Stellar Surface Imaging of II Pegasi via Light-Curve Inversion
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Goal
• Our goal is to map starspots on the surface of the star II Pegasi via the method of Light-curve Inversion and to study how they change over time.

What are starspots?
• Starspots are dark areas on the surface of a star which are analogous to sunspots on the Sun.
• The sun’s energy is produced via nuclear fusion of hydrogen into helium in the core. Surrounding the core is the radiative zone, in which energy is carried outward via radiative diffusion. From the outer boundary of the radiative zone to the surface is the convective zone. Plasma in the convective zone rises to the surface and then sinks back down as it cools, thus transporting energy outward via convection.
• Strong magnetic fields within sunspots disrupt the convection in the surface layer of the sun (the photosphere) by interacting with electrical currents in the plasma, causing the temperature to be lower than the surrounding photosphere. The solar photosphere has a temperature of 5800K, while the temperatures of sunspots are around 4000-4500K.

Why study starspots?
• Starspots are believed to be magnetic phenomena similar to sunspots on the Sun, so that studying starspots on other stars besides the Sun should lead to a more general understanding of stellar magnetic phenomena than could be obtained by studying the Sun alone.

Our target star: II Pegasi
• II Pegasi (HD 224085) is a single-lined spectroscopic binary classified as a RS CVn binary. It has a rotational phase of 6.7 days.
• II Pegasi was chosen for light-curve inversion because it had been observed to have high variations in its brightness with possibility of spots coverage of about 40% of the visible surface.

Light-curve Inversion
• Even through the Hubble Space Telescope, stars other than the Sun appear as featureless pinpoints. We thus must resort to indirect techniques to map their surfaces. Light-curve Inversion is a mathematical technique which infers the appearance of the spots based on the variations in a star’s observed brightness (its light curve) produced as the star’s rotation carries them into and out of view from Earth.

Results for data acquired September 1995 to January 1996
• The first data set we analyzed was acquired by the Vanderbilt/Tennessee State 0.4-m Automated Photometric Telescope on Mount Hopkins, Arizona (Greg Henry, private communication).
  Looking down at 45°/45° Looking down at 45°/225°
  The data were subdivided into five sets according to the time of acquisition. Each set was used to produce a single light curve. The five light curves were then inverted to generate the reconstructed surface.
  • The pictures on the left show the reconstructed surface of II Pegasi for the five data sets. Each row shows two surfaces from the same light curve but with viewing longitudes of 45° and 225°. (By convention, the longitude of disk center for the initial observation is arbitrarily set to 90°.)
  • There are two spots on the surface with a separation of approximately 180° in longitude. The two spots appear to move in longitude relative to each other, with the bigger spot moving faster than the smaller spot. Since the location of the smaller spot appears to be closer to the equator than the bigger spot, this result implies that the spot with higher latitude has a shorter rotation period about the star’s axis than the spot with lower latitude. This is an interesting result because it would mean that the differential rotation of II Pegasi is opposite to the Sun’s.

Results for data acquired November 1988 to September 1992
• The second data set we analyzed was also obtained via the same telescope (Henry, et al. 1995, ApJSS, 97, 513).
  • This data set extends over a period of almost 4 years. We subdivided the data into 15 data sets. The overall results show much interesting surface activity. Several starspots were observed throughout the interval with usually two spots visible at the same time. There appears to be new spots forming while others disappear.
  Looking down at 45°/120°

Solar Differential Rotation
Due to the fact that the Sun is not a solid body, different places on the surface of the Sun rotate with different periods depend on their latitudes. Places at lower latitude have shorter periods than places at higher latitude. The Sun’s equator rotates with period of approximately 25 days.

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This plot shows the light-curve of II Pegasi from one data set. The normalized-intensity is plotted versus the rotational phase (fraction of the period) of the star. The dip in the light curve represent the decline in brightness of the star when starspots rotate into the visible part of the surface. From those variations in brightness, the Light-curve Inversion program maps the spots.

Note: Assumed angle of inclination of rotation axis to line of sight is 45°.