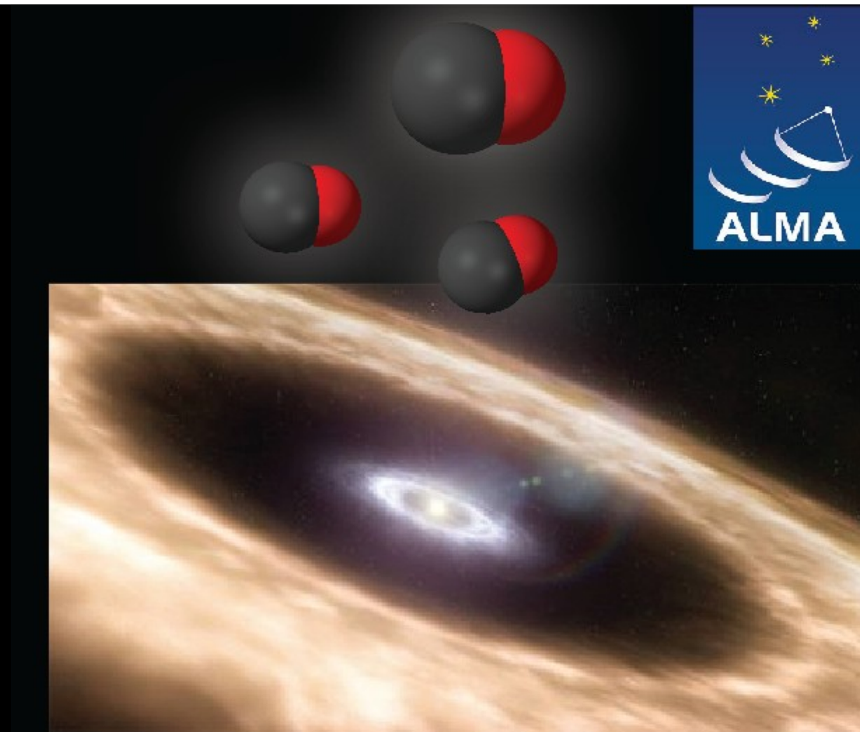
MIND THE GAP

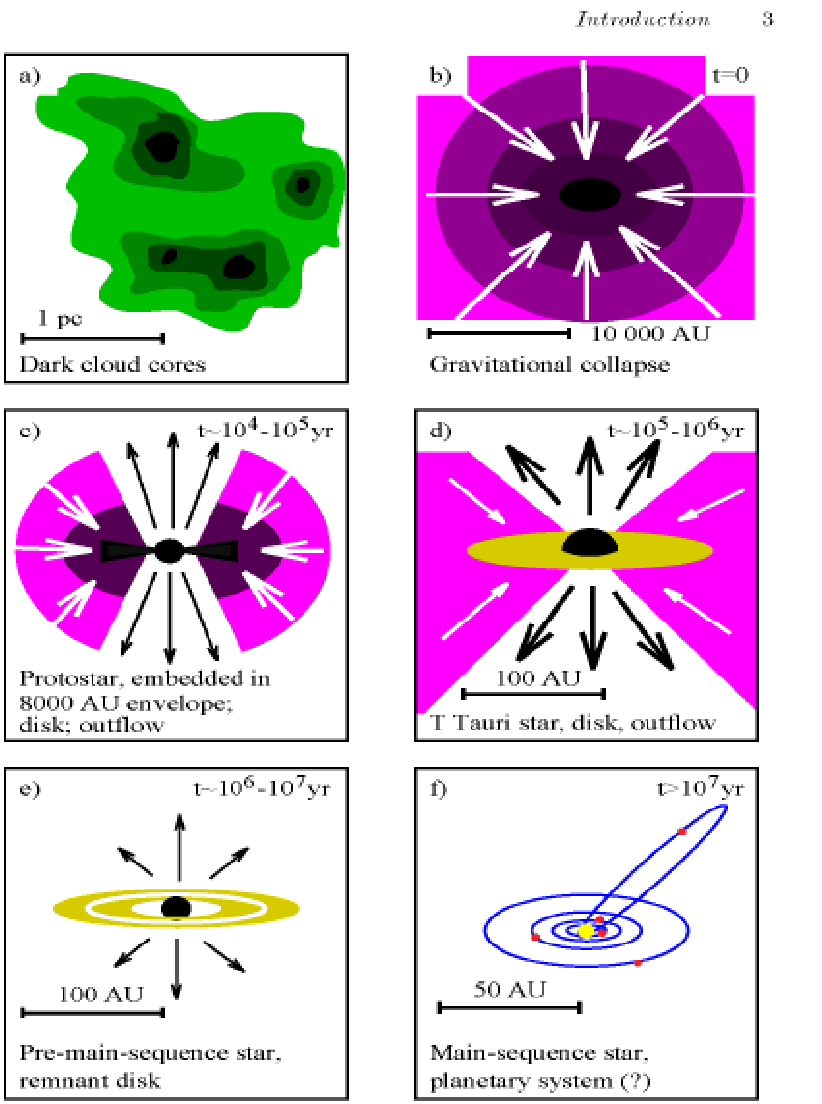
Transitional disks and their host stars



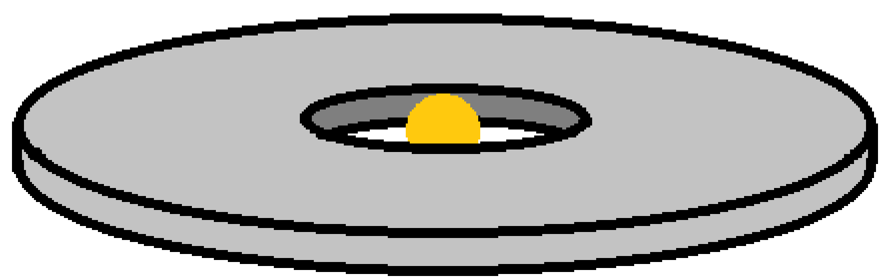
Nienke van der Marel
Leiden Observatory
The Netherlands
August 13th 2013 (ING)

Sterrewacht Leiden

Star and planet formation



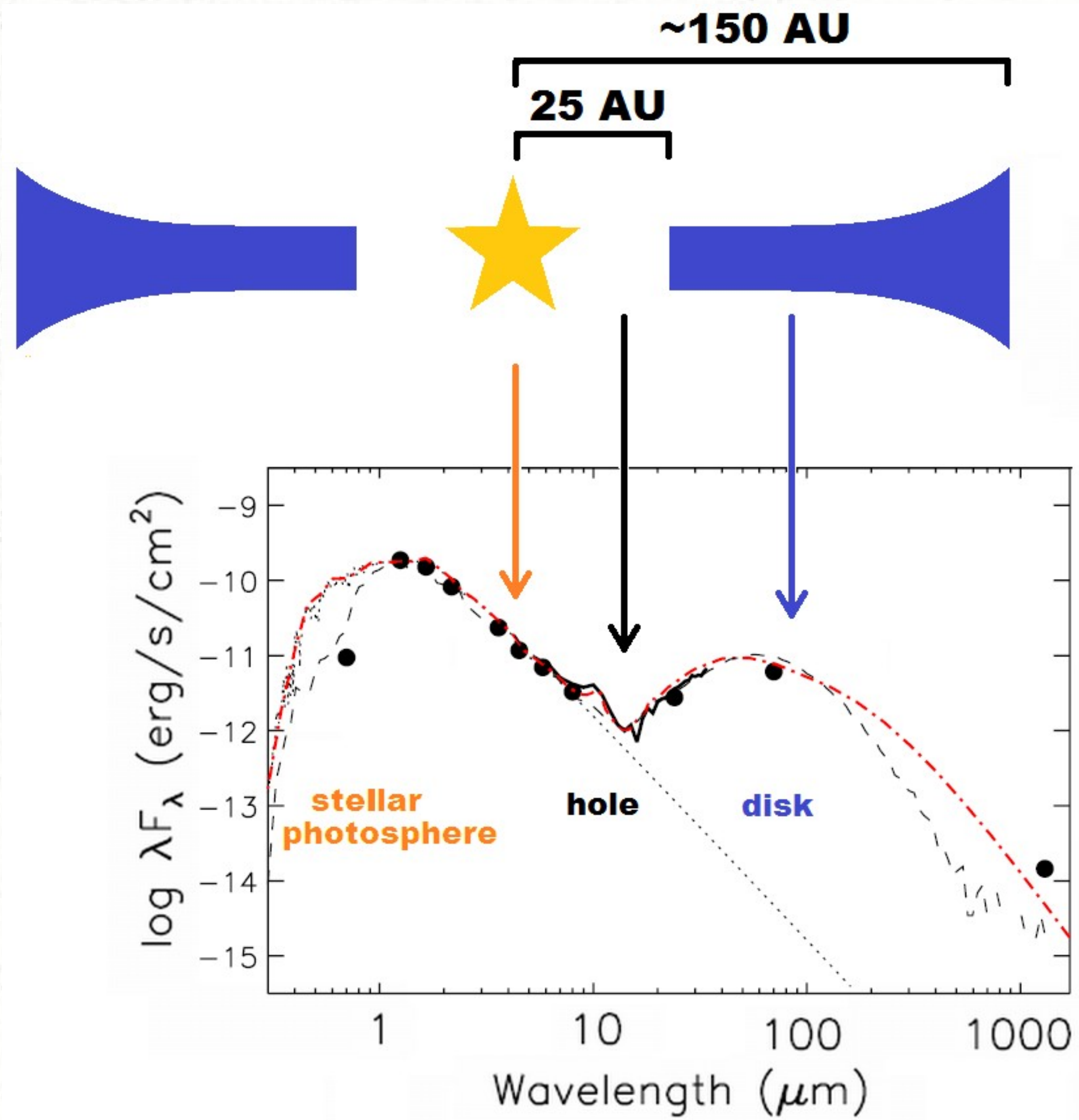
- Class II => III:
  - Transitional disk
  - Dust/gas dissipation
  - Hole/gap



