Towards sub-km/s Radial Velocities of Galactic Centre S-stars with ERIS

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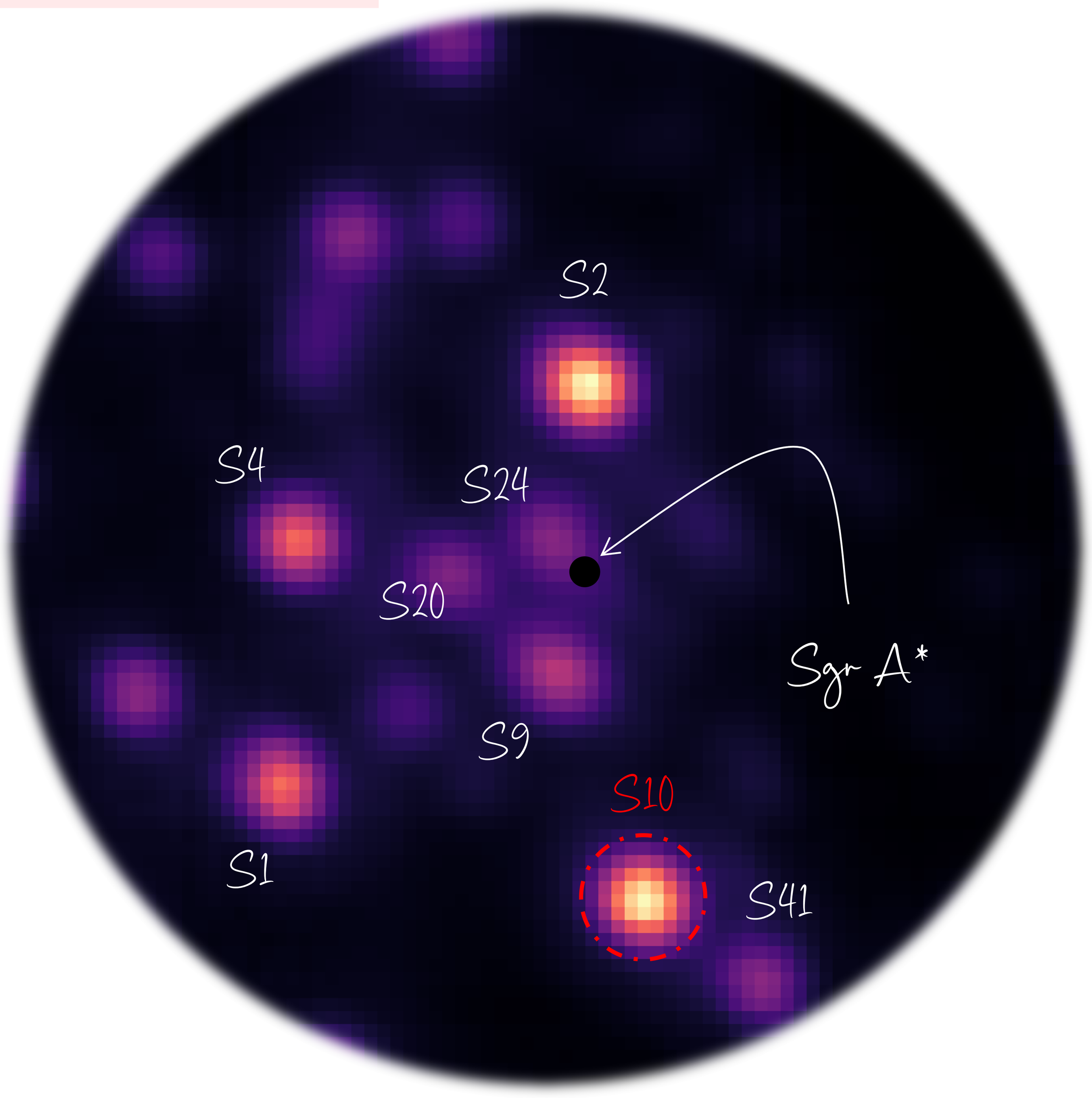
on behalf of the MPE Infrared Galactic Center Team

Why S-star RVs matter?

S-stars orbiting Sgr A* are unique laboratories for testing General Relativity in the strong-field regime. Precise RVs allow us to constrain the spin of the supermassive black hole and probe the *no-hair theorem,* a cornerstone prediction of GR. Previous studies (Waisberg et al. 2018) assumed RV precision of only a few tens of km/s.

Using ERIS at the VLT, we demonstrate that sub-km/s precision is achievable. This opens a new observational window for black-hole physics and substantially tightens the orbital solutions for the inner S-stars.



Snapshot of Galactic Centre taken by ERIS in 2024 (MPE IR GC Team)

What precision can ERIS achieve?

To establish the noise-limited RV floor, we inject realistic detector noise into synthetic spectra and repeat the cross-correlation over 500 realisations. This isolates how RV scatter depends on S/N, K mag, and detector integration time (DIT).

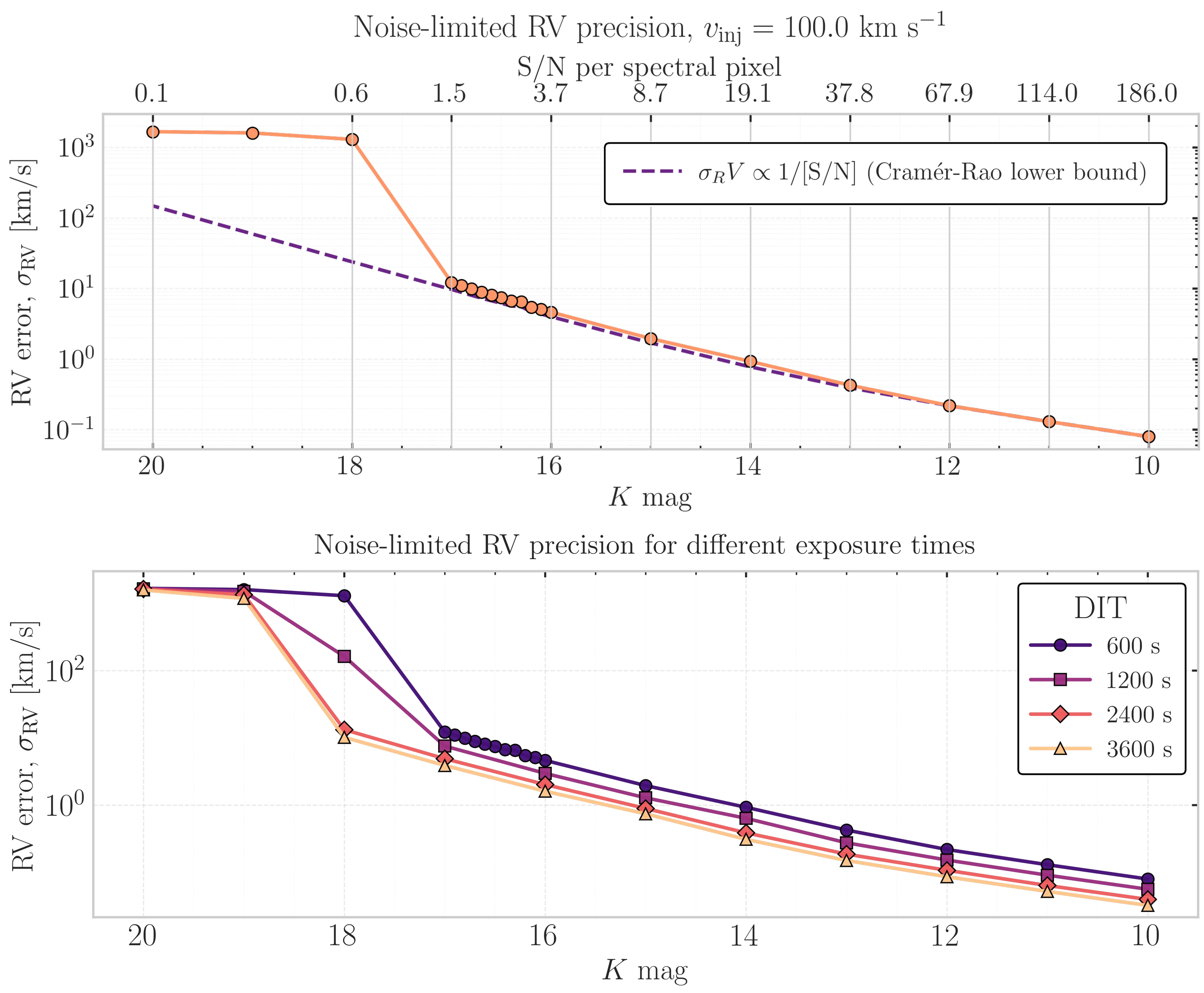
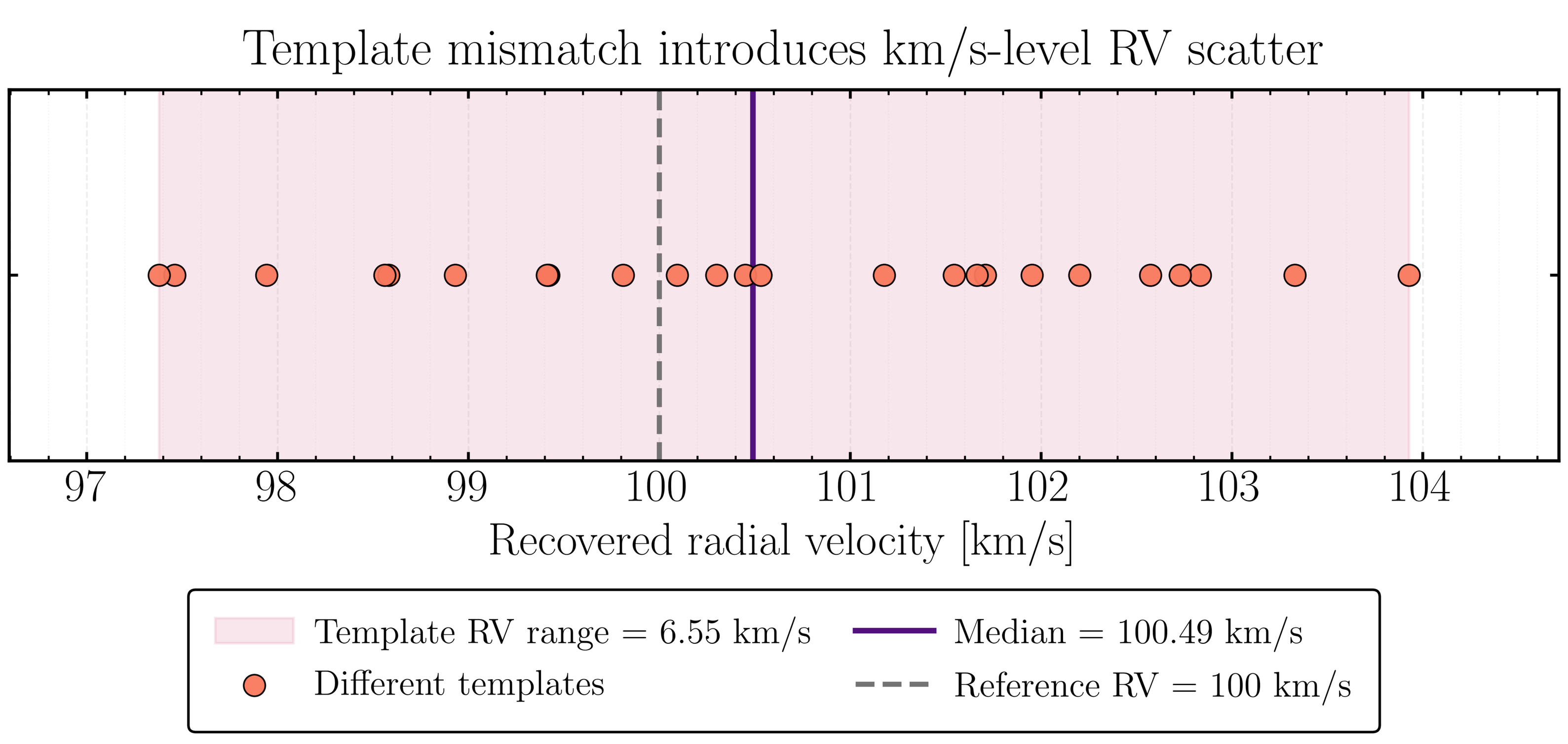


Fig. 2: ***Noise-limited RV precision.***

Top: *RV scatter vs K-band magnitude/(S/N) shows ERIS reaches the Cramér-Rao lower bound.* ***Bottom:*** *increasing DIT systematically improves precision.*

Template mismatch is a key systematic: varying T_{eff} across 2300–4000 K for the S10 spectrum produces km/s-level RV scatter. Precise stellar parameter retrieval, via template-grid fits, is therefore essential to achieve sub-km/s accuracy in practice.



Measuring the RVs

RVs are measured using **maximum likelihood cross-correlation** method (Zucker 2003) with the PHOENIX stellar templates. The technique:

- Transform wavelength to log(λ), so Doppler shifts become translations
- Cross-correlate template & observation via FFT
- Express the normalised CCF as a likelihood (Gaussian noise)
- Peak of the likelihood → RV; curvature of the likelihood → σ_{RV}
- Precision is set directly by the CCF sharpness (Fisher information)

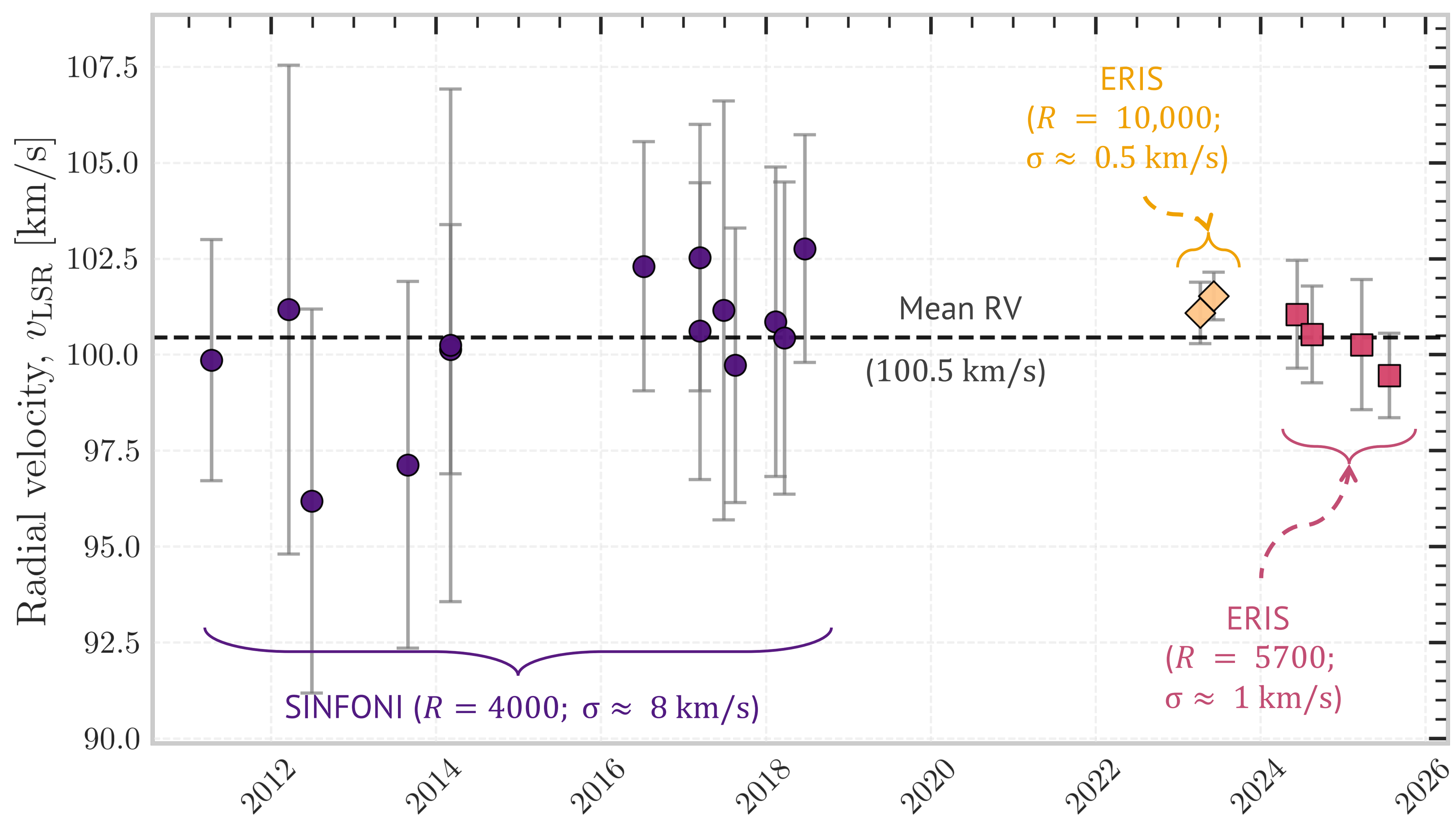


Fig. 1: ***S10 RV monitoring spanning a decade.***
The significant shrinkage of error bars directly showcases the precision leap.

Characterising S-stars with ERIS

Stellar parameters are determined with ForMoSA (Forward Modelling tool for Spectral Analysis; Petrus et al. 2023) – a Bayesian framework for spectral fitting. Using the PHOENIX New Era model grid (Hauschildt et al. 2025), we simultaneously retrieve $T_{eff}, \log g, [Fe/H], and\ RV$ from ERIS K-band spectra. Constraining stellar parameters per target reduces template-driven systematics in RV measurements and enables a census of the inner-parsec stellar population.

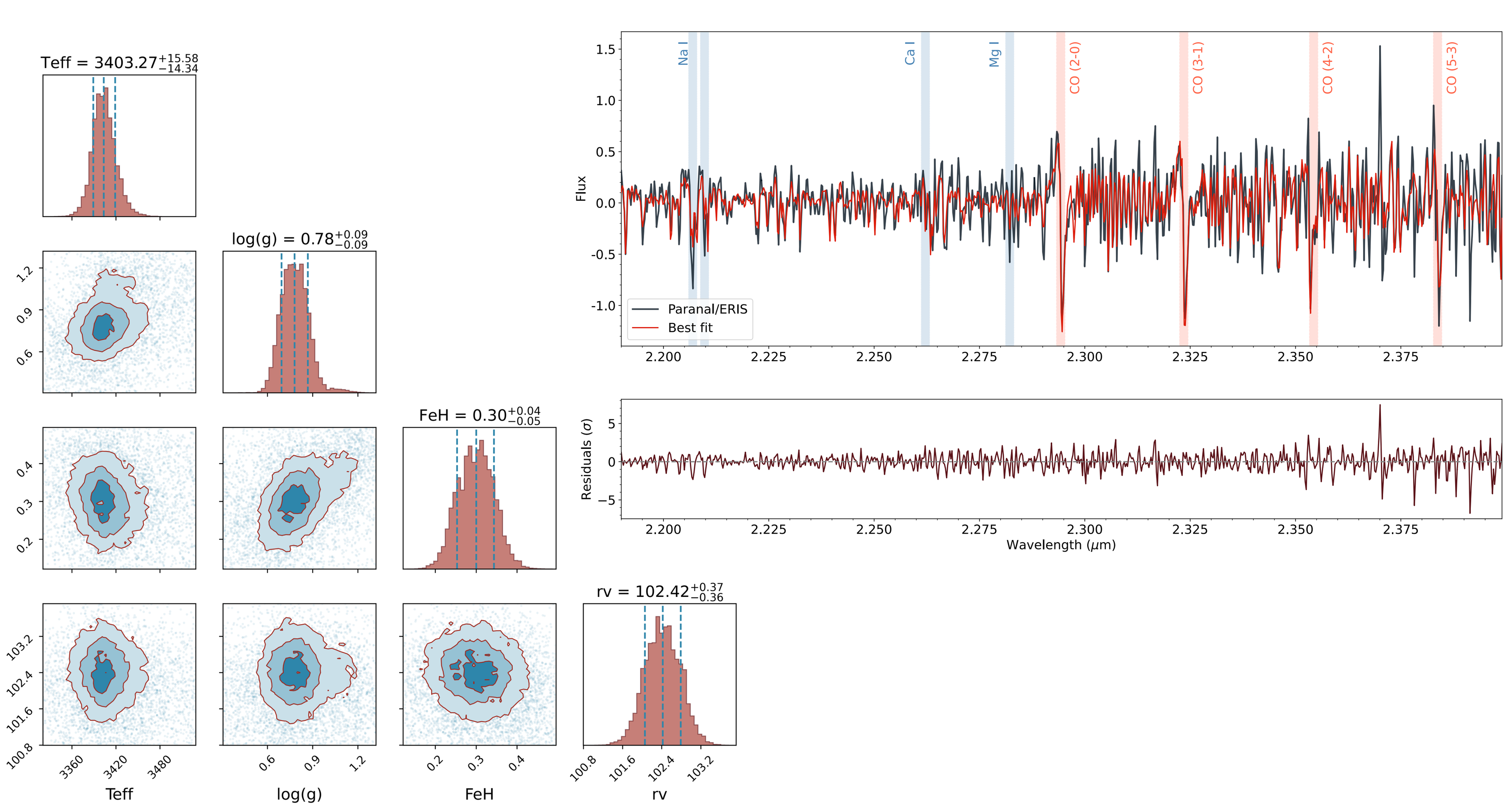


Fig. 4 – ***ForMoSA posterior for S10.***
The well-constrained corner contours demonstrate that ERIS K-band spectra contain sufficient information to break parameter degeneracies. Best-fit RV = 102.42 km/s.

References

[1] Zucker, S. (2003), *MNRAS*, **342**, 1291 [2] Waisberg, I. et al. (2018), *MNRAS*, **476**, 3600 [3] Petrus, S. et al. (2023), *A&A*, **670**, L9 [4] Hauschildt, P. H. et al. (2025), *A&A*, in press

Acknowledgements

S.J. acknowledges support from the MPE Infrared/Submillimetre Group. This work is based on observations collected at the ESO under GTO program. S.J. also thanks Bhavesh Rajpoot from the ForMoSA dev team to provide the code and set it up for GC observations.

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