Соотношение масса-светимость для быстро и медленно вращающихся звезд

Алексей Князев (SAAO/SALT/ГАИШ)
Олег Малков (ИНОСАН, Москва)
Иван Катков и Леонид Бердников
(ГАИШ, МГУ)

Contents

The Mass-Luminosity Relation

The mass-luminosity relation (MLR) is a fundamental law that is used in various fields of astrophysics. It is especially important for the construction of the initial mass function (IMF) from the luminosity function of stars.

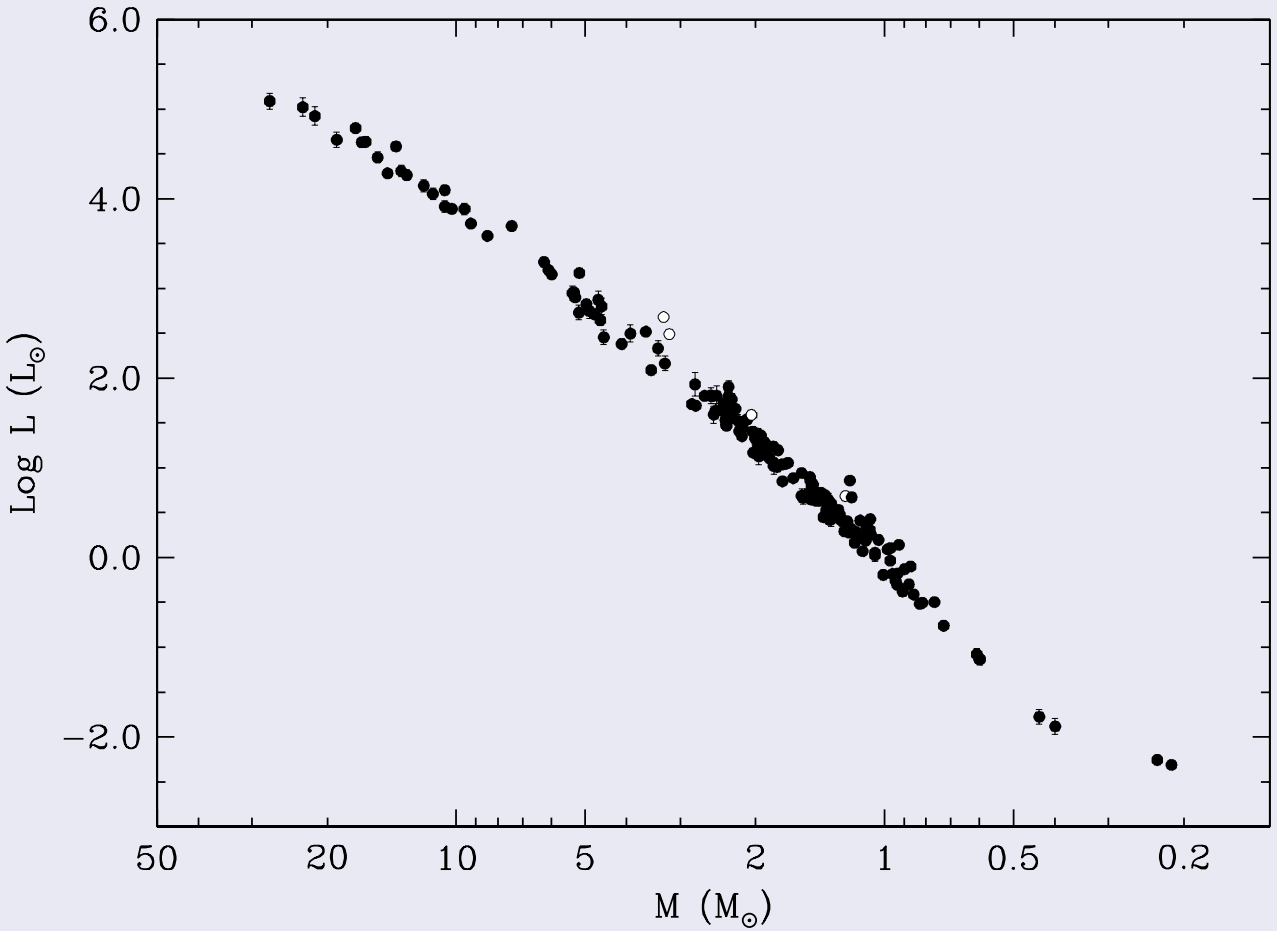
To build LMR astronomers need independent stellar mass and luminosity determination

The Mass-Luminosity Relation: Sources of Data

1. Orbital binaries (visual binaries with known orbital parameters and trigonometric parallax) provide masses of components in the mass range m<1.5 $M_\odot$
2. A main source for the m>1 $M_\odot$ mass range is detached main-sequence eclipsing binaries, with the spectrum lines of the two components (hereafter double-lined eclipsing binaries, DLEB).

