

Yakın Çift Yıldız Sistemi:

HH Car

D. T. Köseođlu, H. Bakış, V. Bakış, C. Nitschelm



Akdeniz Üniversitesi, Uzay Bilimleri ve Teknolojileri Bölümü



<http://annesastronomynews.com/tag/eta-carinae-nebula/>
<http://www.luisargerich.com/blog/2012/7/the-eta-carina-nebula>

HH Car

- O ve B tayf türünden bileşenler içeren bir çift sistemin yanında en az iki görsel bileşen daha içeren bir çoklu sistemdir. (O'Connell, 1968)
- Söderhjelm 1975'te yayınladığı çalışmasında** çiftin yörüngesinin, dairesel olduğunu, ışık eğrisinde görülen asimetric yapıların disk veya gaz akımı şeklindeki çevresel maddeden kaynaklandığını belirtmiştir.
- Mandrini ve Mendez (1985), HH Car sisteminin ilk radyal hız çalışmalarını yapmış ve ilk kez tayfsal yörünge parametrelerini elde etmişlerdir.
- *Baş bileşen: O8V, Yoldaş bileşen: B0 III*

* *Orbital Elements and Apsidal Motion of the Eclipsing Binary HH Carinae*, O'Connell 1968

** *Observations of Six Southern Eclipsing Binaries for Apsidal Motion*, Söderhjelm S., 1975

HH Car'ı neden inceliyoruz ?

- Amacımız, seyrek rastlanan bu türden bir OB çift sistemi olan HH Car'daki , kütle aktarımının sebep olduğu disk veya kabuk yapısı şeklinde görülen çevresel maddeyi modellemek ve fiziksel özelliklerini elde edebilmek.
- Çevresel maddeyi modelleyebilmek için ise, öncelikle sisteme ait temel parametreleri hassas bir şekilde hesaplamak gerekir.

Light Curve Analysis with Phoebe (WD code)

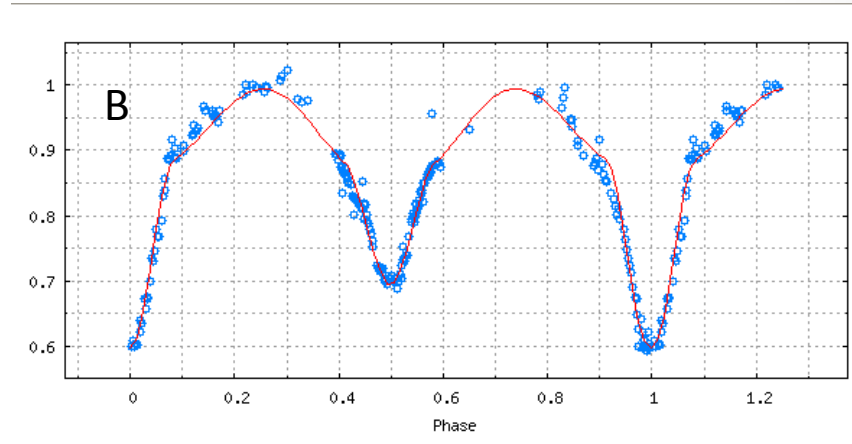
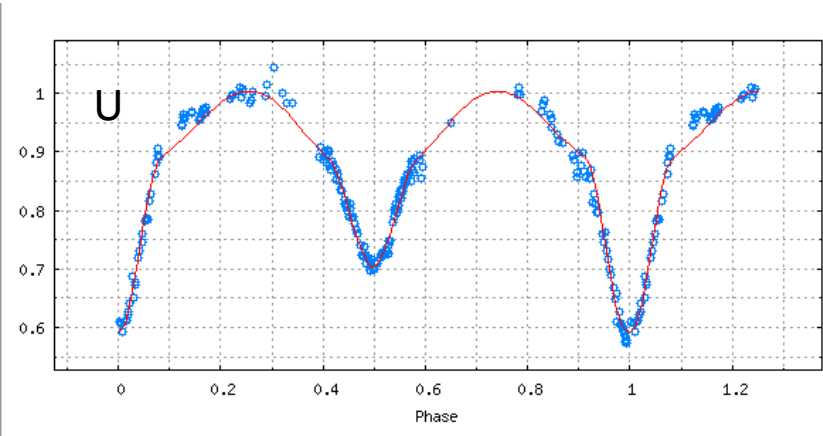
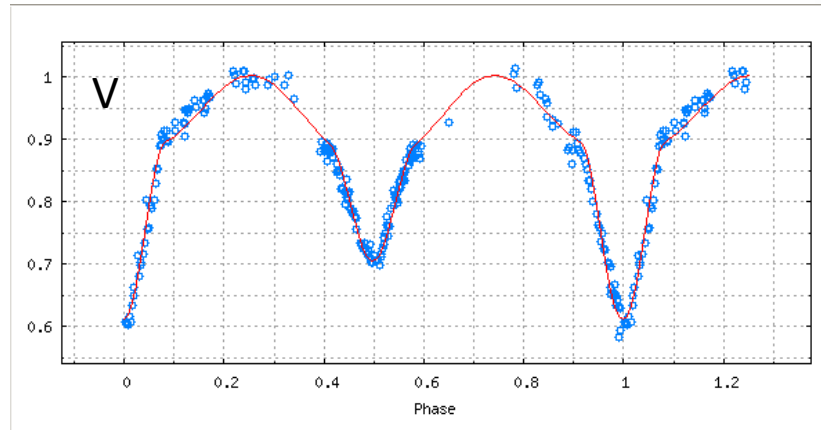


Table 13 *UBV* magnitudes for the visual components of HH Car

| Star | V | B | U |
|-------------------|----------------|----------------|-------------|
| c_1 | 11.11 | 11.64 | 11.68 |
| c_2 | 13.0 ± 0.3 | 13.8 ± 0.3 | 14.5 (ass.) |
| c_3 | 13.3: | 13.9: | 14.2: |
| $c_1 + c_2 + c_3$ | 10.82 | 11.39 | 11.51 |
| HH Car | 10.3-10.8 | 10.7-11.2 | 10.1-10.6 |

