SUPER-EARTH FORMATION IN COMPACT DISKS AROUND M DWARFS

MARIANA SANCHEZ - NIENKE VAN DER MAREL - MICHIEL LAMBRECHTS - GIJS MULDERS & OSMAR GUERRA-ALVARADO

LEIDEN OBSERVATORY - MSANCHEZ@STRW.LEIDENUNIV.NL

INTRODUCTION

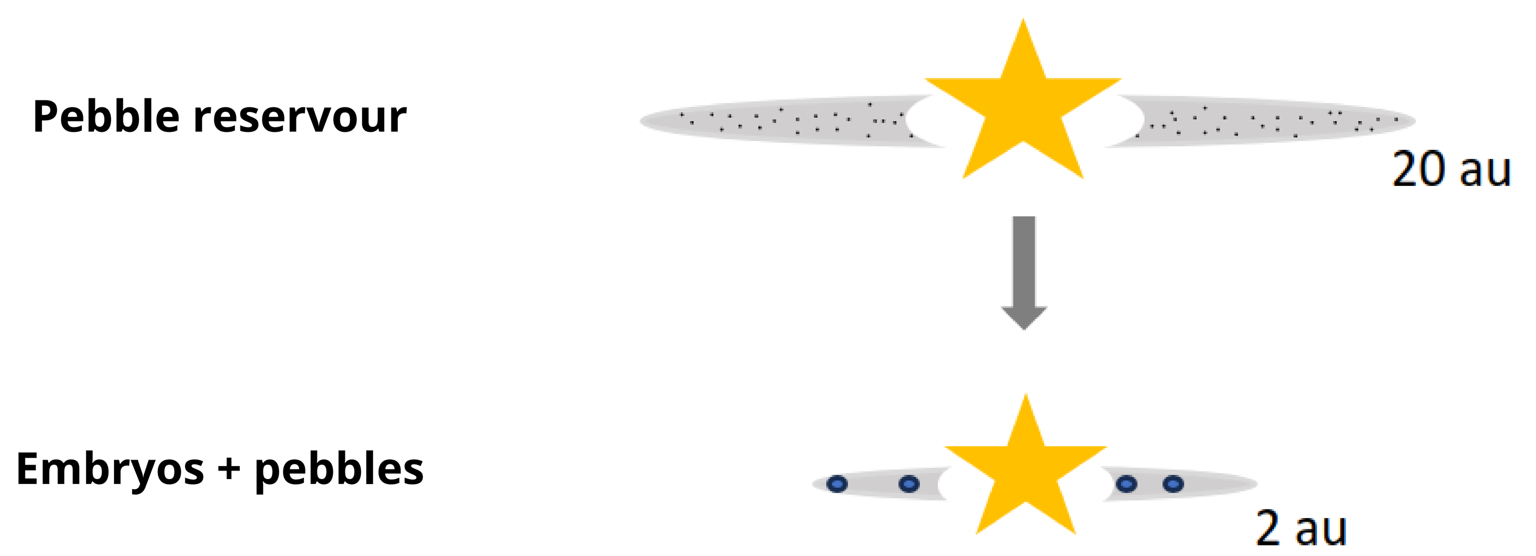
M dwarfs are the most common stars in the solar neighborhood. The majority of the exoplanets they host are rocky ones, in particular close-in super-Earths (SE - with masses between 1 and 10 Earth mass and semi-major axis < 0.1 au). Thanks to the high resolution of ALMA we know that most disks around them are rather compact and small (e.g. Ansdell et al. 2018; van der Marel et al. 2022), which favors the idea of an efficient radial drift that could enhance planet formation in the habitable zone (van der Marel & Mulders 2021; Mulders et al 2021).

