Sub-percent mass determination of bright binaries with CHARA/SPICA

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Introduction

Mass is a fundamental stellar parameter, driving the star's structure, evolution and final fate. Various methods exist to measure stellar masses, each with different viability and precision. The most direct and precise measurements are obtained from **binary systems** through the mutual gravitational interaction between the components. However, the derived mass is strongly tied to the **orbital inclination**, which cannot be measured by spectroscopy alone, thus requiring independent measurements from eclipses or astrometry. **Long-baseline interferometry** can resolve orbits down to ≈ 1 mas, effectively turning spectroscopic binaries into astrometric binaries.

β Aurigae

β Aurigae (Menkalinan) is a very bright ($V1.9$) binary, consisting of two almost equally massive A1 stars [1]. It was one of the first spectroscopic and eclipsing binaries discovered. The stars are slightly evolved, making them interesting for stellar evolution models.

We selected this system because of the already extensive available data – spectroscopy spanning more than a hundred years and excellent precision photometry with the WIRE satellite. This allowed us to validate our methodology by comparison with previous publications.

Fig. 1 (top): β Aur on the night sky.

Methods

- 9 observations of β Aur during 7 nights at CHARA
- Simultaneous observations using **CHARA/SPICA** [2], **MIRC–X**, and **MYSTIC**
- Included unpublished archival data from MIRC
- Simultaneous modelling of
  - radial velocities
  - photometry
  - interferometric observables – squared visibilities and closure phases
- `ellc` [3] and `oimodeler` [4]

Orbit

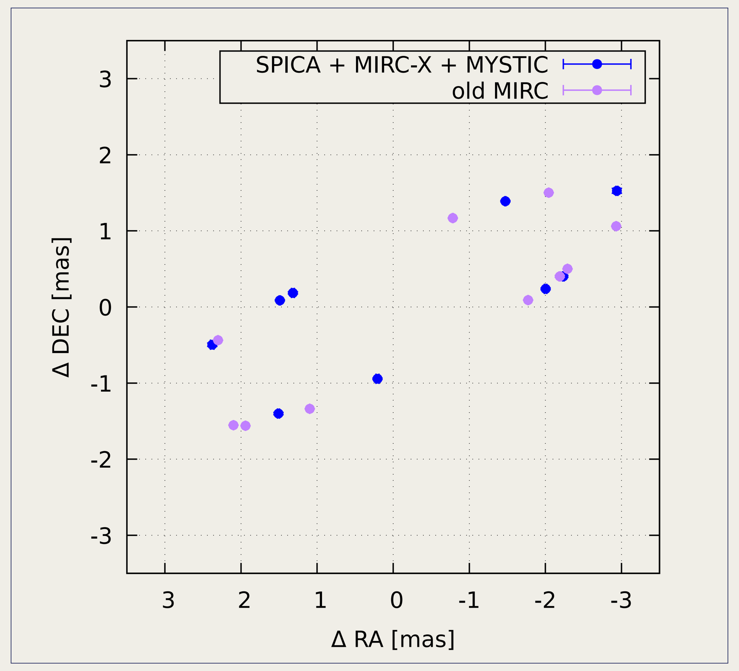


Fig. 2 (top): Reconstructed visual orbit of β Aur – position of the secondary in time, derived from our observations.

