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HD10647 and the Distribution of Exoplanet Properties with Semi-major Axis

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Abstract. At this conference Mayor et al. announced evidence for an exoplanet in orbit around HD10647. Here we consider the Anglo-Australian Planet Search dataset for HD10647. Our dataset amply covers the claimed orbital period and is of substantially higher precision. We do find weak evidence for an exoplanet with similar parameters to those announced by Mayor et al. However, since the amplitude of proposed planet is rather similar to the jitter velocity we are not in a position to confirm a planetary interpretation. We note that claims of small amplitude planets (<20 ms^{-1}) around active stars are fraught with uncertainty, e.g. ϵ Eri.
We also consider the properties of exoplanets with their orbital semi-major axis. We find that there is a steep rise in the numbers of planets towards larger semi-major axes and do not find strong evidence for a short-period peak of exoplanets. We also find interesting correlations of eccentricity and metallicity with semi-major axis. Eccentricities rise steeply out to semi-major axis values of around 0.2 AU at which point a mean eccentricity of around 0.35 is reached. This mean eccentricity shows a slight decline out to several AU. The trends of metallicity with semi-major axis is less robust. Overall, there maybe a decline in metallicity

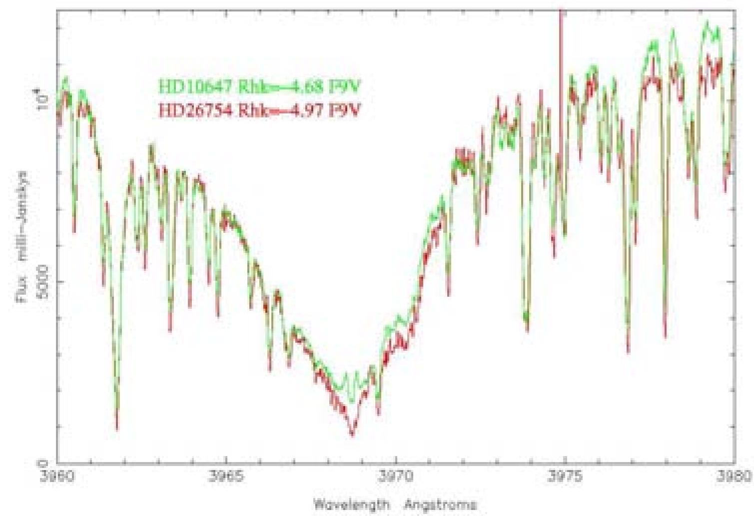

Figure 1. Calcium HK measurement for HD10647 (darker) in comparison with a relatively inactive star of the same spectral type (HD26574 – lighter). The filing in of the line core relative to HD26574 is consistent with HD10647 being chromospherically active.

towards longer semi-major axes arising from the metallicity distribution of low mass exoplanets being more sensitive to semi-major axis.

1. Introduction

In 1995, Mayor & Queloz used the radial velocity variations of the G2V star 51 Peg to infer the presence of a Jupiter mass planet in a 4.2 day orbit. Their discovery was quickly confirmed (Marcy et al. 1997) and corroborated by Doppler evidence for Jupiter mass planets in orbit around a number of other nearby stars (Marcy & Butler 1996; Butler & Marcy 1996; Butler et al. 1997). Less than ten years later, the discovery of exoplanets has dramatically changed the landscape of astronomy. The recent US decadal survey of Astronomy & Astrophysics cites the discovery of exoplanets as the foremost accomplishment in astrophysics during the last decade.

In addition to providing motivation and justification for the next generation of ground (CELT, OWL) and space-based missions (MOST, SIRTF, COROT, Kepler, JWST, GAIA, SIM, Darwin/TPF), existing Doppler surveys also provide first reconnaissance – target lists – for those missions searching for terrestrial planets around nearby stars. It is therefore of great importance that the nearest stars out to 50 parsecs be monitored by precision Doppler groups. With unsupported exoplanet claims, including the double–saturn system orbing HD 83443 (Butler et al. 2002) and the first solar system analog orbiting GJ 777 A (Kerr

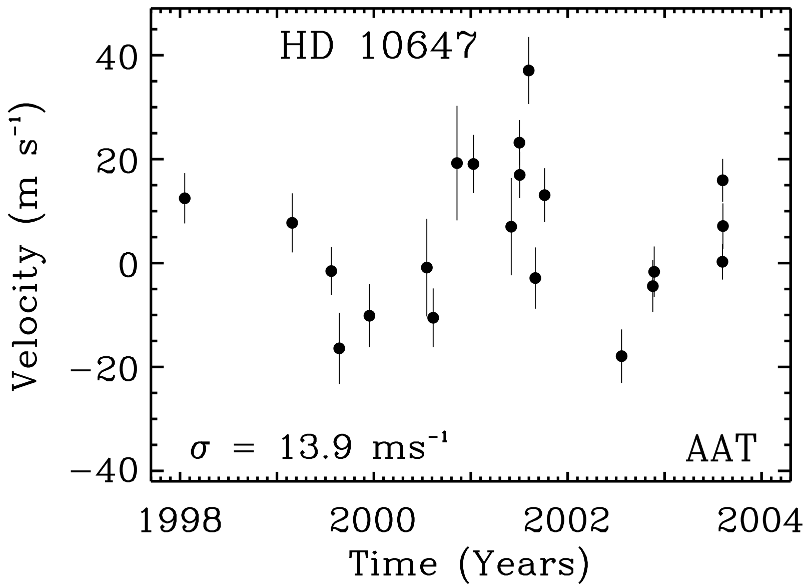

Figure 2. The RMS scatter of the observed radial velocity points for HD10647 about a straight line is 13.9 ms^{-1}. This is consistent with the velocity variations of a chromospherically active F9V star (Wright et al. 2003).

2002), it would seem prudent to have at least two independent groups survey all these stars, and that all claims be independently confirmed. Here we present the evidence for the recently announced CORALIE planet HD10647 from the AAPS dataset.

2. HD10647

The Hipparcos catalogue assigns HD10647 a spectral type of F8V consistent with its F9V entry in the bright star catalogue. Its parallax of 57.63 mas (ESA 1997) together with a V magnitude of 5.52 implies an absolute magnitude of $M_V = 4.32$ and luminosity around 1.5 $L_\odot$ (Mayor et al. 2003). Its inferred age is 1.75 Gyr (Udry et al. 2003), metallicity -0.03±0.04 (Mayor et al. 2003) and temperature = 6143±31 K (Santos et al. 2003).

Figure 1 shows the Ca II H line for HD10647 taken with the UCLES spectrograph on the AAT in August 2002 and indicates it is chromospherically active, confirming the activity index log R'(HK) = –4.68 found by Mayor et al. (2003). While there is no evidence for significant photometric variability in the Hipparcos dataset (ESA 1997), in the past Hipparcos photometry has not proven sufficiently precise to see variability at this level, e.g., HD166435 (Queloz et al. 2001). To discern such variability milli-magnitude photometry (e.g., Henry, Donahue & Baliunas 2002) is required. Evidence for the variability of HD10647 has been reported by Decin et al. (2000), who find it has an infrared excess.

