Hα Monitoring of Early-Type Emission Line Stars

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Introduction

We have begun a narrowband imaging program, using matched 5nm FWHM on-band (656nm) and off-band (645nm) filters, to monitor Hα emission in early-type (primarily Be) stars in young open clusters and associations. Such emission commonly varies over a range of timescales (Porter & Rivinus 2003). Some of the brightest, e.g. γ Cas, have been spectroscopically monitored, but there is little ongoing monitoring in samples including fainter stars (Peters 2009). Observing clusters, rather than individual targets, records multiple known and candidate program stars, and provides reference stars of similar spectral type. We hope to characterize Hα emission variations and search for periodicities that may constrain models of these stars. Observations began in the spring of 2010. Similar observations of other targets, using filters of unequal FWHM, are underway by V. Strelnitski at Maria Mitchell Observatory (e.g., Bedell et al. 2011).

Observations

We use the 0.6-m, f/10 DFM Engineering telescope at Williams College, and an Apogee Alta U9000 CCD camera with a peak QE ~65% near Hα, operating at -20C. The filters are 5nm FWHM Astrodon 50mm square HA5-50S (CWL 656nm) and RedCon5-50S (CWL 645nm). 645nm is a good reference; there are no significant spectral features there in early-type stars, and it is close enough to Hα that corrections are small. Equal bandpasses facilitate analysis.

We used 3×3 binning for an effective pixel size of 1.2" (typical seeing 3"–5") and a field of view of 20'×20'. For linearity, we limit counts to ~1/3 full scale. We take sequences of short exposures to increase dynamic range and enable removal of transient bad pixels. A fresh dark frame is automatically subtracted for each sequence. Initially, our flats were problematic due to reflective light paths bypassing the filter. After adding masks and replacing our canvas target with a nearly Lambertian screen (Draper Cineperm M1300), our dome flats are consistent with twilight flats, and with each other, to <0.5% over >90% of the image.

The target for which we have the most complete data is the Cygnus OB2 association (Massey & Thompson 1991). We use their numbering scheme for stars in Cyg OB2, as in *SIMBAD*, e.g. [MT91]465. The Cyg OB2 field is shown in Figure 1. We have also taken data on ~30 young open clusters, selected via *WEBDA* for the presence of Be stars. Some candidates were excluded due to the presence of strong nebular emission.

Figure 1. The Cyg OB2 field, with [MT91]465 near the center.

Processing

Reduction is done in *MaximDL*. Each exposure is flatted using median normalization to preserve signal levels. Multiple exposures are median combined with automatic star matching to create a single frame with outlier pixels suppressed. A pair of reduced 656nm and 645nm frames constitute an observation.

We often do not know *a priori* which objects will prove interesting, so we do photometry on all objects in each frame. Reduced frames go to *astrometry.net* (Lang et al. 2010), an online service that identifies the field and returns the (RA, Dec) and pixel (x, y) of all stellar objects it finds, typically ~200 in our Cyg OB2 field.

The (RA, Dec) list goes to *SIMBAD* for object identification, and its output is culled for duplicates and errors. The reduced frame and pixel (x, y) list goes to *Aperture Photometry Tool* (*APT*; http://spider.ipac.caltech.edu/staff/laher/apt by Russ Laher) for measurement. We use an aperture of 8px radius, and sky annulus inner/outer radii of 10px/15px. *APT* can use a median sky estimator, minimizing the influence of nearby stars in all but severe overlaps. Observation UTs are converted to JD (Julian Date) using *http://astronomy.villanova.edu/links/jd.htm#CtoJ*.

We wish to express results as an on-band to off-band (656/645) ratio over time, so use of the magnitude system is unnecessary. To correct for transparency and airmass variations we select several dozen stars, excluding known variables and stars near the edge of the field, as candidate references. Their light curves are plotted, outlier stars with variant curves are excluded, and a second culling is done. For each frame, the normalized median of all reference stars is used as an estimator of the correction factor. With enough reference stars, this process effectively corrects for transparency variations while preserving 656/645 ratios.

Preliminary Results for Cyg OB2

Cyg OB2 contains numerous O and early B stars (Massey & Thompson 1991). To date, we have made 20 observations of the central 20'×20' of Cyg OB2, but one was set aside due to bad flats. We used 39 reference stars.

