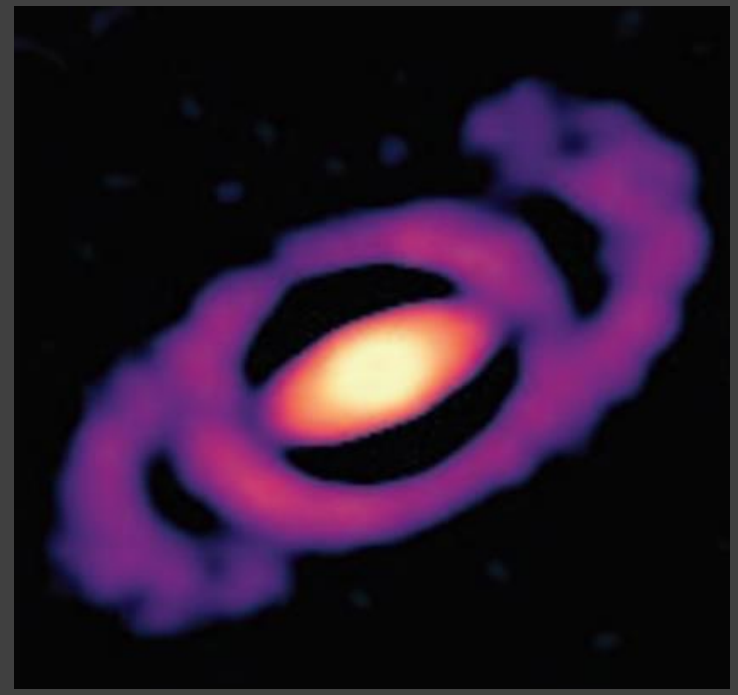
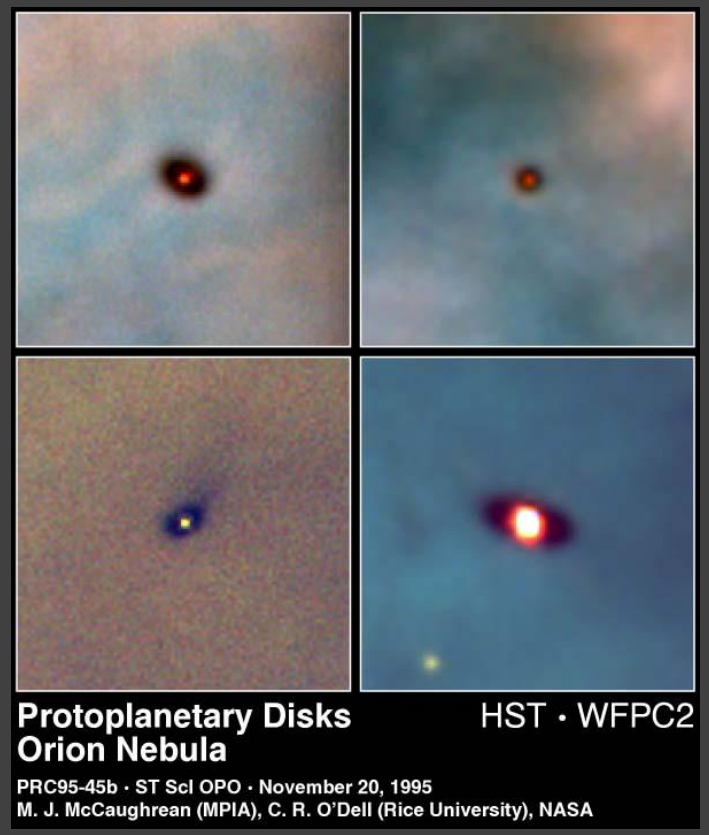
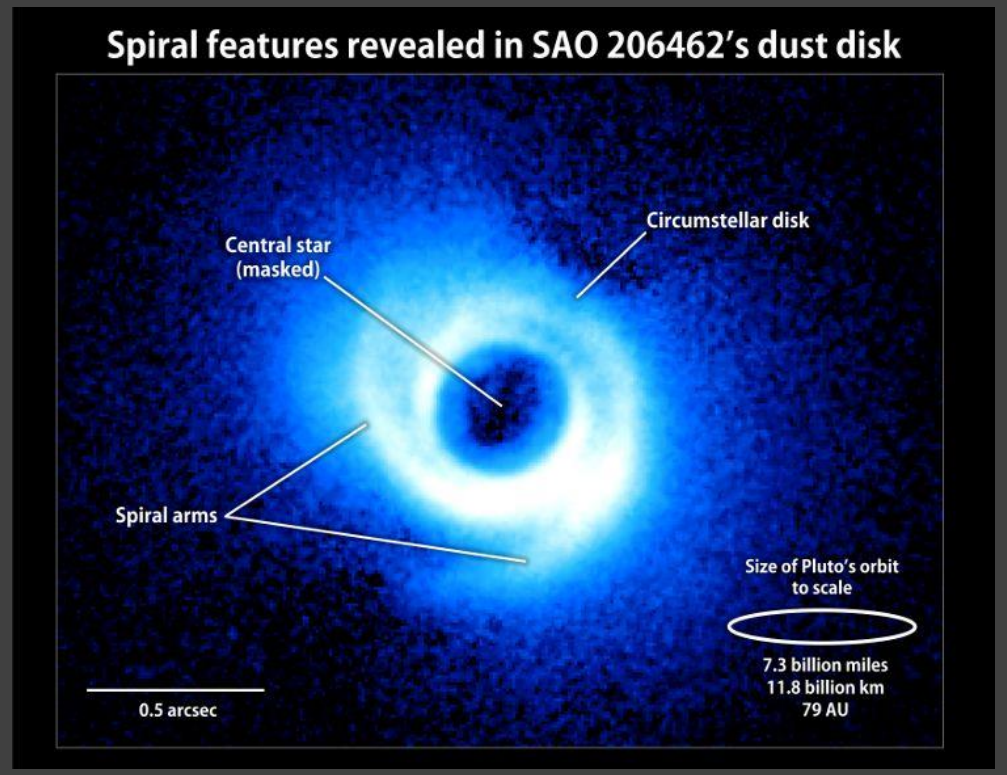


Young planetary systems

SERGEI POPOV

Protoplanetary discs





https://online.science.psu.edu/astro140_sp201314wd001/node/7717
http://news.softpedia.com/news/Exoplanets-Can-Form-Spiral-in-Stellar-Protoplanetary-Disks-228792.shtml

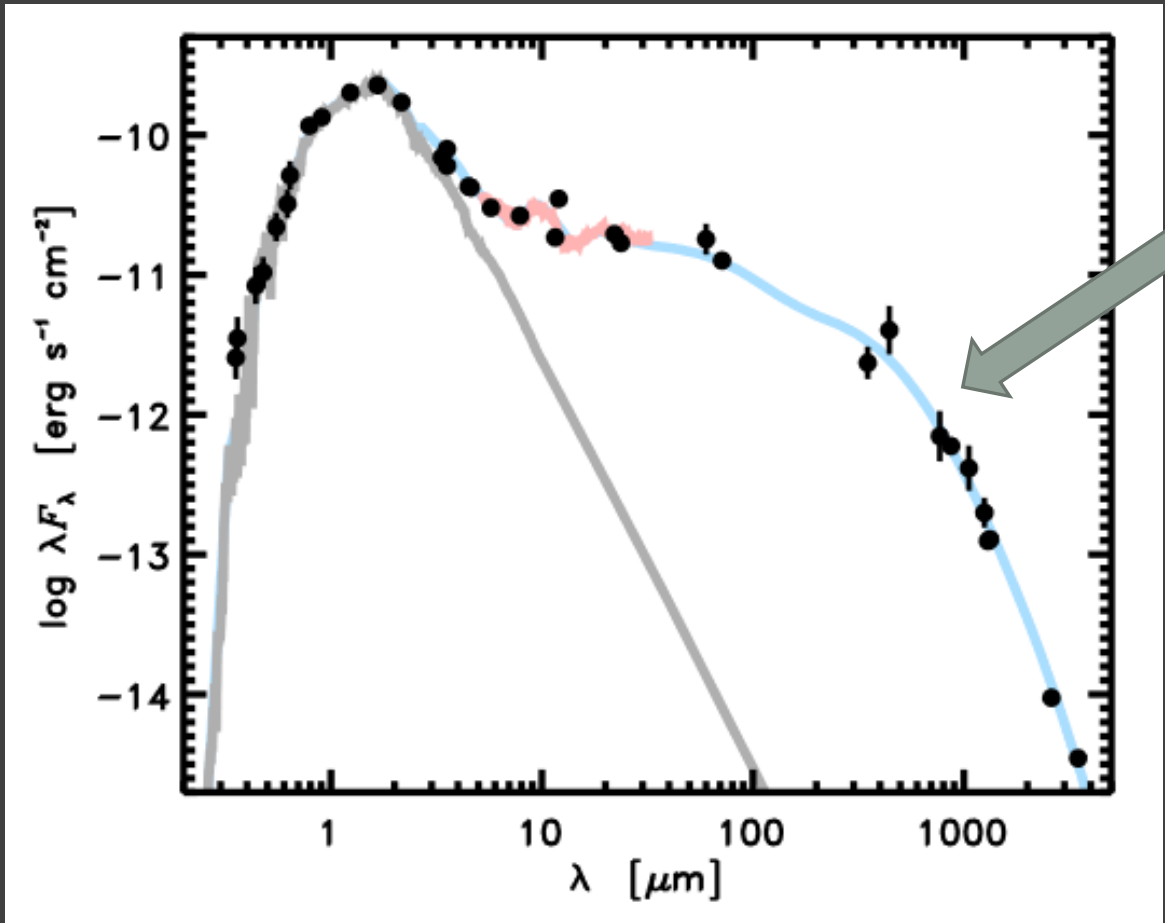
Dusty discs

HST observations

Disc is visible edge-on.

1507.04758

Discs and stars

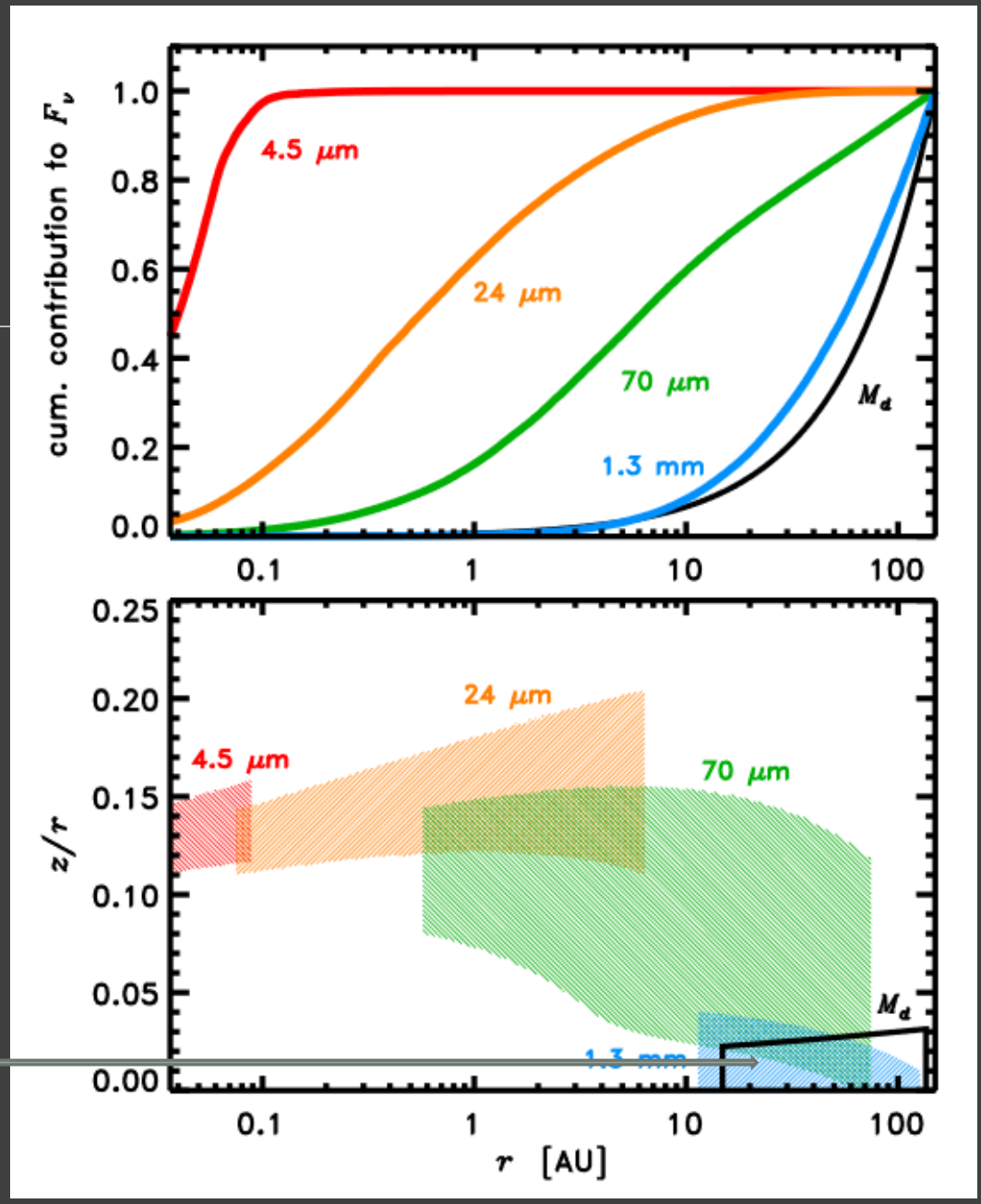


Optically thin disc.
Allows to determine dust mass.

1507.04758

Dust in the disc

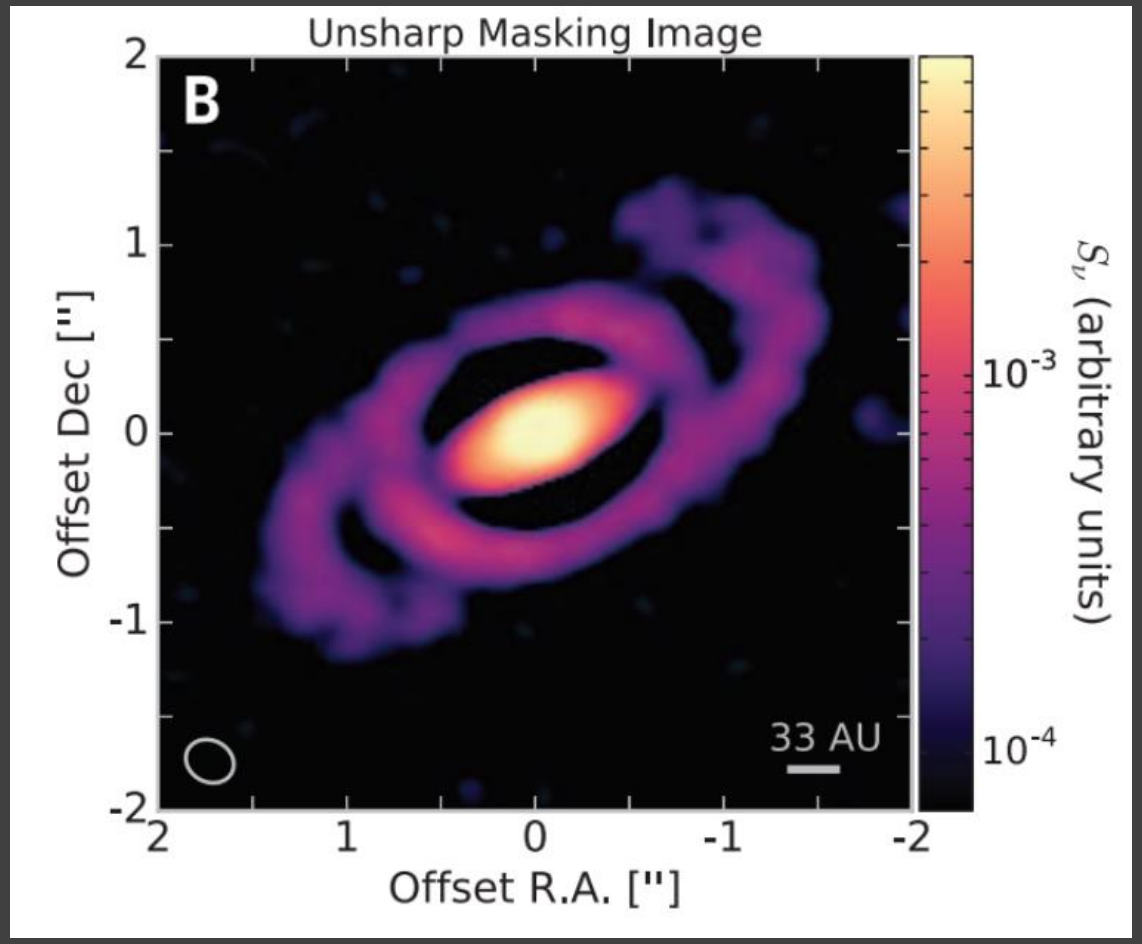
Observations in different wavelengths allow to probe different parts of the disc and determine dust mass and distribution.



