PSL UNIVERSITÉ PARIS

l'Observatoire de Paris | LESIA

Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

Coupling observation techniques for companions detection & characterization

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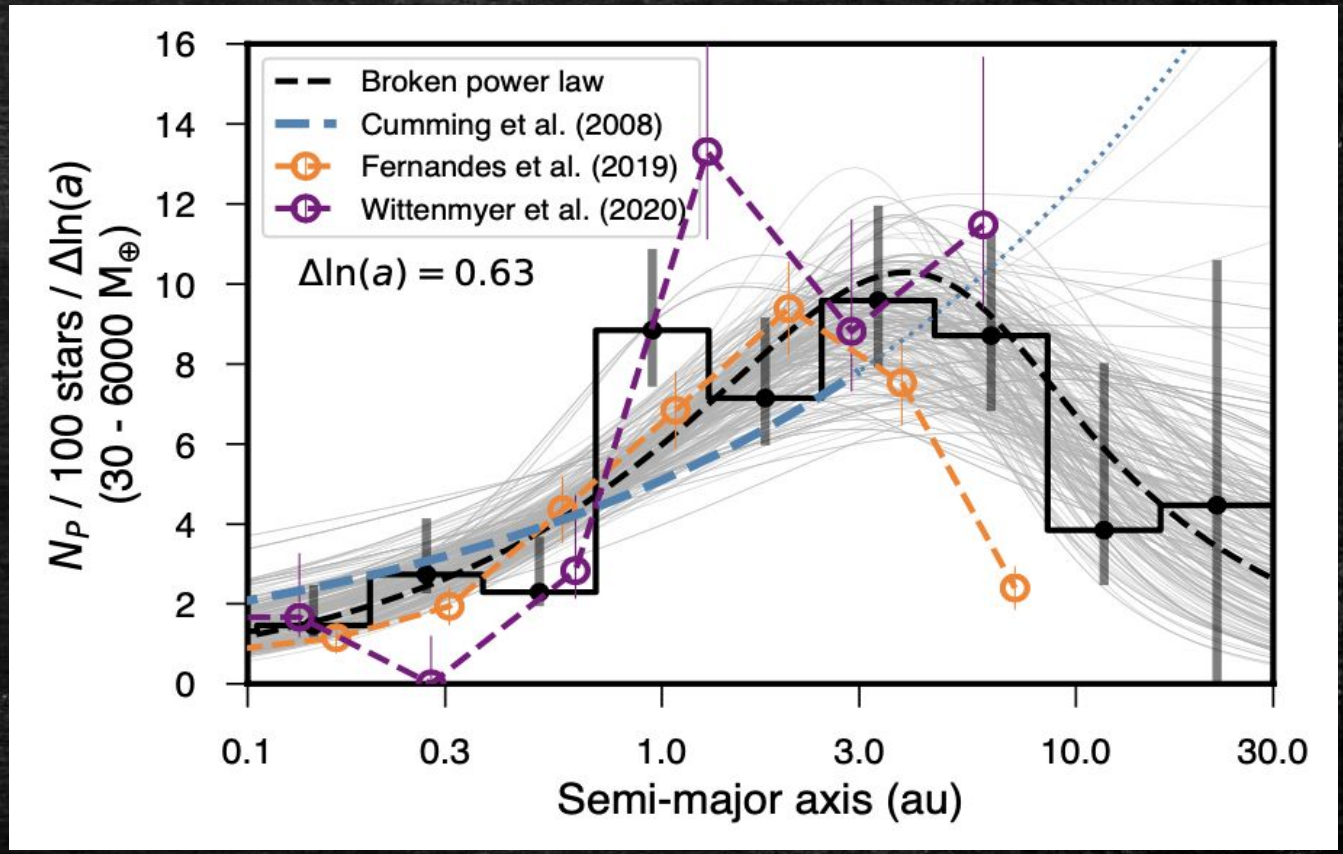
COBREX Workshop 2022

Radial distribution of giant planets

3 recent large surveys:

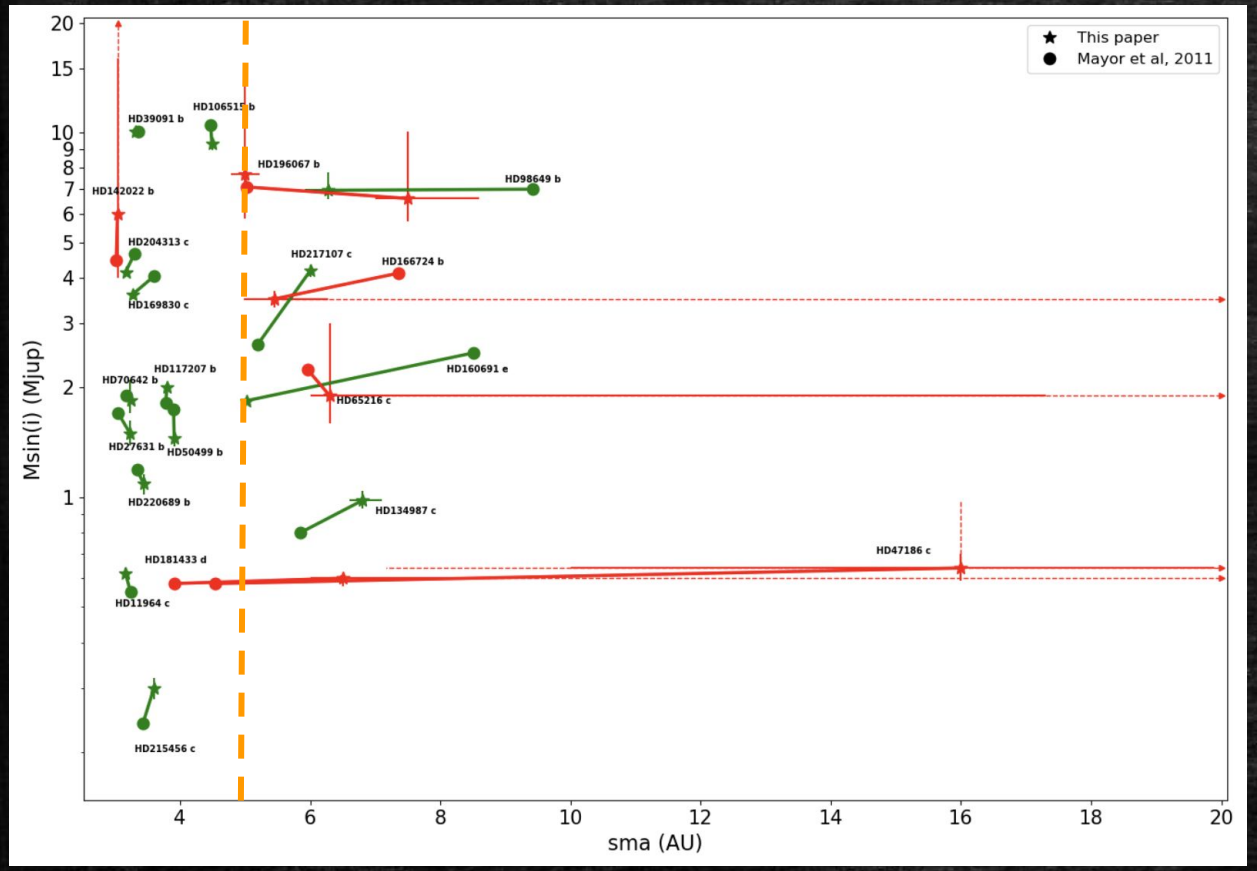
- **CH Survey (Fernandes et al. 2019) : 155 planets / 822 stars over ~ 10 yr (Mayor et al. 2011)**
- AAP Survey (Wittenmyer et al. 2020) : 38 planets / 203 stars over ~ 18 yr
- **CL Survey (Fulton et al. 2021) : 177 planets / 719 stars over 8 - 32 yr (Rosenthal et al. 2021)**



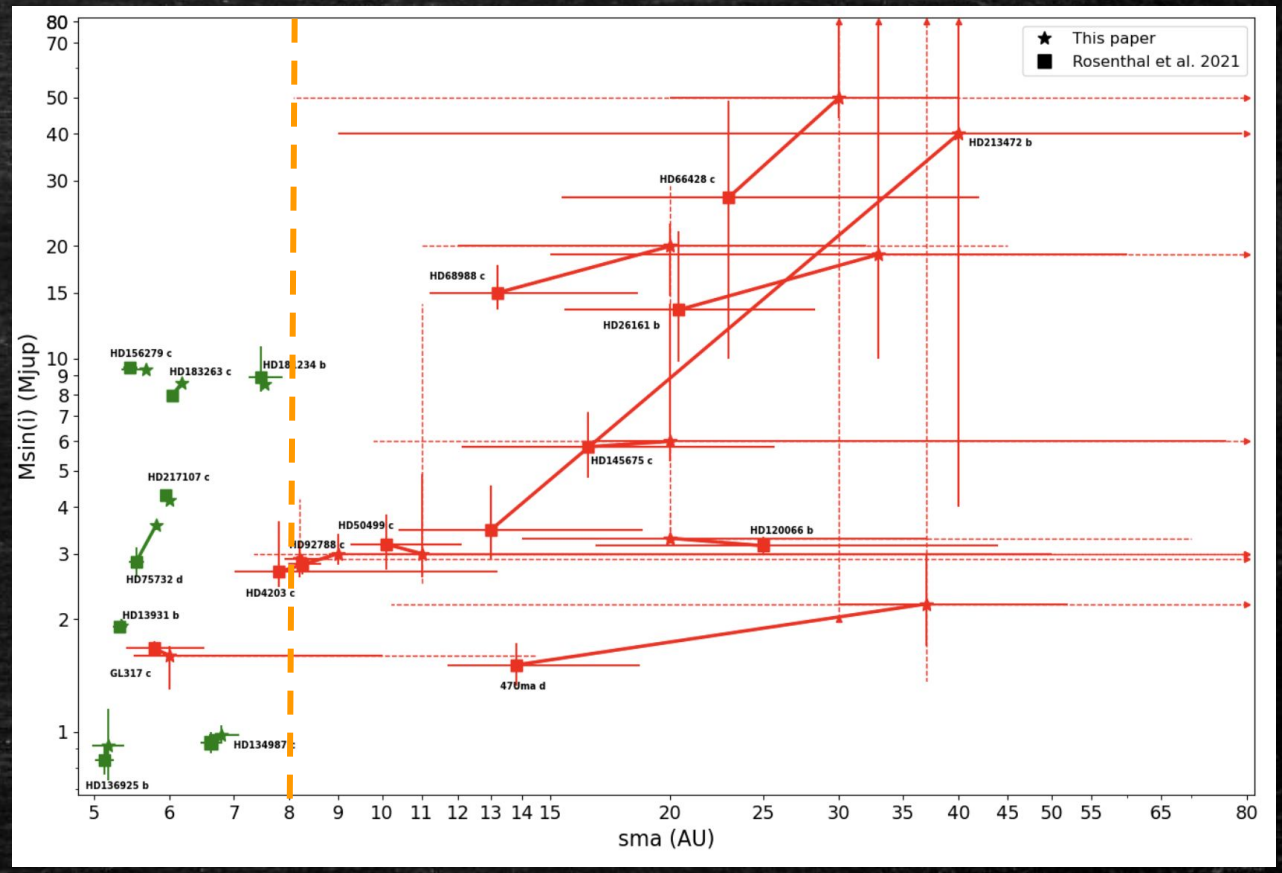
Fulton et al (2021)

Discrepancies with published parameters

Mayor et al (2011): RV baseline ≈ 10 yrs



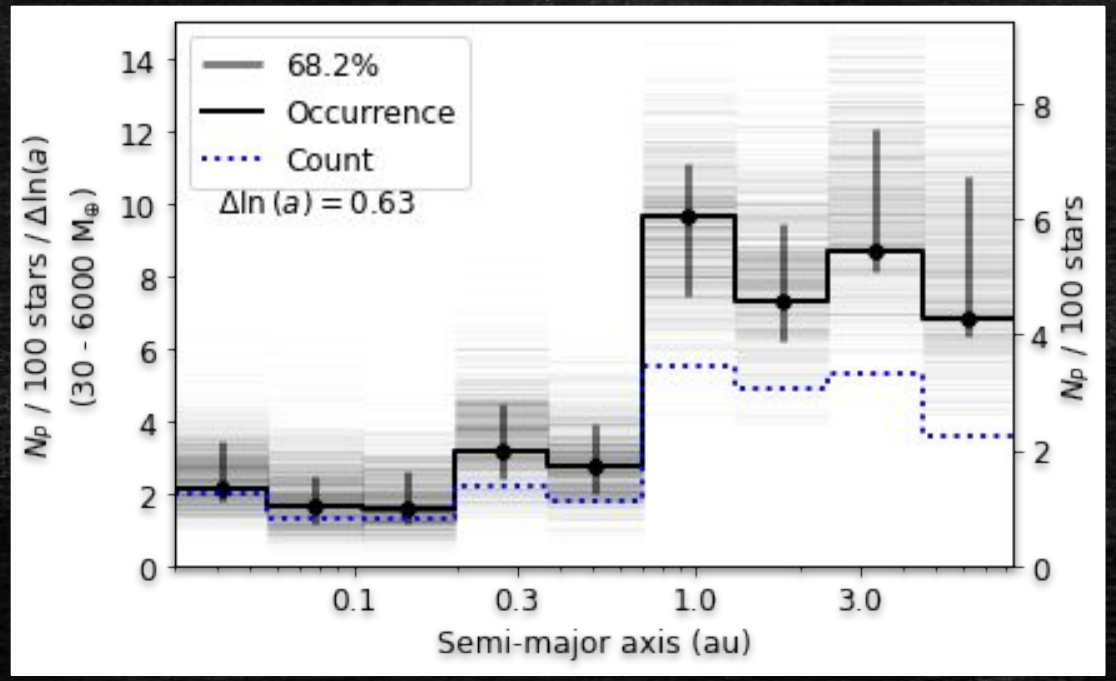
Rosenthal et al (2021): RV baseline ≈ 21 yrs



Lagrange et al. in rev.

