Action thématique
Exosystèmes

ExoSystèmes V

IAP, 31/03-02/04/2026

Modelling the Milky Way exoplanet population

Chloé Padois, Daniel del Ser, Friedrich Anders, et al.

MWGaiaDN

This project is a Horizon Europe Marie Skłodowska-Curie Actions Doctoral Network funded under grant agreement no. 101072454.

ICCUB

Universitat de Barcelona

IEEC
Institut d'Estudis Espacials de Catalunya

Ministerio de Ciencia, Innovación y Universidades

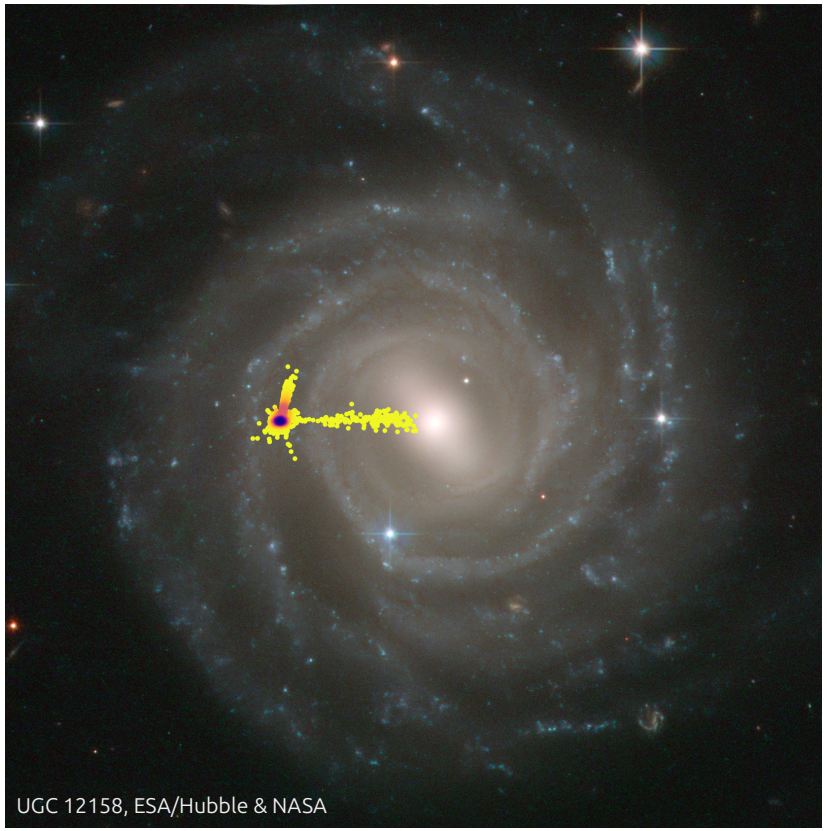
Financiado por la Unión Europea NextGenerationEU

Plan de Recuperación, Transformación y Resiliencia

Agencia Estatal de Investigación

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

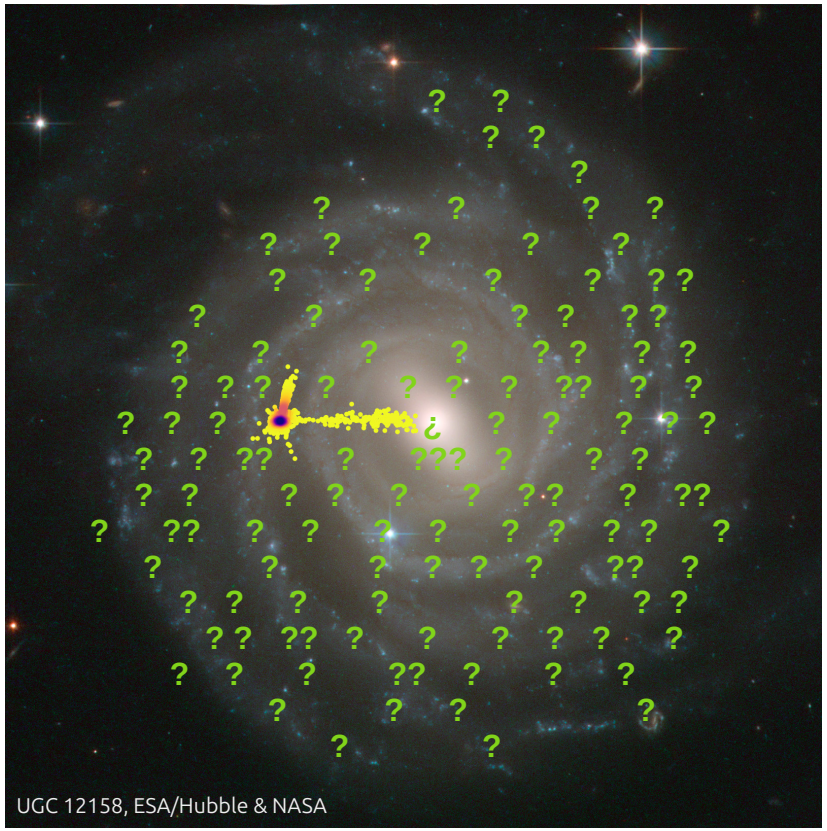

UGC 12158, ESA/Hubble & NASA

Context: study exoplanets from a galactic point of view

- Known exoplanets: observational bias + **restricted to the SN**

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona



Context: study exoplanets from a galactic point of view

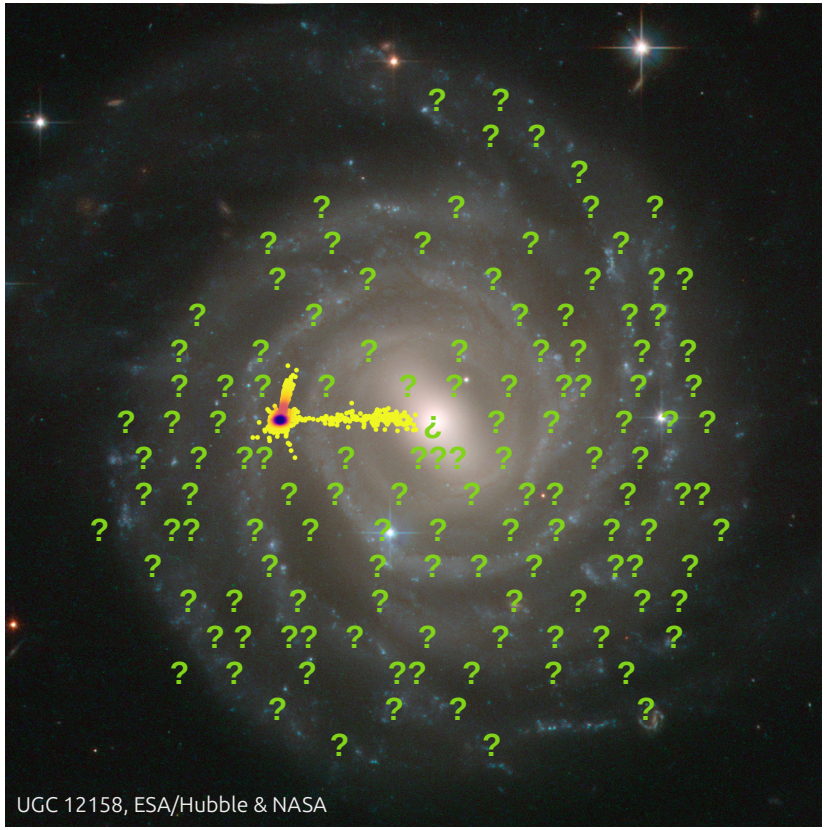
- Known exoplanets: observational bias + restricted to the SN

Goal: simulate the (unbiased) exoplanet population in the MW

- Exoplanets everywhere? Homogeneously distributed?
- Changes with galactic evolution?

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona



Context: study exoplanets from a galactic point of view

- Known exoplanets: observational bias + restricted to the SN

Goal: simulate the (unbiased) exoplanet population in the MW

- Exoplanets everywhere? Homogeneously distributed?
- Changes with galactic evolution?

Method: Framework to quickly generate exoplanet population

- Around any stellar population (mass and metallicity)
- Combining observations and planetary formation models
- Predict yields of future missions → **constrain models**

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

1) General methodology

2) Comparing with observations

Generate exoplanet population

Evaluate our results:

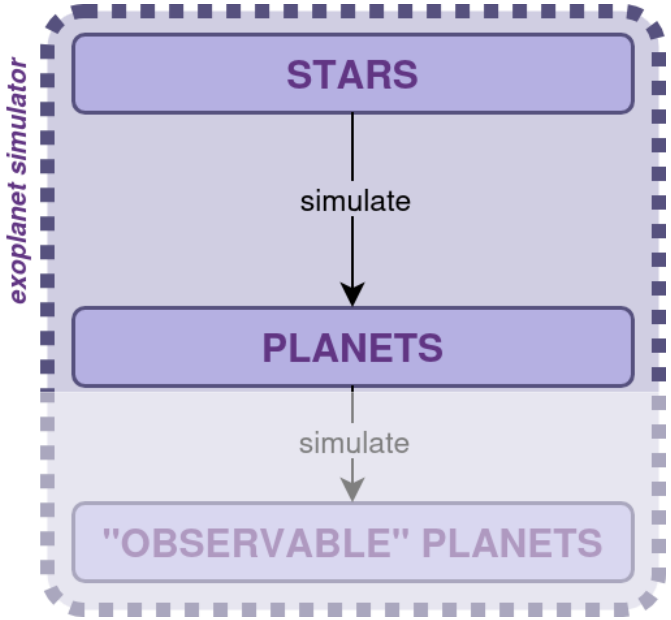
- Detectability by *Kepler*
- Predictions for future surveys