80% of dust

1507.04758

Disc around Elias 2-27



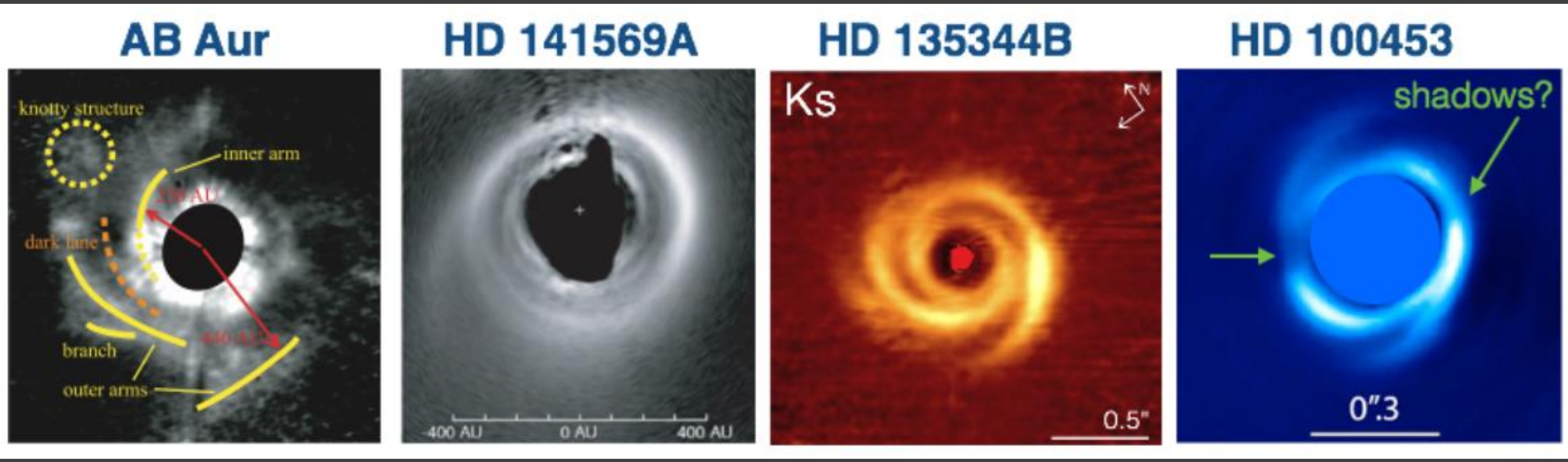
Spiral structure around Elias 2-27
Obtained by ALMA

The star has mass ~0.5 M_{solar},
but a very massive disc (>0.1M_{solar}) around.

It is important that at distance >10 AU
the disc is transparent for 1.3 mm emission.
So, the spiral patter is related to the matter
also in the disc midplane.

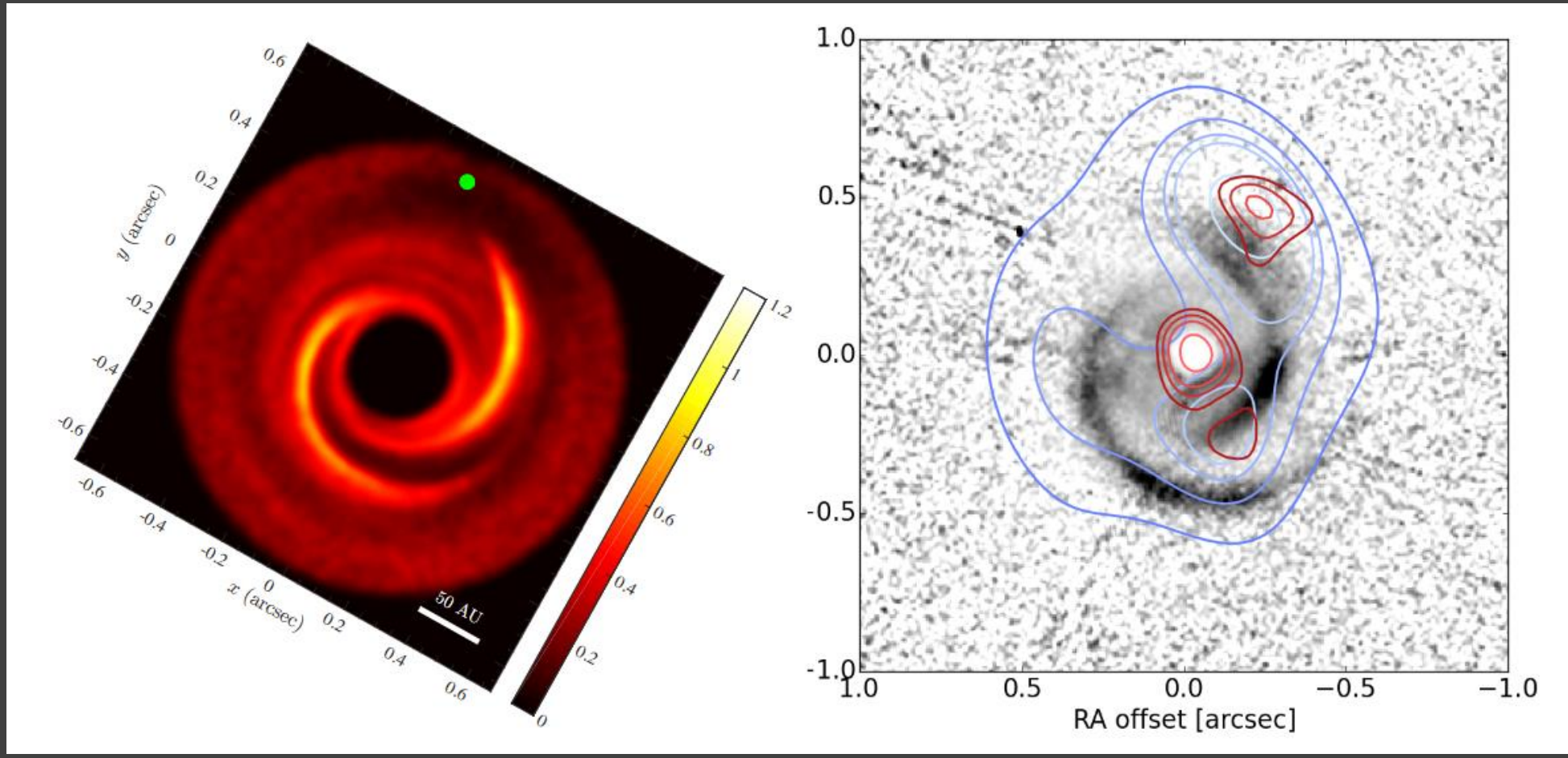
Perez et al. 2016 (1610.05139), taken from the review 1703.08560

