



Preface

C.V. Raman did many things during his life. He started and ran research institutions; he established and published scientific journals and persuaded scientists of India and abroad to publish in them; he established an Academy to encourage talented scientists; he gave popular lectures in schools and colleges and inspired youth to devote themselves to science; he fought anything he felt was a threat to the self-respect and self-reliance of the country and he did all this with gusto. But all these activities were subsidiary to his one real pre-occupation and passion – that of doing science. The pursuit of science was the one basic reason for his existence. Nothing else really mattered. From 1905 to 1970, day in and day out, he did science. For 35 years, when his intuition was at its peak, his science was almost unmatched. His intuition did decline later but not so his passion for science. Altogether he published 475 papers and wrote 5 monographs on topics so varied that one's mind boggles.

Given this range of interests, it would clearly have been a difficult task to organise a conference where one attempted to recall his numerous outstanding contributions; nor would it have been appropriate. Instead, the RAMAN RESEARCH INSTITUTE felt that the best way to commemorate the centennial of its founder was to hold an international conference on WAVES and SYMMETRY. These topics not only excited him, but underlay his thinking throughout his scientific career. Raman was fascinated by wave phenomena even from his youngest days. A few examples may be worth citing.

The common drum with a uniform membrane is musically defective as it cannot produce harmonics. Raman showed that the Indian concert drums – the Mridangam and the Tabala – are true musical instruments which produce at least five harmonics because the membrane is centrally loaded (see page 1016). In the hands of an outstanding player, it can be played like a stringed instrument. He showed that the Indian veena and tambura violate the Young-Helmholtz law because their bridges are curved. Raman's *magnum opus* in this field is, of course, "*The mechanical theory of bowed strings of the violin family*", and it is cited by acousticians even today, 75 years after it was written. One cannot but marvel at his experimental skill in producing vibration curves of great precision and sharpness much before the triode valve or the condenser microphone were invented.

The obsession he had for the beauty of the haloes around the sun and the moon when seen through a thin cloud of water droplets resulted in the discovery of the "speckle" phenomenon, as early as in 1919 (the cover shows speckles in white light). Replacing light by X-rays and droplets by molecules which are closer together, he developed the theory of diffraction of X-rays by liquids. Replacing the molecules by electron clouds, he derived for the first time the X-ray structure-factor of an atom. And allowing for the cloud of electrons moving, he was able to derive on a classical basis the "Compton effect formula".

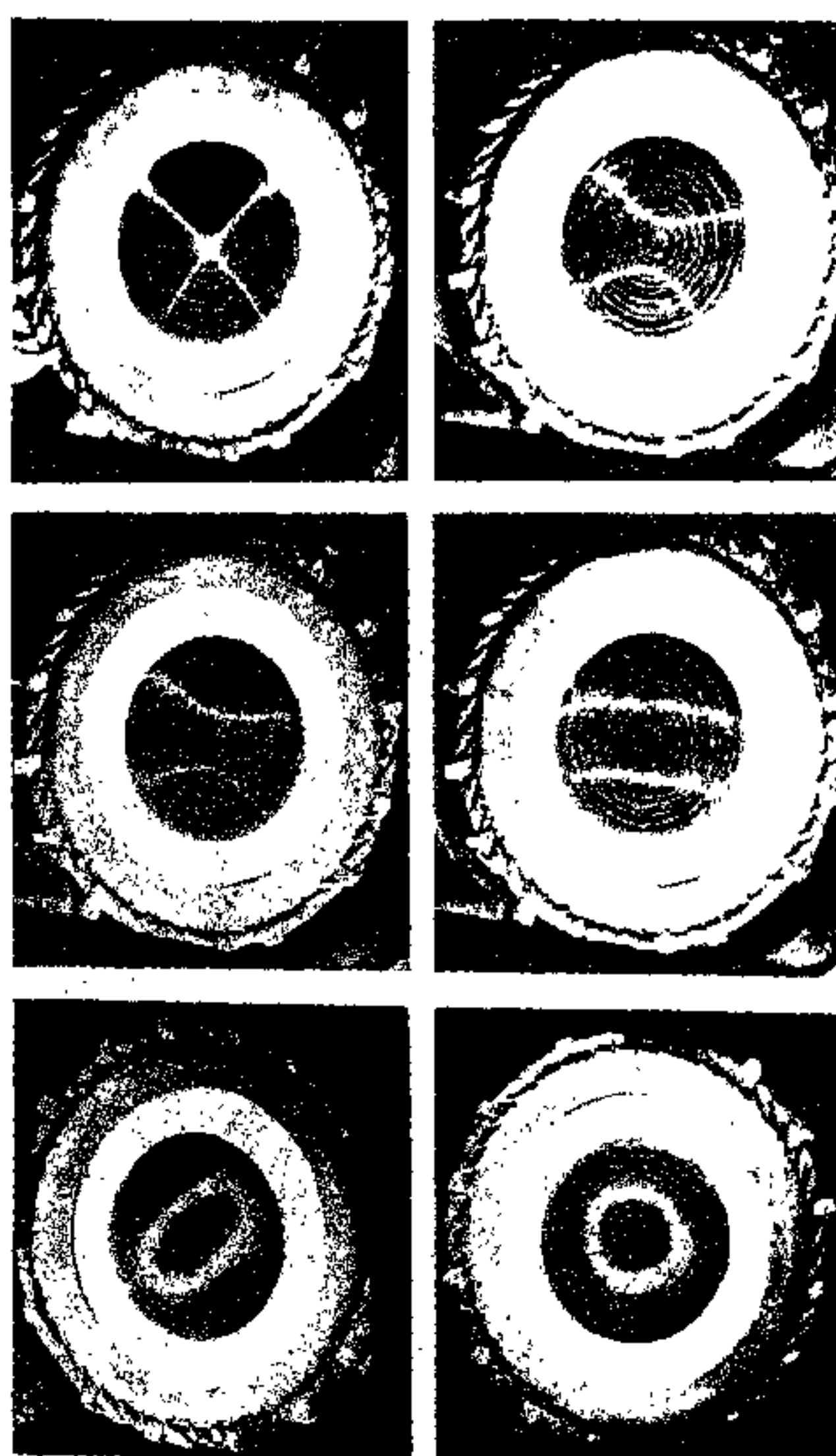
The picture on page 1153 shows the similarity between periodic precipitates in Nature and the wave phenomenon. It had already been attributed to a diffusion wave, but Raman gave substance to this analogy by actually detecting in these precipitates, the existence of phase relationships in the form interference and diffraction effects.

The mathematics introduced by Raman and Nath to deal with the diffraction of light by ultrasonic waves was used twenty years later for the multiple beam dynamical theory of electron diffraction. The first qualitative statement of the presently accepted theory of the scintillation of stars as due to random corrugations of a plane wave front arriving from a distant star due to density variations in the atmosphere was given by Raman. It is interesting also that he made detailed studies of the not-too-well-known ability of the unaided eye to detect polarised light as bees do. And there are many more examples. His deep interest in gems and minerals, birds and butterflies, exemplified his passion for understanding symmetry in nature.

The Symposium on WAVES and SYMMETRY was not intended to recall his numerous contributions to the field, but to see where the frontiers of the subject lay today. The scene has shifted from linear phenomena connected with waves and their interactions to nonlinear phenomena. One of the paradigms of physics today is that *broken* symmetry has many more important consequences than symmetry itself. The distinguished speakers at this Symposium have addressed a very wide variety of topics ranging from phenomena in the microscopic world to the Universe at large. A certain unity in this diversity can be discerned. Sadly, conferences like this are no longer common today. We felt, therefore, that it would be worth publishing these lectures, because as a collection it is somewhat unique.

G. SRINIVASAN
S. RAMASESHAN

★ ★ ★





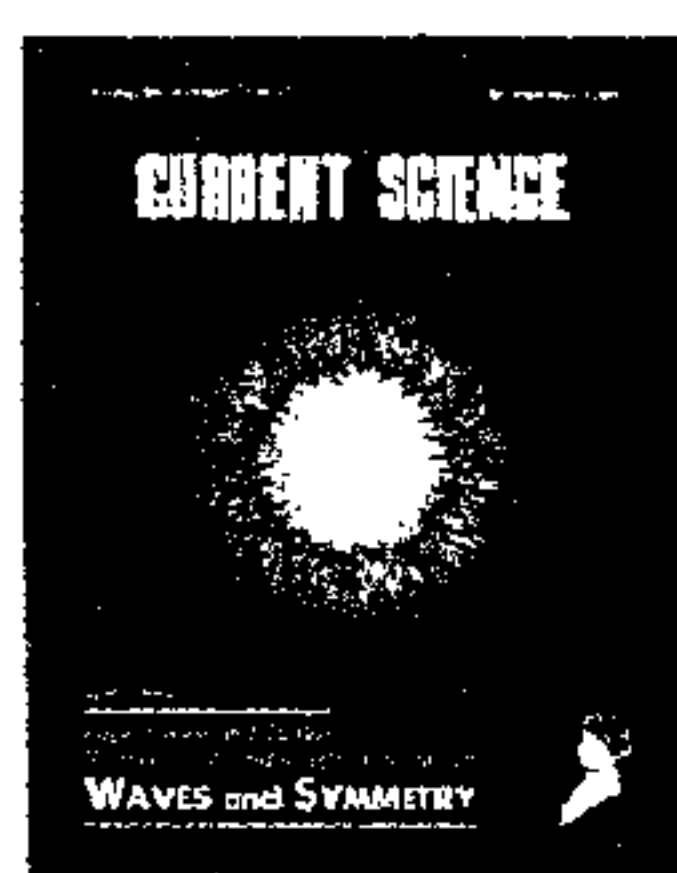
Contents

Volume 59 Numbers 21 & 22

25 November 1990

Preface	1015
Seeing the Sky more Clearly – The Search for Higher Resolving Power R. HANBURY BROWN	1019
Light upon the Structures of the Universe D. LYNDEN-BELL	1036
Gravitational Lenses RAJARAM NITYANANDA	1044
Geometry, Stability and Symmetry A. B. GIVENTAL	1052
Thermodynamics of Nonlinear Plasma Systems P. K. KAW	1065
Electroweak Symmetry G. RAJASEKARAN	1080
Who is afraid of Anomalies? R. RAJARAMAN	1100
Defects in Liquid Crystals G. S. RANGANATH	1106
The Mott Transition T. V. RAMAKRISHNAN	1125
Role of Symmetry and Group Structure in Optics N. MUKUNDA	1135
Geometric Phase – Introductory Remarks N. MUKUNDA	1152

The Poincaré Sphere and The Pancharatnam Phase – Some Historical Remarks S. RAMASESHAN	1154
Geometric Phase, Experiments in Optics – A Unified Description RAJENDRA BHANDARI	1159
Optical Phases and the Symplectic Group R. SIMON	1168
Beyond Rainbows MICHAEL BERRY	1175
Perception of Colour OBAID SIDDIQI	1192



Cover: White light speckle. Photograph by R. P. Riesz, C. Ramachandra Rao and P. S. Sasi Kumar.
Cover design by G. Srinivasan.

Thanks are due to G. Srinivasan for graciously agreeing to be the Guest Editor, without whose help this special issue would not have been possible; to the staff of *Current Science* and Indian Academy of Sciences who helped greatly in bringing out this publication, especially Hema Wesley, Chandrika Ramesh, Shantha Nair, N. A. Prakash, M. S. Venugopal, C. S. Ravikumar and G. Madhavan; to The Eastern Press for their cooperation.

Editor: S. Ramaseshan
Guest Editor: G. Srinivasan

Price of single copy of this Special Issue – India Rs. 30/- Abroad US \$ 12.



Seeing the Sky More Clearly – The Search for Higher Resolving Power

R. HANBURY BROWN

*Professor Emeritus, University of Sydney, Australia;
White Cottage, Penton Mewsey, Near Andover, Hants SP11 0RQ, England.*

This evening I am going to talk about the many attempts which have been made, and are still being made to see what there is in the sky more clearly, in other words about the efforts to see fainter objects and to see them in greater detail.

One of the first people to make a serious attempt to see a more detailed picture of the sky was Galileo. He needed it in his battle with the opponents of the Copernican theory. Among the many serious objections to that theory was the observation that the stars do not appear to move in the sky as they should if the Earth really does travel around the Sun. Galileo argued that this awkward fact might be explained if the stars are at distances which are large compared with the orbit of the Earth, and in an effort to support his argument he tried to measure the angular size of the bright star Vega. To do this he suspended a fine silk cord vertically and measured how far away from the cord he had to stand so that it just occulted the star.

Galileo reached the conclusion that the angular diameter of Vega is 5 arcseconds. As we now know his result is far too large; nevertheless at that time it was a significant advance compared with the currently accepted value of about 2 arcminutes, and Galileo was able to use it to considerable effect in his arguments with the critics of Copernicus.

Galileo's next contribution to our topic was more fruitful. Learning of the invention of the telescope in Holland in 1608 he built one himself and applied it assiduously to looking at the sky. As we all know he saw mountains on the Moon, satellites circling around Jupiter and many more stars than could be seen with the naked eye.

Elementary textbooks tell us that the ability of any instrument to show us fainter things and also greater detail is limited by its physical size. Thus if θ is the smallest angular detail which can be measured, then

$$\theta \approx \lambda / D, \quad (i)$$

where D is the physical aperture of the instrument and λ is the wavelength of the radiation. If, for example, we use the naked eye ($D \approx 3\text{mm}$) then the smallest angle which we can discern is about 40 arcseconds, and a small telescope, say with an aperture of only 12cm, will reduce this angle to 1 arcsecond. Clearly the invention of the telescope represented a major step forward in our search for higher resolving power.

The obvious way of getting an even better view of the sky was to build a larger telescope, but it was soon found that although larger telescopes collect more light and so reveal fainter objects, they do not give the increase in detail that theory predicts. The reason is that, in practice, their resolving power is not limited by simple diffraction but mainly by turbulence in the Earth's atmosphere so that the image of a star seen through a large telescope, no matter how large, looks like a roughly circular blur with a typical angular size of between 1 and 2 arcseconds. This means that once we have built a telescope of about 12cm aperture, any further increase in size is not rewarded