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

1) General methodology

Generate exoplanet population

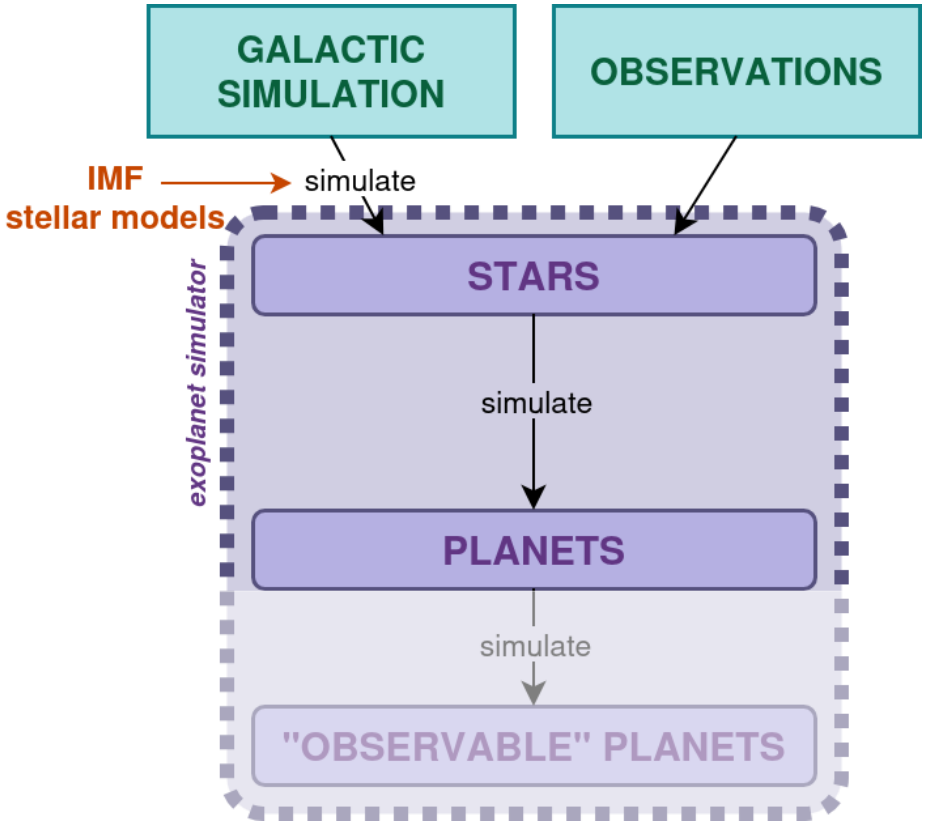


Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

1) General methodology

Generate exoplanet population



Modelling the Milky Way exoplanet population

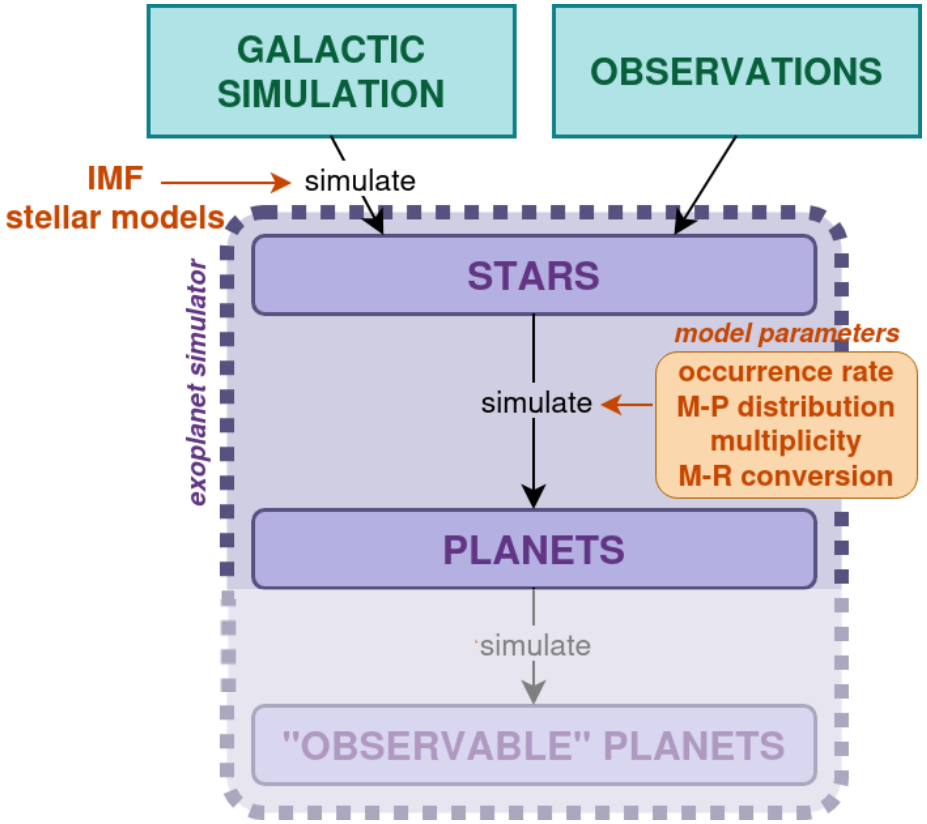
Chloé Padois, Universitat de Barcelona

1) General methodology

Generate exoplanet population

Occurrence rates and multiplicity

Assign physical parameters



Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

General methodology: Creation of a synthetic exoplanet population

Occurrence rates and multiplicity

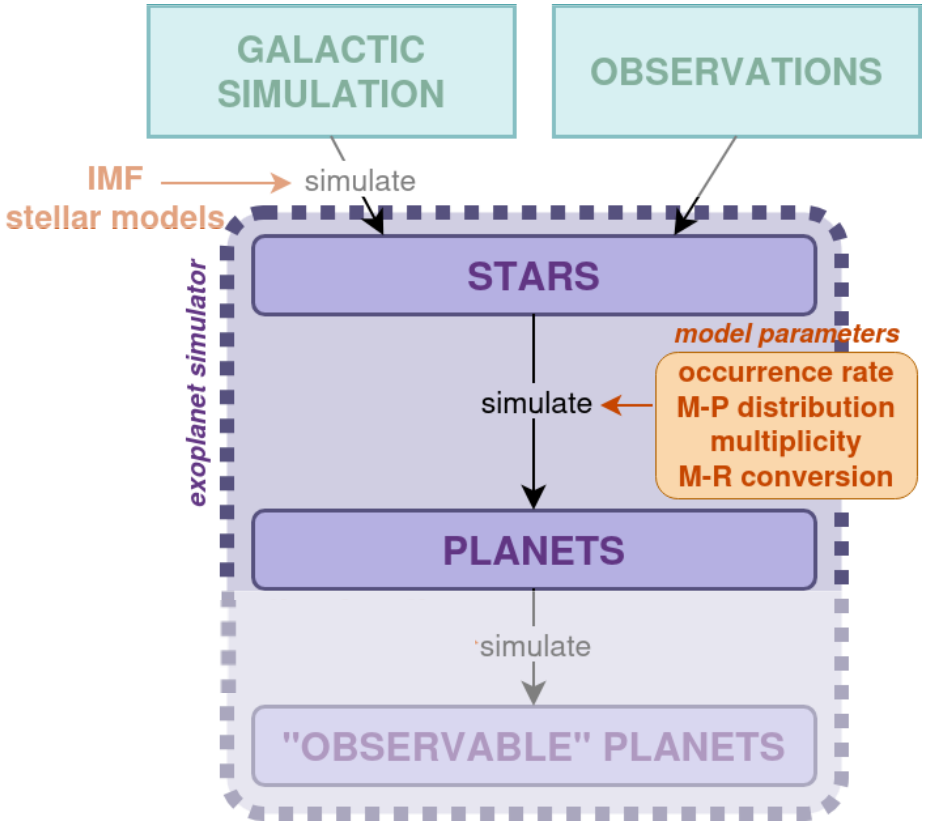
- Probability for a star to harbour planets

→ f(M*, [Fe/H]*)

Earth-like

Super-Earth + Neptunians

Sub-Giants + Giants



Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

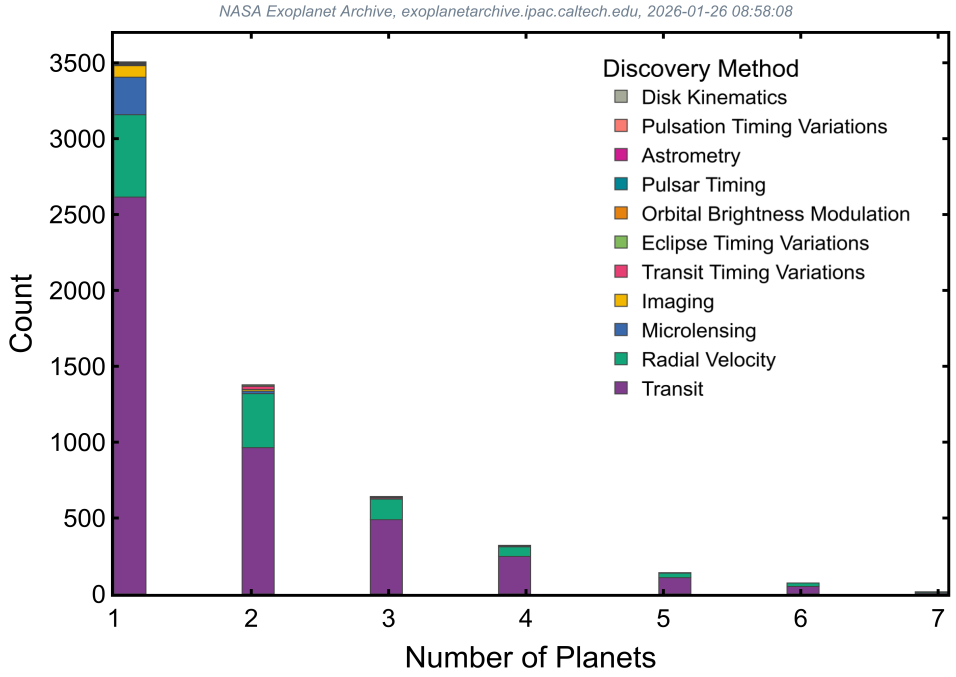
General methodology: Creation of a synthetic exoplanet population

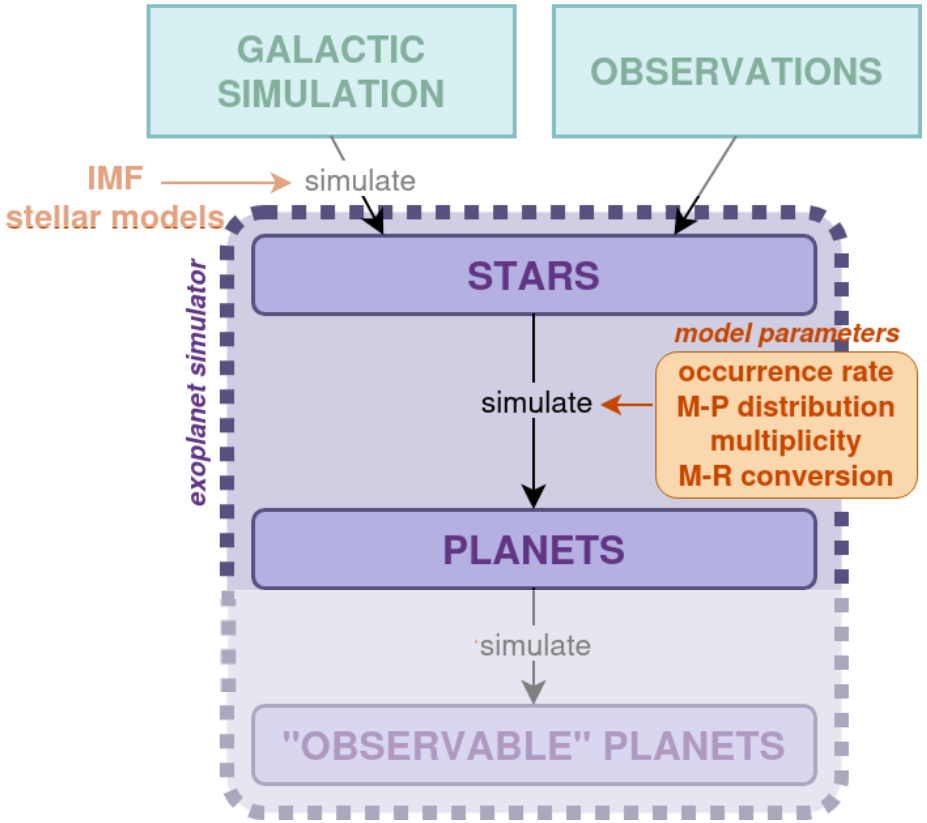
Occurrence rates and multiplicity

- Probability for a star to harbour planets

  → f(M*, [Fe/H]*)

- How many? → multiplicity: f(M*)





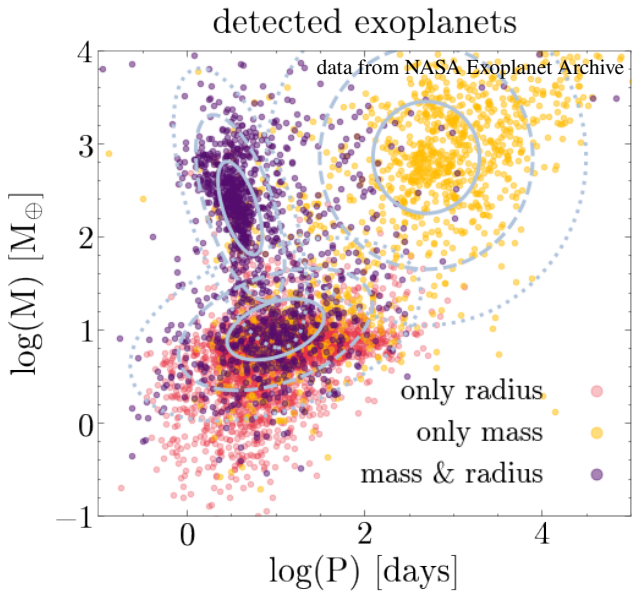
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

