Gas inside the 97 au cavity around the transition disk Sz 91: ALMA + Herschel

Héctor Cánovas (U. Valparaiso)

Matthias Schreiber (U. Valparaiso)

Claudio Cáceres (U. Valparaiso)

François Ménard (U. Chile, Santiago)

Francois Ménard (U. Chile, Santiago)

Christophe Pinte (U. Chile, Santiago)

Geoff Mathews (U. Hawaii)

Lucas Cieza (U. Diego Portales, Santiago)

Simon Casassus (U. Chile, Santiago)

Antonio Hales (ALMA)

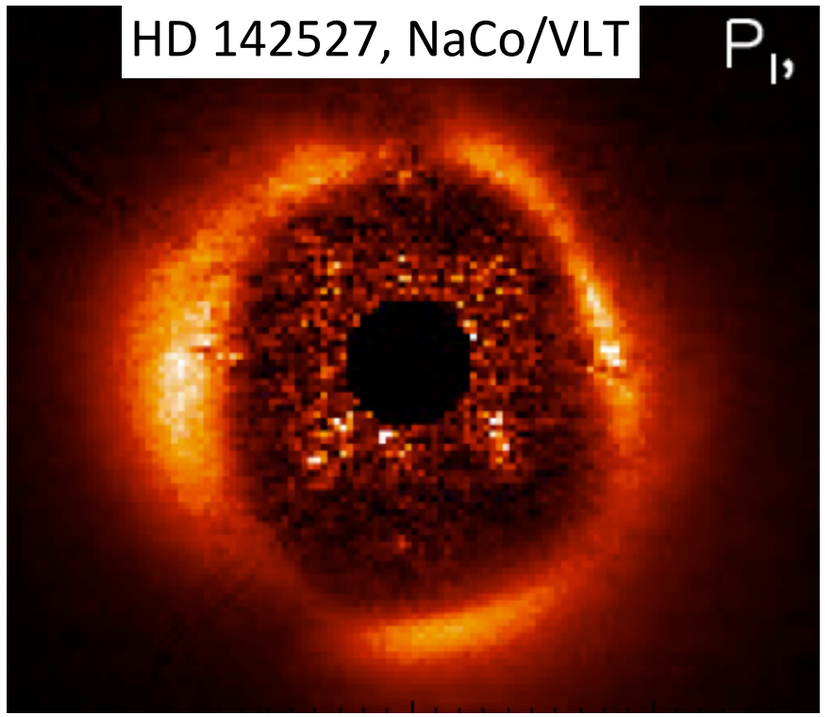
Jonathan Williams (U. Hawaii)

Pablo Roman (U. Chile, Santiago)

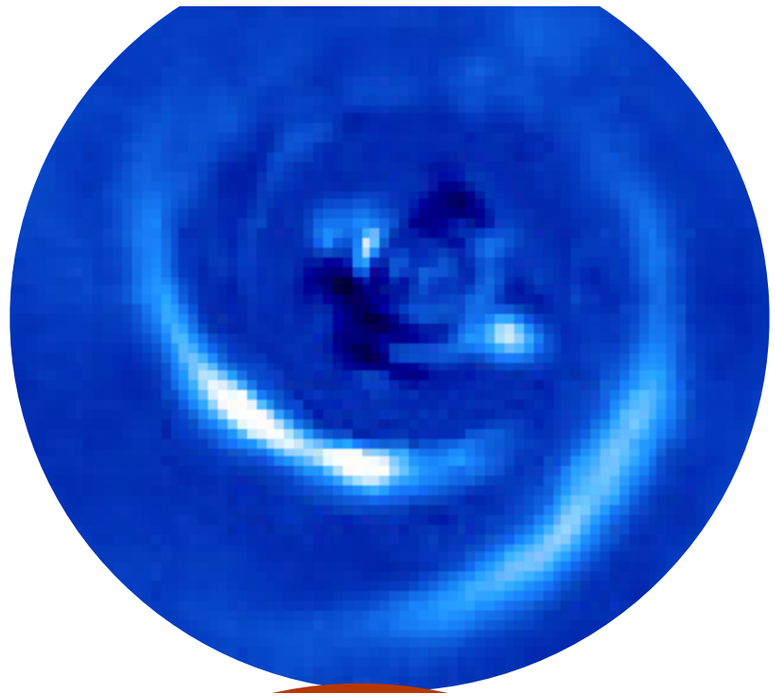
Adam Hardy (Valparaiso)