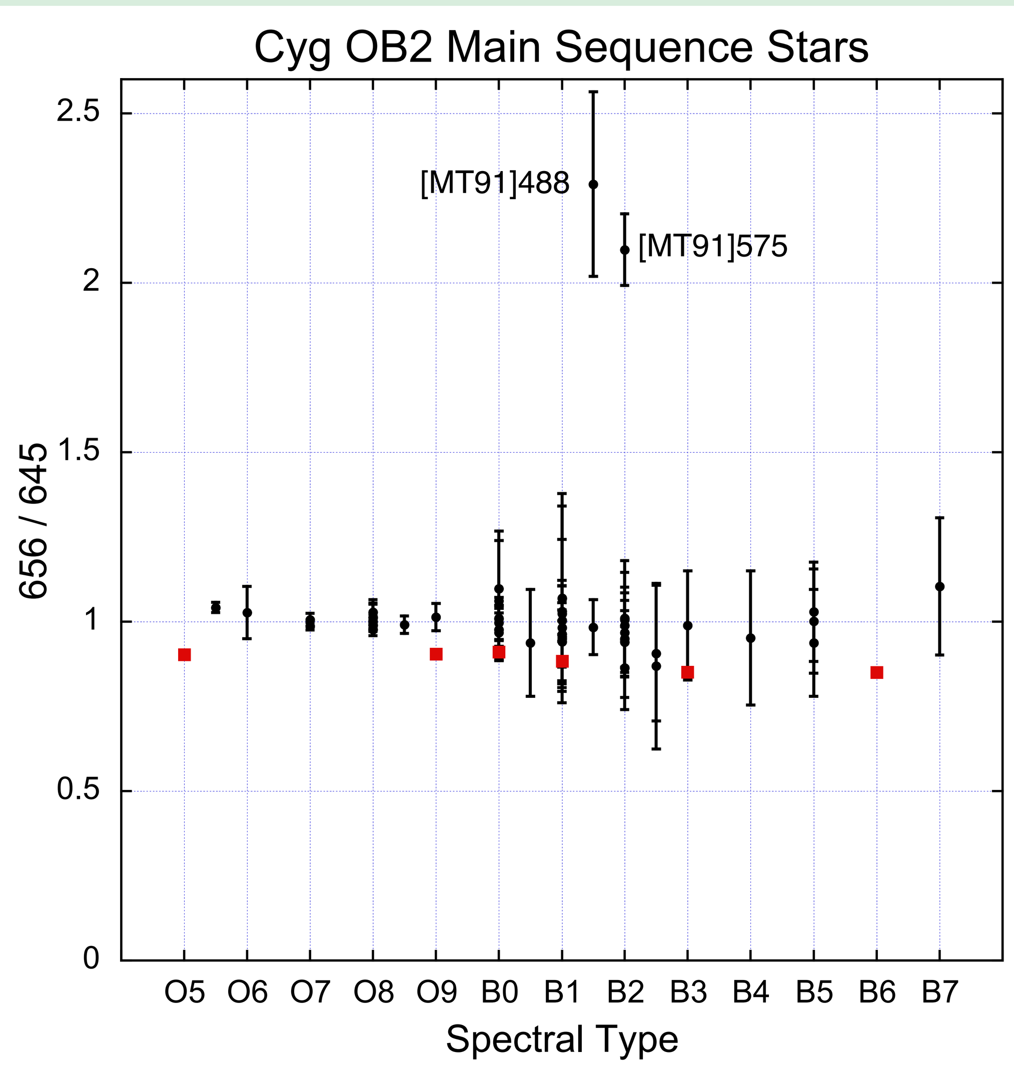

Figure 2. The 656/645 ratio for the 69 classified stars in our Cyg OB2 field. [MT91]488 and [MT91]575 are the only known Be stars in this field. The red squares are calculated ratios from spectrophotometric standards.

Figure 2 shows the median 656/645 ratio vs. spectral type for the 69 main sequence stars in our sample with spectral types in *SIMBAD* or *VizieR*. The red squares are 656/645 calculated from spectrophotometric standards (Pickles 1998) for 5nm bandpasses at both wavelengths. A correction factor near unity is implied, demonstrating that the observing method and reduction process preserve this ratio well. The two known Be stars in this sample – [MT91]575 (R = 12.2), and [MT91]488 = V2188 Cyg (R = 13.9) – are easily distinguished. While [MT91]488 shows no sign of variation in our data, the 656/645 light curve for [MT91]575 in Figure 3 shows an abrupt drop followed by a slow rise. We hope to confirm this variation in the upcoming observing season.