Hogerheijde 1997

Transitional disks

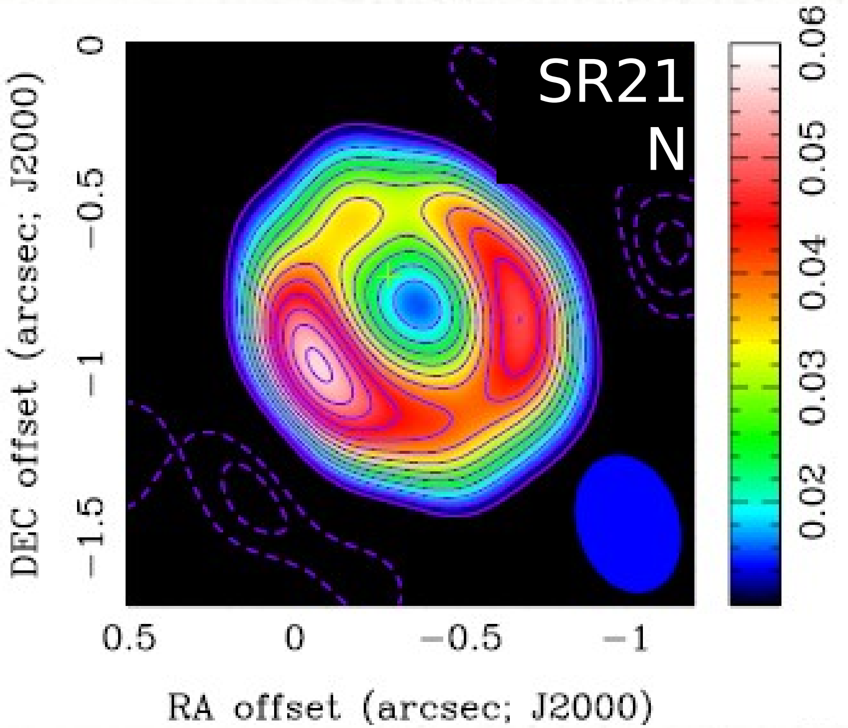
Indirectly:
SED modeling

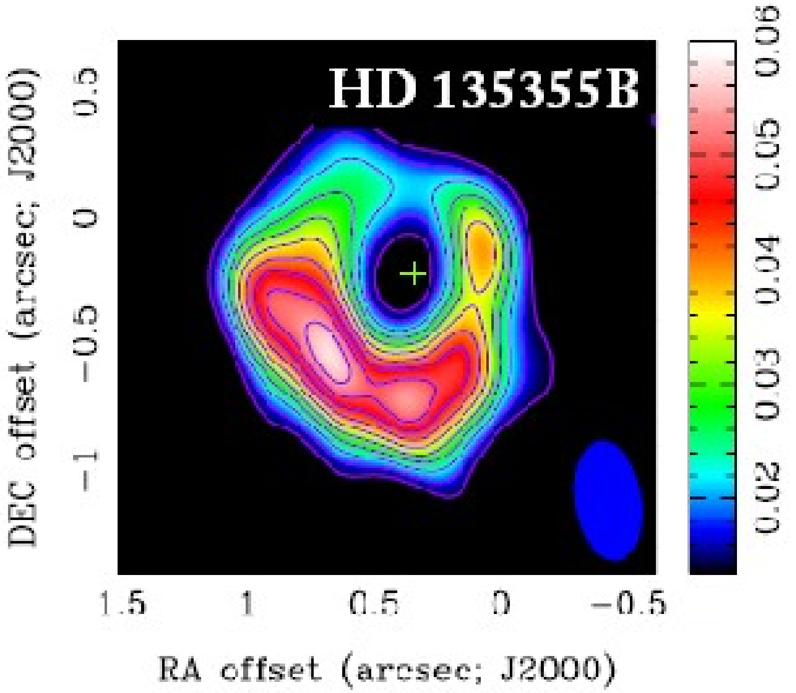


Merin et al 2010

Transitional disks

Direct imaging: Interferometry with SMA

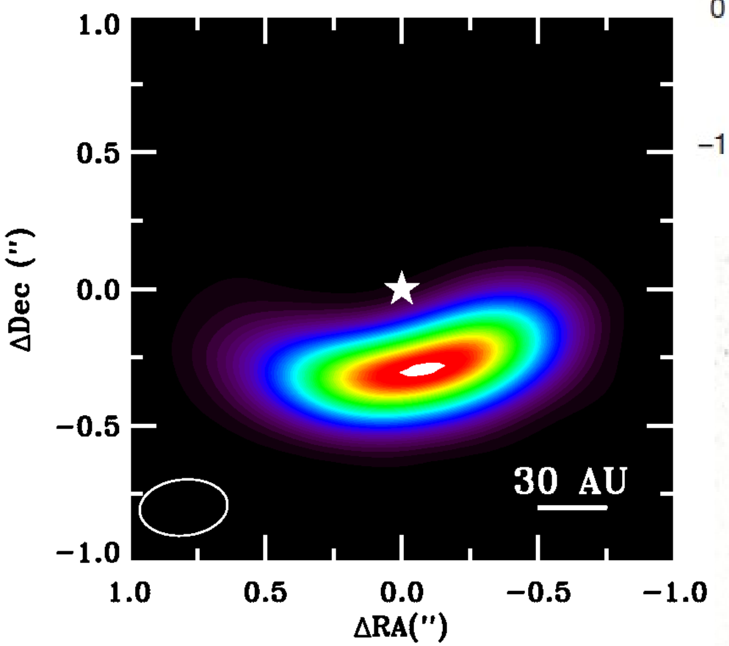


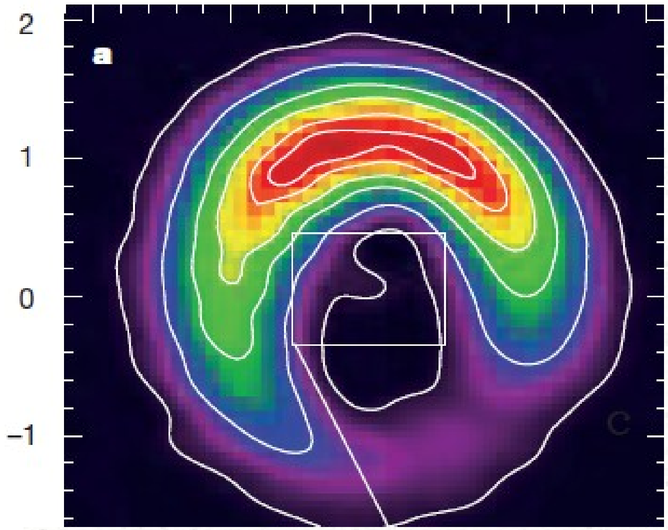


Brown et al 2009

Transitional disks

- Asymmetries (ALMA)



