ACCRETION AND ROTATION: U-BAND PHOTOMETRY OF T TAURI STARS IN NGC 2264 AND IC 348.

W. Herbst, *Department of Astronomy, Wesleyan University, Middletown, CT 06459, USA, (wherbst@wesleyan.edu)*, C. M. Simpson, *Department of Astronomy, Columbia University, New York, NY 10027, USA*, C. Fallscheer, *Max-Planck-Institute for Astronomy, Heidelberg, Königstuhl D-17, Germany*.

Active accretion in pre-main sequence stars is most easily detected at the shortest optical wavelengths, such as the Johnson U band. A pre-main sequence star's brightness in this bandpass is particularly sensitive to "instantaneous" accretion, as indicated by the large variations on short timescales. U-band "excess" emission is most likely due to matter near the photosphere heated by infalling gas in a magnetically channeled accretion column. Variability in the U band may also be due to magnetic reconnection events (flares) and to rotation of a spotted photosphere. In this study we measured U-V excesses of T Tauri stars in two young open clusters, NGC 2264 and IC 348. We examine possible correlations with Hα equivalent width, infrared excess and rotation period.

Observations of both clusters were made with the S2KB CCD on the WIYN 0.9m telescope at Kitt Peak National Observatory. Observations of NGC 2264 were made in the U, V and I bands in January and December, 2005. Observations of IC348 were made in the U, B, V. R and I bands in January, 2007. Data reduction and photometry were done with standard tasks in IRAF. We have defined U-V excess as:

Excess(U-V)=(U-V) – E(U-V) – Intrinsic(U-V).

In NGC 2264 an average cluster extinction, E(U-V), from Rebull et al. (2002) was used. In IC 348 individual extinctions from Luhman et al. (2003) were used. Intrinsic U-V colors of dwarf model atmospheres were taken from Bessel et al. (1998).

Plotted in Figure 1 is U-V excess vs. Hα equivalent width for stars in both NGC 2264 and IC 348. For stars in NGC 2264 the Hα equivalent width measurements were taken from Dahm & Simon (2005). For stars in IC 348 the Hα equivalent width measurements were taken from Herbig (1998) and Luhman et al. (2003). For many stars for which both Herbig (1998) and Luhman et al. (2003) have measured Hα equivalent widths during different epochs, there appear to be significant differences in their measurements, which are most likely due to accretion related variability. Both studies' data are plotted with a horizontal line connecting measurements of the same star. A Spearman rank order test on the data for NGC 2264 gives a correlation coefficient of -0.737 and a two-sided significance value of 1.28 x 10^{-28}, indicating a strong correlation. For IC 348 a Spearman rank order test on the averaged data gives a correlation coefficient of -0.673 and a two-sided significance of 2.68 x 10^{-6}, again indicating a correlation.

Figure 2 shows U-V excess vs. 3.6μm-8.0μm IRAC color measured by Lada et al. (2006) for stars in IC 348. A star with a bare photosphere ought to have a 3.6μm-8.0μm color of 0; a star with a 3.6μm-8.0μm color greater than 0 has an infrared excess. We may infer that stars with infrared excesses have disks. There appear to be two concentrations of stars in this plot, one with a 3.6μm-8.0μm color close to 0 and low U-V excesses; and one with a 3.6μm-8.0μm color close to 1.5 and a range of U-V excesses. It is interesting to note that we see no stars with large U-V excesses and low infrared excesses.

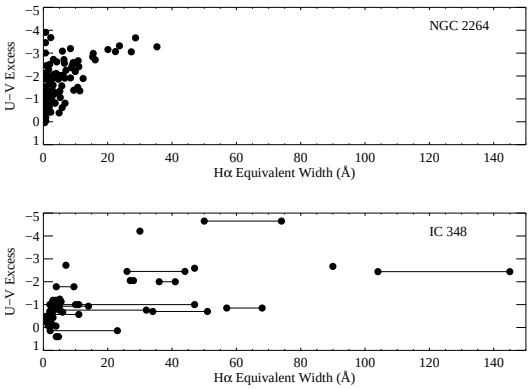

Figure 1: U-V excess vs. Hα equivalent width for stars in NGC 2264 and IC 348.