"The state-of-the-art": direct images of TDs

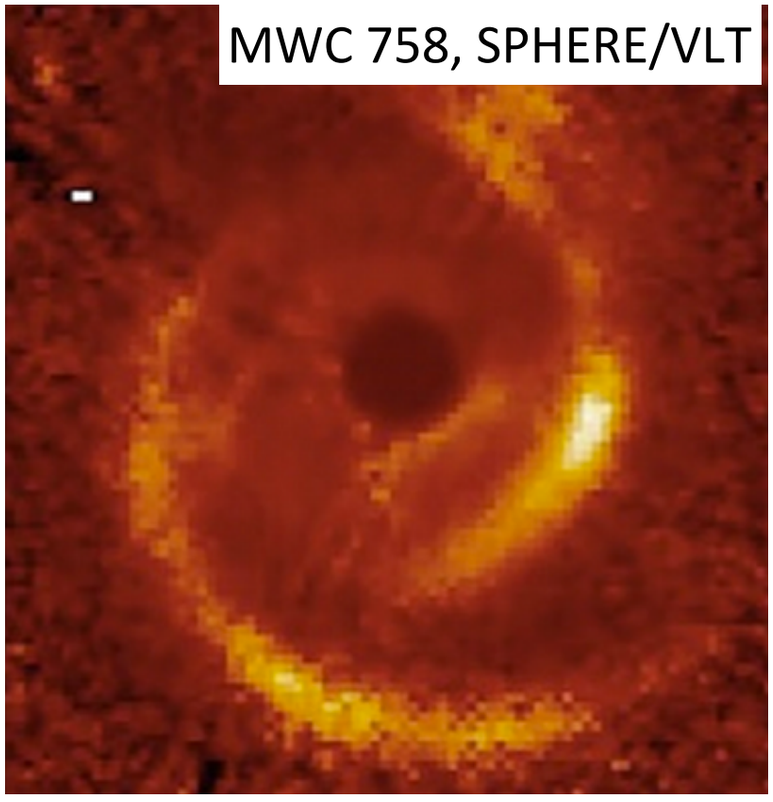
HD 142527, NaCo/VLT



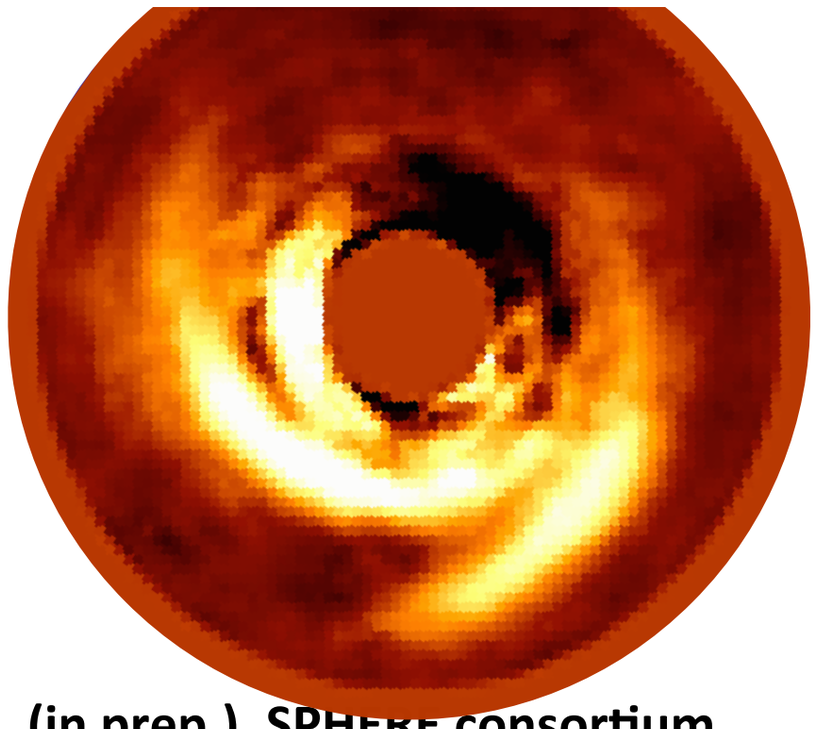
HD 135344, GPI/Gemini



MWC 758, SPHERE/VLT



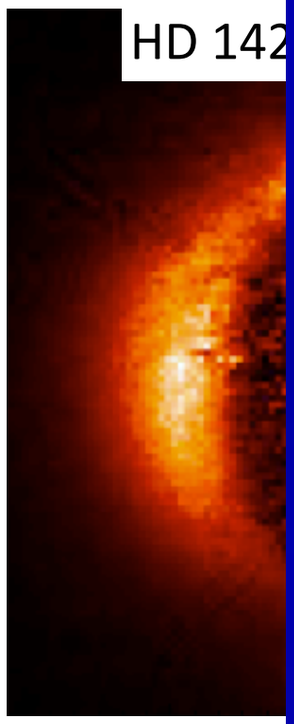
HD 135344, MagAO/Magellan

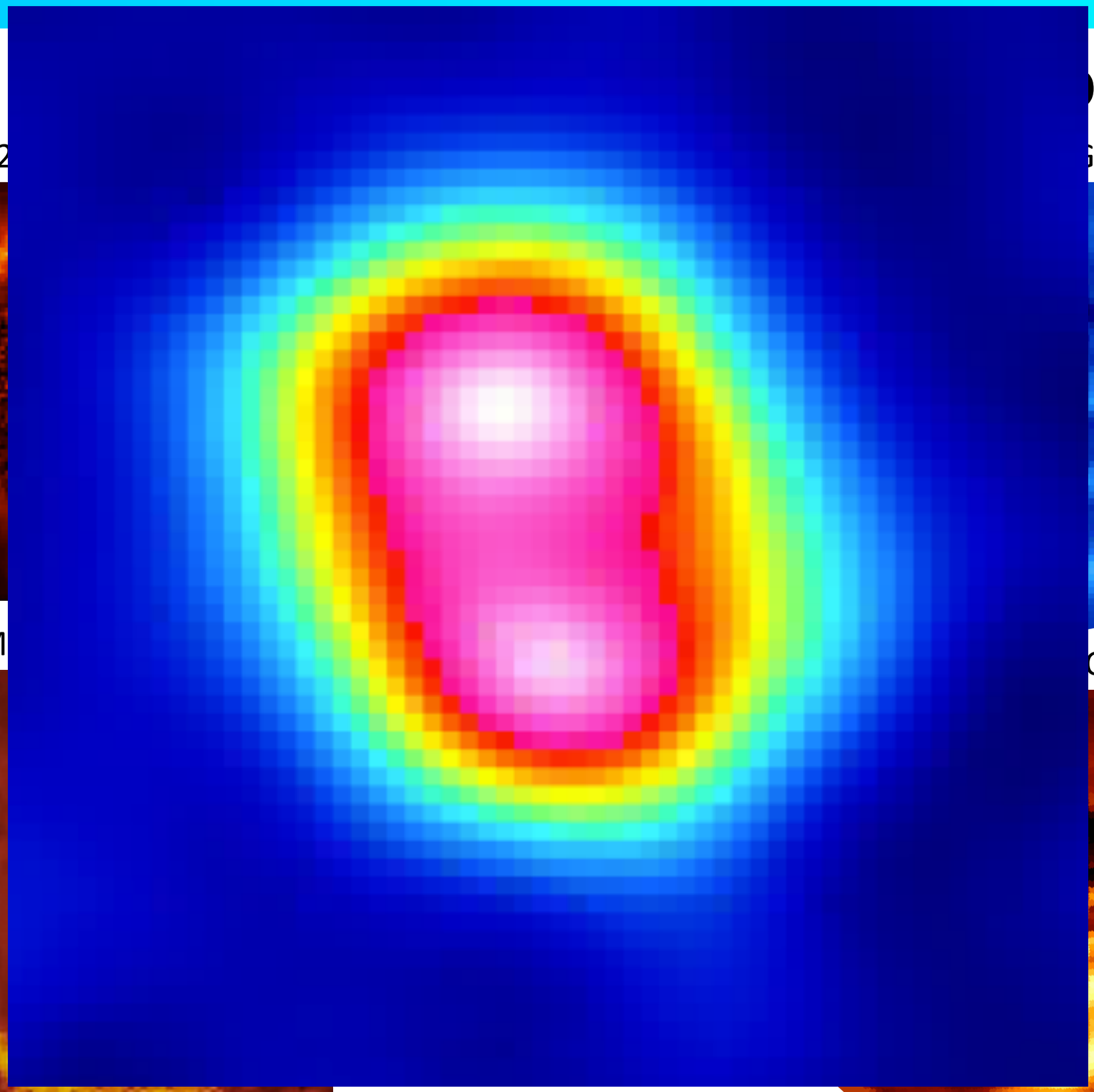


Canovas et al. 2013, Wahhaj et al. 2015 (re-submitted), Menard et al. (in prep.), SPHERE consortium

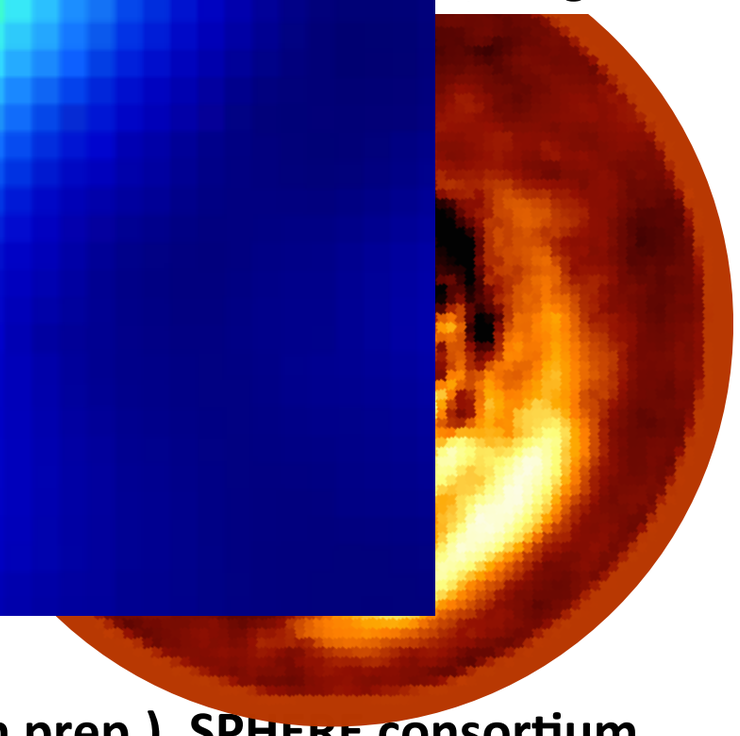
“The … of TDs

HD 142… GPI/Gemini





M… O/Magellan



Canovas et al. 2013, Wahhaj et al. 2015 (re-submitted), Menard et al. (in prep.), SPHERE consortium

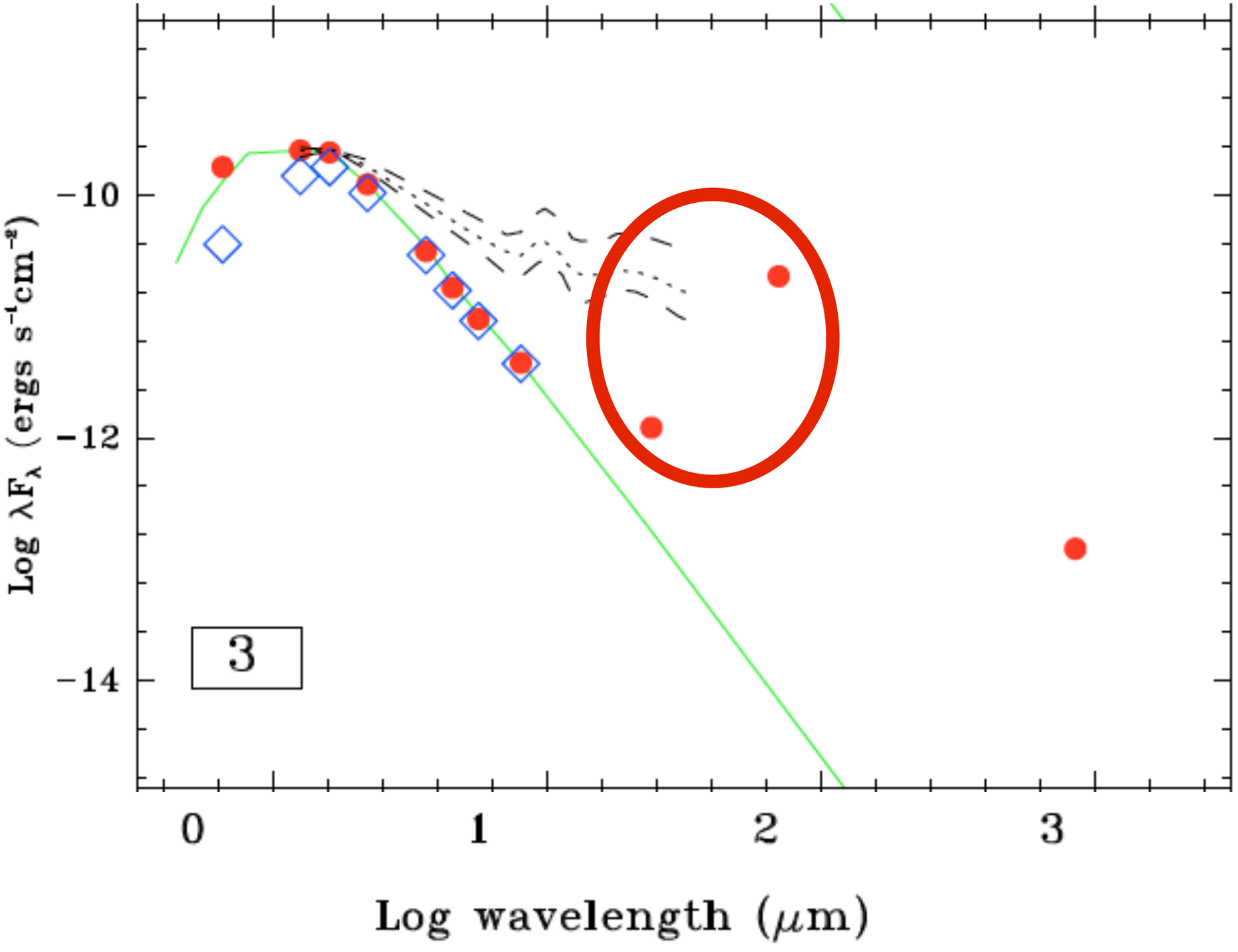
Sz 91: Basic data

- Lupus III Star Forming Region
- distance ~ 200 pc
- Age ~< 1 Myr
- Spt ~ M1.5
- $M_\star$ ~ 0.47 M