METHODS

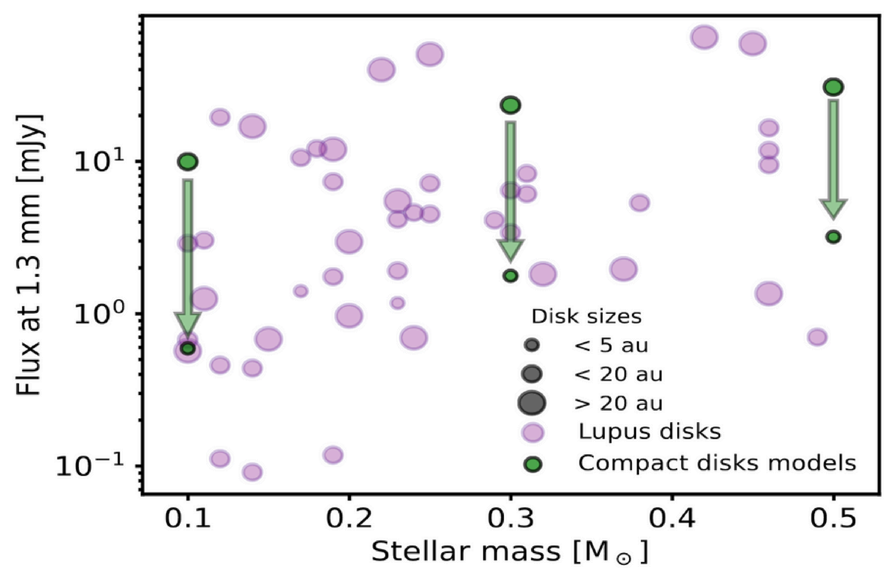
We studied rocky planet formation around M dwarfs driven by pebble accretion through N-body simulations (Sanchez et al. 2024 subm. to A&A).

-Compact disks: model vs observations

We assumed that planet formation took place in compact dust disks (< 20 au) caused by efficient dust radial drift (~100.000 Yr).



We run radiative transfer simulations with RADMC-3D to corroborate that the dust masses estimated with our pebble model are comparable to 1.3 mm fluxes of observed protoplanetary disks around M dwarfs in Lupus (1-2 Myr).

