A Standardized Hα Photometric Index in Cygnus OB2

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ABSTRACT

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Cygnus OB2 is a large OB association that is relatively close to Earth but highly obscured. Its large population of O and B stars almost certainly includes several emission-line objects, making it an ideal testing ground for the standardized Hα photometric system presented by Joner and Hintz (2015), which is similar to the widely used Hβ system pioneered by Crawford in the 1960s. One of the primary benefits of an Hα system is its potential to distinguish between different categories of emission-line objects without requiring time- and resource-intensive spectroscopy. While several previous papers have proposed such a system, none have received widespread use. The research presented in this thesis used the DAOPHOT program to analyze four years of Cygnus OB2 observations that were made with the filter set described by Joner and Hintz (2015), with the intent to identify standard stars and search for emission-line objects in the field. While persistent difficulties calibrating the data have thus far prevented the publication of such a list of standard stars, the benefits that would arise from the development and widespread implementation of an Hα photometric system warrant continued efforts to resolve the issues inhibiting the system's creation and adoption.

Keywords: stellar associations, Cygnus OB2, photometry, Hα photometry

Contents

Chapter 1

Introduction

1.1 Cygnus OB2

Cygnus OB2 (α: 20^h 33^m 12.0^s, δ: +41° 19’ 00” [Kharchenko, Piskunov, Roser, Schilbach, & Scholz, 2005]) is a gravitationally unbound group (Wright et al., 2016), or association, of large, young, bright stars—known as O and B stars—located in the constellation Cygnus, as shown in Fig. 1.1. The association is about 1.4 kpc away (Rygl et al., 2012, p. 11) and has a core diameter

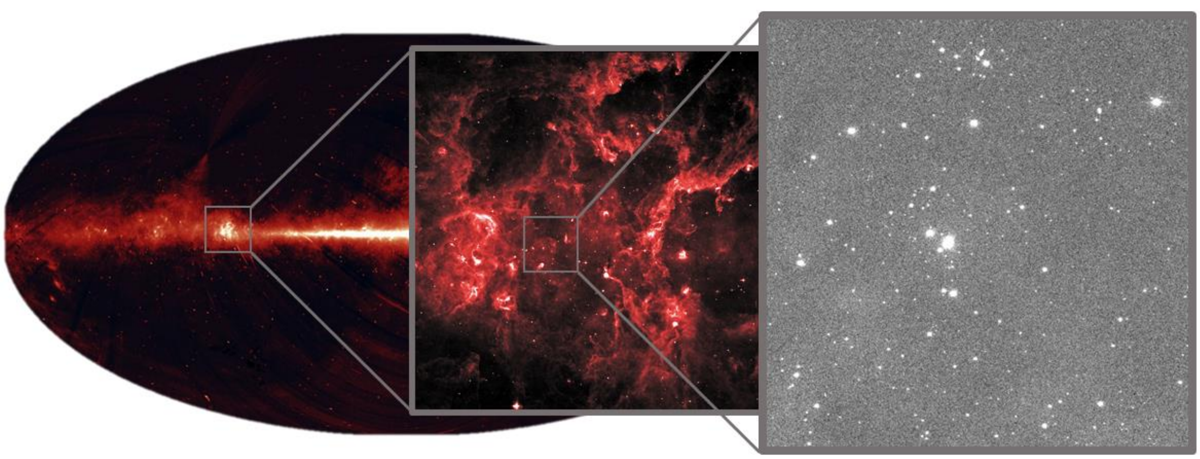

Figure 1.1 The location of Cygnus OB2. Left: The Cygnus region (JAXA, 2007). Middle: The Cygnus X region (NASA/IPAC/MSX, 2011). Right: Cygnus OB2 (WMO, 19 June 2015).

of about 1.3 pc (Wright, Drake, Drew, and Vink, 2010, p. 880). Wright et al. (2010) estimate the association contains 5.7 x 10^4 stars with a total mass of (3 ± 1) x 10^4 $M_\odot$ (p. 880).

Cygnus OB2 was first identified as a clustering of blue giants during a classification of O and B stars at the Tonantzintla Observatory by Münch and Morgan (1953). Johnson and Morgan (1954) soon followed up with photometric and spectroscopic observations, which revealed that the association was significantly dimmed by considerable interstellar absorption (as high as 6 or 7 magnitudes) due to large clouds of dust present in Cygnus, which are known as the Cygnus Rift, the Great Rift, or the Northern Coalstack. Without this absorption, the association would appear roughly as bright as the Pleiades (p. 345). Additional observations by Schulte (1956, 1958) confirmed the previous observations and brought the number of known members of the association up to 31. Further surveys, including Massey and Thompson's (1991) extensive study of the association's massive stars, continued to discover additional O and B stars belonging to the association. One of the most recent studies places the total number of confirmed O and B stars in the association at 221, with 70 of them being O stars (Berlanas et al., 2018, p. 6). This makes the field one of the highest concentrations of spectroscopically confirmed O stars (Wright et al., 2010, p. 871). As Berlanas et al. (2018) point out, the high extinction probably conceals many more young, massive stars, making it likely that such stars will continue to be discovered in the association—Wright et al. (2010) estimate that there are as many as 1200 O and B stars, with up to 75 O stars, in the association (p. 880).

This high concentration of O and B stars makes Cygnus OB2 an association of considerable astronomical interest, since such stars are generally quite rare. As the largest, most luminous stars, O and B stars not only form much less frequently than smaller, cooler stars but are made still more scarce by their short lifespans. Because rapid hydrogen fusion is required to sustain their extreme luminosities, O and B stars shine for no more than a few million years before they exhaust their fuel reserves and disappear in brilliant supernova explosions, leaving their smaller, dimmer counterparts behind to continue burning for millions, even billions, of years afterward. Accordingly, Cygnus OB2 must be quite young to exhibit such an abundance of massive stars. And, indeed, research supports this conclusion. Comerón and Pasquali (2012) find that star formation in Cygnus OB2 began just 10 million years ago and peaked around only 3 million years ago, indicating that there were likely multiple waves of star formation (p. 12; see also Wright et al., 2010, p. 880). While the association's youth and massive contents would make it an interesting object for study under any circumstances, Wright et al. (2010) point out that Cygnus OB2 is even more interesting because it is the nearest massive star-forming region to Earth (p. 871).

Several other characteristics further contribute to the extensive scientific interest in the association. Comerón and Pasquali (2007) conclude that Cygnus OB2 is the birthplace of BD +43 3654, one of the three most massive runaway stars yet discovered. The association is also home to two luminous blue variable candidates, BD +40 4210 (Comerón & Pasquali, 2012, pp. 8 – 9) and the blue hypergiant Cygnus OB2 #12, which is also one of the most luminous stars in the Galaxy (Maryeva et al., 2016). Luminous blue variables are extremely rare, so the possibility that two reside within the same stellar association is of obvious interest to researchers.

1.2 The Hα Index

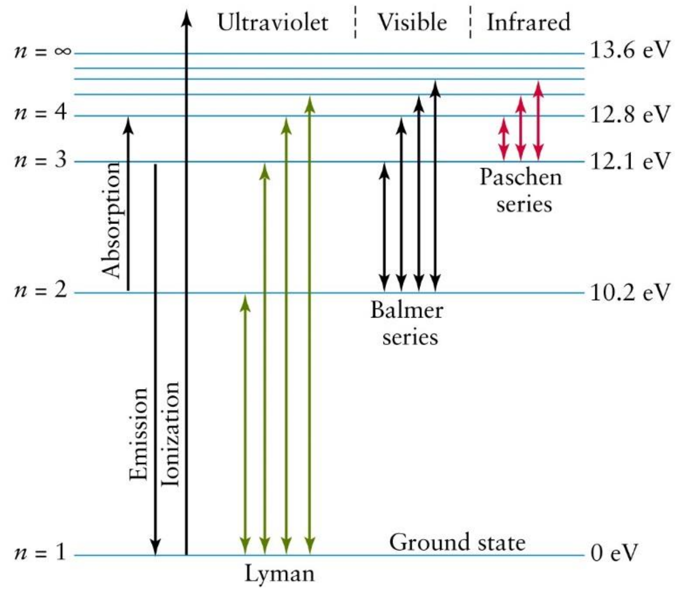

Figure 1.2. The hydrogen electron transitions. All transitions whose lowest energy level corresponds to $n = 2$ are known as the Balmer series. The leftmost Balmer transition ($n = 2 \rightarrow n = 3$) is the Hα transition, next to it is Hβ, and so forth. Reproduced from *elevels.jpg* (n.d.).

When studying stars, such as the members of Cygnus OB2, stellar astronomers often examine the unique patterns and shapes of a star's spectral lines, which contain valuable information about the star's chemical composition, radial velocity, temperature, and surface gravity. The spectral lines are also key to determining a star's luminosity class and spectral type, which indicate its evolutionary stage and its temperature, respectively. Speaking generally, luminosity class is determined by the width of the star's spectral lines, and spectral type by the relative strength of certain key lines.[1] The spectral lines associated with the Balmer series (the electron transitions involving an excitation from or a cascade down to the $n = 2$ energy level in the hydrogen atom) are particularly important in this process and are shown in Fig. 1.2. As Ryden and Peterson (2010) point out, the Balmer lines are an important indicator of a star's temperature: since the lines are the strongest for stars with temperatures around 10,000 K, stellar spectra with weak or nonexistent Balmer lines must indicate one of three possibilities:

1. There is little hydrogen present in the stellar atmosphere—an unlikely scenario, given that both stars and the universe itself are composed primarily of hydrogen.

[1] For a more detailed treatment of spectral types and luminosity classes, see Ryden and Peterson (2010), pp. 339–343.

2. Atmospheric temperatures much greater than 10,000 K have ionized most of the hydrogen atoms present; this situation can be recognized by checking the strength of lines associated with atoms, like helium, that have stronger ionization potentials than hydrogen. All O and most B stars, like those in Cygnus OB2, fall into this category.
3. Temperatures are insufficient (i.e. much lower than 10,000 K) to excite hydrogen electrons to an energy level $n > 2$. The presence of lines associated with atoms, such as sodium, that have low ionization potentials would indicate this situation.

The current OBAFGKM ordering of spectral types based on temperature relies on this sort of Balmer line analysis (pp. 340–341).

The Balmer lines—indeed, *any* spectral line—can be in emission or absorption. The collisional de-excitation of an electron by a photon causes the electron to drop in energy level and emit a photon whose wavelength corresponds to the energy difference between the two levels, producing an emission spectrum. Similarly, an absorption spectrum is produced when an electron absorbs a photon of an energy equal to the difference between the electron's current energy level and a higher one, consequently exciting it to the higher level. As described in Kirchhoff's laws, emission spectra are generally produced by a tenuous gas seen against a relatively cool, dark background, while absorption spectra result when a tenuous gas is seen against a relatively hot, glowing background, such as a star (Ryden & Peterson, 2010, p. 122).

Accordingly, most stellar spectra show absorption; however, emission spectra can result from the presence of substantial circumstellar material. This material may consist of gas that is left over from the star's formation, transferred in a mass exchange with an orbiting binary partner, or less tightly bound as a result of rapid stellar rotation or pulsation. Thus, due to their additional structural complexity, emission-line objects are often of significant astronomical interest. Many examples of these objects are Be stars—non-supergiant stars of late-O, B, and early-A spectral types that exhibit Balmer emission lines, generally restricted to those where the lines are caused by a viscous, Keplerian disk of gas orbiting the star (Rivinius, Carciofi, & Martayan, 2013). The high concentration of O and B stars in Cygnus OB2 makes it likely that the association hosts many Be stars and other emission-line objects.

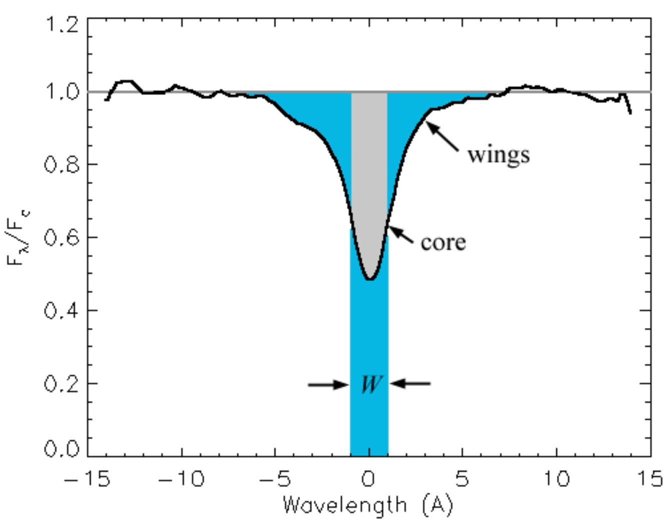

Figure 1.3. Equivalent width is a measure of the area covered by a spectral line (denoted *W* in the figure). While the spectral line itself rarely absorbs 100% of the light at the corresponding wavelength (denoted on the x-axis by 1.0), the equivalent width is the width the line would have with total absorption. Reproduced from Dan (2012).

Unfortunately, as Abt and Golson (1966) note, obtaining the spectroscopy necessary to distinguish between different emission objects, like Be stars and Ia supergiants requires large amounts of highly demanded observing time on large-diameter telescopes (p. 306–307). Crawford (1960) attempts to address this issue with the introduction of a photometric index that allows astronomers to measure the area, or equivalent width, of the Hβ line,[2] which is important in astronomical research. Equivalent width reflects key information about a spectral line and is influenced by both the breadth and the depth of the line (see Fig. 1.3 for an explanatory illustration); while Crawford's (1960) index does not perfectly reproduce all the information found in Hβ spectroscopy, it is able to approximate the line's breadth and depth—and thus to estimate the equivalent width—by comparing an object's

[2] A Balmer transition (i.e., a hydrogen transition in which the lower energy level is the $n = 2$ level) is indicated with a capital *H*; the specific transition, defined by the higher energy level, is indicated by a Greek letter ($n = 3$ corresponds to the letter α, $n = 4$ to β, etc.). The Hβ line, then, results from a transition between the $n = 2$ and $n = 4$ energy levels and has a wavelength of 486.1 nm, which corresponds to a blue-green color.

brightness in a wide filter with its brightness in a narrow filter. The profiles of the wide and narrow Hβ filters described in Crawford and Mander (1966) are reproduced as Fig. 1.4. The difference between the magnitude measured in each filter is called the photometric index value. Herbst and Layden (1987) observe that "if one is only interested in the EW [equivalent width], not the line profile, there are advantages to a photometric approach [like Crawford's]. In particular, reasonably accurate EWs can be obtained quickly on a small telescope with fairly simple instrumentation" (p. 150). Crawford (1960) presents 33 standard stars for the system, with Crawford and Mander (1966) contributing 80 new standards, as well as new filters. As a result of the advantages of such a system, Crawford's Hβ index is now widely used in astronomical research.

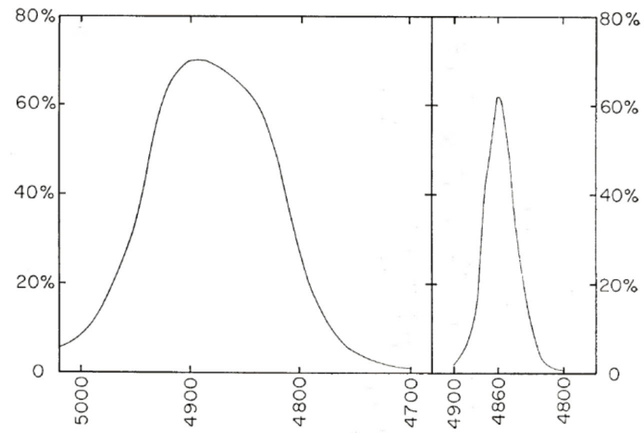

Figure 1.4. Crawford and Mander's (1966) Hβ filter transmission profiles. The filter on the left is the wide filter while the one on the right is the narrow filter. "Wide" and "narrow" refer to the relative sizes of the range of wavelengths that the filters transmit. Reproduced from Figure 1 in Crawford and Mander (1966).

Inspired by the usefulness of the Hβ index, Joner and Hintz (2015) propose the creation of a standardized index centered on the Hα line (656.3 nm). While several different researchers have developed personal Hα indices for their personal research projects (e.g. Peat, 1964, 1966; Abt & Golson, 1966; Herbst & Bishel, 1987; Herbst & Layden, 1987; and Herbst & Miller, 1989; Park, Sung, Bessell, & Kang, 2000), no widely used standardized index system has yet been developed. So far, Strauss and Ducati (1981) have come closest, publishing 168 stars for use as standards in both Hα and Hβ photometry, although their index has not experienced much usage.

