

12.425

Lecture 16

Thursday November 29, 2007

The focus of this lecture is to discuss microlensing and astrometry as planet discovery techniques. Students will be introduced to the techniques of each detection method and the characterizations about planets astronomers can make using these techniques.

The first in-class exercise asks students to look through three cartoons illustrating the concept of microlensing and explain what is being represented. They will also be given five exoplanet detection plots that illustrate the light-magnitude curves of supposed microlensed stars. The students will calculate how long the microlensing event lasted as well as the factor by which the magnitude of the star changed as a result of being lensed.

Students will note in the cartoons that the star being lensed, the more distant star, becomes brighter as its light is affected by the object positioned between it and the observer. The second cartoon shows a conceptual picture of what happens to the brightness if a planet or other small object orbits the object that causes the lensing, and the third cartoon again illustrates how the most distant star is lensed and seen from an observer on earth. Above the illustration is the associated light curve. Students noted that the effect of the small planet around the microlens caused the curve to spike because the magnitude of distant star's light was affected by both the object that lensed it as well as the planet orbiting the lensing object.

In the actual data representing these events, the first example showed the lensed star's magnitude increase by a factor of 4 or 5 over a period of 60 days, but the planet-caused peak led to an cumulative spike in brightness of about 7 or 8 times the star's original (i.e., unlensed) brightness. The second example is the same as the first only the scientists have zoomed in on the spikes in brightness. The next table shows the characterizations this data led scientists to make

about the possible planet they detected using this technique. The parameters have many uncertainties, student noted, but the technique holds promise. The next data plot showed a magnification of 100 times. The period of increased magnitude is not easily identifiable, but the second plot represents an inset of the peak of the first graph's curve. It shows that within that extraordinary magnitude lens is hidden the indication that a planet is adding to the source star's magnification. Students noted that statistically they remain skeptical to the data, but if many examples similar to this one are found, scientists could begin to characterize the relative quantity of certain-sized planets. The next example, OGLE 2005-BLG-390Lb shows a magnification of three and over a period of 40 days, and the last example shows a magnification of about 60 over a period of 80 days. Students also noted that the x timescale is much larger compared to what was seen for exoplanets detected by transits and radial velocity—those scales were on the order of a few days, where these microlensing planets and stars signature changes over upwards of 100 days.

The second and third in-class exercises deal with astrometry. The second exercise asks students to estimate the maximum angular motion astronomers would measure if a sun-like star was being affected by an orbiting Jupiter-mass planet at a distance of five AU. Students should remember that in astrometry  $M_{\text{star}} \text{ times } a_{\text{star}} = M_{\text{planet}} \text{ times } a_{\text{planet}}$ . Also note: one arcsecond equals 1 AU/ 1 Parsecs. Students found that the angular motion would be  $5 \times 10^{-4}$  arcseconds, which is exceedingly small.

That small change in position on the celestial sphere becomes important in the third exercise, which looks at astrometry data taken as astronomers used this technique to try to find exoplanets. The exercise asks students to look at this data, decide what the x and y axes represent and then say if the data offers robust evidence for planet detection. In the first two examples, the

x and y axes represent time and declination and right ascension, respectively, of the studied star. The data does not suggest evidence for a proposed planet detection, but at the time of data collection, the scientist thought his data showed a change in angular motion suggesting the existence of a companion planet. The next two examples plot right ascension versus declination as x versus y and demonstrate how the position changes over time. The hypothetical circle in the Epsilon Eridani example suggests that a planet could be pulling this star in that orbit but more data is needed to the right side of the graph. The scientists will have to wait a few years to get this data, students noted, because as seen in the second Epsilon Eridani plot, the perturbation is on the order of 20 years, which is assessed using radial velocity data. All stars analyzed with astrometry must be fairly close, however, which limits the data astronomers can collect by this method.

Students will understand after this lecture that microlensing is statistically and mathematically difficult, but holds promise for detecting Earth-mass planets. Astronomers right now will require luck in finding these planets because the source star and lens star must be very closely aligned from the view from Earth. Astrometry is fundamentally more simple in calculation and concept, but in practice, the change in angular motion is so small it is hard to resolve a significant verification for a planet's existence and the technique is limited to stars that are near to Earth.