General methodology: Creation of a synthetic exoplanet population

Assign physical parameters

- Distribution in mass-period diagram



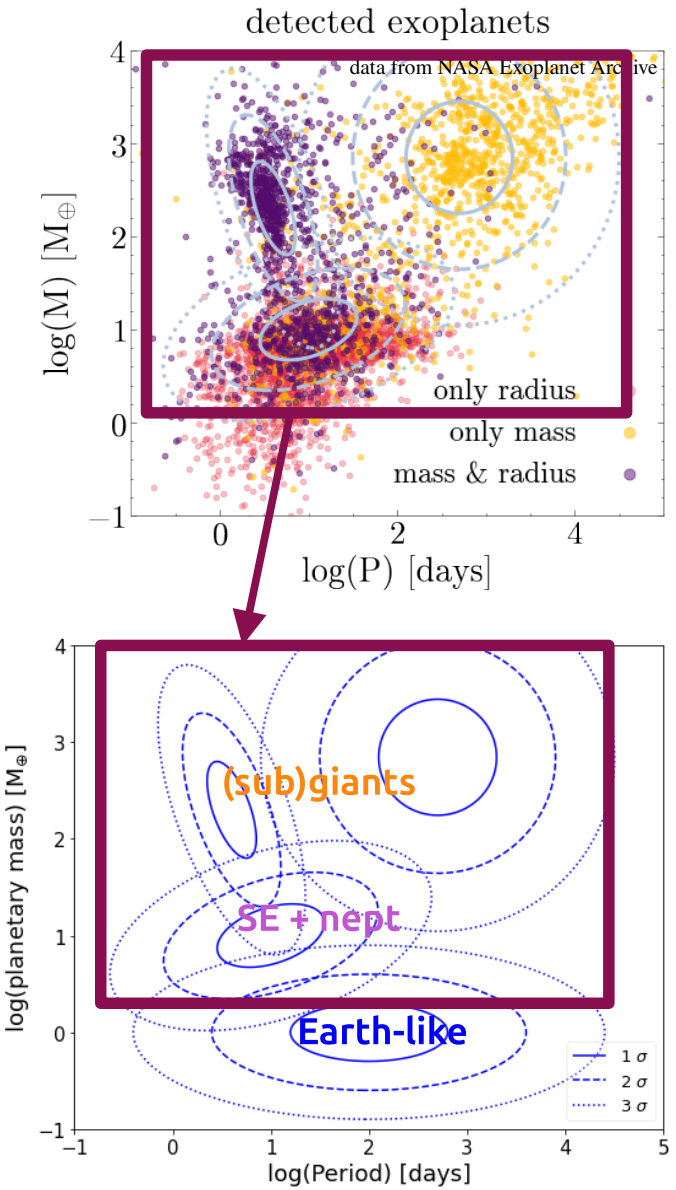
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

General methodology: Creation of a synthetic exoplanet population

Assign physical parameters

- Distribution in mass-period diagram:
  Combining **observations** and **planetary formation model**
  (planetesimal accretion synthesis, from Drążkowska+23)



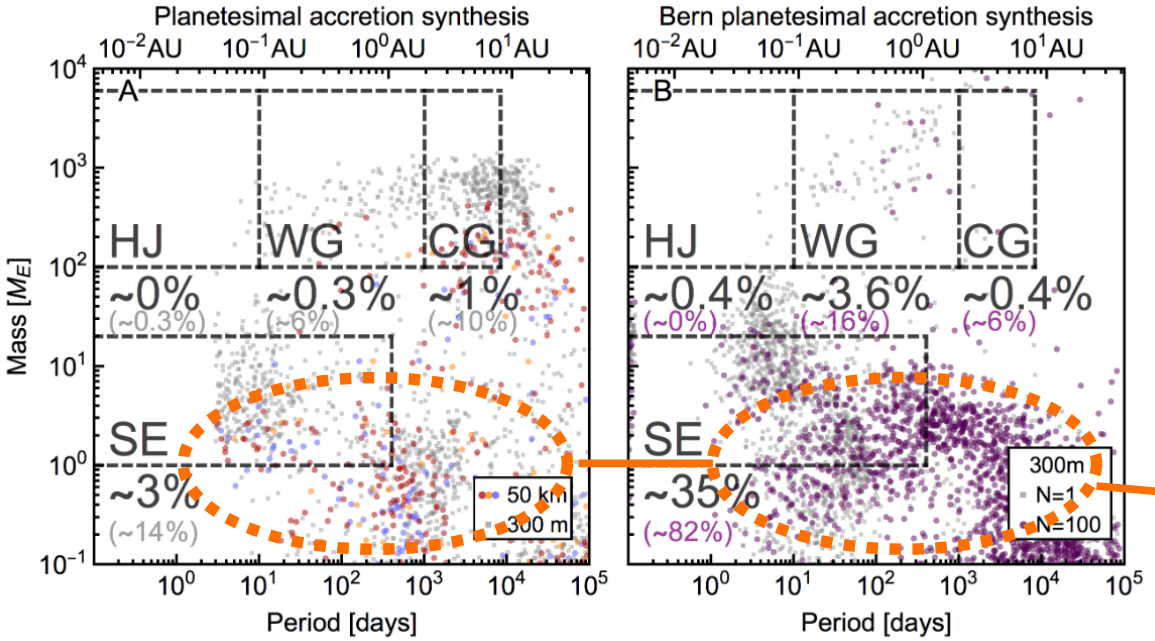
Modelling the Milky Way exoplanet population

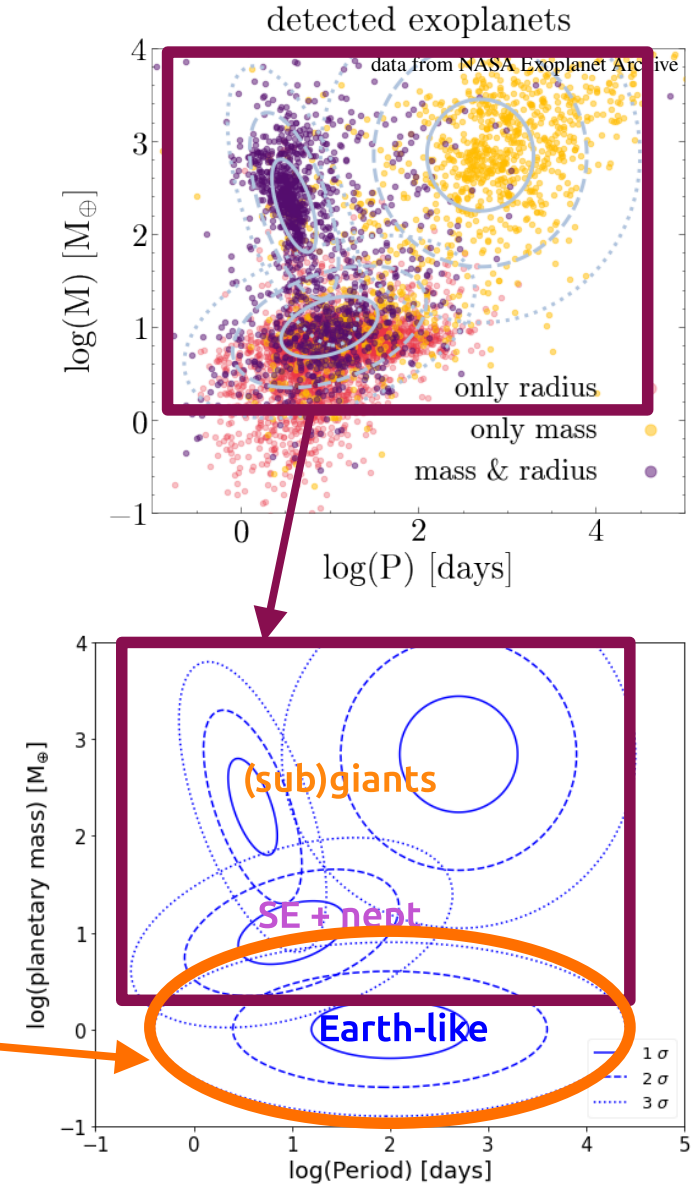
Chloé Padois, Universitat de Barcelona

General methodology: Creation of a synthetic exoplanet population

Assign physical parameters

- Distribution in mass-period diagram:
  Combining **observations** and **planetary formation model**
  (planetesimal accretion synthesis, from Drążkowska+23)





Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

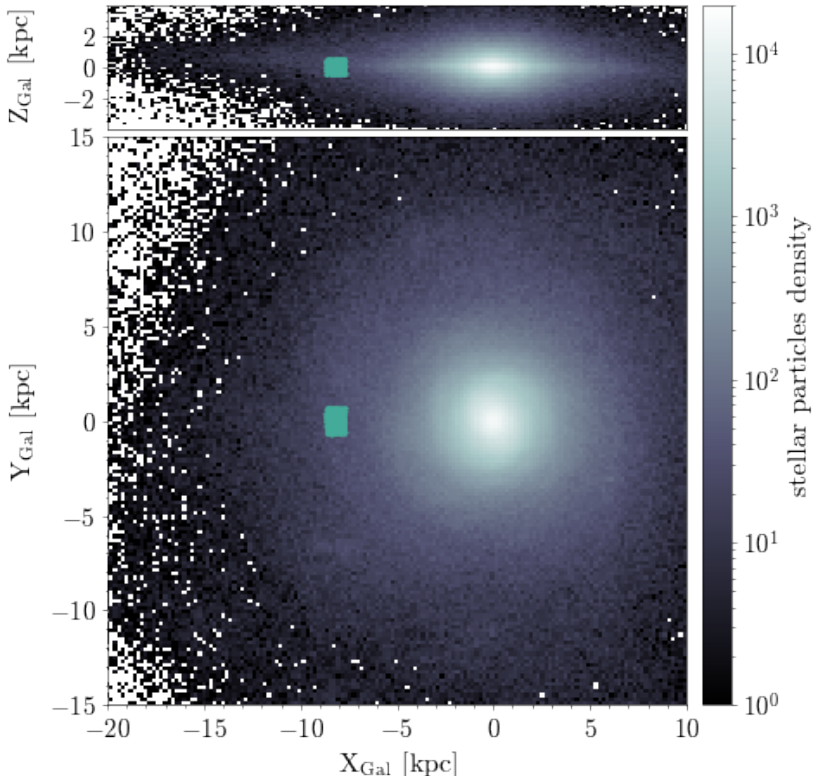
General methodology: Creation of a synthetic exoplanet population

Some results: the Solar Neighbourhood

8.3M stars > 3.4M singles

→ 2.9 million planetary systems
→ **22.5 million planets**

Padois et al., 2025



Modelling the Milky Way exoplanet population

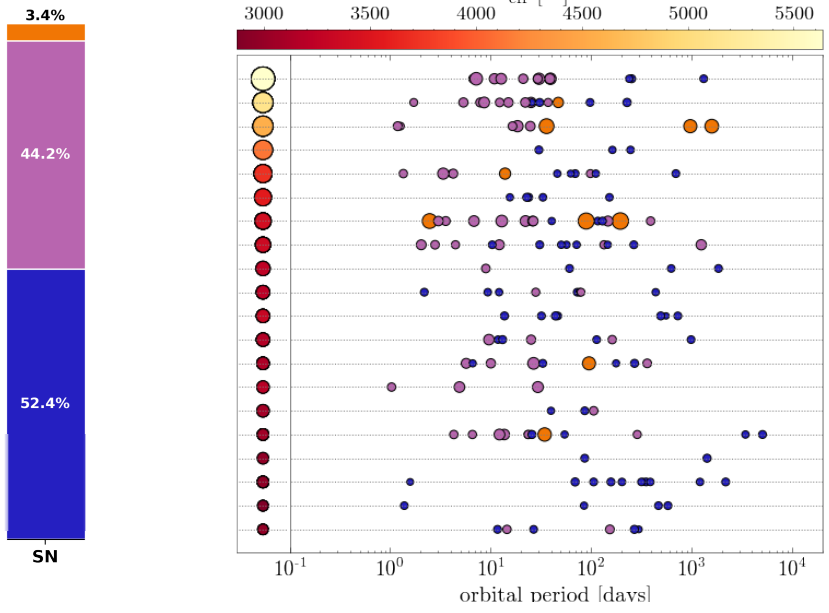
Chloé Padois, Universitat de Barcelona

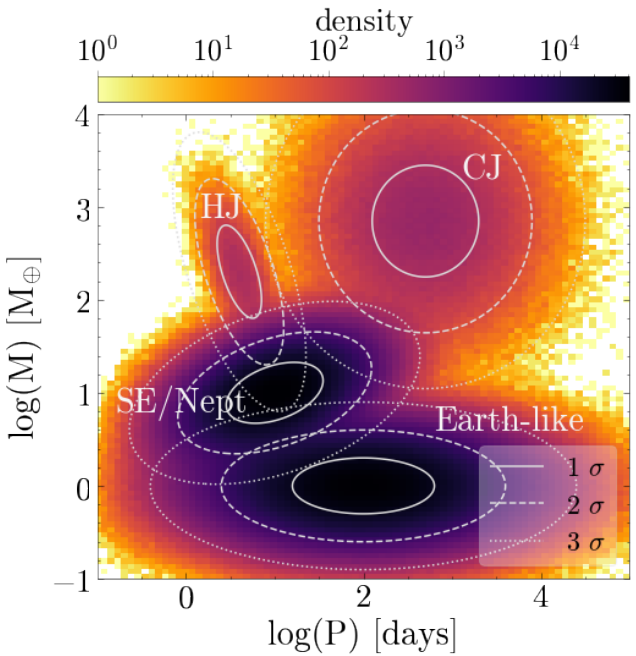
General methodology: Creation of a synthetic exoplanet population

