Planet formation in stellar clusters

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University of London

清华大学 26/11/2020

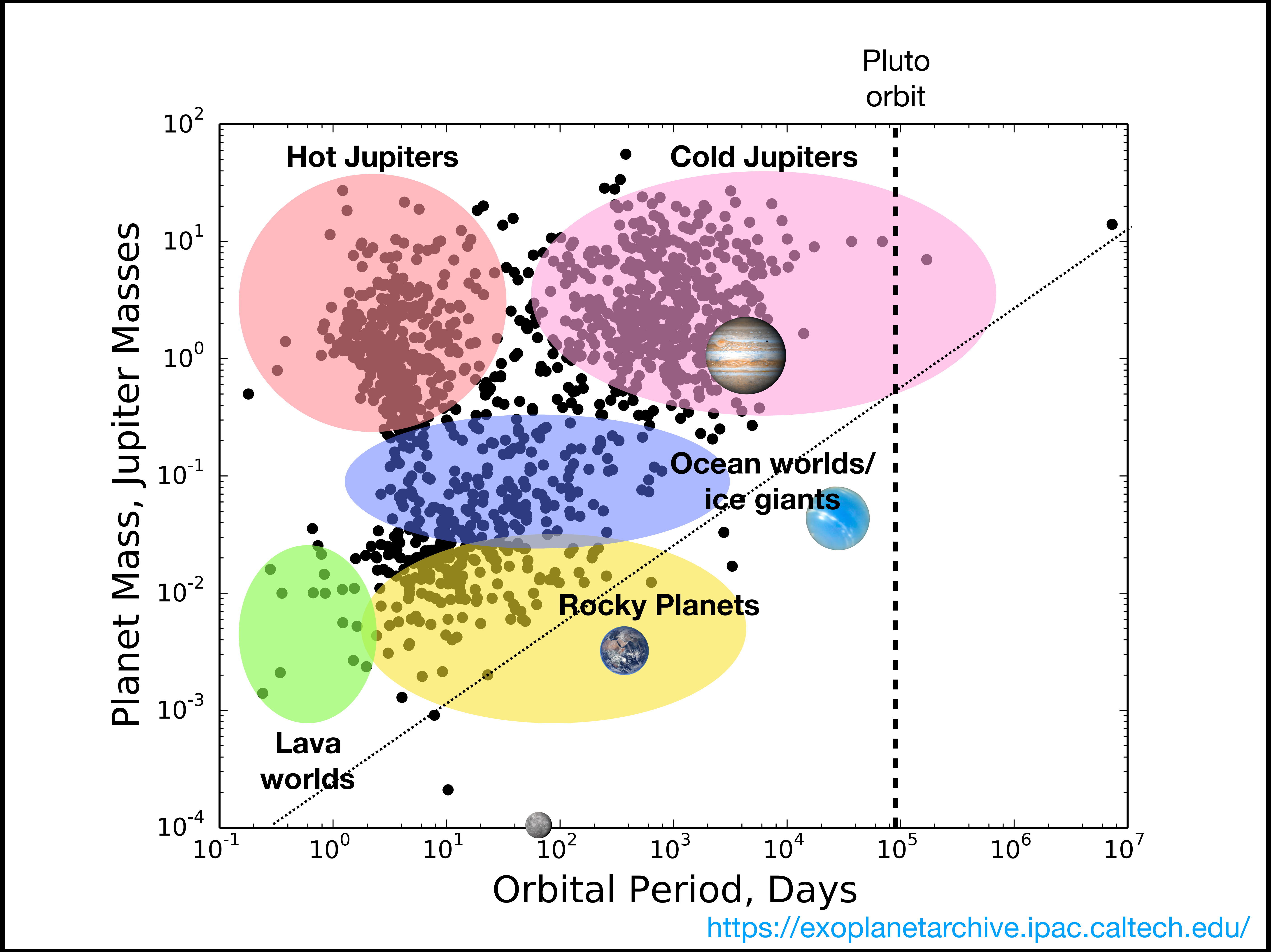
Talk Overview

1. Introduction to planet formation in stellar clusters

2. Can environmental effects compete with early planet formation?

3. Modelling external disc photo evaporation

Exoplanets



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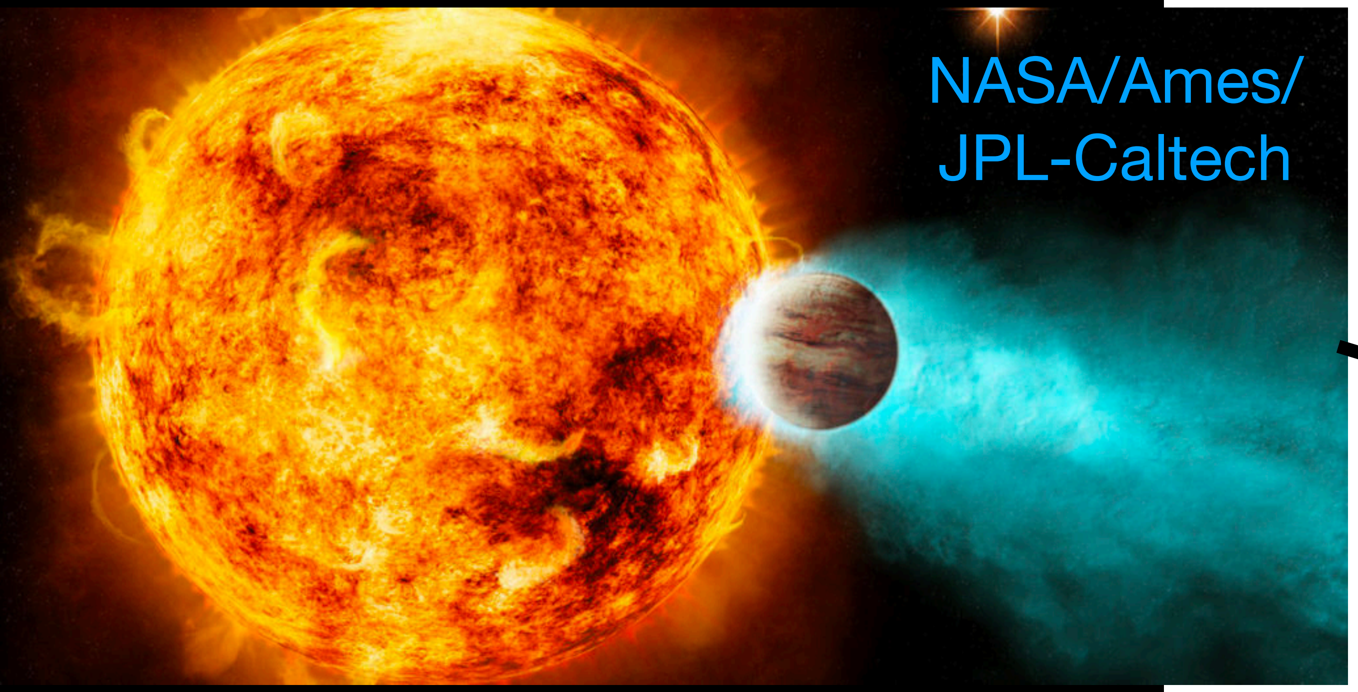
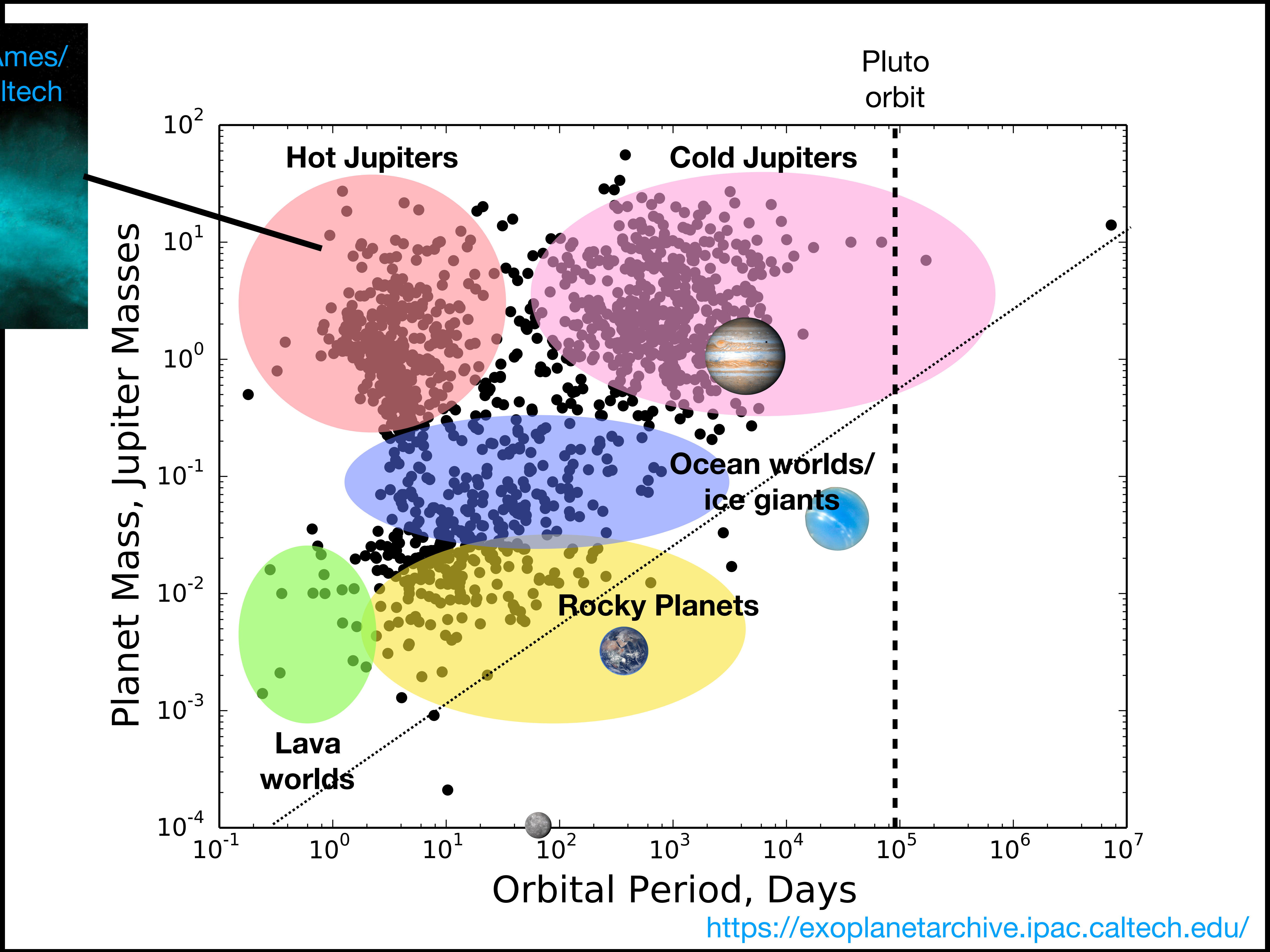
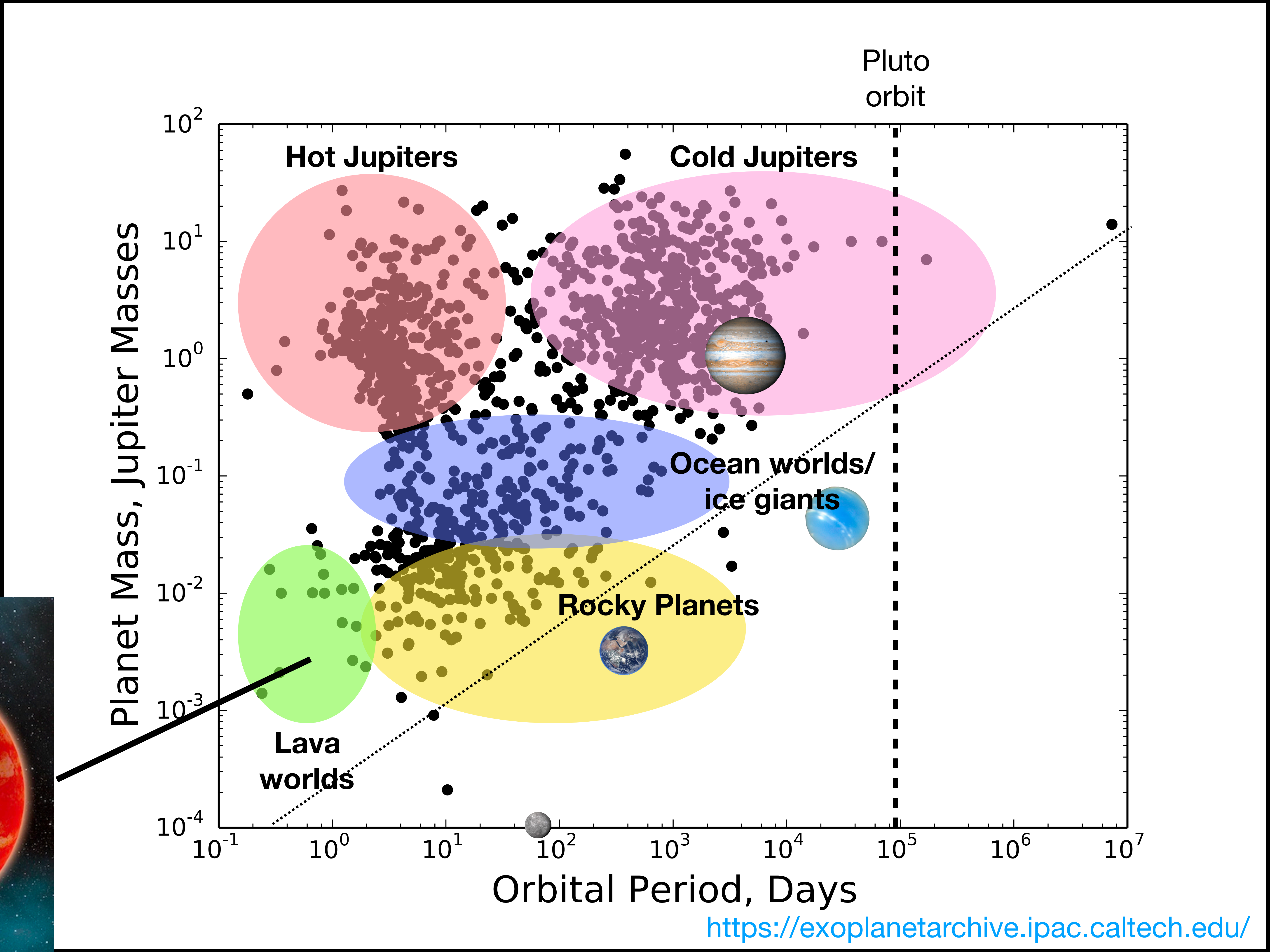
Exoplanets


NASA/Ames/
JPL-Caltech


Pluto
orbit
Hot Jupiters
Cold Jupiters
Ocean worlds/
ice giants
Rocky Planets
Lava
worlds
Planet Mass, Jupiter Masses
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
Orbital Period, Days
https://exoplanetarchive.ipac.caltech.edu/

Exoplanets



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10^4
10^5
10^6
10^7
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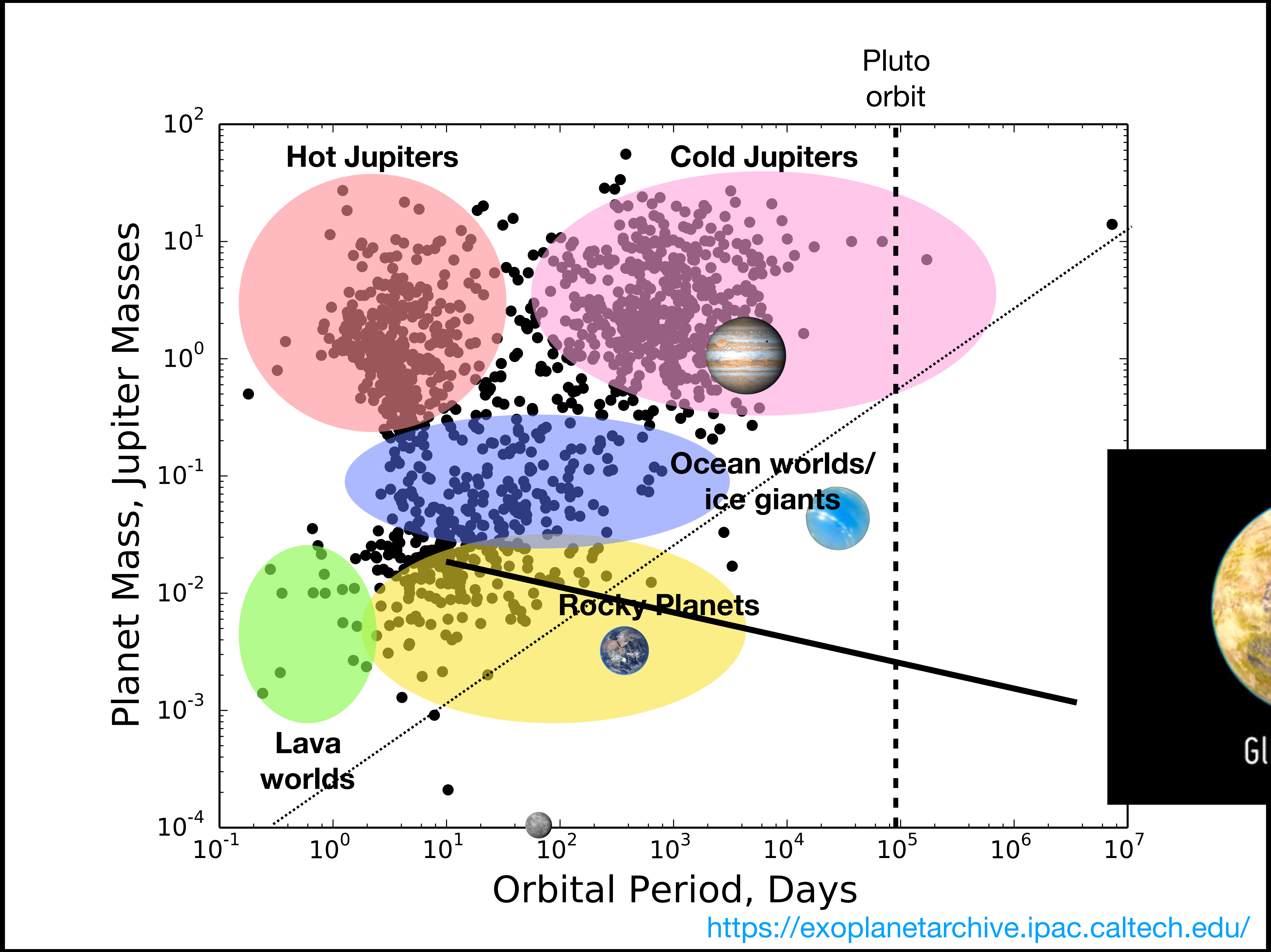
wired.com
Earth
1 mass
Kepler 78b
1.8 mass

Exoplanets



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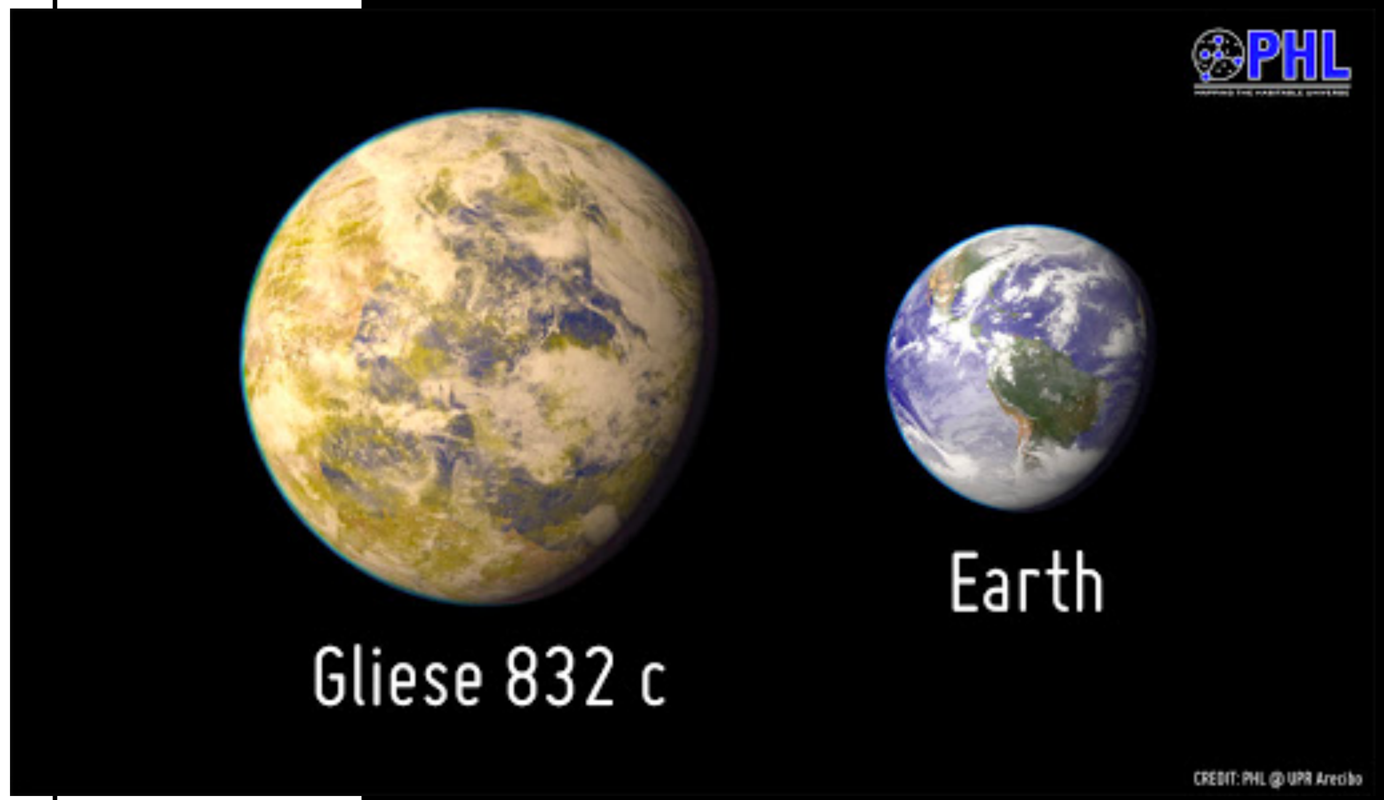
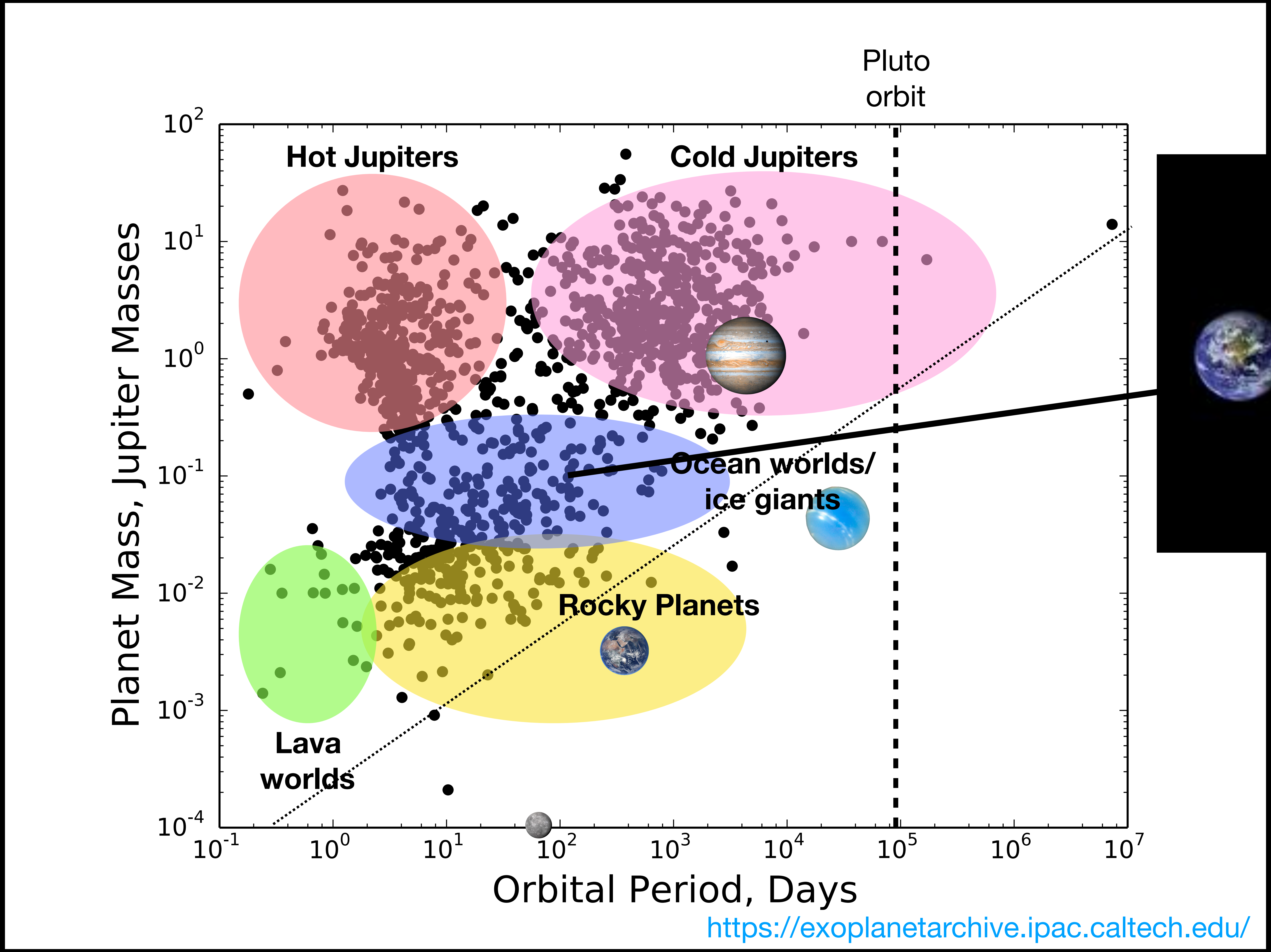


PHL
Gliese 832 c
Earth

Exoplanets



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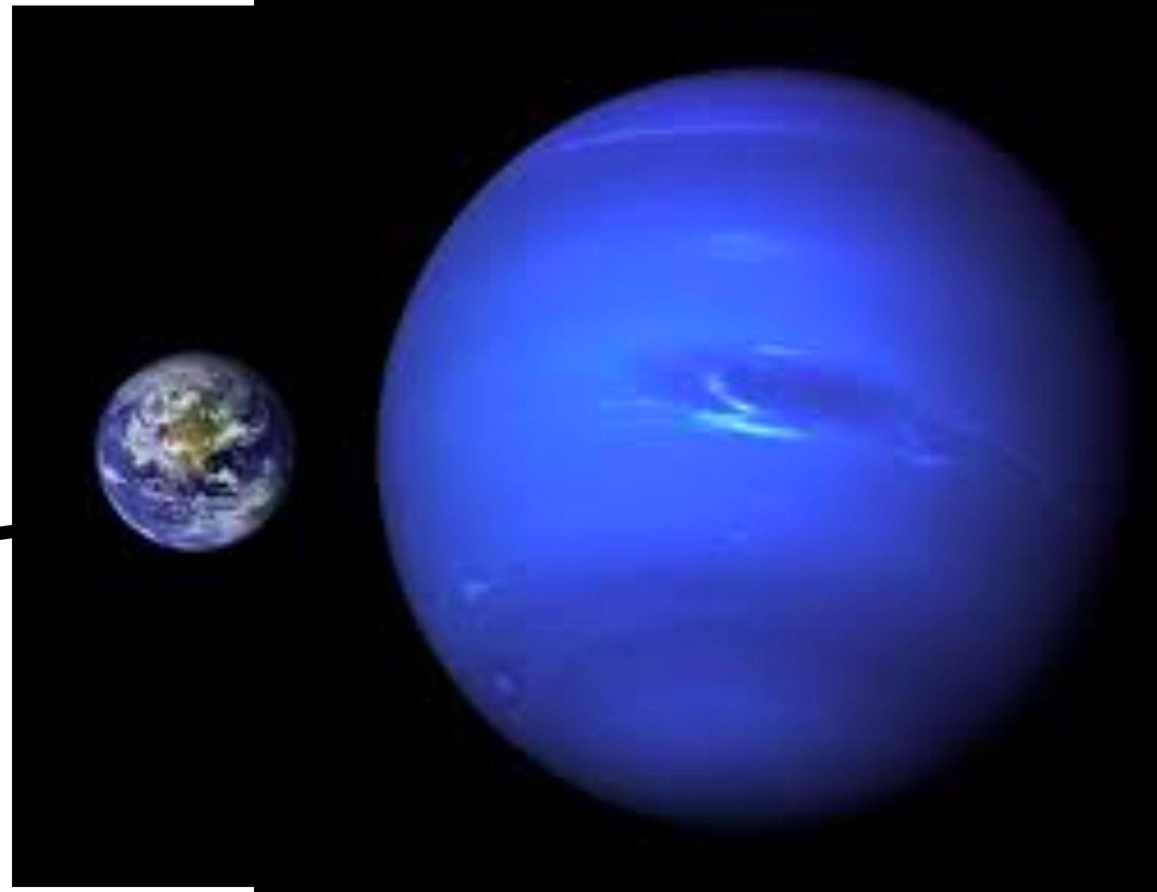
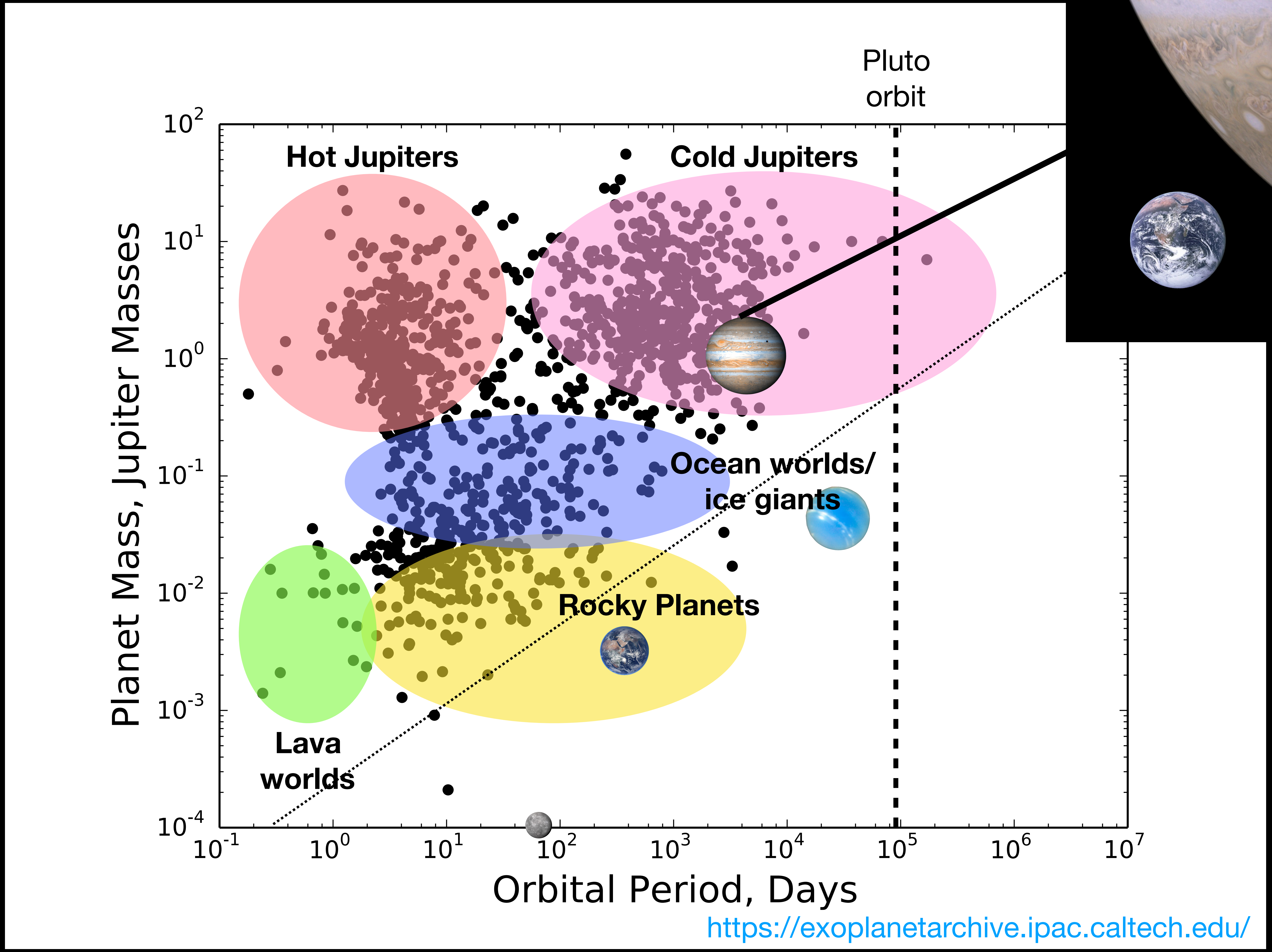


