# A second Jupiter orbiting in 4:3 resonance in the 7 CMa system


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## Abstract

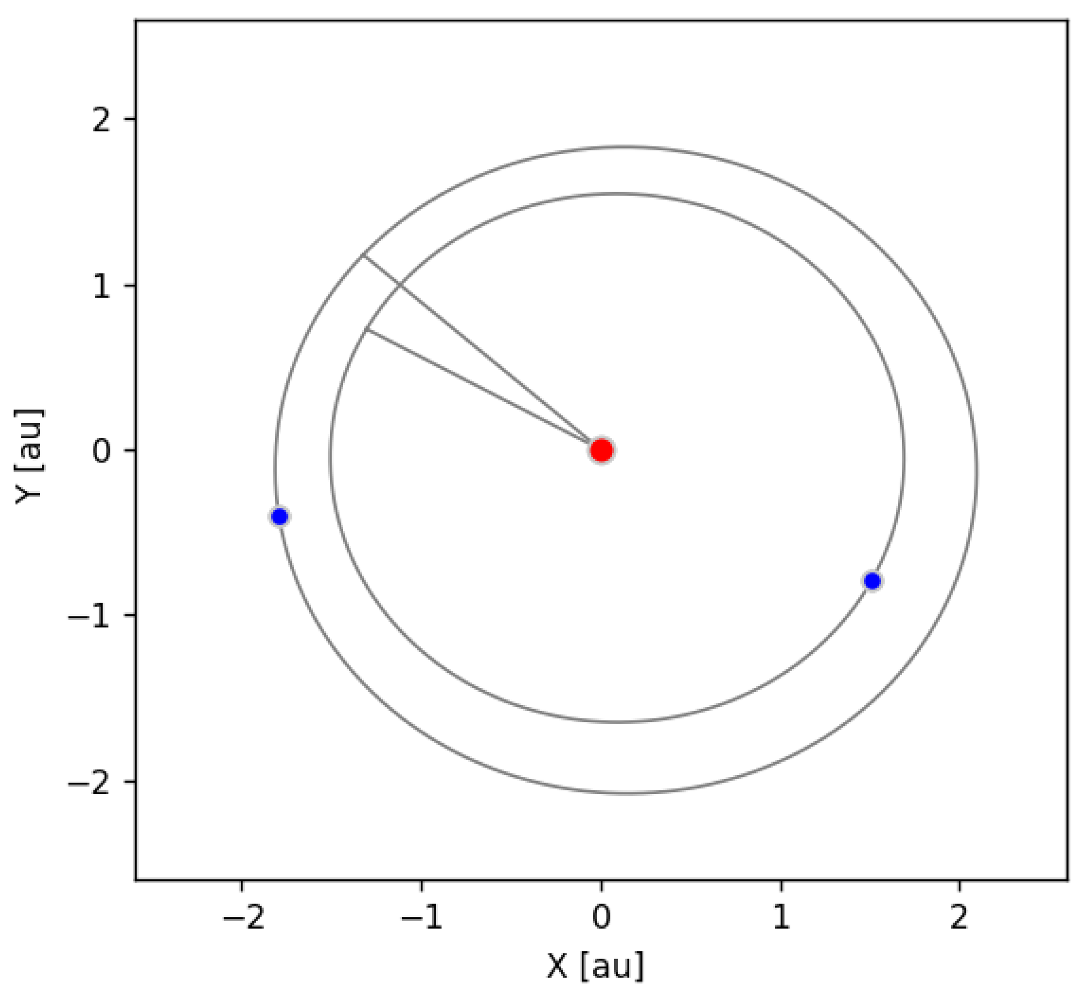
We report **the discovery of a second planet orbiting the K giant star 7 CMa** based on 182 high-precision radial velocities obtained with Lick, HARPS, UCLES, and SONG. A double-Keplerian orbital fit of the data reveals two Jupiter-like planets with minimum masses of 1.9 $M_J$ and 0.9 $M_J$, orbiting at semimajor axes of 1.75 au and 2.15 au, respectively. Given the small orbital separation and the large minimum masses of the planets, close encounters may occur within the time baseline of the observations; thus, a more accurate **N-body dynamical modeling of the radial velocities** is performed. We explore the long-term stable configuration of the system, confirming that 13% of the posterior samples are stable for at least 10 Myr. The result from the stability analysis indicates that **the two planets are trapped in a low-eccentricity 4:3 mean motion resonance (MMR)**. This is only **the third discovered system** to be inside a 4:3 MMR, making this discovery very valuable for planet formation and dynamical evolution models.


