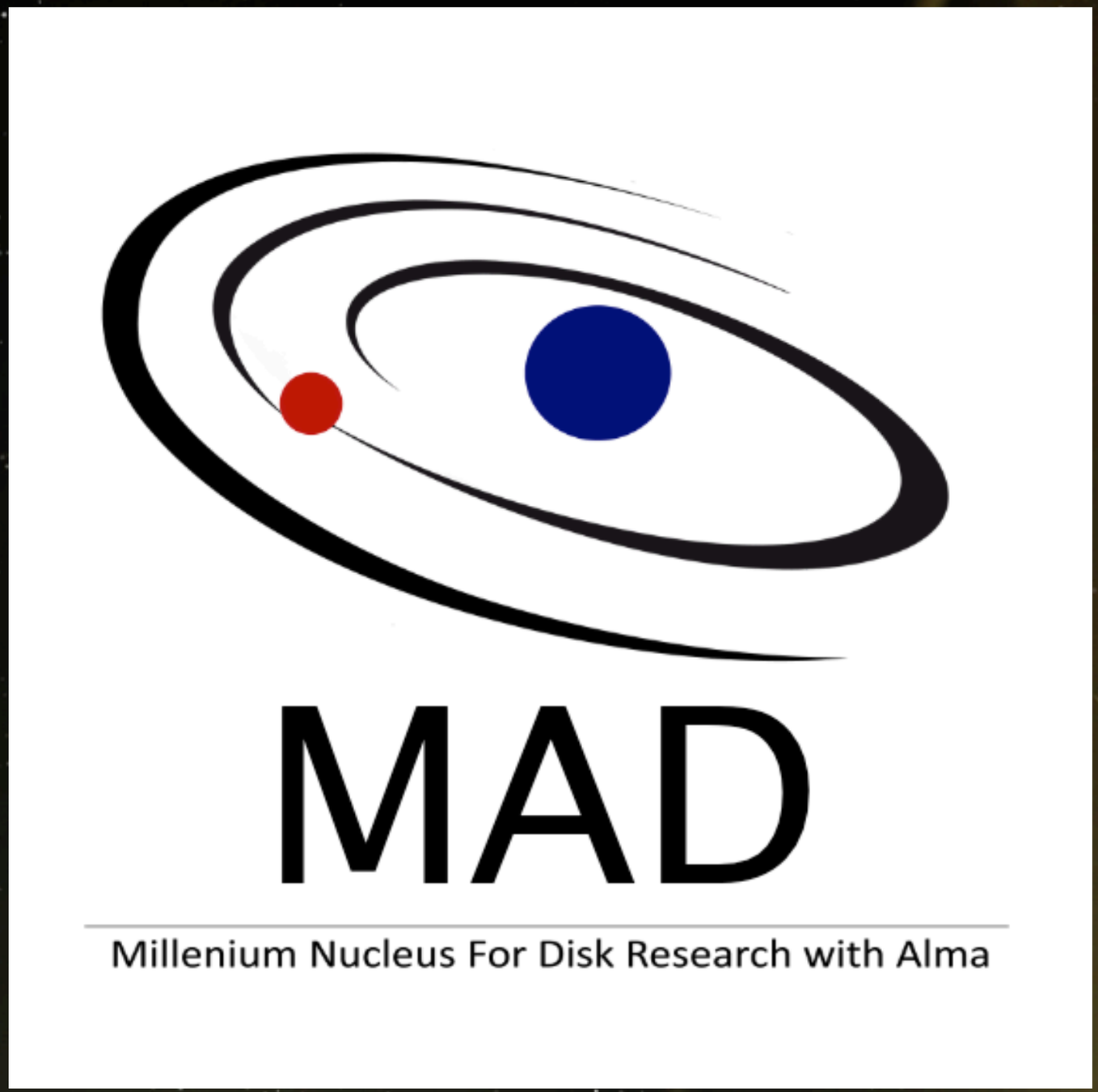
Disentangling the nature of Transition Disks:

Constraints on disk evolution and planet formation



Hector Canovas (Valparaiso)
Claudio Caceres (Valparaiso)
Matthias Schreiber (Valparaiso)
Lucas Cieza (Hawaii)
Sylvestre Lacour (Paris)
Gisela Romero (La Plata)
Alberto Rebassa-Mansergas
Adam Kraus (Hawaii)
Peter Tuthill (Sydney)
Bruno Merin (Madrid)
Jonathan Williams (Hawaii)
Simon Cassasus (Santiago)
Francois Menard (Santiago)
Gerrit van der Plas (Santiago)
Sebastian Perez (Santiago)
Andres Jordan (Santiago)
Antonio Hales (ALMA)

About me...

- 2002-2007: MsC La Laguna (Tenerife) > **Gravitational Lensing**

- 2007-2011: PhD in Utrecht University > **Imaging Polarimetry of Stellar Environments**

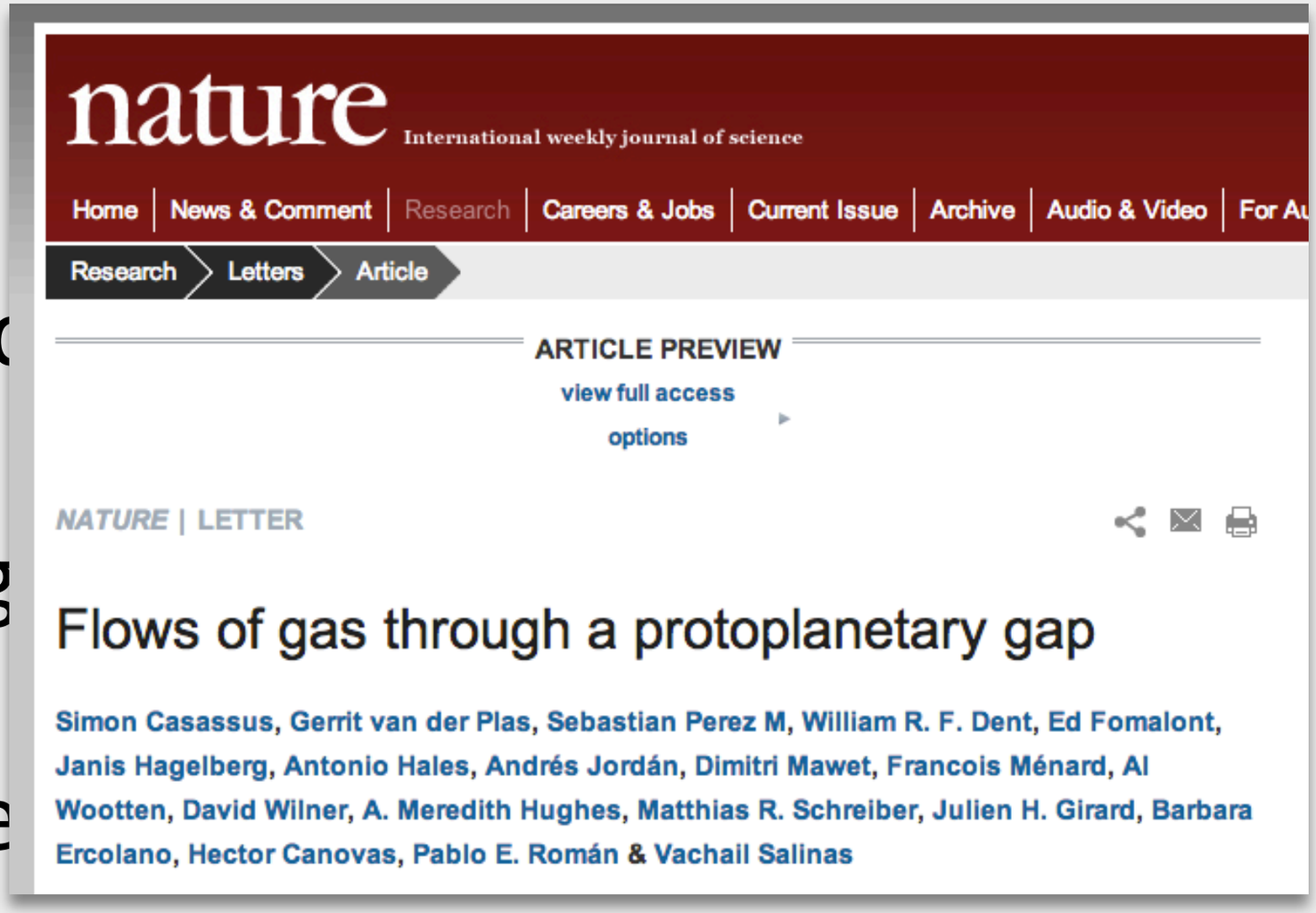
- 2012-2015: PostDoc at Universidad de Valparaiso / MAD group > **Transition Disks**

Outline

- Introduction: Why Transition Disk are cool
- Characterization of Transtion Disks
- Strong Planet Forming Candidates
- Future/Ongoing projects

Outline

- Introd
- Charac
- Strong
- Future



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NATURE | LETTER

Flows of gas through a protoplanetary gap

Simon Casassus, Gerrit van der Plas, Sebastian Perez M, William R. F. Dent, Ed Fomalont, Janis Hagelberg, Antonio Hales, Andrés Jordán, Dimitri Mawet, Francois Ménard, Al Wootten, David Wilner, A. Meredith Hughes, Matthias R. Schreiber, Julien H. Girard, Barbara Ercolano, Hector Canovas, Pablo E. Román & Vachail Salinas

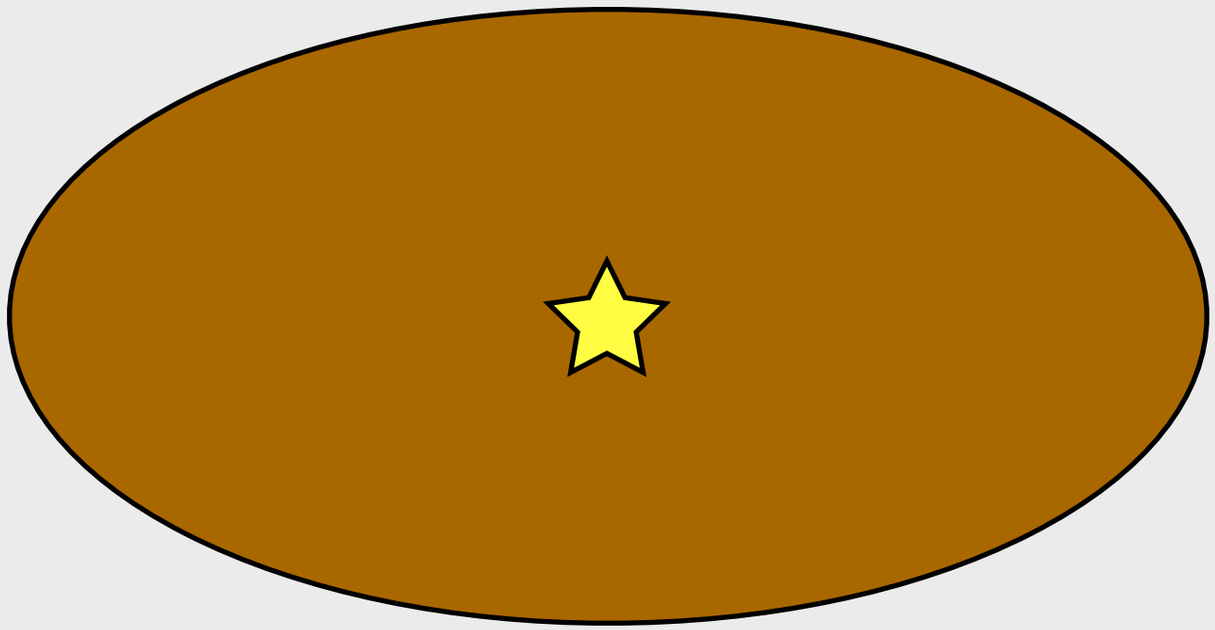
cool

Outline

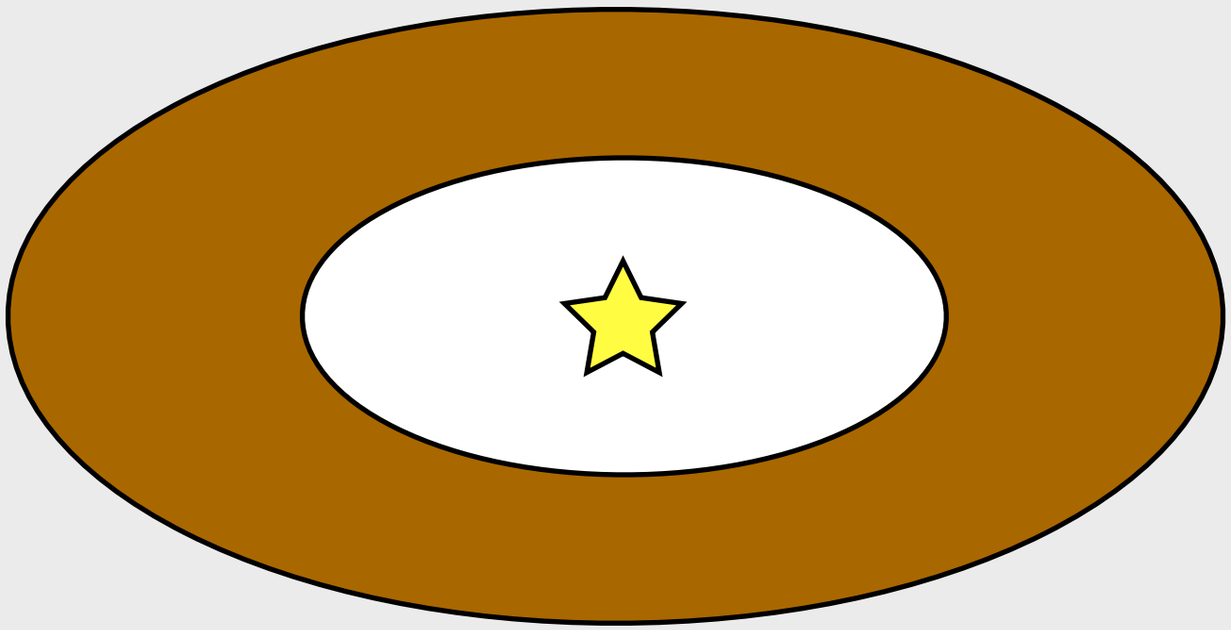
- Introduction: Why Transition Disk are cool
- Characterization of Transtion Disks
- Strong Planet Forming Candidates
- Future/Ongoing projects

WHAT ARE WE TALKING ABOUT?

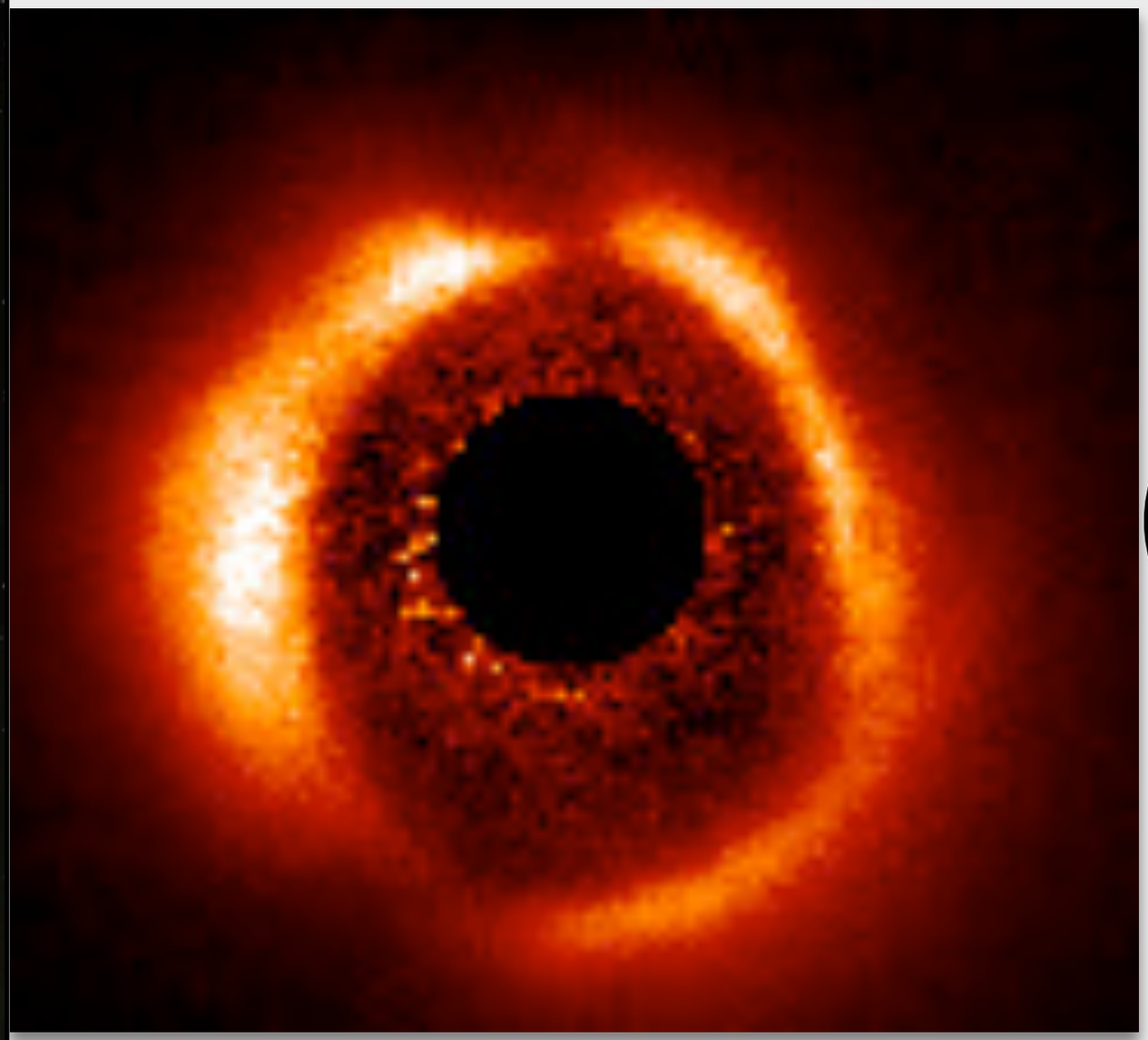
Full Disk



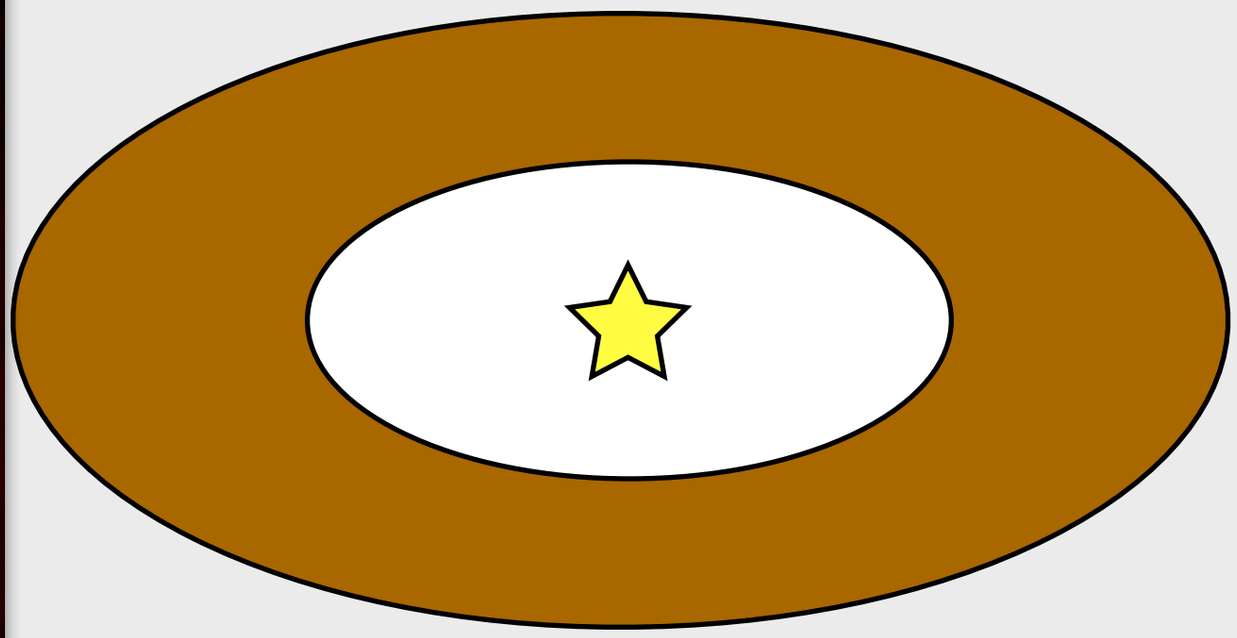
Transition Disk



WHAT ARE WE TALKING ABOUT?



