july 17th, 2025

literary studies + bern iii model

stuff i did

- review papers i discussed from last week
- learning about exoplanet system architecture + formation for better astro background (this was super fun but also super challenging)
- learning about the gen iii bern model

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but this is extremely susceptible to data bias and fake patterns!!

last week…

exoplanet classification – literary studies

Framework for the architecture of exoplanetary systems (2023)
(DOI: https://doi.org/10.1051/0004-6361/202243751)

used a model called the GENERATION III BERN MODEL in the process to create synthetic data (under heading *2.1 Theoretical Dataset: Bern Model*)

- system of classification they use requires ≥ 3 planets per system, thus out of their original dataset there were only 41 data points.
- gen iii bern model to generate 1000 such systems

exoplanet classification – literary studies

Planetary Population Synthesis and the Emergence of Four Classes of Planetary System Architecture (2023)
(DOI: https://doi.org/10.48550/arXiv.2303.00012)

- This paper also uses synthetic data generated using the **GENERATION III BERN MODEL** which seems to be pretty popular.

so i spent **this week…**

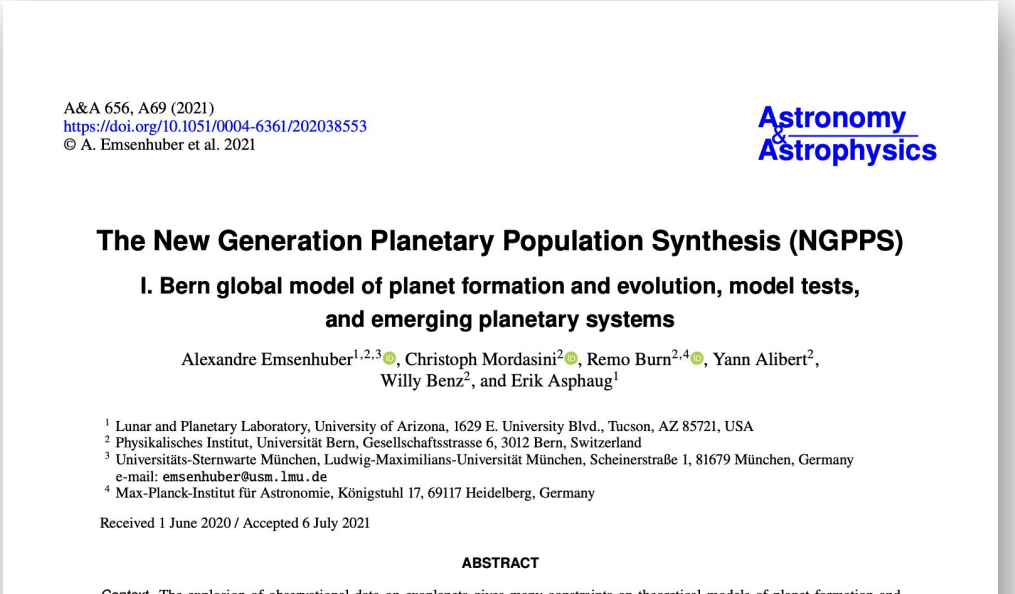
…learning about the
generation iii bern model…

…and some
cool astrophysics!!

extensive study on paper on the creation of the model

The New Generation Planetary Population Synthesis (NGPPS): Bern global model of planet formation and evolution, model tests, and emerging planetary systems

link: https://www.aanda.org/articles/aa/pdf/2021/12/aa38553-20.pdf



A&A 656, A69 (2021)
https://doi.org/10.1051/0004-6361/202038553

Astronomy & Astrophysics

The New Generation Planetary Population Synthesis (NGPPS)

I. Bern global model of planet formation and evolution, model tests, and emerging planetary systems

Alexandre Emsenhuber[1,2,3], Christoph Mordasini[2], Remo Burn[2,4], Yann Alibert[2], Willy Benz[2], and Erik Asphaug[1]

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[3] Universitäts-Sternwarte München, Ludwig-Maximilians-Universität München, Scheinerstraße 1, 81679 München, Germany
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Received 1 June 2020 / Accepted 6 July 2021

ABSTRACT

why the model exists, and what it does

- **what it does:** simulates formation + evolution of planetary systems and predicts physical characteristics (ex. the ones we see in NASA exopl. arch.)

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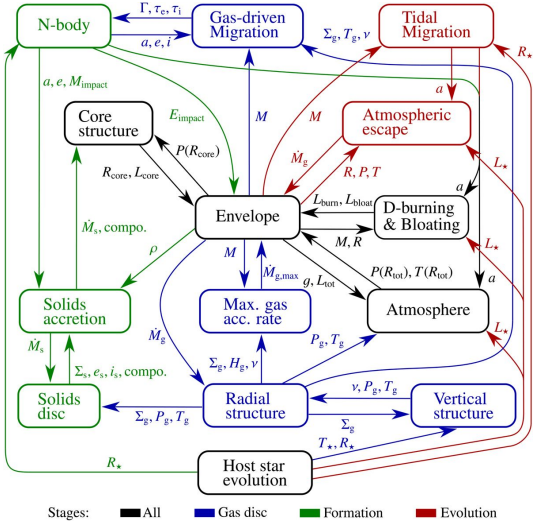
- **why it exists:** lack of model that integrated both formation and evolution

model architecture: two phases

data flow of the model:

FORMATION
(0-20 million years)

EVOLUTION
(billions of years)



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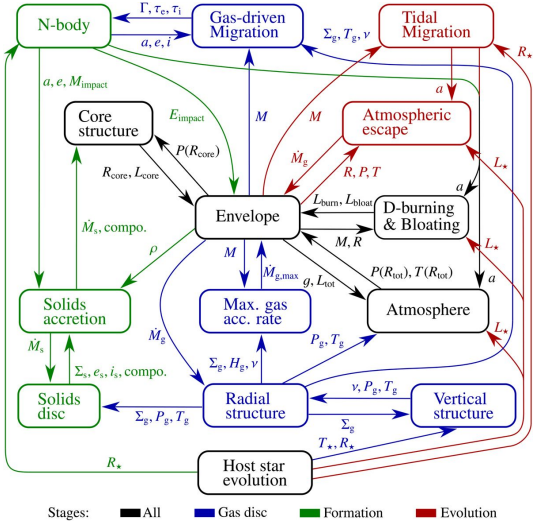
FORMATION STAGES
model tracks how discs of gas and dust, as well as planetesimals (small solids) around a young star will change over time. accretion of planetesimals means a new planet is formed

computer model simulates the interactions these have with the laws of gravity



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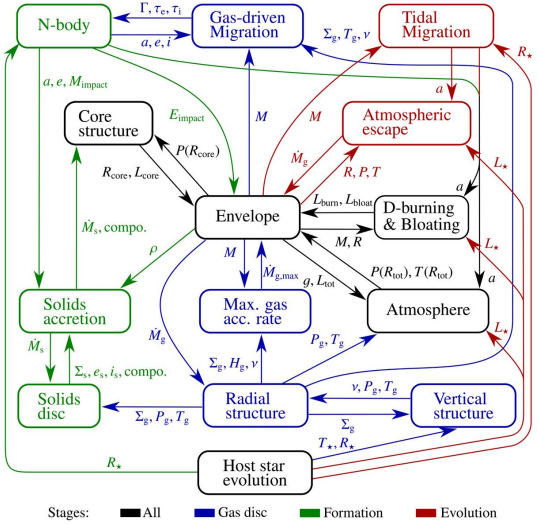

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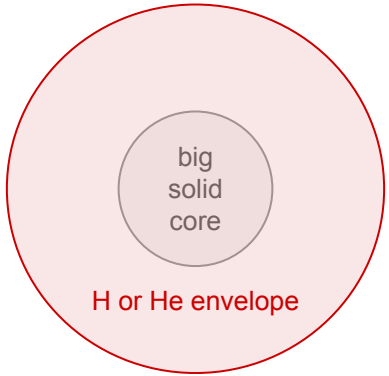

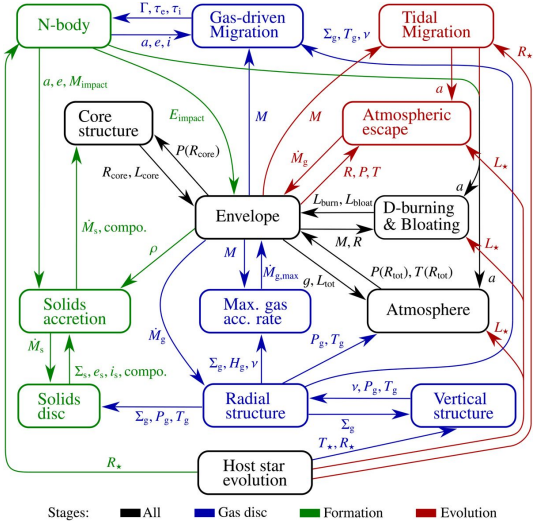

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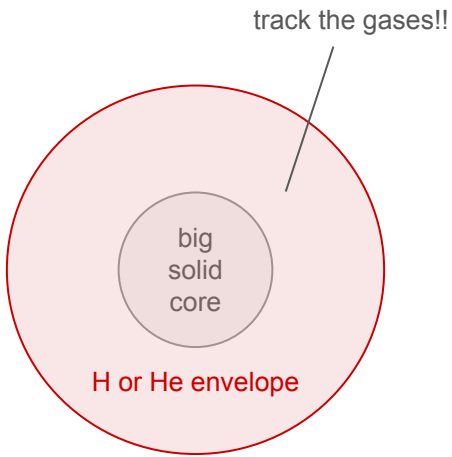

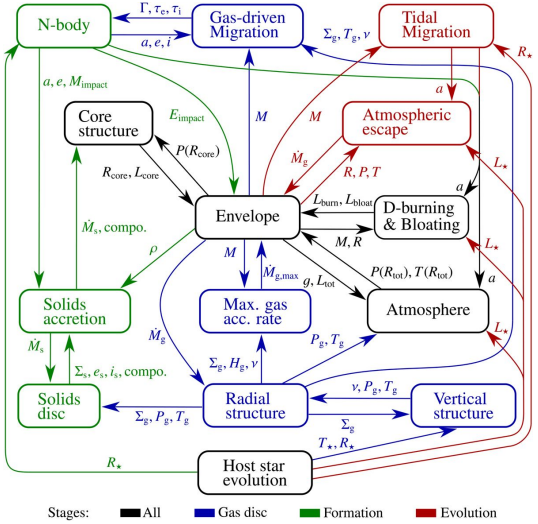

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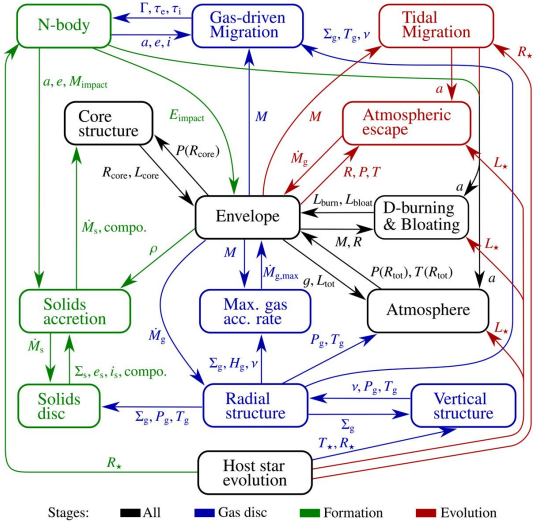
EVOLUTION STAGES
talks all about the long term evolution, taking into account long-term thermal and atmosph. evolution

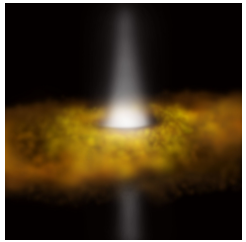
"the standard spherically symmetric internal structure equations, but with different boundary conditions, and taking into account different physical effects like atmospheric escape, or radius inflation. In this phase, the planets evolve individually; N-body interactions and the accretion of planetesimals are no more considered. The orbits and masses of the planets may however still evolve because of effects like tides and atmospheric escape."



section one: formation

disc model: protoplanetary disc physics

uses a **1D viscous α-disc approach**



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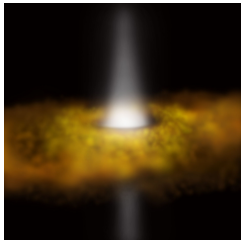

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- essentially, a simplified way to model accretion discs that tracks **radial motion** (in/outward) of matter while assuming disc is thin and behaves like a series of rings rubbing against each other.

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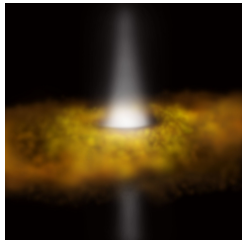

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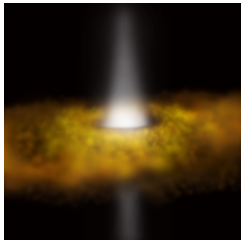

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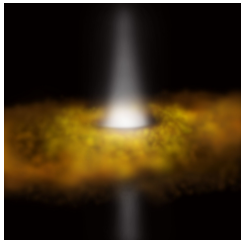

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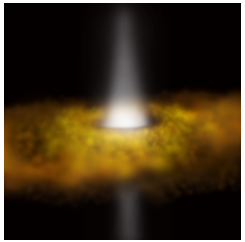

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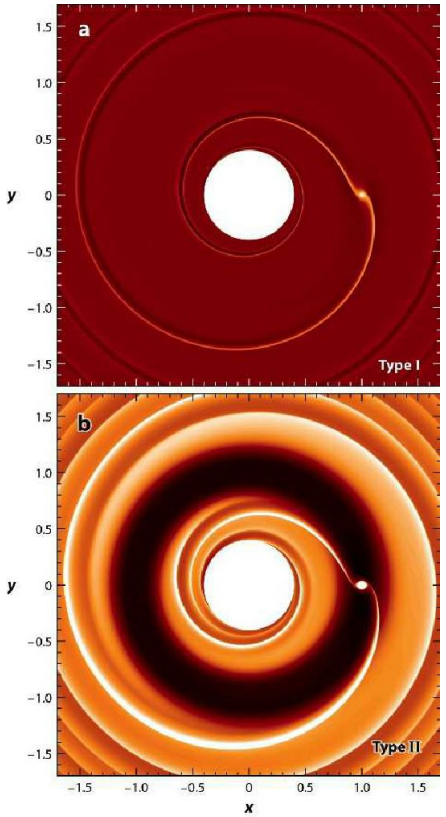
- used by the model to simulate beginning of planetary formation

orbital migration

Type I Migration – a little push

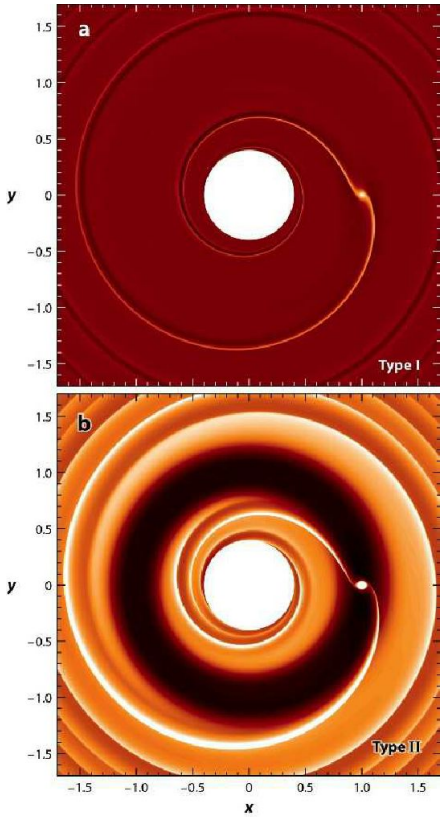
- usually affects smaller planets still within the accretion disc
- gravitational field of a planet creates density waves (i.e. ripples) in the surrounding gas.
    - waves exert torque on the planet
      → loss of angular momentum + usually drift inwards to star
- usually pretty fast – takes 100k years or so. big transformations of inner regions of planet systems



orbital migration

Type II Migration – controlled drift

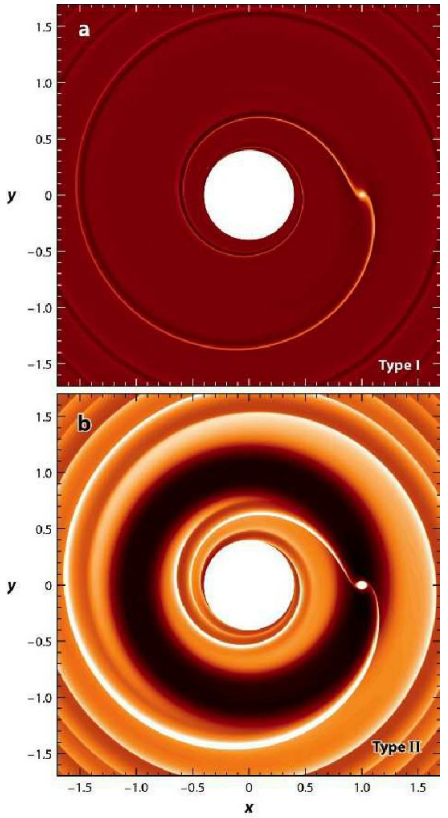
- affects bigger planets (ex. Jupiter, Saturn) that can clear out a big gap in the protoplanetary disc
- planet's gravitational pull creates big ring-shaped gap by pushing gases out of the way and influencing the disc as it does.
    - planet is locked into gap, migrates along with the viscous evolution of the disc as gas slowly accretes onto the star
- very slow – millions to hundreds of millions of years



orbital migration

model simulates both

- planetary ‘embryos’ move in or out depending on their torque balances
- N-body interactions also included
    - can thus simulate resonance captures and orbital instabilities



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talked about this vaguely earlier but

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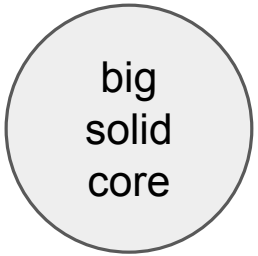

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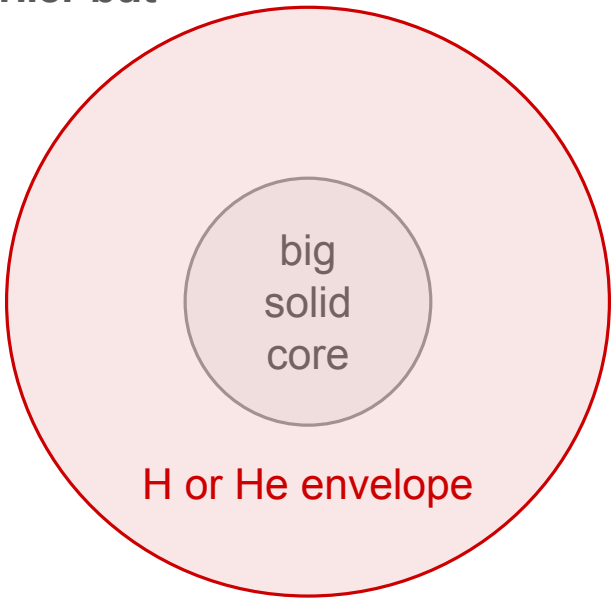

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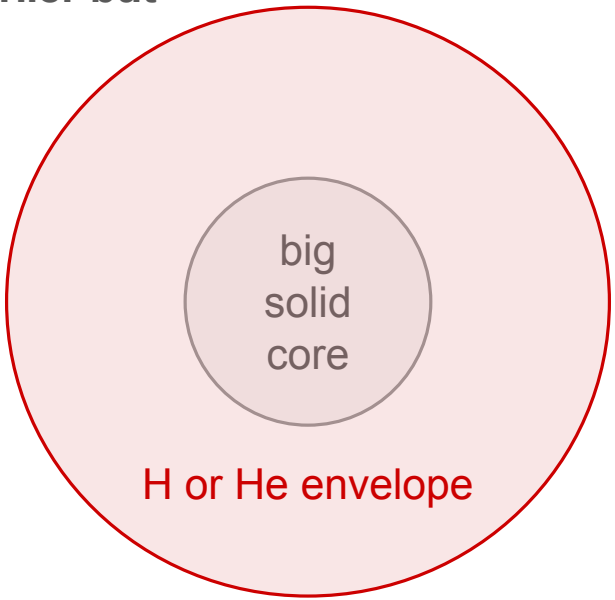

governed by
Kelvin-Helmholtz contraction timescales

$$\tau_{\rm th} = \frac{\text{total kinetic energy}}{\text{rate of energy loss}} \approx \frac{GM^2}{2RL}$$

that’s about it for formation

next week: will work on figuring out evolution!! great way to discover more about astrophysics as well