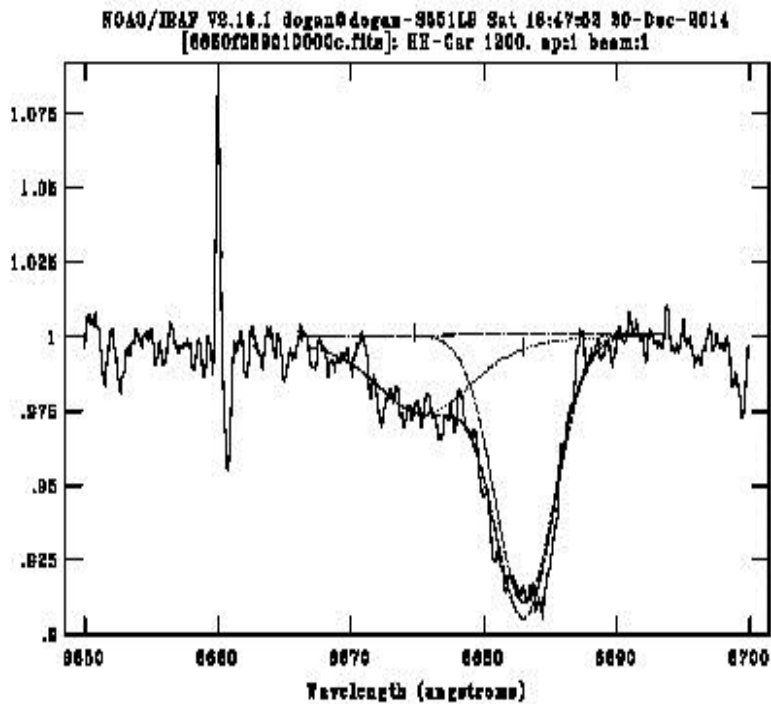
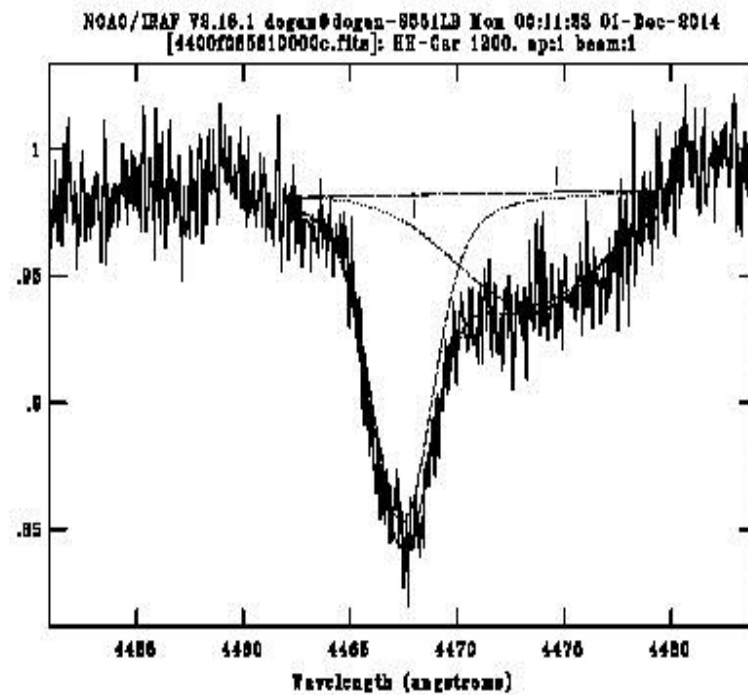


(Soderhjelm, 1975)

Spectral Lines of HH Car

| <u>Wavelength (A)</u> | <u>Line</u> |
|-----------------------|-------------|
| 3770.30 | H I |
| 3797.32 | H I |
| 3889.04 | He I |
| 3969.77 | H I |
| 4026.00 | He I |
| 4088.85 | Si IV |
| 4101.38 | H I |
| 4143.76 | He I |
| 4340.29 | H I |
| 4350.20 | O II |
| 4387.93 | He I |
| 4416.10 | Si IV |
| 4471.48 | He I |
| 4481.13 | Mg II |
| 4541.00 | He II |
| 4649.30 | O II |
| 4712.00 | He I |
| 4860.83 | H I |
| 4921.41 | He I |
| 5875.00 | He I |
| 6563.00 | H-alpha |
| 6678.15 | He I |
| 7064,22 | He I |

«De-blending» with IRAF



STELLAR DATABASE

GCVS: HIP: HD:

Orbital Period: +/-

U-B: +/- B-V: +/-

U-B_0: +/- B-V_0: +/-

Visual absorption A_v: +/- [Fe/H]:

Primary temperature: +/-

Secondary temperature: +/-

Primary velocity semi-amplitude: +/-

Secondary velocity semi-amplitude: +/-

Orbital inclination: +/-

V_gamma: +/-

Eccentricity (e): +/-

Primary rotation velocity: +/-

Secondary rotation vel.: +/-

Type Primary relative radius: +/-

Secondary relative radius: +/-

E(B-V): +/- E(U-B): +/-

Cluster member?

Cluster name

Apsidal motion?

