The Bulletin of
The Canadian Association
of Physicists
Vol. 39 No. 2
March 1983

Physics in Canada

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l'Association canadienne
des physiciens
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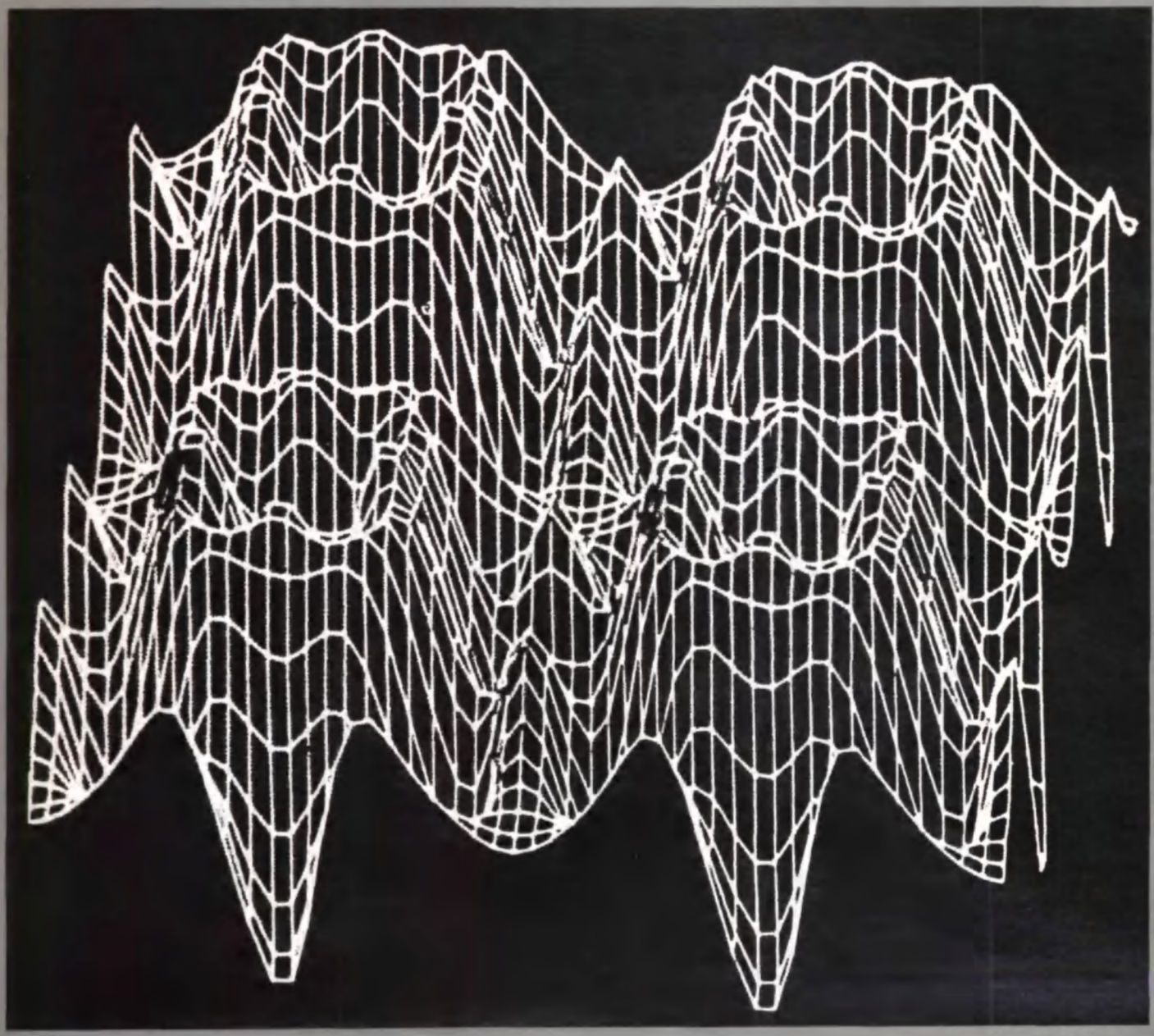
La Physique au Canada



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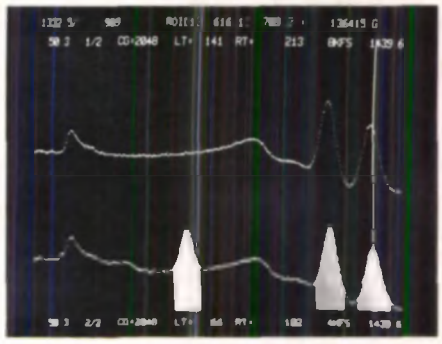

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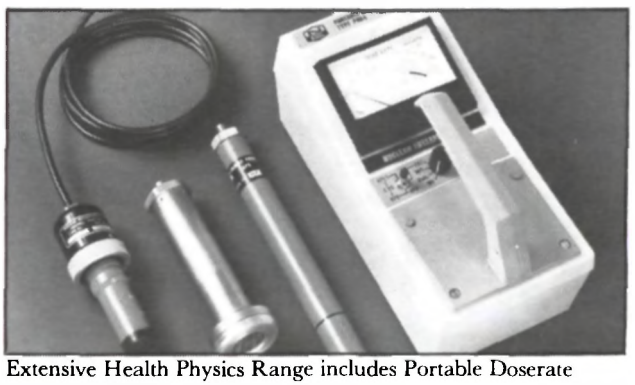

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TABLE OF CONTENTS/SOMMAIRE

Front Cover:

Contour plot of digitally reconstructed RS layer of *S. Ureae*. See article on page 40.

Second Class Mail Registration Number: 5415

ISSN 0031-9147

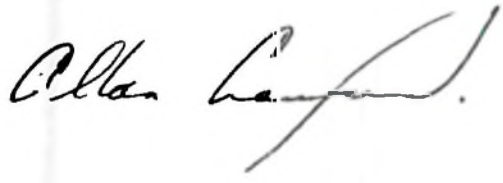
Letter from the President

For several years now the Association has worked at making our activities have more industrial relevance. The Annual Meeting of Corporate Members has been particularly effective in this regard, drawing its audience from the business, industry and university communities. The discussions at those meetings have pioneered in addressing the problems of high-technology industry. This years Corporate Meeting in Toronto in April will continue that pioneering reputation, discussing manpower requirements in the 80's - a key problem for high-technology industries if they are to grow and compete in a world market.

Your executive has continued to be concerned that the Annual Congress be more industrially relevant. With this in mind, we have started a plan that will see an Industrial Training Seminar of five-days duration, on subjects at the cutting edge of applied science in industry, conducted in parallel with the Congress. The seminar will present world leaders in their respective technology an intense five-day tutorial. Attendees will pay a fee of $1,000.00 for the course and attendance will be limited to 100. The first seminar will be held at Victoria this summer. The subject will be VLSI Design and will be concerned with Very Large Scale Integration Microcircuit Design and its development over the next decade.

Fifteen top Canadian students in physics and applied science will qualify for scholarships through funding provided by NSERC to attend the seminar.

If you check through the list of graduates in physics and engineering physics in Canada you'll be surprised to find how many physicists hold senior leadership positions in industry. I hope that initiatives such as The Industrial Seminar will help to ensure that continues.



Le Tokamak de Varennes

par B.C. Gregory, R.A. Bolton, G.W. Pacher et H.D. Pacher, Programme Tokamak de Varennes

1. INTRODUCTION

En novembre 1981, M.P. Bachynski a écrit un article dans La Physique au Canada sur les développements au Canada dans le domaine de la fusion thermonucléaire. Dans son article, le Dr. Bachynski fournit plusieurs détails sur le Tokamak de Varennes (TdeV), qui, à ce moment-là, était dans sa phase d'étude détaillée préliminaire, après la déclaration d'appui financier du ministre John Roberts en janvier 1981. Il est approprié en ce moment de donner à la communauté scientifique canadienne un rapport de progrès sur ce projet qui constitue l'axe principal du programme canadien sur la fusion par confinement magnétique, d'autant plus que l'entente officielle de collaboration entre Hydro-Québec et le Conseil national de recherches du Canada vient d'être signée (le 14 septembre 1982) par le Dr. Lionel Boulet de l'IREQ et par le Dr. Larkin Kerwin du CNRC.

Rappelons que le projet est mené par un groupement de cinq institutions situées dans la région montréalaise. Il s'agit de l'Institut de recherche d'Hydro-Québec (IREQ), l'Institut national de la recherche scientifique — Énergie (INRS-Énergie), l'Université de Montréal, CANATOM Ltée., et MPB Technologies Inc.

Le TdeV coûtera environ 40 millions de dollars à construire. Le gouvernement fédéral, par l'intermédiaire du Conseil national de recherche du Canada, et Hydro-Québec contribueront chacun $18,7 millions aux coûts, avec des contributions plus modestes venant de l'INRS et de l'Université de Montréal. Le premier plasma du tokamak est prévu vers la fin de l'année 1984.

Chaque membre du groupement est associé à un rôle particulier dans le projet. Bien qu'il y ait plusieurs exceptions, l'on peut dire que l'IREQ s'occupe de la direction du projet, du génie électrique et de quelques diagnostics. L'INRS-Energie s'occupe du programme scientifique et de plusieurs diagnostics. L'Université de Montréal s'occupe de deux diagnostics. CANATOM s'occupe du génie mécanique, du génie civil et du support à la gestion du projet. Finalement, MPB Technologies s'occupe de l'instrumentation et du contrôle, et de plusieurs diagnostics. Le design conceptuel détaillé est mené par un groupe d'ingénieurs et de physiciens de tous les membres du groupement.

Le TdeV sera logé dans un grand hall du laboratoire Grande Puissance de l'IREQ à Varennes. Ce tokamak est considéré comme étant une installation nationale comme TRIUMF à Vancouver, et comme telle d'autres physiciens de plasma à travers le pays sont invités à proposer des expériences et à préparer et opérer des systèmes de mesures sur la machine.

L'autorité suprême du projet est le Comité directeur, composé de deux membres de la direction de l'IREQ (L. Boulet et T. Gilsig) et deux membres de la direction du CNRC (J.K. Pulfer et E.P. Cockshutt). Le directeur du projet, R.A. Bolton, est aidé dans sa tâche par un Comité de coordination de la gestion, présidé par M.P. Bachynski, avec un représentant de chaque institution du groupement. Un Comité consultatif avec des représentants nationaux et internationaux d'autres installations de recherche sur la fusion se réunit au moins une fois par année pour évaluer le progrès et assurer le bien-fondé des orientations. Ce groupe se réunira pour la première fois en novembre 1982.

Finalement, un Comité scientifique avec représentants du groupement, du CNRC et des scientifiques à l'extérieur du groupement (nommés par le CNRC) fournit des recommandations au directeur du projet quant à la révision du programme scientifique, l'évaluation des expériences proposées et l'établissement des priorités.

2. LES OBJECTIFS DU PROGRAMME

L'objectif global du projet est d'établir une compétence dans le domaine de la fusion pour les fins stratégiques nationales. Ceci se fait en créant une équipe de chercheurs et d'ingénieurs compétents en fusion magnétique et travaillant dans un Centre national sur une expérience d'intérêt et d'originalité reconnus mondialement.

La visibilité et la crédibilité de notre programme sont importantes, ainsi que la participation et la sensibilisation au projet de l'industrie canadienne.

3. LE PROGRAMME SCIENTIFIQUE ET TECHNOLOGIQUE

L'expérience Tokamak de Varennes a été conçue afin de permettre des contributions nationales significatives dans la filière confinement magnétique de la recherche en fusion thermonucléaire contrôlée. Ceci demande, d'une part, que la taille de l'expérience soit assez grande pour atteindre des paramètres de plasma significatifs et, d'autre part, que l'expérience comporte des aspects innovateurs aussi bien en programme qu'en équipement.

En ce qui concerne la taille de l'expérience, les caractéristiques principales sont données au tableau 1. On remarque que la taille ressemble à des expériences actuellement en fonctionnement comme ISX (Oak Ridge National Laboratory) et donc, que les paramètres du plasma resteront intéressants. Le TdeV préfigure trois des grandes expériences devant entrer en opération dans les 5 ans à venir en la possibilité de fonctionnement quasi-continu, c'est-à-dire une série d'impulsions successives d'une durée totale jusqu'à 30 secondes.

Ce fonctionnement en régime quasi-stationnaire a été adopté comme l'un des principaux domaines de recherche du TdeV. En particulier, ceci comportera l'étude des interactions plasma-parois à facteur d'utilisation élevée par l'intermédiaire de la doublure chauffée et remplaçable, l'étude du fonctionnement des divergeurs triples en impulsion longue, et l'étude du fonctionnement des systèmes de pompage intérieurs rapides en impulsion longue.

Pour permettre le fonctionnement en régime quasi-stationnaire, il est prévu d'inverser le courant du plasma rapidement dans un temps de l'ordre de grandeur du temps de vie. L'étude de cette phase, l'un des principaux aspects innovateurs du TdeV, représente un domaine de recherche avancé qui s'adresse à des problèmes théoriques importants, tels la vitesse de diffusion de courant et l'équilibre, la stabilité et le confinement du plasma avec des couches de courant inversé et à beta poloïdal élevé. Le TdeV sera doté de tous les sytèmes, tels les systèmes de contrôle de la position du plasma passive et active et le système d'inversions rapides du courant ohmique, nécessaires pour étudier l'inversion du courant et les interactions avec le réseau. Un mode de fonctionnement intermédiaire qui maintient un facteur d'utilisation élevé mais ne demande pas l'inversion de courant a été défini. Ce mode permet l'extinction du plasma suivi par un pompage rapide d'une durée jusqu'à une seconde et un rallumage subséquent du plasma. Ceci conserve, en réduisant les exigences de fonctionnement, une grande partie des études d'interactions plasma-parois mais ne permet pas d'étudier, par exemple, l'accumulation d'impuretés.

De bons diagnostics seront nécessaires pour étudier le comportement du plasma lors de ces expériences. Toute la gamme de diagnostics standards est prévue pour établir les paramètres du plasma, les bilans d'énergie et de particules, et le comportement

MHD. Pendant la phase de construction, l'effort majeur sera porté sur ces diagnostics standards. Néanmoins, le développement de diagnostics nouveaux reste l'un des objectifs du TdeV. Ainsi, une station d'analyses de surfaces sera développée pour l'analyse des interactions plasma-parois et l'étude des matériaux de la première paroi. Le développement d'un système de fluorescence laser permettra des mesures de densités d'hydrogène atomique et d'impuretés dans le plasma de bord et éclaircira les processus physiques d'interaction plasma-parois. La diffusion infrarouge pulsée permettra la mesure de la température ionique. La diffusion infrarouge continue permettra des mesures de fluctuations et renseignera sur des processus de transport et d'instabilité.

Ceci résume les grandes lignes du programme actuellement prévu pour le TdeV. Dans l'avenir, ce programme doit subir des changements et des évolutions en fonction des résultats obtenus sur le TdeV et ailleurs. Par exemple, le développement d'autres diagnostics nouveaux doit certainement être entrepris. À long terme, il sera nécessaire d'équiper le TdeV de systèmes de chauffage additionnel pour atteindre des paramètres qui resteront significatifs par rapport à l'évolution internationale. Un premier pas dans cette direction est l'élaboration d'une proposition de chauffage à fréquence cyclotronique des électrons. À plus long terme encore, un système de création non-inductif de courant pourrait être envisagé. Le TdeV a été conçu de façon assez souple pour permettre cette évolution future.

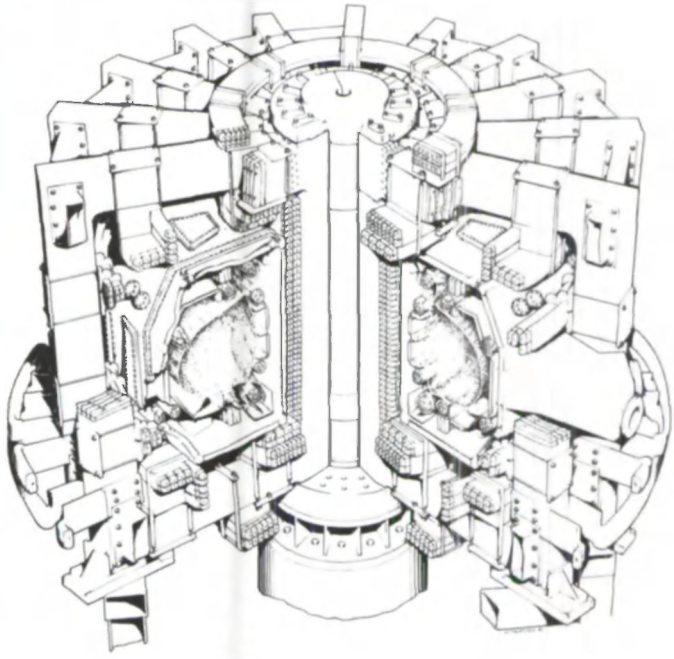


Fig. 1 Le Tokamak de Varennes

Tableau 1

Paramètres principaux du Tokamak de Varennes

Grand rayon	0,85 m
Petit rayon	0,27 m
Champ magnétique toroïdal	1,5 Tesla
Durée maximale de l'impulsion	30 s
Courant plasma q = 3 (q = 2)	200 kA (300 kA)
Deux divergeurs triples	
Système de pompage rapide	
Doublure remplaçable	
Système de contrôle de la position verticale	
Système lent et système rapide de contrôle de la position horizontale	
Système d'inversion rapide du courant ohmique	
Diagnostics standards	
Diagnostics nouveaux	

4. LES INSTALLATIONS

Le tokamak, ses alimentations et sa salle de contrôle seront installés dans la cellule 06 du laboratoire Grande Puissance de l'IREQ qui sera aménagée en deux niveaux. Le rez-de-chaussée servira comme aire principale pour les alimentations. La salle de contrôle se trouve également à ce niveau. La plateforme, à une hauteur de 4,80 m, supportera les diagnostics ainsi qu'une partie des alimentations. Le plan médian du tokamak sera à 1,50 m de hauteur par rapport à ce deuxième niveau.

Une vue d'artiste du TdeV est montrée à la Fig. 1. Essentiellement, le tokamak est composé d'une chambre à vide torique entourée des bobines du champ toroïdal et des bobines du champ poloïdal nécessaires pour créer et contrôler le courant plasma. La chambre à vide toroïdale possède une section rectangulaire à pans coupés. Elle est construite en deux moitiés entre lesquelles est aménagée une discontinuité électrique dans le plan vertical. On peut accéder à l'intérieur de la chambre en dessoudant les deux couvercles supérieurs en forme de C. Afin de réduire le temps de pénétration de champ magnétique et de garder une rigidité suffisante, la chambre sera construite en Inconel et à double parois. Le refroidissement de la chambre sera assuré par la circulation d'un caloporteur entre les deux parois. Entre ces parois et le plasma, se trouve la doublure remplaçable et chauffable. En plus de protéger les parois, elle délimite la chambre de pompage du divergeur dans laquelle se trouvent les éléments de getter au Zr-Al qui assurent le pompage dynamique pendant les impulsions tokamak. La doublure est protégée contre le contact direct du plasma par des limiteurs de garde en métal réfractaire.

Seize bobines de champ toroïdal démontables créent un champ toroïdal de 1,5 Tesla. Chaque bobine comporte quatre spires (97,5 kA par spire) et est démontable au niveau du coin supérieur gauche et au niveau du coin inférieur droit. Les bobines sont supportées par un pilier central et par une série d'entretoises horizontales et de supports verticaux. À l'exception de deux bobines de découplage, les trente bobines de champ poloïdal sont disposées à l'intérieur des bobines de champ toroïdal. Un flux poloïdal induit de ± 1 Wb est créé au centre du plasma par le transformateur (à noyau d'air) de chauffage ohmique, lequel est constitué d'un solénoïde central et de trois paires de bobines de chauffage ohmique supplémentaires disposées autour de la chambre à vide. Une paire de bobines additionnelle sert au besoin à contrôler la position verticale du plasma. Aussi, à l'extérieur de la chambre à vide, deux paires de bobines de champ d'équilibre préprogrammé servent à positionner le plasma radialement. La courbure de ce champ d'équilibre peut être corrigée en utilisant deux autres paires de bobines avec un nombre de tours inférieurs. Une bobine de champ d'équilibre à rétroaction est placée à l'intérieur de la chambre à vide pour corriger rapidement tout écart de la position du plasma par rapport à la position de consigne. Deux autres jeux de trois bobines chacun, également dans la chambre à vide, créent la topologie magnétique des divergeurs poloïdaux aux coins intérieurs de la chambre. Toutes les bobines à l'intérieur de la chambre à vide sont entourées de tubes protecteurs en acier inoxydable réunis de discontinuités électriques dans le sens toroïdal.