Transition Disk



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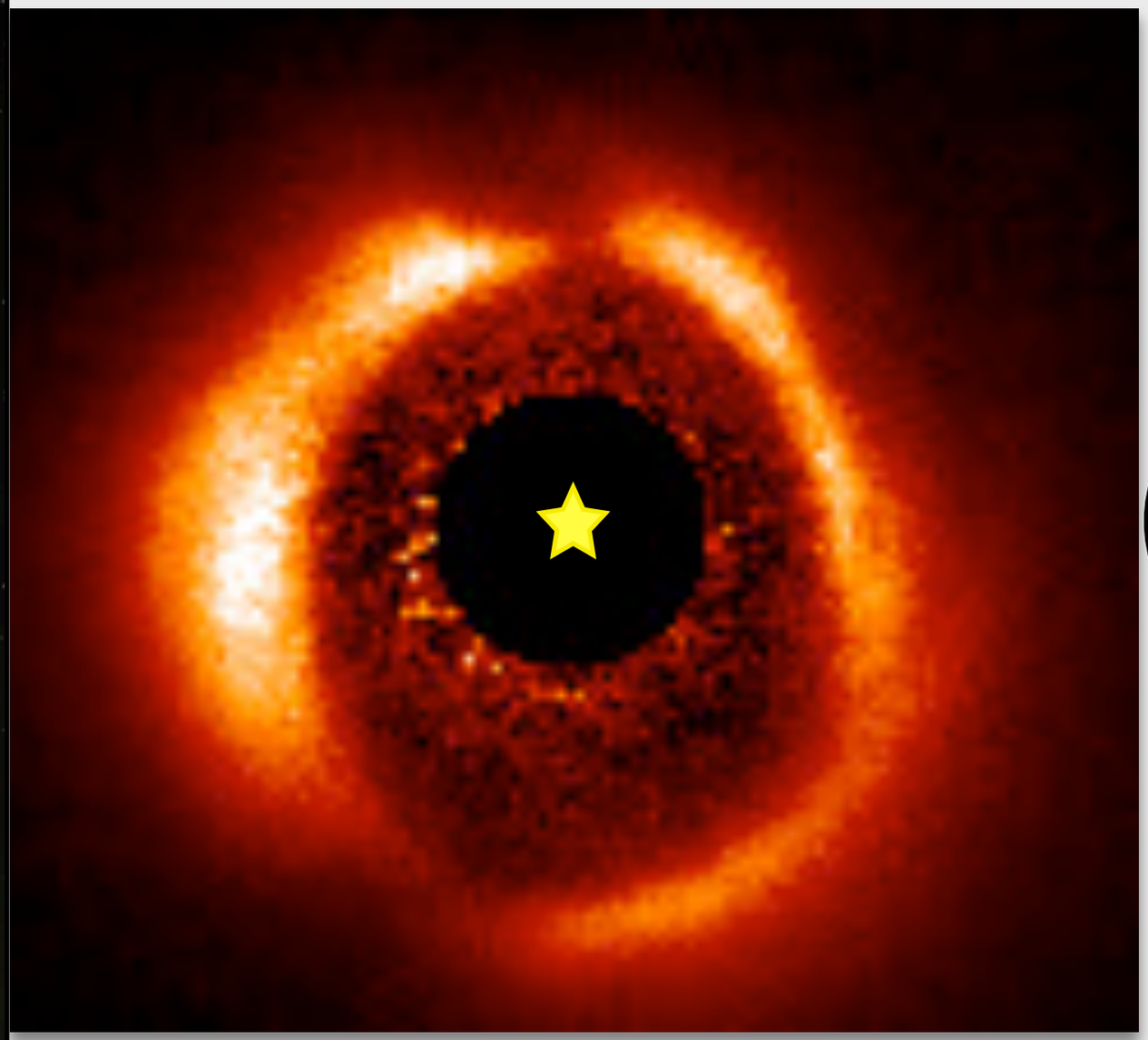
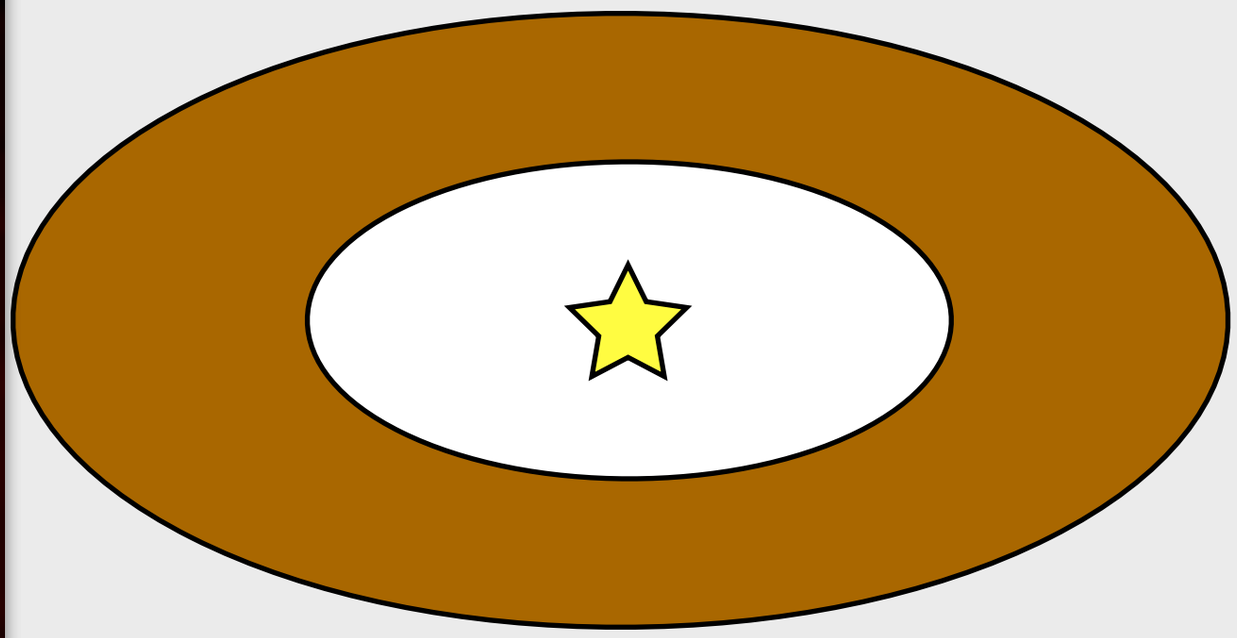
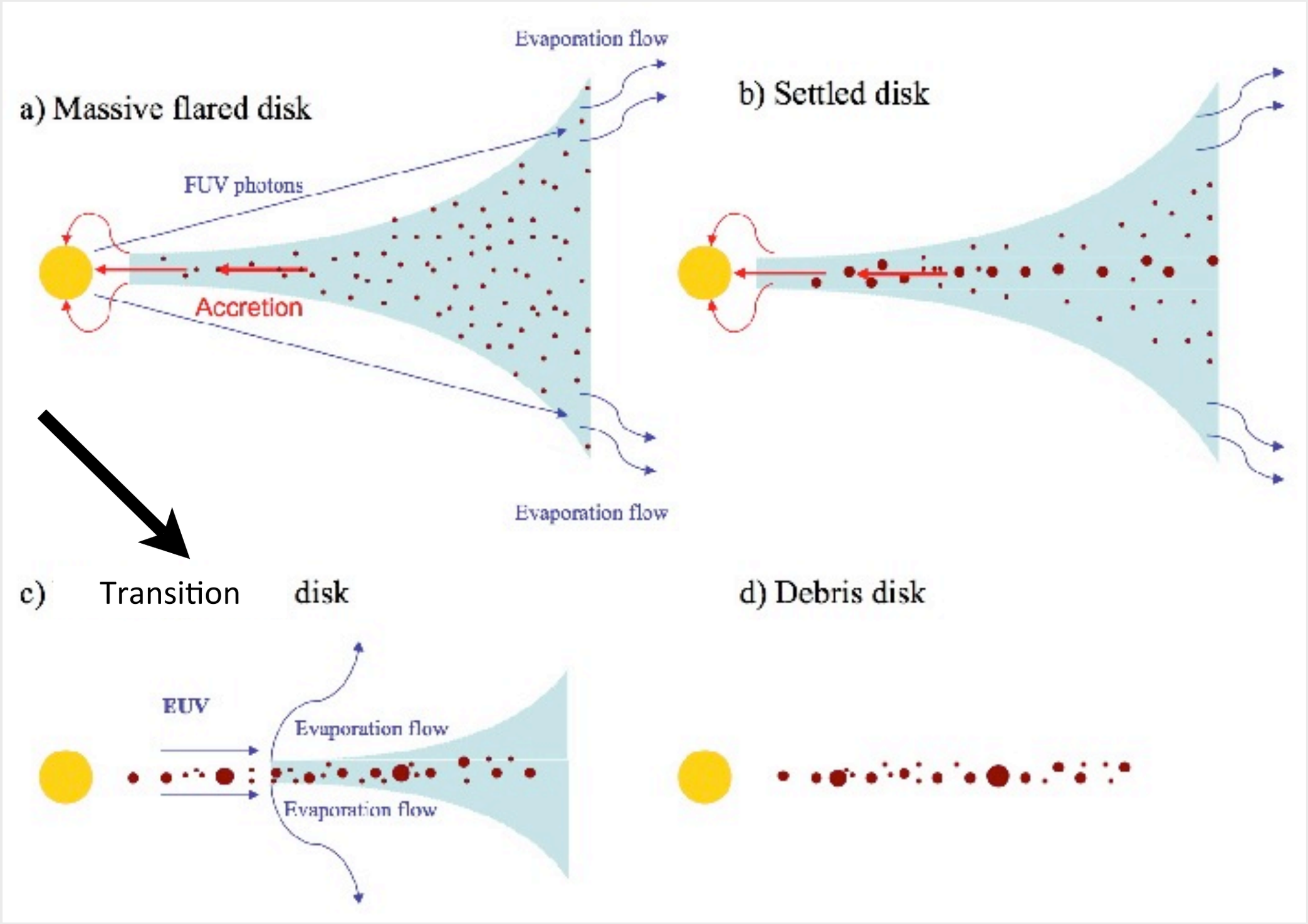


Transition Disk

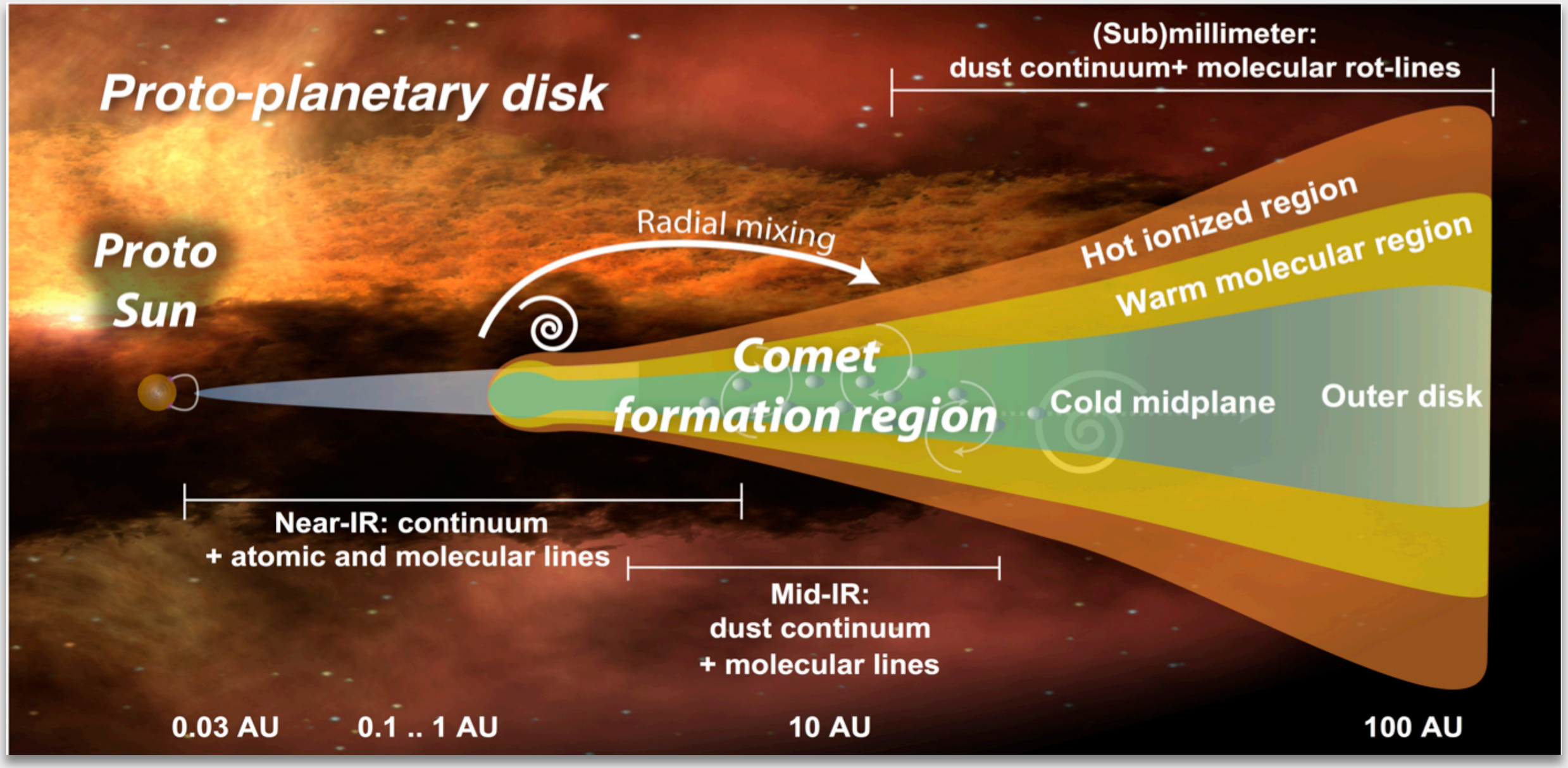


ProtoPlanetary Disks: General Picture I



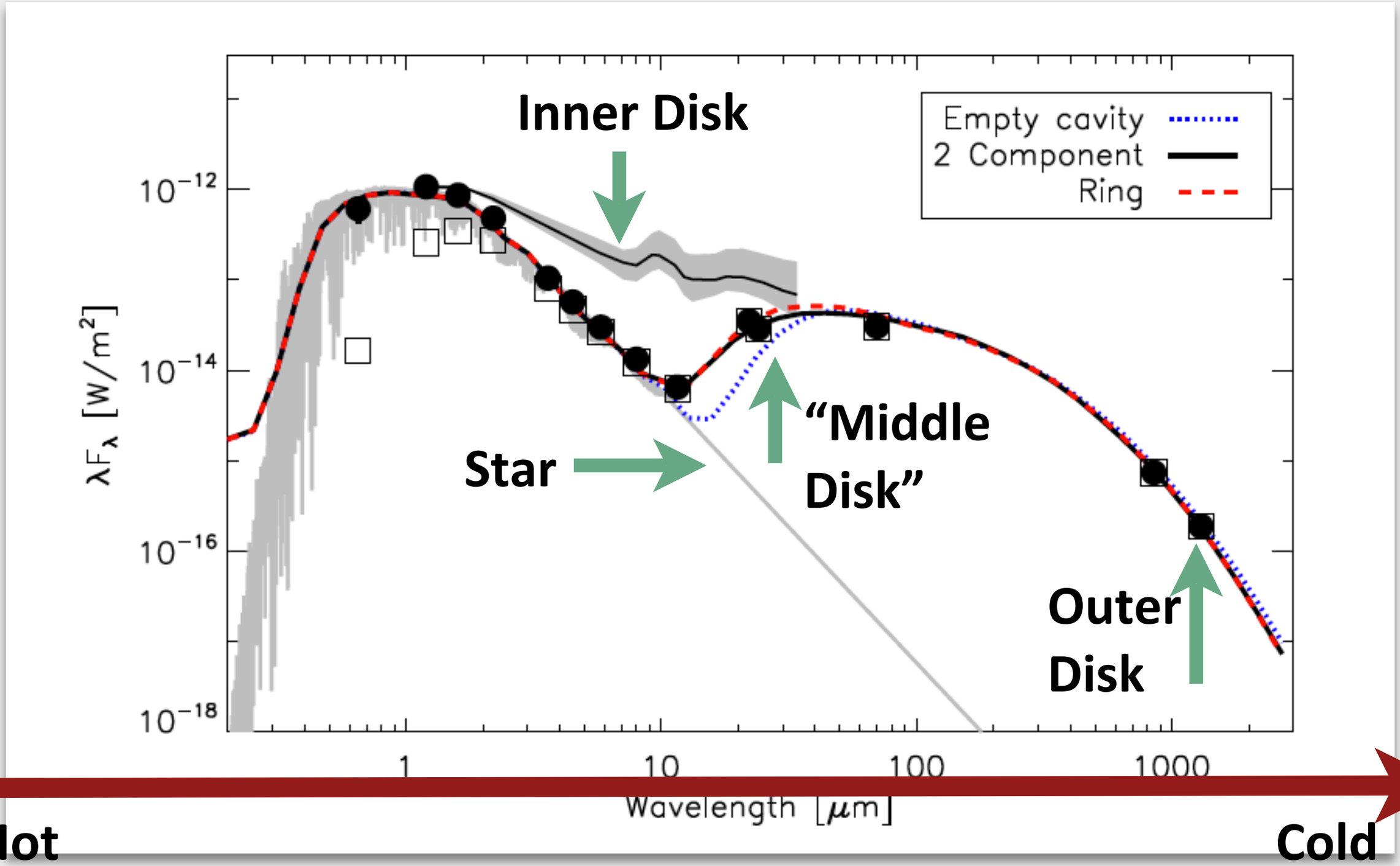
Adapted from Williams & Cieza 2011

ProtoPlanetary Disks: General Picture II



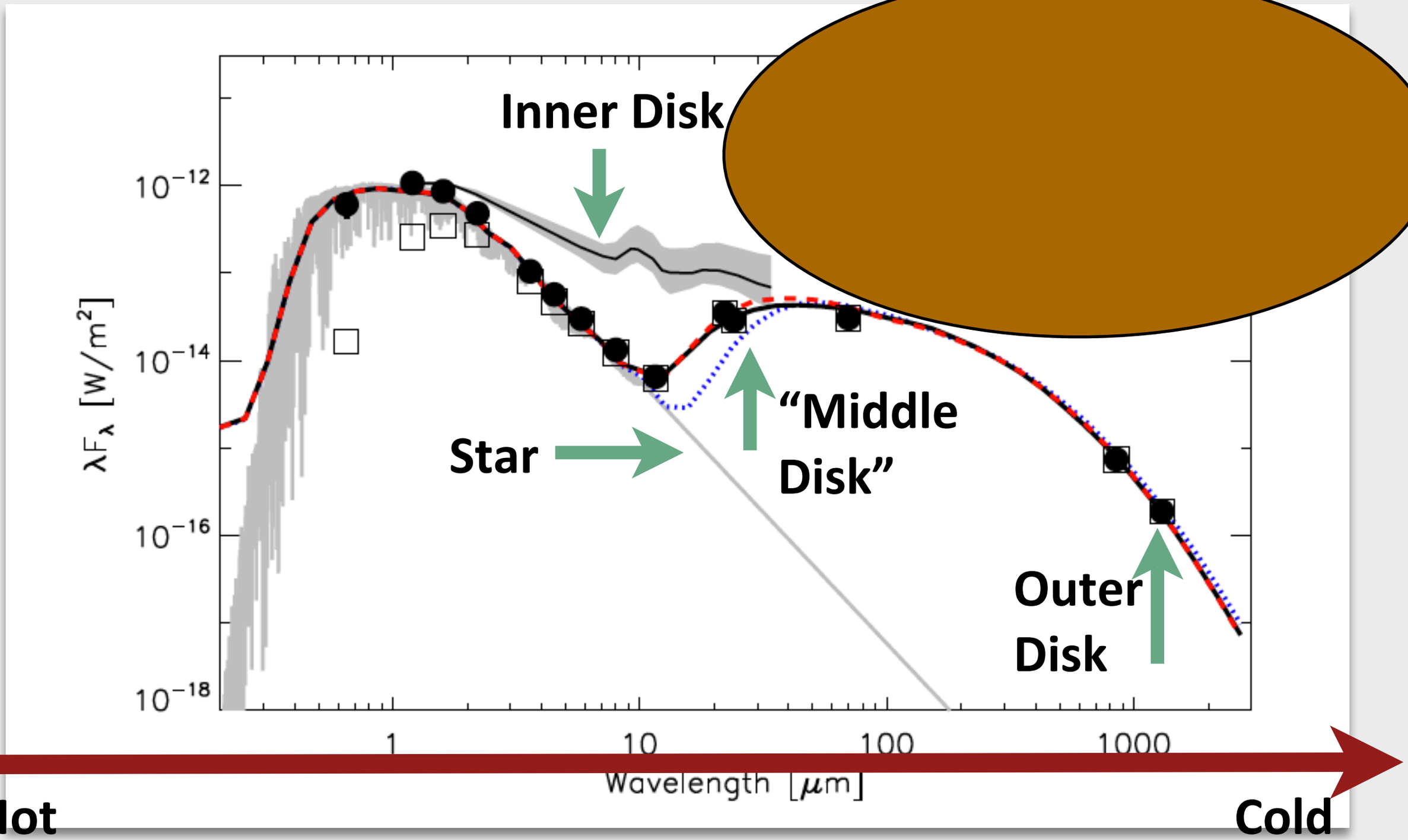
Adapted from Dullemond & Monnier 2010

ProtoPlanetary Disks: General Picture III



Adapted from Cieza et al. 2012

ProtoPlanetary Disks: General Picture III



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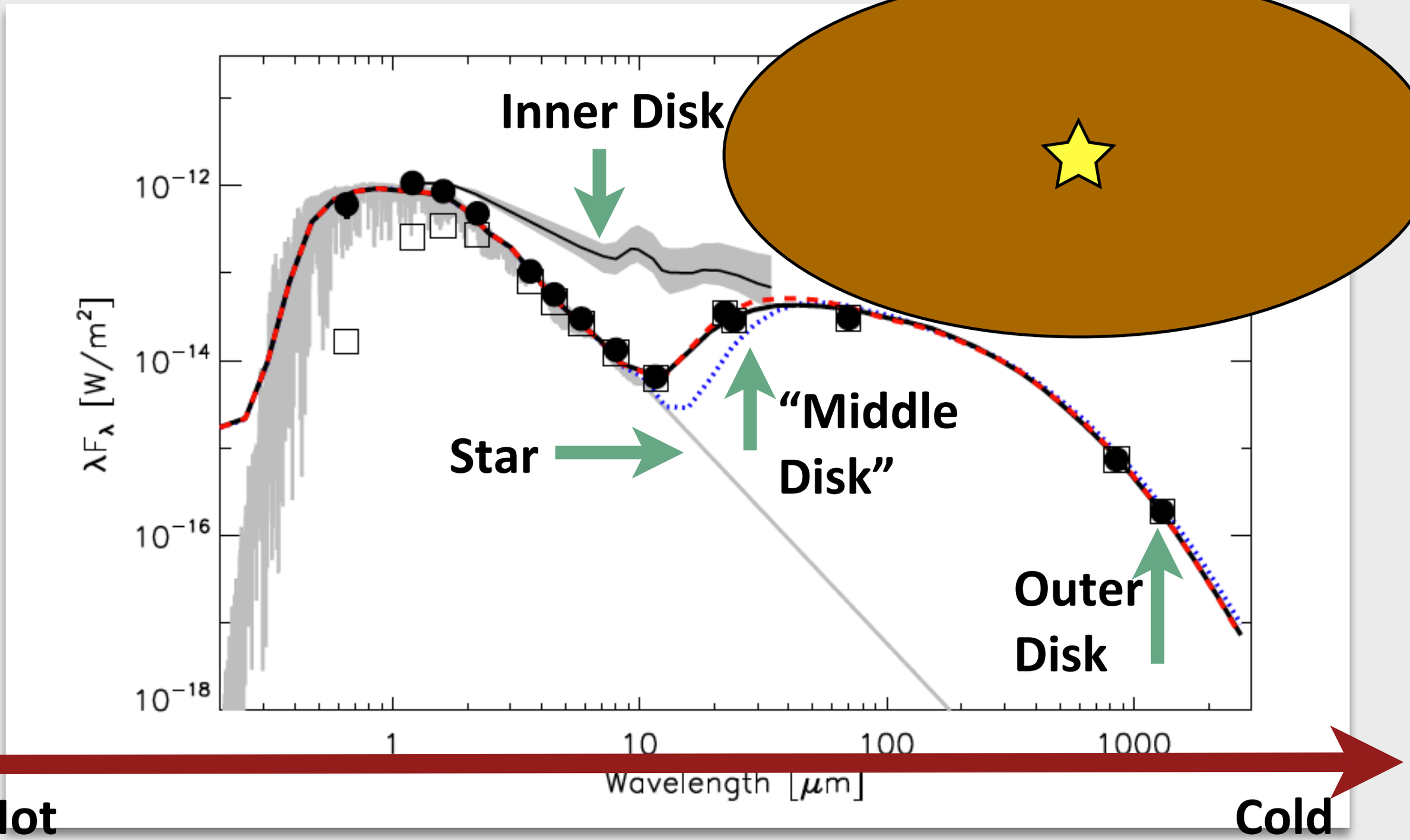

