COMPANION CANDIDATES FOUND AT THE EDGES OF TWO CIRCUMSTELLAR DISKS

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CONTENT

- The whole picture
- Challenges of high contrast imaging
- Planet candidates in prototype systems
    - Young system with an optically thick disk
    - Evolved debris disk
- Lessons learned for both age ranges

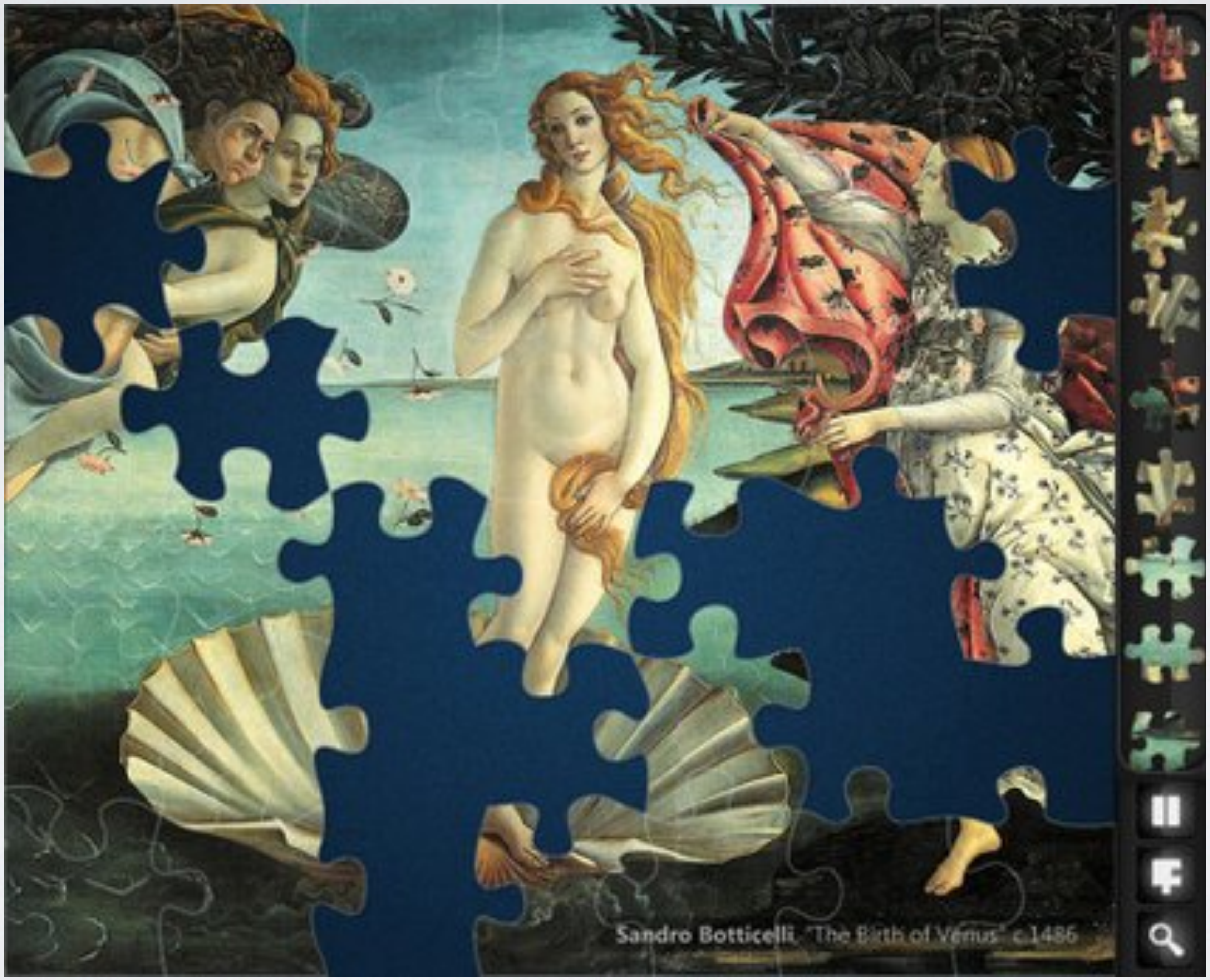
THE WHOLE PICTURE

Transit

RV

Age

SMA



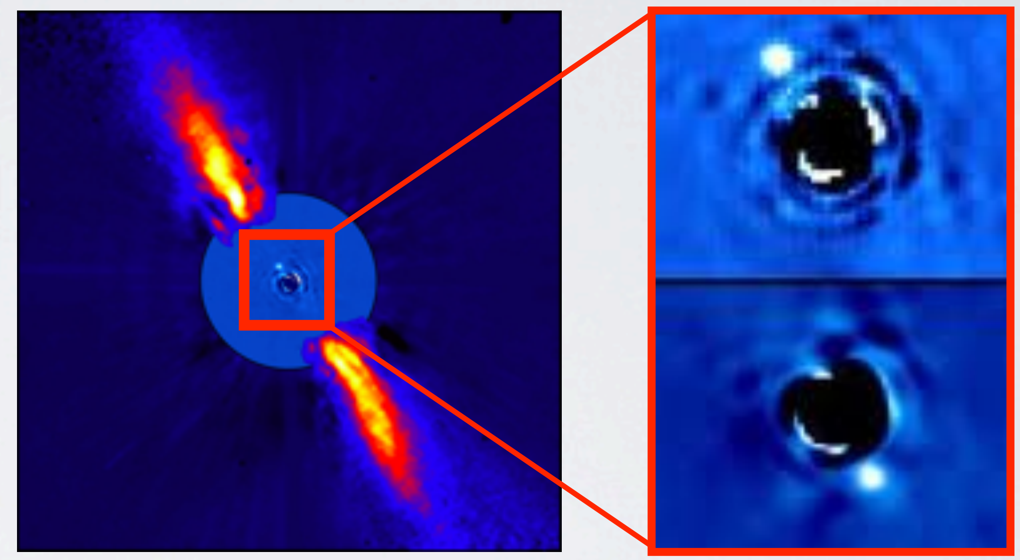
μ-lens

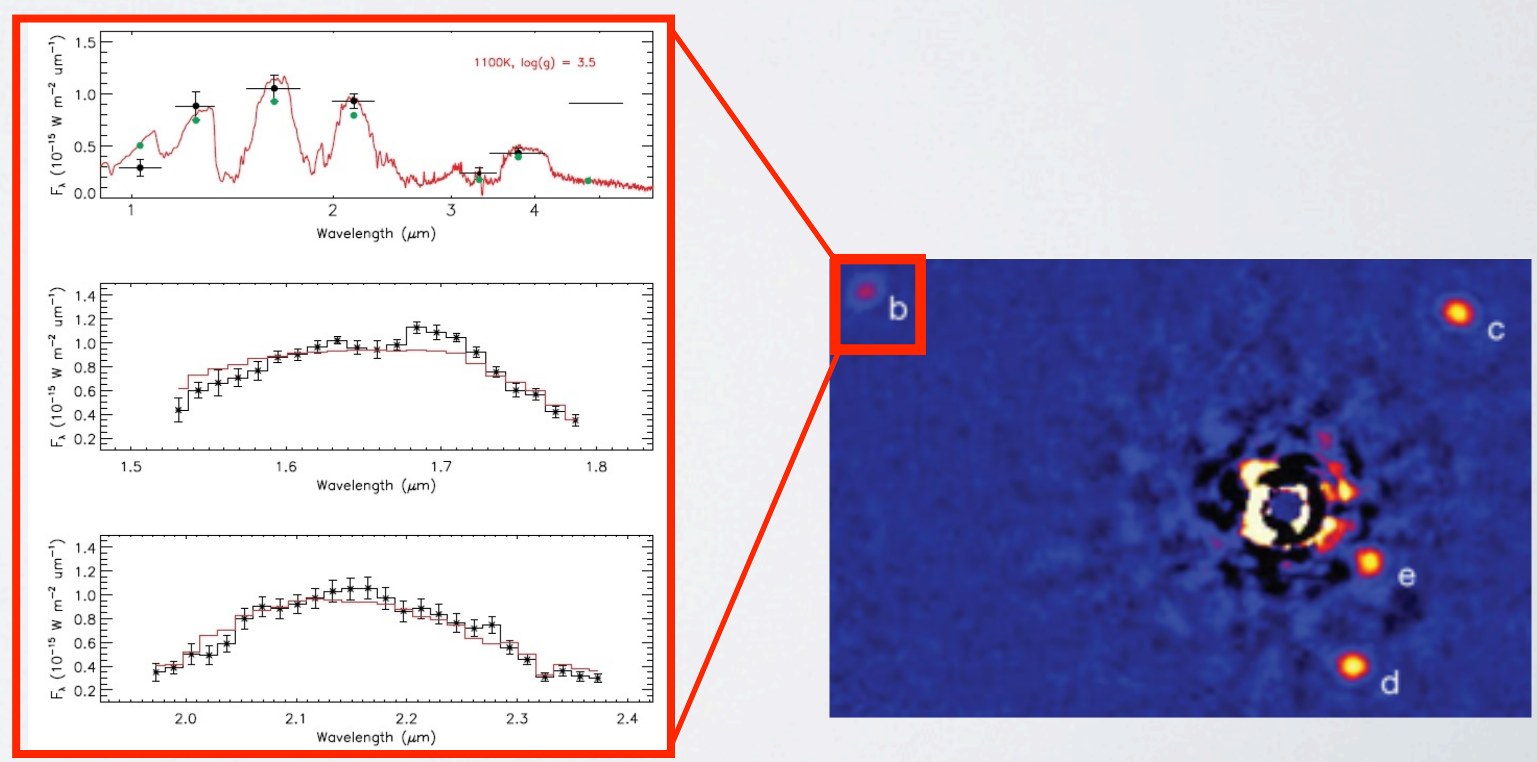
DI

I

DIRECT IMAGING FOR SYSTEM CHARACTERIZATION

- Planet composition through spectro-photometric analysis
- Orbital properties
- In context analysis:
    - interaction with disk
    - other planets
    - Transient events





CHALLENGES OF DIRECT IMAGING

- Observational: instrumental limitations, strategy
- Data reduction
- Interpretation - model:
    - Age determination
    - Proper motion