Pendant la mise en service de la machine et pour des fins scientifiques spécifiques, plusieurs modes de fonctionnement sont prévus. Mais, les caractéristiques des alimentations sont déterminées par le régime quasi-continu des impulsions alternatives

pendant une durée totale de 30 secondes. Certains aspects font l'objet d'une attention particulière :

— la machine devant fonctionner en régime quasi-continu (à raison de 1 à 10 c/s pendant 30 s), il est impossible d'utiliser un commutateur de courant de type mécanique dans les conditions normales de fonctionnement, c'est-à-dire durant chaque impulsion. Il faut donc recourir systématiquement à l'utilisation de thyristors et de diodes ;

— comme l'énergie nécessaire pour faire fonctionner la machine sera fournie par le réseau, on devra veiller particulièrement à minimiser la demande de pointe ;

— Les circuits doivent être aussi simples et fiables que possible.

L'obtention de la forme d'onde voulue pour le courant dans les bobines de champ toroïdal ne pose pas de problèmes particuliers : un courant continu d'amplitude maximale 100 kA est injecté pendant tout le cycle expérimental, c'est-à-dire pendant 30 s. Le circuit projeté comporte un contrôleur c.a. agissant sur le primaire des transformateurs et d'un redresseur à diodes à 12 impulsions. Les alimentations pour le champ ohmique et le champ d'équilibre sont fondamentalement semblables :

a) la tension alternative de la ligne triphasée à 25 kV est abaissée par un transformateur ;

b) un groupe de redresseurs à thyristors alimente les bobines en question sous la supervision de l'ordinateur du système de contrôle central, d'une façon adaptée à la fonction des bobines ;

c) le changement de sens du courant dans le plasma est réalisé grâce au circuit oscillant que forment les bobines avec une batterie de condensateurs ;

d) le système de contrôle central commande les redresseurs et les différents commutateurs à thyristors durant le plateau de courant du plasma et les diverses phases du cycle d'inversion ;

e) le système de contrôle central fixe la durée du plateau de courant de plasma ainsi que celle de l'inversion du sens du courant.

L'alimentation du divergeur sera un hacheur à tension suffisamment élevée pour permettre l'inversion rapide du courant. Effectivement, la faible inductance de ce circuit ne permet pas l'utilisation d'un circuit oscillant pour l'inversion.

Les bobines internes de positionnement radial seront alimentées par un amplificateur de courant, soit à transistors, soit à thyristors, qui reçoit ses signaux d'entrée à partir de détecteurs de position du courant plasma.

Les condensateurs à l'huile nécessaires pour les alimentations seront logés dans un abri protégé contre l'incendie à l'intérieur de la cellule 06, tandis que les gros transformateurs pour toutes les alimentations seront localisés à l'extérieur.

Le refroidissement des alimentations et des bobines sera assuré par une boucle d'eau déminéralisée. La chaleur extraite passera dans une boucle d'eau industrielle comportant une tour de refroidissement qui fera fonction de récepteur thermique ultime.

Tout le système, machine, alimentations et refroidissement, est conçu pour un train d'impulsions de 30 secondes toutes les quinze minutes. Cet intervalle de temps servira non seulement au refroidissement mais aussi au stockage et traitement des données scientifiques obtenues.

5. CONCLUSION

Le projet avance bien, malgré de nombreux défis techniques et administratifs. Nous continuerons à fournir périodiquement des rapports de progrès à la communauté scientifique canadienne.

Nous réitérons notre invitation aux physiciens de plasma canadiens de collaborer avec l'équipe du TdeV en préparant des expériences et des systèmes de mesures. A cette fin, rappelons que le premier plasma du TdeV est prévu pour la fin de 1984.

The Quasi-biennial Wind Oscillation

by Kevin Hamilton, Department of Oceanography, University of British Columbia

Introduction

Perhaps the most intriguing aspect of the global scale circulation in the atmosphere is the "quasi-biennial oscillation" of the prevailing winds in the tropics between altitudes of about 15 and 40 km (i.e. the lower stratosphere). The explanation of this phenomenon is of interest not only as an impressive triumph of theoretical meteorology, but also as a very concrete illustration of the concept of momentum transport by waves.

History

The first information concerning the winds in the tropical stratosphere was derived from observations of the motion of the dust cloud resulting from the eruption of Mount Krakatoa in 1883. This cloud was tracked for a number of weeks as it travelled around the earth several times. These observations clearly showed that the winds blew in an easterly direction (i.e. from east to west). In the early part of the twentieth century it became possible to measure the winds above 15 km directly using balloons. The first such measurements in the tropics were conducted in 1913 by von Berson in East Africa, who found clear evidence for prevailing *westerlies*. These conflicting observations were reconciled by postulating that a very narrow (in latitude) ribbon of westerlies was embedded in a predominently easterly regime.

The study of the meteorology of the tropical stratosphere began to assume considerable practical importance in connection with the post-war American nuclear weapons tests, and regular balloon measurements of the stratospheric winds began at a number of Pacific Island stations around 1950. By 1960 enough data had been gathered for R.J. Reed (University of Washington) to show that the old view of stratospheric circulation was incorrect and that the winds throughout the tropics above 15 km actually have little spatial variability, but undergo long period temporal oscillations[1]. In fact he found a remarkably regular variation with easterly and westerly prevailing winds alternating roughly every other year. It is this phenomenon which is known today as the quasi-biennial oscillation.

Observations

Fig. 1 shows monthly mean values of the observed east-west wind at a height of 30 km over Ascension Island in the tropical Atlantic (8°S) during a six year period (1967-72). The oscillation of the wind from easterly to westerly is clearly apparent. The magnitude of the observed winds is quite appreciable (25 m/sec winds at the ground are classed as gale force winds). Examination of longer time series of observations show that the period of the oscillation seems to change somewhat from cycle to cycle. The best estimate of the average period over the last 30 years is about 27.5 months. The oscillation is largely confined to the tropics and has almost no structure in longitude. The lack of any dependence of the amplitude or phase of the oscillation on longitude means that it can be viewed as an oscillation of a variable defined as the value of the east-west wind averaged along a latitude circle. This variable is obviously a function only of height, latitude and time.

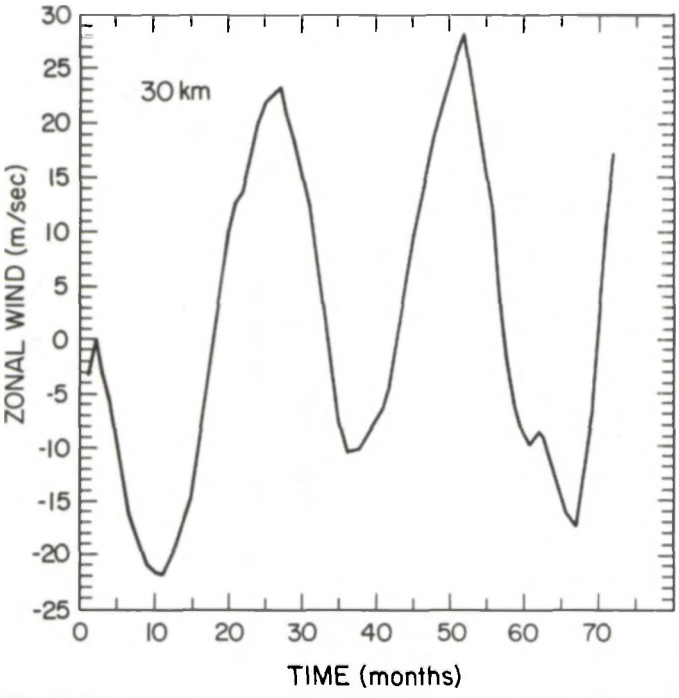


Fig. 1. The observed monthly mean value of the east-west component of the wind at Ascension Island (8°S, 14°W) during the period January 1967 through December 1972. The results are for a height of 30 km, and positive (negative) values refer to westerly (easterly) winds. This figure taken from reference 2.

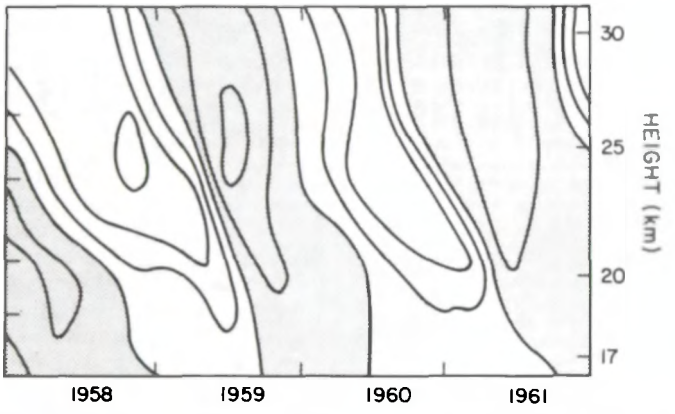


Fig. 2. Contours of the monthly mean wind observed at Canton Island (3°N, 172°W) as a function of time and height. The contour interval is 10 m/sec. Westerly winds are indicated by shading while easterlies are unshaded.

The vertical structure of the quasi-biennial oscillation can be seen in Fig. 2 which shows a time-height section of the winds at another tropical station. When the observations are presented in this format the apparent downward propagation of the wind reversals can be clearly seen. This downward phase propagation has been a characteristic of each and every cycle of the oscillation that has been observed.

Explanation

The peculiar behaviour of the tropical stratospheric winds documented above has naturally led to the creation of an extensive theoretical literature. However, the only theory which has been even remotely successful in explaining the observed features of the oscillation is that advanced during the late 1960's and early 1970's in a series of papers[3,4,5] by R.S. Lindzen (Harvard) and J.R. Holton (University of Washington). In their theory the longitudinally averaged east-west wind (referred to hereafter as the "mean flow") is accelerated by a convergence of a "momentum flux" carried by vertically propagating waves. The concept of momentum transported by waves is one with wide application throughout physics. In the present context it can be most easily understood by considering a fluid confined to move in just two dimensions: x (corresponding to the east-west direction along the equator), and z (the vertical direction). For simplicity we regard the fluid as being incompressible (in reality a poor approximation for the atmosphere). The equation governing the x-momentum of the fluid can be written as

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial P}{\partial x} \qquad (1)$$

where u (x,z,t) and w (x,z,t) are the components of the wind in the x and z directions respectively, P is the pressure and ρ is the density. Now we suppose that the flow consists entirely of a x-average component (the mean flow) plus a single harmonic wave, i.e.

$$u(x,z,t) = u_0(z,t) + u_1(z,t)\exp(ikx)$$
$$w(x,z,t) = w_0(z,t) + w_1(z,t)\exp(ikx)$$
$$P(x,z,t) = P_0(z,t) + P_1(z,t)\exp(ikx)$$

where the wavenumber k, is chosen so that an integral number of wavelengths fit in our domain (corresponding to the circumference of the earth), and where u_1 and w_1 can be complex to account for the relative phases of horizontal and vertical velocities in the wave. W_0 actually must be zero since rising motion at all points simultaneously in our domain would violate mass continuity. Taking the x-average of equation (1) it is easy to see that

$$\frac{\partial u_0}{\partial t} + \tfrac{1}{2}\,\mathrm{Re}\left(w_1^*\frac{\partial u_1}{\partial z}\right) = 0 \qquad (2)$$

where the asterisk denotes complex conjugation. The mass continuity equation is

$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0$$

When averaged over x this implies (remembering that $w_0 = 0$)

$$\frac{\partial w_1}{\partial z} = 0 \qquad (3)$$

Equation (3) can be employed to rewrite (2) as

$$\frac{\partial u_0}{\partial t} = -\frac{\partial F}{\partial z} \qquad (4)$$

where

$$F \equiv \tfrac{1}{2}\,\mathrm{Re}\,(w_1^* u_1)$$

It is conceptually attractive to regard F as a flux of mean flow x-momentum carried vertically by the wave. The mean flow is then accelerated by the convergence of this flux.

In the tropical stratosphere there are two very prominent vertically propagating waves found in the spectra which have been computed from daily wind observations. Both waves have periods of the order of several days and east-west wavelengths of many thousands of kilometres. One wave (known as the "Kelvin wave") has a westerly phase speed of about 25 m/sec, while the other (the "Rossby-gravity wave") has an easterly phase speed of roughly the same magnitude. The origin of these waves is not completely understood but it is thought that they are generated by the latent heat release in organized cloud patterns in the lower atmosphere. The westerly wave has a westerly value of F and thus carries westerly mean flow momentum into the stratosphere. When this wave is attenuated by dissipation processes in the stratosphere the mean flow is accelerated in a westerly direction. Similarly the easterly Rossby-gravity wind can produce easterly mean flow accelerations.

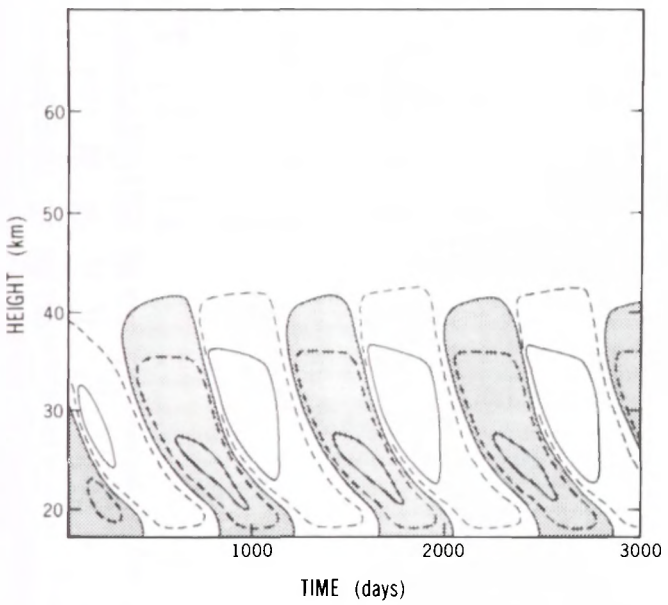


Fig. 3. Simulated mean flow quasi-biennial oscillation presented in a format similar to Fig. 2. The contour interval (including the dashed contours) is 10 m/sec and westerlies are shaded. This figure taken from reference 2.

The effect of either of these waves on the mean flow is self-limiting to a certain extent. In particular the westerly wave is largely prevented from propagating into the stratosphere when the mean flow there is strongly westerly, while the easterly wave will not penetrate efficiently into strong stratospheric mean flow easterlies. Lindzen and Holton regard the quasi-biennial mean flow oscillation as being a consequence of the simultaneous presence of two such self-limiting waves. Thus one can imagine a situation where the stratosphere is initially filled with strong mean flow westerlies. Then the easterly Rossby-gravity wave can act to produce strong easterly accelerations. Under appropriate conditions this process can continue until the stratosphere is filled with strong easterlies, at which point the Rossby-gravity wave will be largely excluded from penetrating vertically. Then the westerly Kelvin wave will take over to produce mean flow westerlies, and the cycle can begin anew.

Lindzen and Holton produced an elegant mathematical model of this process. Their formulation basically consists of our equation (4) for the evolution of the mean flow (suitably modified to account for the effects of compressibility) together with equations which allow the computation of the momentum fluxes, F (z), for each wave for any particular mean flow profile, u_0 (z). The model equations can be numerically integrated to solve for u_0 (z,t). Fig. 3 shows the results of such a numerical integration performed with a slightly improved version of the Lindzen-Holton model[2]. The resemblance to the observations shown in Fig. 2 is really quite remarkable. There are some observed features of the oscillation which are not reproduced in the simulation, of course. For example, in any model simulation each period of the oscillation is identical to all others (at least after some initial transients have died out) and so the theory does not offer a direct explanation for the observed changes in the oscillation period from cycle to cycle. However, there is today a widespread concensus that the Lindzen-Holton theory does describe the basic mechanism of the oscillation, and all recent research in this field of any significance has taken the Lindzen-Holton model as the starting point.

Recent Studies

The theory of the quasi-biennial oscillation continues to be a vigorous area of research. Much of the recent work has involved numerical models designed to simulate the structure of the oscillation in latitude as well as in height.[6,7] Other investigations have focussed on obtaining a more detailed understanding of the physics of the interaction between the waves and the mean flow[8]. Finally, one study has dealt with the implications of the Lindzen-Holton theory for the interaction between the circulation in the stratosphere and that in the lower atmosphere[9].

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Image Enhancement in Electron Microscopy

by S.K. Burley, P.W. Whippey and W.P. Alford, The University of Western Ontario*

1. Introduction

Many of us probably first became aware of the power of image processing when we saw the magnificent pictures from the moon and the planets taken during space missions. The information in these pictures was transmitted to earth in digital form, and then processed by computer to produce bright clear images showing a wealth of detail, much of which is hardly discernable without processing. Many other intriguing problems are being tackled with these techniques. The Mona Lisa is being "cleaned" by Asmus[1], who has produced a computer enhanced image, so that we can now see how the picture would look with the yellowed varnish "removed". A recent TV program on the Shroud of Turin showed image processing techniques being used in a number of different studies of the image. Our purpose here is to describe how such methods can be applied to investigations of the structure of biological materials, by enhancing the images obtained in the electron microscope.

Biological structures, viruses for example, may be built of repeating structural sub-units, hence their electron micrographs are spatially periodic. However, this periodicity is often obscured by noise caused by distortions arising during specimen preparation, or damage due to electron bombardment in the microscope. The image processing techniques we use exploit simple properties of the Fourier transform to extract the structural information from the background noise. Repeating structure in the image appears in the Fourier transform as strong peaks whose positions depend on the spatial periodicities present. Conversely, image "noise" tends to be uniformly distributed in the Fourier transform because of its random nature. An image may be enhanced by first generating its Fourier transform then deleting all parts of the transform thought to consist primarily of "noise" and finally performing an inverse Fourier transform to produce a noise-reduced image.

The type of image enhancement of interest here is currently done either optically or digitally. The optical system is essentially an analogue computer which permits very rapid assessment of the overall quality of micrographs. The digital transform preserves phase information which is normally lost with the optical method, and also permits more precise control of the filtering operation before reconstruction. Its main drawback is the relatively long time required to process a single image. It usually requires a few hours to digitize a micrograph with a microdensitometer, examine the resulting digitized image to select the specific region for study, and then carry out the computation of the transform. In contrast to this it usually requires about a minute to look at the optical transform in order to decide whether a particular image warrants further study. Thus the two approaches are complementary, with the digital analysis being carried out only on the best images which have been identified by their optical transform.

Applications of image analysis to structure problems have been developed by many workers. An optical diffractometer was built by W.L. Bragg[2] in 1939, calling it the x-ray microscope, but major advances had to wait for the development of the laser. Since then, many groups have made contributions to the techniques, eg. Klug and co-workers at Cambridge[3] and Lipson[4]. An excellent introduction can be found in the book by Misell[5] whose references will guide the interested reader to all the major workers in the field.

2. Optical Methods

The optical approach depends on the fact that the Fraunhofer diffraction pattern of an object is just its Fourier transform[6]. Thus if an object is placed in the front focal plane of a positive lens, the Fourier transform is found in the back focal plane. The transform is then filtered by selecting regions corresponding to definite spatial frequencies in this back focal plane.

A schematic diagram of the U.W.O. optical diffractometer is shown in Figure 1, while a photograph of the first half is shown in Figure 2. Light from a 3mW HeNe laser passes through the wedge, shutter, beam alignment device and spatial filter to fall on the electron micrograph which is located in the front focal plane of the first Fourier transform lens. The Fourier transform of the micrograph, i.e. its diffraction pattern, is located in the back focal plane of this lens, where it may be viewed on the TV monitor or passed on to the filter plane via an auxiliary magnifying lens.

Filtering is accomplished by placing an opaque mask in the filter plane, with holes to transmit light only in the vicinity of appropriate peaks in the diffraction pattern. This light then passes through a second Fourier transform lens and a final magnifying lens to the plane of the filtered image.

An application of the optical technique is illustrated in Figure 3. The electron micrograph on the left in this figure was obtained from a negatively stained specimen of a flexuous plant virus, (Papaya Mosaic Virus (PMV)). Though the overall dimensions of the virus particle are easily obtained there is little further structural information apparent in the micrograph. Figure 3b shows the diffraction pattern produced by this micrograph. The portion

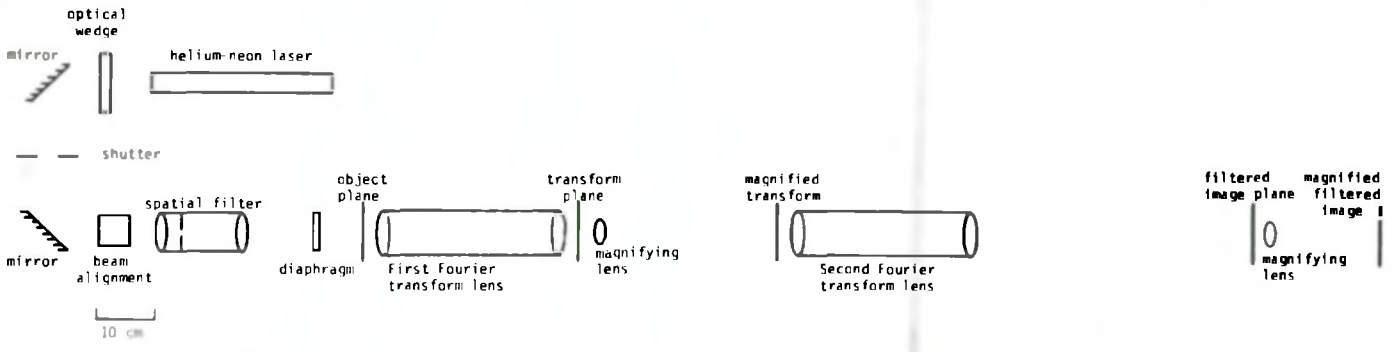

Fig. 1 Plan of the U.W.O. Optical Diffractometer

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of the pattern on the equator results mainly from the mask which defines the region of interest on the micrograph. In addition, a number of strong diffraction peaks can be identified arising from structure of the virus which is largely obscured in the original micrograph. Figure 3c shows a reconstruction of the micrograph obtained by placing a mask in the plane of the diffraction pattern which passes light only in the areas of the peaks which have been delineated in Figure 3b. The resulting image displays considerable detail, including the helical structure of the virus, and the existence of discrete sub-units as structural elements.