Limits for the characterization of long period planets

- Period >> RV baseline → Star RV poorly constrained
- Long term activity may also bias the results
- Turn over of the occurrence rate of giant planets beyond the snow line is not robust
- RV method is not well suited to precisely characterize planets beyond 5-8 au, and to deliver robust statistical results



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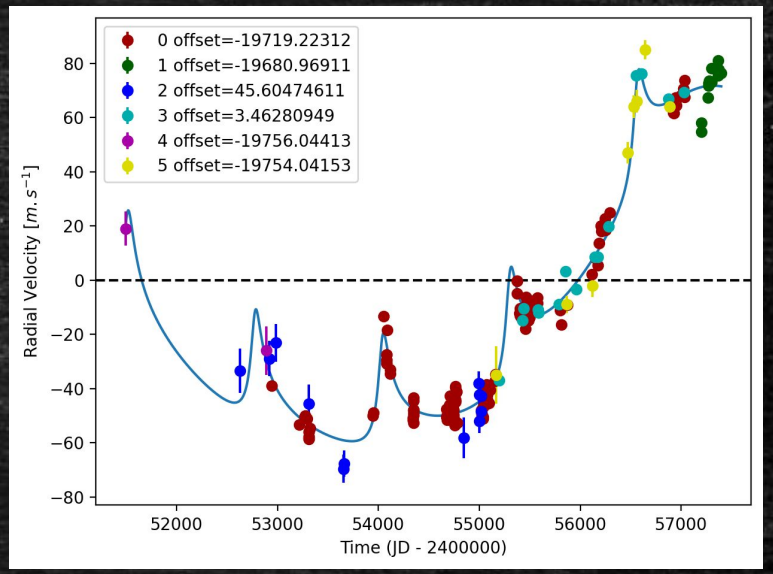
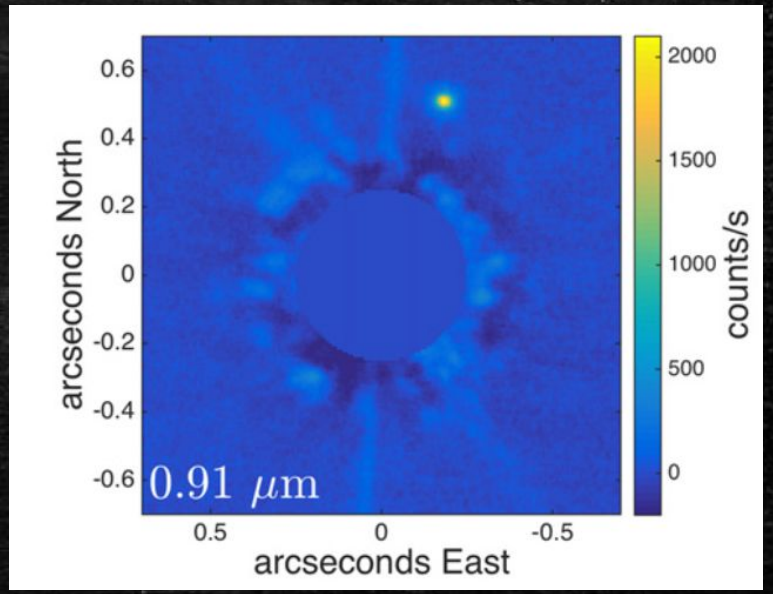
→ Combine RV with other detection methods to better characterize the long period planets

HD7449 outer companion

- RV data :
  - Mayor et al. 2011: 2 M_{Jup} planet at 5.1 au (baseline = 4000 d)
  - Wittenmyer et al. 2019: 19.2 ± 4.2 M_{Jup} BD at 12.7 ± 0.6 au (baseline = 4450 d)

