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Italiadomani

PIANO NAZIONALE
DI RIPRESA E RESILIENZA



Planetary *Growth* and *Migration* Tracks code



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Cost Action – The birth of solar systems (PLANETS), WP2, 17-10-2024

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GroMiT: Tracking planets as they form

Polychroni et al., (2023)



GroMiT, the *Growth and Migration Track* code, tracks how a forming planet accretes pebbles and gas as well as how it migrates depending on the local environment of its native circumstellar disk (e.g. Johansen+2019, Ida+2016, Tanaka+2020).

Born as a plug in for *Mercury-Arxes* to make it self consistent it found plenty of applications also a stand alone in exploring the formation histories of **observed planets**.

Part of the **Arxes** suite of planetary formation codes

GroMiT: Tracking planets as they form

Polychroni et al., (2023)

- A python3 code

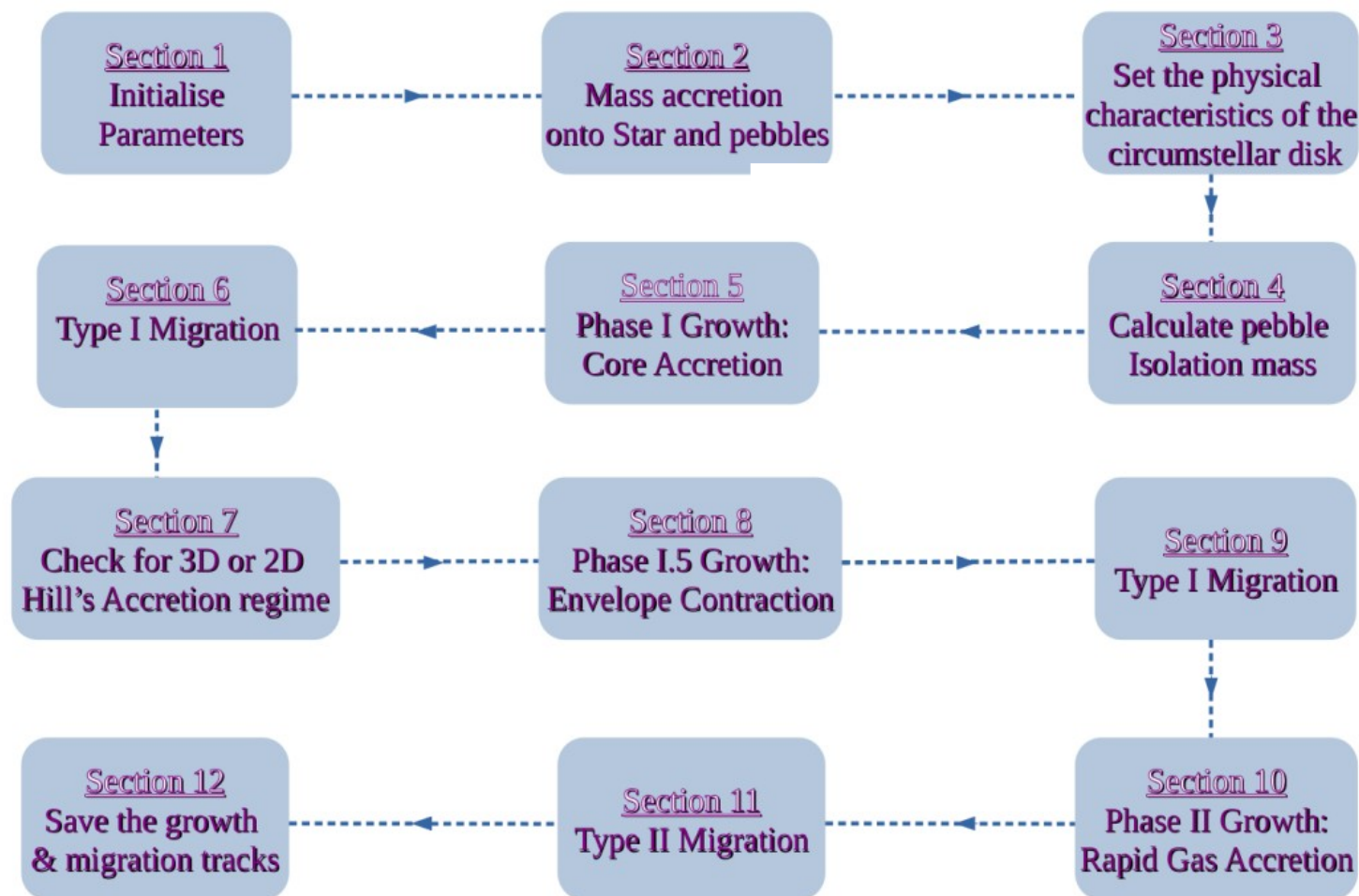
- Pebble Accretion theory

- Two flavors:

Single Planet Mode
Population Synthesis Mode

- Equations mainly derived from the works of:

Johansen et al., 2019
Tanaka et al., 2020
Ledda et al., 2023
Armitage 2020
Ida et al., 2016
Turrini et al., 2023





GroMiT: User Defined Initial Conditions

Run Time:

t_0 ,
time step,
 t_{final}

Stellar Properties:

Mass,
Luminosity,
Mass accretion rate (optional),
Mass Loss due to Photoevaporation

Planet Properties:

Core Mass,
Initial Semimajor Axis

Disk Properties:

Characteristic radius,
Inner disc edge,
Disk Temperature @1au [*analytic or parametric*],
Gas surface density @ R_c ,
Exponent of surface density,
Alpha

Dust Properties:

Dust to gas ratio,
pebble size



GroMiT: Side Equations

- **Gas Drift Velocity** (Johansen+2019)
- **Mass Accretion Rate onto Star @ t_0** [optional]
- **Disk Viscous Temperature @ r** (Ida+2016)
- **Irradiation Temperature @ r** (Ida+2016)
- **Hill Radius @2D regime**
- **Characteristic Timescale, Scale Height, Viscosity, Omega, Keplerian Velocity, Speed of Sound**



GroMiT: Main Code

- **Initiate Parameters at R_0 and t_0**
- **Start the time loop**
- **Mass Accretion onto Star** [parametric or analytic]
- **Disk Temperature** [parametric or analytic]:
parametric given by Johansen+2019; analytic uses Viscous Irradiation temperatures from Ida et al. 2016
- **Use the Condensation sequence of solids in the disk** (Turrini+2023)
(silicate snowline; water and organics snowline) to set up the pebble density



GroMiT: Main Code

- **Set up the pebble accretion (2D Hill accretion)**
- **Use the Weidenschilling (1997) Radial Drift** (generic)
- **Calculate up the Surface density of pebbles**
(and get Stokes number; Scale height; friction time; material density (Armitage 2000); Bondi radius)
- **Calculate up Pebble Isolation Mass and the Gap Mass** (Johansen+2019)



GroMiT: Main Code

- **Split into regimes for:**

Planet Mass < Pebble Isolation Mass

→ **Core Growth** → **Core accretion** + **Type 1 Migration** (Johansen+2019)

Planet Mass < Gap Mass

→ **Planet Growth** → **Envelope Contraction** (Ikoma+2000 for halting contraction) + **Type 1 Migration**

Planet Mass > Pebble Isolation Mass

→ **Planet Growth** → **Rapid Gas Accretion** + **Type 2 Migration** (Tanaka+2020)