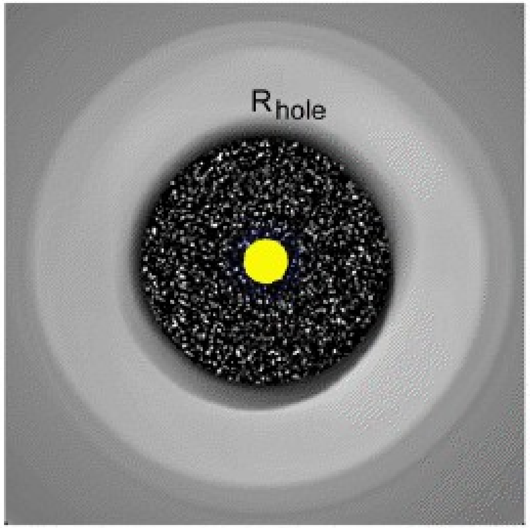


Van der Marel e.a. 2013/Casassus e.a 2013

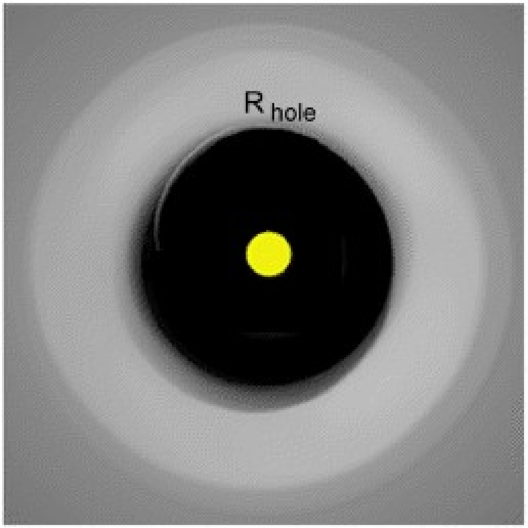
Transitional disks

- Mechanisms dust clearing:

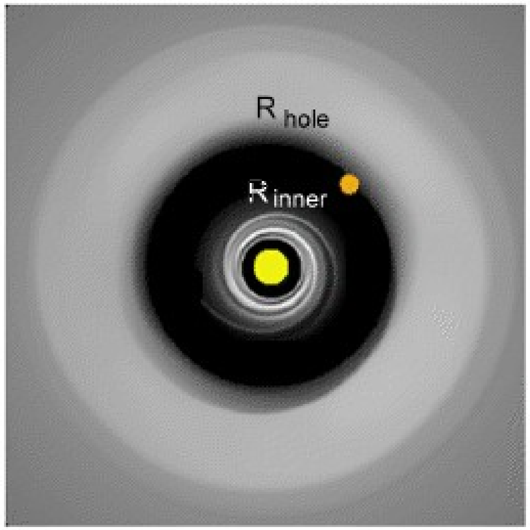
Grain growth



Photoevaporation



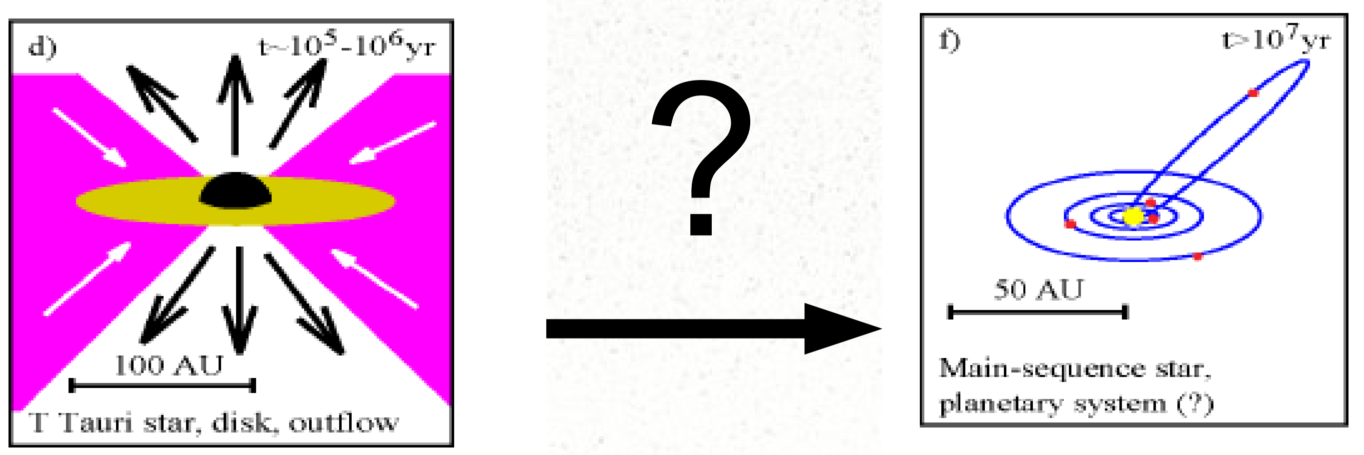
Stellar companion
Forming planet?



Strom & Najita

Transitional disks

- Understanding disk evolution and planet formation



=> statistical studies: large sample!

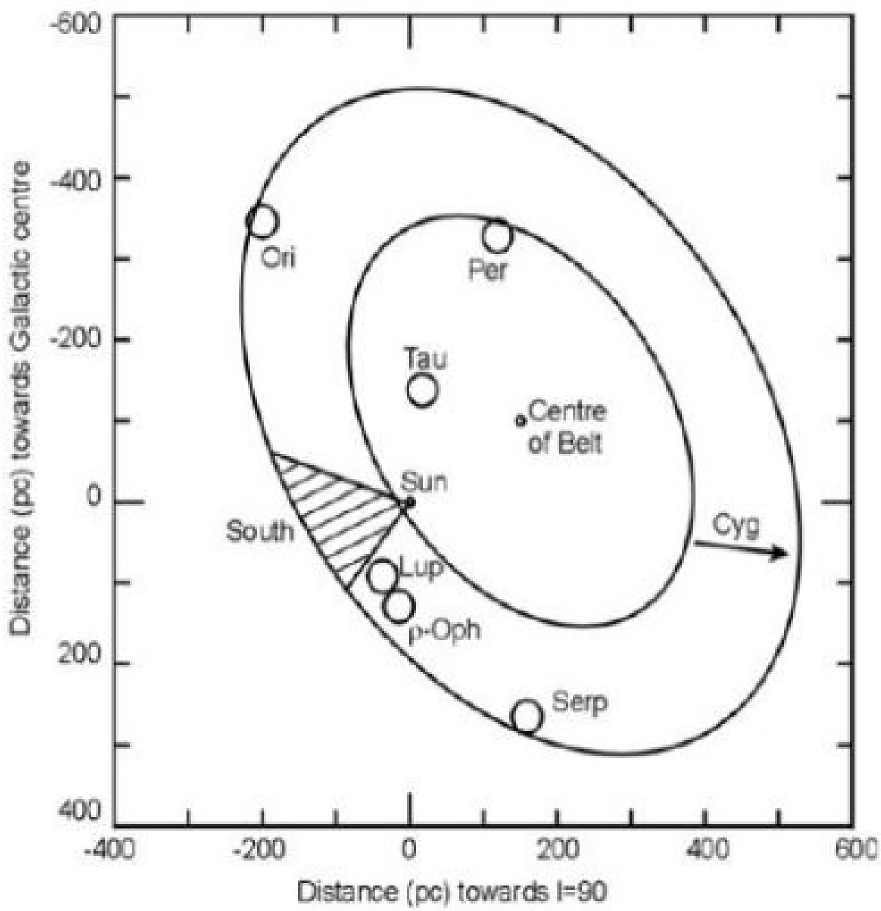
Goals of thesis

- An (unbiased) sample of transitional disks
- Analysis of hole sizes and global disk structure using RADMC SED modeling
- Derivation disk properties and constraining origin of the dust hole
- Link exoplanetary systems to transitional disks