The Mass-Luminosity Relation: current situation

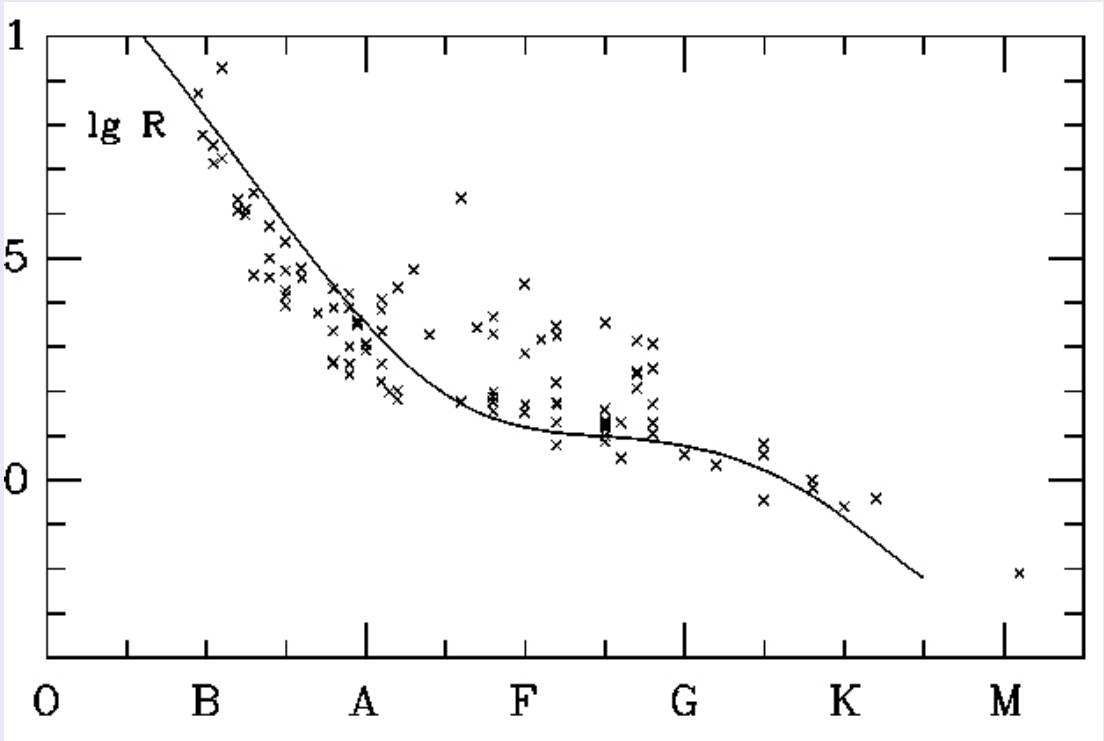
94 eclipsing systems, from Torres et al. (2010)



The Mass-Luminosity Relation: Worry

Are we sure that there is no difference between observational parameters of components of DLEB from ones of isolated stars?

Radii of MS detached DLEB

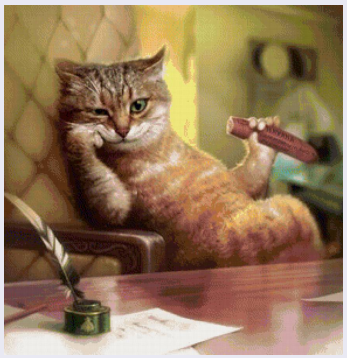


Alternative? - Ducks! (long-period DLEB)

Components of long-period DLEB are presumably not synchronized with the orbital periods. They are, consequently, rapid rotators and evolve similarly with single stars.

We assume, that only those data could be used for the construction of mass-luminosity and other relations of such isolated stars for the m>1.5 $M_{\odot}$ range as masses of components of orbital binaries extremely rarely exceed that limit.

Какие двойные звезды нужны для этого проекта?

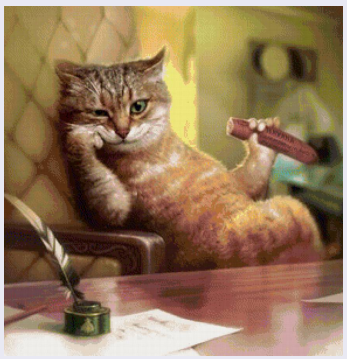


Критерии для отбора двойных звезд из Каталога Переменных Звезд

- Положение на небе $-76^\circ < \delta < +10^\circ$
- $m_V < 13$ mag
- $365 <$ P(дней) < 45
- Спектральный тип: O, B, A, F

С использованием данных критериев отобрано 11 двойных систем

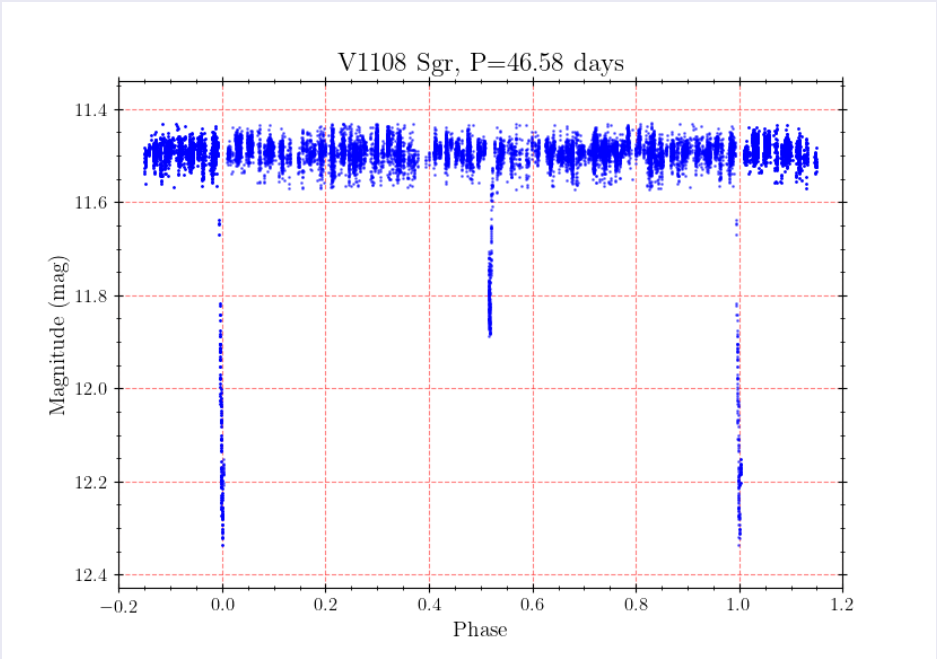
Какие данные нужны для этого проекта?