Apsidal motion period +/-

Absolute Parameters

File Analyze

| <u>Absolute Parameters</u> | | | |
|---------------------------------|--|-------------------------------------|--|
| Mass ratio: | <input type="text" value="0.607"/> +/- <input type="text" value="0.030"/> | Primary synchronization velocity: | <input type="text" value="76.4"/> +/- <input type="text" value="2.3"/> |
| m1*sin^3(i): | <input type="text" value="17.028"/> +/- <input type="text" value="1.100"/> | Sec. synchronization velocity: | <input type="text" value="147.9"/> +/- <input type="text" value="4.0"/> |
| m2*sin^3(i): | <input type="text" value="10.343"/> +/- <input type="text" value="0.792"/> | Synchronization time scale: | <input type="text" value="6.281"/> +/- <input type="text" value="0.059"/> |
| a*sin(i): | <input type="text" value="27.710"/> +/- <input type="text" value="0.638"/> | Orbital circularization time scale: | <input type="text" value="8.071"/> +/- <input type="text" value="0.057"/> |
| Primary mass: | <input type="text" value="17.692"/> +/- <input type="text" value="0.911"/> | Primary absolute magnitude: | <input type="text" value="-3.135"/> +/- <input type="text" value="0.149"/> |
| Secondary mass: | <input type="text" value="10.746"/> +/- <input type="text" value="0.743"/> | Secondary absolute magnitude: | <input type="text" value="-4.300"/> +/- <input type="text" value="0.855"/> |
| Separation: | <input type="text" value="28.066"/> +/- <input type="text" value="0.670"/> | Distance estimate from primary: | <input type="text" value="3717."/> +/- <input type="text" value="317."/> |
| Primary radius: | <input type="text" value="4.883"/> +/- <input type="text" value="0.145"/> | Distance estimate from second: | <input type="text" value="3836."/> +/- <input type="text" value="327."/> |
| Secondary radius: | <input type="text" value="9.452"/> +/- <input type="text" value="0.254"/> | Distance from both component: | <input type="text" value="3777."/> +/- <input type="text" value="322."/> |
| Primary bolometric magnitude: | <input type="text" value="-6.473"/> +/- <input type="text" value="0.115"/> | Paralax: | <input type="text" value="0.26"/> +/- <input type="text" value="0.02"/> |
| Secondary bolometric magnitude: | <input type="text" value="-7.015"/> +/- <input type="text" value="0.855"/> | | |
| Primary luminosity: | <input type="text" value="4.489"/> +/- <input type="text" value="0.046"/> | | |
| Secondary luminosity: | <input type="text" value="4.706"/> +/- <input type="text" value="0.342"/> | | |
| Primary log g: | <input type="text" value="4.308"/> +/- <input type="text" value="0.048"/> | | |
| Secondary log g: | <input type="text" value="3.518"/> +/- <input type="text" value="0.053"/> | | |

Space Velocity Components

U: +/-

W: +/-

V: +/-

S: +/-

(V. Bakış , 2012)

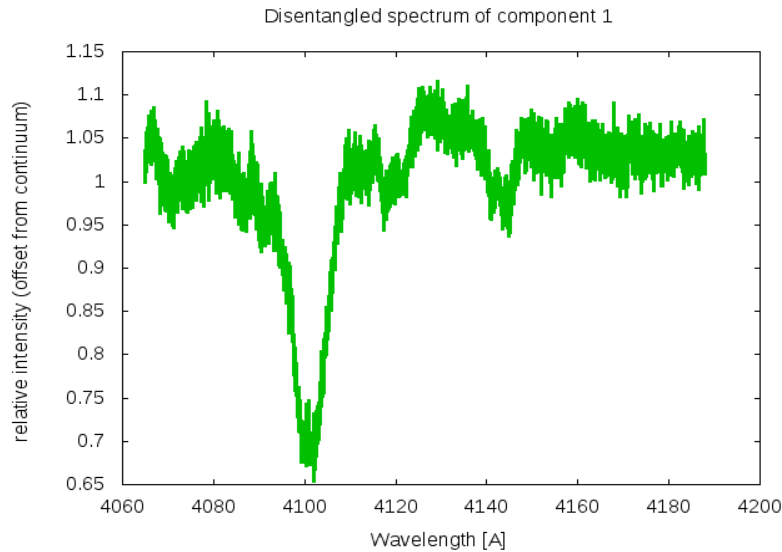
Calculated Parameters of HH Car

| | | |
|---------------------|-------------|---------|
| * T_o (HJD): | 52501.639 ± | 0.0008 |
| *P (gün): | 3.231515 ± | 0.00001 |
| ** m_1 (M_o) | 17.69 ± | 0.91 |
| ** m_2 (M_o) | 10.75 ± | 0.74 |
| ** R_1 (R_o): | 4.88 ± | 0.15 |
| ** R_2 (R_o): | 9.45 ± | 0.25 |
| q | 0.607 ± | 0.036 |
| T_1 (K) | 34500 ± | 500 |
| T_2 (K) | 28200 ± | 620 |
| **log g_1 | 4.308 ± | 0.048 |
| **log g_2 | 3.518 ± | 0.053 |
| i° : | 80.877 ± | 0.068 |
| V_z (km/s): | -14.09 ± | 3.22 |
| **a (R_o): | 28.06 ± | 0.67 |
| ** Mv_1 | -3.14 ± | 0.15 |
| ** Mv_2 | -4.30 ± | 0.86 |
| ** $M_{bol,1}$ | -6.473 ± | 0.115 |
| ** $M_{bol,2}$ | -7.015 ± | 0.855 |
| **d (pc): | 3495 ± | 299 |
| e: | 0.00 | |

* <http://www.as.up.krakow.pl/ephem/>

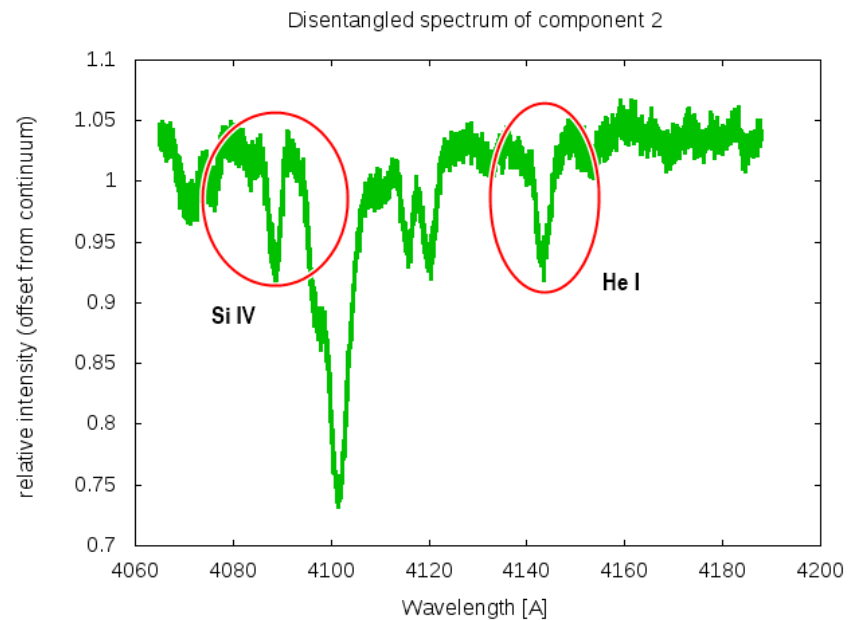
**Stellar Parameters, (Bakış V., 2012)