GroMiT: Output

- **Write text file with the following information per track step:**

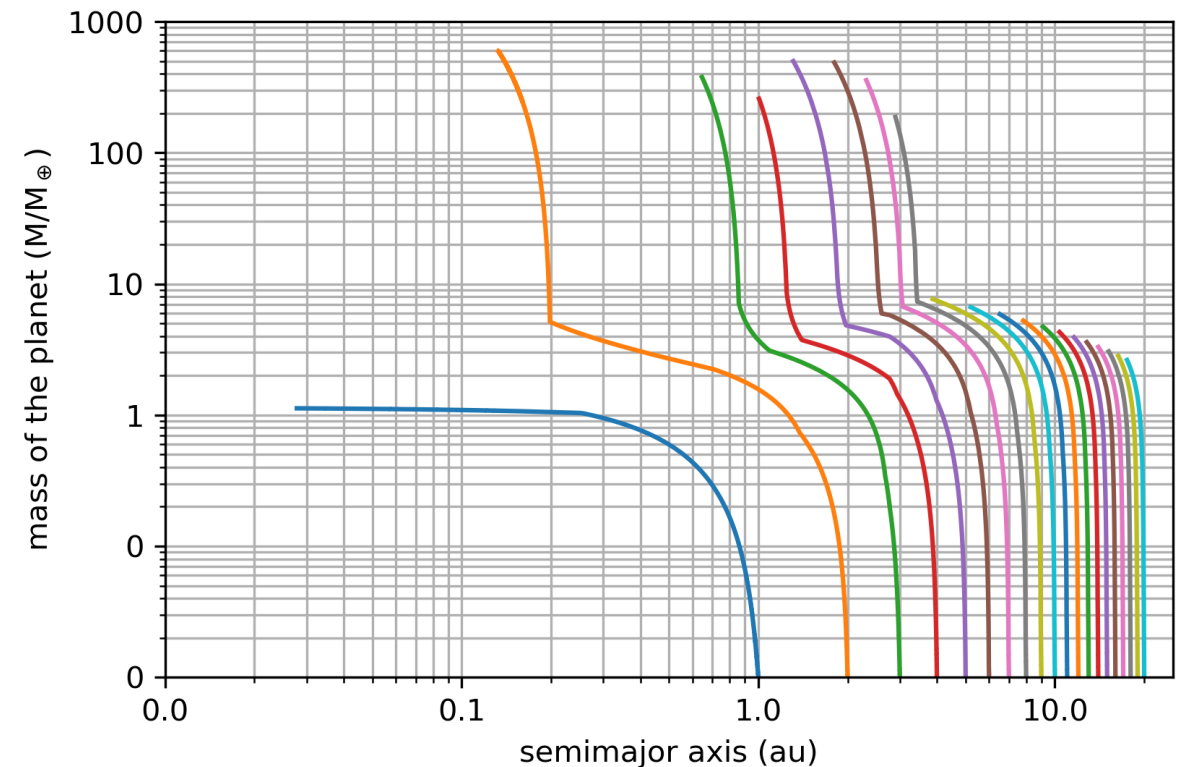
time, semimajor axis,
planet mass, core mass, envelope mass,
pebble isolation mass
mass accretion rate, T

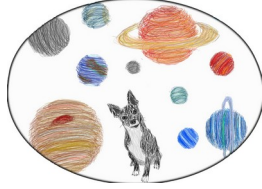
- **Plot the track results**

Example

Stellar Mass: 1.46 solar masses
Characteristic radius: 50 au
Disk Temp: 200 K @ r=1 au

Surface Density: 420 kg/m²
Start tracking @ 0.1-0.2 Myr
Initial Orbit: 1.75-10.0 au
Run Time: 3 Myr





Monte GroMiT: Population Synthesis Mode

- The same main core as GroMiT + Monte Carlo Realisations
- Initial Parameters:

Set Up Monte Carlo Runs
Number of planets to rack

Time Parameters:
 T_0 range
 T_F range

Planet Parameters:
Initial Semimajor
Axes range

Disk Parameters:
alpha parameter range

The rest of the parameters
remain as in the single track
mode

Monte GroMiT: Output

- Text file with a summary of the disk set up
- Text file with the following information (per simulated planet):