## Orbital configuration

Table 1:Most relevant stellar and planet parameters of the 7 CMa system (see Luque et al. 2019 for a comprehensive list).

| Stellar parameters | | |
|---|---|---|
| $\alpha$ | 06:36:41.03 | |
| $\delta$ | −19:15:21.1 | |
| SpT | K1 III | |
| $V$ (mag) | $3.91 \pm 0.03$ | |
| $d$ (pc) | $19.82 \pm 0.16$ | |
| $M$ ($M_\odot$) | $1.34 \pm 0.12$ | |
| $R$ ($R_\odot$) | $4.87 \pm 0.17$ | |
| $L$ ($L_\odot$) | $11.55 \pm 0.31$ | |
| **Orbital parameters** | | |
| | 7 CMa b | 7 CMa c |
| $P$ (d) | $735.1^{+14.8}_{-1.0}$ | $996.0^{+1.5}_{-52.4}$ |
| $e$ | $0.06^{+0.03}_{-0.03}$ | $0.08^{+0.05}_{-0.04}$ |
| $M_p \sin i$ ($M_J$) | $1.85^{+0.06}_{-0.04}$ | $0.87^{+0.06}_{-0.06}$ |
| $a_p$ (au) | $1.758^{+0.024}_{-0.001}$ | $2.153^{+0.003}_{-0.08}$ |

Figure 1: Face-on view of the best fit planetary orbits of the 7 CMa system. Star and planet sizes are not to scale.




## Dynamical RV modeling and long-term stability

The relatively close planetary orbits and the derived minimum masses of the planets indicate that the planets will have relatively **close encounters during the time of the observations**, which may be detected in our data. Therefore, a more appropriate N-body dynamical model is applied, which takes into account the gravitational interactions between the massive bodies.

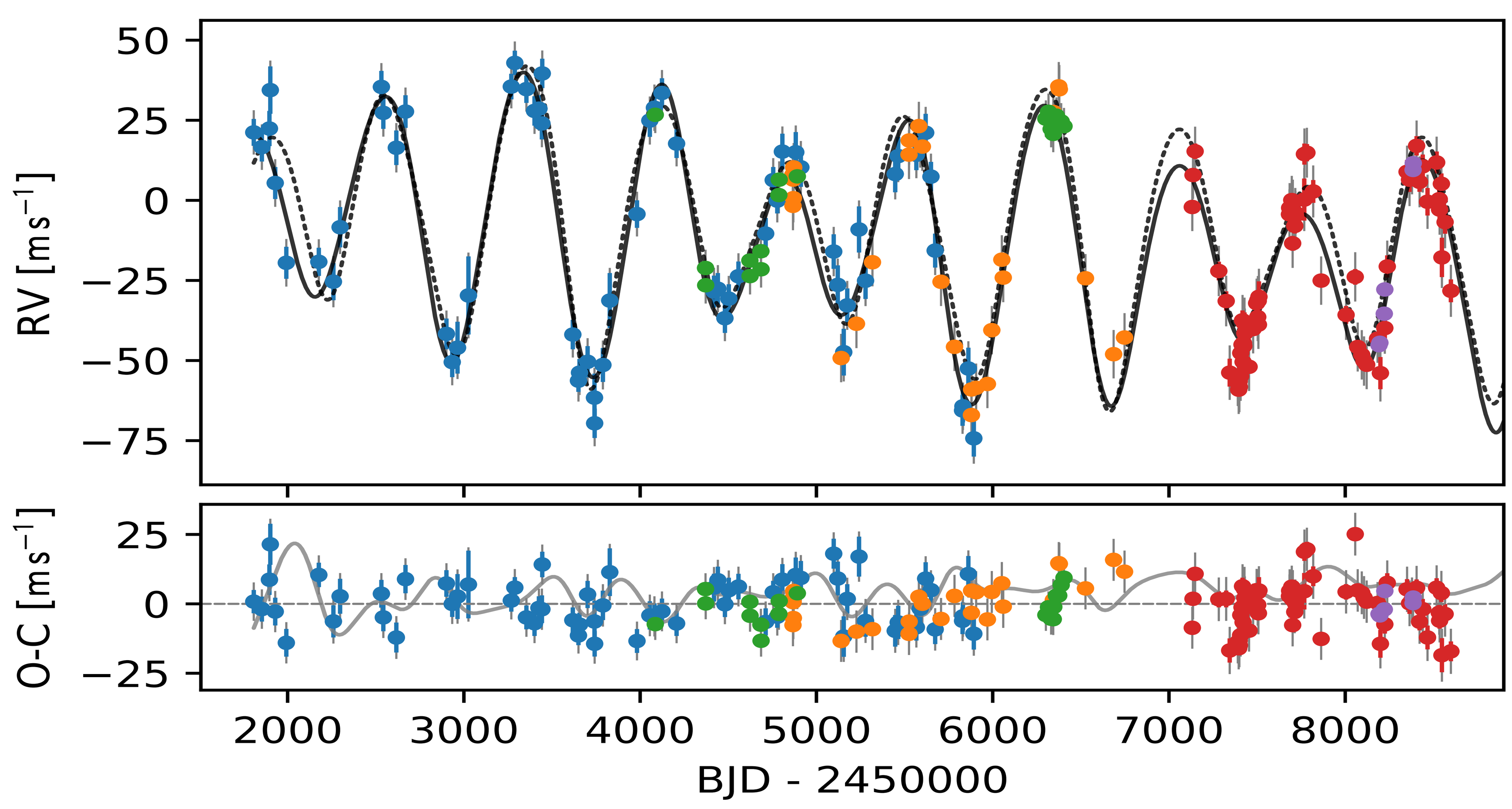



Figure 2: Time series of the 182 RVs obtained for 7 CMa from September 2000 to April 2019. The best double Keplerian fit to the data is drawn with a dotted line, while the solid black line indicates the best dynamical two-planet fit. The difference between the Keplerian and dynamical models (solid gray line) are shown in the bottom panel.