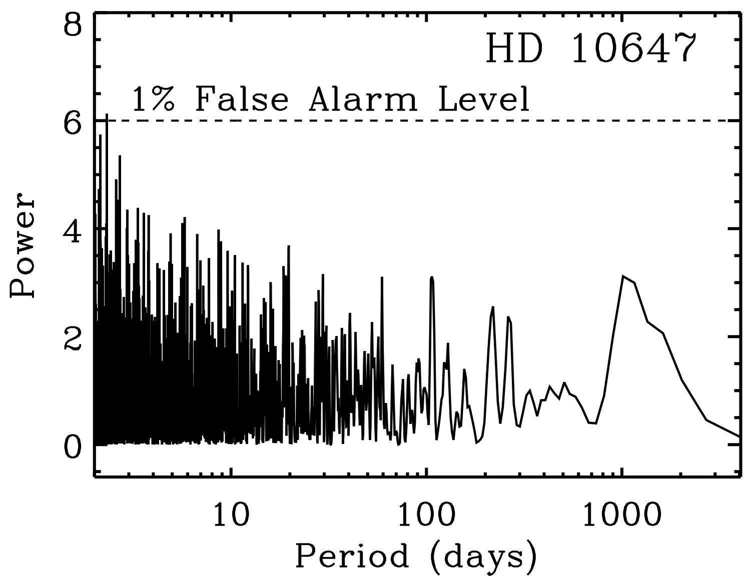

Figure 3. The Mayor et al. (2003) orbit for HD10647 is shown superimposed on the AAPS data points. The RMS scatter of the data is 11.6 ms^{-1}, less than the RMS about a straight line (13.9 ms^{-1}).

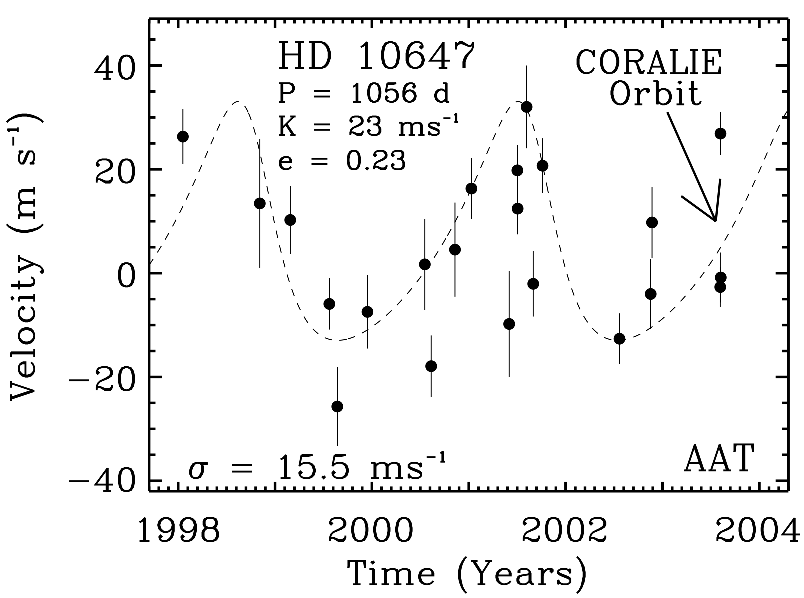

Figure 4. The best fit orbit for HD10647 is shown superimposed on the AAPS data points. The RMS scatter of the data is 10.3 ms^{-1}.

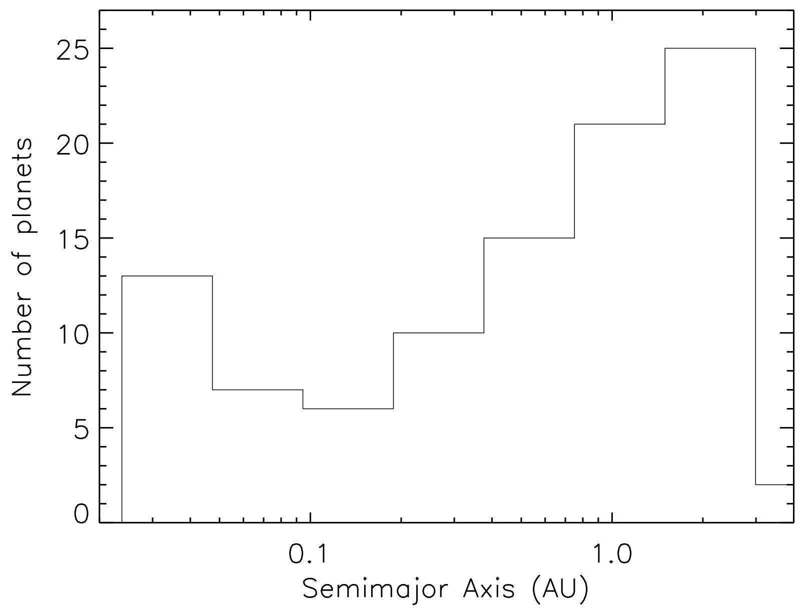

Figure 5. The number of exoplanets discovered with semi-major axis: solid line (all exoplanets), dashed line (> 0.8 $M \sin i$ $\mathrm{M_{JUP}}$).