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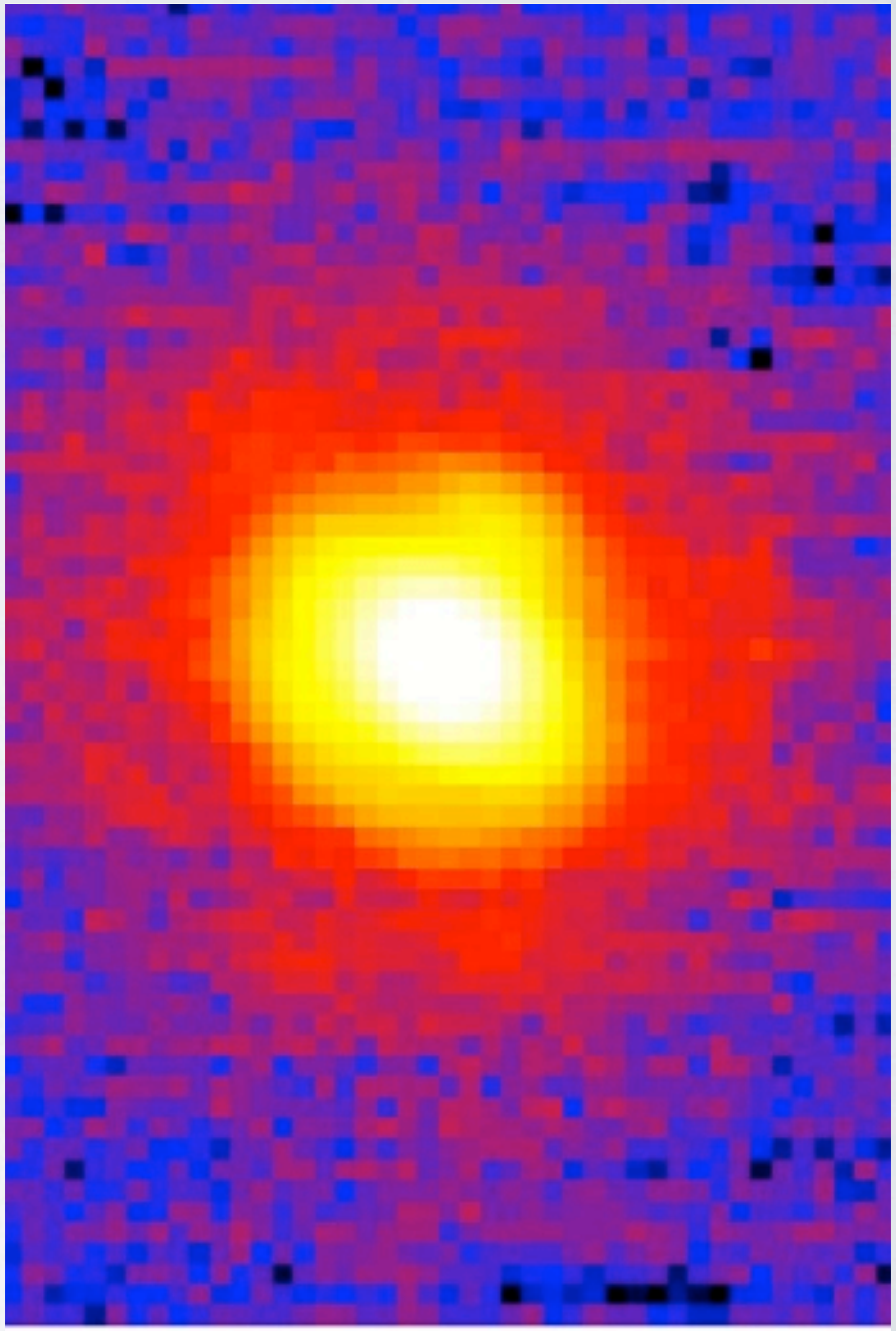
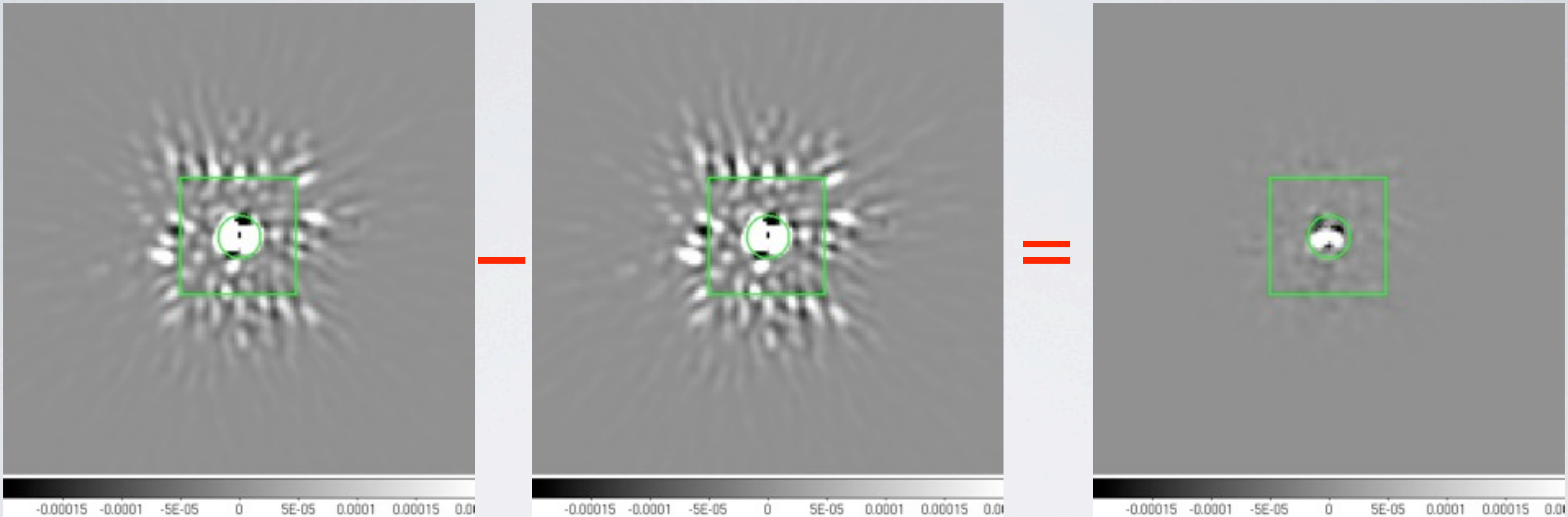
INSTRUMENTAL LIMITATIONS

- 1st gen AO systems on 8-m class telescope, typically limited to SR<30% in H, <45% in Ks, and <80% in L-band
- Static aberrations on the order of 100 nm rms
  - Quasi-static speckle field prominent
- Various drifts and instabilities





OBSERVING STRATEGY

GOAL: subtract out the PSF

It's all about stability => differential imaging

RSDI - ADI - DBI - SDI - PDI

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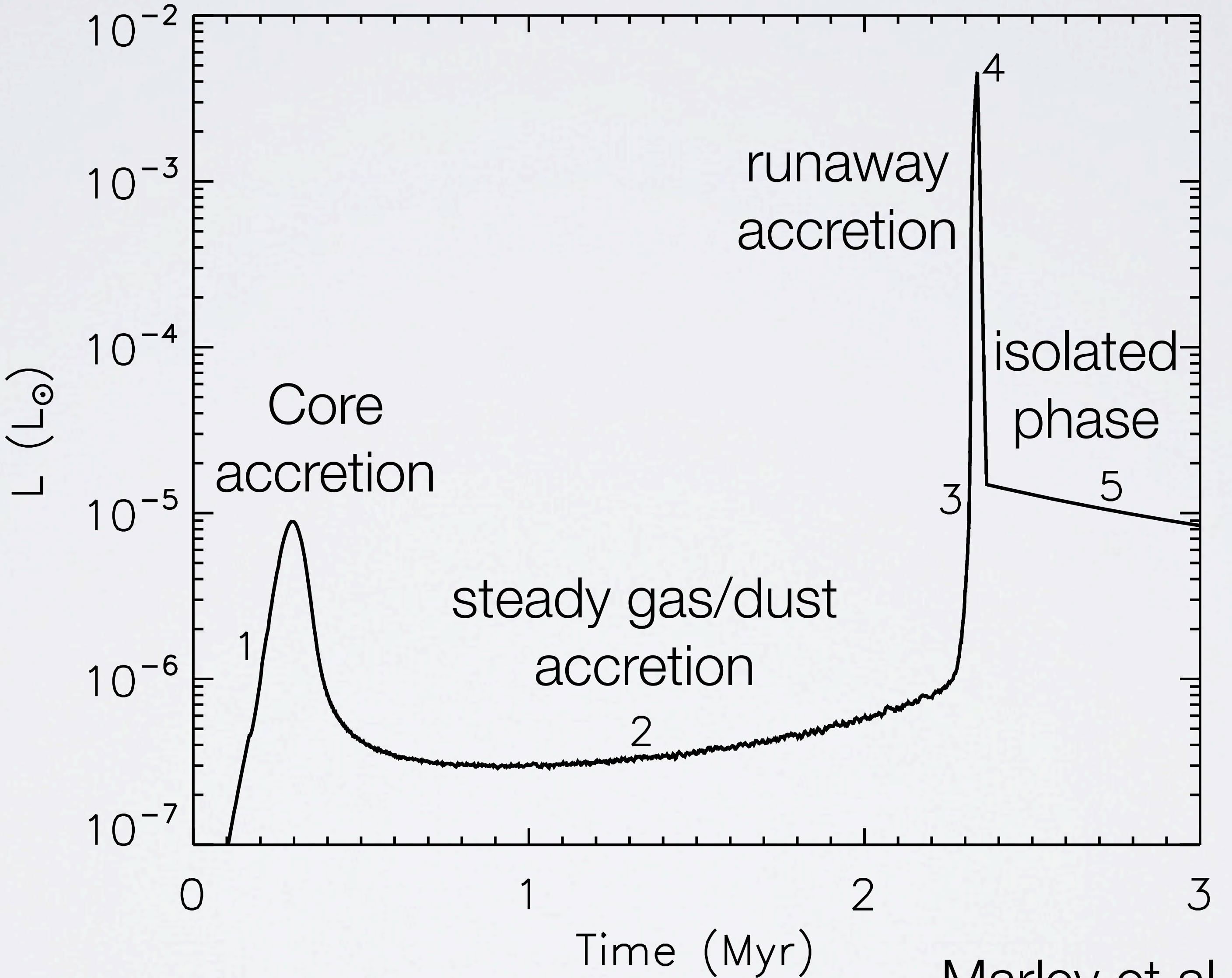
MODELS

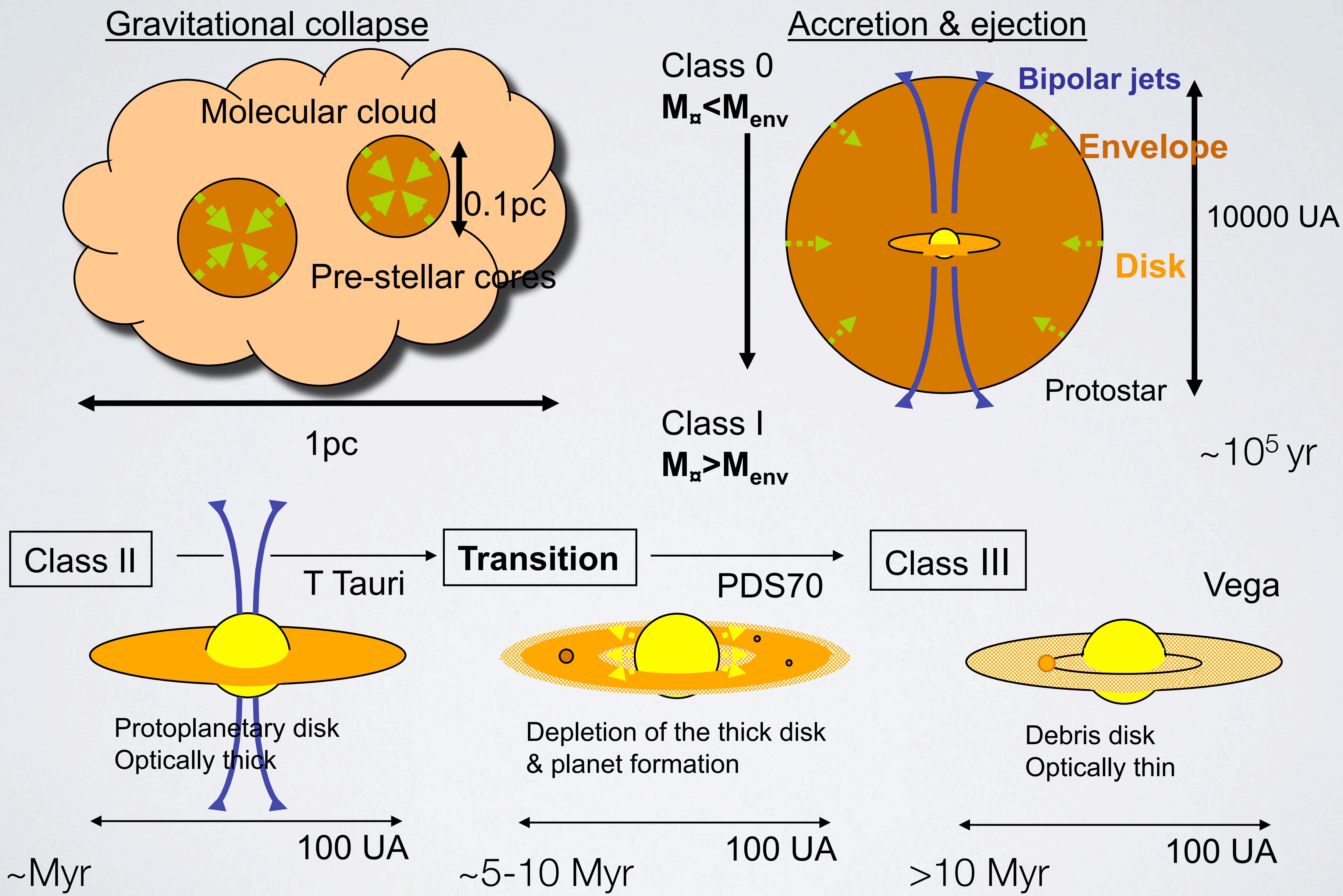
- Models are very poorly constrained by observation



Marley et al.