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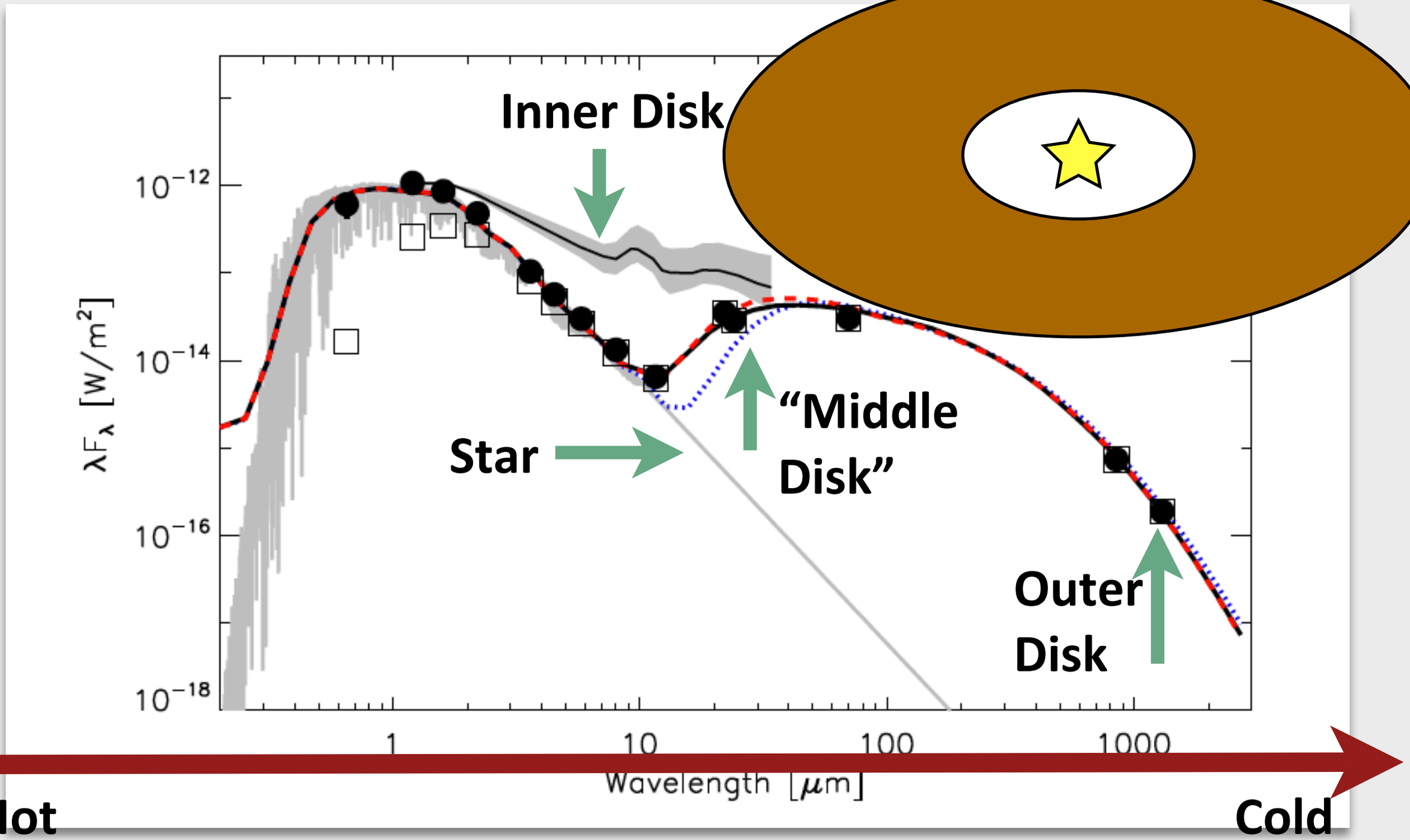
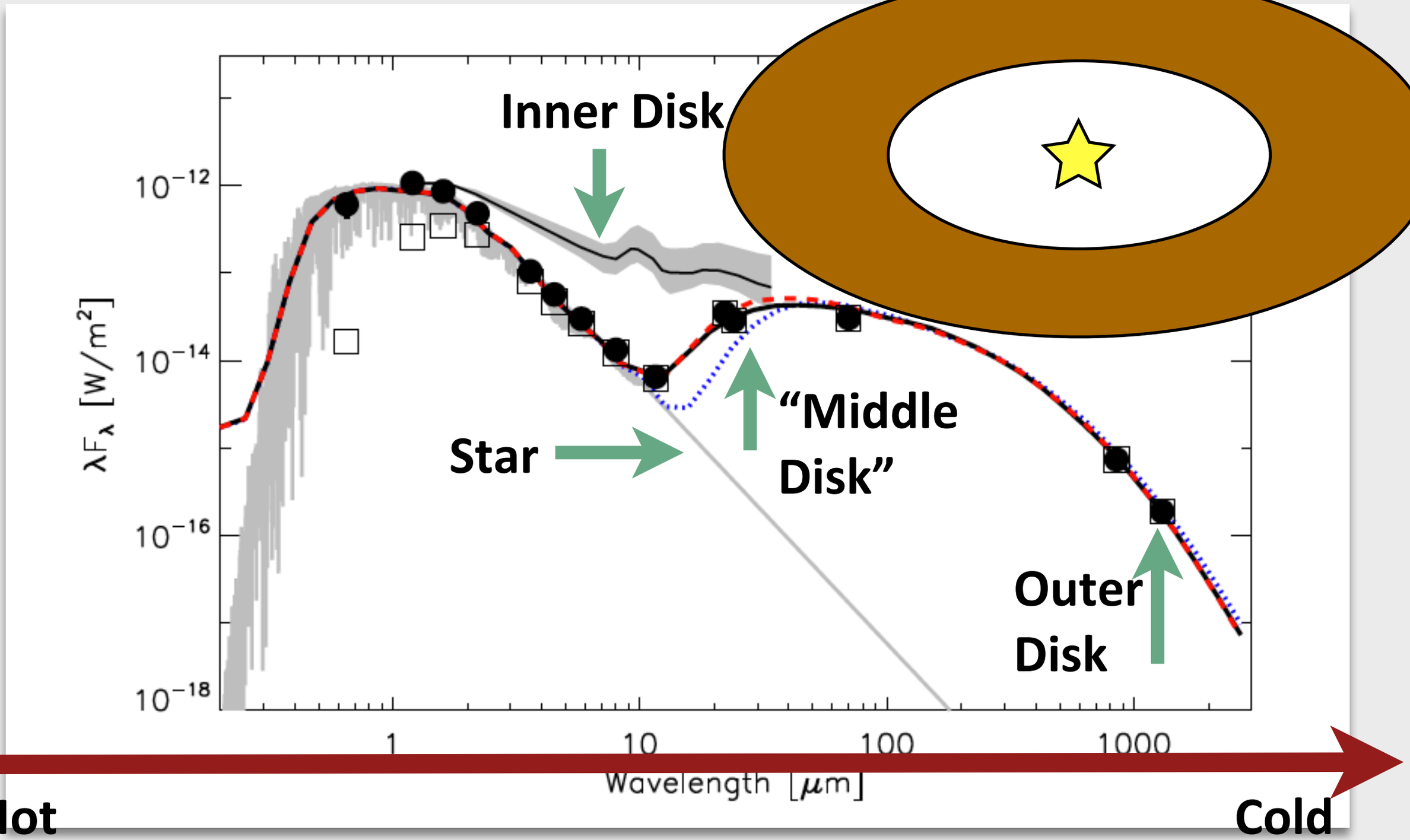


Adapted from Cieza et al. 2012

ProtoPlanetary Disks: General Picture III



Adapted from Cieza et al. 2012

the **IMPORTANT** question

WHY do opacity holes form???

- Dust (grain) Growth
- Photoevaporation
- Effect of companions: Binaries / Giant Planets

the **IMPORTANT** question

WHY do opacity holes form???

⇨ Dust (grain) Growth

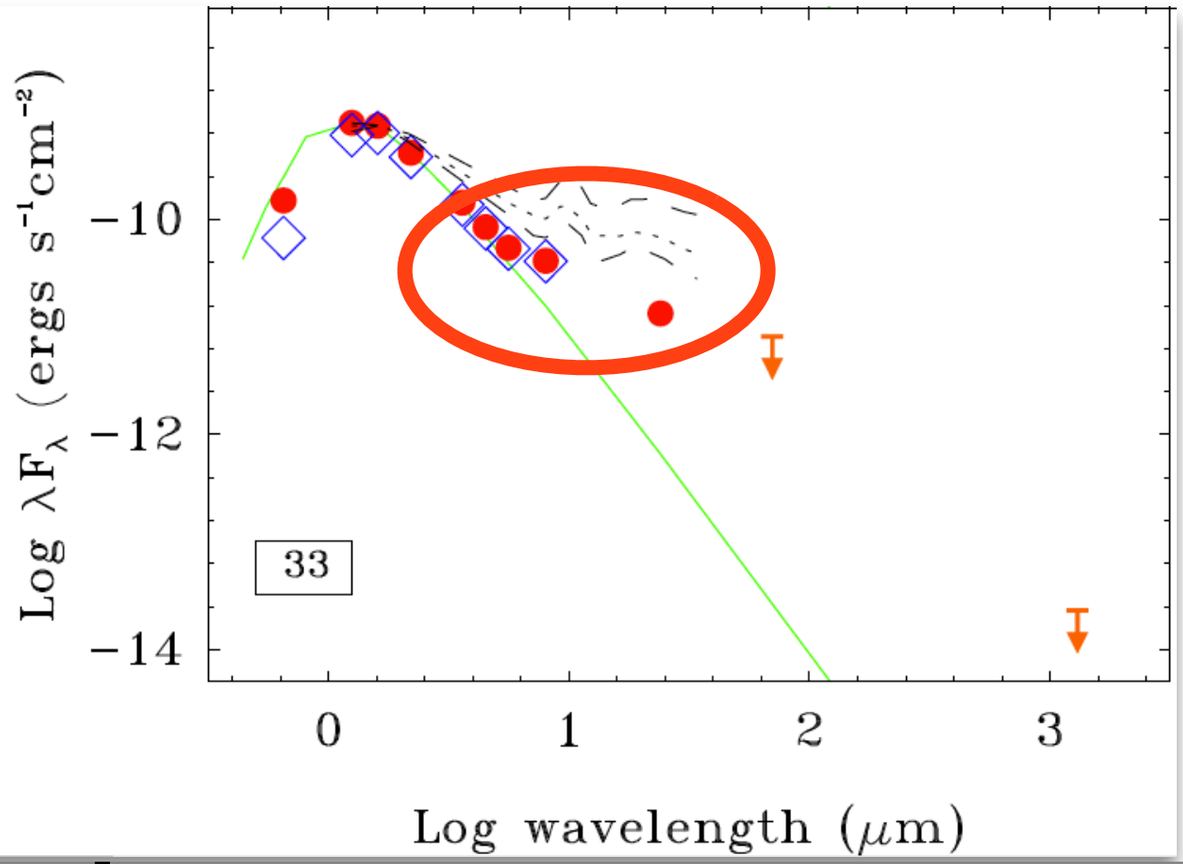
⇨ Photoevaporation

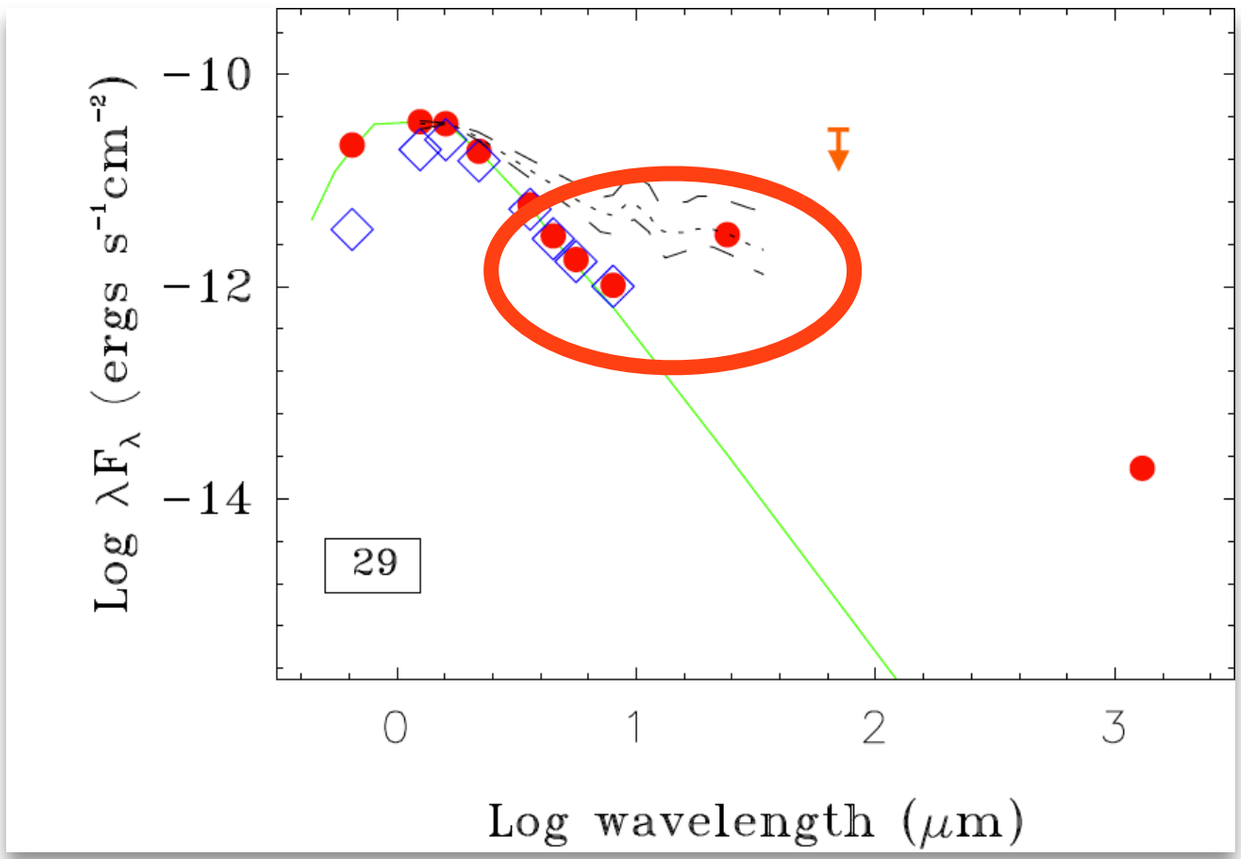
⇨ Effect of companions:
Binaries / Giant Planets

Grain Growth

- Particles grow from inside → outside
  - → Bigger Particles = drop in opacity at NIR
  - → Smooth Dust distribution
  - → Smooth SED at NIR & MIR

Grain Growth





→ Smooth SED at NIR & MIR

Photo Evaporation

- High Energy photons evaporate the disk
- Accretion is overcomed by photoevaporation
  - Accretion: NO
  - SED: NOT smoothed

Companions: Binaries or Planets

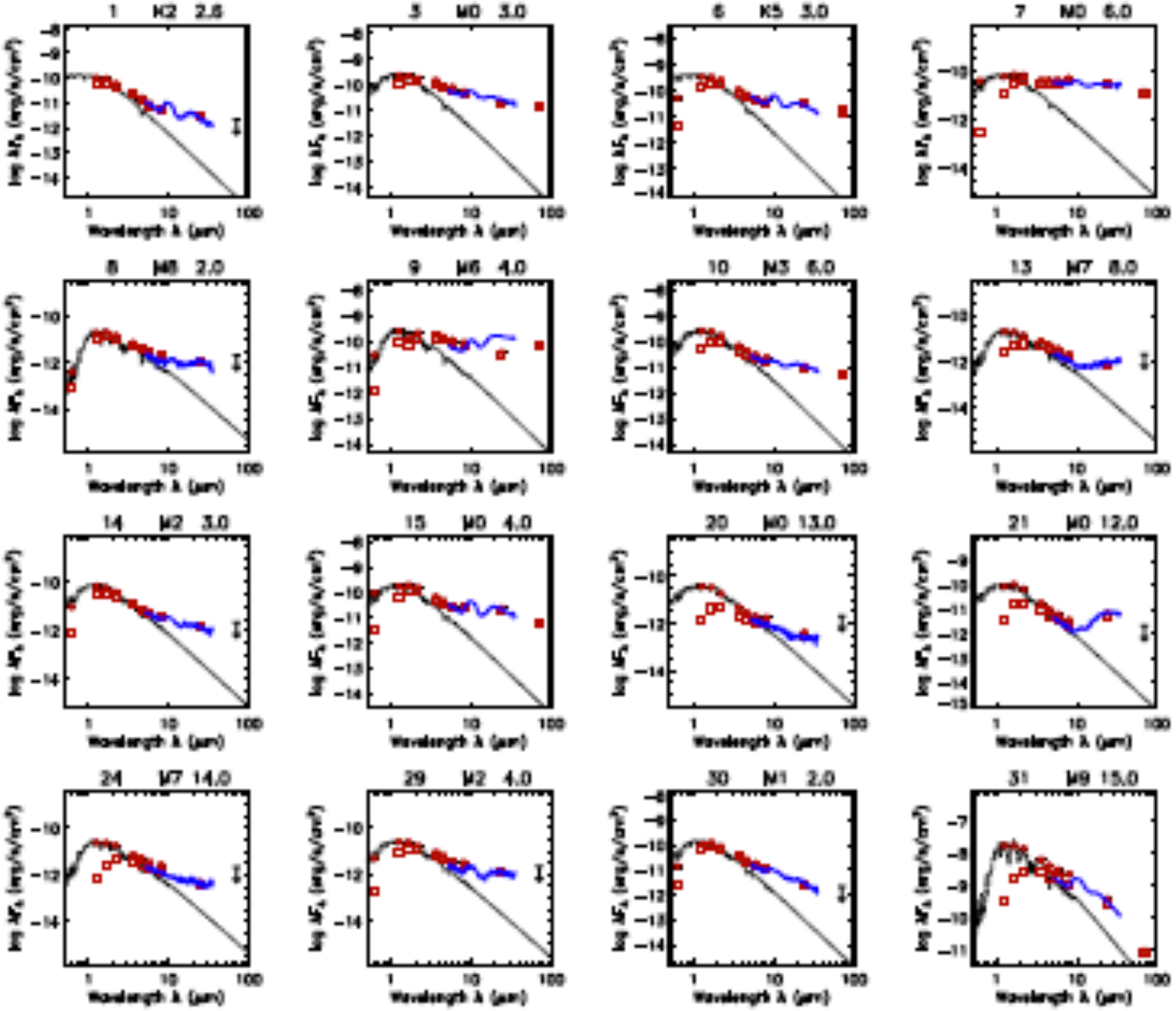
- Dinamical Clearing can make a hole
- Accretion is not stopped by planets or binaries
  - → Accretion: YES
  - → SED: NOT smoothed

Hunting Transition Disks

Road Map

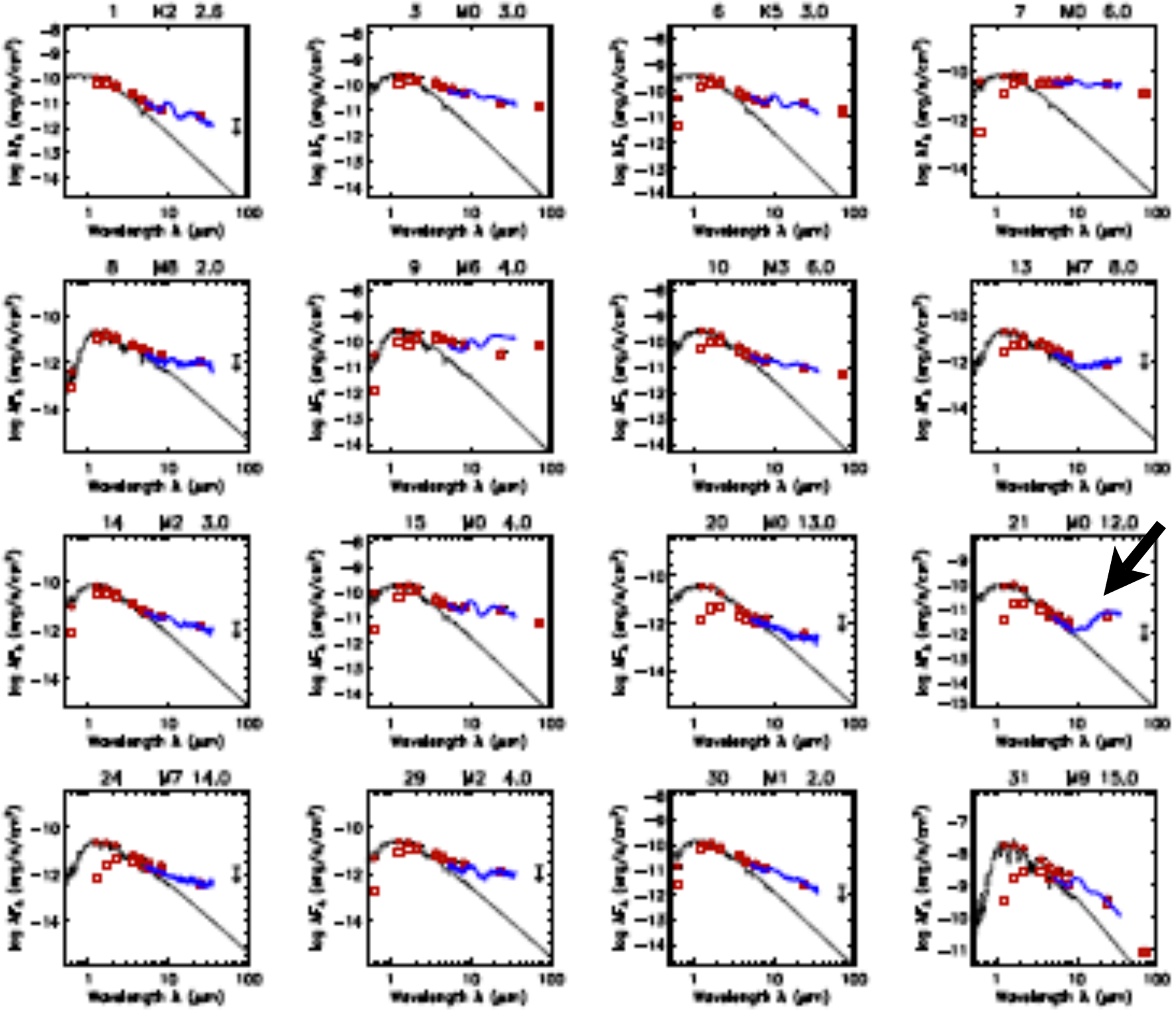
1.- Look for young stars
2.- Identify Transition Disk Candidates
3.- Characterize the sample
4.- Identify the “Hole-making mechanisms”