- Direct imaging + RV data: stellar companion (~ 0.17 $M_{\odot}$) at ~ 18 au

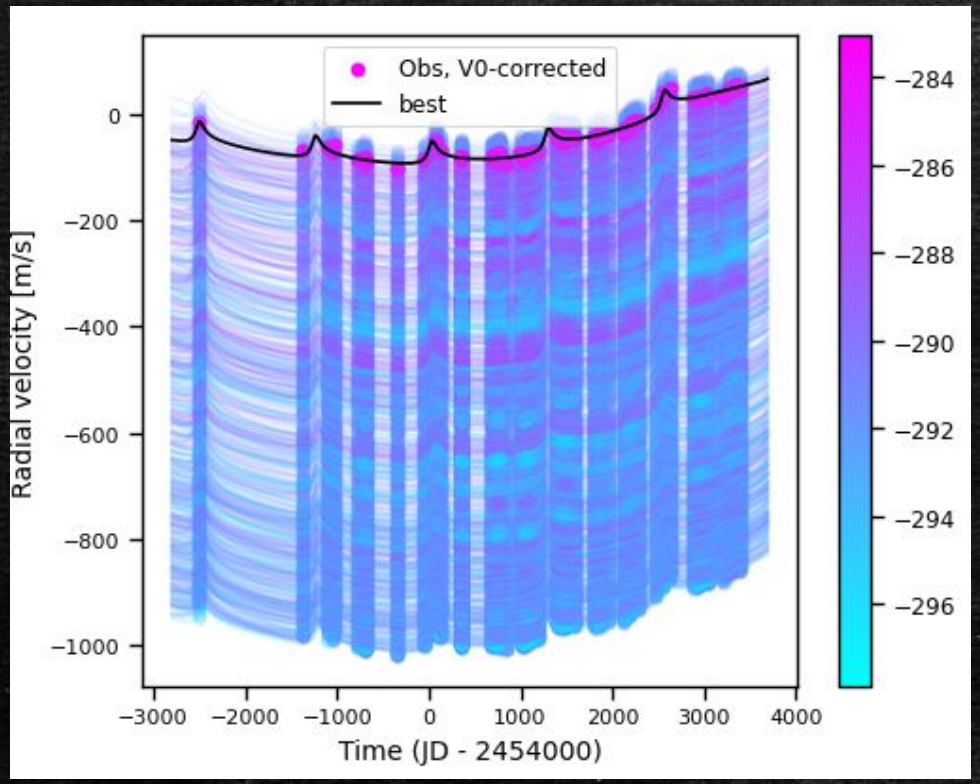


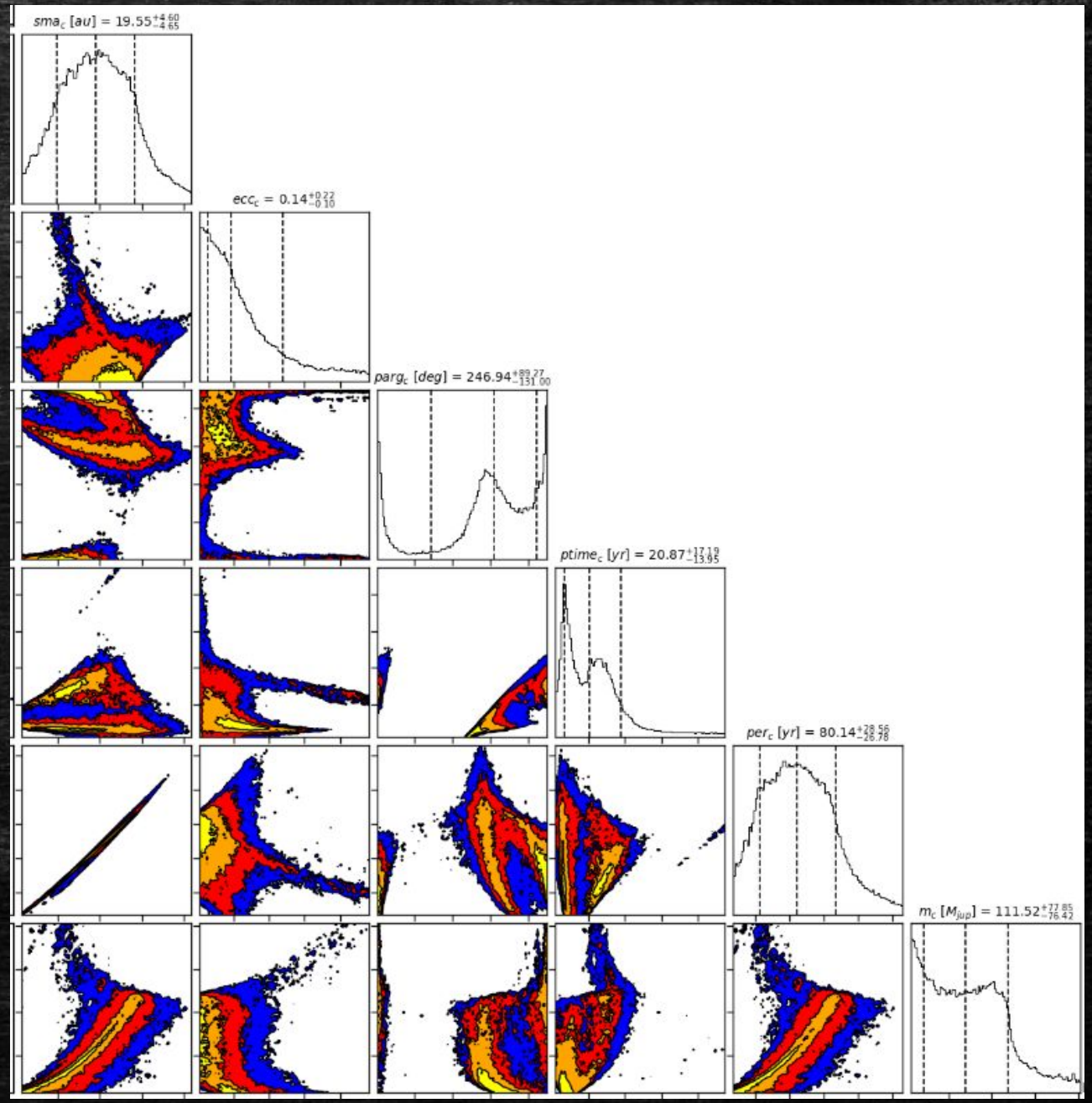


HD7449B (MagAO), Rodigas et al. 2016

HD7449: Coupling RV & HCI

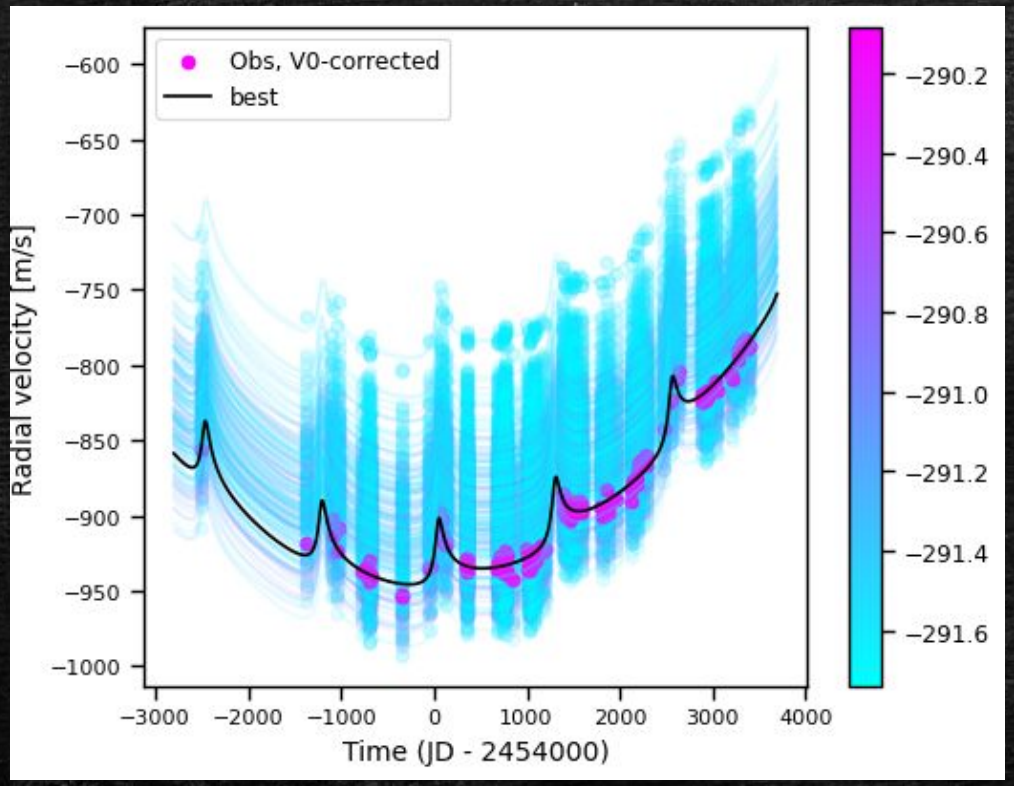
- RV only

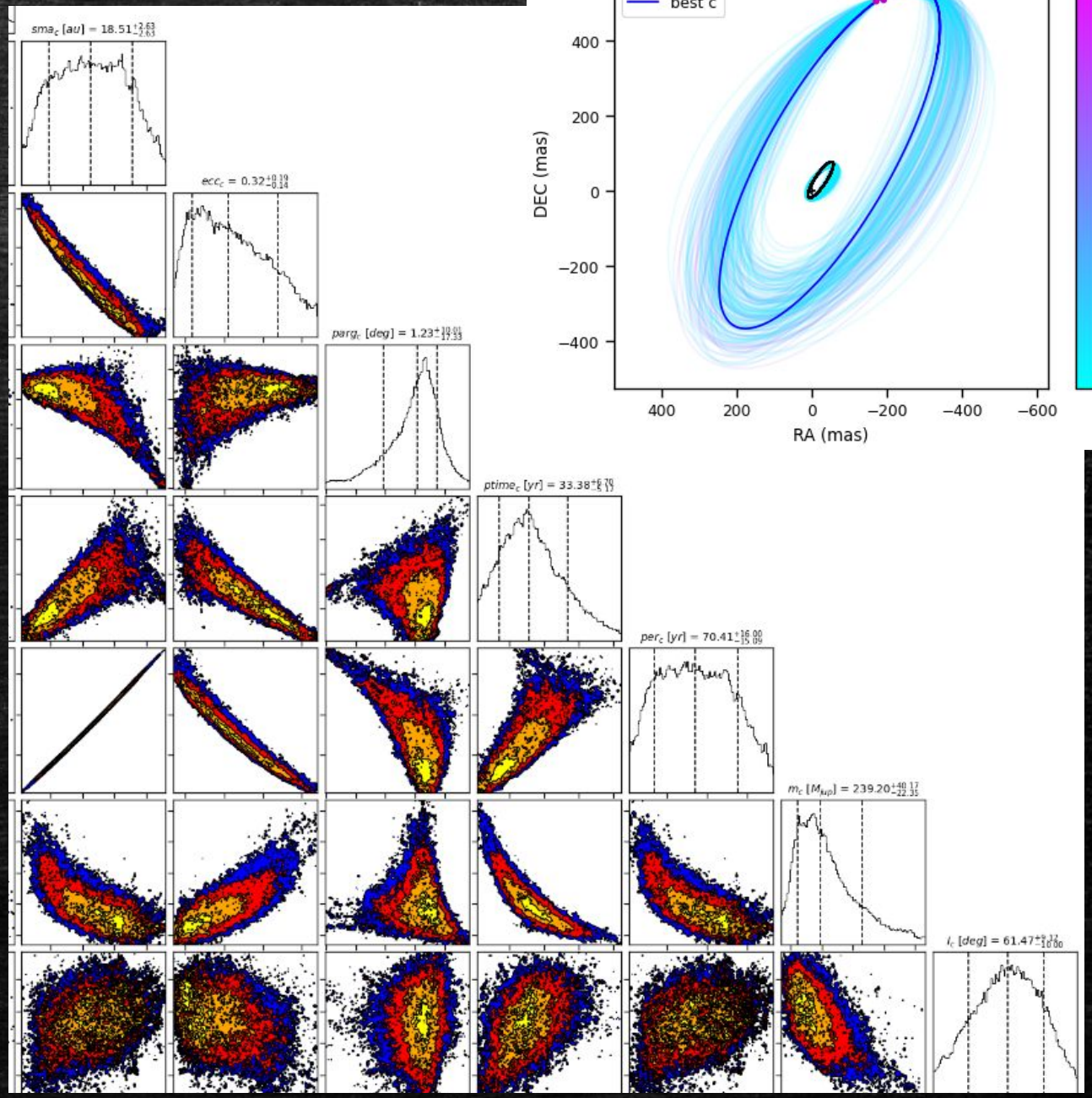




HD7449: Coupling RV & HCI

- RV + HCI





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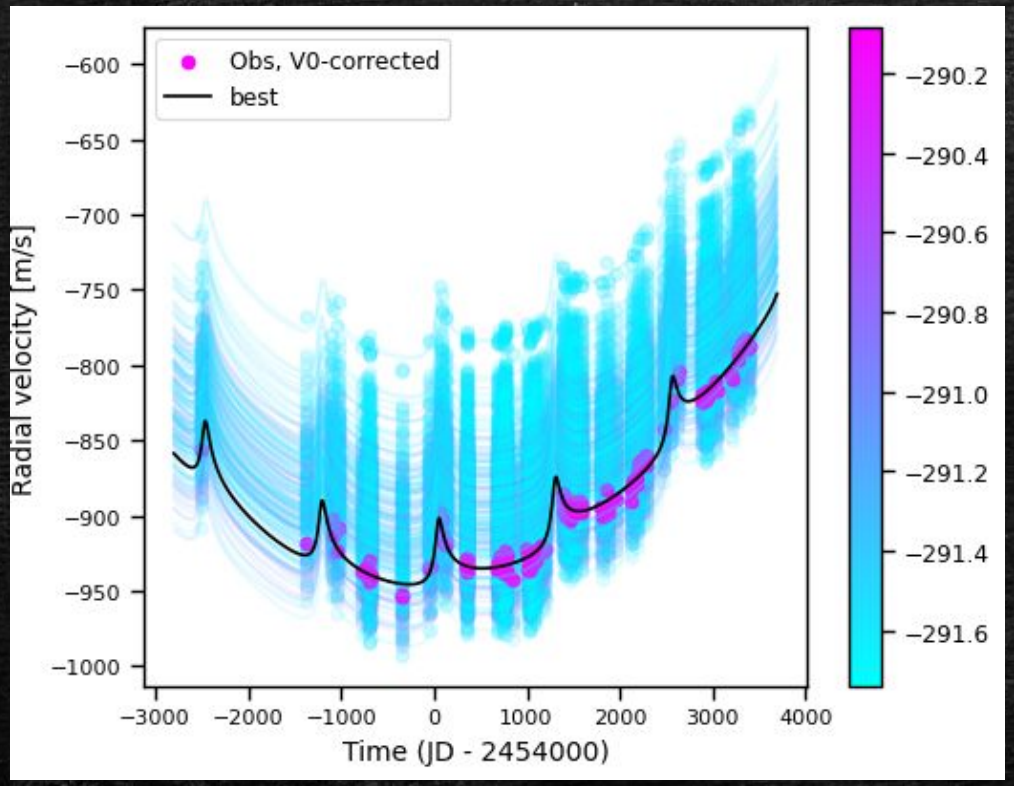
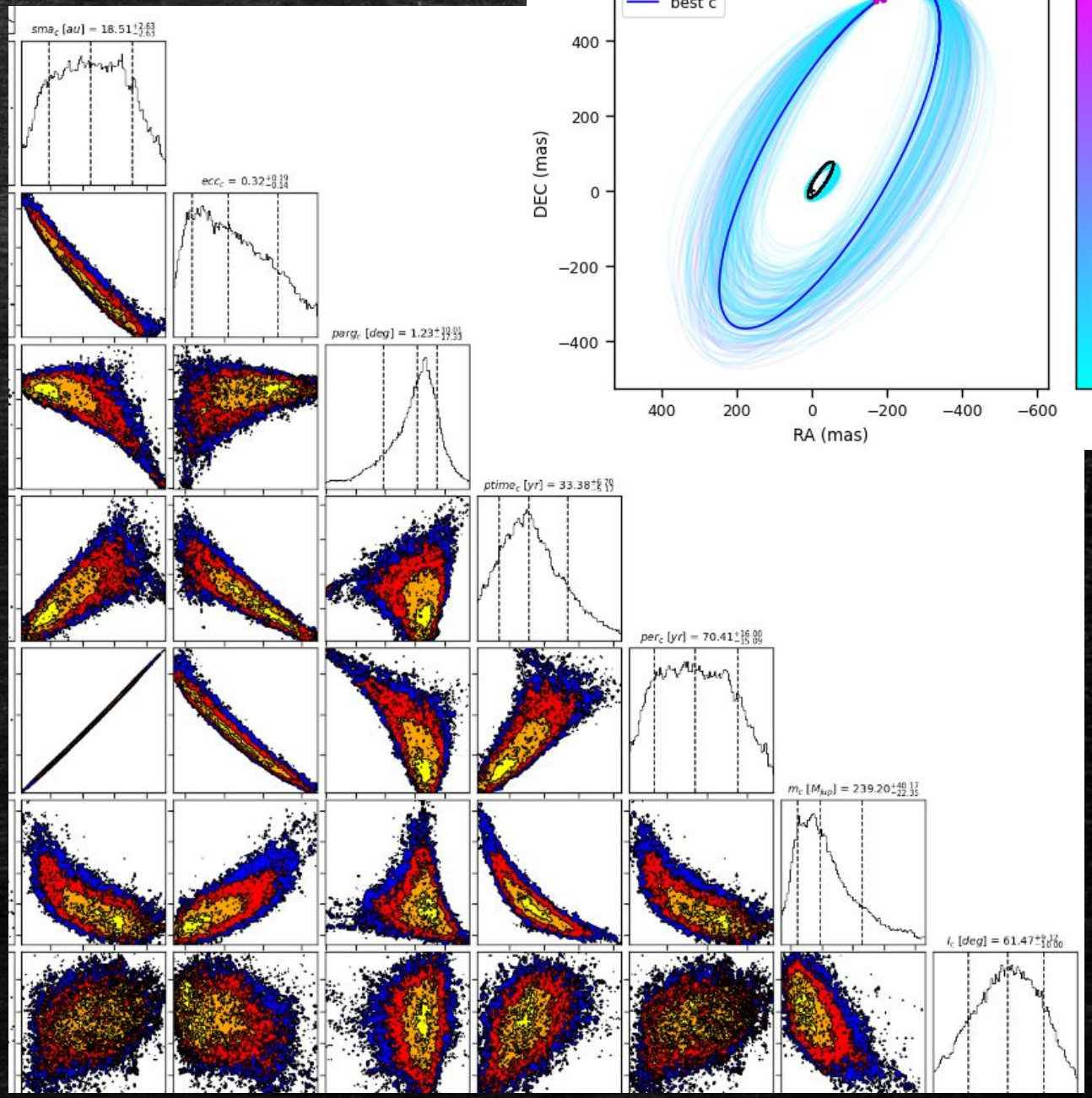




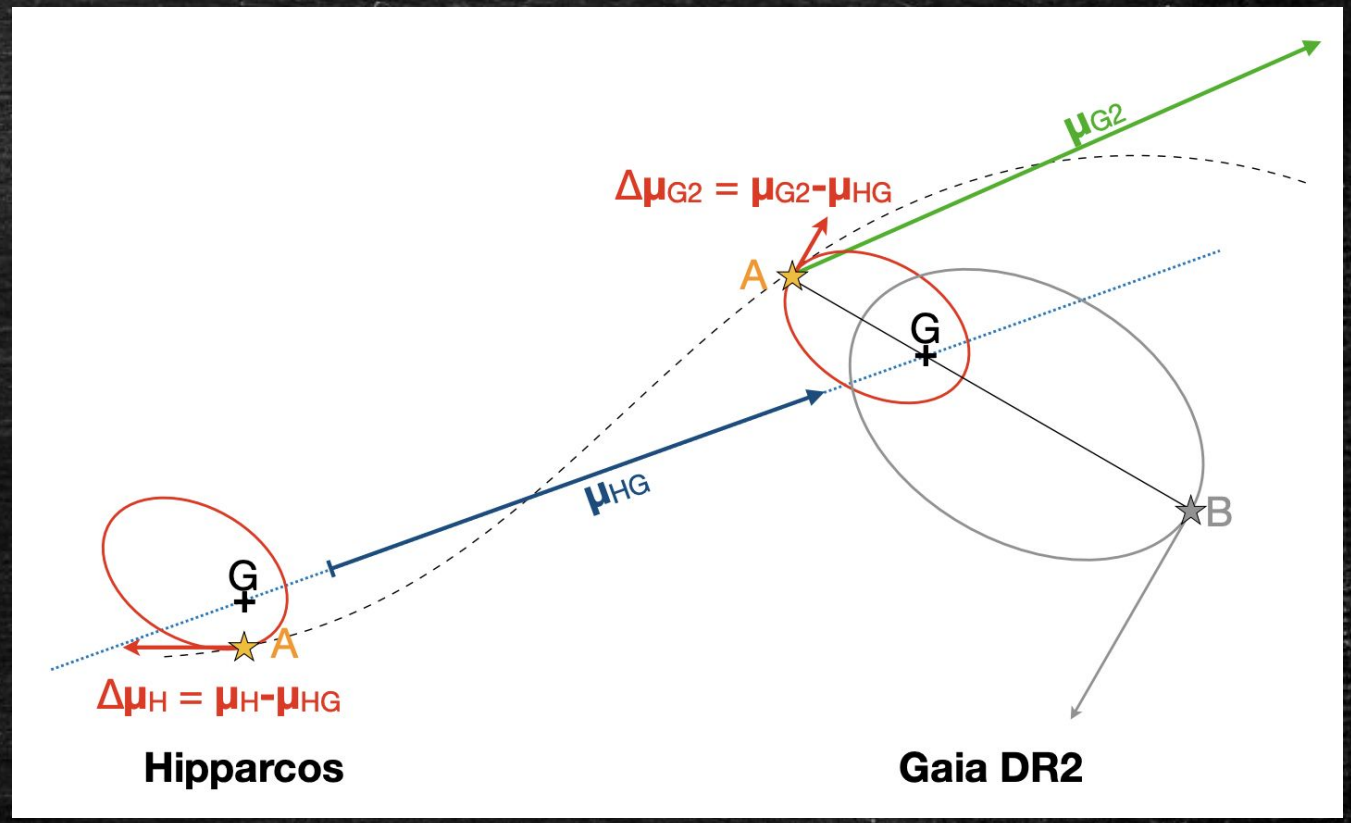
New SCExAO/CHARIS observation will improve the precision !

Hipparcos - Gaia proper motion anomaly (PMa)

- PMa = $\Delta\mu_G - \Delta\mu_{GH}$

  $\Delta\mu_G$: Average Gaia PM (~ 3 yrs)
  $\Delta\mu_{GH}$: Average Hipparcos - Gaia PM (23.75 yrs)

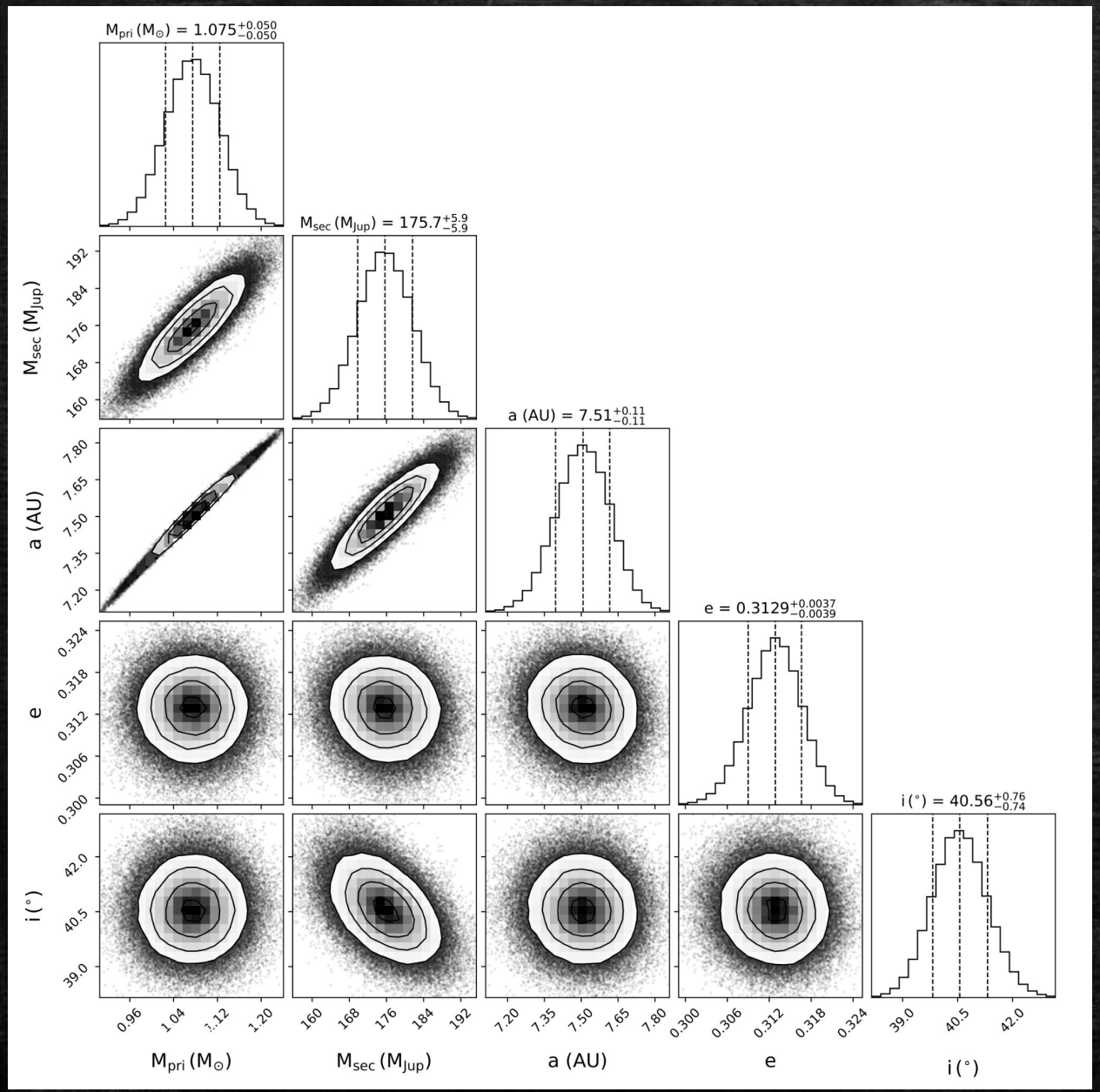
- Without companion, PMa = 0 mas/yr

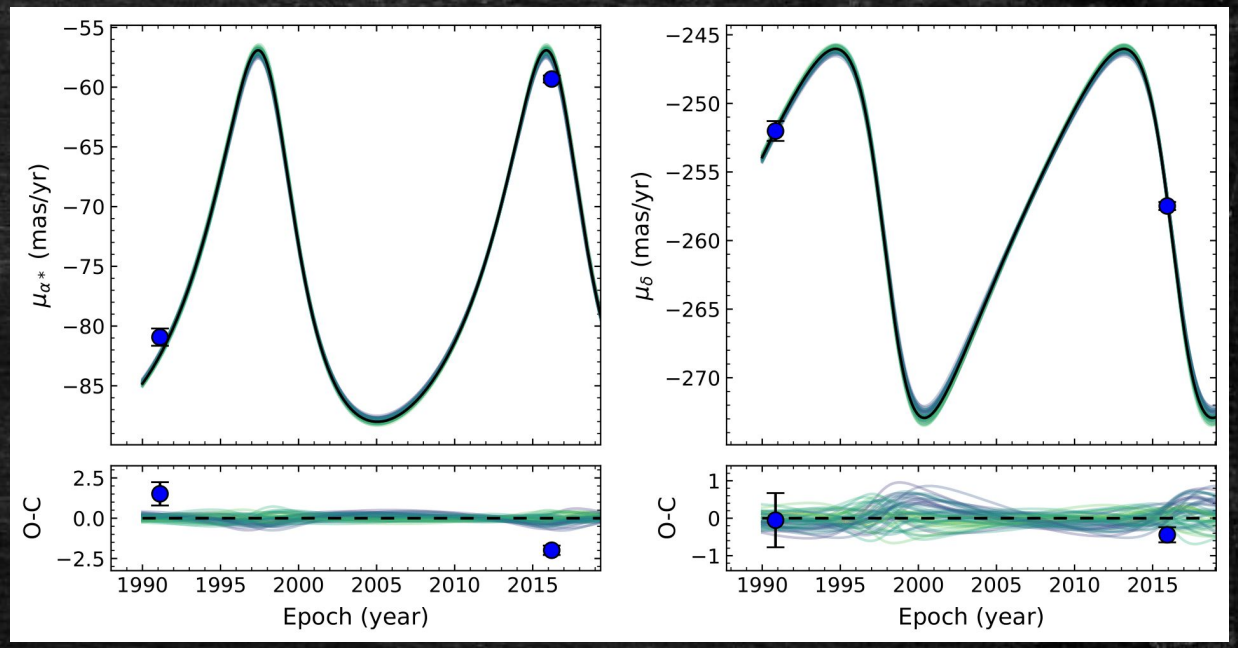


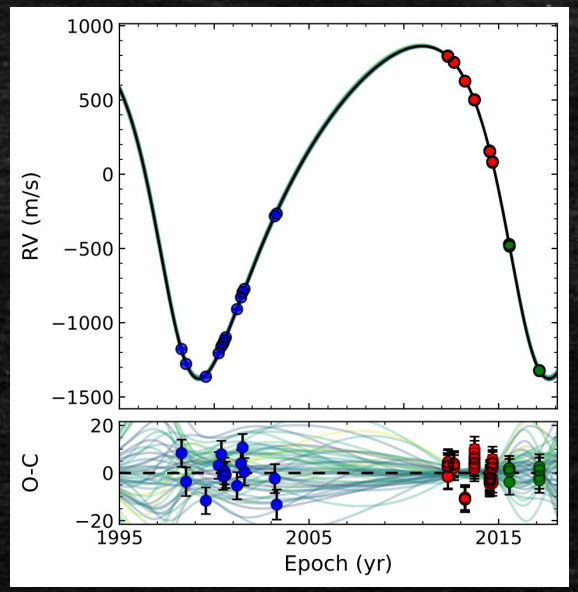
Kervella et al. 2019

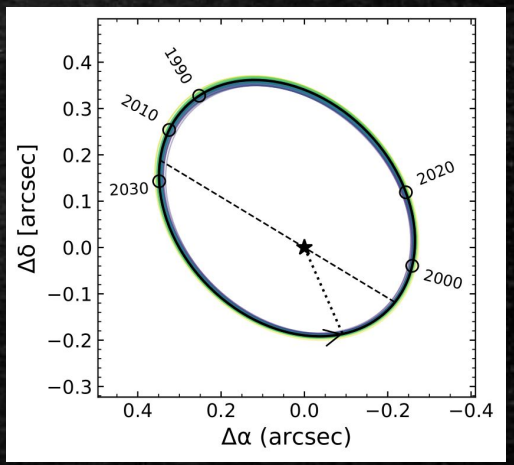
Coupling RV & Hip/Gaia Astrometry

HIP79578 B









Updated characterisation of long period single companions

- 24 single companions with a > 5 au in exoplanet.eu :