- High resolution spectra to calculate Masses (M_1, M_2) and L_1/L_2 ratio $\Rightarrow$ SALT/HRS in MR mode (R 35000)
- Very good photometry to calculate Luminosity (L), Orbital period (P) and inclination angle (i) $\Rightarrow$ ASAS/ASAS-SN/SuperWASP/Our own

Photometry

Photometry for some our targets

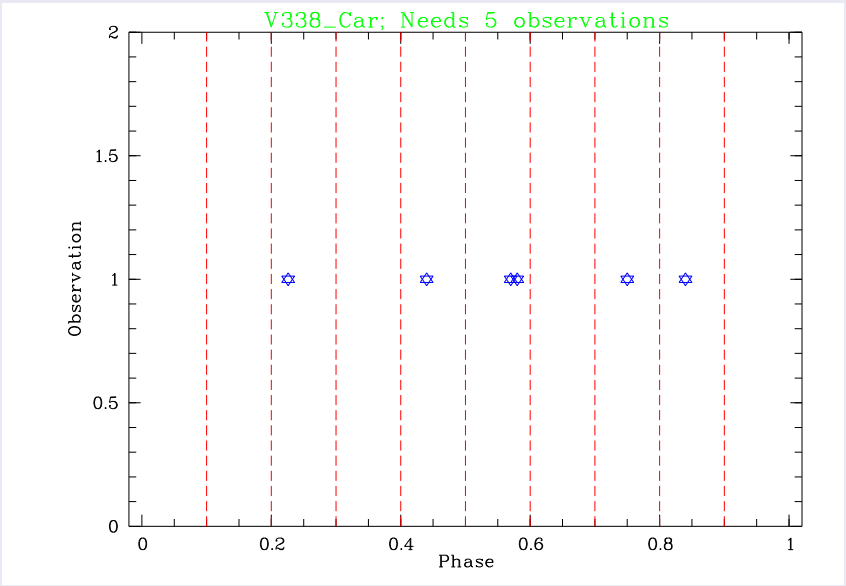


Data and parameters

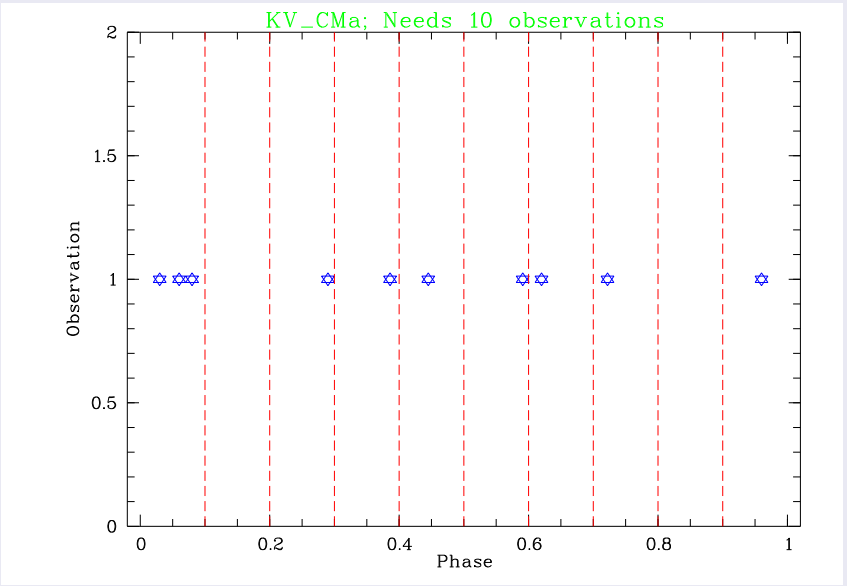
1. ASAS/ASAS-SN photometrical data were collected and Orbital periods (P) were calculated by Leonid Berdnikov
2. Parameters (mainly P and i) were also collected from the previous photometric studies to compare

Plan-minimum for Spectral Observations

Plan for systems with circular orbit (four variables)



Plan for other systems (seven variables)



Altogether 84 HRS observations were obtained starting from May 2017 and till October 2018.