Finding transitional disks

- Basic tool: looking at the SED in IR
- Literature & Selection criteria
- Spitzer mission: lots and lots of IR mapping:
    - IRAC: 3.6, 4.5, 5.8 and 8.0 μm
    - MIPS: 24, 70 (and 160) μm
    - Some targets IRS: spectra 5-34 μm
- Full analysis of Spitzer maps: catalogs

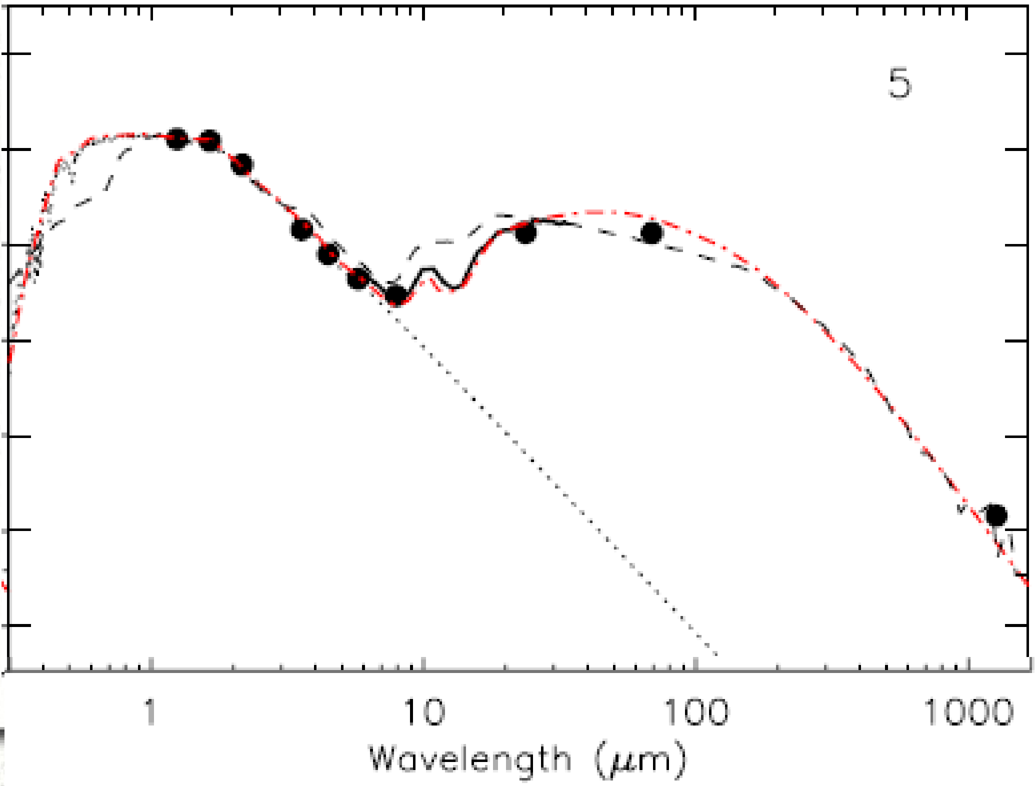
Finding transitional disks



- C2d + GB: local star forming regions
- >3000 YSOs have been found
- How to find transitional disks?

Finding transitional disks

- Study Bruno Merin to develop color criteria: how to identify transitional disk candidates with SED photometric fluxes?
- 33 targets
- Opt+IR+mm photometric fluxes + IRS spectrum
- full SED modeling



Merin et al 2010

Finding transitional disks

\+ * Disk with hole

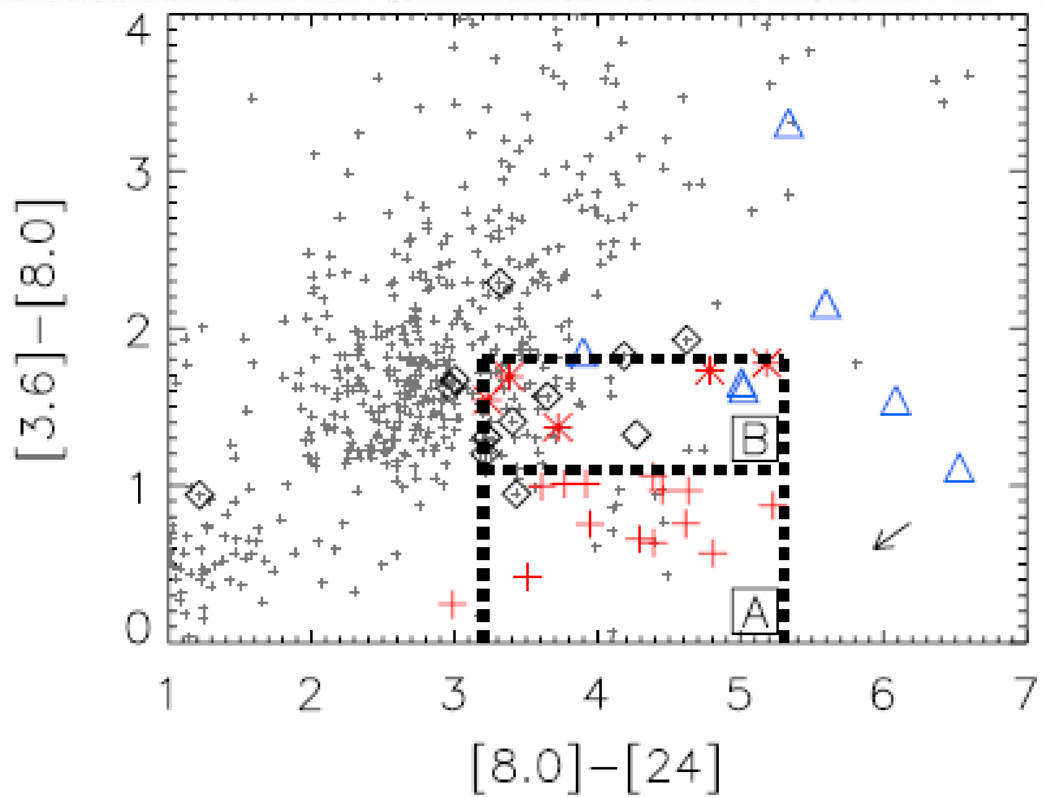
△ Edge on disk

◇ Disk without hole

Color criteria:

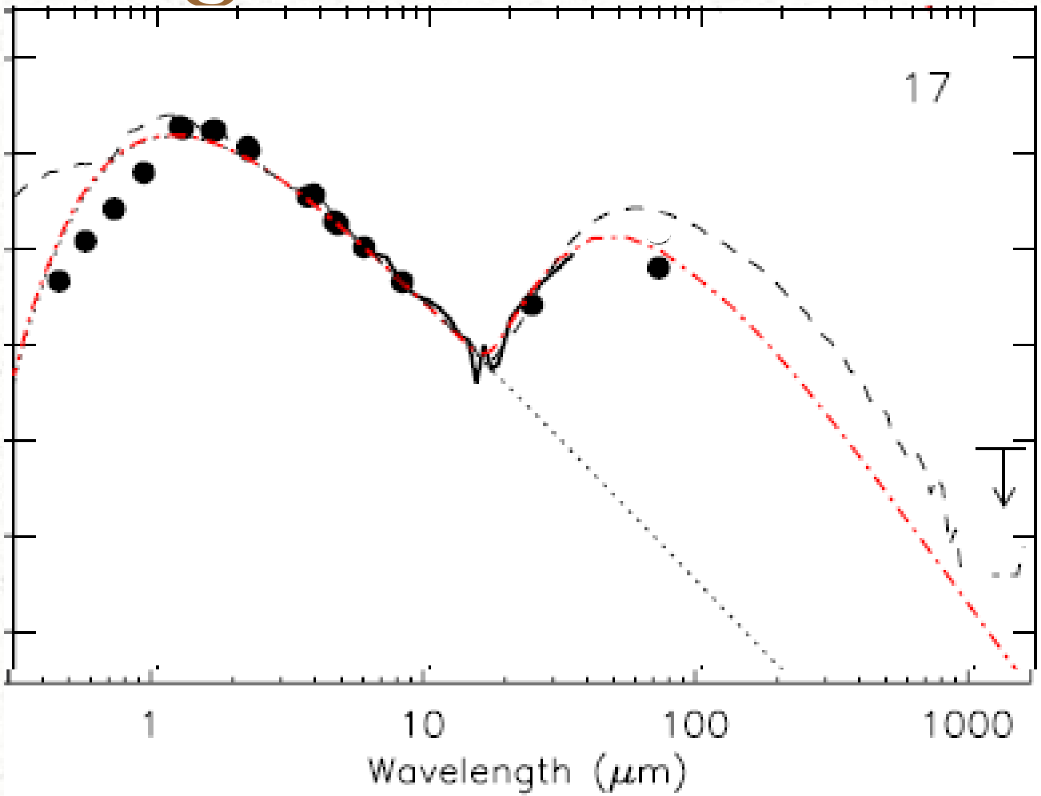
Regions A/B select disks with holes!

