The next generation planetary population synthesis

INFLUENCE OF THE STELLAR MASS

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Bern Planet Formation and Evolution Model *- Next Generation*

(Emsenhuber+ 2020, in prep)

- 1D viscous accretion disk (Hueso&Guillot 2005)
- Planetary growth by accretion of planetesimals (Fortier+ 2013)
- Migration (Dittkrist+ 2014)
- Concurrent 1D Envelope Model and Planet evolution and formation (Mordasini+ 2012; 2015; Jin+ 2014)
- N-Body interactions (Alibert+ 2013)
  - Many embryos per disk (up to 100) integrated for 20 Myr

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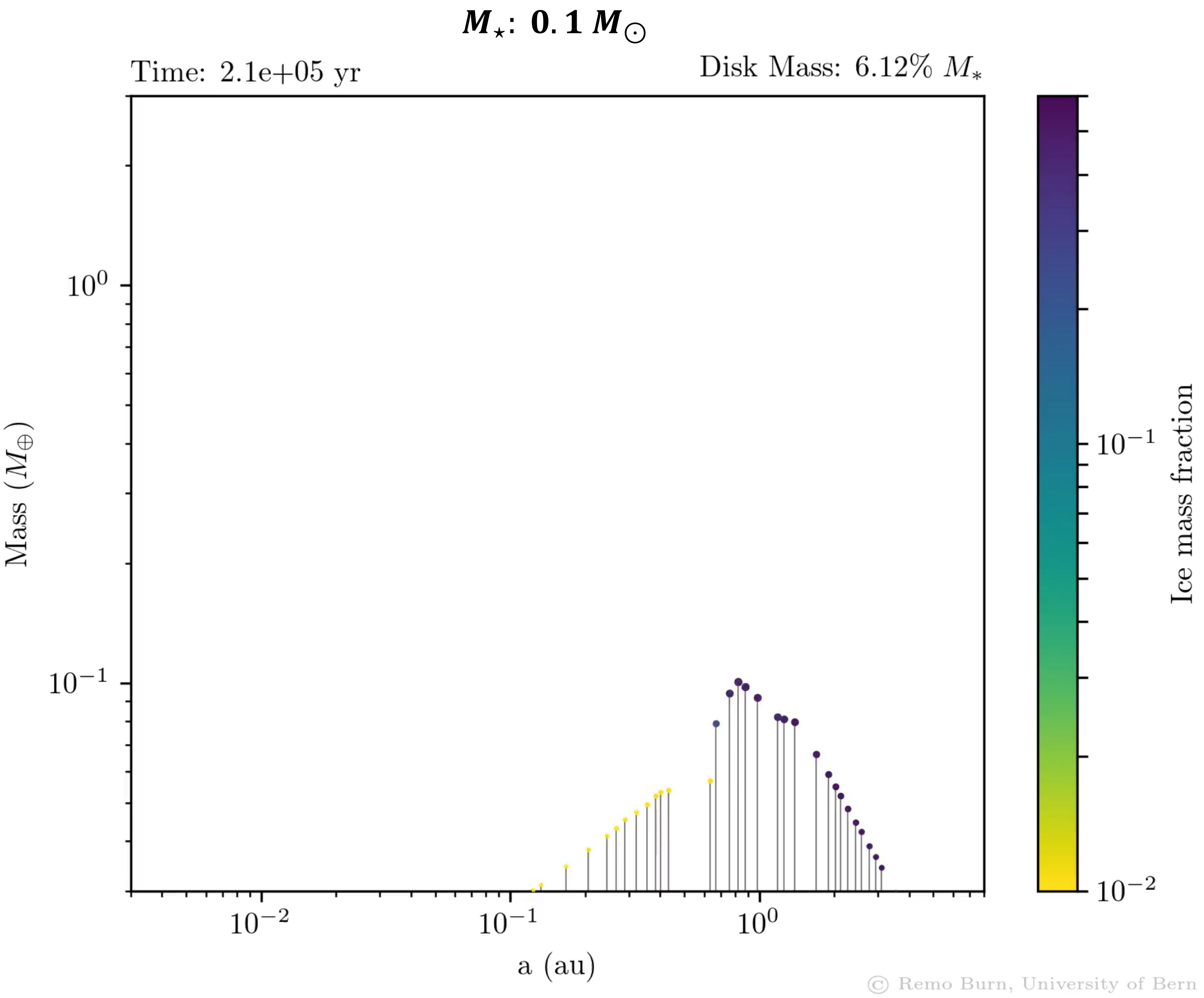

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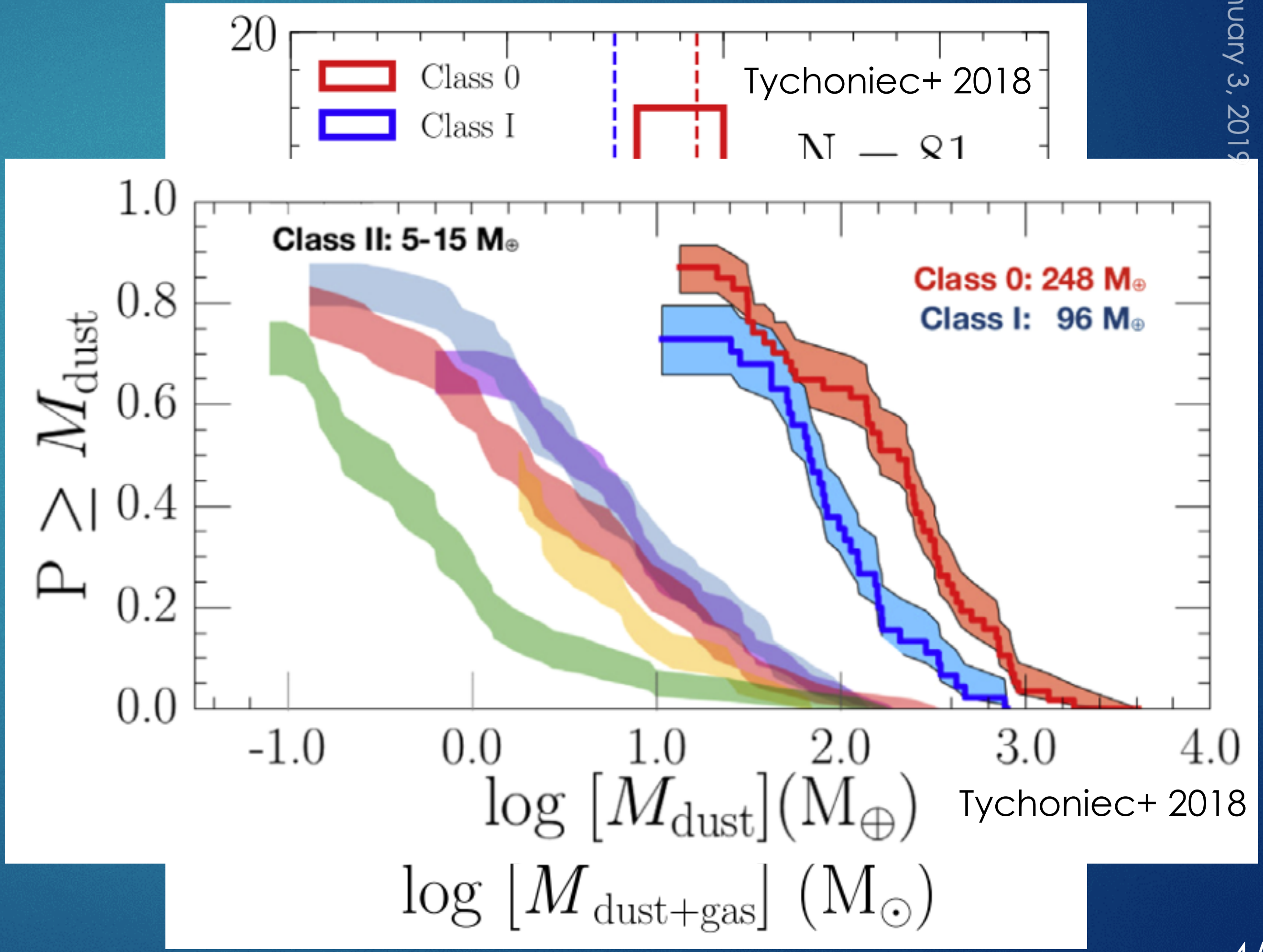
Initial Disk Conditions

