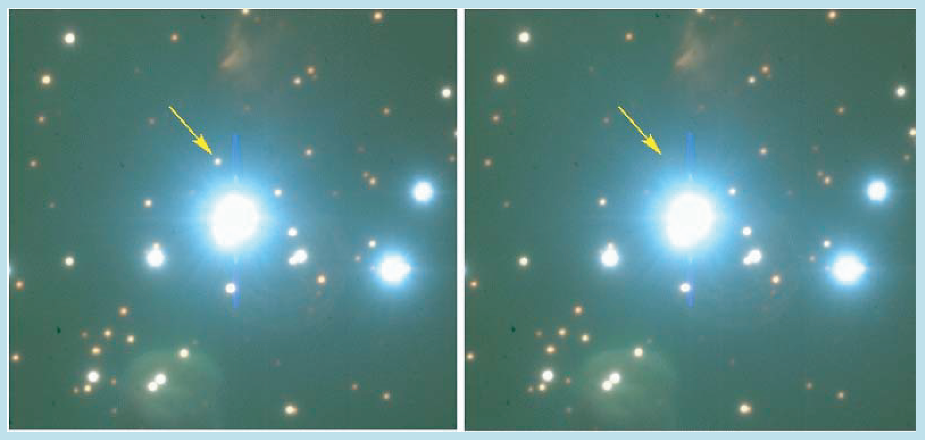

Image from CfA press release 03-19, credit: P. Garnavich

Scattered Light and Polarized Light in Models of KH15D

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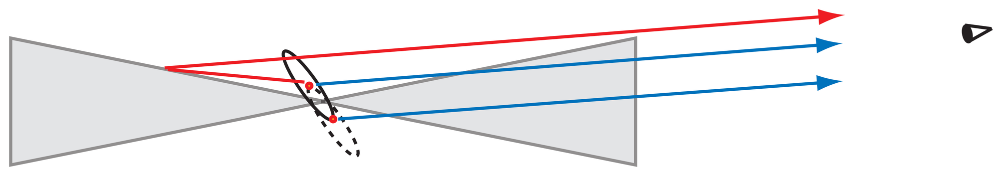
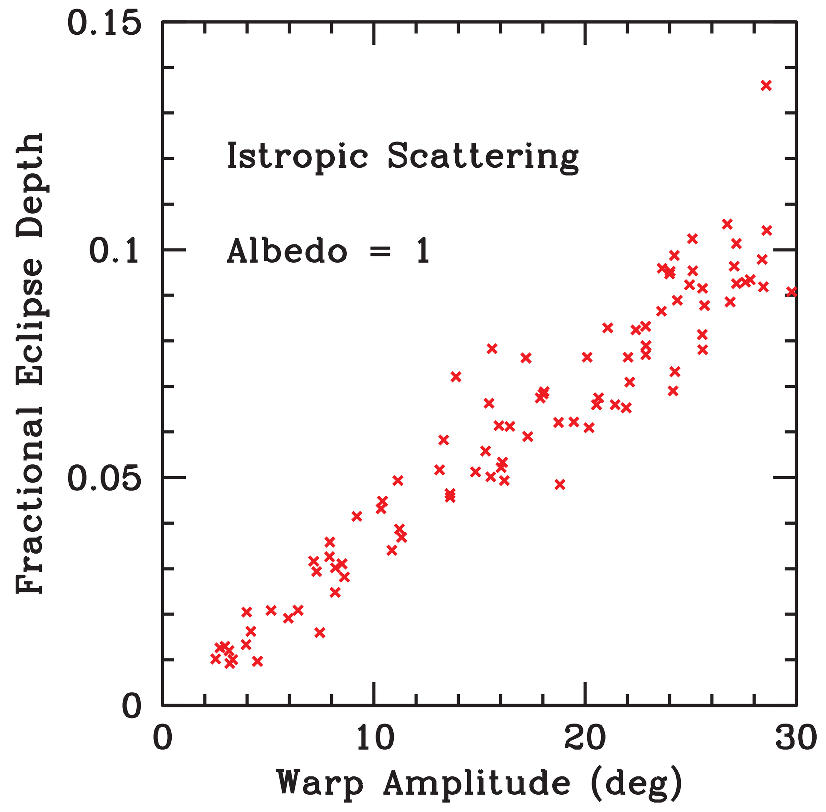
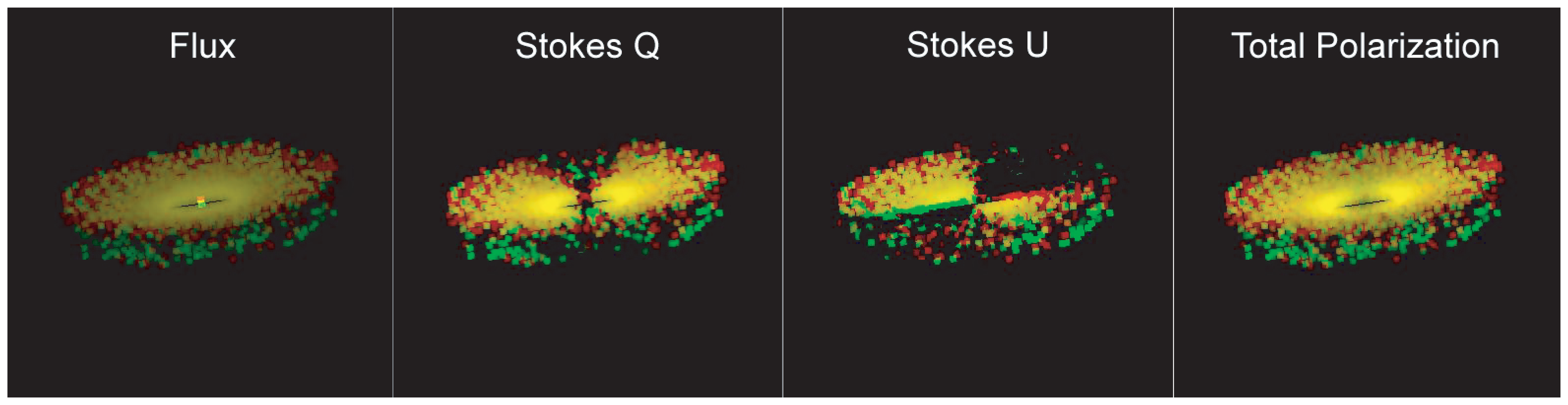
KH 15D is an unusual variable star in the young cluster NGC 2264. It shows a 48-day period featuring stellar eclipses that have varied in depth and shape over the past century (Kearns & Herbst 1998; Winn et al. 2003; Johnson & Winn 2004). The latest theories propose that the object is a pre-main sequence binary system surrounded by a precessing circumbinary disk inclined to our line of sight (Winn et al. 2004; Chiang & Murray-Clay 2004), which blocks out various portions of the binary orbits at various epochs. Such a disk should scatter and polarize incident starlight as well as absorbing it. This effect could explain the observed flux during mid-eclipse (when both stars are occulted), which at modern epochs is 4-5% of the flux outside of eclipse (when only one star is occulted; Herbst et al. 2003). In an effort to understand the origin of this mid-eclipse light, we have calculated the amount and polarization of light scattered by and through the circumbinary disk.