THE NATURE OF TRANSITION CIRCUMSTELLAR DISKS. II. SOUTHERN MOLECULAR CLOUDS*

Gisela A. Romero[1,2,3], Matthias R. Schreiber[1], Lucas A. Cieza[4,9], Alberto Rebassa-Mansergas[1], Bruno Merín[5], Analía V. Smith Castelli[3,6], Lori E. Allen[7], and Nidia Morrell[8]

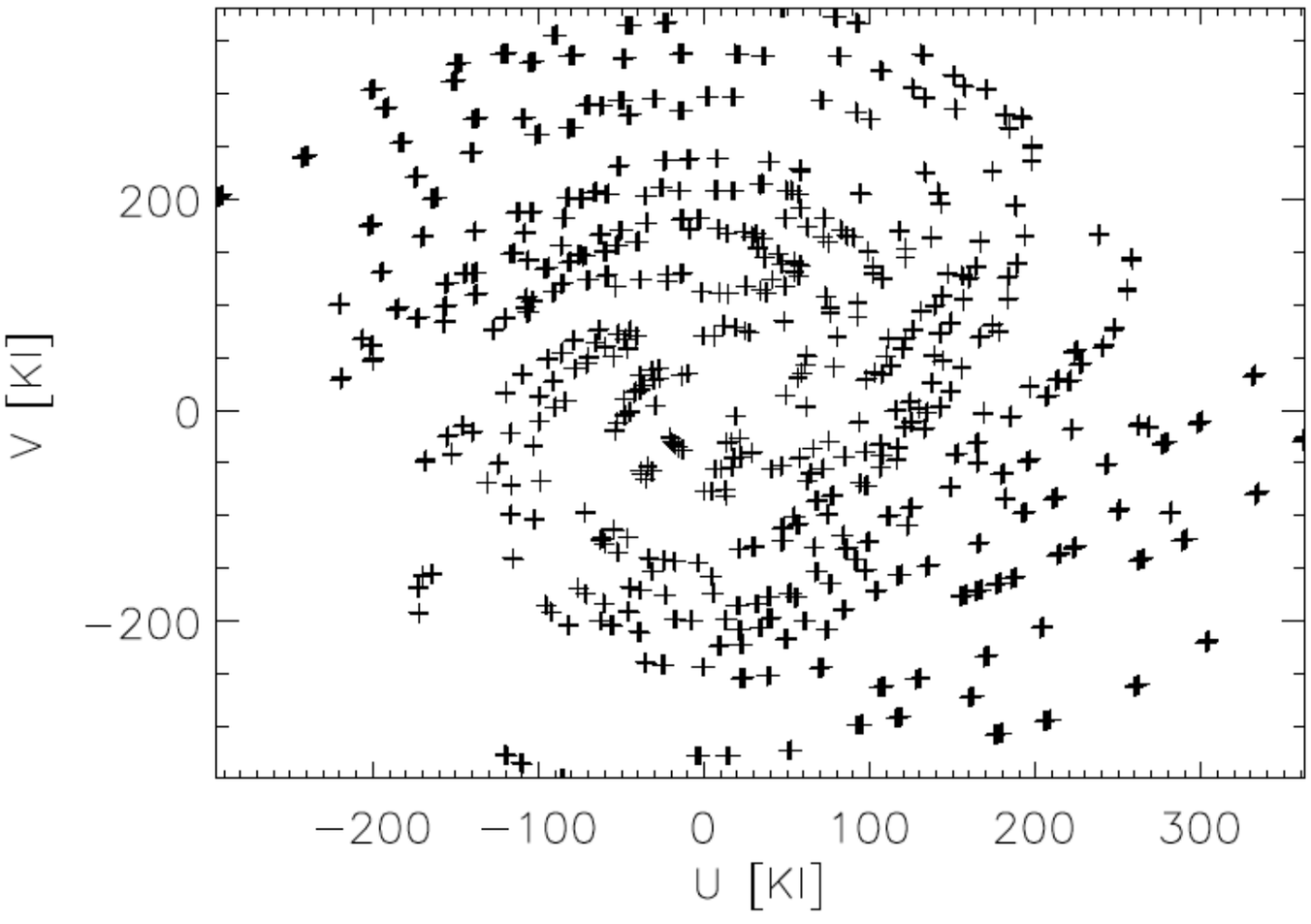
SED: Large Inner Hole

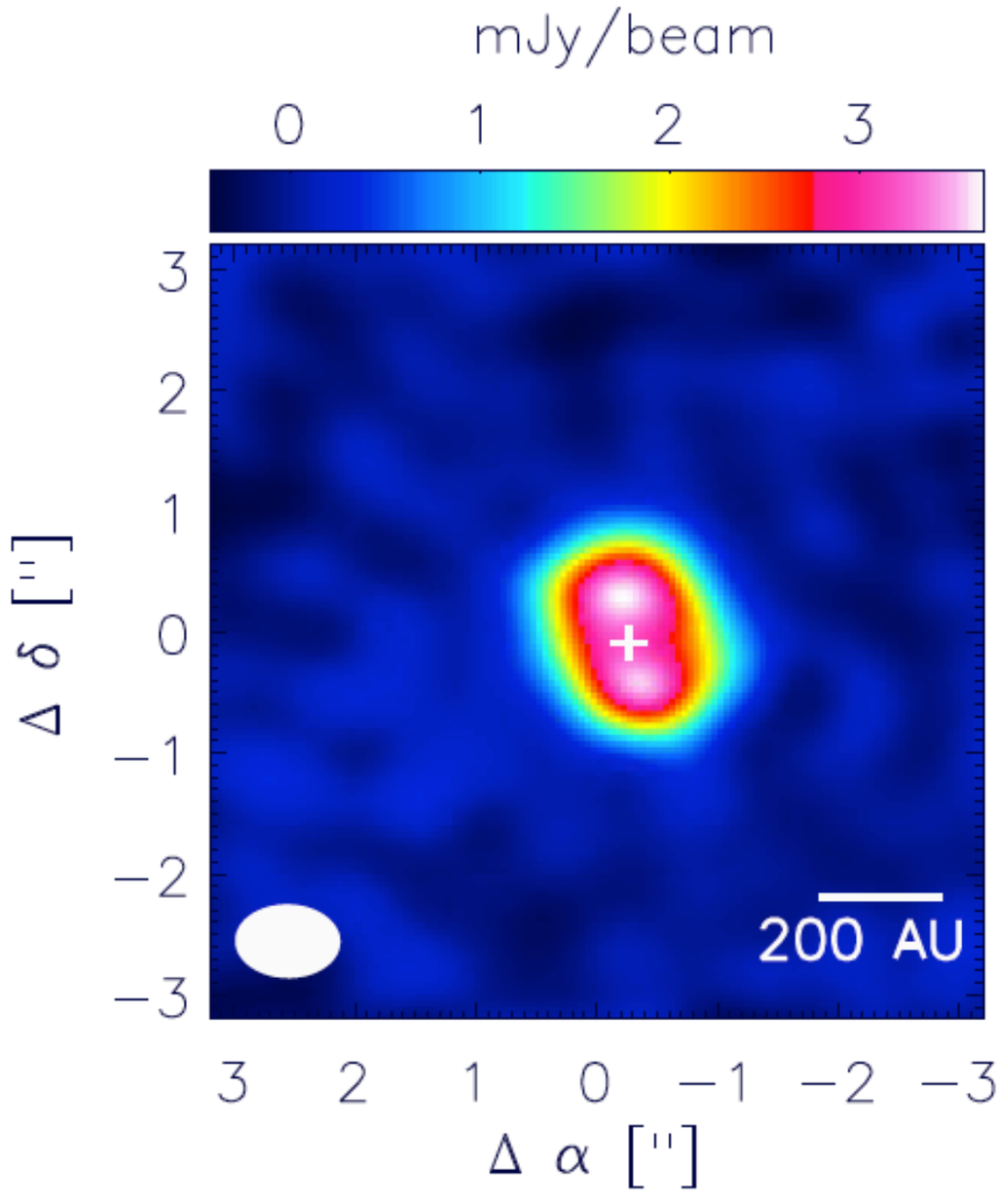


Romero et al. 2012

ALMA data: Continuum (dust) 1.3mm

Observed: UV plane → "cleaned"