Exoplanets



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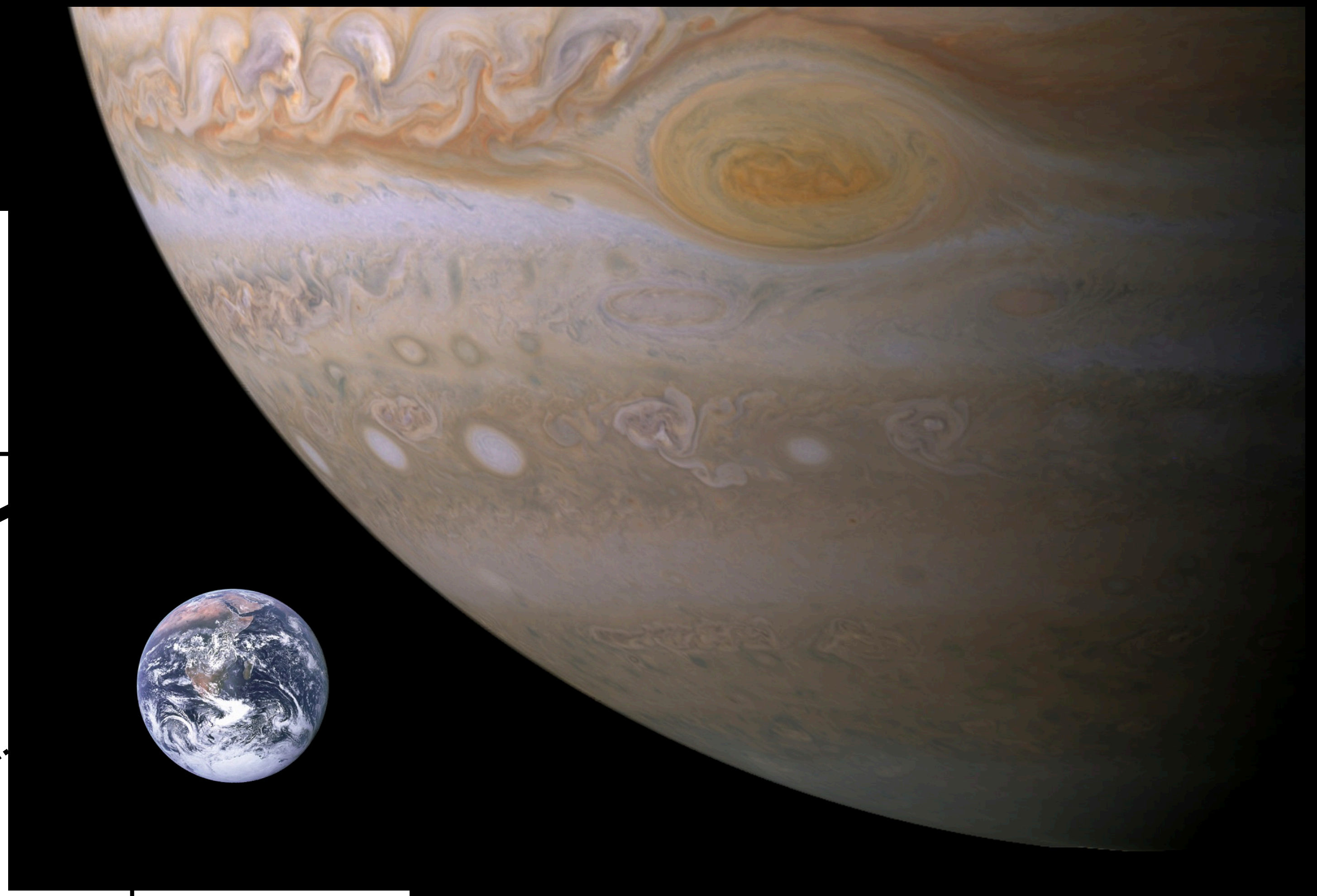
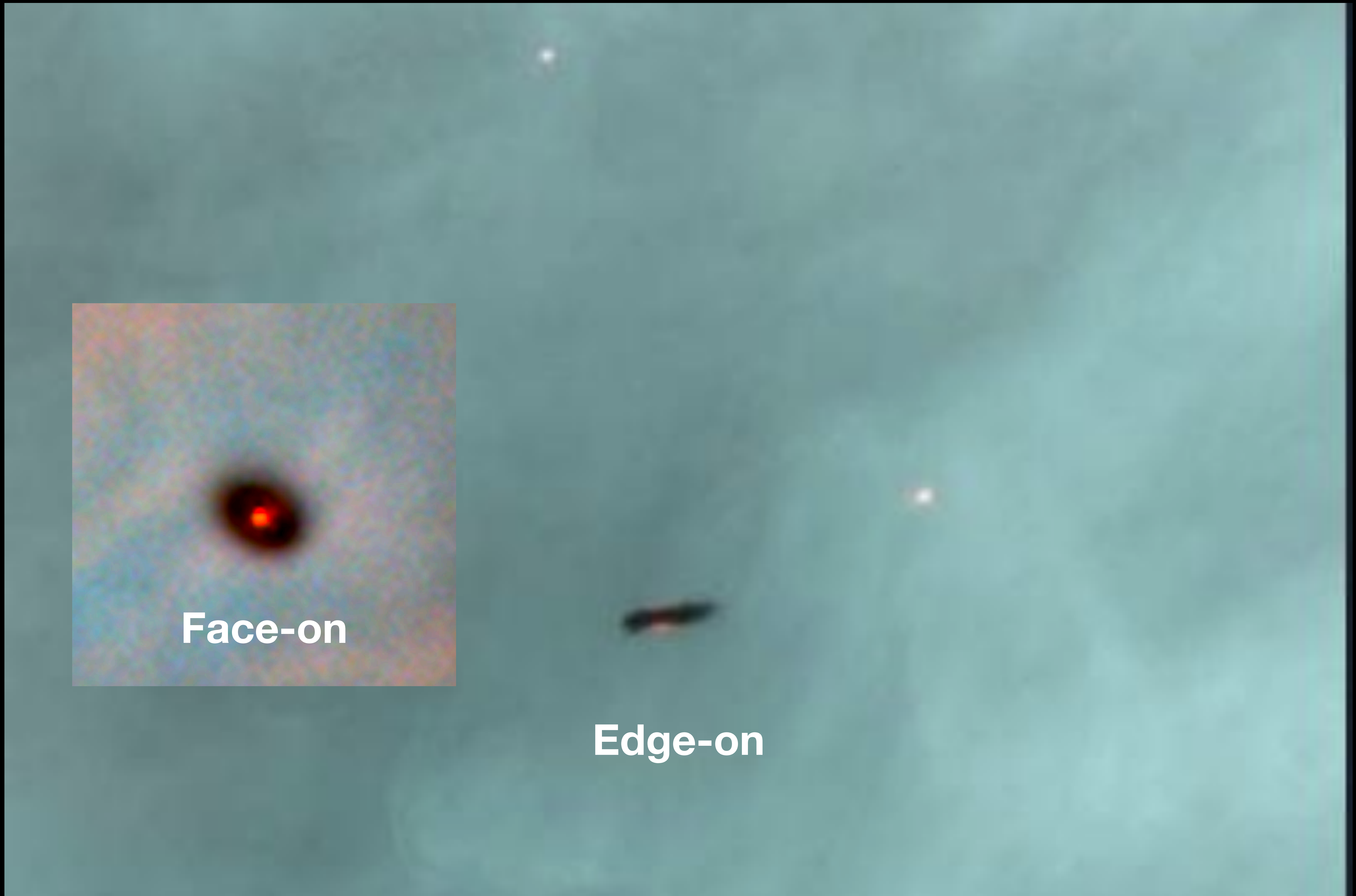


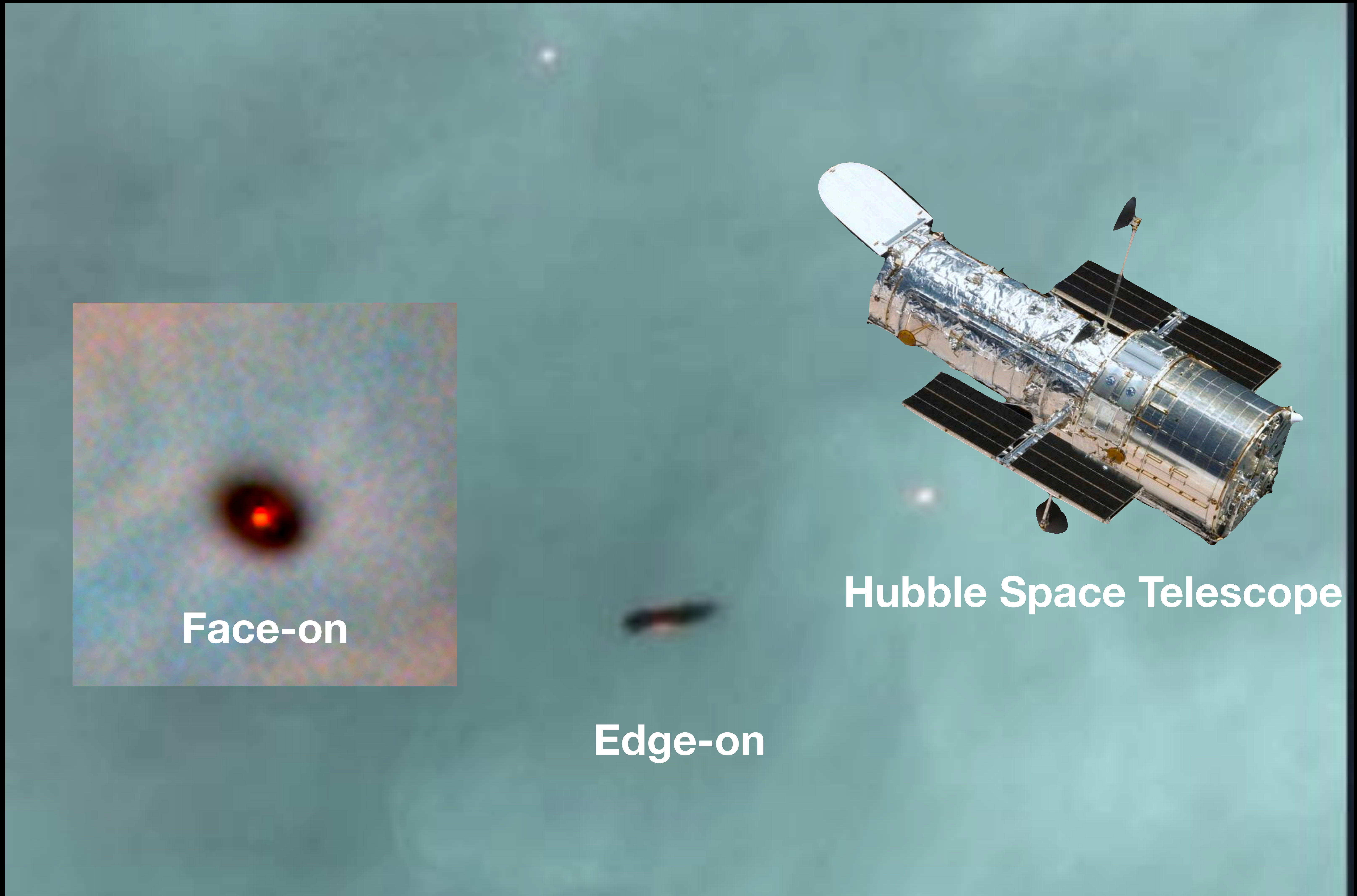
Planet formation: from discs



Papers by O'Dell, McCaughrean, Wen, Henney in the mid 1990's

e.g. O'Dell & Wen 1994

Planet formation: from discs



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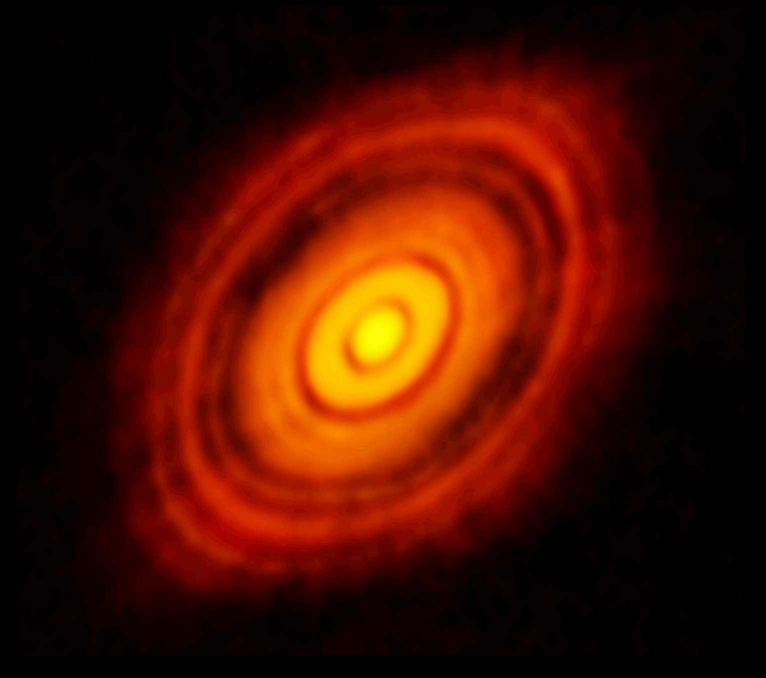
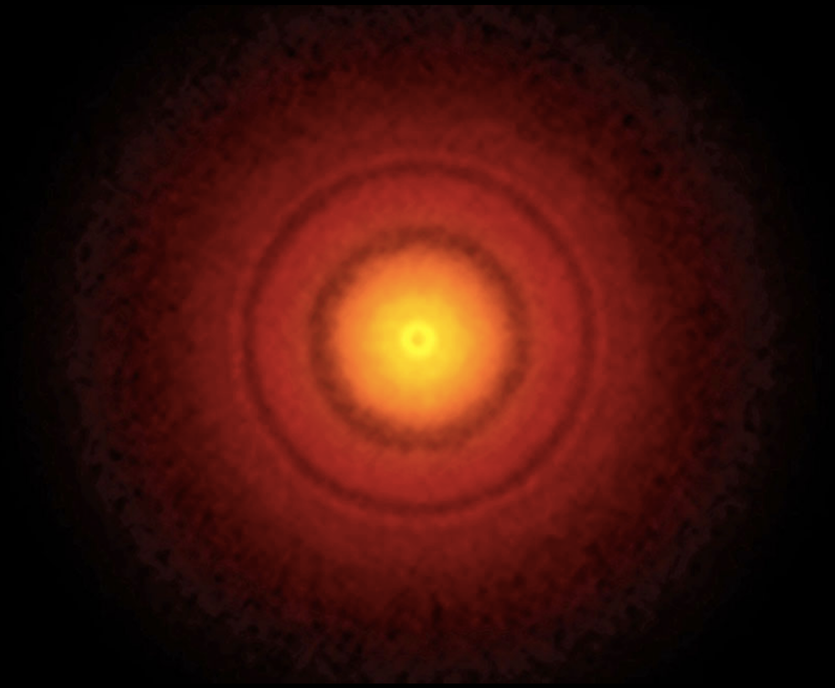
Planet formation: from discs

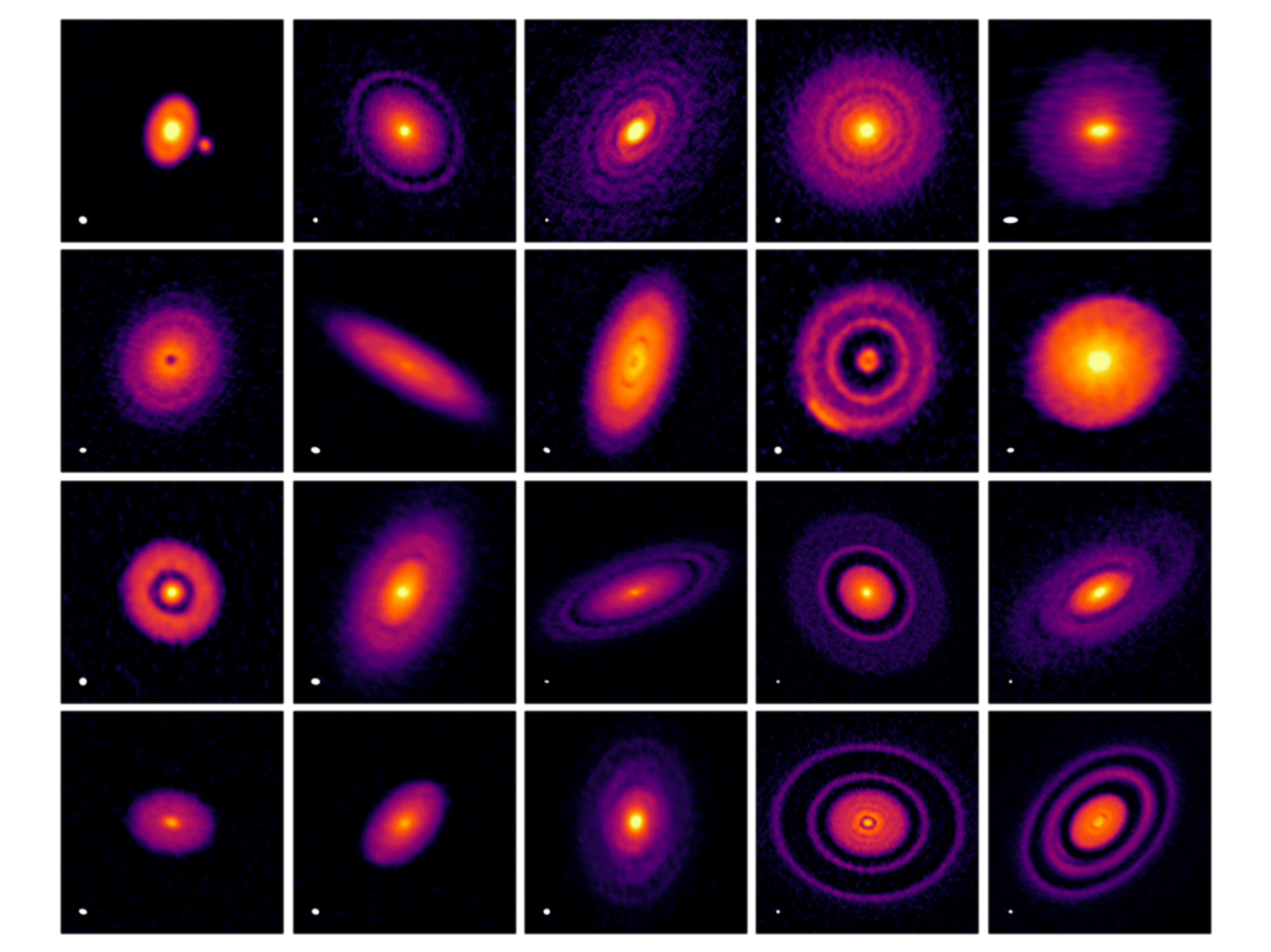
The modern view with ALMA



HL Tau
(ALMA partnership 2015)

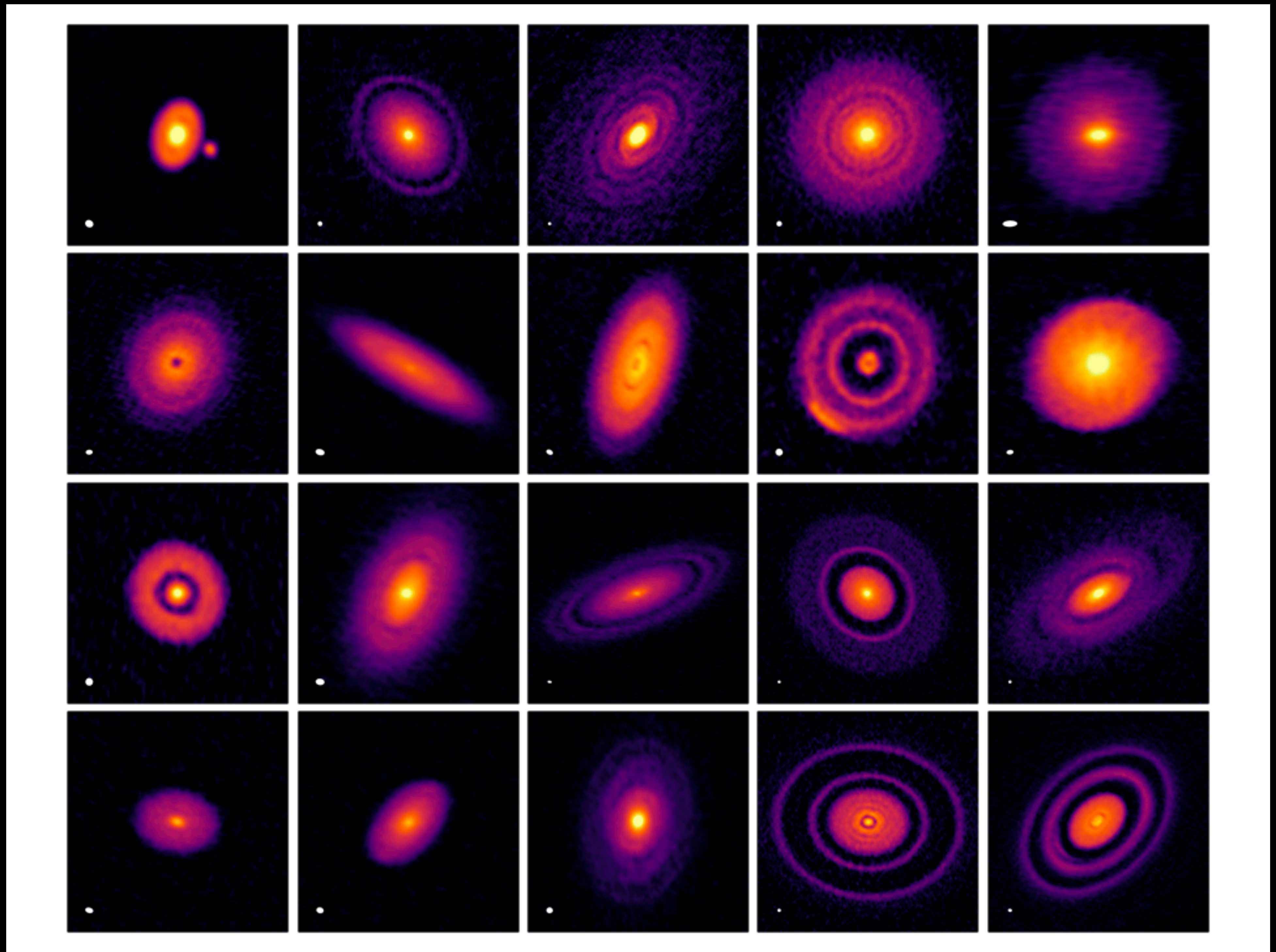


TW Hydra
Andrews et al. (2016)



DSHARP survey
Andrews et al. (2018)

Planet formation: from discs



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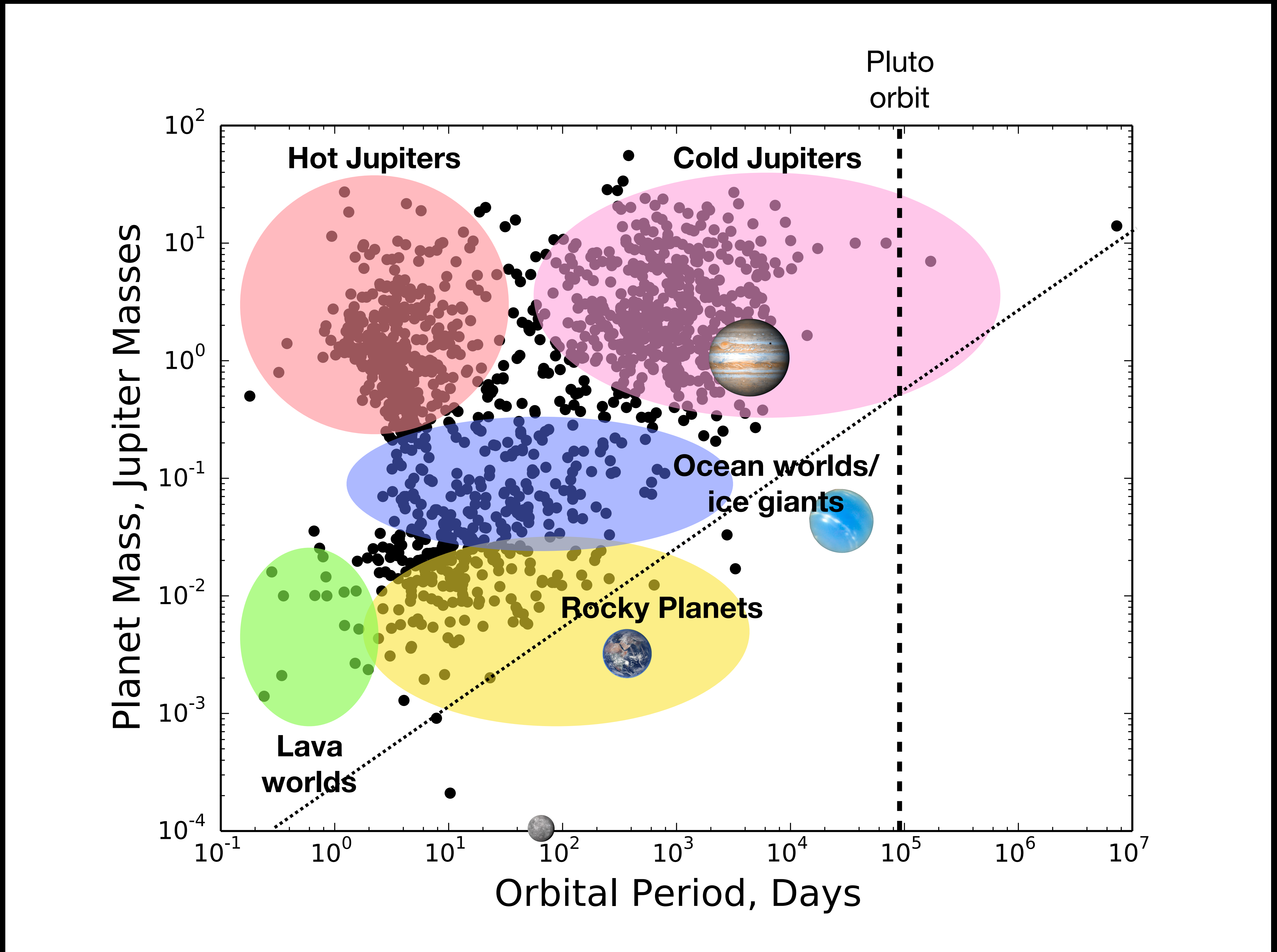


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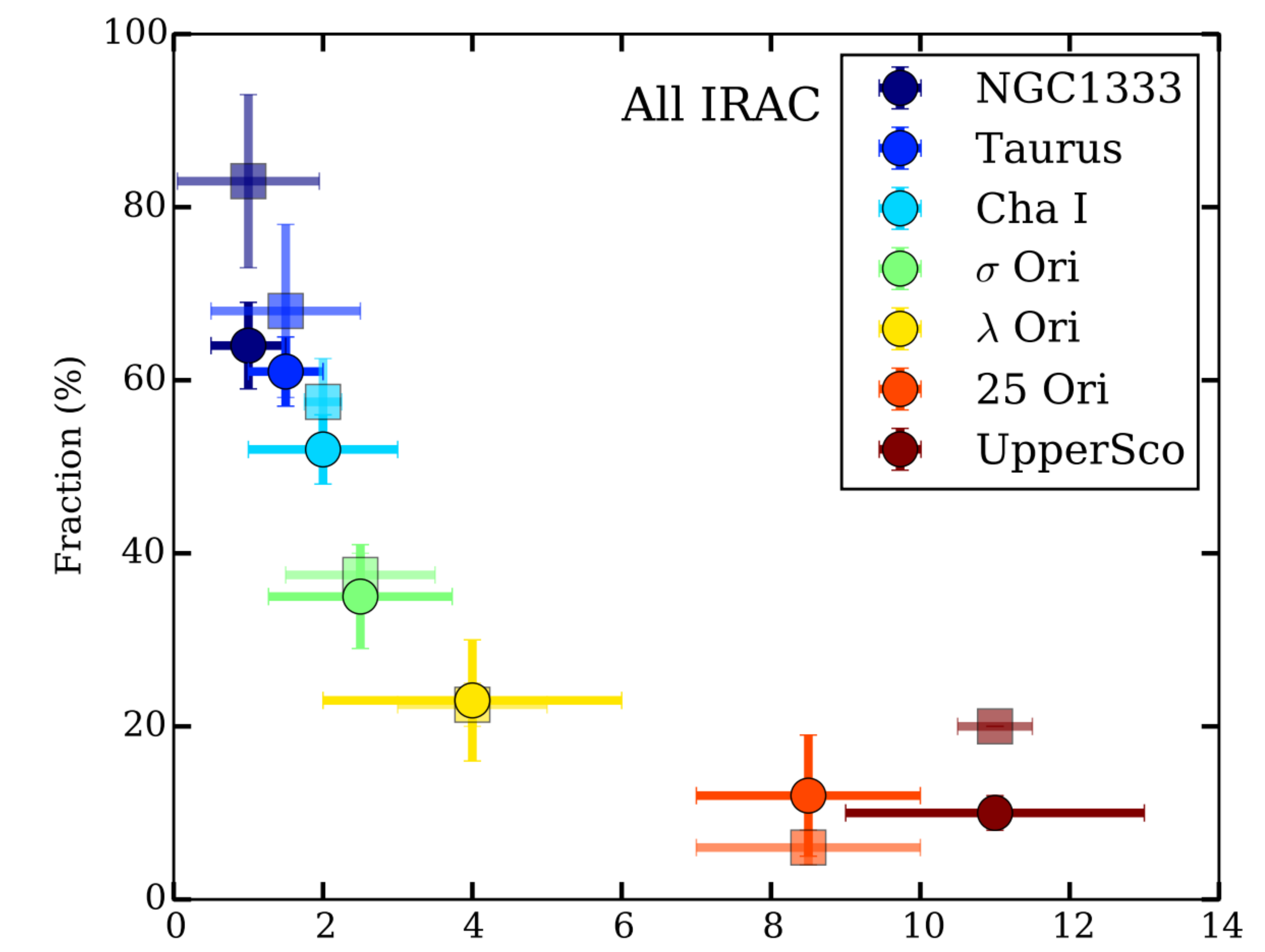
Disc lifetimes



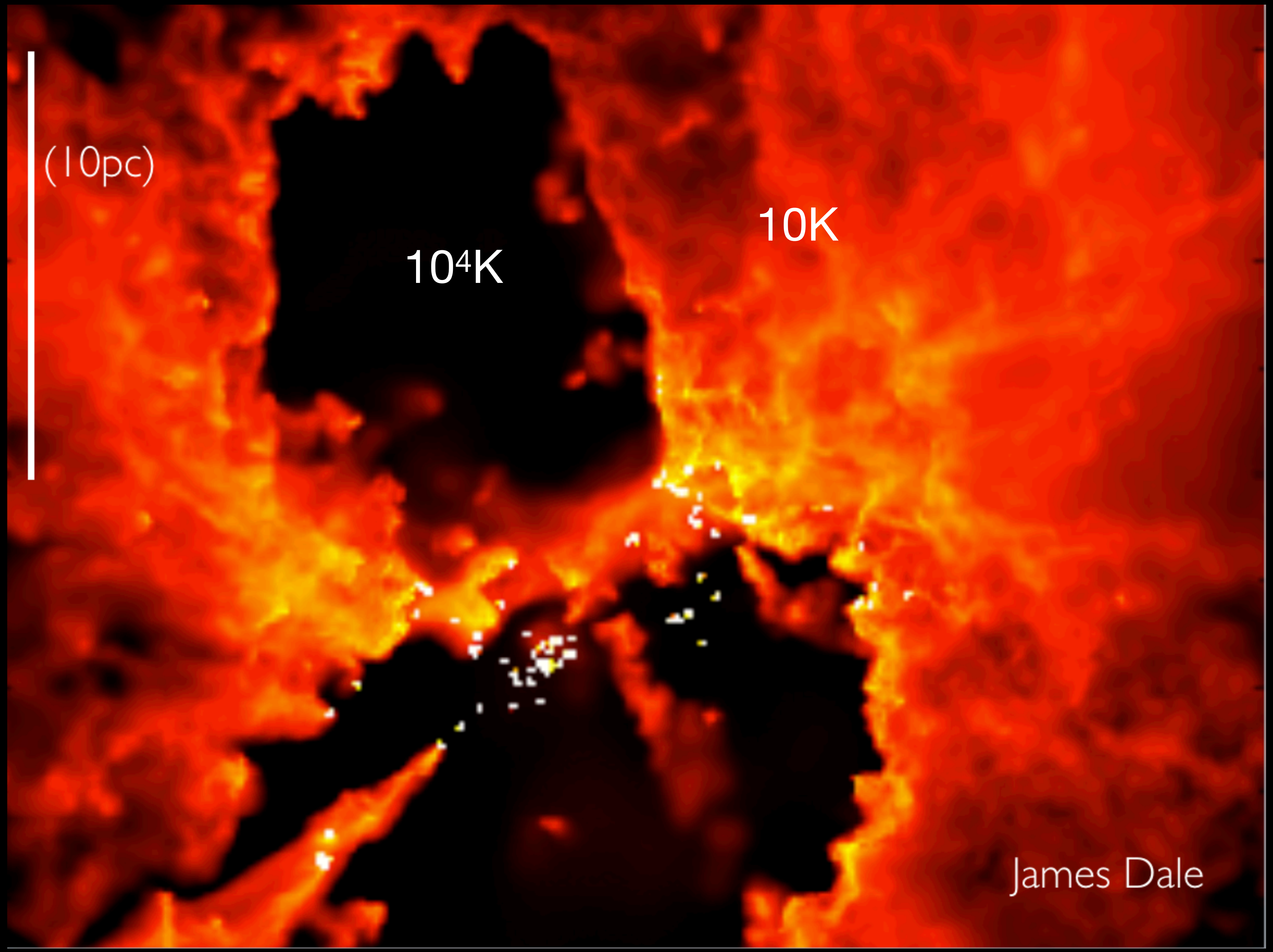
Ribas et al. (2014)

Most discs only last <3Myr

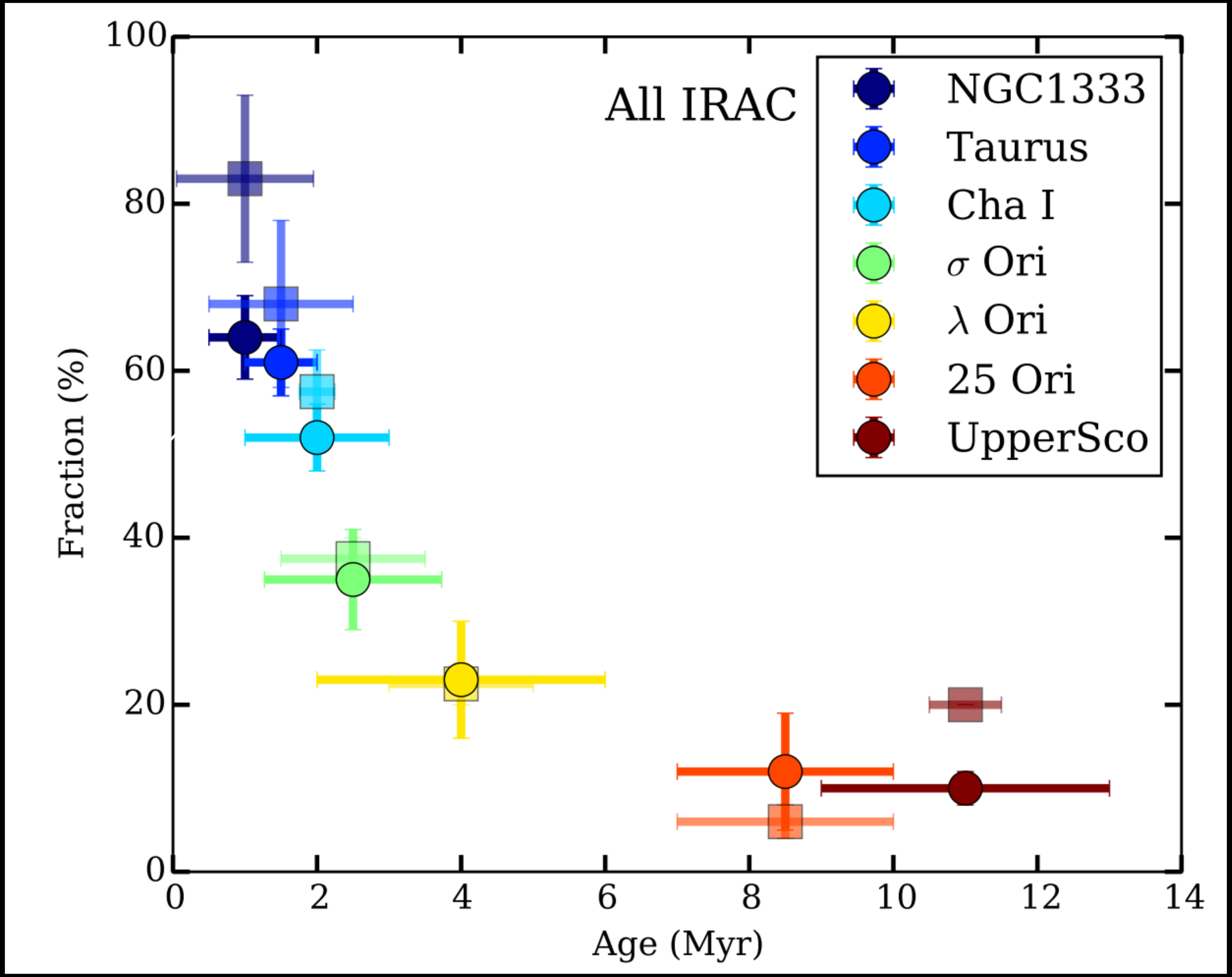
Planet formation has to happen early in the stars life

Planet formation in context

Planet formation in context



Planet formation in context



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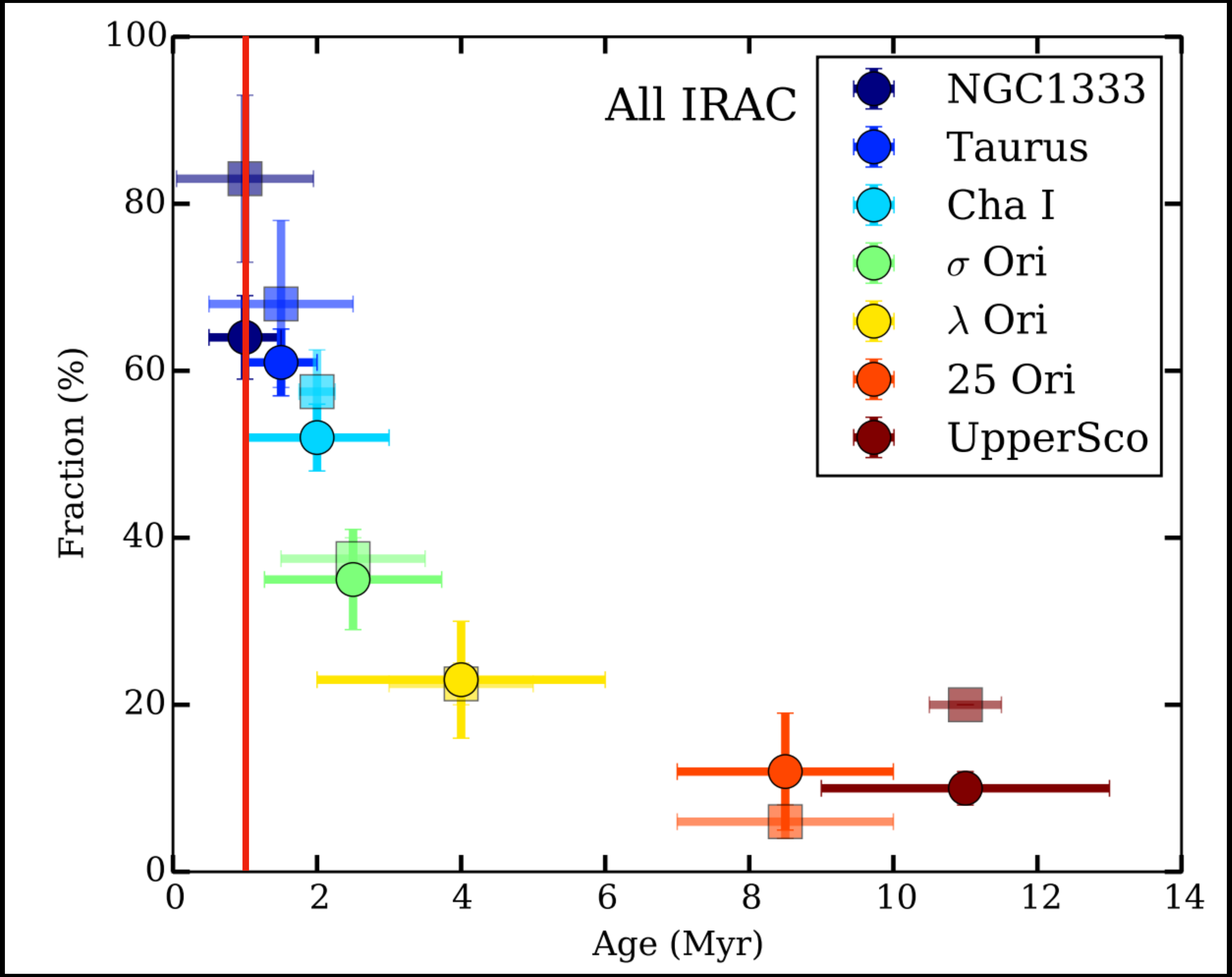