Disentangling the spectra with «Korel» (P. Hadrava, 1995, 2011)



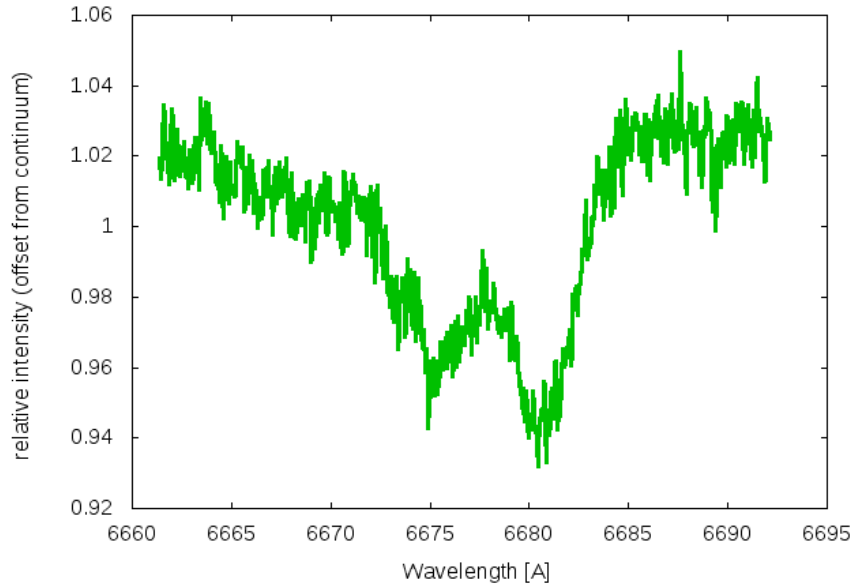
*NIST database

| | |
|----------------|--------------|
| 4088.85 | Si IV |
| 4101.38 | H I |
| 4143.76 | He I |



Disentangling the spectra with «Korel»

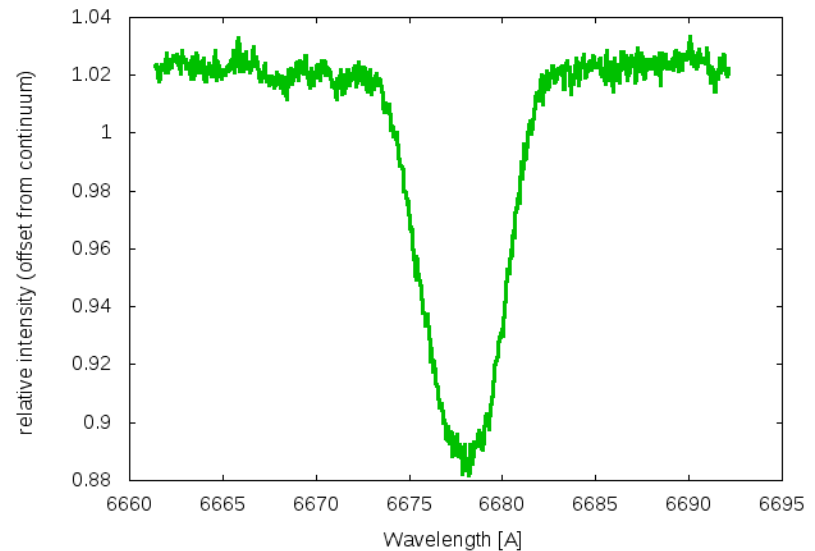
Disentangled spectrum of component 1



6678.15

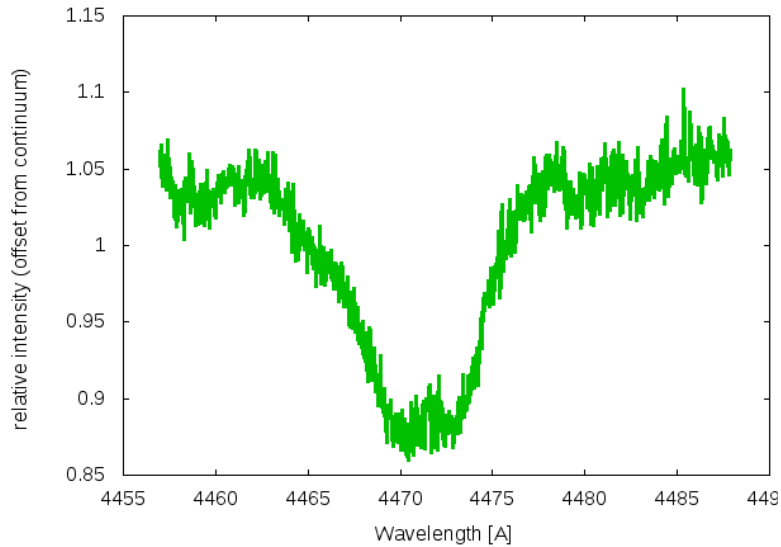
He I

Disentangled spectrum of component 2



Disentangling the spectra with «Korel»

Disentangled spectrum of component 1



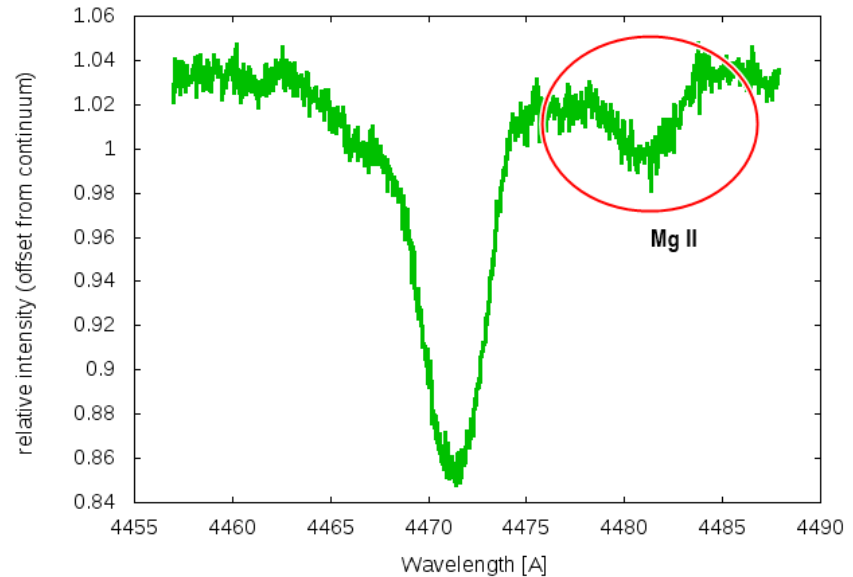
4471.48

He I

4481.13

Mg II

Disentangled spectrum of component 2



Model Atmosphere

- Belirlenmiş sistem parametreleri için NLTE model atmosfer üreten **Tlusty*** ve bu atmosferlerin sentetik tayflarını üreten **Synspec*** kodlarının oluşturduğu hazır model atmosferlerden faydalanılmıştır.
- Bu kodlara ek olarak **Rotin3*** kodu ile, sentetik tayflara dönme hızı da eklenerek, ikinci bileşendeki belirli çizgilere fit yapılmıştır.

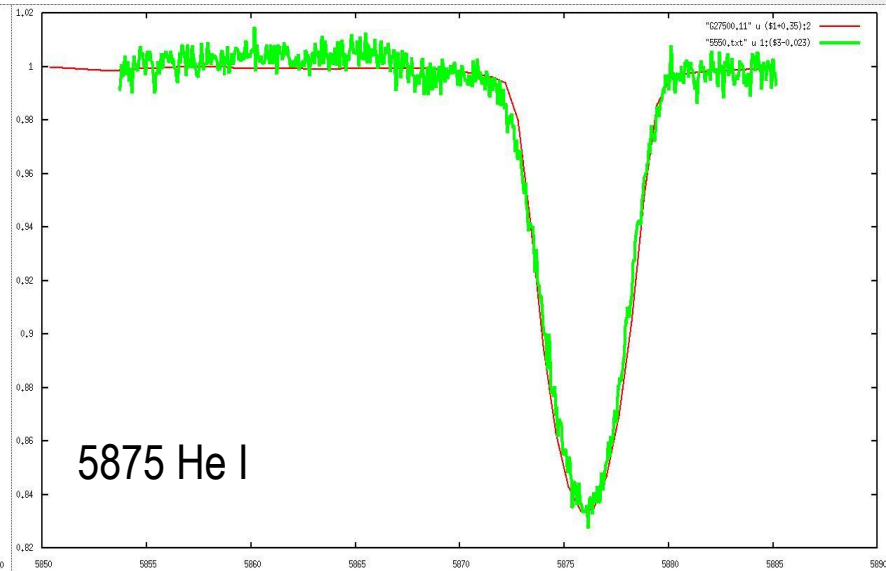
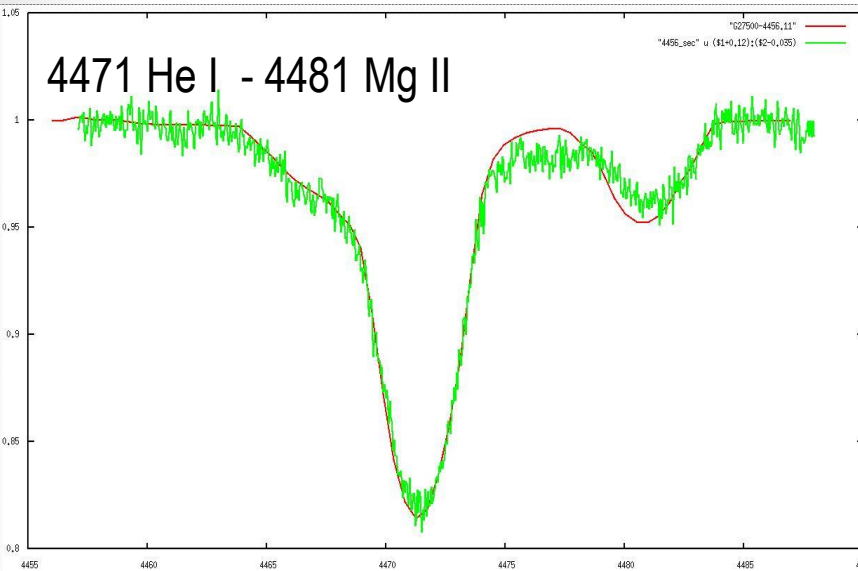
*Hubeny and Lanz 1985, 1988, 1995, 2006

* <http://nova.astro.umd.edu/Tlusty2002/tlusty-frames-down.html>

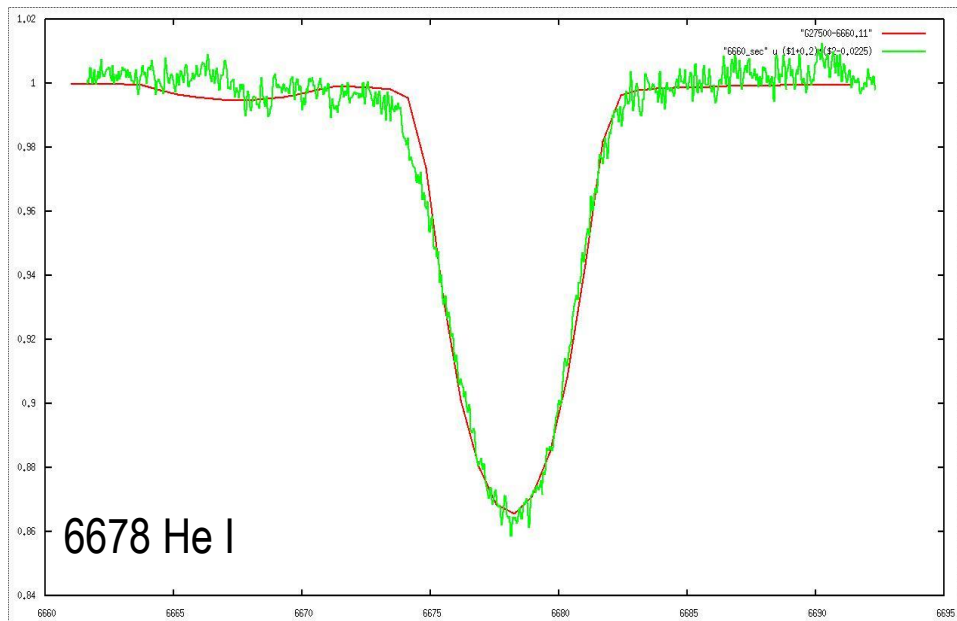
<http://nova.astro.umd.edu/Synspec49/synspec.html>