- 8 already characterized

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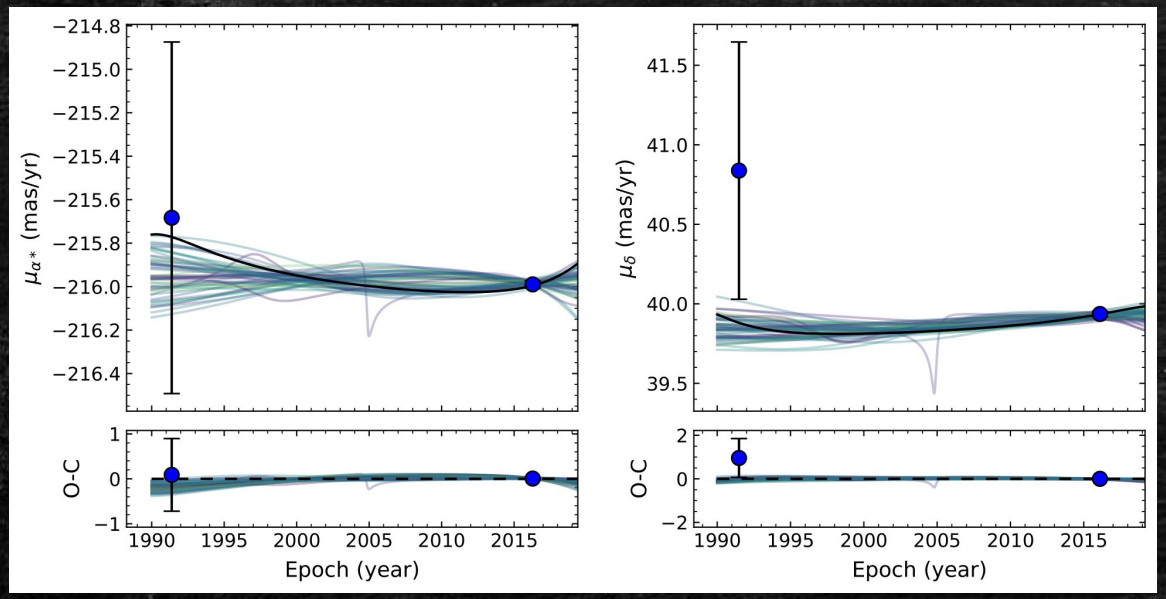
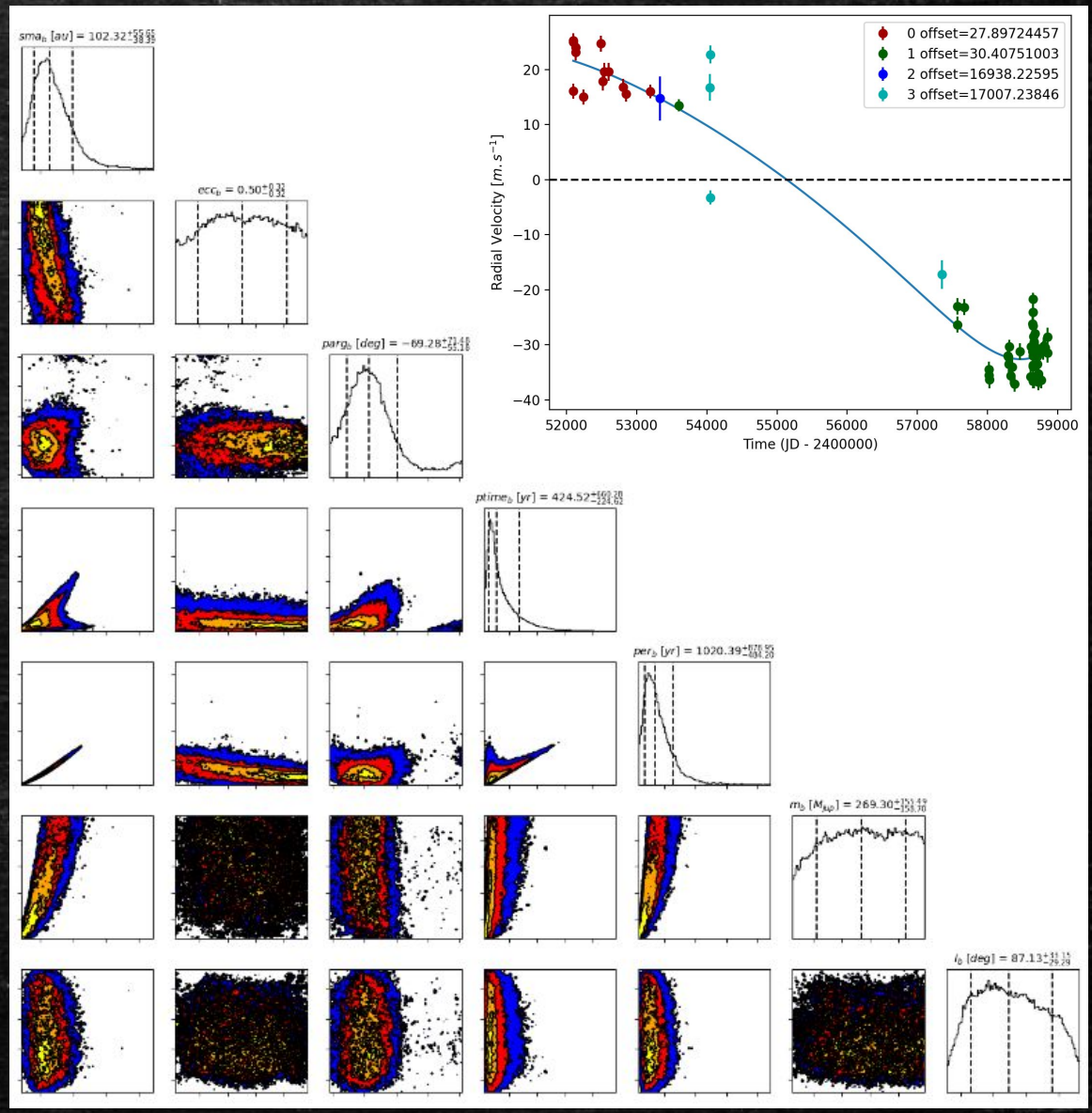


HD213472 b

06/10/2022



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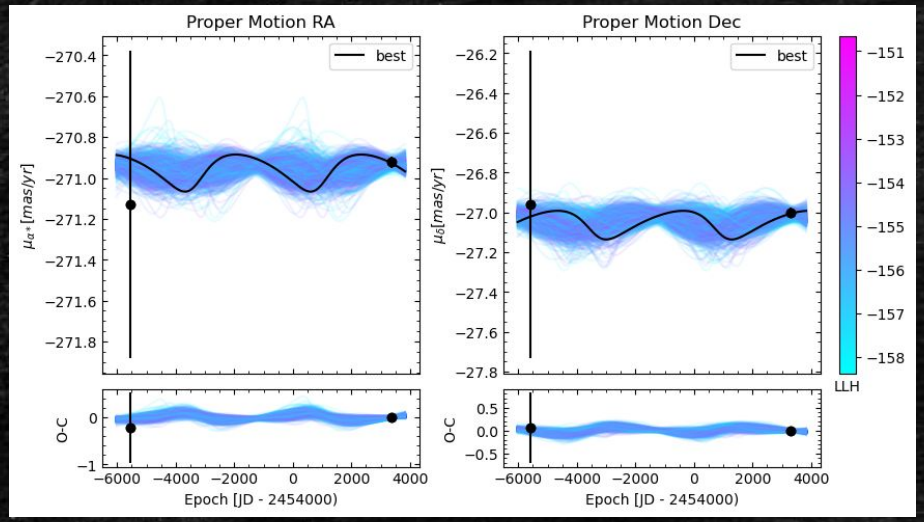

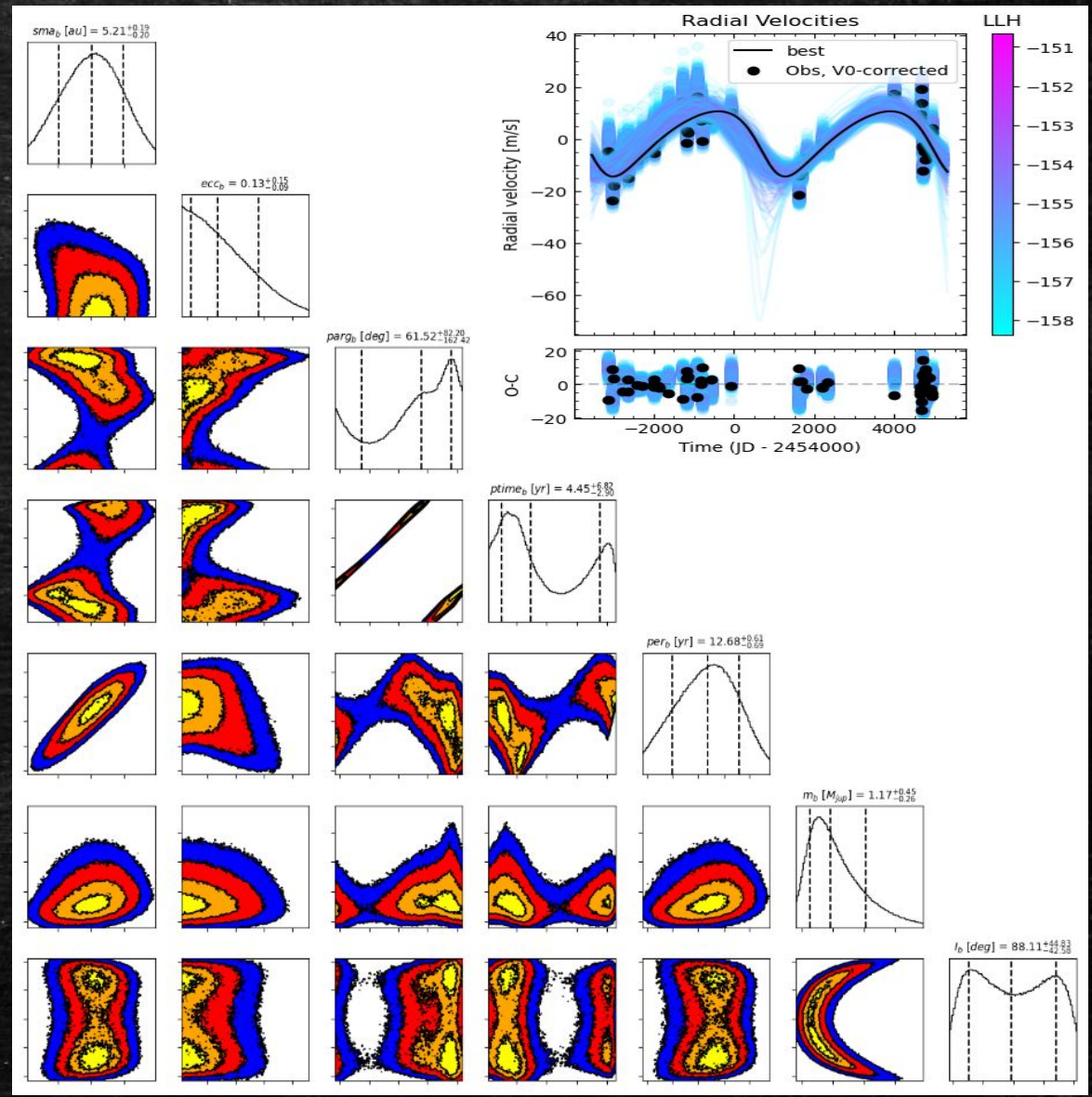

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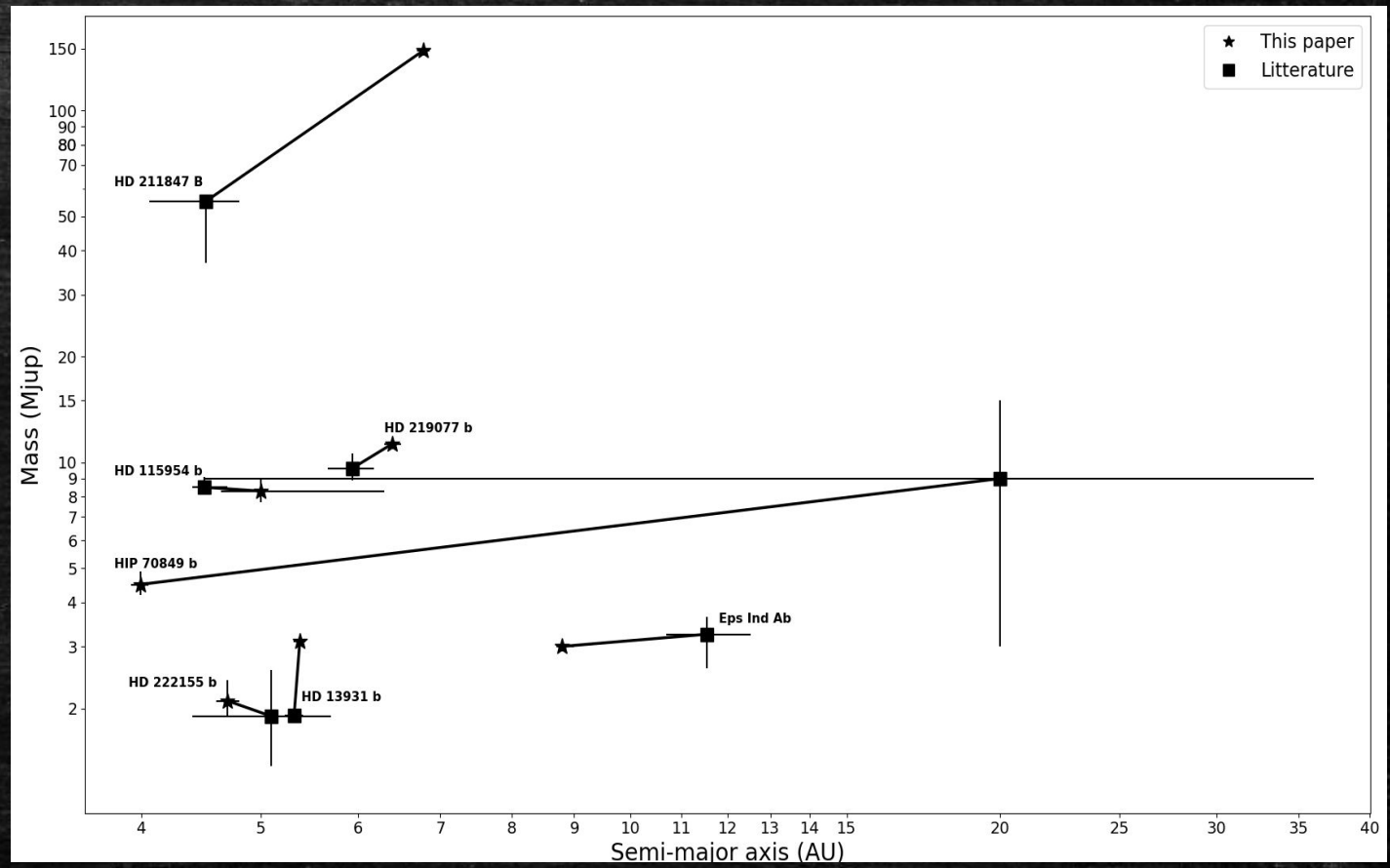
7 new characterisations
(Philipot et al. in prep.)