2.1. Orbital solution for HD10647

Figure 2 shows the AAPS data points for HD10647. The RMS errors of the points about a straight line are consistent with the expected photospheric activity of an active F9V star (Wright et al., 2003). Figure 3 shows the AAPS data together with the best fit solution from the CORALIE data. The RMS scatter of the data about the fit is 11.6 ms^{-1}, slightly less than the greater than 13.9 ms^{-1} scatter about a straight line. Figure 4 shows the AAPS data together with the best fit solution. The RMS scatter about this fit is 10.3 ms^{-1}. Thus we find some weak evidence for a 2.8 yr periodicity which could plausibly be due an extrasolar planet or a natural photospheric cycle. We will continue to obtain high precision (3 ms^{-1}) data for HD10647 in order to assess long period solutions. Our dataset illustrates the problem of finding orbital solutions whose amplitudes are at a similar level to that of the stellar jitter velocity.

3. The semi-major axis distribution for exoplanets

In the following section we plot selected properties of exoplanets with semi-major axis using the compilation of exoplanets of Marcy et al. (2003) as well as metallicities from Santos (2003). The distribution of exoplanets with semi-major axis in Figures 5–7 suggests that exoplanets show key differences with semi-major axis. The solid line in Figure 5 suggests two separate features in the exoplanet semi-major axis distribution. A peak of short-period exoplanets is seen in the 51 Peg-type objects, then a dearth, followed by an smooth rise in the number of exoplanets toward longer periods. However this peak does not appear to be so significant when a simple completeness correction is made. The

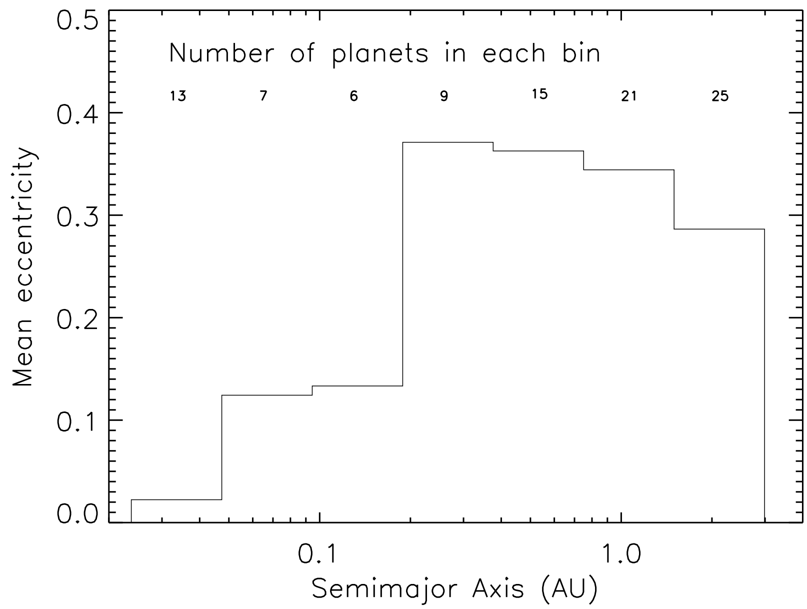

Figure 6. Eccentricity versus semi-major axis for exoplanets.