(no need for modeling)



Merin et al 2010

Finding transitional disks



Sz84: 55 AU hole and falls outside Region A

=> additional set of criteria using MIPS2 (70 μm) (van der Marel et al., in prep.)

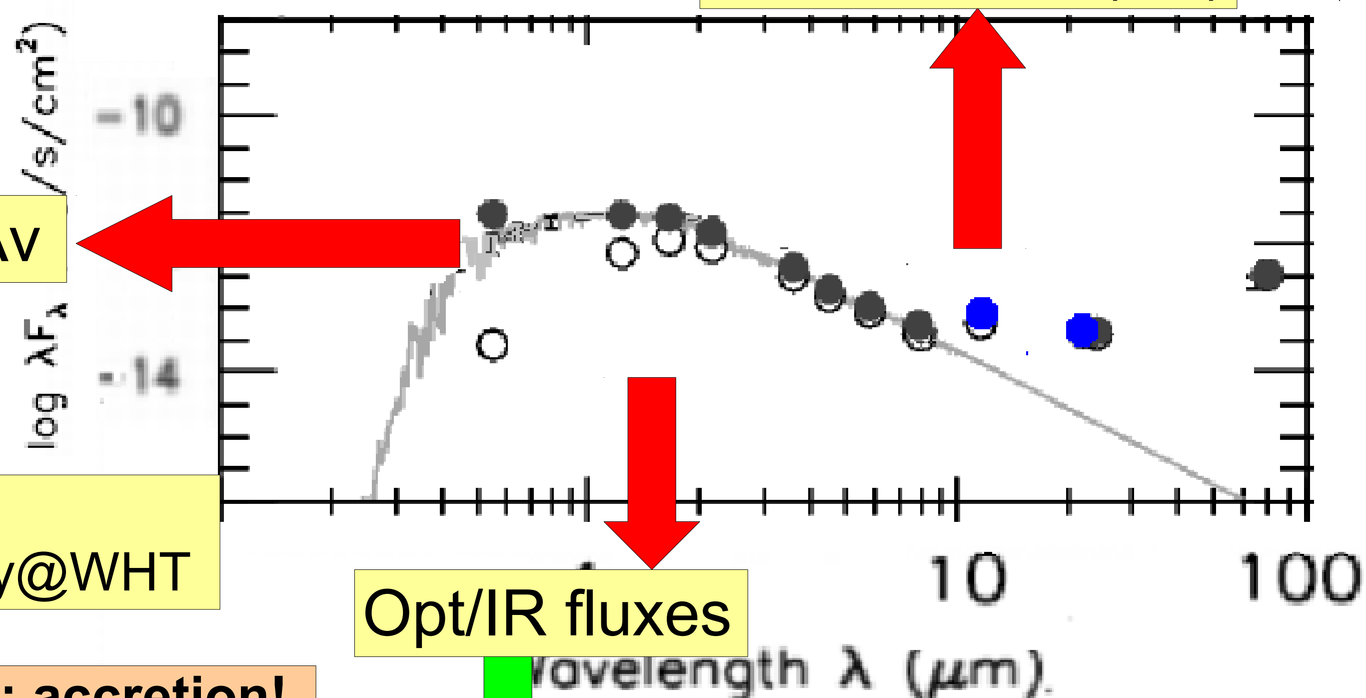
Finding transitional disks

- Selection criteria on c2d and GB in combination with MIPS2 (70 μm) > 40 mJy: bright disks!
- > 100 new candidates found!

  + ~ 70 candidates and confirmed TD from literature
- **Additional data** required to determine properties and confirm TD!

Finding transitional disks

- Requirements before SED modeling



10-15 micron (dip)

IRS-Spitzer/ WISE/VISIR

SpT for Av

Optical/NIR spectroscopy@WHT

Submm fluxes

Flux measurements @JCMT/APEX/SMA

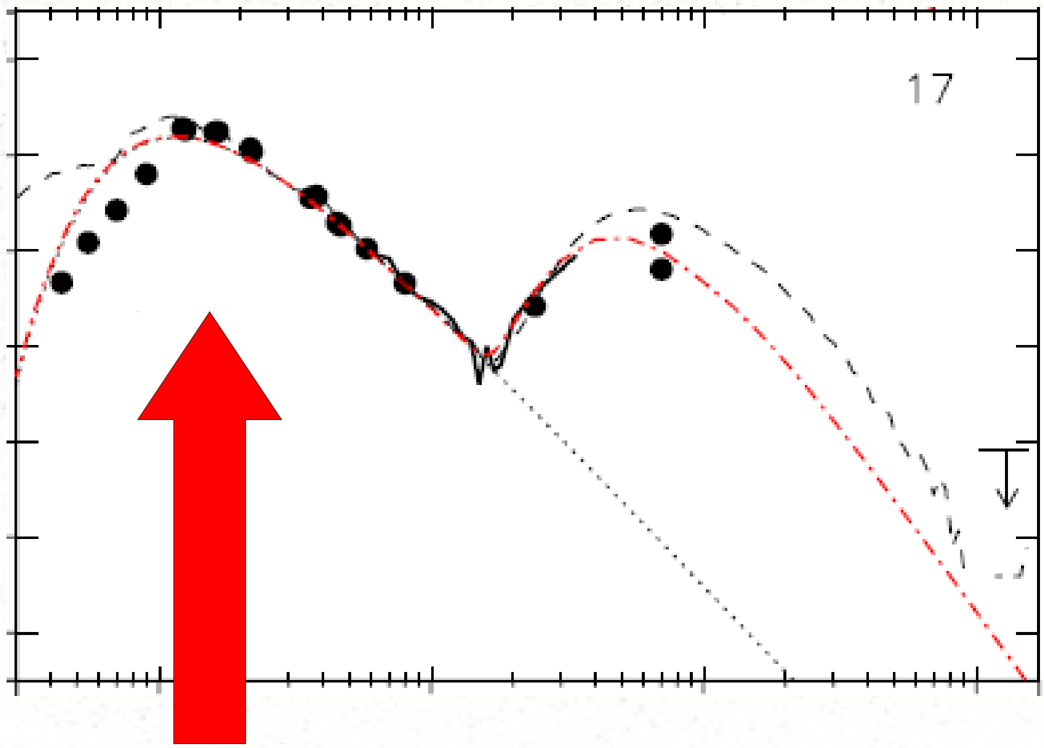
Opt/IR fluxes

Catalogs Spitzer/2MASS/WISE

Also: accretion!