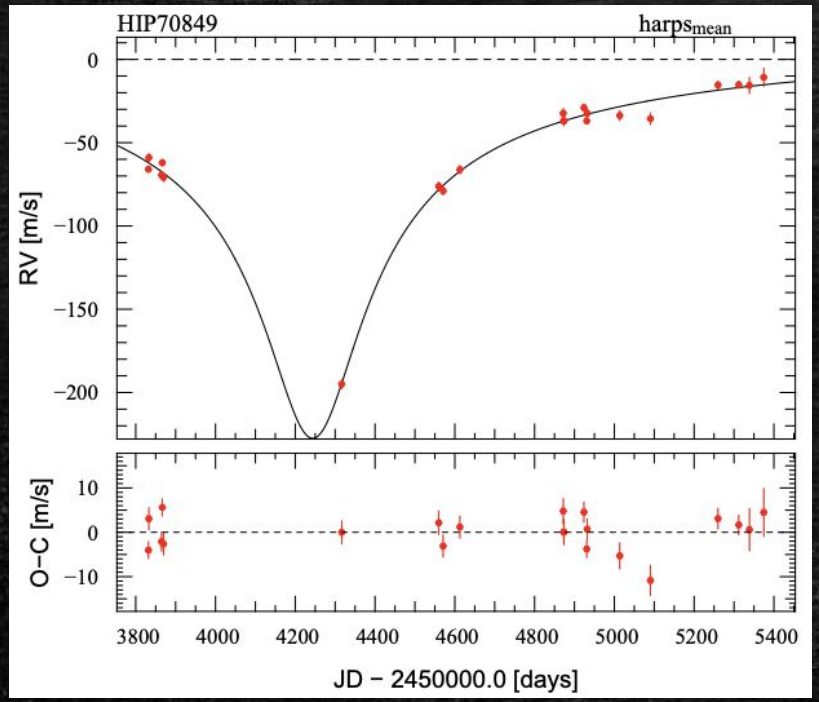


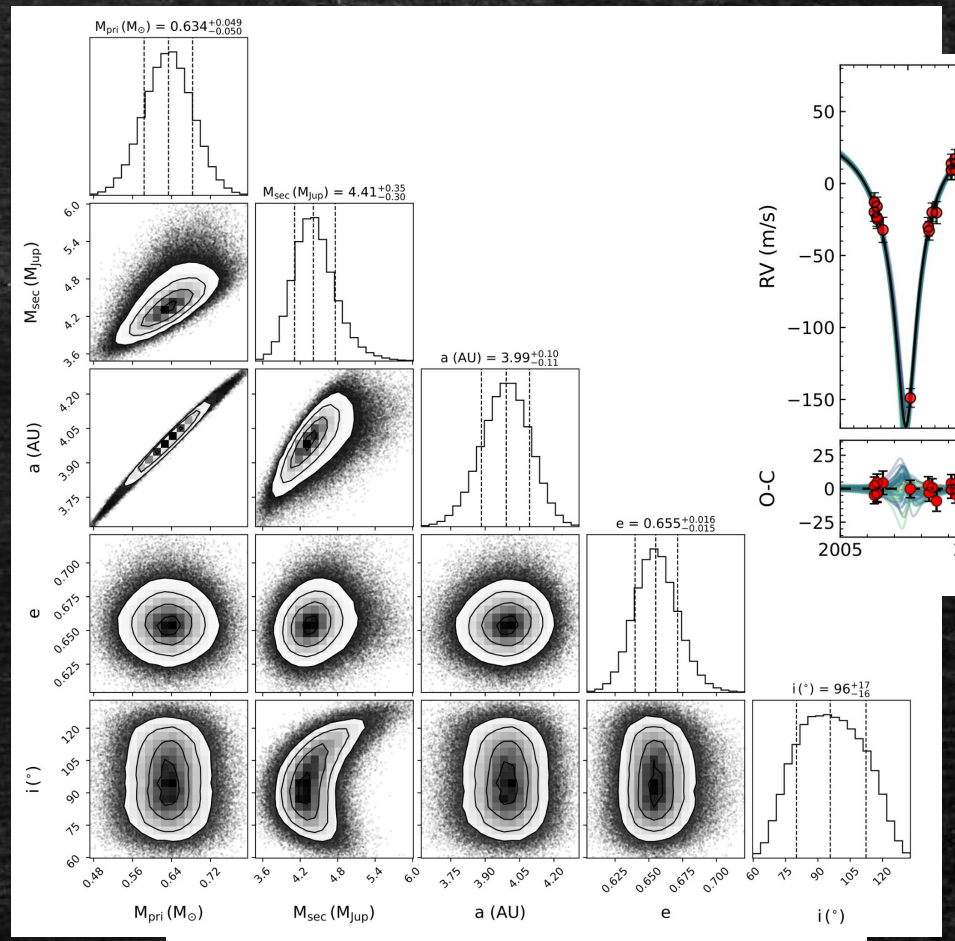
Updated characterisation of long period single companions

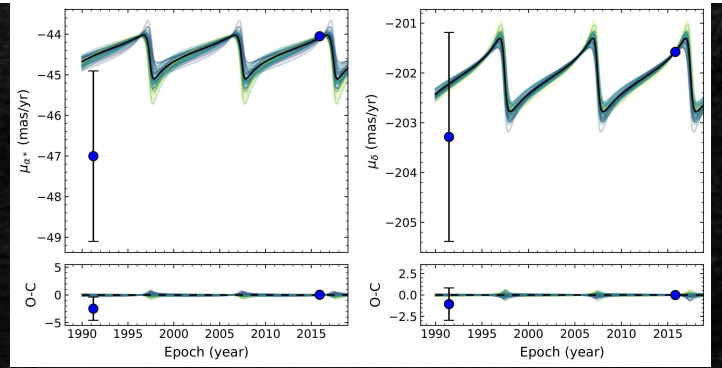
- Additional RV measurements : HIP 70849 b