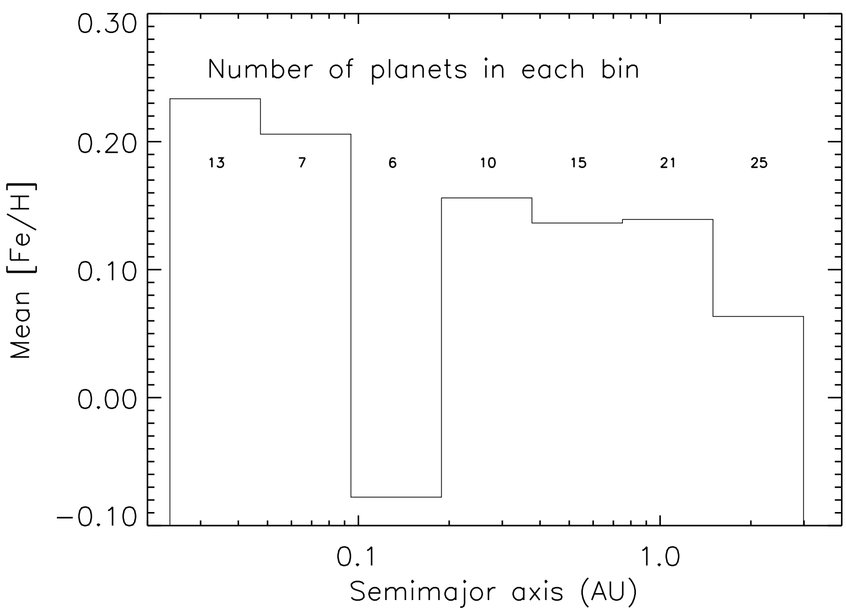

Figure 7. Mean spectroscopic metallicities of the primaries of exoplanets plotted as a function of semi-major axis. The crosses represent the low mass (0.1–1.1 $M \sin i$ $\mathrm{M_{JUP}}$) third of detected exoplanets.

dotted line represents all exoplanets with masses greater than 0.8 $M \sin i$ $\mathrm{M_{JUP}}$ and suggests that the short-period peak may well be a selection effect. The rise in the number of exoplanets towards larger semi-major axes is becoming more apparent as more are discovered and is well reproduced by exoplanet migration scenarios which envisage planets migrating inwards (e.g., Armitage et al. 2002) as well as outwards (Masset & Papaloizou 2003). The distribution of planetary eccentricities and metallicities also shows strong features at different periods. Beyond the short-period planets which are circularised by tidal forces the mean eccentricities of the known exoplanets shown in Figure 6 have values around 0.35 and show a slight decline to longer periods. Figure 7 indicates that mean metallicities appear to show a peak at small semi-major axes and may also decline at large values of semi-major axis. Given that the best explanation for the close-in planets is migration and that migration is modelled to be mass depedent, it is interesting to see if there is any mass dependency. The crosses in Figure 7, represent the low-mass exoplanets ($<$1.1 $M \sin i$ $\mathrm{M_{JUP}}$) and suggest the slight decline to long periods may be contributed by the low-mass third of the exoplanet sample. This result is as expected by migration theories which predict more migration of lower mass objects, however, needs confirmation with more exoplanets and higher precision metallicities.

References

Armitage, P.J., Livio, M., Lubow, S.H., & Pringle, J.E. 2002, MNRAS, 334, 248

Butler, R.P., & Marcy, G.W. 1996, ApJ, 464, L153

Butler, R.P., et al. 1997, ApJ, 474, L115

Butler, R.P., et al. 2002, ApJ, 578, 565

Decin, L., et al. 2002, A&A, 357, 533

Henry, G.W, Donahue, R.A., & Baliunas, S.L. 2002, ApJ, 577, 111

Jones, H.R.A., et al. 2003, MNRAS, 341, 948

Kerr, R.A. 2002, Science, 296, 2124

Marcy, G.W., & Butler, R.P. 1996, ApJ, 464, L147

Marcy, G.W., et al. 1997, ApJ, 481, 926

Marcy, G.W., Butler, R.P., Vogt, S.S., Fischer, D.A., et al. 2003, http://exoplanets.org

Masset, F.S., & Papaloizou, J.C.B. 2003, ApJ, 588, 494

Mayor, M., & Queloz, D. 1995, Nature, 378, 355

Mayor, M., et al. 2003, this conference

Queloz, D., et al. 2001 A&A, 379, 279

Santos, N., et al. 2003, A&A, 398, 363

Udry, S., et al. 2003, http://obswww.unige.ch/˜ udry/planet/hd10647.html

Wright, J.T., Marcy, G.M., Fischer, D.A., & Butler, R.P. 2003, IAUS, 219, 221