EXOPLANETS
IN HIERARCHICAL TRIPLE SYSTEMS

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Detection and Dynamics of Exoplanets (DDE)

Coimbra, 9 July 2025

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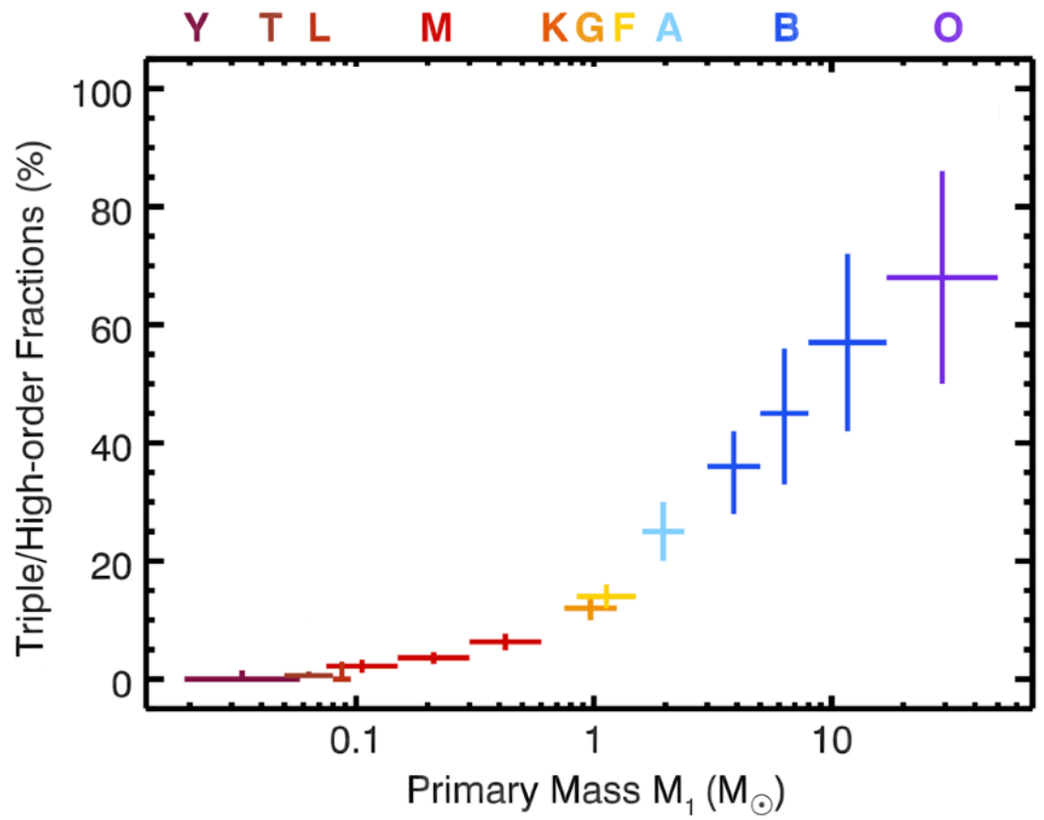
Triple stellar systems

Triple systems

May be underestimated

- **Binary** stars and **high-order** systems are typical products of star formation
- Long-term **dynamical stability** requires a clear separation of orbits: a close inner binary and a distant tertiary star (a_{out} >> a_{in})
- Triple systems account for **~12%** of all solar-type dwarfs in multiple systems[1,2]
- Most known triples and higher-order multiples are **random discoveries**, not the result of systematic surveys

True population of hierarchical triples is likely **underestimated**[3,4]



Adapted from Offner et al. (2023)

[1,2] Raghavan et al. (2010), Tokovinin et al. (2014)

[3,4] Mugrauer et al. (2019), Cifuentes et al. (2025)

Triple systems

1 From compact binaries

Tertiary companions to close spectroscopic binaries★,★★,★★★

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Received 27 October 2005 / Accepted 29 December 2005

ABSTRACT

We have surveyed a sample of 165 solar-type spectroscopic binaries (SB) with periods from 1 to 30 days for higher-order multiplicity. A subsample of 62 targets were observed with the NACO adaptive optics system and 13 new physical tertiary companions were detected. An additional 12 new wide companions (5 still tentative) were found using the 2MASS all-sky survey. The binaries belong to 161 stellar systems; of these 64 are triple, 11 quadruple and 7 quintuple. After correction for incompleteness, the fraction of SBs with additional companions is found to be 63% ± 5%. We find that this fraction is a strong function of the SB period P, reaching 96% for $P < 3^d$ and dropping to 34% for $P > 12^d$. Period distributions of SBs with and without tertiaries are significantly different, but their mass ratio distributions are identical. The statistical data on the multiplicity of close SBs presented in this paper indicates that the periods and mass ratios of SBs were established very early, but the periods of SB systems with triples were further shortened by angular momentum exchange with companions.