- Metallicity: $f_{dg} = 0.0149 \times 10^{[Fe/H]}$
  - Gaussian Distribution for [Fe/H] with $\mu \sim 0.0, \sigma \sim 0.2$ (e.g. Santos+ 2003)
- Disk lifetime
- Disk Gas Mass
- Disk Solid Mass
- Inner Radius at corotation radius (NGC 2264, Venuti+ 2017)
- Dependencies with stellar mass
  - $M_{disk} \propto M_*$
  - Lifetime independent
  - Rotation rate independent



Results: Mass – Semi-Major Axis

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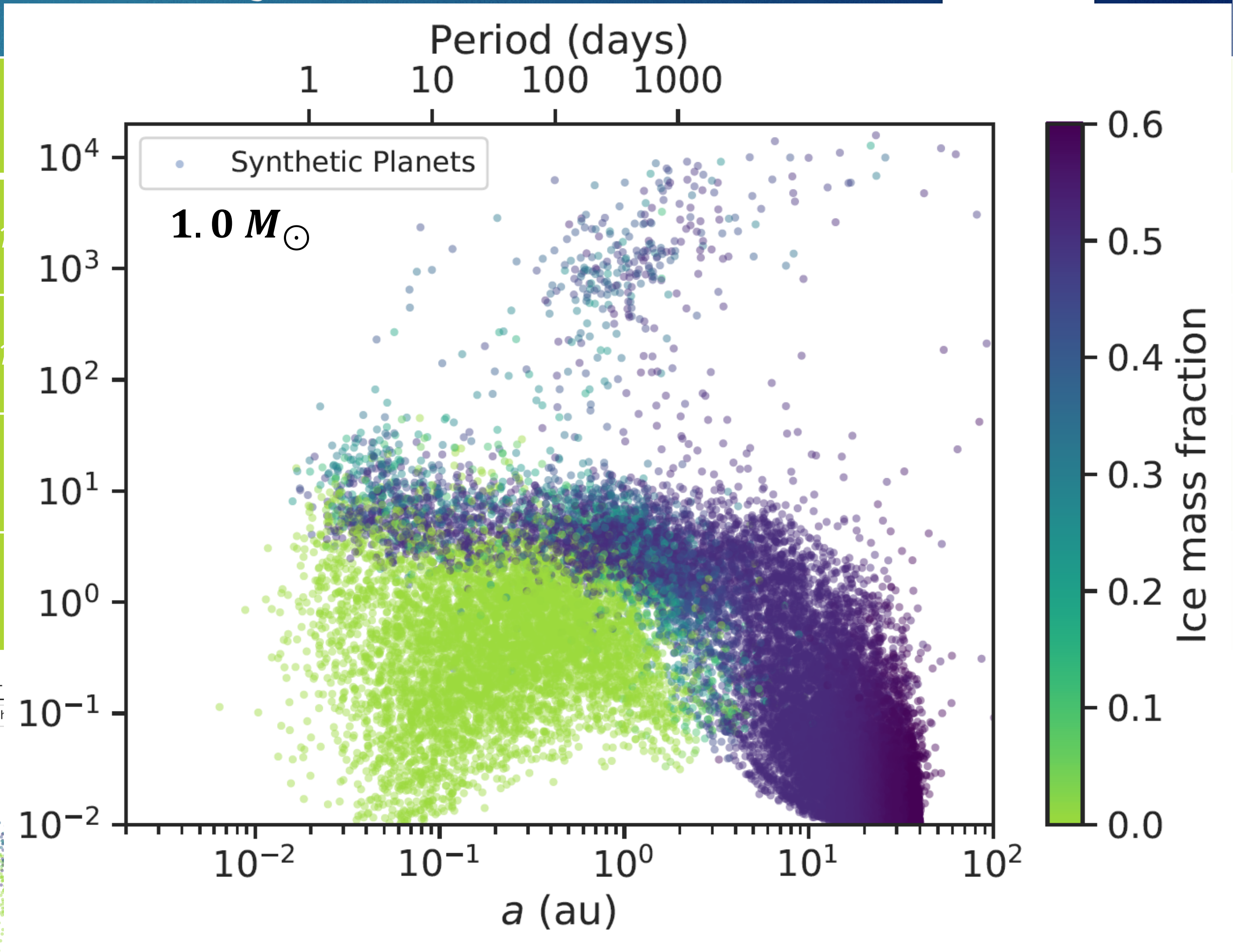
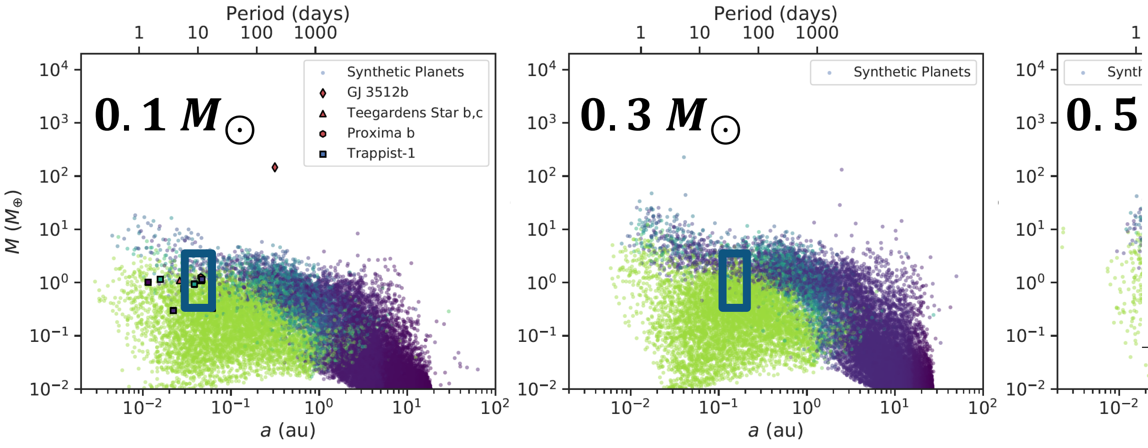
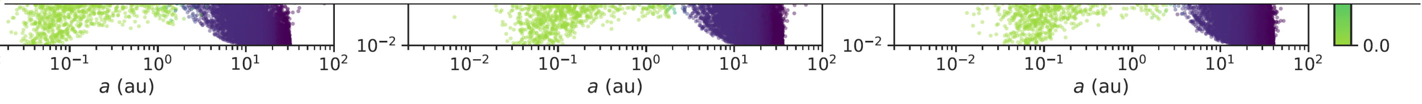
- Significant gas and solid accretion increase with increasing M_*
- Trappist-1 individual planets are reproduced, GJ3512b is not
- Habitable zone (Kopparapu+ 2014) planets most common around $0.3 - 0.5\ M_\odot$ stars