Some results: the Solar Neighbourhood

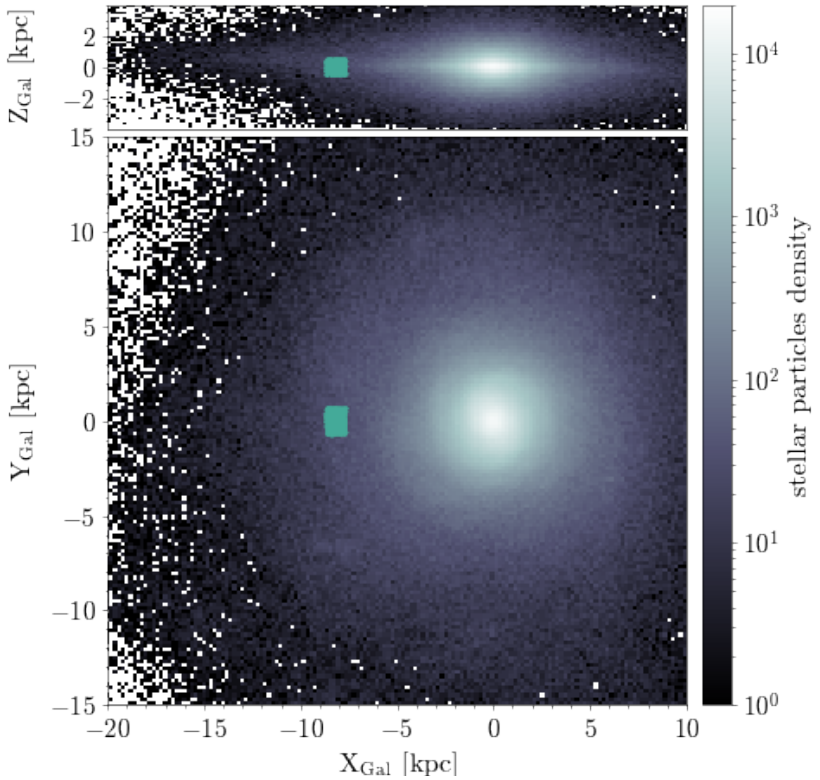
8.3M stars > 3.4M singles

→ 2.9 million planetary systems
→ **22.5 million planets**





Padois et al., 2025



Earth-like

Super-Earth + Neptunians

Sub-Giants + Giants

Padois et al., 2025

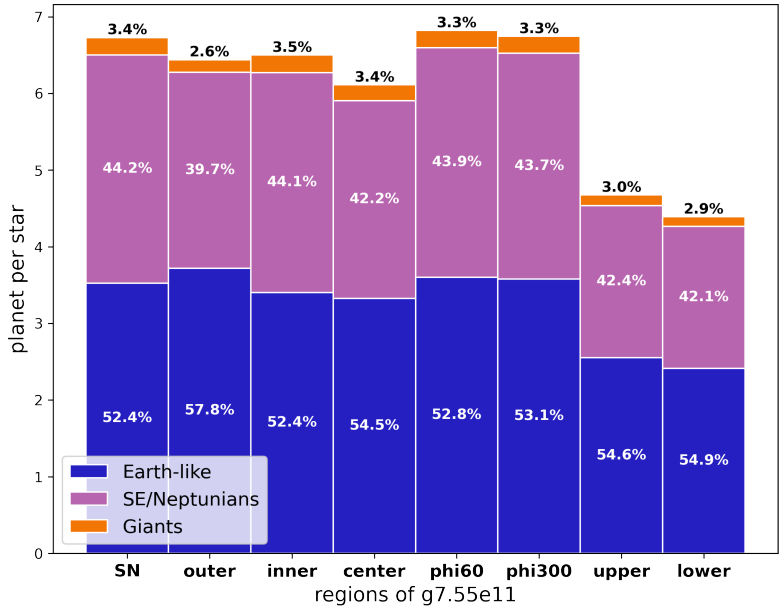
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

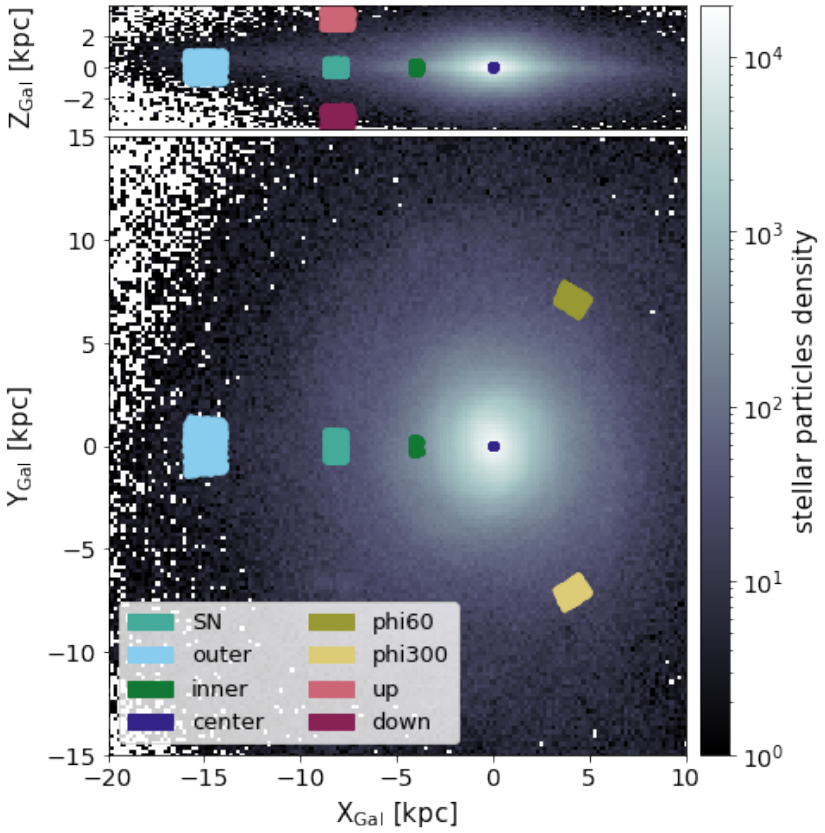
General methodology: Creation of a synthetic exoplanet population

Some results: galactic environment

→ halo regions host less exoplanet per star



Padois et al., 2025



→ **strongly model-dependent**
→ **How realistic is this simulated exoplanet population?**

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

1) General methodology

2) Comparing with observations

Generate exoplanet population

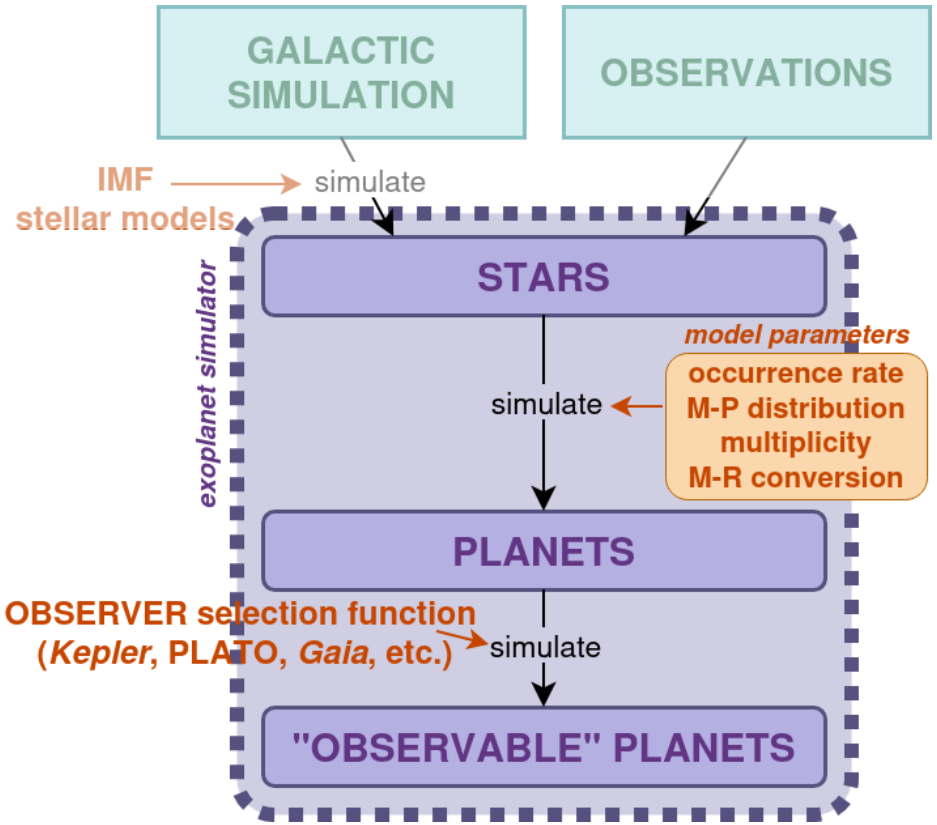
Evaluate our results:

Detectability by *Kepler*

Predictions for future surveys

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona



2) Comparing with observations

Evaluate our results:

- Detectability by *Kepler*
- Predictions for future surveys

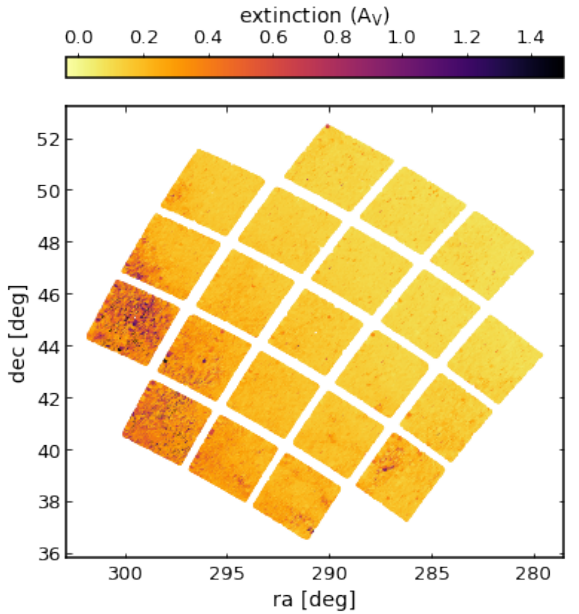
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Comparing with observations: evaluate our results

Kepler field of view

- Apply same process → *Kepler* target list (from Wolniewicz+21)
  → 1.6M planets simulated around 174k stars
- Assign random inclination
- Reproduce *Kepler* observation: compute SNR