Tokovinin et al. (2006)

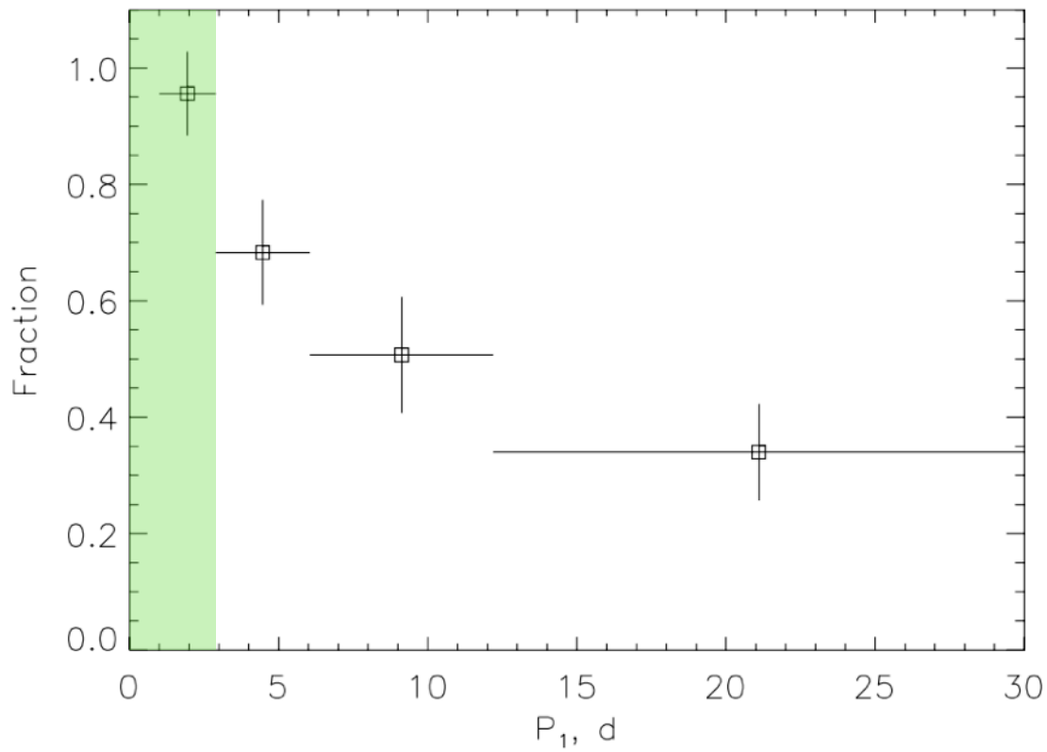
Triple systems

1 From compact binaries

Tertiary companions to close sp

A. Tokovinin[1], S. Thomas[1], M

The frequency of TCs is 63% for the whole SB sample. However, it is a strong function of the SB period, reaching 96% for the close ($P_1 < 3^d$) SBs and decreasing to 34% for SBs with $P_1 > 12^d$ (Fig. 14). The last number is less than the companion frequency of ~50% for G-dwarfs in the field. These results are robust because the TC detection does not depend on the SB period.



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Triple systems

2 From wide binaries

SUBSYSTEMS IN NEARBY SOLAR-TYPE WIDE BINARIES*

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Received 2010 April 13; accepted 2010 June 4; published 2010 July 1

ABSTRACT

We conducted a deep survey of resolved subsystems among wide binaries with solar-type components within 67 pc of the Sun. Images of 61 stars in the *K* and *H* bands were obtained with the Near-Infrared Coronagraphic Imager adaptive-optics instrument on the 8 m Gemini-South telescope. Our maximum detectable magnitude difference is about 5 mag and 7.8 mag at 0.″15 and 0.″9 separations, respectively. This enables a complete census of subsystems with stellar companions in the projected separation range from 5 to 100 AU. Out of seven such companions found in our sample, only one was previously known. We determine that the fraction of subsystems with projected separations above 5 AU is 0.12 ± 0.04 and that the distribution of their mass ratio is flat, with a power-law index of 0.2 ± 0.5. Comparing this with the properties of closer spectroscopic subsystems (separations below 1 AU), it appears that the mass-ratio distribution does not depend on the separation. The frequency of subsystems in the separation ranges below 1 AU and between 5 and 100 AU is similar, about 0.15. Unbiased statistics of multiplicity higher than 2, advanced by this work, provide constraints on star formation theory.

Tokovinin et al. (2010)

Triple systems

2 From wide binaries

We surveyed 33 nearby wide binaries with solar-type primaries and found seven resolved subsystems, most of them previously unknown. We derive the fraction of subsystems with projected separations from 5 to 100 AU to be 0.12 ± 0.04. The mass-ratio distribution in these subsystems appears to be flat, to within a large statistical error.

[2] Gemini Observat d@gemini.edu

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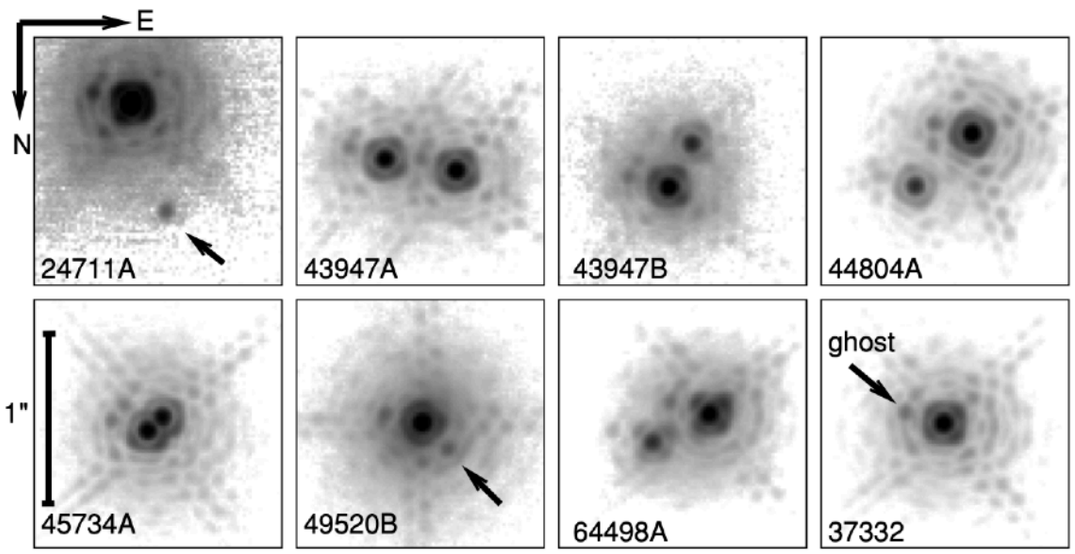
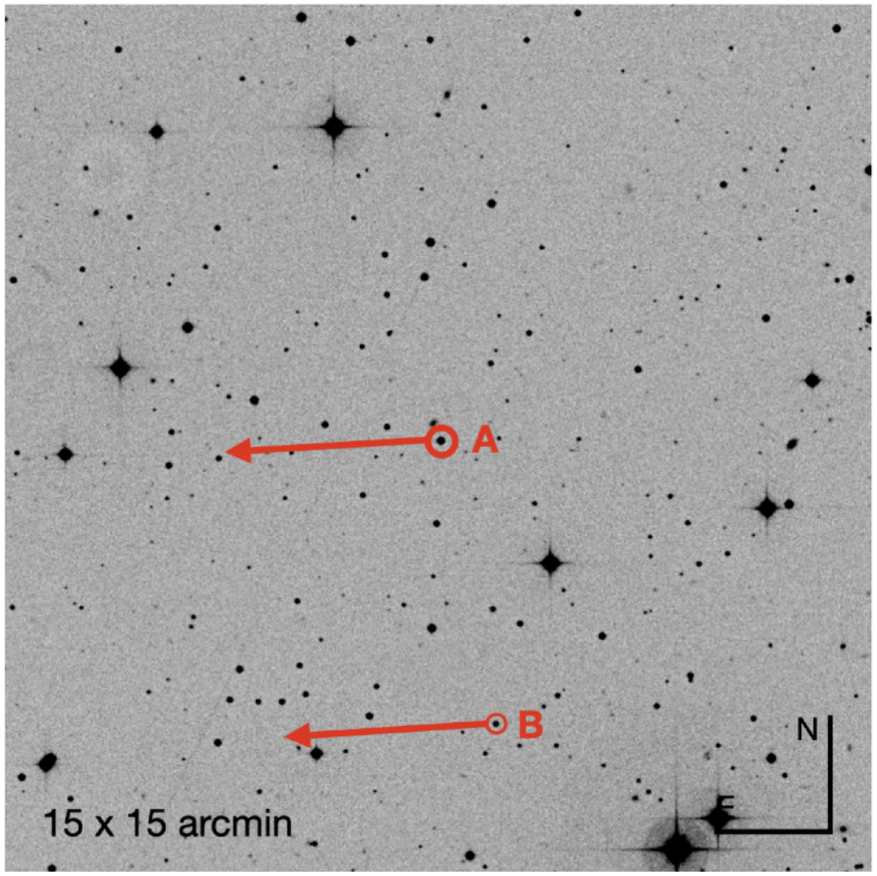


Tokovinin et al. (2010)

Triple systems

3 From anomalous astrometry



WDS 00212-4246

s = 9392 au

Component	**A**	**B**	
SpT	M4.5 V	m5 V	
α	01:56:45.99	01:56:41.74	
δ	+30:33:28.6	+30:28:34.6	
π	31.850 ± 0.076	26.645 ± 0.044	mas
$\mu_\alpha \cos\delta$	210.625 ± 0.092	208.183 ± 0.042	mas a^{-1}
μ_δ	-13.523 ± 0.090	-13.464 ± 0.044	mas a^{-1}
γ	...	...	km s^{-1}
G	13.5151 ± 0.0029	15.1596 ± 0.0028	mag
J	10.323 ± 0.023	11.917 ± 0.023	mag
L	98.6 ± 1.4	31.72 ± 0.46	$10^{-4} L_\odot$
$T_{\rm eff}$	3100 ± 50	3100 ± 50	K
$\mathcal{M}$	0.287	0.153	$\mathcal{M}_\odot$
RUWE	4.582	1.109	
Qflag 2MASS	AAA	AAA	
Qflag AllWISE	AAAB	AAAU	

Cifuentes et al. (2021)

Triple systems

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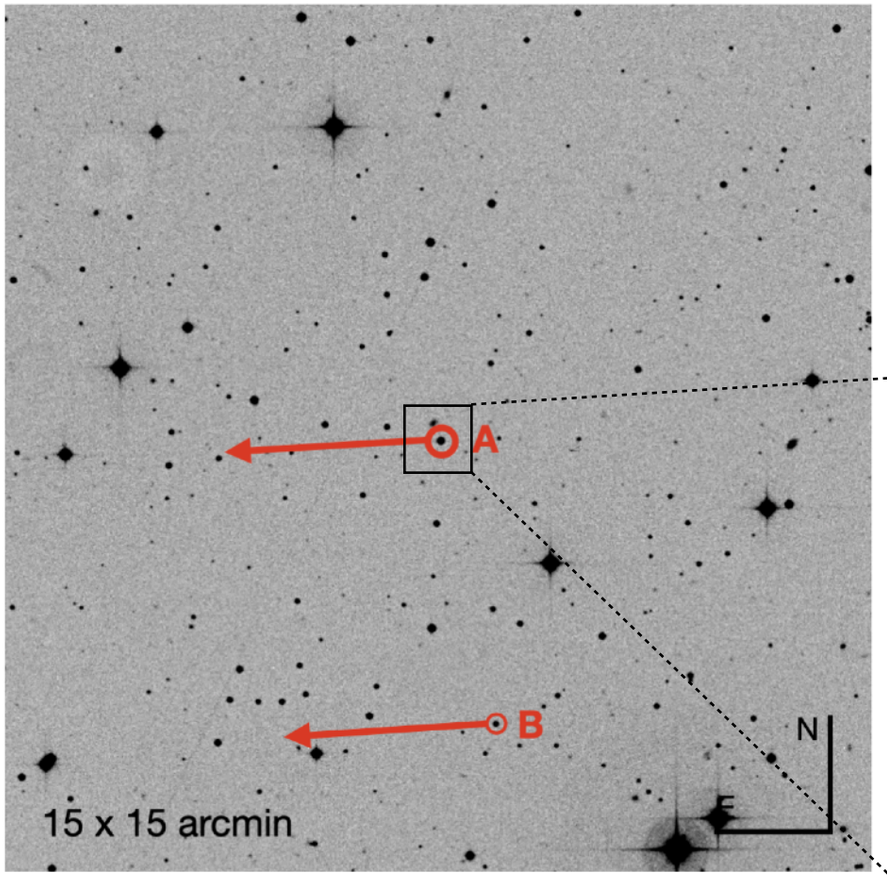

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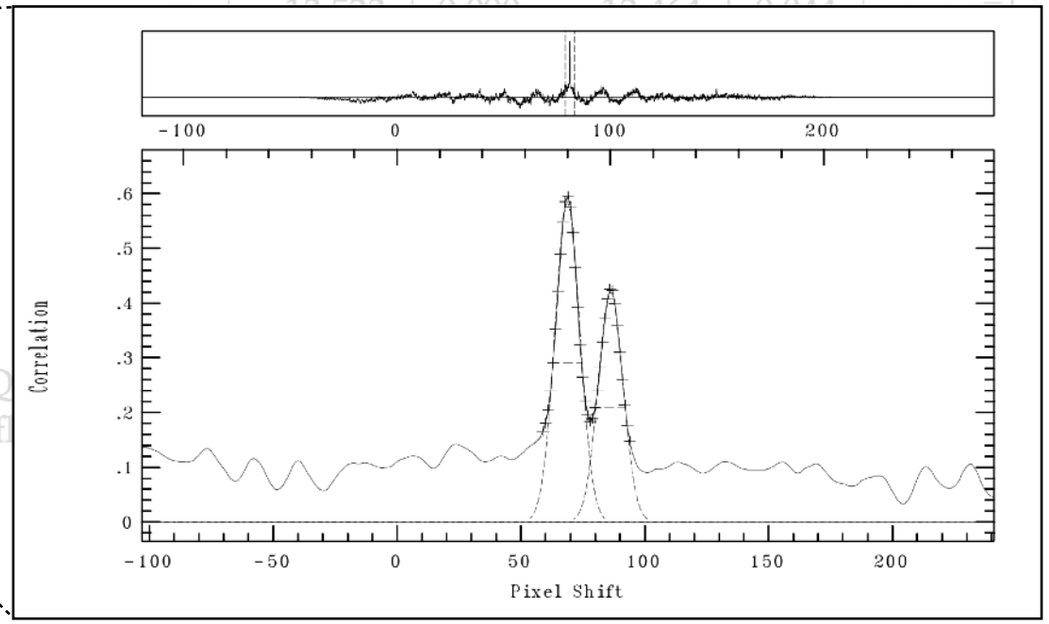


Probably an SB2

Cifuentes et al. (in prep.)

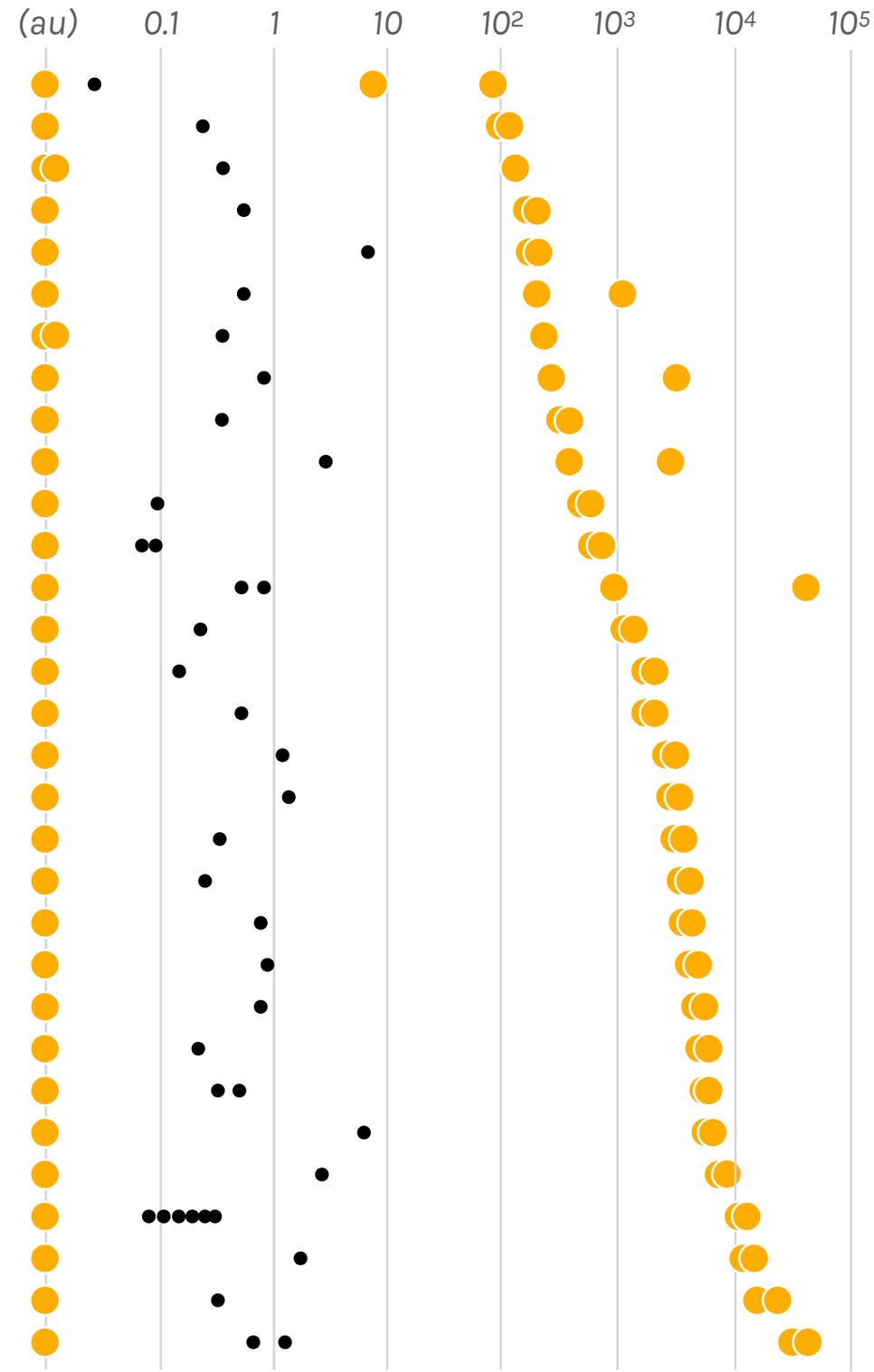
2

Planets in triple systems

Planets in triple systems

Current population

- **Around 30 exoplanets** are confirmed in triple star systems (**~0.5%** of the total planet population)*.
- Most are long-period **gas giants**, often found **serendipitously.**
- Their **planetary architectures are diverse** but poorly constrained, and often incomplete.



Thebault et al. (2025)
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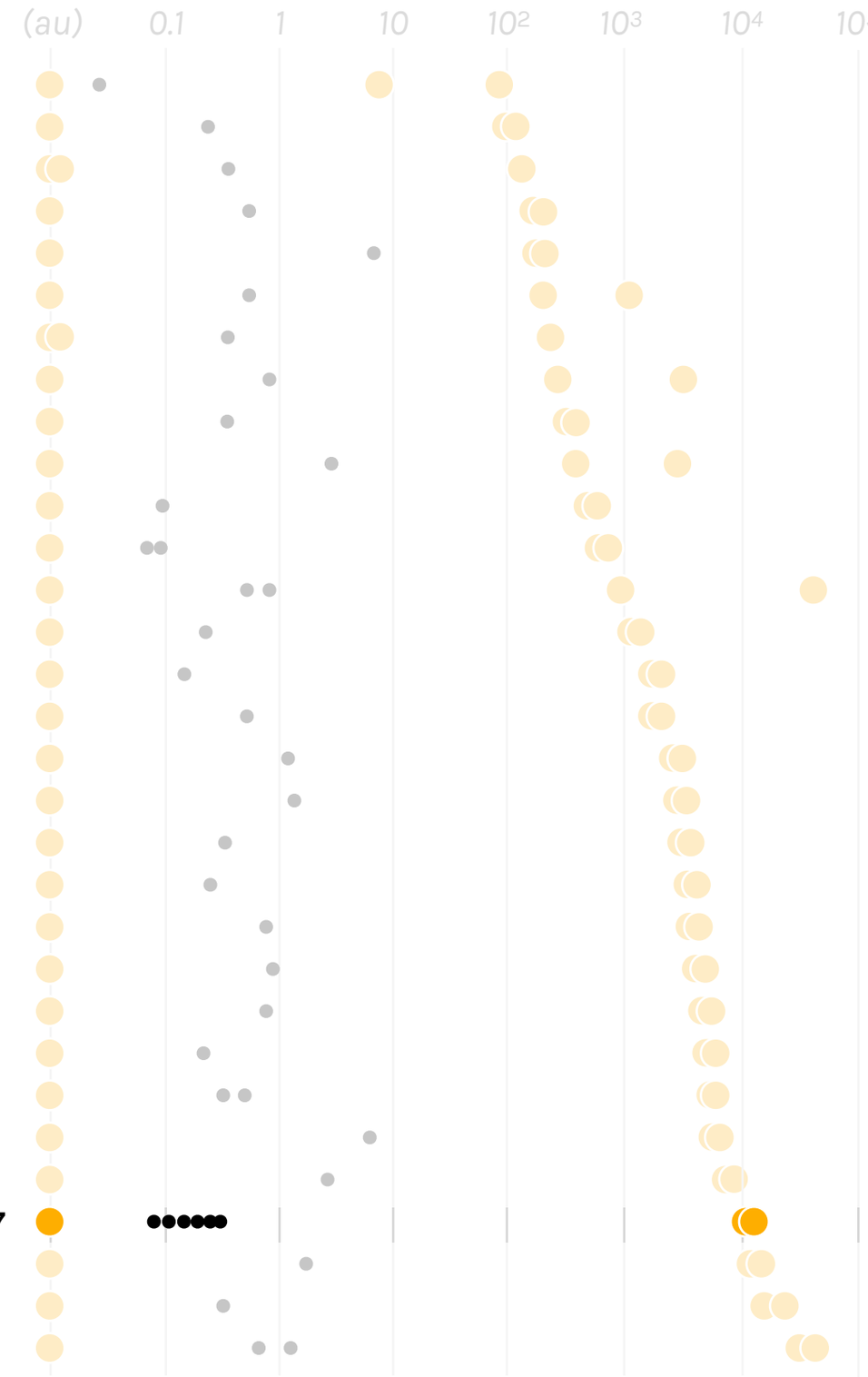

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Planets in triple systems

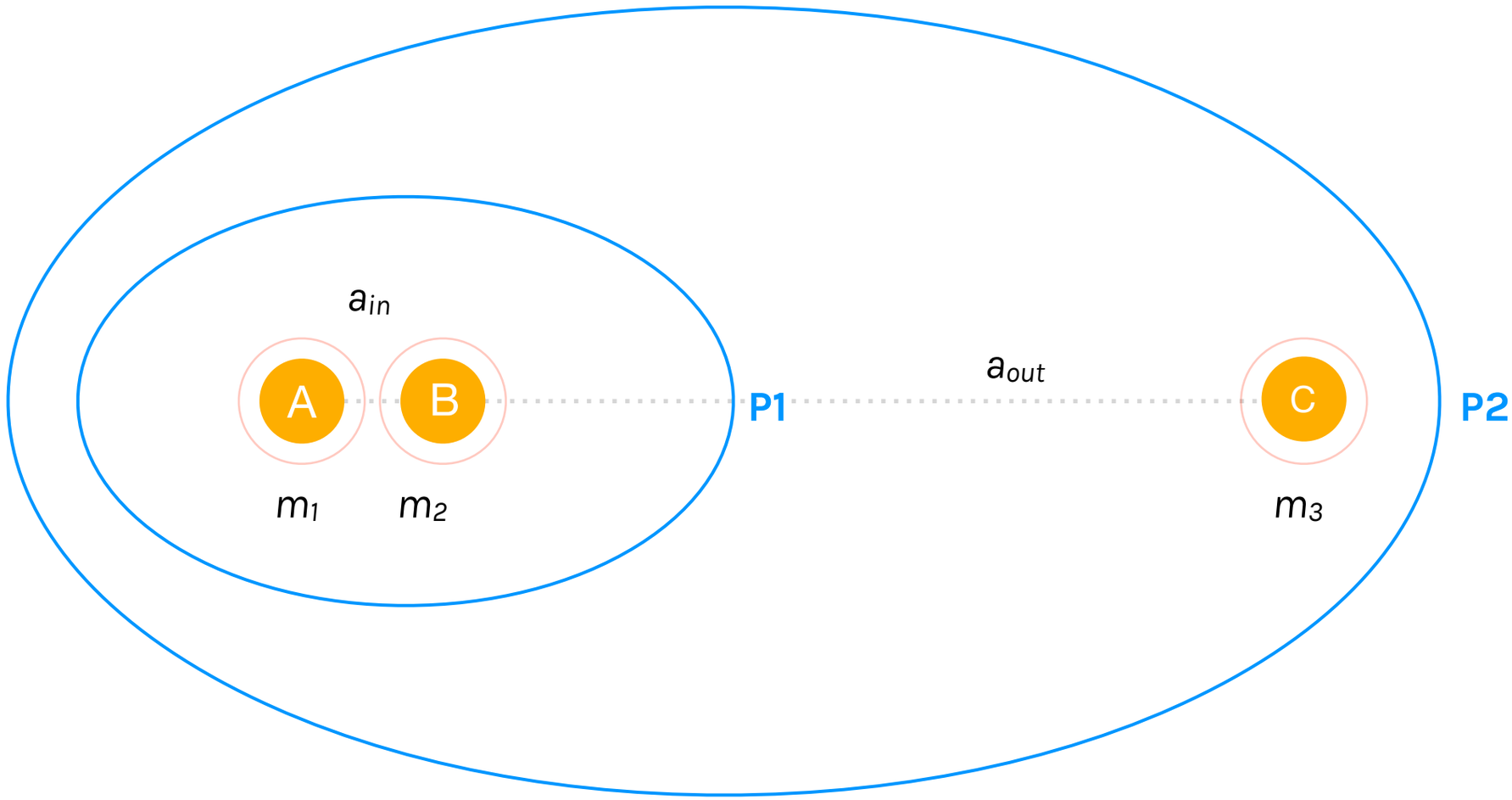
Orbital configurations

S1/S2: **2** found

S3: **26** found

Planets in triple systems

Orbital configurations



S1/S2: **2** found

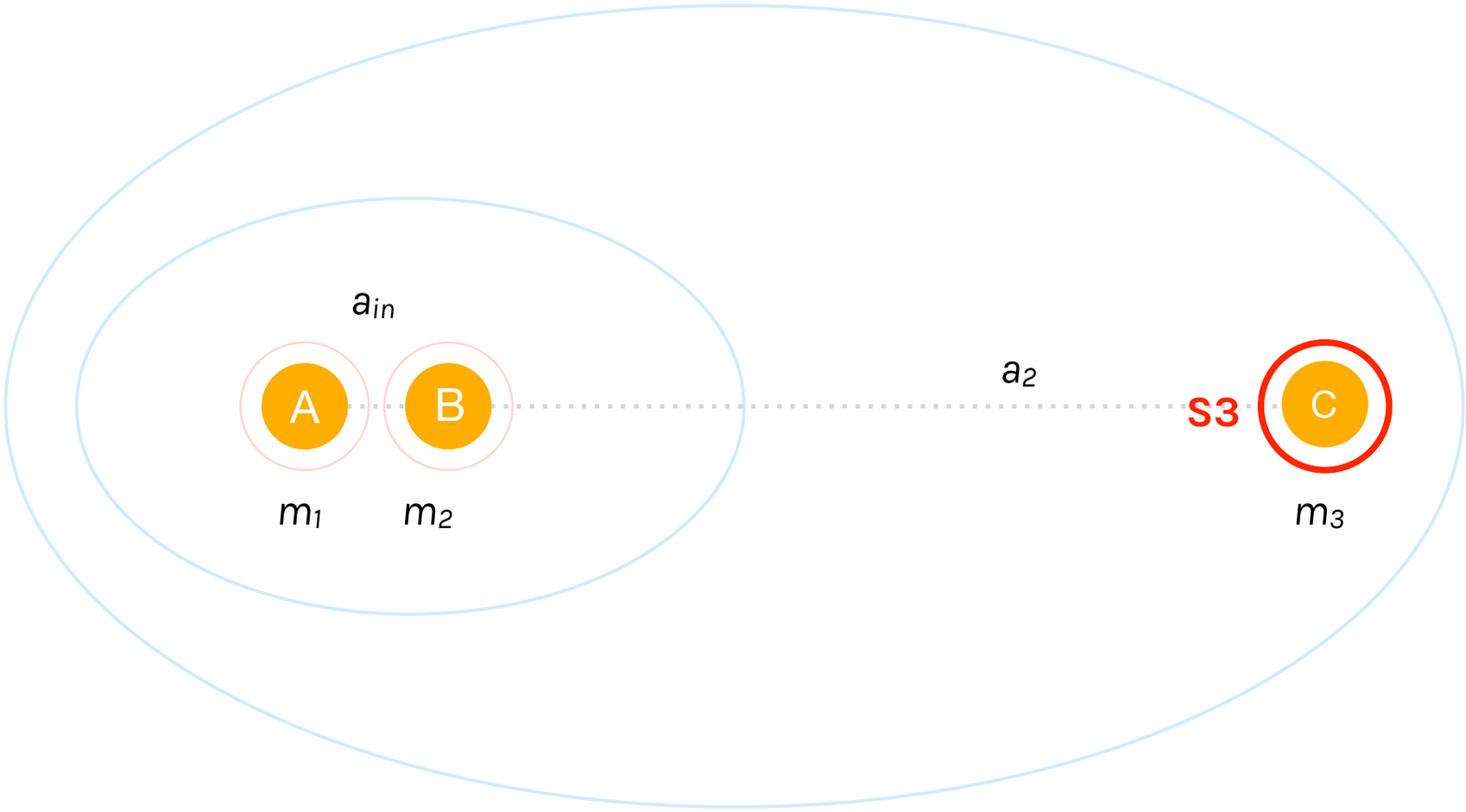
S3: **26** found

P1 (circumbinary): ~**2** found

P2 (circumtriple): **0** found

Planets in triple systems

Orbital configurations



Stability of planets in triple star systems

F. Busetti[1], H. Beust[2], and C. Harley[1]

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[2] Université Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France
e-mail: herve.beust@univ-grenoble-alpes.fr

Table 12. Mean critical semi-major axis ratios for all combinations of orbital motions in S3 orbits.

Orbit type	Critical ratio	Motions[a] Star 3	Planet	Mean critical ratio Min	Mean	σ	Max
S3	a_{io}/a_2	P	P	0.009	0.289	0.098	0.893
			R	0.010	0.361	0.158	0.920
		R	P	0.007	0.287	0.096	0.853
			R	0.009	0.360	0.156	0.908

Notes. [(a)]P – prograde, R – retrograde.

Busetti et al. (2018)

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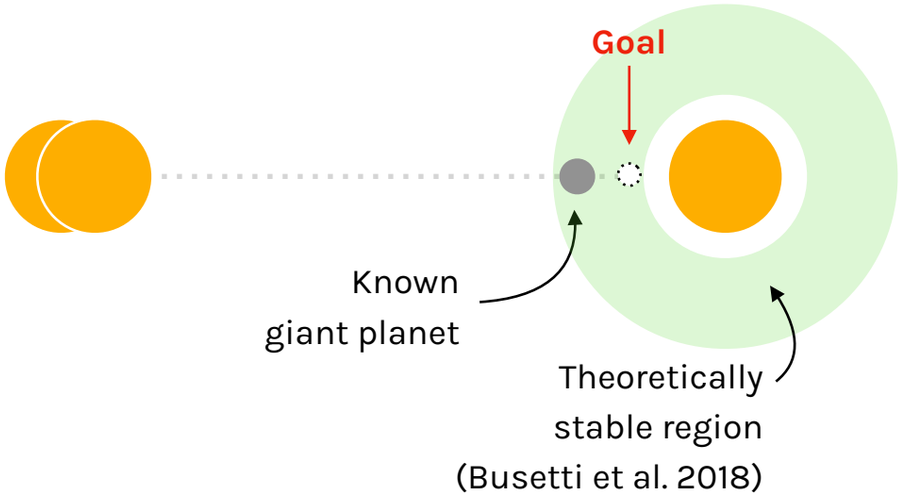
Project: *Triple Trouble*

Project: Triple Trouble

A systematic search for planets in hierarchical triple systems



Sample: Triples hosting long-period planets confirmed via RV

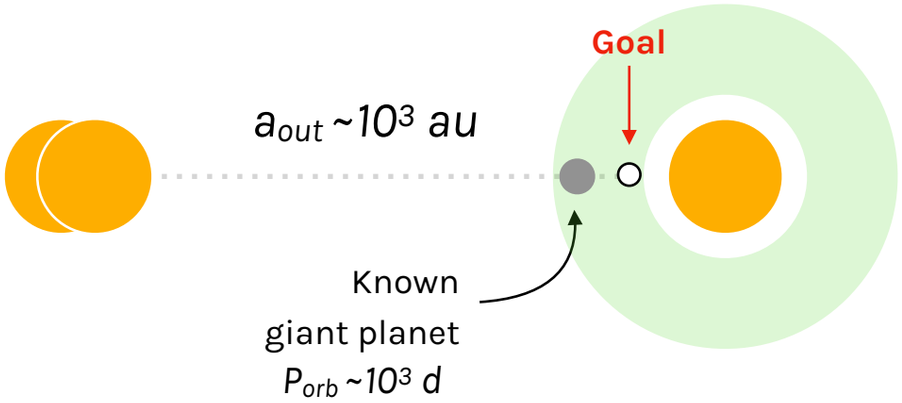
Instrument: CARMENES

Strategy: High-cadence to access P_{orb} < 1 day

Goal: To detect planets in inner orbits

Project: Triple Trouble

A systematic search for planets in hierarchical triple systems



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Instrument: CARMENES

Strategy: High-cadence to access P_{orb} < 1 day

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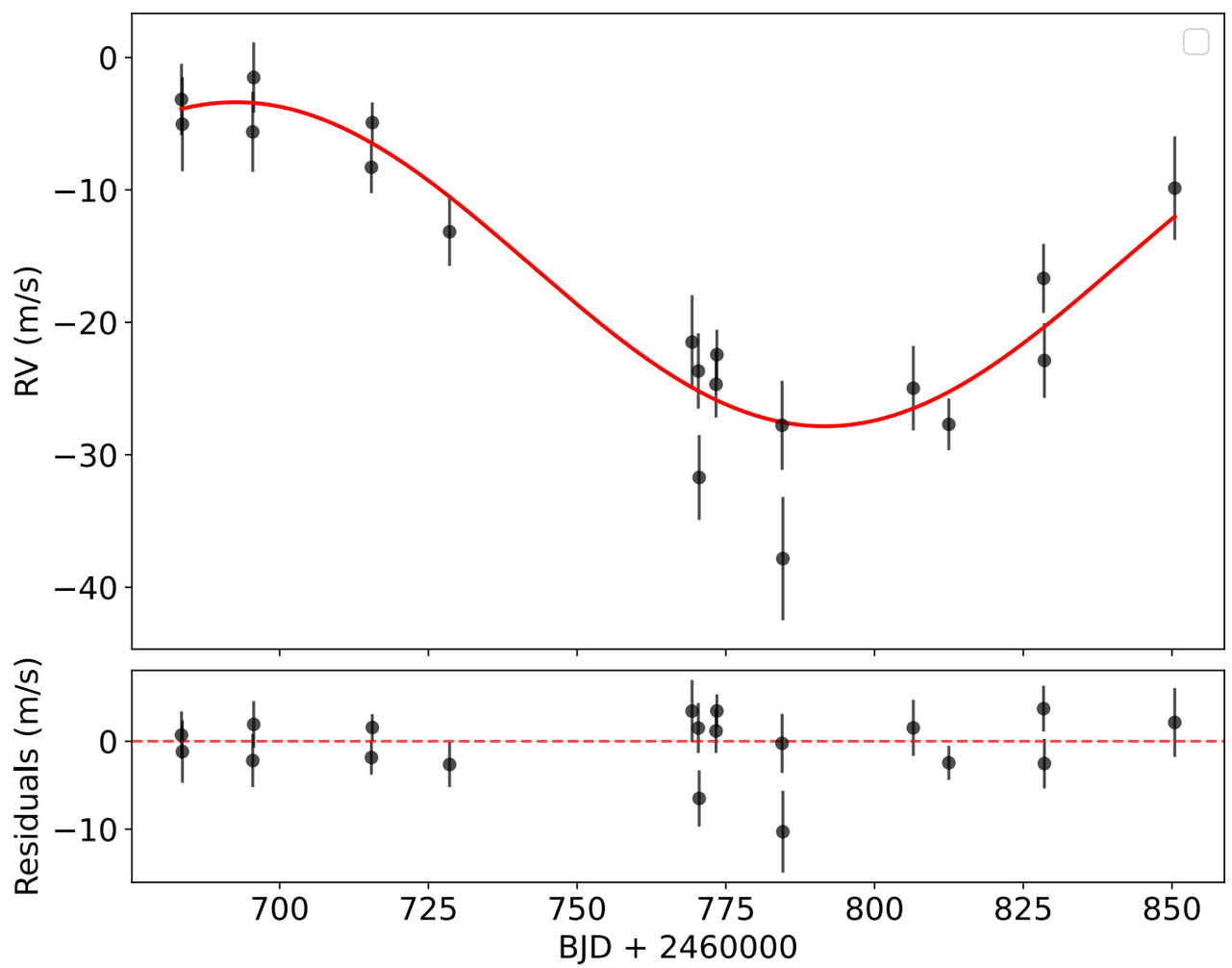
Star #1

Msini = 0.37 M_{Jup}, P_{orb} ≃ 197 d

CARMENES RV series



Project: Triple Trouble

A systematic search for planets in hierarchical triple systems

Goal questions

- Do planets exist in **inner periods** within the stability regions?
- Which **architectures** are present in these planets (e, i, P_1/P_2)?
- Which is the impact of the **wide stellar companion** on…
  - Number of planets?
  - Architectures?

Next steps

- Expand this search:
  - Additional **instruments** (HARPS, ESPRESSO)
  - Additional **targets** (including blind search in triples)
- To characterize the **multiplicity** of stars known to host transiting planets

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Take-aways

Exoplanets in hierarchical triple systems

Take-away points

1. Planet formation *is not* isolated — it unfolds within a **stellar context**.

2. Planets in triple-star systems are **underestimated**.

3. We propose a **project** to focus on them. We are open to **collaborations**!

Exoplanets in hierarchical triple systems

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