- Interpretation of DI observation heavily relies on models

2 PROTOTYPICAL SYSTEMS



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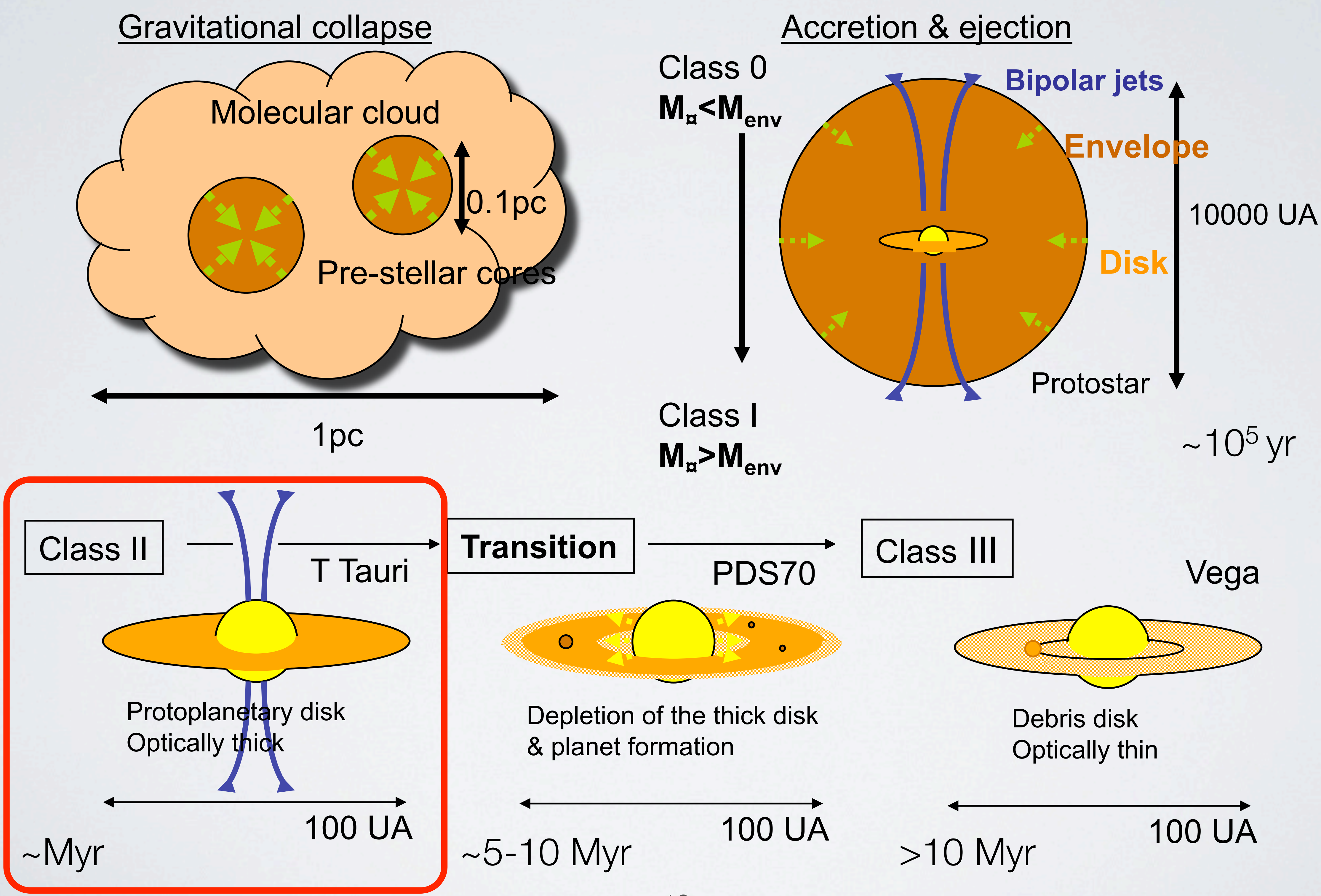
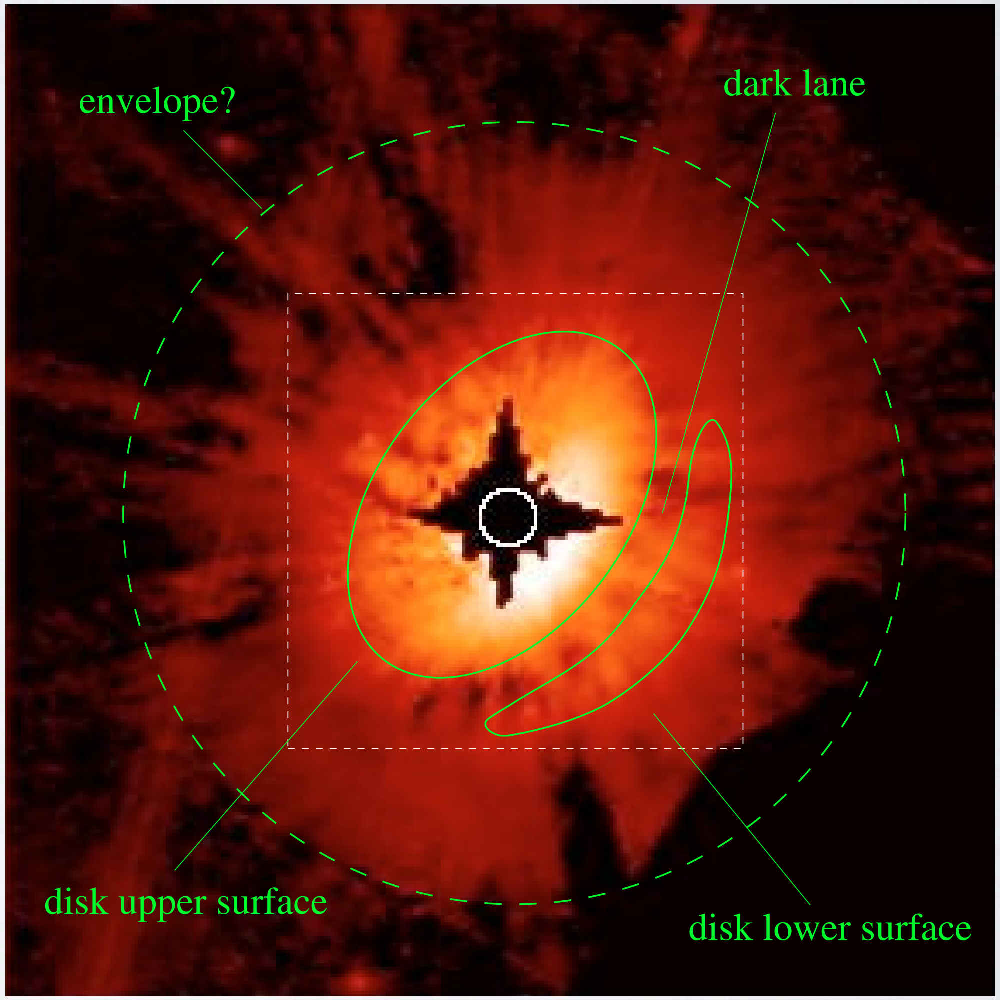


YOUNG SYSTEM PROTOTYPE

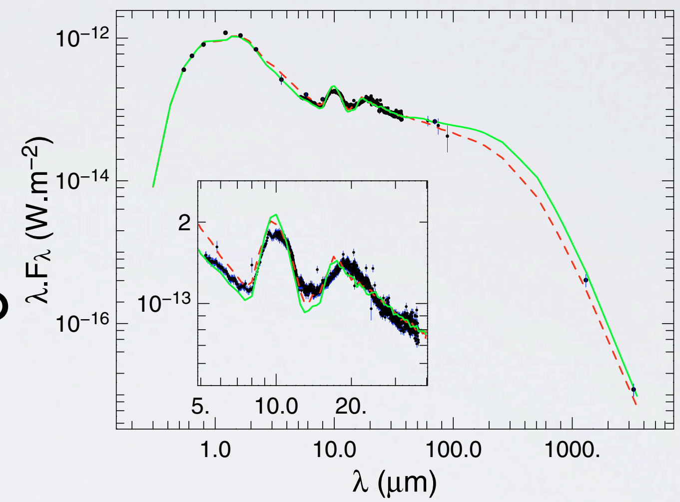
- IM Lupi (Sz82)
- ID card:
  - M0
  - WT Tauri
  - Age: <1.5 Myr
  - d: 140-190 pc
  - Surrounded by optically thick disk
  - Low proper motion

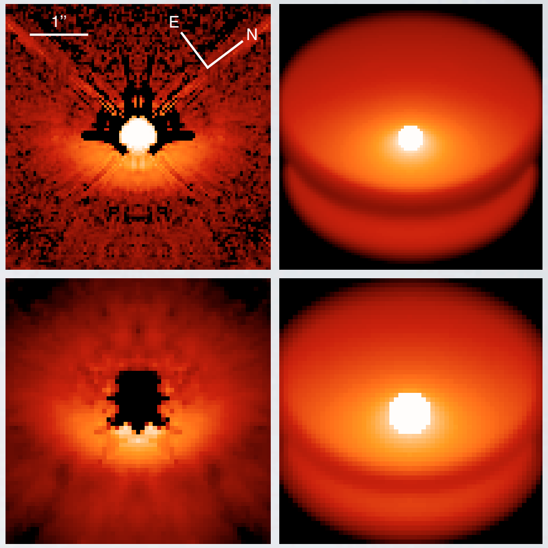
Pinte et al. 2008: HST NICMOS



THE DISK OF IM LUPI

- Strong mm continuum emission (Nuernberger et al. 1997).
- SED compiled by Padgett et al. (2006): modest near-infrared excess, which starts to rise at 5.8μm and is nearly flat between 8 and 70μm.
- CO lines observations: disk is gas rich and consistent with a rotating disk mode
Kempen et al. 2007).
- Scattered light image in 1999 in the
with HST/WFPC2 (PI: Stapelfeldt), fo
in the near-infrared by HST/NICMO
images obtained in 2005 (PI: G. Schn
- An extensive multi-wavelength mod
study by Pinte et al. (2008): quantitat
evidence of dust evolution in the dis
obtained.