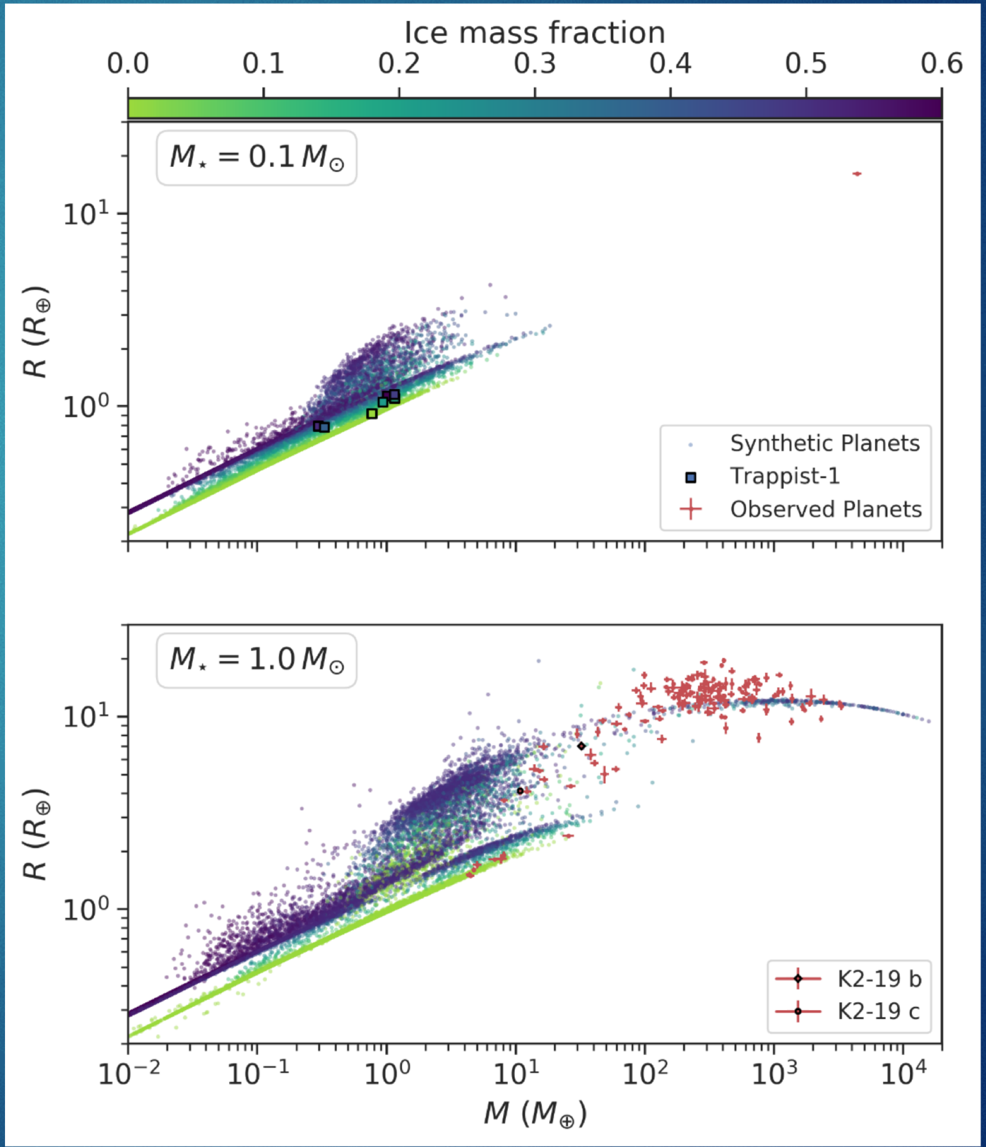






Results: Mass - Radius

- Observed planets for comparison (NASA Exoplanet Archive Nov. 2019)
  - Relative error smaller than 15% in M, R and $M_\star$
- No density spread for giants
  - Inherent to model by using fixed envelope-metallicity
- Less bloated hot jupiters in population



