Historical perspective and research centres in India in the fields of solar astronomy and Sun-Earth relationship*

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A brief account is presented of research being carried out in the field of solar physics and solar-terrestrial relations at several centres in India. The geographical location of India allows monitoring of the solar activity during the intervening period when the Sun sets in the Far-East and rises later in Europe.

The Kodaikanal Observatory and the Indian Institute of Astrophysics

Modern astronomical observations were initiated at the Madras Observatory during 1786-1899. The Helium lines were discovered during the total solar eclipse in 1868 by Pogson and Janssen. This initial effort led to the establishment of the Kodaikanal Observatory in 1899. Daily photographs of the Sun were initiated in 1901 followed soon by daily spectroscopic observations. Evershed Effect was discovered in 1909. Vainu Bappu became the Director of the Observatory in 1958 and soon a 12m solar tower with modern spectrograph was established. Measurements of vector magnetic fields were also initiated during 1960s. The areas of current interest at the Observatory are the following: observations and interpretation of the morphological changes in active regions and their role in occurrence of transients such as flares, (ii) study of contributing factors to chromospheric calcium K indices, and (iii) measurement of vector magnetic fields. Photographs of ~ 100 years are being digitized for long term studies of the last ten solar cycles.

In 1955, an ionosonde and geomagnetic facilities were installed at the Kodaikanal Observatory. Studies on the structure and dynamics of equatorial ionosphere and its response to the solar and interplanetary variability are being carried out. Studies of the equatorial electrojet and of the structure and dynamics of equatorial ionosphere and its response to solar and interplanetary variability are being made.

In 1977, many of the astronomers from Kodaikanal shifted to Bangalore and established the Indian Institute of Astrophysics (IIA), which subsequently constructed a 2.3m optical telescope at Kavalur and recently a 2m telescope at Hanle in the Ladakh region of the Himalayas at a height of 4500m.

Gauribidanur Radio Heliograph: Jointly established by IIA and the Raman Research Institute (RRI), the Heliograph, operating in the frequency range of 30-150 MHz, started functioning in 1997. A digital radio spectrograph was added in the year 2000. The major areas of interest of this facility are in the estimation of brightness temperature of corona, study of pre-event signatures associated with coronal mass ejections, and in the estimation of magnetic field strengths of the corona. The spectrograph is specially used for studying the time and frequency structure of solar radio bursts.

The Indian Institute of Geomagnetism

Geomagnetic observations were started at the Colaba Observatory, Bombay, in 1846. Daily photographic recording of variations in the geomagnetic field began at Colaba in 1872 and were continued until 1905, and thereafter magnetic recording has continued at Alibag magnetic observatory from 1905 till today. The Colaba-Alibag series of records comprise more than 130 years of geomagnetic observations. In 1971, the Colaba-Alibag magnetic observatory was transformed into an autonomous research institute, the Indian Institute of Geomagnetism (IIG). Today, IIG operates nine permanent magnetic observatories at locations

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ranging from the dip equator to the focal latitude of the Solar quiet (Sq) current system in the Indian longitude region. Continuous measurements of the changing pattern of the geomagnetic field contribute extensively in understanding the Sun-Earth relationship, space weather, and also the long-term variations associated with processes related to internal dynamo mechanisms. IIG maintains a World Data Centre for Geomagnetism at Mumbai. This center archives the long series of analogue magnetograms and digital hourly values from Indian magnetic observatories as well as data from other observatories.

IIG has three main areas of research: geomagnetic data based research; upper atmospheric research which includes ionospheric, magnetospheric, and atmospheric studies; Solid Earth research which includes the study of Earth's electrical conductivity distribution using techniques such as magnetotelluric and geomagnetic depth sounding, crustal deformation studies using spaceborne geodetic techniques such as GPS, study of crustal magentic anomalies using ground, aeromagnetic and satellite data; Palaeomagnetic and Environmental magnetism studies. Observations related to some of IIG's research activities are also carried out in Antarctica. IIG has an Equatorial Geophysical Research Laboratory (EGRL) at Tirunelveli, near the dip equator, where a partial reflection medium frequency radar provides continuous measurements of winds around the mesopause region, since 1993. Spaced receiver measurements of ionospheric scintillations are also being carried out at EGRL to study equatorial ionospheric irregularities, which arise due to growth of plasma instabilities, while airglow observations are made at Kolhapur to study the dynamics of ionosphere and thermosphere.

Uttar Pradesh State Observatory (UPSO) [now Aryabhatta Research Institute of Observational Sciences (ARIES)]

UPSO came into existence at Varanasi in 1954 and moved to Manora Peak, Nainital in the Himalayas in 1961. A 1m telescope was established in early 1970s. UPSO was constituted as ARIES in March 2004. The primary objective of the ARIES has been studies of galaxies, stellar populations, stellar variability, stellar energy distribution, star clusters, planetary physics, solar activity and studies related to molecular lines in the Sun.