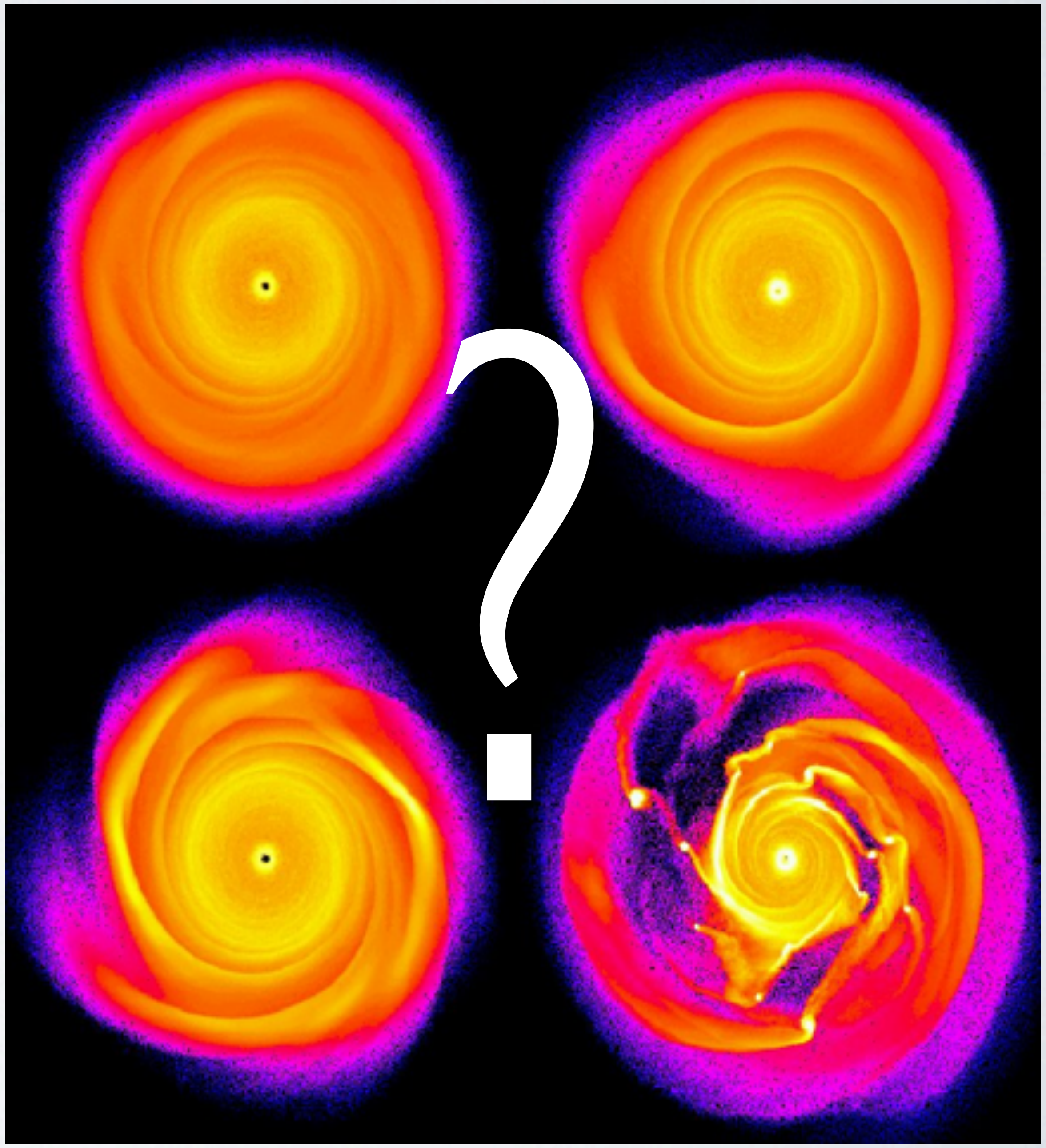
Grain growth up to at least millimetre- sized particles, vertical stratification of micron-sized grains close to the disk surface, and larger grains that have settled towards the disk midplane, as well as the possible formation of fluffy aggregates and/or ice mantles around grains.

ixed

UNSTABLE DISK

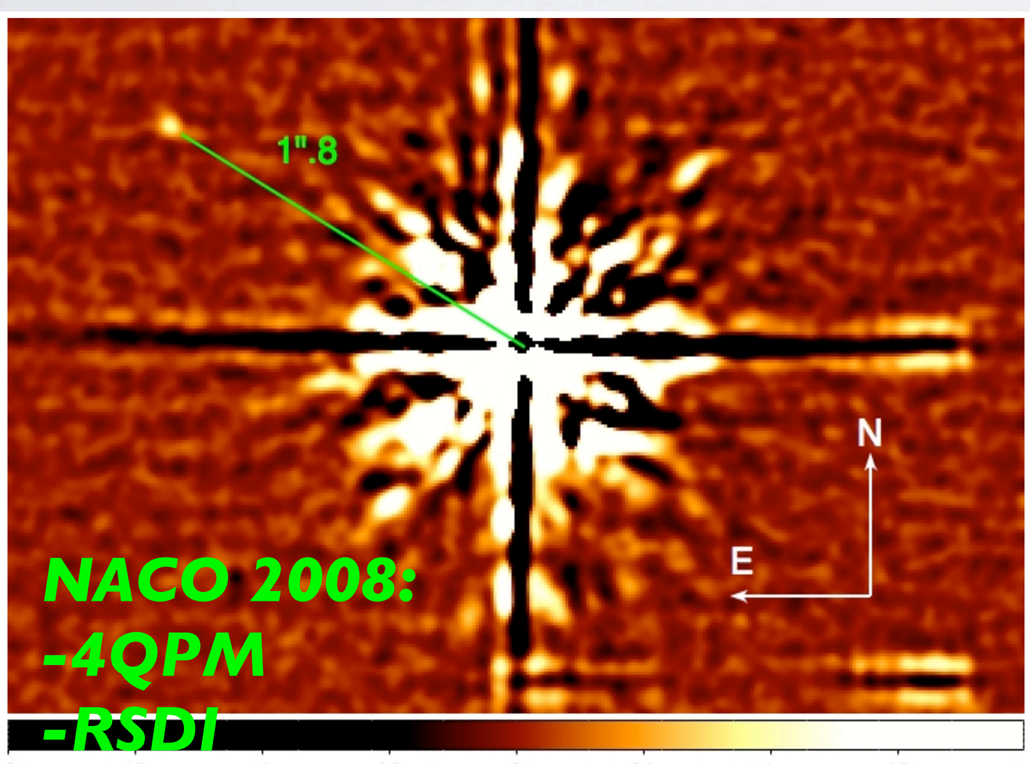
- Pinte et al. 2008: "Considering a probable stellar mass of ≈1 M⊙ and a gas to dust mass ratio of 100, the disc to star mass ratio is ≈0.1, meaning the disc may be unstable through gravitational collapse."

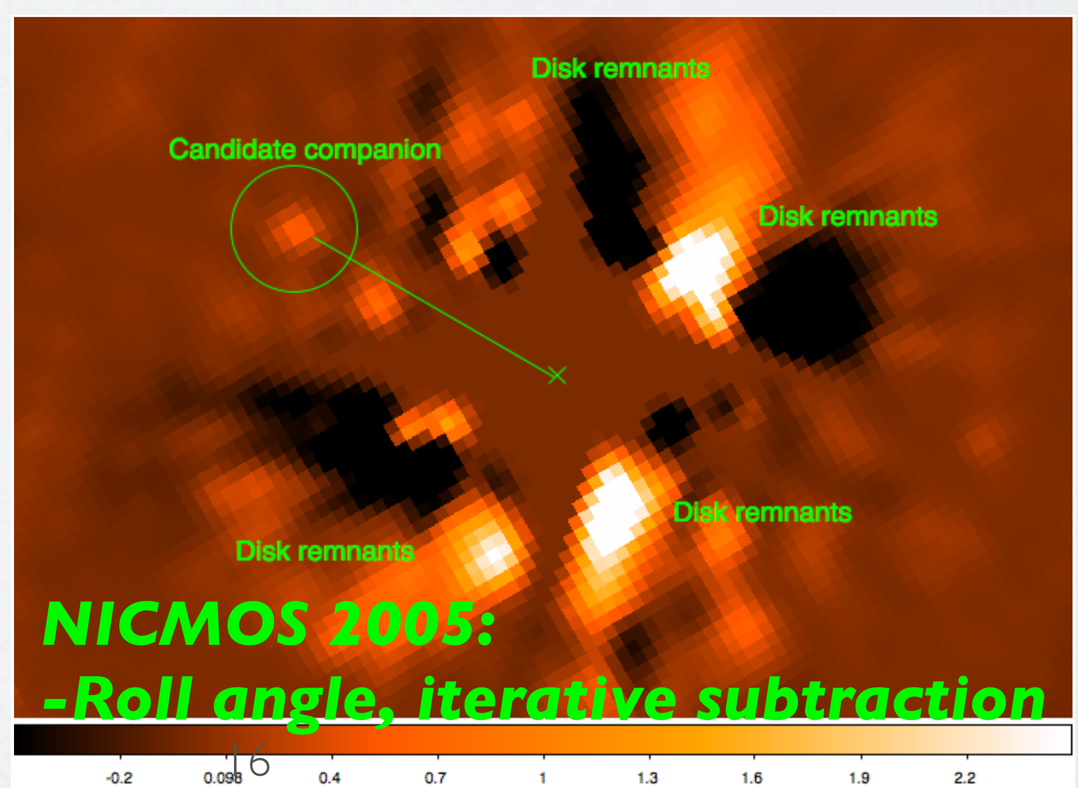
- "[...] The disc of IM Lupi representing about 1/10 of the star mass, local enhancement of density may be sufficient to start planet formation in the disc following this process."



PLANET SEARCH AROUND IM LUPI

Target	α (J2000)	δ (J2000)	Filter	UT date / exp. time	Telescope / instrument	Strategy	Seeing	τ_0^*
Im Lup	15h 56' 09"	-37° 56' 06"	H	29/03/2005 / 1350s	HST/NICMOS	ADI+RDI	-	-
Im Lup	15h 56' 09"	-37° 56' 06"	K	29/03/2008 / 1350s	VLT/NACO	RDI	0.″7	3 m
CD-37 8989[ref1]	13h 54' 27"	-38° 14' 54".6	K	29/03/2008 / 1200s	VLT/NACO	-	0.″7	3 m
CD-35 9033[ref2]	13h 50' 00".8	-36° 33' 40".7	K	30/03/2008 / 1200s	VLT/NACO	-	0.″8	2.5 m
Im Lup	15h 56' 09"	-37° 56' 06"	L'	19/04/2010 / 1350s	VLT/NACO	RDI	0.″6	3 m
LHS3286[ref]	17h 23' 49"	-32° 15' 16"	L'	19/04/2010 / 1350s	VLT/NACO	-	0.″6	3 m
Im Lup	15h 56' 09"	-37° 56' 06"	22/07/2011 / 1350s	K	VLT/NACO	I	0.″6	3 m
Im Lup	15h 56' 09"	-37° 56' 06"	25/07/2011 / 1350s	H	VLT/NACO	I	0.″6	3 m