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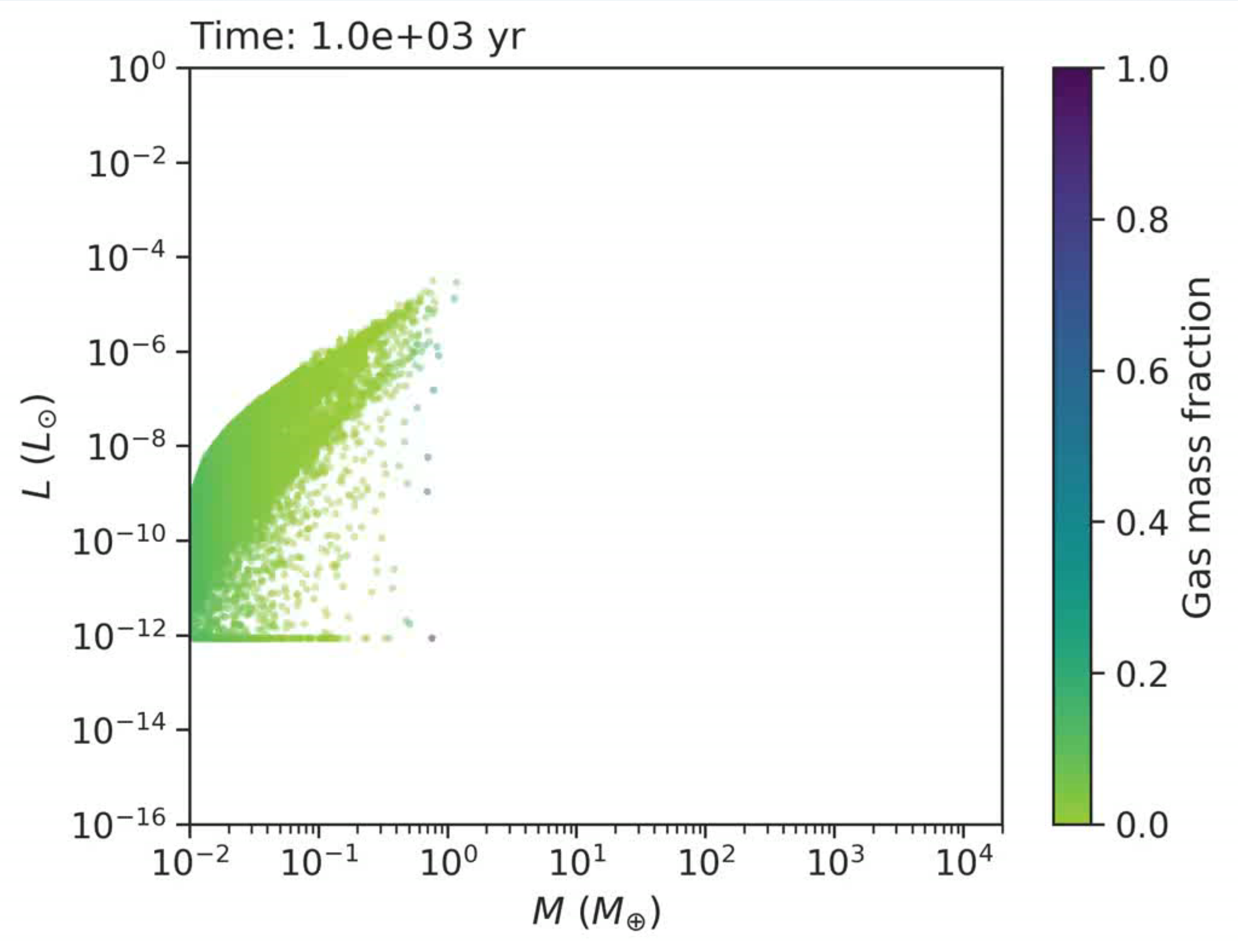