Ségransan et al. 2011: a = 4.5 - 36 au

Msin(i) = 3 - 15 M_{Jup}

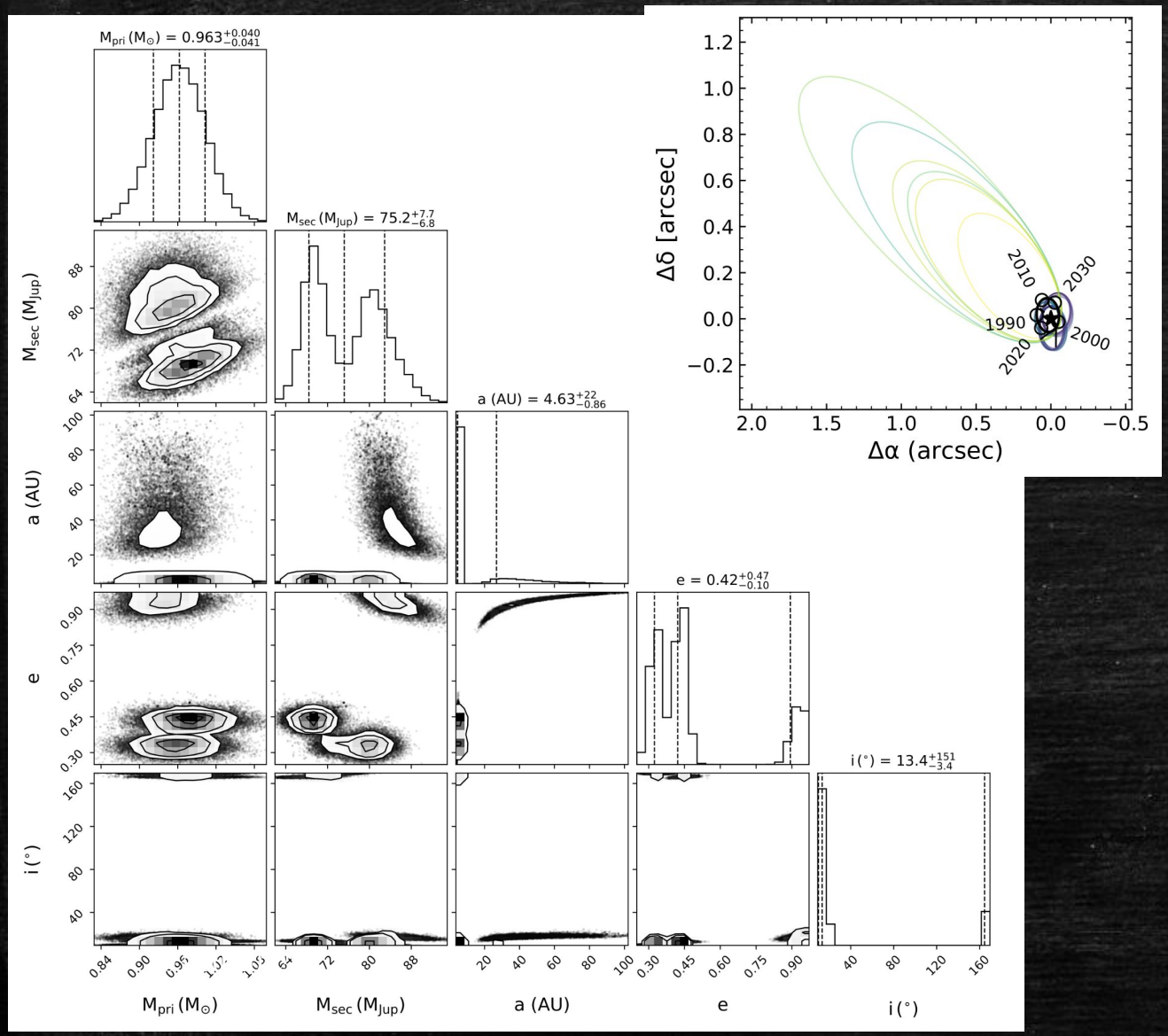


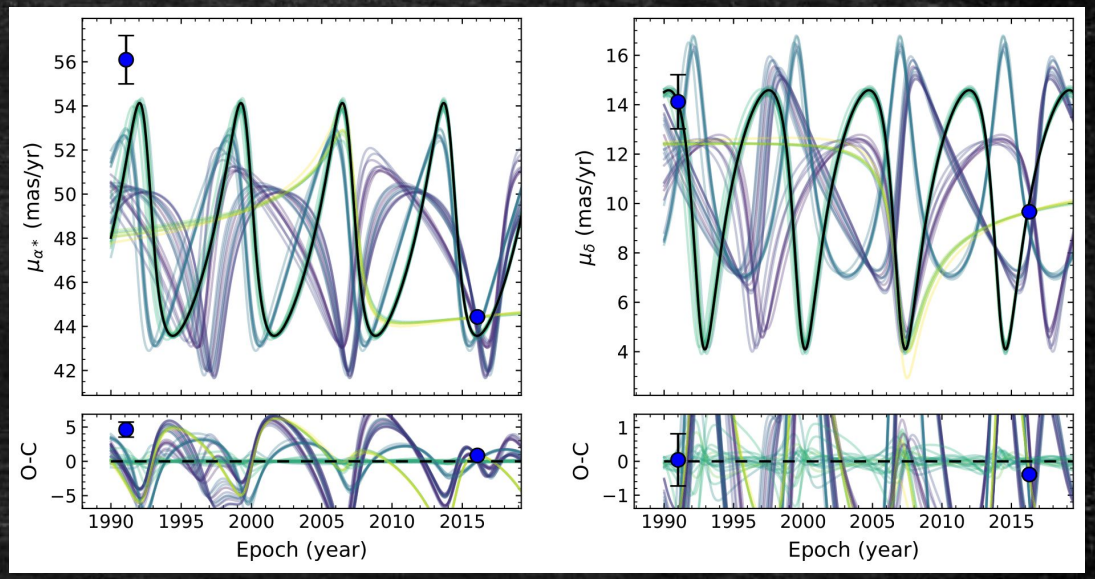


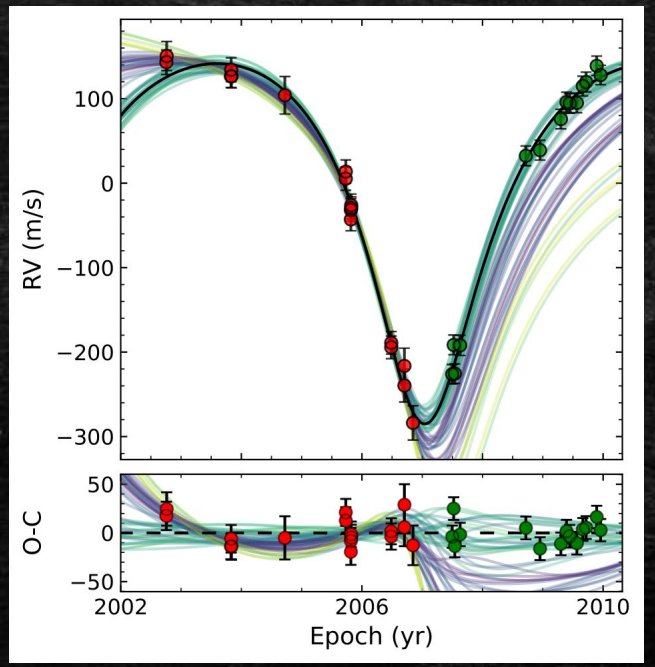


Coupling RV - Hip/Gaia astrometry - Imaging

HD211847 B: RV + Hip/Gaia

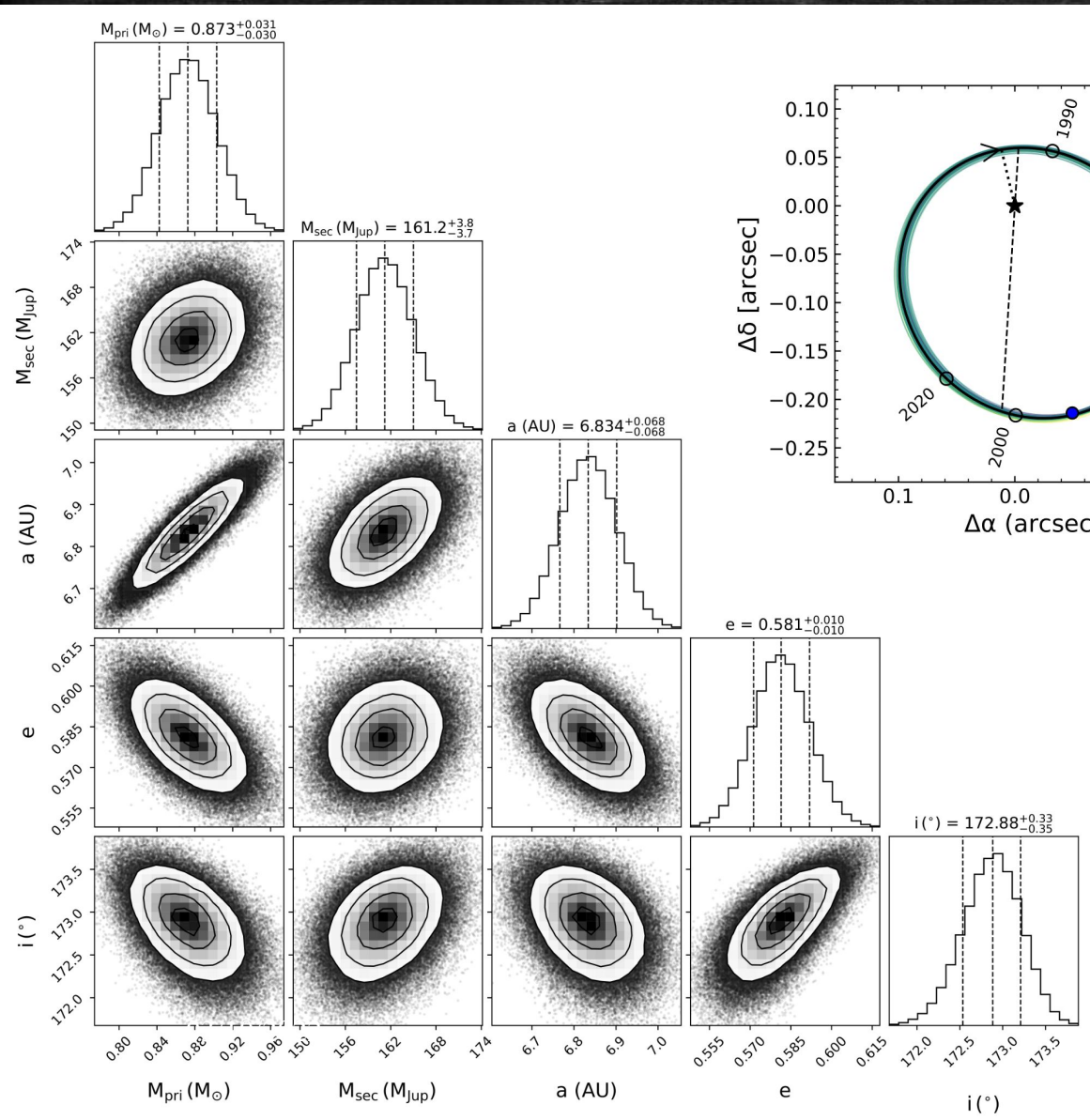


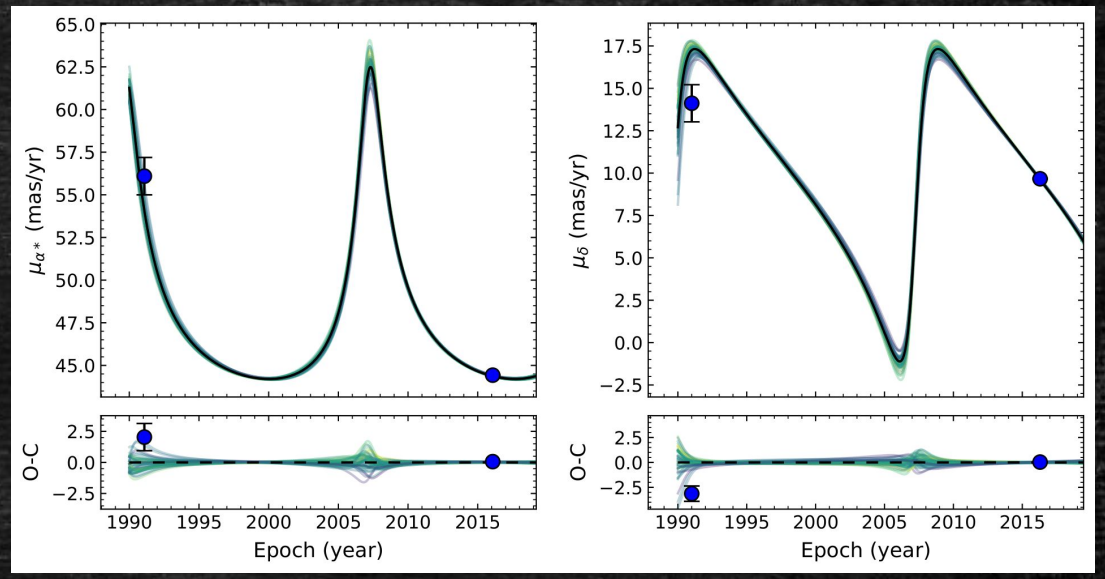


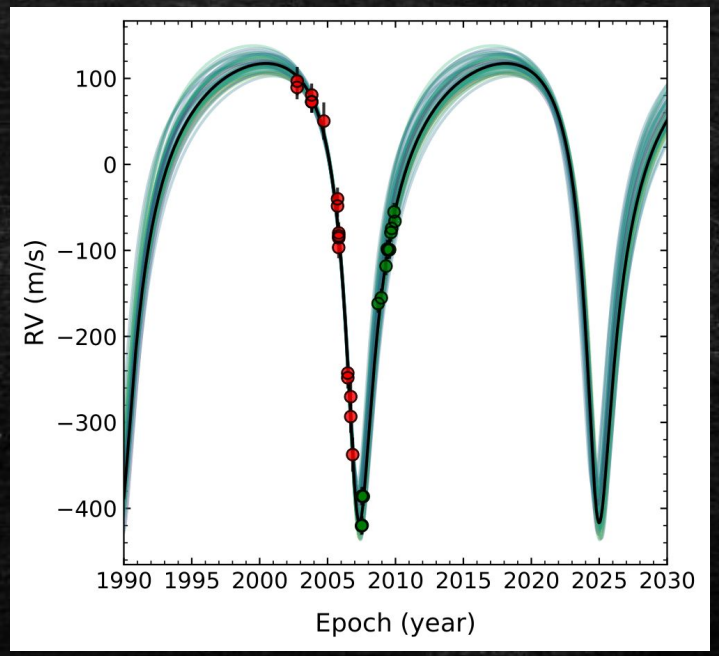


Coupling RV - Hip/Gaia astrometry - Imaging

HD211847 B: RV + Hip/Gaia + HCI



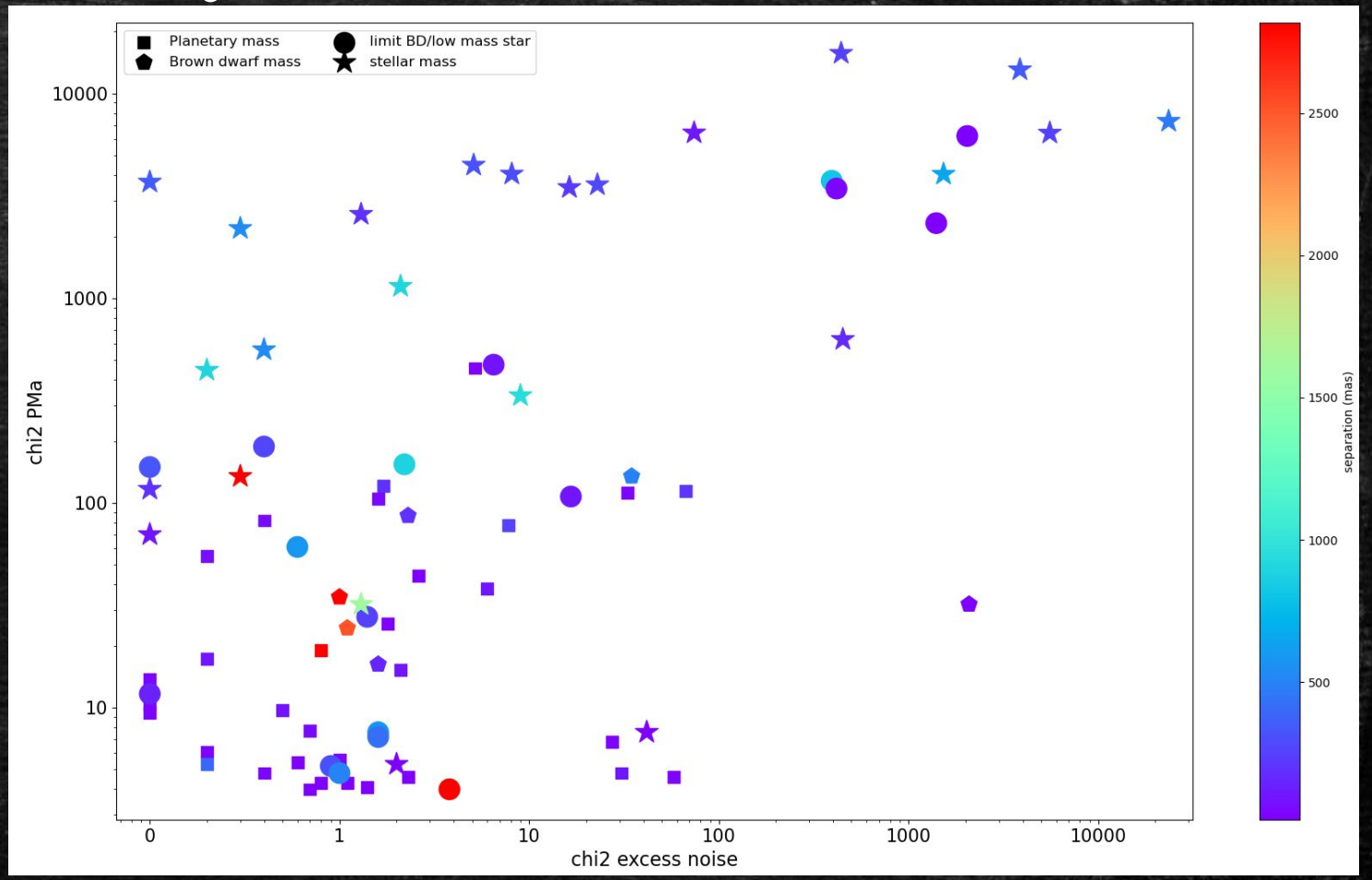




PMa of the star observed by HARPS

- 734 targets: - baseline > 1000 d
  - more than 30 RV data

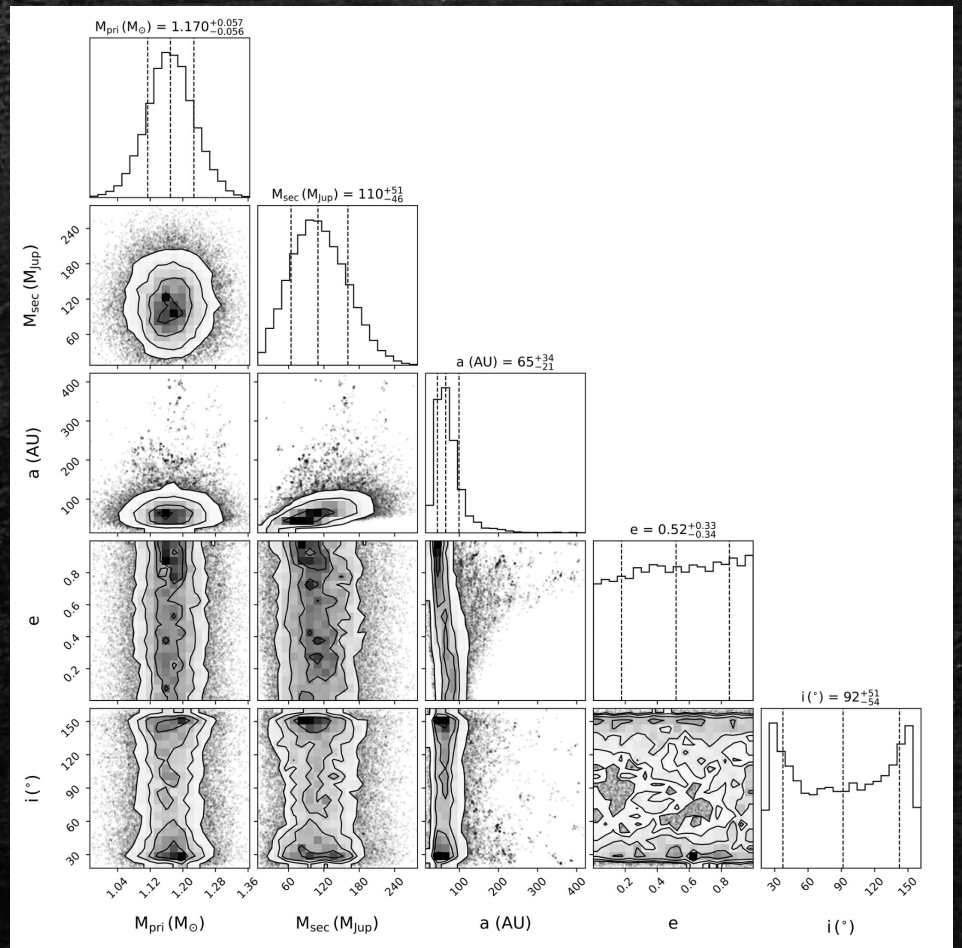
- 140 targets: - PMa > 2**σ** than noise
  - Mass inferred by PMa at 10 au < 200 M_{Jup}

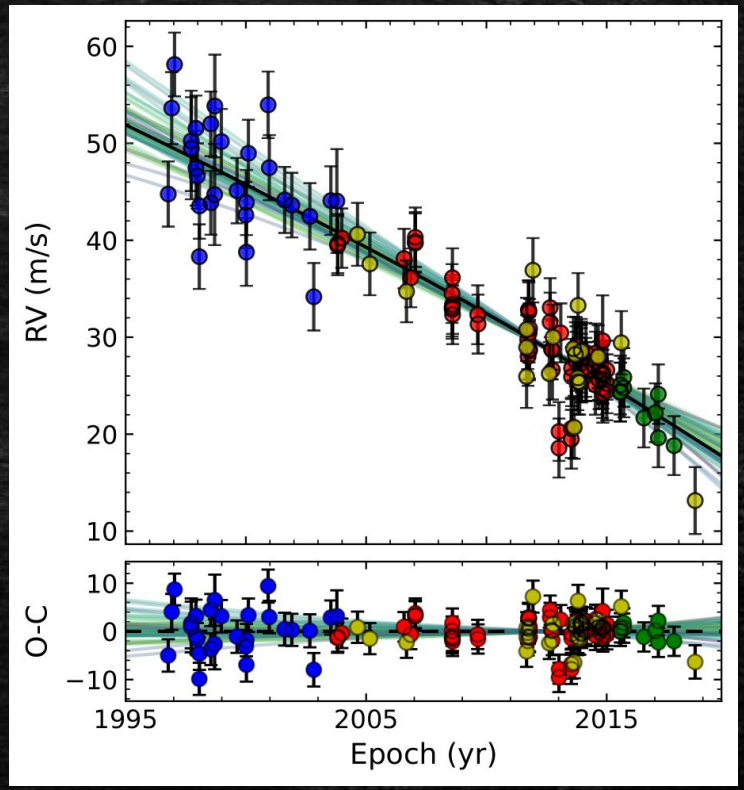


- 28 stellar mass companions
- 21 intermediate mass (BD/star)
- 14 Brown dwarfs (4 potential new)
- 30 planets (9 potential new)

Upcoming objectives

- Precise analysis of each companion and confirmation of new detections
- Combine with HCI for poorly constrained systems (RV Trend)





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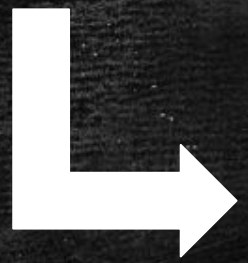


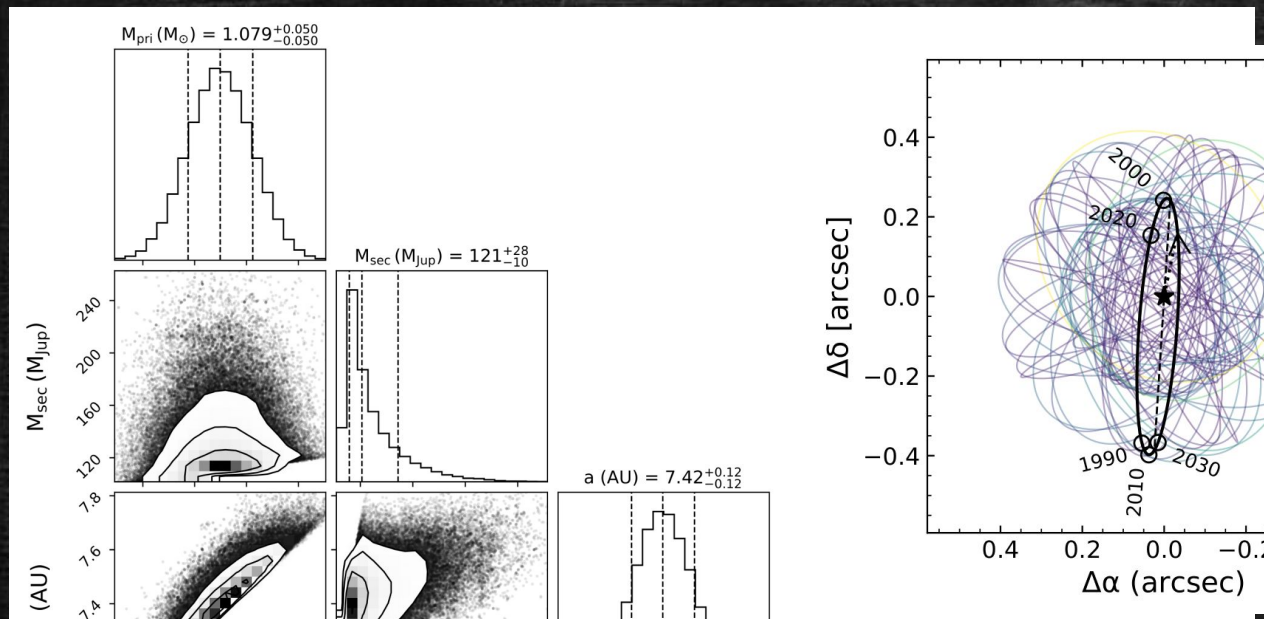
  - 5 new observations with SCExAO/CHARIS (HD7449, HD11505)
  - Proposal SPHERE (P111) for 18 sub-stellar companions
  - 7 companions already imaging