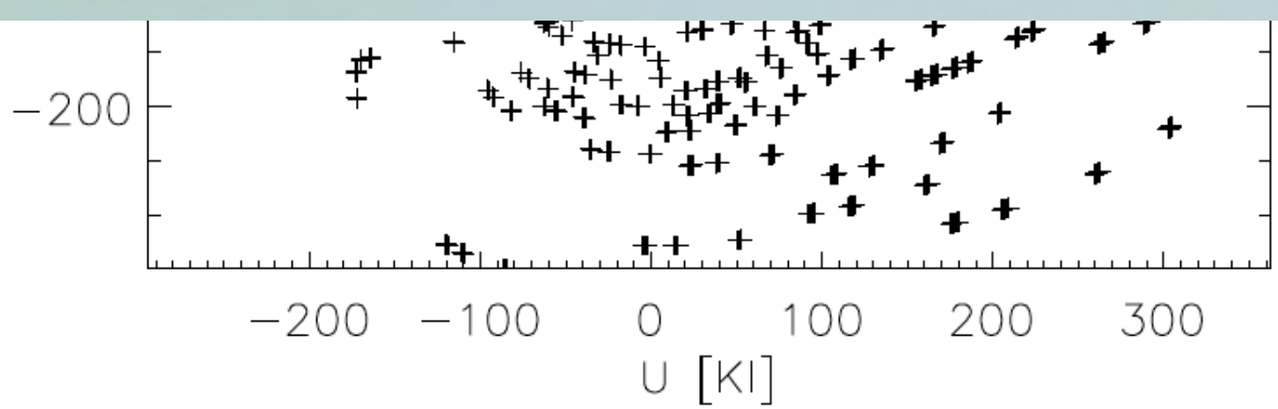


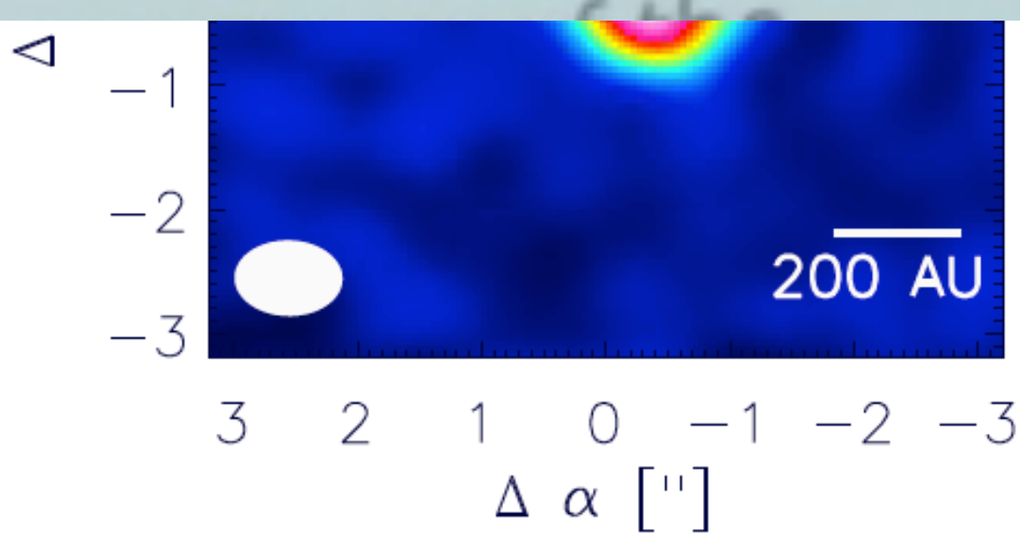
Canovas et al. 2015, quote: Martin Zwaan, Wednesday

ALMA data: Continuum (dust) 1.3mm

Observed: UV plane → "cleaned"

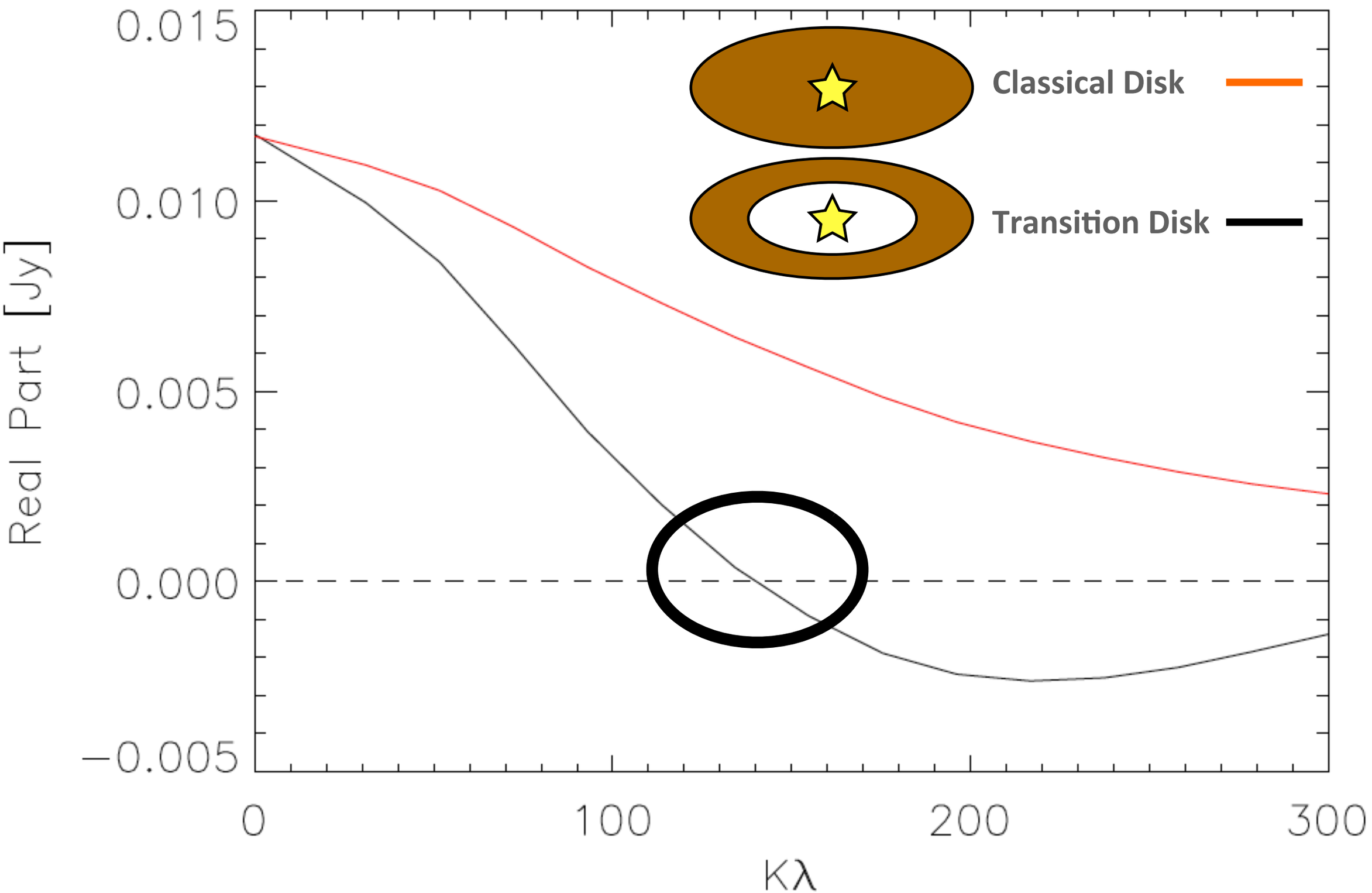
- Deconvolution uses non-linear techniques
- Synthesis imaging: it is easy to make an image, but not easy to know if your image is right!