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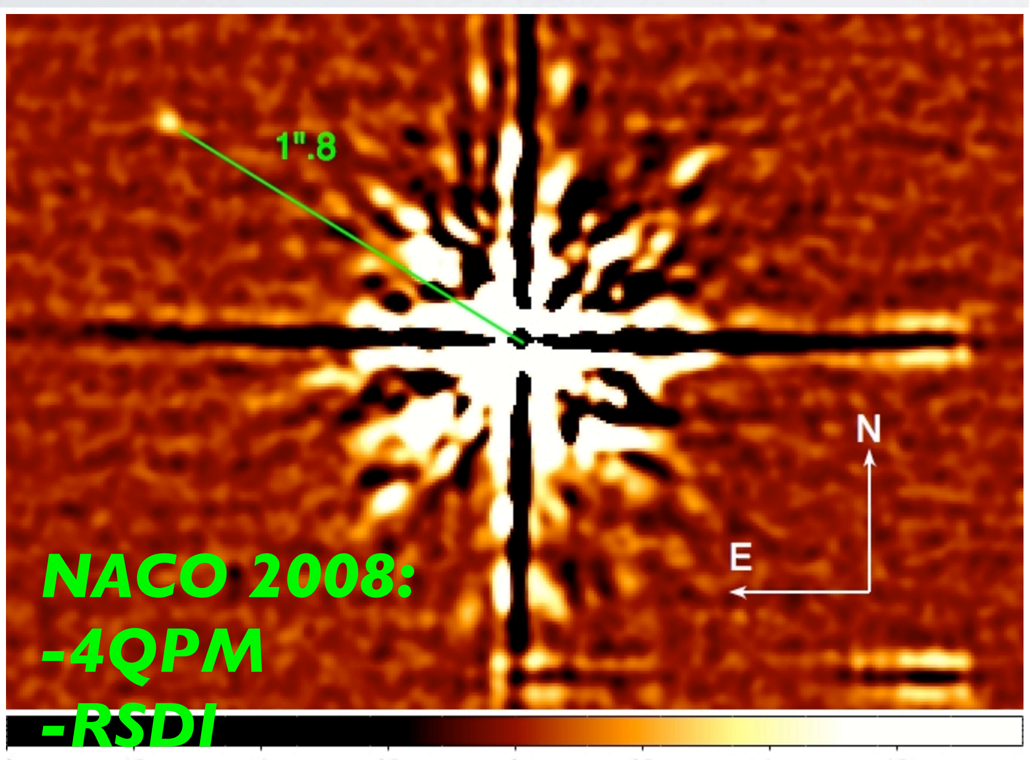
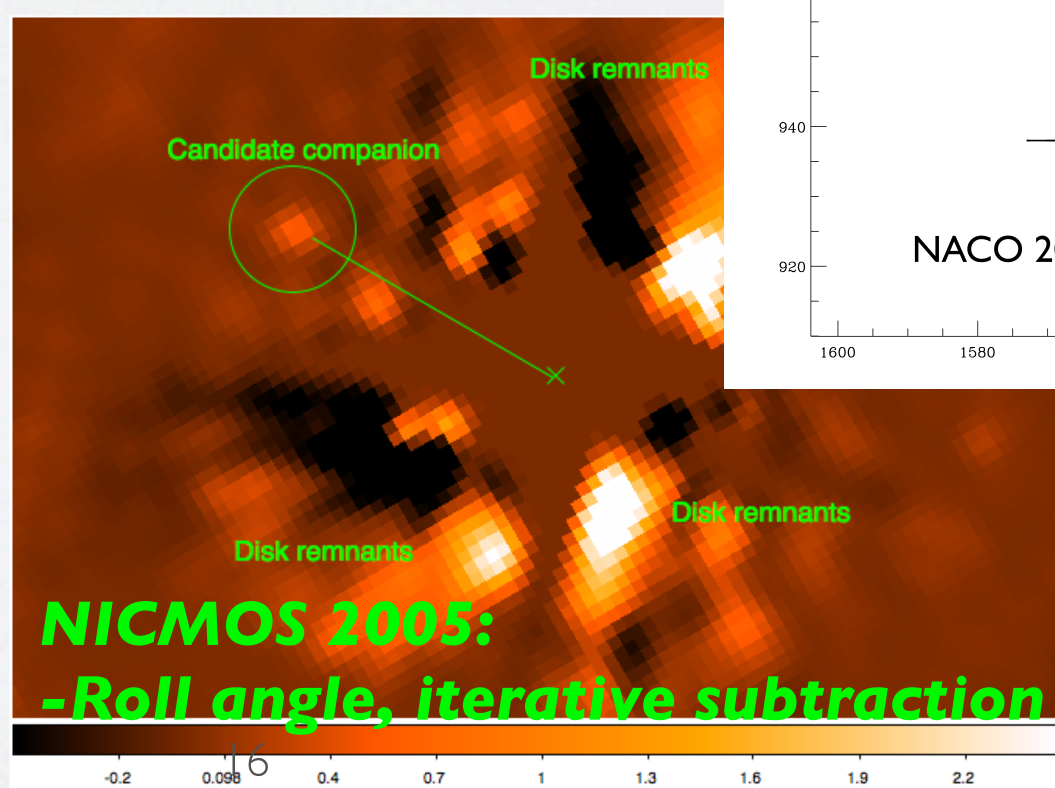
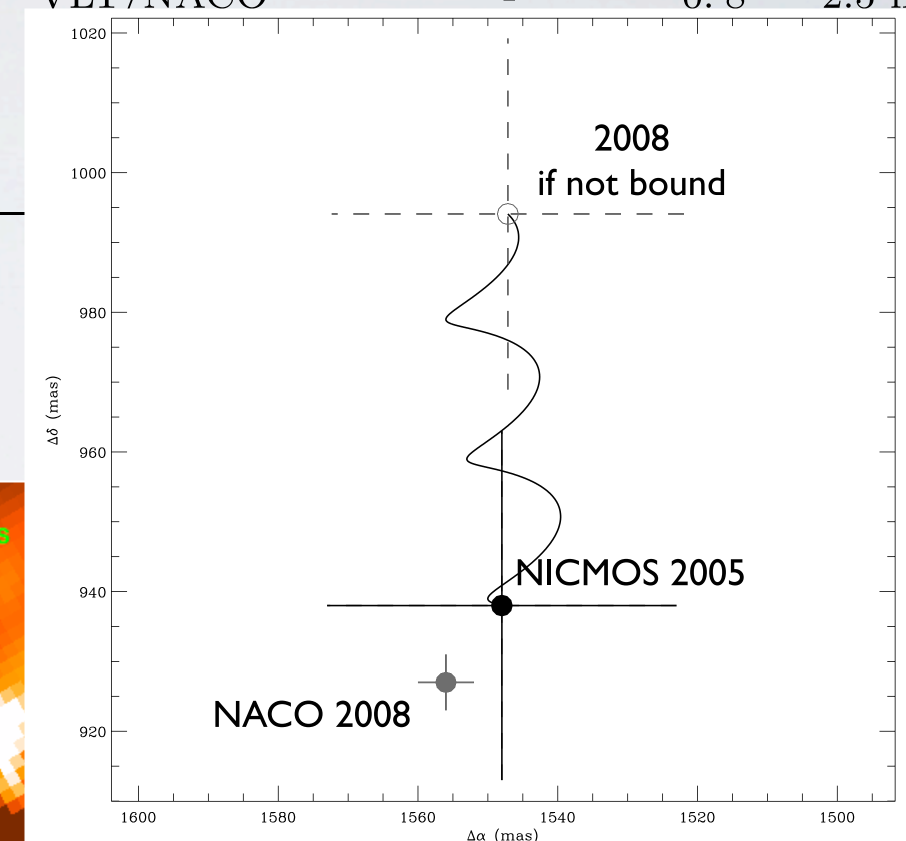






HURDLES

ASTROMETRY - PROPER MOTION

- Hipparcos proper motion (mas/yr):
  - -56.66 -49.97 +/- 15.41 7.31

- Ducourant et al. 2005:
  - for young, distant and obscured (thick disk) objects, Hipparcos measurement bogus!
  - New measurement based on 100+ years of astrometric data (> 10 data points)
    - PMS (Ducourant 2005): -3 -21 +/- 1 2

- Consequence: wait 3 times longer for proper motion confirmation, alas !!! Patience is a virtue !!!

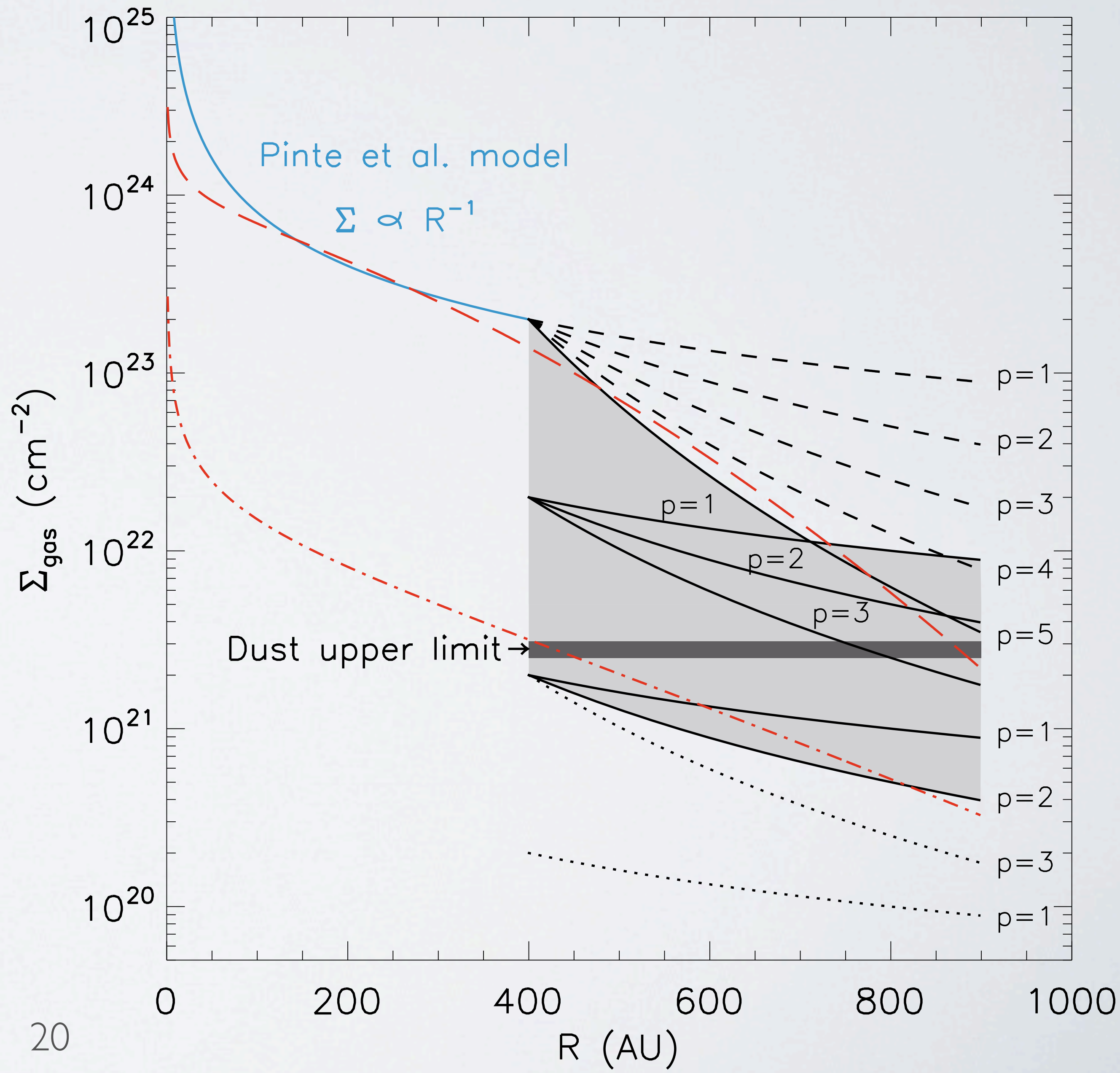
AGE

- Redetermined for our work by Sarah Röttinger (J.-C. Augereau, O. Absil):
- Place the star in the HR diagram where the surface temperature is given by the spectral type (conversion from Luhman et al (2003) for M dwarfs) and the bolometric luminosity for the I and J-band is taken from Kenyon and Hartman (1995). Evolutionary models from Siess and Baraffe are then used to draw isochrones and evolutionary tracks in the HRDs and to interpolate for the observed object.
- Results for d=140 pc: 0.8 - 1.7 Myr
- Results for d=190 pc: 0.5 - 0.6 Myr

