Physics of Planetary Systems — Exercises

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Distributed: 2009-04-23; results due: 2009-04-30.

Set 1

Problem 1.1

State 3 techniques for precise stellar radial velocity measurements and the advantages and disadvantages of each.
(1 point)

Problem 1.2

The Keck HiRes spectrograph has a reported radial velocity error of $\sigma = 2$ m/s on an $m_\mathrm{V} = 12$ mag star in 22 seconds. Calculate the expected error for a CoRoT transiting planet candidate around a star with $m_\mathrm{V} = 15.8$ mag for a one-hour exposure. *(2 points)*

Problem 1.3

You have discovered two new planets. Both have the same period and velocity amplitude (K amplitude). One planet, however, is in a circular orbit and the other is in a highly eccentric orbit with $e = 0.9$. Which planet is the less massive? How much lighter is the low-mass planet compared to the high-mass planet?
(+2 points)

Problem 1.4

Derive the Jeans critical radius and mass more accurately by

- considering a homogeneous sphere of uniform density with radius R and mass $\mathscr{M}$ (instead of an arbitrarily shaped cloud of characteristic size R) and gravitational potential $|U| = \frac{3}{5}\frac{G\mathscr{M}^2}{R}$,
- using $v^2 = \frac{3kT}{\mu m_\mathrm{p}}$ (instead of $v^2 \sim \frac{kT}{m_\mathrm{p}}$),
- and employing the stability limit from the virial theorem: $K < \frac{|U|}{2}$ (instead of $K < |U|$).

(2 points)

Problem 1.5

A rotating molecular core with a specific angular momentum $L/\mathscr{M} = 10^{21}$ cm^2 s^{-1} collapses to form the protosun with $R = R_\odot$. Estimate the theoretical rotation period of that protosun. Show that without the angular momentum transport that protosun would break apart.
(2 points)

Figure 1: The picture shows the Great Nebula in Orion. The Orion Nebula contains many stellar nurseries. These nurseries contain hydrogen gas, hot young stars, protoplanetary disks, and stellar jets. (Image: hubblesite.org)