<http://nova.astro.umd.edu/Synspec49/synspec-frames-rotin.html>

Fitting the Model

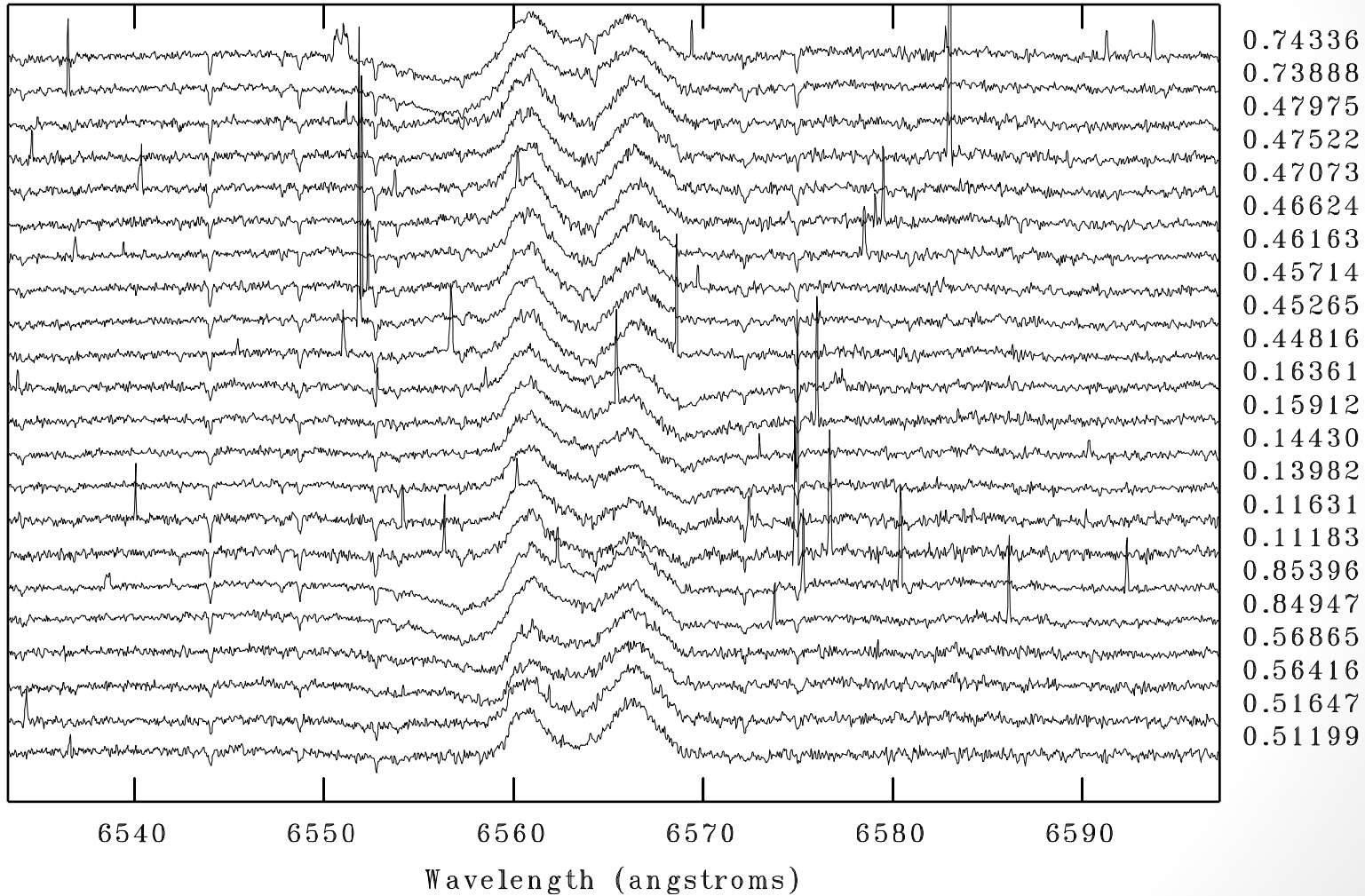


Yoldaş bileşene yapılan çizgi fitleri $T= 27500$, $\log g= 3.50$, $[\text{Fe}/\text{H}]= 0$ ve $V_{\text{rot}} = 150 \pm 5$ km/s değerleri içindir.

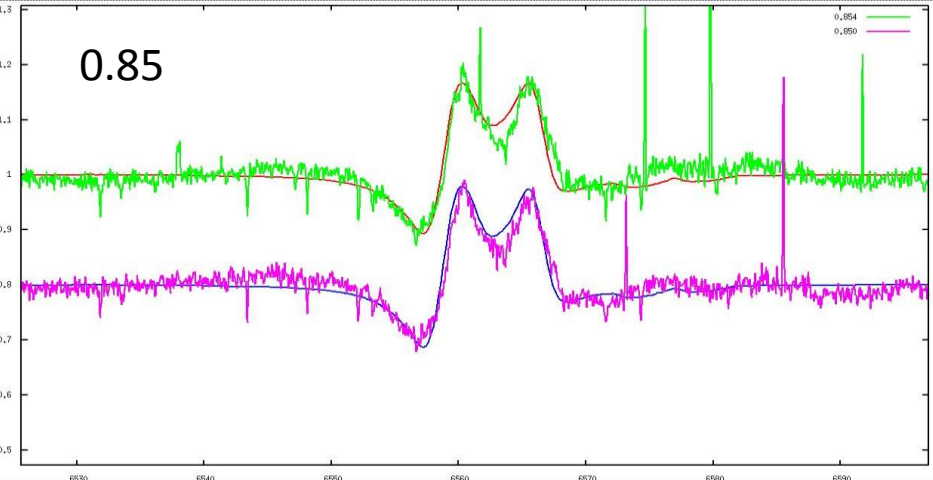
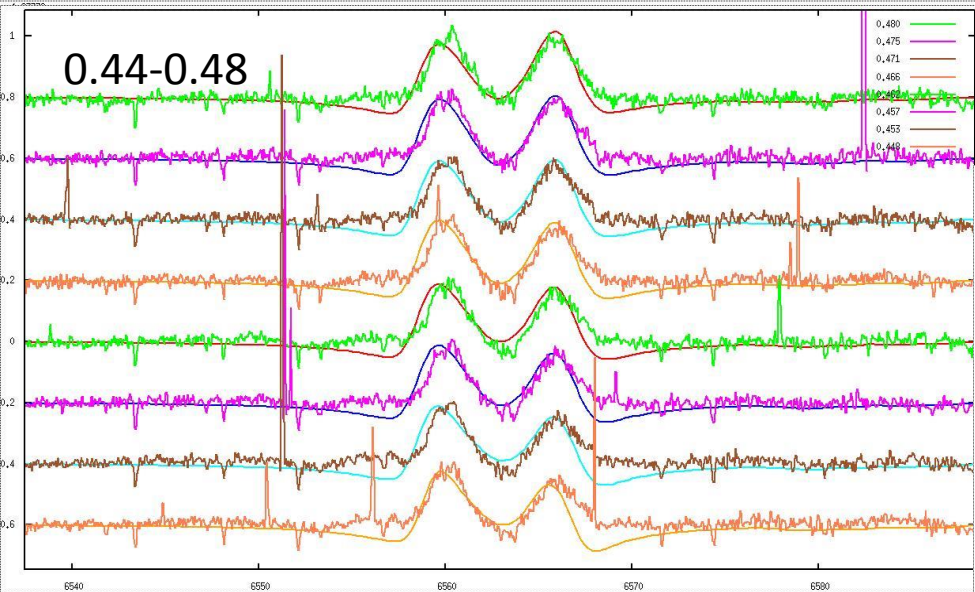
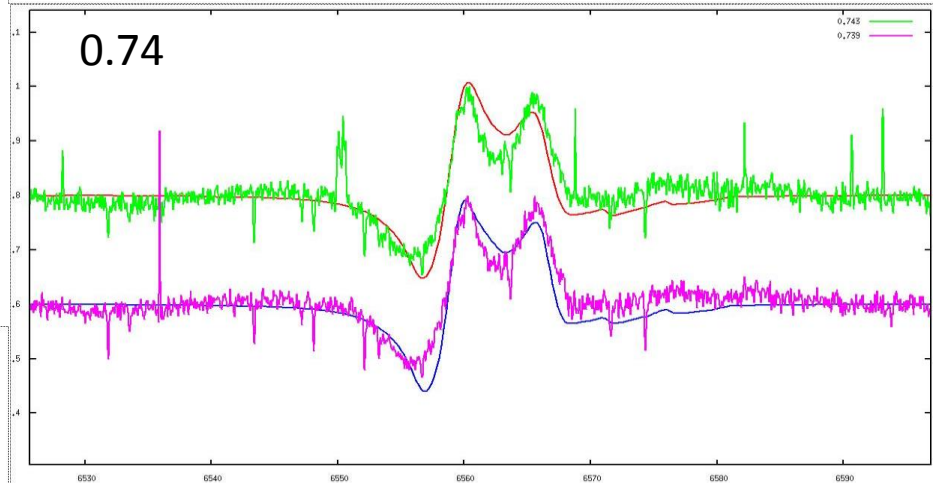
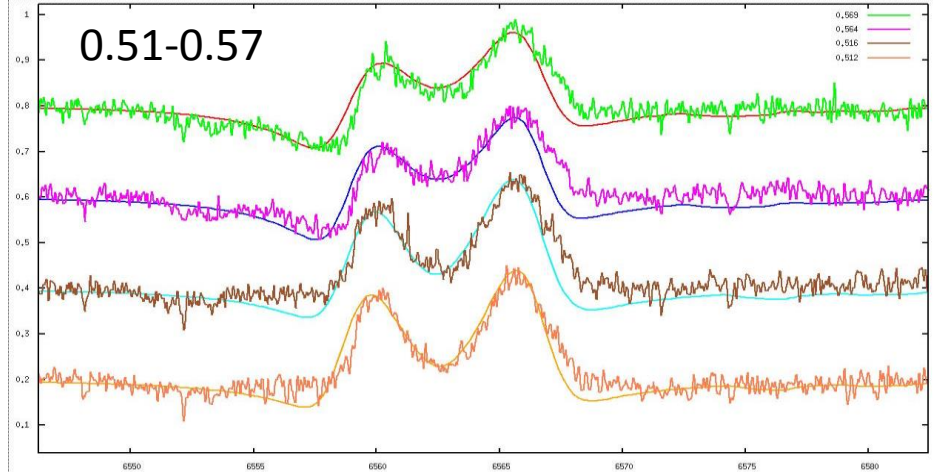
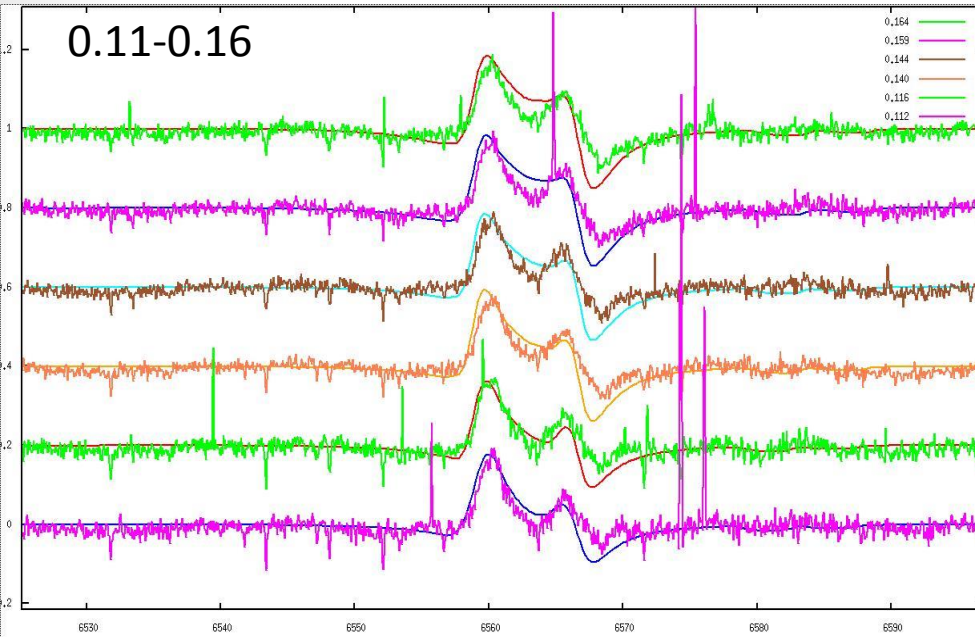


H-alpha lines

NOAO/IRAF V2.16.1 dogan@dogan-S551LB Mon 11:11:18 22-Dec-2014
Separation step = 0.15



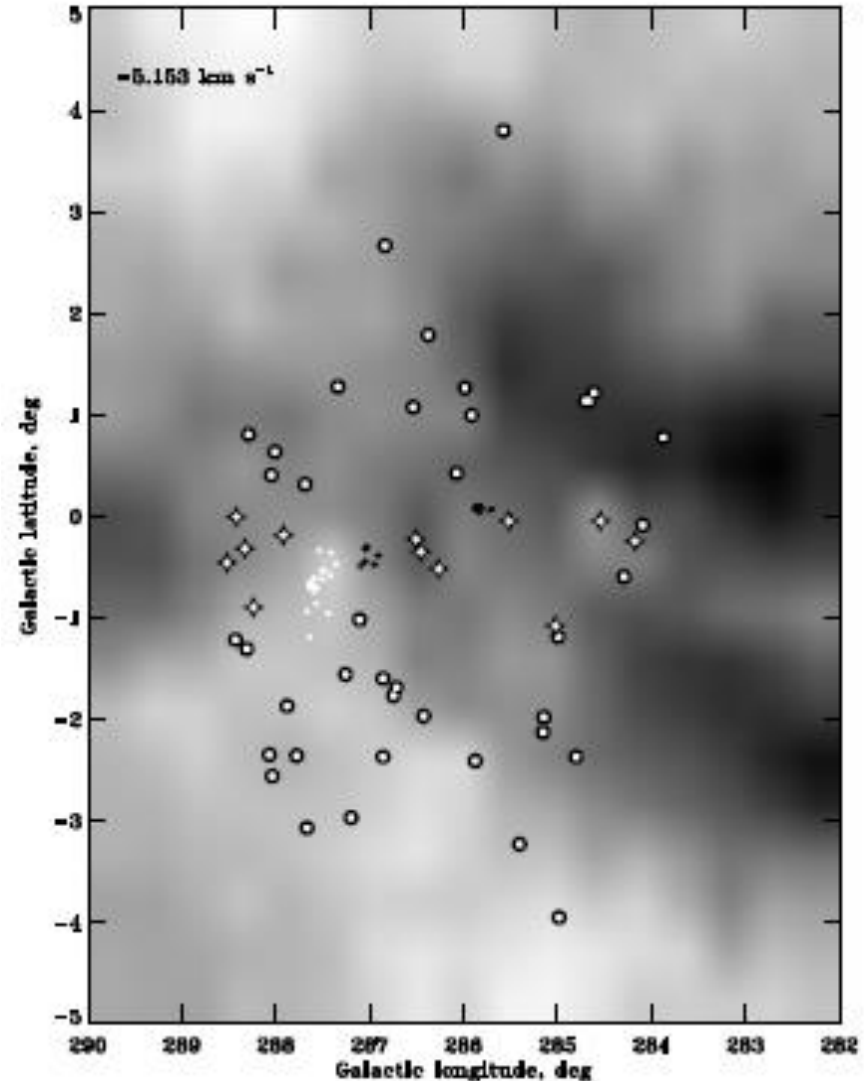
Modelling with Shellspec code



Car OB1 association

- HH Car sisteminin uzaklığı:
 3495 ± 299 pc olarak bulunmuştur.
- Sistemin galaktik koordinatları:
 $l = 288.45862$ $b = +00.06437$
- Car OB1 oynağının galaktik koordinatları:
 $284^\circ < l < 288^\circ$ $-2.2^\circ < b < 0.9^\circ$
Ortalama uzaklığı ise **2.5 kpc**,
derinliği **2 – 6 kpc**'dir.*

*Kaltcheva, N., Golev, V.; 2011



References

- Stellar Parameters, (*Volkan Bakış, 2012*)
- Shellspec (*Budaj and Richards <http://www.ta3.sk/~budaj/shellspec/download/>*)
- Spectroscopic Binary Solver, (*Delwin O. Johnson, 2004*)
- Phoebe, (*Prša et al, 2008*)
- Wilson-Devinney interface, (*Robert. H Nelson, 2009*)
- Tlusty (*Hubeny I., 1988*)
- Synspec & Rotin3 (*Hubeny, Lanz and Jeffrey 1994, 1995*)
- Korel (*Hadrava P., 1995, 2011*)
- JKTL code for limb-darkening (*Southworth J., 2008*)
- Color – Temperature Calibration code (*Worthey & Lee 2006, 2010*)
- Synthetic Spectra of OB-Type Binary Stars (*Robert I. Hynes, 1996*)
- Improved distances to several Galactic OB associations (*N. Kaltcheva, V. Golev, 2011*)
- Orbital Elements and Apsidal Motion of the Eclipsing Binary HH Carinae (*O'Connell 1968*)
- Observations of Six Southern Eclipsing Binaries for Apsidal Motion (*Söderhjelm S., 1975*)
- The Spectrographic Orbit of the Eclipsing Binary HH Carinae (*Mandrini, Mendez; 1985*)
- <http://nova.astro.umd.edu/Tlusty2002/tlusty-frames-OS02.html>
- <https://stelweb.asu.cas.cz/vo-korel/>
- <http://ganymede.nmsu.edu/tharriso/ast110/class19.html>