Stellar properties

- Important for SED: T_{star} (BB) => SpT



Stellar properties

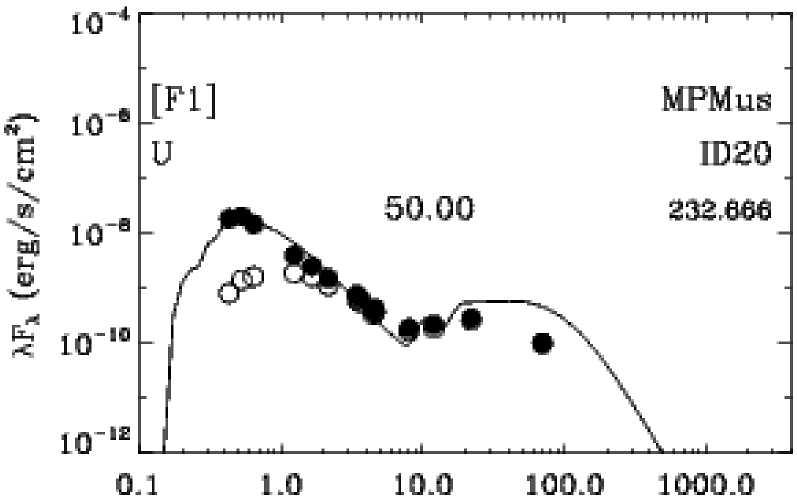
- Spectral types: (OB)AFGKM
- Temperature: 10 000 – 2000 K
- Classification using optical/NIR spectroscopy
  - Atomic/molecular lines
  - Photometry
- ISIS/LIRIS spectroscopy with WHT
- Also: accretion rate dM/dt

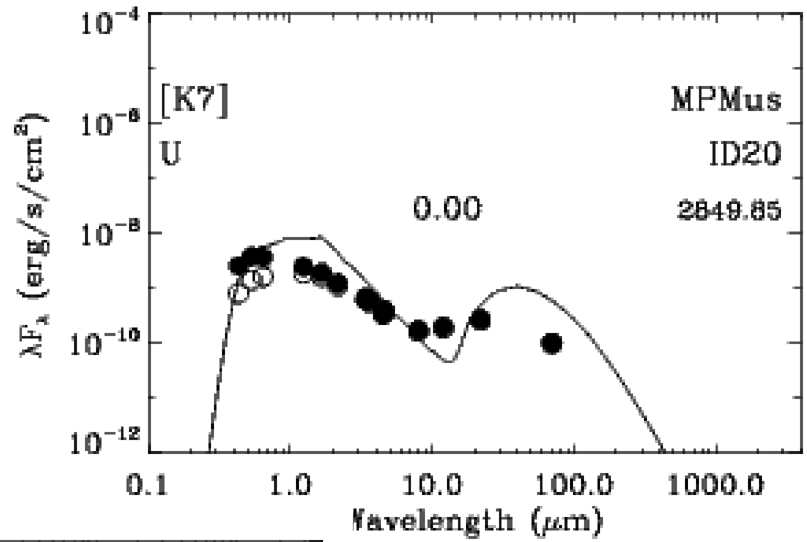
Stellar properties

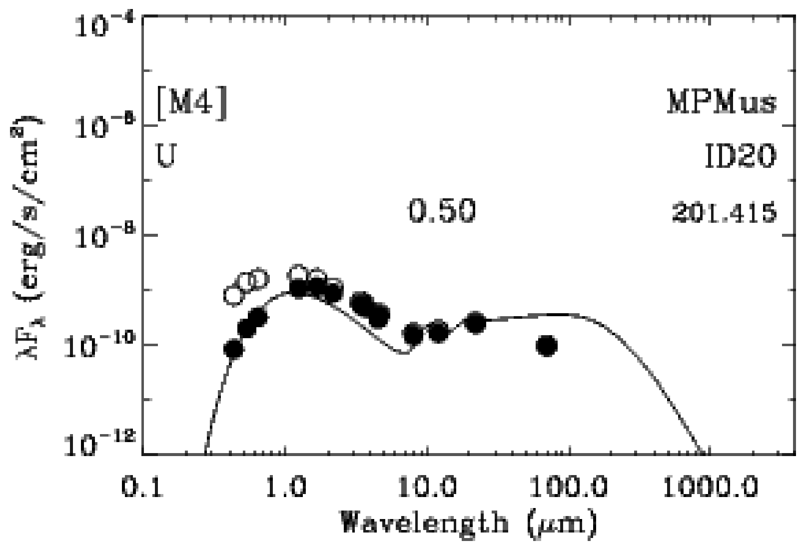
- Two main problems:
  - Accretion shock: veiling
    => excess continuum towards blue
    continuum more blue, lines less visible
  - Interstellar matter: extinction
    => suppression continuum towards blue
    continuum more red
- Both effects to be taken into account!

Stellar properties

- What could happen with wrong SpT...







Stellar properties

- Approach: fitting routine of optical/NIR spectra which fits temperature, extinction and veiling (accretion) simultaneously (Manara et al. 2013)
- Accretion important property as well:

  => photoevaporation only possible when accretion is low!

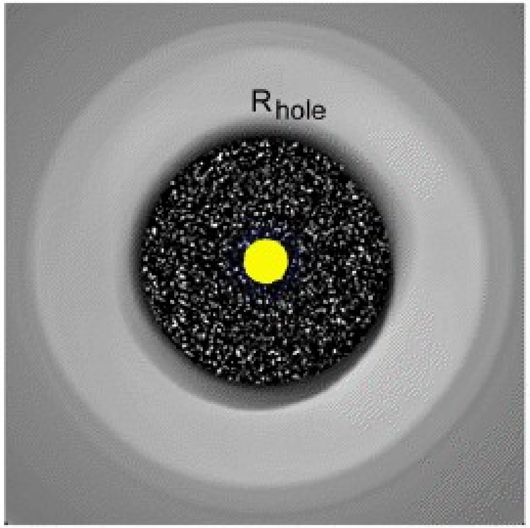
Finding transitional disks

- SED modeling >150 transitional disk (candidates):
  hole sizes ~ 0.5 – 150 AU
- Follow-up resolved dust imaging SMA/ALMA
- Construct robust sample TDs (10-15)
  => largest holes (>5-10 AU) which can be resolved in gas

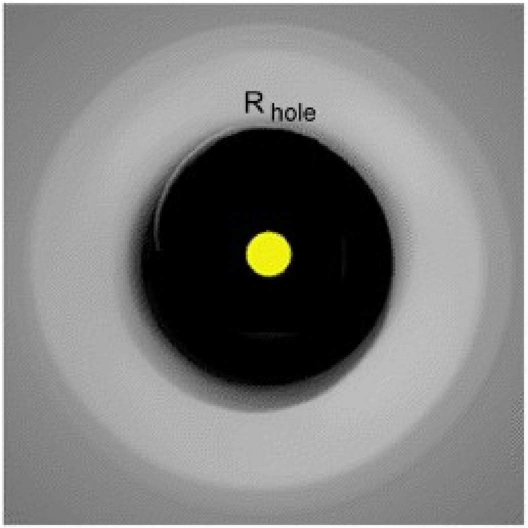
Transitional disks

- Mechanisms dust clearing:

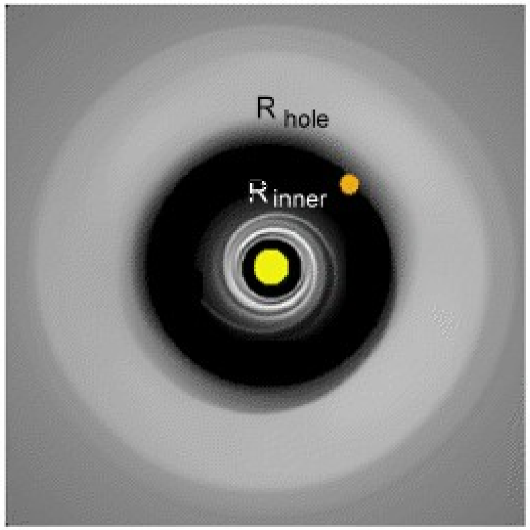
Grain growth



Photoevaporation



Stellar companion
Forming planet?