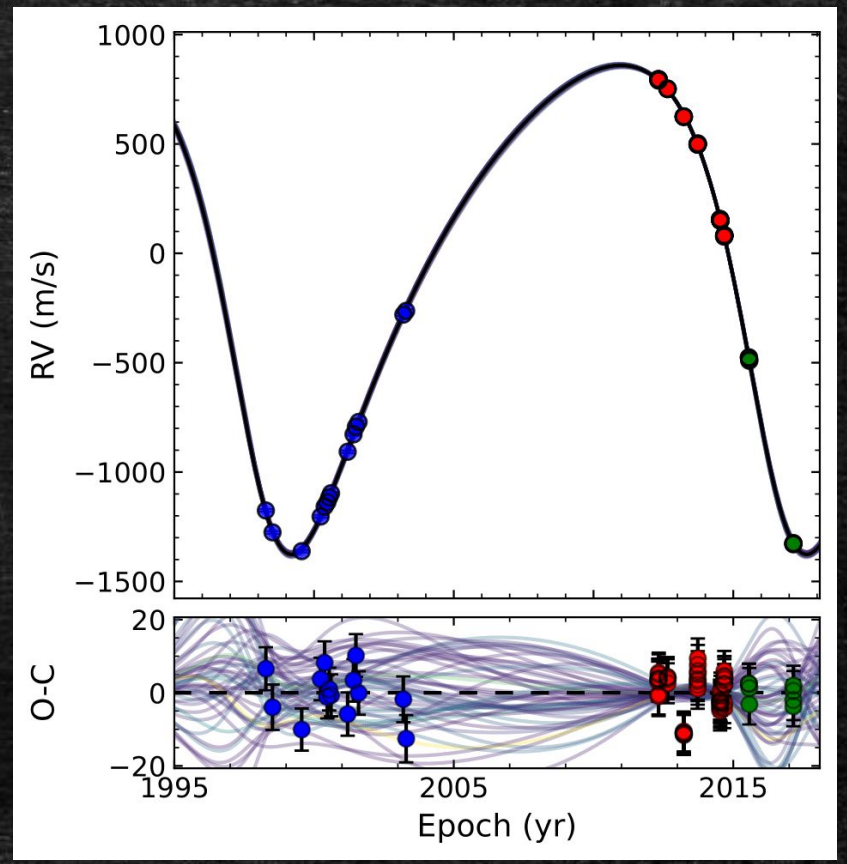
- Using Hip/Gaia astrometry on multiple systems
- Robust determination of mass and orbital parameters → improve the characterisation of atmospheric composition and test the formation pathways of sub-stellar companions.

THANK YOU FOR YOUR ATTENTION !

Coupling RV & Hip/Gaia Astrometry

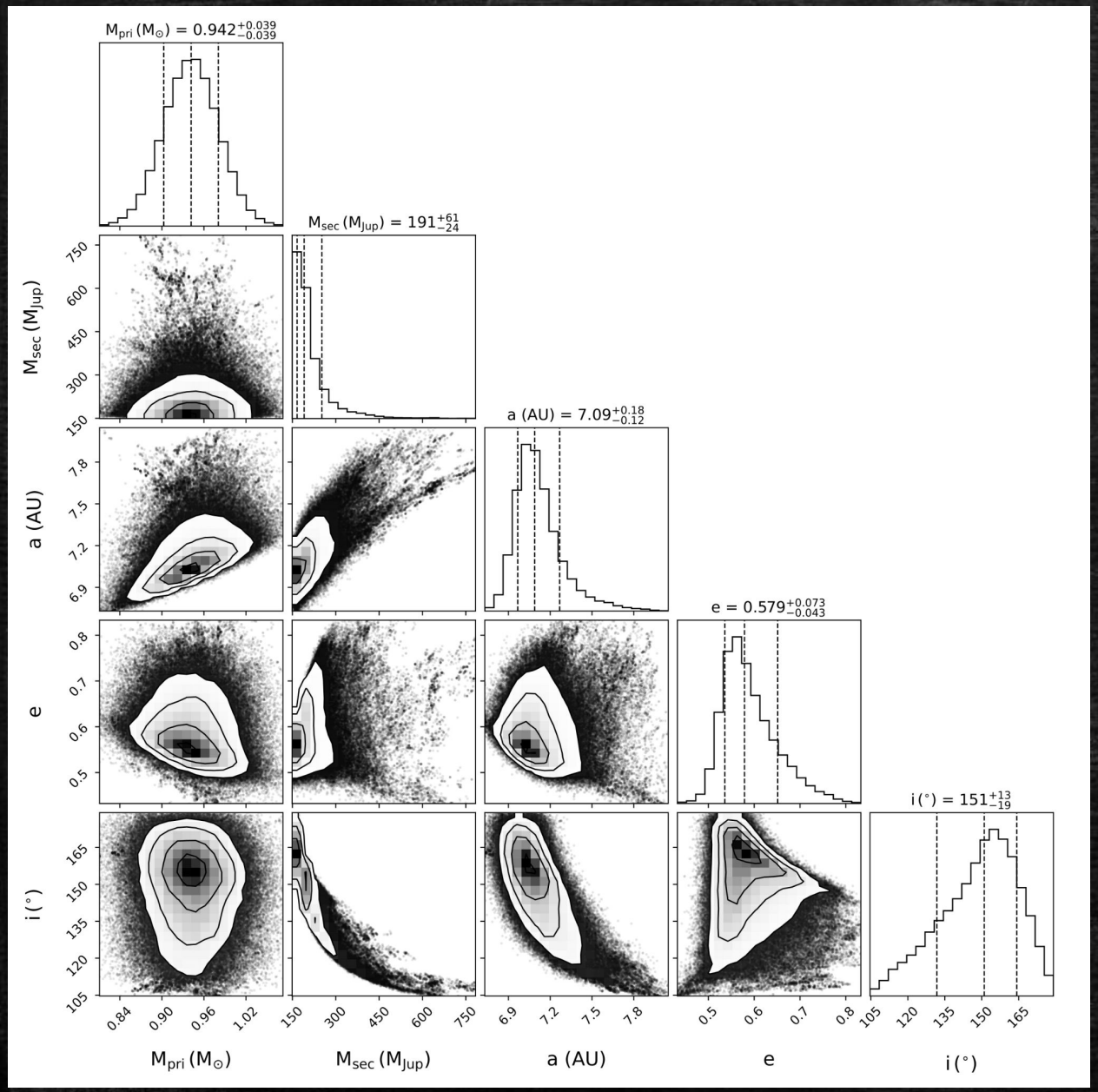
HIP79578 B (RV only)

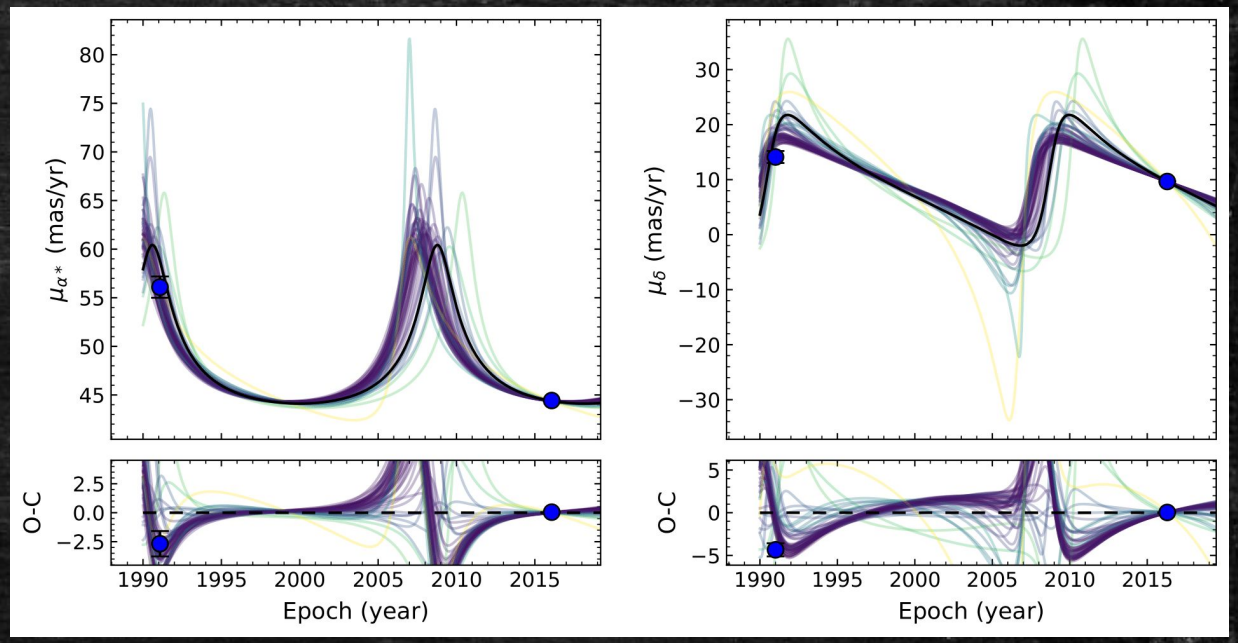


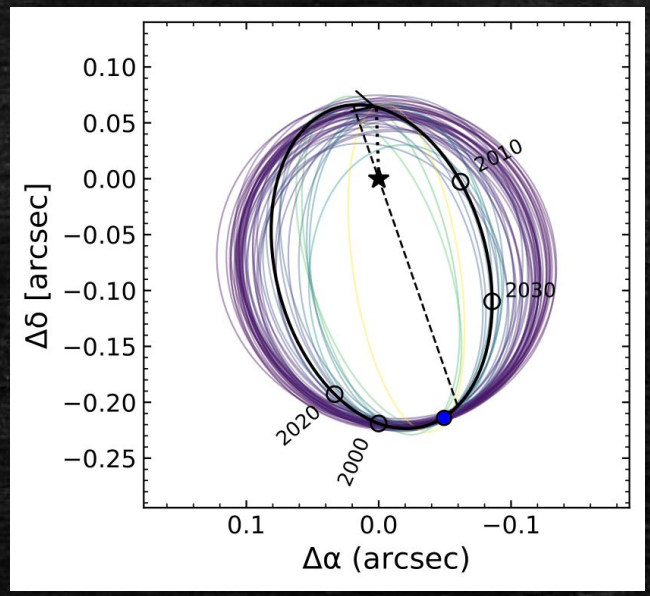


Coupling HCI & Hip/Gaia Astrometry

HD211847 B

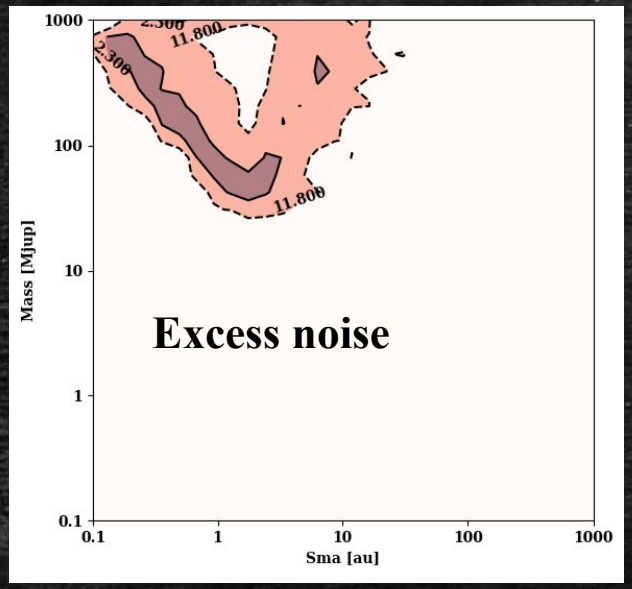


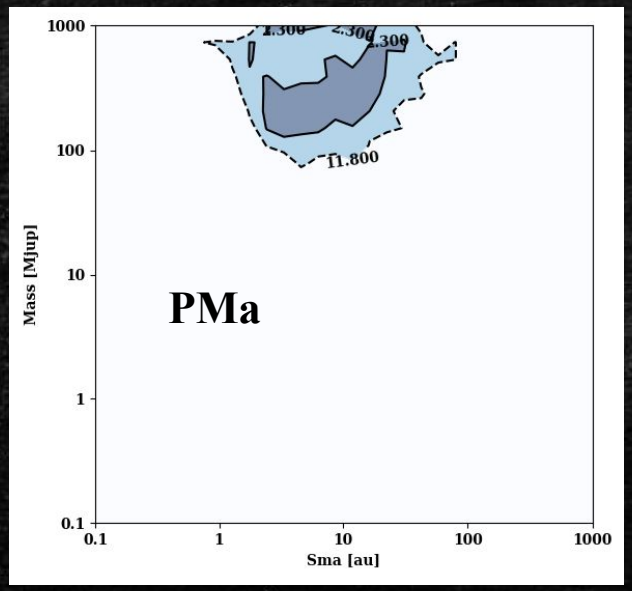


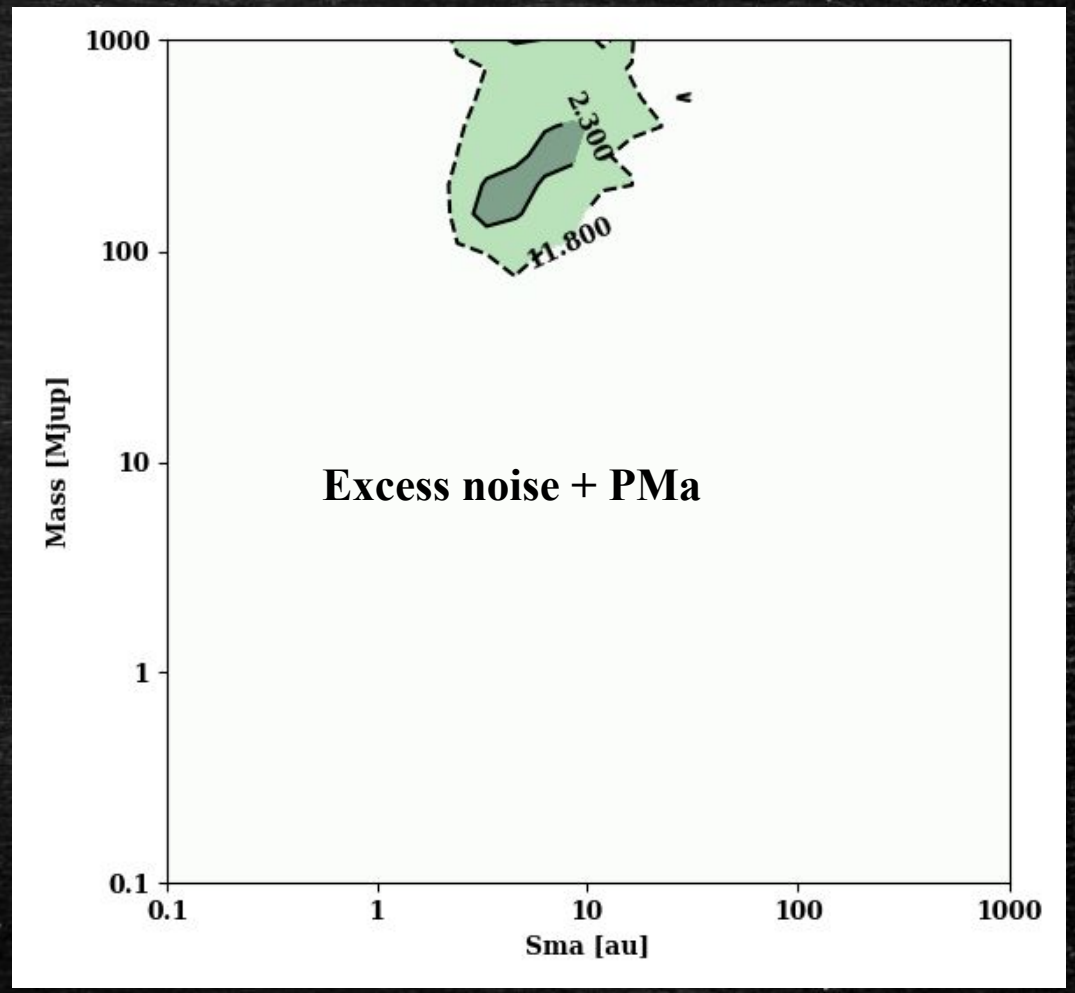


sma/Mass constraint from GaiaPMEx (DR3)