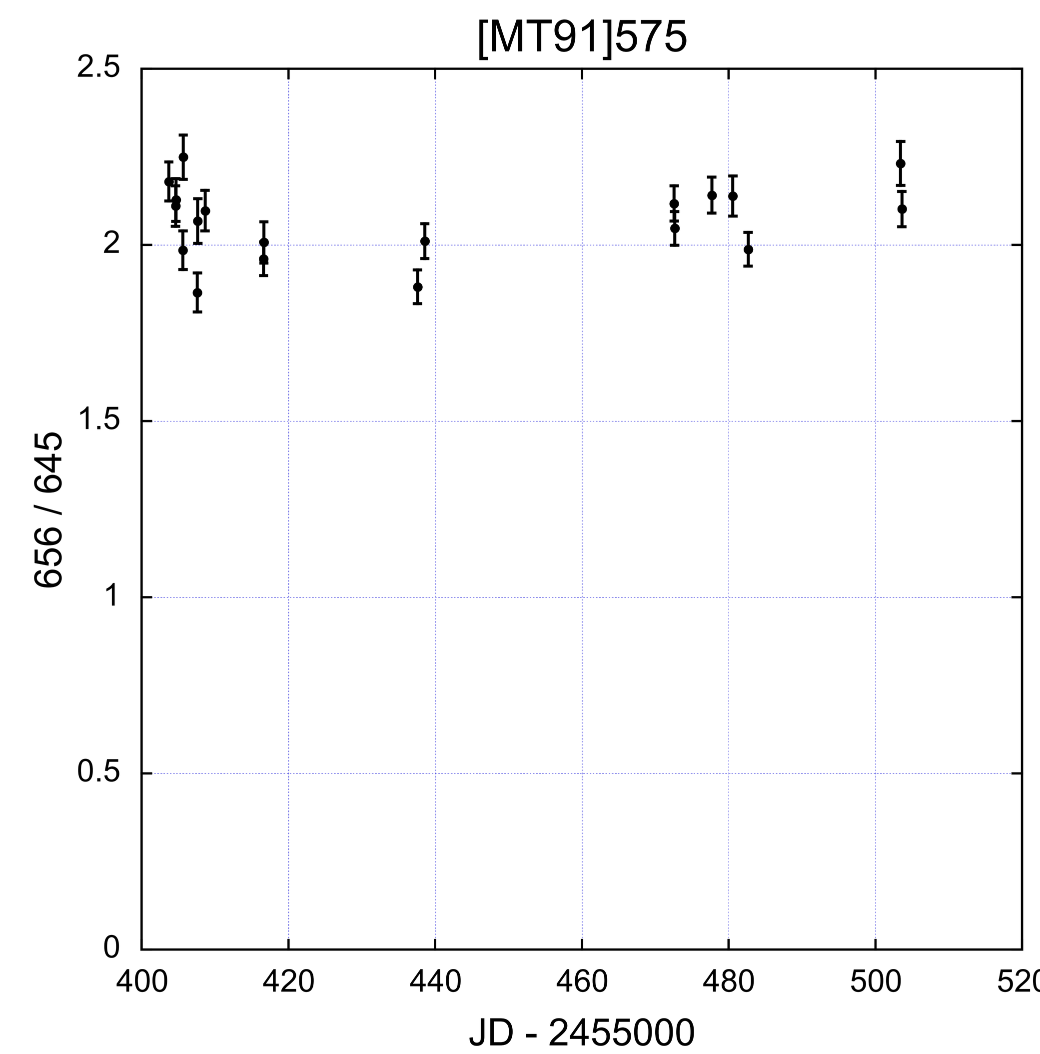

Figure 3. The 656/645 light curve of [MT91]575.

Early type supergiants commonly exhibit both variability and Hα emission. In our field the prime example is [MT91]304 (Cyg OB2 #12, R ~ 9), a very luminous late B supergiant that is known to be a spectrum variable (Souza & Lutz 1980, Kiminki 2010). Figure 4 shows the separate [MT91]304 light curves at 645nm and 656nm, illustrating variability and a near-constant 656/645 ratio of 1.33.

