

## Honors Seminar 256 — cheat sheet for 10/4/2011 — Andrew Baker

### Noyes et al. (1997)

You should read the whole article, and the associated “erratum.” Key questions:

1. How does uncertainty about inclination affect the authors’ conclusions about the companion of  $\rho$  CrB, and why is this uncertainty important?
2. What’s the significance of the “absorption cell filled with iodine vapor” that the authors describe using?
3. Which aspect of Figure 1 do the authors suggest might be due to unspecified “long-term instrumental drifts” (i.e., changes in the response of their instrument to an identical input signal)?
4. What is different about the presentation of the (same) data in Figures 1 and 2?
5. In §4, the authors consider several alternatives to their claim that the companion of  $\rho$  CrB is a planet. How do they argue against these alternatives?
6. Based on the last paragraph of the paper, how do the authors’ results fit in with observations of a different star (47 UMa) by a different team of researchers, and with preexisting views about the formation of planetary systems?
7. Can you explain why the mistake reported in the “erratum” requires changes to some (but not all) of the orbital parameters for the companion of  $\rho$  CrB as they were reported in the original paper?

Key terms:

- **absolute visual magnitude** = way of expressing how bright a star or galaxy *would* appear in a standard “visual” (green) filter if it lay at a distance of 10 parsec. All magnitude scales in astronomy are (sadly) logarithmic and defined so that smaller/less positive numbers correspond to brighter objects.
- **acoustic-gravity mode** = one of several different ways (“modes”) in which a star can pulsate
- **AU** = astronomical unit, the distance from the Earth to the Sun
- **barycenter** = center of mass of the solar system (*not* identical to the center of the Sun, thanks to the effects of Jupiter and the other planets)
- **bolometric correction** = adjustment used to scale the brightness of an object at a particular wavelength to its total (“bolometric”) brightness summed over *all* wavelengths

- **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 chromospherically 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
- **color index** = computed by measuring the ratio of an object’s apparent brightnesses through two different filters, taking the logarithm, and adding a constant; the “ $B - V$ ” color index is measured using the  $B$  and  $V$  filters that are sensitive to blue and green light
- **convective blueshift** = shift of the spectrum of (part of) a star due to the bulk outward motion of a region of its surface
- **cosmic rays** = high-energy particles that have a nasty habit of plowing into/through instruments while astronomers are trying to use them for observations, and whose effects must be carefully removed
- **deuterium** = a (rare) stable isotope of hydrogen that contains a single neutron
- **dissipative** = adjective describing any system (e.g., a cloud of interstellar gas) in which kinetic energy and angular momentum can be lost
- **eccentricity** = measure of how circular an orbit is (0 means perfectly circular)
- **echelle spectrograph** = an instrument that is fed light by a telescope and splits it into a high-resolution spectrum (typically, of a star)
- **effective temperature** =  $T_{\text{eff}}$  = 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”)
- **epoch of periastron** = time when a companion is closest to the star it orbits around (assuming its orbit is not *perfectly* circular)
- **[Fe/H]** = logarithm of iron-to-hydrogen abundance ratio within a star or galaxy (relative to that of the Sun, meaning that a star with solar composition has  $[\text{Fe}/\text{H}] = 0$ )

- **Galactic** = when capitalized, an adjective referring to the Milky Way and its constituents
- **HIPPARCOS** = satellite dedicated to making very precise measurements of the positions of stars (and any changes thereof)
- **inclination** = an angle ranging from  $0^\circ$  (face-on) to  $90^\circ$  (edge-on) that describes the orientation of a disk or other rotating object with respect to our line of sight
- **iterative rejection fitting** = procedure for fitting a model to a set of data points in which one excludes all “bad” data points that differ from the model by more than a fixed threshold, refits, excludes again, refits again, etc., until no more points need to be excluded
- **Keplerian** = adjective describing the motion of a small mass (e.g., a planet) in orbit around a large mass (e.g., a planet)
- **longitude of periastron** = geometrical angle at which a companion is closest to the star it orbits around (assuming its orbit is not *perfectly* circular)
- **opacity** = thickness of a medium
- **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)
- **photometric** = adjective describing observations that involve only taking pictures (i.e., imaging) rather than obtaining a spectrum
- **proper motion** = apparent motion of a star in the plane of the sky (i.e., perpendicular to the “radial” direction), typically extremely small
- **resolution** =  $\lambda/\Delta\lambda$  = the smallest separation in wavelength that a given spectrum can distinguish (the higher  $R$ , the finer the separation)
- **rms** = root mean squared = adjective describing the statistical scatter of points from their mean or from a theoretical fit
- **spectral order** = one of several copies of a spectrum that an echelle spectrograph produces in a single observation
- **surface gravity** = gravitational acceleration at the “surface” of a star; this is a key property in determining the observed spectrum of a star
- **tidal circularization** = process by which the initially eccentric orbit of one object around another evolves to become circular, as a result of their gravitational interactions
- **ultraviolet excess** = difference in color index (for the ultraviolet  $U$  and blue  $B$  filters) relative to that of the Sun

- **velocity zero point** = input signal that corresponds to the radial velocity of a source that is neither approaching nor receding from us
- $\chi^2$  = chi-square = a quantity used to describe how well a set of data points match a model (higher values correspond to a worse match)

### 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* uncertainties 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:

- **albedo** = the fraction (from 0 to 1) or percentage (from 0 to 100) of incident light that an astronomical body reflects
- **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 absorption 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

- **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
- **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
- **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!
- **Schmidt camera** = an optical telescope design that is optimized for observations of wide areas on the sky
- **scintillation** = flickering due to turbulence along the line of sight
- **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