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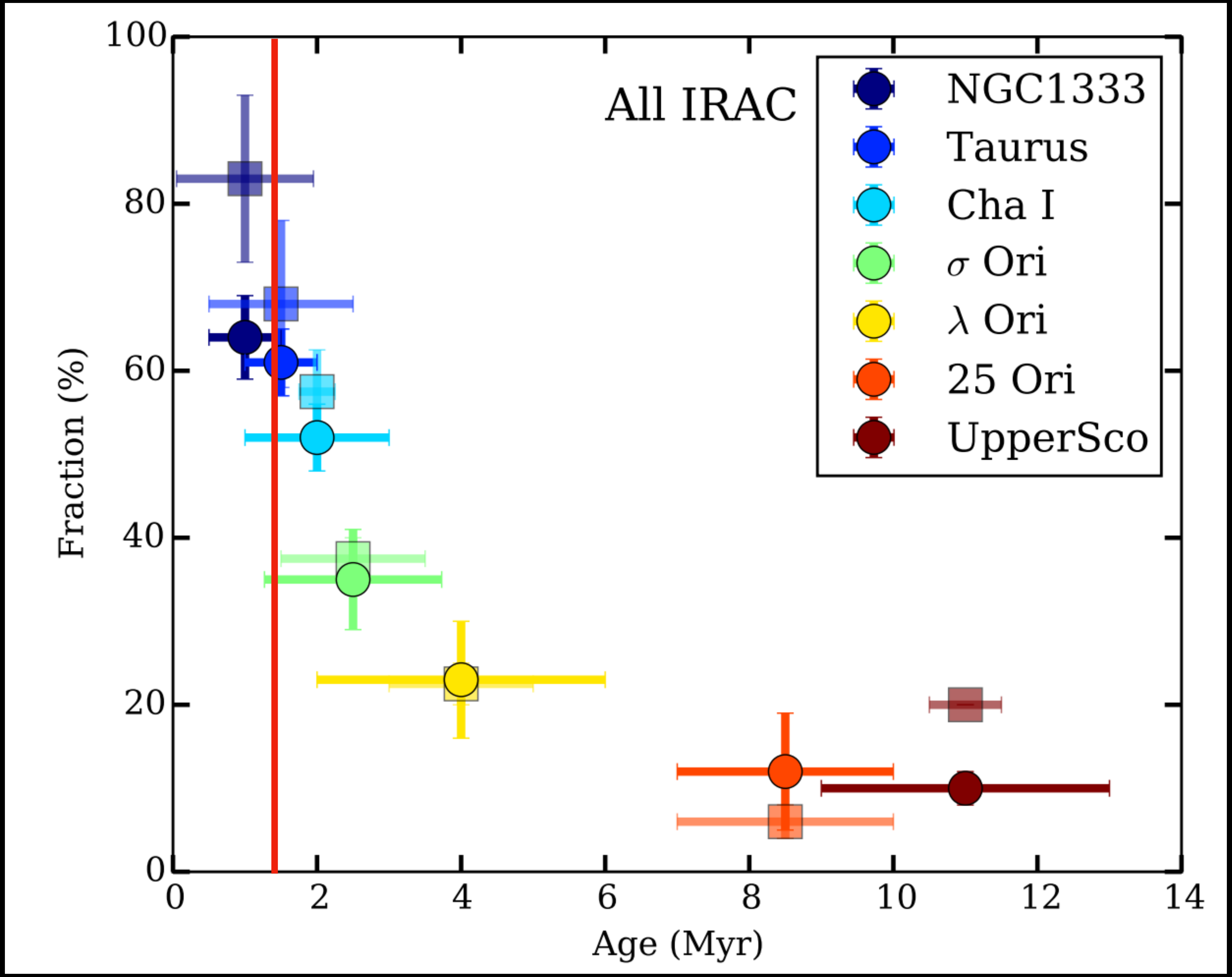
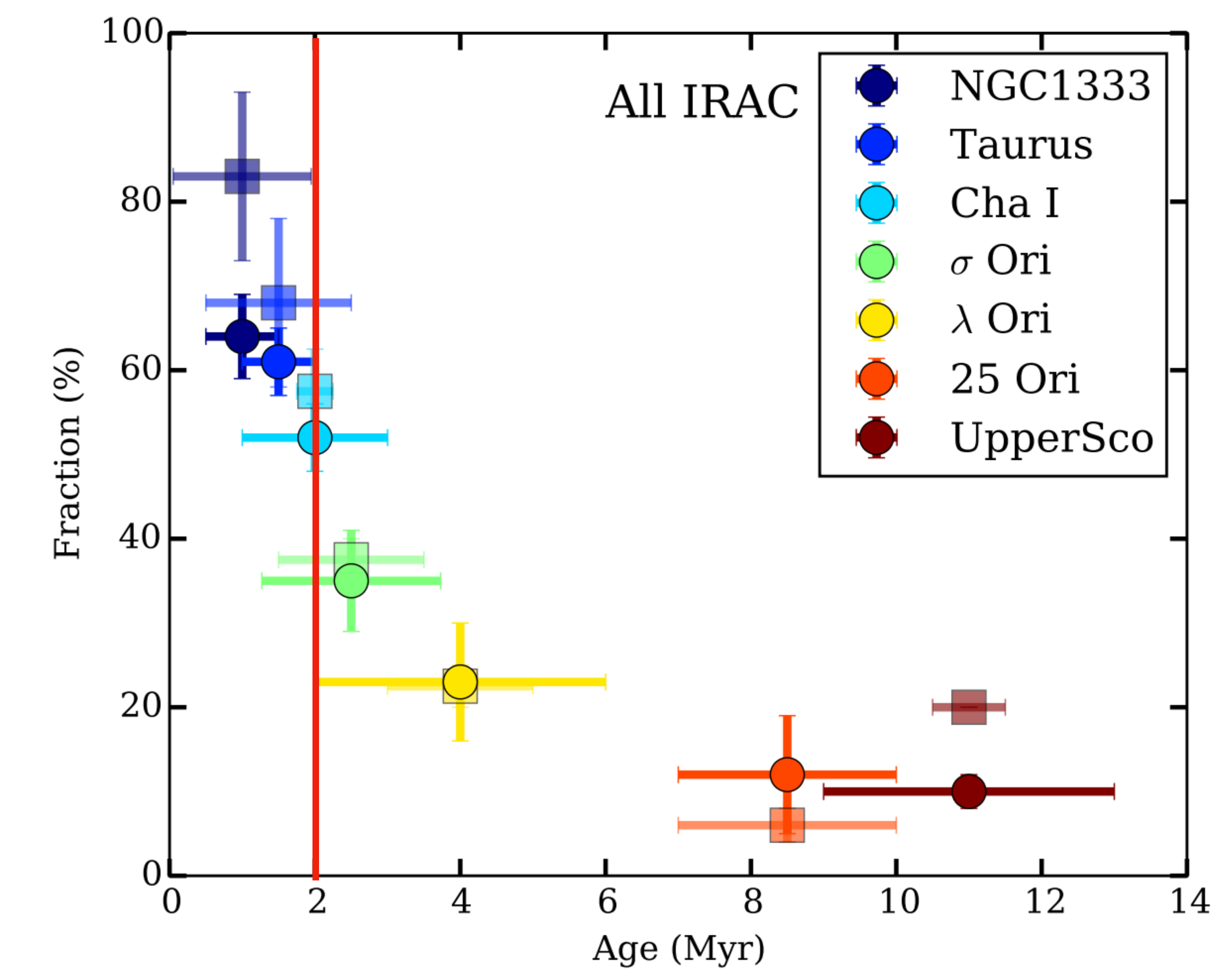


Planet formation in context



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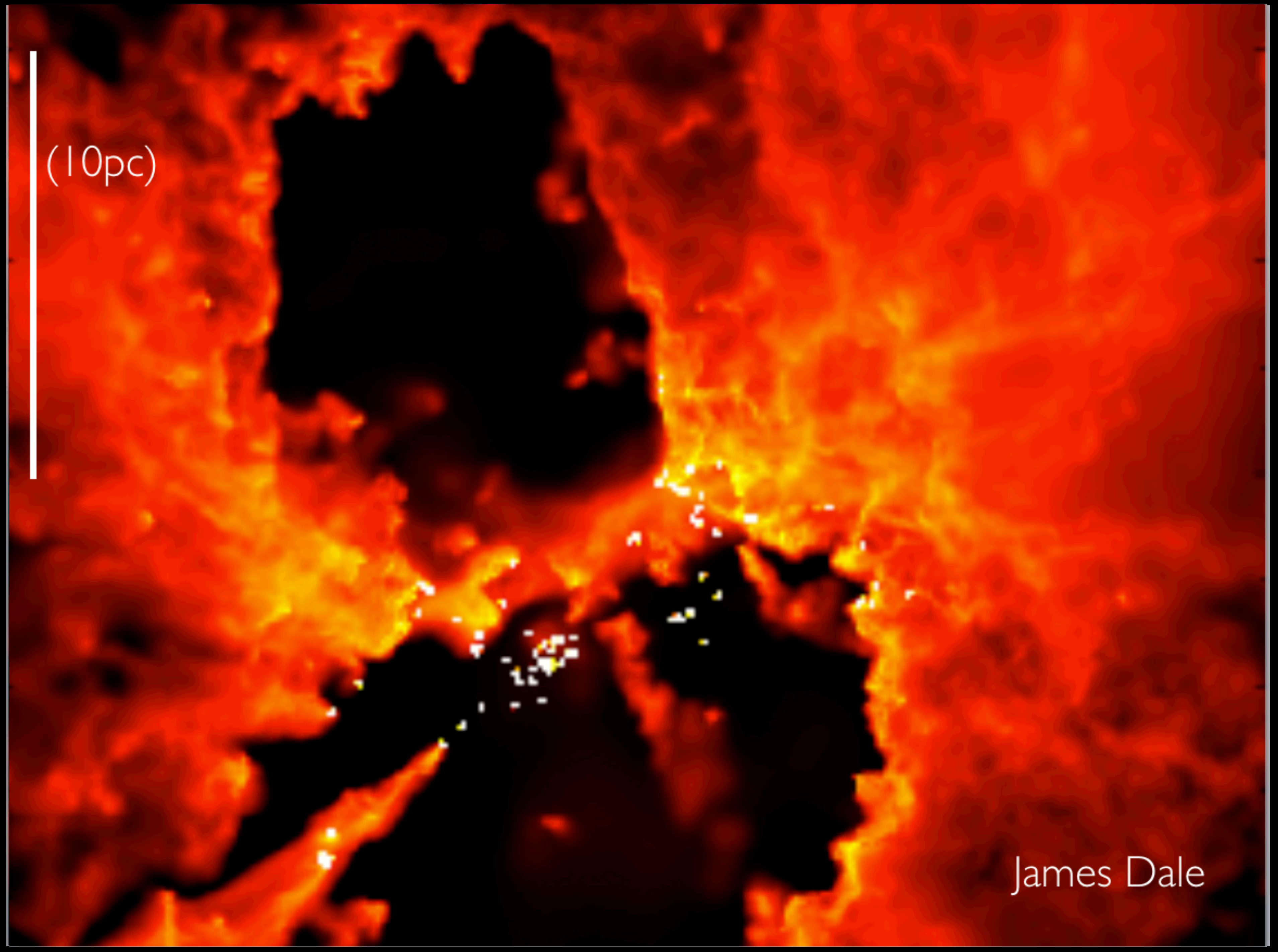
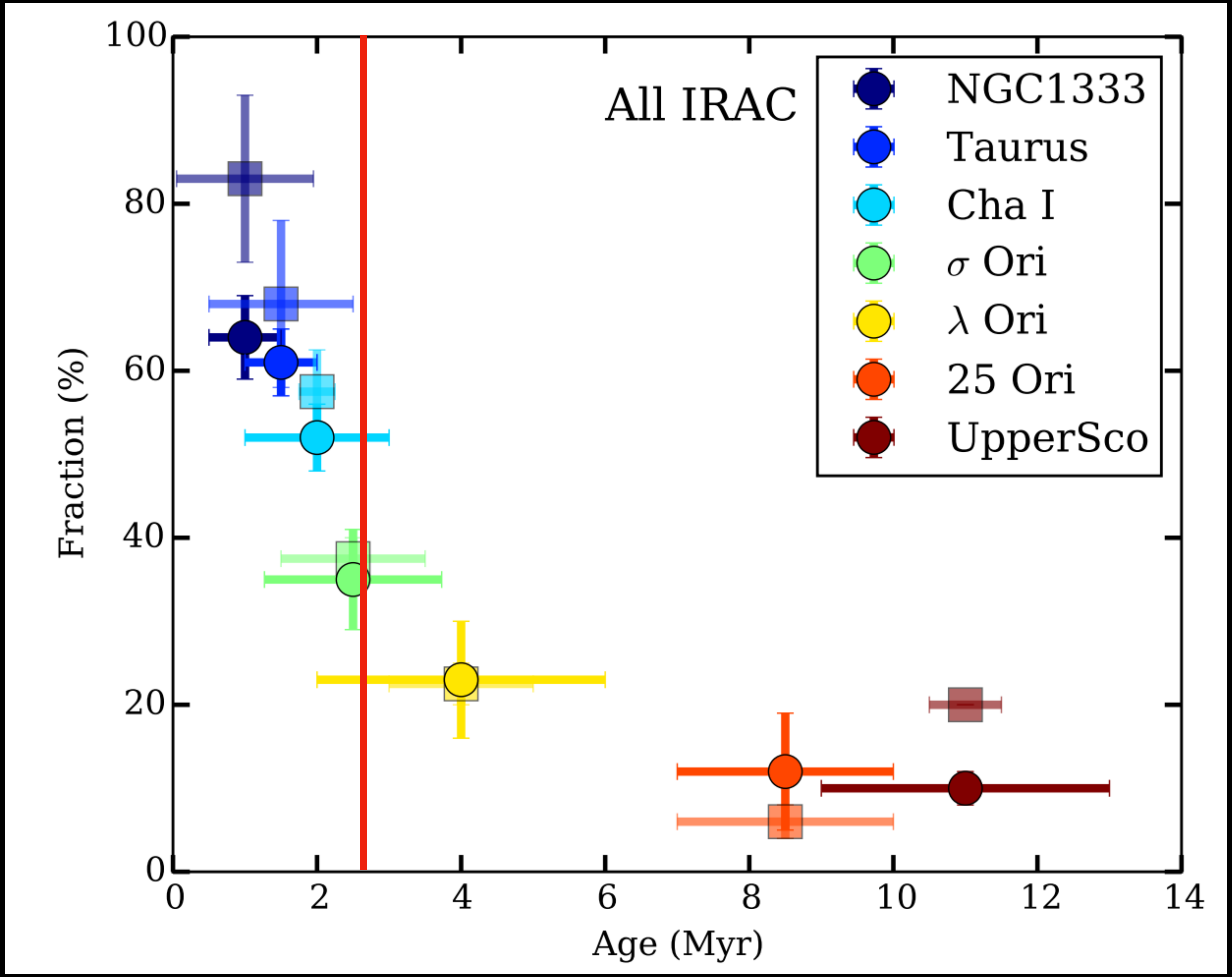
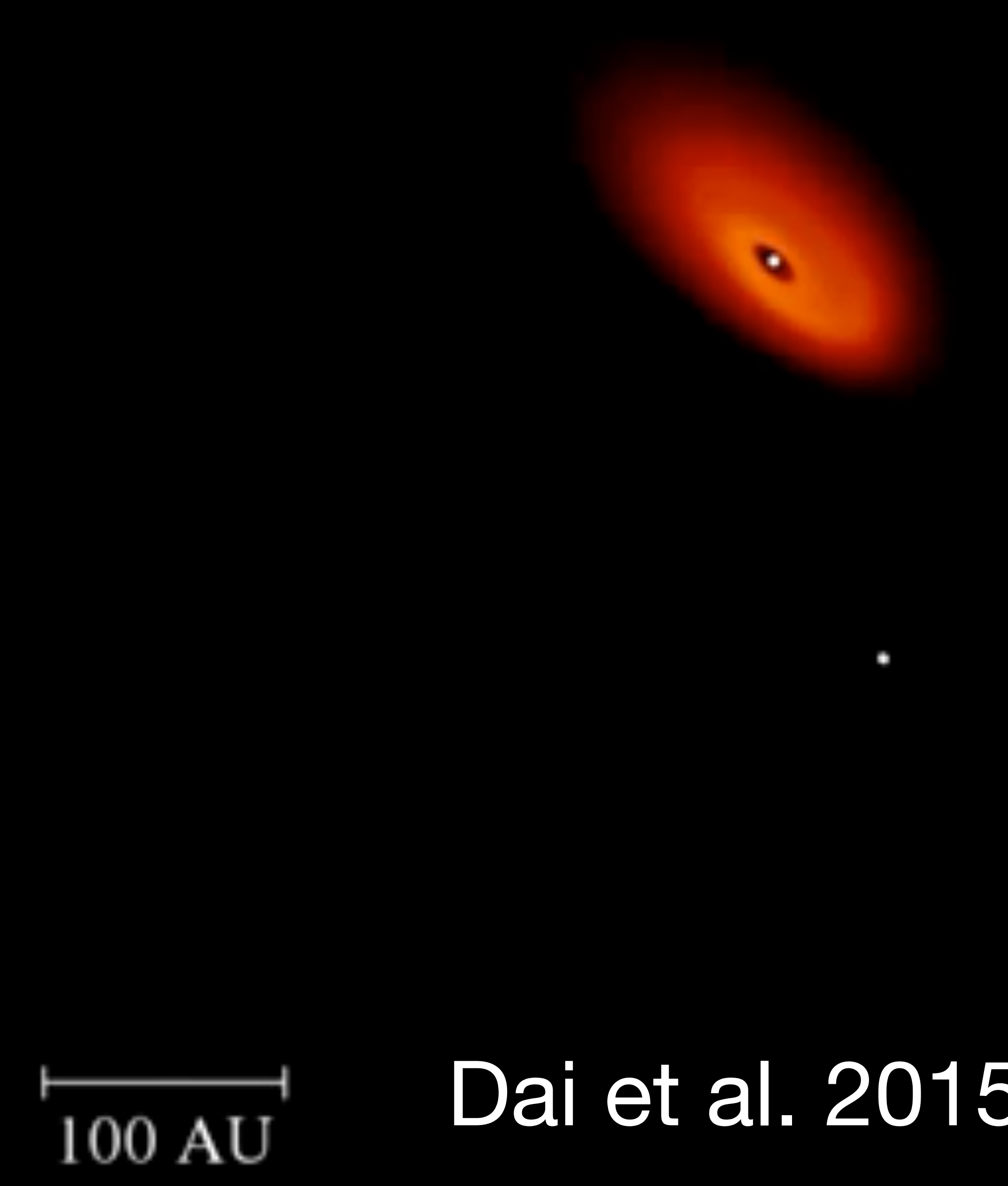




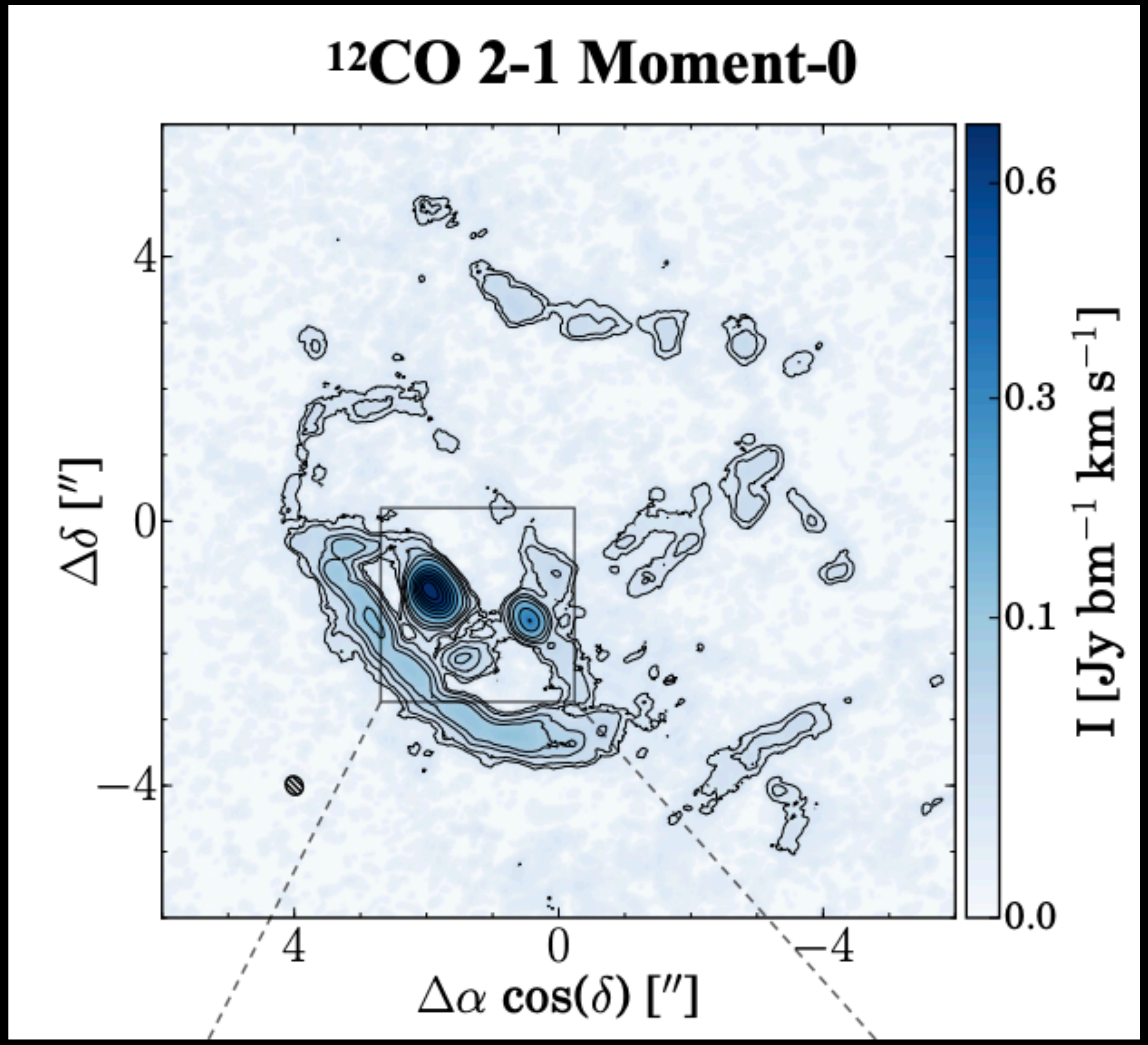
How stellar clusters can affect discs

1. Gravitational interaction — close encounters

RW Auriga



Dai et al. 2015



Rodriguez et al. (2018)

How stellar clusters can affect discs

1. Gravitational interaction — distant encounters

Rosotti et al. (2014)

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How stellar clusters can affect discs

2. External photoevaporation

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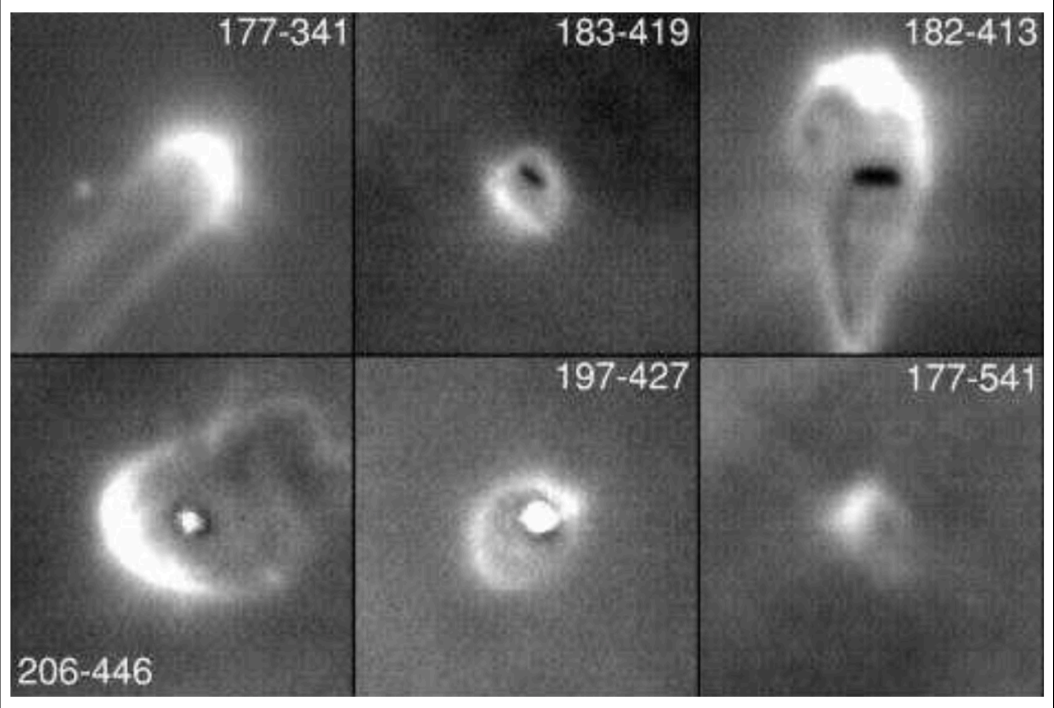
How stellar clusters can affect discs

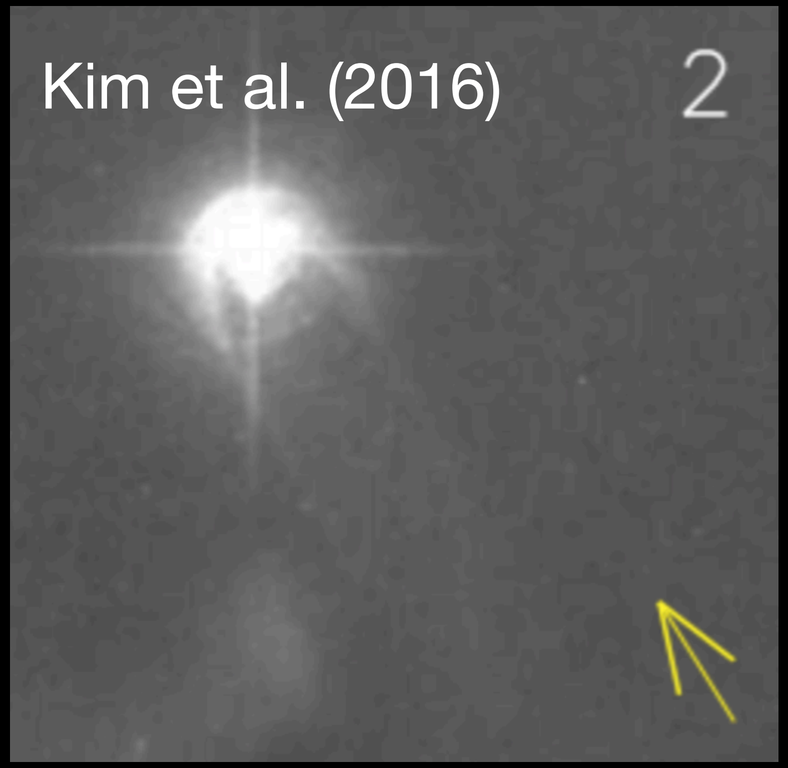
2. External photoevaporation

UV field strength in multiples of Solar neighbourhood value (G_0)

10^5 10^4 10^3 10^2 10 1



e.g. O'Dell, Wen, McCaughrean



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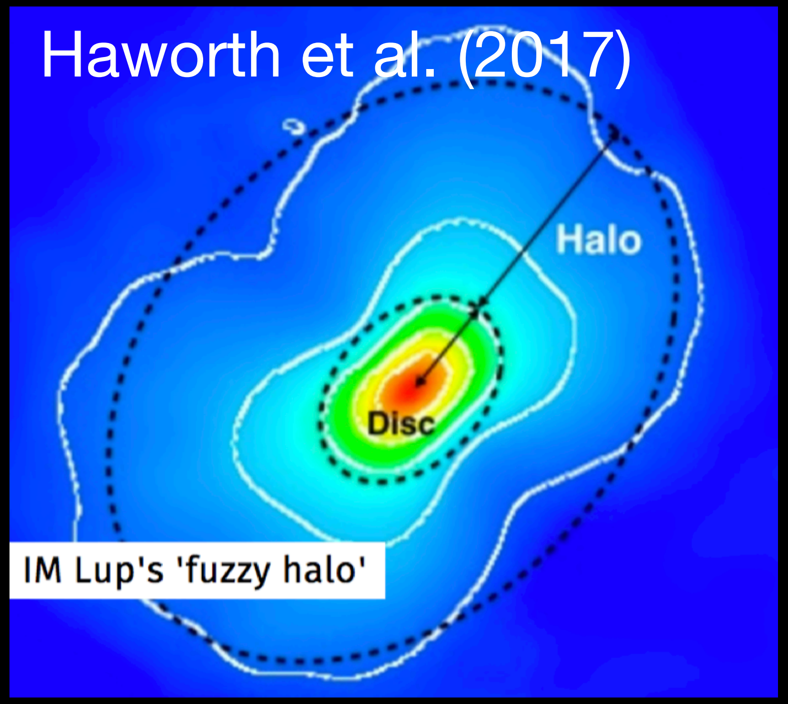
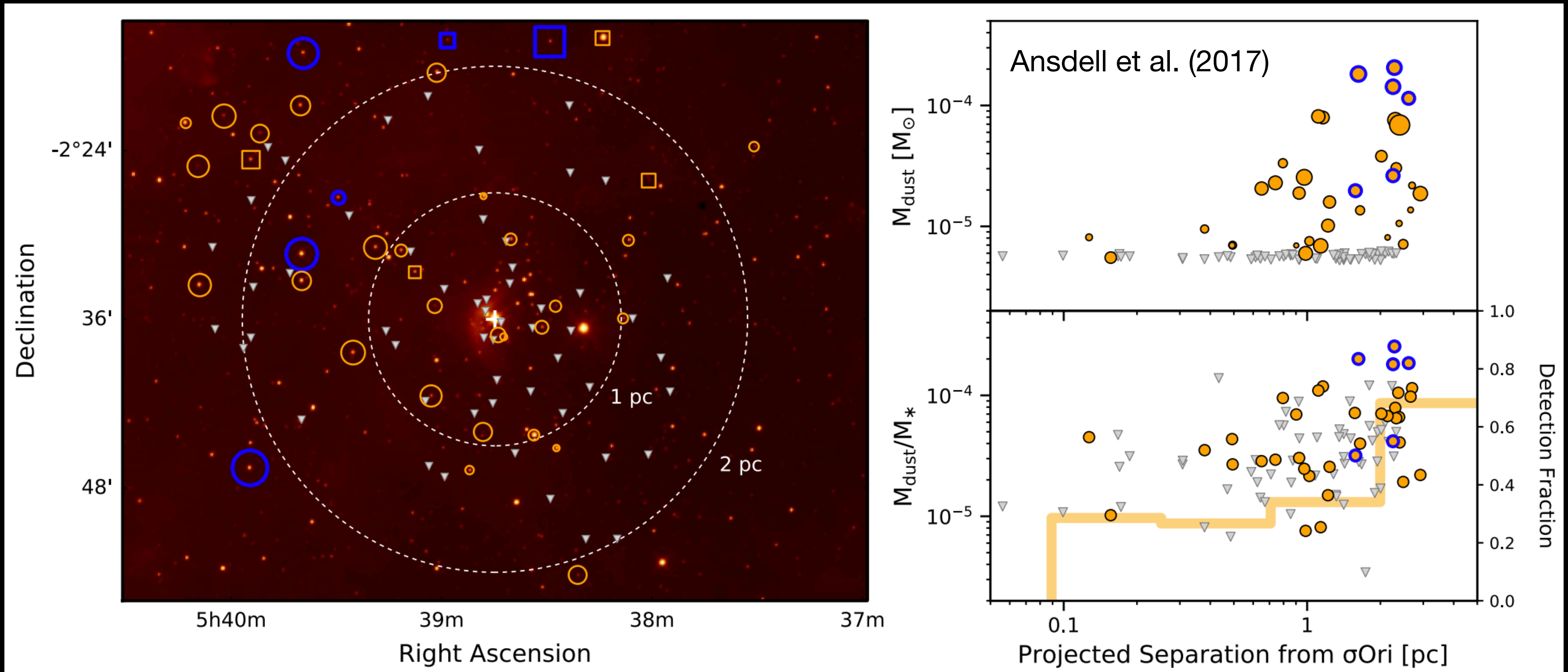


How stellar clusters can affect discs

2. External photoevaporation



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How stellar clusters can affect discs

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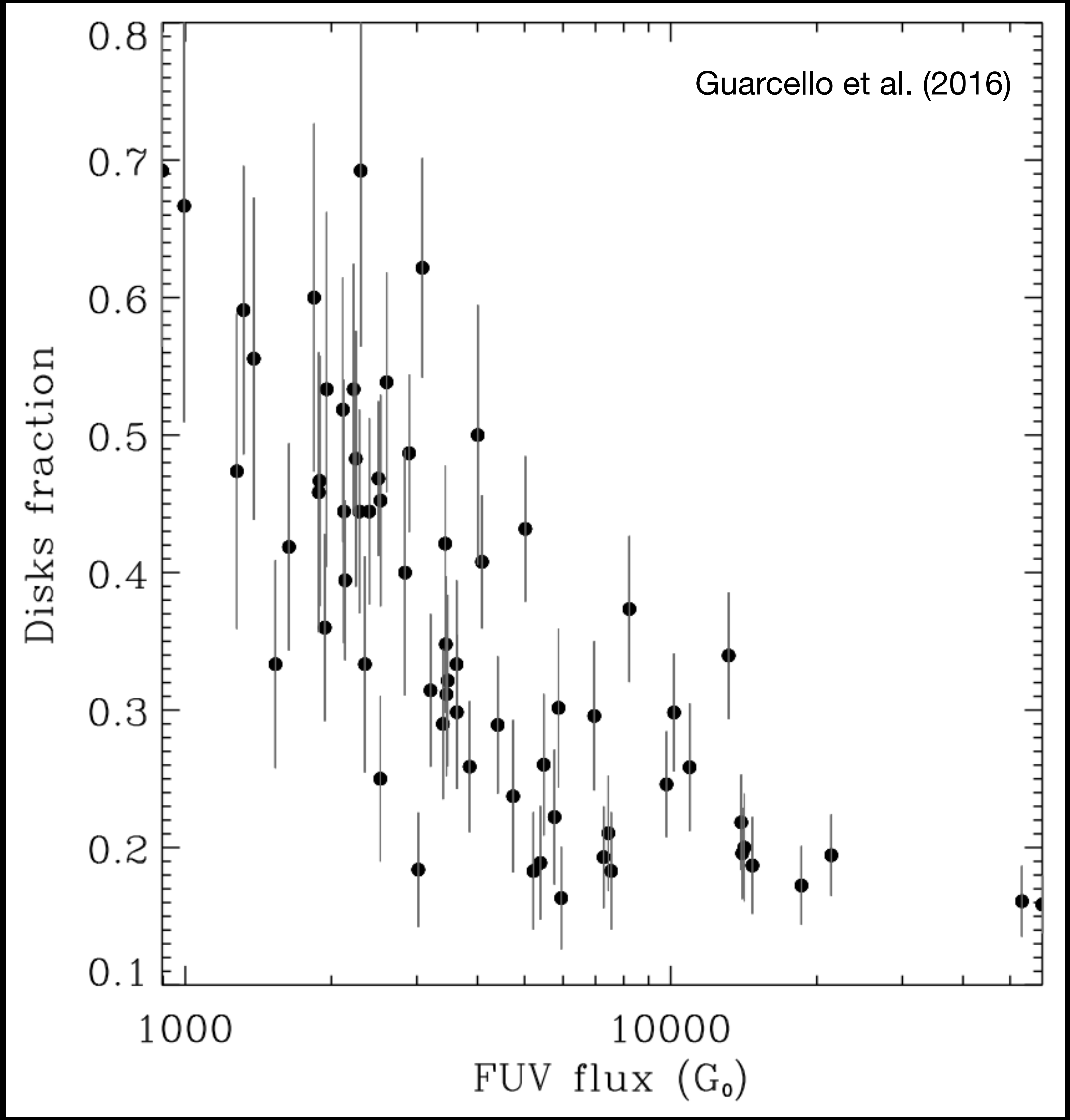