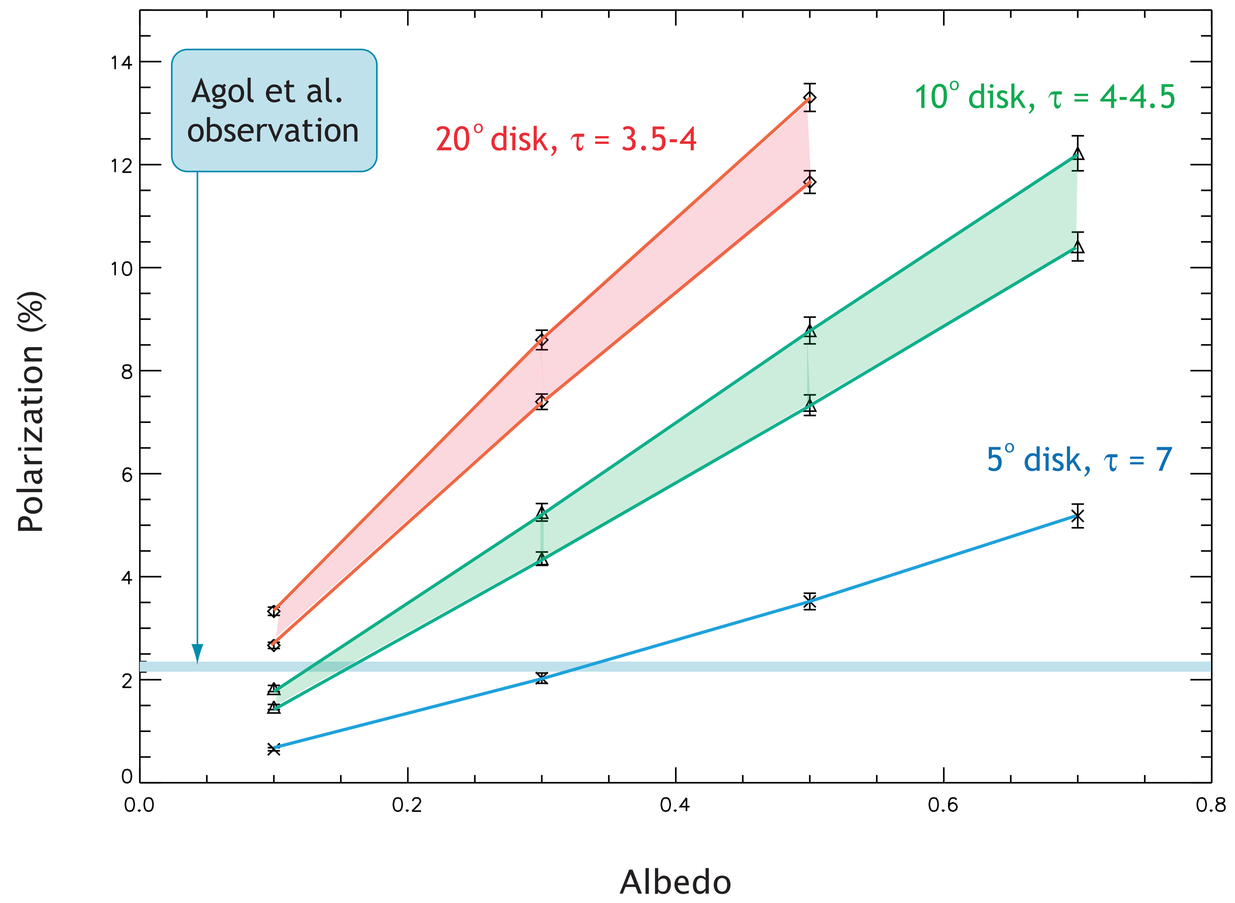
At mid-eclipse, light may reach us from the stars in two ways: by singly scattering off the disk face (left, red arrow) or by scattering through the disk (left, blue arrows). We first constructed single-scattering radiative transfer models of circumbinary disks to investigate whether the first scenario alone could reproduce the observed mid-eclipse flux. Since the color of the observed light does not vary significantly between the eclipsed and the uneclipsed states, we considered scattering off the atmosphere of the disk by large grains with an istrotropic phase function. The disk geometry is constrained by the present light curve and is viewed nearly edge-on. In this approximation, the scattered flux is proportional to the albedo, which we assume to be unity for our simulations. The figure at right shows that even for an unrealistically high albedo of unity, the disk must have a very large warp in order for scattering off the disk face to explain the observed 4-5% eclipse depth. Models with realistic albedos and warp amplitudes (differences in inclination relative to binary orbital plane between the inner and outer edges of the disk) do not produce the observed light at mid-eclipse.