Hunting Transition Disks (1 & 2)



Adapted from Oliveira et al. 2012 & Cieza et al. 2012

Hunting Transition Disks (1 & 2)



Adapted from Oliveira et al. 2012 & Cieza et al. 2012

Hunting Transition Disks (3)

OBSERVE… AS MUCH AS YOU CAN: >240 hours

Hunting Transition Disks (3)

OBSERVE... AS MUCH AS YOU CAN: >240 hours

Closest (YOUNG)
Star Forming Regions:

Ophiucus
Lupus
Corona
Chamaleonis
Taurus-Aurigae
Perseus

Hunting Transition Disks (3)

OBSERVE... AS MUCH AS YOU CAN: >240 hours

Closest (YOUNG)
Star Forming Regions:

Ophiucus	125 pc
Lupus	150 pc
Corona	150 pc
Chamaleonis	160 pc
Taurus-Aurigae	140 pc
Perseus	320 pc

Hunting Transition Disks (3)

OBSERVE... AS MUCH AS YOU CAN: >240 hours

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Ophiucus	125 pc
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Chamaleonis	160 pc
Taurus-Aurigae	140 pc
Perseus	320 pc

Instruments & Telescopes

NaCo & SAM (VLT, 33h, 3n)
NIRI (Gemini N, 10h)
UVES/FLAMES (VLT, 14.5h)
Magellan & DuPont (3n,2n)
CFHT (35h)
APEX (25h)
SMA (8 nights)
JCME (SCUBA, 1.5 h)
ALMA (Cycle0: 4.6h, Cycle1: 5h)

Hunting Transition Disks: Strategy II

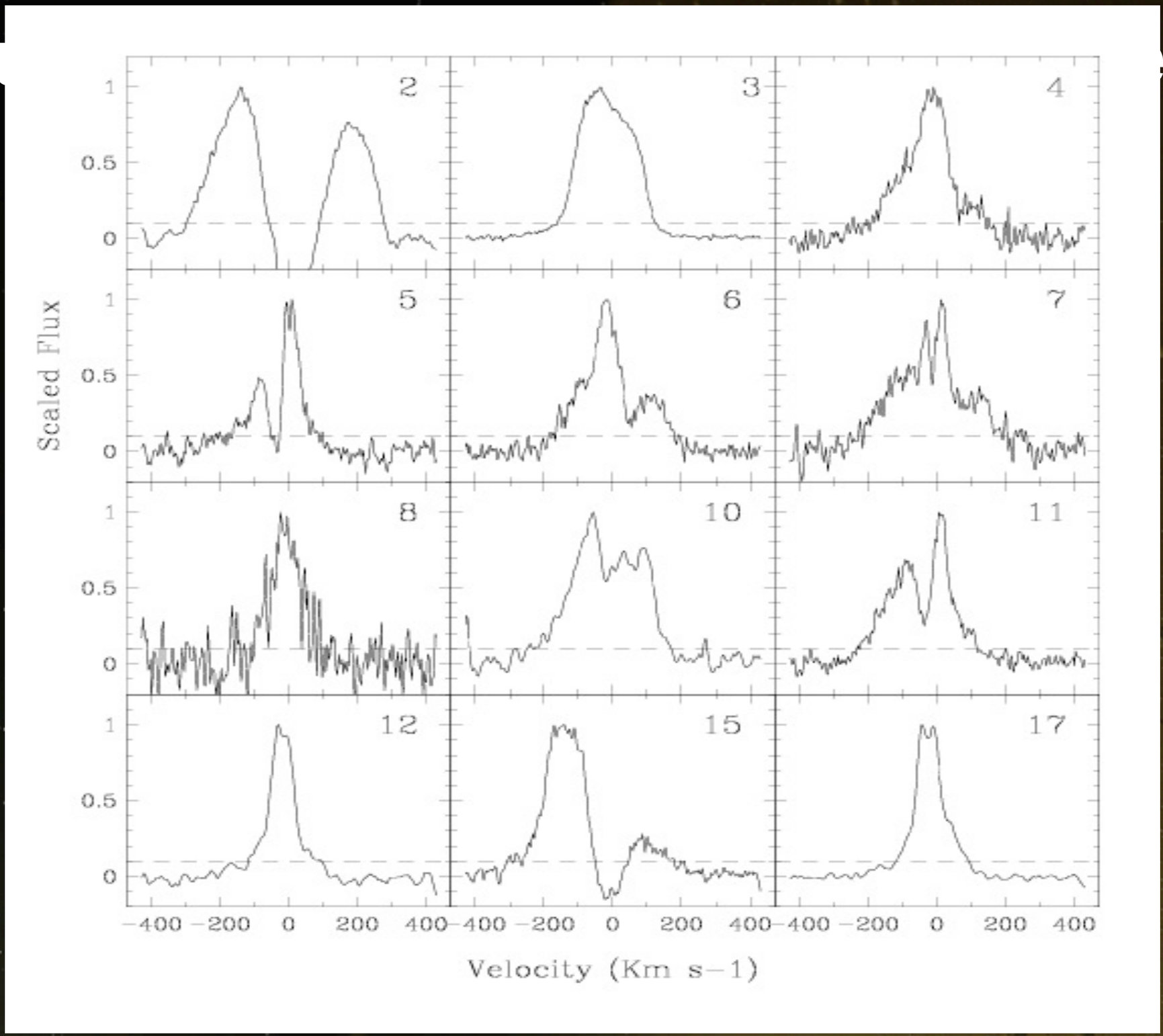
Accretion Rates: H alpha width

Dinamical Clearing: Direct Imaging & interferometry (SAM)

Disk Mass: Millimeter Fluxes

SED modelling (MCFOST)

H gy II


2
3
4
5
6
7
8
10
11
12
15
17
Scaled Flux
1
0.5
0
−400 −200 0 200 400
Velocity (Km s−1)

Hunting Transition Disks: Strategy II

Accretion Rates: H alpha width

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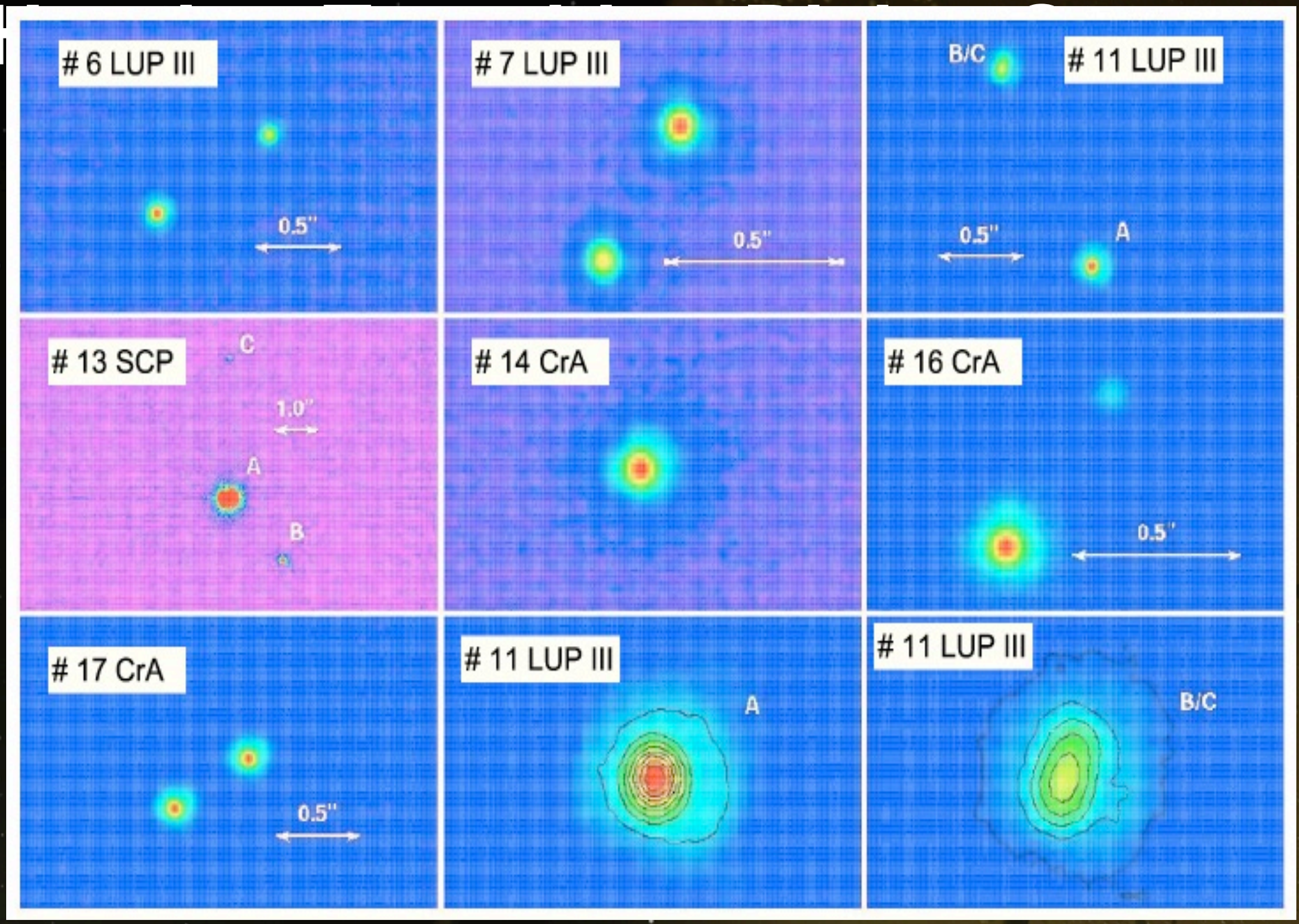
Characterization

y II



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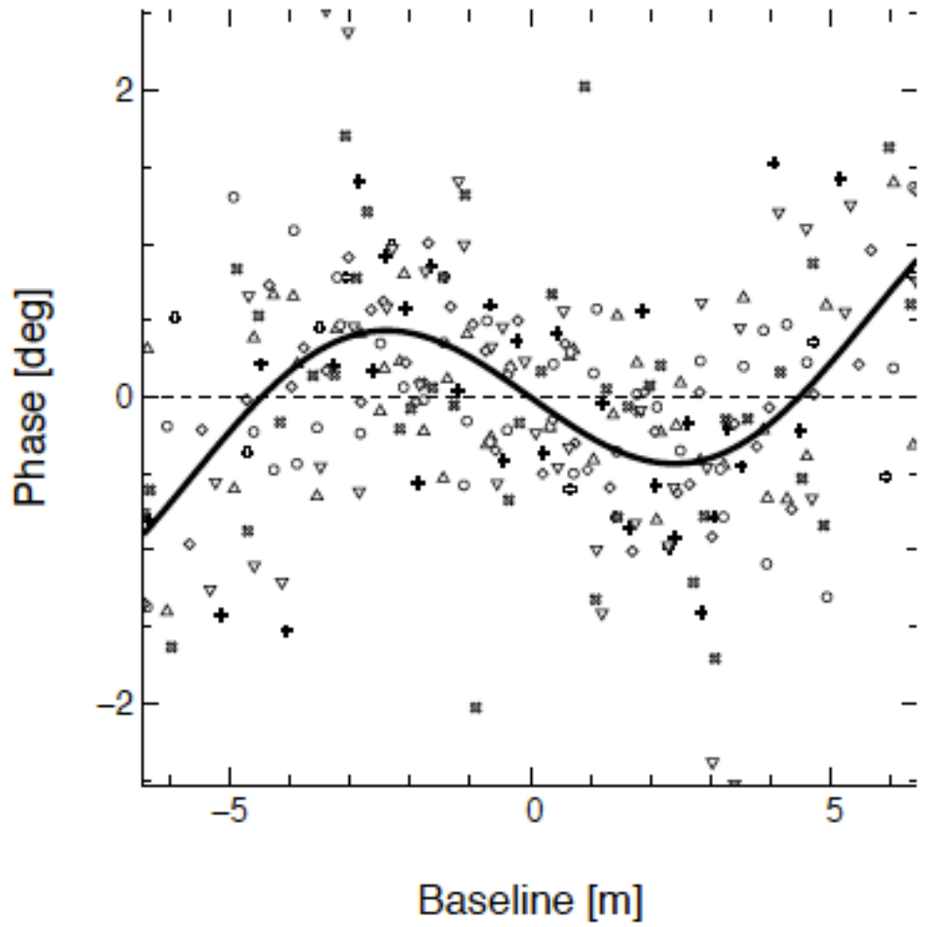

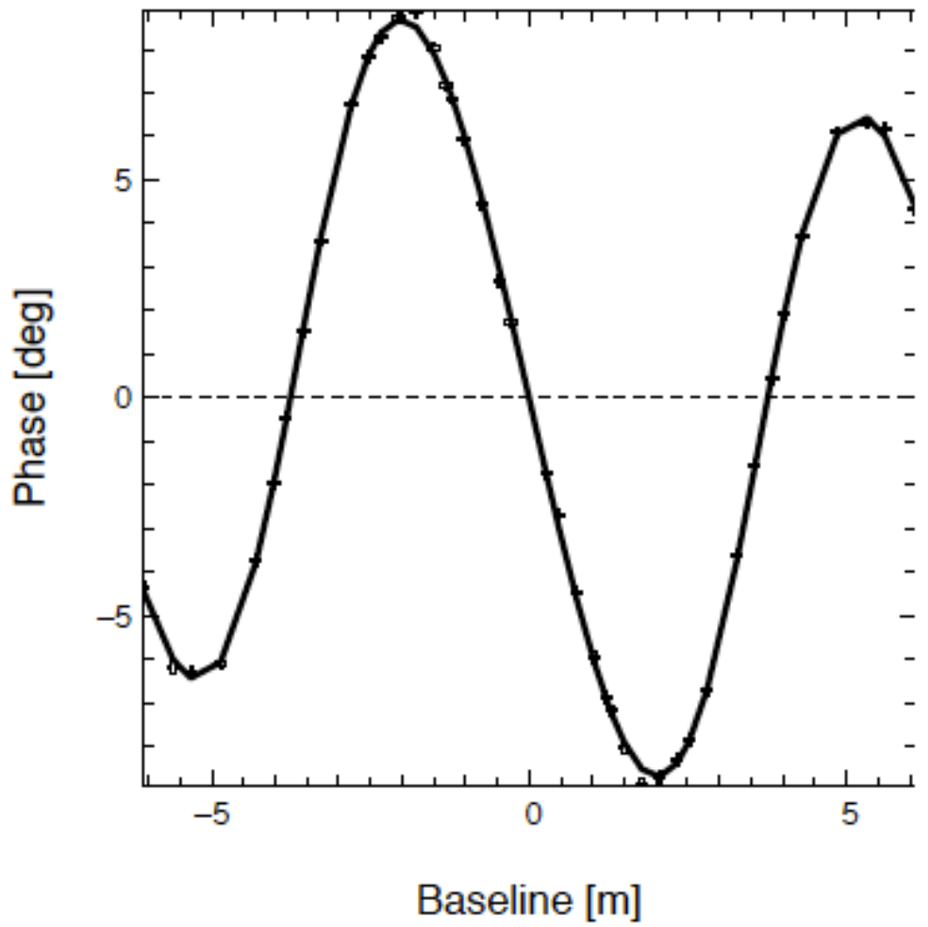

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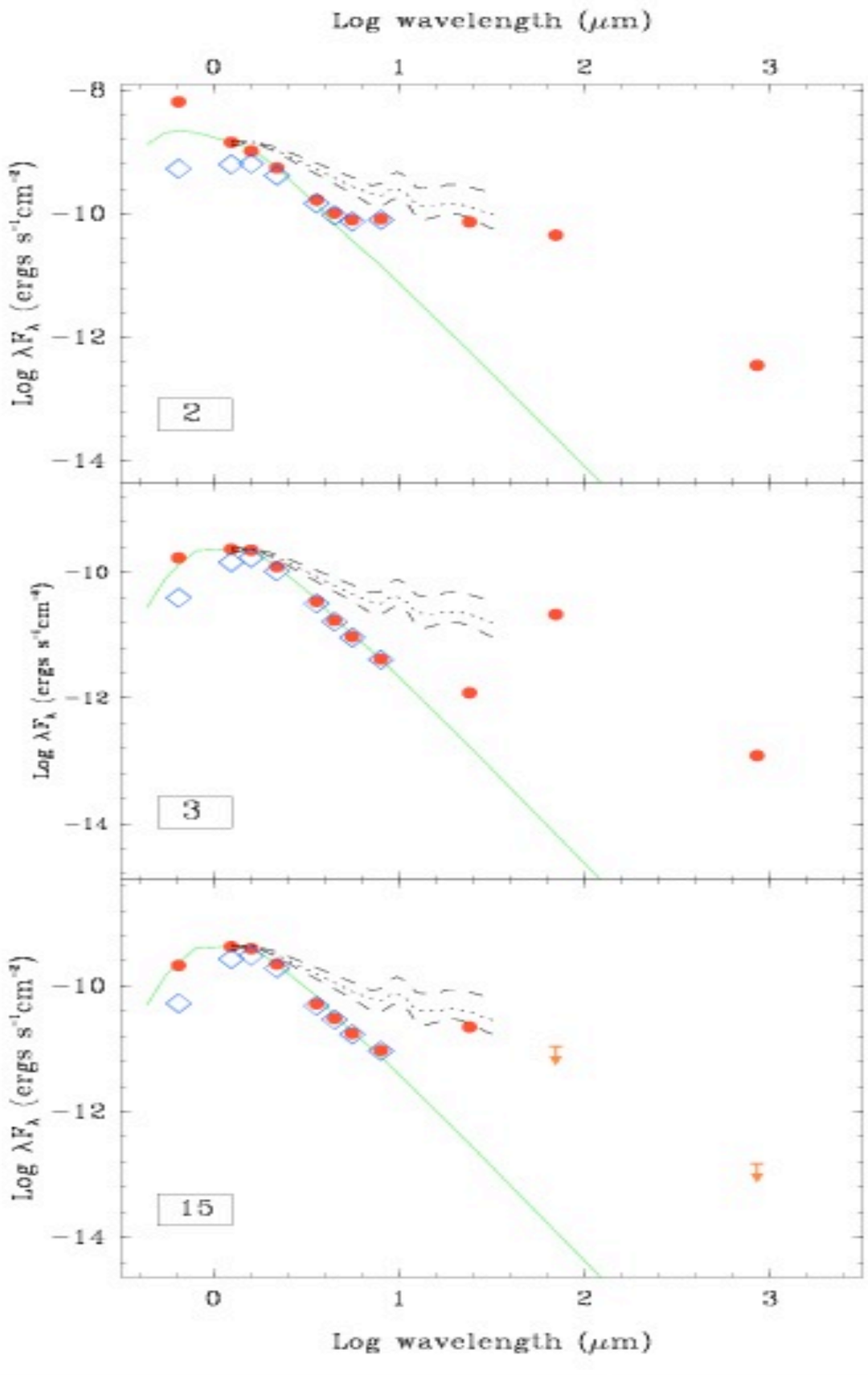

&

Hunting Transition Disks: Strategy II

Accretion Rates: H alpha width

Dinamical Clearing: Direct Imaging & interferometry (SAM)