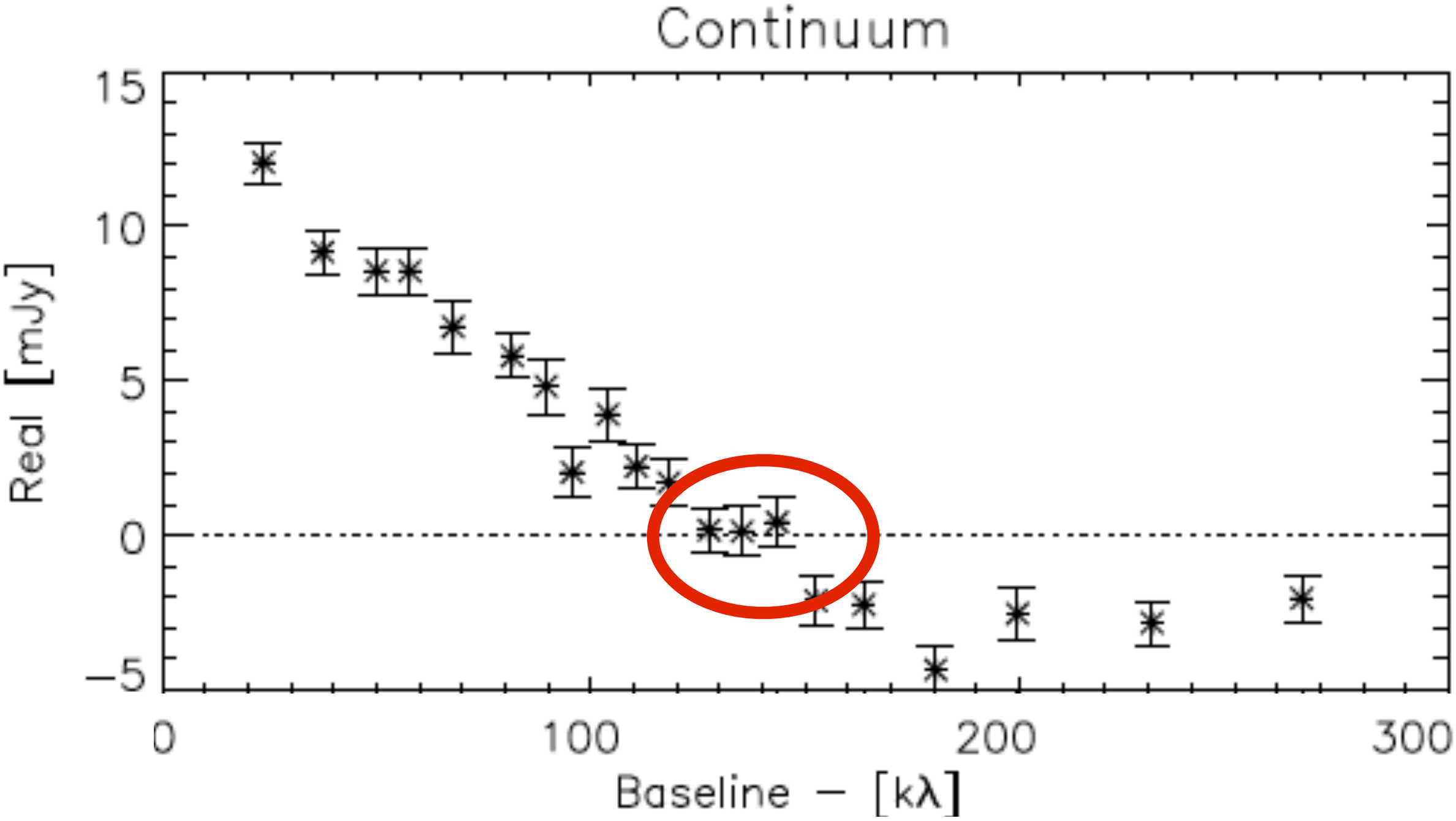


Canovas et al. 2015, quote: Martin Zwaan, Wednesday

Decoding the UV plane



Decoding the UV plane: >70 au cavity

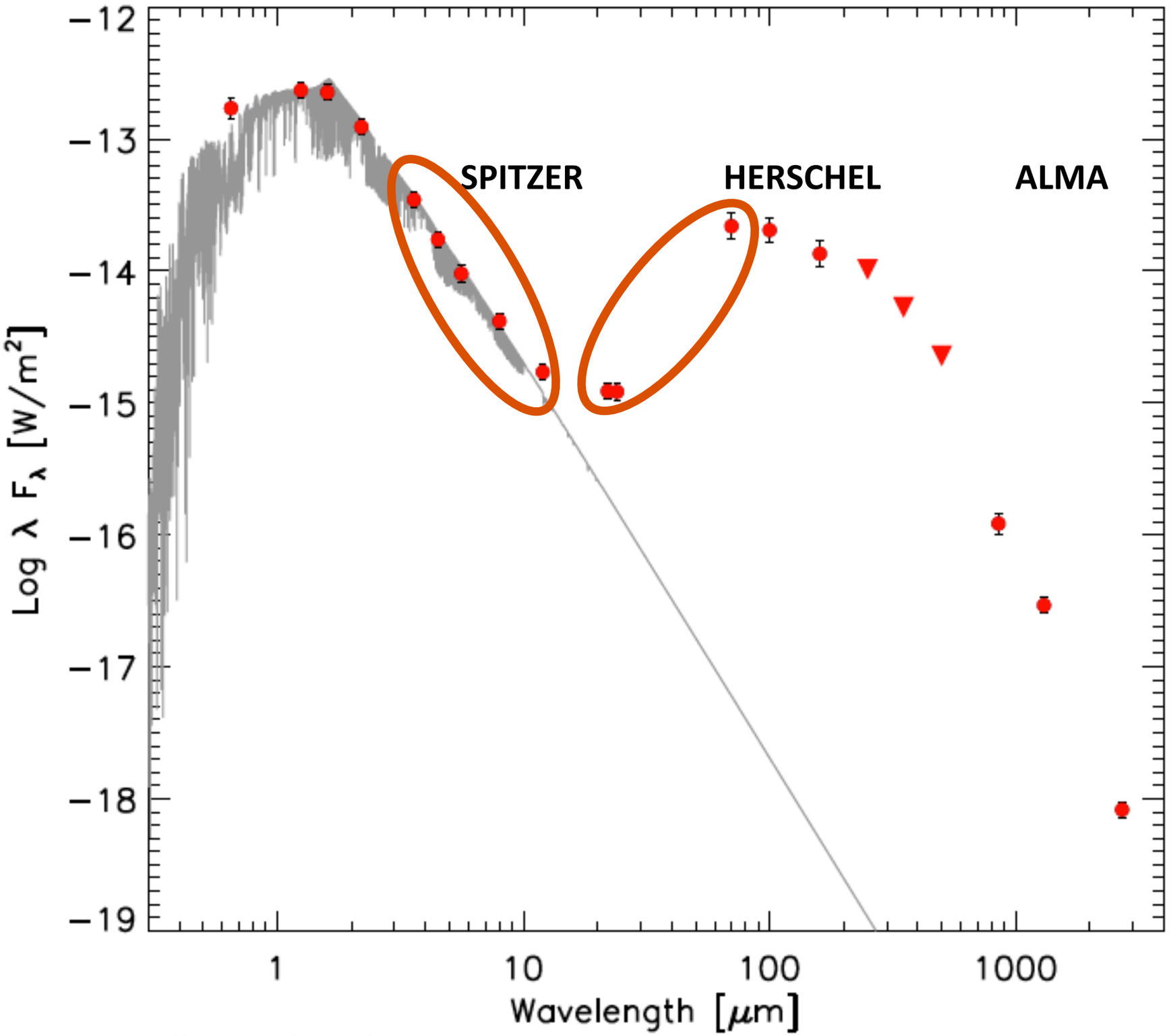


SED: Thermal Structure (dust)

NO IR excess < 12 µm

22/24 µm excess

>70 µm excess
(Herschel + ALMA)