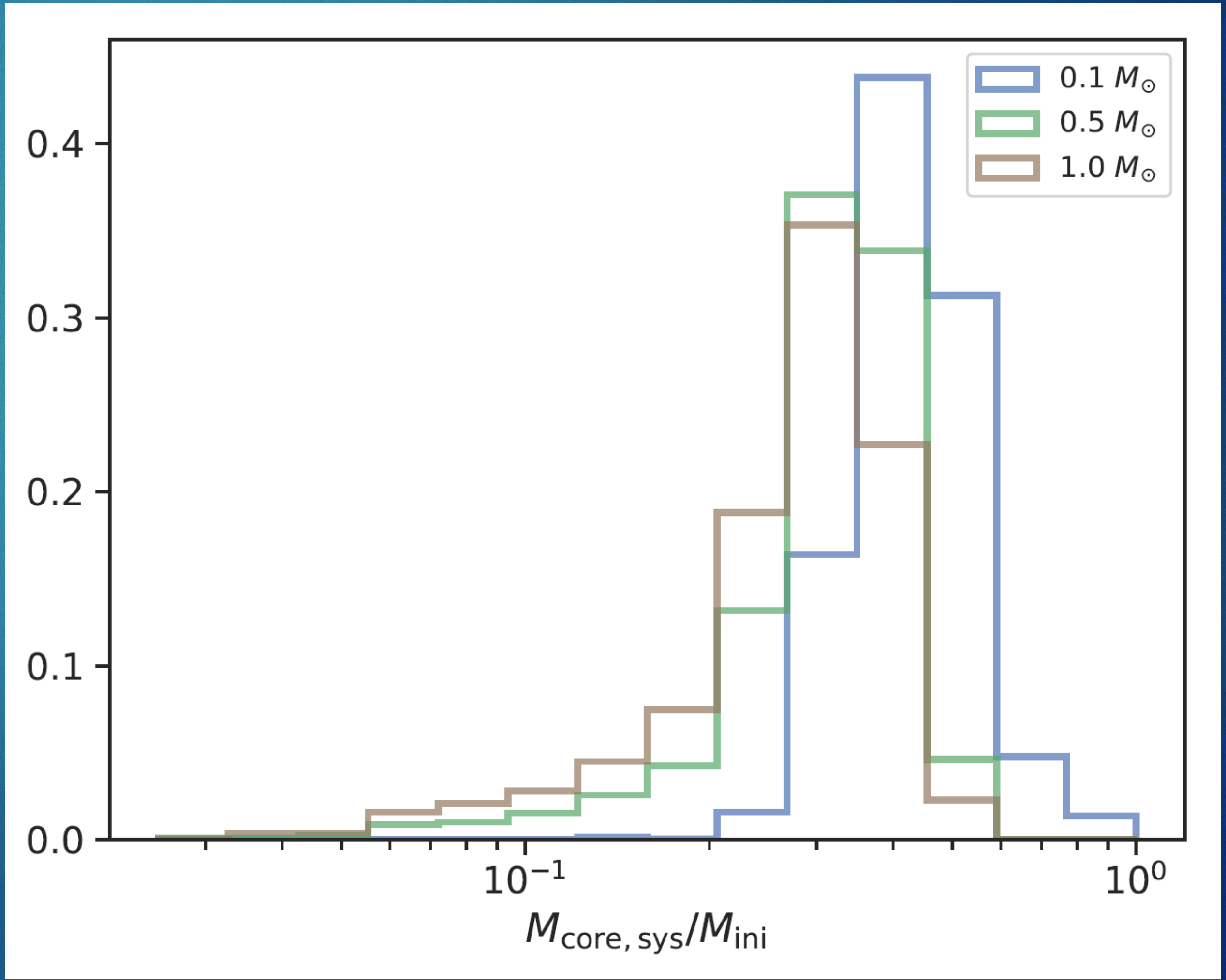
Results: Mass – Luminosity



