Bull. Astr. Soc. India (1996) **24**, 5–6

Discovery of a planetary system around 51 Pegasus

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Received 5 December 1995; accepted 6 December 1995

The past few decades have witnessed significant advances in our understanding of how stars form, and there has been associated increase in our knowledge of conditions and phenomena in the early solar system. These have led to the belief that the solar system is formed from a large, rotating disk of gas and dust which is a natural consequence of star formation process. Hence, some if not all stars should be accompanied by planetary systems and many life forms, perhaps, more intelligent than ours may exist in the Universe. But observational evidence for the existence of planetary systems around a few stars has been established only recently. This has become possible due to improvement in the accuracy of instruments used in the search of other planetary systems. It has reached to the point where perturbation due to Jupiter-like objects in the orbit of nearby stars could be detected. Consequently, for more than ten years several groups have been examining the radial velocities of a number of nearby stars, in an attempt to identify orbital motions induced by the presence of heavy planetary companions. The present discovery is a result of such work.

The star 51 Pegasus (HR8729, HD217014 or Gliese 82) with apparent brightness V = 5.5 mag is just visible to the naked eye. The physical parameters of the star are effective temperature, T_{eff} = 5774 deg K; gravity, Log g = 4.3; metallicity [Fe/H] = 0.19; abundances of higher elements, [M/H] = 0.20; absolute magnitude, M_v = 4.60 and radius, R = 1.29 $R_\odot$ while the corresponding parameters for the Sun are 5780, 4.45, 0, 0, 4.79 and 1 respectively. Thus 51 Peg is quite similar to the Sun. However, it is located at a distance of 13.7 pc (45 ly) and has a spectral type of G2-3 V with slight overabundance of heavy elements. Analysis of photometric and spectroscopic observations indicate no evidence either for eclipses in the system or for duplicity or chemical peculiarities in the object. However, they indicate that the star 51 Peg is slightly older than the Sun. Variation in chromospheric activity indicates a 30-day rotation period for 51 Peg.

The announcement of the discovery of a Jupiter-mass ($M_J = 1.9 \times 10^{30}$gm) object in orbit around 51 Peg was made in Florence on Oct. 6, 1995 at the Ninth Cambridge workshop on *Cool stars, Stellar systems, and the Sun*. The claim is based on precise (accuracy about 13 m/s) radial velocity measurements made during September 1994 to September 1995 with the fibre-fed echelle spectrograph ELOIDE of the Haute-Provence Observatory, France. The radial velocity is computed with a cross-correlation technique that uses the Doppler information of

about 5,000 stellar absorption lines. The very high radial velocity accuracy achieved is a result of the scrambling effect of the fibres, as well as monitoring of instrumental variations during observations with a calibration lamp. The parameters of the orbital motions are Period, P = 4.2293 ± 0.0011 day; epoch of the maximum velocity, T in JD = 2449797.773 ± 0.036; eccentricity, e = 0 (assumed); half amplitude of the velocity variation, K = 0.059 ± 0.003 km/s; $a_1 \sin i = (34 \pm 2)\ 10^5$ metre, where a_1 is the orbital radius. After the announcement of the discovery, independent confirmations of the 4.2 day periodicity in radial-velocity variations were obtained in mid-October 1995 by G. Marcy and P.Butler at the Lick Observatory, as well as by joint teams from the Harvard-Smithsonian Center for Astrophysics (R. Noyes, S. Korsennik, M. Krockenberger and P. Nesenson), the High Altitude Observatory (T. Brown, T. Kennelly and C. Rowland) and Pennsylvania State University (S. Horner). The mass obtained for the companion is $M \sin i = 0.47 \pm 0.02\ M_J$ where i is the (unknown) inclination angle of the orbit. A lower limit of 0.4 for sin i is deduced from the mean $v \sin i$ and the rotational velocity computed from chromospheric activity. This corresponds to an upper limit for the mass of the companion of 1.2 M_J. Even if some misalignment is present in the system, the mass of the planet must still be well below the mass of a brown dwarf.

The difference between the 4.2 day orbital solution and the observed radial velocity curve of 51 Peg displays a variation which is statistically significant in comparison to the accuracy of the measurements. Also it cannot be the result of instrumental drift in the spectrograph. This slow perturbation in the 4.2 day period orbit is probably the signature of a second low-mass companion orbiting at larger distance around 51 Peg. The radial velocity measurements of the star 51 Peg made during more than 12 years with the CORAVEL spectrometer indicate that the orbit of the second companion cannot have a large amplitude variation. Intensive monitoring of the star 51 Peg is in progress to confirm the orbit of second companion.

The observations of chromospheric activity; photometric measurements and some theoretical reasons rule out the possibility of spot rotation or pulsation as possible causes for the observed radial velocity variations. The most convincing reason seems to be the orbital motion of a very low mass companion, orbiting at only about eight million kilometers (0.05 AU) around the star 51 Peg. The companion and the star is certainly not predicted by current models of giant planet formation and is a challenge to theorists. As the temperature of the companion is above 1,300 K, this object seems to be very close to the Jeans thermal evaporation temperature limit. In addition to this, evaporation may also take place due to non-thermal effects. So the formation of present planetary system might be the result of the stripping of a very-low-mass brown-dwarf. Whatever the provenance of this roasting beast, its discovery is an interesting lesson to theorists. May be acceleration in the search for extrasolar planetary system will bring much more interesting and surprising facts.

References

1. The orbital parameters etc. are taken from Mayor, M. & Queloz, D. (1995) Nature, 378, 355, the discovery paper.
2. For a recent review on the search for other planetary systems, one can refer to Black, D.C. (1995) Ann. Rev. Astr. Astrophys., 33, 359.