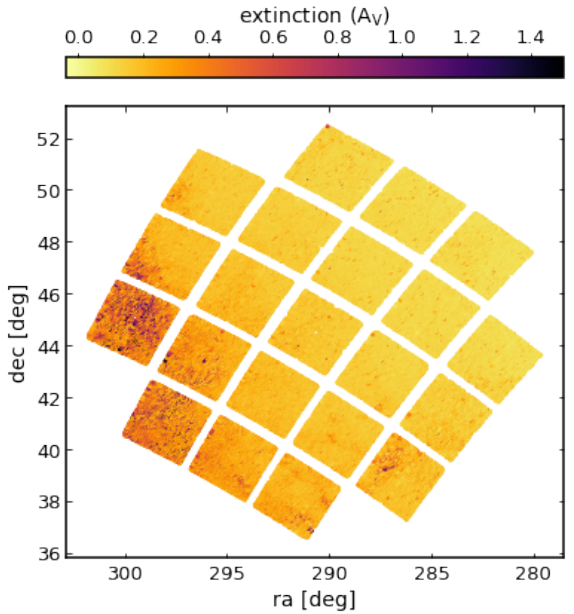
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Comparing with observations: evaluate our results

Kepler field of view

- Apply same process → *Kepler* target list (from Wolniewicz+21)
  → 1.6M planets simulated around 174k stars
- Assign random inclination
- Reproduce *Kepler* observation: compute SNR



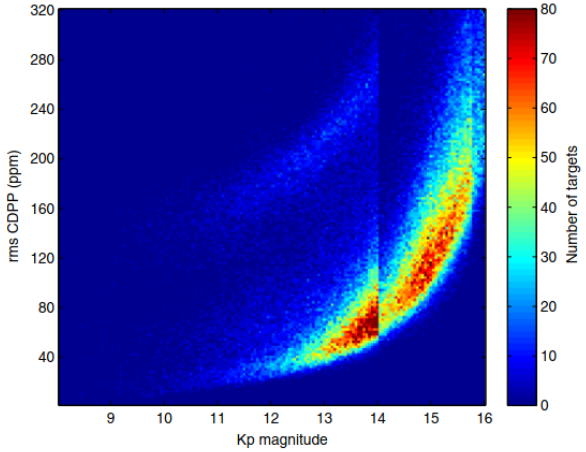
$$\mathrm{SNR} = \sqrt{\mathrm{N_{tr}}} \times \frac{\delta}{\mathrm{CDPP_{eff}}}$$

radius

stellar magnitude

period

Christiansen+12



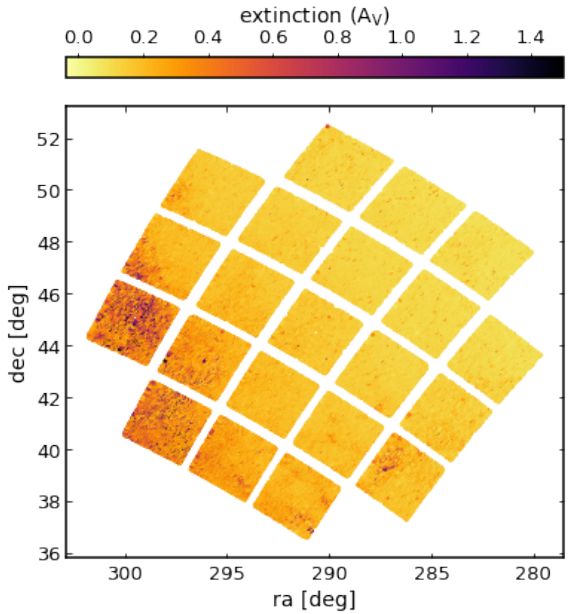
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

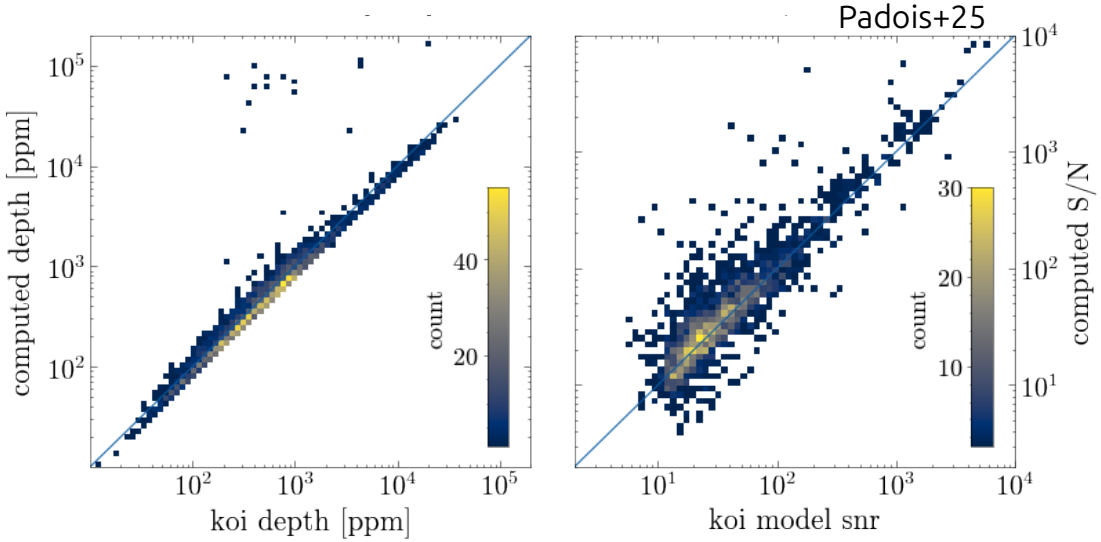
Comparing with observations: evaluate our results

Kepler field of view

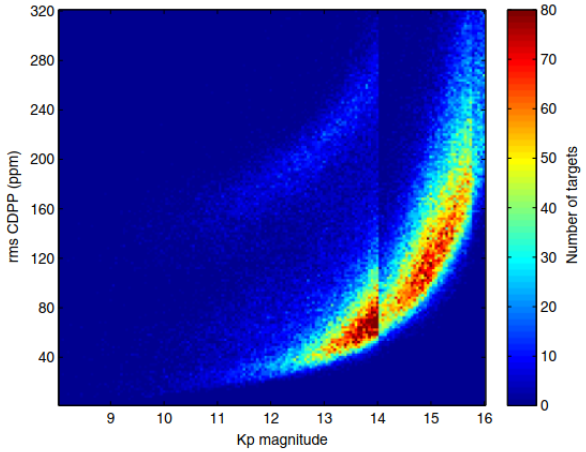
- Apply same process → *Kepler* target list (from Wolniewicz+21)
  → 1.6M planets simulated around 174k stars
- Assign random inclination
- Reproduce *Kepler* observation: compute SNR



Padois+25



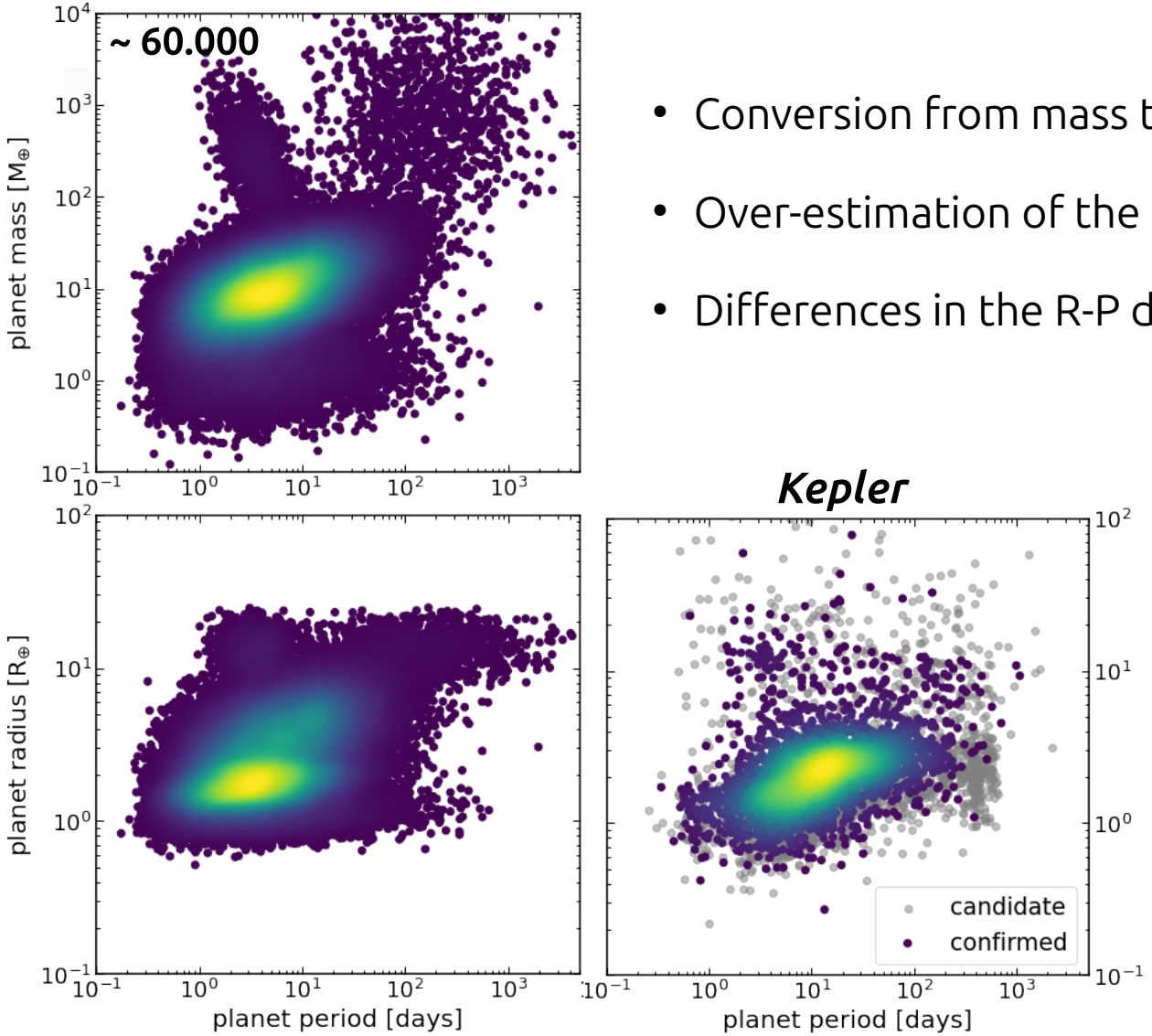
Christiansen+12



Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Comparing with observations: evaluate our results



- Conversion from mass to radius (based on Parc+24)
- Over-estimation of the number of “detected” exoplanets
- Differences in the R-P distribution

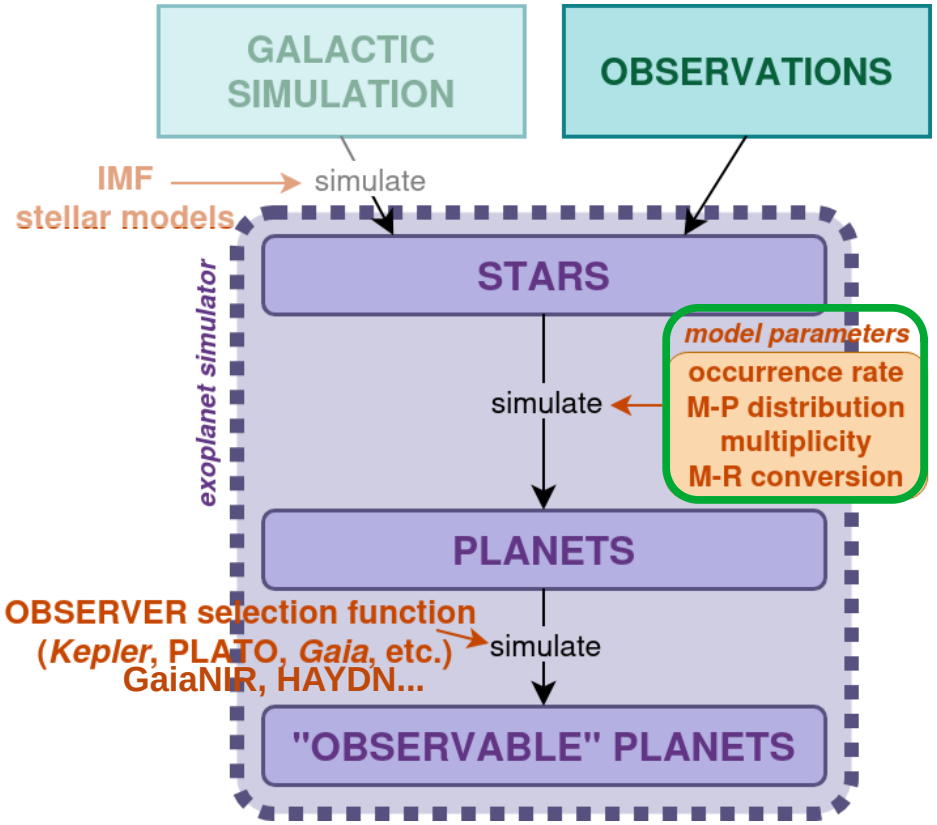
→ Adjust model parameters:

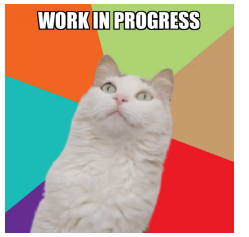
- M-P distributions
- occ. rate, multiplicity, ...