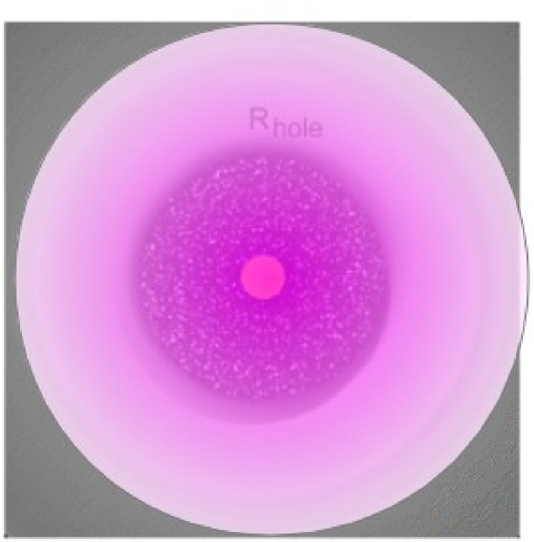
$\Rightarrow$ **What about the gas?**

Strom & Najita

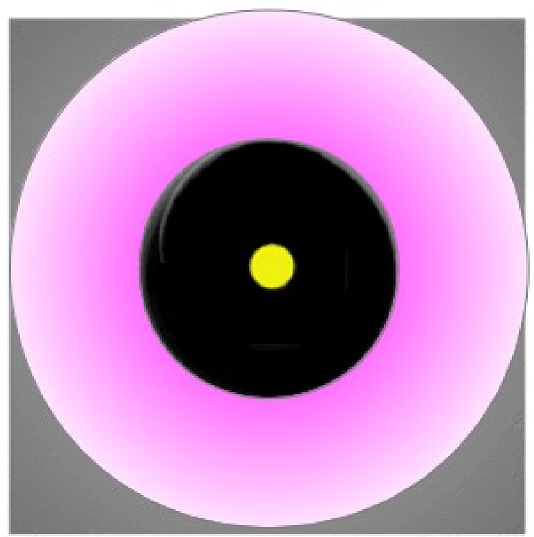
Transitional disks

- Mechanisms dust clearing:

Grain growth



Photoevaporation



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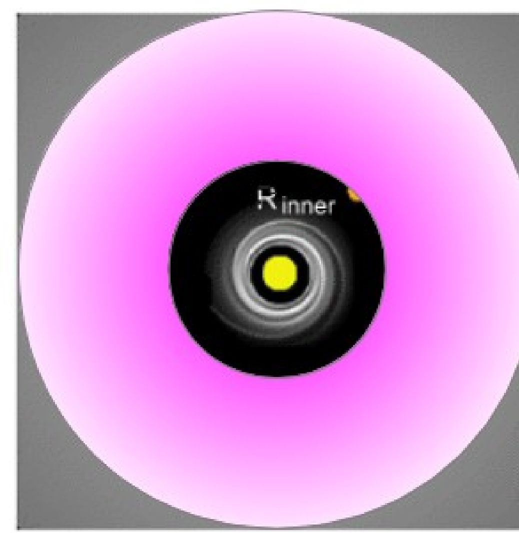


⇒ Need to know the gas distribution and mass < 50 AU ⇒ ALMA

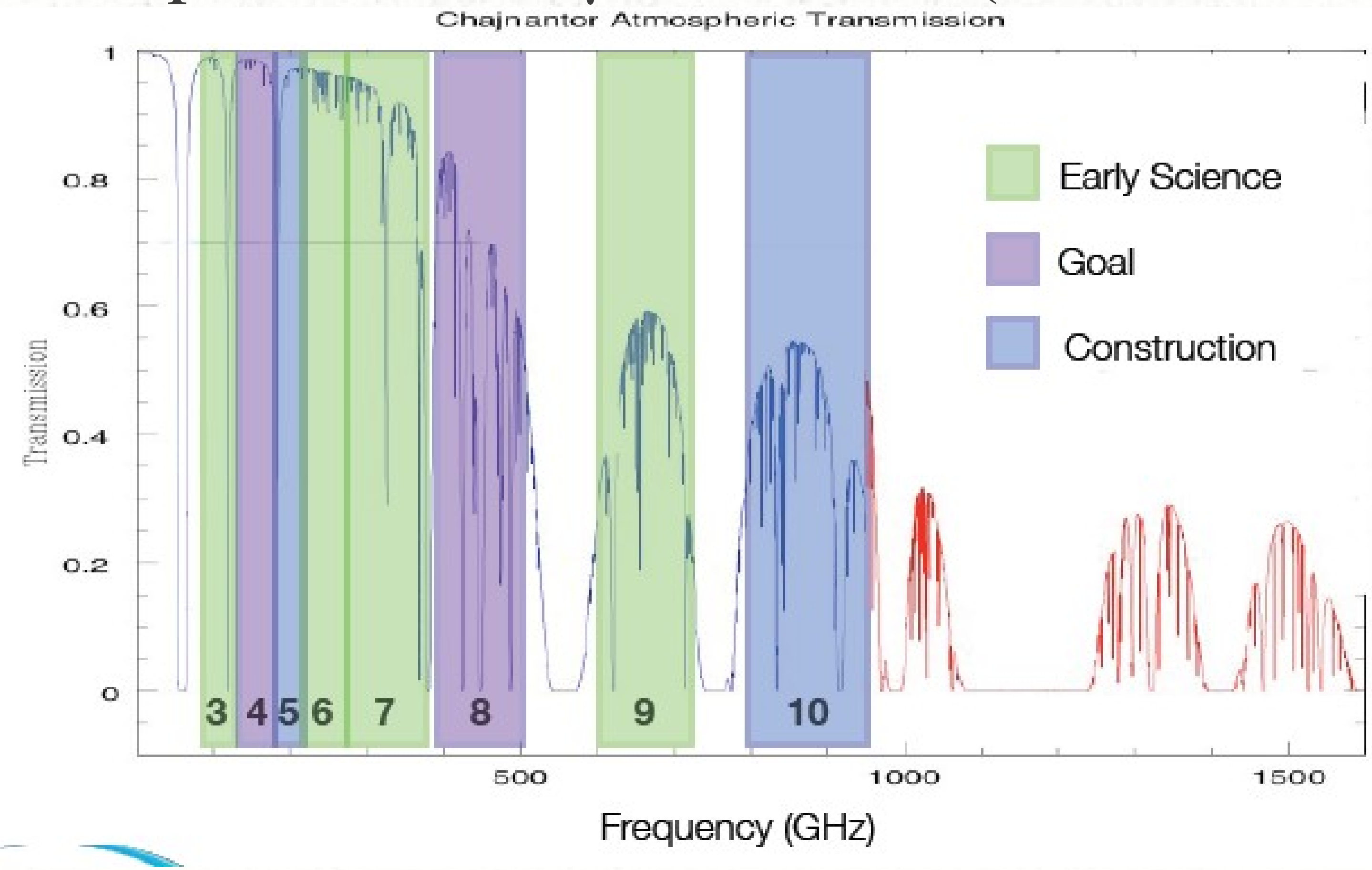
ALMA

- Atacama Large Millimeter Array
- Atacama desert, Chile (5000 m altitude)
- Built and operated by Europe (ESO), North-America (NRAO) and East-Asia(NAOJ)

- Total cost ~1.3 billion $US

ALMA

- Freq bands: 315 µm - 3 mm (80-950 GHz)