Lest we give the impression that simple optical filtering requires a complex and expensive system, we would encourage anyone interested in the technique to try it using a laser and simple optical bench. A 4 × 6 file card and a pin can be used to make a spatial filter. Excellent discussions of the technique at the undergraduate level can be found in the text by Hecht and Zajic[7], and in the study guides for the course "Images and Information", course ST 291 produced by the Open University in the U.K.[8].

Fig. 2 Photograph of the U.W.O. Optical Diffractometer

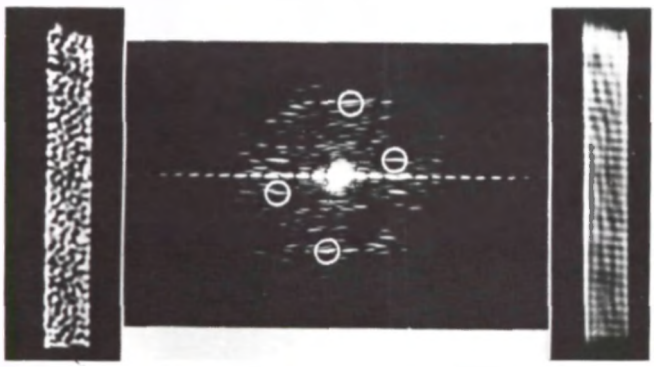

Fig. 3 Papaya Mosaic Virus (PMV)
(a) Electron micrograph
(b) Diffraction pattern
(c) Optically reconstructed image

3. Digital Processing

The digital processing facility at U.W.O. is built around a small dedicated computer which permits on-line digitization and data manipulation. At present, the computer drives a digital TV camera for data acquisition, a video display, graphics terminal, and plotter. Digital images of higher quality are also available from an Optronics drum scanner which provides data input via magnetic tape. An extensive software package is available to carry out the image manipulation and processing.

With this system, digitized images may be viewed on the video monitor and appropriate regions selected for processing. After carrying out the Fourier transform, the regions of the transform representing the structure of interest are masked by multiplying these pixels by unity and all other pixels by zero. An inverse transform is then calculated to provide the final filtered image which may be viewed on the monitor or plotted in a variety of ways.

4. The Cell Wall of a Bacterium

Any structure, which is made from repeating units is a good candidate for image analysis by Fourier transform methods, and we can illustrate the procedures using micrographs of material from the bacterium *Sporosarcina ureae* (*S. Ureae*). Bacteria commonly carry a regular array of protein units on their outermost surface. This regular surface layer (the RS layer) forms the primary interface between the cell and its environment. A major function of the RS layer appears to be the protection of the cell from hostile environmental agents.

Figure 4(a) shows the RS layer of *S. Ureae*, prepared by negative staining of the cell wall. While the tetragonal nature of the layer can be seen, most of the fine structural details are obscured. Figure 4(b) shows the optical Fourier transform of the layer, and the tetragonal symmetry is now readily apparent. Optical filtering produced the much clearer image of the layer shown in Figure 4(c), where individual unit cells can be seen.

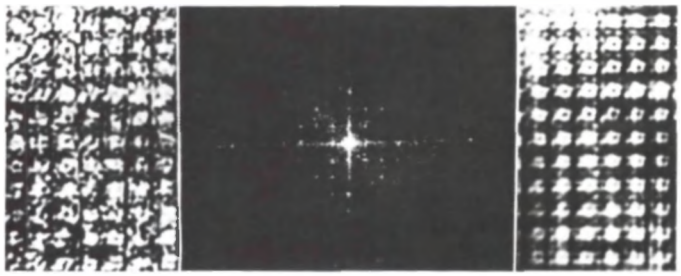

Fig. 4 RS layer of Sporosarcina ureae
(a) Electron micrograph
(b) Optical Fourier transform
(c) Optically reconstructed image.

More extensive image enhancement was carried out with the aid of the computer. Five micrographs were selected for digital transformation, and careful measurements were made of the amplitudes and phases of the strong diffraction spots in the Fourier transform. The results from all five micrographs were averaged, and we also imposed the condition that the Fourier transform spots have four-fold symmetry. We used these measured amplitudes and phases to calculate the inverse Fourier transform. Figure 5 shows this picture displayed on a TV screen, which shows considerable detail within a unit cell to a resolution of about 2.5 nm. Areas of high stain density are indicated by the dark regions. Figure 6 shows the same information displayed as a contour plot.

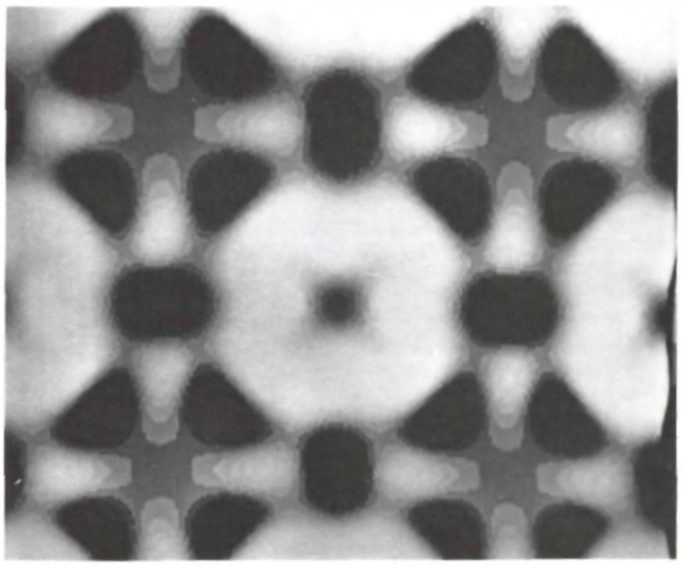

Fig. 5 TV display of digitally reconstructed RS layer of *S. Ureae*.

A study of this same RS layer by Stewart and Beveridge[9] revealed that the underside of the RS layer also contained areas of high stain density. These stained areas occurred at the same place in the layer, suggesting that they were in fact holes with a limiting diameter of about 2 nm. Holes of this size would permit the passage across the layer of small molecules corresponding to the nutrients and waste products of the cell's metabolic activity. This fine protein mesh, however, would prevent potentially fatal lytic enzymes and predators from entering the cell. The role of the RS layer therefore appears to be protective.

The enhanced image displayed in Figure 5 represents the projection of a complex three dimensional structure that is about 200A thick. By recording only the projected view of the RS layer we have missed useful structural information which is clearly pertinent to an interpretation of function. Image processing methods have been developed by Klug[3] and others to provide three dimensional images of structures from their electron micrographs. The procedure, which is analoguous to tomography, involves recording micrographs of the structure at a series of tilt angles with a goniometric electron microscope. Each one of these tilted projections is then spatially filtered with a digital filtering system. Finally, the information contained in each of the tilted images is combined to provide a three dimensional image of the structure.

At present we are upgrading our computing facility so as to permit both rapid digital filtering and three dimensional image reconstruction.

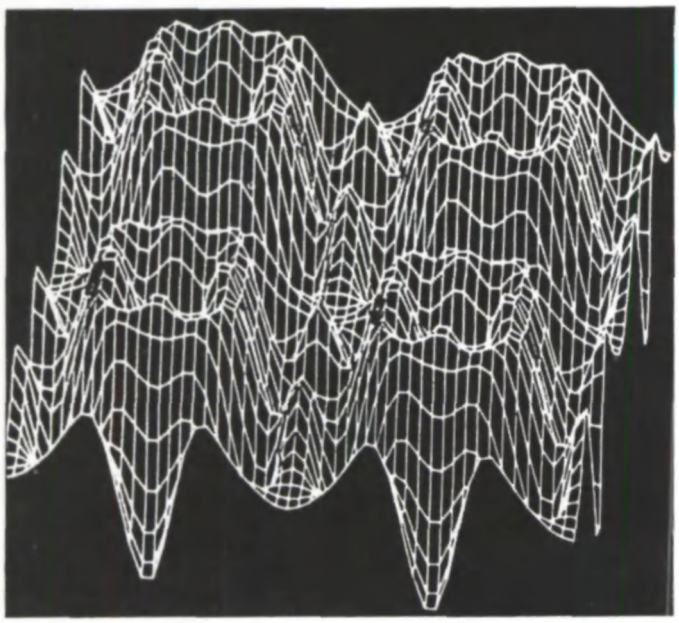

Fig. 6 Contour plot of digitally reconstructed RS layer of *S. Ureae*.

Acknowledgements:

We would like to thank the members of the U.W.O. Biological Structures Group for providing the electron micrographs and Mr. J. Cole for his invaluable technical assistance. Financial support for equipment purchases was provided by the U.W.O. Academic Development Fund. Mr. S.K. Burley was the recipient of a N.S.E.R.C. undergraduate Summer Assistantship during part of this work.

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Anomalons

by Peter Watson, Carleton University, Ottawa and Theory group, SIN, Switzerland

The number of truly surprising discoveries in science is extremely small. I am thinking here of cases like the discovery of pulsars which, although they were finally interpreted in terms of an already predicted object (neutron stars), produced a combination of fascination and bafflement in both the professional and the layman. The discovery of anomalons should be another such example.

The original observations were made in the 1950's, by a number of cosmic ray physicists including Milone[1], Yagoda[2], Friedlander[3] and others[4]. They observed that a cosmic ray primary hitting an emulsion nucleus would produce a shower of secondary particles (fig. 1). The results of the collision can be rather easily split into target fragments (dark tracks which travel in random directions for 100μ) and projectile fragments (light tracks, strongly collimated with the direction of the original beam). Following the primary interaction along the secondary projectile fragments a secondary or even a tertiary interaction is sometimes seen. The crucial quantity here is the mean free path (m.f.p.) between collisions. The emulsion is a mess of various nuclei but empirically there is a relation between range and nuclear charge Z given by

$$\lambda_Z = \lambda^* Z^{-b} \qquad (1)$$

where λ^*, the m.f.p. for protons, is around 30 cm, and b is about .45. It is possible to measure Z to an accuracy of ± 1 (for medium to heavy nuclei) by counting the density of δ-rays[a] on the tracks.

This result follows in a rough fashion from optical models, and corresponds to a black sphere model of nuclei with radius R given by

$$R \sim 1.1\, A^{1/3} \text{ (fm} = 10^{-15} \text{ m)} \qquad (2)$$

Typically the emulsion thickness is 25 cm, so that a charge 20 nucleus would be expected to interact twice.

What the early workers observed were a very few events in which the incoming nucleus and its successive fragments would interact several times. Yagoda's event shows no less than 6 interactions in 15 cm, instead of the expected one, leading to the claim that the probability of observing such an event was 10^{-5}. These interactions become known as extra-nuclear cascades, and caused a mild flurry of interest in the late 1950's. An example is shown in fig. 2, where a nucleus (originally argon) interacts four times, with bits falling off along the way.

That the effect was not forgotten is entirely due to one person: Barbara Judek of the NRC in Ottawa. She observed a few similar events in the 1960's, but realising that no one would believe in the effect until it was put on a statistically sounder basis, she worked painstakingly for 11 years, analysing the mean free paths of secondary nuclei against a background of total indifference from the scientific community. The analysis was done initially using cosmic ray primaries, but later the heavy ion beam from the

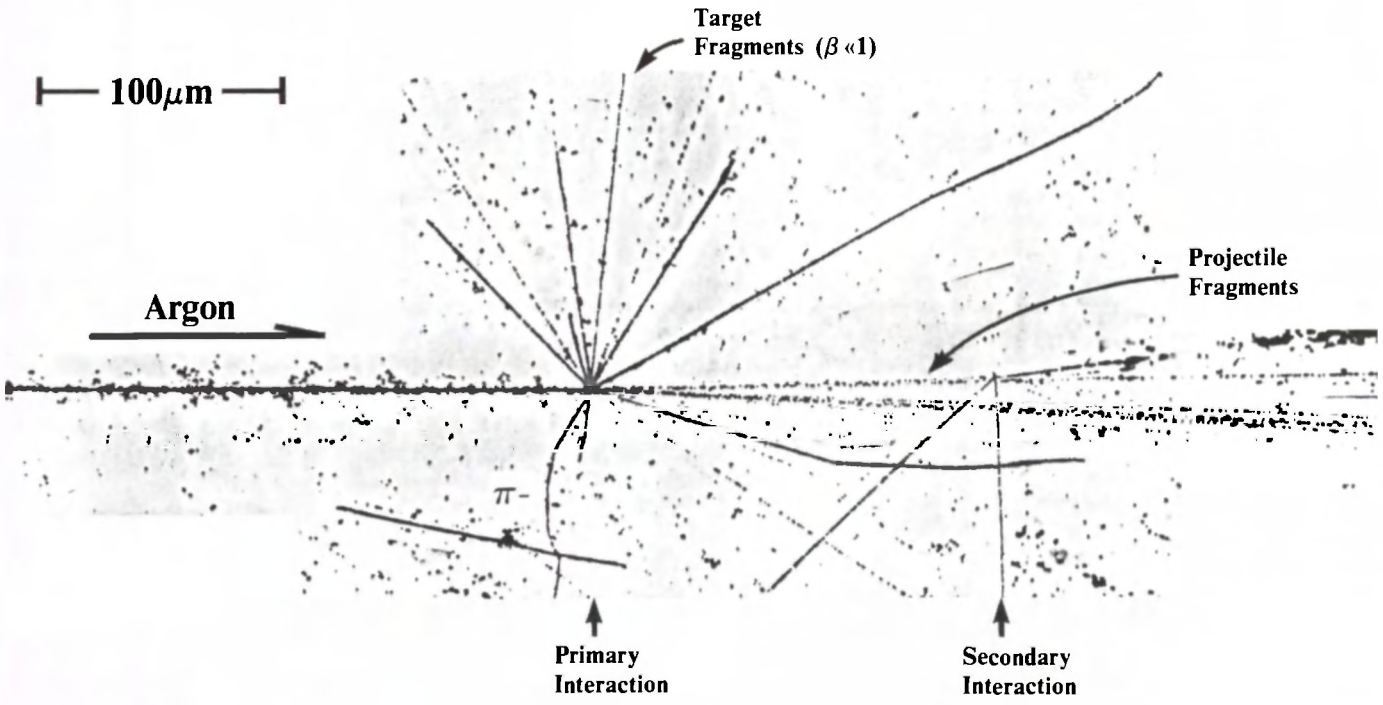

Fig. 1. A cosmic ray argon atom strikes an emulsion nucleus, followed by a secondary interaction.

[a] δ-rays are the electrons produced by the passage of the energetic particles which ionises the emulsion nuclei.

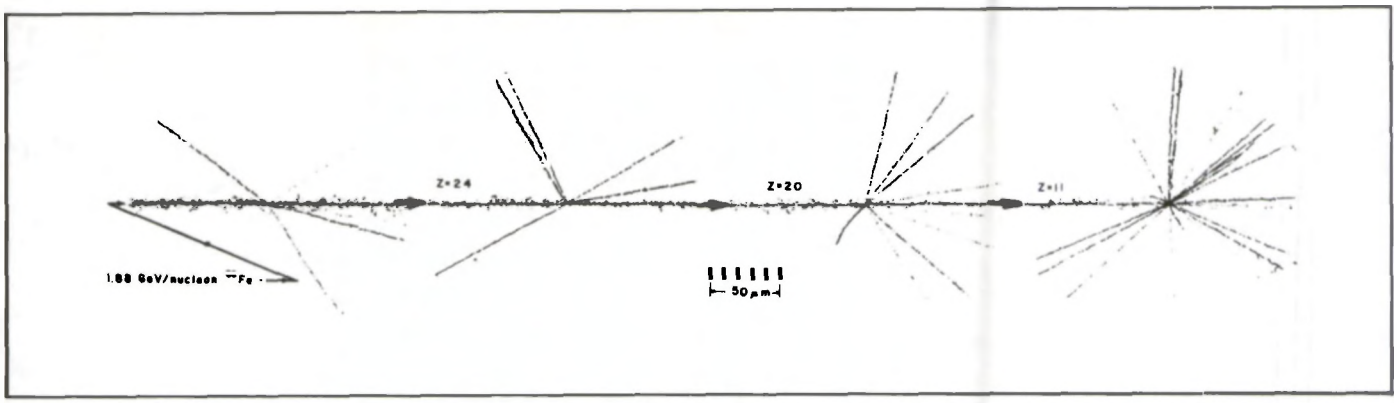

Fig. 2. A chain of events

$$Fe \rightarrow Cr \rightarrow Ca \rightarrow Mg \rightarrow \alpha$$

Note that these 4 events take place within 0.3 mean free path lengths.

Bevalac at Berkeley was used, giving 0^{16} nuclei with an energy of 2 GeV/nucleon. By 1977 her data was sufficiently extensive that a group at Berkeley led by Hechmann and Friedlander carried out a similar analysis with Fe^{56} primaries. A paper[5] published in 1980 combines the results of these two investigations.

Since the Berkeley experiment[5] is, in a sense, the definitive experiment, it is necessary to say in a little more detail how the analysis was done. Projectile tracks are followed from the primary interaction vertex until they either interact or leave the emulsion stack, and their track lengths measured. This is done as a function of the distance d from the vertex in intervals of $\lambda d = d_2 - d_1$ where typically $d_1 = d - 0.5$ cm and $d_2 = d + 0.5$ cm. One can then define the m.f.p. for particles at a distance of d cm from the primary by

$$\lambda^*(d) = \frac{\text{Total track length observed in the interval } d_1 < d \leqslant d_2}{\text{Total number of interactions in the same interval}} \qquad (3)$$

In the absence of anything peculiar, the fragments have no memory and hence λ^* should be independent of d. This is so for primary nuclei where the distances are measured from the beginning of the stack (fig. 3). It is not so for secondary fragments, for which λ^* (d) is statistically much too low at short distances ($d \leqslant 3$ cm). The value of the m.f.p. for secondaries (25 ± 1.1) is dramatically lower than that for primaries (30 ± 1).

This apparently slightly odd method of analysing the data is necessary for reasons of geometry: many fragments leak out of side of the stacks, so that the more easily understood plot of interactions versus distance cannot basically be produced. It is also over-simplified (naturally!): to achieve statistical respectability it is necessary to combine data from secondaries of all charges ($Z \leqslant 26$) using the empirical relationship Eq. (1) above. Considerably more sophisticated analysis confirms the basic observation: too many fragments interact in the first 3 cm.

The simplest and most accepted interpretation of this is that some new variety of nucleus (the anomalous nuclei) is being produced in these collisions. The preferred fit of Friedlander et al. gives 6% of anomalous nuclei produced with a m.f.p. of about 3 cm. This implies a geometric radius of around 10 fm, and appears to be independent of charge: in other words the cross-section is five to ten times larger than it should be. An alternative interpretation, due to the Minnesota group[6], is that all secondaries are slightly anomalous: 100% with an m.f.p. of 24 cm which would mean a new nuclear state with a 20% larger radius. However it is then necessary that the anomalousness (an almost unpronounceable word) decays with a lifetime of 10^{-10} s to give a decay length of 3 cm. In what follows I adopt the first interpretation, but this is purely prejudice on my part.

Beyond these basic facts, it is rather hard to glean any more information from the data. It would, for example, be of enormous interest to know whether the effect occurs for Z=1 secondaries (one hesitates to call them protons). Unfortunately it is difficult to make the measurements, and the statistics are poor.

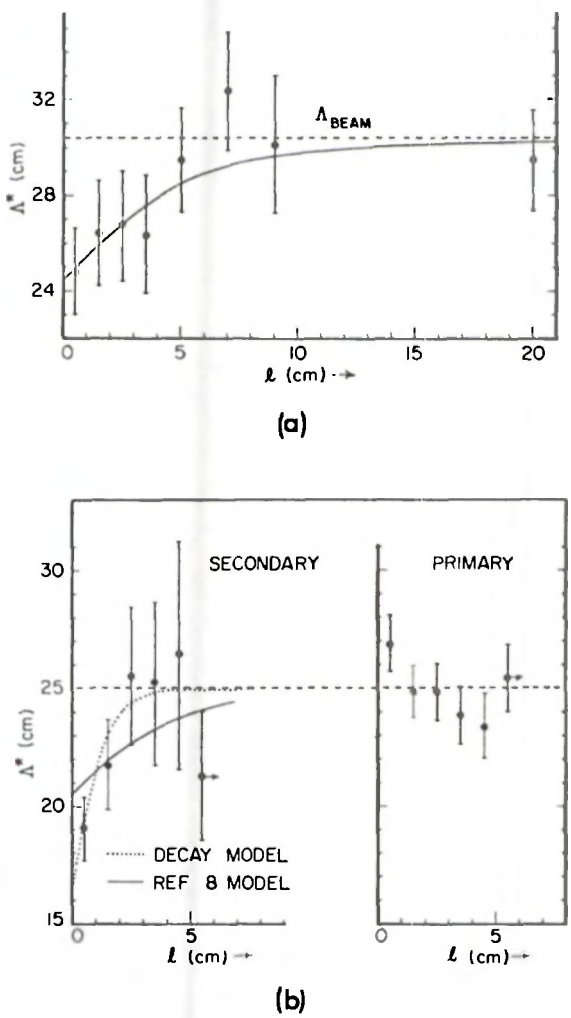

Fig. 3. Plot of $\lambda^* = \zeta^*(d)$ vs l = d from Eq. (3) for secondary and primary nuclei.

Plot (a) is from the data of Friedlander et al.[5] while plot (b) and (c) are from the data of Barber et al.[6]

It can, however, be argued that interactions rather than decays are seen. This is because the secondary interactions give rise to both fast and slow particles: the decay of a fast particle will give rise to only fast particles and hence light tracks. Hence the lifetime of the anamalous state must be at least 10^{-9} s. The anomalous effect does not seem to show up for an energy of less than 1 Gev/nucleon, suggesting some sort of threshold, although this may be misleading. The effect does not seem to show up in proton induced reactions.[b] There are hints that the angular dependence for the production of anomalous nuclei differs from that of ordinary nuclei. What can one do with this? The first reaction is to disregard the effect on the grounds that it must be wrong (precisely what the author did in 1974!). A prominent nuclear theorist is quoted as having said that he would not believe the effect until it reached 5 standard deviations: the cumulative effect is now at 5.5 standard deviations, and he is reported to have upped the ante to 10. It is probably true that the effect will not be believed until it is seen in a medium other than emulsions: high energy and nuclear physicists tend to have a gut prejudice here. It is also unfortunately true that exciting results can disappear, but only after causing an enormous waste of time. Recent notorious examples of this include the split A_2 meson and polywater, which wasted perhaps 1000 man-years apiece.

However it seems unlikely that this effect will disappear, mainly because it has been seen by 3 separate groups. There has been only one semi-serious suggestion as to how scanning biases could produce the effect. Perhaps the thing that will do most to convince people of the reality of the effect is that Louis Alvarez set up a team to make it go away: the conclusion was that either it was a statistical fluke or that there was something real!

Parenthetically one may ask what has happened to the philosophy of science in this episode. Obviously if the effect is real, it is crucial, and we have all been taught that crucial experiments are invariably repeated very quickly, that theories are developed and new experiments are designed in the light of these. If anomalous nuclei represent a genuine new phenomenon, then it is perhaps as important as the discovery of charm, and one cannot forget the incredible speed with which discoveries were made in 1974 compared to the 30 years involved in this effect. I think there are two technical reasons. First there is no quick way of doing new experiments: scanning emulsions is even slower than doing needlepoint. Secondly and most important, the effect is totally unnecesary. Nuclear physics is a field in which the broad outlines have been known for 40 years, and detailed dynamical calculations have been 20% accurate for the past 20 years, and yet here is an observation which indicates that something is fundamentally wrong with the whole picture.

Obviously this is a theoretician's delight. One is comparatively untrammeled by inconvenient facts, because there are so few, and so it is relatively straightforward to devise tests of any given model. The two kinds of models that have been developed to date are nuclear models, in which the nucleus is in some bizarre new collective state (a crude analogy would be to a giant dipole state), and particle models, in which the anomalous nucleus consists of a new particle (the anomalon)[c] bound to conventional nucleons (here the analogy might be to a hypernucleus).

A recent nuclear model is the "pineut" suggestion of McHarris and Rasmussen[7]. This requires the existence of a peculiar bound state of negative pions and ordinary nuclei. While larger than conventional nuclei, these would be much smaller and more tightly bound than conventional pionic atoms, because the relevant interaction would be nuclear rather than electromagnetic, and the long lifetime of the state would be due to the actual lifetime of the pion itself.

At Carleton we have concentrated on the particle model. It is now taken for granted that nucleons consist of quarks. There are three colours of quarks (usually red, blue and green) and the forces are attractive between unlike colours and repulsive between like. Since individual quarks are not normally produced, it is assumed that the force increases with distance in such a way that coloured objects are not seen (fig. 4). One can combine three coloured quarks to form a colourless proton. This picture is part of quantum chromodynamics, or Q.C.D., and is known as confinement.

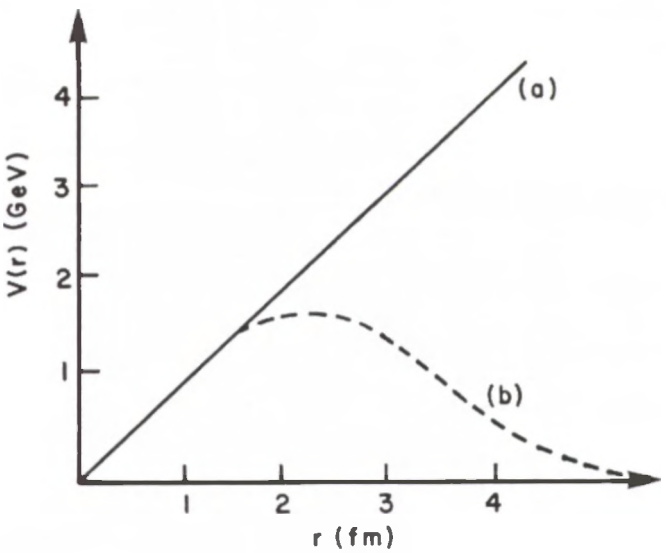

Fig. 4. A confining potential (a) and a hypothetical quasi-confining potential (b).

There are then two possibilities, which I can describe best by analogy. One is the hidden colour idea. Suppose one takes a O^{16} atom and adds two protons to it (along with two electrons to keep it neutral). Then one obtains Ne^{18}, which is roughly similar in size, shape and interactions to O^{16}. However if one asks a chemist what happens in this process, the answer is obviously water! In a rather peculiar sense, water and Ne^{18} are structural isomers, but their differences could hardly be greater. Water molecules interact via dipole forces, are large and have a definite shape. Neon atoms interact via the much weaker Van der Waals force, are small and spherically symmetric. Both systems are, of course, electrically neutral. It is also necessary that one of these is unstable: in fact H_2O will tunnel to Ne with a truly enormous half-life (Ne decays much faster by positron emission!)

It is possible to construct models consistent with conventional Q.C.D. which do much the same with coloured quarks. Bill Romo and I constructed such a model five years ago, with 6 quarks laid out in an arrangement like a childs jack: in other words, a root of 3-dimensional cross. More recently Fredriksson and Jandel have constructed a 6-quark state in a conventional bag-model calculation. These six quark states are isomeric to the normal deuteron, but are expected to have very different proper-

[b]Although one may wonder. A standard discussion with experimentalists may be paraphrased:
"If the effect is real, why isn't it seen in p-p scattering?"
"Have you ever looked?"
"No, but why would anyone look for anything so crazy?"

[c]This generally accepted name arises from a typing error (for anomalous) in a seminar notice at the Riverside campus of the University of California.

ties: they will be heavier, larger, and decay with lifetimes of nanoseconds or more.

The other kind of model is one in which the ideal colour symmetry of nature is assumed to be intrinsically broken: in other words coloured particles could be seen individually, rather than in colourless combinations. To make an analogy here, suppose that only very low energies (<2ev) were available to us. We could then study the interaction of atoms and molecules, but they would necessarily be neutral. By a study of the forces between molecules, some exceptionally brilliant physicist might deduce that atoms were made of "charged" particles, but that these could never be seen individually because the forces between "charges" were too strong. When a threshold energy of 2 ev is reached, charge suddenly becomes a reality and the exact neutrality of nature is lost.

What we need to do here, then, is to break the colour symmetry in such a way that free colour can be seen. A model due to Rudolf Saly, Sundaresan and myself does this formally by making the exact SU(3) symmetry be broken to SU(2)xU(1). This has the consequence that coloured states can be produced, but only with integral charge (in other words, quarks still cannot be seen). Unlike the electromagnetic analogy above, free colour will decay with a fairly long lifetime, compatible with anomalon observations. The large cross-section arises fundamentally because the states actually have colour. Variants of this kind of model have been discussed by several other authors.

Two important consequences follow from this kind of model. Firstly why does one require heavy ions in the collision to produce the anomalons? There are at least two possible answers: the anomalon contains a large number (6 is large in the sense of 1,2,3, many!) of quarks, and so to produce it economically requires a lot of quarks. (If the deuteron could only be produced in pp collisions, it would not have been discovered until the mid-1960's, because the cross-section is so small.) Alternatively, the force between coloured particles is quasi-confining (fig. 4): this can be guessed at in some of the broken colour models. Then the requirement is that for coloured objects to be produced, one would need an object larger than the confining potential, perhaps 3 fm if the confining potential peaks at 2 fm. Detailed calculations support this picture. If it is indeed size that is important, then perhaps anomalons could be produced in deuteron collisions. Richard Hemingway and others are looking at this possibility.

Secondly, what must one look at to confirm these models? The broken colour models require the associated production of colour at the primary vertex: here the analogy with strangeness is precise. Hence there must be colour in some of the other fragments, most likely the target fragments, and so the decays should be visible.

Some of these models predict negatively charged anomalons (note that these are not anti-nuclei, but Q=-1, positive baryon number states). If these could be seen, then it would seem most probable that the particle models are correct.

The basic need in this field is for some new experiments, preferably with techniques supplementing emulsions. There is some recent data from a propane bubble chamber experiment from Dubina[8] which is strongly suggestive that the effect is visible there. If the effect survives, then it could well be one of the seminal experiments of the 20th century. At the very least, it should teach us something about scientific method!

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7. W.C. McHarris and J.O. Rasmussen, Phys. Lettr. *120B*, 49 (1983)
8. J. Bogdonowicy, talk at 5th Nordic Meeting on High and Intermediate Energy Physics, Geilo, Norway (1983).

CANADIAN ASSOCIATION OF PHYSICISTS
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GIVEN NAMES .....

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From	To	University or College	Course	Highest Degree	Year Granted

RECENT EMPLOYMENT

From	To	Employer	Position held

REFERENCES Name, position or title, and address of a member of the CAP to whom the Membership Committee may refer with respect to your qualifications.

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2. **FOR AFFILIATE MEMBERSHIP ONLY**

Affiliate category applied for: ☐ a ☐ b ☐ c

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Expected date of graduation .....

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Applicants for student membership are required to obtain the signature of a sponsor to the following statement.

I hereby certify that the applicant is regularly enrolled as an undergraduate

student at .....

Name of sponsor (print) Signature of sponsor

_____

I hereby certify that the above statements are correct and enclose a cheque for $ ..... in payment of the membership fee for the first year.

Date ....
Signature of Applicant

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CANADIAN ASSOCIATION OF PHYSICISTS/ASSOCIATION CANADIENNE DES PHYSICIENS

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INFORMATION ON MEMBERSHIP AND FEES

The membership in the Association consists of:

- **Full members**, who shall be entitled to all the rights and privileges of the Association.
- **Affiliate members**, who shall be entitled to all the rights and privileges of the Association except the right to vote and to hold office, and who shall receive only such journals from the Association as may from time to time be decided by Council. Affiliates may, however, vote for and hold the office of Director of Affiliates.
- **Student members**, who shall be entitled to all the rights and privileges of the Association except the right to vote and to hold office, and who shall receive only such journals from the Association as may from time to time be decided by Council. Students may, however, vote for and hold the office of Student Director.
- **Coporate members**, who shall be entitled to all the rights and privileges of the Association. Any corporation, firm, institution, or individual interested in physics may apply for corporate membership and if elected by the Executive shall pay a minimum fee which shall be credited to the Educational Trust Fund.

ADMISSION TO MEMBERSHIP

- **Full members:** A person who holds a bachelor's degree in physics or a related subject, and who has a continuing interest in the area of physics, is eligible as a full member. Non-Canadian physicists permanently residing in Canada and Canadian physicists residing abroad are encouraged to become full members.
- **Affiliate members:** An applicant for membership may be admitted as an affiliate if
  (a) he does not fulfill the requirements as given above for "Full Members" but does possess a degree of Bachelor of Arts, Bachelor of Science or an equivalent degree or diploma from a recognized institution; or
  (b) he holds professional membership in an association acceptable for these purposes to the Membership Committee; or
  (c) he has such other qualifications as Council may from time to time decide.
- **Student members:** Only those who are registered as **undergraduate** students in a course leading to a bachelor's degree in physics or in a related subject are normally eligible as student members.
- **Corporate members:** Any corporation, firm, institution or individual interested in physics may apply for corporate membership. The membership fee is eligible for income tax deduction as a donation to the Educational Trust Fund.

JOINT MEMBERSHIP WITH THE CHEMICAL INSTITUTE OF CANADA

It is now possible for a member of the Canadian Association of Physicists to become a member of the Chemical Institute of Canada and pay a special combined fee. The fee payable by such persons is 70% of the total applicable fees for both organizations. For 1983 the joint fee will be $89.60.

If you are already a member of the CIC, please check the appropriate box on the application form, and remit the above amount.

If you are not a CIC member, but wish to take advantage of this new service, check the appropriate box, and remit the above amount.

MEMBERSHIP FEES

	Age 30 and over	Below age 30
Full members	$59.00	$29.50
Affiliate members	35.00	29.50
Student members	5.75	5.75
Corporate members (minimum — $150.00)	—	—
Full & Aff. members permanently residing outside Canada	29.50	29.50
Full-time graduate students (Full members)	29.50	29.50
Joint membership	89.60	89.60

The membership year starts on the first day of January. Membership fees are due at the beginning of the membership year. Members who have reached age 30 before the beginning of the membership year pay the fee for age 30 and over. Physics teachers joining as affiliate members will pay the reduced fee of $29.50 for the first year of membership in C.A.P., even if they are 30 years of age or older. Retired members over 65 years of age are eligible for membership at half fees.

SUBJECT DIVISIONS

Members may join specialized subject divisions by paying the corresponding fees. A member may join more than one Division. There are presently 11 subject divisions. The Division fees for student members are $1.00. The Division fees for full members and affiliate members are:

Division of Aeronomy and Space Physics	$5.00
Division of Atomic and Molecular Physics	5.00
Canadian Geophysical Union — A Joint Division of CAP/GAC	6.00
Division of Condensed Matter Physics	2.00
Division of Medical and Biological Physics	8.00
Division of Nuclear Physics	5.00
Division of Optical Physics	2.00
Division of Particle Physics	5.00*
Division of Physics Education	2.00
Division of Plasma Physics	2.00
Division of Theoretical Physics	2.00
Division of Industrial and Applied Physics	5.00
Division of Surface Science	5.00

*Student Members $2.50

LOCAL SECTIONS

The constitution makes provision for the formation of local sections within the Association. These geographically organized groups hold regular meetings. At present there is one local section in the Ottawa area which members living in this area may join without any additional fee.

EDUCATIONAL TRUST FUND

Members who wish to do so are invited to make donations to the Educational Trust Fund for the support of CAP educational activities. Official receipts will be sent for these tax exempt donations.

JOURNALS

	Regular Rate	Rate to Members
Canadian Journal of Physics	$ 45.00	$ 26.00
Canadian Journal of Earth Sciences	45.00	23.00
Contemporary Physics	—	106.00
Physics in Medicine and Biology*	312.50	56.50
The Physics Teacher	60.00	44.00
Quebec Science	23.00	21.00
Physics Today	70.00	44.00
Physical Review Letters	375.00	145.00
Medical Physics	—	85.00
Physics Bulletin	170.00	56.50
Physics Education	100.00	35.00
Physics in Technology	150.00	35.00
Physics in Canada: sent free of charge to all classes of members.	10.00	Free

*The Official Journal of the Division of Medical and Biological Physics.

CANADIAN ASSOCIATION OF PHYSICISTS
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1. **À ÊTRE REMPLIE PAR TOUS LES CANDIDATS**

Titre : ☐ Dr ☐ M ☐ Mme ☐ Mlle

NOM .....

PRÉNOMS .....

ADRESSE POSTALE .....

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ADRESSE PERMANENTE .....

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DATE DE NAISSANCE .....
jour mois année téléphone

LE CANDIDAT DEMANDE À ÊTRE ADMIS DANS LA CATÉGORIE DE

☐ membre titulaire ☐ membre affilié ☐ membre étudiant ☐ membre conjoint

FORMATION UNIVERSITAIRE

De	A	Université ou collège	Cours	Diplôme obtenu	Année

EMPLOIS RÉCENTS

De	A	Employeur	Poste ou titre

RÉFÉRENCES Nom, fonction ou titre, et adresse d'un membre de l'ACP auprès duquel le Comité d'admission peut s'enquérir de vos qualifications

.....

.....

2 **CANDIDATS AU GRADE DE MEMBRE AFFILIÉ SEULEMENT**

Catégorie de membre affilié : ☐ a ☐ b ☐ c

Veuillez spécifier .....

.....

INDIQUER LES PRINCIPALES ASSOCIATIONS SCIENTIFIQUES, TECHNIQUES OU PROFESSIONNELLES DONT VOUS ÊTES MEMBRE ET SPÉCIFIER LA CATÉGORIE DE MEMBRE À LAQUELLE VOUS APPARTENEZ

Nom de l'association	Date d'entrée	Catégorie de membre

3 **A L'INTENTION DES ÉTUDIANTS DE DEUXIÈME/TROISIÈME CYCLE** (membres titulaires)

Université fréquentée .....

Grade postulé .....

Date probable de l'obtention du diplôme .....

4 **A L'INTENTION DES ÉTUDIANTS DE PREMIER CYCLE**

Le Candidat demandant à être admis dans la catégorie de membre étudiant doit obtenir ci-dessous la signature d'un répondant

Je déclare par la présente que le candidat est régulièrement inscrit comme étudiant

de premier cycle à .....

.....

Nom du répondant (en lettres moulées) Signature du répondant

Je déclare par la présente que les déclarations ci-dessus sont exactes et j'inclus un chèque de $ ..... en paiement de la cotisation pour la première année.

Date ....

Signature du candidat

A l'usage du secrétariat

ASSOCIATION CANADIENNE DES PHYSICIENS/CANADIAN ASSOCIATION OF PHYSICISTS

151 Slater, Suite 805, Ottawa, Ontario K1P 5H3

INFORMATION CONCERNANT LES CATÉGORIES DE MEMBRES ET LES COTISATIONS

Les catégories de membres sont les suivantes :

- Les **membres titulaires** qui jouissent de tous les droits et privilèges de l'Association.
- Les **membres affiliés** qui jouissent de tous les droits et privilèges de l'Association, sauf qu'ils ne sont pas habilités à voter ou à occuper un poste. Ils peuvent toutefois élire le Directeur des membres affiliés ou être élus à ce poste. Ils reçoivent de l'Association les périodiques désignés de temps à autre par le Conseil.
- Les **membres étudiants** qui jouissent de tous les droits et privilèges de l'Association, sauf qu'ils ne sont pas habilités à voter ou à occuper un poste. Toutefois, ils peuvent élire le Directeur-étudiant ou être élus à ce poste. Ils reçoivent de l'Association les périodiques désignés de temps à autre par le Conseil.
- Les **membres corporatifs** qui jouissent de tous les droits et privilèges de l'Association. Toute corporation, société commerciale, institution ou personne intéressée à la physique peut demander de devenir membre corporatif et, si elle est agréée par l'Exécutif, elle devra payer une cotisation minimale qui sera versée au Fonds d'éducation.

LES CONDITIONS D'ADMISSION SONT LES SUIVANTES:

- **Membres titulaires :** Sont normalement admises comme membres titulaires seulement les personnes qui détiennent un baccalauréat en physique ou dans une discipline connexe et qui s'intéressent à la physique de façon continue. Les physiciens non canadiens qui demeurent au Canada de façon permanente et les physiciens canadiens qui demeurent à l'étranger sont invités à faire partie de l'Association à titre de membres titulaires.
- **Membres affiliés :** Un candidat peut devenir membre affilié s'il remplit l'une des conditions suivantes :
  (a) à défaut de satisfaire aux exigences énoncées à la Section 2, avoir un grade ou diplôme équivalent décerné par une université reconnue;
  (b) être membre d'une association professionnelle qui remplit les conditions exigées par le Comité d'admission;
  (c) satisfaire aux autres normes de compétence que le Conseil peut fixer de temps à autre.
- **Membres étudiants :** Sont admises comme membres étudiants seulement les personnes inscrites à un cours de **premier cycle** conduisant à un baccalauréat en physique ou dans une discipline connexe.
- **Membres corporatifs :** Toute entreprise, firme, institution ou individu qui s'intéresse à la physique peut soumettre une demande d'adhésion comme membre corporatif. La cotisation de membre corporatif peut être déduite au complet de l'impôt sur le revenu en tant que don au Fonds d'éducation de l'Association.