Dullemond et al. 2010

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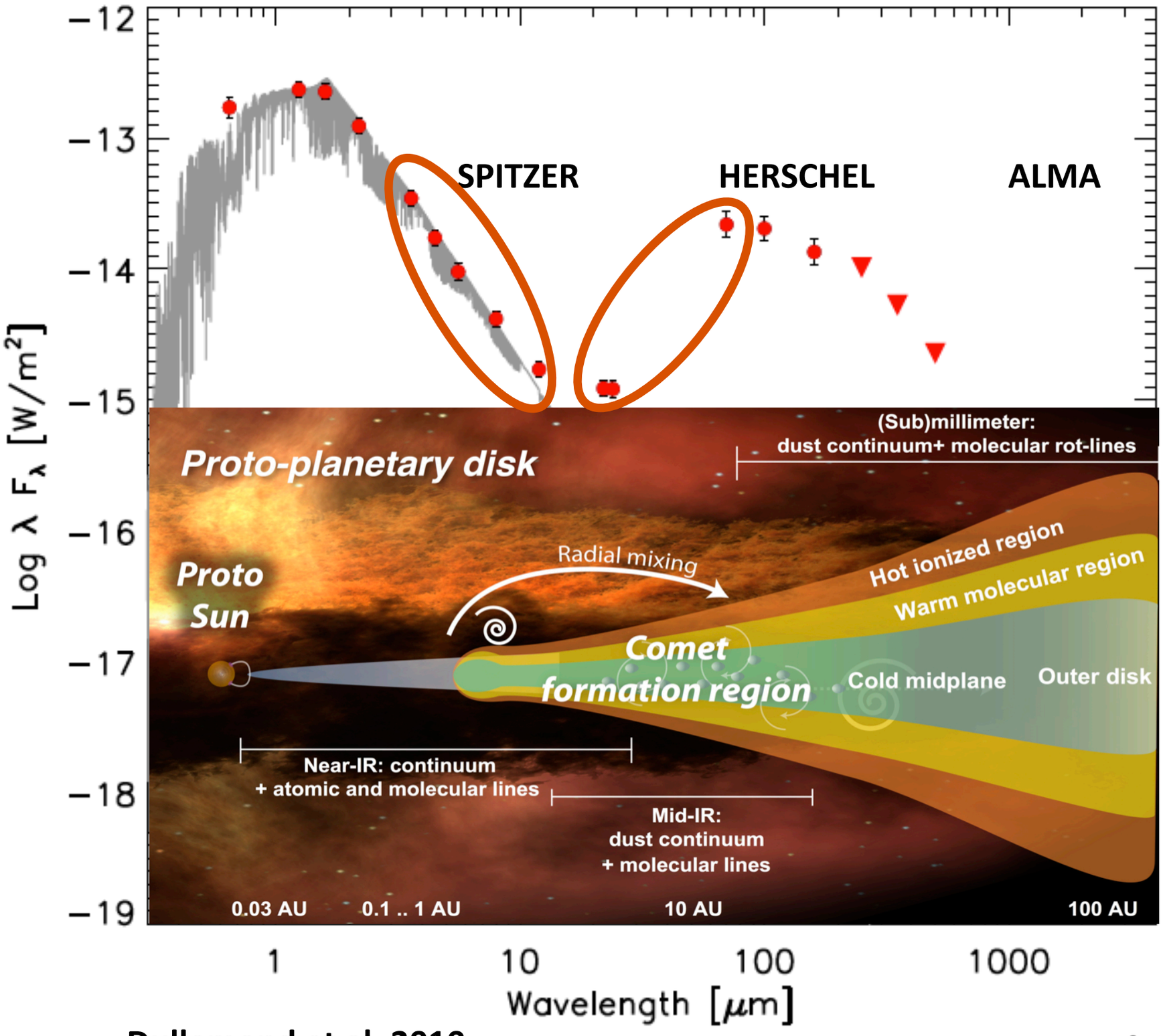
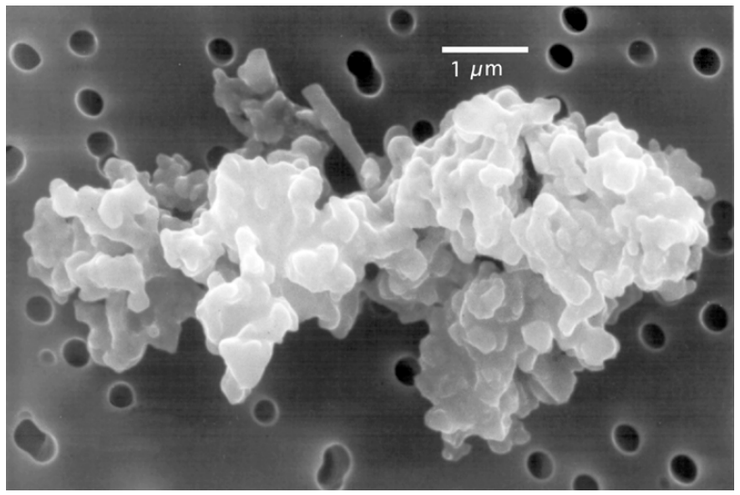
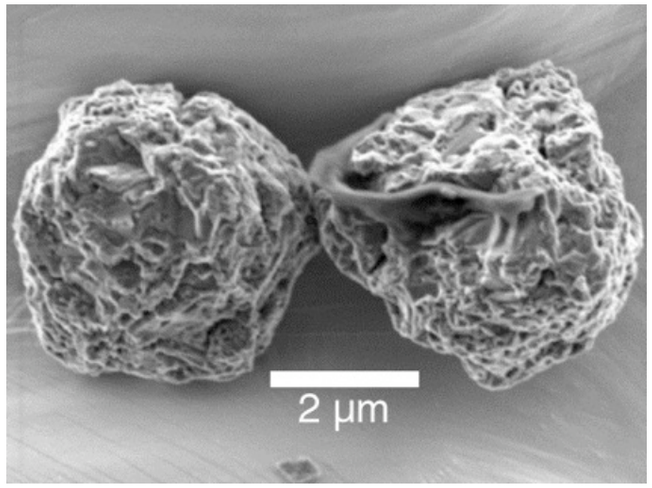
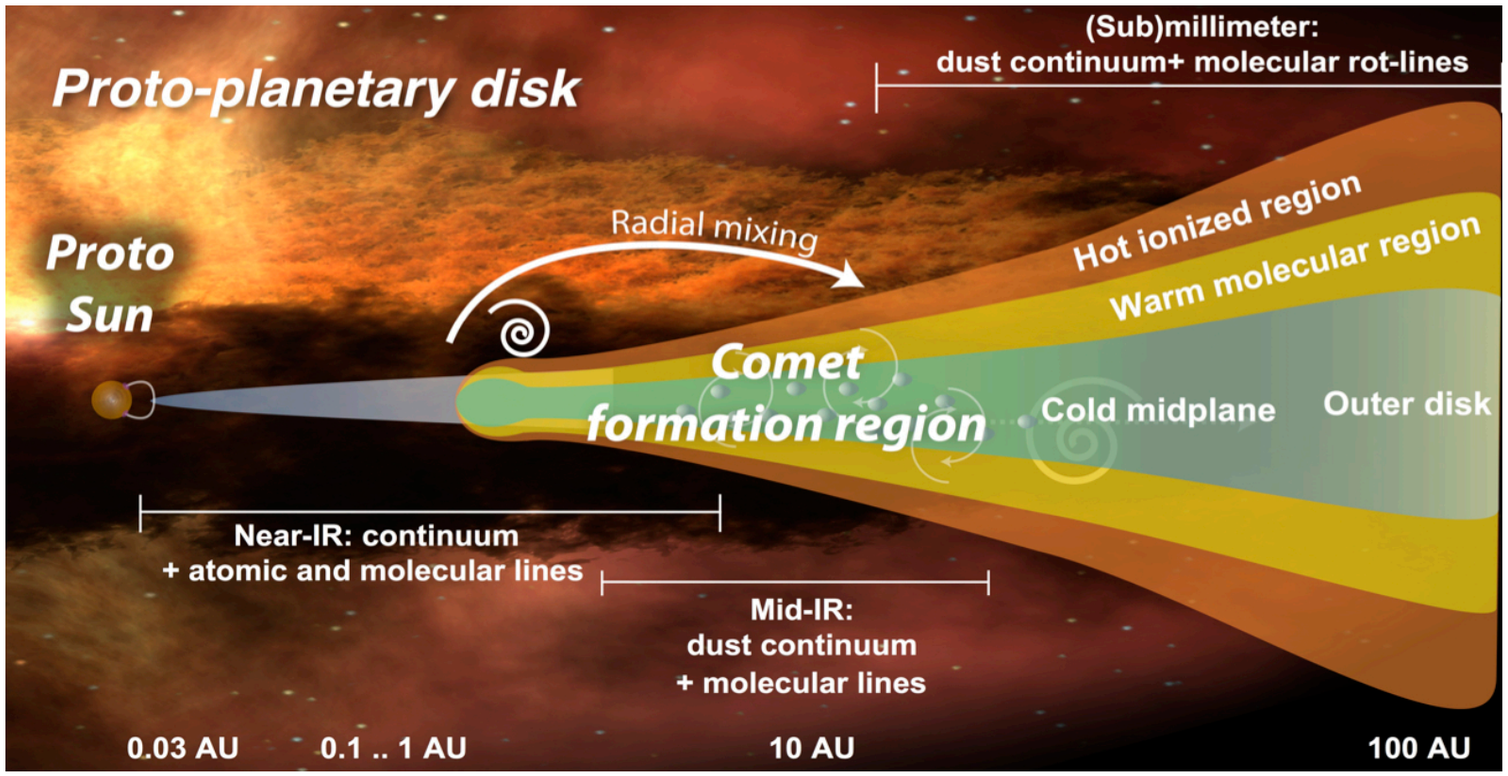


Dullemond et al. 2010

Radiative Transfer model







COMPLEX!!

$$dn(a) \propto a^{-p} da$$

$$\Sigma(r) = \Sigma_C \, r^{-\gamma} \exp\left[-\left(\frac{r}{R_C}\right)^{2-\gamma}\right]$$