Gallery of spirals



1602.06523

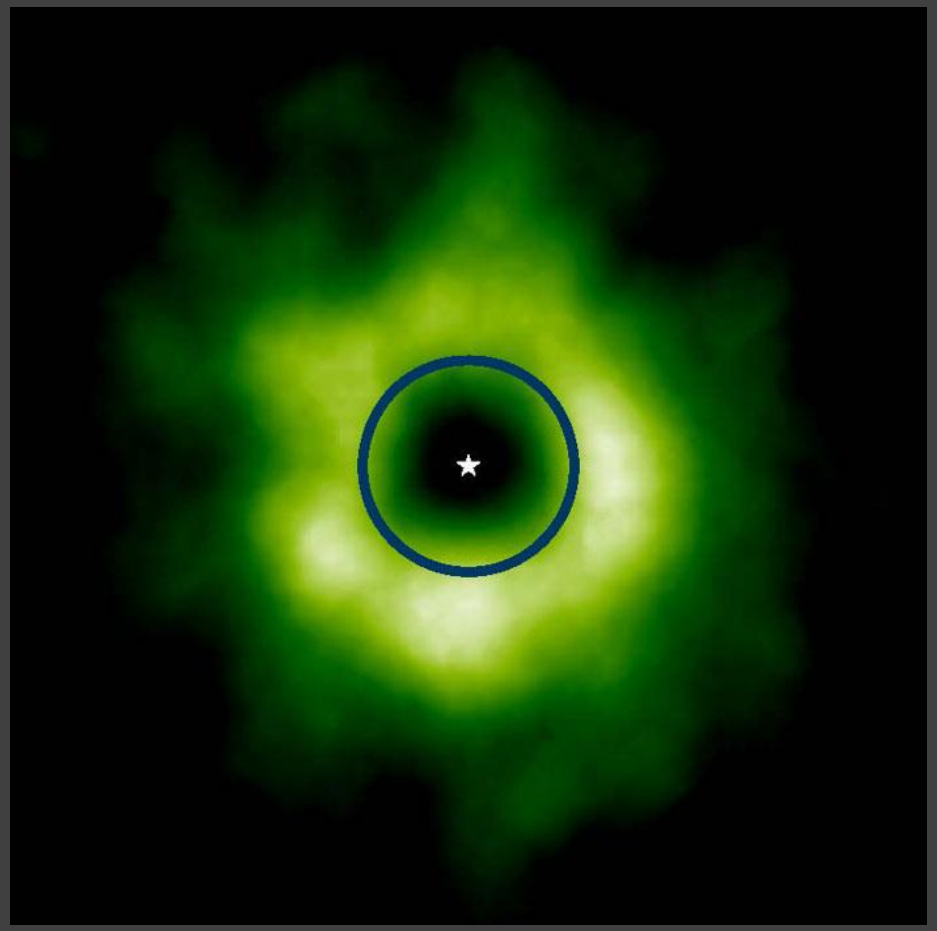
Spirals: model and observations

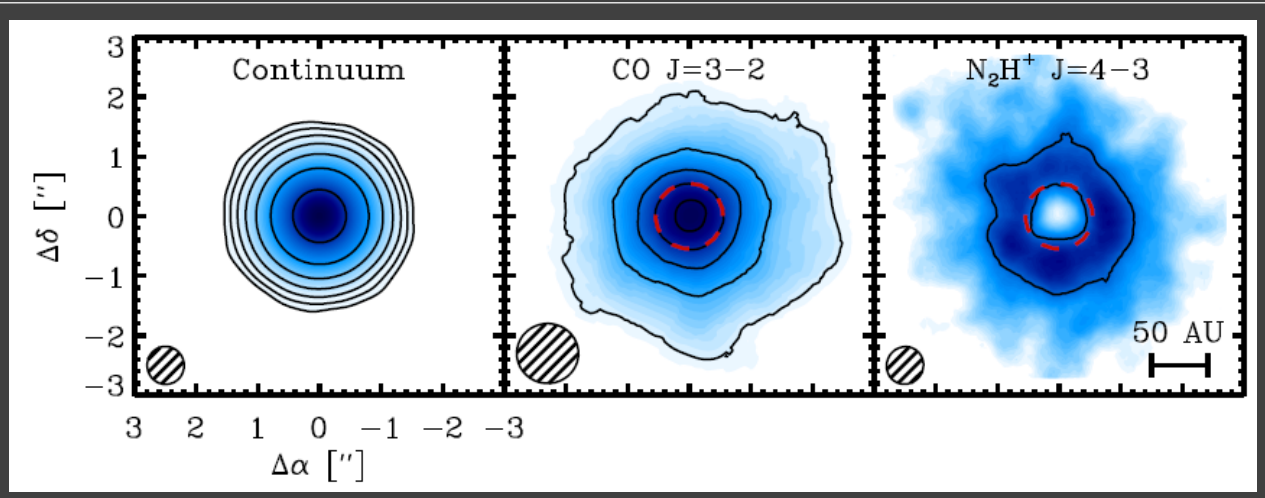


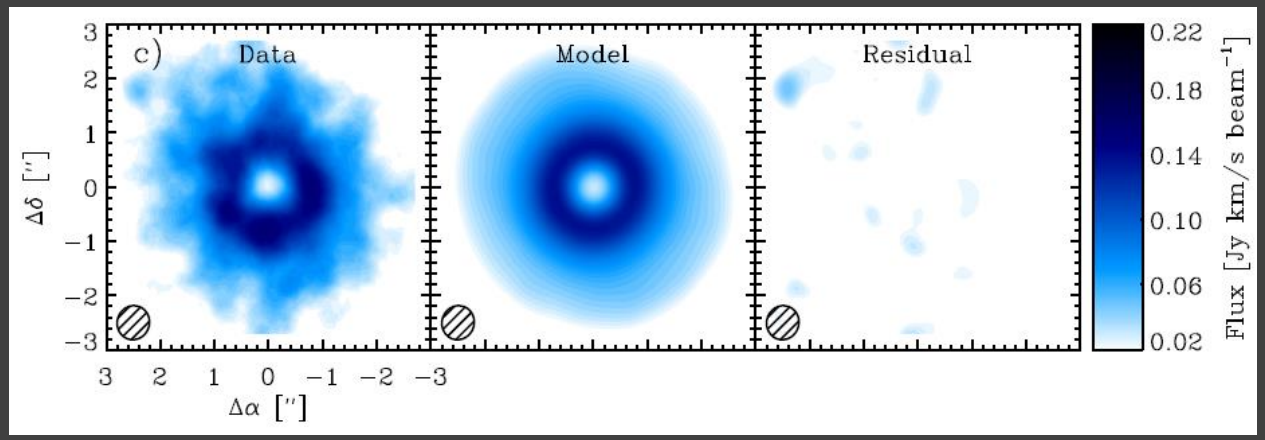
1602.06523

TW Hydra

N_2H^+ visible only if CO is frozen out

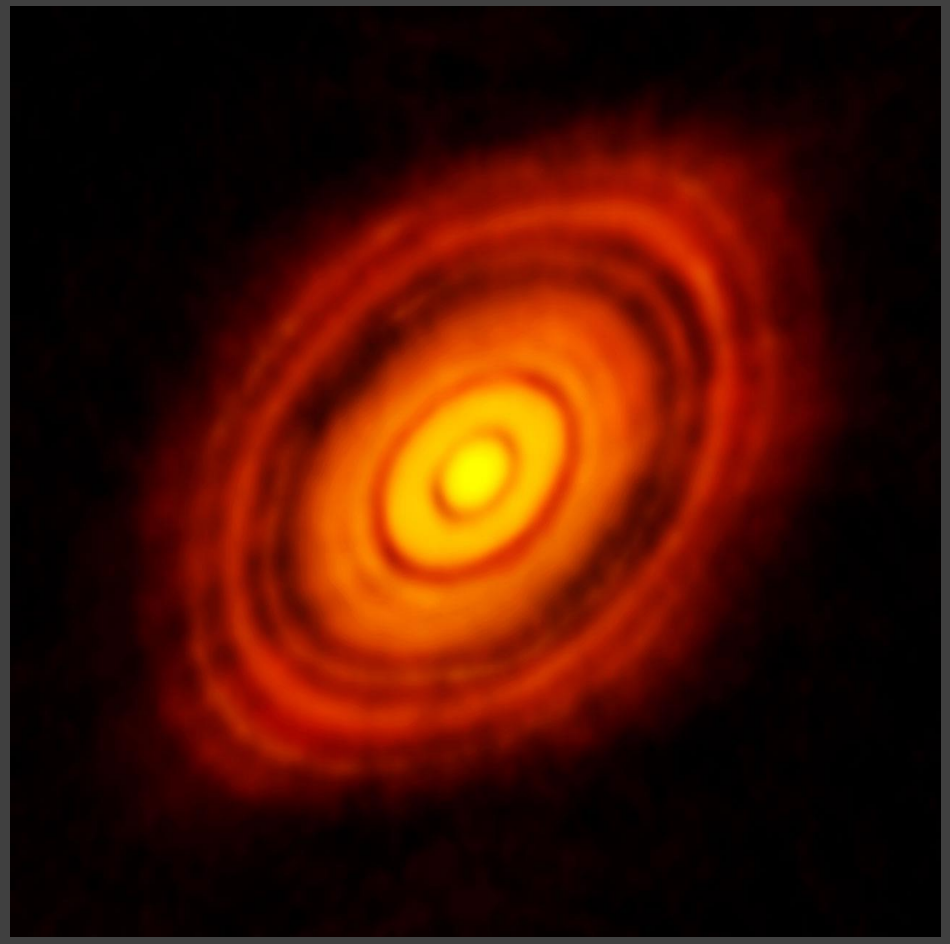


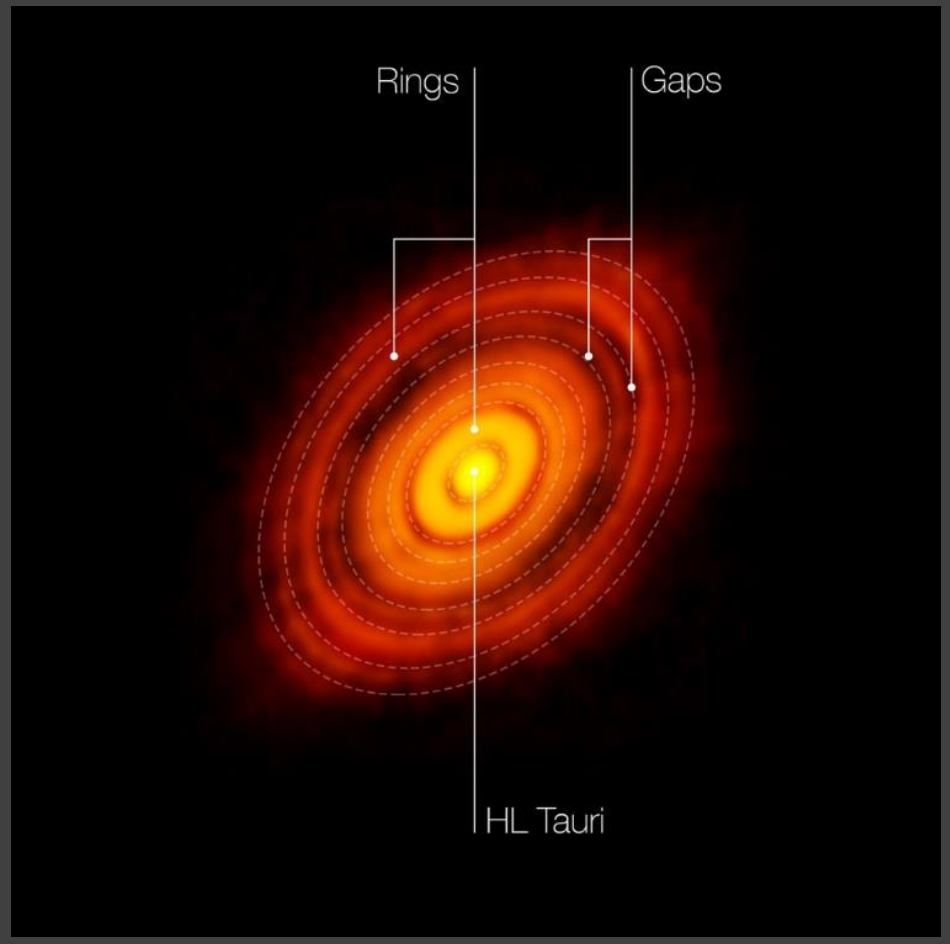




1307.7439

Protoplanetary disc of HL Tau

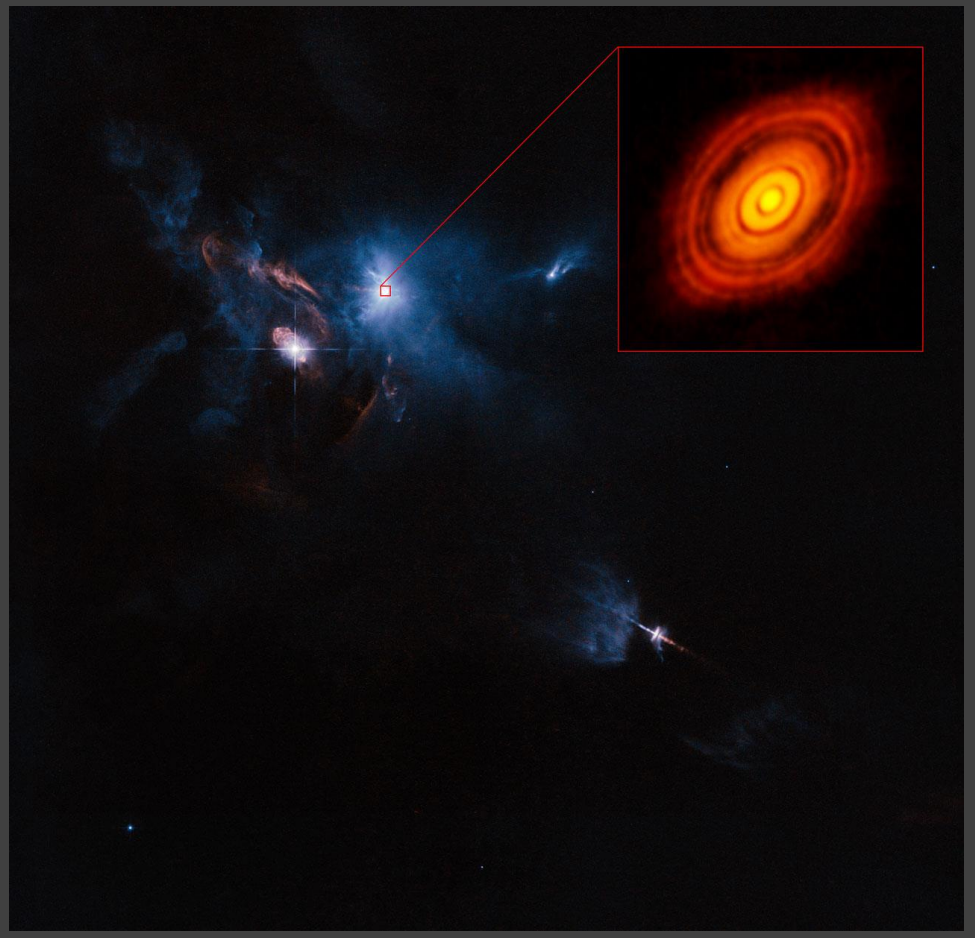




140 pc
Massive disc
Jet
Age <1-2 Myrs

http://www.eso.org/public/images/eso1436a/

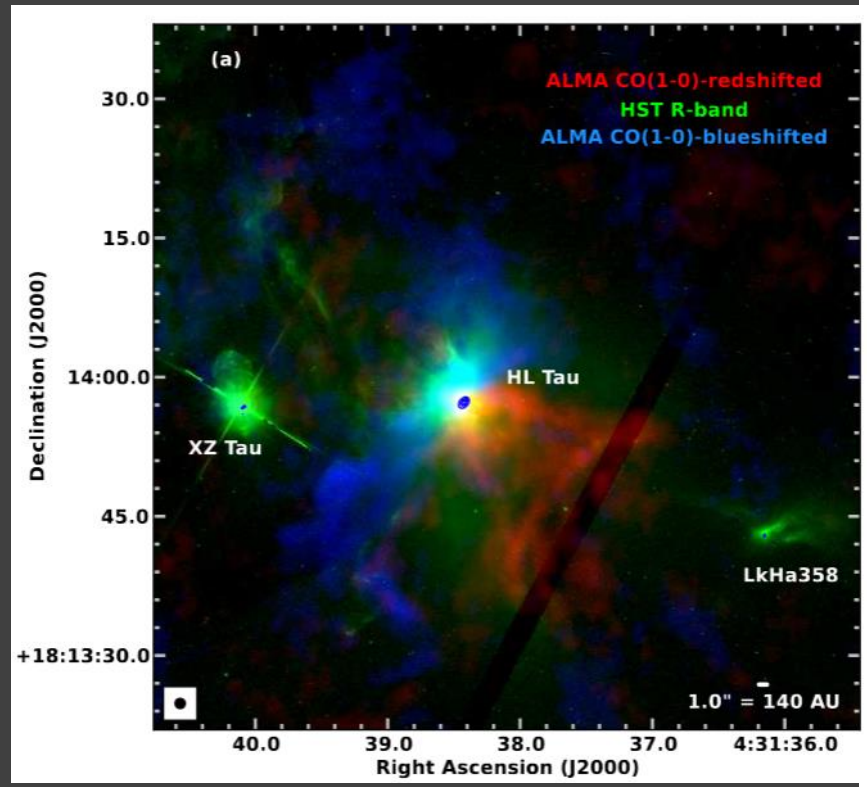
Where stars are born

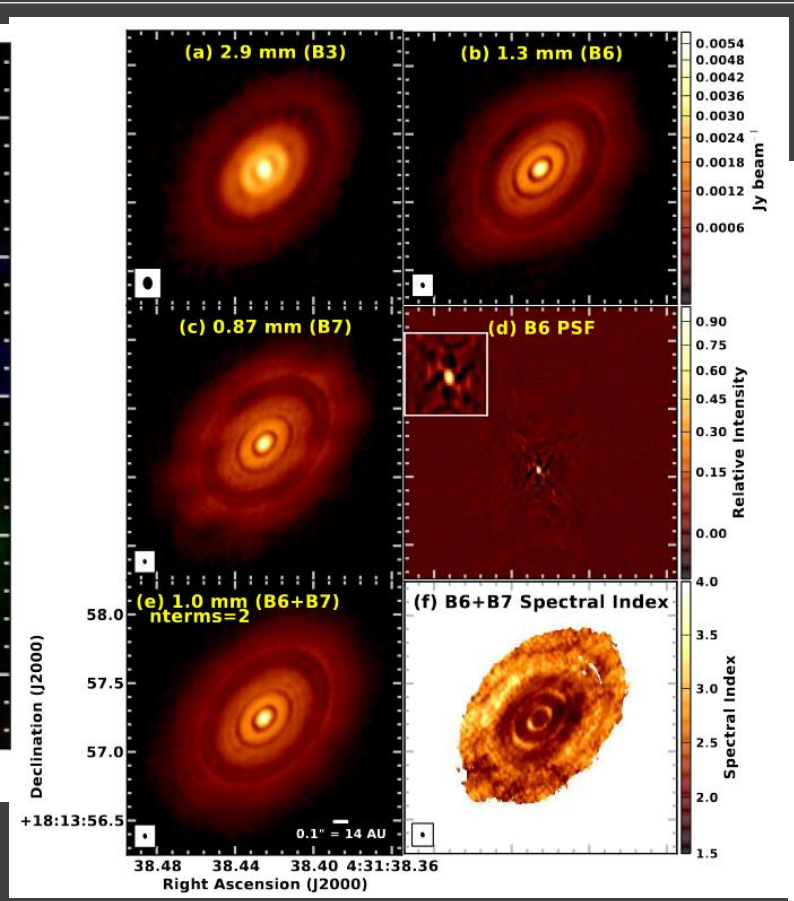


http://www.eso.org/public/images/eso1436b/

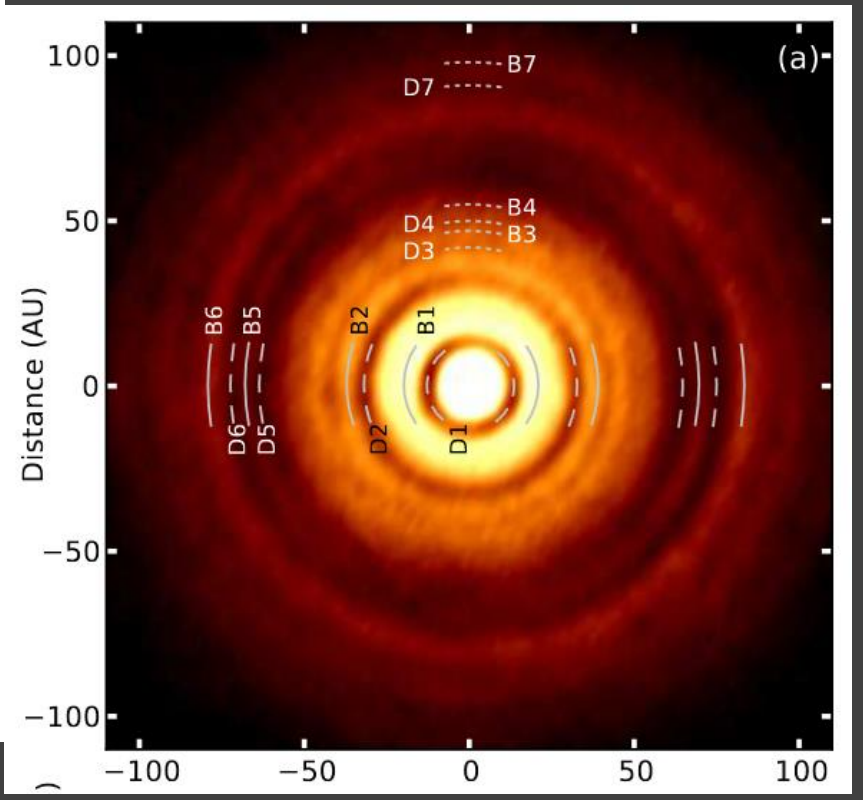
https://public.nrao.edu/AlmaExtras/

More details on the disc of HL Tau



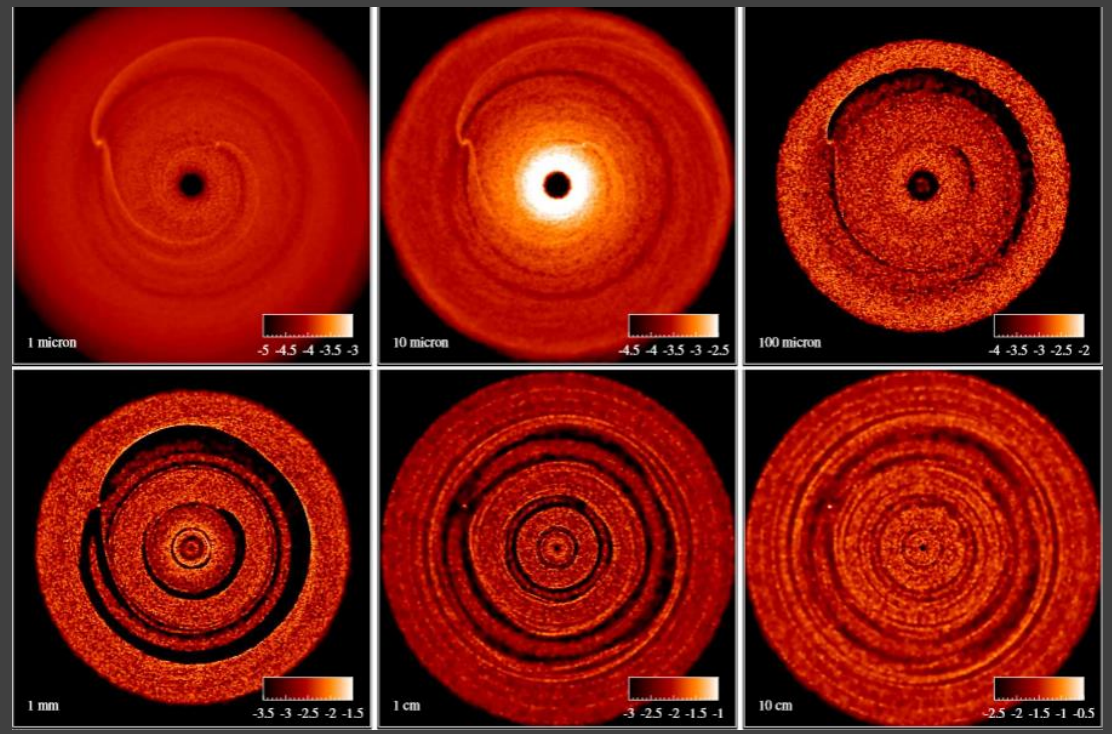


Some rings are in resonance with each other.

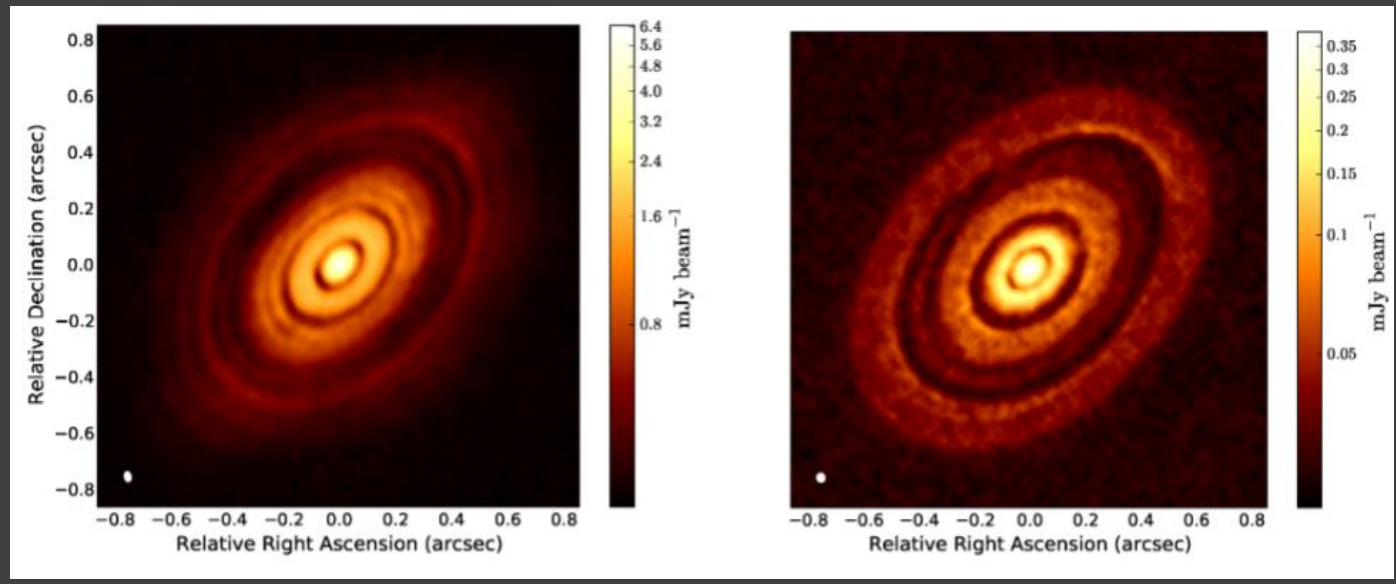


1503.02649

Modeling of the HL Tau disc



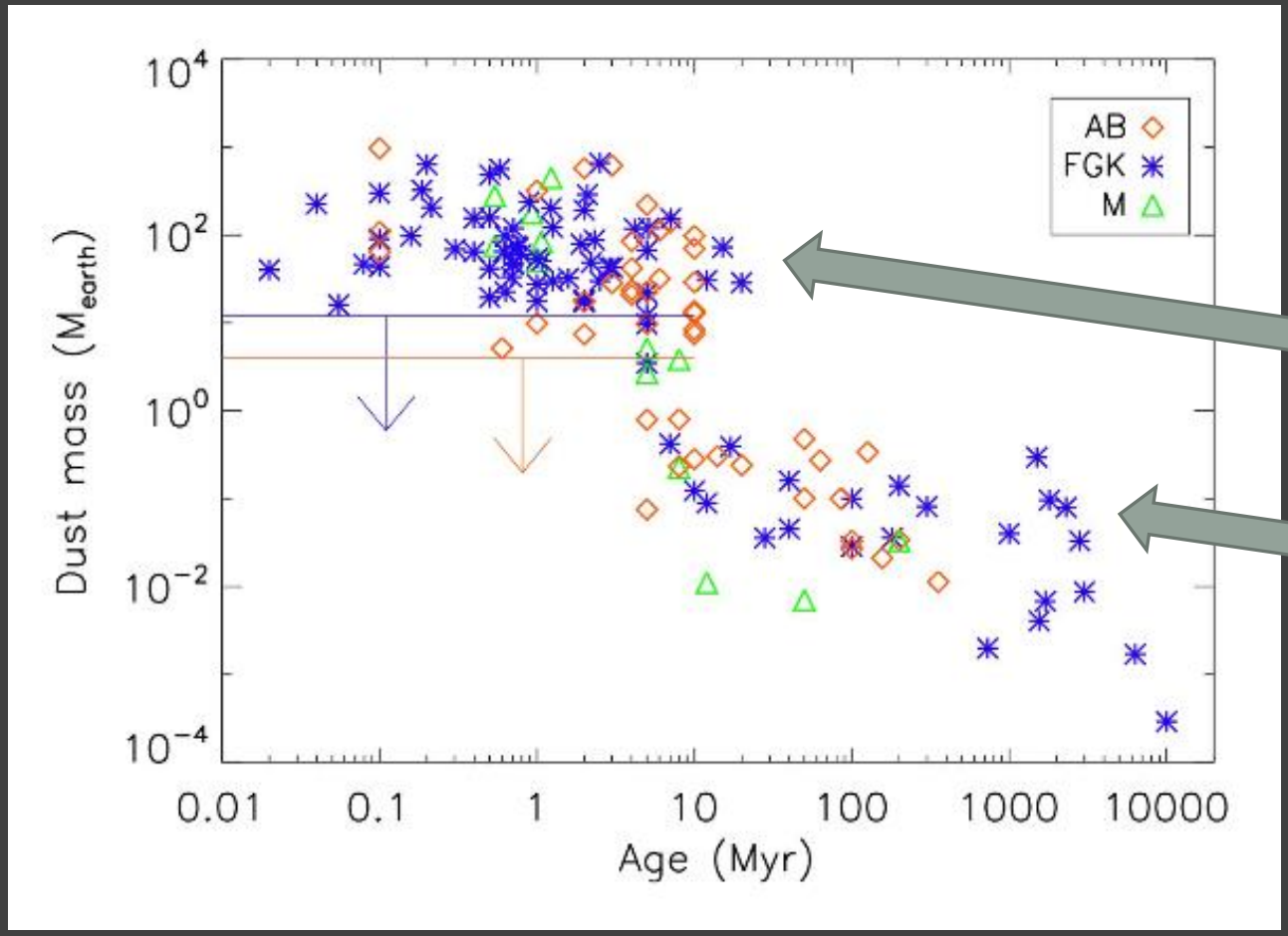
Three planets with masses from 0.2 up to 0.55 Jupiter mass



Observations Modeling

1507.06719

Evolution of the dust mass in discs

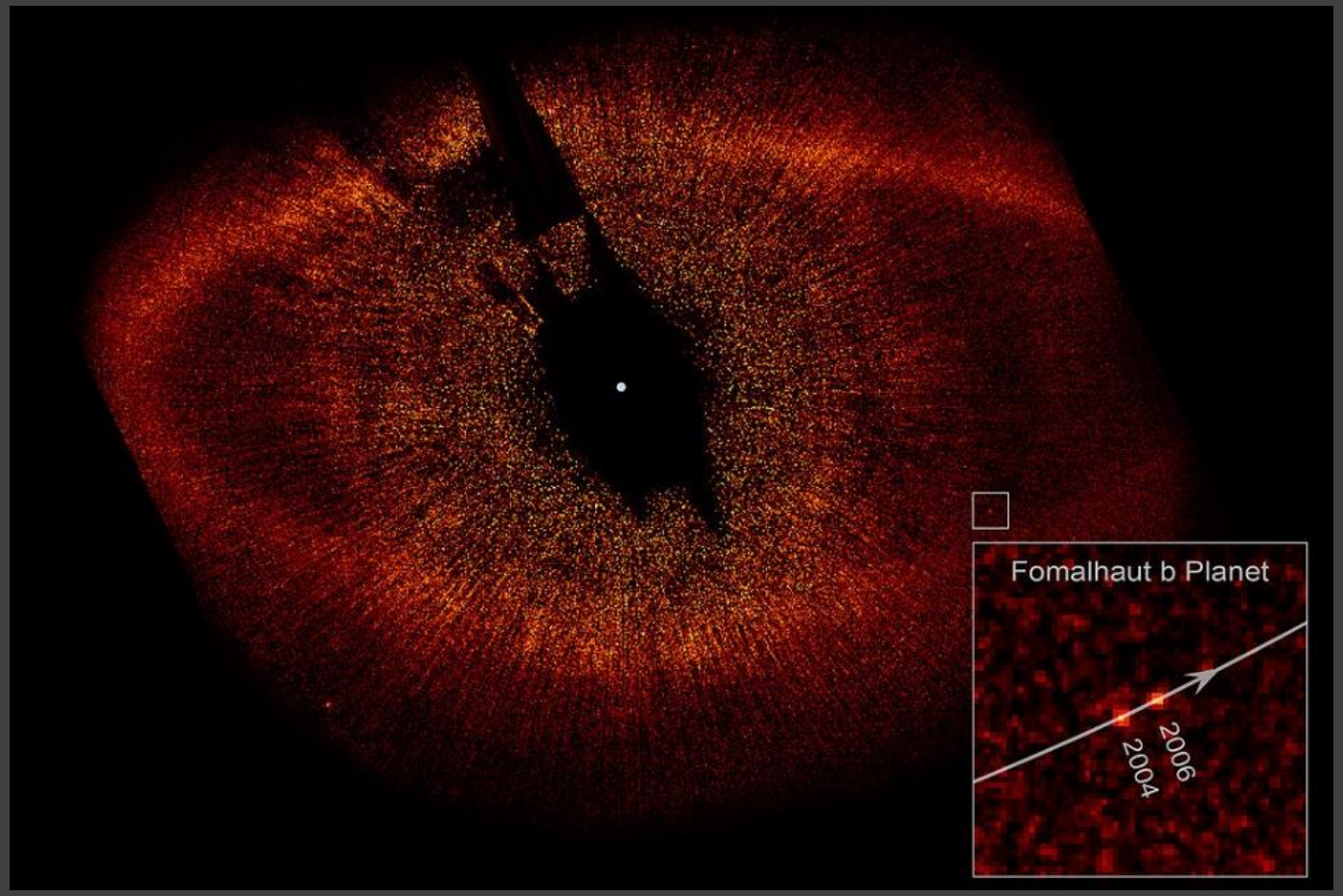


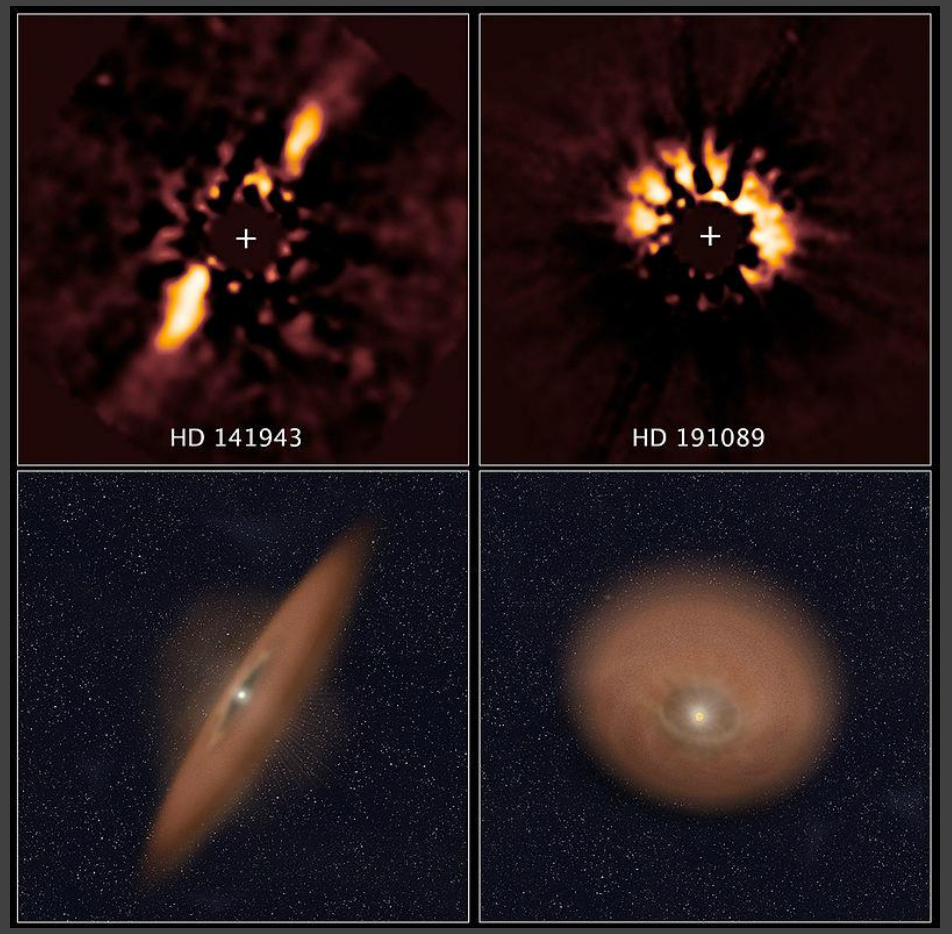
Protoplanetary discs

Debris discs

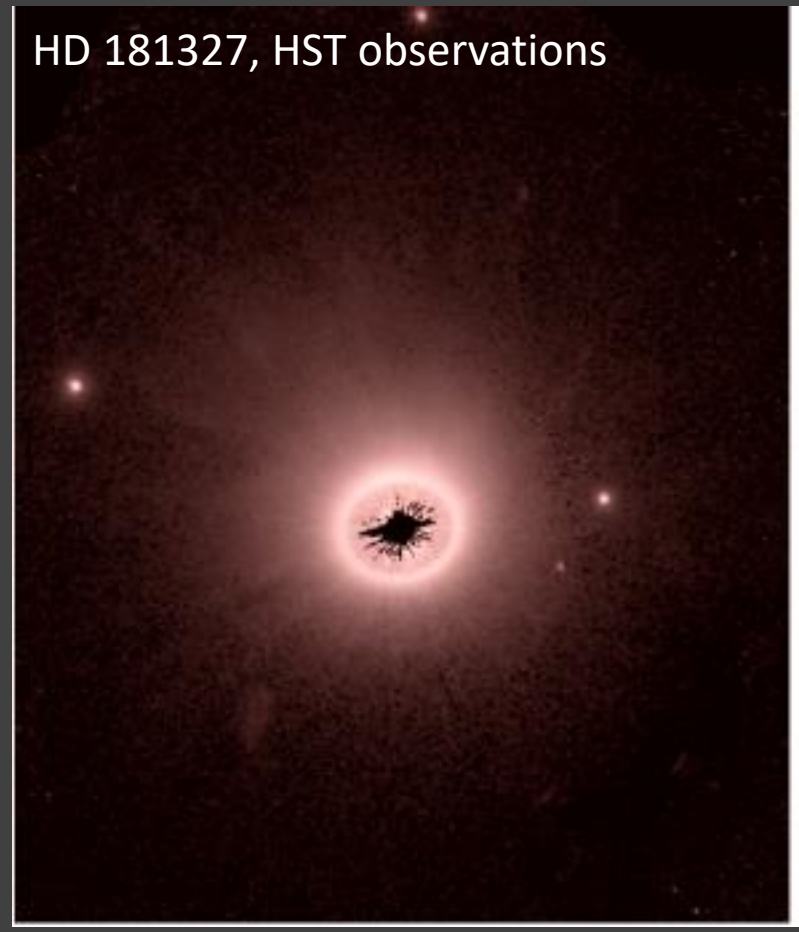
Panic et al. 2013, taken from the review 1703.08560

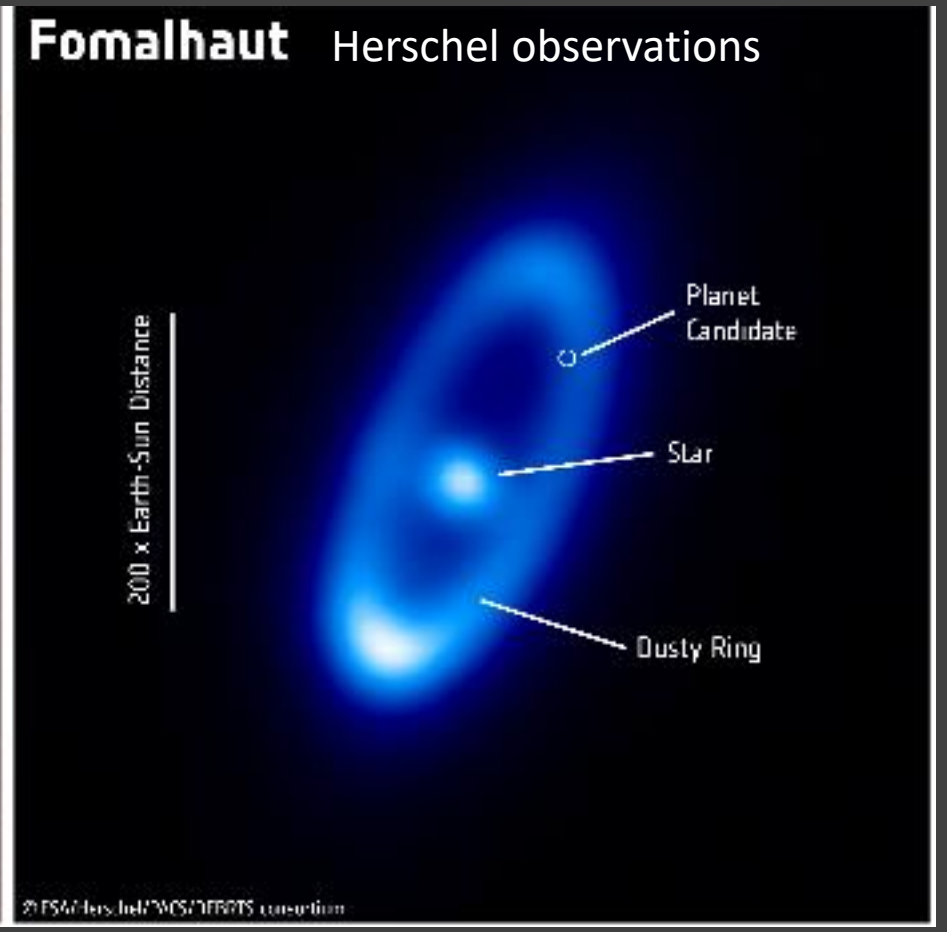
Debris discs





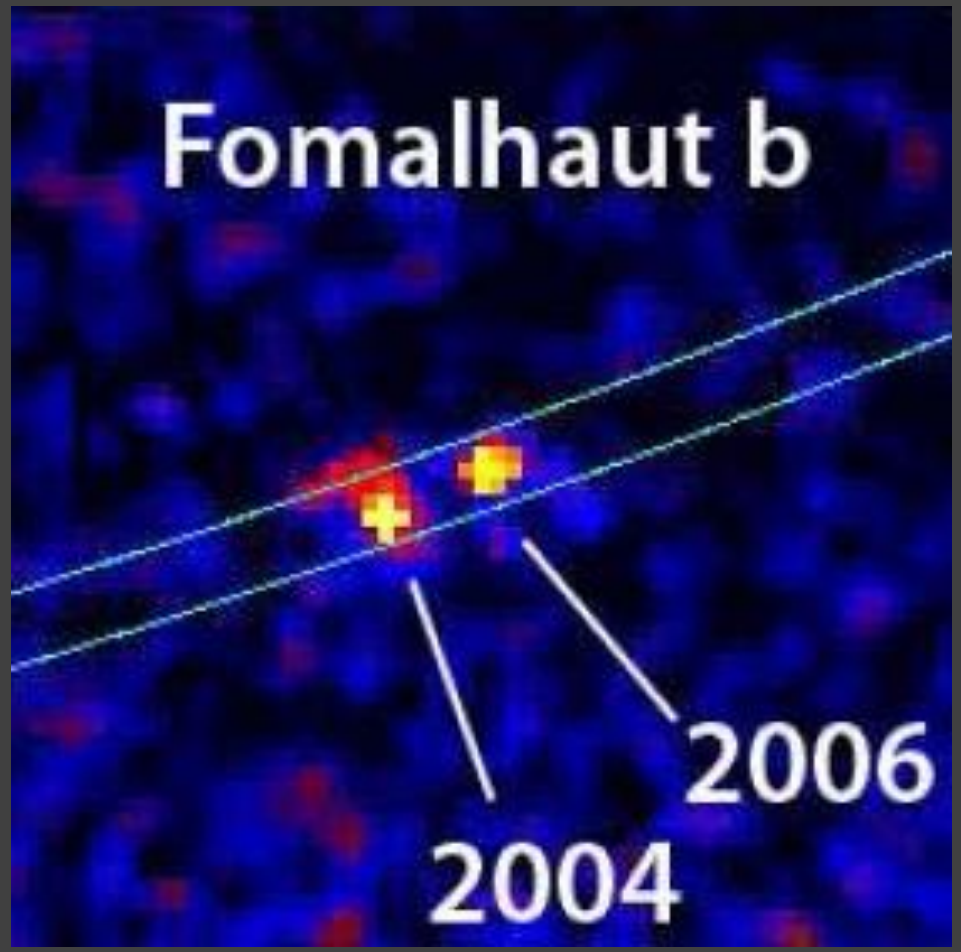
Two debris disc examples





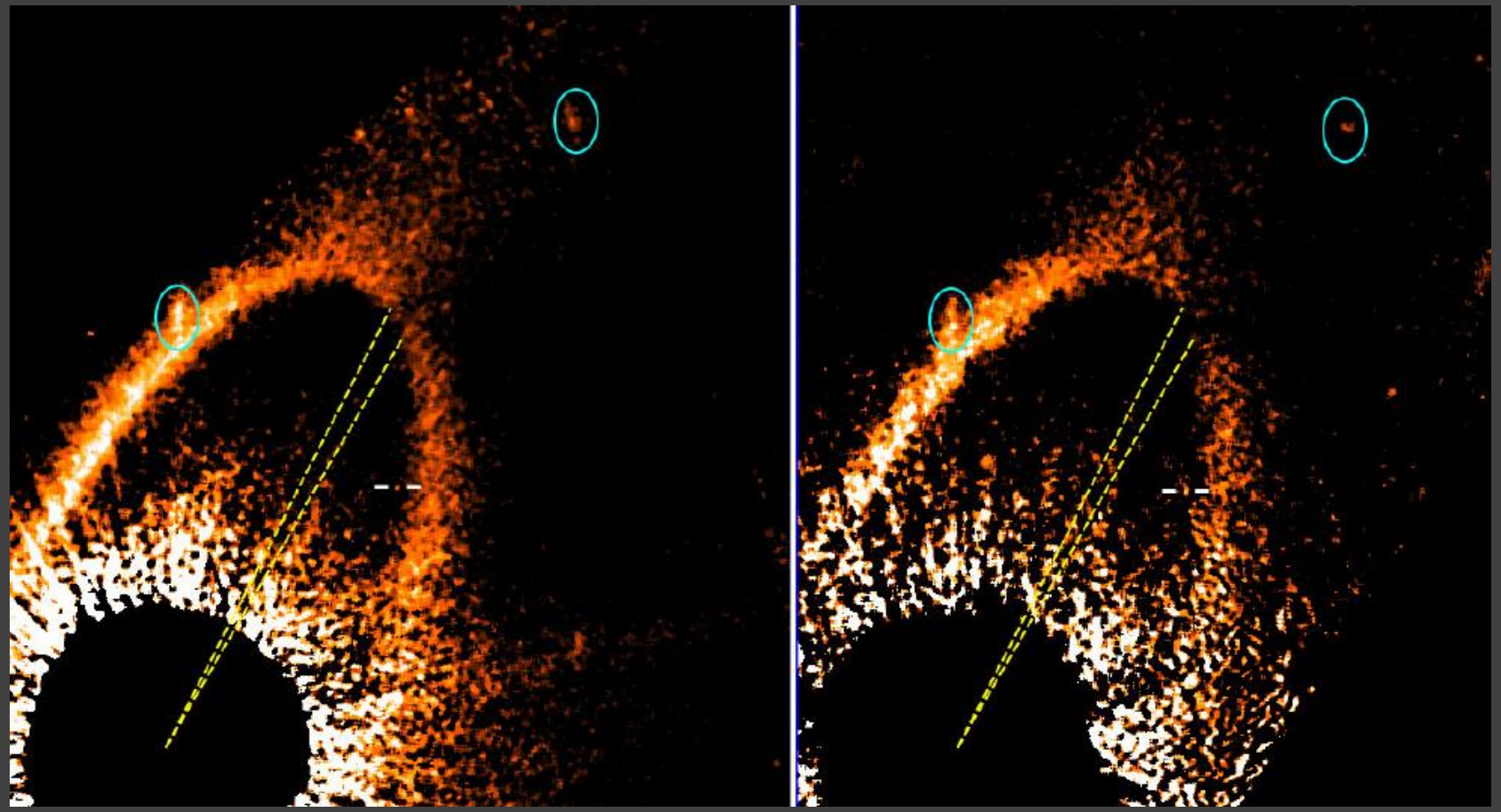
taken from the review 1703.08560

Fomalhaut b



115 AU from the star

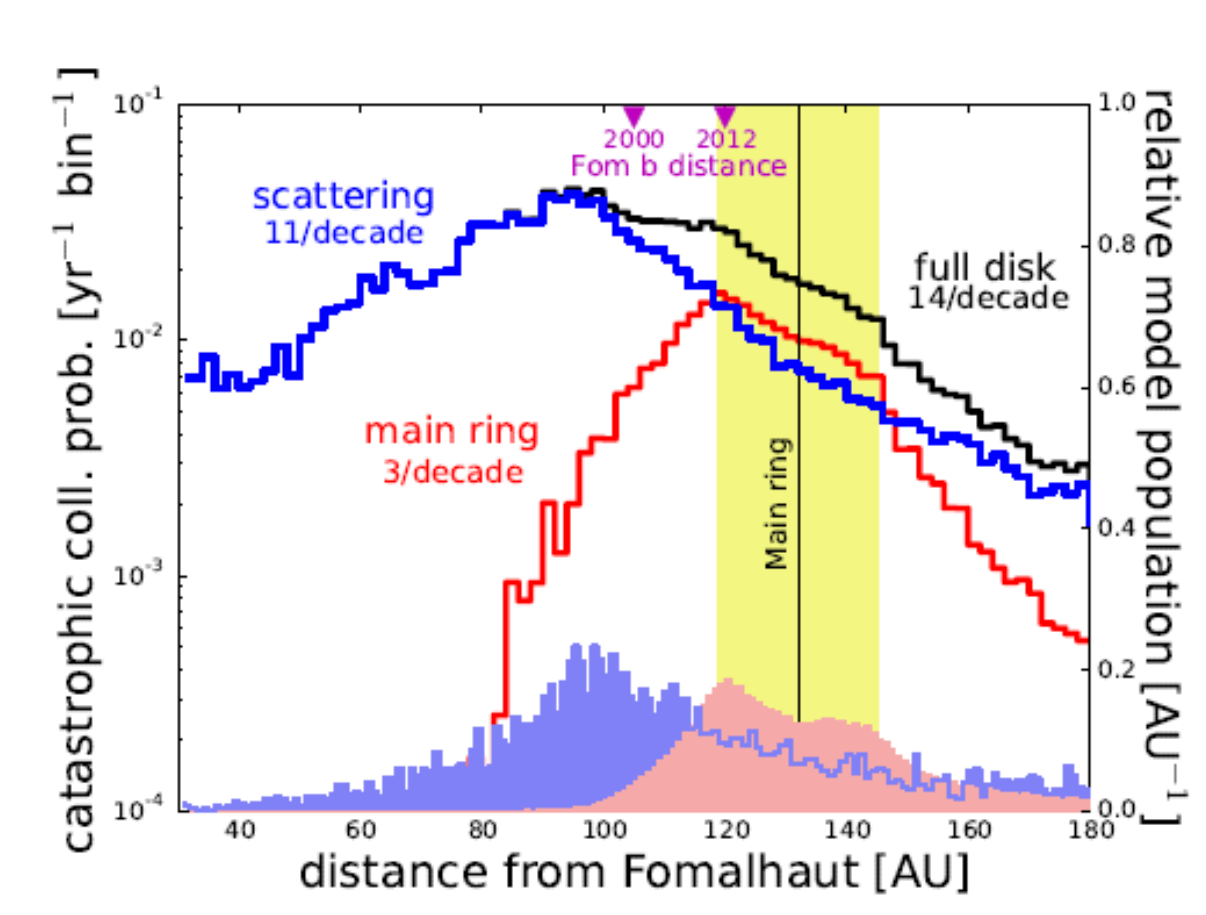
Is Fomalhaut b a real planet?



A planet or not a planet?
This is the question!

1305.2222

Result of a recent collision?



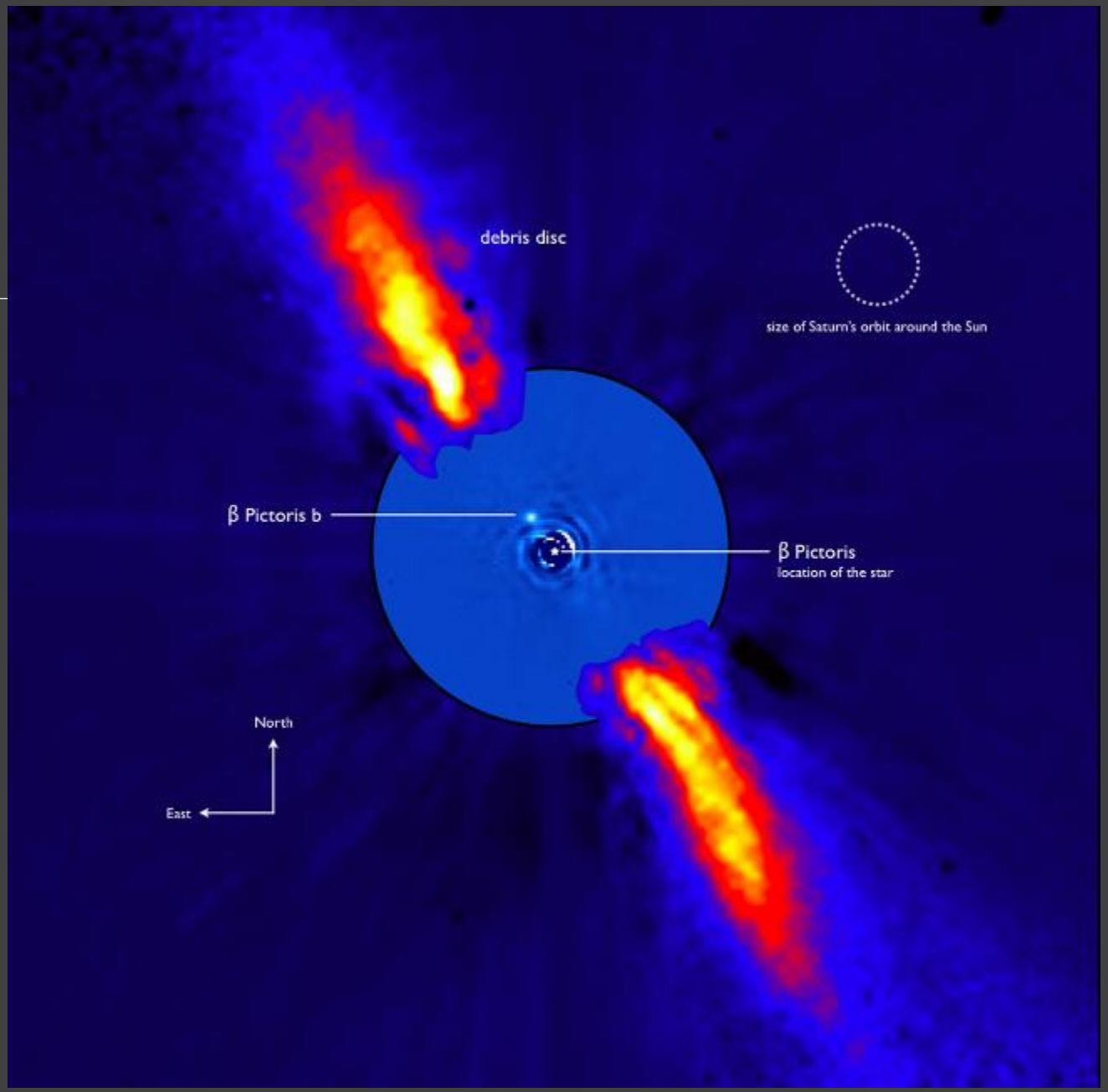
The object is situated in the region where collisions are very probable.

Two bodies with ~100 km size might be enough.

1412.1129

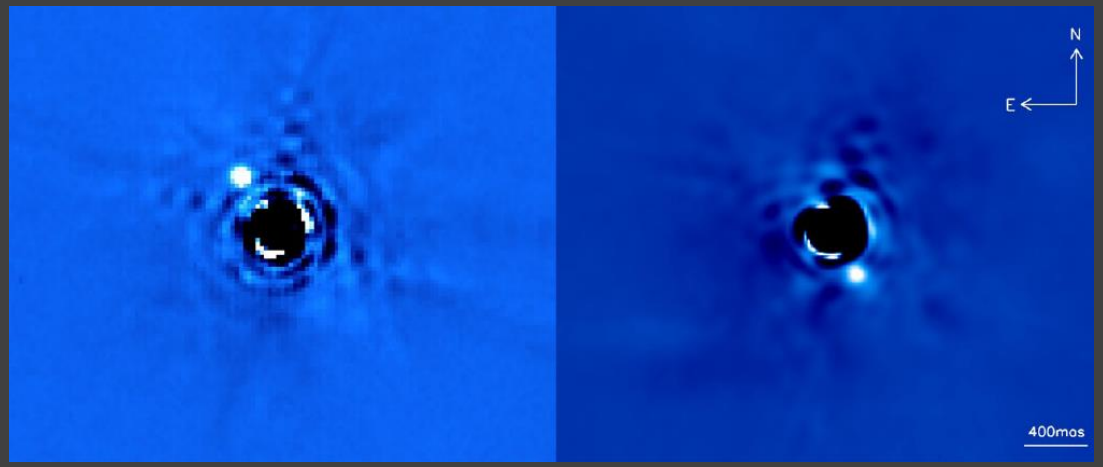
Beta Pictoris

Composite image obtained
by two instruments

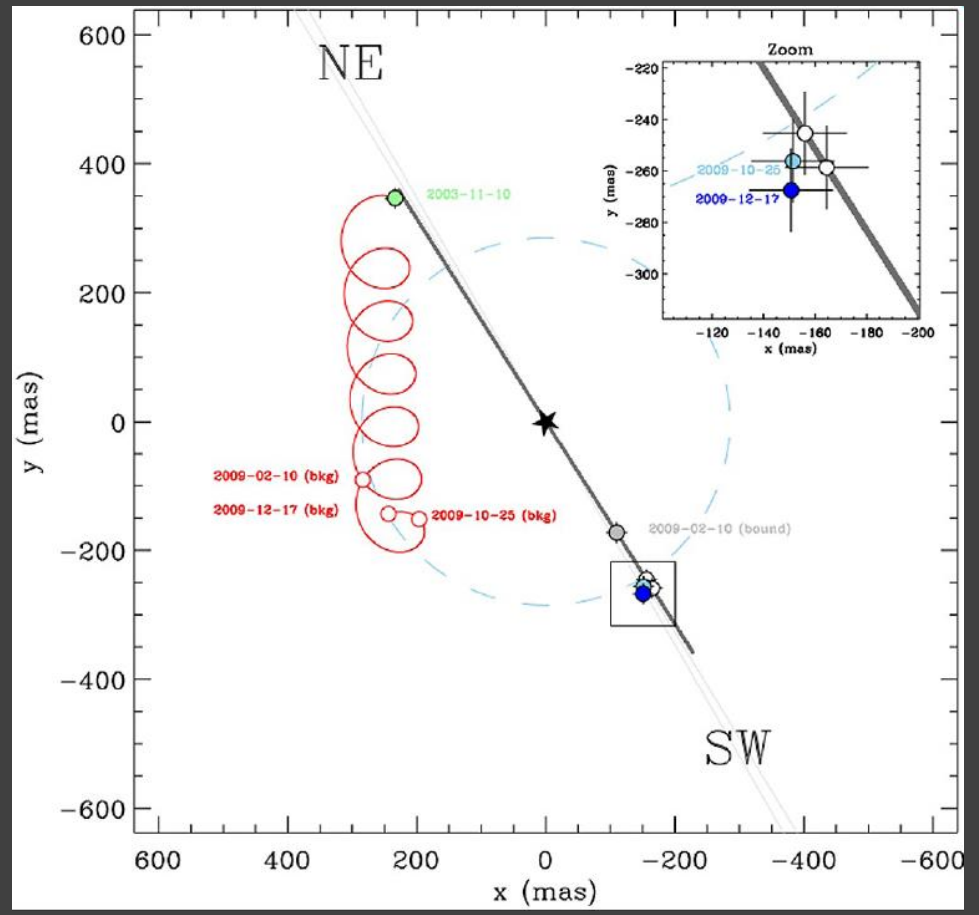


taken from the review 1703.08560

Beta Pictoris



Age ~10 Myr
Distance ~ 9 AU



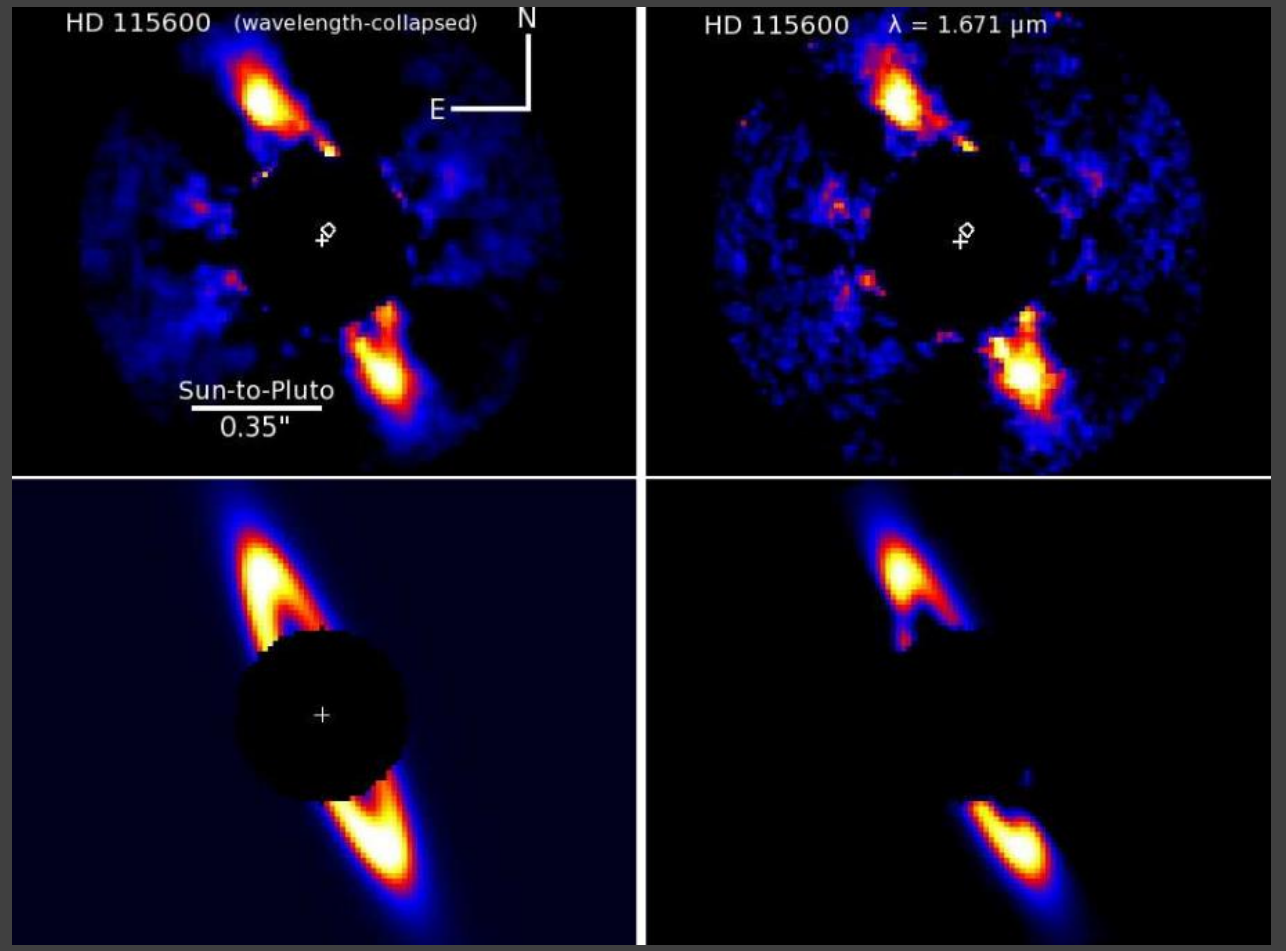
1006.3314

Young Kuiper belt-like debris disc

HD 115600
110 pc
15 Myrs
1.4 solar mass star

Gemini planet imager

Size of the disc 48 AU



1505.06734

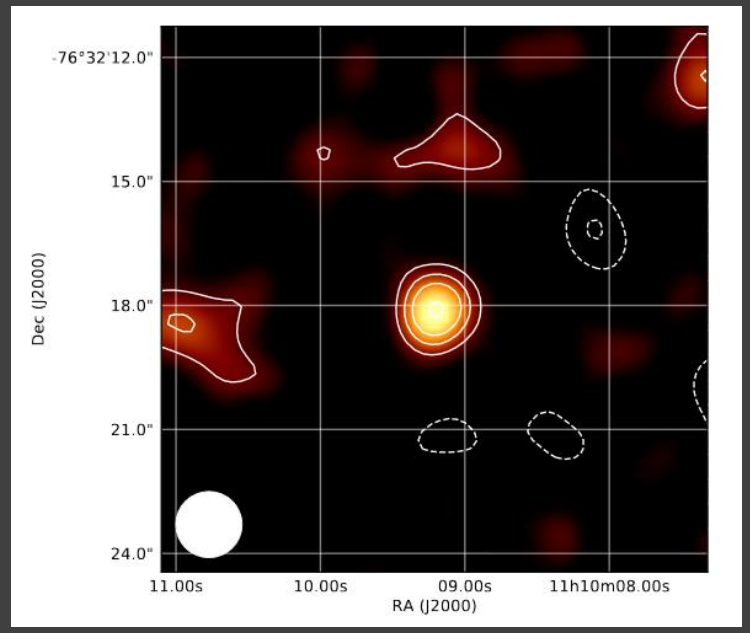
Disc around planetary mass object

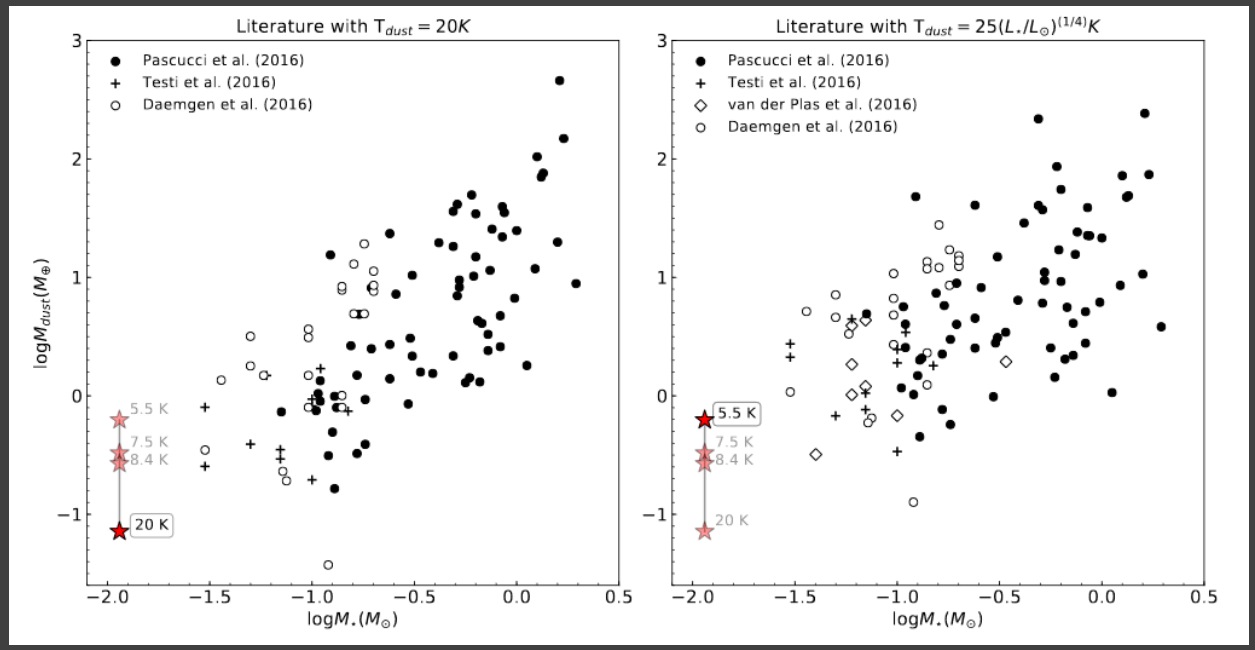
OTS44 is one of only four free-floating planets known to have a disc.
Mass ~12 $M_{jupiter}$

IR excess seen by Spitzer and Herschel

ALMA observations

$M_{dus}t$ ~0.07-0.7 M_{Earth}





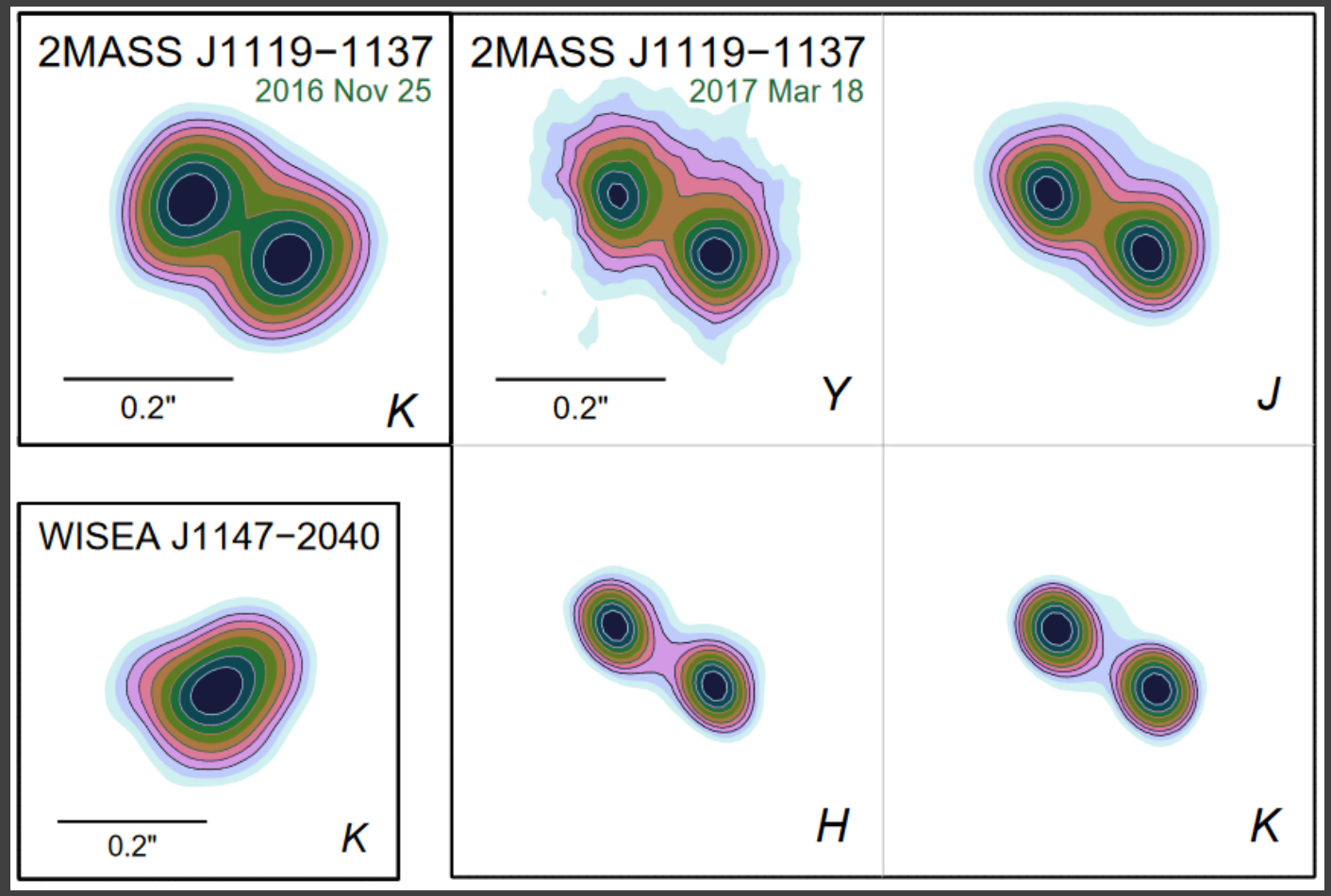
1705.06378

A brown dwarf is a pair of planets

2MASS J11193254−1137466

Age ~10 Myr
20-30 pc

M ~ 3-5 $M_{jupiter}$
Orbital period ~50-150 yrs
3-5 AU



1706.01883

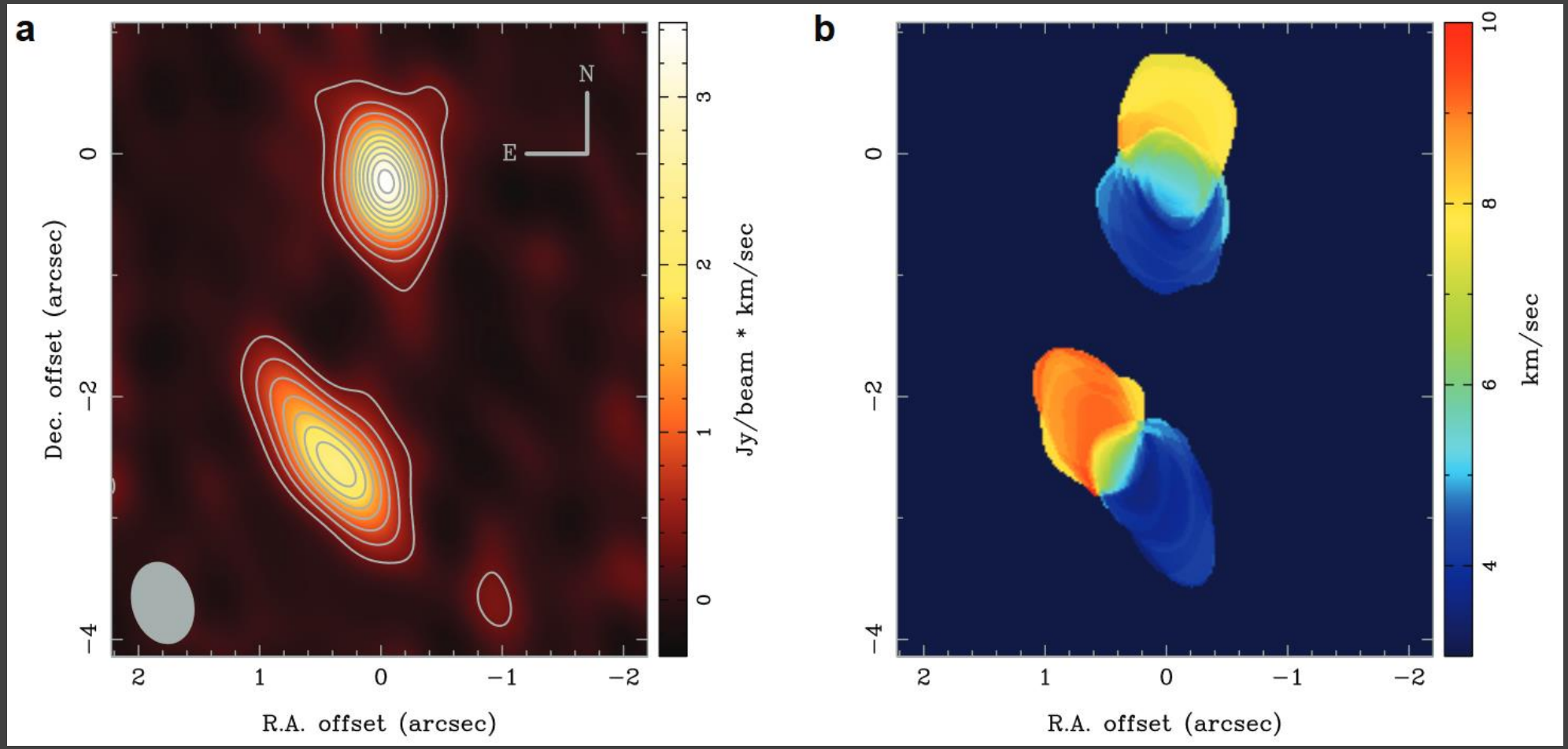
Protoplanetary discs in a binary system

HK Tau
161 pc

1-4 Myr

386 AU binary

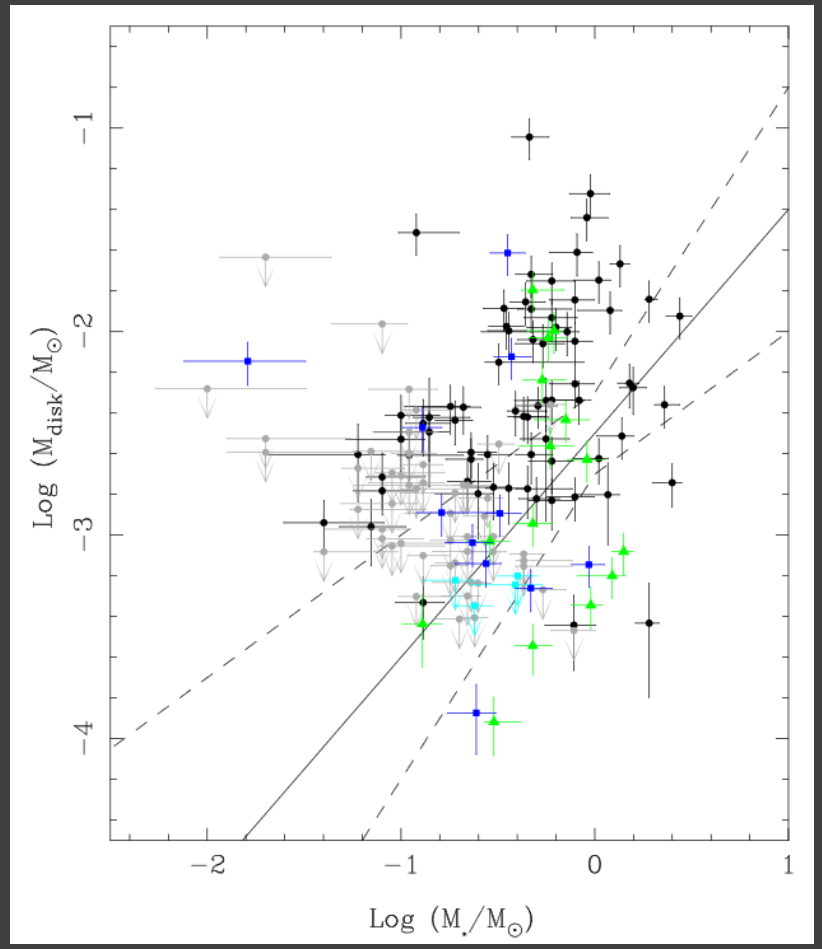
ALMA observations



1407.8211

Statistics of circumstellar discs in binaries

17 binary systems
100-1400 AU
ALMA observations

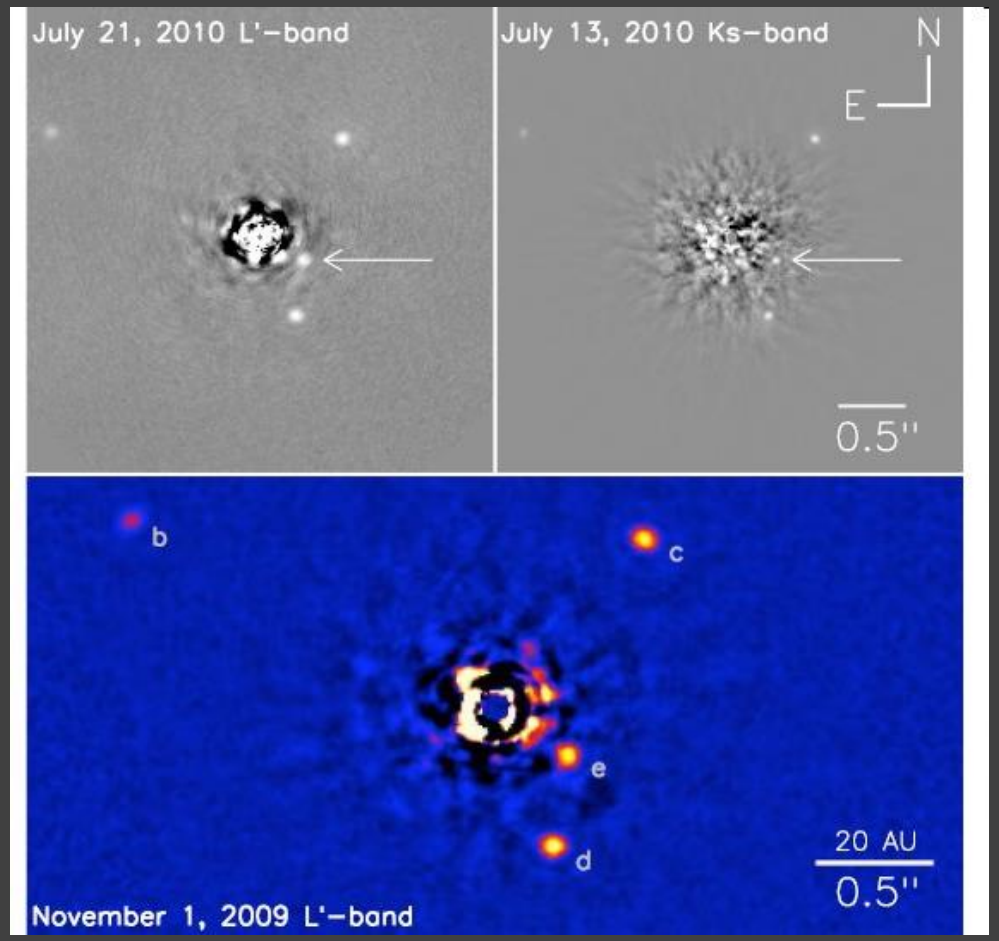


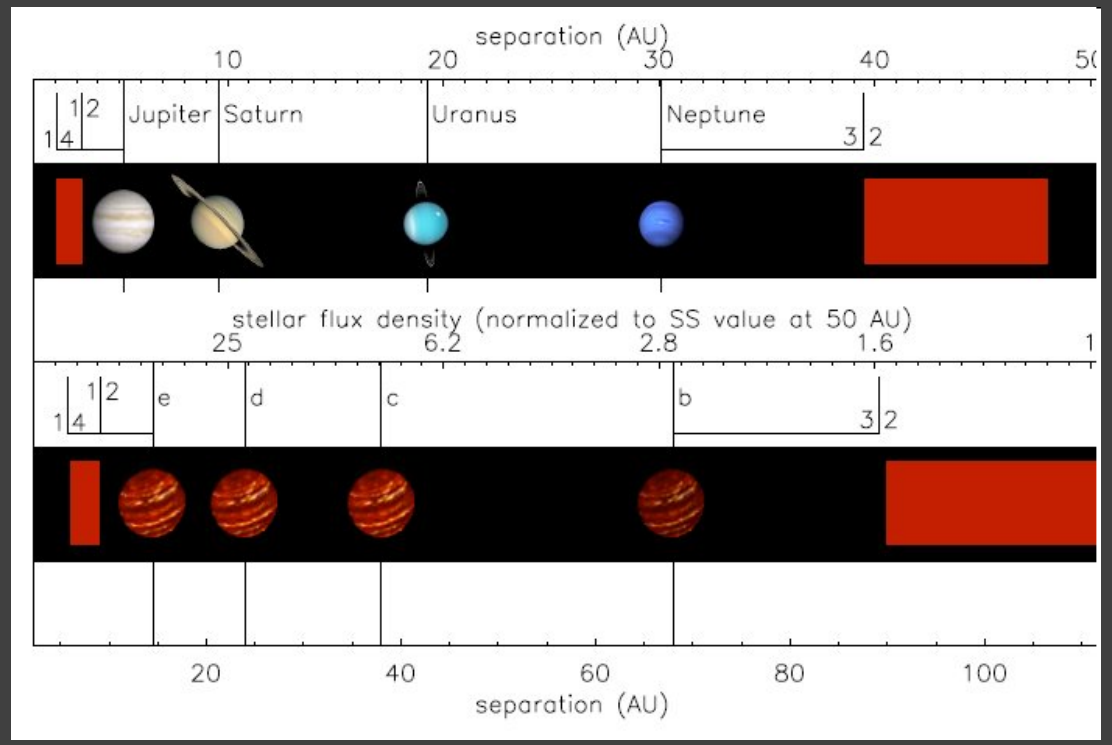
Green triangles – primaries;
Squares – secondaries
(dark blue – detected,
light blue – non-detected);
black dots – single stars
from other studies of the Tauris;
grey dods – single non-detections.

Secondary discs in two cases are brighter than discs around primaries.

1402.5363

HR 8799



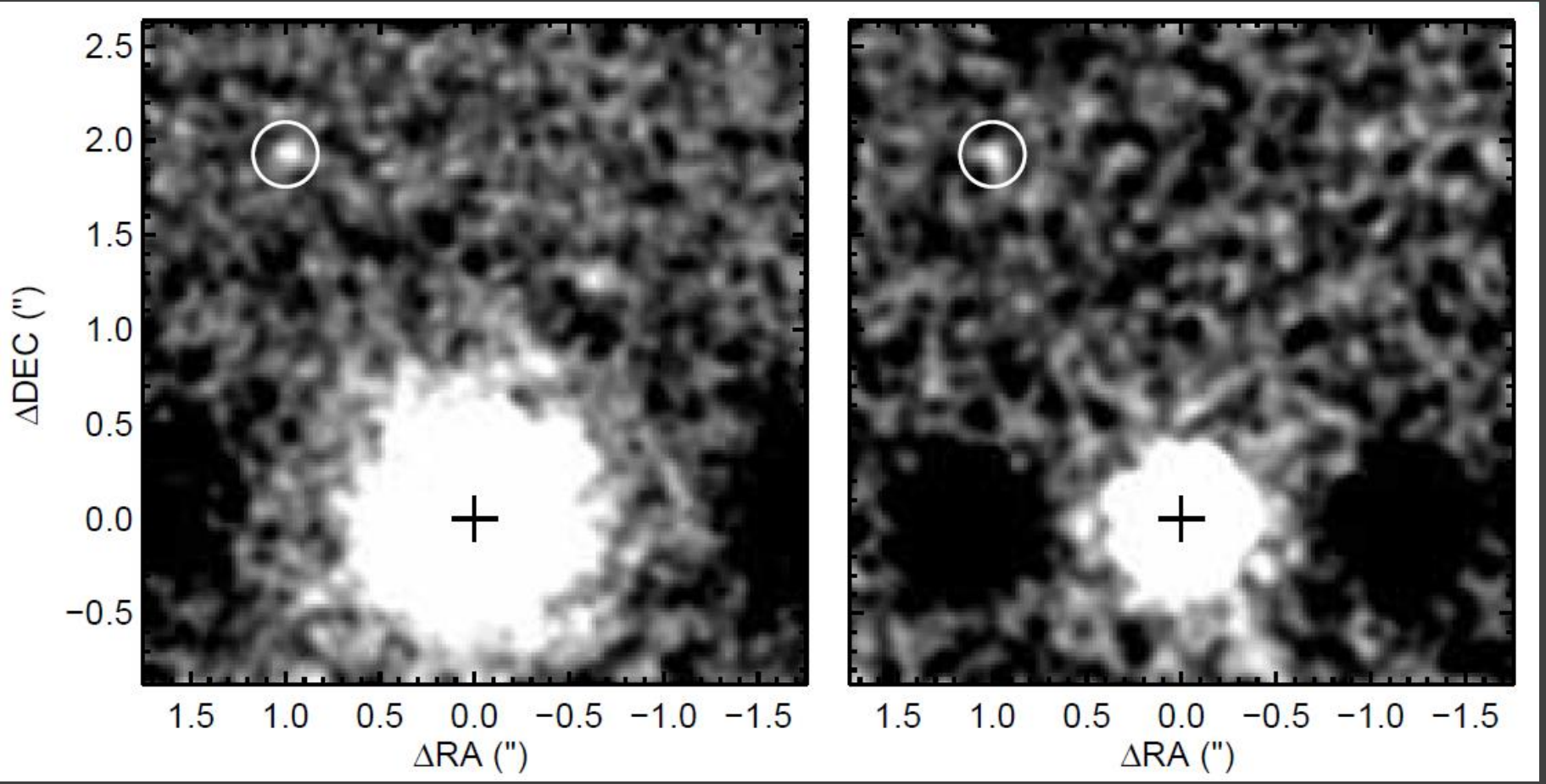


Keck II

Structure similar to the Solar system,
but if expanded by factor 2

1011.4918

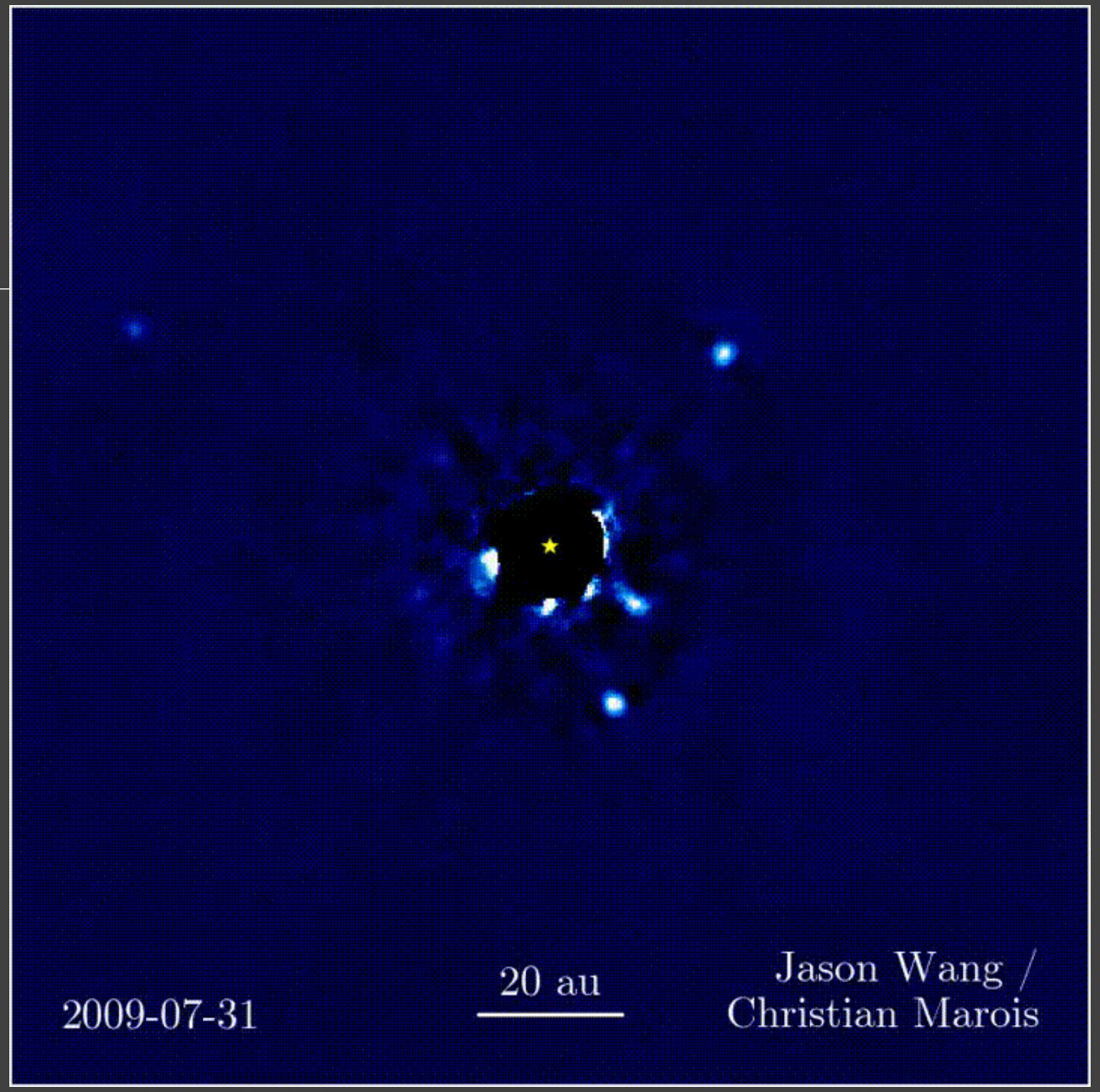
Young star 1RXS J160929.1-210524



Gemini North

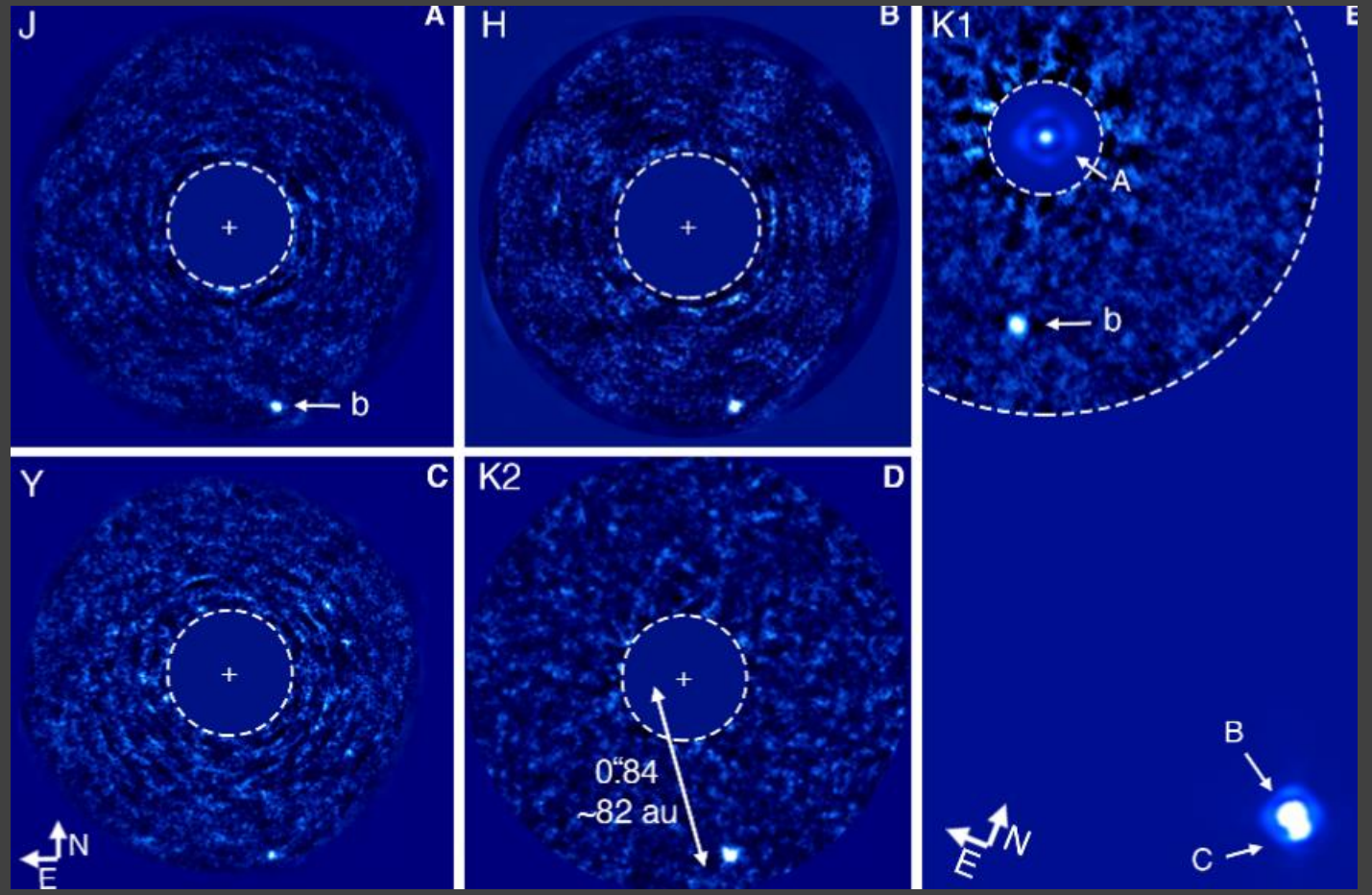
1006.3070

HR 8799



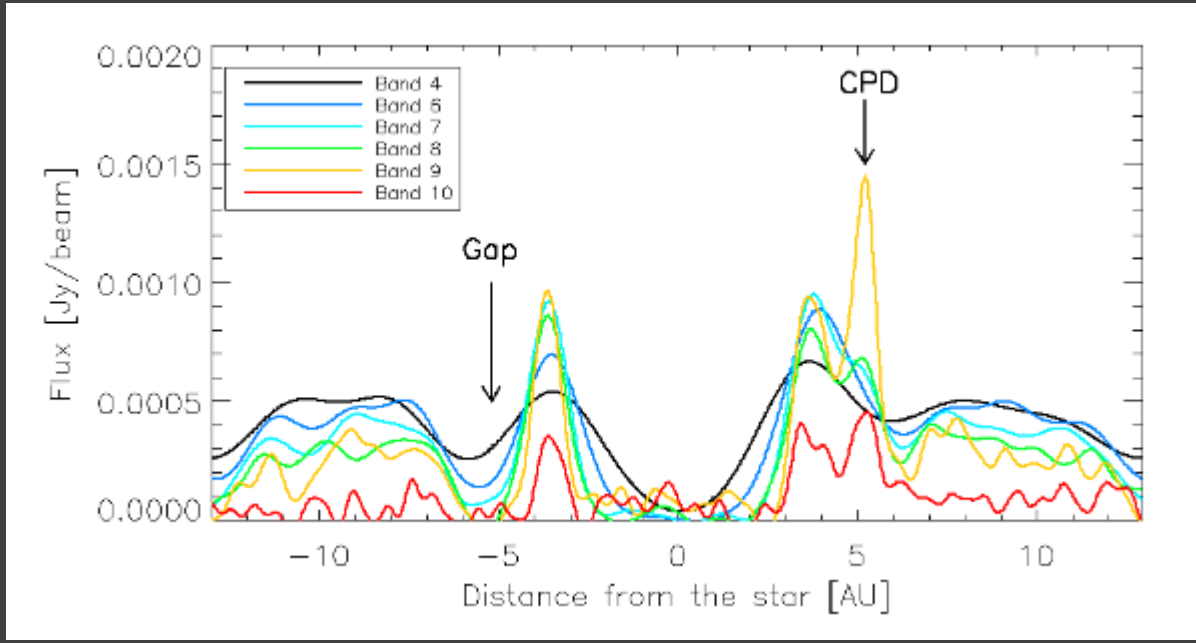
Planet in a triple system

Young planet ~16 Myr.
Observed by VLT
Orbit might be unstable.



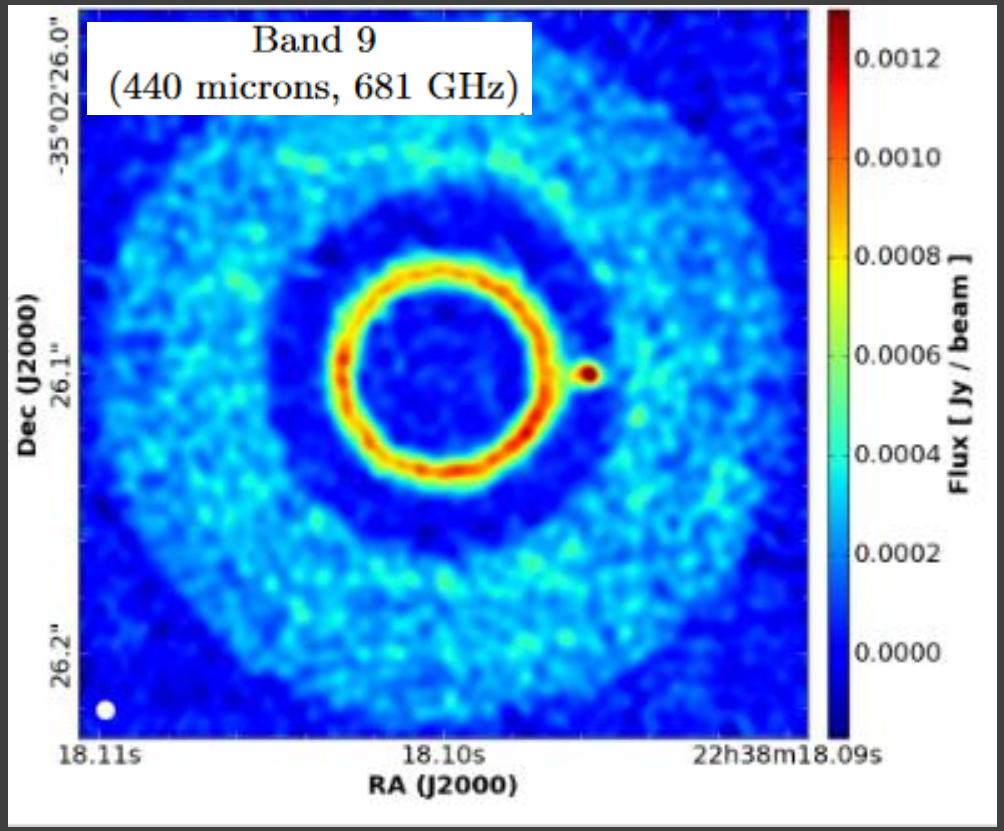
1607.02525

Circumplanetary discs (mock simulations)



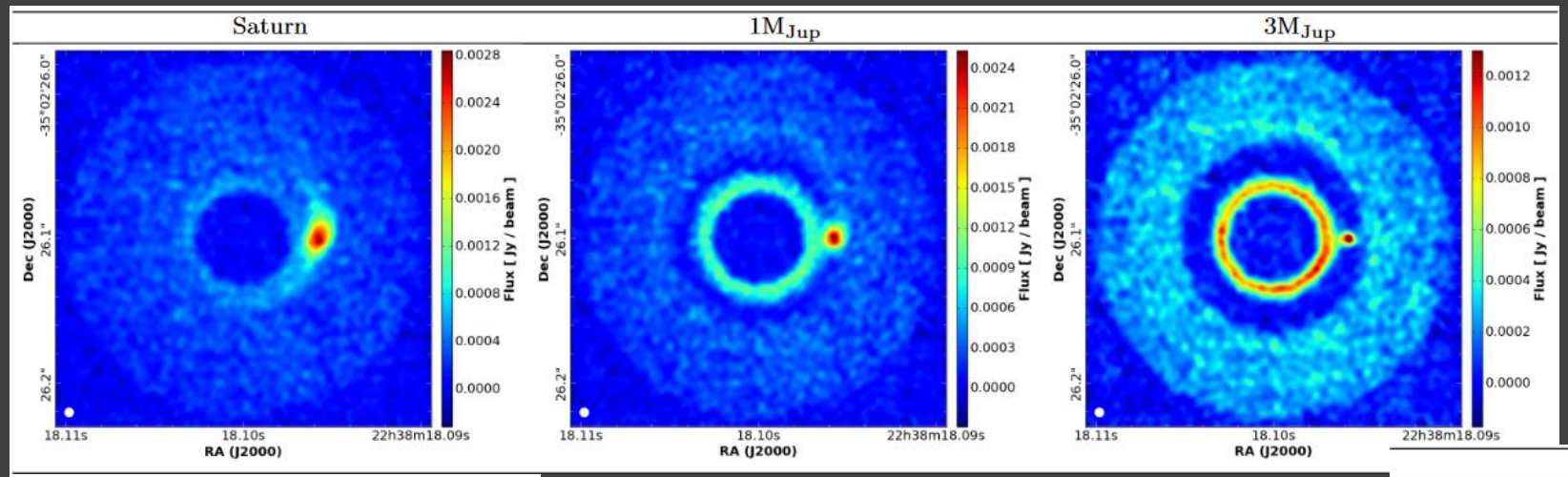
3 Jupiter masses
5 hours of observations
Better visible at shorter wavelengths
Gap opening is important
Planet temperature 4000K (age ~1 Myr)

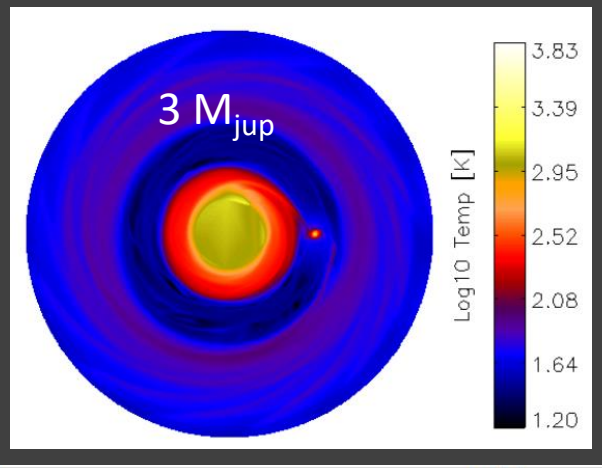
Size of a circumplanetary disc is about ½ of the Hill sphere. Thus, it can be hardly resolved by ALMA, but can be detected.

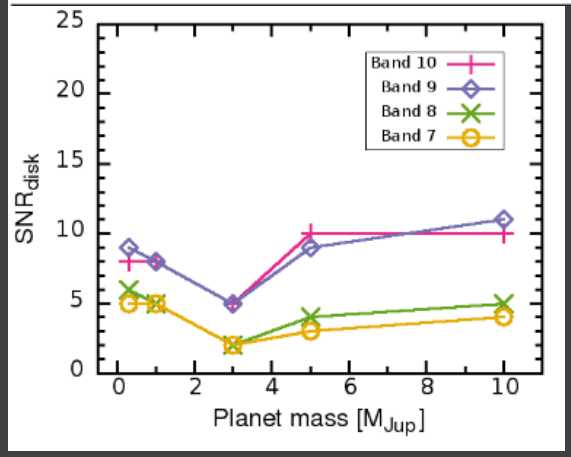


1709.04438

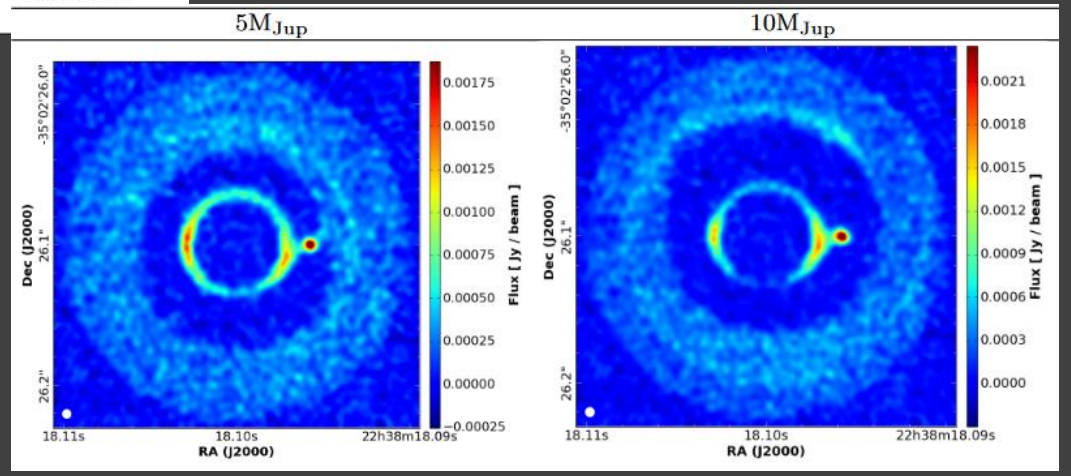
Dependence on the planet mass







Light planets, like Saturn, can also be detected.



1709.04438

Literature

arxiv:1507.04758 Observations of Solids in Protoplanetary Disks

arxiv:1703.08560 Circumstellar discs: What will be next?

arxiv:1602.06523 Resolved observations of transition disks

arxiv:1607.08239 The International Deep Planet Survey II:
The frequency of directly imaged giant exoplanets with stellar mass

arxiv:1709.04438 Observability of Forming Planets and their Circumplanetary Disks I. -- Parameter Study for ALMA