Several reasons to develop a standardized Hα index exist. Joner and Hintz (2015) argue that such a system would be "useful in cases where it is combined with information from other systems such as Hβ or four-color or when used alone to locate objects of astrophysical interest in survey fields" (p.1). The system would be especially useful for the observation of emission-line objects. For example, Abt and Golson (1966) found that, in a sample of Be stars and Ia supergiants, the ratio of relative strengths of the Hα and Hβ lines allowed them to correctly identify two-thirds of each group (p. 311). Herbst and Miller (1989) note that "real variation in $W_{H\alpha}$ [the equivalent width of the Hα line] is a common occurrence among emission-line stars" (p. 893). In an abstract submitted for a conference of the American Astronomical Society, Hintz and Joner (2012) report that Hα observations revealed variable emission in a group of high-mass X-ray binaries that was not seen in the Hβ index.

The index system proposed by Joner and Hintz (2015) is composed of a narrow and a wide filter both centered on the same spectral line (in this case, Hα), as does Crawford's Hβ system. Such systems have the advantage of avoiding the effects of atmospheric extinction and interstellar reddening, unlike those in which the filters center on different wavelengths (p. 2). The Hα filters used by Joner and Hintz (2015) are shown in Fig. 1.5.

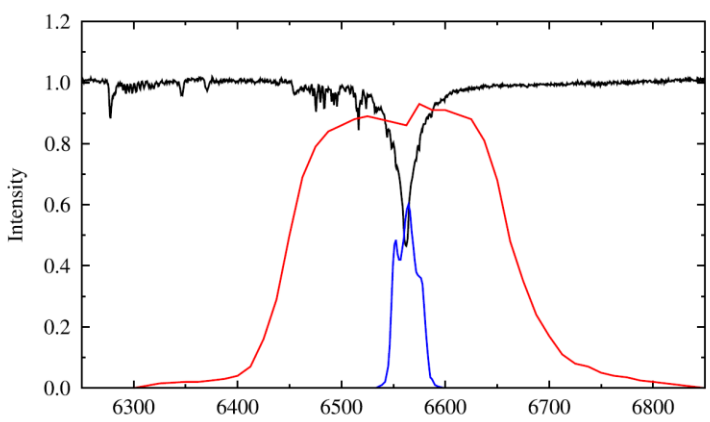

Figure 1.5. Joner and Hintz's (2015) Hα filter transmission profiles. The wide filter is shown in red while the narrow filter is depicted in blue. The black line is the part of a stellar spectrum containing the Hα line. Adapted from Figure 3 in Joner and Hintz (2015).

This thesis builds on the proposal of Joner and Hintz (2015) to standardize an Hα index by presenting four years of observations of Cygnus OB2 that were made with the filter set utilized in their research. It seeks to identify members of the association that are relatively bright and free from luminosity fluctuations to serve as a set of standard stars. Careful study of these stars would produce known, standardized Hα index values for each standard that would be published for use in future research. Because night-to-night fluctuations in observing conditions cause non-physical variations in the measured magnitudes of stars, such standards serve as an important way for researchers to quickly calibrate their photometric observations. Instead of being forced to resort to time- and resource-intensive spectroscopy, researchers can simply calculate the difference between their measured magnitudes and the known values of the standards and add the result (known as an offset) to the measured value of each star in the field. Naturally, the offset for the individual standard stars will vary slightly, but this is easily remedied by averaging the individual offsets together before applying that average offset to the remaining field stars.

Chapter 2

Observations

All observations were made on the 0.91-meter telescope at the West Mountain Observatory over 91 nights between 10 July 2013 and 17 July 2016. The telescope alternated between narrow and wide filters for each exposure so that frames were shot in narrow/wide pairs, generally with two or three pairs being shot on each night of observations, for a total of 195 pairs. Narrow-filter exposures ranged from 100–150 seconds in length while wide-filter exposures ranged from 20–30 seconds. All frames were shot on a FLI PL 3041UV CCD, which was cooled to temperatures between -25 and -35°F. A chart of the date, narrow- and wide-filter exposure lengths, airmass, and CCD temperatures is provided as Table 2.1.

Table 2.1 Observation Data

Date	HJD	N-Exp (s)	W-Exp (s)	Airmass	CCD Temp (°F)
2013-07-10	2456483.828	150	30	1.018264	-25
2013-07-21	2456494.901	150	30	1.047169	-25
2013-08-14	2456518.902	150	30	1.218358	-25
2013-08-15	2456519.910	150	30	1.270881	-25
2013-09-20	2456555.780	150	30	1.148393	-30
2013-09-21	2456556.721	150	30	1.032223	-30
2013-09-23	2456558.891	150	30	1.980553	-30
2013-09-24	2456559.744	150	30	1.084043	-30

Date	HJD	N-Exp (s)	W-Exp (s)	Airmass	CCD Temp (°F)
2013-10-27	2456592.678	150	30	1.150015	-35
2013-11-02	2456598.670	150	30	1.178766	-35
2014-06-30	2456838.837	150	30	1.039668	-25
2014-07-01	2456839.802	150	30	1.100278	-25
2014-07-08	2456846.825	150	30	1.030986	-25
2014-07-17	2456855.806	150	30	1.022431	-25
2014-07-18	2456856.791	150	30	1.036303	-25
2014-07-23	2456861.781	150	30	1.035165	-25
2014-07-24	2456862.790	150	30	1.019422	-25
2014-07-25	2456863.776	150	30	1.030292	-25
2014-08-15	2456884.754	150	30	1.003415	-25
2014-08-16	2456885.747	120	30	1.005252	-25
2014-08-17	2456886.716	150	30	1.028738	-25
2014-08-18	2456887.718	150	30	1.021339	-25
2014-08-28	2456897.710	120	20	1.007569	-25
2014-08-29	2456898.702	150	20	1.010414	-25
2014-09-01	2456901.687	150	20	1.016713	-25
2014-09-02	2456902.661	150	20	1.043025	-25
2014-09-03	2456903.656	150	20	1.046654	-25
2014-09-11	2456911.643	150	20	1.034395	-25
2014-09-12	2456912.618	150	20	1.069390	-25
2014-09-13	2456913.665	150	20	1.008277	-25
2014-09-16	2456916.615	150	20	1.049768	-25
2014-09-17	2456917.615	150	20	1.050394	-25
2014-09-18	2456918.618	150	20	1.041893	-25
2014-09-20	2456920.614	150	20	1.039054	-25
2014-09-25	2456925.606	150	20	1.032586	-25
2014-09-26	2456926.603	150	20	1.032139	-25
2014-10-03	2456933.613	150	20	1.006630	-30
2014-10-10	2456940.594	150	20	1.006190	-30
2014-10-11	2456941.583	150	20	1.011227	-30
2014-10-14	2456944.588	150	20	1.003694	-30
2014-10-15	2456945.587	150	20	1.003306	-30
2014-10-19	2456949.640	150	20	1.028884	-30
2014-10-20	2456950.622	150	20	1.013101	-30
2014-10-25	2456955.609	150	20	1.013088	-30
2014-10-29	2456959.608	150	20	1.022143	-30
2014-11-06	2456967.582	120	20	1.018671	-30
2014-11-07	2456968.565	120	20	1.007998	-30
2014-11-08	2456969.566	120	20	1.010164	-30
2014-11-17	2456978.552	120	20	1.018909	-30
2014-11-18	2456979.520	120	20	1.001826	-30
2014-11-19	2456980.515	120	20	1.001345	-30
2015-05-30	2457172.736	150	30	2.229918	-30

Date	**HJD**	**N-Exp** (s)	**W-Exp** (s)	**Airmass**	**CCD Temp** (°F)
2015-06-04	2457177.951	150	30	1.001111	-30
2015-06-09	2457182.931	150	30	1.005512	-30
2015-06-13	2457186.864	150	30	1.072481	-30
2015-06-14	2457187.918	150	30	1.004422	-27
2015-06-18	2457191.920	120	20	1.001079	-27
2015-06-19	2457192.898	120	20	1.008954	-27
2015-06-22	2457195.919	120	20	1.000278	-27
2015-06-26	2457199.933	120	20	1.008425	-25
2015-06-27	2457200.929	120	20	1.007057	-25
2015-07-12	2457215.919	120	20	1.036114	-25
2015-07-17	2457220.934	120	20	1.077563	-25
2015-07-24	2457227.848	120	20	1.003315	-25
2015-07-28	2457231.924	120	20	1.134190	-25
2015-08-21	2457255.923	120	20	1.413276	-25
2015-09-07	2457272.647	120	20	1.044691	-25
2015-09-09	2457274.636	100	20	1.054238	-25
2015-09-10	2457275.653	100	20	1.026759	-25
2015-09-11	2457276.649	100	20	1.028313	-30
2015-09-12	2457277.653	100	20	1.020873	-30
2015-09-19	2457284.636	100	20	1.018611	-30
2015-09-20	2457285.622	100	20	1.031430	-30
2015-10-24	2457319.605	100	20	1.007909	-30
2016-05-14	2457522.932	100	20	1.094598	-30
2016-05-19	2457527.876	100	20	1.228229	-30
2016-05-28	2457536.850	100	20	1.234270	-30
2016-05-29	2457537.834	100	20	1.294868	-30
2016-05-31	2457539.755	150	30	1.880814	-30
2016-06-01	2457540.840	150	30	1.231277	-30
2016-06-02	2457541.849	150	30	1.187927	-30
2016-07-04	2457573.836	150	30	1.026837	-25
2016-07-06	2457575.869	150	30	1.001208	-25
2016-07-07	2457576.881	150	30	1.000603	-25
2016-07-08	2457577.856	150	30	1.003426	-25
2016-07-09	2457578.895	150	30	1.007172	-25
2016-07-12	2457581.843	150	30	1.004510	-25
2016-07-13	2457582.835	150	30	1.006814	-25
2016-07-14	2457583.921	150	30	1.048883	-25
2016-07-15	2457584.947	150	30	1.105681	-25
2016-07-17	2457586.832	150	30	1.003146	-25

Chapter 3

Methodology and Analysis

The raw frames were reduced in IRAF using the standard method of subtracting zero, dark, and flat frames from the original image. After this process, I analyzed the data according to the following methodology.

3.1 Calculating Stellar Magnitudes with DAOPHOT

The first step of the analysis was to measure the photometric magnitude of the stars in the field. To do this, I processed the raw frames using the DAOPHOT software package, developed by Peter Stetson of the Dominion Astrophysical Observatory and described in Stetson (1987, 1992). This package is available in the noao.digiphot directory in IRAF. While this thesis does not provide a comprehensive guide to using DAOPHOT, a brief, qualitative description of its purpose and function is presented.

DAOPHOT was designed to perform differential photometry in crowded stellar fields like Cygnus OB2. In uncrowded fields, such photometry is relatively straightforward; it ordinarily consists of measuring the photon counts per pixel within a circular aperture placed around the desired target, subtracting the brightness of the surrounding sky, and electronically converting this value into a stellar magnitude. This becomes more difficult in crowded fields, where stars are often superimposed on each other, making it time-consuming or even, in some cases, impossible to manually separate the light from the overlapping stars. DAOPHOT attempts to resolve these problems by fitting a modelled stellar brightness profile, known as a point spread function (PSF), to each star in the frame; if the light of multiple stars is blended, DAOPHOT scales and superimposes individual PSFs to fit the image data (Stetson, 1987, p. 193). The majority of DAOPHOT's work consists of fitting PSFs and then calculating stellar magnitudes.

Before actually performing the PSF fit, I used a DAOPHOT subroutine called DAOFIND to identify all of the stars in the frame. DAOFIND creates a coordinate file (marked .coo) that assigns each star a number and saves its coordinates on the frame. Because the telescope does not point at exactly the same spot every night, there inevitably are small night-to-night variations in the stars visible in the frame. If the DAOFIND routine were separately run for each frame, the numbering system that identifies each star would vary from night to night, making it impossible to track long-term variations in the magnitude of individual stars. In response to this issue, I chose a frame that appeared to include most of the stars visible in the majority of the other frames and ran it through the DAOFIND routine, generating a standard coordinate file, which contained a total of 580 stars. This file was adapted for use on all other frames by superimposing the apertures of the original coordinate file on a new frame, selecting all 580 apertures, and then simultaneously dragging them to align with the positions of the stars in the new frame.

Due to the large number of frames to be processed and because DAOPHOT's PSF-fitting process requires the execution of many subroutines, I utilized a computer script written by my advisor, Dr. Eric Hintz, to load the individual frames into the program and execute the subroutines in the appropriate sequence. This script is provided in Appendix A. The averaged initial wide-filter magnitudes calculated by DAOPHOT are provided in Appendix B, as are the averaged initial Hα index values described in the following section.

3.2 Calculating Hα Index Values

After obtaining stellar magnitudes for the stars in each frame, I calculated their initial Hα photometric index values by subtracting each star's magnitude in the wide-filter frame from its value in the corresponding narrow-filter frame. Naturally, the data initially contained a lot of noise resulting from night-to-night variations in measured magnitude that did not represent real variations in stellar brightness but, rather, inevitable variations in the observing conditions.

To correct for these variations, I calibrated the data obtained on 15 August and 23 September 2013 by comparing it with photometric observations of the open cluster NGC 752 taken on the same nights by the same telescope. As shown in Table 3.1, each night of NGC 752 observations had two pairs of narrow- and wide-filter frames, for a total of four narrow/wide pairs. The NGC 752 photometric data was paired with spectroscopic observations of the same targets that allowed the true index values of the stars in the table to be calculated. I calculated the average offset between photometric and spectroscopic index values for the two nights (0.696426 for 15 August 2013 and 0.637725 for 23 September 2013) and added it to the Cygnus OB2 values on the corresponding nights, under the assumption that observing conditions would be consistent for observations of Cygnus OB2 and NGC 752 on the same night.

Table 3.1. Comparison of NGC 752 Photometry and Spectroscopy

Star	Type	Hα	N-W1	Offset	N-W2	Offset	N-W3	Offset	N-W4	Offset
BD+37 428	G8 III	2.64247	1.962	0.68047	1.983	0.65947	1.979	0.66347	2.019	0.62347
BD+37 433	F3 III	2.73336	2.03	0.70336	2.056	0.67736	2.063	0.67036	2.098	0.63536
BD+37 426	F0 III	2.75469	2.073	0.68169	2.099	0.65569	2.108	0.64669	2.156	0.59869
BD+37 432	G9 III	2.63922					1.986	0.65322	2.044	0.59522
BD+37 431	F2 III	2.75632	2.054	0.70232	2.071	0.68532	2.078	0.67832	2.147	0.60932
	K0 V	2.63929	1.868	0.77129	1.892	0.74729	1.993	0.64629	2.007	0.63229
Average				0.707826		0.685026		0.659725		0.615725
Std. Dev.				0.037113		0.03691		0.013158		0.017156
Night Avg.						**0.696426**				**0.637725**

Table 3.1 Spectroscopic and photometric Hα index values for NGC 752, which were compared in order to calculate an offset between the true, spectroscopic index value and the photometric value measured on a given night. *Hα* denotes the spectroscopic index value while *N-W* denotes the measured photometric value, with *N-W1* and *2* corresponding to the narrow/wide filter pairs shot on 15 August 2013, and *N-W3* and *4* to those shot on 23 September 2013. *Offset* is the difference between the two index values. *Average Offset* is the average of all the individual offsets in a frame, with *Night Avg.* the average of the two narrow/wide pairs shot on the same night. *Night Avg.* is the offset used to calibrate the Cygnus OB2 photometry obtained on the same two nights.

After completing this procedure, I calculated the standard deviation in each star's index values across the two nights. There was still a considerable amount of scatter among dimmer stars, but I was able to identify 10 stars in Cygnus OB2 that were relatively stable (reflected by low index-value standard deviations) and that were relatively isolated from other stars (to avoid problems introduced by overlapping PSFs). I averaged the index values of each of these 10 stars and took the result to be its true value. The corrected values from the two nights, as well as the average (true) value, for each of the standard stars are shown in Table 3.2.

These 10 stars served as my standards for calibration of the remaining nights. I calculated the average offset of the standard stars in a specific frame and then added this offset to all 580 stars. I then checked this calculation by computing the standard deviation of the individual offsets for each night. Most nights had a standard deviation $\sigma < 0.05$, until 6 July 2016, at which point nearly all nights exhibited wide variations in each star's individual offset. These offsets and standard deviations can be found in Appendix C.

