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NEW INSTRUMENTATION EFFORTS IN SOLAR STUDIES*

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Although the sun and the stars belong to the same category of celestial objects, the technique of observation in the two cases differ considerably Major differences arise due to the fact that the radiation flux received on earth from the two objects differs considerably, light from the sun is more than ten thousand million times stronger than that received from the brightest stars Also, the sun being more than a million times nearer than the nearest stellar objects, it is possible to study minute feature of solar surface a feat so far denied by nature to earth bound stellar scientists The techniques of solar studies aim at high magnification and resolutions, extremely high dispersion spectroscopy and experiment to unveil the mysteries of a variety of weak but vital physical processes which hold clues to our understanding the nature of cosmos

In the early days of telescopes, the differences in techniques were not so apparent, but as the telescope apertures grew in size, the problem of application of stellar methods surfaced On special events, such as total eclipses, the scientists became aware of the necessity and possibility of using higher magnifications and resolution in solar studies The basic design of stellar telescopes viz that of pointing an optic tube to the sun imposed severe restrictions, the idea of using a stationary telescope tube with auxiliary tracking devices viz siderostats or coelostats gave birth to a new type of solar instruments, which dominated the scene for the next hundred years Major advances in our knowledge of solar astrophysics were achieved by those instruments, which gave the required high magnification dispersion and resolution But these also introduced inevitable defects which came up with further developments

Major defects which were introduced by these long focus high magnification instruments were of three types 1) polarization, 2) scattering and 3) seeing The cumulative effect of these put up a formidable barrier to further advancements in solar studies

Polarization is introduced mainly through oblique reflections at the coelostat mirrors The nature and degree of these polarizations at the Kodaikanal Solar Tower Telescope have been studied (Balasubramaniam 1985) Compensating these distortions is theoretically possible but practical arrangements for carrying it out became cumbersome Experiments like vector magnetic field measurements are based on subtle polarization change along spectral line profiles, instrumental polarization tends to mask these effects and reduce the level of reliability of derived results Conventional stellar type design (not Coude configuration) avoids this type of distortions, at the cost of magnification and image resolution In the new types of solar telescopes under design, efforts are being made to introduce minimum instrumental polarization without sacrificing large magnification and spatial resolution

All ground based optical instruments suffer from defects of atmospheric and instrumental scattering This point becomes glaringly visible at times of total solar eclipses Under normal times the scattered light from the very bright solar photosphere totally drowns otherwise bright corona, once the photospheric light is prevented from reaching the scattering layers of our atmosphere, the extended outer envelope of the sun with all its fine, intricate markings become visible Realizing this limitation, Lyot had placed his coronograph at high mountain altitudes with some degree of success Real improvement on this point will be on a space platform, failing which a high altitude location of minimum atmospheric aerosol content will meet the requirement partially The

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Image distortion due to seeing is another problem which had appeared at one stage to be beyond our control There are two distinct parts of this disturbance (1) the one whose origin is in the telescope and the building, the so called dome seeing and (2) the other in the atmosphere Many innovative ideas have been tried and still being attempted for improving the dome seeing Such ideas include evacuated light tubes, Helium filled tubes, stratified linear airflow arrangements etc Atmospheric seeing optimization has so far been done by careful choice of observatory sites, for best day time seeing, a site surrounded by a large body of water has been found to be good The Big Bear lake observatory in US or the Udaipur lake observatory s location are based on this principle Other types of topography also provide extended periods of good seeing, some of the future solar telescopes are proposed to be installed in such locations

Solar telescopes so far have been designed for specific purposes Long focus large aperture instruments had high resolution spectrophotometry in view, special steps being taken to reduce turbulence and scattering inside telescope and spectrograph Longitudinal magnetic field measurements have posed no problems, but transverse zeeman effect of line wings gets tangled with instrumental polarization Some attempts to use pointing tubes for total magnetic fields have, therefore, been made

Coronographs scrupulously avoid any additional optical elements than what is considered absolutely necessary Coelostat systems are totally ruled out, as every reflect ling surface add to the scattered light Imaging lenses, if used, are usually single ones, carefully selected, as achromatic combinations necessarily mean more interfaces and more scattered background Magnification and resolution have necessarily to be sacrificed to achieve a practical instrument

Scientific goals achieved with the help of these instruments were limited, and need for a new generation of solar telescopes was keenly felt Over the past two decades various new ideas in this direction have been aired Several instruments incorporating these ideas have been built, not always with desired results Examples of domeless solar telescopes at Capri or Zeiss solar telescope at Hida observatory may be quoted in this connection (Engvold, 1985)

More novel ideas are coming in this direction An international group of solar physicists has drawn up a plan for installing a large earth based solar telescope (LEST) at a location in the Canaries Islands The instrument will have large aperture reflection optics, of long focal length Heat generated by the solar beam is proposed to be removed from the instrument through an ingenious device Oblique reflections will be used, but all polarization detection operations will be placed ahead of these LEST will combine the sensitivity and resolution of large telescopes without affecting its performance on polarization, scattering and dome seeing

Some new ideas are also being applied in the direction of a national new techno logy solar telelscope proposed to be built by the scientists of the Indian Institute of Astro physics Prof Sivaraman will present details of this design later (Sivaraman 1987) This will have reflection optics, with an evacuated ray path and an active mirror to reduce the seeing fluctuations to a minimum

Having briefly covered the new instrumentation efforts in solar physics, I would like to have a brief review of the observational projects which are likely to be covered by these Many new questions about solar processes have come up as a result of new observations over a wide band of electromagnetic radiations and particle streams The questions are about several aspects of physical processes occurring from deep solar interior to the outer stretches of the corona In most cases, optical observations may not yield direct answers, but can provide clues to our understanding of the sun

Let us take the puzzle about the solar interior first The temperature structure of the solar core which was modelled earlier was not corroborated by neutrino experiments (Davis 1978) Knowing the limitations of the present system, while fresh attempts are on to build new instruments with wider spectrum neutrino detectors (Hampel 1981), other methods of finding the temperature structure of solar interiors were being sought Such a method has been found in helioseismology, where the periods and wavelengths of various oscillation components of the solar photosphere are supposed to provide a clue to this riddle (Deubner 1984)

The obvious experimental requirement for this is the recording of a continuous series of dopplergrams of the solar disc The amplitudes of some of the oscillation components are very, very low, it is imperative that high spectral resolution with a minimum of scattered light be employed for these recordings, hence the need for the new instrument

There are other possible alternative methods also Global oscillations should also cause a periodic change of solar dimensions, which, even though extremely small, would still be measurable if appropriate methods are employed (Rosch 1981) A prime requisite will be minimization of seeing distortions and application of modern image processing techniques Applications of latest technology in instrumentation and computer applications are called for in these experiments

Let us consider another example of enigmatic physical processes in the outer layers of the sun The chromosphere and the corona are at much higher temperatures than the underlying photosphere The mechanism of energy transfer across the photosphere chromosphere interface is not fully understood yet For a long time it was believed that acoustic waves generate shock fronts and dissipate energy in the upper layers This may account for part of the heating, but several peculiarities of temperature structure in the lower corona suggest other MHD processes As of today, we do not have any direct method of finding this out, observations in other bands of electromagnetic waves may eventually discover one

But with a new generation of solar telescopes, we will be able to map the vector magnetic fields with high spatial resolution and sensitivity covering areas large enough to provide us with clues pointing to the building up and conversion of magnetic energy Even the enigmatic process of solar flares may yield its secrets to such probings

There are many fine, small scale features visible in the photosphere and the chromosphere which get obliterated because of defects in the imaging arrangements; new generation of telescopes should bring these features within the reach of ground based solar physicists Such features in the quiet and active regions of the sun remain only vaguely understood, availability of clear sharp images will help advancing solar studies by several steps towards our complete understanding of our nearest star

It is true that the total physical processes going on in the sun cannot be studied only through optical observations, as different reactions convey information in different forms of radiation But the important point is that the tools employed for optical observation have been developed to such a degree of refinement that the quality of physical information obtained through this narrow window surpasses those obtained through other means Many indirect deductions can be drawn from precise observations in the optical band which will enhance our understanding of the solar phenomena

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