Splitting Those Double Stars

By Greg Morgan and Randy Steiner

How close can two stars be to each other and still be seen as two distinct stars? A simple formula gives us a theoretical limit: resolution (arcseconds) = 4.56 / diameter of objective (in inches). This lower limit of resolution is known as **Dawes Limit** see Fig 1. Double stars are fascinating objects for viewing because the closer they get, the more challenging they are to observe. To get close to Dawes Limit everything has to be near perfect, both stars should be close to the same magnitude, the atmosphere needs to be ideal and the optics need to be well tuned. For example, if you have a 5 inch scope Dawes Limit is 0.91 asec, in a 10 inch scope it is 0.46 asec. Although it is useful to know this limit, in the real world where atmospheric distortions control the seeing, it is difficult to get down below the 1.0 asec threshold. Even on good nights, a large scope like the 4.2m William Herschel Telescope has trouble getting down below the 0.5 asec level.

In Fig 2 and Fig 3 the inset image is a 1 second exposure taken with the ST-7 and a 10" LX200 at ~f/45. The 3D graphs plot the raw pixel data that was transferred from the digital camera image to an Excel spreadsheet. The actual raw data for each star creates a conical shape called a centroid.

The shape of the centroid differs from the theoretical PSF due to various factors. These include but are not limited to seeing, distortions in the light wave front as it propagates through the atmosphere, the inability of any scope to be optically perfect and the CCD camera noise or signal to noise characteristics. To deal with these factors successfully, one can model the raw data collected from many images. As a result, the centroid's 3D shape and asymmetry unveil intriguing result. If two stars are so close together that individual peaks do not show up in an image, there is still an intrinsic statistically measurable asymmetry to the centroid. This means that a statistical analysis of the centroid shape should be able to "resolve" doubles closer than Dawes Limit!

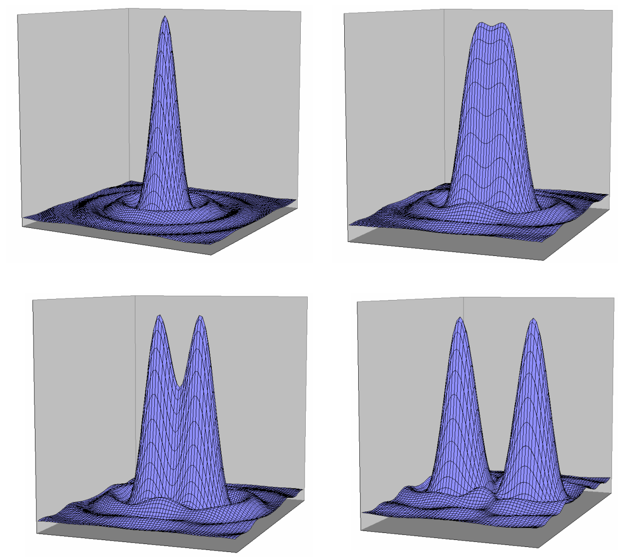

Fig 1. These four graphs show: UL, A theoretically perfect centroid of two superimposed stars. Note the central airy disk and the first and second diffraction rings. UR, The airy disk and diffraction ring "wave" interactions of two stars separated by **Dawes Limit**. LL, A simulation of two stars separated by 2.5 arcseconds seen through a 10 inch scope. LR, Well separated centroids. These 3D graphs were generated in Excel by rotating and co-adding the Point Spread Function (PSF), Y(x) := (sin(x)/x)^2.

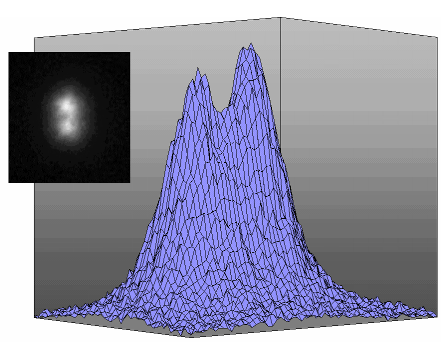

Fig 2. Epsilon 2 Lyra separation 2.3 asec. Data were collected at Randy Steiner's home on 7/13/01 11:13PM. This is the southern pair of the famous double double in Lyra. The brighter (taller) star is mag 5.21, its companion is 5.38.

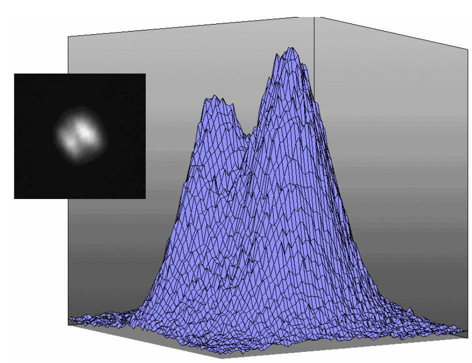

Fig 3. Zeta Aquarius separation 1.7 asec. Data were collected at Glacier Point on 7/21/01 1:54AM. The brighter (taller) star is mag 4.30, its companion is 4.45.