Table 3.2. Preliminary Standard Stars for Cygnus OB2

Offset:	0.696426		0.637725			
Star ID	**N-W 1**	**N-W 2**	**N-W 3**	**N-W 4**	**Average**	**Std. Dev.**
25	2.652426	2.673426	2.640725	2.656725	2.6558255	0.01354214
26	2.732426	2.751426	2.707725	2.726725	2.7295755	0.01799203
105	2.852426	2.878426	2.845725	2.864725	2.8603255	0.01440556
134	2.697426	2.709426	2.665725	2.690725	2.6908255	0.01843539
186	2.756426	2.782426	2.757725	2.741725	2.7595755	0.01687335
230	2.651426	2.660426	2.648725	2.680725	2.6603255	0.01449048
265	2.779426	2.795426	2.734725	2.773725	2.7708255	0.02576048
392	1.668426	1.688426	1.667725	1.668725	1.6733255	0.01007572
435	2.538426	2.542426	2.519725	2.552725	2.5383255	0.01378584
507	2.639426	2.643426	2.652725	2.659725	2.6488255	0.00915624

Table 3.2 Calibrated Hα index values for the 10 stars used as standards in the preliminary zero-point calibration of the Cygnus OB2 observations. *Offset* denotes the average difference between photometric and spectroscopic values for observations of NGC 752 on the corresponding night, used to calibrate the Cygnus OB2 index values obtained on the same nights. *Star ID* is the identifying number produced by the DAOFIND task that is used to label each star. *N-W 1* and *2* refer to the narrow/wide filter pairs shot on 15 August 2013, and *N-W 3* and *4* refer to those shot on 23 September 2013. The average of the four measured index values for each star is taken to be its true value.

After applying this initial offset, I applied a second, finer offset following a similar procedure: identifying stars with relatively stable magnitudes to serve as standards (listed in Table 3.3), calculating an offset, and applying it to the corresponding night. To select new standards for this second offset, I first removed all pairs (a total of 20 narrow/wide pairs) of corrected data for which the standard deviation of the standard stars' individual offsets was $\sigma > 0.05$ so that I could calculate reliable average values for individual stars. I then identified a new set of standard stars by limiting my sample to only those stars that had a standard deviation $\sigma < 0.01$, indicating that their brightness was relatively constant. Next, I averaged the corrected index values for each standard over all 175 remaining pairs of observations and took this average to be the star's true value. As before, for each of these 11 stars, I calculated the difference between this true (averaged) value and the measured Hα value on any given night, averaging the individual differences to obtain a single offset for the frame. The resulting offsets are found in Appendix D (those nights in which the initial standards had a standard deviation σ > 0.05 are left blank).

Table 3.3. Second Standard Set

Star ID	Avg.	σ
70	2.686384	0.009007
78	2.686021	0.009781
109	2.690946	0.008938
131	2.864341	0.009894
134	2.691119	0.007588
166	2.706224	0.009532
206	2.690360	0.009809
230	2.661483	0.008200
265	2.769588	0.009943
276	2.627012	0.009440
376	2.671576	0.009990

Table 3.3 The second set of standard stars, used to calculate the second set of nightly offsets. *Avg.* is the average Hα index value of the star over all 91 nights. Note that stars 134, 230, 265 are standards in both the first and second sets.

3.3 Results

Despite these efforts, the data still show a considerable amount of scatter. The data are represented in Fig. 3.1, where each object's wide-filter magnitude is plotted against its calibrated Hα index value. The values of the plotted points are available in Appendix C. Theoretically, the points should echo the shape of a typical H-R diagram.

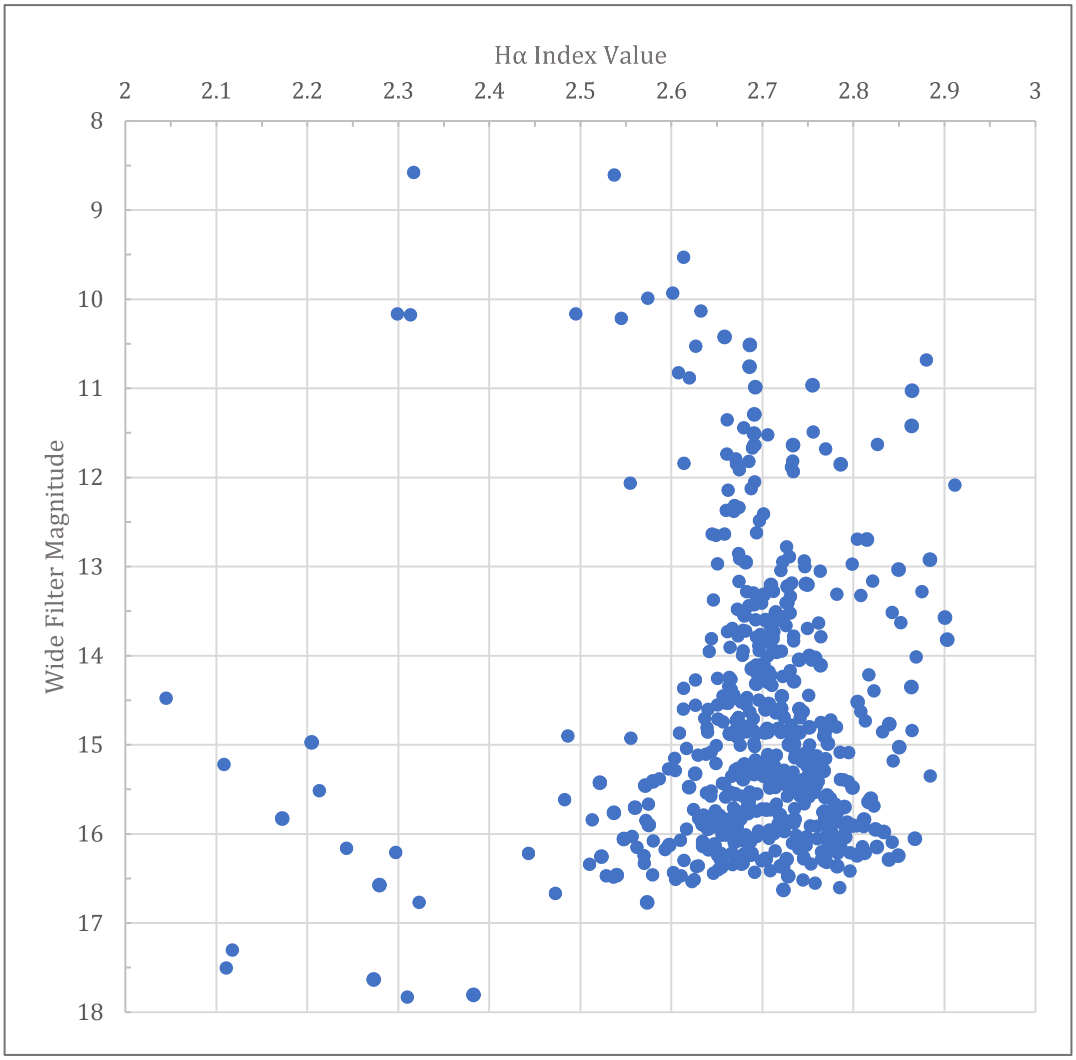

Figure 3.1 Average calibrated Hα index values for each star are plotted on the x-axis against their average wide-filter magnitude on the y-axis. A handful of outliers (13) with index values between 0.5 and 2.0 are not shown.

Similarly, when an error plot is created, the data do not follow the expected form. Fig. 3.2 is an example of such a plot. In theory, the dimmer magnitudes on the right of the x-axis should have a higher scatter in the error while those toward the left end of the axis (corresponding to brighter stars), creating a flaring feature at the right end. This, however, is not the case, as those stars with a lower average wide-filter magnitude appear to have lower errors than their brighter counterparts.

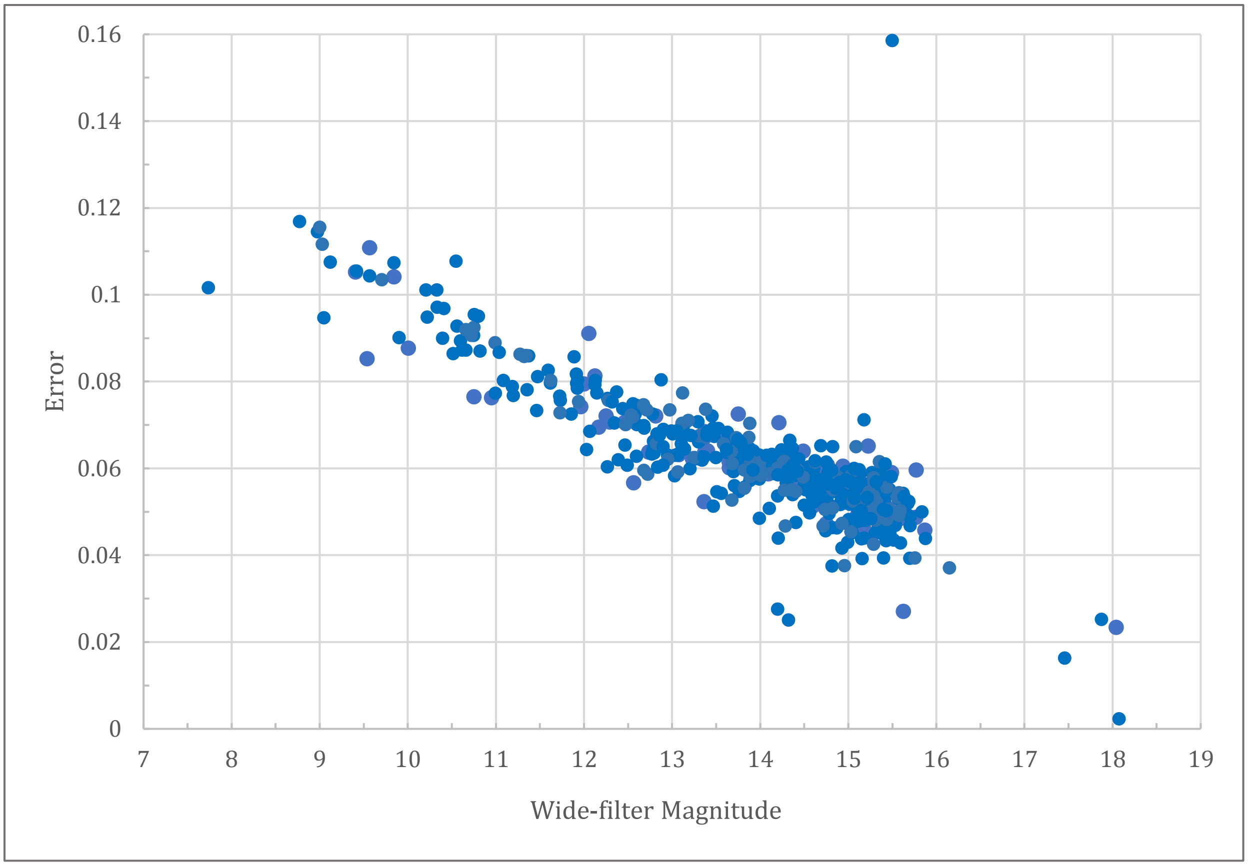

Figure 3.2 A plot of the error vs. wide-filter magnitude for a night of observations of Cygnus OB2. This plot corresponds to 19 May 2016. Error is calculated with the following formula: $|m_{night} - m_{avg}|/m_{avg}$, where m_{night} is the measured wide-filter magnitude on the given night and m_{avg} is the averaged wide-filter magnitude over all nights.

Chapter 4

Conclusion

The scatter in Fig. 3.1 and the inverted relationship between error and magnitude in Fig. 3.2 indicate that there is still much work to be done on this index before the benefits predicted by Joner and Hintz (2015) can be realized. Though their Hα photometric system shows promise, it is, for the present, plagued by technical problems. Given the success of similar systems, such as Crawford's Hβ system, and the promising preliminary results presented by Joner and Hintz (2015), it seems almost certain that these problems reflect difficulties with the software, rather than a theoretical barrier.

One such technical problem has already been discovered and corrected. During early attempts to remove the effects of night-to-night fluctuations in observing conditions and calibrate the observations, I encountered persistent scatter in the brightness of the standard stars for all but the earliest observations in 2014 and all observations from 2015–16. This result was suspect because the 2013 and early 2014 observations were relatively free of this effect. After an extensive search, I discovered that the source of the problem was the addition of a single aperture to the beginning of the coordinate file used to place the DAOPHOT apertures, meaning that star

1 had been marked as star 2, and so on. As I was no longer comparing the standards to themselves, it was only natural that scatter should appear in the data.

Future research should focus on identifying the source of these problems and removing it. One potential cause is an inexplicable change in the image dimensions of the frames received from West Mountain Observatory. Prior to 2015, each image was 2025x2048 pixels; beginning in 2015, however, all images were 2000x2000 pixels. I first attempted to find an existing function in places like IRAF’s images directory that would rescale the dimensions of the image or coordinate file but was unable to discover a suitable function. With the failure of this approach, I tried to manually adjust the coordinate file so that the apertures were better aligned with the slightly distorted image; however, as with my previous attempts, my efforts on this front were similarly ineffective.

Once these issues are resolved, the remainder of the project should be relatively straightforward. With scatter mostly eliminated, bright, stable standard stars in the field can be identified. Future researchers should compile and publish a list of these standards so that other teams studying objects in Cygnus OB2 can calculate important values based on a standardized index. In addition to providing data that can be compared across studies, such standardization would also have the benefit of providing a clearly defined value past which a star would be considered in emission (Joner & Hintz, 2015, p. 4).

Appendix A

DAOPHOT Scripts

daowmoset.cl

```
centerpars.calgorithm = "none"
centerpars.cbox = 13.56
centerpars.cthreshold = 0.
centerpars.minsnratio = 1.
centerpars.cmaxiter = 10
centerpars.maxshift = 5.424
centerpars.clean = no
centerpars.rclean = 1.
centerpars.rclip = 2.
centerpars.kclean = 3.
centerpars.mkcenter = no
centerpars.mode = "ql"

datapars.scale = 1.
datapars.fwhmpsf = 4.52
datapars.emission = yes
```

```
datapars.sigma = 11.35

datapars.datamin = INDEF

datapars.datamax = 55000.

datapars.noise = "poisson"

datapars.ccdread = "rdnoise"

datapars.gain = "gain"

datapars.readnoise = 0.

datapars.epadu = 1.

datapars.exposure = "exptime"

datapars.airmass = "airmass"

datapars.filter = "subset"

datapars.obstime = "hjd"

datapars.itime = 1.

datapars.xairmass = INDEF

datapars.ifilter = "INDEF"

datapars.otime = "INDEF"

datapars.mode = "ql"


findpars.threshold = 7.

findpars.nsigma = 1.6

findpars.ratio = 1.

findpars.theta = 0.

findpars.sharplo = 0.2

findpars.sharphi = 1.

findpars.roundlo = -1.

findpars.roundhi = 1.

findpars.mkdetections = no

findpars.mode = "ql"

fitskypars.salgorithm = "mode"

fitskypars.annulus = 24.86

fitskypars.dannulus = 5.

fitskypars.skyvalue = 0.
```

```
fitskypars.smaxiter = 10
fitskypars.sloclip = 0.
fitskypars.shiclip = 0.
fitskypars.snreject = 50
fitskypars.sloreject = 3.
fitskypars.shireject = 3.
fitskypars.khist = 3.
fitskypars.binsize = 0.1
fitskypars.smooth = no
fitskypars.rgrow = 0.
fitskypars.mksky = no
fitskypars.mode = "ql"
photpars.weighting = "constant"
photpars.apertures = "5.876"
photpars.zmag = 20.
photpars.mkapert = no
photpars.mode = "ql"
daopars.function = "auto"
daopars.varorder = 1
daopars.nclean = 2
daopars.saturated = no
daopars.matchrad = 5.424
daopars.psfrad = 22.6
daopars.fitrad = 6.328
daopars.recenter = yes
daopars.fitsky = no
daopars.groupsky = no
daopars.sannulus = 24.86
daopars.wsannulus = 5.
daopars.flaterr = 0.75
daopars.proferr = 5.
```

```
daopars.maxiter = 50

daopars.clipexp = 6

daopars.cliprange = 2.5

daopars.mergerad = INDEF

daopars.critsnratio = 1.

daopars.maxnstar = 10000

daopars.maxgroup = 60

daopars.mode = "ql"
```

daowmoset2.cl

```
group.image = "NGC752-001NB.fits"

group.photfile = "default"

group.psfimage = "default"

group.groupfile = "default"

group.datapars = "datapars"

group.daopars = "daopars"

group.wcsin = "logical"

group.wcsout = "logical"

group.wcspsf = "logical"

group.cache = yes

group.verify = no

group.update = no

group.verbose = yes

group.mode = "ql"


nstar.image = ";qwq;wqa"

nstar.groupfile = "default"

nstar.psfimage = "default"

nstar.nstarfile = "default"

nstar.rejfile = "default"

nstar.datapars = "datapars"

nstar.daopars = "daopars"

nstar.wcsin = "logical"

nstar.wcsout = "logical"

nstar.wcspsf = "logical"

nstar.cache = no

nstar.verify = no

nstar.update = yes

nstar.verbose = yes

nstar.mode = "ql"

phot.image = "NGC752_209-001WA"
```

```
phot.coords = "default"

phot.output = "default"

phot.skyfile = ""

phot.plotfile = ""

phot.datapars = "datapars"

phot.centerpars = "centerpars"

phot.fitskypars = "fitskypars"

phot.photpars = "photpars"

phot.interactive = no

phot.radplots = no

phot.icommands = ""

phot.gcommands = ""

phot.wcsin = "logical"

phot.wcsout = "logical"

phot.cache = no

phot.verify = no

phot.update = no

phot.verbose = yes

phot.graphics = "stdgraph"

phot.display = "stdimage"

phot.mode = "ql"

psf.image = "NGC752_209-001WA.fits"

psf.photfile = "default"

psf.pstfile = "default"

psf.psfimage = "default"

psf.opstfile = "default"

psf.groupfile = "default"

psf.plotfile = ""

psf.datapars = "datapars"

psf.daopars = "daopars"

psf.matchbyid = yes

psf.interactive = no
```

```
psf.mkstars = no

psf.showplots = no

psf.plottype = "mesh"

psf.icommands = ""

psf.gcommands = ""

psf.wcsin = "logical"

psf.wcsout = "logical"

psf.cache = no

psf.verify = no

psf.update = no

psf.verbose = yes

psf.graphics = "stdgraph"

psf.display = "stdimage"

psf.mode = "ql"

pstselect.image = "NGC752_209-001WA"

pstselect.photfile = "default"

pstselect.pstfile = "default"

pstselect.maxnpsf = 25

pstselect.mkstars = no

pstselect.plotfile = ""

pstselect.datapars = "datapars"

pstselect.daopars = "daopars"

pstselect.interactive = no

pstselect.plottype = "mesh"

pstselect.icommands = ""

pstselect.gcommands = ""

pstselect.wcsin = "logical"

pstselect.wcsout = "logical"

pstselect.cache = no

pstselect.verify = no

pstselect.update = yes
```

```
pstselect.verbose = yes

pstselect.graphics = "stdgraph"

pstselect.display = "stdimage"

pstselect.mode = "ql"
```

frameproc.cl

```
##Things to adjust:
#image-framenumberfilter.fits    #image name
#image.coo.framenumber           coordinate file
#image.mag.framenumberfilter     photometry file
#image.pst.framenumberfilter     psf star list file
#image.psf.framenumberfilter     psf image file
#image.pstout.framenumberfilter  output psf star list file
#image.psg.framenumberfilter     star list group file
#image.psf.framenumberfilter.fits[1]       psf .fits image file
#image.psfout.framenumberfilter.fits[1]    output .fits image psf
#image.nst.framenumberfilter     nstar photometry
#image.nsj.framenumberfilter     nstar rejections
#image-framenumberfilter.nst.txt nstar text output
#image.als.framenumberfilter     allstar photometry
#image.arj.framenumberfilter     allstar rejections
#image-framenumberfilter.als.txt allstar text output

##PHOT
phot.verify=no   #do not confirm phot parameters

phot image-framenumberfilter.fits image.coo.framenumber image.mag.framenumberfilter
#image name
#coord file name
#output photometry file

##PSTSELECT
pstselect.verify=no #do not confirm phot parameters

pstselect image-framenumberfilter.fits image.mag.framenumberfilter
image.pst.framenumberfilter 25
#image name
#photometry file
#output psf star list
#max number of psf stars (default=25)

##PSF
psf.interac=no   #turn off interactive
psf.verify=no #do not confirm phot parameters

psf image-framenumberfilter.fits image.mag.framenumberfilter
image.pst.framenumberfilter image.psf.framenumberfilter image.pstout.framenumberfilter
image.psg.framenumberfilter
#image name
#photometry file
#psf star list
#output psf image
#output psf star list
#output psf star group

##GROUP
group.verify=no  #do not confirm phot parameters

group image-framenumberfilter.fits image.mag.framenumberfilter
image.psf.framenumberfilter.fits[1] image.grp.framenumberfilter
#image name
#photometry file
#psf image name
#group file

##SEEPSF and DISPLAY
seepsf image.psf.framenumberfilter.fits[1] image.psfout.framenumberfilter.fits
```

```
#psf image name
#output image name

display image.psfout.framenumberfilter.fits[1] 2
#psf output image name
#display in frame 2

##NSTAR and TXDUMP
nstar.verify=no  #do not confirm nstar parameters

nstar image-framenumberfilter.fits image.grp.framenumberfilter
image.psf.framenumberfilter.fits[1] image.nst.framenumberfilter
image.nsj.framenumberfilter
#image name
#group file
#psf image name
#output nstar photometry
#output nstar rejections

txdump image.nst.framenumberfilter ID,MAG,XCENTER,YCENTER yes > image-
framenumberfilter.nst.txt
#print ID, magnitude, x- and y-coord to text file

##ALLSTAR and TXDUMP
allstar.verify=no   #do not confirm allstar parameters

allstar image-framenumberfilter.fits image.mag.framenumberfilter
image.psf.framenumberfilter.fits[1] image.als.framenumberfilter
image.arj.framenumberfilter image.sub.framenumberfilter
#image name
#photometry file
#psf image name
#output allstar photometry
#output allstar rejections

txdump image.als.framenumberfilter ID,MAG,XCENTER,YCENTER yes > image-
framenumberfilter.als.txt
#print ID, magnitude, x- and y-coord to text file
```

wmodaophot.cl

```
# WMODAO -- Fix West Mountain Headers for DAO work
#

procedure wmodao (images)

string images    {prompt="Root name of images to fix"}
struct *list, *list2

begin
    # Local variables
    string imagelist, imagenst, imagenrj
    string img, output
    string imgroot
    string coordfile, tmp5
    int    i, end1, end2, tmp1, tmp2, tmp3, tmp4
    real   temp, FWHM, temp2, temp3, intfwhm, inthwhm, STDE
    real   fwb, sigb

    # Create a text file list of images to phot.
    imagelist = mktemp ("tmp$night")
    imgroot = images
    #sections (images//"*", > imagelist)
    sections ("*.fits", > imagelist)

    # Open the list of images and scan through it.
    list = imagelist
    #coordfile = center_file
    while (fscan (list, img) != EOF) {
            print (img)
        print ("Point to open spots and press (m). Do two or three spots.")
            print ("Point to two or three stars and press (a)")
        imexamine (img, 1)
        print ("Input the FWHM for this frame.")
        scanf ("%f", FWHM)
        print ("Input the average STDEV of the Background")
            scanf ("%f", STDE)
        fwb = FWHM
        sigb = STDE
    # set parameters based on value of FWHM and the deviation in the sky
        centerpars.maxshift=1.2*fwb
            centerpars.cbox=3*fwb
            daopars.matchra=1.2*fwb
            daopars.psfrad=5*fwb
            daopars.fitrad=1.4*fwb
            daopars.sannulu=5.5*fwb
            daopars.wsannul=5
            datapars.fwhmpsf=fwb
            datapars.sigma=sigb
            fitskypars.annulus=5.5*fwb
            fitskypars.dannulu=5
            photpars.aperture=1.3*fwb
            photpars.zmag=20
    # Run Photometry with default values
        phot (img, "", coords="default", output="default", verify=no, update=no,
verbose=no)
            print ("Phot ", img, " done")
    # Select PSF Stars
        pstselect (img, photfile="default", pstfile="default", verbose=no, maxnpsf=25)
        print ("PSTSELECT ", img, " done")
    # Make PSF
```

```
        psf (img, photfile="default", pstfile="default", psfimage="default",
opstfile="default", groupfil="default", verbose=no)
        print ("PSF ", img, " done")
    # Group stars
        group (img, photfile="default", psfimage="default", groupfil="default",
verbose=no)
        print ("Group ", img, " done")
    # Run Point Spread Function Photometry
        nstar (img, groupfil="default", psfimage="default", nstarfil="default",
rejfile="default", verbose=no)
        print (img, " completely done. TXDumping.")
         # Try to make TXDUMP command
             txdump (img//"*.nst.1", "id,mag", "yes", headers=no, parameters=yes, >
img//".total")
        txdump (img//"*.nrj.1", "id,mag", "yes", headers=no, parameters=yes, >>
img//".total")
    }
end
```

Appendix B

Initial Magnitudes and Hα Values

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
1	1.349667	0.22419	17.8506	0.331994
2	1.872328	0.313871	14.77769	0.397782
3	1.960627	0.527635	15.15469	0.599171
4	2.114936	0.455806	14.68329	0.364965
5	1.25125	0.474591	14.54744	0.394316
6	2.150036	0.324031	15.52035	0.417126
7	2.105337	0.415061	14.8383	0.358994
8	1.8665	0.432739	17.178	1.109249
9	2.220466	0.369089	15.39068	0.358757
10	2.175312	0.366921	15.63309	0.40846
11	-1.72682	76.39542	26.82213	65.48771
12	0.602074	65.34776	27.36799	68.50416
13	-4.0149	73.19216	43.46676	97.92236
14	-46.8549	134.6159	120.3769	176.7763
15	-8.12587	114.8444	64.87801	125.2319
16	3.725723	108.0028	43.80173	102.0876
17	20.00021	113.0948	29.56341	74.8927
18	16.64766	113.7051	23.77722	62.72097
19	13.26003	57.98787	12.42468	0.414753
20	2.07169	0.341883	14.33168	0.418382
21	1.97113	0.405533	14.80617	0.375557
22	2.188072	0.335341	15.58651	0.490582
23	2.20763	0.365958	13.67287	0.361749
24	2.056519	0.612569	14.16012	0.51685
25	2.020121	0.363733	9.770584	0.35008
26	2.097809	0.488501	10.9975	0.427973

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
27	2.066717	0.301338	13.87581	0.3679
28	1.3205	0.510089	17.83821	0.430446
29	2.07381	0.36287	15.95495	0.367909
30	2.177585	0.367696	13.84038	0.389788
31	2.141545	0.369423	11.20479	0.398496
32	2.098503	0.451788	12.56642	0.371491
33	2.102359	0.411818	14.25379	0.455535
34	1.993663	0.320251	15.51907	0.366025
35	2.108647	0.400457	14.33338	0.347868
36	2.154844	0.402271	15.32814	0.501091
37	2.144763	0.400322	15.0393	0.323129
38	1.556926	0.396218	14.32597	0.381485
39	1.912289	0.385222	16.11852	0.487739
40	2.064348	0.449512	13.94605	0.492858
41	1.648754	0.323232	15.93156	0.454378
42	2.051783	0.370482	14.47179	0.368152
43	2.051181	0.409041	13.31091	0.377954
44	2.128786	0.419531	15.16796	0.499691
45	2.054247	0.376084	13.94003	0.322674
46	2.075185	0.468533	13.46489	0.370534
47	2.098304	0.500058	15.18203	0.575394
48	2.043793	0.732259	10.33906	1.097749
49	2.088357	0.376247	14.61508	0.471725
50	2.102954	0.432279	15.0857	0.348201
51	2.054016	0.382886	13.13474	0.53685
52	2.075907	0.46182	12.74376	0.360179
53	2.039576	0.484714	12.95669	0.406842
54	1.879778	0.487122	15.47797	0.907802
55	1.980856	0.348614	15.47075	0.290858
56	1.968705	0.395265	15.23272	0.361016
57	2.06238	0.379776	15.82105	0.381914
58	2.141289	0.409319	14.93855	0.418706
59	2.023815	0.39061	14.62537	0.34813
60	2.132037	0.342331	15.6091	0.340935
61	1.885539	0.305289	15.61562	0.274768
62	2.039677	0.38999	15.69688	0.353724
63	2.089853	0.400887	15.30552	0.367439
64	1.984711	0.346757	15.15386	0.310582
65	1.998226	0.390019	14.87804	0.362239
66	1.919656	0.38113	15.23951	0.347066
67	2.032338	0.366227	15.05847	0.340566
68	1.976558	0.679422	15.24931	0.53424
69	2.072328	0.394942	14.19326	0.655202
70	2.024821	0.549312	9.846251	1.005443
71	2.036759	0.407492	12.67604	0.667659

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
72	2.046154	0.467932	13.08851	0.391384
73	2.033949	0.39571	13.60748	0.391391
74	2.090974	0.368544	15.23826	0.568201
75	2.080581	0.49684	12.53116	0.7325
76	2.018713	0.60049	14.71143	0.629324
77	2.068092	0.392856	14.78773	0.645812
78	2.024441	0.761699	10.09268	1.243666
79	2.134876	0.384376	15.27332	1.095266
80	2.122389	0.371376	15.5442	0.351751
81	2.035645	0.46471	14.11949	0.52476
82	2.080702	0.390589	14.46029	0.43792
83	2.178795	0.552155	12.37667	0.704559
84	2.04598	0.483017	14.10285	0.66179
85	2.05234	0.324416	15.62886	0.522434
86	1.882124	0.410338	15.81844	0.346826
87	2.06987	0.466856	14.62375	0.511224
88	2.236878	0.416097	12.26013	0.463475
89	2.151655	0.533603	14.81112	0.875529
90	1.913764	0.468455	14.74229	0.453606
91	2.09083	0.555959	15.55677	0.447368
92	2.016657	0.54719	12.57062	0.894324
93	2.11146	0.626221	10.32334	0.538947
94	2.048923	0.397925	13.44887	0.702234
95	2.104649	0.410555	15.7216	0.506846
96	2.008662	0.406139	14.98192	0.378137
97	2.050374	0.433613	13.64267	0.486905
98	2.090241	0.433132	12.54118	0.41196
99	2.008632	0.440788	15.63087	0.677349
100	1.953646	0.391014	14.6616	0.398841
101	2.168097	0.473965	12.01792	0.670811
102	2.232318	0.436033	13.16892	0.42855
103	2.10181	0.571712	15.222	0.555839
104	2.097325	0.379735	14.89894	0.41641
105	2.211781	0.608108	10.33499	1.056185
106	2.071393	0.361824	14.33411	0.454549
107	1.993609	0.445175	15.26148	0.344896
108	2.012015	0.434432	13.488	0.569719
109	2.005865	0.753768	10.87248	0.838464
110	2.077641	0.40808	13.63926	0.639719
111	2.178139	0.387374	14.36829	0.378174
112	2.102294	0.37479	15.27643	0.341363
113	1.505	1.286558	17.14195	1.1906
114	2.099633	0.416154	13.35206	0.475563
115	2.078662	0.448121	13.39017	0.38665
116	2.000979	0.403875	15.41334	0.545961

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
117	2.11434	0.381899	15.36845	0.402528
118	2.024344	0.37971	14.55449	0.385583
119	1.869333	0.376576	14.76008	0.421626
120	1.887379	0.375317	15.04832	0.329789
121	1.985399	0.438174	14.192	0.453222
122	2.055302	0.36437	14.16502	0.323034
123	2.001544	0.439577	12.89066	0.508763
124	1.993149	0.382255	14.90494	0.515873
125	2.236169	0.411077	12.89883	0.548951
126	2.119764	0.444177	13.37261	0.509309
127	1.521954	0.389975	15.16845	0.484555
128	2.030469	0.484013	15.17208	0.441432
129	2.037875	0.483859	13.28756	1.127552
130	2.032974	0.466302	12.29916	0.307421
131	2.202313	0.717901	10.77483	0.786165
132	1.896728	0.550683	15.47973	1.004092
133	2.133031	0.527365	14.10718	0.489563
134	2.047974	0.667261	10.63139	0.907711
135	2.047954	0.506325	12.56804	0.593277
136	1.993828	0.369227	15.64714	0.680188
137	1.879833	0.712859	17.12166	1.315765
138	2.152349	0.317298	15.29688	0.28075
139	2.035297	0.401358	14.64301	0.366595
140	2.091943	0.390032	15.09832	0.353543
141	2.050282	0.36666	14.69431	0.395682
142	2.105328	0.413852	14.17463	0.367322
143	1.887574	0.360554	15.10199	0.408446
144	2.044359	0.378047	15.12095	0.330055
145	2.11239	0.388405	15.22386	0.388708
146	2.065412	0.412914	13.78438	0.489677
147	2.135785	0.411798	14.98847	0.407212
148	2.057041	0.445332	13.9359	0.477548
149	2.050954	0.404808	15.32845	0.465094
150	2.114815	0.409739	14.13766	0.443252
151	2.000326	0.410609	13.90769	0.330628
152	2.118318	0.458143	15.46859	0.642582
153	2.064879	0.496726	15.88696	0.415375
154	2.134026	0.381321	13.95918	0.529139
155	1.909771	0.444244	14.71722	0.381737
156	2.066895	0.410198	13.57704	0.348643
157	2.052179	0.579353	11.96228	0.560842
158	2.080314	0.38777	15.49643	0.767607
159	1.931877	0.365395	14.61006	0.398673
160	2.076611	0.413269	14.6581	0.374535
161	2.100703	0.454345	13.36211	0.570064