A period ratio close to 1.33 does not ensure that the system is indeed trapped in a 4:3 MMR. The long-term stability of the orbital solution and the resonant angles must be studied. The confinement of $\sigma_c$ around 180 deg, shows that the 7 CMa system is **effectively trapped in the narrow stable region of the 4:3 MMR**. The existence of such a system challenge formation models since migration scales for passing through the 2:1 and 3:2 MMR are extremely short.

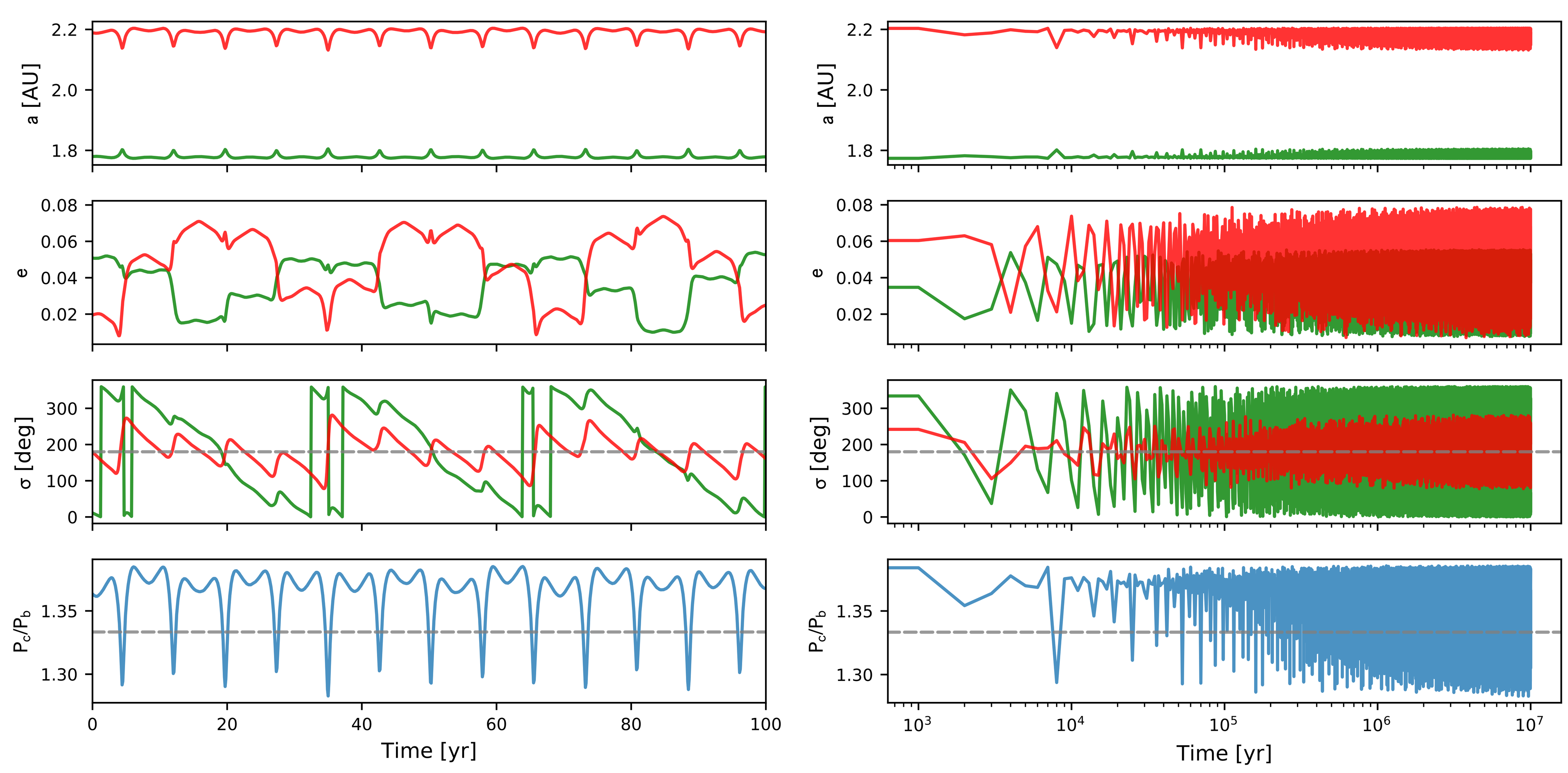



Figure 3: Semi-major axes, eccentricities, resonant angles, and period-ratio evolution of a stable orbital solution. The system endures strong gravitational interactions in short timescales, but it preserves stability for 10 Myr.


## Acknowledgements

INPhINIT "la Caixa" Fellowship Programme — "la Caixa" Banking Foundation

This project has received funding from the European Union's Horizon 2020 research and innovation and innovation programme under the Marie Skłodowska-Curie grant agreement No 713673.