Honors Seminar 259 — cheat sheet for 10/1/2008 — Andrew Baker

Marcy & Butler (1996)

You should read the whole article. Key questions:

1. How does undertainty about inclination affect the authors' conclusions about 70 Vir B, and why is this uncertainty important?
2. What's the significance of the "iodine absorption cell" that the authors describe using?
3. Why do the authors talk about observations of stars that do *not* have planetary companions?
4. What is different about the presentation of the (same) data in Figures 2 and 3?
5. In §4, the authors consider several alternatives to their claim that 70 Vir B is a planet. How do they argue against these alternatives?
6. Based on the last paragraph of the paper, do you think the authors were expecting to find a planet like 70 Vir B when they first began observing 70 Vir?

Key terms:

- **albedo** = the fraction (from 0 to 1) or percentage (from 0 to 100) of incident light that an astronomical body reflects
- **brown dwarf** = an object that is in the grey zone between a large planet and a small star: it is not massive enough to produce energy by the fusion of hydrogen to helium in its core (i.e., it is less than 80 times as massive as Jupiter), but it is massive enough to produce energy by fusing *deuterium* (i.e., it is more than 13 times as massive as Jupiter), and it forms from its own collapsing nebular cloud rather than from a protoplanetary disk
- **Ca II IR triplet** = a trio of absorption lines that can appear in the spectrum of a star, or in the spectrum of a galaxy (when the light from all its stars is added together); in chsomorpherically active stars, these lines can have an emission component
- **chromospheric activity** = a variety of "excess emission" signatures that arise in an outer layer of a star's atmosphere (the chromosphere) and are due to changes in the star's magnetic field
- **Clausius–Clapeyron equation** = an exact relationship describing the separation between two phases (e.g., gas and liquid) of matter
- **degeneracy pressure** = a form of pressure that arises due to the quantum mechanical requirement that no two fermions (a category of fundamental particles that includes electrons) can occupy the same state at the same time
- **deuterium** = a (rare) stable isotope of hydrogen that contains a single neutron

- **dex** = a logarithmic interval of 1, corresponding to a factor of 10 (e.g., 0.1 dex corresponds to a factor $10^{0.1} = 1.26$)
- **echelle spectrometer** = an instrument that is fed light by a telescope and splits it into a high-resolution spectrum (typically, of a star)
- **effective temperature** = $T_{\rm eff}$ = the temperature a perfect blackbody would need to have in order to produce the same total flux as a particular star (this is usually close to the temperature of a star's "surface")
- **G dwarf** = a star like the Sun, with a spectral type of G and a "dwarf" mass that puts it on the main sequence in the HR diagram
- Hα = the transition from the $n = 3$ to the $n = 2$ electronic state in a hydrogen atom; this can produce a very strong emission line in an optical spectrum
- **inclination** = an angle ranging from 0° (face-on) to 90° (edge-on) that describes the orientation of a disk or other rotating object with respect to our line of sight
- **Keplerian** = adjective describing the motion of a small mass (e.g., a planet) in orbit around a large mass (e.g., a planet)
- **Kepler's (third) law** = the relationship between the period of a planet's orbit and the radius (more precisely, the semi-major axis) of that orbit: $P^2 \propto a^3$
- **periodogram** = a transformation of a time sequence of data that reveals the presence and frequency of any underlying repeating pattern(s)
- **phase** = a number between 0 and 1 that indicates the fraction of its orbit that a planet has passed through at a given time (the exact choice of "zero" is often arbitrary)
- **photospheric** = adjective referring to the "surface" of a star
- **resolution** = $\Delta\lambda/\lambda$ = the smallest separation in wavelength that a given spectrum can distinguish
- **rms** = root mean squared = adjective describing the statistical scatter of points from their mean or from a theoretical fit
- **Schmidt camera** = an optical telescope design that is optimized for observations of wide areas on the sky
- **subgiant** = a category of stars that are slightly brighter than the "dwarf" stars on the main sequence in the HR diagram

Charbonneau et al. (2000)

You should read the whole article. Key questions:

1. How did the authors choose HD 209458 as a target for observation?

2. What is responsible for the dips in Figures 1 and 2?

3. In Figure 3, why do the dotted contours for a larger star require a larger planet and a smaller inclination?

4. Scientists draw a distinction between *random* or *statistical* uncertainities or errors, which result from inexact measurements, and *systematic* uncertainties or errors, which cannot be reduced no matter how many measurements are made. How does Figure 3 illustrate this distinction?

5. What new information is available with a transit measurement that was not available from Doppler measurements alone? What are the prospects for detecting other planets in the same planetary system using the transit and Doppler techniques?

6. Would it be possible to detect the atmosphere of this transiting planet?

Key terms:

- **aperture photometry** = measurement of the light from an astronomical object within a particular region ("aperture") on the sky
- **atmospheric extinction** = loss of light from an astronomical object on its way to a telescope due to abssorption and scattering by the atmosphere
- BVR = set of three filters that are sensitive to blue, green, and red light
- **cadence** = frequency of observation, in the sense of daily, weekly, or monthly
- **CCD** = charge–coupled device = digital camera
- **ephemeris** = a table that specifies the position of a fast-moving (i.e., solar system) object as a function of time
- **escape velocity** = the velocity with which an object must be moving in order to escape the gravitational attraction of the body on which it starts
- **limb darkening** = the fact that the disks of stars (including the sun) are less bright at their rims ("limbs") than at their centers; this is due to the lower temperature and lower projected column density along the line of sight
- **magnitude** = annoying astronomical expression for the brightness of a star or galaxy: it is logarithmic, and fainter objects have *larger* magnitudes
- **master bias** = a synthetic image that reflects what a CCD would "see" even if not exposed to the sky
- **master flat** = a synthetic image that reflects the relationship between incoming photon intensity and output counts at each pixel of a CCD
- **photometric** = adjective describing observations that involve only taking pictures (i.e., imaging) rather than obtaining a spectrum

- **point spread function** = the two-dimensional shape that a star's light has in an image, which results from the settings of the telescope and instrument
- **saturation** = when so many photons hit the same pixel of a detector that the electronic response is no longer linearly proportional to the incident flux; this is a bad situation, and should be avoided!
- **scintillation** = flickering due to turbulence along the line of sight
- **surface gravity** = gravitatational acceleration at the "surface" of a star; this is a key property in determining the observed spectrum of a star
- **thermal velocity** = the characteristic speed of a given atom that is determined by the temperature of the gas in which it finds itself (hotter gas leads to higher random velocities)
- **UT** = Universal Time = an absolute time scale that can be used to define the epoch of any observation by a telescope on the Earth or in space
- χ^2 = chi-square = a quantity used to describe how well a set of data points match a model (higher values correspond to a worse match)