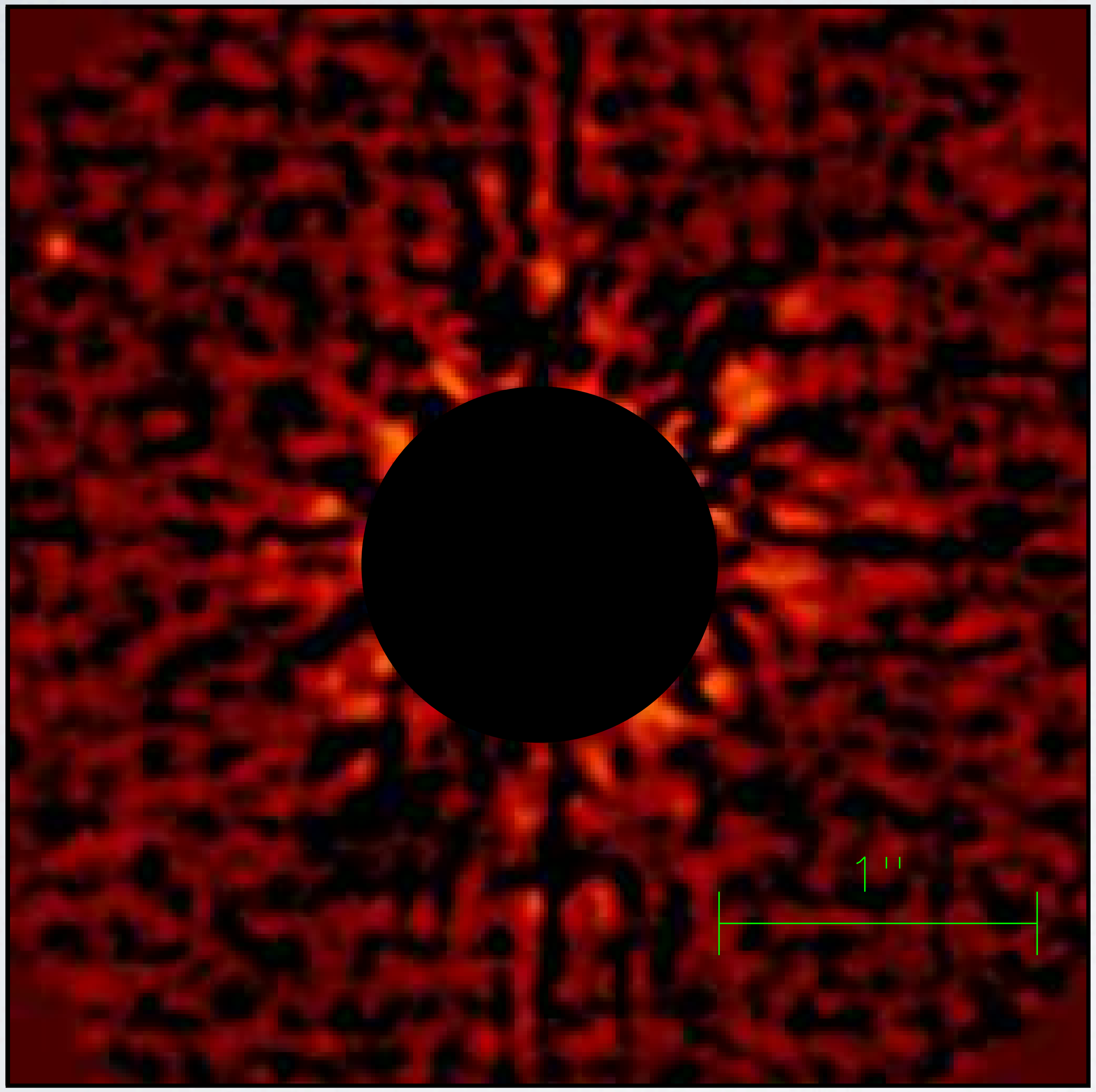
IN THE MEANTIME: PANIC!

Excitement meter

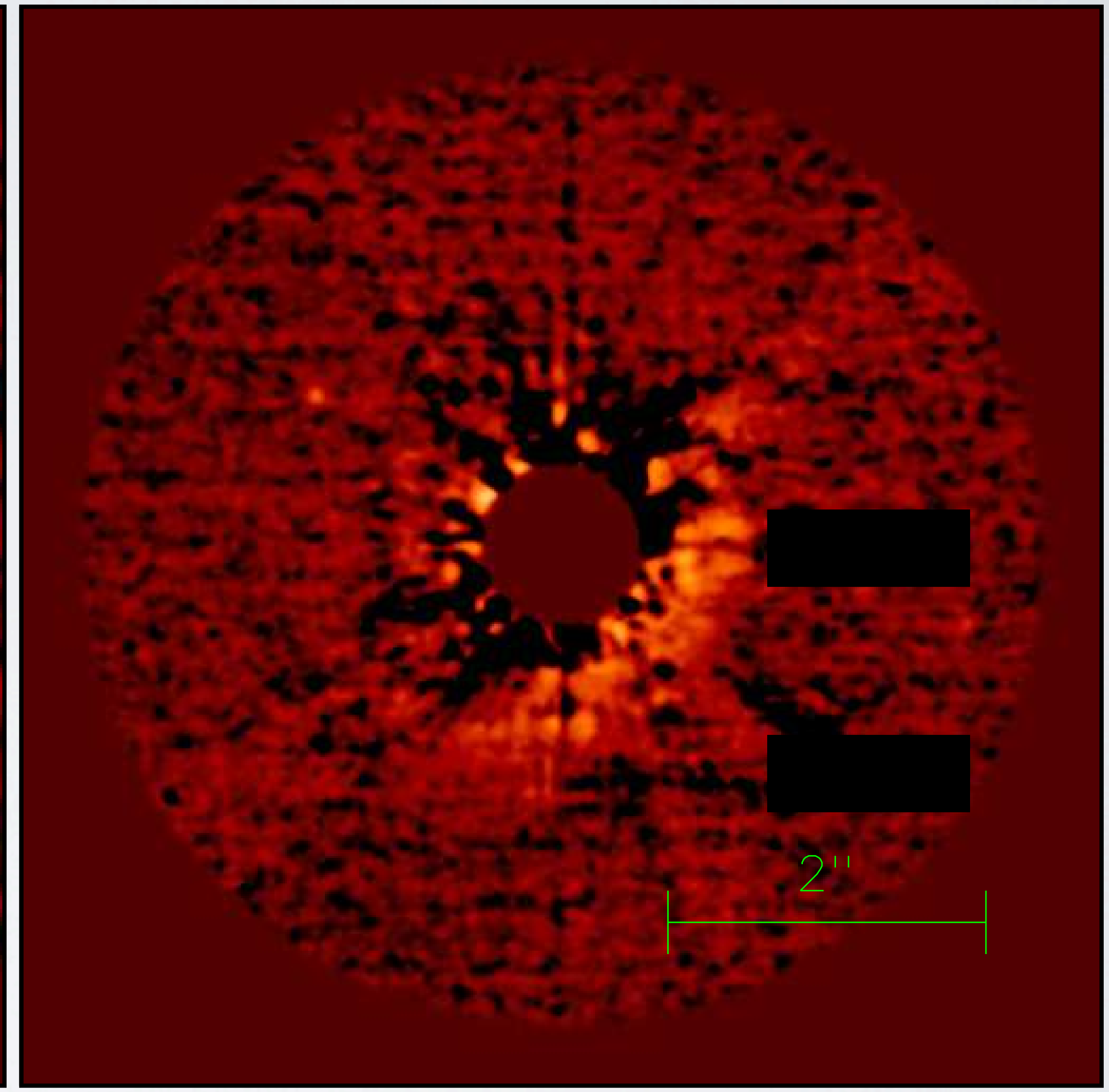
- Panic et al. 2009:
  - SMA
  - Disk of gas and dust extends to 900 AU (vs 400)
  - Break in density at 400 AU
- Interpretation: "A companion body. Another explanation for the break in the disc density structure around 400 AU would be the presence of a companion near this radius. A companion of ~1 MJup at 400 AU could open a gap in the disc and affect the viscous disc spreading. No companions at this separation are visible in the HST images of (Pinte et al. 2008) or in K-band direct imaging (Ghez et al. 1997)."