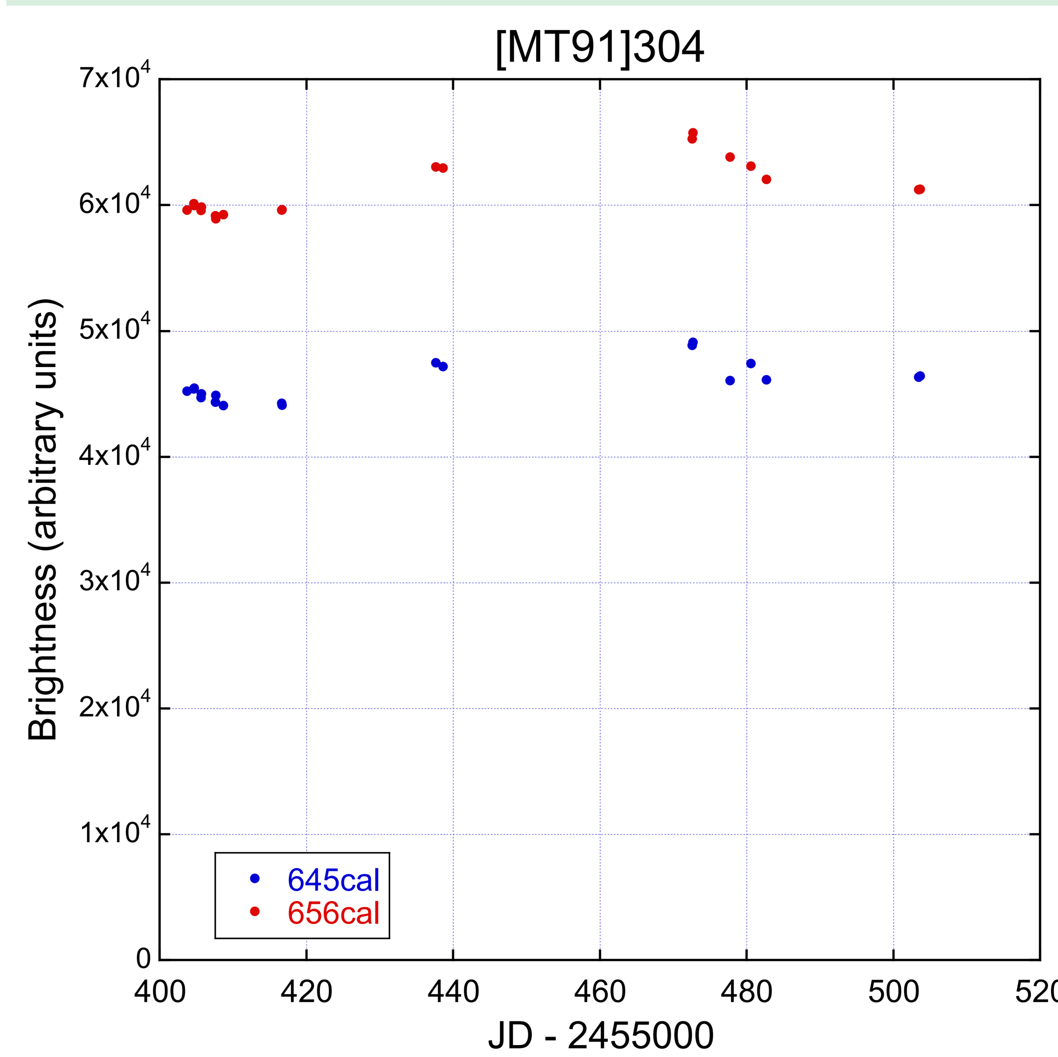

Figure 4. The separate 656nm and 645nm light curves of [MT91]304. Error bars are roughly the size of the plotted symbols.

Of the 145 stars in our sample, [MT91]696 showed dips reminiscent of unphased eclipses. Indeed, it was recently found to be a contact binary (Rios & DeGioia-Eastwood 2005). Figure 5 shows a partial light curve of [MT91]696 from our data, phased using its spectroscopic 1.4694 day period (Kiminki 2010).