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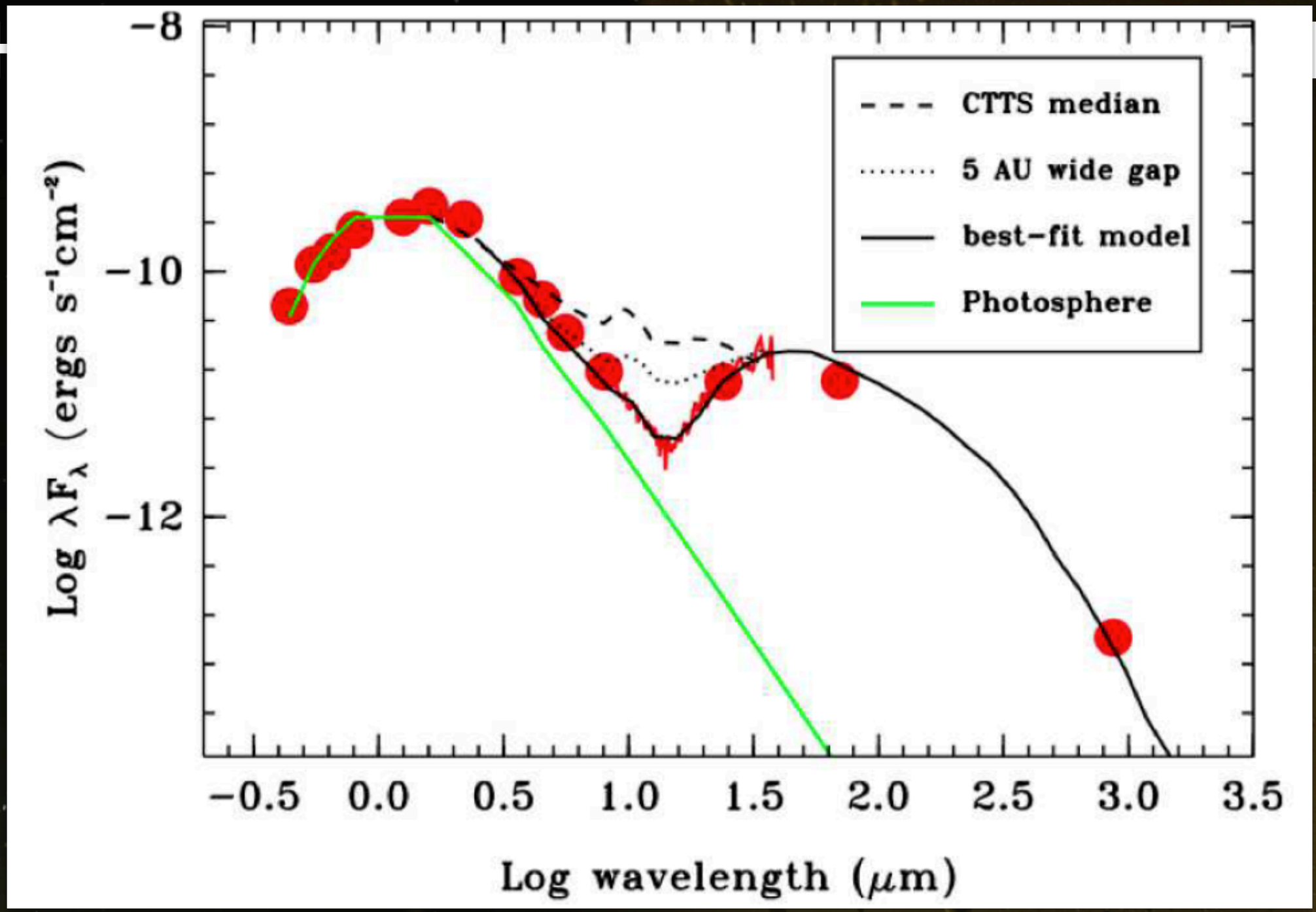
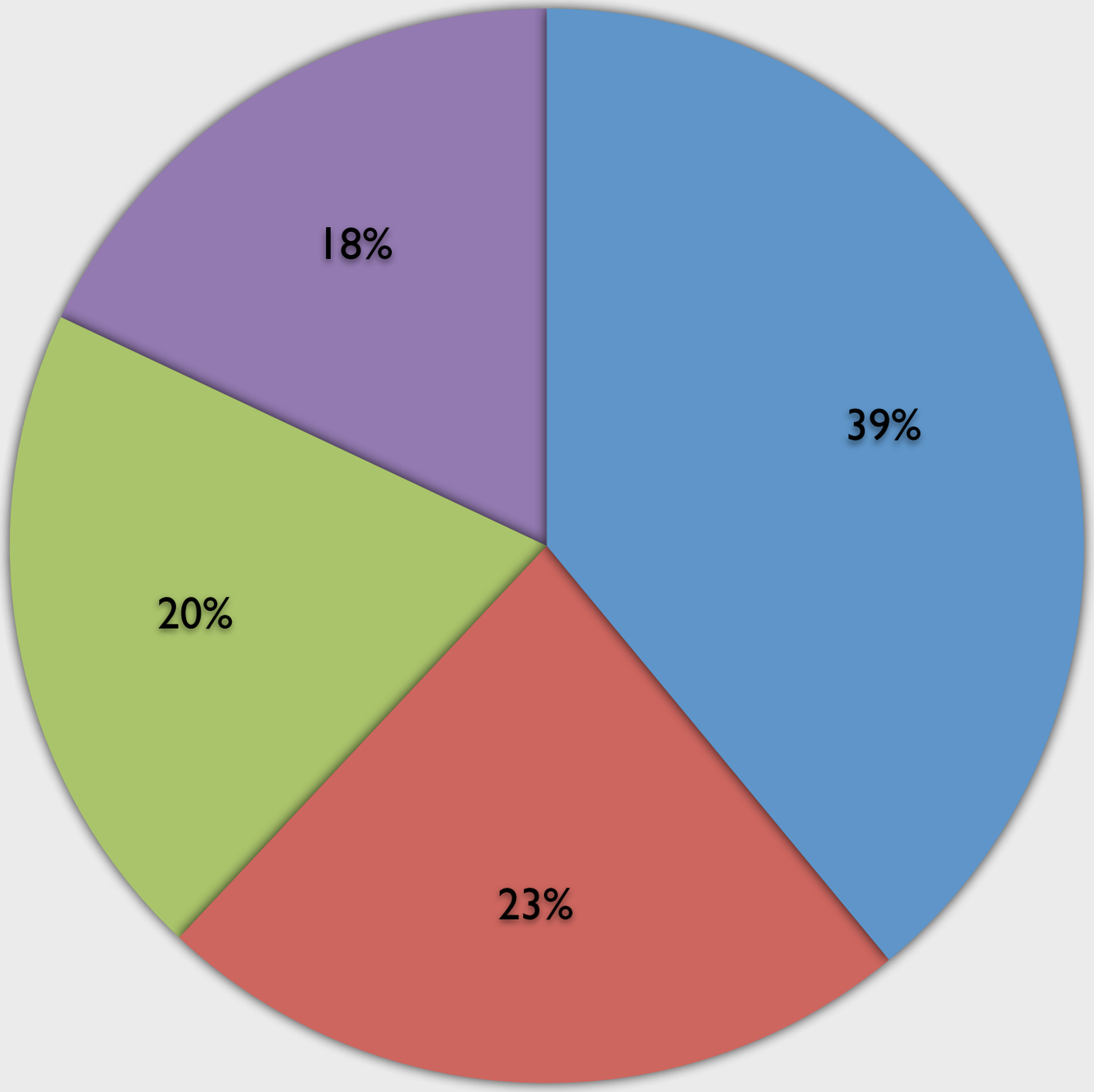

CTTS median
5 AU wide gap
best-fit model
Photosphere
Log λF_λ (ergs $s^{-1}cm^{-2}$)
−8
−10
−12
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Log wavelength (μm)

TENTATIVE Statistics

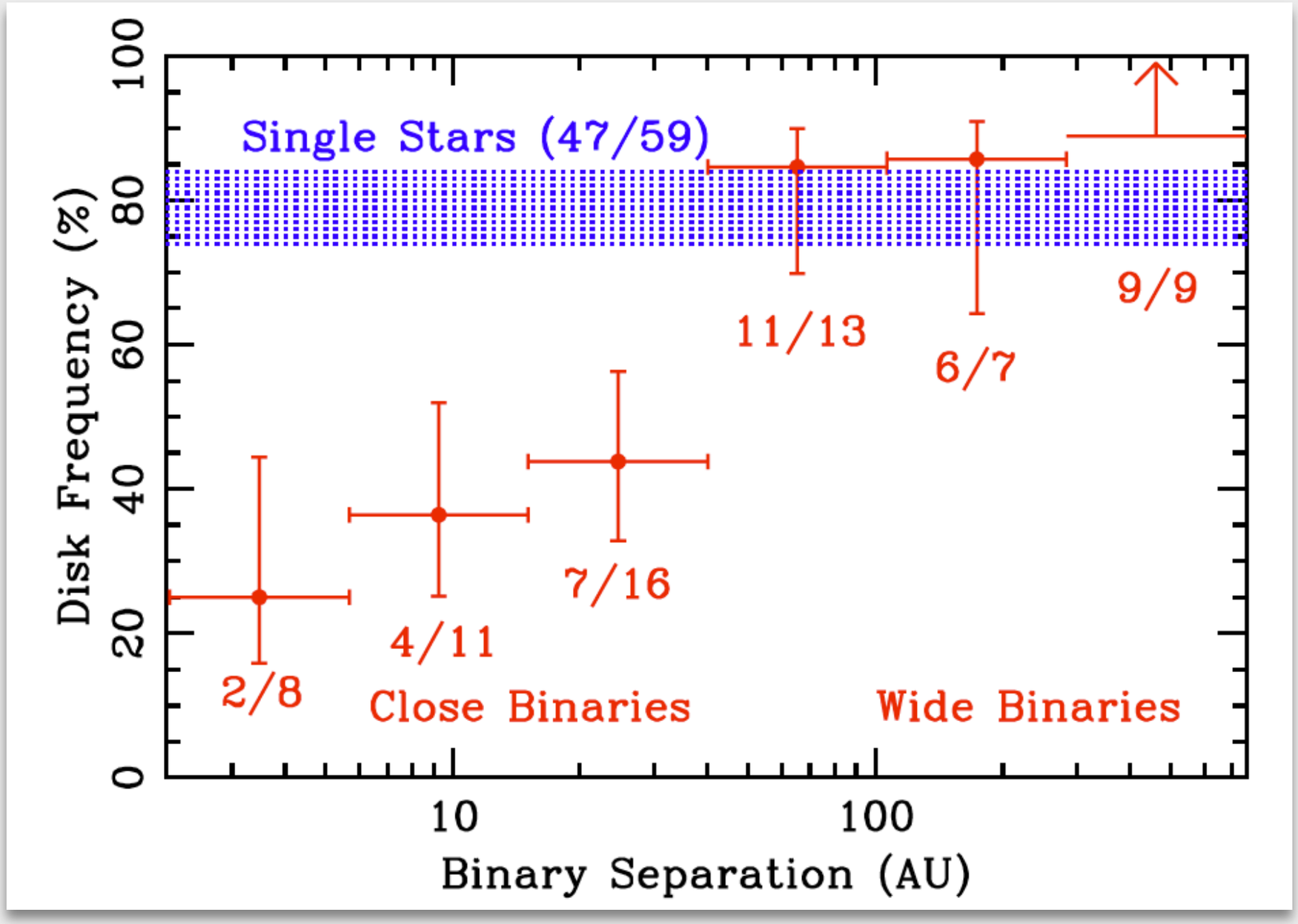
- Grain Growth (29/74)
- Debris Disks (17/74)
- Photoevaporating (15/74)
- Planet Forming (13/74)

+ Circumbinary Disks ??...



Warning: Unseen Binaries!!!!!

Lack of “close-in” binary surveys



Adapted from
Kraus et al. 2012

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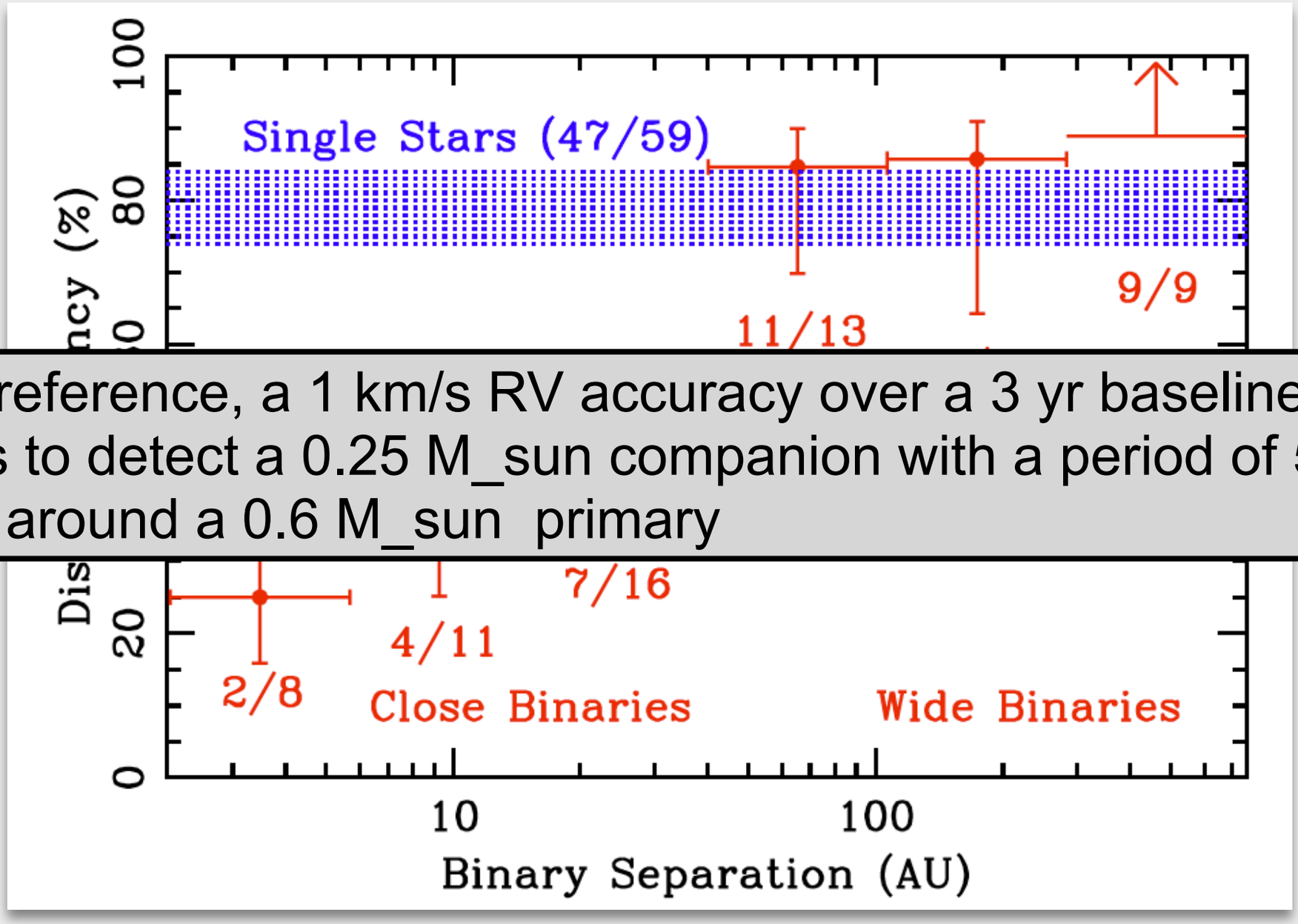
Lack of “close-in” binary surveys



As a reference, a 1 km/s RV accuracy over a 3 yr baseline allows to detect a 0.25 M_sun companion with a period of 5 years around a 0.6 M_sun primary

Adapted from Kraus et al. 2012

Next Step: hunting Planet-Forming Candidates

Problems:

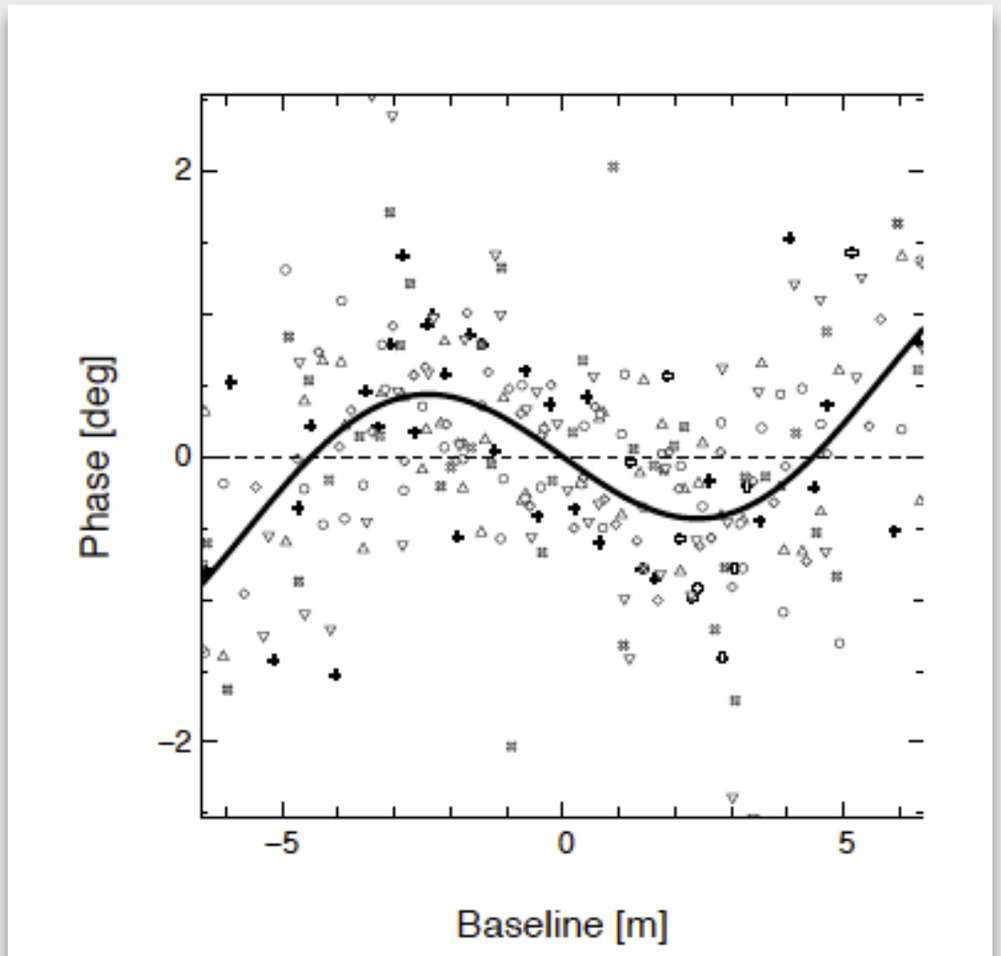
* High Contrast Ratios
* Very Small Angular Scales

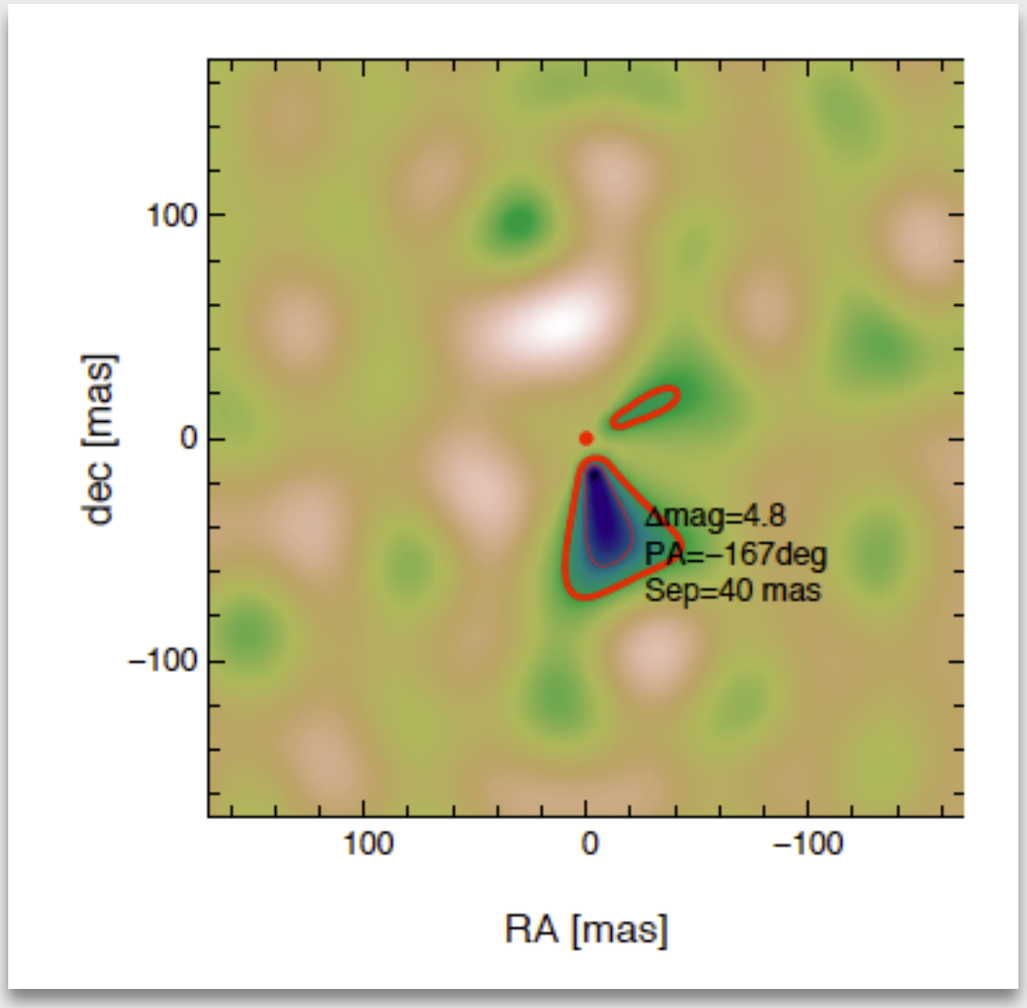
Solutions:

* NIR Interferometry (e.g. SAM)
* ALMA (radio interferometry)

FL Cha: A sub-stellar companion or a Disk-Projection effect?

Fit to Closure Phase >>>> Derived Chi^2 map

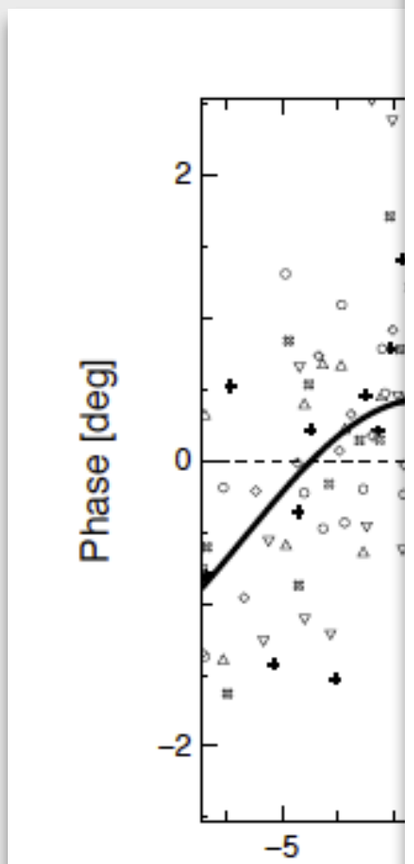


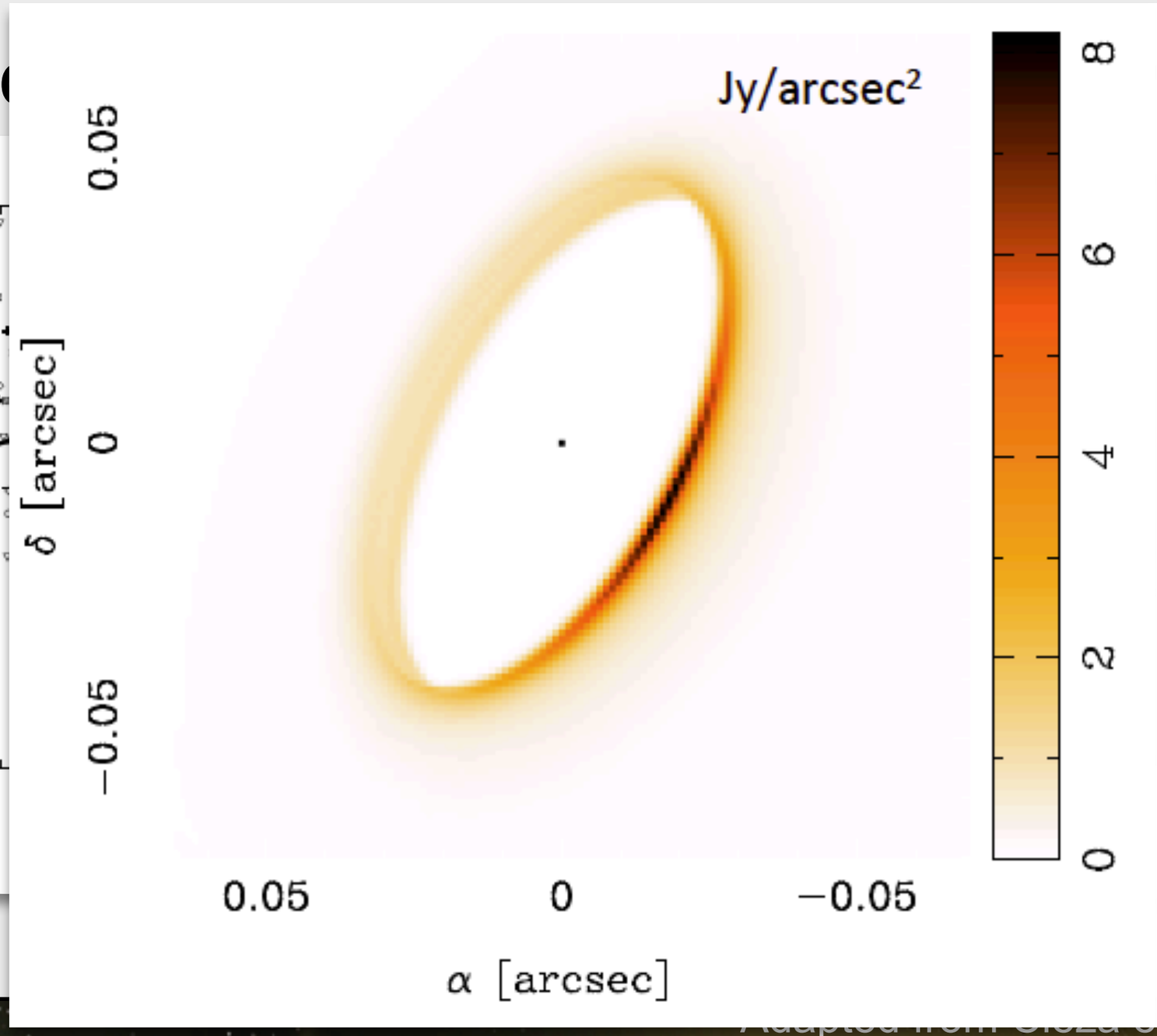


Adapted from Cieza et al. 2012d

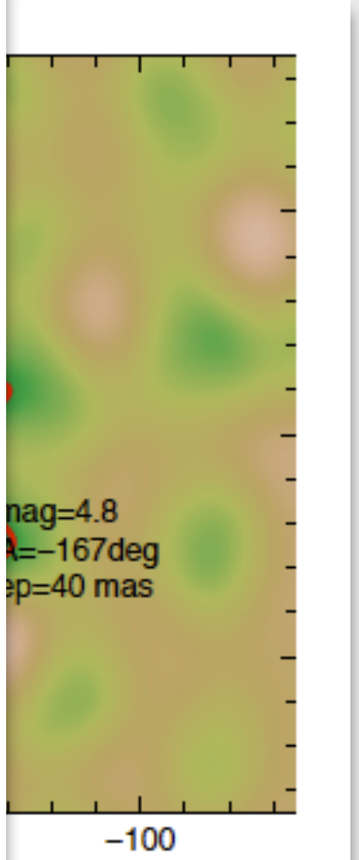
FL Cha: A sub-stellar companion or a Disk-Projection effect?

Fit to Cl



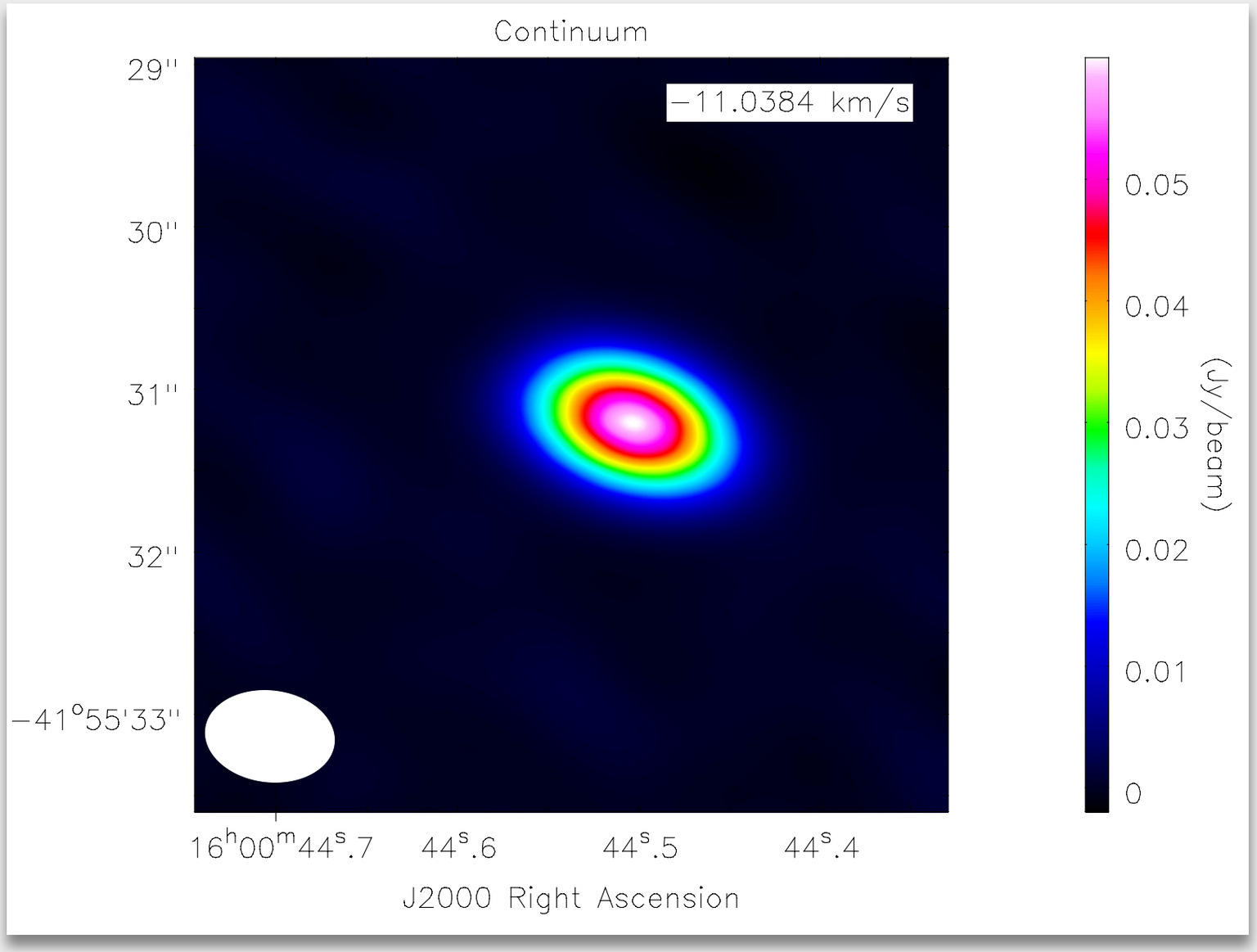


2 map



Adapted from Sicilia et al. 2012d

MY LUP (and 14 other disks)
ALMA Cycle 0



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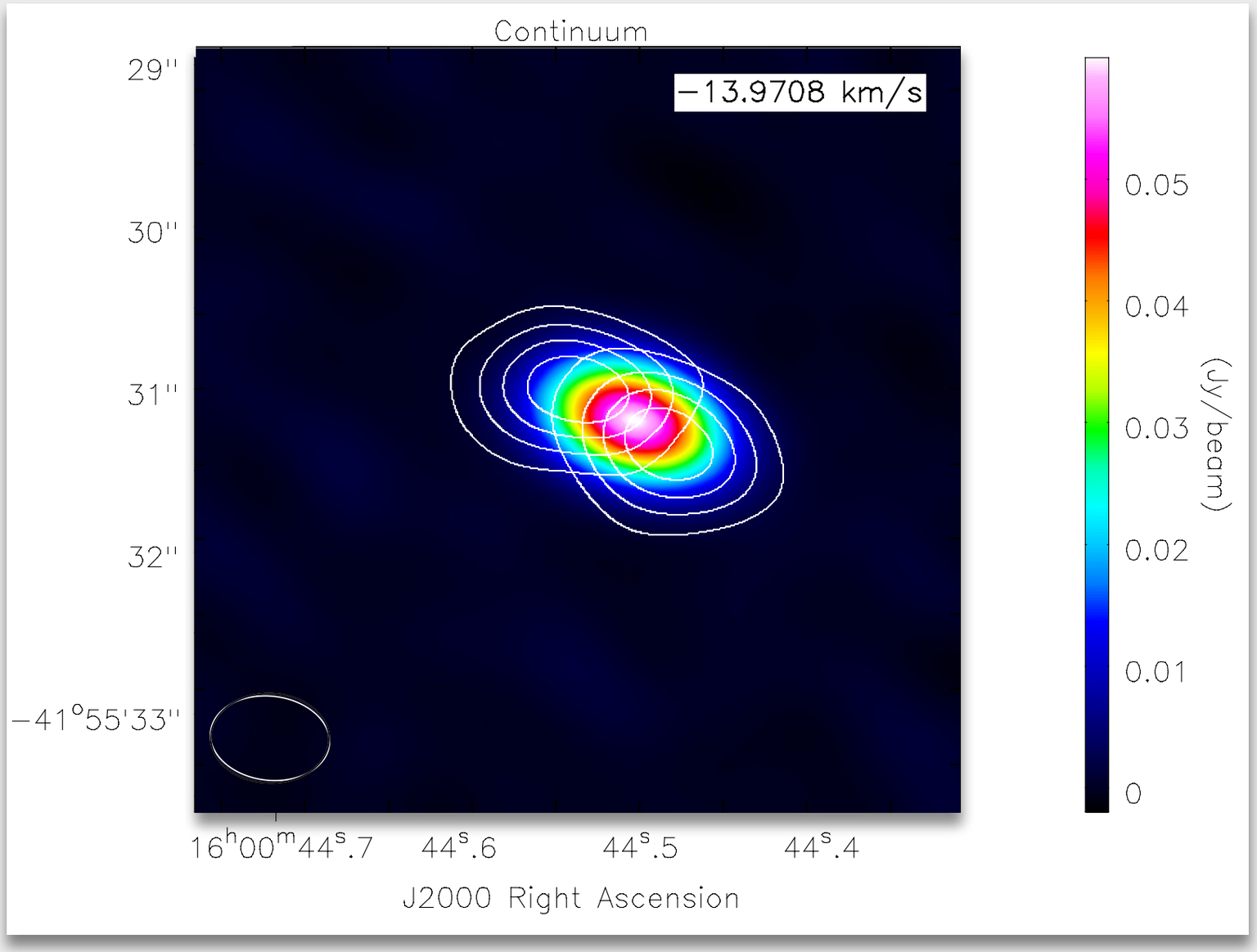


MY LUP (and 14 other disks)
ALMA Cycle 0

What I want to do:

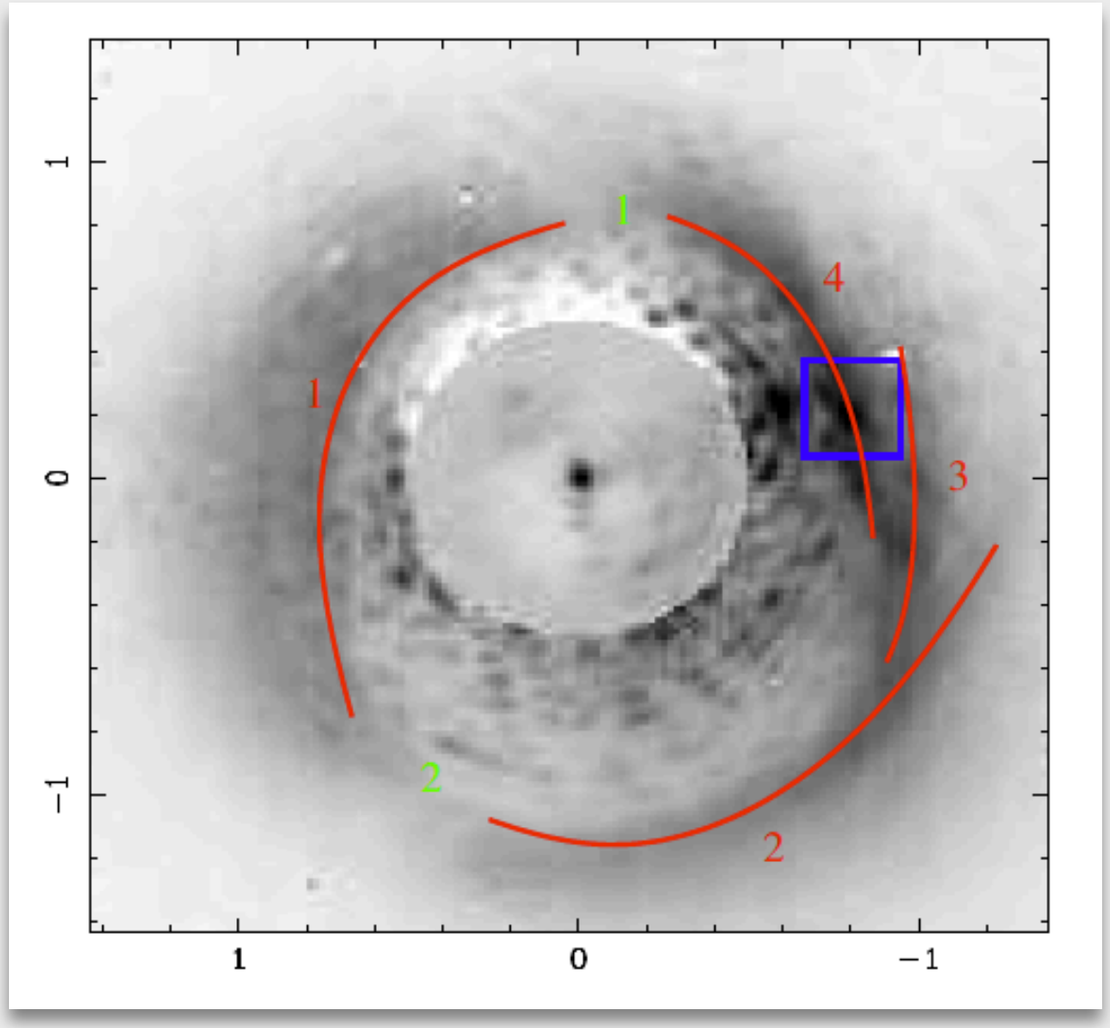
Measure the MASS of dust & gas

Put new constrains to current models:
everybody assumes a Gas to Dust ratio of 100!!!

HD 142527 - Previous Facts

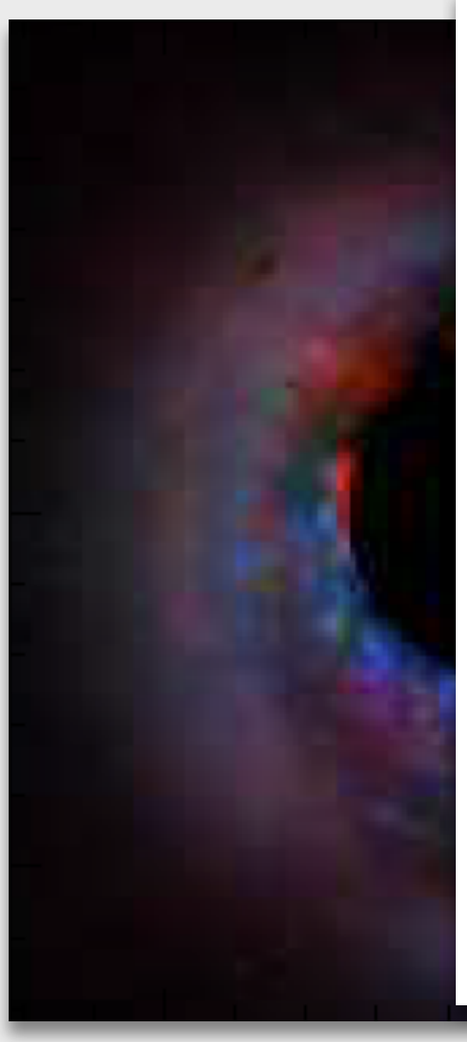
* Transition Disk Structure
* Strong Accretion Rate
* Large Gap (10-140 AU)
* Horse-Shoe Continuum-emission shape
* Disrupted Outter Disk

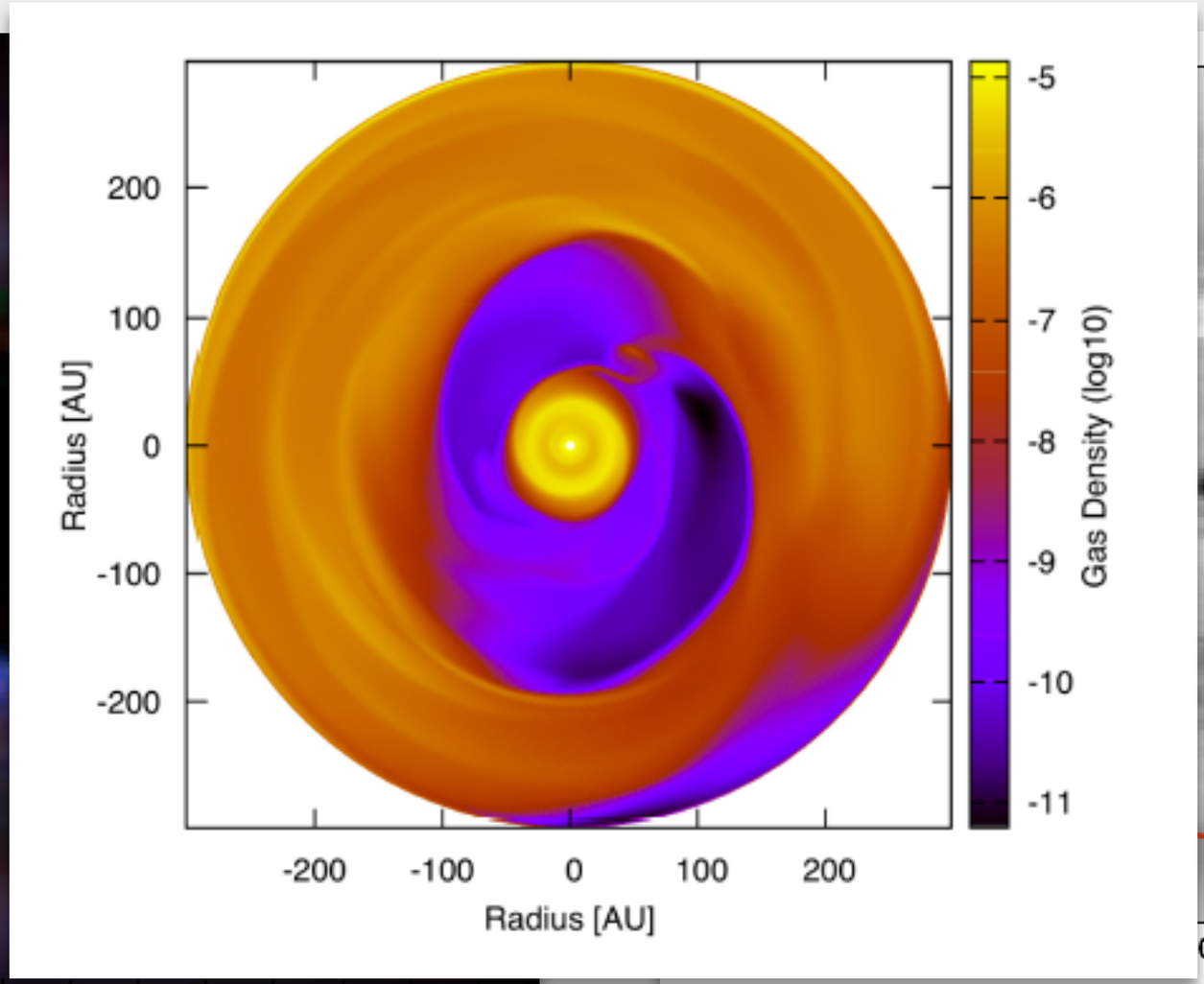
HD 142527 - Disrupted Disk!