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Comparing with observations: adjust model parameters



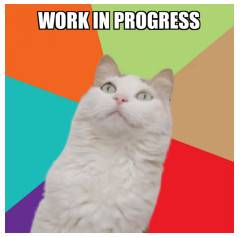


Simulation-Based Inference (SBI)

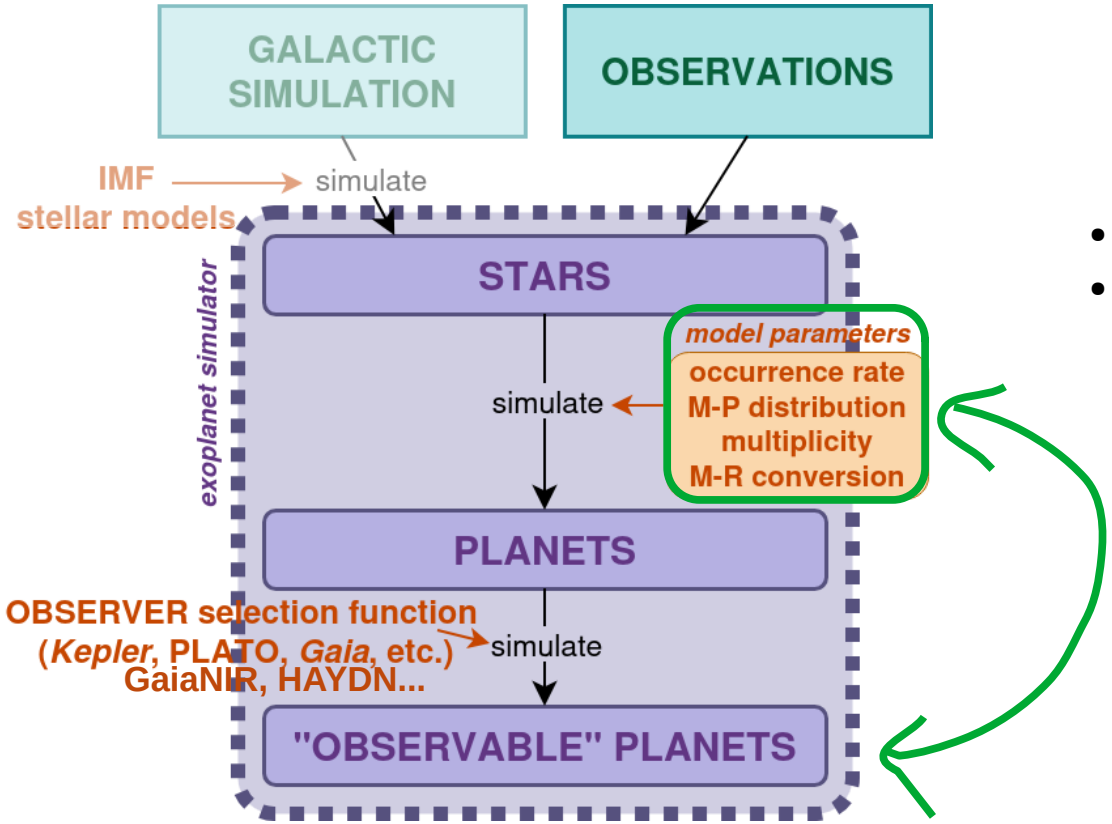
- Variation of the model parameters

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona



Comparing with observations: adjust model parameters



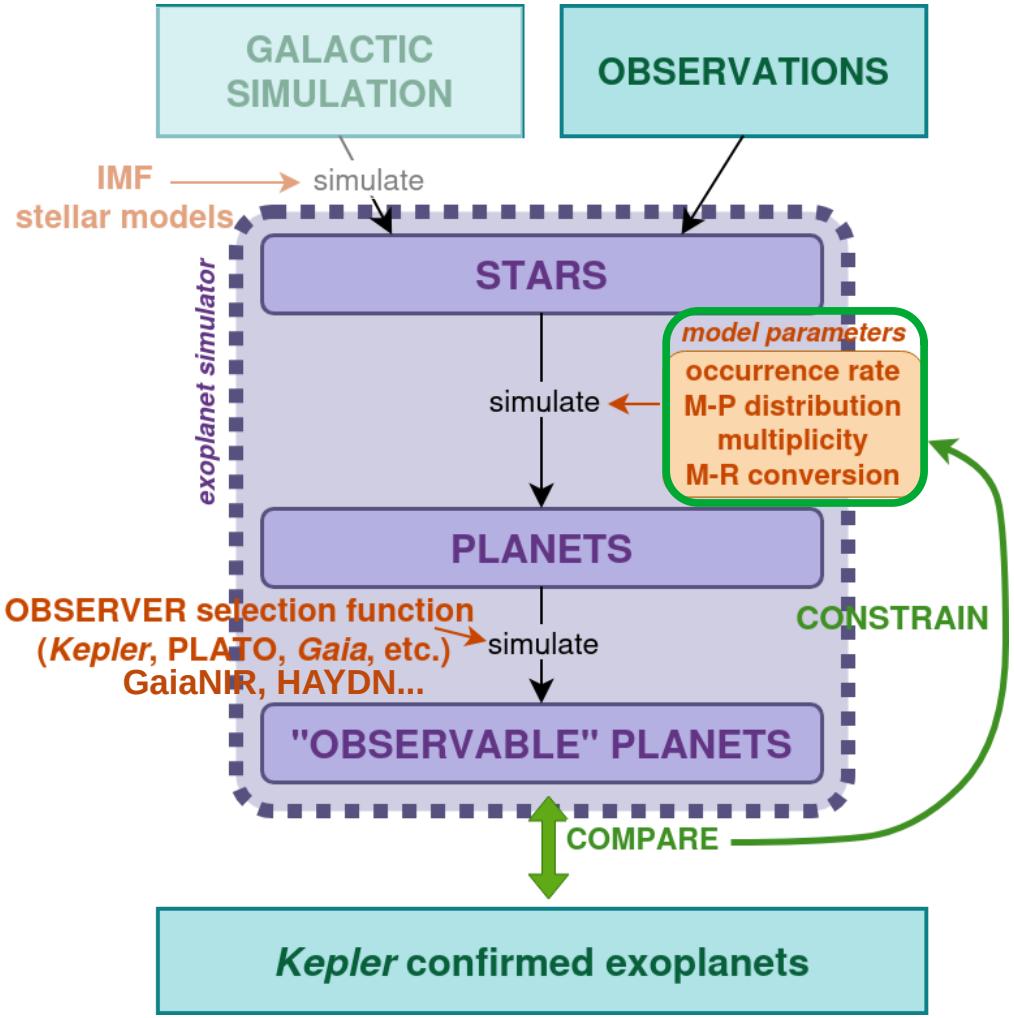
Simulation-Based Inference (SBI)

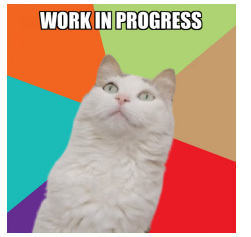
- Variation of the model parameters
- Learn input parameters-output relation

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Comparing with observations: adjust model parameters





Simulation-Based Inference (SBI)

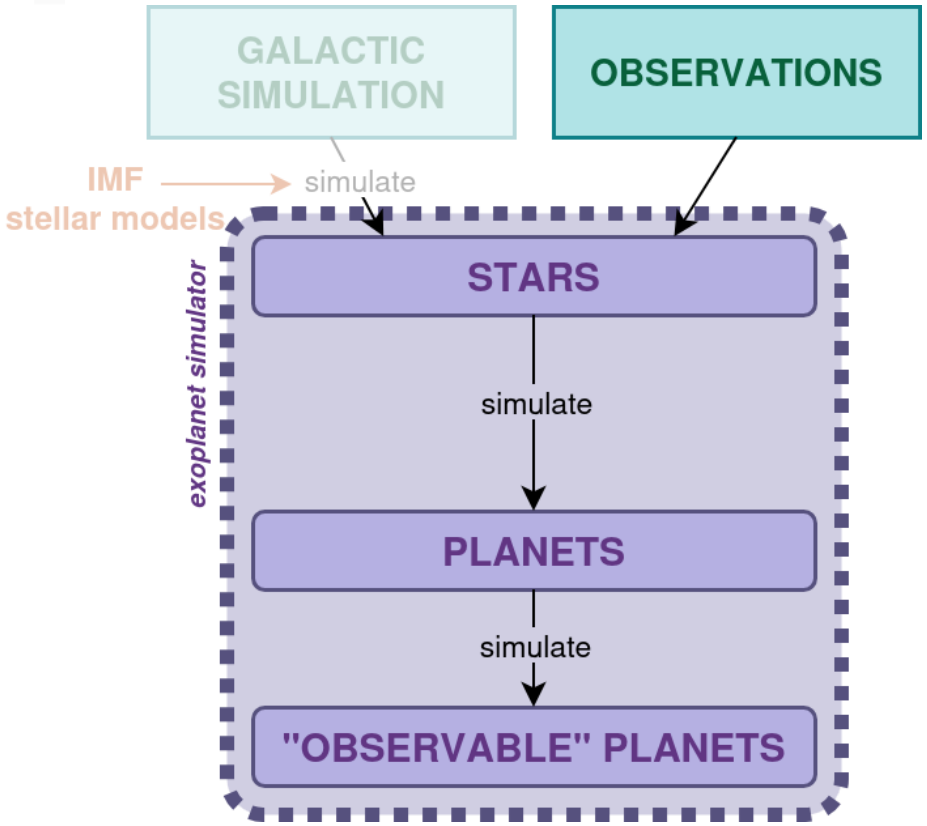
- Variation of the model parameters
- Learn input parameters-output relation

- Infer model parameters giving the closest output population

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

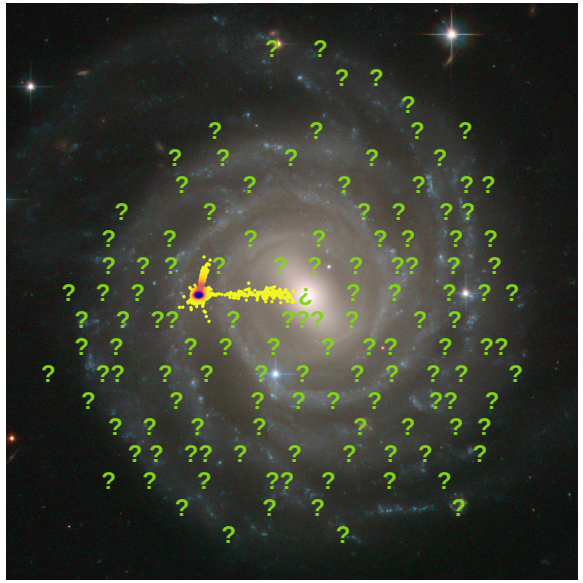
Next step: predict yields of different missions



