

Course 12.425. Problem Set 6. Due Thursday Dec. 6, 2007.

For all problems be sure to show your work including all steps taken.

1. Atmospheric Escape

Note: this is the same problem given in Problem Set 5, but with a correction to b. We assume your answers in c and d will also change.

In class we discussed atmospheric escape as the primary sink for atmospheric loss.

a. Derive a formula for escape velocity.

b. Make a plot of **relative stellar heating** (in units of solar luminosity $L_{\oplus} = L_{\odot}/4\pi a_{\oplus}^2$ at Earth) (y axis) vs. escape velocity (x axis) for all solar system planets and Earth's moon. On the same plot, plot all transiting exoplanets. You may find the transiting exoplanet data from the website <http://exoplanet.eu/catalog.php>, but only consider exoplanets with measured masses and radii. Because star luminosity data is not available, you may assume that

$$\frac{L}{L_{\odot}} = \left(\frac{M}{M_{\odot}} \right)^{3/5}. \quad (1)$$

If an exoplanet's host star's mass and/or radius is not available, make your best guess. Hint: use a log/log plot.

c. Based on the plot from 3b, discuss (in one to two paragraphs) which solar system planets are affected by atmospheric escape and which exoplanets may be affected by atmospheric escape.

d. Based on the plot from 3b, choose a planet mass, radius, and semi-major axis for a planet orbiting a sun-like star that would be dramatically affected by atmospheric escape.

2. Exoplanet Spectra

In class we discussed qualitatively where absorption lines come from. For this problem, use the solution to the radiative transfer problem derived in Lecture 15 to explain why a planet atmosphere with increasing temperature with increasing altitude results in emission lines.

3. Comparison of Exoplanet Detection Techniques

Figure 1 summarizes four different exoplanet detection techniques including radial velocity, transit searches, astrometry, and microlensing.

Radial Velocity.

a. Using the equation for radial velocity semi-amplitude, qualitatively describe the slope of the radial velocity detection lines.

b. At approximately 5 AU, the radial velocity detection lines change slope. Why?

Transits vs. Radial Velocity

c. Look at the COROT transit curve and the radial velocity 2010 curve. Why does the transit search technique do better at smaller semi-major axes than the radial velocity technique? Why does the transit technique do worse at larger semi-major axes?

Astrometry

d. The STEPS, VLTI and KECK, and SIM curves are all astrometric planet searches. Using mass balance, quantitatively describe the astrometry detection curve at small semi-major axes.

e. Why is there the curve "V"-shaped?

f. Why does the semi-major axis location of the dip in the "V"-shape differ for different surveys?

Microlensing

g. How does the microlensing detection limit differ from the three other planet search techniques shown?

General

h. If you were to start a planet survey, which technique would you choose and why?

Bonus Question

i. What is the green shaded region?

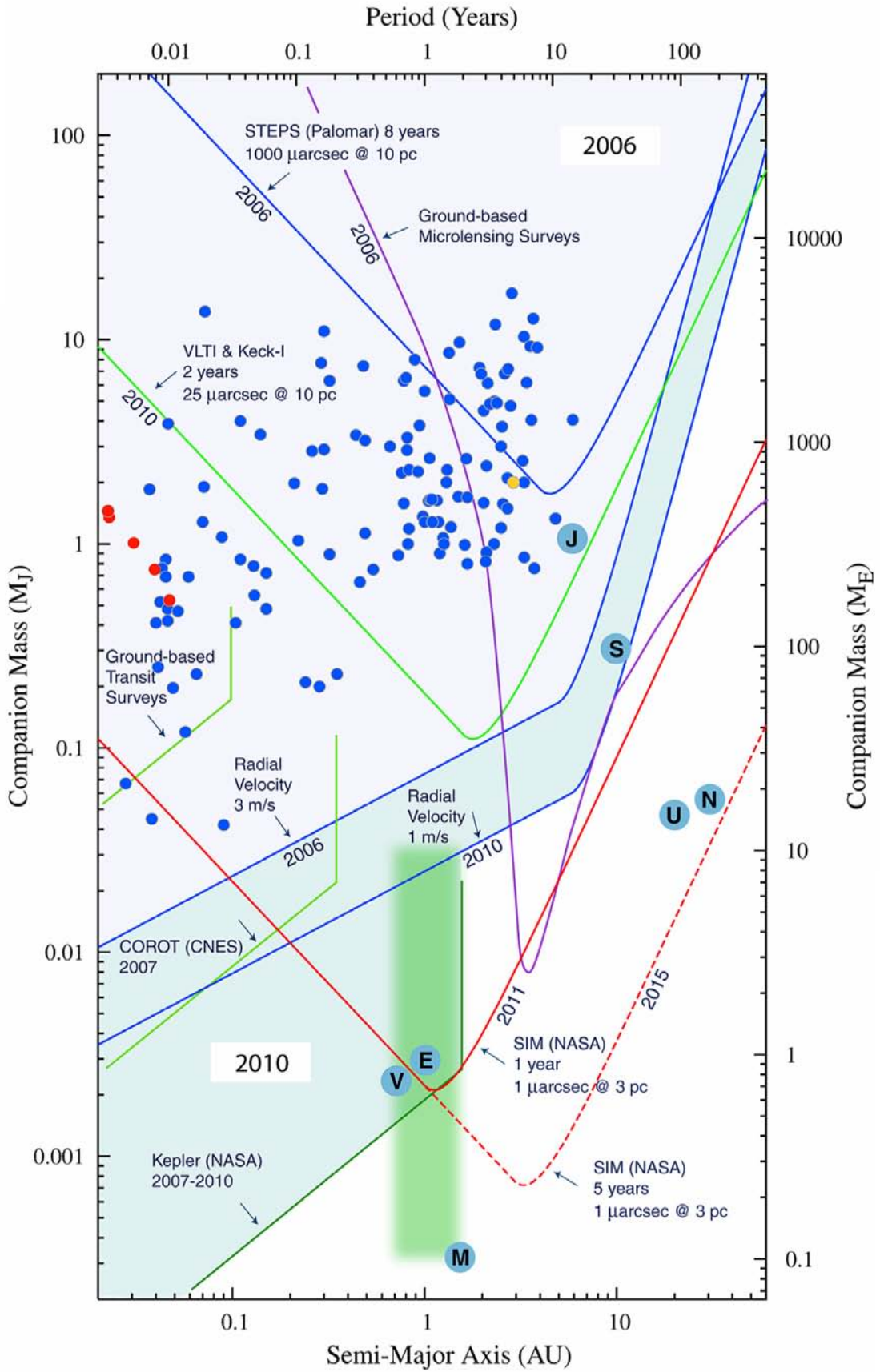


FIG. 1: