Dynamical Stability of Triple Star HD 152246

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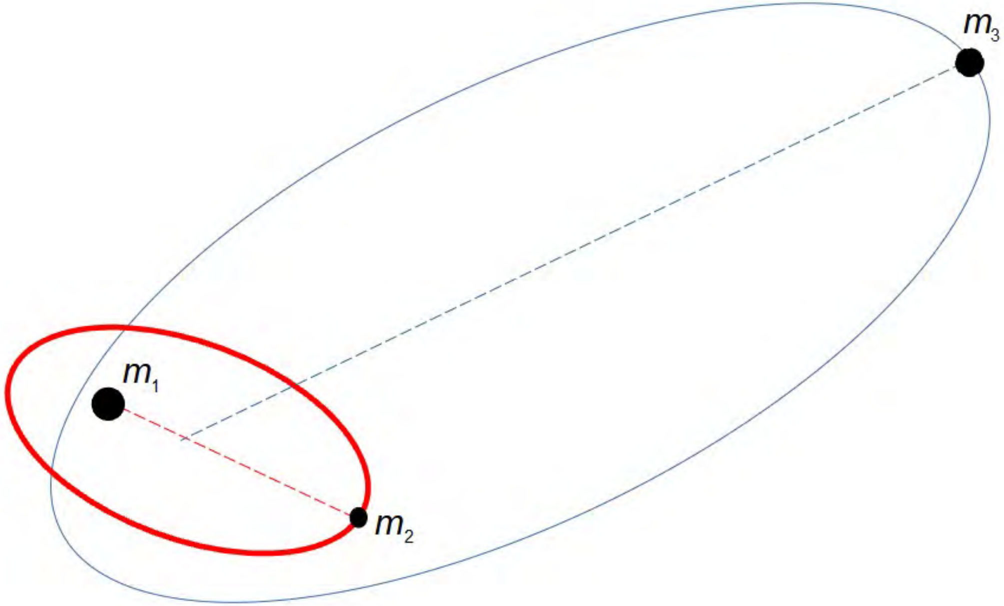
Multiple star systems

- Trapezium systems
- Stars in comparable distances

Credit: HST



- Hierarchical systems
- Two close stars
- Third star further away
- Inner and outer binary

Dynamical stability of a triple star

- Hierarchical configuration
- Different stability criteria
- High ratio of sizes / periods of the outer and inner orbit
- Mass ratio and eccentricity

- Instability: first system temporarily appears as hierarchical
- Later the motion of stars becomes chaotic
- In the end of one of the components is ejected out of the system

Dynamical stability of a triple star

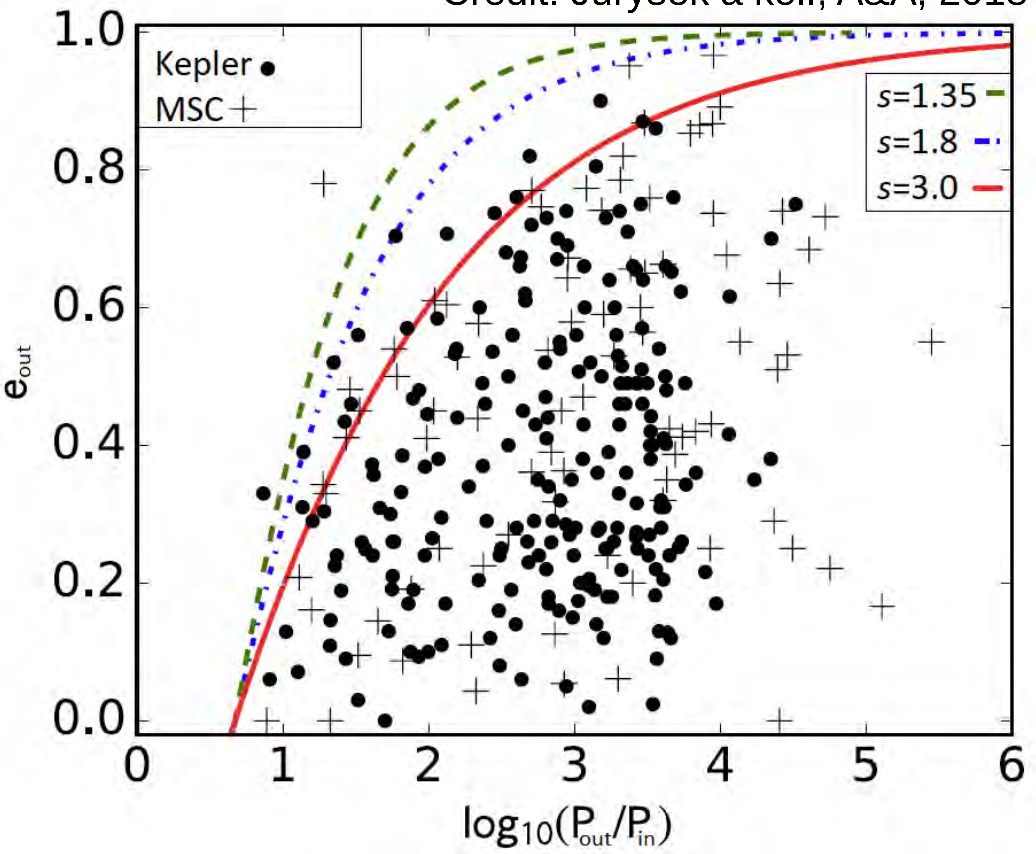
- Examples of stability criterion

$$\frac{P_{out}}{P_{in}} \geq 4.7(1+q_{out})^{1/10}\frac{(1+e_{out})^{3/5}}{(1-e_{out})^{s}}$$

$$q_{out} = \frac{m_3}{m_1+m_2}$$

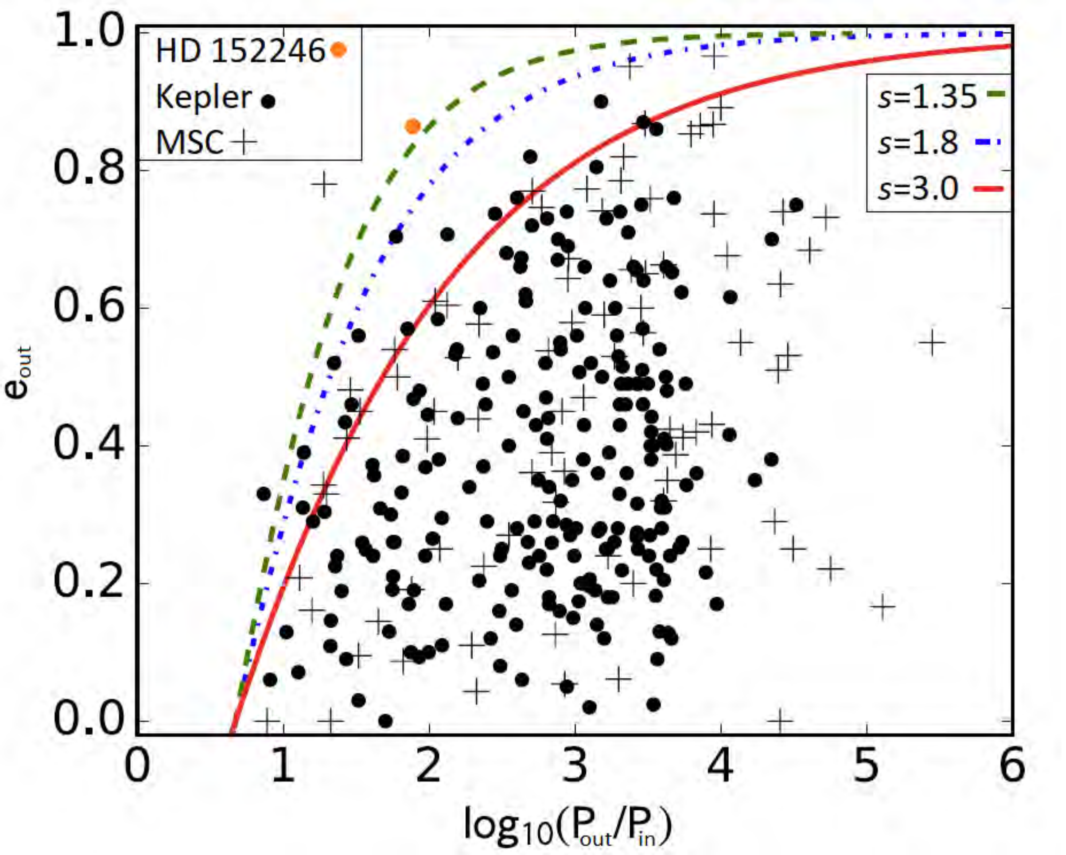
- Different values of the exponent s
- s = 1.35 (Sterzik, Tokovinin, 2002)
- s = 1.8 (Mardling, Aarseth, 2001)
- s = 3.0 (Tokovinin, 2004)

Credit: Juryšek a kol., A&A, 2018



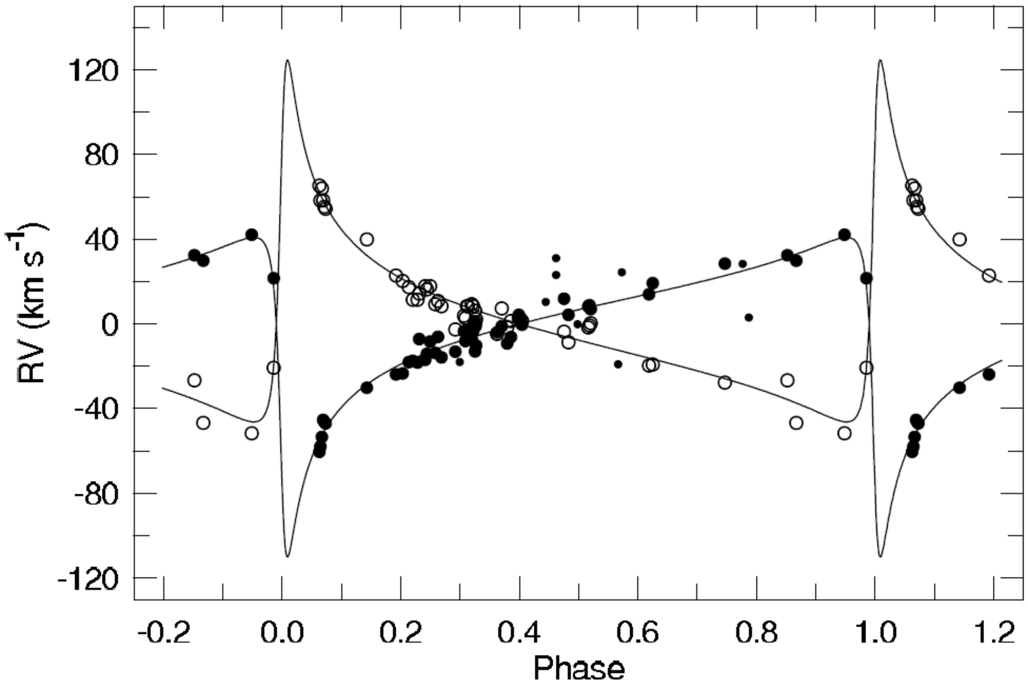
HD 152246

- Nasseri a kol., A&A, 2014 - hierarchical triple system
- Spectra from the years 1999-2013, older published radial velocities
- O-type star and a colder star on a close 6-day orbit
- Third star on a 470-day orbit has spectral type O, high value of eccentricity $e \approx 0.86$
- The system should not be dynamically stable



HD 152246

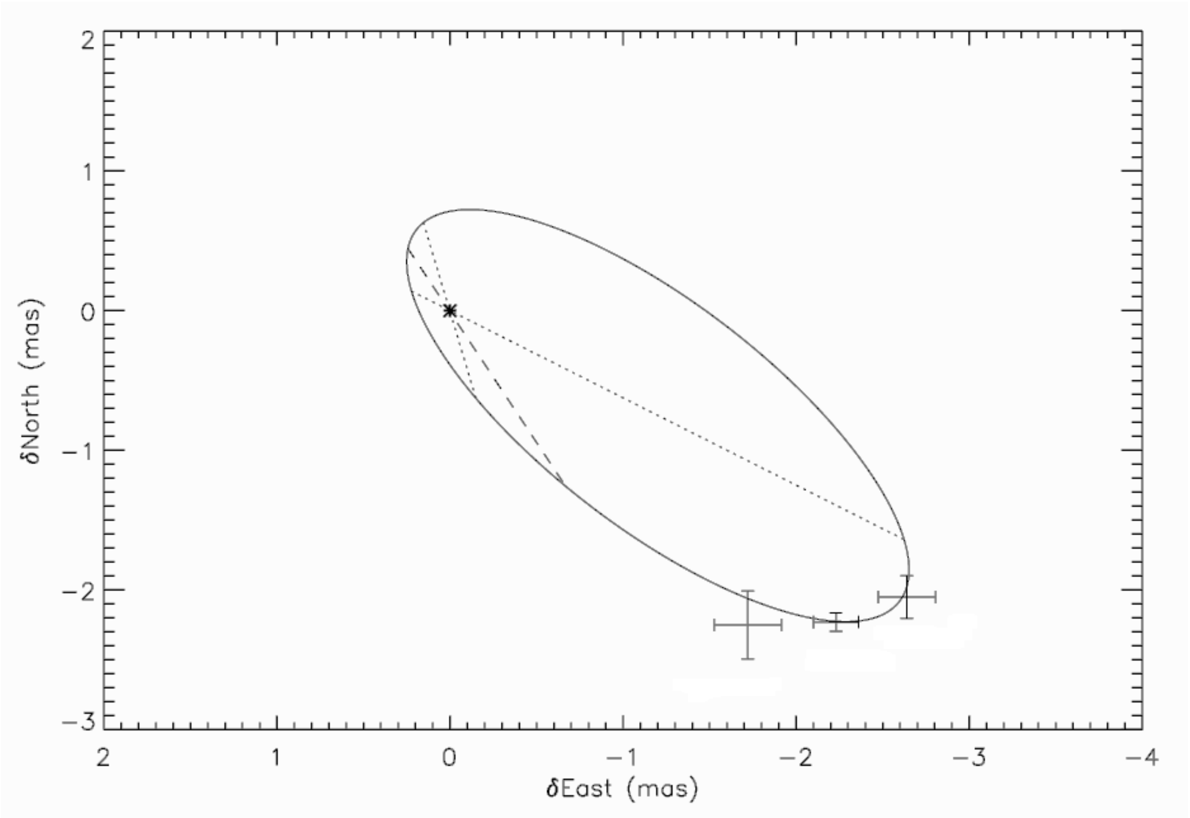
- No data around periastron – most important for determining eccentricity
- 49 spectra during 11 orbital periods



Credit: Nasseri a kol., A&A, 2014

HD 152246

- Interferometry
- PIONIER, ESO VLT
- 1.8-m Auxiliary Telescopes
- 2014
- 3 measurements in 73 days
- Only a small part of the orbit is covered



Credit: Nasseri a kol., A&A, 2014

HD 152246

- New spectra from the years 2021 a 2022
- Only one orbital period of the third star
- Mostly around the time of periastron passage
- Periastron passage predicted on 12.4.2022
- More accurate and precise orbital elements, especially eccentricity

- New & old spectra, changes of orbital elements in time

Spectra

- Spectrograph CHIRON, Cerro Tololo Inter-American Observatory, Chille
- 1.5-m telescope SMARTS
- 215 echelle spectra, resolution $R \sim$ 25 000, wavelength 450-890 nm

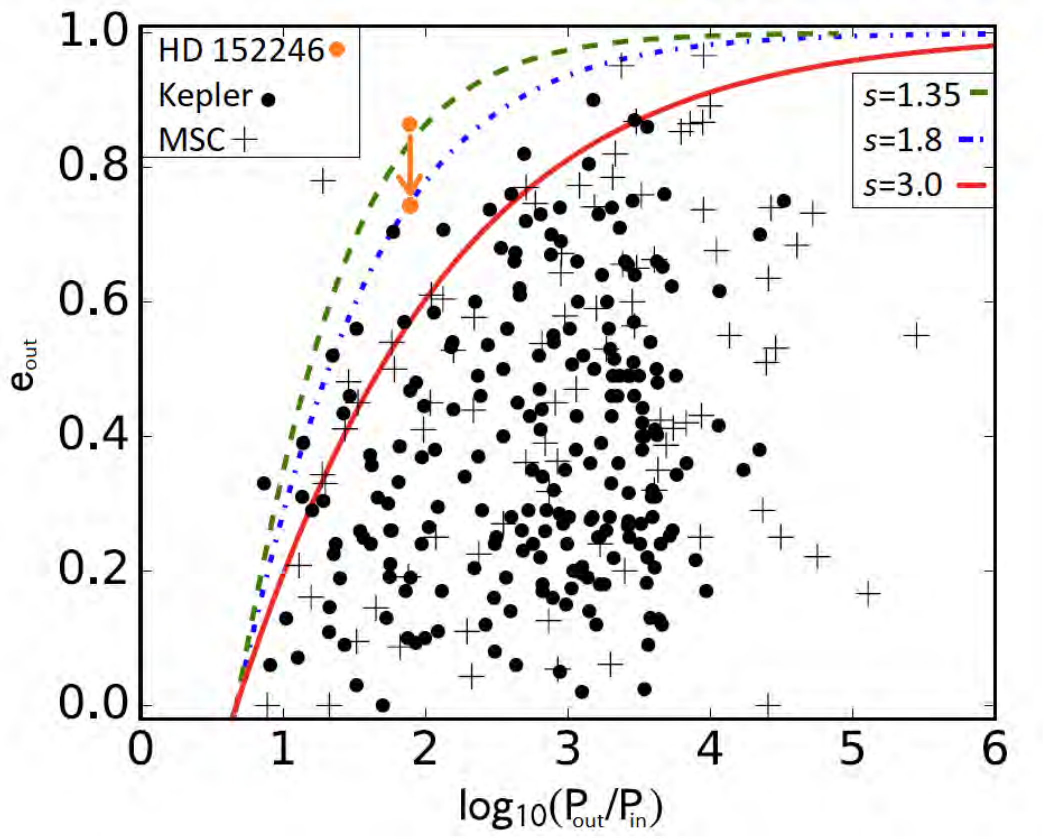
- Spectrograph HERCULES, University of Canterbury Mount John Observatory, New Zealand
- 1-m McLellan Telescope
- 62 echelle spectra, resolution $R \sim$ 41 000, 390-750 nm

KOREL

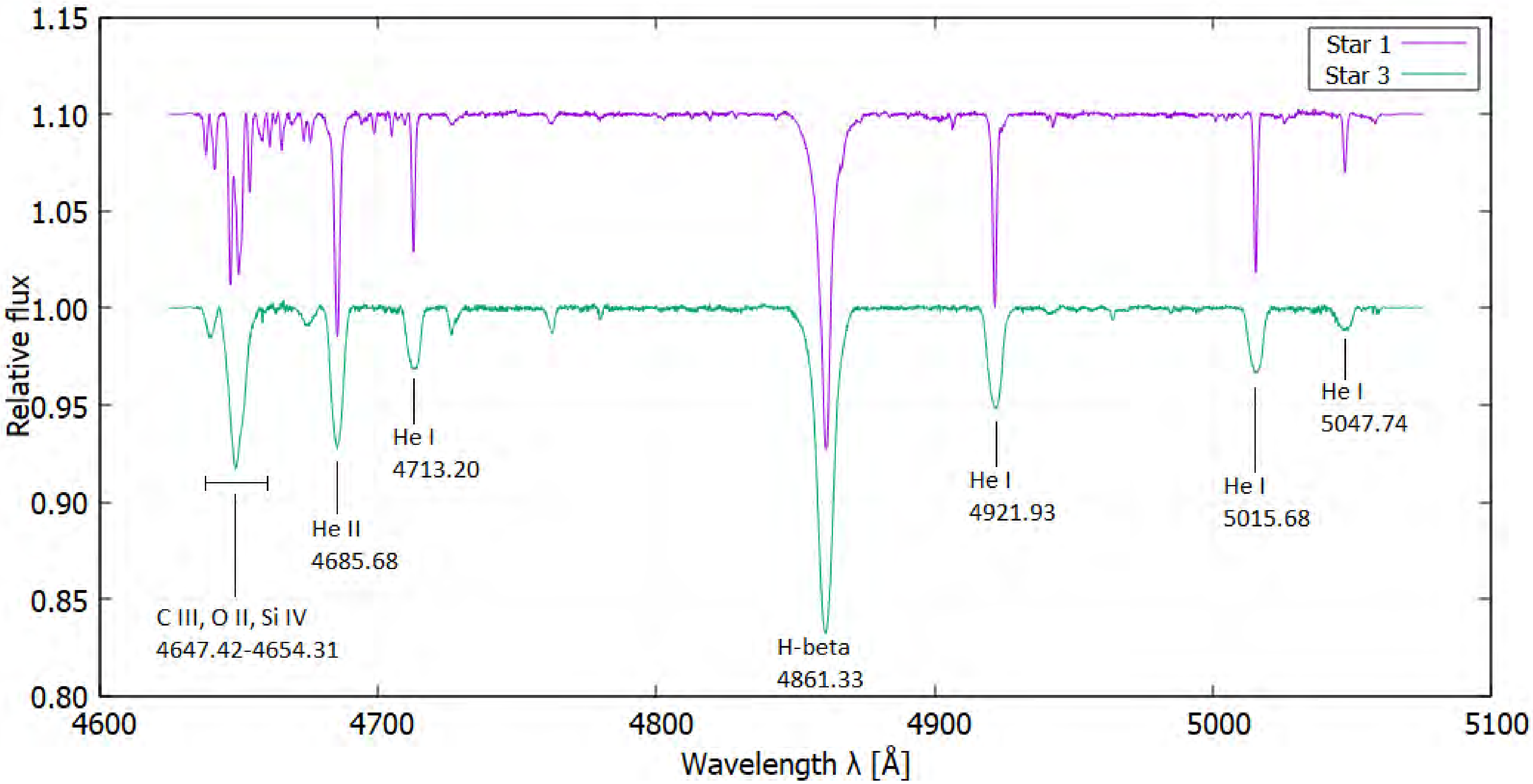
- Program uses Fourier transformation to disentangle the spectra
- Decomposition of the observed spectrum into the spectra of the individual components
- Radial velocity measurements
- Orbital elements, their time derivatives
- Before disentangling, the spectra have to be normalised

KOREL

- Periastron passage occurred on 22.4.2022 (predicted on 12.4.2022)
- No spectral lines from the 3rd star were detected
- Lower value of the eccentricity, $e = 0.75$
- The system satisfies the stability criterion

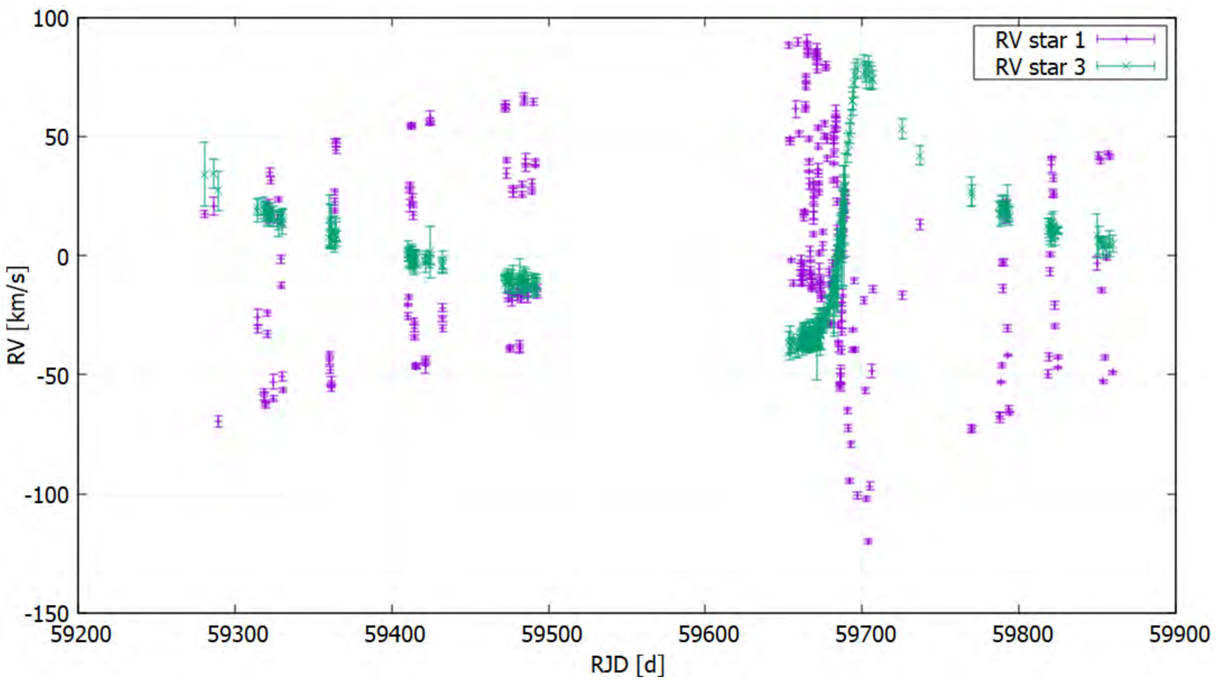


Disentangled Spectra



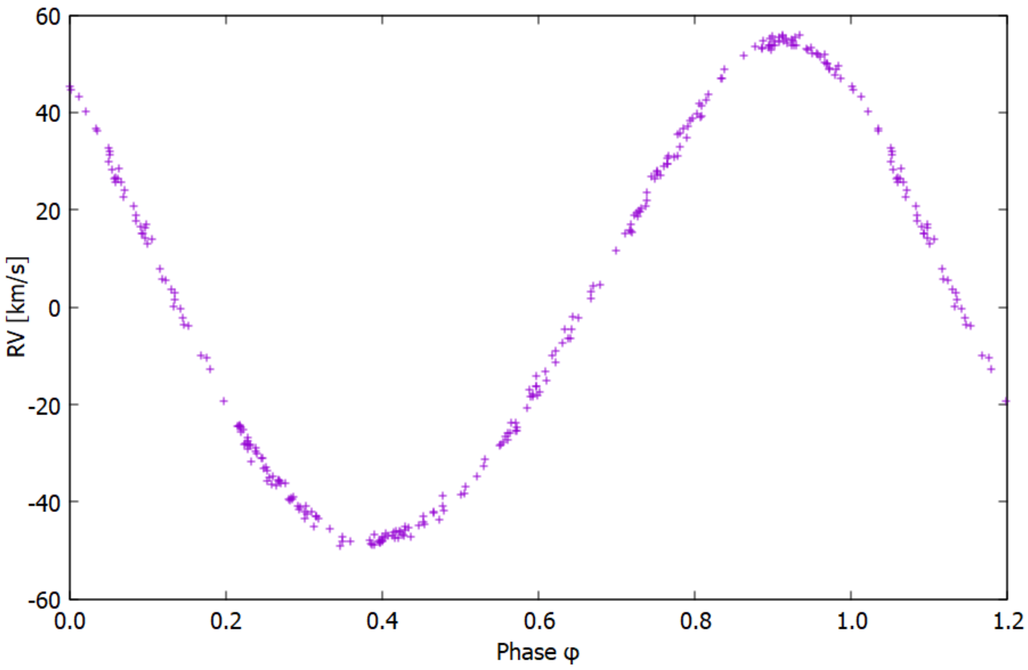
Results

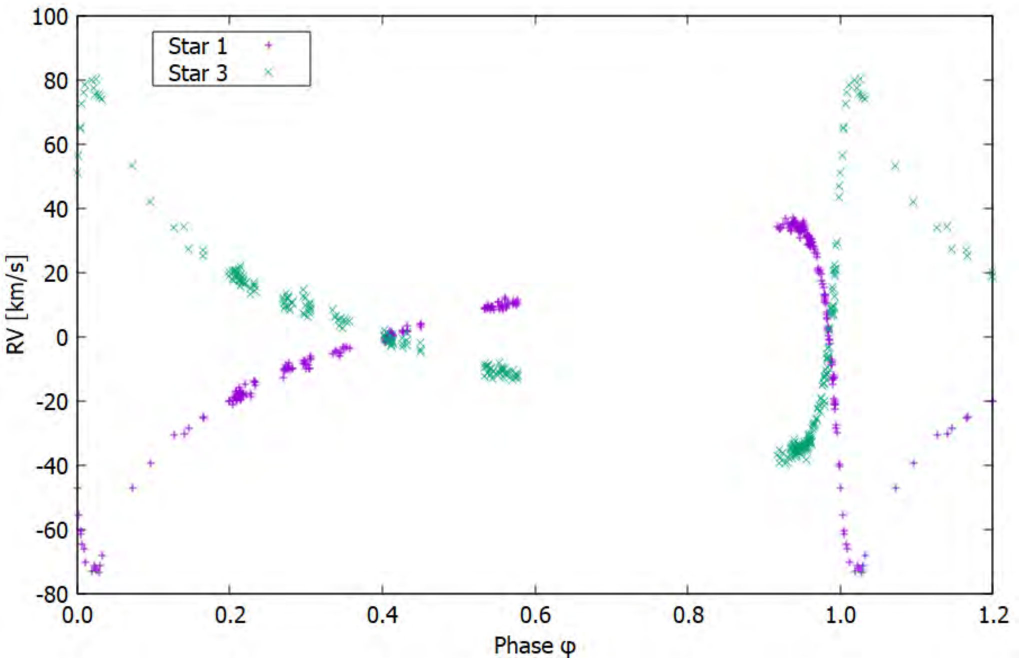
- Inner orbit: $T_p = 59671.346 \pm 0.004$, $e = 0.084 \pm 0.004$,
  $\omega_p = (37.1 \pm 0.1)°$, $K_1 = (51.15 \pm 0.32)$ km/s



- Outer orbit:
- $T_p = 59691.5 \pm 0.4$
- $e = 0.751 \pm 0.001$
- $\omega_p = (119 \pm 1)°$
- $K_{1+2} = (54.8 \pm 1.1)$ km/s
- $q = 0.96 \pm 0.07$
- $K_3 = (57.4 \pm 3.3)$ km/s

HD 152246

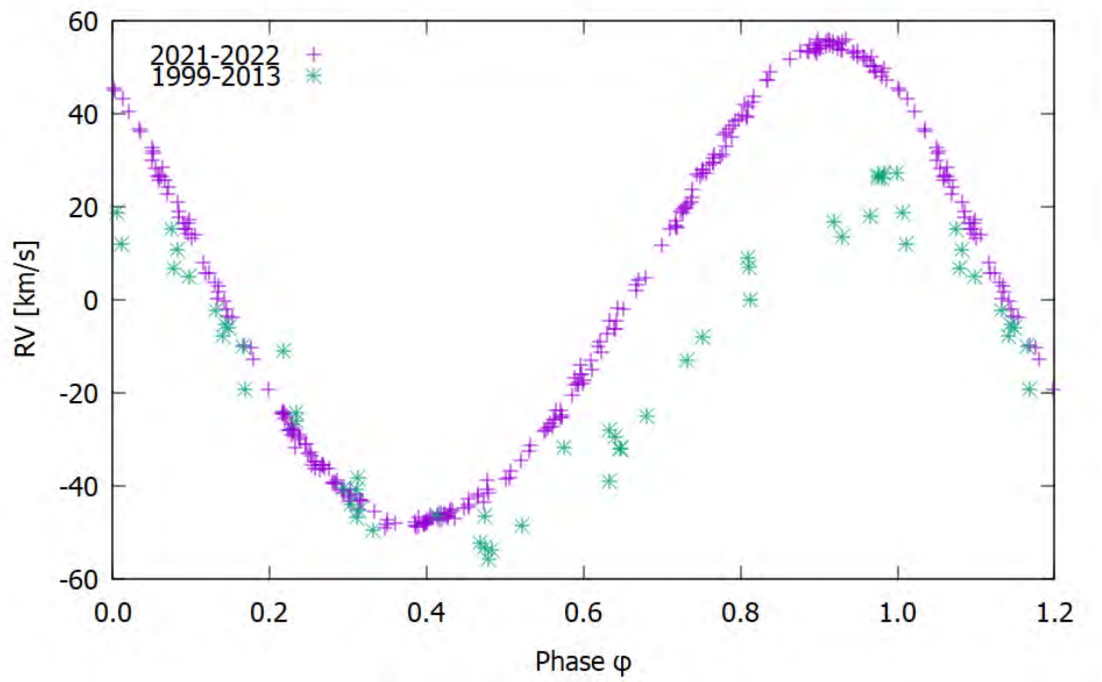




- Phase diagram - inner orbit
- Phase diagram – outer orbit

HD 152246

- Old & new spectra
- RV amplitude of the inner orbit K_1 is increasing
- Change of the inner orbit's inclination
- Possibly becomes an eclipsing binary in the future



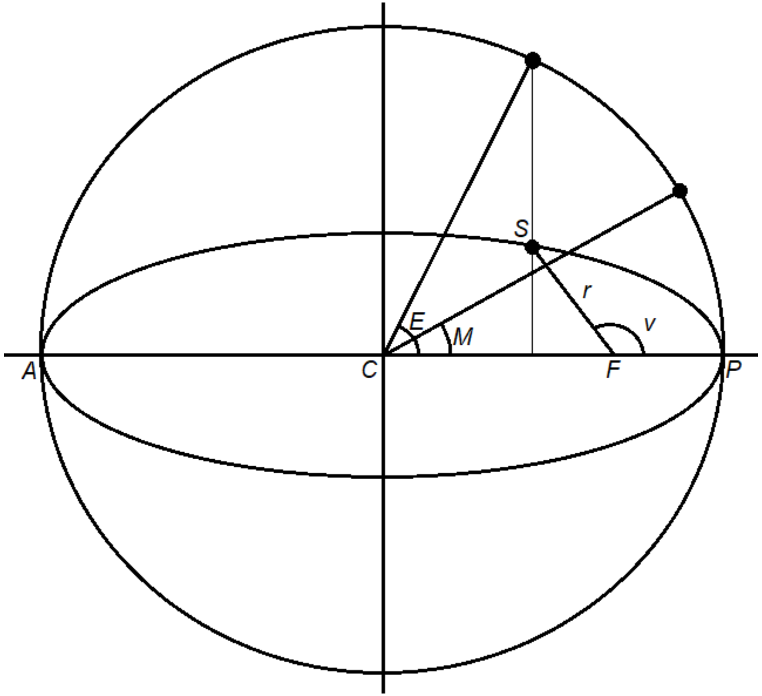
Astrometric orbit

- Projection of the orbit on the sky
- Thielle-Innes constants

$$\delta_{East} = B(\cos E - e) + G\sqrt{1-e^2}\sin E$$

$$\delta_{North} = A(\cos E - e) + F\sqrt{1-e^2}\sin E$$

- *A, B, F, G* depend on orbital elements:
- Angular size of semi-major axis α
- Inclination i
- Argument of periastron ω_p
- Longitude of ascending node Ω

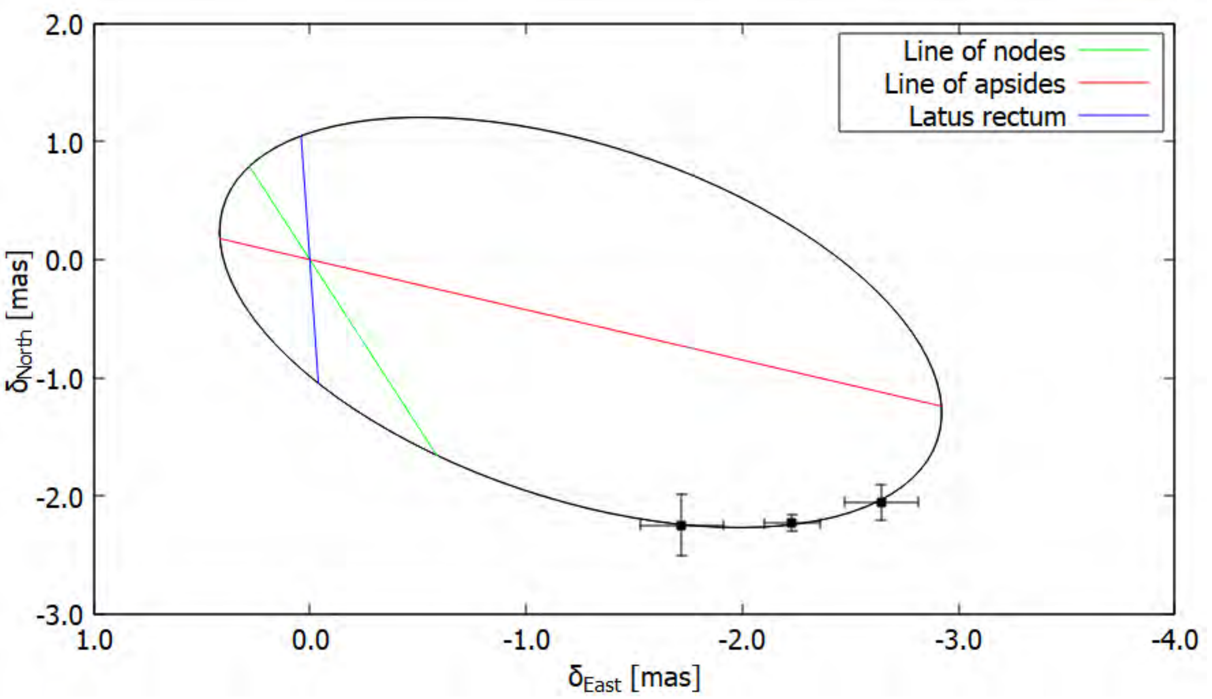


Astrometric orbit

- Eccentricity, time of peristron passage are known from spectroscopy
- $\alpha = (2.6 \pm 0.1)$ mas
- $i = (126 \pm 3)°$
- $\omega_p = (118.1 \pm 2.5)°$
- $\Omega = (19.5° \pm 2.5)°$
- Semi-major axis:

  $a = 3.95$ au
- Masses of the components:

  $M_1 + M_2 = 18.9\ M_\odot, \quad M_3 = 18.2\ M_\odot$



Further Observations

- Observations with spectrograph CHIRON
- Verification of the change of the inner orbit’s inclination
- Periastron passage of the outer orbit will occur on 5.8.2023
- Next 470-days period

- New interferometric measurements available in summer 2023
- More precise astrometric orbit

Conclusion

- Correction of the eccentricity value, other orbital elements determined more precisely
- Disentangling of spectra, only the 2 bright stars
- System is close to the border of dynamically stable region
- Changes of the inclination of the inner orbit
- The inner binary might become an eclipsing binary
- Astrometric orbit
- Size of the orbit, masses of the stars