t_0 , t_{final} ,

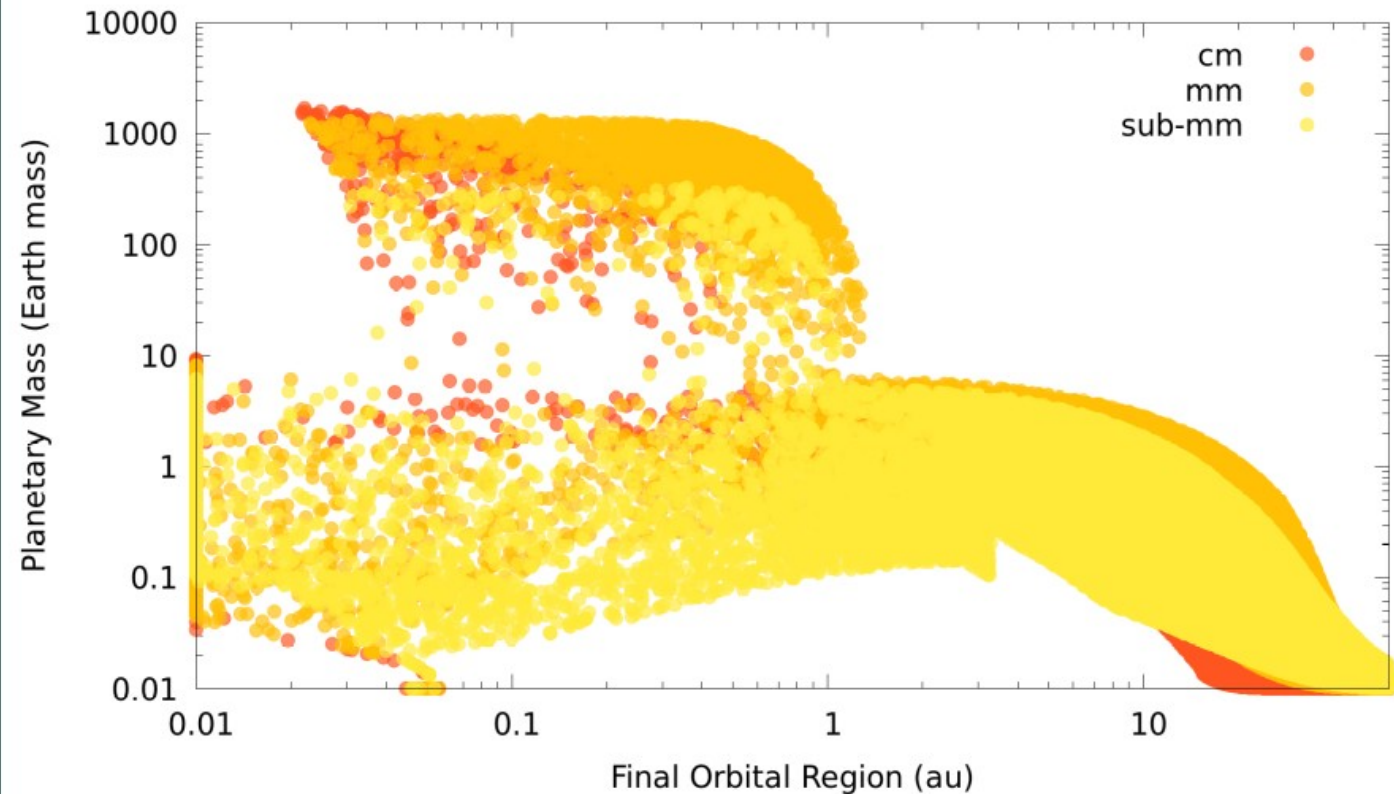
initial semimajor axis, final semimajor axis,