Observational facilities for solar research were established in the year 1966. For making sequential observations of solar activities, i.e. flares, prominences, surges etc., a 25-cm coelostat with 0.5/0.7 Å Halle Hd filter associated with robot photographic camera was installed and a 46-cm coelostat feeding a 25-cm f/66 off-axis telescope with a 9-meter focal length double-pass spectrograph was installed for spectral studies. During 1988-1991, two 15-cm Coude refractors from Carl Zeiss, Jena in East Germany, with heat rejection filter at the top were procured. During 1992-1993, the photographic observations of solar activity were replaced by CCD camera system. ARIES has made significant contributions in the field of solar physics, particularly in the areas of spectroscopic studies of solar molecules, studies of solar active regions, multi-wavelength studies of solar flares, prominences and statistical studies of solar phenomena. The studies related to prediction of solar molecules, correlation of twisting index of magnetic neutral lines of solar active regions with the frequency of flare occurrence and solar active zones and extremely impulsive flare of 10 March 2001 associated with CME, type II radio bursts and hard X-ray source rotation are some of the noteworthy contributions.

The Udaipur Solar Observatory (USO)

USO was established in 1976 by Arvind Bhatnagar on a small island surrounded by a large body of water in the Fatehsagar lake, Udaipur. This site provides on an average of 270 clear days in a year, which is important for intensive study of solar phenomena. Several telescopes and back-end instruments are available at USO: (i) a 15-cm aperture spar telescope for small field, high resolution study of the solar chromosphere, in Hα 6563 Å. (ii) a multi-slit Littrow spectrograph to obtain the line-of-sight component of the velocity field simultaneously at several locations, (iii) full-disk telescope for synoptic observations of solar activity, and (iv) video magnetograph for active region magnetic fields (being upgraded to a vector magnetograph). In addition, USO also operates one of the six identical telescopes of the international

Global Oscillations Network Group (GONG) to obtain full disk velocity field images required for helio-seismology, i.e., the study of solar internal structure and dynamics by solar oscillations.

The major research activities being carried out at USO are magnetic and velocity field evolution in active regions, flares and CMEs, space weather, and helioseismology. A strong correlation of helioseismic parameters with solar activity has been found, giving a peek into the fundamental nature of solar activity. P-mode power is found to be larger during the period of high flare activity. Flaring active regions are found to be distinguished by steep gradient in the meridional velocity below a depth of 5 Mm. USO is currently engaged in setting up the adaptive optics system to improve the limitations imposed by atmospheric seeing. Studies conducted at USO have shown that the full potential of adaptive optics can be realized up to a telescope aperture of 50 cm, given the good daytime "seeing" conditions at USO lake site. It is planned to install such a telescope at USO for multiple applications, named Multi-Application Solar Telescope (MAST). The main strength of MAST will be its capability to perform precision spectroscopy and polarimetry over both the solar photosphere and chromosphere.

National Centre for Radio Astrophysics (NCRA/TIFR)

The Ooty Radio Telescope: Interplanetary Scintillation (IPS) method exploits the scattering of radiation from compact radio sources (e.g., quasars and radio galaxies) by the solar wind density irregularities, which move radially outward from the Sun. This method is a powerful tool to probe the solar wind at regions inaccessible to space missions. The IPS measurements with the Ooty Radio Telescope (ORT) provide an inexpensive ground-based technique of detecting and tracking CMEs in three-dimensional space. The large collecting area of the ORT and its high sensitivity allow measurements on a grid of more than ~700 radio galaxies/quasars per day and provide images of CMEs and reliable estimations of CME density turbulence and speed at all heliographic latitudes and at a range of distances from the Sun. Ooty measurements have shown variations of large-scale properties of the quiet solar wind as well as the characteristics of propagation of CMEs in the Sun-Earth distance range. Ooty studies have also shown the acceleration of magnetically driven CMEs and the physics of their interaction with the ambient solar wind and/or other preceding slow CMEs.

The Giant Metrewave Radio Telescope (GMRT): Many of the astronomers from the Ooty group moved to Pune in 1989 to setup the GMRT near Khodad, about 80 km to the north of Pune. The GMRT consists of thirty 45m dishes located in an array of about 25 km in extent. It is primarily used for galactic and extragalactic research but is also a powerful facility for observations of the Sun. Several CME events have been mapped and also observations have been made of noise storms, and the quiet and active Sun.

Conclusion

India has today several active centres for studies of the Sun and also the Sun-Earth relations. I have described here only the major observatories. Many universities are also involved in studies of solar-terrestial relationship including ionospheric research. An active programmme is also pursued by the National Physical Laboratory and the Indian Space Research Organization. Theoretical research is also carried out at various institutes, particularly at IIA and the Tata Institute of Fundamental Research (TIFR).

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