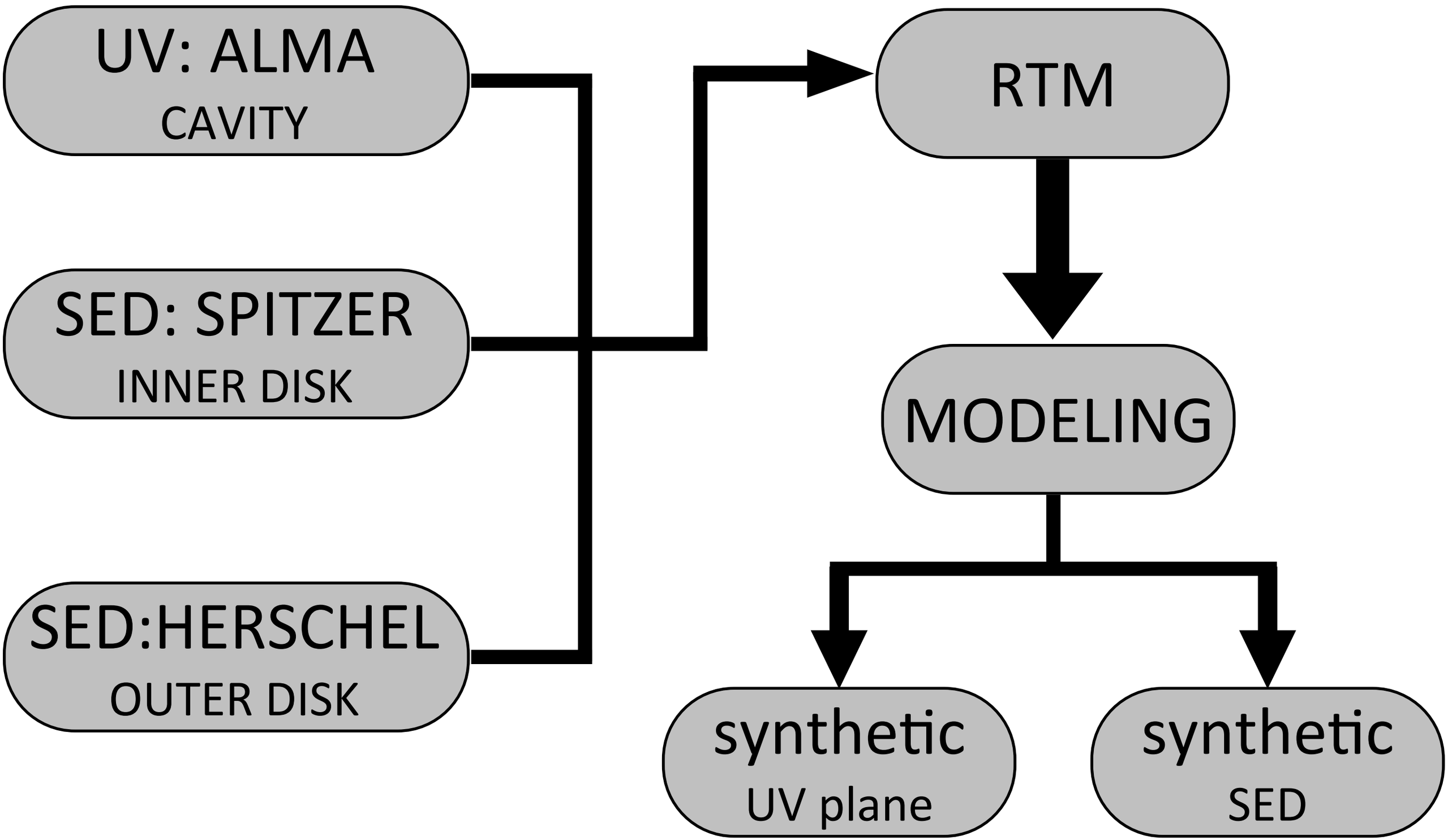
$$H(r) = H_0 (r/100\mathrm{au})^{\psi}$$

$$V_{th} = \sqrt{2 k_b T_{CO}/m_{CO}}$$

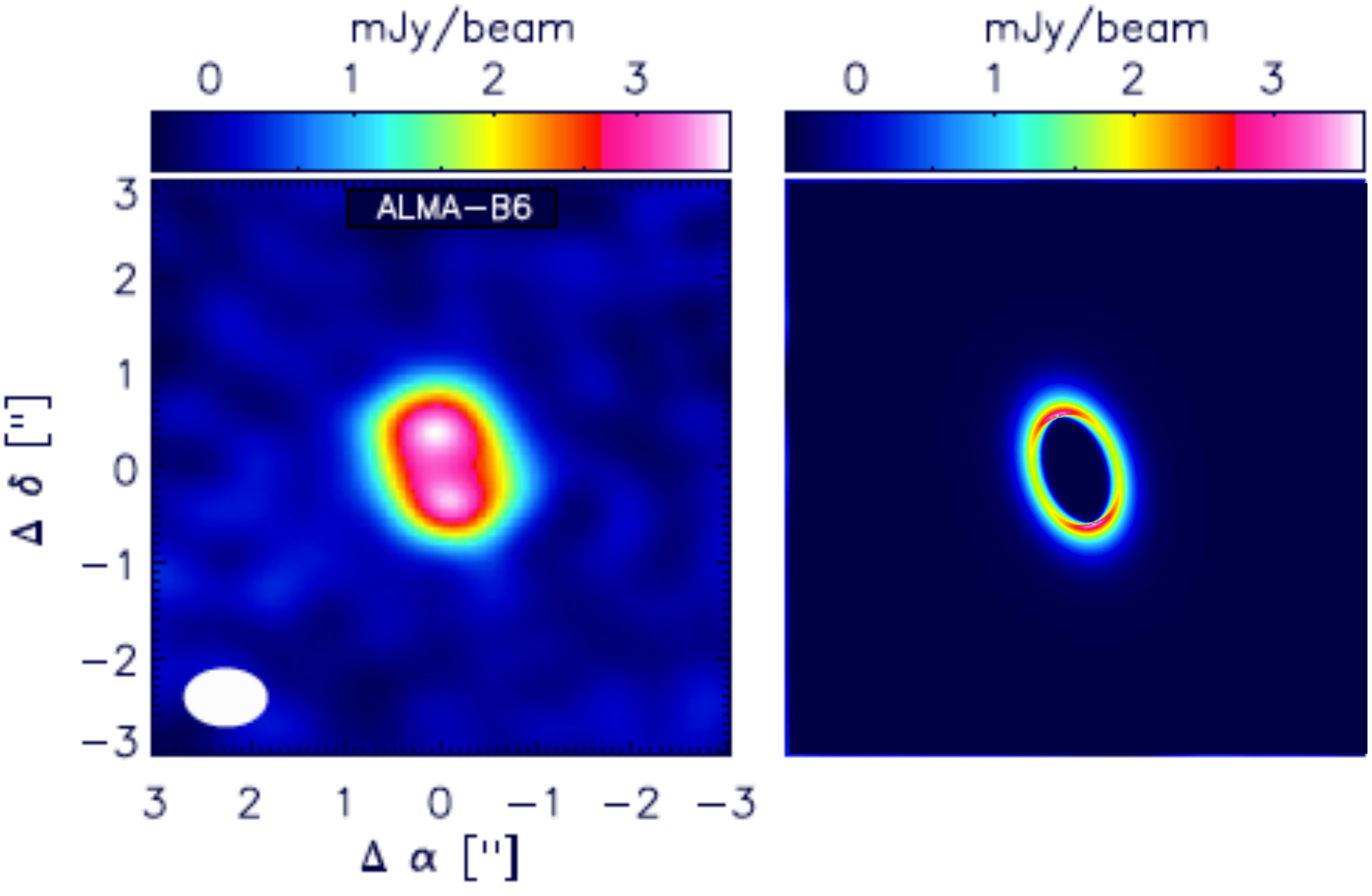
$$\rho(r,z) = \rho(r,0) \exp\left[-\frac{z^2}{2H(r)^2}\right]$$

MCFOST, Pinte et al. 2006

MODELING APPROACH



Radiative Transfer results: 97! au (radius)



Canovas et al. 2015

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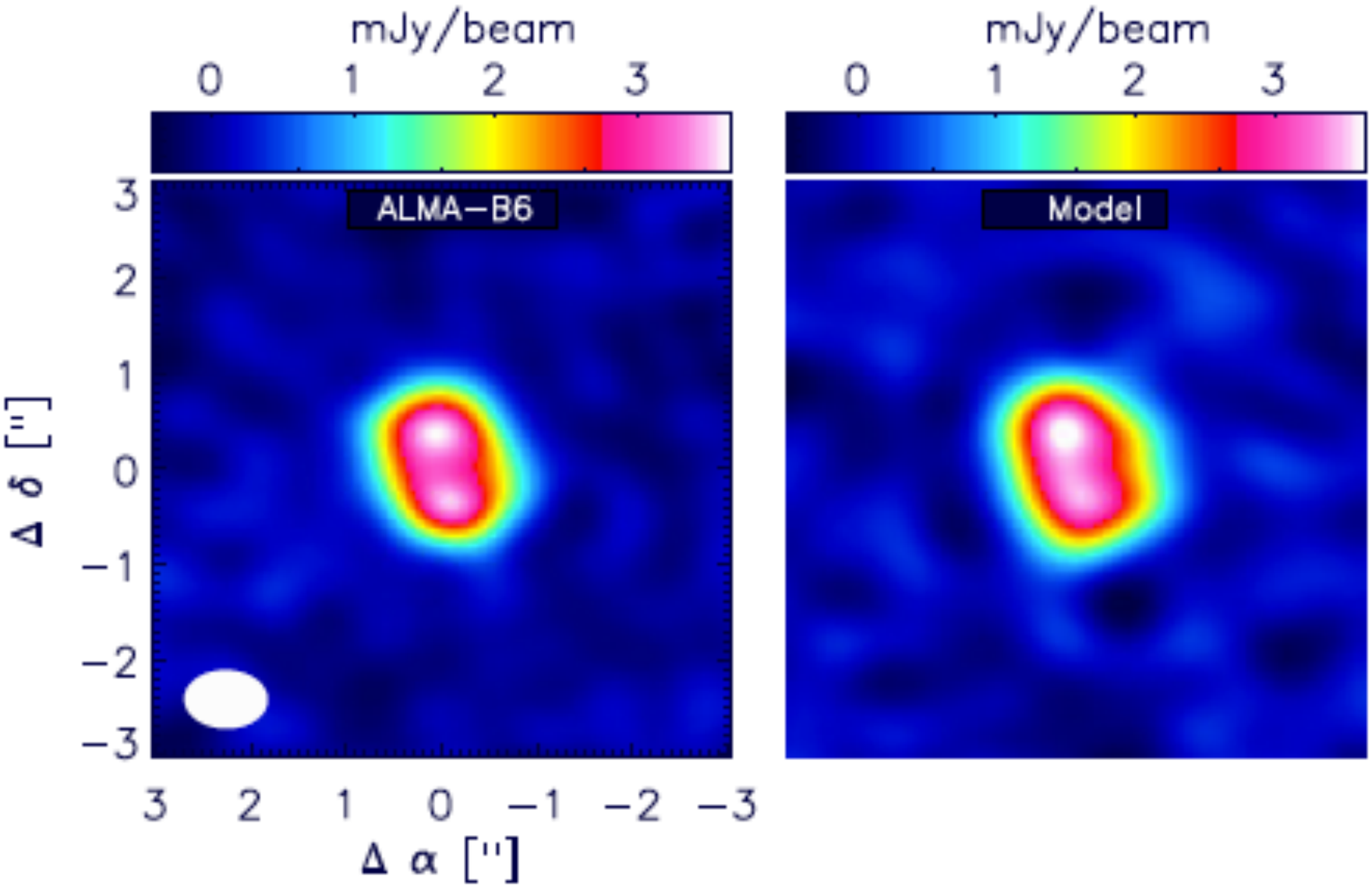