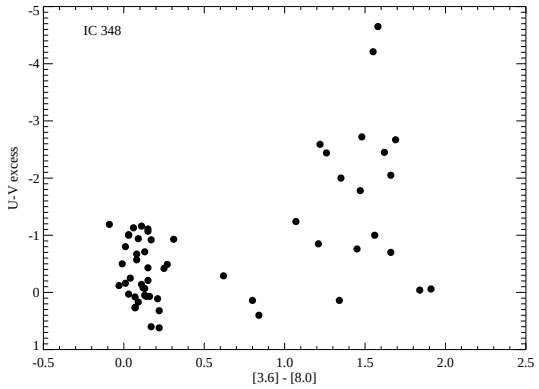

Figure 2: U-V excess vs. 3.6μm-8.0μm IRAC color for stars in IC 348.

Shown in Figure 3 is U-V excess vs. rotation period for stars in NGC 2264 and IC 348. Rotation periods for stars in NGC 2264 were taken from Lamm et al. (2005) and Makidon et al. (2004). Rotation periods for stars in IC 348 were taken from Nordhagen et al. (2006), Cieza & Baliber (2006), Kiziloğlu et al. (2005) and Littlefair et al. (2005). In IC 348 we detected few stars in the U band with short rotation periods. A one-sided 2 x 2 Fisher's exact test may be used to test for a correlation in these plots. We choose the division between fast and slow rotators to be 6 days and the division between accretors and non-accretors to be -1 magnitude. In NGC 2264, the one-sided Fisher's exact test gives a probability of correla-

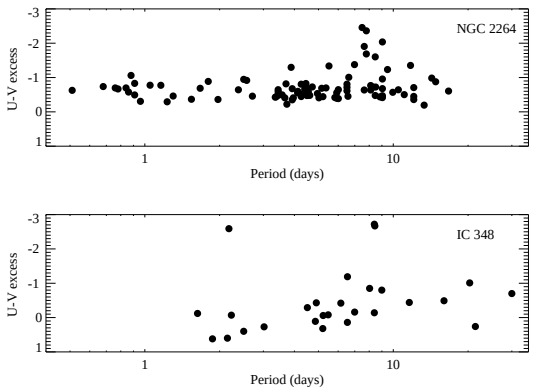

Figure 3: U-V excess vs. rotation period for stars in NGC 2264 and IC 348.

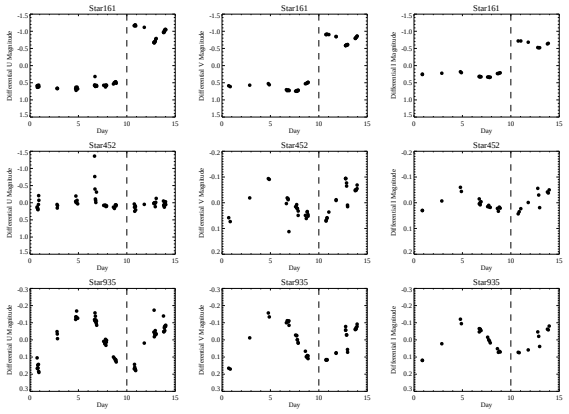

Figure 4: U, V and I light-curves of three stars in NGC 2264. The vertical dashed lines mark the division between the January and December epochs.

tion of 99.7%; in IC 348 it gives a probability of correlation of 81.4%. In both cases we find, therefore, no inconsistency with the hypothesis that active accretion is associated with slow rotation. While the IC 348 result is not significant by itself, the important point is that it does not contradict the disk-locking hypothesis, as has sometimes been claimed.

It is important to recognize that T Tauri stars demonstrate several types of U-band variability. Shown in Figure 4 are U, V and I light-curves for three stars in NGC 2264. Data to the left of the dashed line were taken during the January, 2005 epoch and data to the right were taken during the December, 2005 epoch. Star 161 increased in brightness between the two epochs by over a magnitude in all three bands. Star 452 had a dramatic flare in U-band brightness during one night in the January epoch of over a magnitude. This is most likely due to a magnetic recombination event on the surface of the star. In the V and I bands the star shows periodic brightness variations characteristic of the rotation of a spotted photosphere. Star 935 also shows periodic brightness variations characteristic of rotation in the U, V and I bands.

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