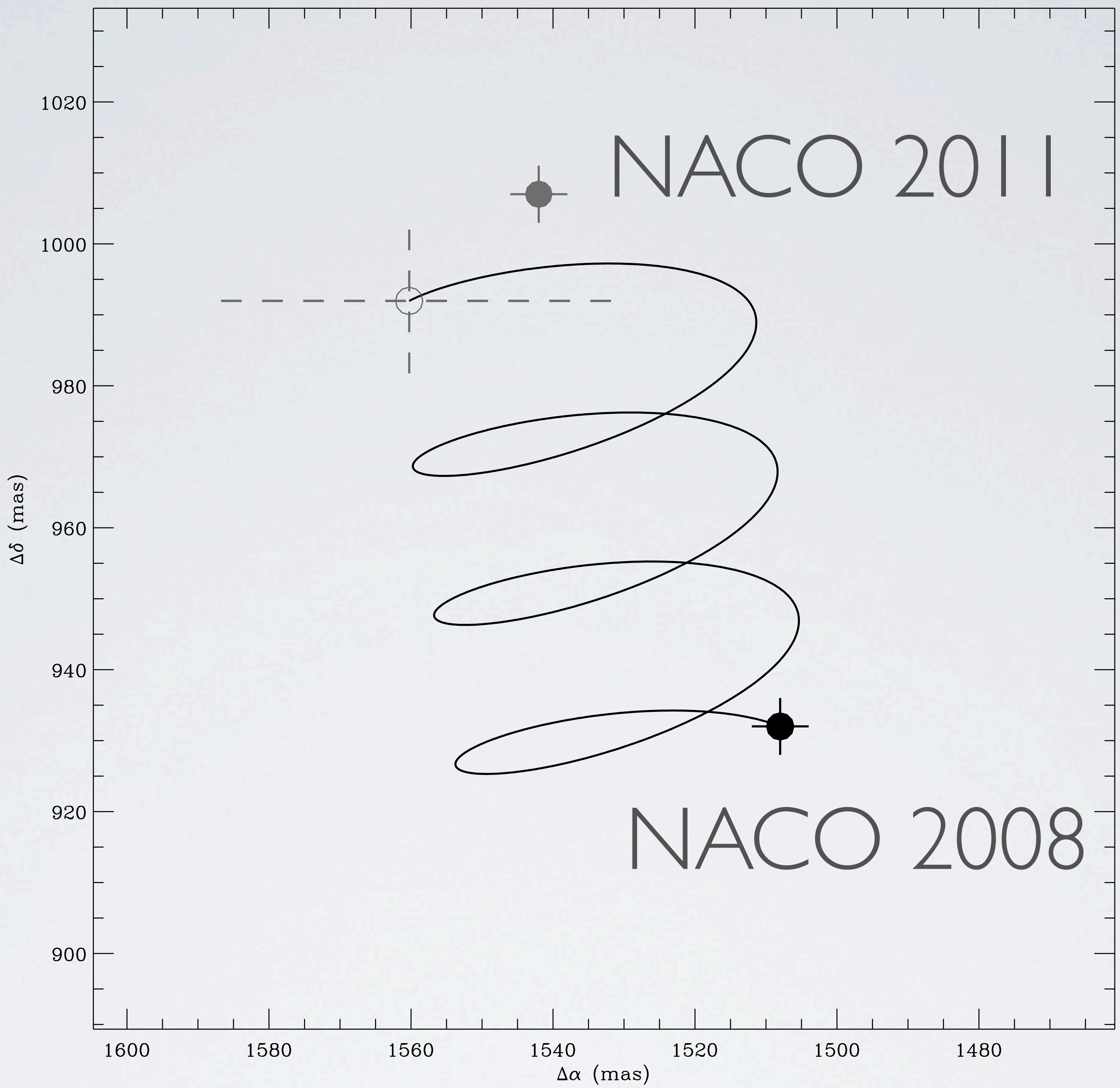
2011 NACO DATA



LOCI



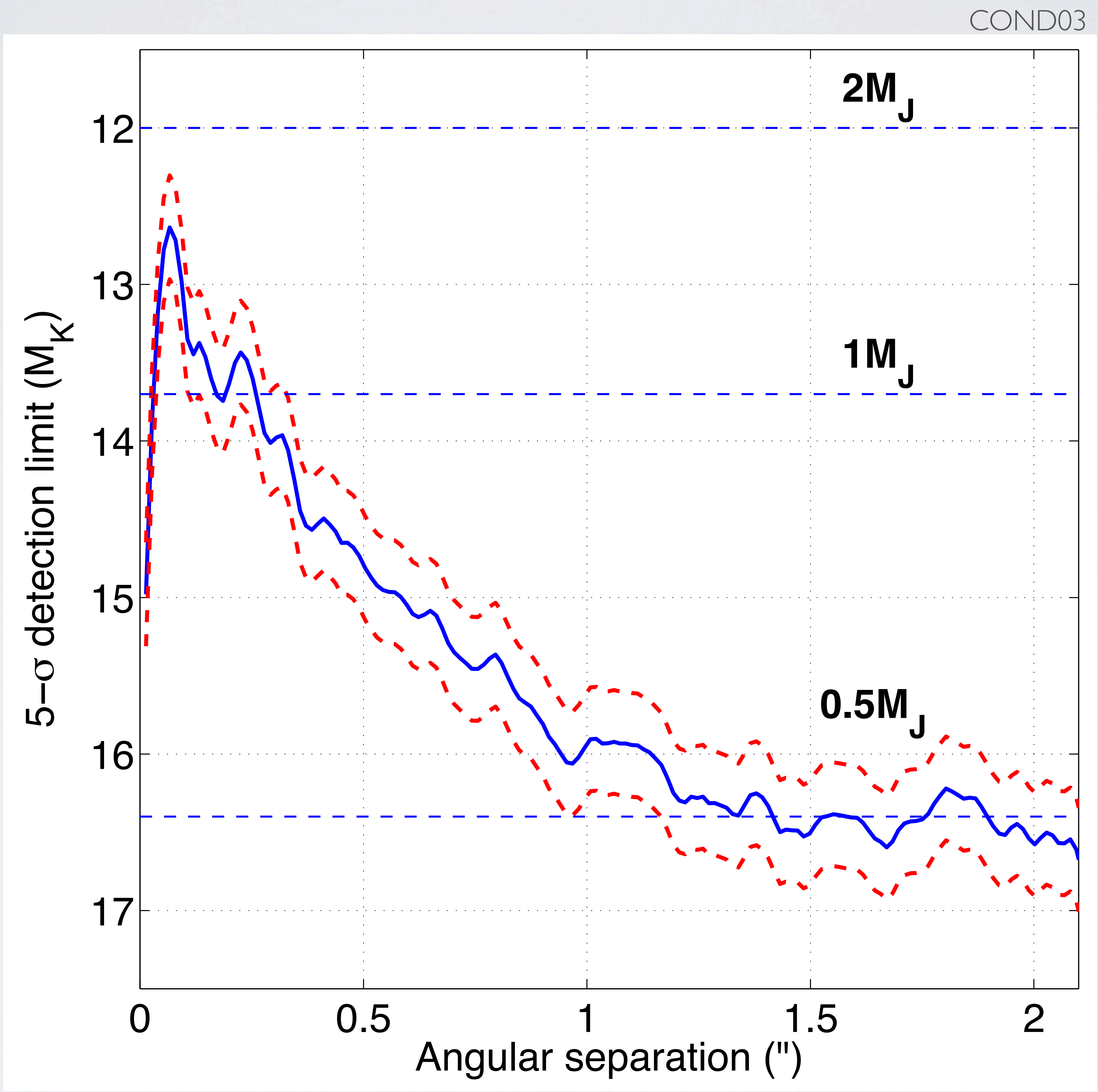
Damped-LOCI
(Pueyo et al. 2012)



AND... BUSTED!!!

And we found... a quasar (or more likely a reddened background star)!

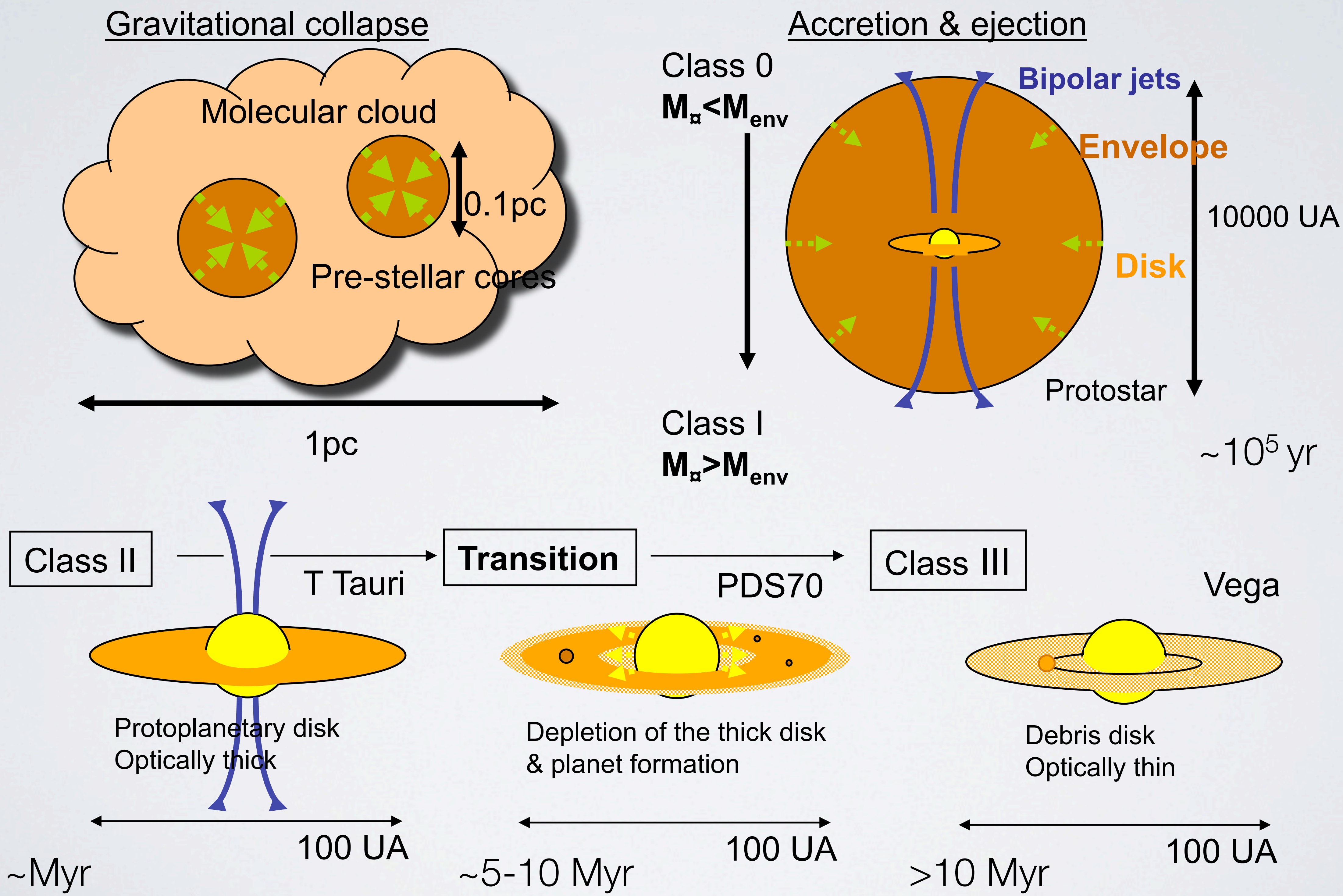
CONSTRAINTS



LESSONS LEARNED FOR YOUNG SYSTEMS

- Don't trust hipparcos measurement > 100 pc, for young objects, and objects with disks
- Absolute astrometric precision is a chimera
- Relative astrometric precision between different instruments is a nightmare (e.g. HST-NACO, NIRC2-NACO, NICI-NACO)
- Age determination is tricky, depends on distance