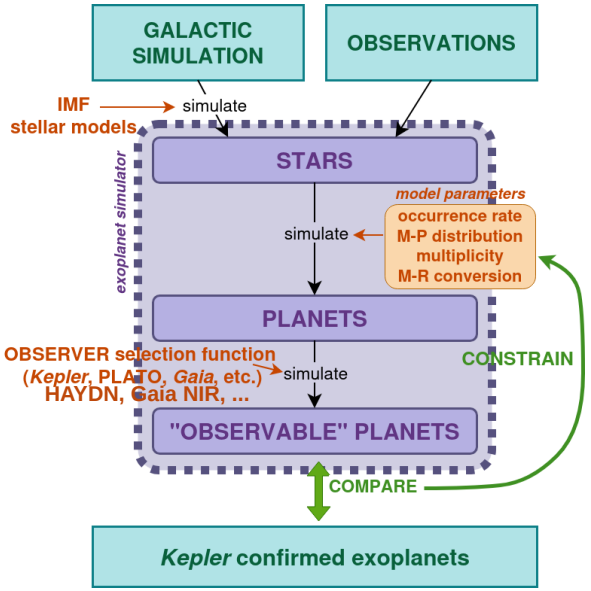
Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Summary



- Goal: study exoplanet distribution from a Galactic point of view (Padois et al., 2025)
- Created an hybrid exoplanet population synthesis framework
- Can be applied to simulated as well as observed stellar populations



- Apply our framework on *Kepler* field → **improvements**
- Future: Predictions for future missions
  → **refine planetary formation models parameters**

Action thematique
Exosystèmes

ExoSystèmes V

IAP, 31/03-02/04/2026

Modelling the Milky Way exoplanet population

Chloé Padois, Friedrich Anders, Daniel del Ser, et al.

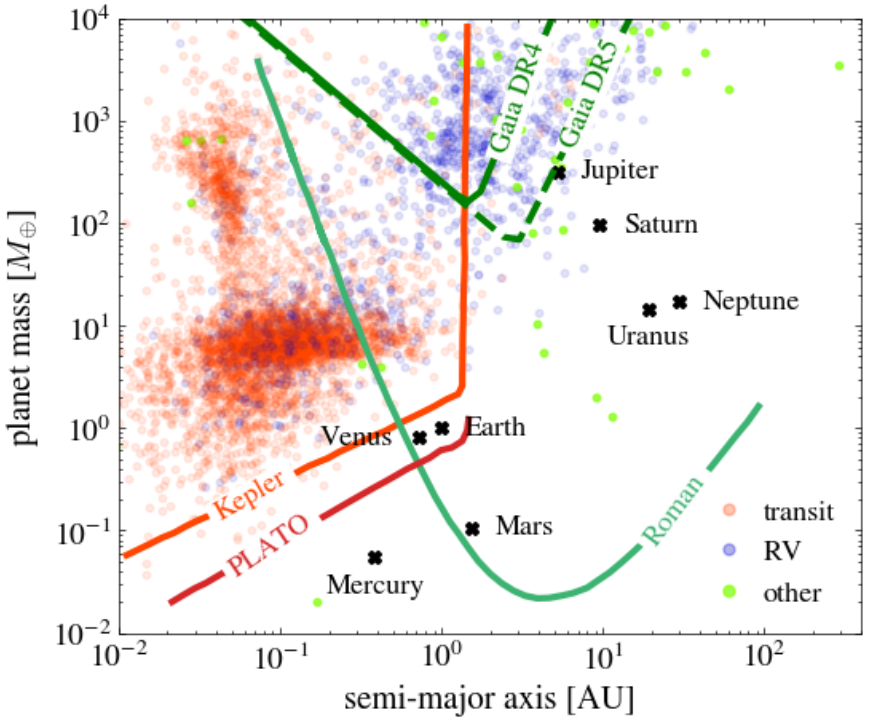
Merci!

MWGaiaDN

This project is a Horizon Europe Marie Skłodowska-Curie Actions Doctoral Network funded under grant agreement no. 101072454.

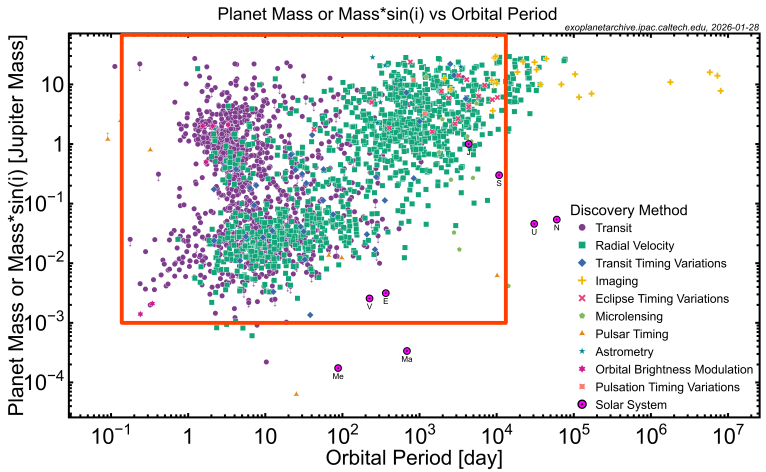
Modelling the Milky Way exoplanet population