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
162	2.062725	0.388432	14.21688	0.375416
163	1.82981	0.402292	14.94653	0.383098
164	2.088203	0.673572	15.4047	0.677961
165	2.006042	0.461901	15.12764	0.269584
166	2.067113	0.632199	10.85483	0.987852
167	1.840041	0.491243	15.19657	0.971342
168	2.003177	0.451675	14.50832	0.432842
169	2.098667	0.466186	12.26828	0.574199
170	2.078708	0.415512	14.88572	0.613815
171	2.0156	0.425412	13.78256	0.458
172	2.056072	0.412715	15.00761	0.41799
173	1.826234	0.438898	15.68666	0.395677
174	2.110323	0.398394	12.63477	0.702359
175	1.240635	0.429517	13.90456	0.441475
176	2.013361	0.531609	12.86346	0.534492
177	1.973973	0.55342	15.43605	0.717491
178	1.173455	1.62708	17.48904	1.021089
179	2.149663	0.48584	12.038	0.60623
180	1.763083	0.892221	15.98468	2.884953
181	2.128144	0.388974	15.41282	0.4407
182	2.074103	0.45175	15.8616	0.502634
183	2.112713	0.447016	15.2546	0.313371
184	2.056718	0.435491	13.96581	0.470724
185	2.029713	0.498113	11.82905	0.6626
186	2.092318	0.447554	12.98432	0.465189
187	2.084123	0.452354	13.00231	0.340034
188	2.091049	0.454635	14.80616	0.533978
189	1.947518	0.334074	15.53693	0.29587
190	2.054862	0.383788	14.90828	0.363236
191	2.03379	0.437038	14.82334	0.372923
192	2.067662	0.460721	12.95855	0.504133
193	2.05315	0.38186	14.7946	0.502976
194	2.022301	0.401792	15.59297	0.374666
195	1.977979	0.406919	14.19205	0.475991
196	2.048833	0.411569	14.91459	0.402338
197	2.197532	0.478975	12.99638	0.594214
198	2.146	0.480964	14.90653	0.669681
199	2.035765	0.389629	14.45221	0.368647
200	2.047731	0.460223	13.62554	0.399827
201	2.132376	0.425507	14.05225	0.527671
202	1.892813	0.424683	15.59489	0.482383
203	2.051667	0.47892	12.74496	0.760005
204	2.007185	0.509242	13.99466	0.449471
205	1.976841	0.475284	13.58919	0.440538
206	2.032503	0.691657	10.9837	0.876042

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
207	2.053944	0.463745	13.69654	0.659958
208	2.023228	0.339804	15.38508	0.420661
209	2.079088	0.411123	15.39337	0.398716
210	2.008108	0.40284	15.66494	0.430381
211	1.9445	0.535087	15.84337	0.672684
212	2.141022	0.439239	15.47786	0.516954
213	2.106311	0.355532	15.5639	0.299742
214	2.037448	0.560702	15.52756	0.449543
215	2.141922	0.451585	14.51047	0.500752
216	1.990615	0.409183	11.95394	0.633504
217	2.019283	0.399995	12.8028	0.42007
218	1.9309	0.801565	16.37859	2.150919
219	1.529444	0.465712	17.68129	0.744995
220	1.510333	0.554141	17.46236	0.988205
221	2.025713	0.493167	11.71335	0.321782
222	2.055263	0.74358	12.16007	0.459929
223	2.069894	0.365827	14.72967	0.370692
224	2.117113	0.514155	15.52288	0.744826
225	2.072342	0.478199	15.69911	0.311872
226	2.014655	0.397443	15.09592	0.366628
227	2.041626	0.543457	12.76777	0.656147
228	1.956381	0.581992	13.46494	0.456137
229	2.125767	0.379562	15.55493	0.397557
230	2.029564	0.687195	10.68359	1.135868
231	2.063376	0.460337	14.45436	0.991137
232	2.079085	0.343636	14.84116	0.350153
233	1.586159	0.371924	14.84785	0.325315
234	1.94449	0.380371	15.18537	0.308594
235	2.080062	0.375447	15.0799	0.727327
236	1.995708	0.518958	14.35042	0.501135
237	2.125626	0.424145	14.07865	0.372384
238	2.086794	0.372778	15.612	0.579299
239	2.016907	0.382187	14.05304	0.516527
240	2.042856	0.743799	15.14987	0.533298
241	2.096051	0.446729	14.85674	0.642794
242	1.969328	0.702674	9.334841	0.643385
243	1.982231	0.45948	15.14372	1.194917
244	2.000851	0.524185	14.76524	0.369554
245	2.027769	0.484545	12.62071	0.67854
246	1.997713	0.53567	11.40214	0.657258
247	2.053662	0.460687	12.69201	0.534363
248	2.176128	0.712268	10.97894	0.71282
249	2.084742	0.486102	13.19084	0.571269
250	1.800544	0.379423	15.58241	0.551444
251	1.848803	0.436924	15.82729	0.441299

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
252	1.956191	0.356747	15.71922	0.366271
253	2.014369	0.374989	15.42023	0.331958
254	1.998518	0.337166	15.41786	0.484856
255	2.016026	0.443376	14.77129	0.451969
256	1.681214	0.871517	16.65664	1.811686
257	2.116075	0.37317	15.92654	0.513794
258	2.037479	0.394255	14.6984	0.562724
259	2.070221	0.520845	14.56027	0.427737
260	1.964396	0.412015	15.89631	0.414415
261	2.074767	0.366573	12.27939	0.696288
262	2.072775	0.402821	13.03312	0.428386
263	2.042755	0.425532	13.58157	0.325222
264	2.036154	0.436248	13.10631	0.423897
265	2.102441	0.624702	11.02877	0.769402
266	2.113231	0.467375	14.19643	0.949736
267	2.086561	0.386326	14.35451	0.61192
268	2.063549	0.555127	15.15283	0.521144
269	1.978835	0.462268	13.29024	0.538147
270	2.024696	0.379596	14.89536	0.496575
271	2.126828	0.416446	14.73259	0.388094
272	2.086903	0.53619	15.29608	0.390713
273	2.069601	0.401873	15.36958	0.389884
274	2.056311	0.564476	15.38695	0.457055
275	2.126072	0.391662	14.71821	0.366552
276	2.006701	0.79206	9.876134	1.110748
277	1.93651	0.571542	14.18571	1.33649
278	2.023118	0.32892	15.6614	0.497089
279	1.965608	0.390691	14.48471	0.361872
280	1.893651	0.413537	14.26551	0.40133
281	1.86976	0.455984	15.50038	0.429481
282	2.084751	0.468712	15.65593	0.439225
283	2.052133	0.400873	14.63388	0.403994
284	2.039087	0.534579	12.93866	0.636745
285	2.142282	0.426976	14.74233	0.498097
286	2.159385	0.444588	12.49309	0.605968
287	2.092021	0.489064	14.94572	0.585323
288	2.128472	0.534413	12.31173	0.787878
289	2.05383	0.442356	15.24558	0.680241
290	2.007046	0.445877	15.56027	0.415538
291	2.055147	0.417507	15.48756	0.315268
292	2.077948	0.615687	14.08786	0.90719
293	2.099943	0.429844	14.49913	0.507112
294	2.023186	0.50124	10.97025	0.908095
295	2.089995	0.561816	12.39789	0.586781
296	2.036634	0.453251	13.29312	0.395982

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
297	2.120922	0.64845	15.52132	0.656502
298	2.063069	0.419978	15.66484	0.540899
299	1.411703	0.65655	14.56772	0.450944
300	2.088547	0.391742	15.68376	0.403808
301	1.867957	1.137206	8.883967	2.347791
302	2.021833	1.021235	7.987991	0.806238
303	2.013169	0.454562	13.55455	1.237757
304	2.035751	0.467087	11.24414	0.389624
305	2.046503	0.394964	14.64268	0.724557
306	2.011046	0.747164	9.457538	1.229032
307	1.939313	0.533492	14.07079	0.979879
308	2.090211	0.385645	15.35073	0.387679
309	2.071733	0.37893	14.4789	0.383797
310	2.0104	0.544055	13.85668	0.481312
311	2.062	0.373393	14.21279	0.335871
312	1.999192	0.740175	14.03816	0.476022
313	1.845405	0.39384	14.24635	0.357783
314	1.967041	0.711546	9.251687	1.24369
315	2.063268	0.379254	14.76244	1.142208
316	2.061579	0.513651	12.52232	0.731406
317	2.083881	0.390292	14.92166	0.573916
318	2.076298	0.721539	14.43273	0.463417
319	1.751565	0.641785	9.460237	3.193823
320	2.108222	1.927624	8.064317	1.261513
321	2.119516	0.360999	14.42459	0.333493
322	1.98501	0.416437	15.25025	0.509084
323	2.089944	0.38397	15.4989	0.383037
324	2.071205	0.476686	14.53721	0.407266
325	2.105513	0.398599	15.40026	0.414783
326	1.277323	0.578087	11.77705	0.855145
327	2.078913	0.439813	15.01994	0.756676
328	2.062474	0.444335	15.45382	0.569671
329	2.055933	0.388685	14.69738	0.531152
330	2.056487	0.489681	15.15568	0.442566
331	2.055744	0.438197	14.51266	0.589396
332	2.030477	0.404385	13.19263	0.496093
333	2.092753	0.460552	15.08887	0.704481
334	1.96959	0.479455	12.30966	0.769346
335	2.021056	0.532922	15.05255	0.701594
336	2.027636	0.460408	12.93565	0.639661
337	1.993887	0.43977	14.18847	0.422249
338	1.934738	0.407686	14.63567	0.368426
339	2.001931	0.485896	14.20213	0.382996
340	2.00478	0.425845	13.25839	0.34519
341	2.030882	0.431235	13.52256	0.364193

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
342	2.02341	0.546154	11.48201	0.557571
343	2.016585	0.577665	11.48046	0.59743
344	2.033021	0.438341	13.85314	0.603607
345	2.054318	0.584648	11.16291	0.832606
346	2.074979	0.45567	15.39841	1.072414
347	2.050195	0.629827	11.14985	1.0204
348	2.020826	0.482868	14.92308	0.885993
349	2.017891	0.402835	14.61014	0.375133
350	1.999052	0.444339	15.45614	0.419968
351	1.976227	0.547707	15.26576	0.391743
352	2.036764	0.430251	14.44759	0.407746
353	2.057133	0.443666	13.97727	0.406412
354	2.046328	0.515944	12.90667	0.518669
355	1.987554	0.385853	15.14485	0.556625
356	2.059222	0.647066	11.21966	1.05201
357	1.956295	0.440776	15.48578	0.89457
358	1.905869	0.501906	15.81999	0.309502
359	2.064686	0.405539	14.75493	0.481743
360	2.066397	0.641232	10.75534	0.978171
361	2.049385	0.469815	12.64449	0.509014
362	2.048897	0.370164	15.20298	0.746685
363	1.887677	0.36963	15.80355	0.380174
364	2.048467	0.558256	15.69203	0.528788
365	1.938738	0.382431	15.77494	0.339297
366	1.99357	0.363122	15.56284	0.353487
367	2.070822	0.473696	15.63918	0.260607
368	2.063485	0.381214	15.43727	0.363633
369	2.026497	0.373393	15.34204	0.337242
370	1.97584	0.377482	15.2078	0.363957
371	1.939058	0.385768	15.66577	0.363825
372	1.844923	0.713257	17.1564	1.300578
373	2.204786	0.399401	12.62132	0.56768
374	1.979253	0.48428	15.37782	0.613607
375	2.021246	0.444213	13.80587	0.522337
376	2.016385	0.646773	11.19586	0.733943
377	2.020656	0.400929	14.80681	0.815131
378	2.196803	0.394939	14.16391	0.391564
379	1.952338	0.520819	15.31568	0.549182
380	2.000444	0.350148	15.41455	0.349799
381	2.033225	0.40481	14.36084	0.356647
382	1.4136	1.210204	16.58262	1.79323
383	2.193761	0.420259	14.69921	0.673756
384	1.999569	0.45888	15.34888	0.421291
385	2.068933	0.52533	14.66386	0.521935
386	2.021497	0.397873	14.04807	0.390376

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
387	1.976754	0.470649	14.45104	0.431615
388	1.987497	0.559894	14.88172	0.493766
389	2.062282	0.439376	15.60625	0.342265
390	1.977151	0.495194	15.15894	0.623294
391	2.019887	0.530988	13.12106	0.61448
392	1.057872	0.536617	12.99703	0.3674
393	1.976328	0.603259	15.53665	0.676222
394	1.824356	0.392389	16.02044	0.425021
395	1.954262	0.43836	14.34864	0.740232
396	1.96535	0.617874	14.65339	0.465242
397	2.045534	0.492037	13.85583	0.475469
398	1.914528	0.668235	9.550051	1.01196
399	2.024897	0.391499	14.91398	1.157156
400	1.999574	0.484716	13.32809	0.50631
401	1.890953	0.520307	15.41789	0.560704
402	1.988631	0.400335	14.53639	0.461272
403	1.97181	0.517917	11.98168	0.703097
404	1.963819	0.457658	15.74346	0.855328
405	1.966487	0.514789	11.17141	1.003614
406	1.960345	0.369186	15.10289	0.861046
407	2.104989	0.452293	14.50816	0.422768
408	1.943576	0.539211	14.14339	0.347566
409	2.014262	0.423664	13.92136	0.649336
410	1.868021	0.757493	9.497959	1.15348
411	2.010913	0.453183	12.81439	0.811326
412	2.012264	0.380496	13.48632	0.393274
413	2.046195	0.493946	12.85712	0.459305
414	2.024769	0.380177	13.97241	0.397362
415	2.04721	0.53536	12.86004	0.458996
416	1.969323	0.570164	14.39385	0.642069
417	2.045107	0.407697	15.75972	0.325614
418	2.015385	0.441002	13.05497	0.669713
419	1.964418	0.443118	13.16126	0.452163
420	1.982518	0.416424	14.86161	0.456567
421	2.064369	0.510255	11.72931	0.768887
422	1.989212	0.403127	14.09257	0.628412
423	2.002149	0.606742	15.39276	0.457967
424	1.968051	0.453092	13.94839	0.53538
425	1.688745	0.725315	9.509453	1.107262
426	1.940228	0.382292	14.9079	1.219922
427	2.010154	0.41813	15.54735	0.429204
428	2.054072	0.443536	13.52619	0.531287
429	2.031918	0.459476	14.20028	0.422685
430	2.143256	0.393528	15.02214	0.414883
431	1.999415	0.396823	13.68063	0.463549

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
432	2.022436	0.419013	14.59182	0.506343
433	2.007251	0.564117	15.06127	0.366678
434	2.024579	0.445886	13.44678	0.537556
435	1.931491	0.551427	11.38326	0.669701
436	2.00445	0.360208	14.79976	0.794433
437	2.076176	0.407614	14.52038	0.443215
438	1.690672	0.335784	16.13448	0.448761
439	2.013809	0.422155	13.85643	0.552385
440	1.593238	0.526625	15.51893	0.737513
441	2.011243	0.467822	13.07902	0.434267
442	2.012246	0.408613	14.04045	0.38561
443	2.029831	0.612169	11.12244	0.827998
444	1.998067	0.48532	13.78803	0.692583
445	1.999662	0.400951	14.34979	0.36799
446	1.920197	0.372241	15.81938	0.43887
447	2.076675	0.419969	14.24976	0.475541
448	1.569302	0.427351	15.51474	0.562126
449	2.021536	0.47912	13.82549	0.586836
450	2.030212	0.495444	11.98646	0.378282
451	2.04449	0.369313	15.02309	0.820385
452	1.950015	0.613704	15.48102	0.369133
453	2.042923	0.390297	15.30094	0.354008
454	1.994803	0.685989	10.14481	1.093274
455	2.172369	0.50278	12.87659	0.699809
456	2.025523	0.498626	15.23422	0.556246
457	2.066104	0.424588	14.52274	0.424916
458	2.049144	0.432917	13.33695	0.499348
459	2.004918	0.533942	12.25981	0.575607
460	2.012887	0.472833	14.95506	0.627628
461	1.990067	0.363505	15.56839	0.393364
462	2.022318	0.551601	11.69641	0.963016
463	2.136742	0.42314	15.46053	0.850567
464	2.029228	0.482153	15.33439	0.378281
465	2.029411	0.593111	15.79708	0.567733
466	2.049309	0.55641	11.73464	0.929167
467	2.0225	0.445564	13.2383	0.457054
468	2.028639	0.434538	14.22443	0.387973
469	2.013631	0.646062	11.07815	0.875384
470	2.036351	0.394767	15.32482	0.917587
471	2.027969	0.385179	14.45689	0.461513
472	1.574533	0.897954	16.85741	1.791744
473	2.001766	0.375302	14.71593	0.392821
474	1.988706	0.392655	15.43956	0.429001
475	2.025244	0.447988	13.01921	0.596357
476	2.083402	0.367973	15.61875	0.618834

