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Search for low-mass companions to solar-type stars

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An exciting observational program that can be carried out with moderate sized optical telescopes the one metre Sampurnanand telescope (and the proposed three metre telescope) of the Uttar Pradesh State Observatory, is the search for low-mass companions (Jupiter-sized planets and brown dwarfs) to solar-type stars. That such a programme is viable and would bring in rich scientific dividends has been established by the remarkable discovery, during the last few years, of more than a dozen low-mass companions to stars. This tally exceeds the familiar nine planets of the solar system and includes brown dwarfs, Jupiter-sized gas giant planets and pulsar planets. These recent discoveries have almost transformed planetary astronomy in that the research activity for the detection of more such objects has increased much. Just as the accidental discovery of the new planet, Uranus, on 13th March 1781 by the pioneer observational astronomer William Herschel, had a tremendous impact on the public opinion in England, the announcement of the discovery of a Jupiter-mass companion to the solar-type star 51 Pegasi on 6th October 1995 by Michel Mayor and Didier Queloz of the Geneva Observatory, not only brought the star to special notice of the public, but also activated the planetary astronomers to search for such objects, and the theoretical scientists to formulate theories of the mechanism of formation of such planetary bodies in different environments.

Until the discoveries of the gas giant planets and brown dwarfs during the past few years, the most massive planet known was Jupiter with a mass one thousandth ($.001 M_{\odot}$) of the mass of the sun and the least massive stars on the main sequence had masses equal to or greater than eight one hundredth of the mass of the sun ($0.08\ M_{\odot}$). It is interesting that the newly detected low mass objects associated with the extra solar-type stars bridge the gap of this factor of 80 almost completely (e.g. the planet 51 Peg B ~ 0,5 m_J and the brown dwarf Gliese 229 B ~ 20 to 50 m_J : m_J is the mass of Jupiter). This aspect itself stresses the importance of search for such objects in order to understand their nature and their formation processes. Detection of these low-mass objects and understanding their nature are also of considerable significance for many astrophysical problems such as determination of the critical Jeans mass for star formation from interstellar gas clouds due to self-gravitation, identification of "missing mass" component of the galactic disk etc. Successful searches

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for planetary companions to solar-type stars would throw light on the long-standing problem of the ubiquity of planetary systems and would guide in targeting the systems for the exotic programme of search for extra terrestrial intelligence (SETI).

The techniques for detection of these substellar companions to solar-type stars comprise of two categories: i) direct method ii) indirect method. In the direct detection the target object is sensed by means of the photons that it actually emits or reflects. This method poses a great challenge for observations with modest sized telescopes because of their inadequate angular resolution and the large brightness contrast between the parent star and the low-mass companion. Hence, all of the successful detections of extra-solar planets have been accomplished mainly by means of the indirect methods. These comprise of three different measurements based on observations of light emitted by the star (rather than that from the planet itself) and recording the variations caused by the orbital motion of the planet around the star. These three measurements are the variations in (i) the star's orbital velocity (ii) its orbital position (iii) its brightness. The orbital position method (the astrometric method) ideally requires measurements over a complete orbital period and hence is a prolonged operation. This method was used to detect the planetary companions of the star Lalande 21185. The third method of observing the variations in brightness requires that the plane of the orbit of the target system must lie perpendicular to the plane of the sky in order to observe the variations in the brightness of the star. The orbital velocity method involving the measurements of the radial velocity of the star is well suited for modest sized telescopes. The Doppler shifts of lines in the spectra of the star are obtained with high dispersion, high resolution echelle spectrographs. It is noteworthy that this method has been used for the successful detection of substellar companions to solar-type stars so far.

These telescopes used in these detections are the following: i) 0.6 m coude auxiliary telescope of Lick Observatory. (ii) 0.8 m photoelectric telescope of Tennessee state University (iii) 0.9m coude feed telescope of Kitt Peak National Observatory (iv) 1.0m telescope of the Haute - Provence Observatory (v) 1.5 m Danish telescope of ESO - La Silla in Chile (vi) 1.93m telescope of Haute - Provence Observatory and (vii) 3.0m Shane telescope of Lick Observatory.

The echelle spectrographs used are (i) the CORAVEL spectrograph with the 1.0 m telescope of the Haute - Provence Observatory and 1.5 m telescope of the Danish telescope at ESO - La Silla, (ii) the ELODIE spectrograph with the 1.93 m telescope of the Haute - Provence Observatory and (iii) the Hamilton spectrograph with the 0.6 m coude auxiliary telescope and the 3.0 m telescope of Lick Observatory.

The requirements for measuring the line of sight velocities of the star orbiting around the centre of mass of the star-companion system are : a very high resolution (echelle) spectrograph, a fiducial spectrum (e.g. Iodine) and plenty of computer time to extract the tiny signal (~ 0.001A) out of the data. The advantage, if the star has a large number of absorption lines in its spectrum, is obvious.

From the successful detections of low-mass companions to solar-type stars reported so far it is evident that such an observational programme will be an exciting one for the 1.0 m Sampurnanand telescope (and the proposed 3.0 m telescope) of UPSO along with a high resolution echelle spectrograph incorporating state of the art technology of detectors, coatings and optical glasses.

The importance of the discovery and exploration of the extra-solar plane systems has been stressed in the following statement in the concluding paragraph of the report entitled "TOPS: Toward Other Planetary Systems " of NASA's solar exploration division : "The universality of this undertaking makes it a compelling project for the international scientific community and it would be especially appropriate for peoples of our world to work together in the quest for knowledge of other more distant worlds. The goal of reaching out to other Earths and perhaps other life is within our reach: the first steps can be taken now ".

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Suggested Reading

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