2 PROTOTYPICAL SYSTEMS



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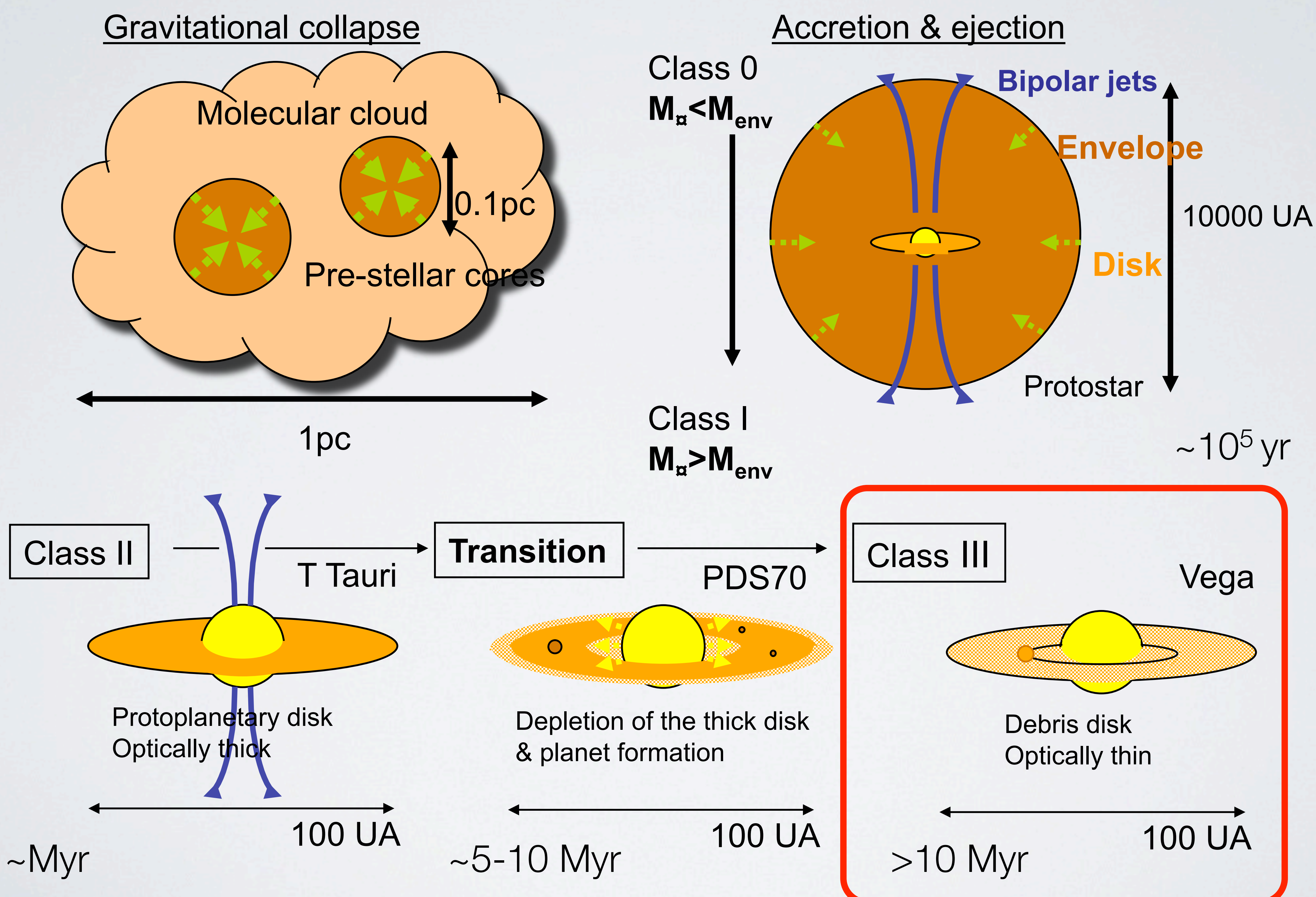
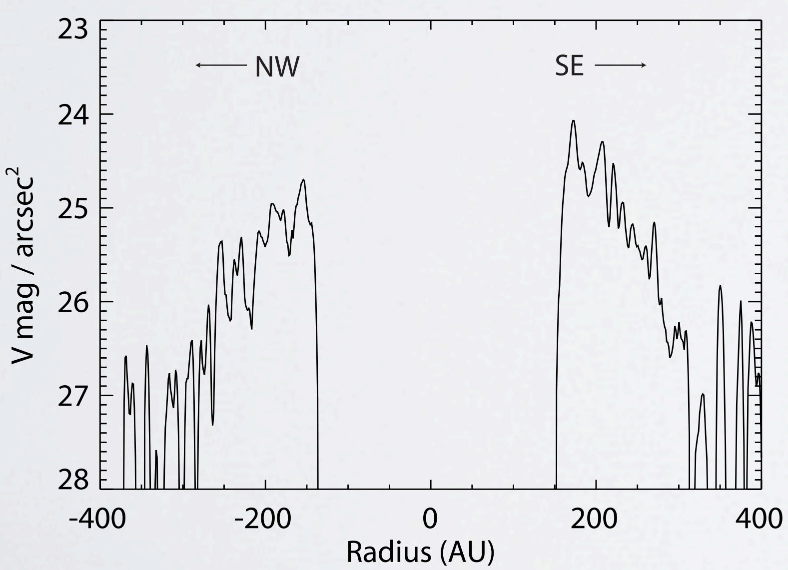


NEW DISK

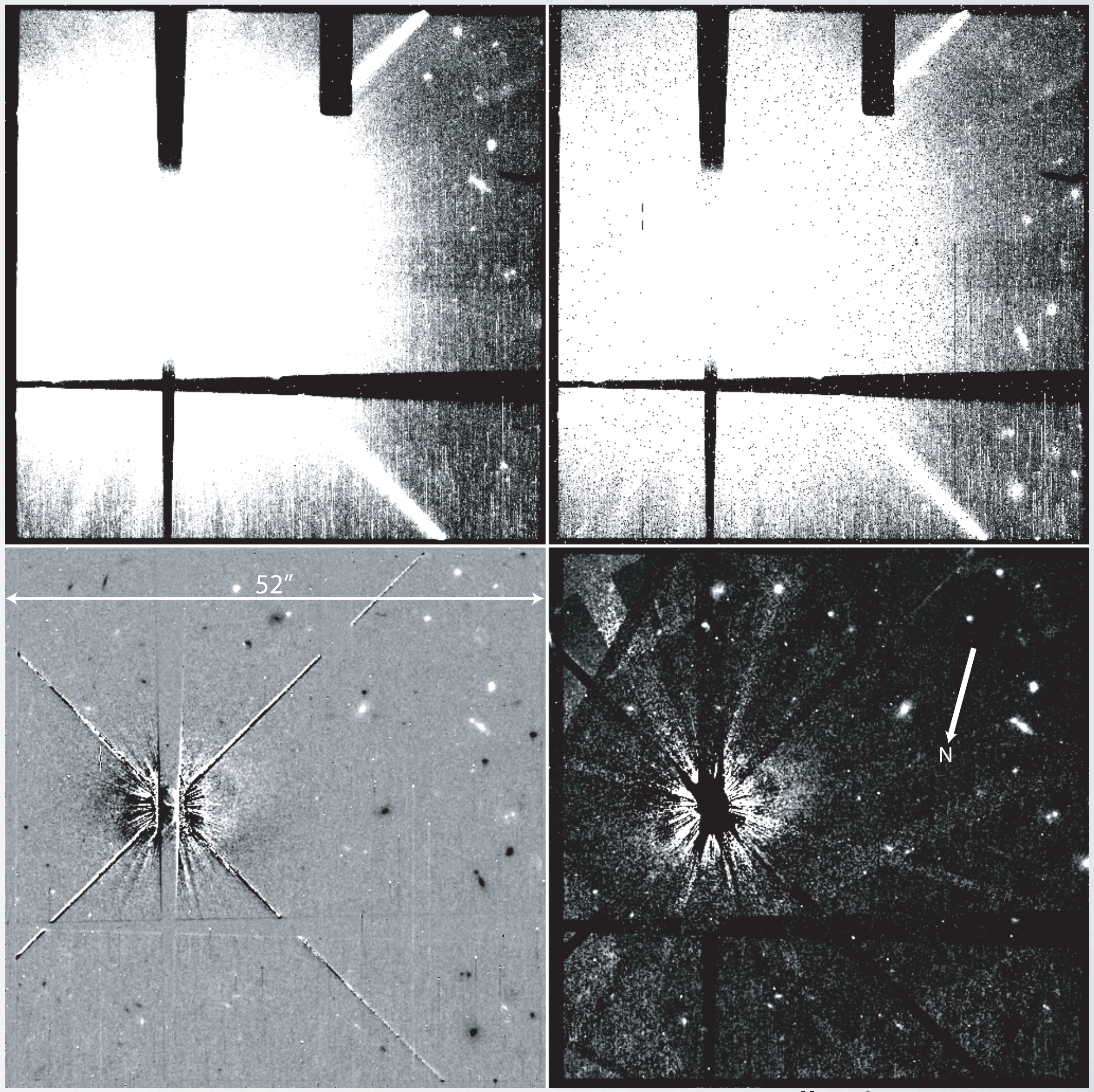
- New disk around G5V star (STIS, Krist et al. 2011, 2012, submitted)
- Faintest disk ever imaged in scattered light (excess at 70 µm)
- Inclined ring offset by ~19 AU from the star



Disk radial surface brightness (assuming neutral scattering) measured as the mean in each column of a 1.6″ high band that is oriented along the apparent major axis. HD 202628 has the faintest debris disk yet detected in scattered light (HD 207129 is second at V=23.7 mag/arcsec^2).

Unsubtracted Roll 1

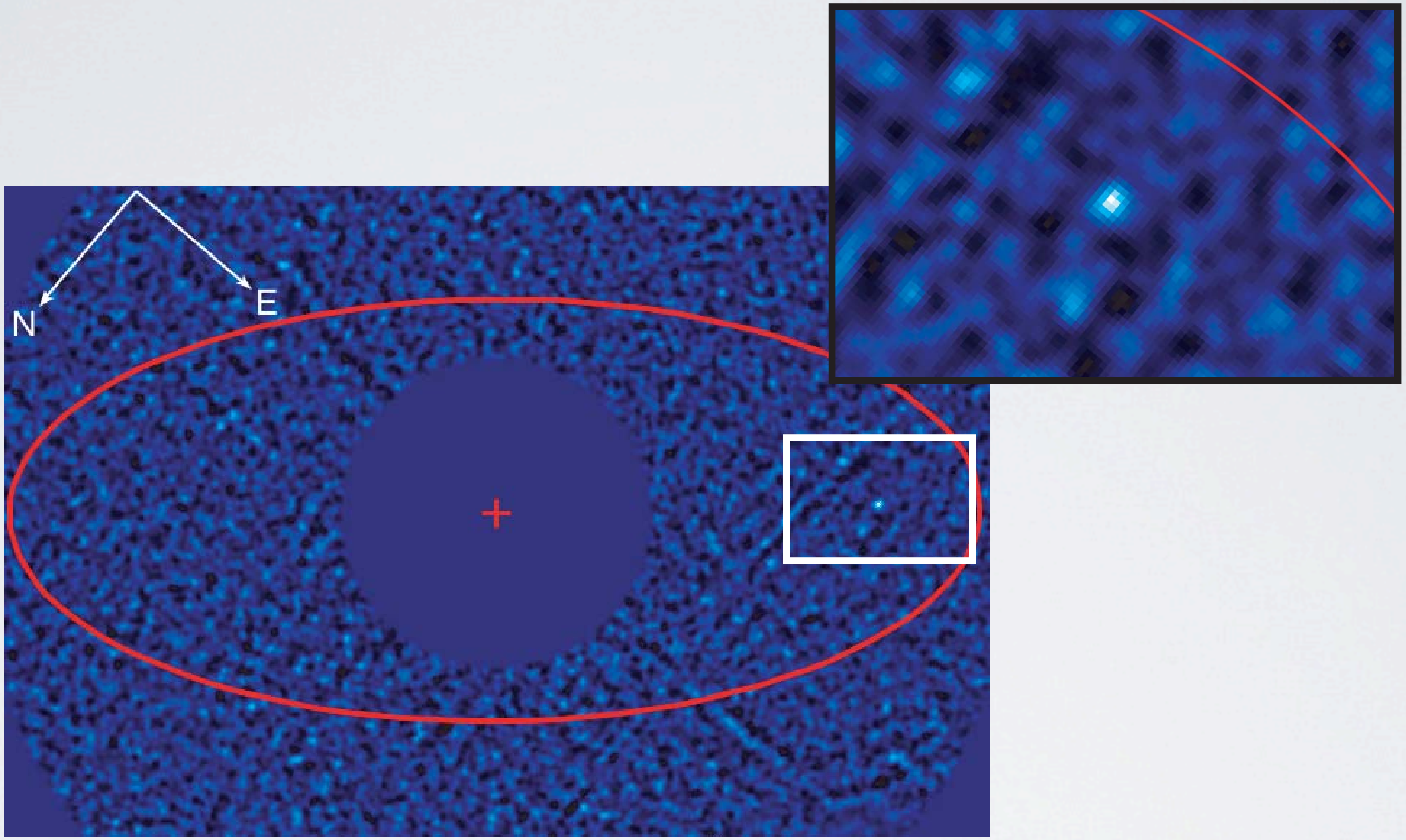
Unsubtracted Roll 2 (Δ=28°)



Roll1 - Roll 2 (no rotation registration)

Iterative Roll Subtraction

L' NACO IMAGING 2010



- L' / ADI image processed with LOCI
- Detection of a point source (sole point source detected in the whole FoV) > 5 σ
  - PA matching that of the disk and radius right at the inner edge!
- L' absolute magnitude ~ 14 +/- 0.5
- Age very uncertain (0.3-2 Gyr)
- >10 MJ

TO BE CONTINUED...

HIGH PROPER MOTION STAR

LESSONS LEARNED FOR EVOLVED SYSTEMS

- Age determination is prevalent to any further progress
  - Evolved system => only more massive companions detectable with current and even nextgen systems
- Generally closer (selection effect of course)
  - Proper motion analysis should be easy
  - Angular separation of objects makes them easy to detect