How stellar clusters can affect discs

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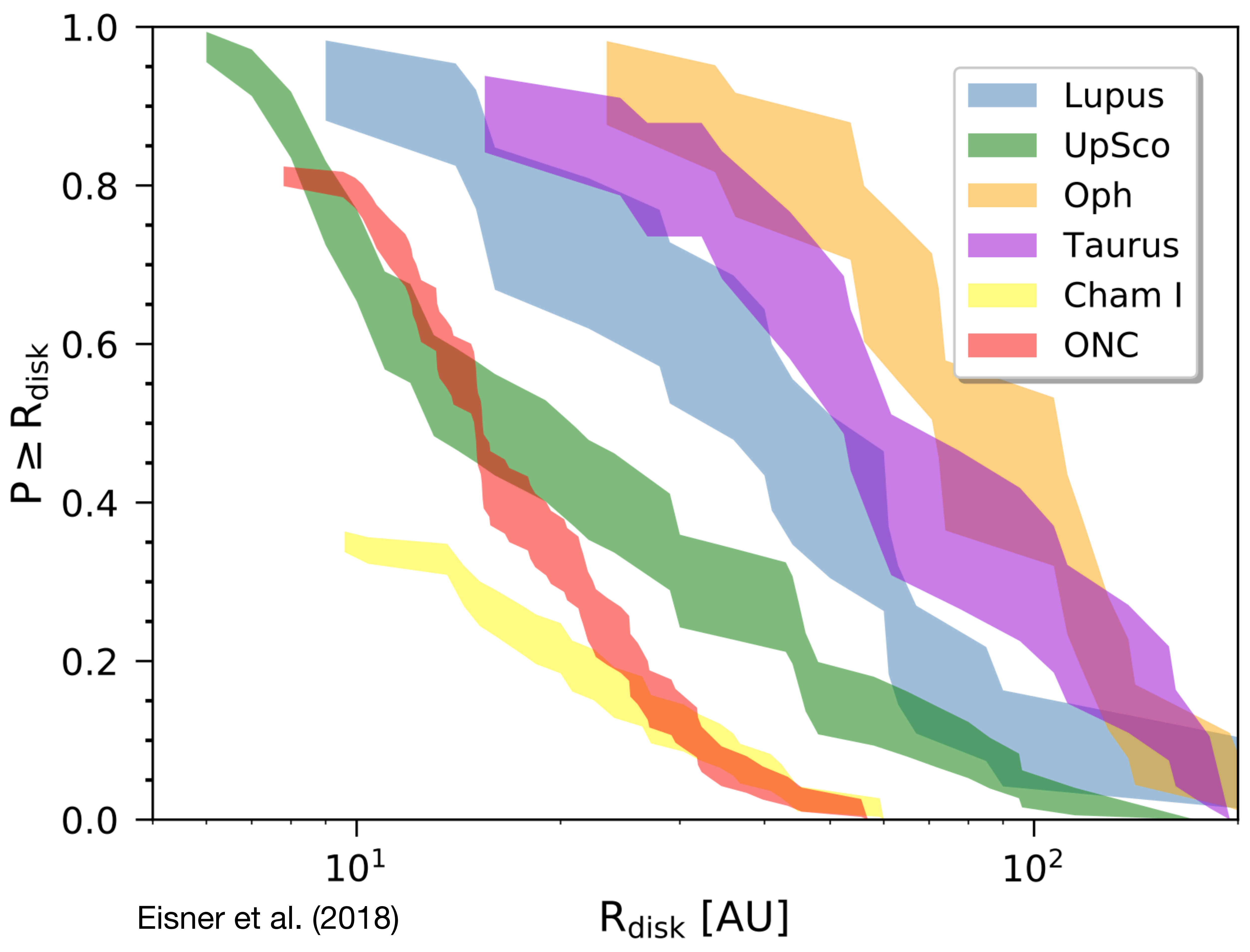
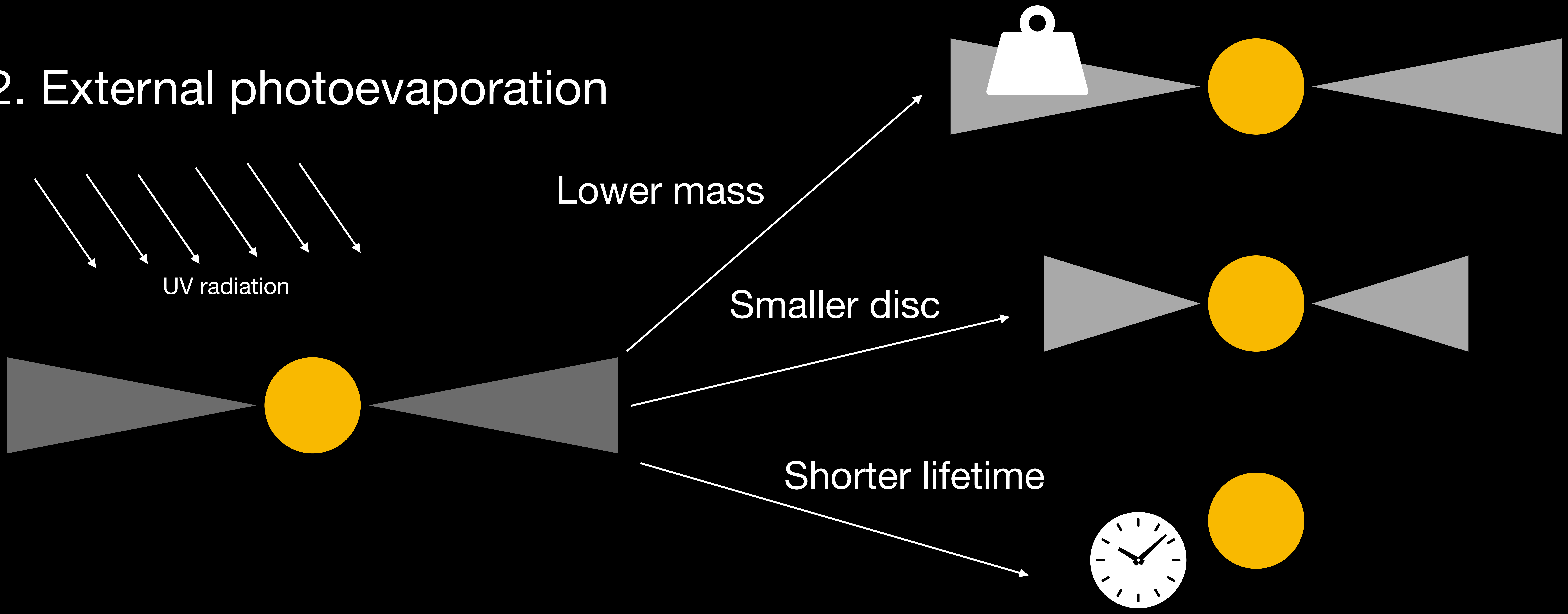


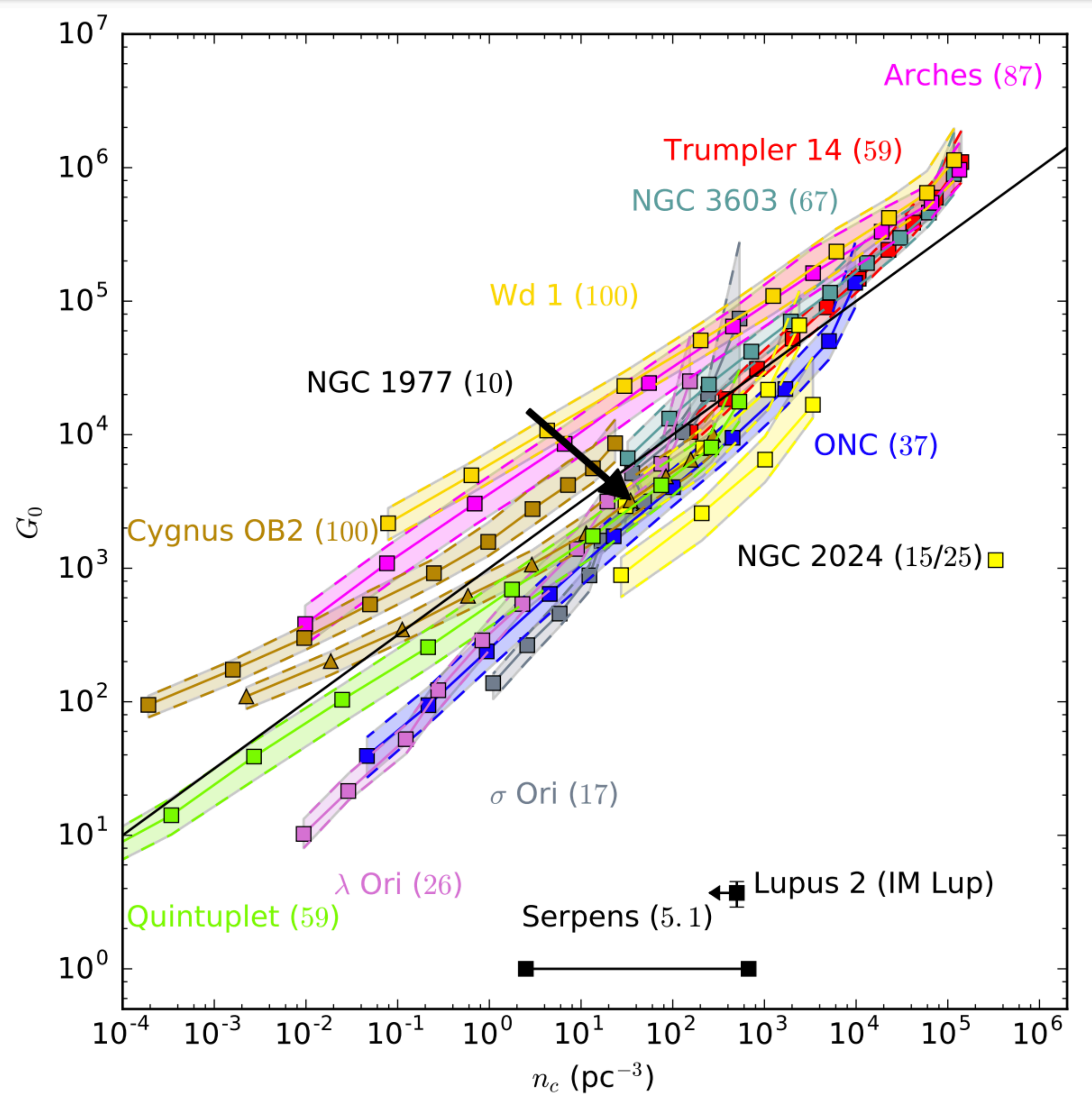
Eisner et al. (2018)

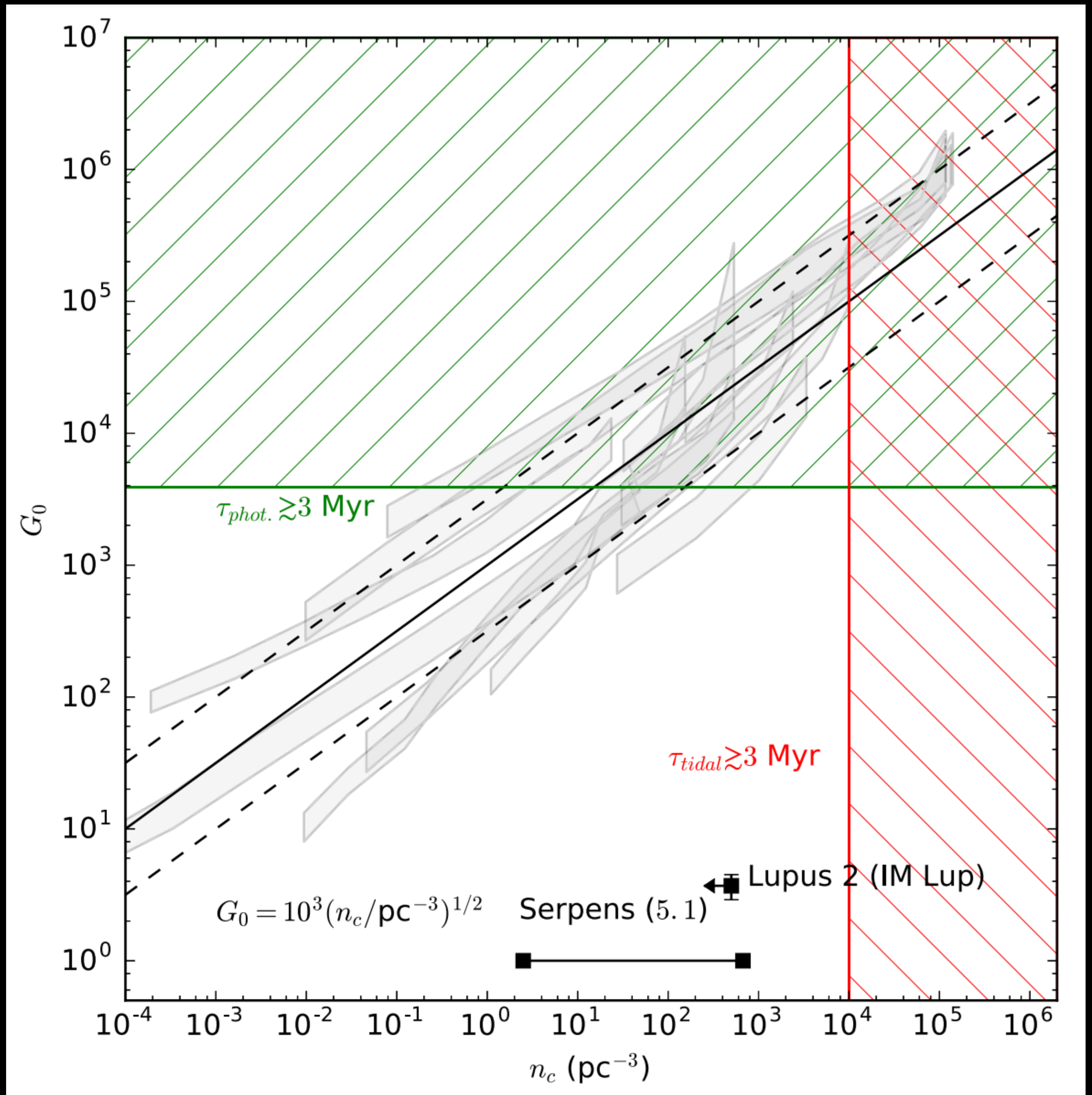
How stellar clusters can affect discs

2. External photoevaporation



Encounters vs external photoevaporation

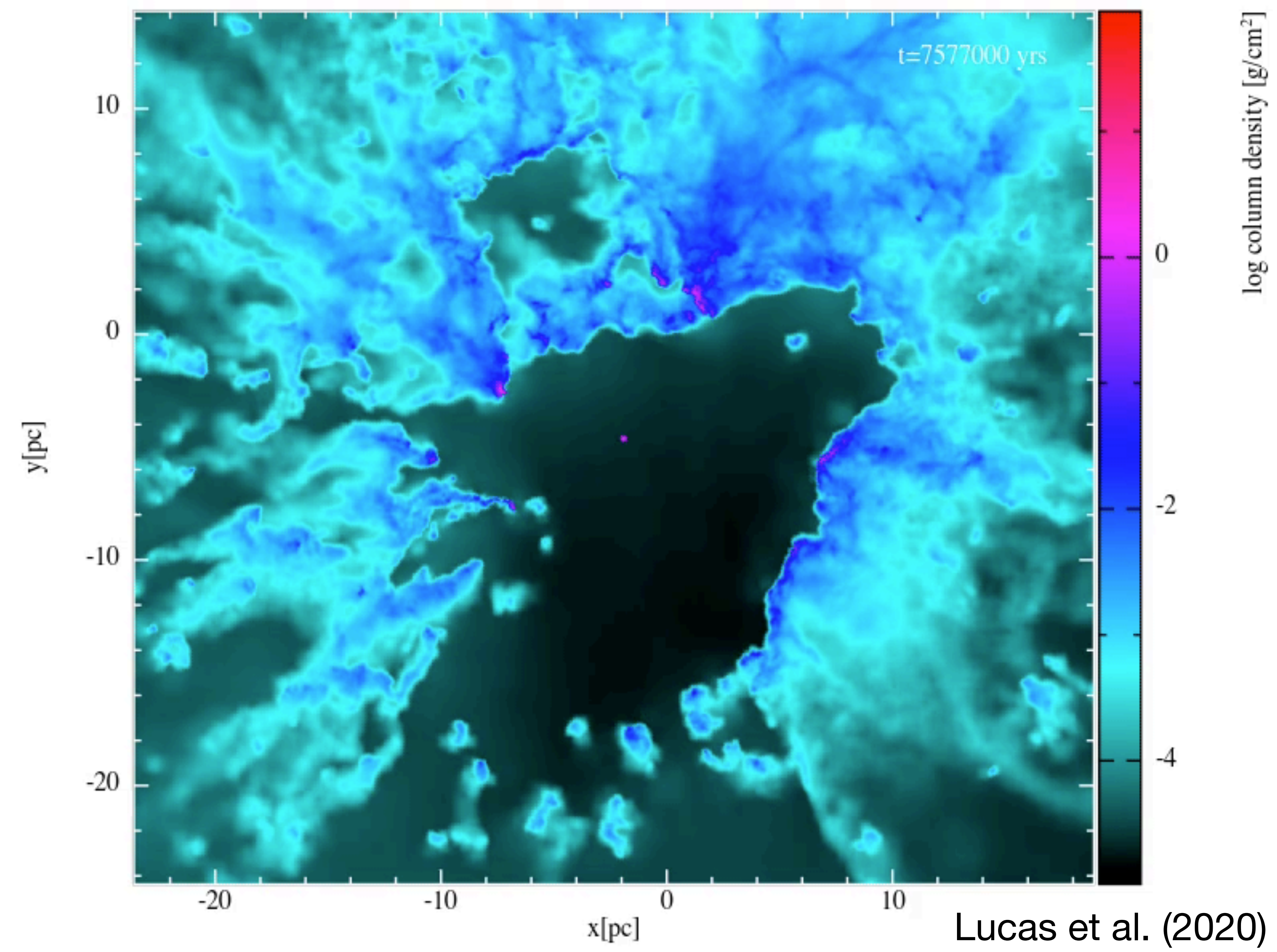




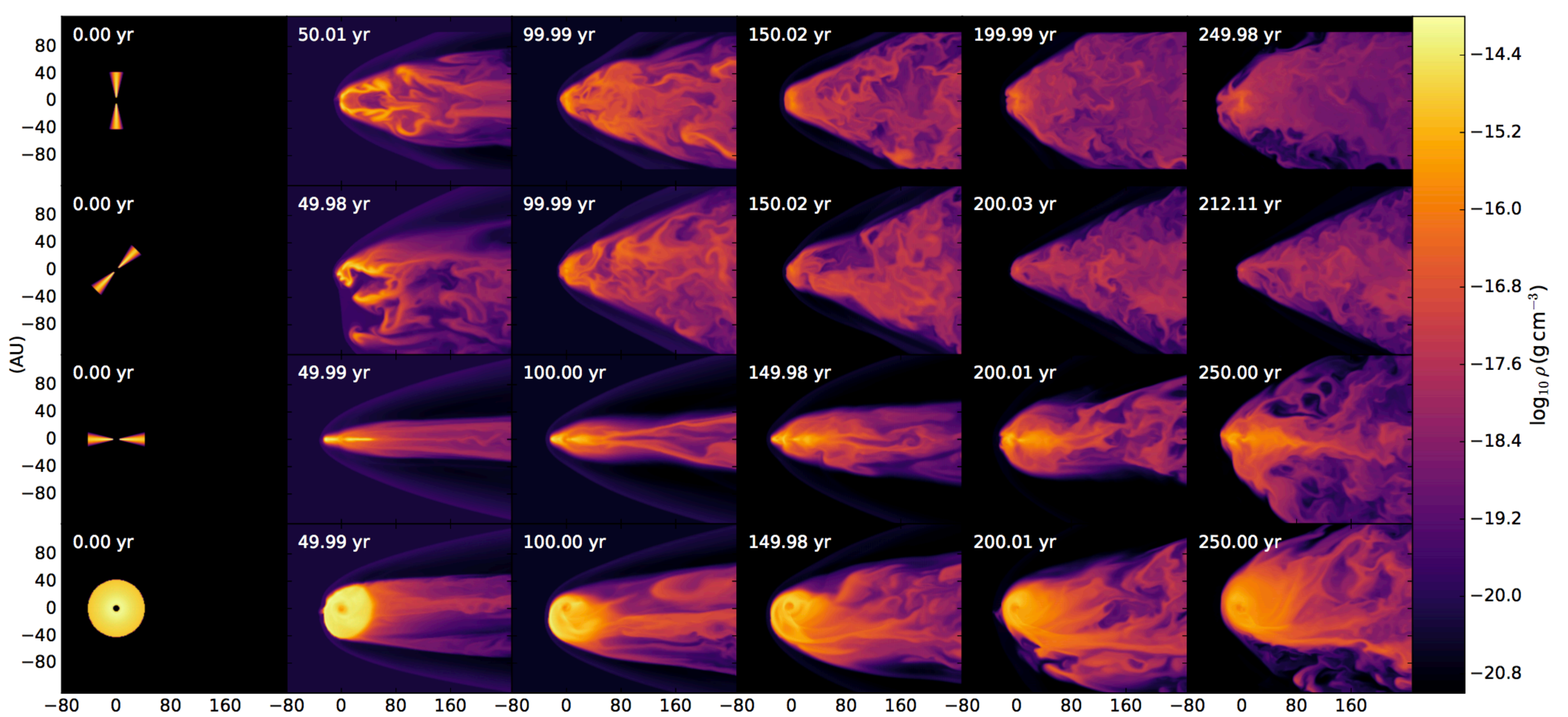
Winter et al. (2018)

How stellar clusters can affect discs

3. Supernovae?



Lucas et al. (2020)

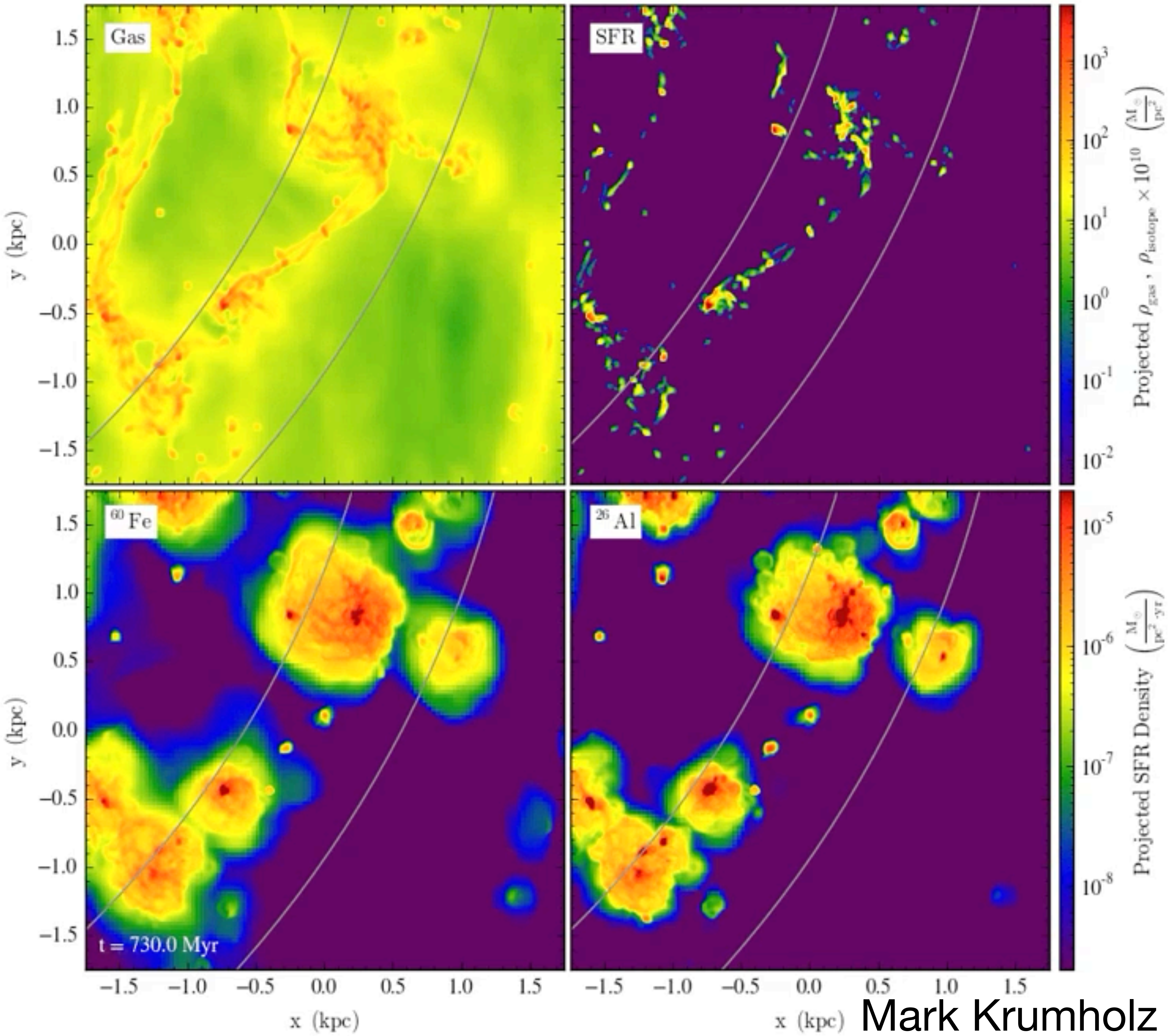


Close & Pittard (2017)

Effect/importance not very well understood

How stellar clusters can affect discs

3. Supernovae? Chemical enrichment



Mark Krumholz

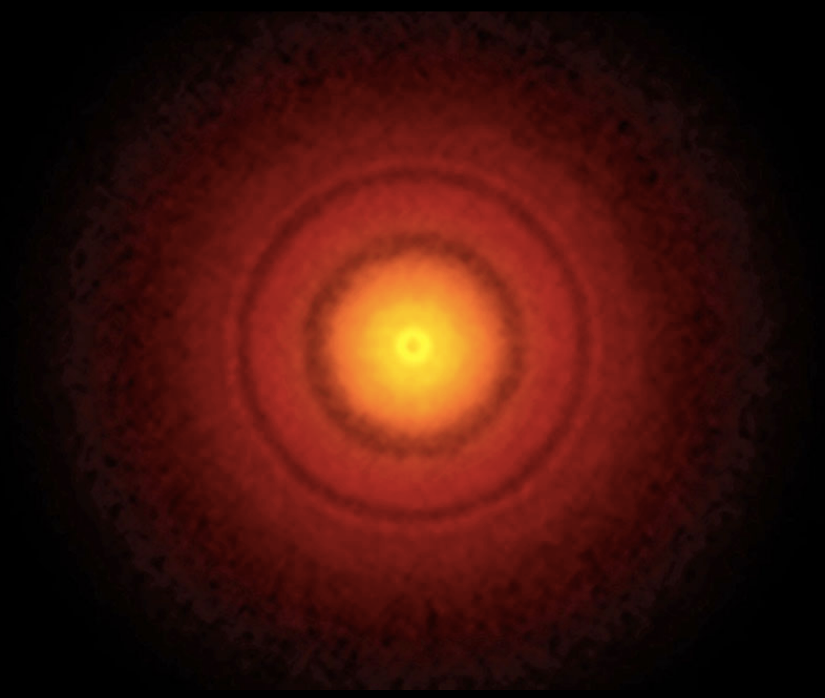
Queen Mary
University of London

Planet formation: from discs

These are all quite close to the Sun

Their clusters are small and the UV radiation is weak

We are focusing on unusual discs



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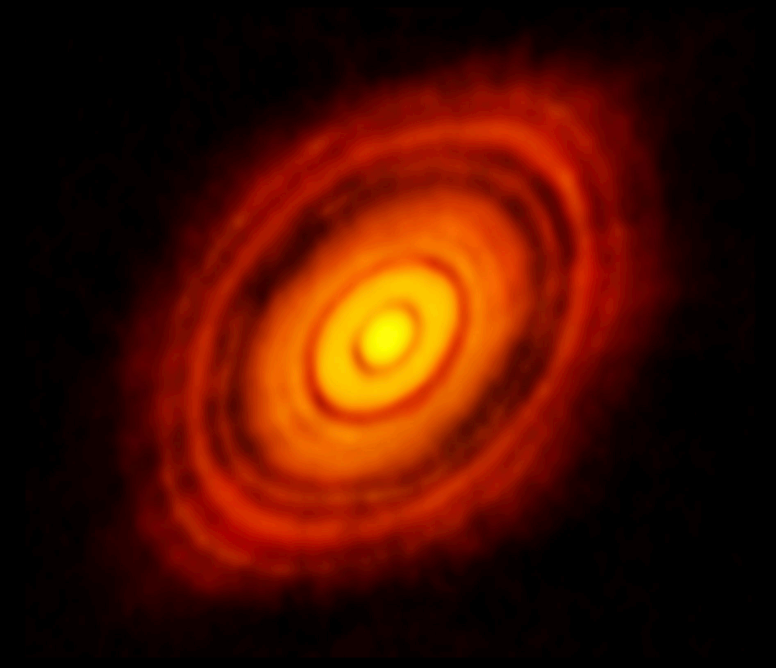
Andrews et al. (2016)



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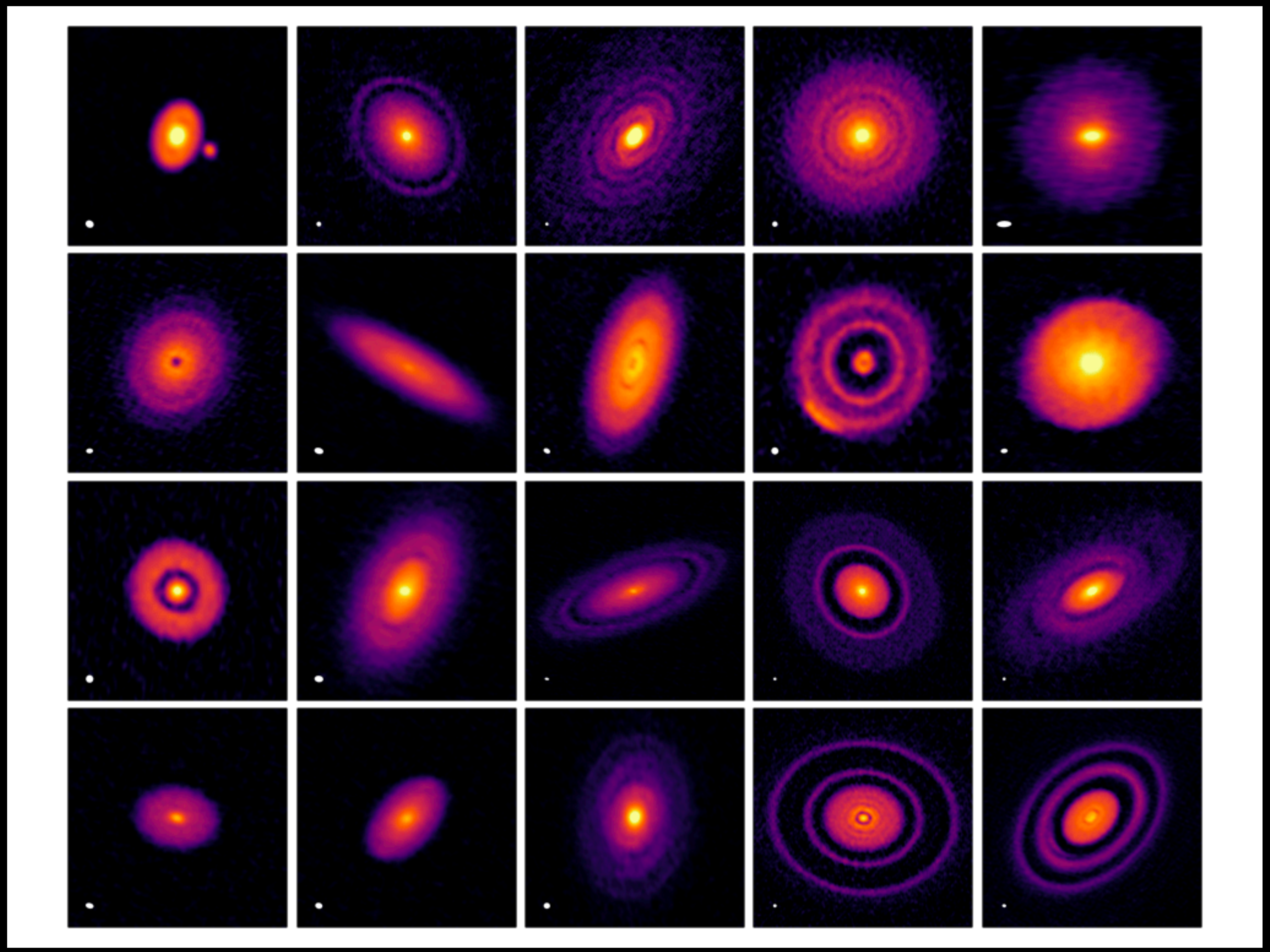

DSHARP survey
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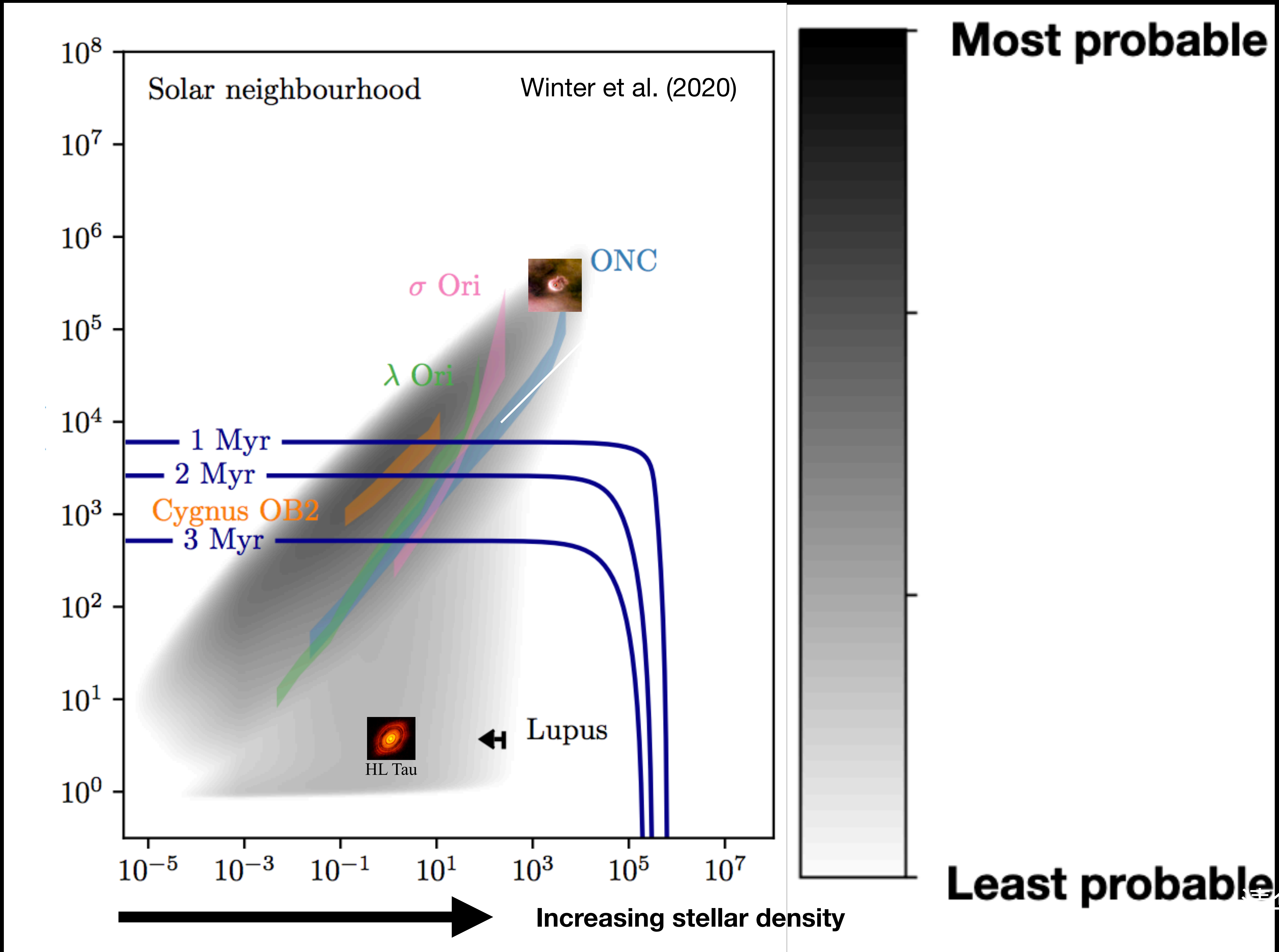
Increasing UV field strength



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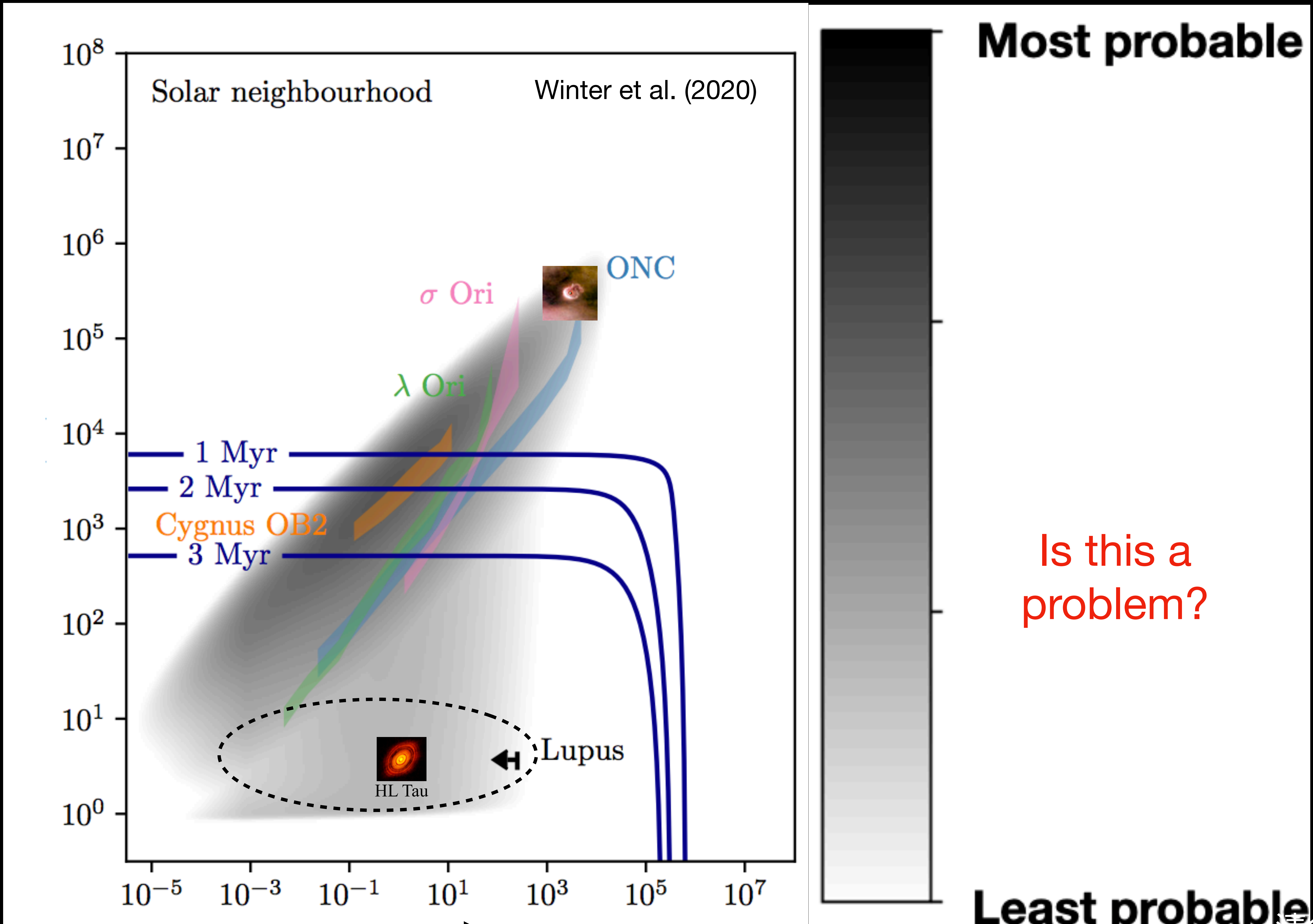
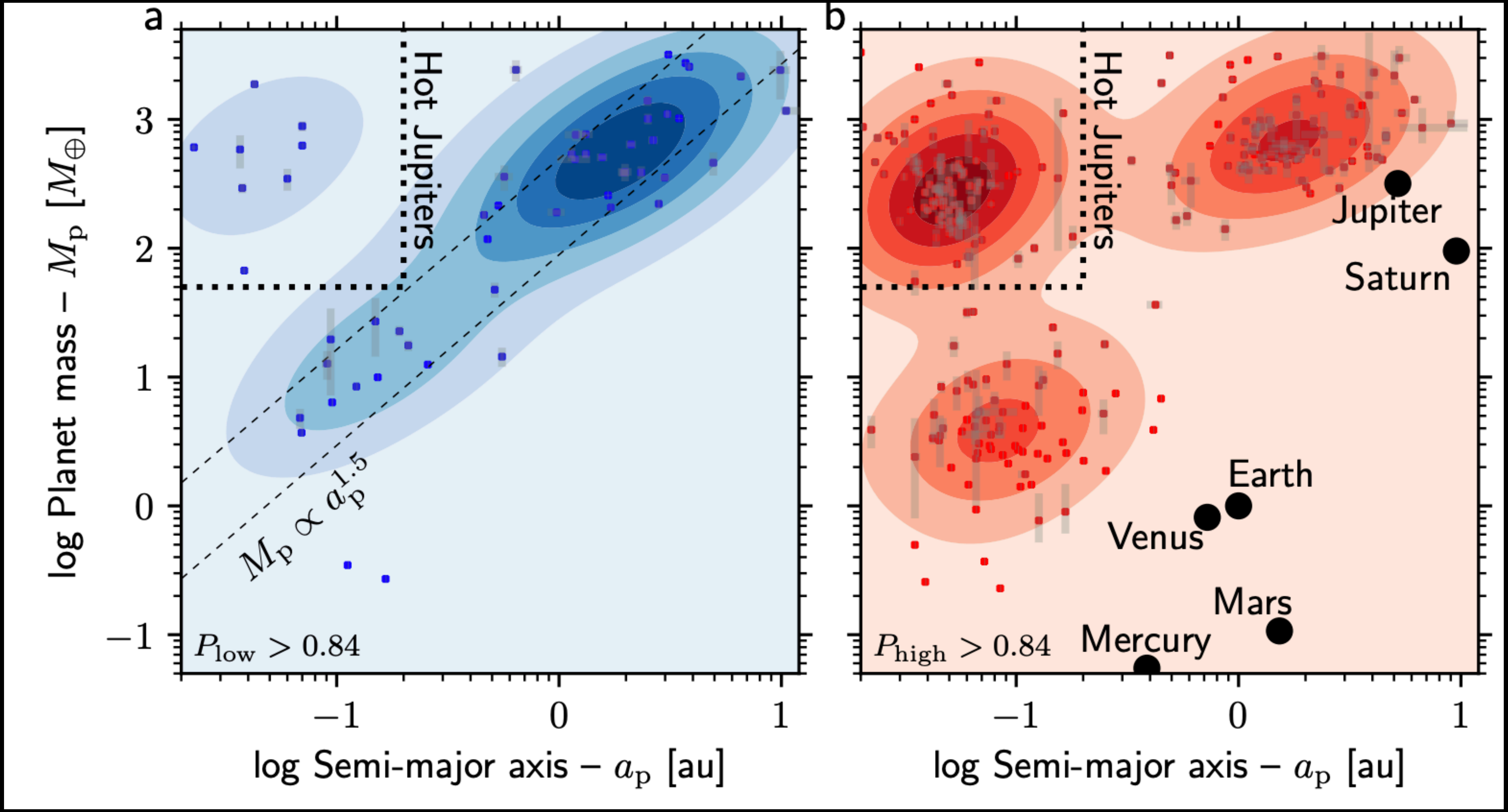


Is this a problem?

Increasing stellar density

Evidence for planet sensitivity to environment



Winter et al. (2020c)

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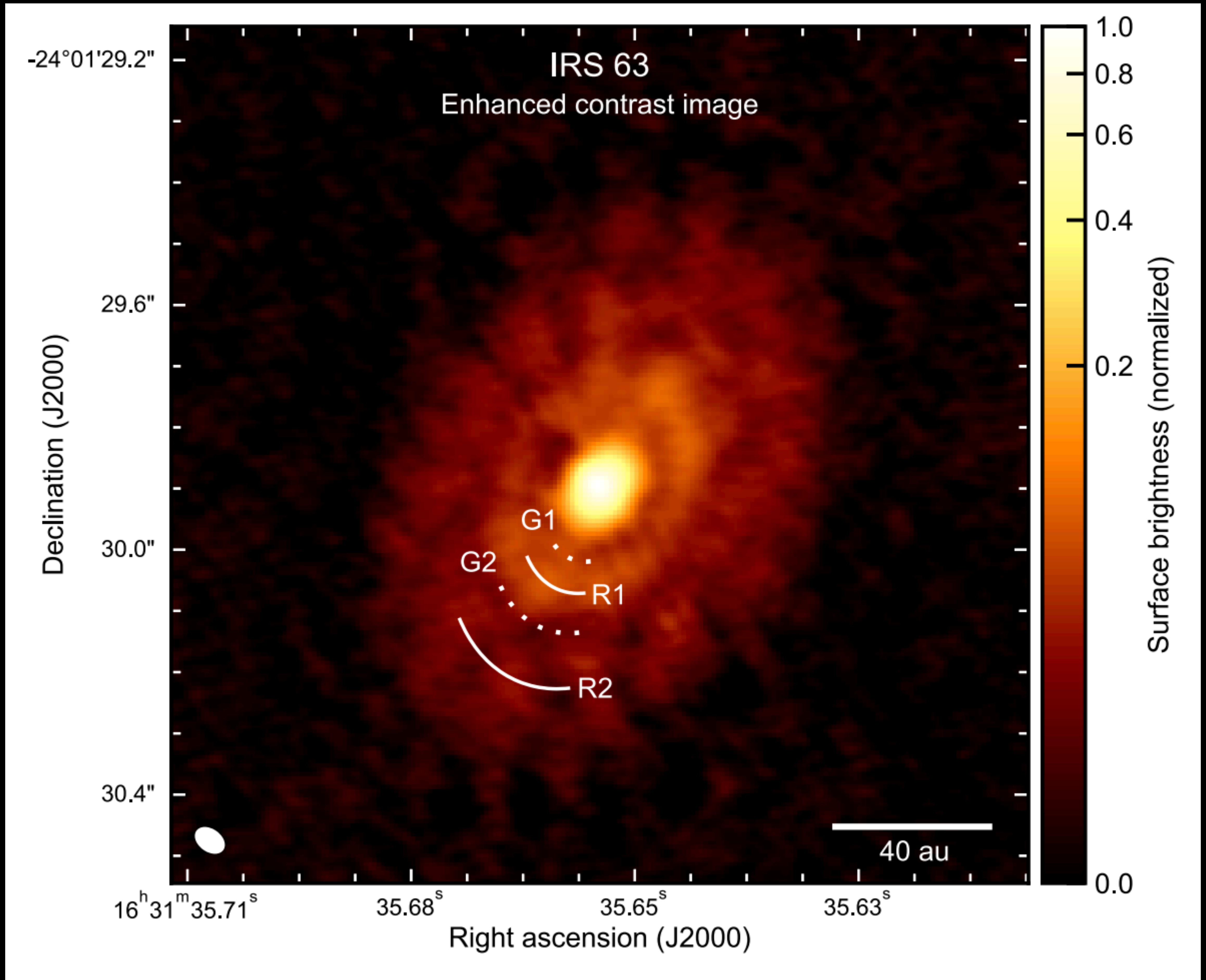
“Planets form very quickly so environment is unimportant”

Evidence for early planet formation?

Rings in a 0.5Myr old disc

Maybe due to planet formation

Maybe not…



Segura-Cox et al. (2020)

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Can we find evidence for very early environmental impact on discs?

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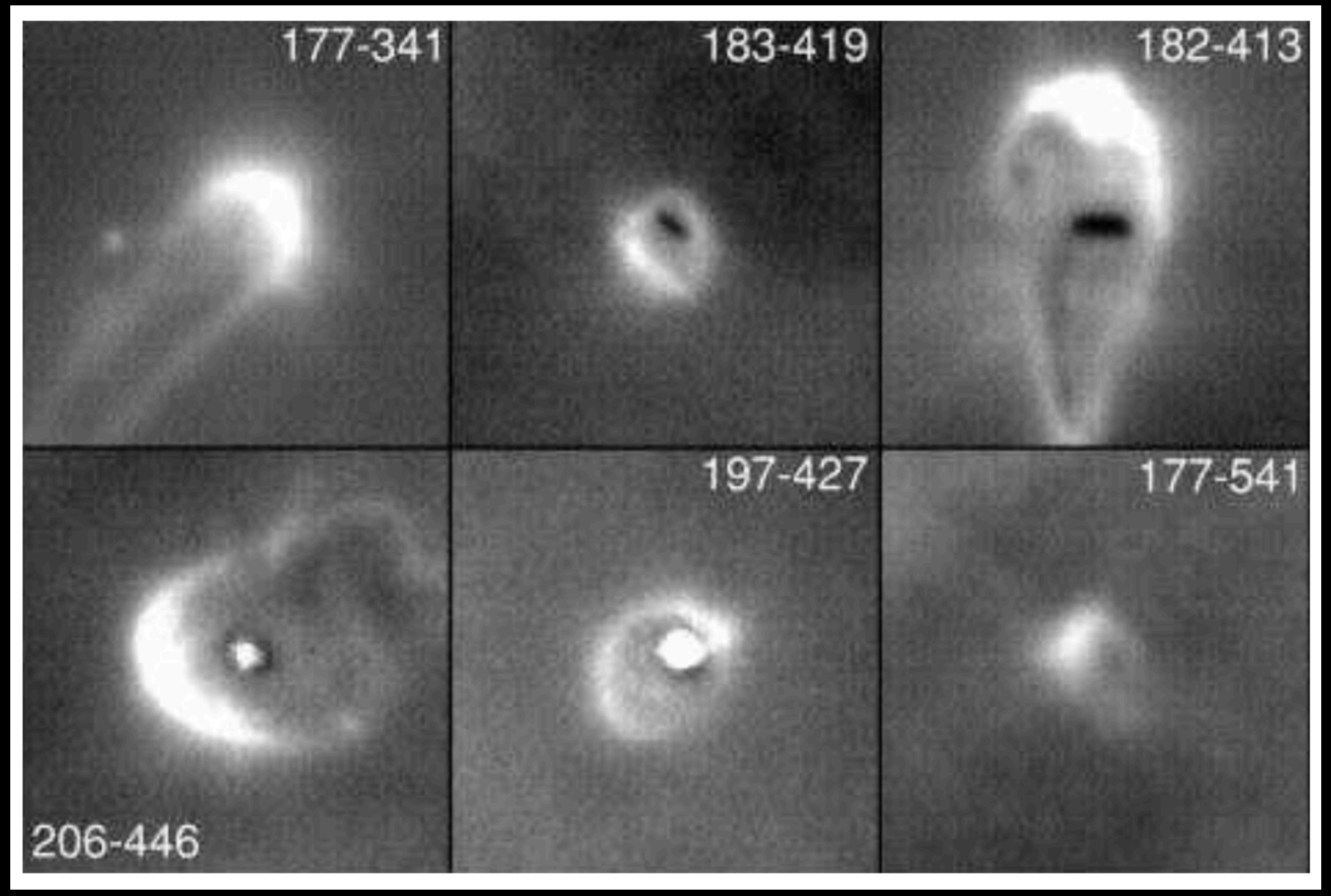
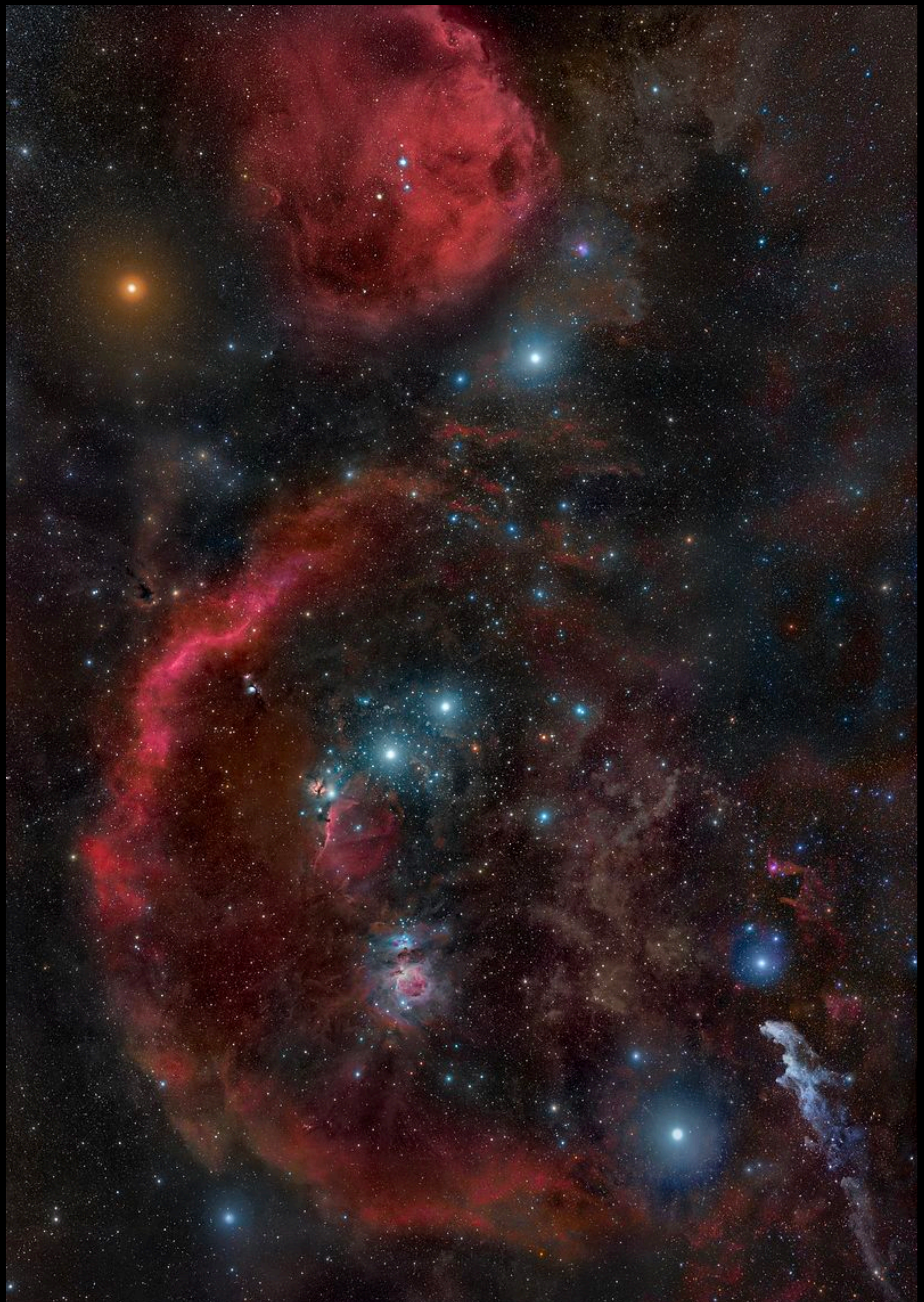


Proplyds

Searching for proplyds in NGC 2024



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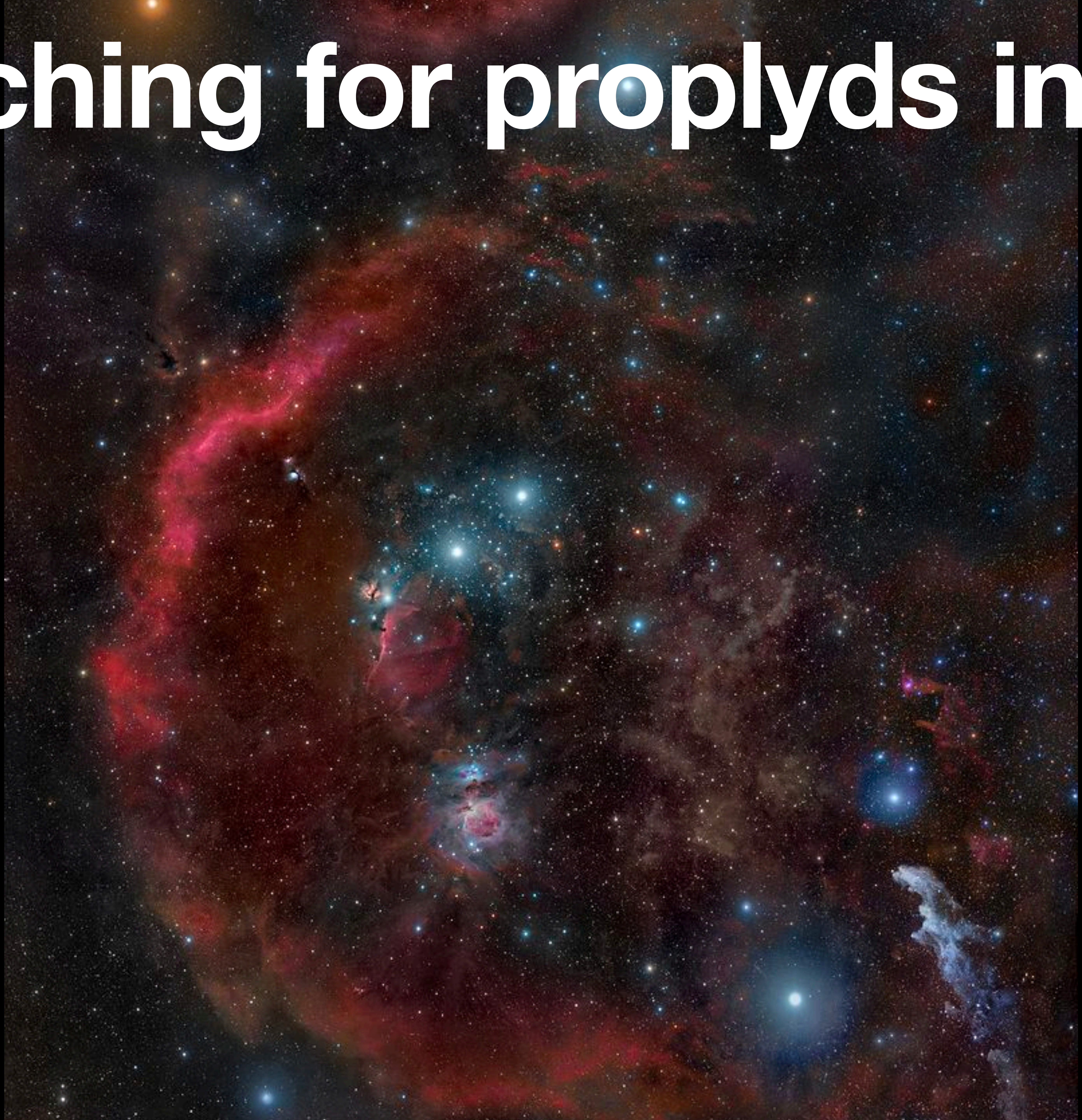

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Searching for proplyds in NGC 2024

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Searching for proplyds in NGC 2024

Youngest star forming region in Orion

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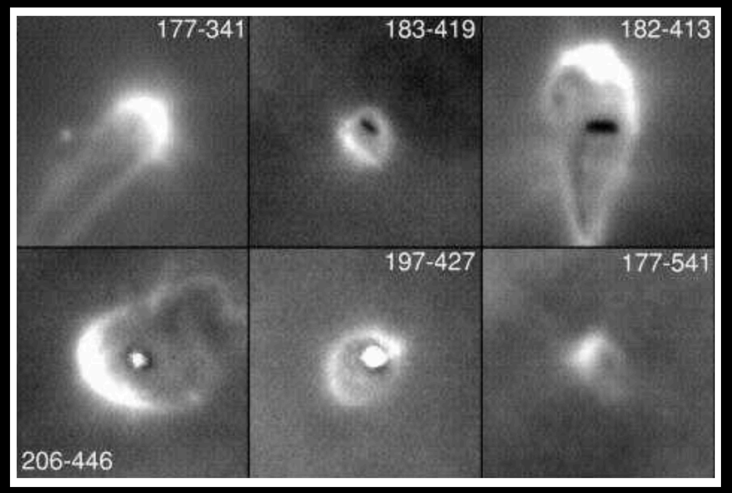
Searching for proplyds in NGC 2024

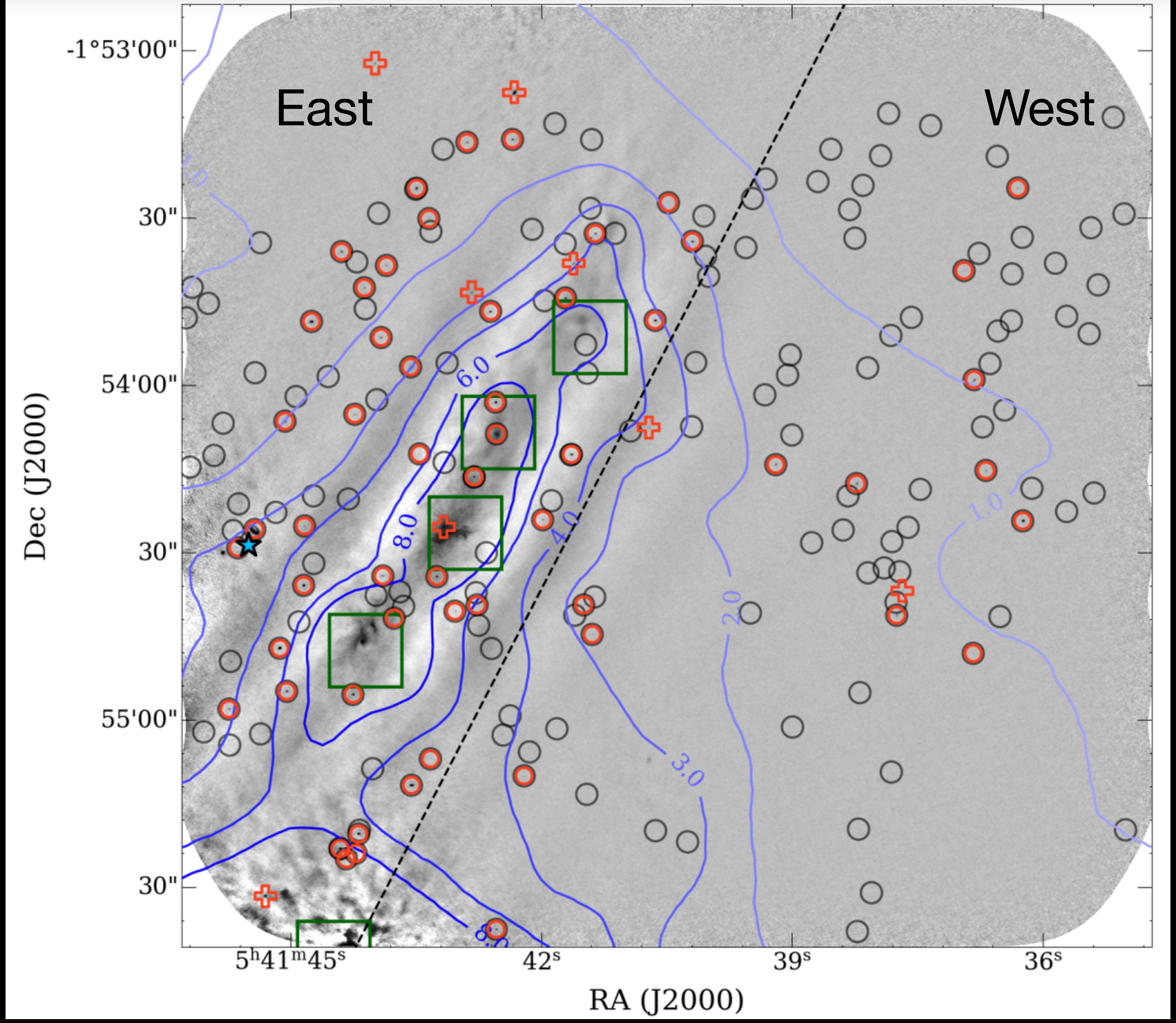
ALMA continuum survey

West population ~1Myr and mm continuum disc fraction of ~15%

East population 0.2-0.5Myr and mm continuum disc fraction of ~45%

I thought I would look for evaporating discs (proplyds)





van Terwisga et al. 2020

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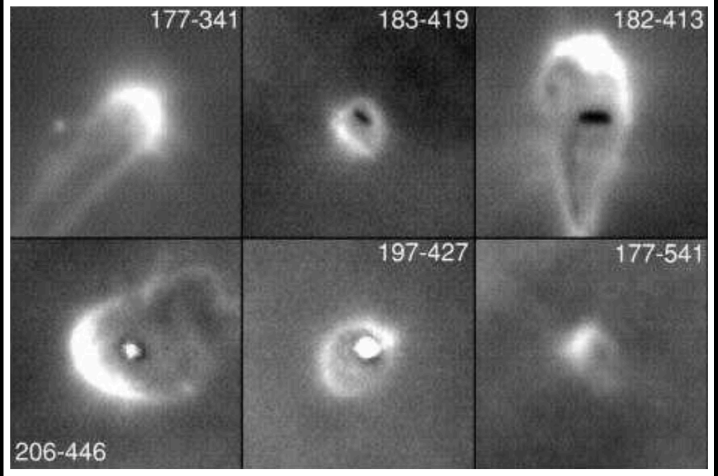

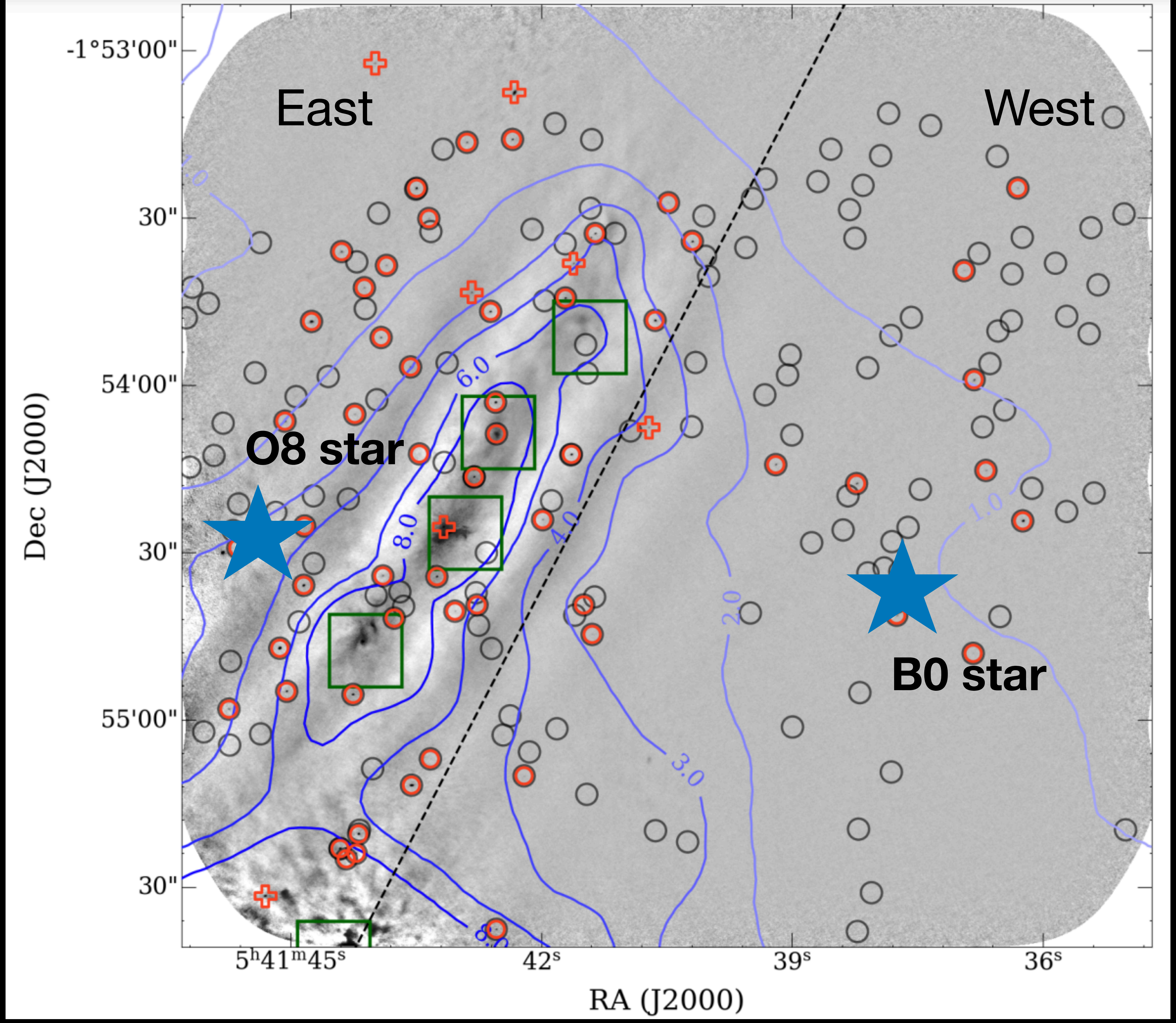

van Terwisga et al. 2020

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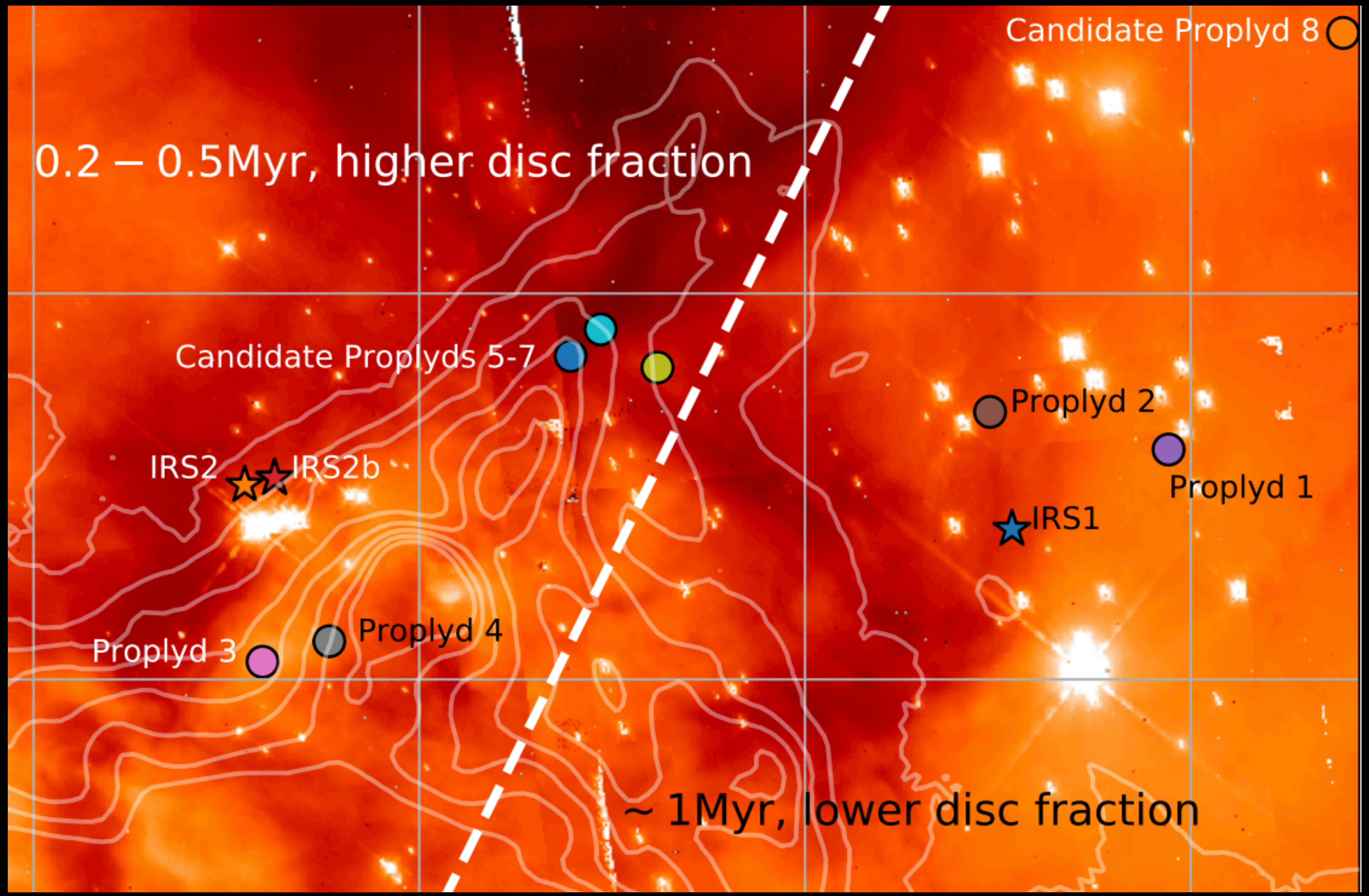
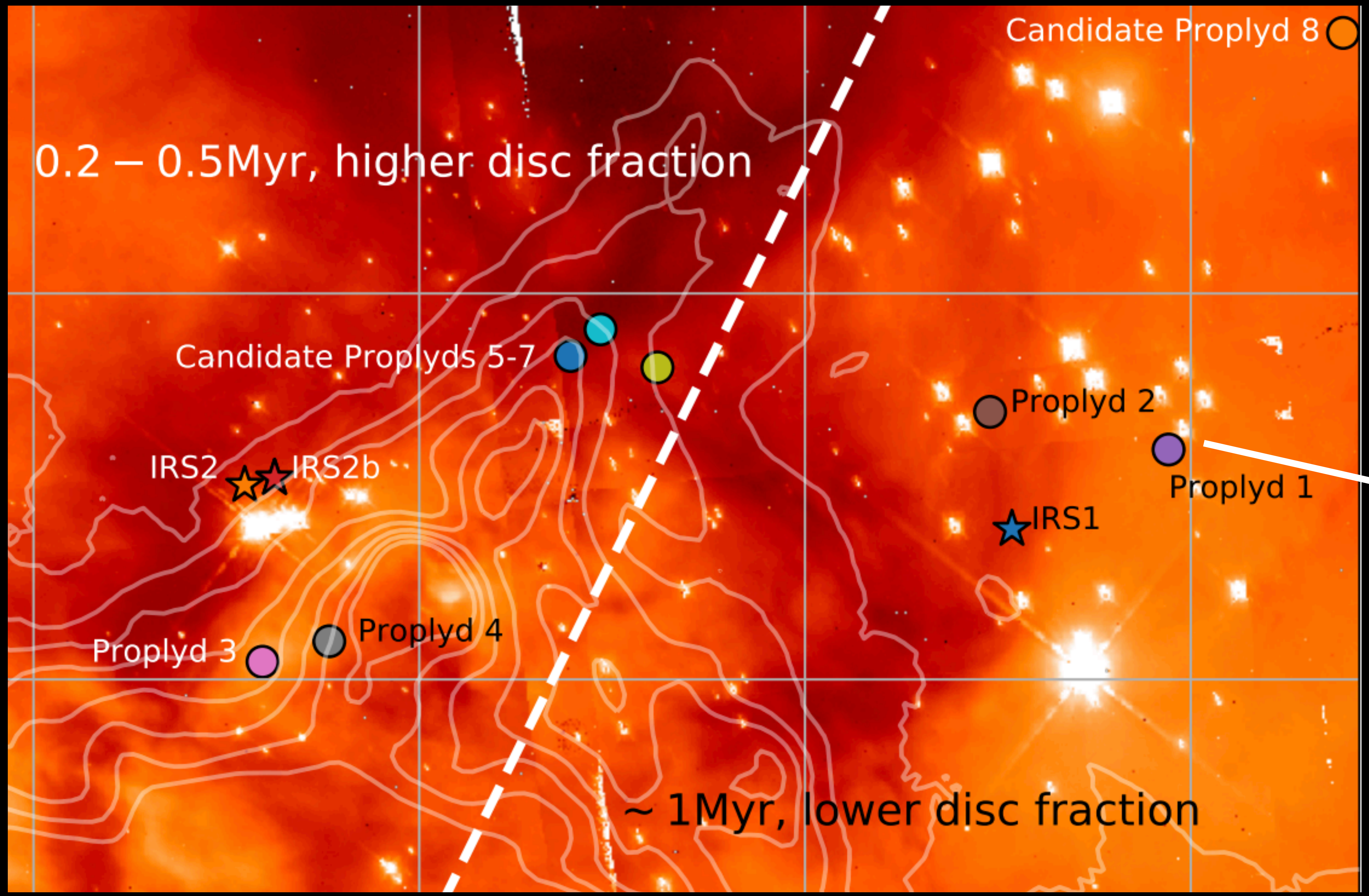
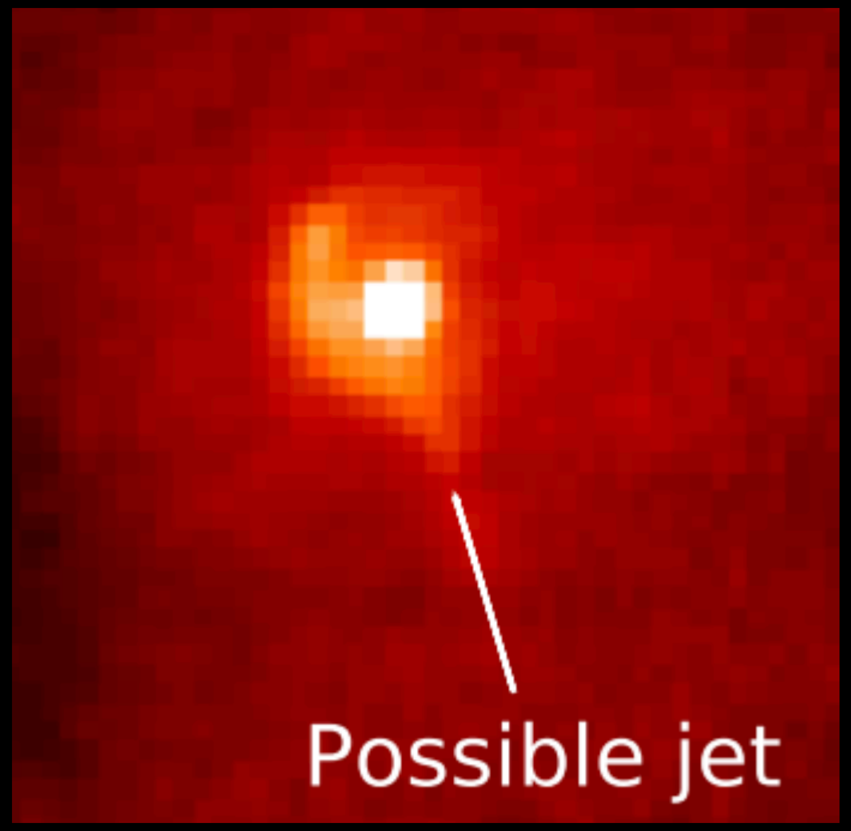
Proplyds in NGC 2024



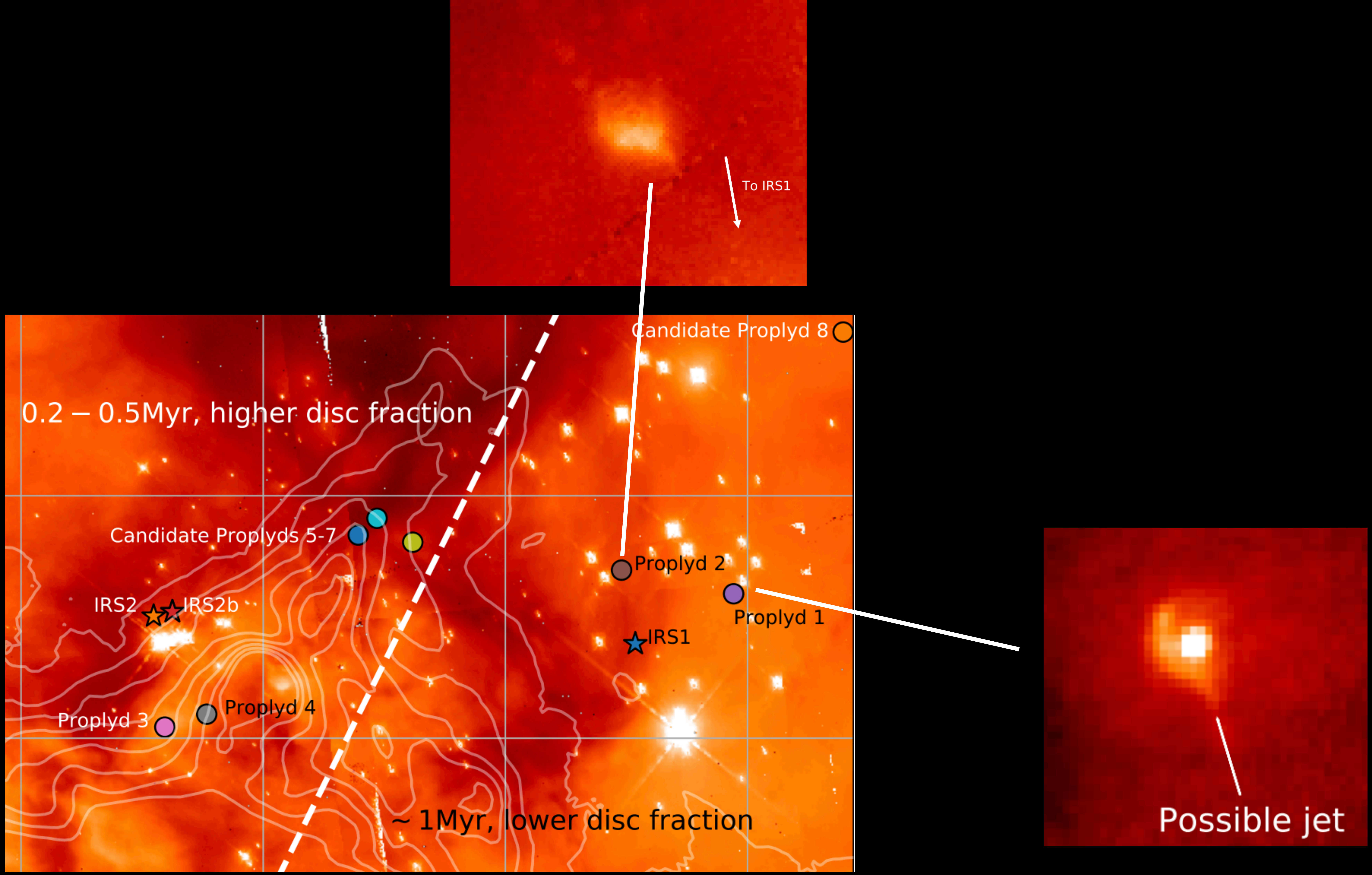
Haworth et al. (submitted)

Proplyds in NGC 2024





Haworth et al. (submitted)



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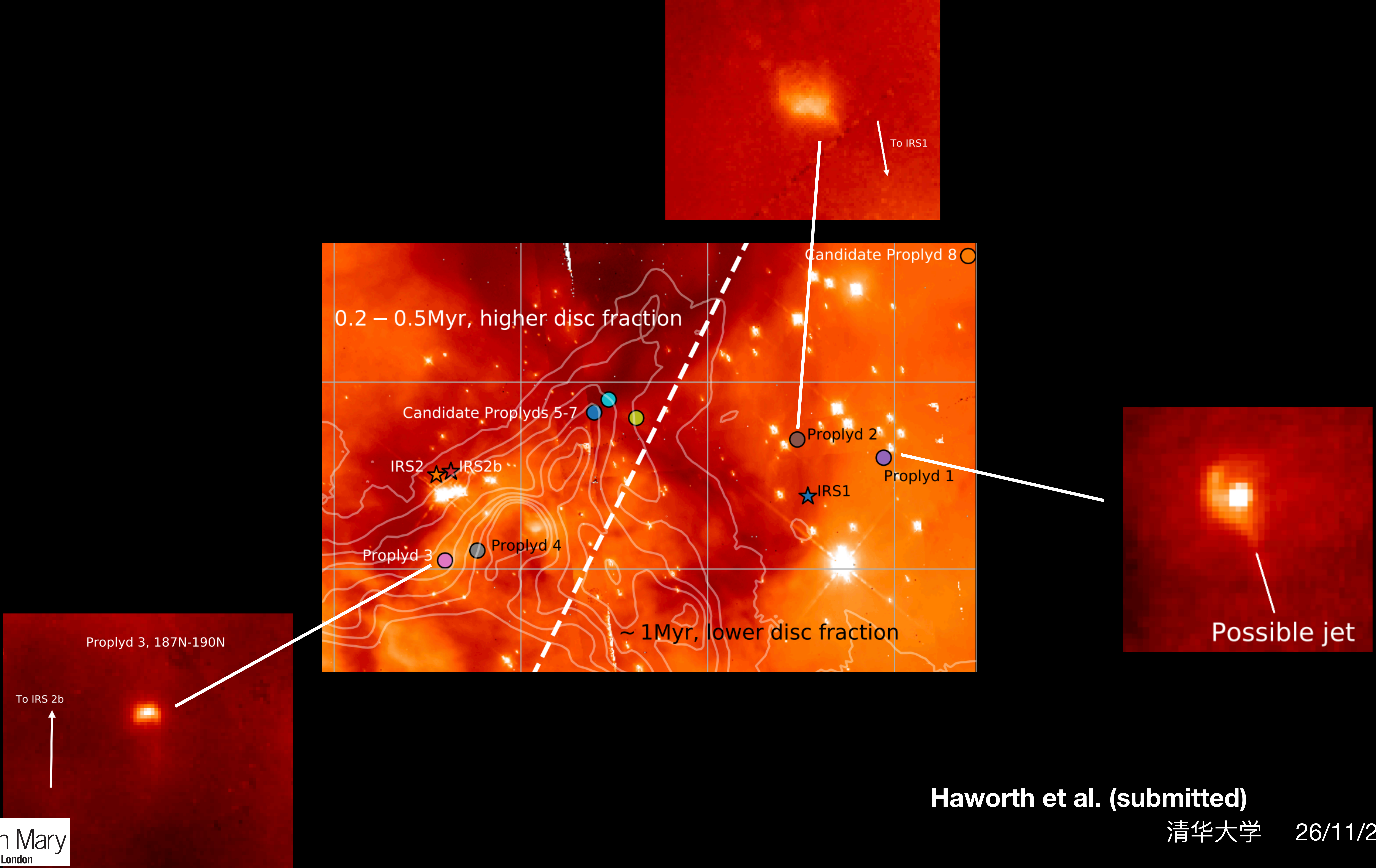

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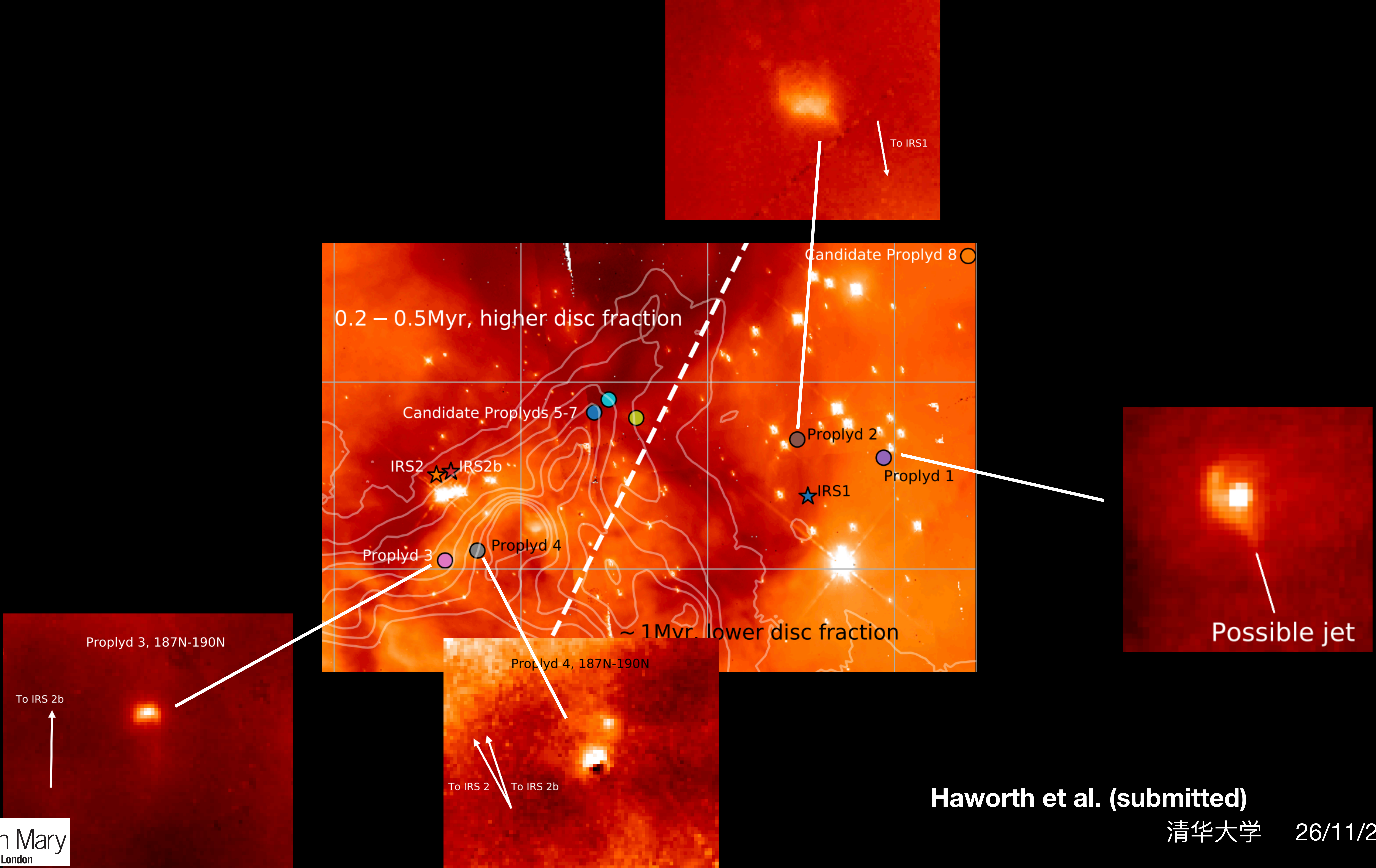

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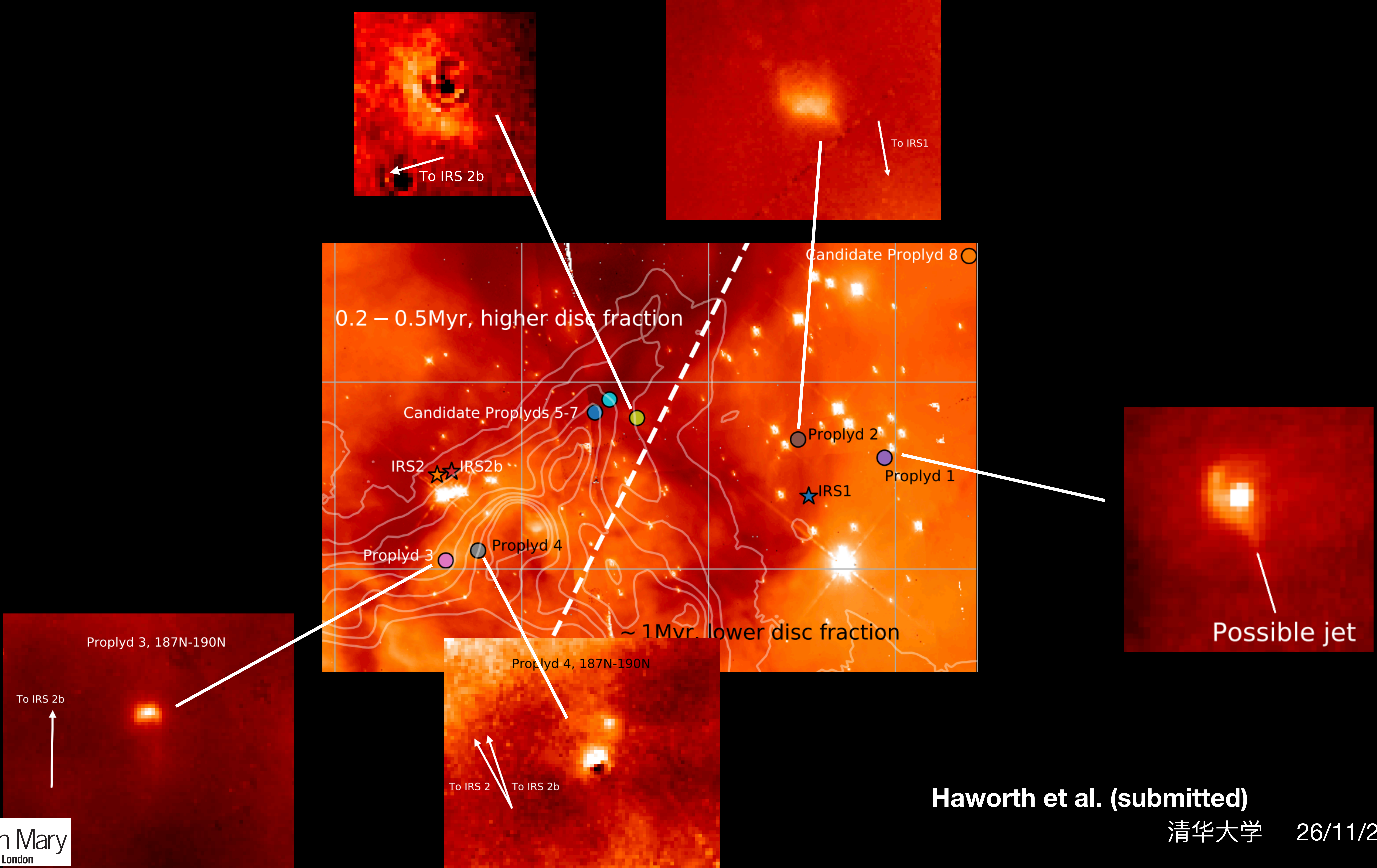

Haworth et al. (submitted)

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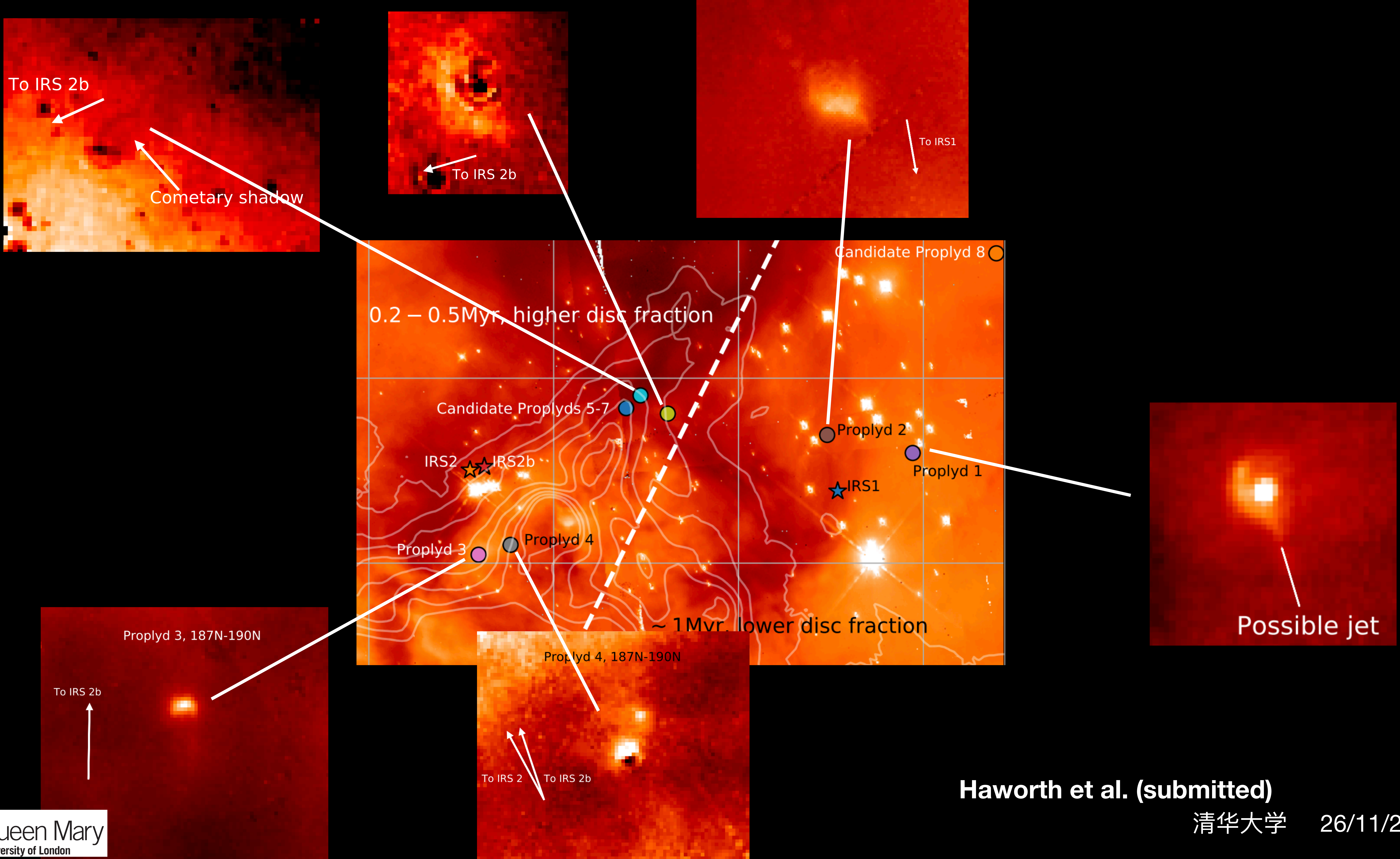

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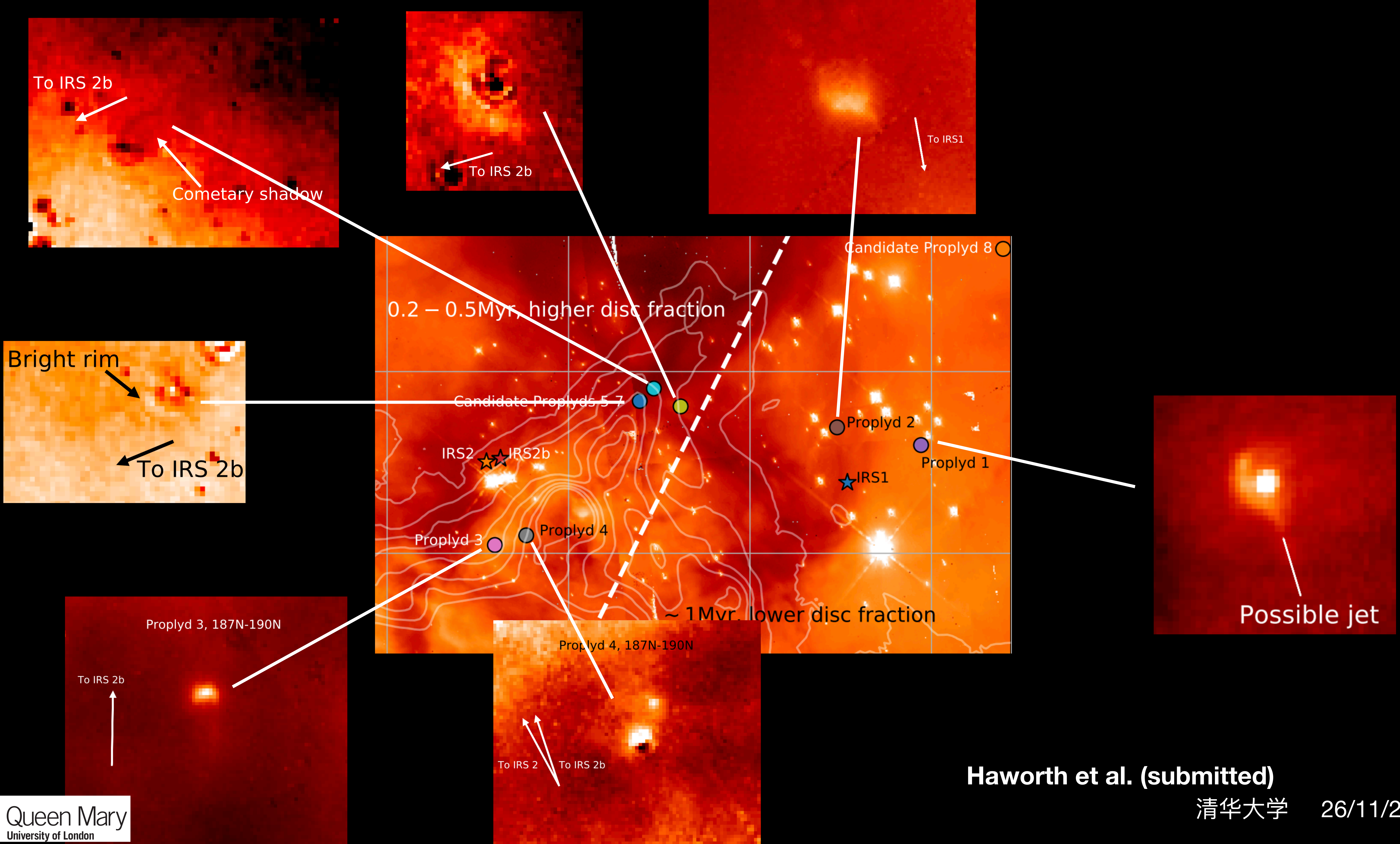

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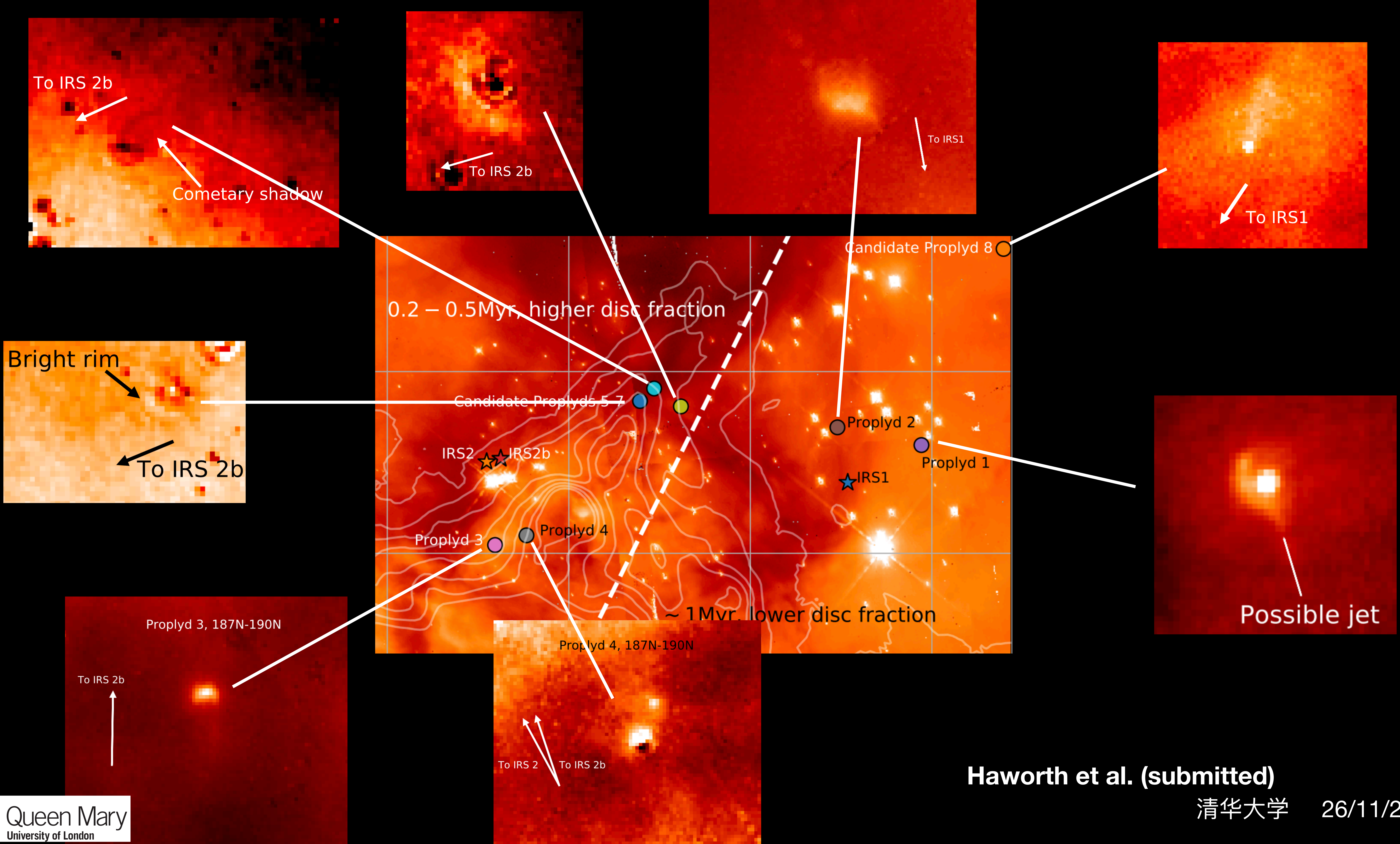
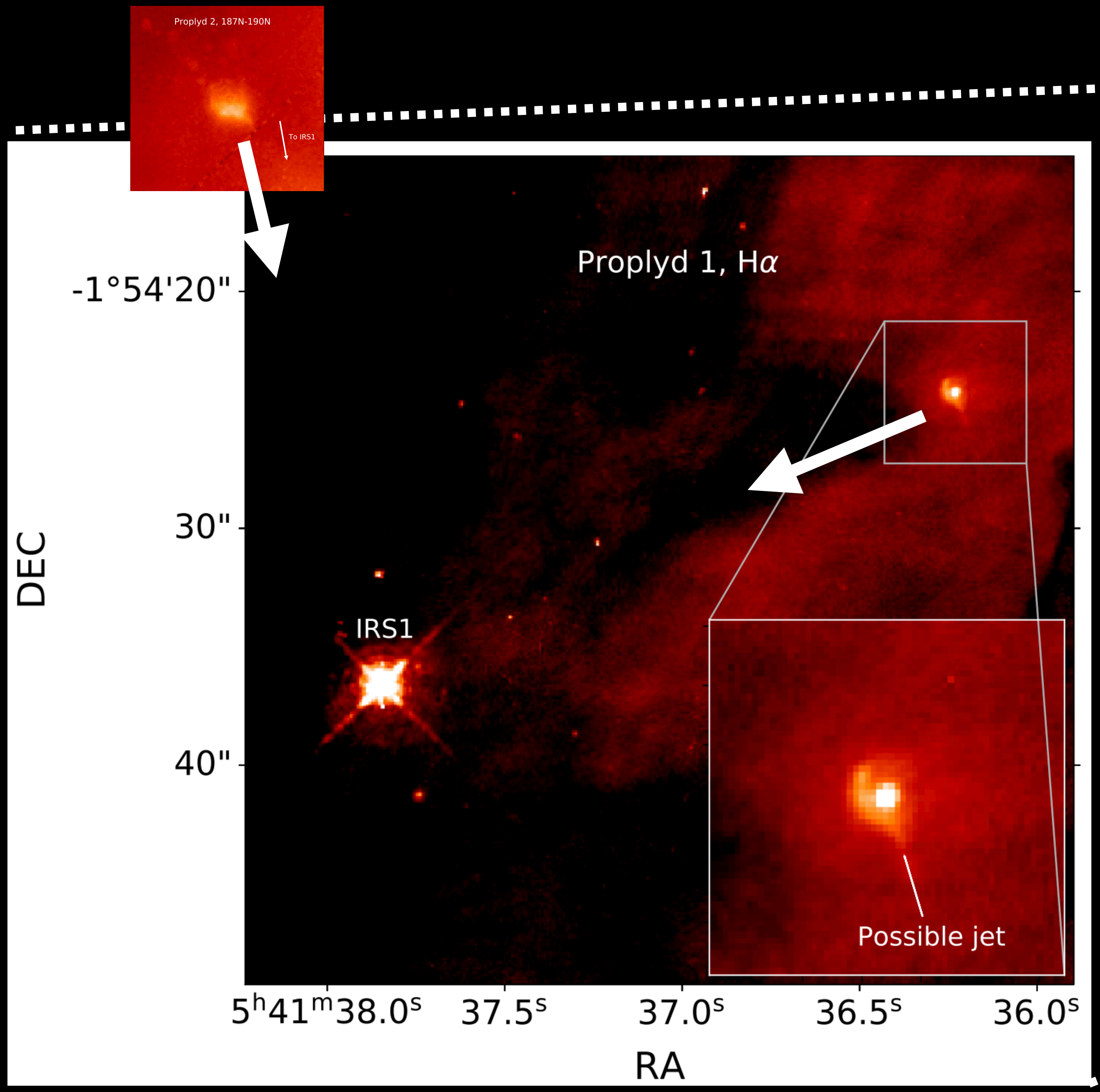


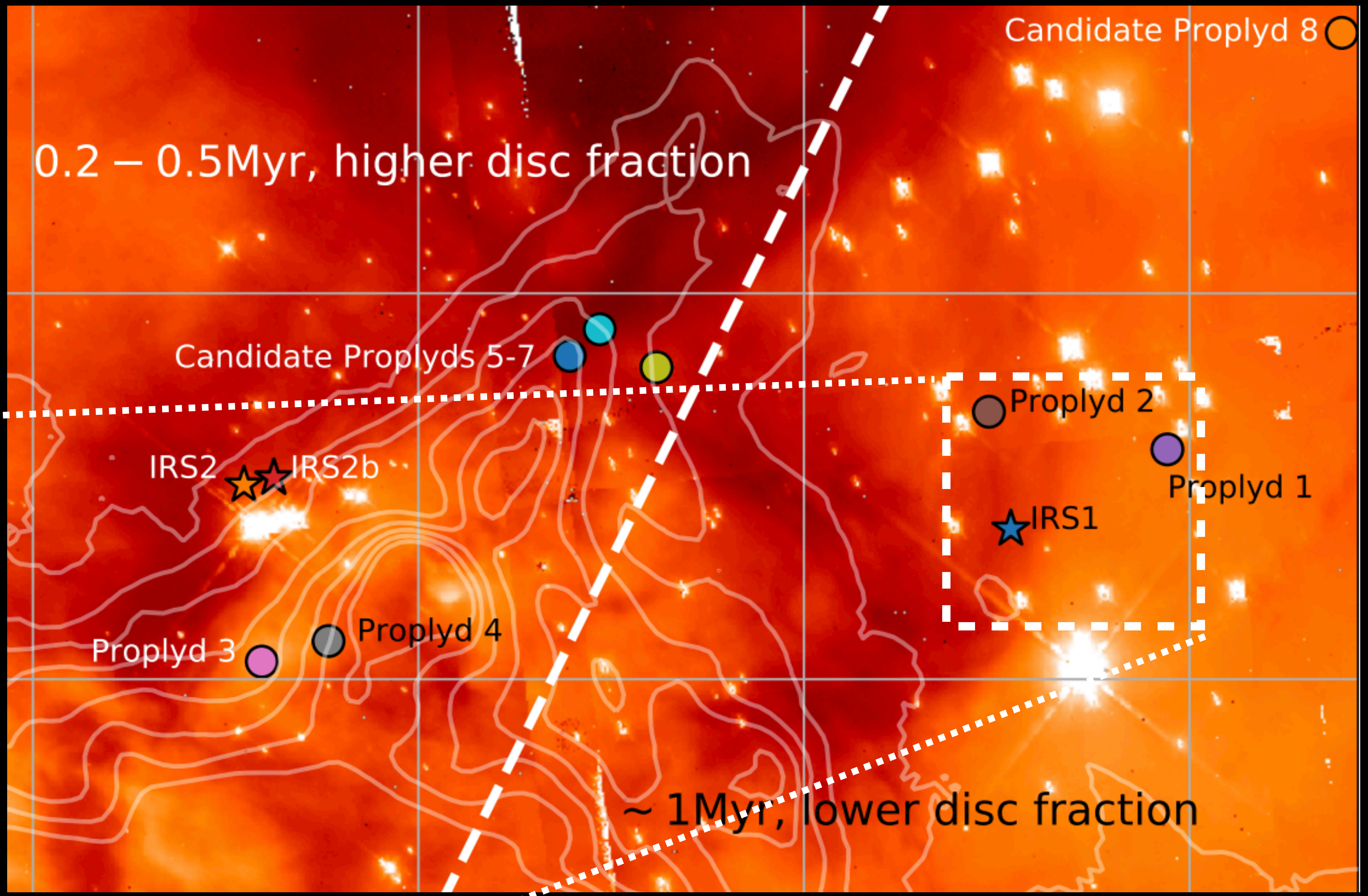
Haworth et al. (submitted)

Proplyds in NGC 2024

Two important implications

1. B stars can play an important role in evaporating discs





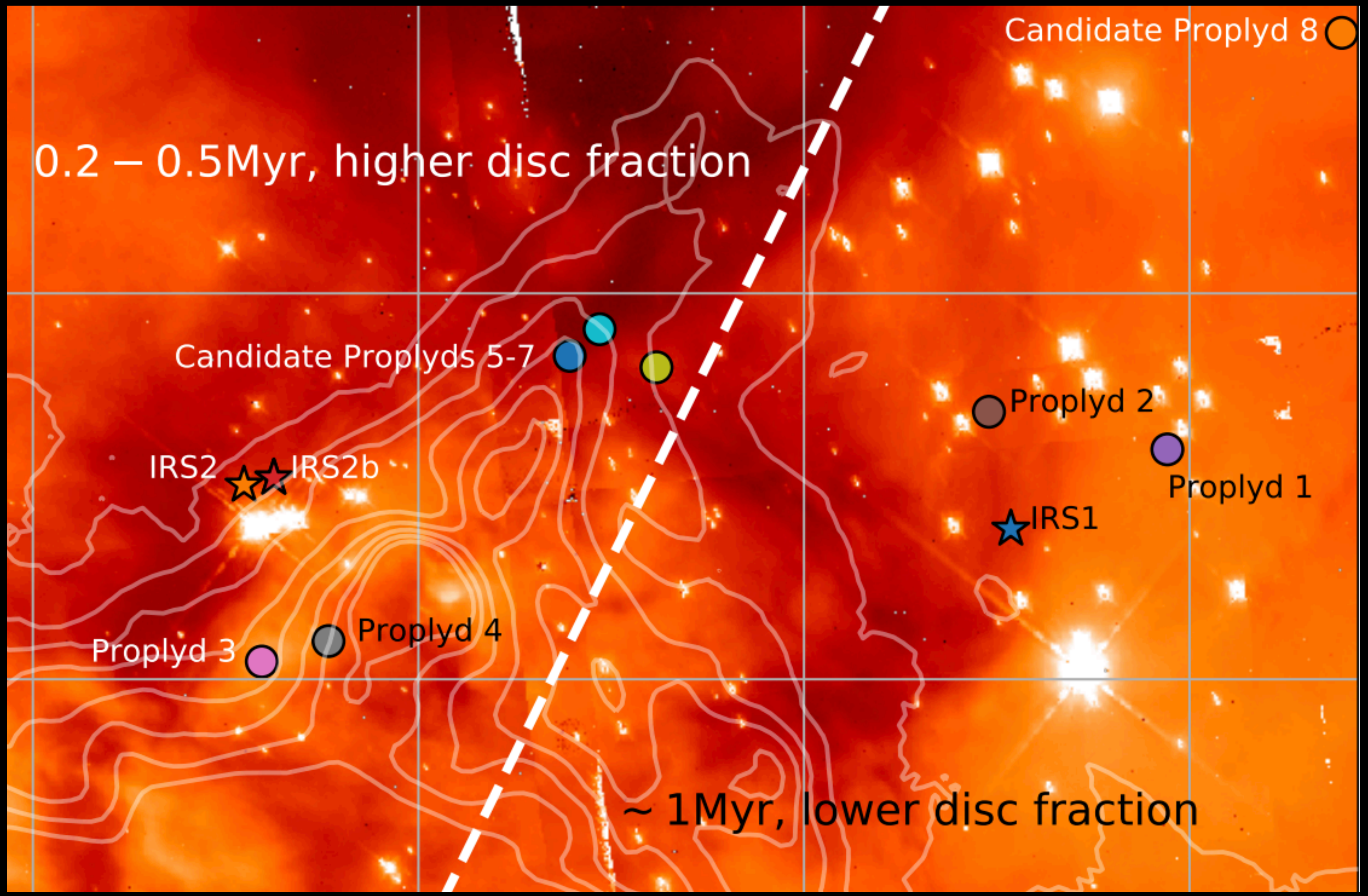
Haworth et al. (submitted)

Proplyds in NGC 2024

Two important implications

2. Evaporation can happen very early (0.2-0.5Myr)

In part of NGC2024 the mm continuum disc fraction is only ~50% at 0.2-0.5Myr compared to 70% in the 1-2Myr old Lupus star forming region



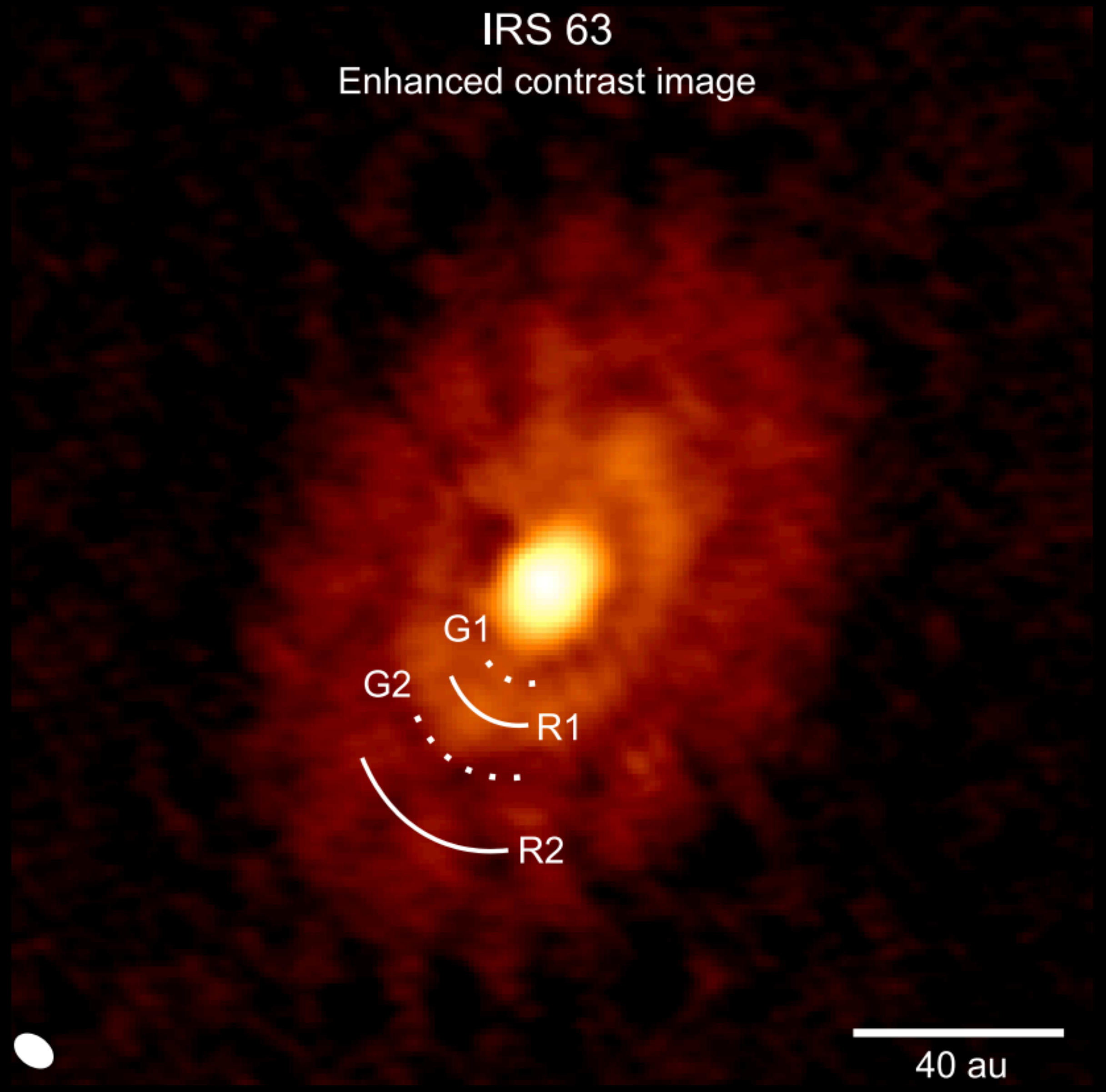
Haworth et al. (submitted)

Proplyds in NGC 2024

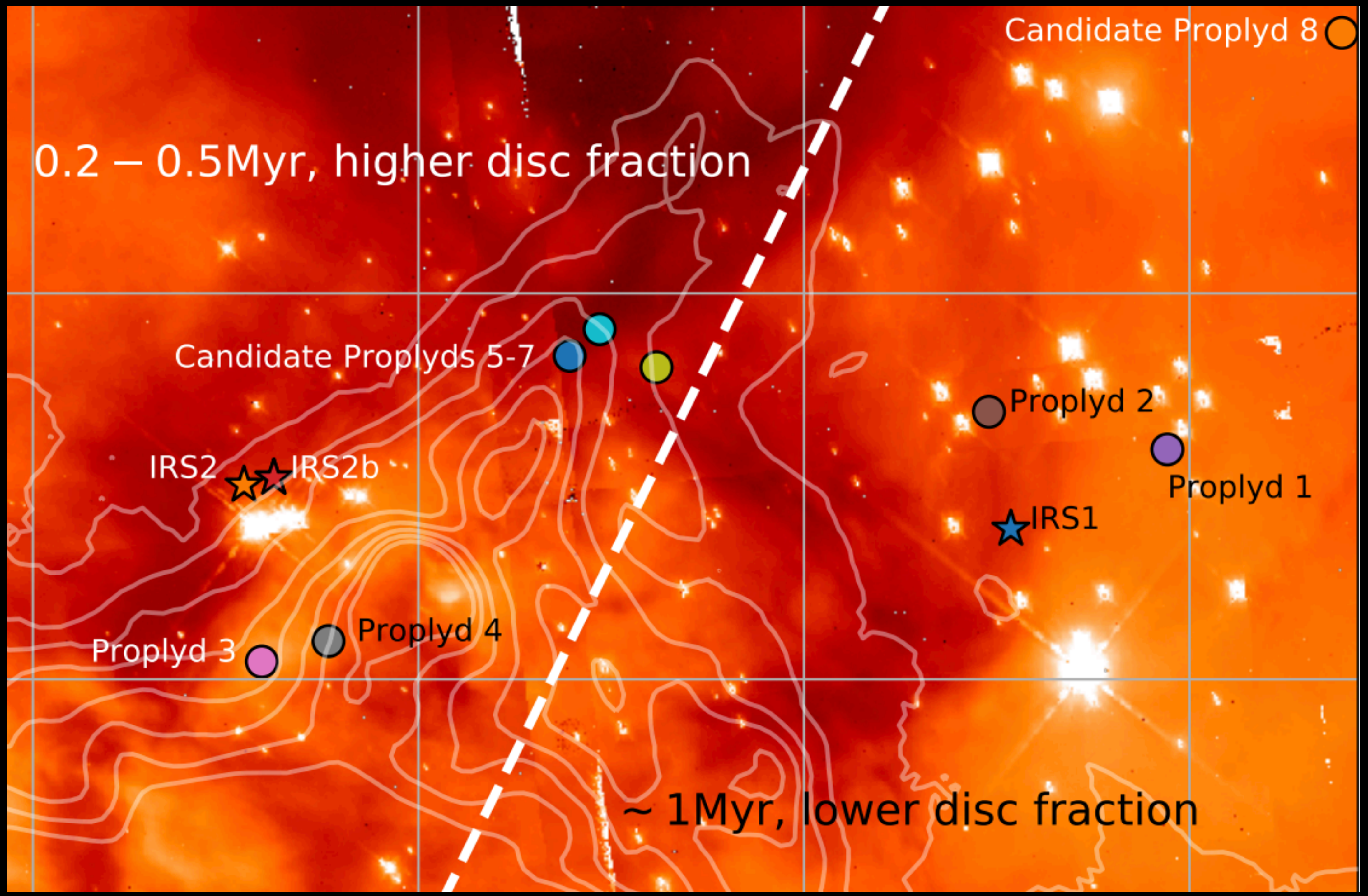
Two important implications

2. Evaporation can happen very early (0.2-0.5Myr)

So planet not necessarily safe, even if they form early (this is 0.5Myr)



Segura-Cox et al. (2020)



Haworth et al. (submitted)

“Planets form early so environment is unimportant”

Maybe, maybe not. In NGC 2024 there is external photoevaporation at < 0.5Myr.

In part of NGC2024 the mm continuum disc fraction is only ~50% at 0.2-0.5Myr compared to 70% in the 1-2Myr old Lupus star forming region

Proplyds in the Flame Nebula NGC 2024

T. J. Haworth[1⋆], Jinyoung S. Kim[2], Andrew J. Winter[3], Dean C. Hines[4], Cathie J. Clarke[5], Andrew D. Sellek[5], Giulia Ballabio[1,6], Karl R. Stapelfeldt[7]

Talk Overview

1. Introduction to planet formation in stellar clusters

2. Can environmental effects compete with early planet formation?

3. Modelling external disc photo evaporation

Modelling external photoevaporation

THE FRIED GRID

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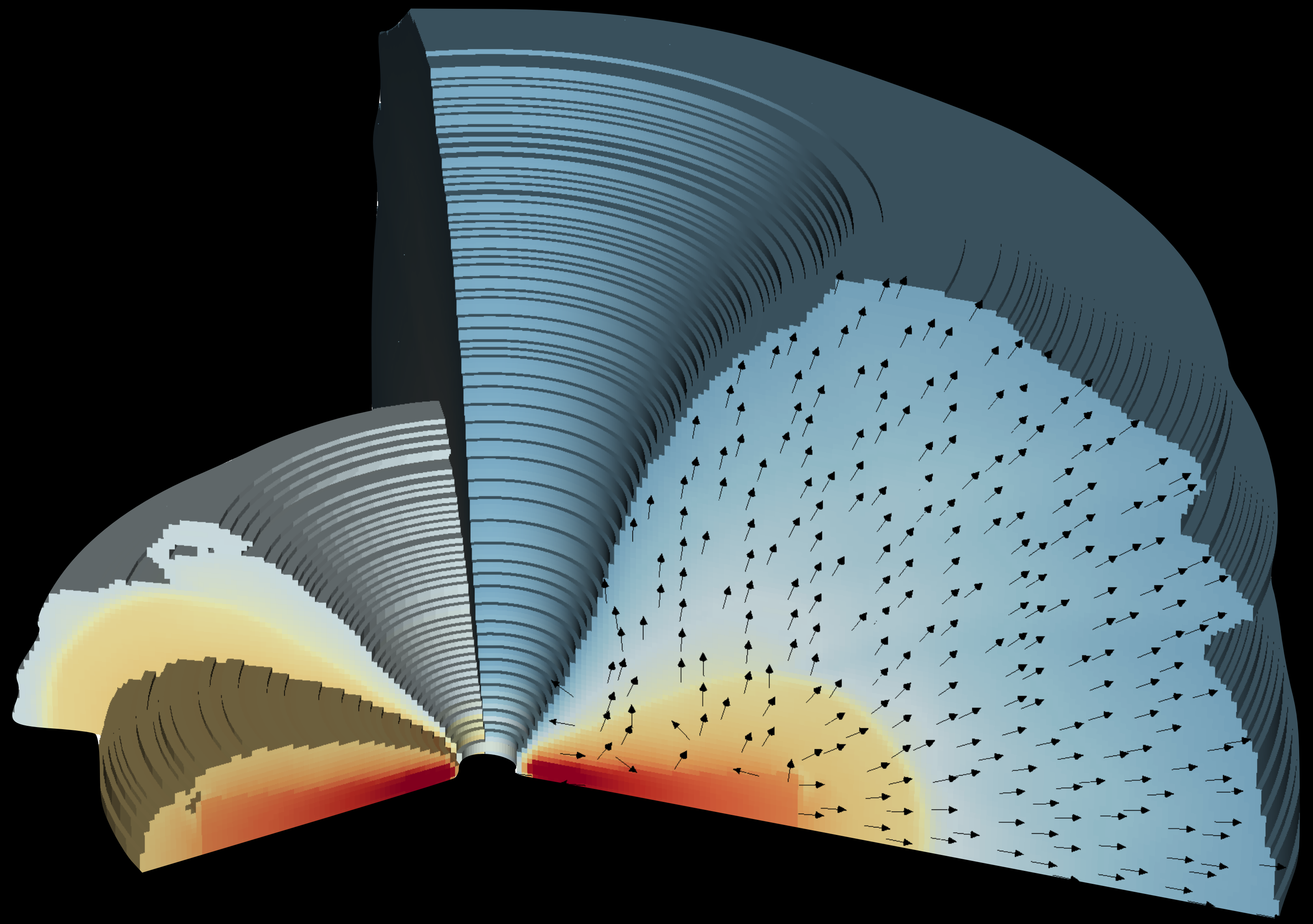
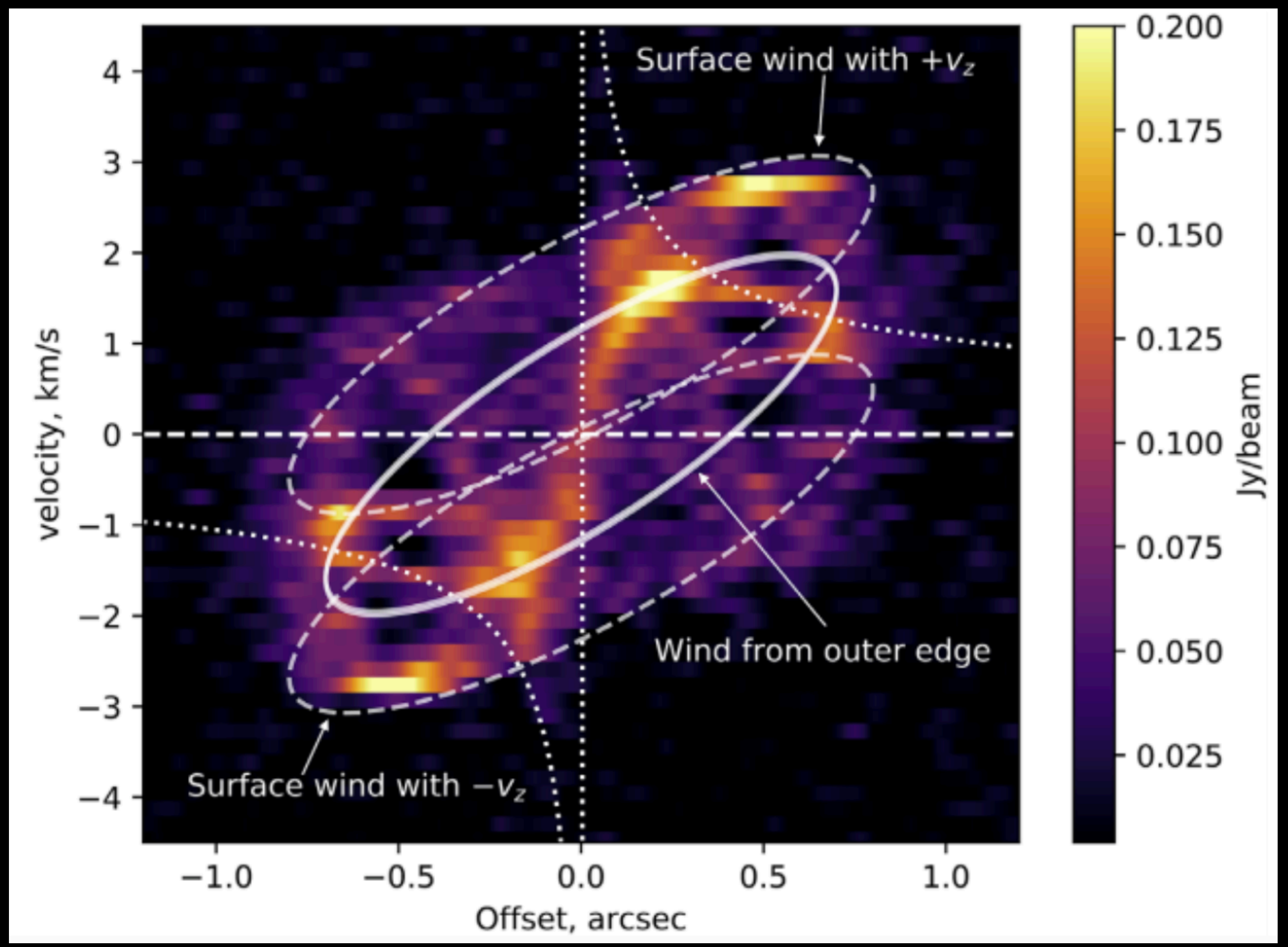
For a given star/disc
\+ UV field FRIED tells
you the mass loss rate

Haworth et al. (2018)



Haworth & Clarke (2019)

Ballabio et al. (in prep)



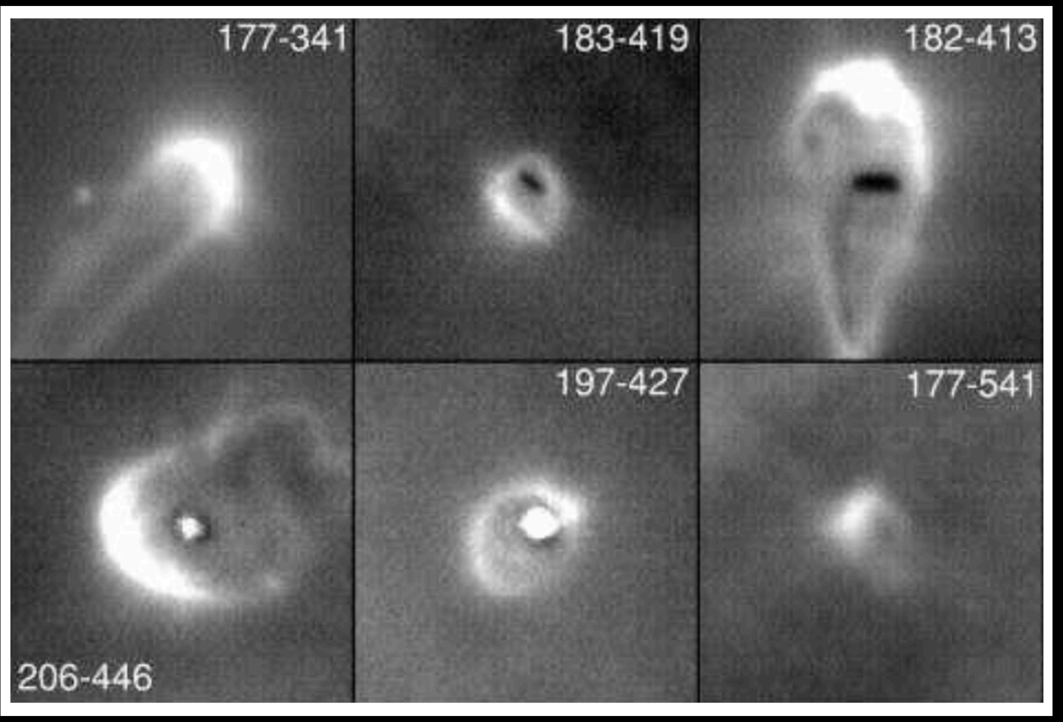
Haworth & Owen (2020)

How stellar clusters can affect discs

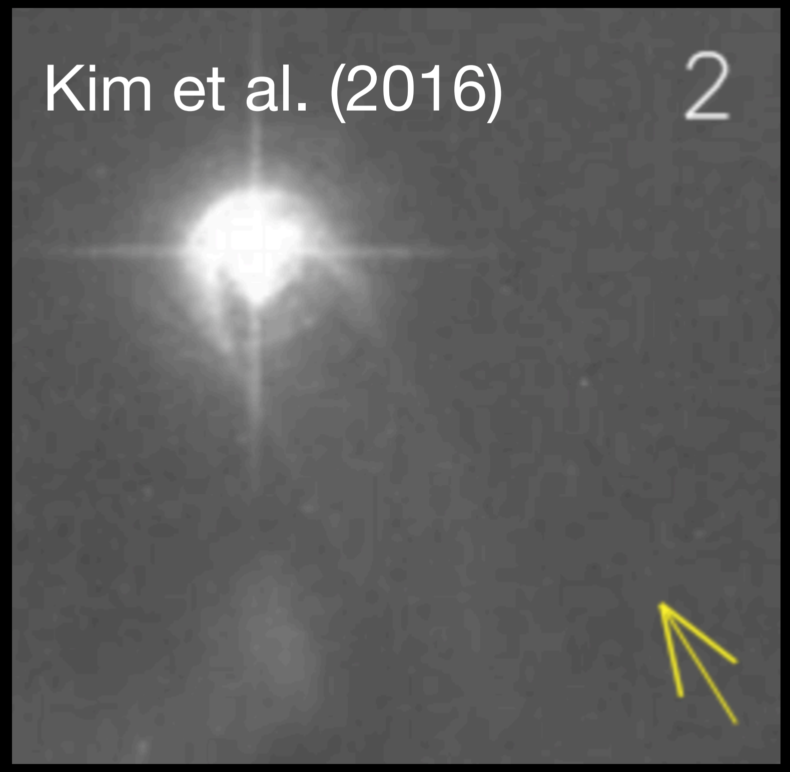
2. External photoevaporation

UV field strength in multiples of Solar neighbourhood value (G_0)

10^5 10^4 10^3 10^2 10 1



e.g. O'Dell, Wen, McCaughrean



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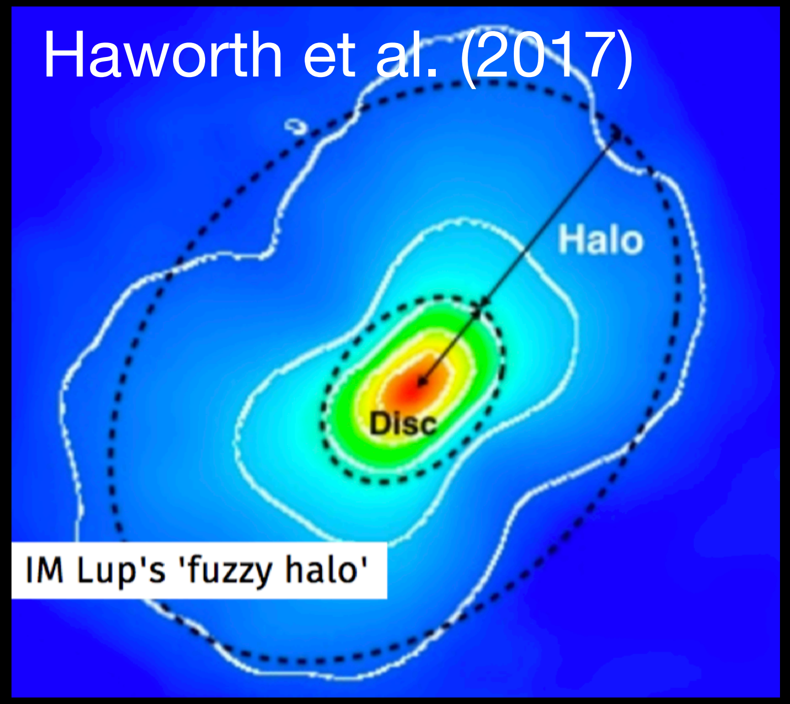

Modelling external photoevaporation

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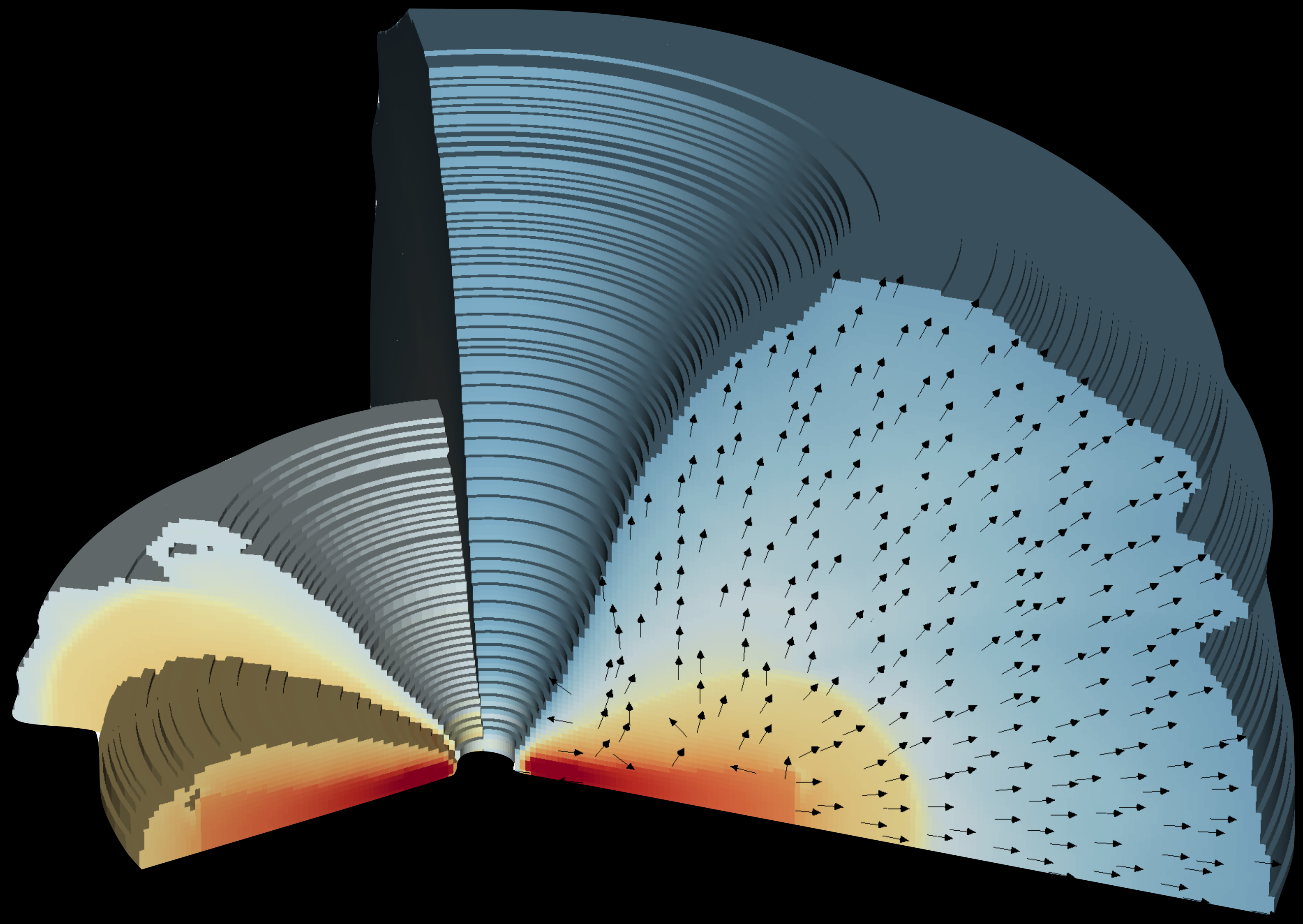

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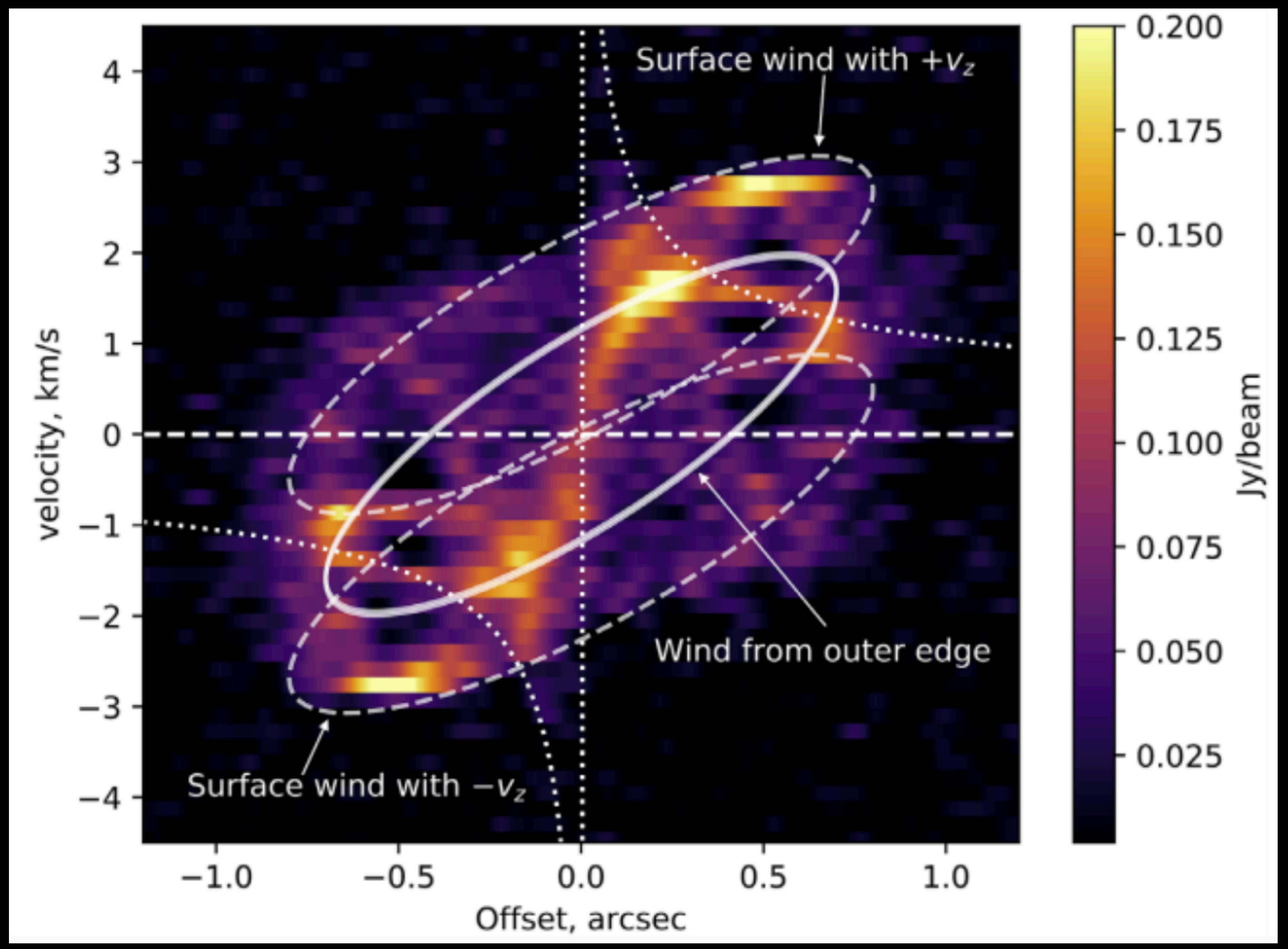

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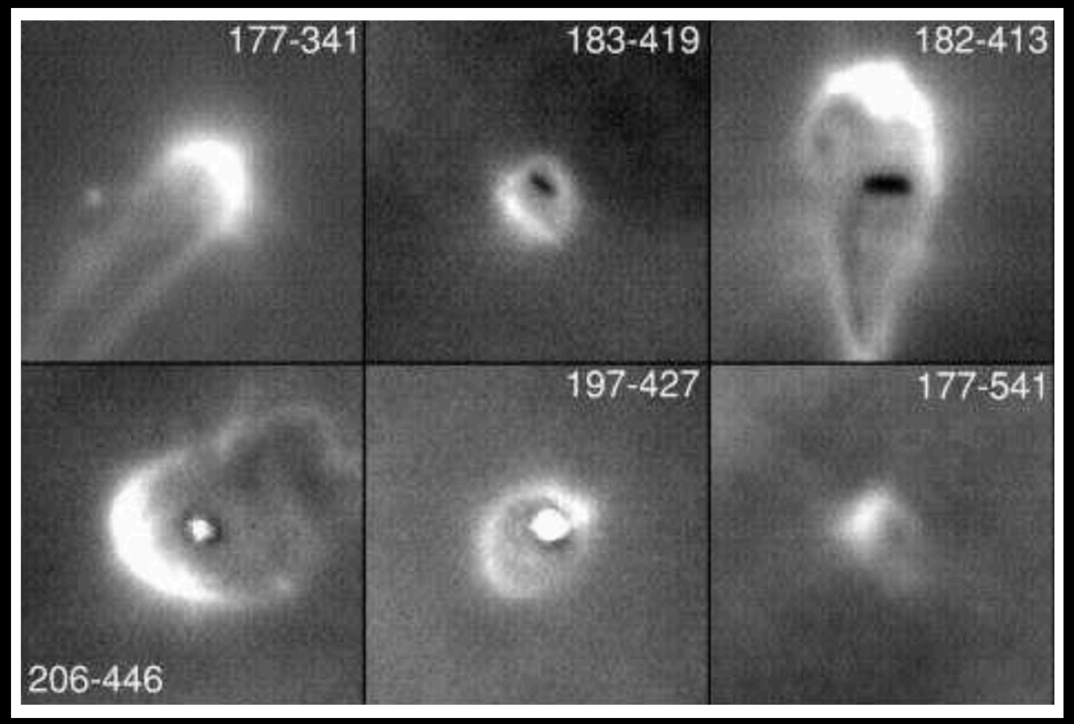

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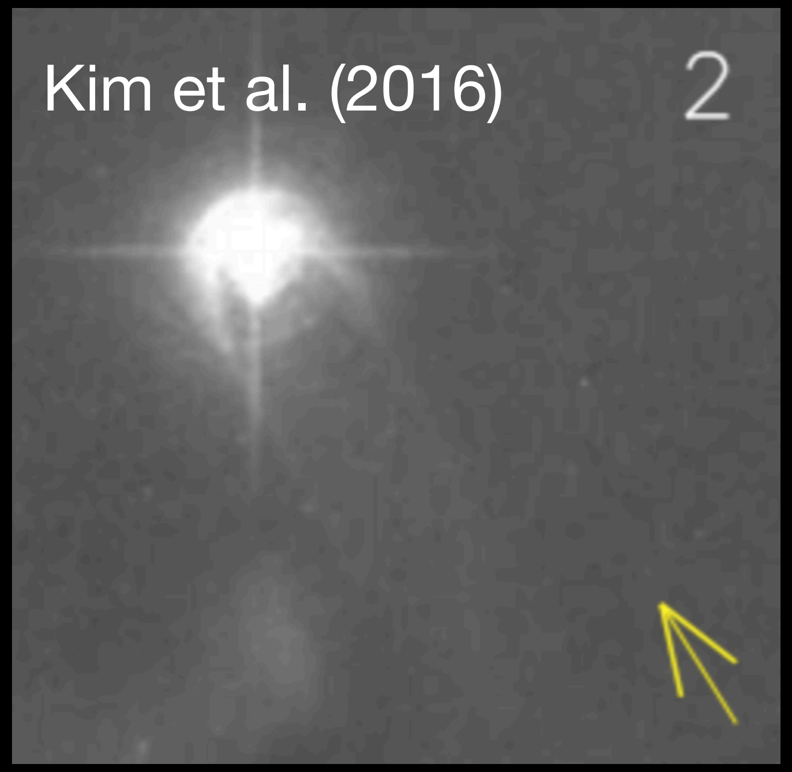

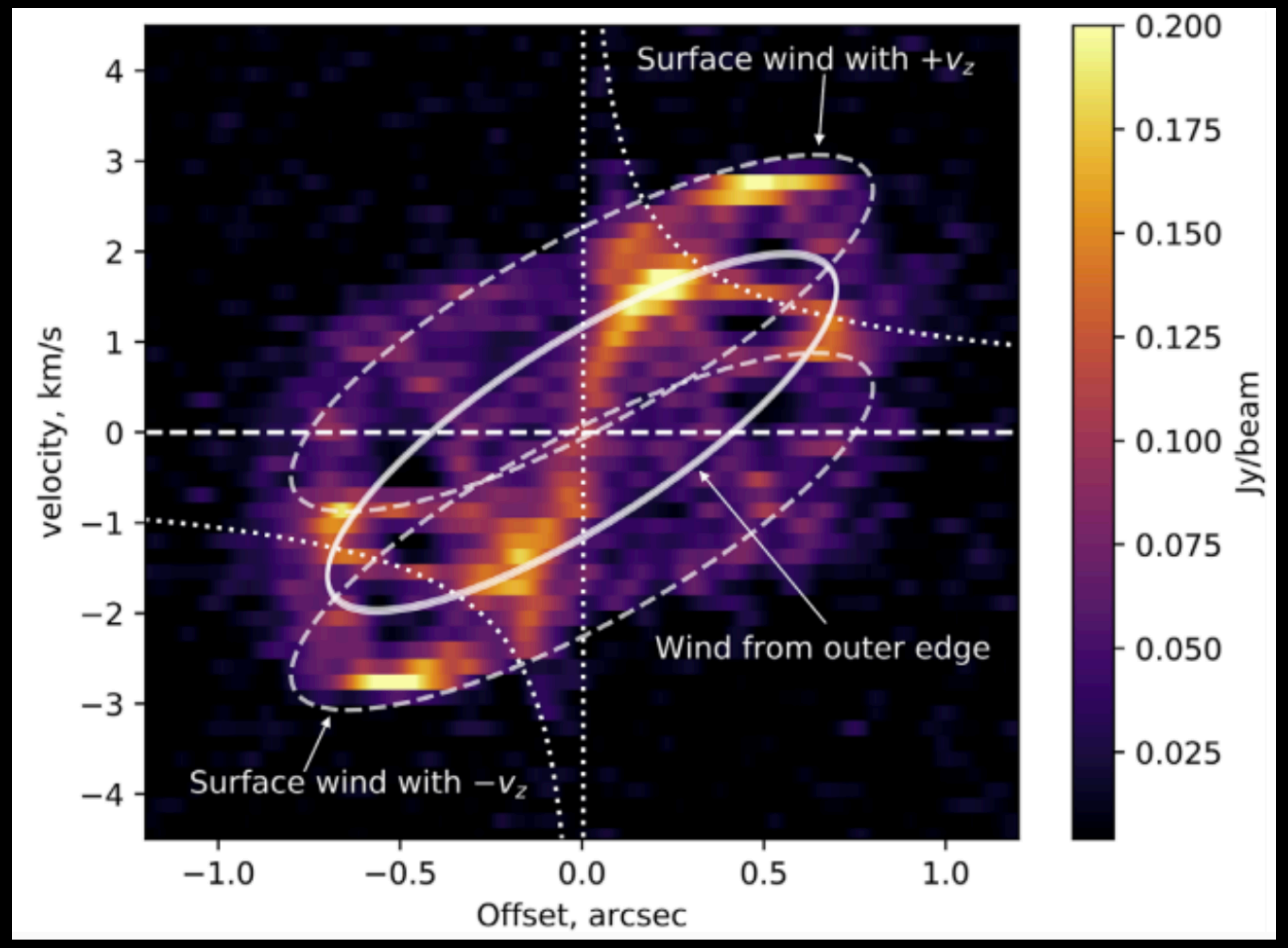

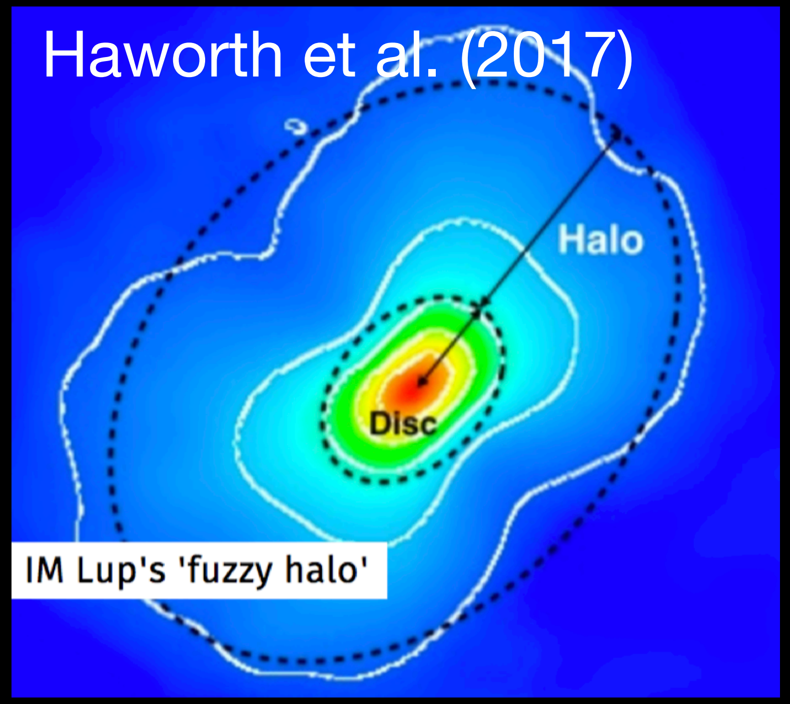

Summary

Planet forming discs are not isolated systems!

Discs are certainly affected by radiation and dynamical encounters in the environment, even really early on as in NGC2024

Are planet populations affected too? We don't know yet

Queen Mary is one of the largest supporters of the China Scholarship Council (CSC) in the UK and awards **60 joint QMUL-CSC PhD scholarships every year.**

Under the scheme, Queen Mary will provide scholarships to cover all tuition fees, whilst the CSC will provide living expenses and one return flight ticket to successful applicants. This scholarship is available to both new and continuing (current 1st year) students. Associate students who want to come to Queen Mary for 3-24 months are also able to apply.

Applicants must first have an offer for admission to Queen Mary's PhD programme and then they should apply to CSC for the scholarship between 20th March and 31st March. Results are released at the end of May.

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Get in touch with our super-friendly PhD team:

Robert Miles (email r.miles@qmul.ac.uk)
Kostya Trachenko (email k.trachenko@qmul.ac.uk) to

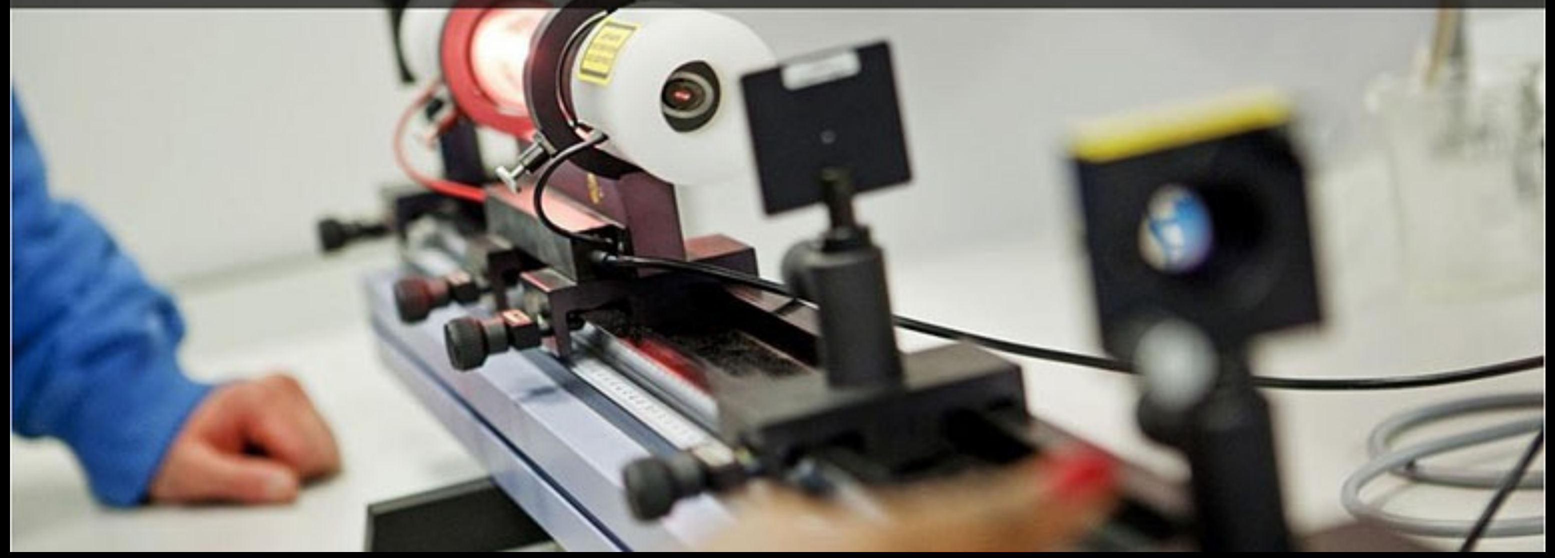
✓ let them know you are applying

✓ ask any questions you might have

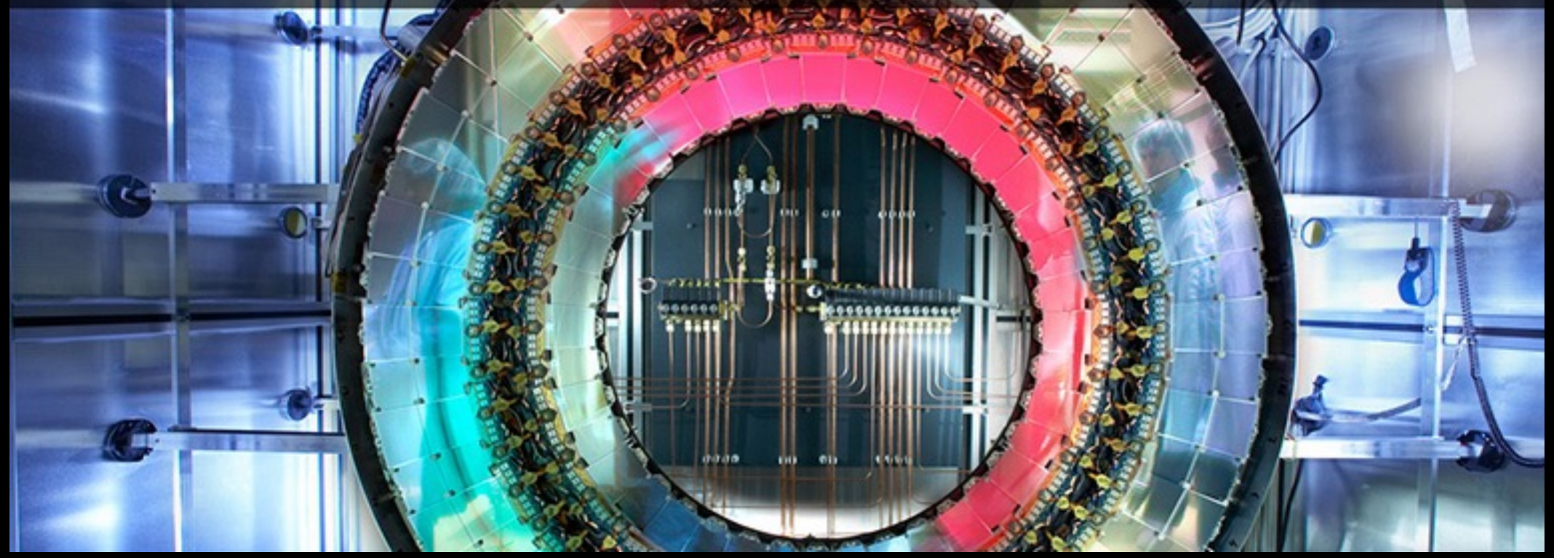
Next deadline for CSC applications to QMUL is 27th January 2021

Queen Mary
University of London

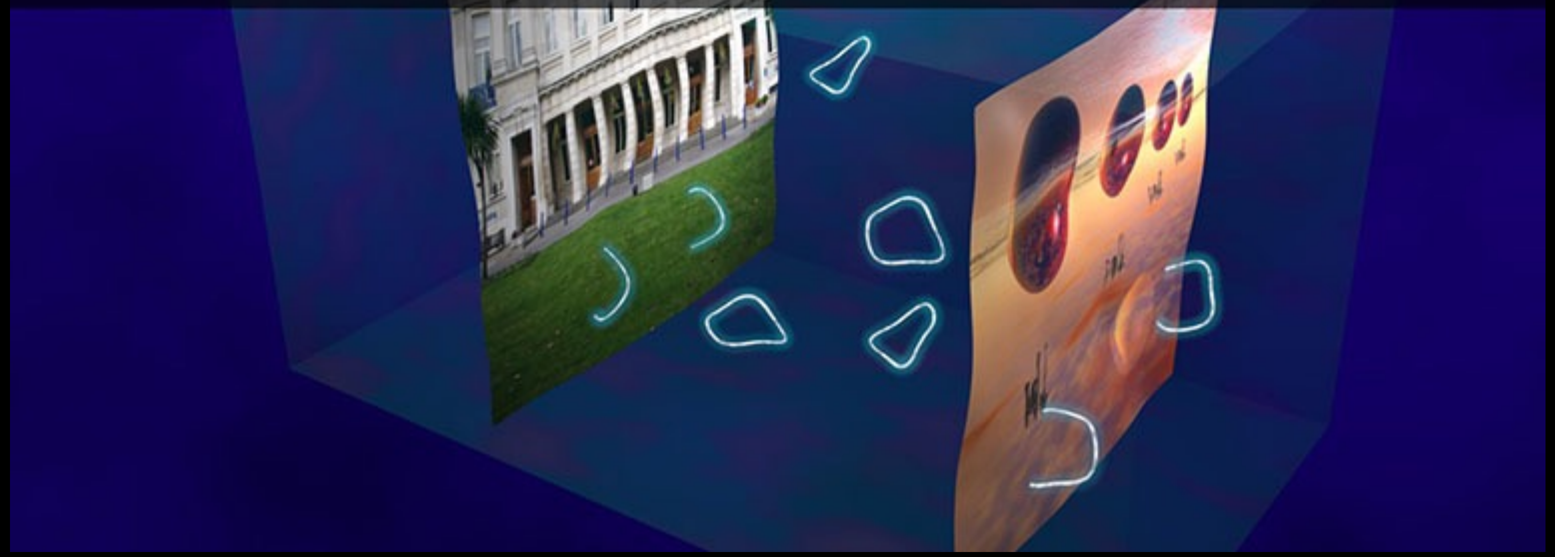
Centre for Condensed Matter & Materials



Particle Physics Research Centre



Centre for Research in String Theory

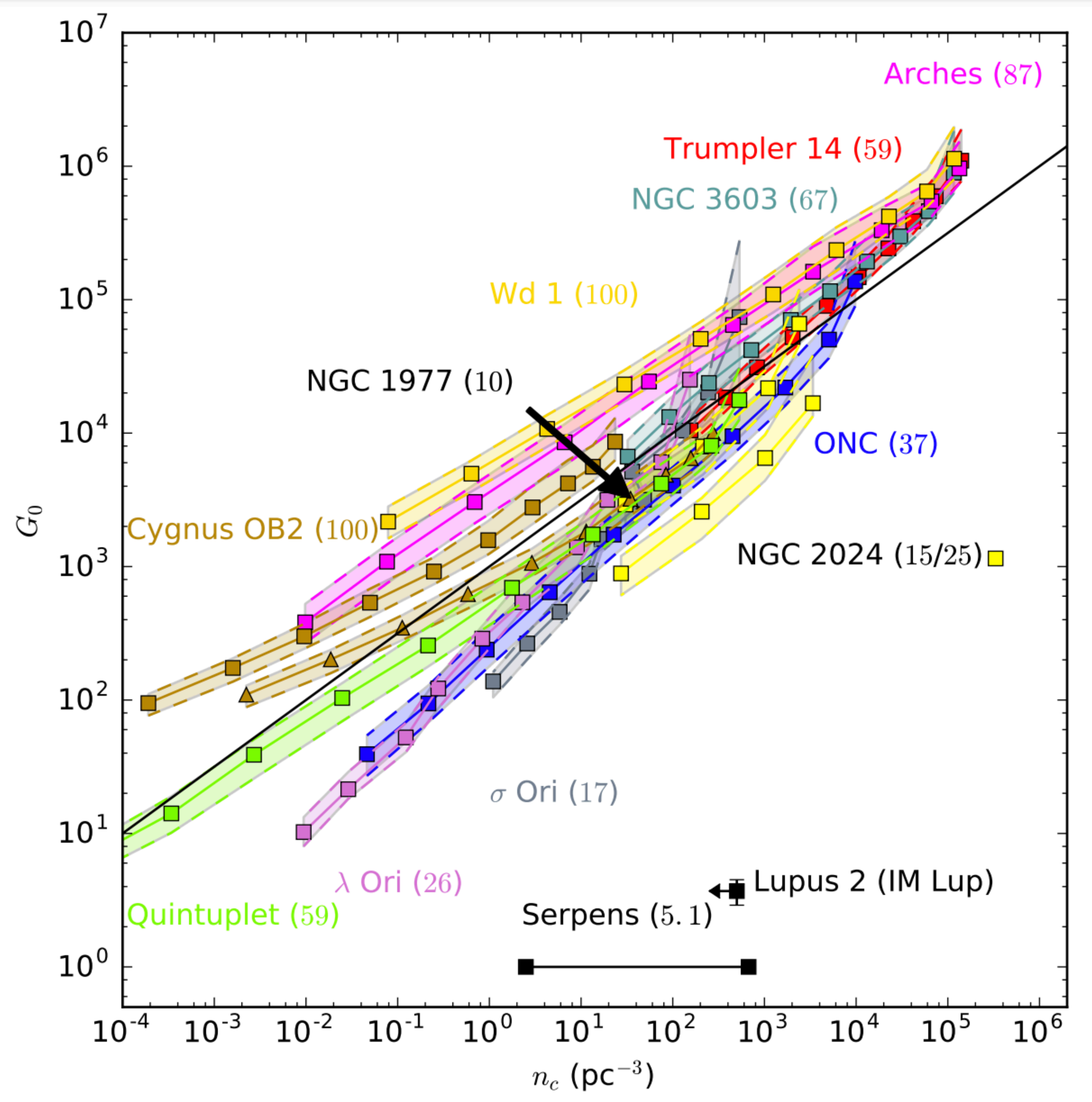


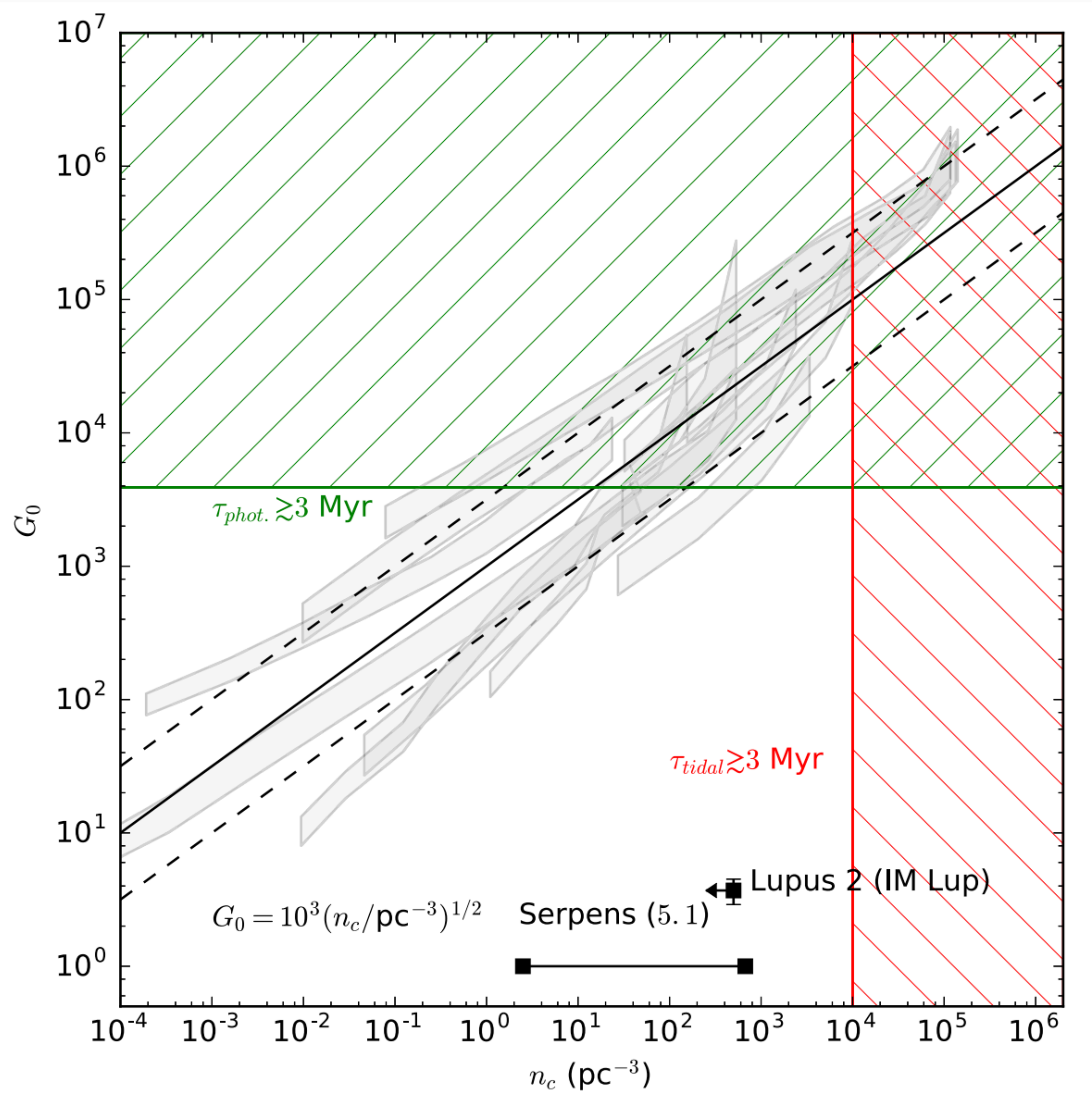
Astronomy Unit

Illustrious history of world leading research, students & staff

- Sir Prof Peter Mansfield - graduated 1974 - nobel laureate for development of MRI in 2003
- Sir Prof Josef Rotblatt (FRS) - professor of physics
  campaigned against nuclear arms and awarded Nobel prize 1995
- Involved in the discovery of the Higgs boson at CERN
  2013 nobel prize for Higgs/Englert's prediction
- String Theory was born at Queen Mary in 1980s

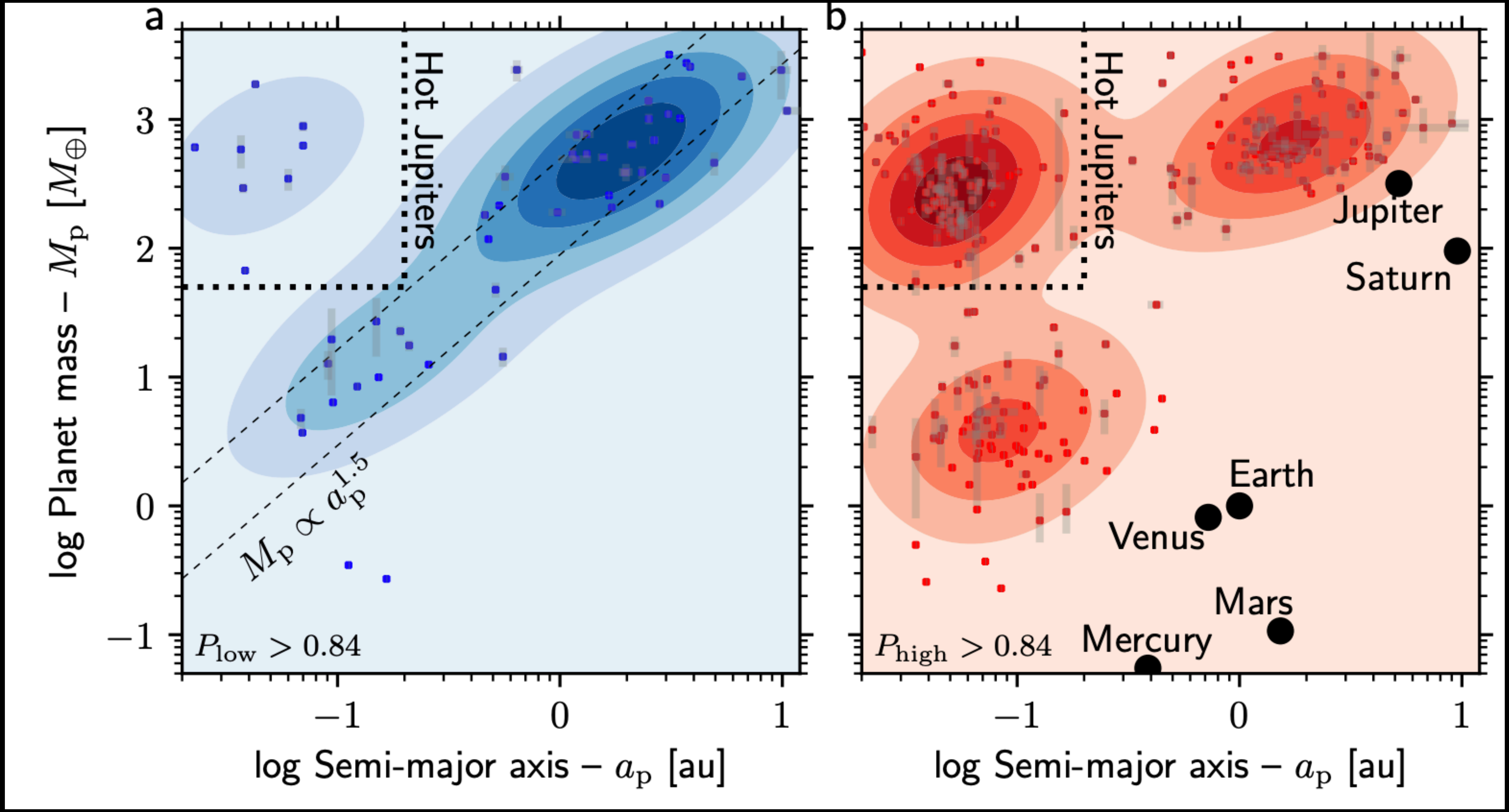
Encounters vs external photoevaporation





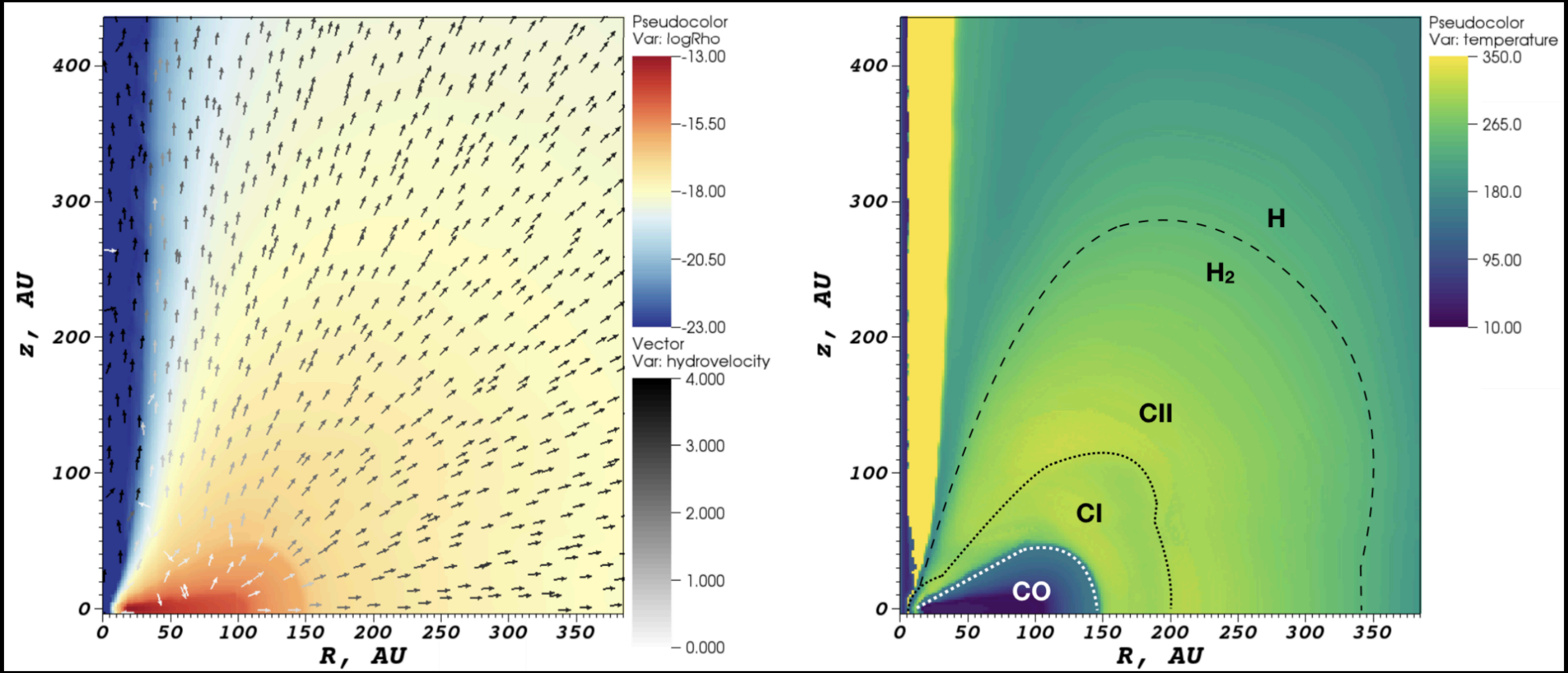
Winter et al. (2018)

Evidence for planet sensitivity to environment



Winter et al. (2020)

More on models



Haworth & Clarke (2019)

Questions

What was important for the evolution most protoplanetary discs, gravitational encounters or external photoevaporation (or neither)?

Across what range of UV fields is external photoevaporation important?

Do the resulting planets actually care about environmental effects, or is it just the disc?