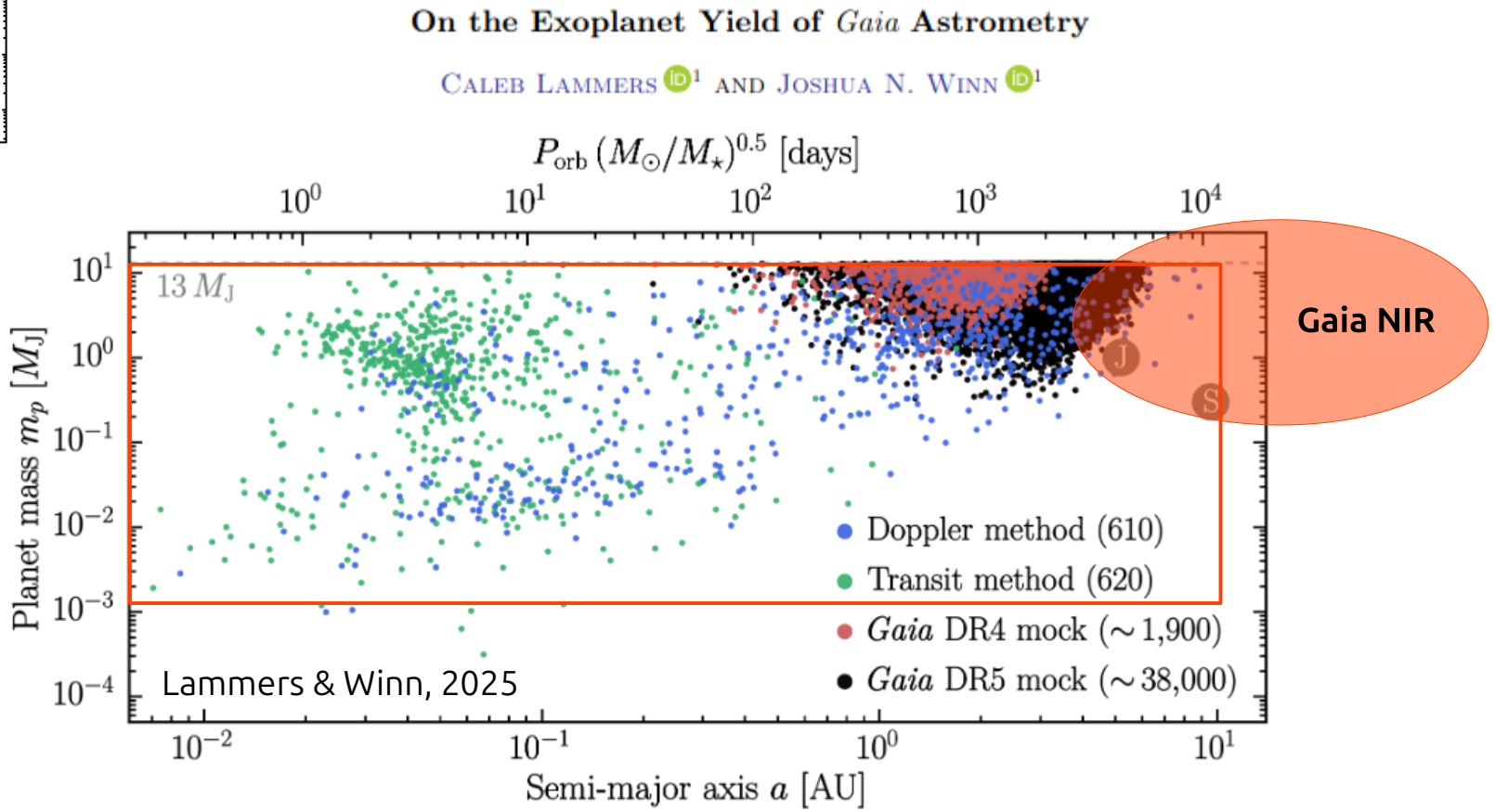
Chloé Padois, Universitat de Barcelona



Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

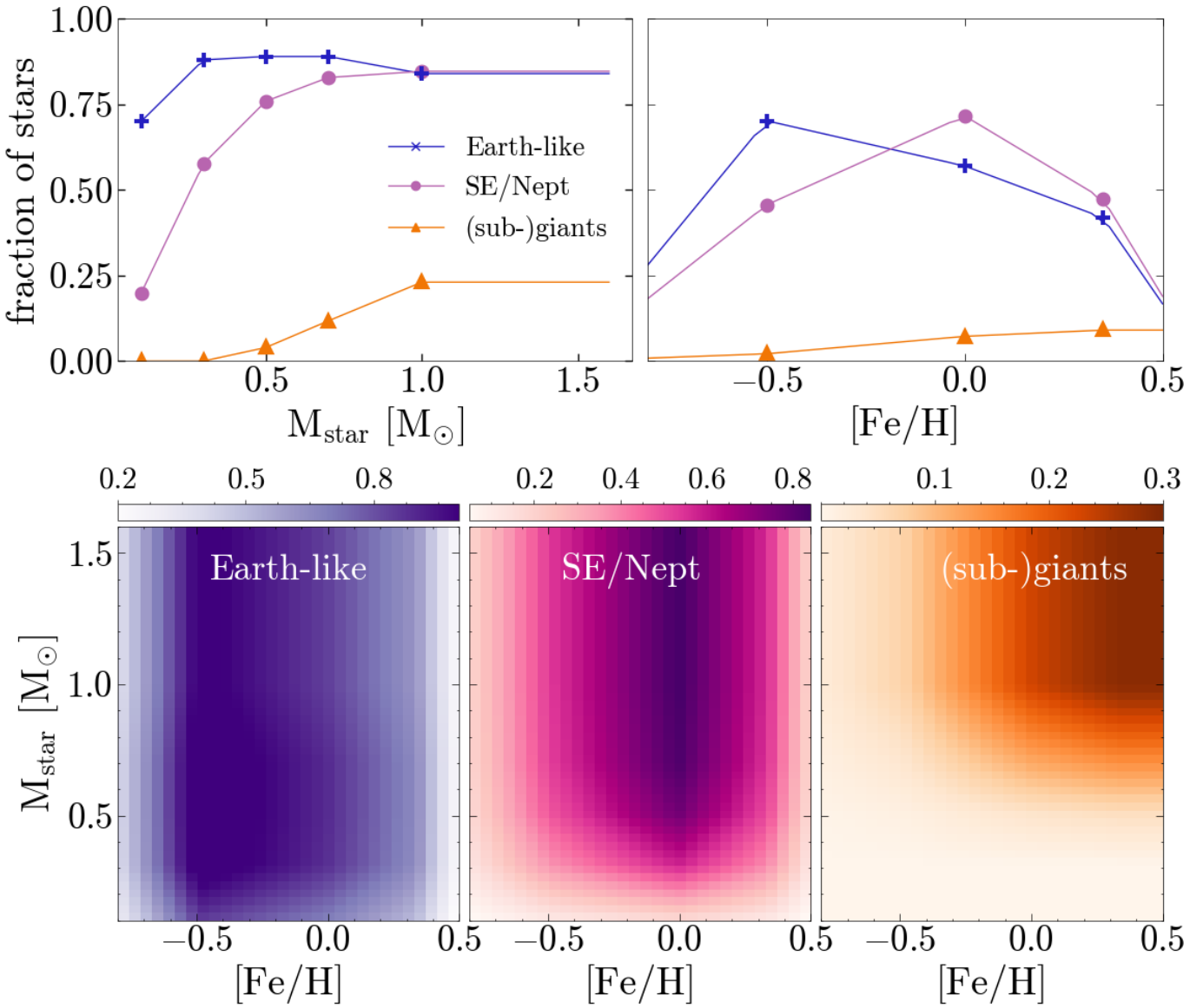




Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

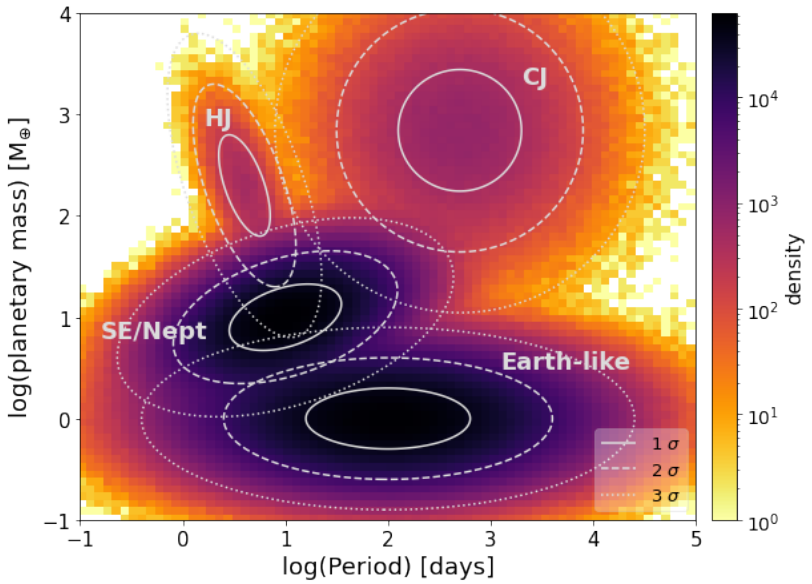
Extra slides:

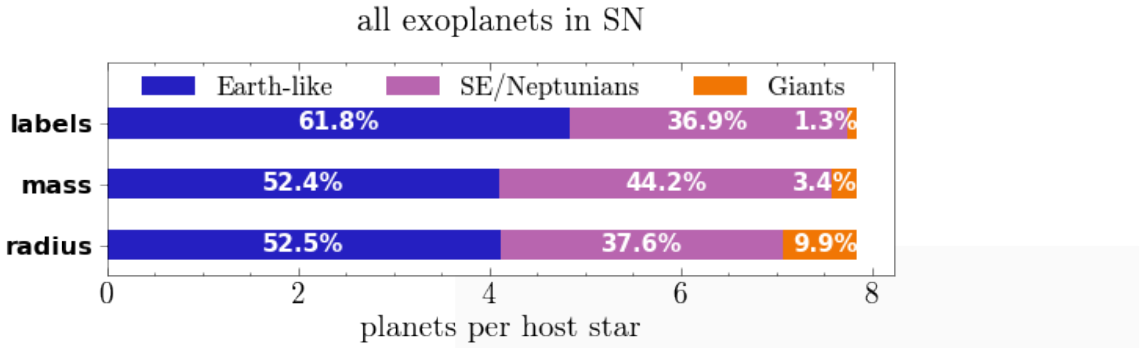


Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Extra slides:



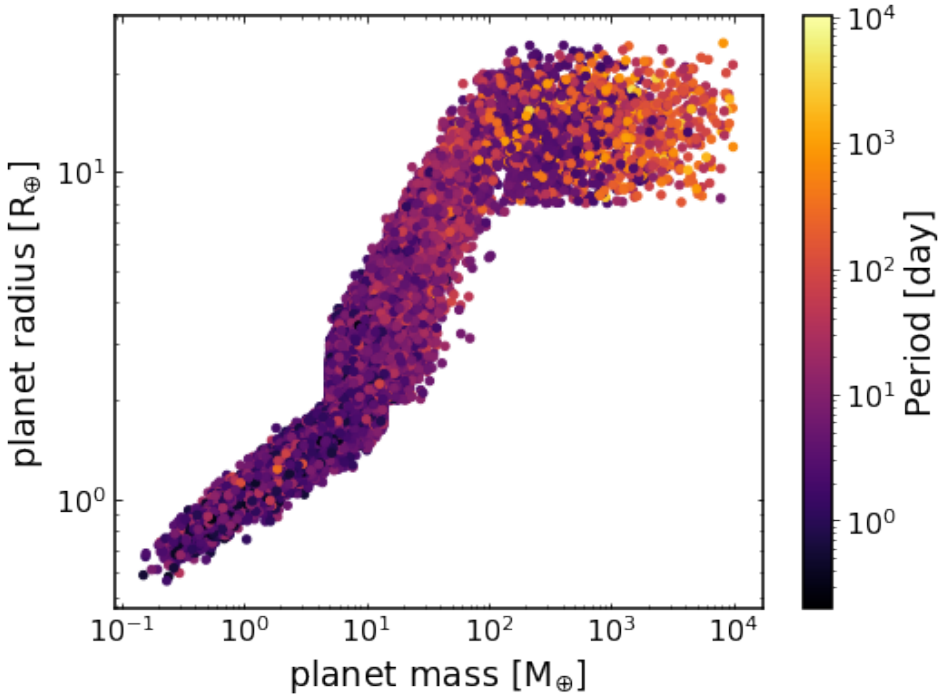


	Earth-like	SE/nept	Giants
radius	R < 1.25 Rearth	1.25 < R < 4	4 < R
mass	M < 2 Mearth	2 < M < 30	30 < M

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Extra slides:



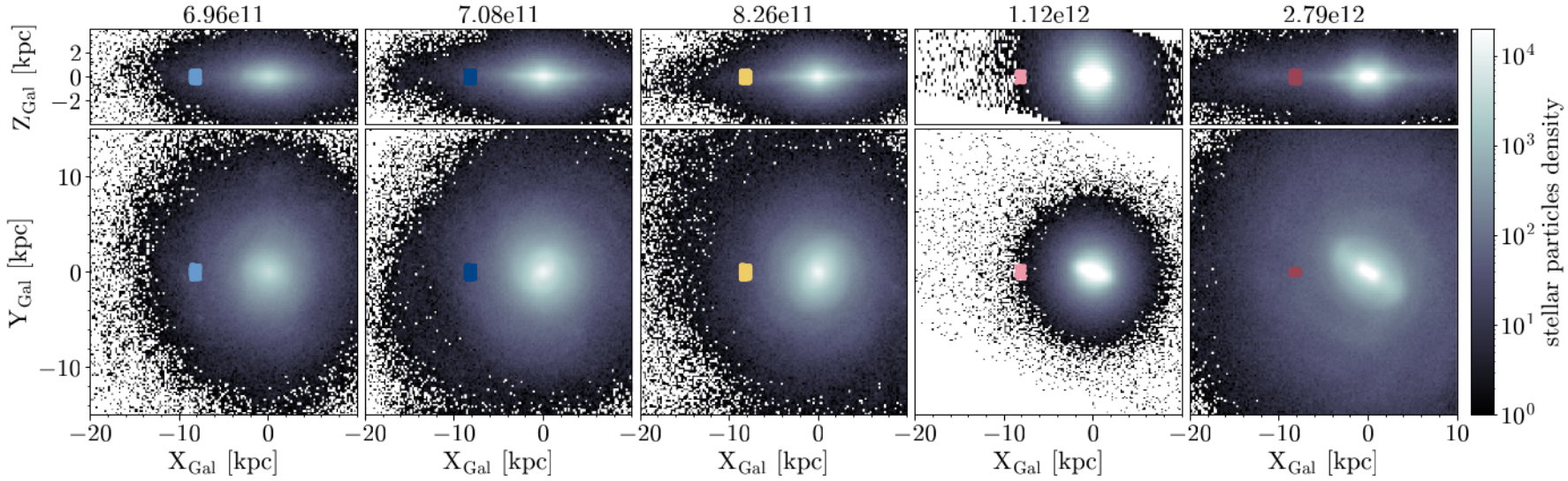
Slopes from Parc+24

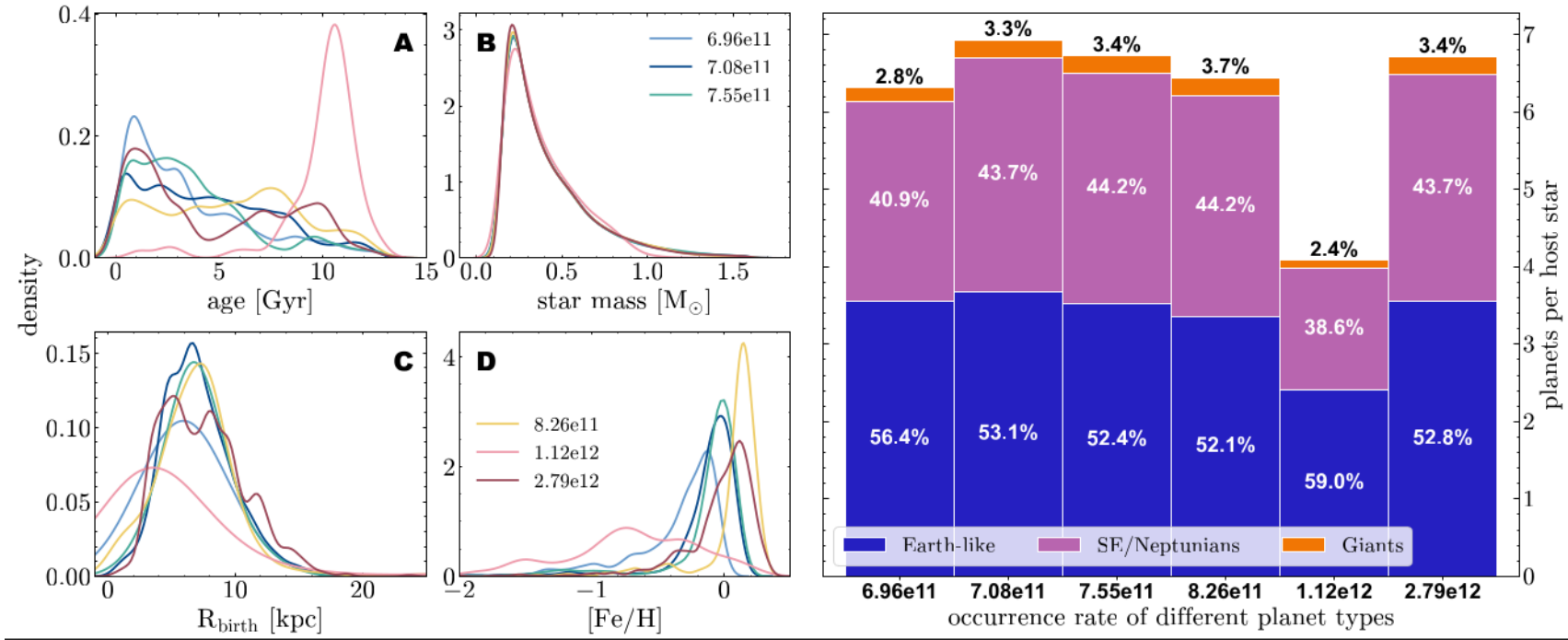
→ for *Kepler* “detectable” planets

Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Extra slides:





Modelling the Milky Way exoplanet population

Chloé Padois, Universitat de Barcelona

Extra slides: