

# Exoplanets

Lecture 9  
19 November 2021  
MFF UK

# Outline

- Formation of Solar System (intro)
- Interesting cases in Solar system
- Journal club review of interesting articles
  - Saturn rings presentation
  - New hot Jupiters paper presentation

# Solar System formation

- Widely accepted formation theory is the nebular theory
- There are other alternative theories of formation such as capture theory
- Nebular theory has still its flaws but the nebular theory refined with new knowledge also from exoplanet research can explain most accurately observed Solar system features

# Capture theory

- Woolfson 2017 <https://arxiv.org/pdf/1709.07294.pdf>
- It was proposed in early early sixties in the past century by M. Woolfson
- It states that the Sun and a passing protostar interacted
- The matter from the Sun and from the protostar was the building stone for planets
- Earth and Venus were created by collision of two large protoplanets
- Mars and Mercury were escaped moons by one of the collided planets as well as dwarf planets

# Capture theory

- The encounter of stars is only less probable
- Hot gas would not contract to form planets but it would expand

# Nebular theory

- Solar nebula collapse
  - what was the event causing the formation?
  - perhaps supernova?
  - how do we know? We do not but we have hints from material in Solar System, namely short lived isotopes which needed to be produced in Supernovae
- Banerjee et al.  
<https://www.nature.com/articles/ncomms13639>

Cameron & Truran [1977Icar...30..447C](#)

# Solar System formation



Credit NASA

# Solar System formation

- Protoplanetary disc rotates
- Angular momentum conservation
- The sun and clumps of planets are formed
- Inner (rocky) planets and outer (gas) planets
- Beyond ice line ice giants formed
- Large planets migrated inwards and back outwards
  - see e.g. Nesvorny et al. 2018 Nat Astronomy  
<https://arxiv.org/pdf/1809.04007.pdf>
  - Pierens & Raimond <https://www.aanda.org/articles/aa/pdf/2011/09/aa17451-11.pdf>
  - D Angelo  
<https://iopscience.iop.org/article/10.1088/0004-637X/757/1/50/meta>



# Jumping Jupiter?

- Migration of Jupiter and Saturn inwards and outwards (700M years)
- Preventing growth of Mars
- Ejection of 5<sup>th</sup> large planet?
  - Batygin <https://arxiv.org/pdf/1111.3682.pdf>
  - Nesvorny <https://arxiv.org/pdf/1109.2949.pdf>
- Changing climate on Venus?
  - <https://iopscience.iop.org/article/10.3847/PSJ/abae63/pdf>

# Planet IX?

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[https://www.nature.com/news/polopoly\\_fs/1.19182!/menu/main/topColumns/topLeftColumn/pdf/529266a.pdf?origin=ppub](https://www.nature.com/news/polopoly_fs/1.19182!/menu/main/topColumns/topLeftColumn/pdf/529266a.pdf?origin=ppub)

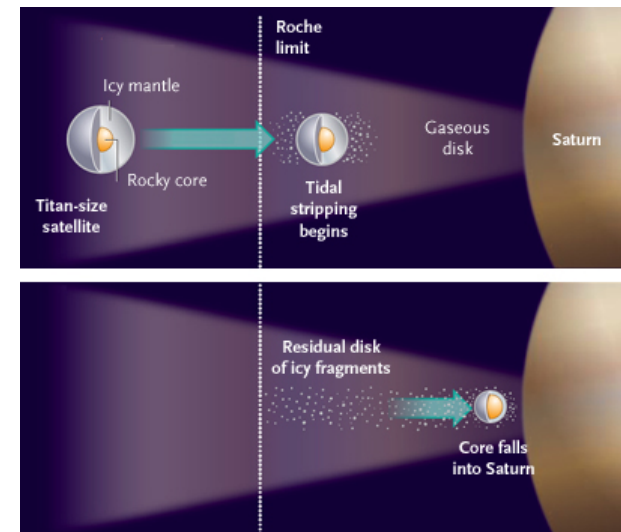
- <https://www.nature.com/news/evidence-grows-for-giant-planet-on-fringes-of-solar-system-1.19182>

# The mystery of Saturn's rings

- Young or old? Were the rings formed in the early history of the Solar System or more recently?
- The rings are composed from ice but if they were from the early Solar System, there would be also some silicates and they would appear darker.....
- Canup 2010, Nature,  
<https://www.nature.com/articles/nature09661>(  
<https://www.boulder.swri.edu/~robin/canup2010.pdf>)
- Charnoz et al.

- <https://arxiv.org/abs/0809.5073>

LHB role for formation of Saturn's rings



Credit: Nature

# The Saturn rings mystery

- Or young.....
- Crida et al. 2019, Nature,  
<https://www.nature.com/articles/s41550-019-0876-y>
- The measured mass of the rings  $10^{19}$  kg is consistent with young but also with old rings scenario
- For old rings scenario a cleaning mechanism is needed, to clean-up silicates

# Next lecture

- Exoplanetary systems formation described
- The composition of exoplanets
- Does a Solar system have an analogue?