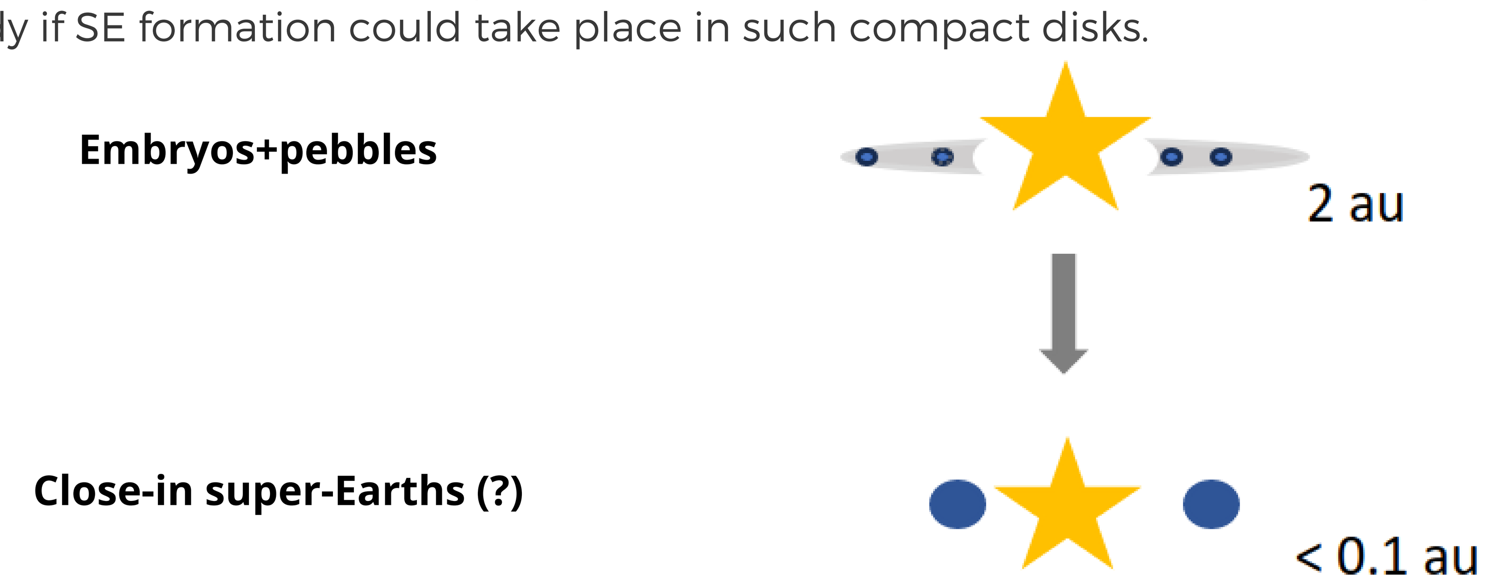


Disk models

$M_\star$ ($M_\odot$)	Radius (au)	Mass ($M_\oplus$)	**Obs mass ($M_\oplus$)**
0.1	2	1.5	**0.45**
0.1	20	15	**7.6**
0.3	3	10	**1.4**
0.3	20	50	**17.9**
0.5	4	12	**2.5**
0.5	20	85	**23.5**

-SE formation: N-body simulations

We run different sets of N-body simulations with a modified version of Mercury code to study if SE formation could take place in such compact disks.



Inputs

-Sample of lunar-mass embryos located beyond the snowline.
-Gas-disk viscosity coefficient alpha=0.0001.
-Stellar masses 0.1, 0.3 or 0.5 Msun.
-Incoming pebble flux consistent with observed compact dust disks in Lupus (see Figure + Table above).