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Les membres de l'Association Canadienne des Physiciens peuvent maintenant s'inscrire à l'Institut de Chimie du Canada en payant une cotisation conjointe de 70% du total des cotisations des deux sociétés. En 1983 le coût de la cotisation conjointe est de $89.60.

Si vous êtes membre de l'ICC vous n'avez qu'à l'indiquer à l'endroit approprié sur la formule de cotisation et nous remettre le montant ci-haut mentionné.

Si vous n'êtes pas membre de l'ICC, veuillez l'indiquer sur la formule et nous remettre le montant ci-haut mentionné.

COTISATIONS DE MEMBRES

	30 ans et plus	Moins de 30 ans
Membres titulaires	$59.00	$29.50
Membres affiliés	35.00	29.50
Membres étudiants	5.75	5.75
Membres corporatifs (Minimum — $150.00)	—	—
Membres titulaires et affiliés demeurant à l'étranger	29.50	29.50
Étudiants post-grade à temps complet (membres titulaires)	29.50	29.50
Cotisation conjointe	89.60	89.60

Les cotisations annuelles sont dues le 1er janvier de chaque année. Ceux qui ont atteint l'âge de 30 ans avant le 1er janvier doivent payer la cotisation pour les membres âgés de 30 ans et plus. Les enseignants acceptés comme membres affiliés paieront la cotisation réduite de $29.50 la première année, même s'ils ont 30 ans et plus. A 65 ans les membres retraités peuvent profiter d'une réduction de 50% de la cotisation normale.

DIVISIONS

Les membres de toute catégorie peuvent faire partie des divisions spécialisés en versant les cotisations appropriées. Un membre peut appartenir à plus d'une division spécialisée. La cotisation de division est de $1.00 pour les membres étudiants. Les cotisations de division pour les membres titulaires et les membres affiliés sont les suivantes :

Division de l'aéronomie et de la physique de l'espace	$5.00
Division de la physique atomique et moléculaire	5.00
Union canadienne de géophysique — division conjointe de l'ACP/AGC	6.00
Division de la physique de la matière condensée	2.00
Division de la physique médicale et biologique	8.00
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Division de la physique des particules	5.00
Division de l'enseignement de la physique	2.00
Division de la physique des plasmas	2.00
Division de la physique théorique	2.00
Division de la physique industrielle et appliquée	5.00
Division de la science des surfaces	5.00

SECTIONS LOCALES

La constitution prévoit la formation de sections locales à l'intérieur des cadres de l'Association. Des groupes régionaux peuvent ainsi se réunir régulièrement. Actuellement il existe une section locale dans la région d'Ottawa, à laquelle les membres qui habitent cette région peuvent appartenir sans frais supplémentaires.

FONDS D'ÉDUCATION

Les membres qui le désirent peuvent verser un don au Fonds d'éducation et contribuer à l'appui des activités de l'ACP à caractère éducatif. Un reçu officiel sera envoyé pour les dons qui sont exempts de l'impôt.

PÉRIODIQUES

	Tarif régulier	Tarif réduit
Canadian Journal of Physics	$ 45.00	$ 26.00
Canadian Journal of Earth Sciences	45.00	23.00
Contemporary Physics	—	106.00
Physics in Medicine and Biology*	312.50	56.50
The Physics Teacher	60.00	44.00
Québec Science	23.00	21.00
Physics Today	70.00	44.00
Physical Review Letters	375.00	145.00
Medical Physics	—	85.00
Physics Bulletin	170.00	56.50
Physics Education	100.00	35.00
Physics in Technology	150.00	35.00
La physique au Canada: envoyé gratuitement aux membres	10.00	*gratis

*Le journal officiel de la Division de la physique médicale et biologique.

1983

Trends in Postgraduate Enrollments in Physics at Canadian Universities

by Gordon Rostoker and Patricia Campbell, University of Alberta

After a gradual approach to stability in numbers of physics graduate students and postdoctoral researchers in temporary positions, this year's statistics reflect a significant change. While the numbers of degrees granted last year at both the M.Sc. and Ph.D. level are virtually unchanged, the number of M.Sc. students has jumped by ~9% while the number of Ph.D. students has increased by ~8%. However, it is worth noting that the percentage of the graduate population in Canadian physics programs constituted by visa students has increased sharply from ~11.9% last year to ~14.4% this year. This represents an increase of 28 students which is a not inconsequential part of the total increase of 86 students in Canadian physics programs. Thus, while the participation rate of Canadian students has increased, it is not a substantive increase (being ~6%).

A second important change has been a large jump in the number of postdoctoral researchers employed at Canadian universities. Part of this increase can be attributed to the increased number of NSERC URF's (which now total 34 across Canada in the various disciplines of physics including astrophysics). Perhaps the changes here might be put into perspective by noting that, prior to the introduction of the NSERC program, there were 273 postdoctoral researchers in physics departments at Canadian universities. In addition to the NSERC Fellows, there are now 288 postdoctoral researchers which represents a slight increase in numbers independent of the NSERC URF program. Nonetheless the increase in young researchers is bound to have a positive effect on the research activities carried out in Canadian universities. It is possible that the dramatic changes in the Canadian economy have had some influence on the number of Canadians staying in universities as graduate students or in a postdoctoral capacity. Precisely what effect the economy is having on the participation rate is difficult to assess at the present time so that it is not possible to project what effect this year's increased number of M.Sc. students and postdoctoral researchers will have in the long term.

Finally, we note that there is a small increase in the number of undergraduate students in the final year of their physics program (398 this year compared to 377 last year). There has apparently been a large increase in university enrollments across Canada this year but this will take another three years to work its way through the undergraduate system. Thus it will not be until the 1985-86 period that we will learn if the increased participation rate in universities will be reflected in an increased supply of young Canadians capable of carrying out graduate work in physics.

STUDENTS IN AND GRADUATES FROM POSTGRADUATE PROGRAMS IN PHYSICS ACROSS CANADA 1981 - 1983

	Students Enrolled 1981-82		Students Enrolled 1982-83		Degrees Granted Last Year		PDR's and RA's 1981-82	PDR's and RA's 1982-83
	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.		
TOTAL	523	483	570	523	165	85	279	323.5[d]
Breakdown by Region								
Maritimes	31	5	35	7	8	0	12	14
Quebec	114	108	134	109	33	18	48	68
Ontario	225	252	242	280	84	44	96	116.5
West	153	118	159	127	40	23	123	125
Breakdown by Field								
Theoretical	73	66	56	81	22	12	45	59
Condensed Matter (formerly LTSS)	94	84	105	104	30	11	56	56
Nuclear and Particle Physics	69	74	72	73	14	12	70	70
Biophysics[a]	28	28	29	27	6	6	9	6
Geophysics[b]	53	31	52	25	21	11	18	19.5
Astrophysics and Astronomy[c]	54	35	55	48	18	6	18	21
Aeronomy, Space and Atmospheric	26	36	42	33	6	4	13	18
Plasmas	11	11	12	9	3	4	12	10
Optics	21	25	22	24	9	5	7	18
Atomic and Molecular	46	63	51	58	17	8	17	32
Others	48	30	74	41	18	6	14	14

[a]Includes only cases where these subject areas are dealt with in physics departments plus Department of Biophysics at University of Western Ontario

[b]Includes only cases where these subject areas are dealt with in physics departments plus the Department of Geophysics and Astronomy at UBC, and Department of Geophysics at University of Western Ontario

[c]Includes only cases where these subject areas are dealt with in physics departments plus Department of Geophysics and Astronomy at UBC, and Departments of Astronomy at Toronto, Western Ontario and St. Mary's

[d]Includes 34 NSERC University Research Fellows

News/Nouvelles

ORDER OF CANADA TO B.P. STOICHEFF

The investiture of Professor Boris P. Stoicheff, Vice President of CAP and Professor of Physics, University of Toronto, as Officer of the Order of Canada was announced in the recent Governor General's List.

SUMMER INSTITUTE IN THEORETICAL PHYSICS
Queen's University, July 18 - August 15, 1983

The Theoretical Physics Division of the CAP has launched a program of Summer Institutes in Theoretical Physics. The 1983 Institute has been made possible through the support of NSERC and Queen's University. The purpose of the Institute is to provide a working environment for theoretical (and some experimental) physicists from Canada and other countries. Computational and secretarial facilities will be available. Scientists may bring research fellows or advanced graduate students. It is intended that the Institute will promote work on problems of current and common interest and stimulate collaboration with the U.S., European and other scientists in residence.

A National Advisory Committee has been formed under the chairmanship of Jules Carbotte (McMaster).

The first Summer Institute will be held next summer (July 18 - August 15, 1983) at the Donald Gordon Centre, on the campus of Queen's University in Kingston. Two topics have been chosen:

Session 1		**Session 2**	
Collective Excitations in Nuclei		**Fundamental Aspects of Density Functional Theory**	
July 18 - August 1, 1983		August 2 - August 15, 1983	
M. Rho	(Saclay)	V. Von Barth	(Lund, Sweden)
G.R. Satchler	(Oak Ridge)	A. Zunger	(SERI, Colorado)
H. Lipkin	(Fermi Lab.)	J. Harris	(Jülich)
C. Mahaux	(Liege)	D. Langreth	(Rutgers)
J.M. Irvine	(Manchester)	J. Perdew	(Tulane)
L. Zamick	(Rutgers)	M. Levy	(Tulane)
		M. Rasolt	(Oak Ridge)
		A. Williams	(IBM)

To attend the Institute please write to Dr. B. Castel, for Session 1, or Dr. E. Zaremba, for Session 2, Physics Department, Queen's University, Kingston, K7L 3N6, Ontario, Canada. Early applications will be appreciated in view of the demands on office and residential space.

SCIENTIFIC EXCHANGE PROGRAM WITH THE ROYAL SOCIETY OF LONDON

In August 1982, the Royal Society of London and NSERC signed a Memorandum of Understanding on scientific cooperation to promote visits of selected candidates in the natural sciences and engineering disciplines. These visits will enable the participants from both countries to engage in productive interchanges and collaboration with colleagues.

The new program with the Royal Society will come into effect in April 1983 and will provide support for up to 20 participants annually in each direction. Candidates selected for such exchanges must have established prior contact with the host scientist(s) and have agreed upon a specific scientific activity or research project to be undertaken, as well as a suitable period and duration for the visit in the other country.

The cooperation with the Royal Society raises to five the number of bilateral exchange programs between NSERC and corresponding organizations in other countries. For a list of these organizations and general description of the exchange programs, as well as eligibility and application procedures, the reader is referred to the NSERC Awards Guide 1983-84, page 58.

For further information on this new exchange program, please contact Dr. Alfred Kugler at (613) 993-9681.

PROGRAMME D'ÉCHANGES SCIENTIFIQUES AVEC LA ROYAL SOCIETY OF LONDON

En août 1982, la Royal Society of London et le CRSNG ont signé une entente sur la coopération scientifique afin de favoriser les échanges entre des candidats choisis dans les disciplines des sciences naturelles et du génie. Ces visites permettront aux participants des deux pays de collaborer avec leurs collègues et d'entreprendre des échanges productifs.

Ce nouveau programme avec la Royal Society entrera en vigueur en avril 1983 et, chaque année, 20 chercheurs de chacun des pays pourront en bénéficier. Les candidats choisis devront préalablement avoir pris contact avec le ou les chercheurs qui les accueilleront afin de déterminer l'activité scientifique ou le projet de recherche collectif ainsi que le moment et la durée de la visite dans l'autre pays.

Cette coopération avec la Royal Society porte à cinq les programmes d'échanges bilatéraux entre le CRSNG et des organismes semblables d'autres pays. Le Guide des subventions 1983-84 donne à la page 58 la liste de ces organismes et une description générale des programmes d'échanges, des critères d'admissibilité et des modalités de demande.

Si vous désirez obtenir plus de renseignements sur ce nouveau programme d'échanges, veuillez appeler le Dr Alfred Kugler au (613) 993-9681.

DIAP COMPETITION FOR YOUNG PHYSICISTS

The Division of Industrial and Applied Physics of the Canadian Association of Physicists, in order to publicize and promote innovative applications of physics by young physicists in universities, industries, research and development organizations, will invite selected young physicists to present their achievements at the division meeting during the Canadian Association of Physicists Annual congress. The first competition is being started this year for speaking at the forthcoming congress in Victoria, British Columbia, at the end of June. All selected speakers will be given a small cash prize. Their names will appear in Physics in Canada with a description of their accomplishment. The guidelines which will apply to this competition have been sent to all physics department chairmen, industries which are members of the CAP and a few other R & D organizations. For further information, contact the division chairman:

La Division de physique industrielle et appliquée de l'Association canadienne des physiciens, afin de promouvoir l'innovation par de jeunes physiciens(nes) dans les universités, les industries, les centres de recherche et développement, se propose de sélectionner quelques jeunes physiciens(nes) et de les inviter à présenter leur réalisation à la réunion de la division, dans le cadre du congrès annuel de l'Association canadienne des physiciens. Le concours est ouvert la première fois cette année pour le prochain congrès qui se tiendra à la fin juin à Victoria, Colombie Britannique. Un prix modeste en argent sera attribué aux conférenciers sélectionnés et leurs noms apparaîtront dans La Physique au Canada avec la description de leur réalisation. Les règles qui s'appliqueront à ce concours ont été envoyés à tous les directeurs de départements de physique, les compagnies membres de l'ACP et quelques autres organisations de R & D. Pour plus d'information, contacter le président de la division :

J.-P. Monchalin
Industrial Materials Research Institute/
Institut de génie des matériaux
750 Bel-Air
Montréal, Québec H4C 2K3

Tel: (514) 935-8513

NEW APPOINTMENT AND NEW LOCATION

Frank Snape, Ph.D. has recently been appointed President of Radionics Scientific Inc. This follows the recent acquisition of Radionics from Canada Wire and Cable Company Limited, by a group of investors headed by Dr. Snape.

Dr. Snape has ten years experience in the Sales/Marketing of high-technology instrumentation to Universities, Governments, and Industry. For the past two and a half years he was employed by the Federal Government in Ottawa, most recently as Director General — Technology for Public Works Canada.

Dr. Snape is located at the Company's new Head Office, 585 Canarctic Drive, Downsview, Ontario M3J 2P9.

CANADIAN METAL PHYSICS MEDAL

The 1983 award for distinguished service to Metal Physics in Canada has been won by John J. Jonas, McGill University.

Nominations for future winners, signed by a minimum of two sponsors and accompanied by a current curriculum vitae of the nominee should be sent to:

T.S. Hutchison,
Professor of Physics
Royal Military College of Canada
Kingston, Ontario K7L 2W3

ICSMA 7 IN MONTREAL IN 1985

Montreal has been chosen as host of the Seventh International Conference on the Strength of Metals and Alloys, which will be held in 1985 August 12 - 16. The traditional theme of ICSMA, the sixth of which was held in Melbourne, Australia in August 1982, remains the relationships between the microstructure, the mechanical properties and the fabrication procedures.

The organization of ICSMA 7 is undertaken by Montreal's three Faculties of Engineering, Concordia University, Ecole Polytechnique and McGill University, and by the Canadian Committee for Research on the Strength and Fracture of Materials. Sponsorship also includes the Materials Engineering Committee of the Metallurgical Society of the CIM and the Canadian Council of the ASM. Further information about ICSMA 7 may be obtained from:

H.J. McQueen
Chairman — ICSMA 7
Prof., Mechanical Engineering
Concordia University
Montreal, P.Q. H3G 1M8
Canada

ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN CANADA

On February 8, 1983, the AASC received legal recognition of its existance by the Minister of Consumer & Corporate Affairs.

At its Annual General Meeting on November 29, 1982, the members of SCITEC initiated a dramatic change by voting to focus the organization's efforts on fostering an understanding of the significance of science, technology and engineering to Canadian Society. The re-oriented organization also adopted a new name: The Association for the Advancement of Science in Canada (AASC).

The new name was adopted by members on the understanding it would be interpreted as implying the advancement of human welfare through the intelligent application of science, engineering and technology. The AASC will encourage the active participation of the Canadian public in the consideration of scientific and technological issues having social and economic implications.

Further information may be obtained from the AASC National Office, 805-151 Slater Street, Ottawa, Ont. K1P 5H3

Canadian Physicists
Physiciens canadiens

AT THE UNIVERSITY OF ALBERTA . . . Members of the department on leave during 1982-83 are Dr. M.E. Evans (Centre Géologique et Géophysique, Montpellier, France), Dr. W.K. Dawson (TRIUMF) and Dr. H.J. Kreuzer (Dalhousie).

Effective July 1st, 1982, Drs. D.P. Hube and J.A. Kernahan were promoted to Professor.

New Post-Doctoral Fellows and/or Research Associates this year include Dr. P. Meenakshi Raja Rao (Bhabha Atomic Research Centre, Bombay) working with the Astrophysics group; Dr. M. Araki (Osaka University), Dr. Y. Nakano (Kyushu University), Dr. C.C. Wright (Australian National University) and Dr. M.A. Schweizer (University of Zurich) at the Theoretical Institute; Dr. C. Yonge (McMaster) in the Institute of Earth and Planetary Physics; Dr. A. Rastogi (National Physical Laboratory, New Delhi) in the Low Temperature and Solid State group; and Dr. C.A. Davis (U. of Wisconsin) working with the TRIUMF group of the Nuclear Research Centre.

Long-term visitors to the department include Dr. J.A. Majorowicz (Geophysics Institute, Warsaw) in the Institute of Earth and Planetary Physics.

AT THE UNIVERSITY OF BRITISH COLUMBIA . . . David Llewelyn Williams has been appointed Head for a 5-year term, effective July 1, 1982. Bill Unruh was chosen by the Royal Society of Canada to receive the 1982 award of the Rutherford Memorial Medal in Physics. Irving Ozier has been awarded a U.B.C. Izaak Walton Killam Memorial Senior Fellowship for 1982/83 and is spending his sabbatical year at the Herzberg Institute of Astrophysics at N.R.C. John Eldridge has received a commemorative scroll as one of the authors of the best condensed matter physics paper published in the Canadian Journal of Physics in 1981. Dr. Frances Bates, a Research Associate in the Dept. of Physics was co-author of the paper. Mr. Lorne Whitehead, a Research Associate has been awarded the Edwin Guth Memorial Lighting Design Special Citation by the Illuminating Engineering Society of North America. Mr. Whitehead has developed a system for illuminating hazardous areas with light brought into the area through a reflecting light-pipe.

Recently returned from sabbatical is John Berlinsky, who spent the past year at M.I.T. John was also the recipient of a U.B.C. Isaak Walton Killam Memorial Fellowship for 1981-82. H.P. Gush has recently returned from visits to both the Dept. of Physics at the University of Cologne and the Institute for Extraterrestrial Studies at the Max Planck Institute in Garching, West Germany. He is carrying out collaborative research work in the area of molecular physics with both institutions. Currently on sabbatical are Ed. Auld (CERN - Geneva), Jesse Brewer (S.I.N. - Switzerland and K.E.K. - Japan), Frank Curzon (Vortek - Vancouver), Garth Jones (TRIUMF), and Irving Ozier (N.R.C. - Ottawa).

AT THE UNIVERSITY OF GUELPH . . . Professor J.L. Campbell has returned from a year's sabbatical with the nuclear microprobe group at the Harwell Laboratories of the UKAEA. While in Britain he received the degree of Doctor of Science from the University of Glasgow.

A current visitor is Professor R.H. Dalitz, F.R.S., Royal Society Research Professor, Oxford University. He is visiting Guelph from March 28 to April 2 and McMaster from April 3 to April 8, and is giving a number of talks at both institutions.

AT THE UNIVERSITY OF TORONTO . . . Professor R. List has been appointed Deputy Secretary-General of the World Meteorological Organization.

Calendar/Calendrier

9TH CANADIAN SEMINAR ON SURFACES, 23-24 June 1983, Vancouver, B.C. Canada

For further information contact:

Dr. Keith Mitchell
Surface Canada 83
Department of Chemistry
University of British Columbia
Vancouver, B.C. V6T 1Y6

This meeting is sponsored by the Joint CAP/CIC Division of Surface Science, and is being held immediately before the CAP Congress in Victoria.

WORKSHOP ON TIME PROJECTION CHAMBERS and experiments based on TPC's will be held at TRIUMF on June 23-25, 1983. Speakers will include representatives of nearly all groups in the world with operating or major plans for TPC's.

For further information contact either Co-Chairman of the Organizing Committee:

J.A. MacDonald
TRIUMF, 4004 Wesbrook Mall
Vancouver, B.C. V6T 2A3

or

E.P. Hincks
Department of Physics
Carleton University
Ottawa, Ontario K1A 5B6

Books Received/Livres reçus

Les livres suivants nous sont parvenus pour la critique qui peut être faite en anglais ou en français. Si vous êtes intéressé à nous communiquer une revue critique sur un ouvrage en particulier, vous êtes invité à vous mettre en rapport avec le rédacteur responsable de la critique des livres, J.P. Svenne, Department de Physique, Université du Manitoba, Winnipeg, Manitoba, R3T 2N2, téléphone (204) 474-9856.