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
477	2.011482	0.442961	15.68132	0.460614
478	2.006601	0.355643	15.34423	0.433289
479	2.002056	0.432307	14.9252	0.443057
480	1.961057	0.512392	15.70124	0.424501
481	1.9472	0.385415	14.19846	0.465185
482	2.096508	0.551873	13.54897	0.50277
483	2.011291	0.370881	14.25792	0.337575
484	1.729267	0.695153	16.61058	2.055669
485	1.982409	0.456114	14.91149	0.528004
486	1.995974	0.392366	15.26534	0.382665
487	1.996554	0.489763	15.71684	0.592705
488	1.985032	0.416219	15.13726	0.548004
489	2.017056	0.404742	14.67653	0.35978
490	2.038405	0.427456	12.60421	0.586374
491	2.056508	0.433034	12.74437	0.409762
492	2.033737	0.389825	14.54174	0.483324
493	1.965631	0.410929	14.45428	0.56283
494	1.690308	0.775766	16.70531	1.900361
495	1.965106	0.446466	15.47192	0.410237
496	1.994959	0.427495	14.03171	0.480572
497	2.000482	0.430511	13.60392	0.356397
498	2.015128	0.429655	14.19311	0.411125
499	2.078764	0.374735	15.25536	0.458559
500	2.0226	0.411448	14.06558	0.4642
501	1.956887	0.472372	15.06254	0.435454
502	1.999237	0.489156	15.02977	0.364079
503	2.010667	0.463471	12.49601	0.642277
504	1.8204	0.876967	16.23079	2.431004
505	1.98314	0.439449	15.13042	0.35561
506	2.086253	0.512926	12.33066	0.754315
507	2.018708	0.562999	11.66425	0.524628
508	2.001185	0.375744	14.67351	0.672215
509	2.000138	0.384612	15.09055	0.389324
510	1.912459	0.504118	15.42205	0.395009
511	2.089124	0.44503	15.7508	0.488037
512	2.110031	0.691771	10.82404	1.143813
513	2.016108	0.434871	13.08074	0.60399
514	1.946492	0.445046	15.85937	0.67525
515	2.060015	0.383957	14.68445	0.433495
516	2.098415	0.389636	14.08349	0.364496
517	2.06579	0.426005	13.50954	0.39228
518	2.185859	0.428323	13.35641	0.41809
519	2.106995	0.432363	13.13035	0.367201
520	1.996867	0.420177	14.14718	0.442549
521	1.950134	0.363072	15.29632	0.708132

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
522	0.789103	0.419111	14.75715	0.475763
523	2.011954	0.452567	15.05082	0.395046
524	2.032067	0.382131	14.34964	0.401192
525	2.050797	0.473984	14.54811	0.506898
526	2.006213	0.441376	15.30446	0.425592
527	2.0815	0.506956	14.61628	0.671908
528	1.967247	0.405434	15.2411	0.386873
529	1.980036	0.427982	13.87009	0.507792
530	1.403994	0.433488	13.81762	0.405717
531	1.902	0.469354	13.71502	0.349688
532	1.228	1.64089	16.679	1.74392
533	2.050123	0.39024	13.12001	0.328615
534	1.972487	0.400662	14.43368	0.470137
535	1.914518	0.369574	15.00369	0.415334
536	2.01912	0.377396	14.12308	0.531489
537	1.975518	0.380117	15.5614	0.519436
538	2.032232	0.39315	14.66821	0.663177
539	2.078651	0.378472	14.91023	0.390944
540	2.01836	0.362641	15.36565	0.527248
541	1.677643	0.782067	16.49109	1.96466
542	2.091989	0.583657	15.18741	0.521084
543	1.858957	0.46201	15.13477	0.568282
544	1.973083	0.636139	10.23433	0.639526
545	2.0705	0.487076	12.98708	0.689088
546	1.970978	0.448306	15.59156	0.609545
547	1.996678	0.512672	15.75586	0.614959
548	2.137956	0.400248	12.65967	0.660295
549	2.085028	0.382063	15.24836	0.663464
550	2.079915	0.533712	11.25406	0.940538
551	1.894788	0.414149	15.36658	0.975804
552	1.96993	0.542412	15.40007	0.546642
553	1.996953	0.405242	15.03156	0.390921
554	2.011271	0.5092	15.53992	0.496649
555	2.0239	0.425432	14.67574	0.412841
556	1.983386	0.453438	13.71255	0.472793
557	1.993353	0.427444	13.27134	0.385876
558	2.137325	0.423645	13.72559	0.402505
559	2.220759	0.605588	11.42751	0.717551
560	1.913333	0.650546	13.58427	0.73383
561	2.003331	0.396351	13.87083	0.352613
562	2.208096	0.689579	10.0077	0.956772
563	1.993147	0.571522	14.10254	1.461121
564	2.093832	0.437973	15.36251	0.343696
565	2.042033	0.417128	12.1834	0.76383
566	2.059471	0.487041	12.38479	0.339033

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
567	1.963853	0.376103	13.95578	0.458416
568	2.008545	0.480326	12.7018	0.543374
569	2.100547	0.497292	13.29863	0.388784
570	2.045247	0.395989	13.56896	0.308071
571	1.244375	1.492199	16.72844	1.929594
572	2.09815	0.671213	13.09794	0.861003
573	2.06343	0.510831	11.01601	0.601524
574	1.991284	0.523329	15.16471	1.010553
575	1.960432	0.527736	14.72813	0.607142
576	2.010588	0.413752	13.62144	0.31852
577	2.089362	0.384227	14.40243	0.352882
578	1.923326	0.378165	15.68035	0.418993
579	1.974165	0.676446	15.5947	0.479545
580	2.075054	0.392772	12.22721	0.636661

Appendix C

First Offsets

HJD	σ	OFFSET
2456484	0.01089	0.698476
2456484	0.011801	0.677176
2456495	0.01651	0.544276
2456495	0.013651	0.714276
2456519	0.010478	0.568876
2456519	0.011796	0.521976
2456520	0.008689	0.661076
2456520	0.01602	0.647176
2456556	0.008984	0.624176
2456557	0.013438	0.659876
2456557	0.012485	0.595676
2456559	0.007383	0.591776
2456559	0.015495	0.603176
2456560	0.015279	0.771976
2456560	0.015592	0.626676
2456593	0.00896	0.634576
2456593	0.011101	0.538276
2456599	0.012016	0.598576
2456599	0.016075	0.593776
2456840	0.018306	0.693976
2456840	0.018032	0.578076
2456902	0.028991	0.673476
2456902	0.026438	0.644076
2456903	0.373123	2.658919
2456903	0.376679	2.672669
2456934	0.018853	0.634476

HJD	σ	OFFSET
2456934	1.428208	-2.62132
2456904	0.031	0.219544
2456904	0.0362	0.716919
2456968	0.015201	0.632276
2456968	0.014844	0.667376
2456969	0.007173	0.558876
2456969	1.959438	-1.44662
2456847	0.05487	0.759676
2456847	0.020236	0.694876
2456970	0.015804	0.515176
2456970	0.011147	0.657176
2456941	0.023852	0.686376
2456941	0.01376	0.757876
2456942	0.016089	0.661919
2456942	0.020861	0.606294
2456912	0.009877	0.815544
2456912	0.030708	0.830794
2456913	0.015455	0.641776
2456913	0.015026	0.543876
2456914	0.027114	0.587676
2456914	0.026375	0.597876
2456945	0.01335	0.755676
2456945	0.016489	0.824176
2456885	0.030587	0.965076
2456885	0.023343	0.579176
2456946	0.023562	0.658076
2456946	0.01435	0.663476
2456886	0.027125	0.600876
2456886	0.025767	0.572076
2456917	0.021497	2.240776
2456917	0.016662	2.373276
2456887	0.021063	0.719976
2456887	0.024347	0.551476
2456856	0.015839	0.682576
2456856	0.016984	0.605776
2456979	0.014488	0.588376
2456979	0.011863	0.496876
2456918	0.02357	0.751376
2456918	0.014336	0.693376
2456888	2.046781	3.379476
2456888	0.019458	1.075576
2456857	0.014912	1.071476
2456857	0.017178	0.881476

HJD	σ	OFFSET
2456980	0.01661	0.668576
2456980	0.016865	0.612176
2456919	0.024655	0.780919
2456919	0.032058	0.663544
2456981	0.010114	0.642276
2456950	0.010665	0.745276
2456951	0.031052	0.561776
2456951	0.02158	0.723776
2456921	0.016687	0.655169
2456921	0.035367	0.528544
2456862	0.01916	0.668976
2456862	0.018085	0.683076
2456863	0.075288	-0.55162
2456863	0.05461	-1.56002
2456864	0.022515	0.732576
2456864	0.022905	0.656776
2456956	0.006173	0.570576
2456956	0.017713	0.648376
2456926	0.028589	0.661544
2456926	0.024531	0.622794
2456927	0.023905	0.705419
2456927	0.023172	0.715794
2456898	0.025252	0.763676
2456898	0.015411	0.672876
2456899	0.026504	0.811576
2456899	0.026905	0.670176
2456960	0.021805	0.731276
2456960	0.01294	0.708076
2456839	0.017498	0.655603
2456839	0.021421	0.564714
2457173	0.018213	0.617076
2457173	0.025933	0.764176
2457178	0.025632	0.617492
2457178	0.022432	0.494381
2457178	0.023594	0.396048
2457183	0.0189	0.602888
2457183	0.020491	0.555763
2457183	0.023138	0.655763
2457187	0.018147	0.582263
2457187	0.018277	0.600513
2457187	0.020519	0.649388
2457188	0.012925	0.703013
2457188	0.020991	0.547638

HJD	σ	OFFSET
2457188	0.023133	0.592763
2457192	0.012076	0.840513
2457192	0.015087	0.604638
2457192	0.0159	0.707388
2457193	0.01325	0.899617
2457193	0.019329	0.602117
2457193	0.021498	0.510451
2457196	0.020329	0.614576
2457196	0.011897	0.630676
2457200	0.013254	0.703776
2457200	0.014487	0.514976
2457200	0.016064	0.372376
2457201	0.015368	0.767276
2457201	0.010201	0.451876
2457201	0.014796	0.583176
2457216	0.081991	0.626263
2457216	0.019534	0.386388
2457216	0.02302	0.629263
2457221	0.025142	0.533876
2457221	0.053271	0.849376
2457228	0.01916	0.608476
2457232	0.026098	0.610276
2457232	0.025503	0.731376
2457232	0.024787	0.637376
2457256	0.027497	0.692076
2457256	0.029847	0.736076
2457256	0.031057	0.688476
2457273	0.043498	0.615433
2457273	0.034659	0.644576
2457273	0.029348	0.59629
2457275	0.041461	0.617576
2457275	0.024207	0.639576
2457276	0.034584	0.661176
2457276	0.034342	0.599676
2457277	0.027716	0.613794
2457277	0.035941	0.656669
2457278	0.033983	0.611669
2457278	0.03135	0.597294
2457285	0.03718	0.652794
2457285	0.036232	0.648794
2457286	0.039295	0.753919
2457286	0.039416	0.733169
2457320	0.037882	0.544876

HJD	σ	OFFSET
2457320	0.036878	0.612976
2457523	0.043774	0.551138
2457523	0.034313	0.927888
2457528	0.037213	0.514276
2457528	0.037383	0.513876
2457537	0.040786	0.482276
2457537	0.042994	0.537076
2457537	0.039199	0.627576
2457538	0.039148	0.661714
2457538	0.051154	0.50127
2457538	0.050448	0.541159
2457540	0.04397	0.594976
2457540	0.039422	0.646676
2457541	0.043571	0.552544
2457541	0.046229	0.753919
2457542	0.047014	0.437992
2457542	0.045238	0.394476
2457574	0.056701	0.531176
2457574	0.043393	0.388176
2457576	0.065755	0.688147
2457576	0.058163	0.609433
2457577	0.052327	0.739276
2457577	0.054851	0.612176
2457577	0.052414	0.601676
2457577	0.05022	0.678476
2457578	0.057355	0.492881
2457578	0.054114	0.498214
2457578	0.055714	0.581276
2457578	0.046136	0.383176
2457579	0.053641	0.664433
2457579	0.056266	0.570576
2457582	0.347962	0.477076
2457582	0.361735	0.509876
2457583	0.355823	0.436919
2457583	0.364972	0.417544
2457584	0.350218	0.245419
2457584	0.34218	0.477544
2457585	0.352843	0.478419
2457585	0.353396	2.649294
2457587	0.391279	-0.47308

Appendix D

Second Offsets

HJD	σ	Offset
2456484	0.009969	0.009530
2456484	0.007073	0.006830
2456495	0.015429	0.010457
2456495	0.011033	0.007093
2456519	0.004924	0.004130
2456519	0.007163	0.007939
2456520	0.005483	0.007839
2456520	0.007743	0.010466
2456556	0.005957	0.005648
2456557	0.008243	0.002493
2456557	0.005591	0.005602
2456559	0.008044	0.003230
2456559	0.009727	-0.00444
2456560	0.008502	0.009848
2456560	0.005287	0.008330
2456593	0.005408	0.004430
2456593	0.007072	0.004911
2456599	0.004048	0.005157
2456599	0.006538	0.006048
2456840	0.004052	0.003120
2456840	0.002717	0.005111
2456902	0.005216	-0.00611
2456902	0.005316	-0.00543
2456903		
2456903		
2456934	0.004787	-0.00193

HJD	σ	Offset
2456934		
2456904	0.012522	0.012188
2456904	0.00722	-0.01482
2456968	0.00797	0.004548
2456968	0.007026	0.001993
2456969	0.005967	0.006948
2456969		
2456847		
2456847	0.008711	-5.2E-05
2456970	0.006235	0.003375
2456970	0.007551	0.004102
2456941	0.00584	0.006993
2456941	0.009448	0.006311
2456942	0.007289	0.004540
2456942	0.007805	-0.00147
2456912	0.014232	0.005188
2456912	0.008687	-0.00024
2456913	0.006797	0.003775
2456913	0.006356	0.000402
2456914	0.006741	0.000420
2456914	0.00747	-0.00396
2456945	0.005017	0.004148
2456945	0.011629	0.005375
2456885	0.008919	0.001748
2456885	0.005568	-0.00408
2456946	0.004997	-0.00434
2456946	0.00624	-0.00556
2456886	0.006976	0.002675
2456886	0.00581	-0.00253
2456917	0.005941	0.003048
2456917	0.006115	0.003329
2456887	0.005733	-0.00524
2456887	0.006241	-0.00393
2456856	0.007463	0.002702
2456856	0.004317	-0.00259
2456979	0.004307	0.003720
2456979	0.005404	0.003584
2456918	0.005464	-0.00373
2456918	0.006032	-0.00137
2456888		
2456888	0.006883	-0.00184
2456857	0.006155	0.003620
2456857	0.007421	0.002620

HJD	σ	Offset
2456980	0.003933	-0.00075
2456980	0.007122	-0.00072
2456919	0.00843	-0.00064
2456919	0.005286	-0.00645
2456981	0.006602	-0.00409
2456950	0.006975	0.005184
2456951	0.018914	0.005139
2456951	0.014053	-0.00323
2456921	0.007701	0.008654
2456921	0.004696	-0.00536
2456862	0.008808	0.005575
2456862	0.005576	0.005839
2456863		
2456863		
2456864	0.00601	-0.00075
2456864	0.004646	-4.3E-05
2456956	0.005332	0.001611
2456956	0.013644	-0.00101
2456926	0.005819	0.002734
2456926	0.008856	0.005665
2456927	0.009206	-0.00769
2456927	0.006297	-0.00261
2456898	0.010015	0.000148
2456898	0.004306	-0.00305
2456899	0.008782	-0.00875
2456899	0.009643	-0.00690
2456960	0.0074	9.32E-05
2456960	0.007219	0.005293
2456839	0.005716	0.005493
2456839	0.004994	0.002382
2457173	0.009136	-0.00171
2457173	0.010175	-0.00044
2457178	0.016081	-0.00040
2457178	0.015725	-0.00183
2457178	0.011908	0.004412
2457183	0.0077	-0.00448
2457183	0.006631	-0.00216
2457183	0.007907	-0.00386
2457187	0.003509	-0.00417
2457187	0.005648	-0.00360
2457187	0.005245	-0.00475
2457188	0.005723	0.001790
2457188	0.007133	0.002265

HJD	σ	Offset
2457188	0.007956	0.005240
2457192	0.006075	0.005674
2457192	0.00384	0.005185
2457192	0.009268	0.005072
2457193	0.007402	-0.00161
2457193	0.006271	0.007986
2457193	0.003166	-0.00115
2457196	0.006525	0.003611
2457196	0.00726	0.004239
2457200	0.005473	-0.00113
2457200	0.006418	0.010939
2457200	0.010328	0.001630
2457201	0.005698	-0.00354
2457201	0.007727	0.002402
2457201	0.004605	0.007920
2457216		
2457216	0.009702	0.005253
2457216	0.012657	0.002287
2457221	0.011665	0.003766
2457221		
2457228	0.005608	-1.6E-05
2457232	0.006585	0.001002
2457232	0.004408	0.003266
2457232	0.005755	0.003720
2457256	0.007806	-0.01089
2457256	0.008701	-0.01043
2457256	0.008756	-0.00083
2457273	0.003529	-0.00915
2457273	0.007978	-0.00457
2457273	0.008034	-0.00338
2457275	0.007083	-0.00484
2457275	0.005663	-0.00684
2457276	0.007122	-0.00072
2457276	0.006381	-0.00858
2457277	0.010532	-0.00606
2457277	0.007676	-0.00776
2457278	0.009607	-0.01021
2457278	0.007095	-0.00447
2457285	0.005174	-0.01115
2457285	0.006202	-0.01379
2457286	0.009941	-0.01428
2457286	0.00634	0.000472
2457320	0.007258	0.002220

HJD	**σ**	**Offset**
2457320	0.004936	-0.00743
2457523	0.008486	-0.00322
2457523	0.011175	-0.00170
2457528	0.005118	-0.00027
2457528	0.005719	-0.00478
2457537	0.008763	-0.00618
2457537	0.006245	-0.00434
2457537	0.006496	-0.00557
2457538	0.016752	-0.00989
2457538		
2457538		
2457540	0.004968	-0.00597
2457540	0.004917	-0.00222
2457541	0.004887	-0.00536
2457541	0.004253	-0.00346
2457542	0.008704	-0.00126
2457542	0.00986	-0.00520
2457574		
2457574	0.007536	-0.00344
2457576		
2457576		
2457577		
2457577		
2457577		
2457577		
2457578		
2457578		
2457578		
2457578	0.007176	-0.01026
2457579		
2457579		
2457582		
2457582		
2457583		
2457583		
2457584		
2457584		
2457585		
2457585		
2457587		

Appendix E

Final Hα Index Values

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
1	0.740845	0.332401	18.38355	0.36935
2	2.571343	0.054362	15.45952	0.70447
3	2.655072	0.298169	15.82961	0.90203
4	2.75114	0.085837	15.34798	0.65101
5	1.867962	0.153748	15.21928	0.67932
6	2.825821	0.118791	16.14847	0.5981
7	2.73872	0.112119	15.49913	0.62518
8	2.273131	0.538351	17.63484	1.21753
9	2.867778	0.093029	16.05492	0.62584
10	2.839055	0.151378	16.28798	0.66888
11	-1.48568	80.54523	28.37695	67.8237
12	1.073403	69.17268	24.10719	53.6996
13	-2.72507	75.91236	37.09782	85.0255
14	-39.5445	122.9653	113.4369	173.327
15	-10.502	119.4199	64.20644	125.324
16	4.600051	113.8419	47.22665	107.639
17	20.43716	118.1006	26.26191	56.1501
18	19.09418	120.4106	25.28496	65.8971
19	11.00875	42.33893	13.07509	0.58778
20	2.729225	0.054367	14.99983	0.65017
21	2.619648	0.06975	15.47793	0.60482
22	2.849295	0.161499	16.24657	0.61148
23	2.863804	0.0323	14.35301	0.598
24	2.702873	0.04434	14.86113	0.61231
25	2.65872	0.010993	10.42498	0.54255
26	2.733629	0.011354	11.63963	0.54519

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
27	2.707192	0.03521	14.5435	0.58043
28	1.973784	0.447441	18.47333	0.35543
29	2.723086	0.187122	16.63071	0.56208
30	2.804729	0.039918	14.52208	0.56592
31	2.786252	0.026663	11.85409	0.59398
32	2.727717	0.028242	13.22562	0.54769
33	2.768116	0.046535	14.9016	0.63124
34	2.640972	0.096557	16.17258	0.52649
35	2.772054	0.045134	14.98818	0.52648
36	2.833481	0.117891	15.97986	0.68086
37	2.790312	0.096896	15.70052	0.53014
38	2.204915	0.035195	14.97337	0.53183
39	2.573647	0.215365	16.76959	0.62745
40	2.74091	0.043158	14.60186	0.60498
41	2.279458	0.139951	16.57396	0.55102
42	2.707507	0.044737	15.13878	0.53731
43	2.715789	0.021494	13.95726	0.51764
44	2.811953	0.119378	15.84002	0.70515
45	2.703705	0.033316	14.60545	0.5265
46	2.764047	0.02554	14.10958	0.52378
47	2.732233	0.104311	15.85798	0.65763
48	2.692204	0.014938	10.98685	1.08043
49	2.758185	0.062691	15.26689	0.68525
50	2.768516	0.111672	15.74949	0.56176
51	2.711363	0.019517	13.80692	0.73913
52	2.727534	0.018228	13.40736	0.61972
53	2.703395	0.017906	13.60078	0.5999
54	2.547717	0.166087	16.05819	1.15595
55	2.635401	0.113766	16.10912	0.43205
56	2.634413	0.083381	15.89399	0.6184
57	2.728412	0.158407	16.47449	0.59136
58	2.81908	0.087316	15.60501	0.65508
59	2.673337	0.04888	15.27355	0.52239
60	2.803957	0.139067	16.24261	0.51062
61	2.523152	0.10586	16.25625	0.42869
62	2.719987	0.132252	16.36192	0.6114
63	2.775593	0.115384	15.98236	0.63517
64	2.643254	0.092095	15.80975	0.50896
65	2.665366	0.078797	15.54021	0.61057
66	2.575124	0.082475	15.90039	0.60119
67	2.704298	0.078942	15.72666	0.59506
68	2.640133	0.111324	15.94422	0.63497
69	2.740677	0.041109	14.86388	0.84707

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
70	2.686403	0.007573	10.51406	1.11611
71	2.701571	0.017023	13.31803	0.85457
72	2.712068	0.021586	13.73694	0.59681
73	2.696981	0.030794	14.27761	0.63123
74	2.771223	0.099712	15.88964	0.78151
75	2.74798	0.038171	13.19658	0.87641
76	2.678987	0.07056	15.38685	0.75658
77	2.736366	0.071639	15.43853	0.83912
78	2.685999	0.008482	10.75843	1.30474
79	2.799246	0.134071	15.9087	1.24249
80	2.812509	0.131749	16.21105	0.59766
81	2.717504	0.046553	14.82459	0.75439
82	2.746379	0.052146	15.10685	0.61564
83	2.84972	0.021941	13.0355	0.81801
84	2.751882	0.047903	14.80656	0.93969
85	2.726701	0.131612	16.28405	0.70872
86	2.54006	0.137471	16.4644	0.51543
87	2.767412	0.157232	15.29253	0.68655
88	2.884379	0.014966	12.92295	0.59711
89	2.79918	0.18858	15.47883	1.03431
90	2.579869	0.162482	15.41169	0.71038
91	2.807198	0.182158	16.21829	0.69872
92	2.709234	0.083473	13.2647	1.03673
93	2.755341	0.016838	10.96781	0.59943
94	2.701062	0.027266	14.09935	0.89629
95	2.782315	0.164632	16.36257	0.68506
96	2.684925	0.075725	15.64753	0.61486
97	2.693478	0.025178	14.31766	0.69742
98	2.749478	0.012984	13.20336	0.63459
99	2.703998	0.139688	16.27954	0.87136
100	2.626236	0.055551	15.32489	0.62867
101	2.814913	0.010754	12.69736	0.84721
102	2.903229	0.021765	13.82032	0.64999
103	2.793186	0.171812	15.87486	0.78914
104	2.771012	0.084223	15.56858	0.65423
105	2.864385	0.010558	11.02668	1.20831
106	2.734756	0.056088	14.99543	0.6837
107	2.670249	0.102462	15.89959	0.51367
108	2.688354	0.023231	14.14939	0.74301
109	2.691037	0.006284	11.50902	0.80148
110	2.734689	0.031592	14.28786	0.83939
111	2.850385	0.055457	15.02953	0.6295
112	2.772701	0.099348	15.92222	0.55596

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
113	1.156414	2.017968	17.75044	1.4234
114	2.758136	0.023546	14.02459	0.71915
115	2.740528	0.020717	14.04742	0.61134
116	2.678453	0.159692	16.06988	0.77786
117	2.790987	0.108185	16.03715	0.64833
118	2.680515	0.053277	15.22161	0.62597
119	2.521528	0.061341	15.42483	0.6513
120	2.560068	0.081642	15.70665	0.59165
121	2.664317	0.043647	14.87589	0.69654
122	2.705434	0.043637	14.82296	0.5273
123	2.680459	0.015164	13.5489	0.67805
124	2.670167	0.073604	15.55592	0.73158
125	2.900664	0.023243	13.57379	0.74627
126	2.75449	0.024902	14.04336	0.71418
127	2.172465	0.085768	15.82762	0.69658
128	2.735714	0.187638	15.8383	0.69595
129	2.751724	0.085065	14.0032	1.30287
130	2.681695	0.012076	12.95277	0.49678
131	2.864335	0.00728	11.42319	0.84312
132	2.597851	0.156903	16.12749	1.18959
133	2.839503	0.039011	14.76975	0.68417
134	2.691161	0.006416	11.29225	0.99884
135	2.709403	0.014019	13.20906	0.75422
136	2.654582	0.158177	16.29025	0.85361
137	2.382702	0.349553	17.80637	1.48288
138	2.824413	0.126039	15.94962	0.43418
139	2.693453	0.056106	15.30567	0.60013
140	2.781981	0.083207	15.75666	0.61276
141	2.713739	0.060278	15.36236	0.64034
142	2.769347	0.035592	14.83264	0.60127
143	2.536956	0.075712	15.76376	0.64788
144	2.719515	0.101208	15.78801	0.58524
145	2.789931	0.102135	15.89223	0.63715
146	2.721434	0.033438	14.45764	0.71102
147	2.816615	0.09184	15.64097	0.64059
148	2.720677	0.030172	14.59486	0.66633
149	2.724208	0.161267	15.97689	0.65053
150	2.781521	0.033805	14.8024	0.65985
151	2.626727	0.033997	14.55858	0.54801
152	2.786167	0.135824	16.1364	0.81399
153	2.758165	0.255004	16.55428	0.68086
154	2.808155	0.039387	14.62772	0.72243
155	2.586912	0.061908	15.38277	0.6483

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
156	2.722608	0.029354	14.23469	0.52369
157	2.693545	0.011241	12.62383	0.72843
158	2.772031	0.144709	16.14212	0.95429
159	2.596931	0.053425	15.27342	0.61424
160	2.758443	0.063551	15.32206	0.62286
161	2.740503	0.02744	14.04794	0.76794
162	2.720477	0.051974	14.86289	0.57011
163	2.482783	0.066055	15.6183	0.65773
164	2.775937	0.269536	16.08704	0.87444
165	2.676482	0.093841	15.77152	0.42811
166	2.706099	0.00714	11.52492	1.10243
167	2.512975	0.205702	15.84285	1.16667
168	2.69241	0.058269	15.17059	0.64528
169	2.746043	0.01502	12.9389	0.76942
170	2.757	0.074492	15.53719	0.81693
171	2.656925	0.028432	14.45272	0.68515
172	2.746031	0.085532	15.66196	0.6524
173	2.510169	0.119432	16.34222	0.59404
174	2.782006	0.013308	13.3115	0.87872
175	1.852416	0.068466	14.5577	0.68323
176	2.714167	0.013882	13.51907	0.68878
177	2.68338	0.199289	16.09703	0.95111
178	2.07475	0.421791	18.03005	1.23974
179	2.804441	0.011737	12.6925	0.66617
180	1.646157	0.476776	16.55356	3.09053
181	2.778559	0.135128	16.08629	0.60044
182	2.744707	0.23566	16.51771	0.62109
183	2.811504	0.103985	15.91882	0.51496
184	2.745087	0.034618	14.62824	0.656
185	2.696832	0.01017	12.48688	0.78965
186	2.761857	0.019304	13.63323	0.66437
187	2.726211	0.016627	13.66339	0.60062
188	2.759499	0.165493	15.46044	0.78184
189	2.593274	0.108144	16.17651	0.47173
190	2.74118	0.073104	15.57466	0.60352
191	2.708149	0.070101	15.48606	0.62858
192	2.707329	0.01659	13.62797	0.70967
193	2.725478	0.071726	15.44853	0.72462
194	2.687569	0.159094	16.24065	0.58491
195	2.639981	0.034955	14.85934	0.69638
196	2.727373	0.089315	15.57711	0.6509
197	2.85222	0.022903	13.63189	0.659
198	2.768468	0.361966	15.59287	0.77363

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
199	2.715579	0.054973	15.11807	0.62324
200	2.705971	0.028904	14.30395	0.66047
201	2.775354	0.038812	14.72201	0.67093
202	2.569958	0.12085	16.24536	0.66774
203	2.726093	0.013905	13.40938	0.88739
204	2.714906	0.033744	14.64289	0.66252
205	2.663739	0.02968	14.24397	0.62811
206	2.690416	0.007327	11.63736	0.94367
207	2.71067	0.031306	14.33592	0.83273
208	2.694015	0.11759	16.02805	0.61464
209	2.760528	0.183364	16.05542	0.65603
210	2.678875	0.173354	16.33017	0.68409
211	2.6049	0.210972	16.51133	0.84818
212	2.810126	0.199474	16.14378	0.68429
213	2.782833	0.11858	16.21718	0.51545
214	2.740065	0.174354	16.16785	0.61342
215	2.843863	0.050001	15.18274	0.71018
216	2.644834	0.014821	12.63573	0.83069
217	2.685366	0.017847	13.44066	0.58163
218			16.84753	2.42644
219	1.93296	0.454885	18.33504	0.7484
220	1.967338	0.503578	18.11367	1.03385
221	2.660428	0.009314	12.37134	0.50099
222	2.726711	0.013749	12.78153	0.7225
223	2.731049	0.068326	15.37877	0.57793
224	2.765105	0.133259	16.2007	0.87106
225	2.753506	0.139176	16.3393	0.48778
226	2.693721	0.080618	15.74712	0.57516
227	2.691174	0.013261	13.43157	0.80905
228	2.690421	0.047988	14.12807	0.69015
229	2.796335	0.118134	16.21394	0.61042
230	2.661465	0.007265	11.3543	1.2411
231	2.759656	0.065793	15.12448	1.20403
232	2.749441	0.072252	15.49368	0.53925
233	2.213298	0.063838	15.51523	0.584
234	2.63019	0.102843	15.8285	0.52721
235	2.779646	0.083798	15.73577	0.9237
236	2.616801	0.039281	15.04177	0.62106
237	2.813335	0.038786	14.73345	0.60337
238	2.769764	0.125272	16.2689	0.79289
239	2.651205	0.034612	14.711	0.65162
240	2.768478	0.111563	15.81994	0.70258
241	2.754005	0.075619	15.53966	0.85504

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
242	2.574205	0.009689	9.991203	0.7109
243	2.684483	0.107818	15.77452	1.34921
244	2.71431	0.058214	15.42164	0.59971
245	2.712323	0.014832	13.27802	0.79358
246	2.69159	0.010812	12.05043	0.74376
247	2.730981	0.016135	13.33568	0.69625
248	2.826739	0.010547	11.62988	0.79238
249	2.734538	0.025457	13.83501	0.76794
250	2.44304	0.133383	16.22108	0.72834
251	2.536545	0.204909	16.4854	0.7077
252	2.627677	0.13122	16.36857	0.57292
253	2.687441	0.111124	16.08754	0.58788
254	2.671327	0.108895	16.05925	0.66012
255	2.658559	0.066596	15.44363	0.66255
256	1.995482	0.635309	17.17158	2.02602
257	2.784944	0.156334	16.60279	0.67722
258	2.666285	0.058671	15.35325	0.69924
259	2.748838	0.051447	15.24132	0.62439
260	2.622739	0.150219	16.5366	0.57377
261	2.722515	0.0119	12.94725	0.77234
262	2.749764	0.023949	13.69556	0.67433
263	2.709632	0.042918	14.22093	0.46471
264	2.698105	0.045084	13.76406	0.6209
265	2.769615	0.008595	11.68018	0.85026
266	2.832107	0.051133	14.85627	1.19118
267	2.752142	0.080647	15.00126	0.7716
268	2.676454	0.234835	15.8348	0.5927
269	2.641795	0.021665	13.9537	0.70949
270	2.69414	0.112822	15.55259	0.73
271	2.789201	0.418193	15.39338	0.49472
272	2.803834	0.147546	15.91238	0.69774
273	2.737286	0.106707	16.01816	0.60013
274	2.748579	0.116149	16.03483	0.61937
275	2.785788	0.063677	15.39162	0.59858
276	2.626908	0.007248	10.52736	1.16627
277	2.683001	0.17435	14.85633	1.60804
278	2.699208	0.136911	16.3028	0.64087
279	2.603869	0.053988	15.15361	0.49417
280	2.555482	0.042608	14.92804	0.63344
281	2.562302	0.176829	16.15172	0.62814
282	2.767751	0.208307	16.30489	0.6616
283	2.706633	0.067531	15.30177	0.63783
284	2.715058	0.045532	13.60974	0.83633

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
285	2.794465	0.076555	15.41495	0.63454
286	2.821267	0.013959	13.16574	0.79932
287	2.775049	0.079171	15.60345	0.78802
288	2.798869	0.013568	12.97393	0.89803
289	2.734855	0.251095	15.87733	0.83614
290	2.679534	0.196964	16.22754	0.67867
291	2.748296	0.222647	16.12957	0.53809
292	2.731521	0.037333	14.77872	0.99603
293	2.769509	0.052386	15.1577	0.73096
294	2.692093	0.009114	11.63754	1.03011
295	2.763515	0.014075	13.05255	0.79943
296	2.696401	0.024619	13.94482	0.62826
297	2.781664	0.13686	16.18918	0.65247
298	2.677168	0.277846	16.34358	0.58329
299	2.108615	0.053669	15.22058	0.58876
300	2.770569	0.15286	16.32021	0.56284
301	2.613674	0.024178	9.530375	2.34746
302	2.537231	0.458065	8.608925	0.80298
303	2.693863	0.03169	14.19685	1.47502
304	2.674751	0.011692	11.91634	0.52561
305	2.724093	0.068681	15.28719	0.91429
306	2.632739	0.017959	10.13305	1.34328
307	2.636726	0.039863	14.70388	1.14887
308	2.789335	0.104835	16.01364	0.6351
309	2.735714	0.050423	15.14627	0.61561
310	2.696032	0.061183	14.49857	0.7003
311	2.729304	0.040865	14.86347	0.51426
312	2.741638	0.038323	14.69577	0.70448
313	2.486428	0.047818	14.90053	0.59446
314	2.601552	0.015223	9.930959	1.36646
315	2.745161	0.082825	15.39193	1.31039
316	2.73231	0.019148	13.18673	0.86569
317	2.751434	0.090164	15.58449	0.76112
318	2.794774	0.222746	15.08874	0.6732
319	2.298914	0.045469	10.16522	3.26059
320	2.317114	0.037371	8.578968	0.9238
321	2.785465	0.043269	15.08639	0.51183
322	2.647024	0.097322	15.92109	0.71114
323	2.777975	0.119984	16.15709	0.63447
324	2.759099	0.053903	15.21469	0.62934
325	2.772938	0.130529	16.06284	0.65848
326	1.882987	0.011527	12.4417	0.98009
327	2.780111	0.099687	15.66877	0.94761

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
328	2.733219	0.1326	16.1058	0.74643
329	2.720472	0.061964	15.36222	0.74177
330	2.721	0.097081	15.83327	0.63103
331	2.710024	0.05549	15.18593	0.77998
332	2.70782	0.020997	13.85721	0.69247
333	2.766583	0.106433	15.7557	0.86276
334	2.650826	0.011265	12.96956	0.88322
335	2.699826	0.100171	15.72076	0.86322
336	2.692788	0.017465	13.59849	0.79077
337	2.681366	0.045794	14.84338	0.65606
338	2.604583	0.049414	15.29158	0.61349
339	2.706489	0.040907	14.86428	0.63341
340	2.664434	0.021753	13.90594	0.50808
341	2.70741	0.026209	14.1819	0.60789
342	2.66254	0.010064	12.14443	0.74141
343	2.687608	0.00964	12.12738	0.71376
344	2.676981	0.038759	14.52135	0.78487
345	2.733267	0.010789	11.81921	0.91491
346	2.773639	0.17029	16.03029	1.25798
347	2.68536	0.014387	11.81976	1.12342
348	2.659633	0.079107	15.58943	1.02552
349	2.670215	0.055143	15.28426	0.61163
350	2.668946	0.190502	16.09978	0.64772
351	2.664746	0.181396	15.91397	0.61091
352	2.736174	0.049909	15.10493	0.62125
353	2.719695	0.033653	14.63179	0.61286
354	2.722776	0.017763	13.56321	0.67595
355	2.653316	0.075855	15.79283	0.76688
356	2.731892	0.014732	11.8878	1.14397
357	2.634354	0.229544	16.14	1.06373
358	2.579469	0.156783	16.46074	0.46619
359	2.761664	0.059574	15.41064	0.68614
360	2.679552	0.009246	11.44349	1.12234
361	2.69031	0.017151	13.29712	0.72652
362	2.724049	0.100504	15.84756	0.94056
363	2.528689	0.140878	16.47236	0.61571
364	2.723608	0.173538	16.3752	0.68724
365	2.602316	0.141163	16.4338	0.59037
366	2.666664	0.123894	16.21802	0.54588
367	2.745488	0.138421	16.28192	0.43606
368	2.737801	0.115099	16.10501	0.61571
369	2.706776	0.115501	16.00292	0.59226
370	2.653962	0.089636	15.8737	0.63544

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
371	2.613857	0.119447	16.29946	0.52493
372	2.309846	0.365323	17.834	1.62219
373	2.875472	0.016199	13.28183	0.68497
374	2.655657	0.113425	16.01683	0.78701
375	2.683217	0.031552	14.47101	0.71916
376	2.671615	0.008391	11.84916	0.82112
377	2.708521	0.069068	15.44635	0.99948
378	2.86436	0.041885	14.84143	0.62974
379	2.666327	0.141208	15.9664	0.7908
380	2.673247	0.108765	16.08108	0.5568
381	2.691633	0.043688	15.00664	0.49795
382	1.099937	1.661095	17.17652	2.07028
383	2.884441	0.080704	15.3517	0.82741
384	2.660354	0.156721	16.01355	0.68098
385	2.701111	0.060648	15.35292	0.63142
386	2.690136	0.034602	14.70725	0.61128
387	2.62936	0.186737	15.11632	0.69514
388	2.686316	0.069657	15.5322	0.71113
389	2.745733	0.121331	16.26346	0.59285
390	2.662401	0.090797	15.83438	0.79627
391	2.673205	0.020566	13.77816	0.74841
392	1.626938	0.036986	13.66155	0.60501
393	2.714229	0.212856	16.19091	0.90706
394	2.472613	0.226085	16.66954	0.62225
395	2.64926	0.044126	15.0109	0.92303
396	2.673966	0.068557	15.31343	0.72593
397	2.681993	0.034843	14.54979	0.62334
398	2.545142	0.014018	10.2172	1.12004
399	2.678739	0.094005	15.57592	1.29335
400	2.678279	0.023663	13.99827	0.71188
401	2.580191	0.203703	16.08078	0.7685
402	2.649205	0.050423	15.20983	0.68186
403	2.658677	0.01224	12.6362	0.81123
404	2.651379	0.199585	16.40287	1.035
405	2.613993	0.009332	11.84416	1.13453
406	2.648478	0.092336	15.74338	1.04233
407	2.761513	0.054738	15.19198	0.63368
408	2.639079	0.04	14.80765	0.60718
409	2.70613	0.035368	14.57286	0.83914
410	2.495	0.010641	10.16448	1.23901
411	2.672646	0.019874	13.48058	0.96195
412	2.697695	0.026635	14.13777	0.61618
413	2.714689	0.018967	13.51052	0.63213

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
414	2.686447	0.03697	14.63114	0.64154
415	2.730565	0.020169	13.52251	0.66671
416	2.690918	0.071404	14.98486	0.89881
417	2.708865	0.163923	16.4143	0.47125
418	2.678844	0.018854	13.71906	0.83227
419	2.644239	0.02292	13.80963	0.66676
420	2.643906	0.071753	15.5206	0.68374
421	2.701571	0.011896	12.40973	0.93273
422	2.656845	0.045553	14.7442	0.82367
423	2.707447	0.122042	16.05117	0.69482
424	2.640198	0.032385	14.60414	0.71191
425	2.313437	0.027958	10.1769	1.19554
426	2.638559	0.10712	15.54186	1.39144
427	2.688714	0.124198	16.21632	0.65804
428	2.700751	0.025065	14.19328	0.71859
429	2.693993	0.155919	14.87442	0.61733
430	2.822639	0.089373	15.68891	0.66504
431	2.663093	0.026058	14.34711	0.66398
432	2.71331	0.054375	15.23637	0.71905
433	2.708714	0.084698	15.73013	0.62303
434	2.693453	0.023556	14.10502	0.70102
435	2.555032	0.014152	12.06452	0.84636
436	2.656149	0.066173	15.43506	0.97551
437	2.755776	0.057744	15.1809	0.66721
438	2.323016	0.168443	16.77032	0.60059
439	2.662366	0.026679	14.53647	0.60328
440	2.297192	0.135121	16.20991	0.9574
441	2.681627	0.019413	13.7242	0.54105
442	2.67354	0.0402	14.69552	0.62618
443	2.670733	0.009745	11.79092	0.96356
444	2.668788	0.035223	14.44133	0.88655
445	2.675913	0.041275	15.00791	0.60982
446	2.610764	0.155443	16.47197	0.66958
447	2.732018	0.04217	14.93331	0.57724
448	2.243031	0.095077	16.16366	0.73982
449	2.751096	0.035639	14.44565	0.51647
450	2.649031	0.012507	12.6494	0.5363
451	2.715465	0.094952	15.66803	1.00774
452	2.648074	0.11848	16.1535	0.60638
453	2.707652	0.107782	15.95941	0.56443
454	2.608087	0.037651	10.82608	1.24248
455	2.84259	0.025638	13.51534	0.85662
456	2.717354	0.095109	15.88907	0.77034

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
457	2.743795	0.053641	15.18866	0.65844
458	2.70608	0.024263	14.00295	0.68802
459	2.675161	0.013194	12.91355	0.70772
460	2.685925	0.081634	15.61495	0.82059
461	2.680571	0.117847	16.22586	0.63828
462	2.674412	0.0107	12.33868	1.00384
463	2.842813	0.486983	16.0959	0.95019
464	2.713207	0.121742	15.99751	0.62782
465	2.691702	0.556944	16.43274	0.67046
466	2.66886	0.012978	12.38242	1.00083
467	2.696259	0.197921	13.88791	0.61968
468	2.675316	0.041421	14.88541	0.63022
469	2.661149	0.009299	11.73927	0.97377
470	2.695919	0.120867	15.96697	1.09694
471	2.705863	0.115267	15.11204	0.64375
472	2.110841	0.414458	17.5058	2.0719
473	2.679329	0.062187	15.38155	0.55687
474	2.647323	0.121945	16.11144	0.64068
475	2.666888	0.02078	13.69618	0.78039
476	2.765515	0.14059	16.27669	0.82143
477	2.667217	0.187205	16.34666	0.70644
478	2.681621	0.12079	16.01042	0.6641
479	2.684329	0.149918	15.58439	0.69347
480	2.629865	0.208309	16.35988	0.63451
481	2.609031	0.038098	14.86987	0.68254
482	2.817173	0.050233	14.21696	0.74859
483	2.671434	0.044141	14.90942	0.52964
484	2.117738	0.497085	17.30586	2.37163
485	2.643478	0.214535	15.57847	0.70898
486	2.672726	0.095434	15.92962	0.63453
487	2.655245	0.188234	16.37887	0.75126
488	2.670276	0.097248	15.80385	0.76018
489	2.691316	0.053205	15.33828	0.60524
490	2.682801	0.018432	13.28271	0.77323
491	2.699366	0.01609	13.41288	0.63838
492	2.697559	0.057431	15.19509	0.70195
493	2.638347	0.048878	15.10567	0.76892
494	1.8543	0.210464	17.33888	2.3094
495	2.648497	0.183811	16.13492	0.61461
496	2.651751	0.040485	14.71689	0.6509
497	2.665683	0.030287	14.26787	0.61012
498	2.69026	0.041539	14.84006	0.62628
499	2.752764	0.106253	15.91301	0.69177

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
500	2.671335	0.04089	14.73064	0.68905
501	2.624592	0.084737	15.72822	0.67839
502	2.683366	0.085362	15.70173	0.61039
503	2.67454	0.018739	13.16785	0.81191
504			16.72117	2.68824
505	2.677782	0.096733	15.79368	0.55038
506	2.746732	0.016501	13.00143	0.88979
507	2.669478	0.013241	12.31524	0.65759
508	2.671832	0.061286	15.32435	0.86786
509	2.673683	0.095592	15.75253	0.63293
510	2.609969	0.110426	16.07291	0.60008
511	2.796174	0.17517	16.41874	0.71822
512	2.75608	0.017067	11.49095	1.22687
513	2.661869	0.020863	13.73113	0.7972
514	2.625043	0.171023	16.51497	0.86829
515	2.734211	0.064529	15.35765	0.65214
516	2.764298	0.044277	14.75307	0.61292
517	2.730465	0.027637	14.16968	0.61832
518	2.869032	0.033327	14.01439	0.62917
519	2.76426	0.023691	13.7909	0.60716
520	2.672186	0.045369	14.80024	0.65686
521	2.616745	0.116549	15.94711	0.90531
522	1.379521	0.071225	15.41824	0.70325
523	2.735608	0.082222	15.71635	0.63538
524	2.691577	0.054899	15.02172	0.63574
525	2.754671	0.090056	15.23188	0.77794
526	2.665801	0.20761	15.96652	0.6489
527	2.733945	0.076508	15.30696	0.82684
528	2.642266	0.098018	15.92058	0.60953
529	2.65954	0.031708	14.53257	0.69156
530	2.044961	0.037436	14.47825	0.62426
531	2.613734	0.203373	14.36694	0.41335
532	0.567732		17.14132	2.12018
533	2.693639	0.025087	13.79355	0.5098
534	2.643915	0.056065	15.083	0.68839
535	2.575052	0.069265	15.6658	0.65883
536	2.681396	0.044526	14.79298	0.74558
537	2.654549	0.133296	16.21947	0.74466
538	2.688454	0.060334	15.32925	0.85378
539	2.74876	0.092177	15.58541	0.63841
540	2.670843	0.111641	16.02462	0.69762
541	1.725369	0.560455	17.11547	2.15331
542	2.778197	0.09777	15.88004	0.6594

Star ID	Avg. Hα	σ (Hα)	Avg. Wide	σ (Wide)
543	2.572156	0.113299	15.85111	0.83667
544	2.619896	0.014216	10.88247	0.657
545	2.708652	0.031097	13.66079	0.86497
546	2.670212	0.154759	16.24949	0.81977
547	2.646161	0.232897	16.44376	0.82146
548	2.808216	0.024776	13.32447	0.75868
549	2.760074	0.110514	15.91527	0.871
550	2.734154	0.018799	11.93808	1.08649
551	2.557024	0.184769	16.03078	1.1568
552	2.634235	0.280047	16.08374	0.81594
553	2.668281	0.08244	15.71143	0.65576
554	2.681138	0.124734	16.24128	0.645
555	2.703667	0.057748	15.35682	0.66338
556	2.665874	0.03303	14.38223	0.68834
557	2.678807	0.021757	13.94692	0.6458
558	2.82275	0.039123	14.39593	0.66365
559	2.911654	0.015103	12.08731	0.81249
560	2.650756	0.055664	14.25687	0.9724
561	2.650956	0.035763	14.55404	0.56353
562	2.880221	0.015745	10.68169	1.07819
563	2.724048	0.078976	14.68877	1.68512
564	2.770166	0.11766	16.02745	0.52235
565	2.673964	0.035915	12.85629	0.89096
566	2.72038	0.343072	13.04729	0.51195
567	2.613344	0.060663	14.60168	0.62259
568	2.646368	0.33858	13.3757	0.68024
569	2.721084	0.098053	13.95163	0.56407
570	2.698726	0.034018	14.22329	0.50467
571	1.23005	2.130601	17.21487	2.15284
572	2.734479	0.621306	13.78221	0.99394
573	2.689123	0.087806	11.67076	0.74351
574	2.635364	0.274604	15.7905	1.15954
575	2.714446	0.088644	15.48211	0.78364
576	2.626646	0.049632	14.27294	0.4043
577	2.750712	0.062632	15.06153	0.52611
578	2.570307	0.169473	16.33233	0.6091
579	2.65092	0.32186	16.23985	0.61404
580	2.72981	0.019616	12.89299	0.68014

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