Next, we considered the possibility that the light during mid-eclipse reaches us through the disk rather than by scattering off the disk face. We assumed the opacity in the disk is dominated by electron scattering. Agol et al. (2004) considered electron scattering an unlikely source of their observed polarization of KH 15D, but they assumed a nearly symmetric scattering region. Flattened electron-scattering disks can produce polarization of up to a few percent, depending on the scattering albedo (Wood et al. 1996). These images show the results of an multiple-electron-scattering disk model with an opening angle of 10°, an electron density varying as r^{-4} and linearly with polar angle, and an albedo of ~0.3, viewed from a noneclipsing angle of 75°. Green and red regions represent light originating, respectively, from a central star and a second star with a small vertical offset.

Here we have treated the two sources as one for simplicity. We created disk models like those at left with several different opening angles and the r^{-4} electron density law. For each disk, we varied the albedo and optical depth until the ratio of emergent light at a viewing angle of 90° to that at a viewing angle of 0° matched the 4.5% observed fractional eclipse depth. We then calculated the polarization observed for each model; the results are shown above. Disks with small opening angles can reproduce the observed polarization for intermediate optical depths and low albedos. No additional scattering regions are required to match the observed polarization.



Our models of light singly and isotropically scattered by large dust grains in the atmosphere of the cirucmbinary disk of KH 15D were unable to explain the currently observed flux at mid-eclipse using reasonable albedos and warp amplitudes. However, our initial models of light multiply scattered through the disk indicate that thin electron-scattering disks can reproduce the observed flux and polarization at mid-eclipse with reasonable values for optical depth and albedo. In the future, we will improve these models by imposing additional constraints on the geometry of the disk and by investigating other types of scattering within the disk.

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