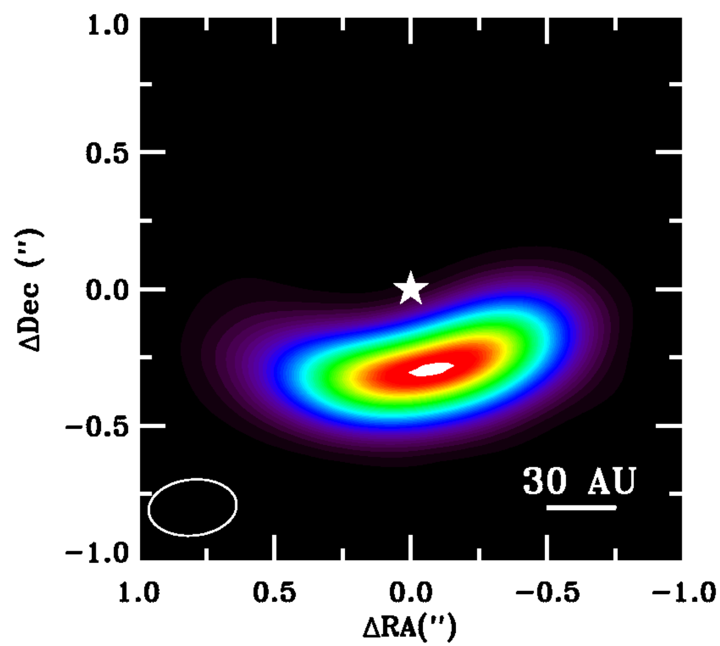


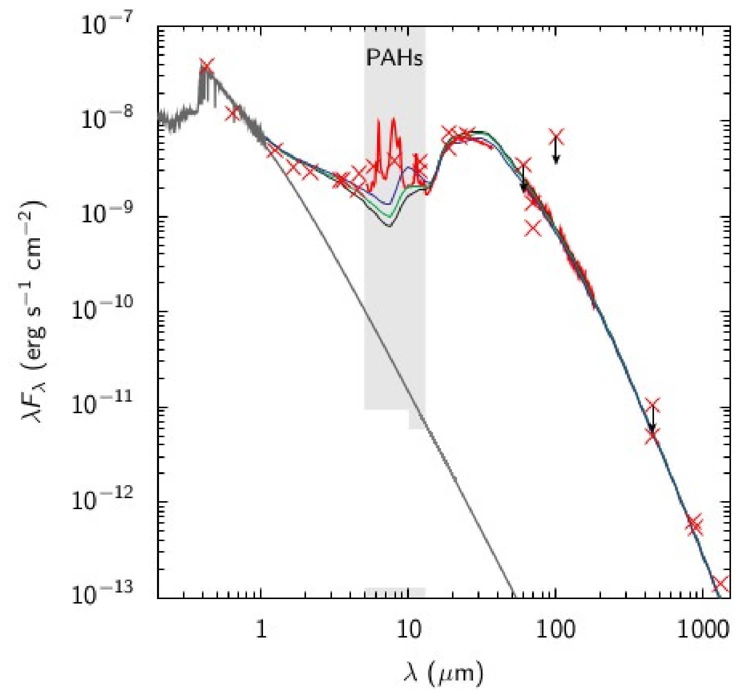
ALMA

- Final array 66 antennas:
  - 50 12-m (25 EU and 25 US)
  - 16 (12 7-m)Short spacings (East Asia):
- Baselines up to 16 km (0.005” at 650 GHz)
- State of the art wide-band receivers and high resolution correlator
- ALMA allows measurement of gas distribution on <20 AU scales
- Early Science programs (2012-2014) on TDs

ALMA

- First target (observed in 2012): Oph IRS 48
- Asymmetry: interpreted as dust trapped in vortex => important step in planet formation





Van der Marel e.a. 2013/Bruderer e.a in prep.

ALMA next cycles

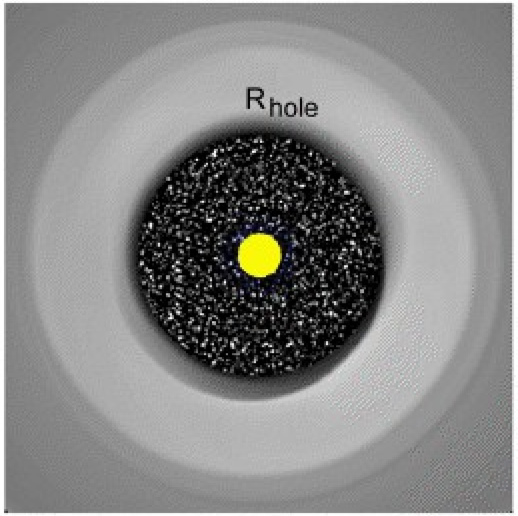
- Future ALMA: increase resolution and sensitivity
- Observe unbiased sample of transitional disks:
    - Resolve gas distribution range of Tds

=> Large, broad sample of TD's with known distribution of gas and dust

ALMA next cycles

- With knowledge of gas, dust and accretion:

Grain growth



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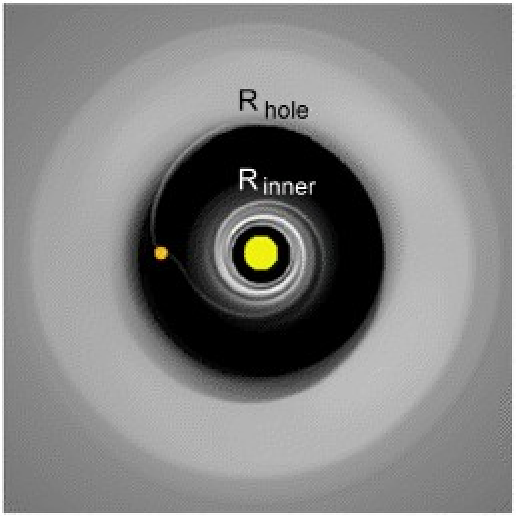

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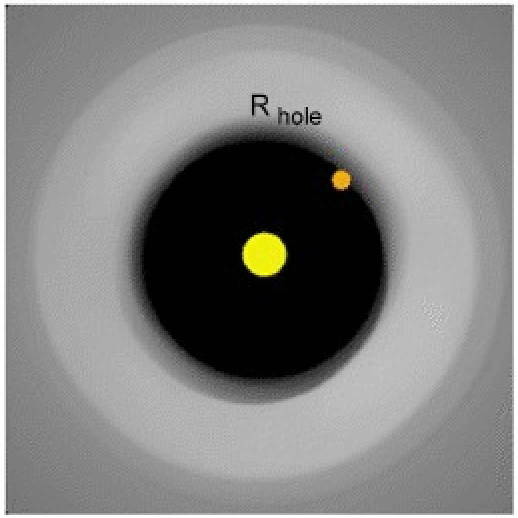


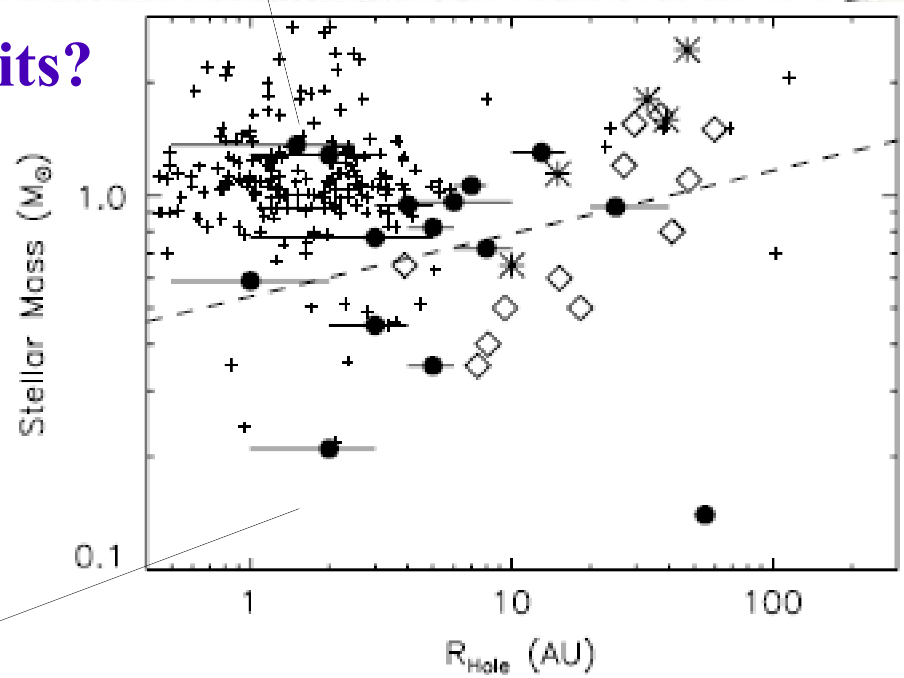
Strom & Najita

ALMA next cycles

Future possibilities

- More molecules: **chemistry**
- Other frequencies: **temperature**
- Substructure in holes: **planet orbits?**
- Comparison with other samples of TTS and debris disks: **evolution**
- Comparison hole size distribution with exoplanetary systems: **planet formation**

(+) *planet (exoplanet.eu 2009)*



(*,◇,●) *Transitional disks*
(Merin et al 2010,Kim et al 2009,Brown et al 2007)

Merin et al 2010

Questions?