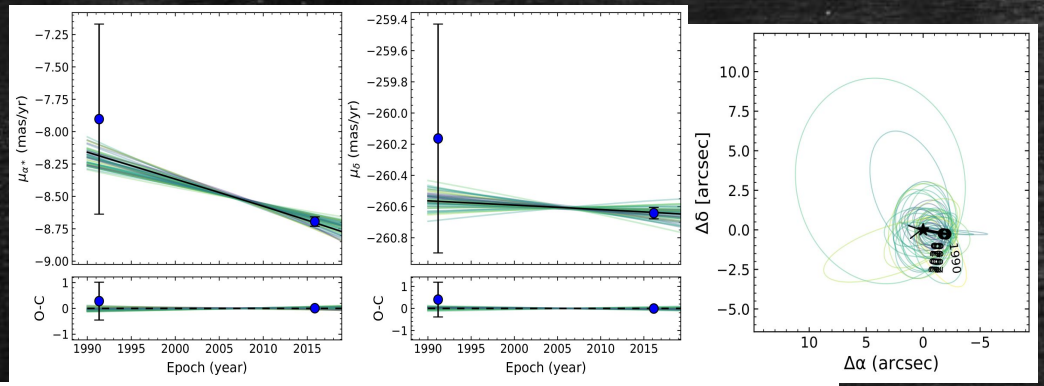
HIP79578 B

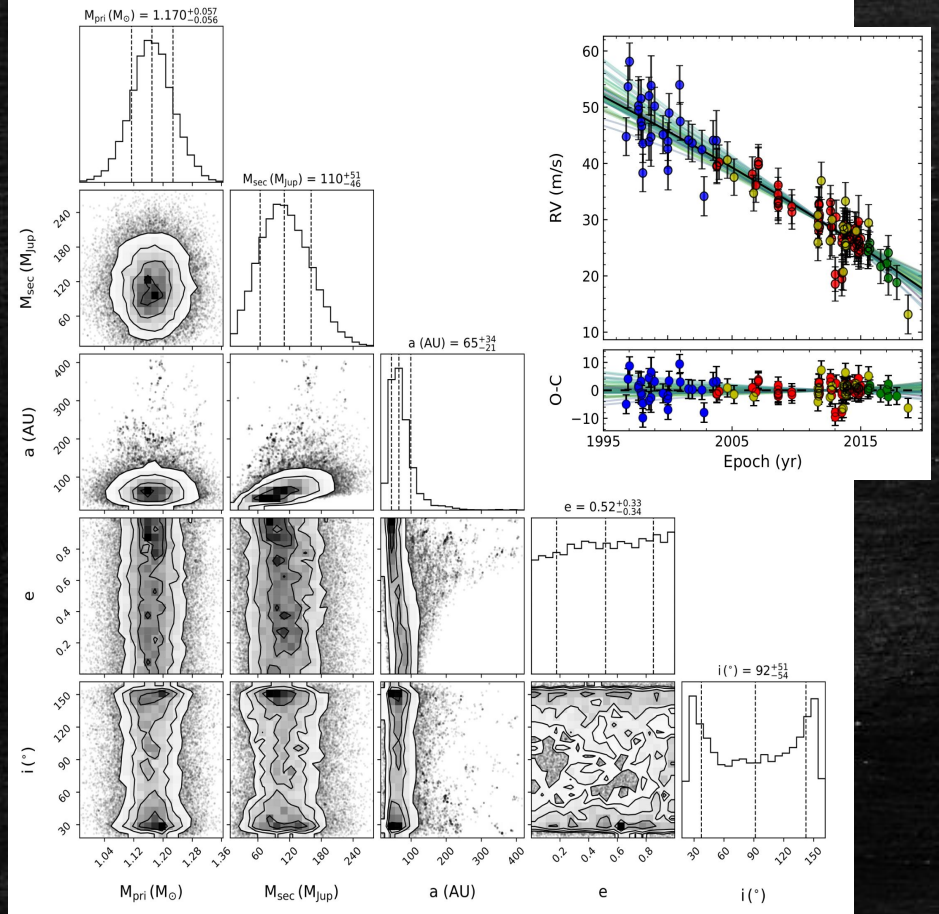




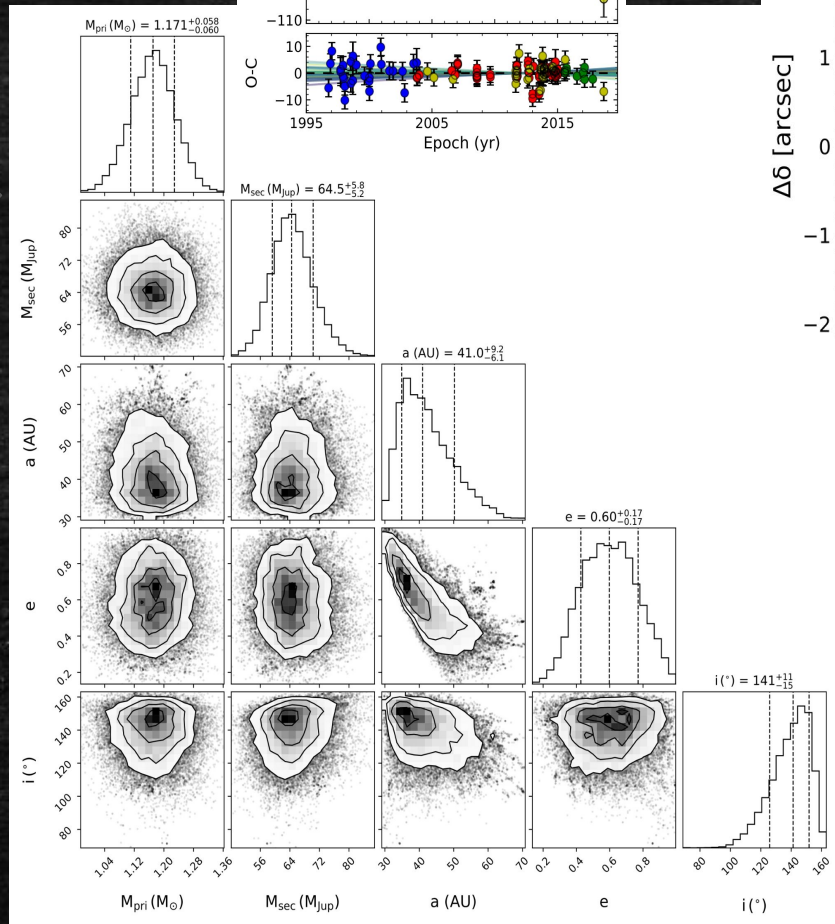


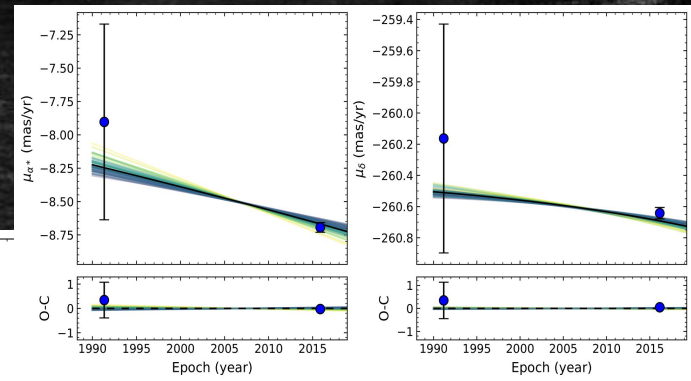
Coupling RV & Hip/Gaia Astrometry & HCI

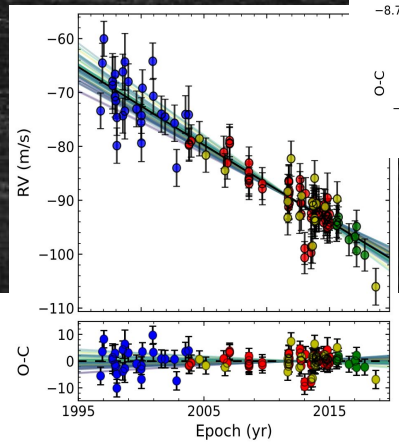


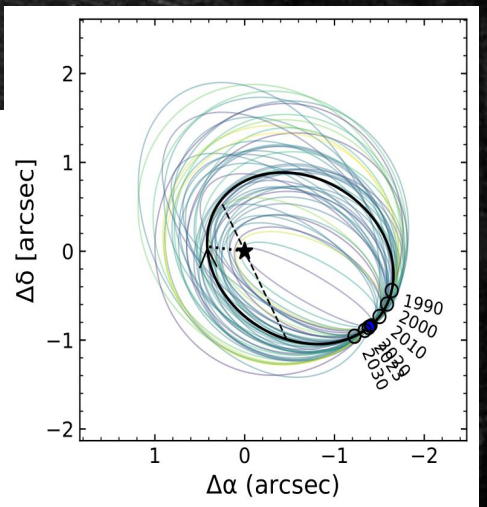


+ HCI data

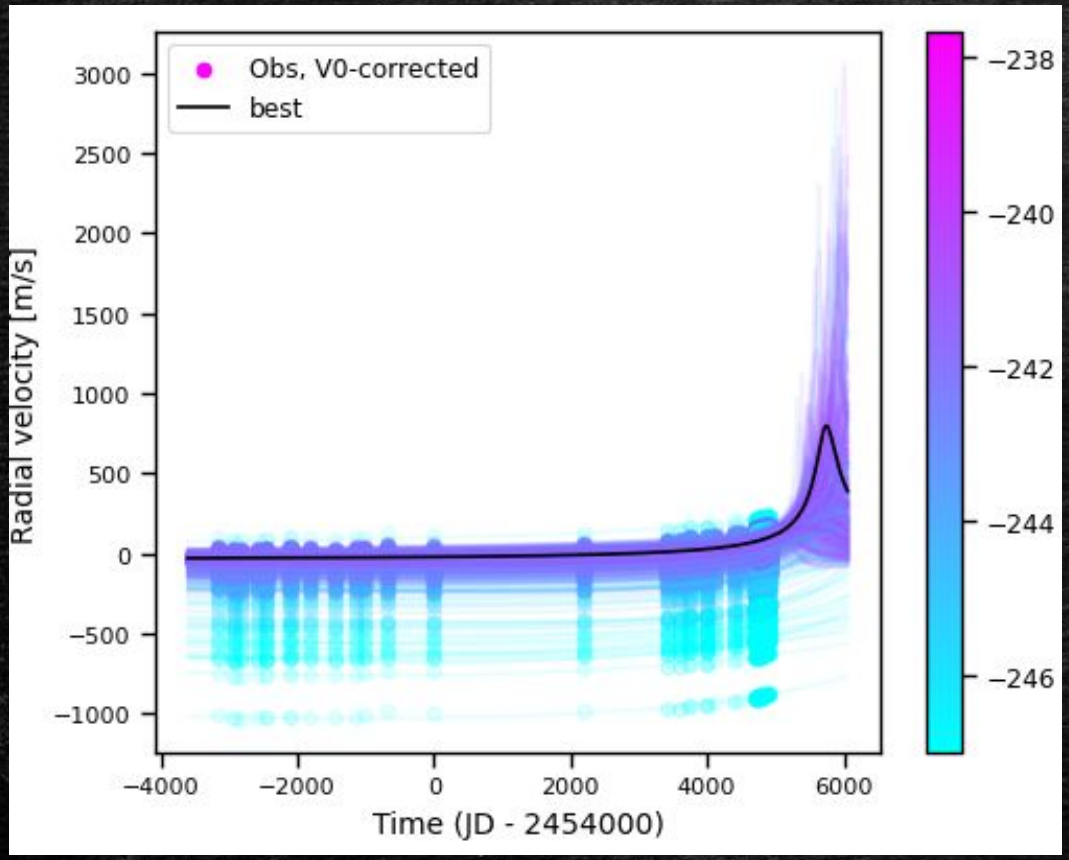


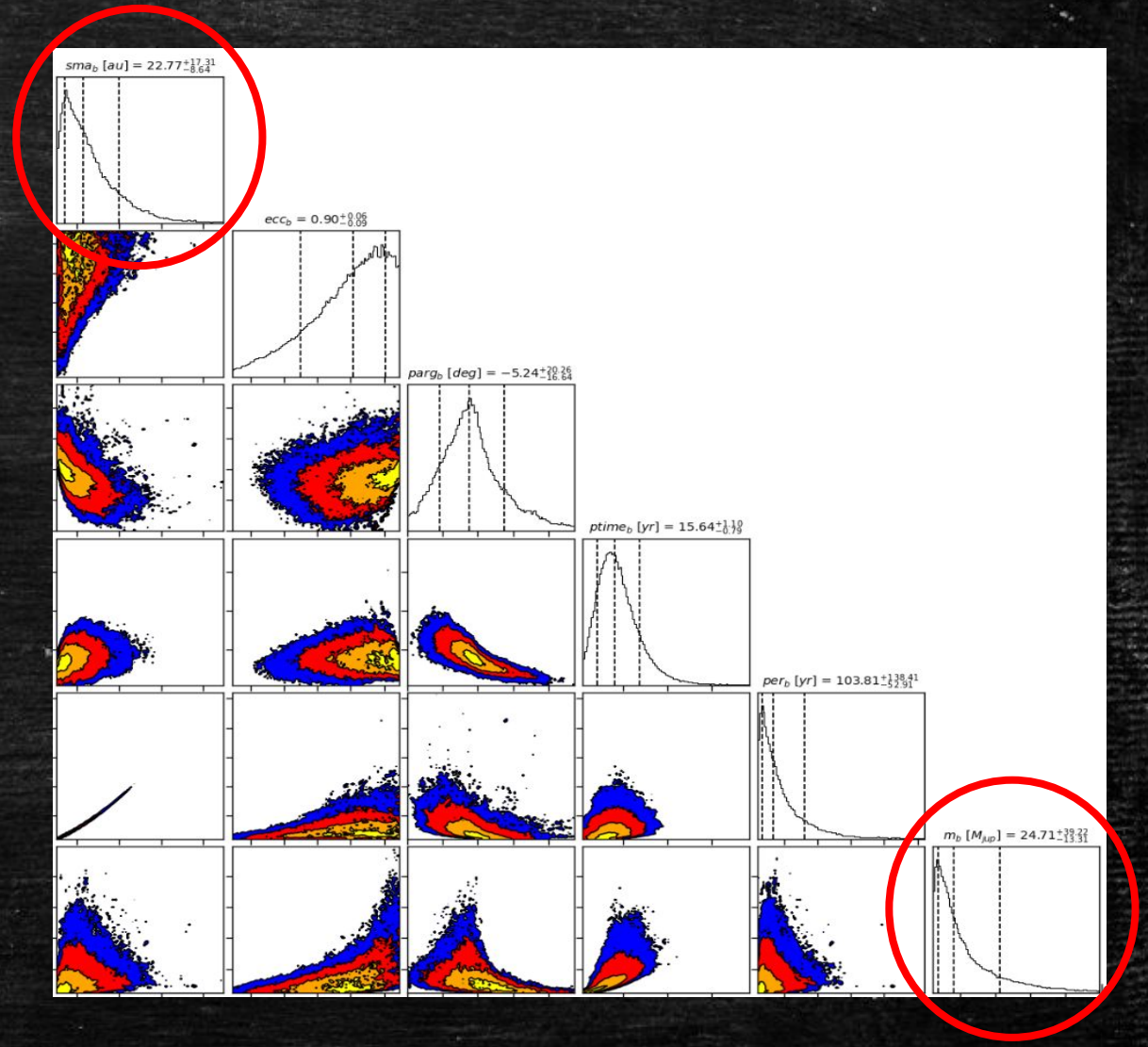






MCMC:





HD26161

Test with a fake planet

- Fake planet signal with the same calendar as HD26161 : sma = 240 au
  Msin(i) = 70 Mjup
  ecc = 0.95

- MCMC sampling strongly peaked on sma << 100 au ↔ real HD26161 data