Simultaneous modelling of RV, LC and interferometry

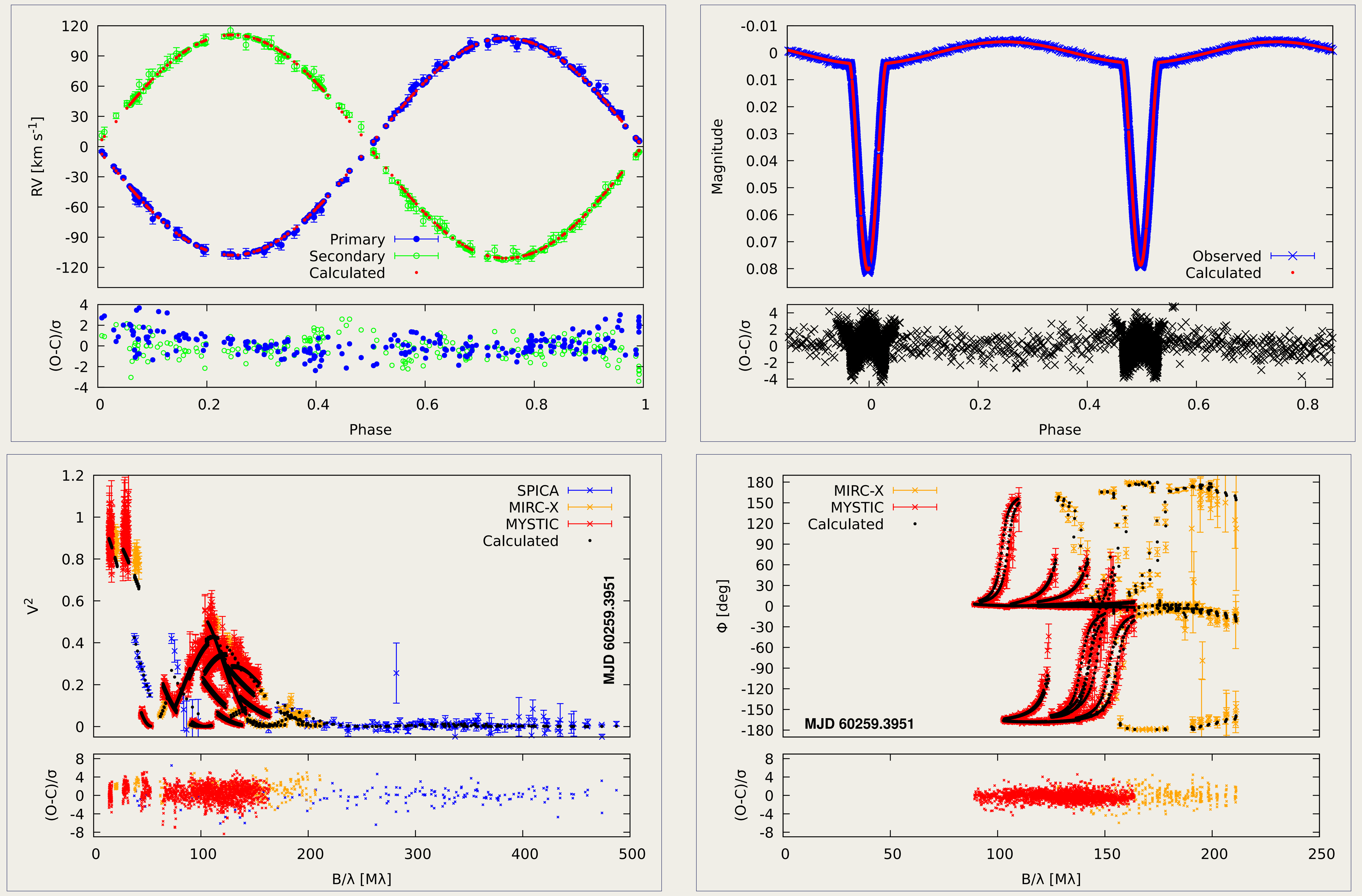


Fig. 3: Comparison between the observed data and the best-fitting model: radial velocities (top left), light-curve (top right), and one epoch (Nov 11 2023) of squared visibilities V^2 (down left) and closure phases Φ (down right).

Result

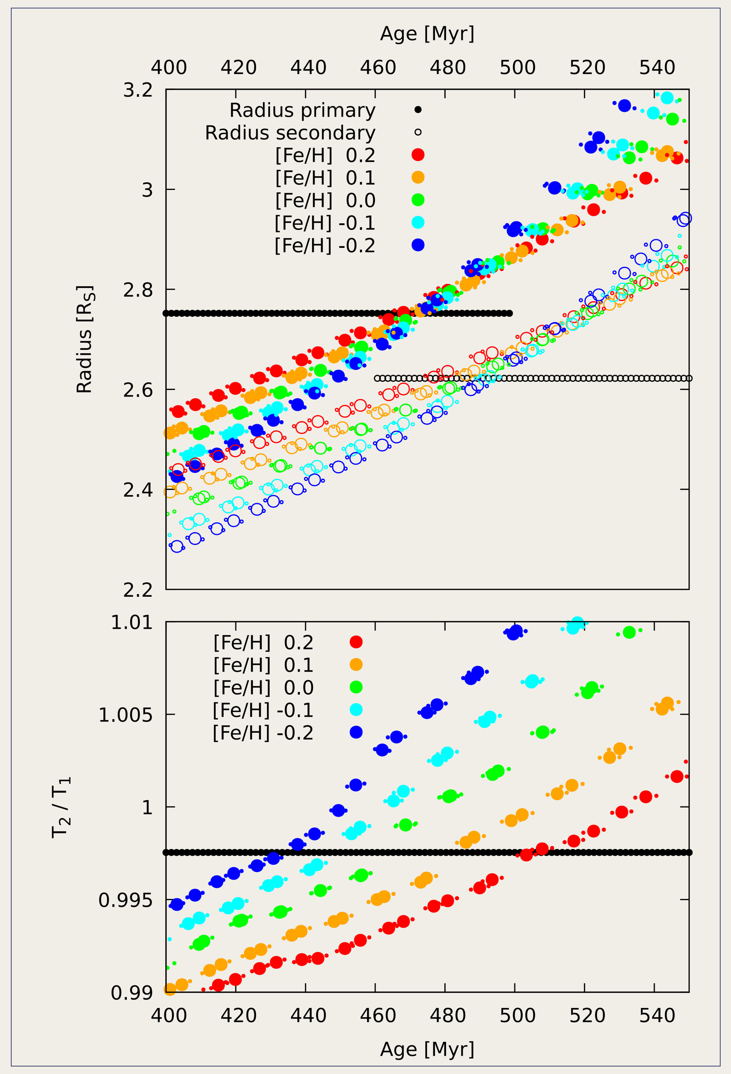
Primary	
M_1 [$M_\odot$]	2.359 $\pm$ 0.005 0.20%
R_1 [$R_\odot$]	2.752 $\pm$ 0.002 0.06%
Secondary	
M_2 [$M_\odot$]	2.293 $\pm$ 0.004 0.19%
R_2 [$R_\odot$]	2.622 $\pm$ 0.002 0.06%
d [pc]	24.30 $\pm$ 0.05 0.21%

Table 1: Result parameters of our model, the masses and radii of the two components, as well as the derived distance. Both absolute and relative uncertainty are displayed.

Simultaneous modelling allowed us to achieve **0.2% precision** on the mass of both components and on the distance to the system.

Comparison with stellar evolutionary tracks indicates a consistent age estimation of approximately 480 Myr for both components. However, more detailed evolutionary modelling is required.

Fig. 4 (right): Comparison with theoretical stellar evolution tracks of the two stars for the radii (top) and temperature ratio (bottom). In the top figure, the primary is plotted with full circles, the secondary with empty ones. Evolution tracks corresponding to the 1σ uncertainty of mass are represented by smaller points.



Further details are available in Jonák, J., Mourard, D. et al. (2026), A&A, in press.

Future prospects

Our next goal is to apply our methodology to a large sample of spectroscopic and eclipsing binaries, using CHARA/SPICA, MIRC–X, MYSTIC and VLTI/PIONIER.

We identified a large sample of viable objects spanning from **late-O to mid-K** spectral types. Analysis of additional systems is ongoing.

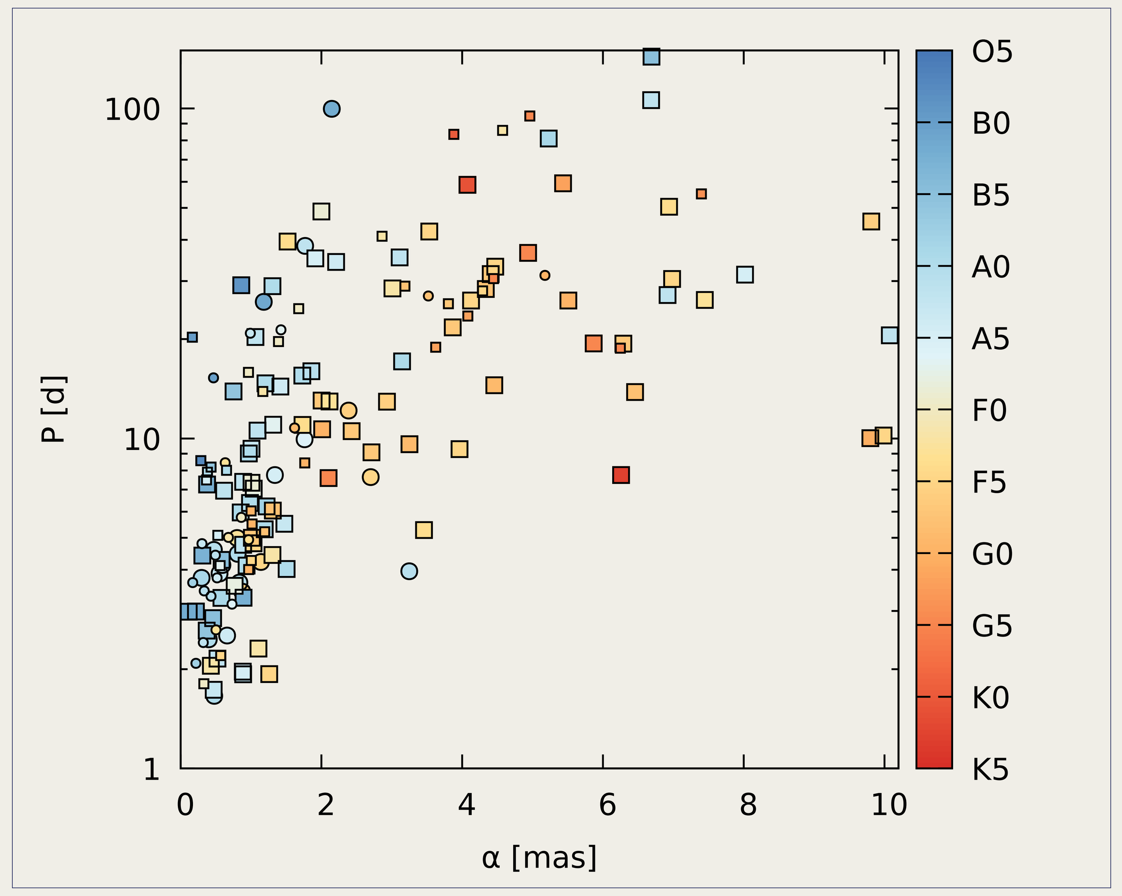


Fig. 5: Sample of our further targets, distribution of period and semimajor axis. Spectroscopic binaries are denoted as squares, while eclipsing as circles. The colours correspond to the spectral type of the primary component. Objects of smaller size are less bright ($V > 7$).

Conclusion

The combination of spectroscopy, photometry and interferometry in a self-consistent model can greatly improve our understanding of spectroscopic binaries and can deliver sub-percent mass precision. For the first time, we used data from the new SPICA instrument into a multi-chromatic interferometric analysis.

References

[1] Southworth, J. et al. (2007), A&A, 467, 1215S
[2] Mourard, D. et al. (2026), A&A, in review
[3] Maxted, P. (2016), A&A, 591, A111
[4] Meilland, A. et al. (2024), SPIE Conf. Series