00 General

More Random Walks in Science, R.L. Weber, ed., Heyden & Son, Inc., 1982; pp. xv + 208. Price: U.S. $19.50.

The Historical Development of Quantum Theory, Volume 1, Parts 1 and 2, by J. Mehra and H. Rechenberg. Springer-Verlag, 1982; pp. xlvii + 878.

Nuclear Energy, Nuclear Weapons Proliferations and the Arms Race. Symposium by the Forum on Physics and Society of the APS, Jan. 26, 1982, San Francisco. J. Hollander, Ed. A.A.P.T., 1982, CONF; pp. vi + 48. Price: $3.00

Non-Relativistic Quantum Electrodynamics, by W.P. Healy. Academic Press, 1982; pp. viii + 191. Price £22.00

General Relativity and Matter, by M. Sachs. D. Reidel, 1982; pp. xx + 208. Price: U.S. $39.00

Classical Fields: General Relativity and Gauge Theory, by M. Carmeli. John Wiley & Sons, 1982; pp. xvii + 650. Price: U.S. $44.95

10 Elementary Particles and Fields

Gauge Theories as a Problem of Constructive Quantum Field Theory and Statistical Mechanics, by E. Seiler. Springer-Verlag, 1982; pp. v + 192. Price: U.S. $9.40 (paper)

An Introduction to Gauge Theories and the "New Physics", by E. Leader and E. Predazzi. Cambridge University Press, 1982; pp. xiv + 498. Price: U.S. $65.00 (cloth) $27.50 (paper)

An Informal Introduction to Gauge Field Theories, by I.J.R. Aitchison. Cambridge University Press, 1982; pp. ix + 174. Price: U.S. $22.50.

Fundamental Interactions. Proceedings of the NATO Advanced Summer Institute, Cargèse, France, July 1981. M. Levy, J.-L. Basdevant, D. Speiser, J. Weyers, M. Jacob and R. Gastmans,eds. Plenum Press, 1982, CONF: pp. xvi + 696. Price: U.S. $89.50.

28 Nuclear Engineering and Nuclear Power Studies

Energy Reviews: Nuclear Power Systems, Vol. 1 L.A. Melentiev, ed. Soviet Technology Reviews (Harwood Academic Publishers) 1982; pp. ix + 334. Price: U.S. $175.00

A Plutonium Recycling Scenario in Light Water Reactors. Report of the Commission of European Communities. E.E.C., eds. Harwood Academic Publishers, 1982; pp. iv + 167+appendices. Price: U.S. $29.50.

Research and Development on Radioactive Waste Management and Storage. First annual Progress Report of the European Community Programme 1980-84. E.E.C., eds. (S. Orlowski, Foreword). Harwood Academic Publishers, 1982; pp. 129. Price: U.S. $19.75

Actinide Recovery from Waste and Low-Grade Sources. Proceedings of the International Symposium, New York, Aug. 1981. J.D. Navratil, W.W. Schulz and A.E. Talbot, eds. Harwood Academic Publishers, 1982, CONF; pp. xiii + 386. Price: U.S. $63.50.

30 Atomic and Molecular Physics

Applied Atomic Collision Physics. Vol. 3: Gas Lasers E.W. McDaniel and W.L. Nighan, eds. Academic Press, 1982; pp. xiii + 469. Price: U.S. $67.00

Molecular Dynamics, by M. Evans, G.J. Evans, W.T. Coffey and P. Grigolini. John Wiley & Sons, 1982; pp. xxvi + 866. Price: U.S. $115.00

40 Classical Areas of Phenomenology

Physics Demonstration Experiments at William Jewell College, by W.A. Hilton, A.A.P.T., 1982; pp. ix + 104. Price: U.S. $7.50

Similarities in Physics, by J.N. Shive and R.L. Weber. John Wiley & Sons, 1982; pp. xiii + 277. Price: U.S. $27.95

Color and Color Vision. Selected Reprints. P.L. Pease, Ed. American Assoc. of Physics Teachers, 1982; pp. 129. Price: U.S. $4.00 (paper).

Color Science, 2nd Ed., by G. Wyszecki and W.S. Stiles. John Wiley & Sons, 1982; pp. xv + 950. Price: U.S. $75.00

Lasers. Selected Reprints, D.C. O'Shea and D.C.Peckham, eds. American Assoc. of Physics Teachers, 1982; pp. 139. Price: U.S. $4.00 (paper)

Waves and Photons: An Introduction to Quantum Optics, by E. Goldin. John Wiley & Sons, 1982; pp. xi + 211. Price: U.S. $25.95.

Energy: Its Physical Impact on the Environment, by D.W. Devins. John Wiley and Sons, 1982; pp. xii + 572. Price: U.S. $32.95.

Traceable Temperatures, by J. V. Nicholas and D.R. White. DSIR Science Information Division (N.Z.), 1982; pp. 226. Price: N.Z. $18.50

Dynamics - The Geometry of Behavior. Part 1: Periodic Behavior. Vol. 1 of the Visual Mathematics Library, by R.H. Abraham and C.D. Shaw. Aerial Press, 1982; pp. x + 220. Price: U.S. $25.00 (paper).

50 Fluids, Plasmas and Electric Discharges

Equilibrium Properties of Fluid Mixtures: 2, by M.J. Hiza, A.J. Kidnay and R.C. Miller. Plenum Press, 1982; pp. vii + 246. Price: U.S. $115.00

Mécanique des Fluides Incompressibles, par J.S. Darrozes et C. François. Springer-Verlag, 1982; pp. xvii + 461. Price: U.S. $18.80 (paper).

Unconventional Approaches to Fusion. Proceedings of the International School of Fusion Reactor Technology, Erice, Italy, March 1981. B. Brunelli and G.G. Leotta, eds. Plenum Press, 1982, CONF; pp. xvii + 526. Price: U.S. $65.00

International Tokamak Reactor: Phase One. Report of the International Tokamak Reactor Workshops 1980-81, Vienna. INTOR Group, eds. I.A.E.A., 1982. CONF; pp. 860.

60/70 Condensed Matter

Electromagnetic Surface Modes. A.D. Boardman, ed. John Wiley & Sons, 1982; pp. x + 776. Price: U.S. $83.00

Interfacial Aspects of Phase Transformations. Proceedings of the NATO Advanced Study Institute, Erice, Italy, Aug-Sept. 1981. B. Mutaftschiev, ed. D. Reidel, 1982, CONF; pp. x + 708. Price: U.S. $79.00

Chemistry and Physics of Solid Surfaces IV. Proceedings of the International Summer Institute in Surface Science, Milwaukee, Jan. 1982. R. Vanselow and R. Howe, eds. Springer-Verlag, 1982, CONF; pp. xiii + 496. Price: U.S. $44.00

Molecular Crystals and Liquid Crystals, Parts A-F. Proceedings of the International Conference on Low-Dimensional Conductors, Boulder, Colo. Aug, 1981. A.J. Epstein and E.M. Conwell, eds. Gordon & Breach 1981, CONF; 6 vols, approx. 350 pp/vol. Price: U.S. $620.00 (set).

High-Temperature Superconductivity. V.L. Ginzburg and D. A. Kirzhnits, eds. (tr. by A.K. Agyei and J.L.Birman). Consultants Bureau (Plenum Press), 1982; pp. xv + 364. Price: U.S. $55.00

80 Cross Disciplinary Physics

Chemical and Biological Generation of Excited States. W. Adam and C. Cilento, eds. Academic Press, 1982; pp. xi + 388. Price: U.S. $59.50.

Operations Manual for Machine Tool Technology, by C. Oliver. John Wiley & Sons, 1982; pp. 222. Price: U.S. $15.95

VLSI Electronics: Microstructure Science. Vol. 5 N.G. Einspruch, ed. Academic Press, 1982; pp. xii + 404. Price: U.S. $54.00

Intense Charged Particle Beams, by R.B. Miller. Plenum Press, 1982; pp. x + 351. Price: U.S. $45.00

Optics in Biomedical Sciences. Proceedings of the International Conference, Graz, Austria, Sept. 1981. G. von Bally and P. Greguss, eds. Springer-Verlag, 1982, CONF; pp. x + 274. Price: U.S. $37.00

90 Geophysics, Astronomy and Astrophysics

LANDOLT-BÖRNSTEIN, New Series, Group V, Vol. 1 Physical Properties of Rocks, subvol. b. G. Angenheister, ed. Springer-Verlag, 1982; pp. xix + 604. Price: approx. U.S. $400.40

Physics of Stellar Evolution and Cosmology, by H.S. Goldberg and M.D. Scadron. Gordon & Breach, 1981; pp. xiv + 390. Price: U.S. $59.50

Heterogeneous Atmospheric Chemistry. Proceedings of the Conference on Multiphase Processes, June-July, 1981, Albany, N.Y. D.R. Schryer, Ed. American Geophysical Union, 1982, CONF; pp v + 274.

Artificial Particle Beams in Space Plasma Studies. Proceedings of the NATO Advanced Study Institute, Geilo, Norway, April 1981. B. Grandal, ed. Plenum Press, 1982, CONF; pp. xviii + 704. Price: U.S. $85.00

Book Reviews/ Critiques des livres

MATHEMATICAL METHODS FOR MATHEMATICIANS, PHYSICAL SCIENTISTS AND ENGINEERS, by J. Dunning-Davies. John Wiley & Sons 1982; pp. 416. Price: U.S. $57.95 (cloth), Can. $24.00 (paper).

Some textbooks -- like some foods -- do become staple items. Books on methematical methods have become such staples in the menu of instructional and reference texts for the scientist.

The need for a convenient listing of well-proven mathematical tools for the practicing physicist, engineer, and applied mathematician would appear to be of some age but it seems it was not generally met until the 2-volume Courant and Hilbert Methoden der Mathematischen Physik appeared in 1937. Worthy followers of this pioneering accomplishment soon appeared; among the more widely used were the von Karmen and Biot Mathemetical Methods in Engineering (1940). Morse and Feshbach Methods of Theoretical Physics (1953) and the Courant-Hilbert translation in 1962. Presently, any university library probably contains scores of books of this subject with most published during the past 2 or 3 decades.

Dunning-Davies' book Mathematical Methods for Mathematicans, Physical Scientists and Engineers is a 400 page, flexi-cover bound (available also in hard-cover), type-set book designed for the undergraduate student at the 2nd or 3rd year level. Algebra, trigonomentry and geometry are assumed. The subjects treated are functions of one and several variables, differentiation/integration, matrix and vector algebra, ordinary and partial differential equations, algebraic and Fourier series, special function as well as tensors. Examples of problems solved are spread throughout the text and exercises are listed at the end of each chapter.

Not treated in the book are topics of statistics, numerical methods, extremal considerations, and transform methods. Though the notation is generally conventional there are some exceptions such as $j = \sqrt{-1}$ and some variations in the placement of limits of integration. The type set is generally clear with bold type used for vectors and emphasis.

Dunning-Davies brings to the subject a rather compact style of exposition. It is for this reason that he is able to cover much ground with an economy of words and pages. The beneficiary will be the student who cannot afford expensive multi-volume books on the subject.

An undesirable pedagogical deficiency of the book -- though understandable in view of the page count -- is the absence of any description of the source of many of the equations; if used as an instructional text, the teacher would well need to supplement this deficiency. On the other hand, the compact style of describing mathematical methods should render the book most effective for review purposes.

On balance, the rising cost of textbooks and the need for compact reference-review material suggests that the book would be a useful item in the diet of both students and practitioners in the physical sciences.

A.A. Harms,
Department of Physics and
Engineering Physics
McMaster University

AN INTRODUCTION TO ERROR ANALYSIS: The study of uncertainties in physical measurements, by John R. Taylor. University Science Books, 1982.(20 Edgehill Road, Mill Valley, California 94941); pp. xx + 270. Price: U.S. $15.00 (cloth), U.S. $9.50 (paper).

The cover designer of this book is to be congratulated for making it attention-grabbing, and for injecting a note of humour into what many students find an otherwise dull subject. The cover contains a photograph of a steam locomotive hanging from the upper half of Montparnasse railway station, the train driver having obviously committed a significant error in failing to stop. Any possible confusion of the scientific term "error" with its more general meaning of "blunder" or "mistake" is quickly dispelled by the subtitle, the preface and the introductory chapter, where the author very lucidly explains, using simple everyday examples, the nature and origin of uncertainties in physical measurements.

Chapter 2 continues in a philosophic, non-mathematical way to describe what we mean, for example, by $T = 2.4 \pm 0.1$ seconds; the significance (and, in this age of pocket calculators, non-significance) of Significant Figures; deciding if two measured values are in agreement; error bars on graphs; absolute and fractional (percent) error and approximate methods of error propagation through sums, differences and products.

Chapter 3 delves more deeply into error propagation, examining the concepts of dependent, independent and random uncertainties, and introduces the more precise method of adding errors in quadrature. Halfway through this chapter, when confronted with the problem of estimating the error in sines, cosines, square roots etc., we are, reluctantly it almost seems, introducted to the use of differential calculus, and a general formula for error propagation is developed.

The college physics students, at whom this book is primarily aimed should have no difficulty here. Indeed, many of them may find the early material somewhat belaboured, but this is surely no crime in an introductory textbook.

Others, such as the surprising (to me) number of laboratory technicians who have managed to avoid exposure to elementary calculus, will experience increasing difficulty from this point on, but may skip the derivations and accept the final results on faith.

Chapters 4 and 5 cover the statistical analysis of random uncertainties, including mean and standard deviation, the Normal Distribution and confidence limits. Considerable effort is devoted to promoting an understanding of the material with the use of simple examples and actual numbers, as well as deriving necessary formulae.

Chapters 6 to 12 comprise Part II of the book and are short independent chapters dealing with specific and more advanced topics that the more "serious" student is bound to meet sooner or later. The topics are: rejection of data, weighted averages, least squares fitting, covariance and correlation, the Binomial Distribution, the Poisson Distribution and the χ^2 Test. The treatment is excellent, but necessarily limited. The chapter on least squares, for example, only extends as far as the linear parameter problem for equally weighted data points, with the usual linear transform technique described for the important case of exponential functions.

Each chapter in the book ends with a problem set with selected answers at the back. Throughout the text, important results are highlighted by a grey background, and the inside covers contain a summary of the principal formulae arranged in order of chapter.

The author has admirably achieved his objective of producing a text for an introductory course in error analysis, which can also be used as a useful refresher/reference book for more "mature" students, and as a prelude to more advanced texts such as Bevington's popular book.

Wes Spiers,
Toronto General Hospital

NON-RELATIVISTIC QUANTUM DYNAMICS, by W.O. Amrein. D. Reidel Publishing Co., 1981; pp. viii + 237. Price: U.S. $34.50 (paper).

This self-contained volume presents some new methods of approaching the spectral and scattering theories for Schrödinger operators from a time-dependent framework. The methodology and mathematical argumentation presented by Professor Amrein are a welcome complement to mainstream treatises whose derivations of the spectral/scattering theories of operators follow the stationary point of view and make extensive use of the spectral theorem and resolvent estimates.

The lucidity of the exposition combined with the inherent simplicity of these new time-dependent arguments bring this volume in Mathematical Physics closer to the realm of physical intuition. The reader is given the opportunity to examine the physics underlying the numerous mathematical theorems concerning the time evolution of quantum states in configuration space.

This book has been used by Professor Amrein in an advanced undergraduate course in Mathematical Physics. I would suggest that it is also very appropriate for beginning graduate students and theoretical researchers with a strong background in continuous unitary one-parameter groups, although the text is self-explanatory in many respects. The first three of the six chapters introduce and develop the basic mathematical tools, namely Hilbert space operators and operator calculus in Chapter 1, self-adjoint operators and Schrödinger operators in Chapter 2, and Hilbert-Schmidt and compact oeprators in Chapter 3. Chapter 4 is a complete description of Evolution Groups, essentially focussed on a discussion of strongly continuous unitary one-parameter groups. Chapter 5 contains the asymptotic properties of such groups with a description of operator existence and completeness conditions. This discussion leads directly to some useful results on wave operators and spectral theory. For the interest of the theoretician it should be noted that, in contrast to stationary methods, the present time-dependent treatment avoids the spectral theorem completely. Chapter 6 introduces basic concepts from Scattering Theory, notably scattering operators and the S-Matrix, as well as a brief but clear discussion on scattering cross-sections.

Overall, the book is primarily recommended to those with a sound basic knowledge in Mathematical Physics who are actively involved in non-relativistic quantum theory or as a reference book.

A. Mandelis
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Relativity theory for everyman:

WHAT IS THE THEORY OF RELATIVITY, by L. Landau and Yu. Rumer (tr. by A. Zdornykh). Mir Publishers,* 1976; pp. 61. Price: $1.20

DISCOVERING RELATIVITY FOR YOURSELF, by Sam Lilley. Cambridge University Press, 1981; pp. xi + 425. Price: U.S. $49.50 (cloth), $19.95 (paper).

UNDERSTANDING THE SPACE-TIME CONCEPTS OF SPECIAL RELATIVITY, by A. Evett. John Wiley & Sons, 1982; pp. x + 162. Price: U.S. $19.95.

These three books all attempt to teach relativity theory to the layman -- people with little or no background in physics or mathematics. That is the only thing they have in common. The book by Landau and Rumer is very small and qualitative, that of Lilley very ambitious in that it also includes general relativity and takes an original approach, the Evett book is the most conventional of the three. However all three make a significant contribution towards explaining relativity theory to the average reasonably intelligent reader.

The book by Landau and Rumer is not a new book; its first printing was in 1961. It is very small -- little more than a pamphlet, yet it packs into a small space a reasonably complete qualitative description of what

the special theory of relativity is all about. It seems to be quite successful in "de-mystifying" the field, by using illustrations of other commonplace situations where our senses can deceive us, and by putting the specifically relativistic consequences in an everyday context (a Russian one, however). The use of mathematics is very minimal, being confined only to simple arithmetical calculations, and even in these the numbers have been chosen so that the calculations can be done mentally. A further help are the clear, simple and often amusing cartoons used to illustrate the book. The translation is reasonably good, with only the occasional awkward construction or misuse of articles. Occasionally, however, in their effort to simplify, the authors make some incorrect statements. The most glaring example is in the discussion of the twin paradox, where they have one twin travelling on a large circular railway track, ignoring the fact that the frame of reference is not an inertial one, so is beyond the scope of special relativity.

*Books published by Mir Publishers were reviewed also in the September 1982 and January 1983 issues. Canadian distributors for Mir Publishers (Moscow) are Progress Books, 71 Bathurst Street, Toronto, Ont. M5V 2P6.

The book by Lilley is much more ambitious. He states he has been teaching relativity since 1958 to "carpenters and clerks, housewives, miners and insurance agents" at the Department of Adult Education of the University of Nottingham (and elsewhere). He has come to appreciate the difficulties of the layman in understanding the topic, and concludes that these difficulties are quite different from those of the physics major. As a result, he has developed a unique approach to teaching the subject, which he has attempted to embody in this book. The book is set up as a self-study text with frequent questions and exercises interpersed throughout the text (identified in bold type). It is hard to judge to what extent this approach succeeds in guiding a layman to a thorough understanding of relativity, including the general theory, without actually doing it. However it seems to me that anyone who follows Lilley's instructions seriously, and works through the book as suggested, doing all the exercises as they come up, cannot help but arrive at a very deep understanding of relatitivity theory. To someone who already knows some physics and mathematics, the going can seem painfully slow and pedantic.

The use of mathematics has been kept to a minimum, and what is used is taught as it is needed. The style of writing in the book is a conversational one, and continually demands response from the reader. The technical production is excellent, with many simple, clear diagrams.

The book by Arthur Evett has much more modest aims. He proposes to start with students who likewise have little previous physics or mathematics background and take them through to an understanding of only the space-time aspects of special relativity (as implied by the title). As the other two authors, he uses no mathematics beyond algebra, but his book is aimed at college students. The book is in two parts: the first introduces the consequences of the principle of relatitivity on simultaneity, time, distance and relative velocity, the second goes through a number of examples of the application of these results. Somewhat unusual in this book are the way the basic principles are derived and the choice of the examples covered in part two. The derivations are remarkably clear and detailed, and deal with each item independently. Only at the end of part one is everything put together to obtain the Lorentz transformation. The first chapter of part two (ch. 8) gives the clearest, most complete discussion I have seen anywhere of the twin paradox. It is treated from no less than five different points of view, all yielding the same result: that the stay-at-home twin ages more, and should forever put aside any further controversy on this question. In the final chapter (15), entitled "Where do we go from here?", Evett mentions some of the things he has not covered in this book: mass-energy relation, dynamics, and the general theory. One is led to expect a sequel which may cover these topics with equal clarity, but no hint is given whether a second book is contemplated.

In summary, each of the three books, in its own way, accomplish quite well its aim in making relativity theory more accessible to the general audience. Of the three, only Evett's book could be considered useful for a textbook for a course. Liboff's book requires no instructor, Landau and Rumer's is too brief and qualitative for a course text. Evett's book also contains a number of exercises, with answers, as well as a brief annotated bibliography.

J. P. S.

AN INTRODUCTION TO STATISTICAL PHYSICS, by W.G.V. Rosser. Halsted Press, John Wiley & Sons, 1982; pp. xiv + 382. Price: U.S. $55.00

Some undergraduate texts (and courses) are overly concerned with mathematical rigour and advanced techniques, at the expense of fostering students' physical understanding. Others, on the other hand, are excessively qualitative and "wordy". This recently published book, which is intended to serve as an undergraduate text in Statistical Physics, avoids both these extreme tendencies.

The reader is expected to have a good grounding in Newtonian mechanics, and would do well to have had some contact with thermodynamics and quantum mechanics. The material required in the latter two areas is reviewed nevertheless, and capable students could manage without any previous background in them.

Consistent with Feynman's pronouncement, "although most problems are more difficult in quantum mechanics than in classical mechanics, problems in statistical mechanics are much easier in quantum theory!", the author uses quantum principles almost entirely, and relegates classical statistical mechanics to an optional section in Chapter four. (Such sections, denoted by asterisks, are found throughout the book and are suitable for more advanced readers or those with specialized interests).

Although the topics covered by Rosser are generally those found in standard undergraduate texts in Statistical Physics, there are some noteworthy features of his presentation which are worth pointing out. One is the frequent use of a numerical calculation on a simple model system to illustrate an important idea or trend, before proceeding to a general discussion. Some examples of this effective pedagogical approach are found in the discussions of particle indistinguishability, fluctuations, and negative temperatures. Another positive feature is the author's emphasis on the relevance of general results to the real world, through the performance of calculations using actual numerical values pertinent to real systems and substances. In addition, Rosser uses some "contemporary" examples such as lasers, cosmic background radiation, white dwarfs, and neutron stars.

One unusual aspect of the book is the deferral of a discussion of the grand canonical distribution until the second to last chapter of the book, after more specialized topics such as the heat capacity of solids have been covered. This ordering could be modified as desired without introducing any complications.

The book has a modest number of problems for which answers are given to all having numerical solutions.

In summary, this book is an excellent undergraduate text, combining a clear elucidation of physical ideas with a good mathematical description. It would offer a sound basis for a subsequent Graduate course in Physics or Chemistry.

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GAUGE FIELDS. N.P. Konopleva and V.N. Popov, (translated from Russian by N.M. Queen (original published in 1980)),Harwood Academic Publishers, 1981; pp. vi + 264. Price: U.S. $75.00

In the last ten years there has been a renaissance of gauge field theory in elementary particle physics. Quantization of these theories has shifted from the canonical formalism to the more intuitive path integral formalism of Feynman. Yet, until very recently there have been few books devoted to these advances. Gauge Fields looks at the formulation of classical gauge field theories and the quantization of these theories. The book is divided into four chapters and an appendix. The first three chapters and appendix, written by Konopleva, cover the philosophical underpinnings of gauge theories and their classical formulations. The fourth chapter, written by Popov, discusses the quantization of field theories.

The first chapter starts with a general introduction to the recent developments of gauge theories. By looking at how these gauge theories can be understood in terms of geometry it gives some interesting new perspectives. Konopleva continues with an account of the strong and weak interactions and their unification with electromagnetism. With the exception of an unnecessary digression into the classical solutions of Yang Mills equations which bogs down in mathematics giving no physical insight, this chapter makes interesting reading. In chapter two the Lagrangian theory of gauge fields is developed. Although a more formal approach than one normally sees is used and a considerable amount of space is devoted to the gravity field, the subject of building Lagrangians is treated more clearly in other books, for example Field Theory by P. Ramond.* In chapter three Konopleva discusses the geometrical theory of gauge fields. Here she becomes very mathematical assuming a fair knowledge of differential geometry on the part of the reader. Although it is a nice overview little physical insight is obtained.

Popov begins the chapter on the quantization of gauge fields in great detail. However, in describing the perturbative expansion of the path integral in terms of Feynman disgrams he is concise to the point that the uninitiated would have difficulty in obtaining a working knowledge of the technique. There are some new perspectives to such important problems as the treatment of gauge fixing and the quantization of the gravitational field, but again one must have a reasonable background to appreciate it. The chapter concludes with a discussion of vortex-like excitations in quantum field theory and makes connection with the strongly interacting particles of hadron physics. However, there is no mention of Quantum Chromodynamics which is considered to be the candidate theory of the strong interaction.

By looking at gauge theories as an aspect of geometry this book gives new insights. Its fault lies in its failure to be at one consistant level. At times it is introductory, while at other times it is highly sophisticated, constantly jumping back and forth between the two extremes. This is not a book for the beginner, nor a reference full of useful techniques, but a book that one reads to get new perspectives on a familiar subject. Although at seventy-five dollars U.S. I would not recommend buying this book, it would be interesting for the specialist to peruse the library's copy.

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*reviewed in Physics in Canada 38, No. 5.

LIE ALGEBRAS IN PARTICLE PHYSICS, by Howard Georgi. Frontiers in Physics, vol. 54, Addison-Wesley, 1982; pp. xxii + 255. Price: U.S. $14.50

La théorie des groupes est un outil mathématique dont l'utilisation a fait progresser de façon importante la compréhension des symétries apparentes des particules élémentaires. Depuis l'introduction en 1961 du groupe SU(3) jusqu'aux modéles récents proposant l'unification des interactions fondamentales de la matiére par des théories de jauge (le choix du groupe de jauge étant contraint par les observations expérimentales), l'impact de cette branche des mathématiques sur la physique est tel que son étude s'impose maintenant à tout étudiant.

Si les livres de théorie des groupes sont nombreux, l'originalité des notes de cours réunies ici est qu'elles s'adressent à des physiciens et que l'auteur refuse délibérément de se laisser "piéger" par la beauté du sujet, tentation qui méne souvent, on le sait bien, loin de la lisibilité vers une notation certes plus compacte et générale mais trop abstraite.

L'intérêt du présent volume réside sans doute principalement dans sa grande actualité, les exemples historiques du spin et de l'isospin étant vite suivis de l'introduction des notions de couleur et de grande unification. Ceci est dû au fait que les développements récents des théories de jauge non abelienne, c'est à dire de théories dont le Lagrangien est invariant sous l'action d'un groupe de Lie non commutatif, sont responsables de l'intérêt que l'auteur (et de nombreux physiciens) porte aux groupes. L'espoir que toutes les interactions fondamentales, l'electromagnétisme, les interactions nucléaires faibles et fortes et (peut-être) la gravité, puissent être décrites par une théorie unifiée, est en effet dû aux succés de leur description par des Lagrangiens de formes trés semblables. De nombreuses expériences testent actuellement les prédictions de telles théories. Bien qu'il soit encore trop tôt pour savoir si ces développpements amèneront une meilleure compréhension des phénomènes physiques, ils sont à coup sûr un exemple éloquent de construction théorique présentant un réel attrait esthétique et mathématique.

La publication de ce livre devrait aider à la compréhension du lien profond et fécond qui existe entre les mathématiques et la physique moderne.

Bernard Pire
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LANDOLT-BORNSTEIN, NEW SERIES, GROUP I, VOL. 9b: PION NUCLEON SCATTERING, PART 1. G. Hohler, ed. Springer-Verlag, 1982; pp. viii + 407. Approx. U.S.$228.10 (cloth).

This is one of the high-quality reference volumes for which the Landolt-Bornstein series is well known. The classification is becoming, perhaps by historical necessity, somewhat awkward, however. Group I (of six groups) is devoted to Nuclear and Particle Physics. It contains 9 volumes (comprising several more books) of which volume 7 (1973) had already as its topic: Elastic and Charge Exchange Scattering of Elementary Particles. Volume 9, with the same topic, is therefore a "Supplement to Volume I/7 and Extension to High Energies". The subvolume "a" of Vol. 9 is on "Nucleon Nucleon and Kaon Nucleon Scattering" (1980) and the subvolume "b" of Vol. 9 deals with Pion Nucleon Scattering. The book to be reviewed is part 1 of this subvolume (Vol. 1/9b1): Tables of Data (1982).

This book contains indeed, exclusively, tables of data and references to the literature. The compiler is G. Hohler who has a solid reputation in πN-scattering. Although a theorist, it is clear that he had to review the experimental data (part 1) in order to provide up-to-date analyses (part 2, in preparation). I think that the user of these tables can have confidence in the correctness and completeness of the data. Some slight adjustments seem to have been made to the original published data due to the fact that more recent values for the charged pion (π) and the proton (P) masses have been used in the kinematical caluclations.

The tables contain total π^+P and π^-P cross sections (2 pages) giving always error estimates and references and extending to kinetic energies of the incoming pion in the lab system from 72 MeV to about 340 GeV. The majority of the pages (245), of course, give differential cross sections for π^+P and π^-P elastic scattering, listing at some energies more than 100 different angles. The rest of the tables deals with differential cross sections for π^-P charge exchange (45 pages), polarization parameters (68 pages) for π^+P and π^-P elastic and π^-P charge exchange scattering, spin-rotation parameters R and A (1 page) and lists of experiments, survey indexes and literature (ca. 40 pages).

The book, although expensive, will prove very useful for libraries and research groups.

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PLASMA PHYSICS AND NUCLEAR FUSION RESEARCH. R.D. Gill, ed. Academic Press, 1981; pp. xx, Price: $27.60.

This volume is based on lectures given during 1978-80 at the Culham Summer School on Plasma Physics. It presupposes a first degree knowledge of kinetic theory, classical electromagnetism and mechanics. In the editor's frank admission, the material ... "has always been biased towards our own particular interests" (magnetic confinement fusion), hence..."some important topics such as Astrophysical Plasmas, the Magnetosphere and Ionosphere and Solid State Plasmas are omitted or treated only briefly." However, in the view of this reviewer, this volume does considerable credit to the Summer School and its distinguished faculty of over twenty noted experts in the field of plasma physics.

The book is divided into six sections: I. Introduction, II. Theory, III. Advanced Theory, IV. Experimental Devices, V. Heating and Diagnostics, VI. Further Topics. The first two deal with classical topics most of which can be found in other texts. (In fact, much of Ch. 7 is reprinted from the text by Boyd and Sanderson).

Nevertheless, the reader will be grateful to have this introduction in ready access together with the more advanced subjects. Section III treats the theory of microinstabilities, plasma turbulence, anomalous transport and nonlinear plasma laser interactions. Section IV reflects the "bias" of Culham towards magnetic confinement: pinches and tokamaks, stellarators, mirrors and next-generation tokamaks. The last chapter of this section gives an exposition of fusion reactor studies on a number of selected devices, including the Saturn Laser-Fusion Reactor, which in this context appears to be an outsider. Section V introduces the reader to neutral injection and radio frequency plasma heating, plasma diagnostics with lasers and those using X-rays and particles. The last section deals with inertial confinement, charged particle beams, astrophysical plasmas and computational plasma physics. Despite the editor's remarks, this section occupies 110 pages and, as an introduction, is surprisingly explicit.

In a rapidly developing field, such as fusion research, it is difficult to keep abreast of progress with a text that may take more than a year to produce. However, the recent graduate or researcher switching fields will find this book a welcome introduction and a base on which to stand before immersing himself into the confusing world of progress reports and topical conferences. The technical production is competent and acceptable, if one discounts the unsightly photo-offset process one has come to expect in the itnerest of economy.

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GEOMETRICAL AND STRUCTURAL CRYSTALLOGRAPHY, by J.V.Smith. John Wiley & Sons, 1982; pp. xii + 450. Price: U.S. $27.95

The author has attempted to write a text which will serve both as an introduction to crystal form and symmetry for geologists and other non-specialists as well as serving as an in-depth guide for students who propose to adopt X-ray crystallography as a career.

To this end the treatment provided ranges from very elementary, and sometimes tedious, to advanced and detailed discussions of such complex inorganic structures as the perovskites and clathrates.

First there is a discussion of symmetry elements in the plane leading to elementary group theory. This is well related to physical reality although the discussion of the matrix approach to group manipulation is too condensed to be of use to students who have no previous background in the subject.

Stereographic and other projection methods, and the use of the Wulff net, are examined in detail as are the representation and generation of the various polyhedra. The "demonstration" of the Euler relationship (F + V = E + 2) in terms of Schlegel diagrams is inadequate and could well be replaced by the far more rigorous and appealing proof given in Courant & Robins: "What is Mathematics".

The treatment of Bravais lattices is well done and there is some discussion, and a wealth of structural example, for practically all of the space groups.

The illustrations are of particularly high quality, and the use of a number of stereo pairs to illustrate some of the more complex structures will do much to aid the student who does not have access to an extensive collection of mineral structural models.

To facilitate his objective of producing a book for both generalists and intending specialists, the author has divided his very extensive collection of problems and answers into two classes: easy and more difficult. All are interesting and practically orientated.

All in all, a first-rate text for students and for non-specialist workers who desire an acquaintance with classical crystallography.

A.D. Booth
Autonetics Research Assocs..Inc.
Sooke, B.C.

THE THEORY OF HOMOGENEOUS TURBULENCE, by G.K. Batchelor. Cambridge University Press, 1982; pp. xi + 197. Price: U.S. $13.95 (paper)

This well known standard work, which has been out of print for a number of years, has now been re-issued in an inexpensive form in the "Cambridge Science Classics" series.

Although it was first published in 1953, the book has a freshness of approach which is often lacking in more recent and austere books on the same subject.

In essence, what the Cambridge group showed in the 1930's and 40's was that the Eulerian approach to hydrodynamics, which results in the Navier-Stokes equation and the associated equation of continuity, can be combined with a statistical analysis to provide information as to the temporal behaviour of a turbulent fluid field assuming that the velocities concerned are much less than the speed of sound.

On re-reading this book after a lapse of 30 years or so, the reviewer found a number of interesting pieces of re-written history. The most notable is the so-called Wiener-Khintchine theorem which, one is reminded, is actually only another version of the Parseval integral.

Despite the passage of time, the analysis and results presented are still topical and will be of use, not only to students, but also to all workers in ocean physics and aerodynamics.

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NONEQUILIBRIUM SUPERCONDUCTIVITY, PHONONS and KAPITZA BOUNDARIES, Kenneth E. Gray, ed., Plenum Press 1981; pp. vii + 699. Price: U.S. $85.00.

This book contains the published Proceedings of a NATO summer school held at Maratea, Italy in the summer of 1980. It corresponds to an attempt to bring together two complementary areas in low temperature solid state physics; non-equilibrium superconductivity and Kapitza resistance, which are linked together by the phonon concept. The consummation of this marriage does not shine through the 700 page text in a transparent way, so we have found it convenient to divide the contents into four sections;phonons, tunnelling,non-equilibrium superconductivity and transport.

The phonon chapters (1,2,3,4 and 21) are spearheaded by four "grands messieurs" in this area. The first chapter by Anderson is exemplary as he has been responsible for much of the recent progress in understanding solid-solid boundaries. Wyatt's contribution is likewise very

representative. Eisenmenger comes probably closer to anyone in the book to treating the relationship between the two subjects in a simple physical way. Finally, Narayanamurti has come up with a sound account of the application of heat pulses to semiconductor physics.

The tunnelling subsection (Chs 5,6,7,12,17,19,22) includes detailed accounts of the use of the tunnelling technique in studying non-equilibrium superconductivity. Effects related to phonon trapping, microwave enhancement, quantum and classical tunnelling channels, collective modes and Josephson effects are discussed in some detail. Thinking of Pippard's contribution (Ch. 12), I couldn't help feeling that deGenne's well known paper on the Josephson effect in the 1967 Les Houches scool or a similar pedagogical treatment would have found its place here.

The non-equilibrium superconductivity area (Ch. 7,8,9, 10,11,18) presumably corresponds to what this school was really all about. The question of gap enhancement (microwaves, heating etc.) in non-equilibrium situations was at the forefront at this time. The theoretical and experimental aspects are most ably presented by A.-M. Tremblay. Finally, an attempt (Ch. 18) has been made to show that the study of such effects in one dimension clarifies the question. Such studies are much easier in the superconducting state than in the normal state due to the generally large value of the superconducting coherence length.

The transport section (Ch. 12,13,14,15,16,20) treats various aspects related to non-equilibrium superconductivity in which the transport properties are predominant. The concept of charge imbalance is central here; in the various phenomena considered, charge is exchanged between the quasi-particles and the superfluid. This idea is used to explain interface resistance phase slip and supercurrent flow in the presence of a temperature gradient.

Overall, I have the following comments: The book is perhaps too large and too expensive to qualify for the individual market, but it should definitely be in every university library. It is really the only available teaching text in the subject and most of the material of that nature is unlikely to become dated soon. Finally, it was certainly worthwhile to bring non-equilibrium superconductivity and Kapitza resistance together, but one feels that the latter is not really necessary to advance our understanding of the former. It has simply to be understood (as it is for solid-solid interfaces) and then included along with all of the other physics needed to treat non-equilibrium superconductors.

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LARGE SCALE INTEGRATION; DEVICES, CIRCUITS AND SYSTEMS
M.J. Howes and D.V. Morgan, eds. Wiley & Sons, 1981; pp. xii + 346. Price: U.S. $35.95.

This book is one of a series dealing with device physics and device-circuit interactions in various type of electronic applications. The aim of this volume is "all aspects of present LSI" (ie. Large Scale Integrated Silicon Circuits). It contains seven chapters, each written by a different author. While this inevitably leads to some repetition, it is not extensive enough to be objectionable. However, different authors appear to be aiming at different readerships. The introductory first chapter deals with the speed and chip complexity evolution. While this is most useful to readers unfamiliar with the IC field, much of the terminology is undefined although it would not be evident to this type of reader. Similarly, the second chapter on bipolar devices assumes that the reader has a good understanding of this technology and the terminology. However, the reader with this background would probably not find it useful. The succeeding chapters do not assume this level of understanding and lead the reader step by step from basic MOSFET devices to inverters (Chapter 3) and hence to actual circuits. Chapter 4 deals with the integration of these inverters, etc. into circuits. It covers the very important, but often neglected, topics of buffers, drive circuits, protection devices and on-chip clocks, etc. The application of design rules and computer aided design tools is explained as are the difficulties and concerns with being able to test circuits even during the design phase. The fabrication steps for LSI is the subject of Chapter 5. Since whole books can be written on this topic, and even on individual processes, it is not surprising that the treatment is rather superficial. Lithography is given the most detailed treatment and the applications of different types of equipment are presented. Chapter 6 develops the topics of static and dynamic memories in an interesting way. After discussing the principles of the memory cell, the design of a commercial chip (Intel's 2147 4096 bit static RAM and Mostek's 4027 4096 bit dynamic RAM) is analyzed with attention being drawn to the important considerations of chip area, pin count and manufacturing yield. Chapter 7 discusses the options in custom LSI such as macrocells, programmable logic arrays and discretionary wiring.

This book would be a good textbook or reference for a graduate course of MOSFET circuit design and applications. It provides an insight into the concerns and considerations which influence the design of actual circuits. It provides a good idea of the many complex steps which must be taken from the conception and fabrication of a single device to obtain a useful and economic integrated circuit.

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THE PHYSICAL UNIVERSE - AN INTRODUCTION TO ASTRONOMY, par F.H. Shu. University Science Books, 1982; pp. xvii + 584. Prix: U.S. $28.00

Comme le souligne l'auteur dans sa préface, il est légitime de se demander: "pourquoi encore un nouveau livre d'introduction à l'astronomie?". Et certes, il existe bien des manuels de ce niveau et on pourrait s'attacher à en comparer les mérites respectifs. L'originalité des cours que F. Shu dispensait à Stonybrook et à Berkeley et dont le présent ouvrage tire sa substance est sans doute d'abord leur ambition à presenter l' "unité de l'univers", c'est à dire à organiser et expliquer les principaux faits astronomiques à partir des quelques principes fondamentaux de la physique moderne; l'auteur veut en particulier insister sur les liens du monde microscopique des particules, atomes et molécules avec le monde macroscopique des hommes, des étoiles et des galaxies.

On ne s'étonnera donc pas de voir développés les chapitres traîtment, certes de façon abrégée et succinte, de la mécanique quantique, de la relativité, de la thermodynamique et de la physique des particules; une connaissance minimale de ces notions est bien indispensable à la compréhension de l'évolution des étoiles ou de l'expansion de l'univers. Mais l'auteur renoncerait à son ambitieux programme s'il n'essayait aussi de traîter dans les derniers chapitres de l'origine de la vie sur terre et dans l'univers, de son évolution et même de l'émergence de l'intelligence et des sociétés organisées. Nul doute que cette partie prête plus le flanc à la critique que le corps principal de l'ouvrage consacré aux sujets habituellement développés dans un livre d'astronomie: on ne peut faire justice à un sujet d'une telle ampleur et d'une telle complexité en une cinquantaine des pages. Le souci d'unité de l'auteur est cependant respectable et on doit lui savoir gré d'avoir osé relever un tel défi. Les défauts, minimes à mon avis, de ce livre sont aussi les marques de son originalité et ne peuvent faire oublier ses immenses qualités pédagogiques et scientifiques. Ajoutons que ce livre est remarquablement illustré et que la grande actualité de son contenu est manifeste.