Results: Efficiency

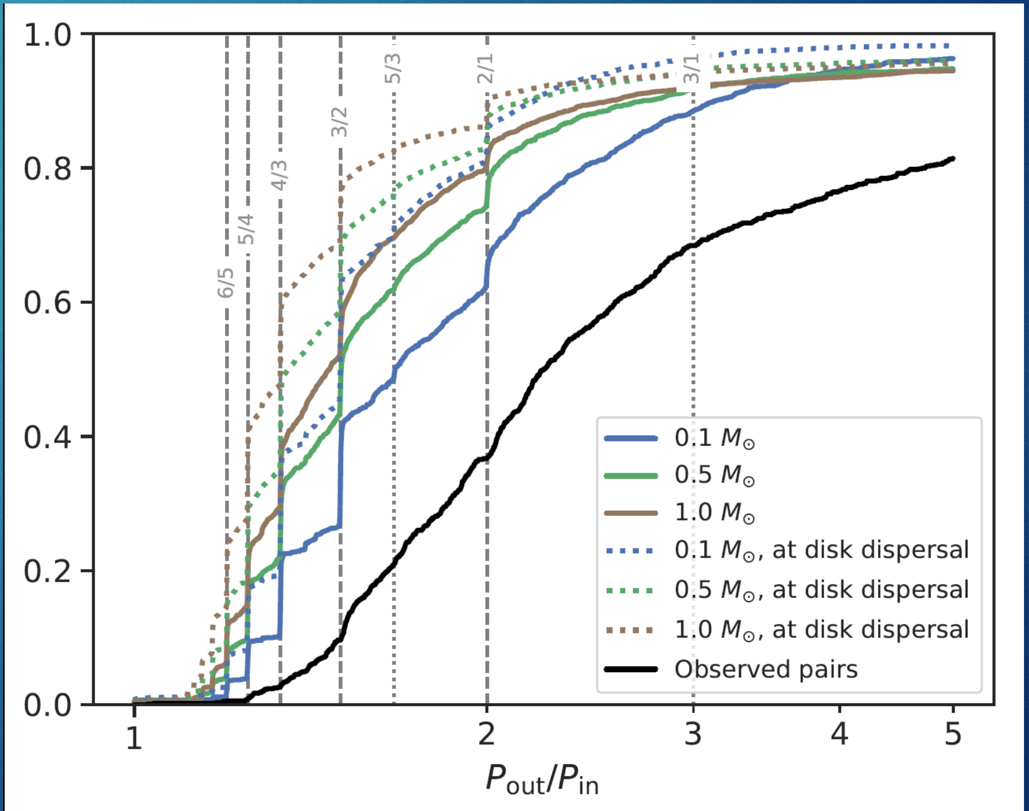
- Conversion of solids to planetary cores decreases with stellar mass
  - Ejection of planets
  - Ejection of planetesimals
  - Eccentricity and inclination distribution of planetesimals
    $\frac{de^2}{dt} \propto \frac{M}{M_\star}$



Results: Dynamics

	$0.1\,M_\odot$	$0.5\,M_\odot$	$1.0\,M_\odot$
2/1	0.06	0.06	0.04
3/2	0.16	0.11	0.09
4/3	0.12	0.12	0.11
5/4	0.05	0.09	0.10
6/5	0.02	0.05	0.07
5/3	0.03	0.02	0.01
$\sum$	0.47	0.47	0.45

- More resonant systems than observed
  - Cuts at 0.1 earth mass and periods of 1 year
  - Time evolution leads to larger period ratios
  - More pairs in wider resonances for lower stellar masses
  - Sensitive to initial number and placement embryos



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Conclusions

- Already at 0.5 M_* giant planets are rare
- Habitable planets are most common around non-ultra-late M dwarfs
- Conversion and conservation of solids in planets is more efficient around lower mass stars
- More planets are in resonance around lower mass stars
- Trappist-1 system can be reproduced
  - Requires a disk with a relatively high solid mass

Outlook

- Planetesimal and embryo formation model
  - O. Völkel, H. Klahr, C. Mordasini
- Detailed comparison to CARMENES survey
  - M. Schlecker
- Pattern recognition using machine learning approaches
  - L. Mishra, Y. Alibert, M. Schlecker, D. Pham
- Hybrid planetesimal and pebble accretion
  - N. Brügger, Y. Shibaike, Y. Alibert