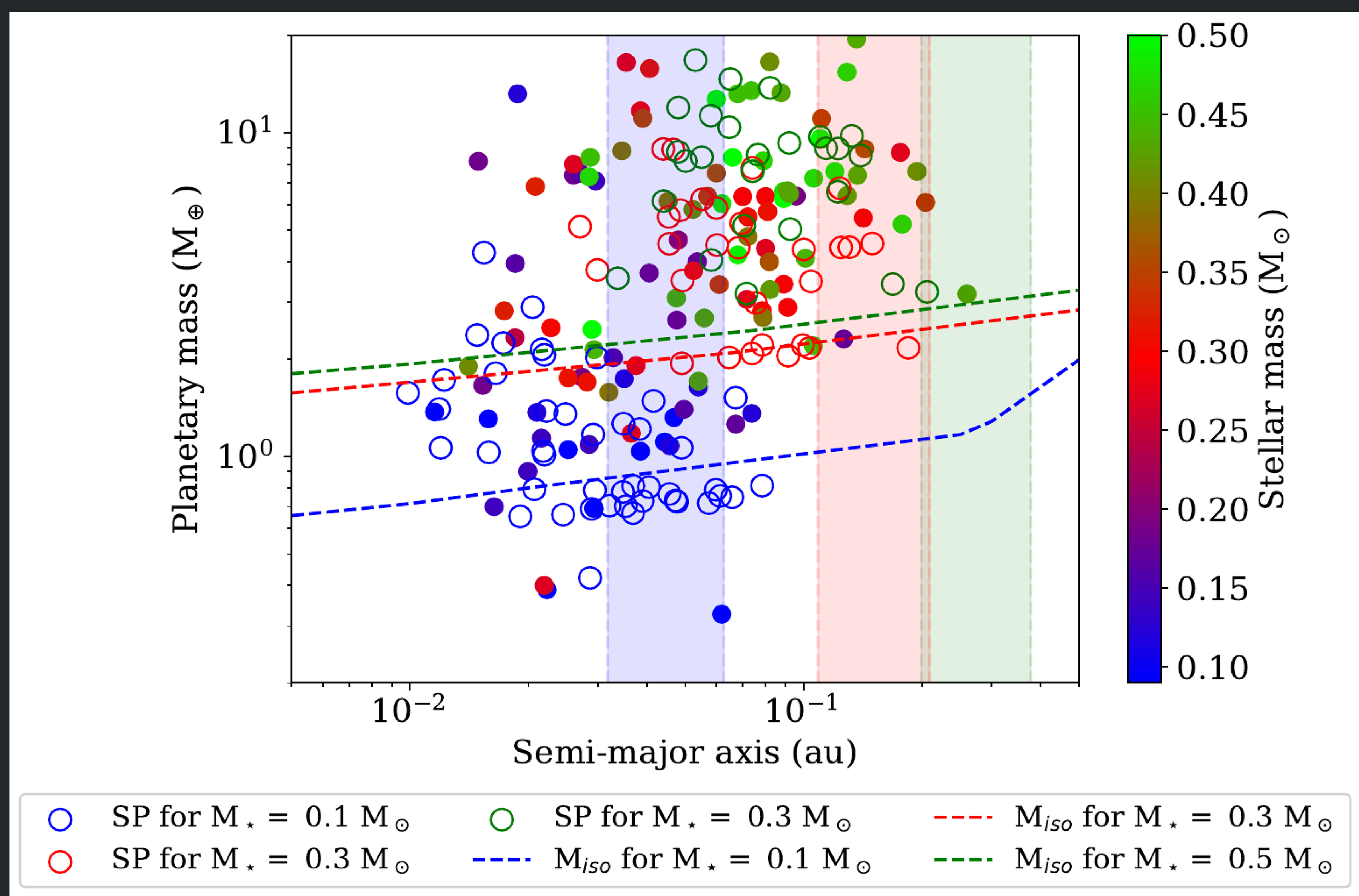
Modifications into the N-body code

(Sanchez et al 2024 subm; Sanchez et al 2022)