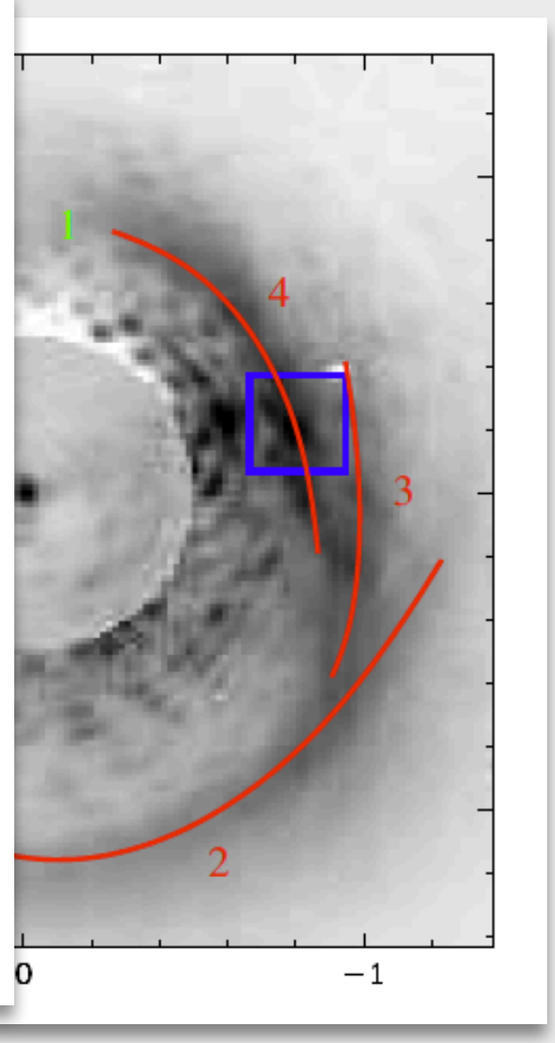


Adapted from Casassus et al. 2012

HD 142527 - Disrupted Disk!







Adapted from Casassus et al. 2012

HD 142527 - NEW ALMA Data

Adapted from Casassus et al. 2013

HD 142527 - NEW ALMA Data

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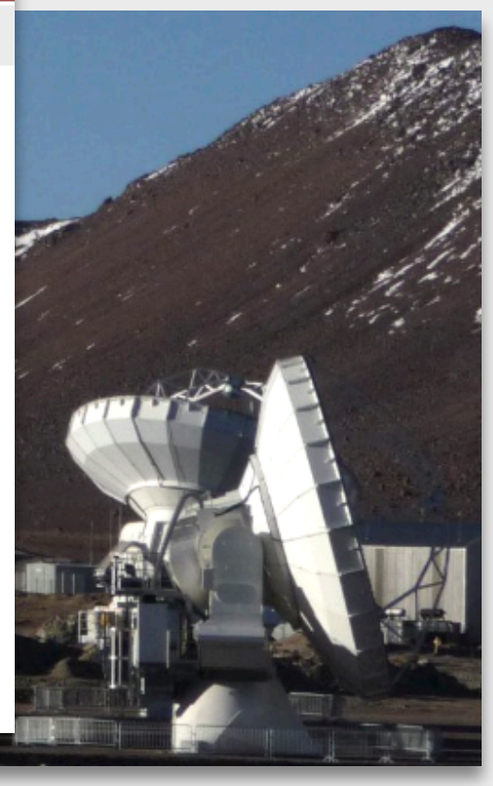
Flows of gas through a protoplanetary gap

Simon Casassus, Gerrit van der Plas, Sebastian Perez M, William R. F. Dent, Ed Fomalont, Janis Hagelberg, Antonio Hales, Andrés Jordán, Dimitri Mawet, Francois Ménard, Al Wootten, David Wilner, A. Meredith Hughes, Matthias R. Schreiber, Julien H. Girard, Barbara Ercolano, Hector Canovas, Pablo E. Román & Vachail Salinas

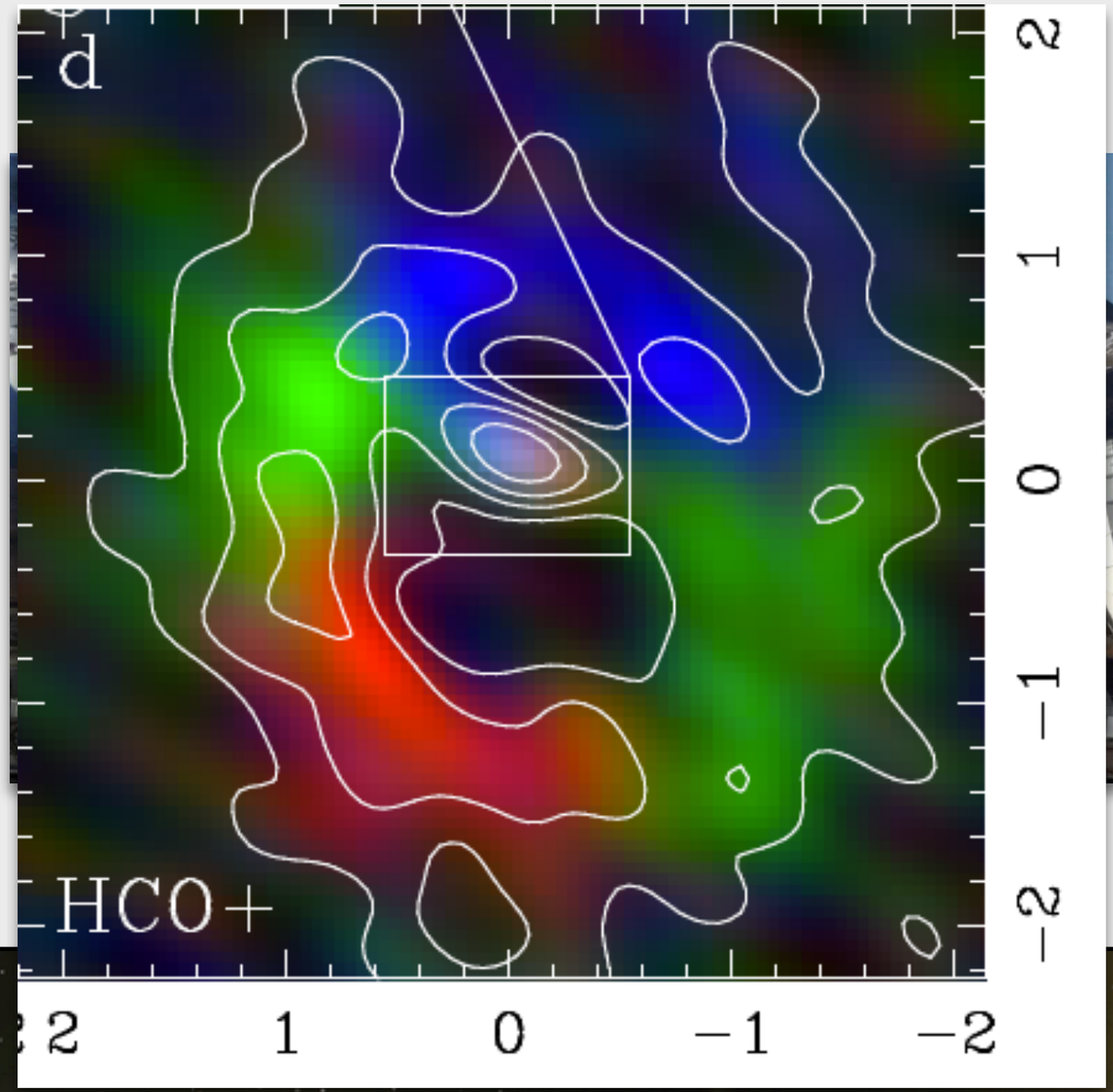


Adapted from Casassus et al. 2013

HD 142527 - NEW ALMA Data

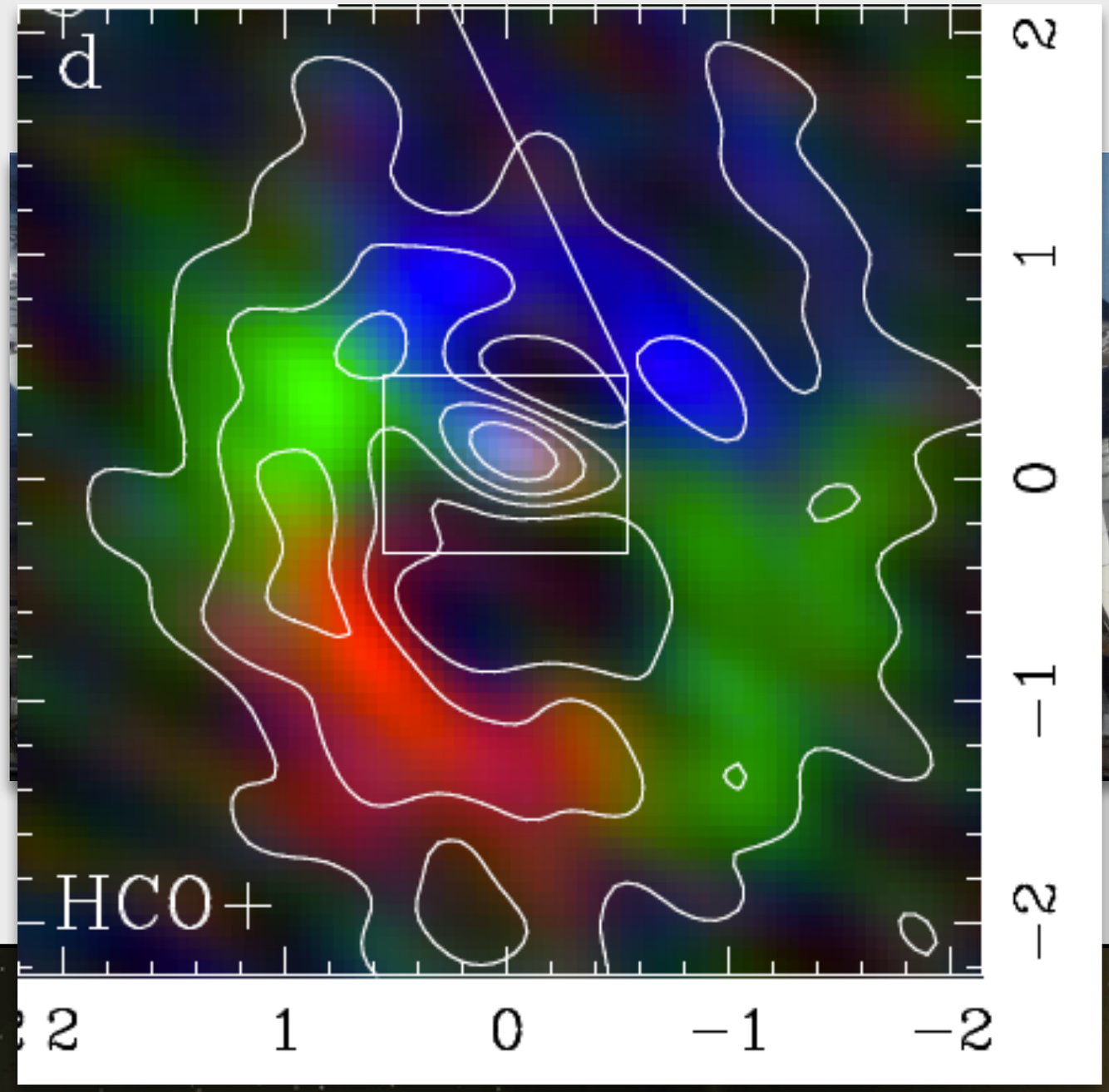
Adapted from Casassus et al. 2013

HD 142527 - NEW ALMA Data



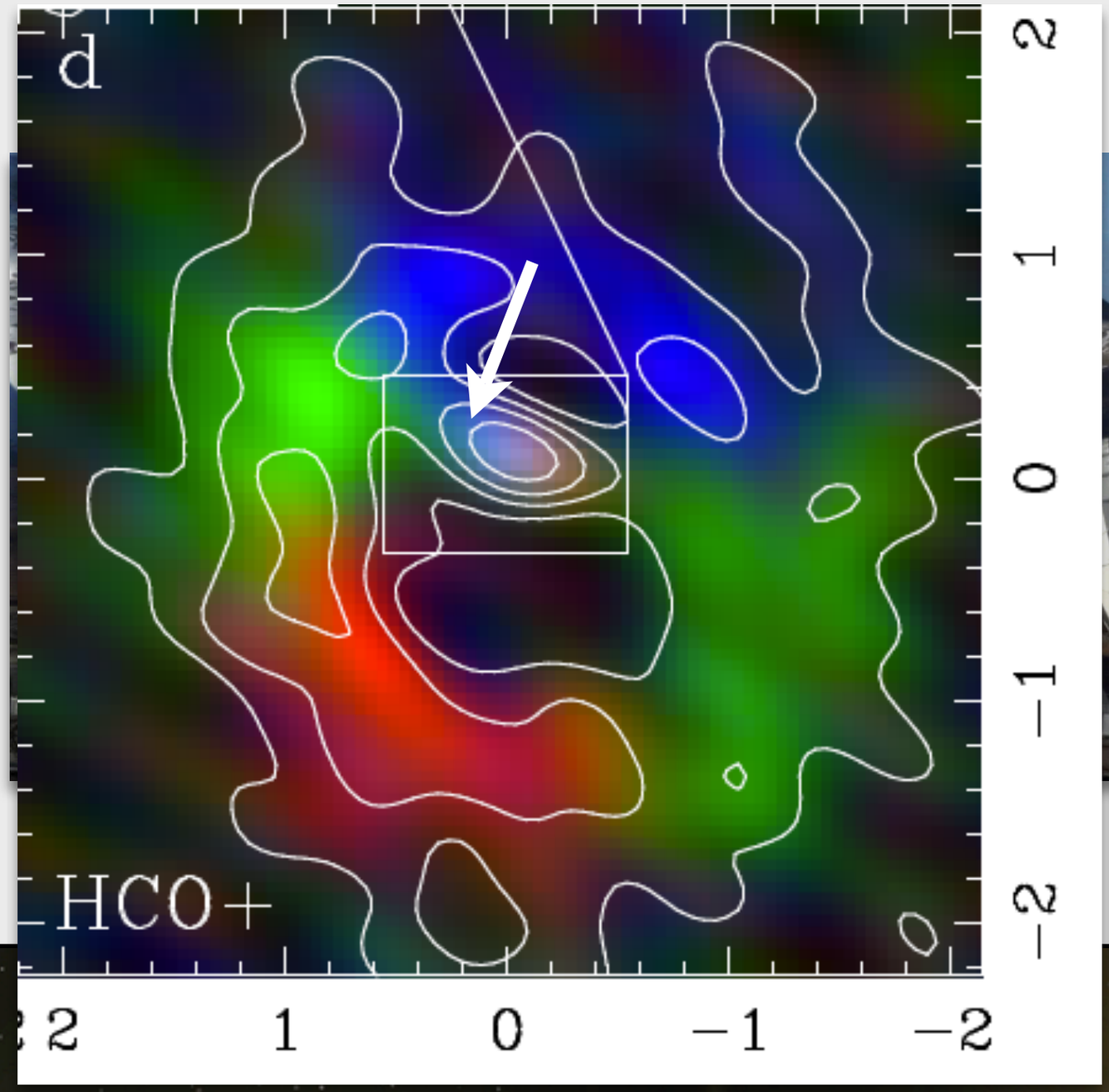
Adapted from Casassus et al. 2013

HD 142527 - NEW ALMA Data



Adapted from Casassus et al. 2013

HD 142527 - NEW ALMA Data



Adapted from Casassus et al. 2013

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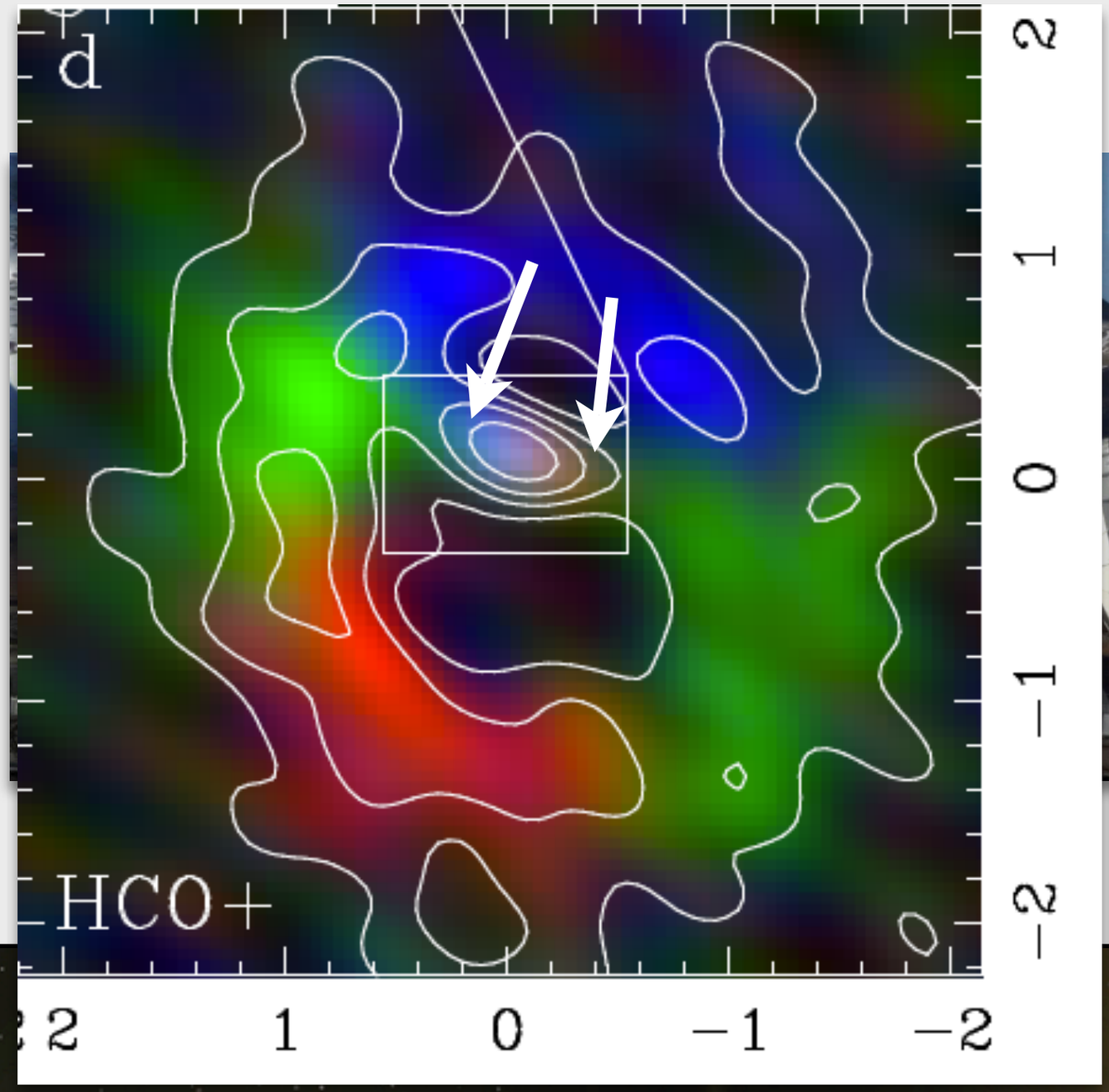

Adapted from Casassus et al. 2013

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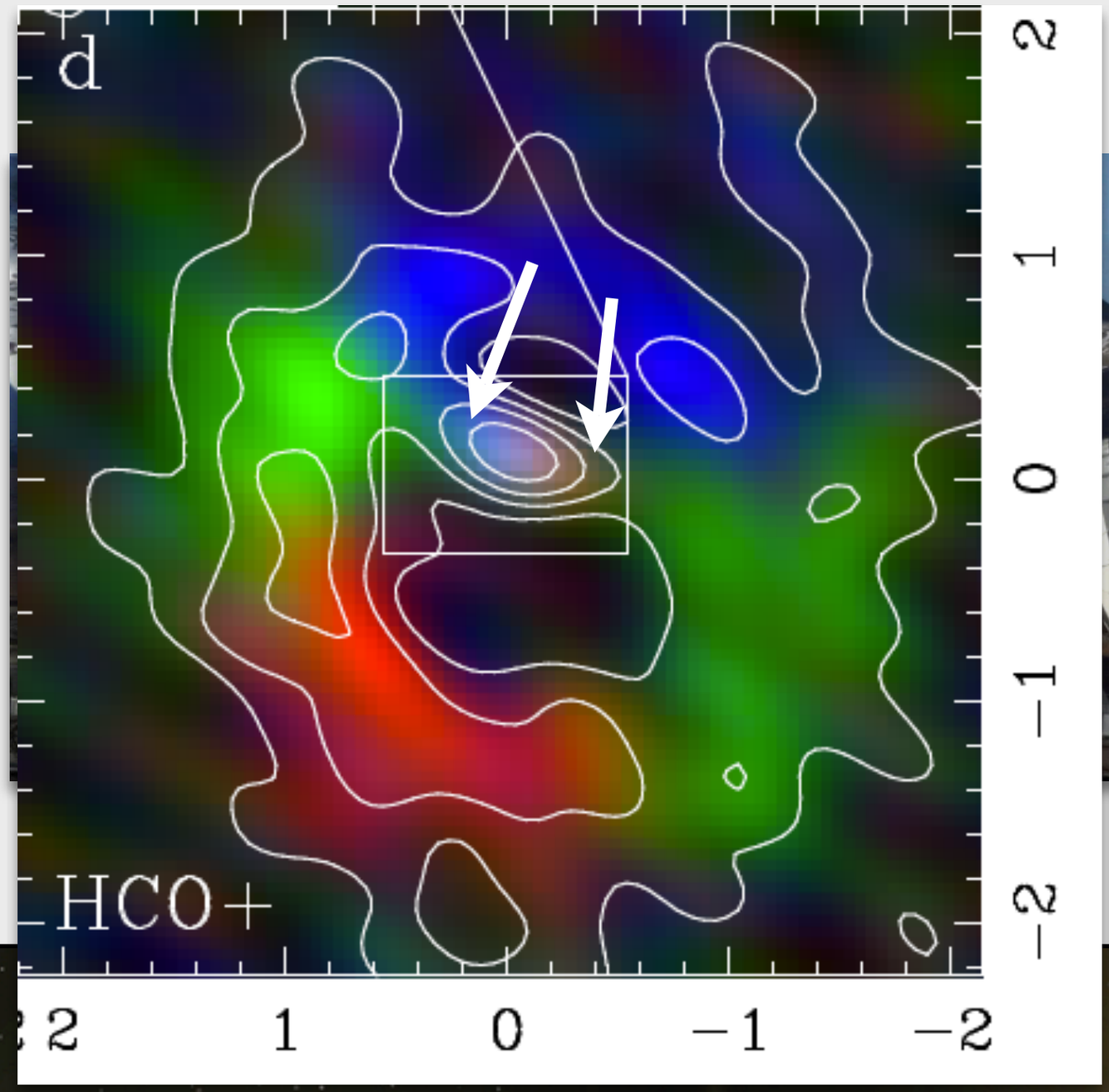
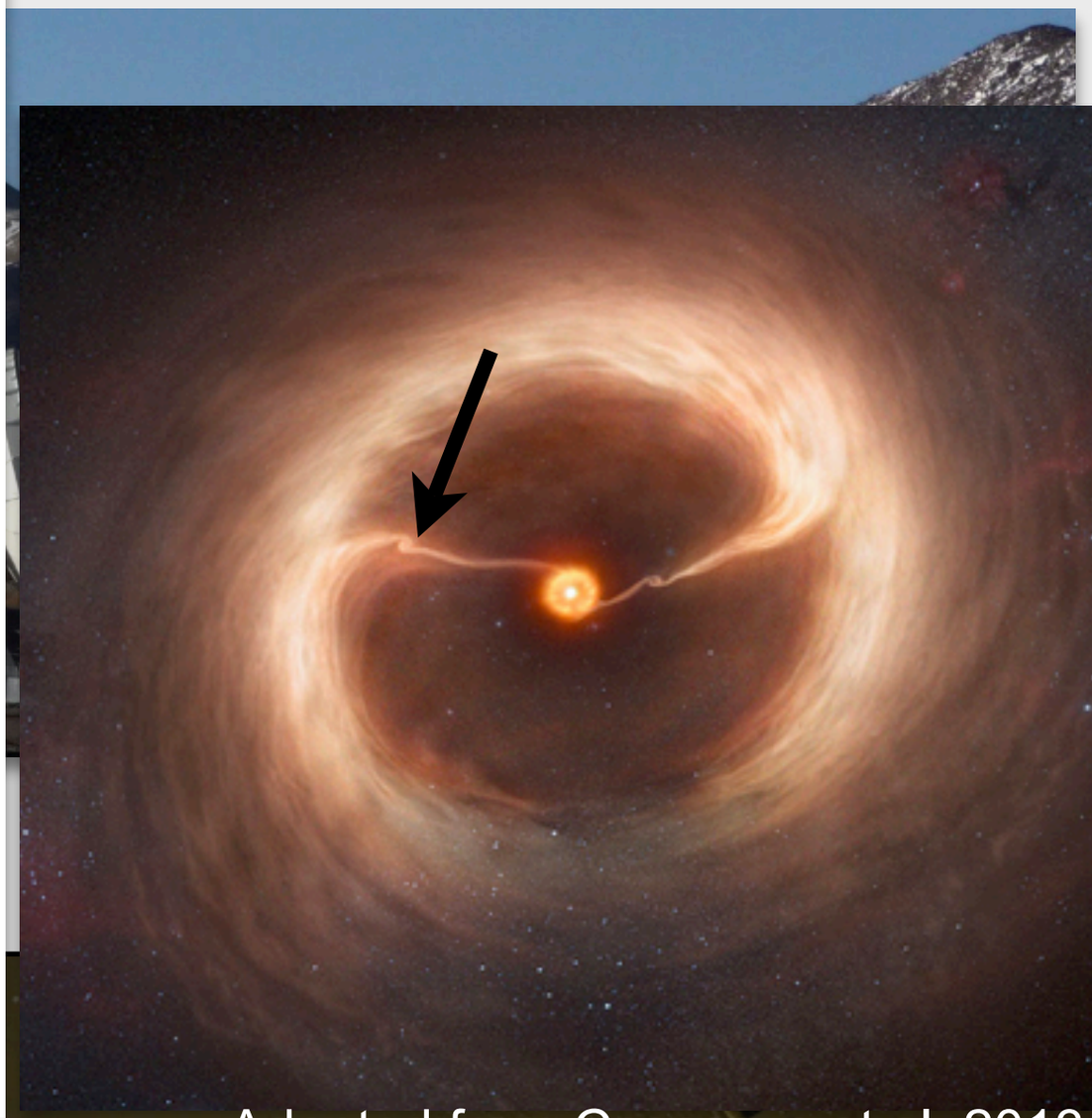
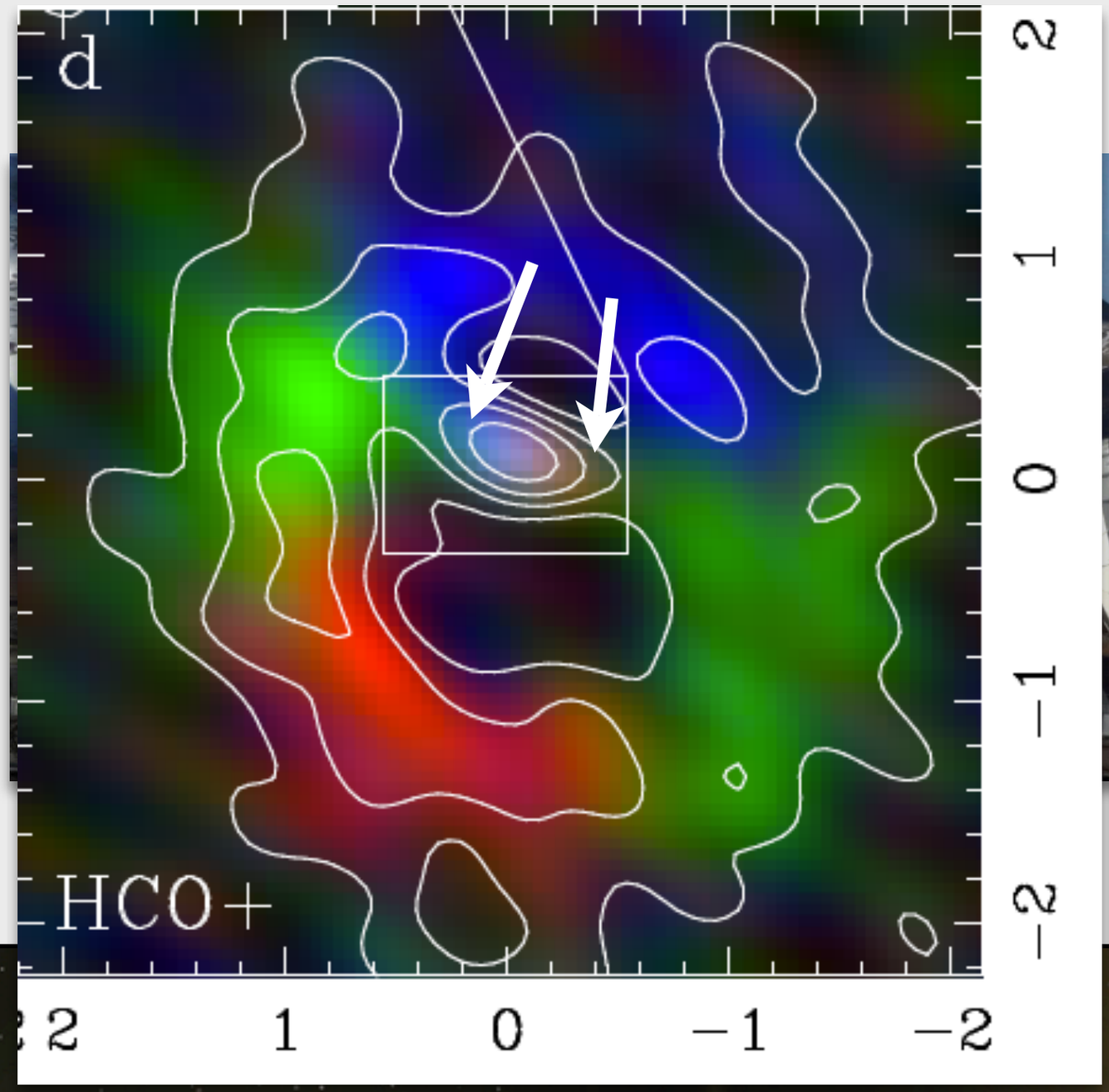
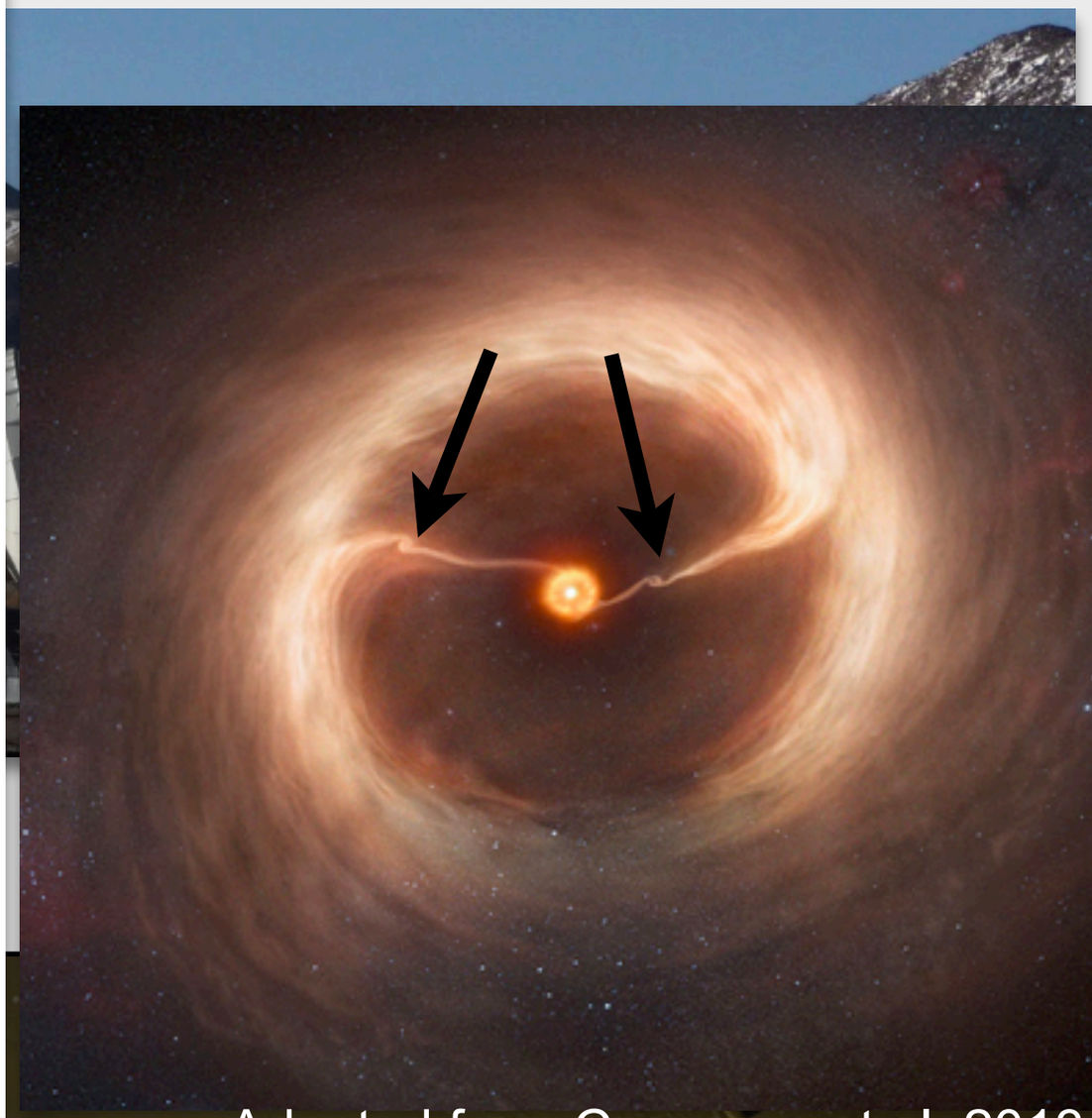




Adapted from Casassus et al. 2013

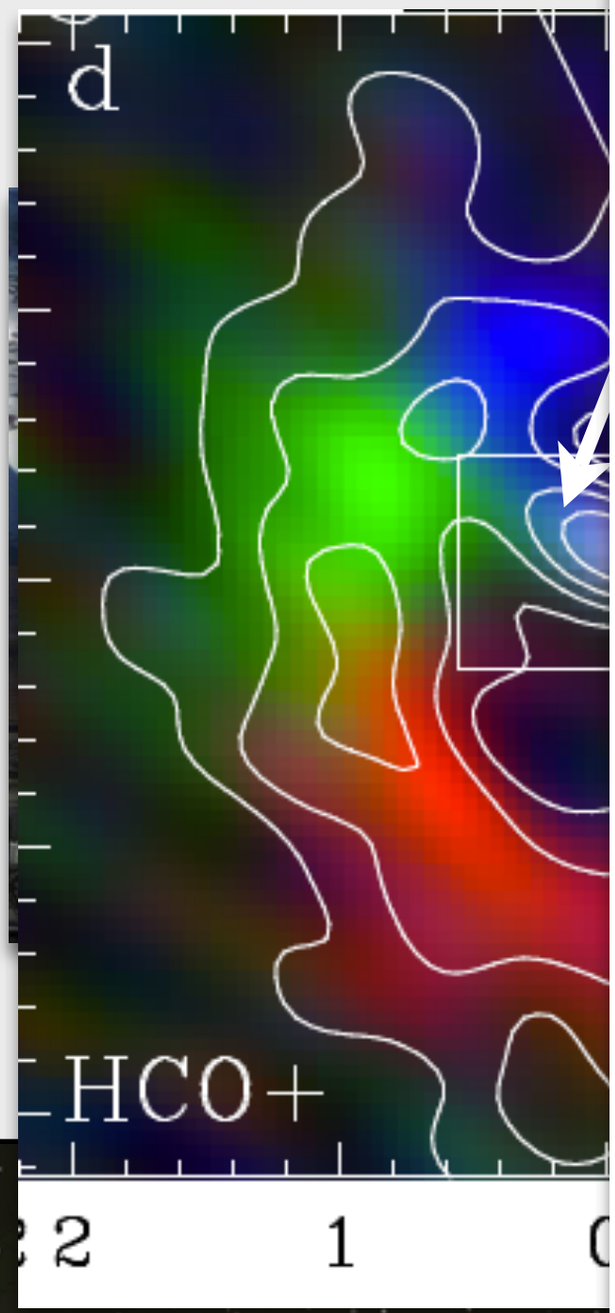
HD 142527 - NEW ALMA Data

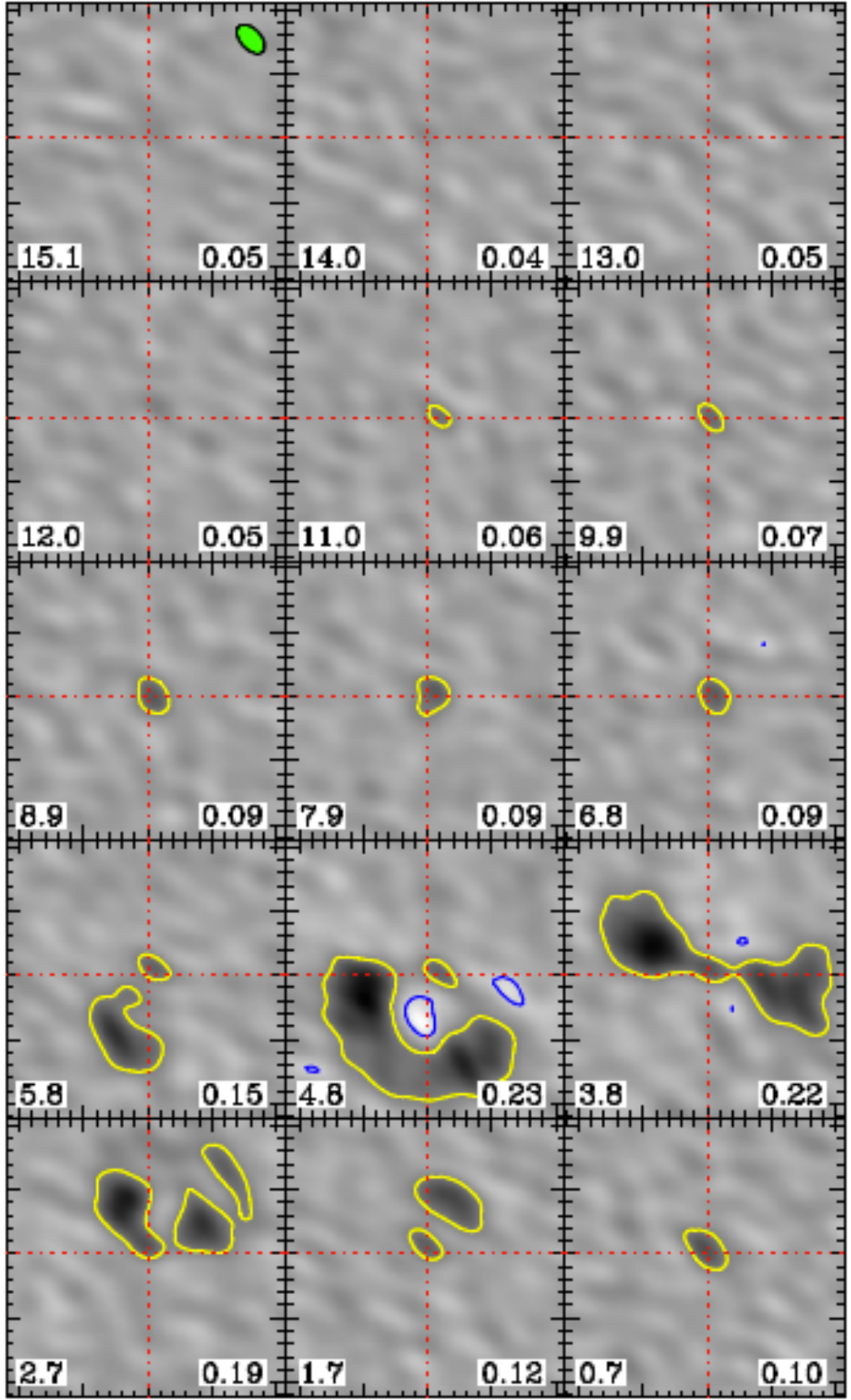




Adapted from Casassus et al. 2013

HD 1 A Data

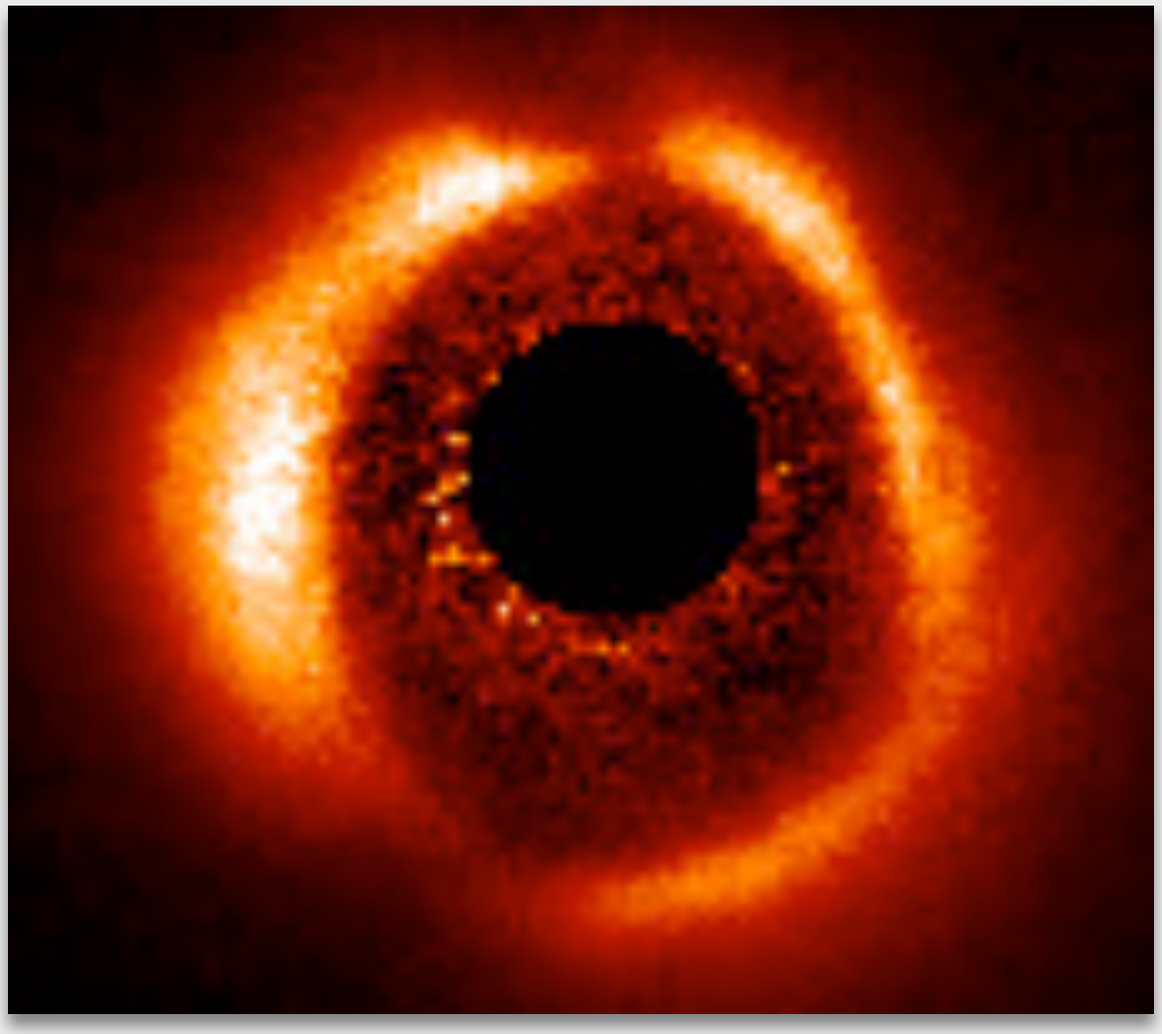




rom Casassus et al. 2013

HD 142527 - Polarimetry

HD 142527 - Polarimetry



FUTURE PLANS

→ **fresh CYCLE-0 ALMA DATA**:
* GAS & DUST masses in a set of accreting & non-accreting Transition Disks

→ **aproved CYCLE-1 ALMA** proposal (PI Claudio Caceres):
* Testing the photoevaporation scenario:
Disk Masses in Non-Acretting Transition Disks

→ Radial Velocity Data: improving the Binarity Constrains

→ APEX Data: Measuring the Disk Masses of more Transition Disks...

FUTURE PLANS

THANKS!!!