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The Canadian Association of Physicists cordially invites interested corporations and institutions to make application for Corporate membership and will welcome the inquiries addressed to the Executive Secretary.

L'Association Canadienne des Physiciens invite cordialement corporations et institutions à faire partie des Membres Corporatifs. Renseignements auprès du Secrétaire Exécutif.

CANADIAN ASSOCIATION OF PHYSICISTS/ASSOCIATION CANADIENNE DES PHYSICIENS
151 Slater, Suite 805
Ottawa, Ontario K1P 5H3

TRIUMF

MESON RESEARCH FACILITY
University of Alberta
Simon Fraser University
University of Victoria
University of British Columbia

Competition #386-122

RESEARCH SCIENTIST

Applications are invited for a permanent Research Scientist in the μSR Group at the TRIUMF cyclotron in Vancouver, Canada. Candidates must have a Ph.D. or equivalent degree with at least two years post-doctoral experience in fast electronics and CAMAC based data acquisition systems, particularly PDP-11 computers utilizing the RSX11-M operating system. A background in polarized muon physics and familiarity with cryostat operation and design, gas handling systems, magnet and vacuum technology are other desirable qualifications for the position.

The successful candidate will be expected to spend about 50% of his (her) time coordinating the operation of a large multi-user μSR programme at TRIUMF and about 50% of his (her) time on μSR research of his own choosing. Salary will be commensurate with age and experience, starting at $27,500 per annum.

All interested persons are encouraged to apply but, in accordance with Canadian immigration requirements, priority will be given to qualified candidates who are also Canadian citizens or landed immigrants.

Applications with curriculum vitae outlining experience and research interests, list of publications, etc., and at least 3 letters of recommendation should be sent **by May 1, 1983** to:

Dr. Donald G. Fleming
c/o TRIUMF Personnel (Competition #386)
4004 Wesbrook Mall, Univ. of B.C.
Vancouver, B.C.
CANADA V6T 2A3

We offer equal employment opportunities to qualified male and female applicants. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

TRIUMF

MESON RESEARCH FACILITY
University of Alberta
Simon Fraser University
University of Victoria
University of British Columbia

Competition #385-122

RESEARCH ASSOCIATE POSITIONS

Applications are invited for Research Associate positions in the field of gas phase muon (μ^+) physics and chemistry at the TRIUMF cyclotron. It is anticipated that two positions will be available, starting around July 1, 1983. Applicants should possess a Ph.D. or equivalent degree in Chemistry or Physics, with an interest in pursuing gas phase studies in atomic and molecular physics and chemical reaction dynamics. Current interests are in the field of muon spin relaxation (μSR) in gases, akin to NMR studies, in μ^+ (proton) charge exchange and muonium (H atom) formation, in electron spin exchange and chemical reaction studies of the muonium atom.

One position is a permanent position for a person with at least 2 years experience in the field of (gas phase) μSR, to help coordinate the efforts of the group as a whole. The second position is not a permanent one; no prior experience in μSR is required but some familiarity with fast (CAMAC based) electronics, PDP-11 computers, and vacuum gas handling technology are desirable qualifications. Salary will be commensurate with age and experience in both cases, starting at no less than $25,000 per annum.

All interested persons are encouraged to apply but, in accordance with Canadian immigration requirements, priority will be given to qualified candidates who are also Canadian citizens or landed immigrants.

Applications with curriculum vitae outlining experience and research interests, list of publications, etc., and at least 3 letters of recommendation should be sent by **May 1, 1983** to:

Dr. Donald G. Fleming
c/o TRIUMF Personnel (Competition #385)
4004 Wesbrook Mall, Univ. of B.C.
Vancouver, B.C.
CANADA V6T 2A3

We offer equal employment opportunities to qualified male and female applicants. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

UNIVERSITY OF ALBERTA
Department of Physics

RESEARCH ASSOCIATE IN ATOMIC PHYSICS

The Department of Physics at the University of Alberta invites applications for a Research Associate in the area of Fast Ion Beam Spectroscopy. The position is of an indefinite duration, subject to satisfactory performance and budget approval each year.

Candidates must possess a Ph.D. in Physics with specialization in fast-beam atomic physics or laser excitation of fast ions. A minimum of two years experience at the post-doctoral level in this area is required. Some experience in the use of mini-computers in the control of laboratory experiments is also necessary.

The starting salary will be in the range $21,000 to $23,000 per annum.

Applications will be received until March 31, 1983.

Candidates interested in applying should submit a curriculum vitae plus the names of three referees to:

Dr. E.H. Pinnington,
Department of Physics,
University of Alberta,
Edmonton, Alberta, Canada,
T6J 2G1.

The University of Alberta is an equal opportunity employer but, in accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

INDUSTRIAL RESEARCH FELLOW

ONTARIO HYDRO

The Research Division of Ontario Hydro is currently seeking a recent Ph.D. in Physics to nominate as an NSERC Industrial Research Fellow.

The successful candidate will be expected to perform research, to evaluate new scientific discoveries and to aid in the introduction of new technologies. Flexibility, wide-ranging interests and good communication skills are very desirable qualities. It is anticipated that the Fellowship will develop into a permanent position.

The Research Division is concerned with the future needs of Ontario Hydro. At the same time, it provides technical and scientific support for the operation of a large power system that includes hydraulic, fossil-fuelled and nuclear-fuelled generation, and a transmission and distribution network that serves most of Ontario. The Research Division is located in Etobicoke at the western terminus of the Toronto subway system.

Recent Ph.D.'s or those about to graduate who are interested in applying for the above position should telephone or write to:

G.M. Keyser
Science Section
ONTARIO HYDRO
800 Kipling Ave
Toronto, Ontario, M8Z 5S4
Telephone: (416) 231-4111, Ext 6731

Applications will be accepted until May 31, 1983

Research Associate

McMASTER UNIVERSITY

Applications are invited for the position of research associate in the area of surface science at McMaster University. Candidates should have a Ph.D. degree or equivalent in Chemistry, Physics, or Materials Science and experience of modern surface analytical techniques such as Auger spectroscopy or SIMS. The position will involve operation of a new Perkin-Elmer PHI multiprobe 600. The initial appointment will be for one year, renewable upon mutual satisfaction with the objective of establishing a permanent research position. Salary will be commensurate with experience.

Applications with a curriculum vitae and the names of two referees should be sent to:

Dr. W.W. Smeltzer
Metallurgy & Materials Science
McMaster University
Hamilton, Ontario, Canada L8S 4M1

MANITOBA CANCER TREATMENT AND RESEARCH FOUNDATION

MEDICAL PHYSICIST

The Department of Medical Physics has an opening for a suitably qualified and experienced physicist to join a team working in the area of Radiotherapy Planning. This section of the Department, comprising four physicists, a dosimetrist and five technologists, is responsible for the operation of two simulators, preparation of treatment plans, and dosimetry associated with both tele- and brachy-therapy. A 250 kV x-ray unit, two cobalt units and two linacs (4 and 25 MeV with electrons) are available for external beam therapy. Planning is carried out on a recently commissioned AECL Theraplan computer. Mold room, mechanical and electronic engineering facilities are excellent.

The Radiotherapy Planning Section forms part of a dynamic Department with a staff of 40, which is actively involved in all areas of radiation physics, including nuclear imaging, diagnostic radiology, CT scanning, digital fluoroscopy, hyperthermia, image processing, radiation protection and microprocessor development. A training program exists for radiotherapy technologists and a Master's degree course in Medical Physics, in conjunction with the University of Manitoba is currently being planned. High scientific standards are maintained through departmental seminars and journal clubs.

The successful applicant for this post is likely to have achieved at least an Upper Second in Honours Physics at the Bachelors degree level, a Masters degree or Doctorate in Medical Physics and to have at least two years of relevant experience in a clinical setting.

Candidates are invited to send a copy of their C.V., a list of publications and the names of three referees to:

Dr. S. Shalev, Director
Department of Medical Physics
Manitoba Cancer Foundation
100 Olivia Street
Winnipeg, Canada R3E 0V9

UNIVERSITY OF ALBERTA

THEORETICAL GEOPHYSICIST

Applications are invited for the positions of a Postdoctoral Fellow or Research Associate in the field of theoretical studies of direct and inverse problems in seismic wave propagation for complicated geological structures. The positions are available immediately and are initially for a one year period with the possible extension for a second year.

The annual salary for the Postdoctoral Fellow position is in the $17,000-$19,500 range. The minimum annual salary for the Research Associate is $24,000.

Interested applicants should submit a resumé, a summary of research interests and arrange for three letters of reference to reach

Dr. F. Hron or Dr. M. Razavy
Department of Physics
University of Alberta
Edmonton, Alta. T6G 2J1

from whom further particulars can be obtained.

The University of Alberta is an equal opportunity employer. Preference given to Canadian citizens and permanent residents.

UNIVERSITY OF ALBERTA

DEPARTMENT OF PHYSICS

GRADUATE ASSISTANTSHIPS

The Department of Physics invites applications for admission to programs leading to the degree of M.Sc. or Ph.D. Excellent facilities exist for research in ASTRONOMY (observational and theoretical), ATOMIC PHYSICS, BIOMEDICAL and RADIOLOGICAL PHYSICS, GEOPHYSICS, LOW TEMPERATURE and SOLID STATE PHYSICS, MASS SPECTROMETRY, NUCLEAR PHYSICS (low and medium energy), SPACE PHYSICS and THEORETICAL PHYSICS (statistical physics, particle physics, quantum field theory, general relativity, condensed matter physics and nuclear physics).

GRADUATE ASSISTANTSHIPS are available with stipends ranging up to $11,500 per annum (for 1983-84). Scholarship and Fellowship holders may be eligible for partial assistantships in addition to their award.

For further information, please write to:

Associate Chairman,
Department of Physics,
University of Alberta,
Edmonton, Canada T6G 2J1
Phone (403) 432-3518

INDUSTRIAL POSTDOCTORATE FELLOWSHIPS

MPB Technologies Inc. is seeking candidates to nominate for Natural Sciences and Engineering Research Council of Canada Industrial Postdoctorate Fellowships.

The Fellowships will normally be tenable in the Laboratories of MPB Technologies Inc. located at Ste. Anne de Bellevue, P.Q.

Projects in which successful candidates may be involved include:

- Electromagnetic Science and Technology
- Lasers and Laser Applications
- Fusion Energy (Magnetic and Inertial Confinement)
- Plasma and Space Science
- Electronic Graphics and Microprocessor Applications

Salaries and other benefits are the same as for permanent staff of equivalent experience.

Interested recent graduates, individuals currently completing postdoctoral fellowships, or candidates who will graduate in the near future with a background in physics, electrical engineering or computer science are invited to write or call:

Dr. M.P. Bachynski
MPB Technologies Inc.
Ste. Anne de Bellevue, Que.
H9X 3L5, P.O. Box 160
Telephone: (514) 457-2035.

UNIVERSITY OF TORONTO

RESEARCH ASSOCIATE IN INTERMEDIATE ENERGY PHYSICS

A Research Associate position is expected to be available for research in experimental intermediate energy physics. Candidates should have some background and/or interest in reactions induced by protons from the 200-500 MeV TRIUMF cyclotron.

Salary will be commensurate with experience at a minimum of $21,000.00 per year. The term of the appointment is one year, normally renewable, starting summer 1983.

Applications with curriculum vitae, and names of (3) referees should be sent to:

Professor R.E. Azuma
Department of Physics
60 St. George St.
Toronto, Ontario, Canada
M5S 1A7

In accordance with Canadian Immigration regulations, this advertisement is addressed to Canadian citizens and permanent residents.

Simon Fraser University

Postdoctoral Fellowship or Research Associate

Applications are invited for an appointment as a post doctoral fellow or research associate (depending upon the candidates' experience) to work on the theory of electronic structure and transport properties of liquid and amorphous metals. A Ph.D. and experience in the theory of condensed matter is required, and computer programming skills will be advantageous. Initial appointment will be for one year, (starting approx. 1 Oct. 1983), but will be renewable. Minimum salary $16,560 for p.d.f.; $19,500 for r.a.

Please send resumé and names of three references to

Dr. L.E. Ballentine
Dept. of Physics
Simon Fraser University
Burnaby, B.C. V5A 1S6

by 30 April 1983

OPPORTUNITIES FOR B-QUARK PHYSICS WITH ARGUS

The Canadian Group participation in the ARGUS experiment at DESY has two openings for Research Associates to be resident in Hamburg. ARGUS is a new detector which has just started to take data at the DORIS-II storage ring.

The Canadian group is composed of physicists from McGill, Toronto, York and Carleton Universities. We have provided a VAX-11/780 computer which is used as an on-line monitoring system for the ARGUS experiment. In addition, a high precision cylindrical vertex detector is being built in Canada, with installation planned for the spring of 1983.

There are opportunities in on-line software, hardware associated with the vertex detector and/or physics analysis. Interested applicants should submit a curriculum vitae and two letters of reference to: Dr. R.S. Orr or Dr. M. Goddard, DESY, F15, Notkestrasse 85, 2000 Hamburg 52, West Germany, Telephone: 8998-3683; OR Professor T.S. Yoon, Department of Physics, McLennan Physical Labs, University of Toronto, Toronto Ontario M5S 1A7, Telephone: 978-7047.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

ROYAL MILITARY COLLEGE OF CANADA

DEPARTMENT OF PHYSICS

Applications are invited for a tenure-track Assistant Professor position starting July 1, 1983. The salary range will be $26,000 to $38,000 per year. Responsibilities include undergraduate and graduate teaching and active participation in research. Candidates should have a Ph.D. or equivalent. Current research in the department includes Materials Science, Optics, Condensed Matter and Low Temperature Physics.

Candidates should have a strong interest in lecture and laboratory teaching and research interests which are compatible with current departmental research.

Knowledge of the English language is essential for this position, and knowledge of French would be very useful. The position is open equally to male and female candidates. Additional information is available by writing to the address below.

Send application form and or resumé with the names and addresses of three references to:

Dr. Martin H. Edwards
Head, Department of Physics
Royal Military College
Kingston, Ontario K7L 2W3

Tout renseignement relatif à ce concours est disponible en français et peut être obtenu en écrivant à l'adresse ci-haut.

University of British Columbia

POST-DOCTORAL FELLOWSHIPS IN LOW TEMPERATURE PHYSICS

Two positions are available at the Post-Doctoral level for recent Physics Ph.D.'s with experience in Low Temperature Physics. One position will be concerned with efforts underway in this laboratory to observe Bose-Einstein Condensation in Spin-Polarized Atomic Hydrogen Gas at very low temperatures. The other position will be mainly devoted to the design, construction and testing of a cryogenic Atomic Hydrogen Maser. Successful applicants for both positions will be expected to assist in the supervision of graduate students working in the laboratory. Funding for these positions is expected to be available after April 1, 1983.

Applicants should enclose a curriculum vitae and arrange for three letters of reference to be sent to:

Profs. W.N. Hardy and A.J. Berlinsky
Department of Physics
University of British Columbia
6224 Agriculture Road
Vancouver, B.C.,
Canada V6T 2A6

DEPARTMENT OF PHYSICS
UNIVERSITY OF WINDSOR

Windsor, Ontario, Canada
N9B 3P4

GRADUATE ASSISTANTSHIPS

The Department of Physics offers teaching and research assistantships to students qualified for admission to graduate studies and wishing to proceed to the M.Sc. or Ph.D. in Physics. Research is proceeding in theoretical and experimental atomic physics (calculations of atomic and molecular structure, electronic and atomic collisions, electron-, vacuum u.v.-, far infrared- and laser-spectroscopy); ESR, PER, condensed matter spectroscopy, physics of surfaces and thin films; theory of relativity and its applications; nuclear physics. Stipends not less than $9,000 at the M.Sc. level, $10,000 at the Ph.D. level, depending on qualifications and duties in the Department.

POSTDOCTORATE FELLOWSHIPS

There are several Fellowships available in the above fields of research at stipends on the NSERC scale.

Enquiries should be addressed to the Head of the Department.

Applications are invited from physicists with training or equivalent experience in the instrumentation and apparatus of experimental high energy physics. Minimum academic level is an M.Sc. in nuclear science. The successful applicant will be expected to work at McGill University in Montreal and at Fermilab, Batavia, Illinois. Initial appointment will be for two years. Closing date for applications is May 1, 1983. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. Application: curriculum viate with names of two referees to:

D.G. Stairs
Physics Department
McGill University
3600 University Street
Montreal, P.Q. H3A 2T8
Canada

Theoretical research in electonic properties of metallic glasses

The solid state group at McGill University expects to be able to fund a postdoctoral or research associate position for one or two years beginning in the fall of 1983. The project will involve the calculation of electronic energy levels for application to transport theory and/or EXAFS spectra, and will supplement an active experimental program. Applicants should send a CV and the names of two referees as soon as possible to:

Prof. R. Harris
Rutherford Physics Building
McGill University
3600 University Street
Montreal, Quebec
Canada H3A 2T8

In accord with Canadian government immigration regulations, preference for the research associate position will be given to qualified Canadian citizens or landed immigrants.

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Innovation put us on top. Products like the Model 380D will keep us there.

Spectra-Physics

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1250 W. Middlefield Road
Mountain View, California 94042
(415) 961-2550

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Siemensstrasse 20
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West Germany
(06151) 708-0

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Head Office
6620 Kitimat Road
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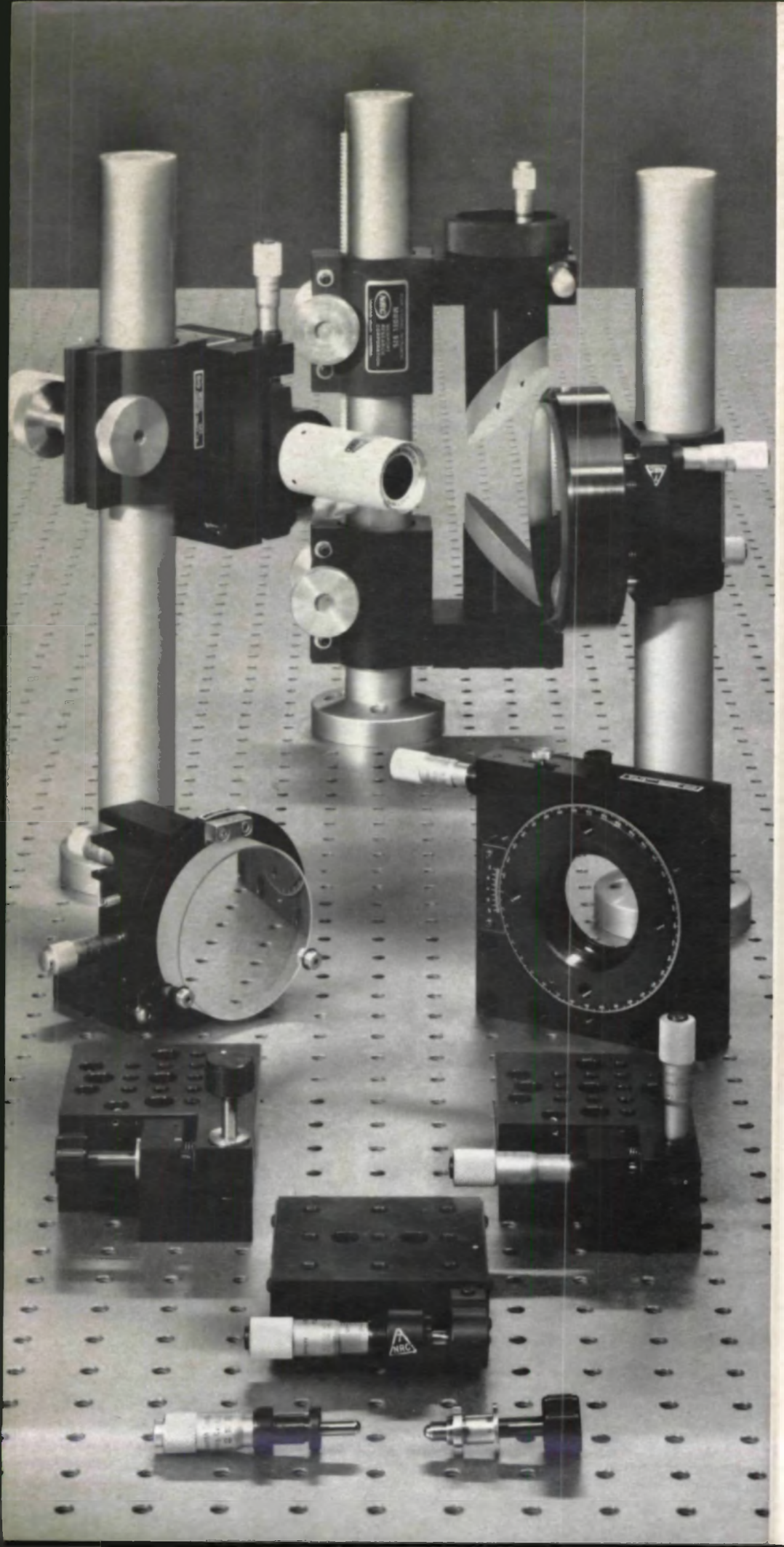
Telephone 416 826 7752



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