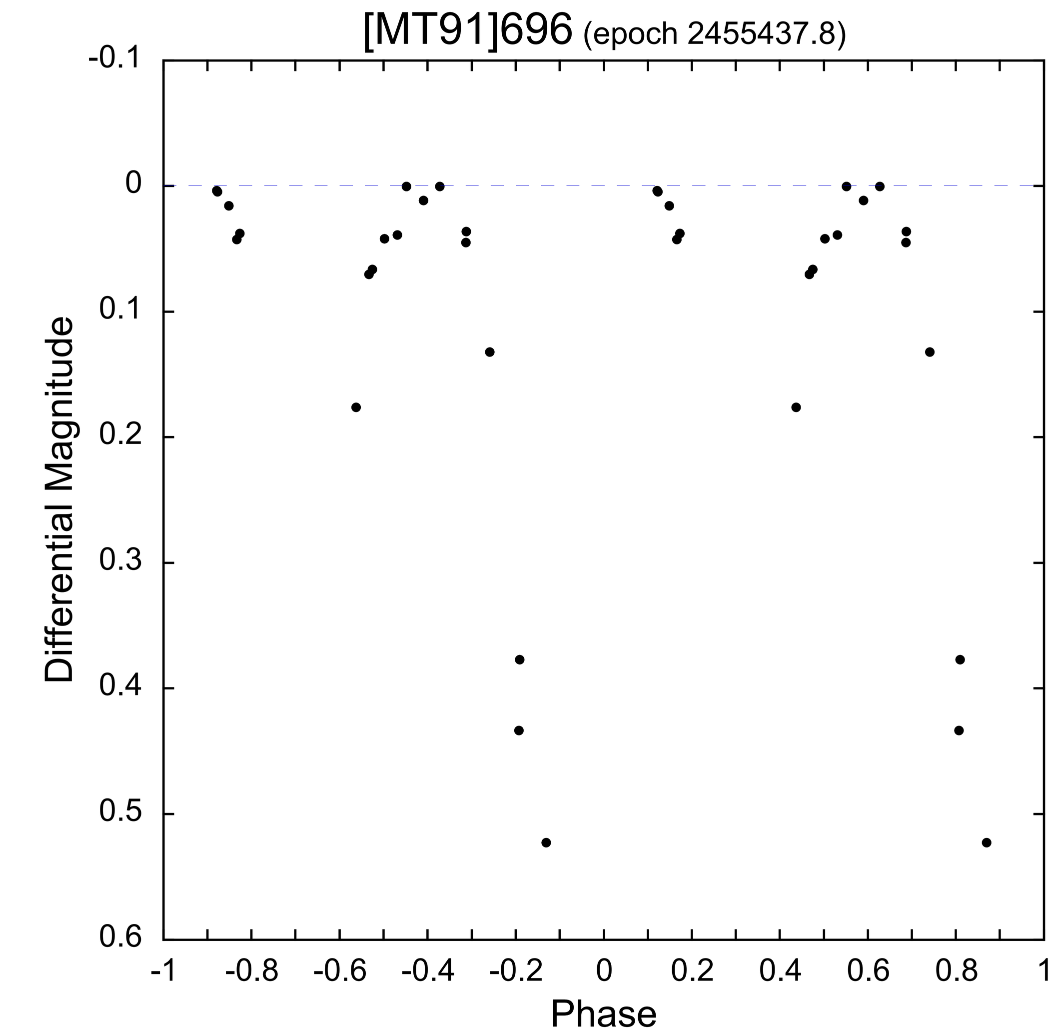

Figure 5. Phased light curve of the 1.4694 day contact binary [MT91]696.

Conclusion

Narrowband imaging using matched 5nm FWHM 645nm and 656nm filters is an effective means of observing early-type emission line stars, and permits monitoring Hα emission over time. The two known Be stars in our Cyg OB2 field are easily recovered. Our transparency correction process is effective, and 656/645 ratios for normal stars compare well with those calculated from spectral standards. Our observations have the potential to discover new variables and emission line stars.

References

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- *SIMBAD* and *VizieR* databases, CDS, Strasbourg, France
- *WEBDA* database, Institute for Astronomy, University of Vienna
- *http://astronomy.villanova.edu/links/jd.htm#CtoJ*

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