HRS Spectral data Reduction

- Primary Data Reduction with SALT pipeline (Crawford et al., 2010)
- Echelle Data Reduction with SALT MIDAS pipeline (Kniazev et al., 2016), and specifically about MR mode (Kniazev et al., 2019)

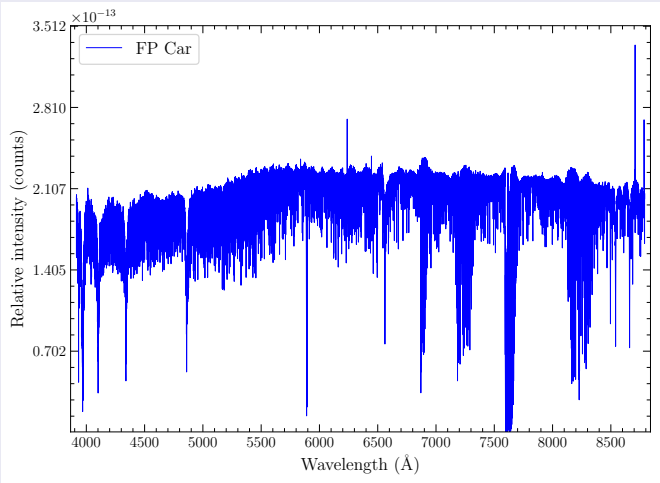
  `http://astronomers.salt.ac.za/software/hrs-pipeline/`

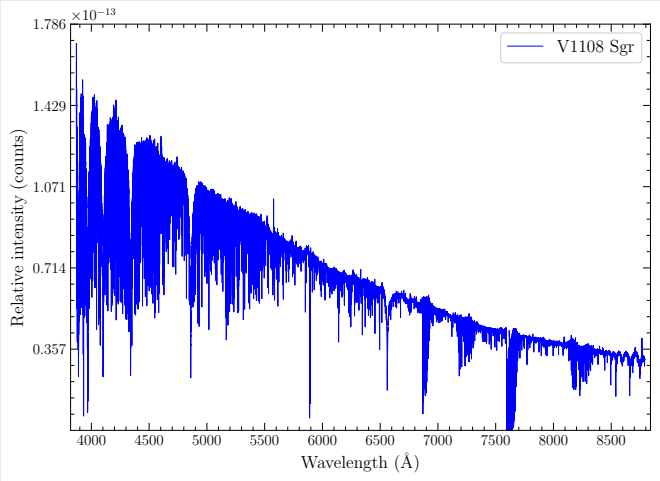
  Data are totally reduced at the middle of the next day and are sended to PIs.
- Additional iteration for re-merging HRS data, including errors and correction for sensitivity curve

  `http://astronomers.salt.ac.za/software/hrs-pipeline/`

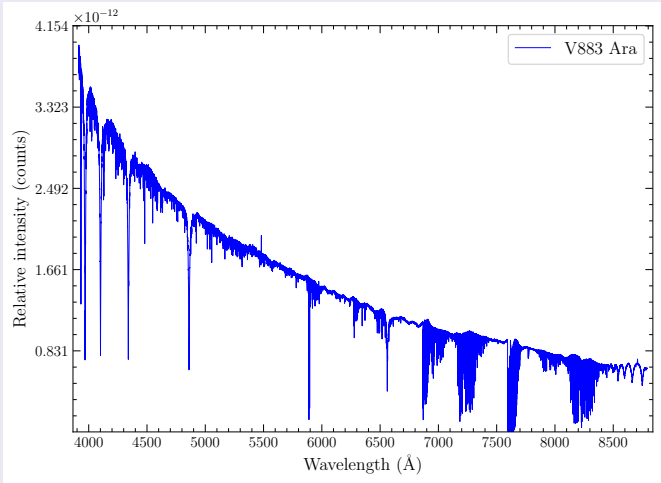
HRS Spectral data after Reduction

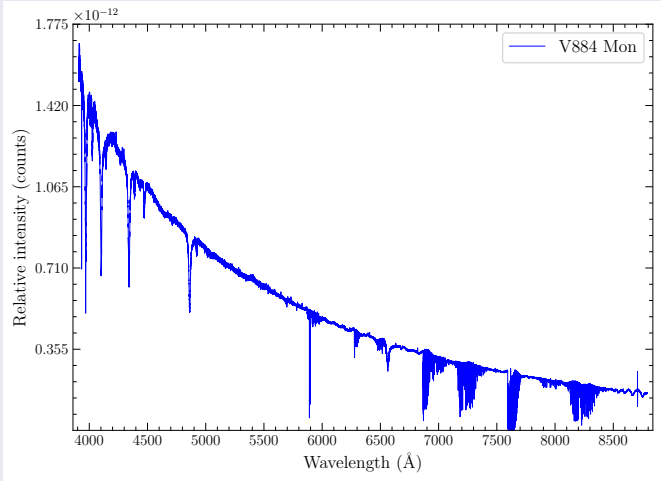
SALT HRS spectra in MR mode





SALT HRS spectra in MR mode





Spectral data Analysis

Python software for the analysis of HRS spectra of binary systems

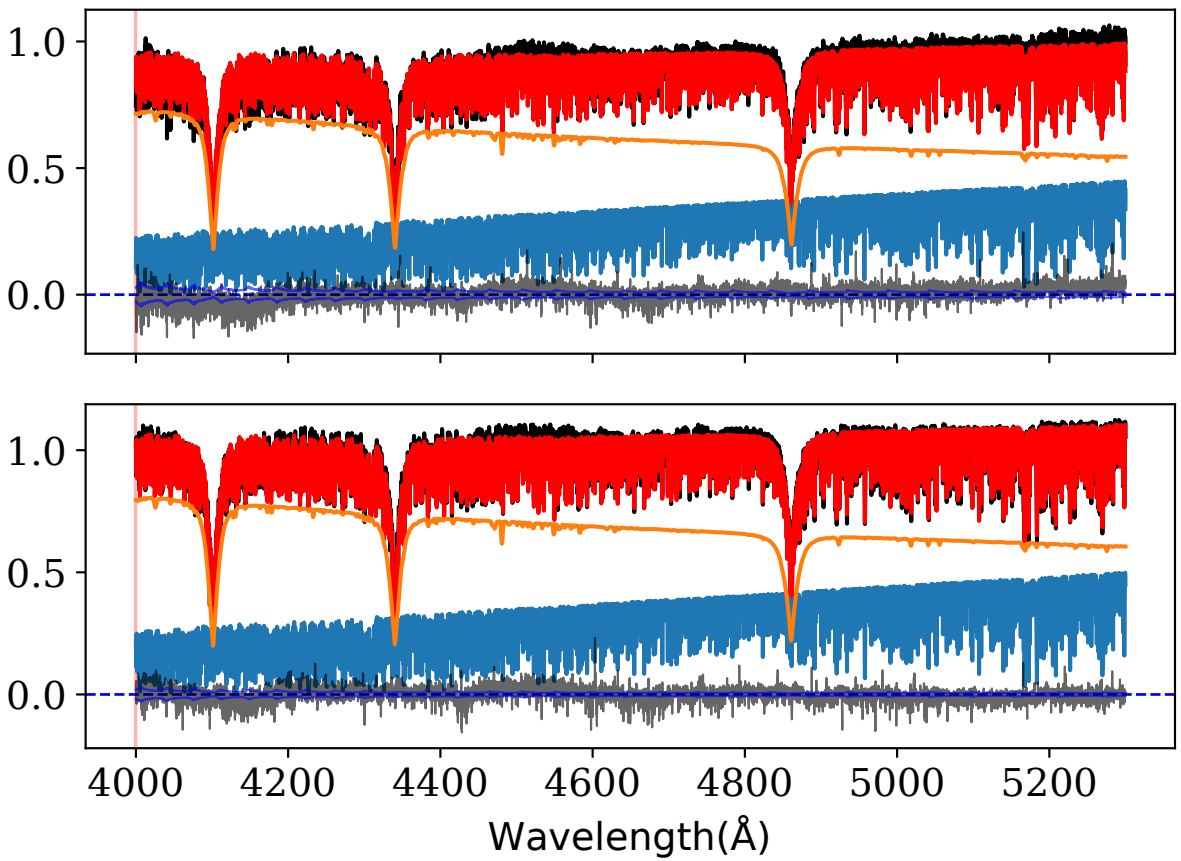
Software was designed to calculate amount of stellar parameters and velocities for components of binary systems:

- T_{eff1}, T_{eff2} (fix, = and !=)
- log g_1, log g_2 (fix, = and !=)
- $[M/H]_1$, $[M/H]_2$ (fix, = and !=)
- V sin(i)$_1$, V sin(i)$_2$ (fix, = and !=)
- E(B-V) (fix and =)
- Weight of each component into spectrum ($K_1 + K_2 = 1$) (fix, = and !=)
- V_{hel1}, V_{hel2} – first spectrum (fix and !=)
  V_{hel1}, V_{hel2} – second spectrum (fix and !=)
  ...
  V_{hel1}, V_{hel2} – n-th spectrum (fix and !=)

Software is based on the stellar libraries like Coelho (2014) or Tlusty (http://nova.astro.umd.edu/), that were rebined to HRS LR/MR/HR resolutions using equstions for R(λ) from Kniazev et al. (2019).

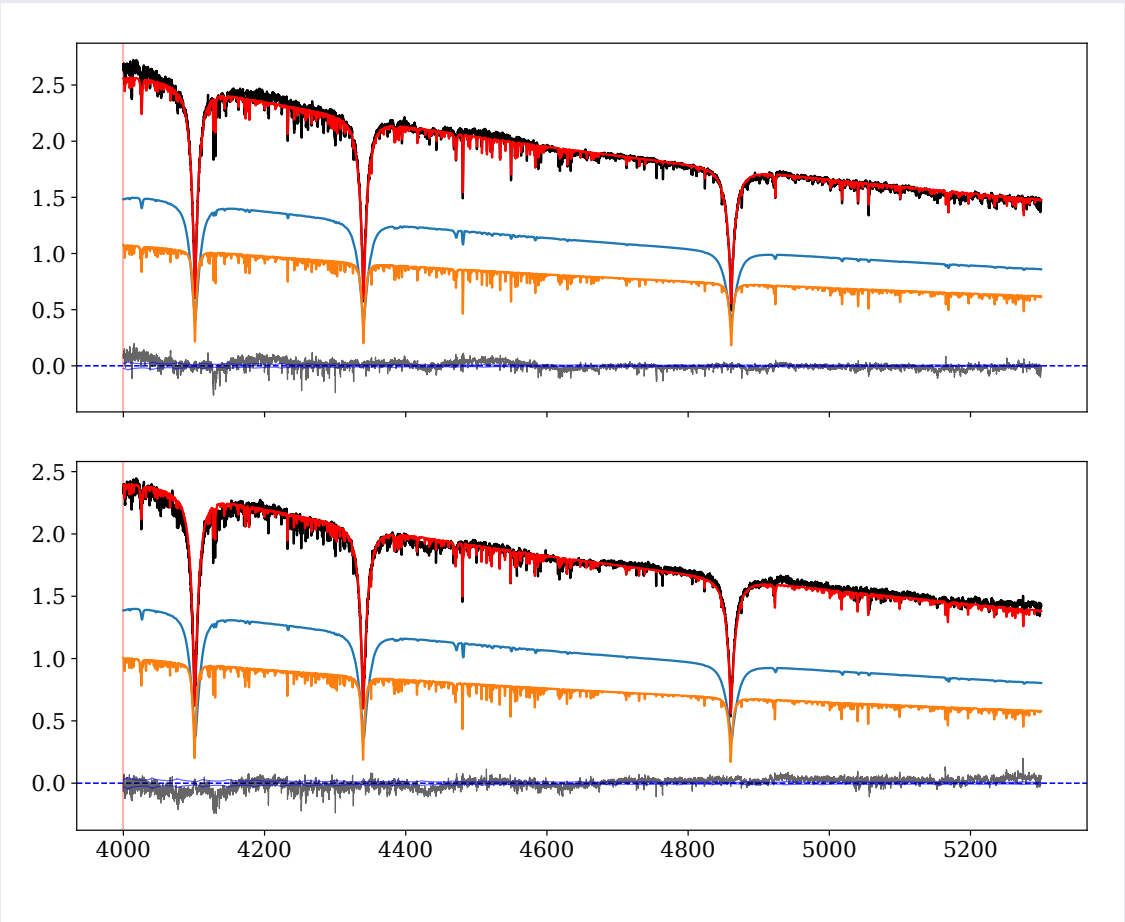
Spectral data Analysis Example (1)

FP Car binary system



Spectral data Analysis Example (2)

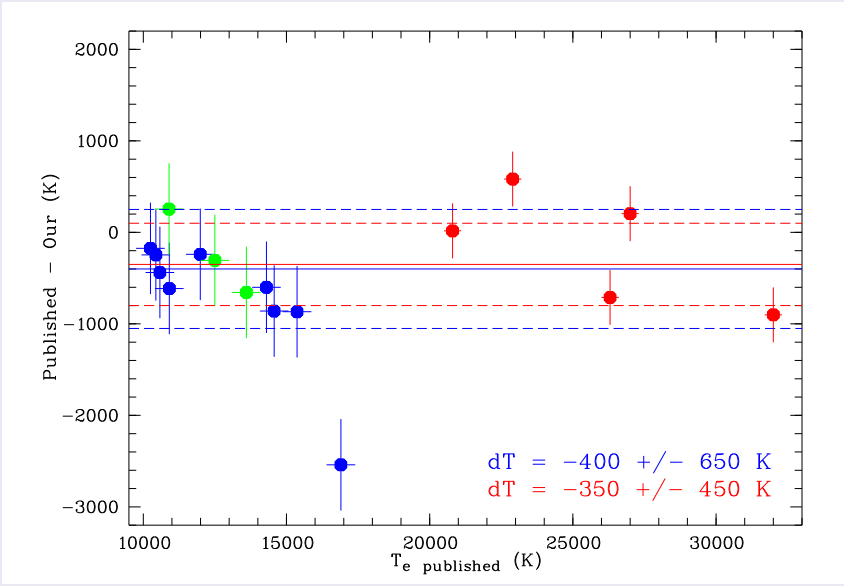
V883 Ara binary system



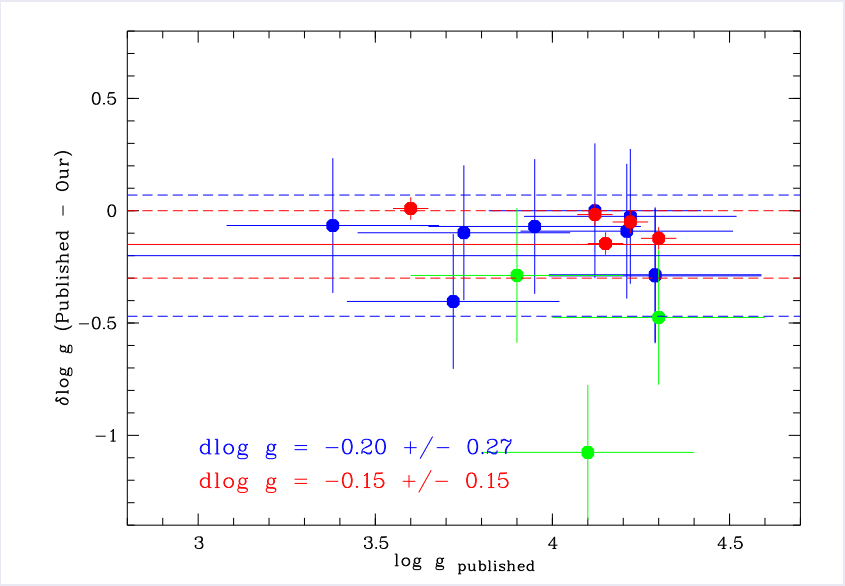
Calculation of External accuracy

The sample of early and late B-type stars based on FEROS echelle spectra from Dr. Valery Kovtyuh (Odessa University, Ukraine)

Comparison for T_{eff}

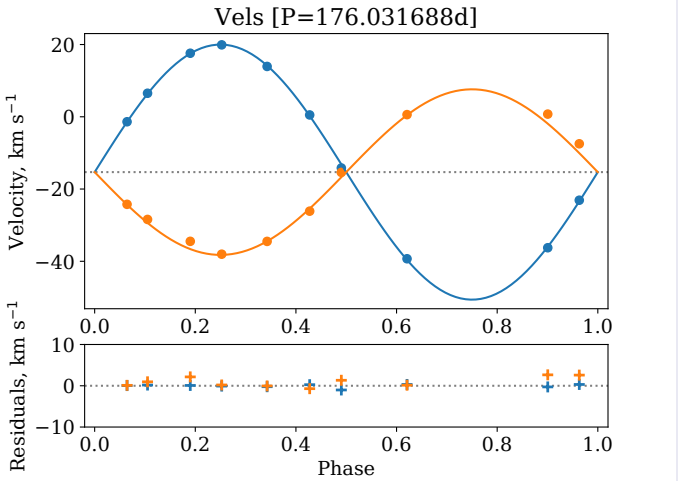


Comparison for log g

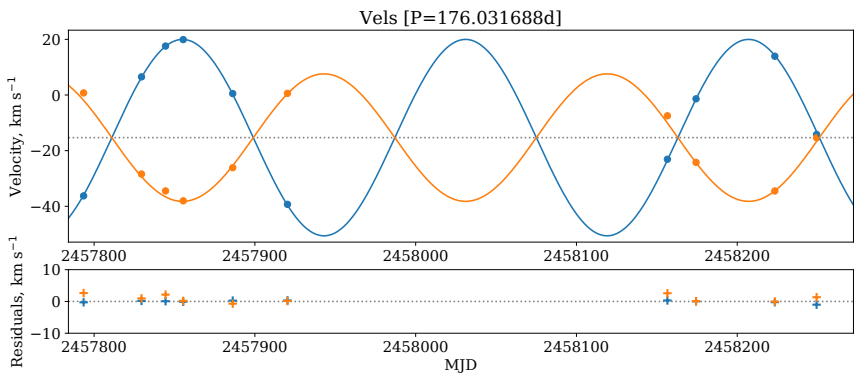


Analysis of the total set of spectral data (1)

Calculation of parameters for the binary system FP Car

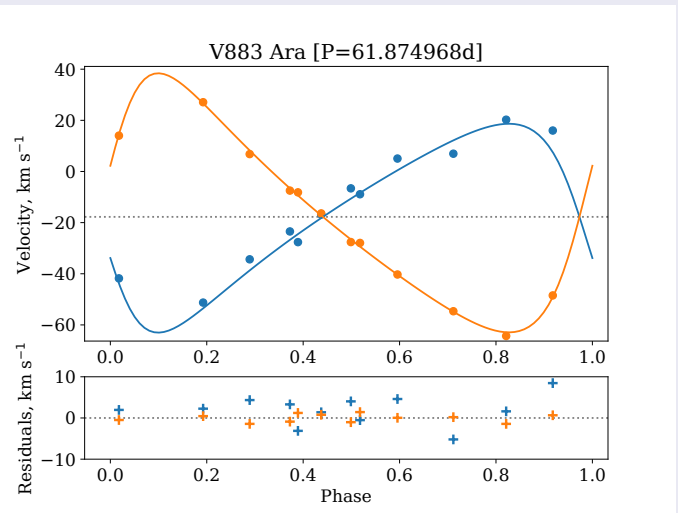


Calculation of parameters for the binary system FP Car

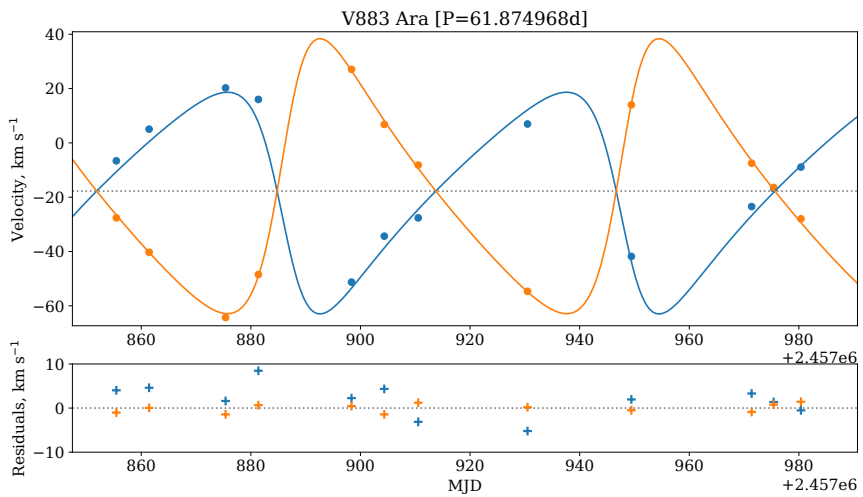


Analysis of the total set of spectral data (2)

Calculation of parameters for the binary system V883 Ara



Calculation of parameters for the binary system V883 Ara



The final statistic

1. 11 binary systems were selected

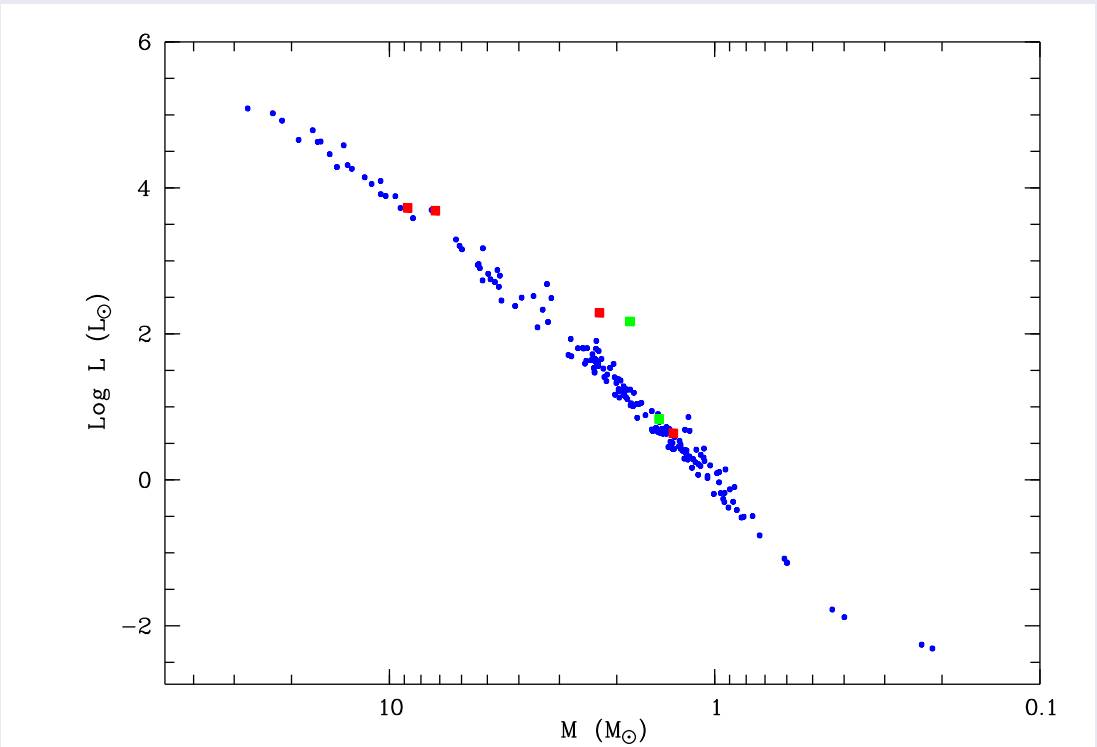
2. Spectra of 2 binary systems show Balmer and He emissions and show complex photometric curves. Finally were rejected from our list

3. Spectra of 2 binaries show only one system of lines (SB1) and have either very strong Vsin(i) = 343 km/s or supergiant component. Rejected from the list

4. Only 7 binary systems could be used from the primary selected list

Comparison with the current mass-luminosity relation

Our result and MLR from Torres et al. (2010)

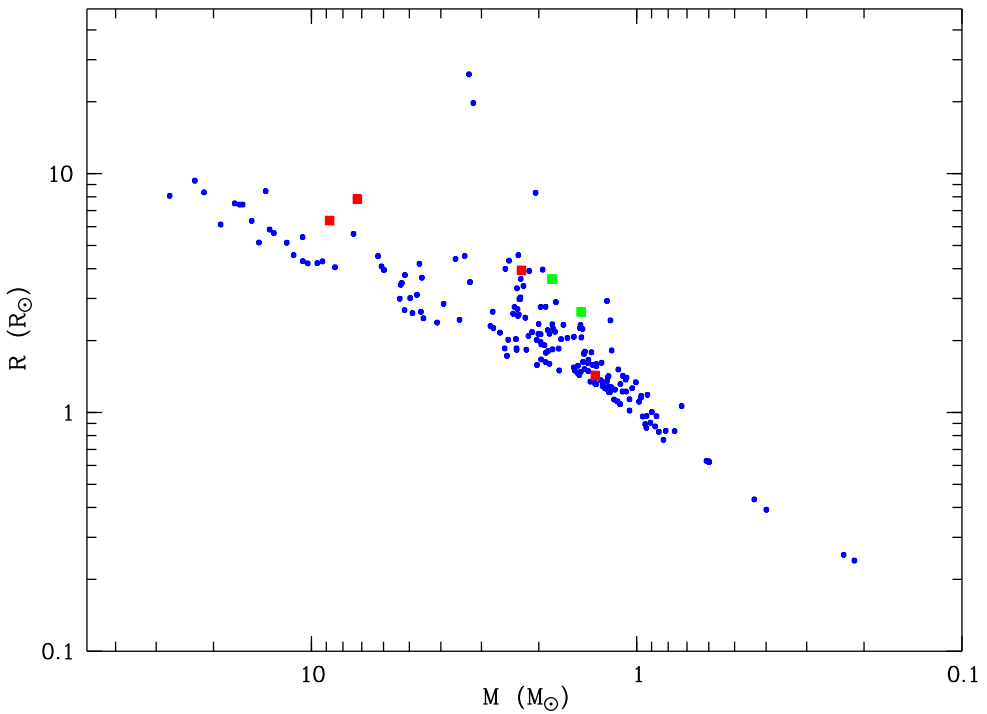


The modern MLR:

Torres et al. (2010) presented 94 detached binary systems containing 188 stars, where the mass and radius of both stars be known within errors of $\sim 3\%$ or better.

Comparison with the current mass-radius relation

Our result and MR from Torres et al. (2010)



The modern MR:

Torres et al. (2010) presented 95 detached binary systems containing 190 stars, where the mass and radius of both stars be known within errors of $\sim 3\%$ or better.

Conclusions

1. Small sample of 11 binary systems was formed for the pilot program with HRS/SALT
2. 84 spectra were taken with SALT/HRS and were reduced
3. Software package for spectral data analysis was developed and its external accuracy was checked
4. Photometric data from ASAS/ASAS-SN were collected and preliminary analysis was done and shows that **We need much better photometry!!!**
5. First binary systems from our sample were analysed and the general correctness of our method was prooved