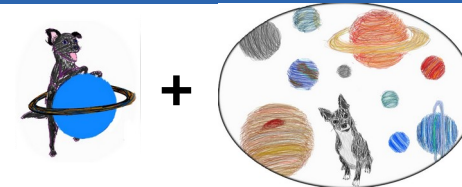
planet, Core, Envelope mass,

isolation mass, gap mass, t_{iso} , t_{KH} contracion, t_{run}

away,

temperature

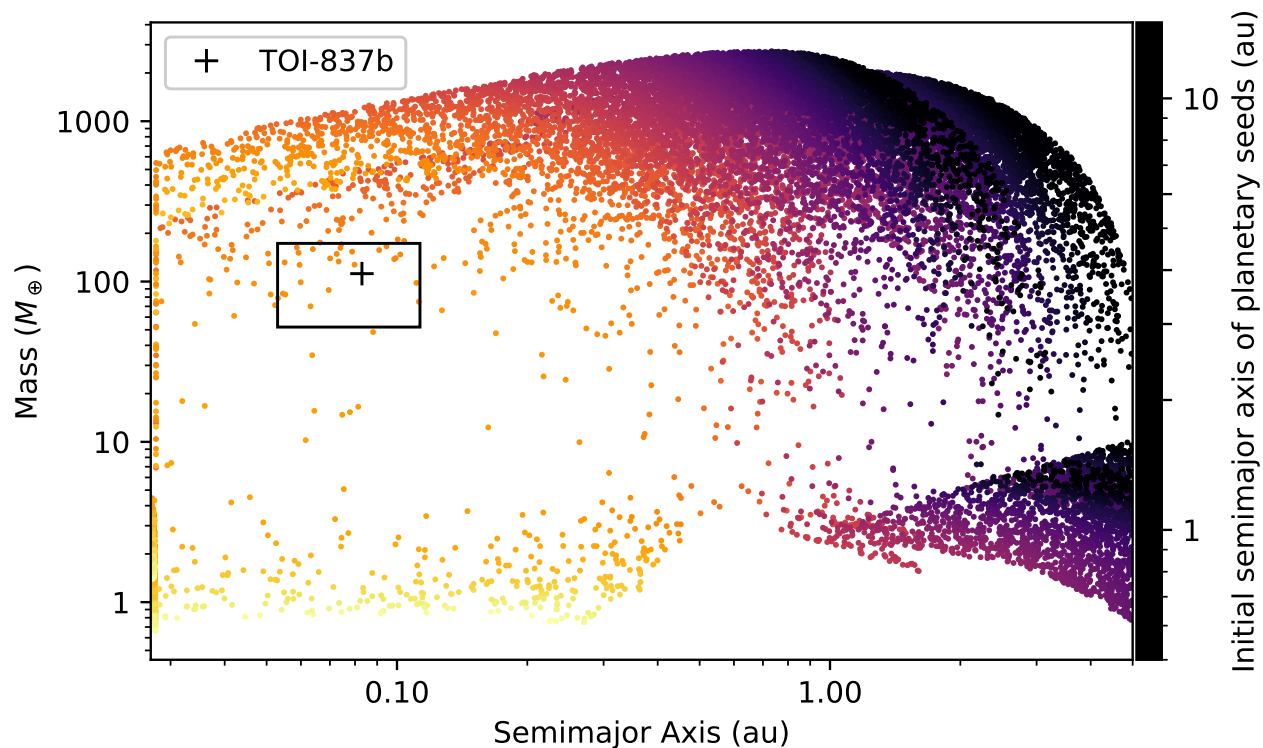
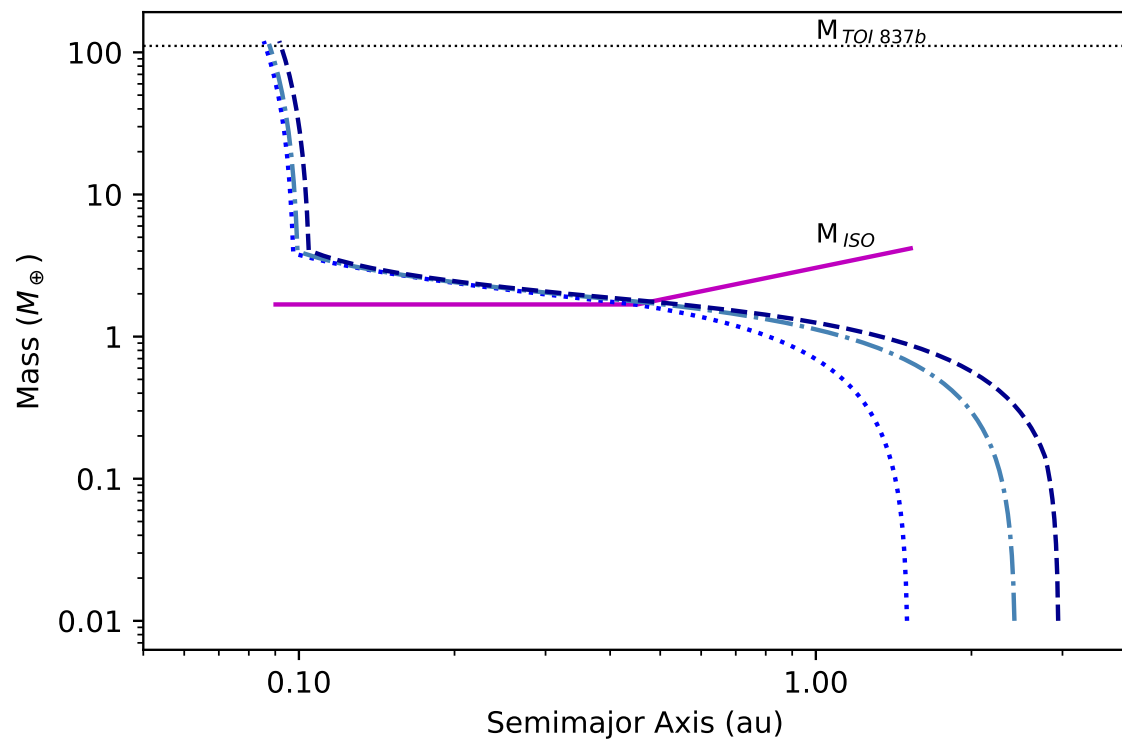




Monte GroMiT + GroMiT: Applications In Real Systems

Damasso+2024;

TOI 387



Monte GroMiT + GroMiT: Comparative Planetology

(Mantovan+2023a,b; Zingales+2024; Naponiello+sub)