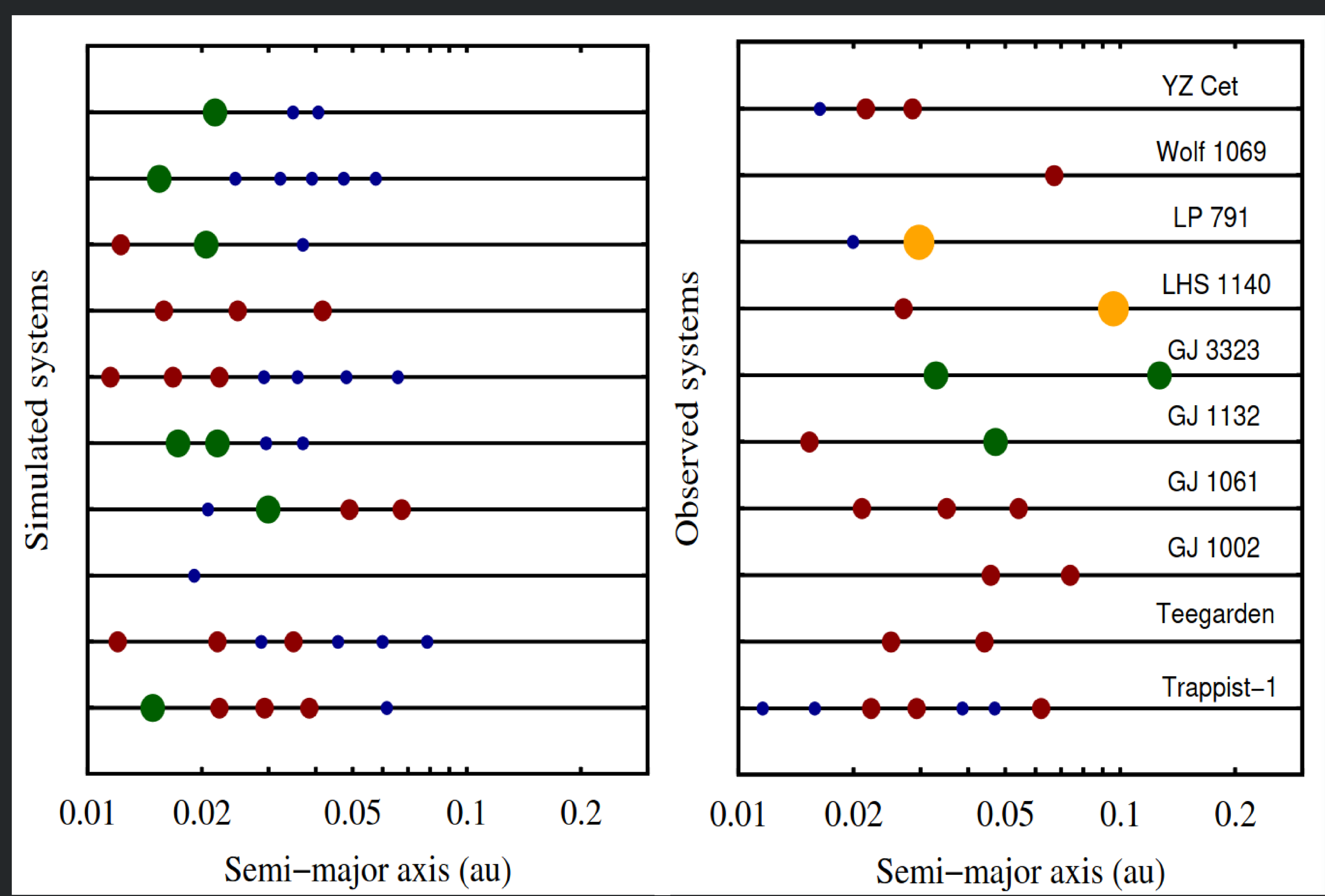
-Pebble accretion model.
-Evolving gas disk model (evolving luminosity and gas accretion rate).
-Planet-disk interactions: type I migration, eccentricity and inclination decay.
-Star-planet tidal interactions that include the evolution of the radius and rotational period of the star.
-General relativistic corrections.

RESULTS

Super-Earths can be formed around M dwarfs in close -in orbits and in multi-planetary systems with compact configurations. The planetary masses increase with the stellar mass. The final masses depend on both the isolation mass of the outermost planet (that stops the pebble drift inwards) and the planet-planet interactions.



The simulated planets (SP) are in agreement with the confirmed rocky exoplanet population around M dwarfs in close-in orbits[1] in terms of masses, semi-major axis, and the percentage of planets in the habitable zone (shadow areas). The comparison between the simulated systems around 0.1 Msun and the observed ones is shown below.



[1]HTTPS://EXOPLANETARCHIVE.IPAC.CALTECH.EDU/

CONCLUSIONS

-Close-in super-Earth formation is possible around M dwarfs from compact dust disks with low pebble scale heights (alpha=0.0001) when the core accretion is driven by an efficient pebble radial drift.

-The simulated planets are in agreement with the rocky exoplanet population around M dwarfs in terms of masses, semi-major axis and location inside the habitable zone.

-Simulations that include planetesimal accretion or higher viscosity cannot reproduce the observed planet population.

REFERENCES

Ansdell, M., Williams, J. P., Trapman, L., et al. 2018, ApJ, 859, 21
Mulders, G. D., Dr̨ ażkowska, J., van der Marel, N., Ciesla, F. J., & Pascucci, I. 2021, ApJ, 920, L1
Sánchez, M. B., de Elía, G. C., & Downes, J. J. 2022, A&A, 663, A20
van der Marel, N. & Mulders, G. D. 2021, AJ, 162, 28
van der Marel, N., Williams, J. P., Picogna, G., et al. 2022, arXiv e-prints