AST 381: Planetary Astrophysics

Homework #1, Due Sep 19

Reminder: Show your work! A correct answer with no supporting work gets no credit. An incorrect answer with all the right supporting work and some minor calculation error will receive most or all of the credit. Each problem is worth 25 points, 100 in all. **Solutions should be typeset with LaTeX. Hand-written solutions will not be accepted. All code should be posted on github, in such a way that I can access it, and the link should be given in the TeX.**

Question 1: Orbit Predictions. (25 pts) Using your programming language of choice, write a function that computes the expected relative astrometry, absolute astrometry, and radial velocities of a two-body system. That is, it should take the time, the orbital elements, and some way of describing the object masses (either both masses or the mass ratio) as input. It should return: 1) the on-sky projected separation and position angle of B with respect to A, 2) the on-sky projected separation and position angle of both objects with respect to the center-of-mass position, and 3) the RVs of both objects with respect to the center-of-mass RV.

Note that by returning all of these numbers, your new routine can flexibly serve as the core of an orbit fitter for a wide range of data types: RVs, direct imaging (such as from AO imaging), photocenter motion (such as from Gaia or Hipparcos), and transits. If you can think of something else that sounds useful to return, feel free to implement that too.

You can adopt the appropriate equations from the Exoplanets textbook, but note that you need to implement a solver for the transcendental equation. You don't need to consider light travel times, but at least keep in mind that we're getting into a realm of data precision where that could matter. (I actually had to do this for my recent paper on the young eclipsing binary UScoCTIO 5. It turns out that Kepler data really is that good.)

Question 2: Extreme Planetary Orbits. (25 pts) The transiting planet HD 80606 b is notable for being a transiting planet on a very extreme orbit, with eccentricity of $e = 0.934$. Go out into the literature and find the orbital elements for this planet, and use your orbit prediction code to predict the RV curve over the course of this semester. You should turn in a plot of stellar RV versus time spanning August-December. If you were going to ask for telescope time on the McDonald 2.7m in order to measure the extreme maximum and minimum, which nights would you want?

Question 3: Extreme Transits. (25 pts) Use your orbit prediction code to predict when the planetary transit or transits would occur over the same timeframe. (Note, just looking up timing on the internet would not be sporting, though you can feel free to look around for some way to confirm your answer. Show evidence of how you calculated your result using your code, though.)

Would the transit or transits be visible from McDonald? If so, what fraction? Note that you might find it useful to know when objects are observable from McDonald. You can find this by going to http://nexus.as.utexas.edu/, clicking on "Observing Support" and then "Sun and Moon Calendars". If you plan to observe out there regularly, you should go ahead and bookmark this for planning your future observing runs.

Question 4: Extreme Astrometry. (25 pts) Use your orbit prediction code to predict the astrometric motion (in arcseconds or a subdivision thereof) of HD 80606 due to its planetary companion. You should go out on the internet and find a reputable source in the literature (that you can and should cite) that gives the typical per-epoch astrometric precision that Gaia can obtain for a star like HD 80606. Assuming Gaia observes HD 80606 at 100 randomly timed epochs over 5 years, make plots showing simulated data (with the above uncertainties added in) for the RA and DEC as a function of time accounting for:

1. Just the planet's influence on the star
2. Above, plus the parallax motion
3. Both of above, plus the proper motion

I suggest that each should be three panels: RA versus time, DEC versus time, and DEC versus RA. If you need a reference for coordinates, proper motion, and parallax, I suggest adopting numbers from Gaia, as this star was included in the Gaia-Tycho Astrometric Solution. You can find those on the Vizier website.

Note that trying to all of this from scratch, using spherical trig, is a massive headache that you shouldn't grapple with at this point. You might find the discussion of annual parallax in this set of notes highly useful: http://star-www.st-and.ac.uk/ fv/webnotes/