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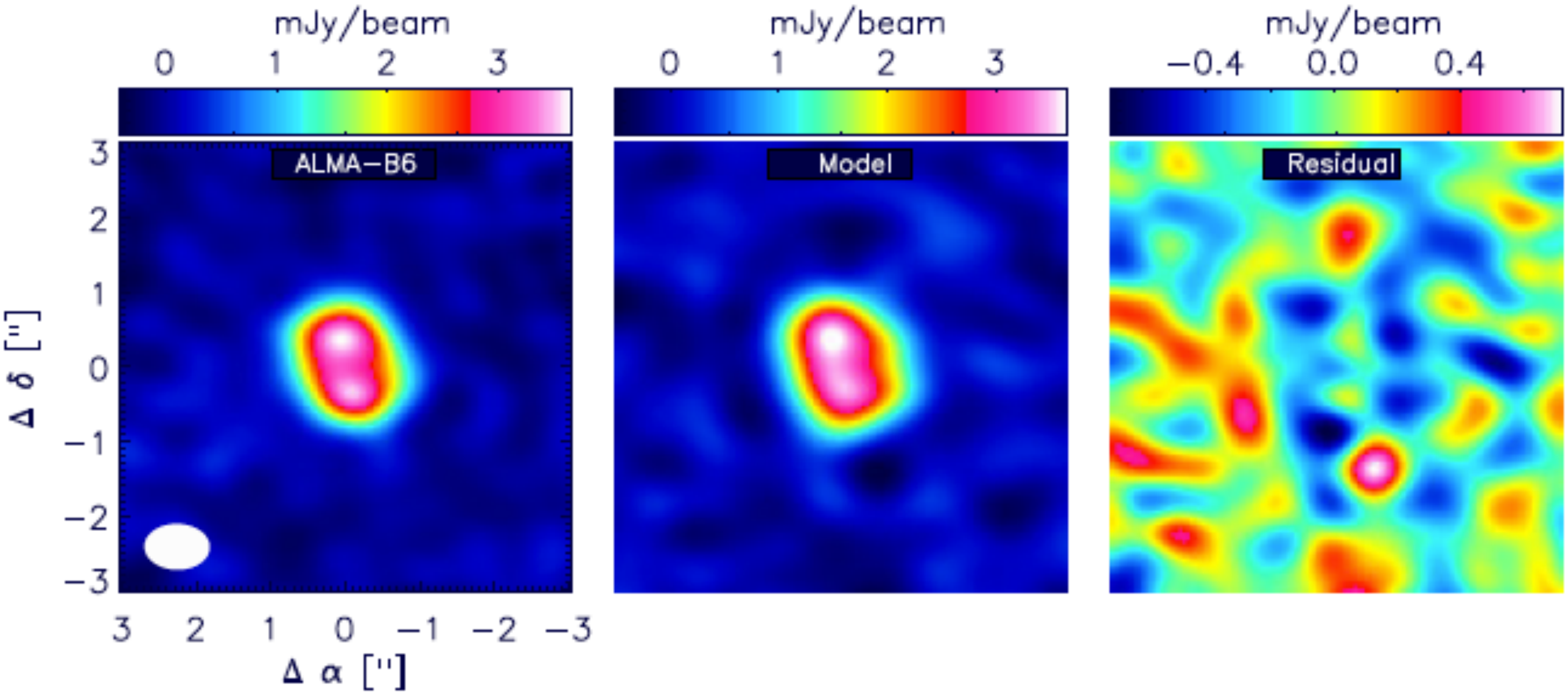

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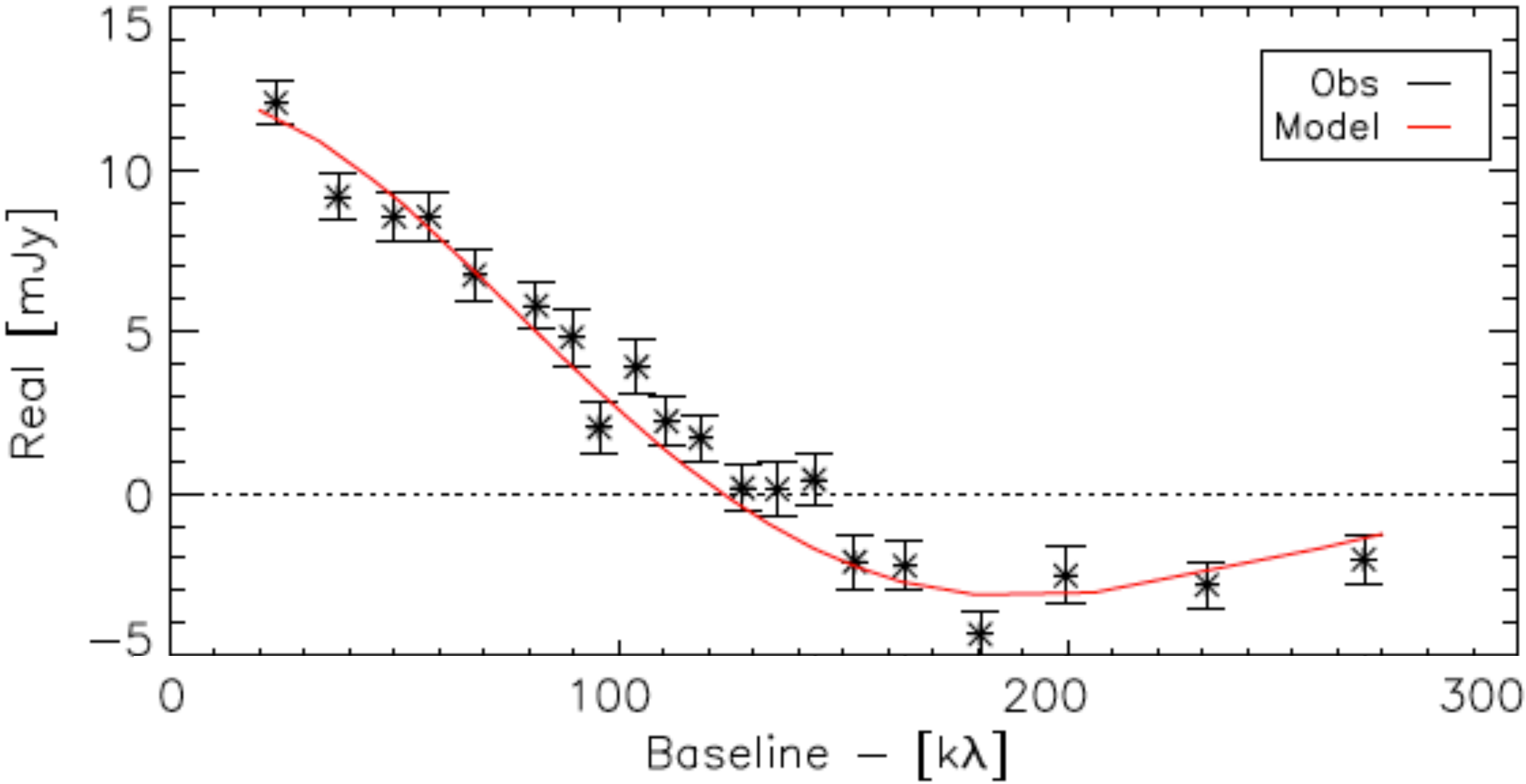
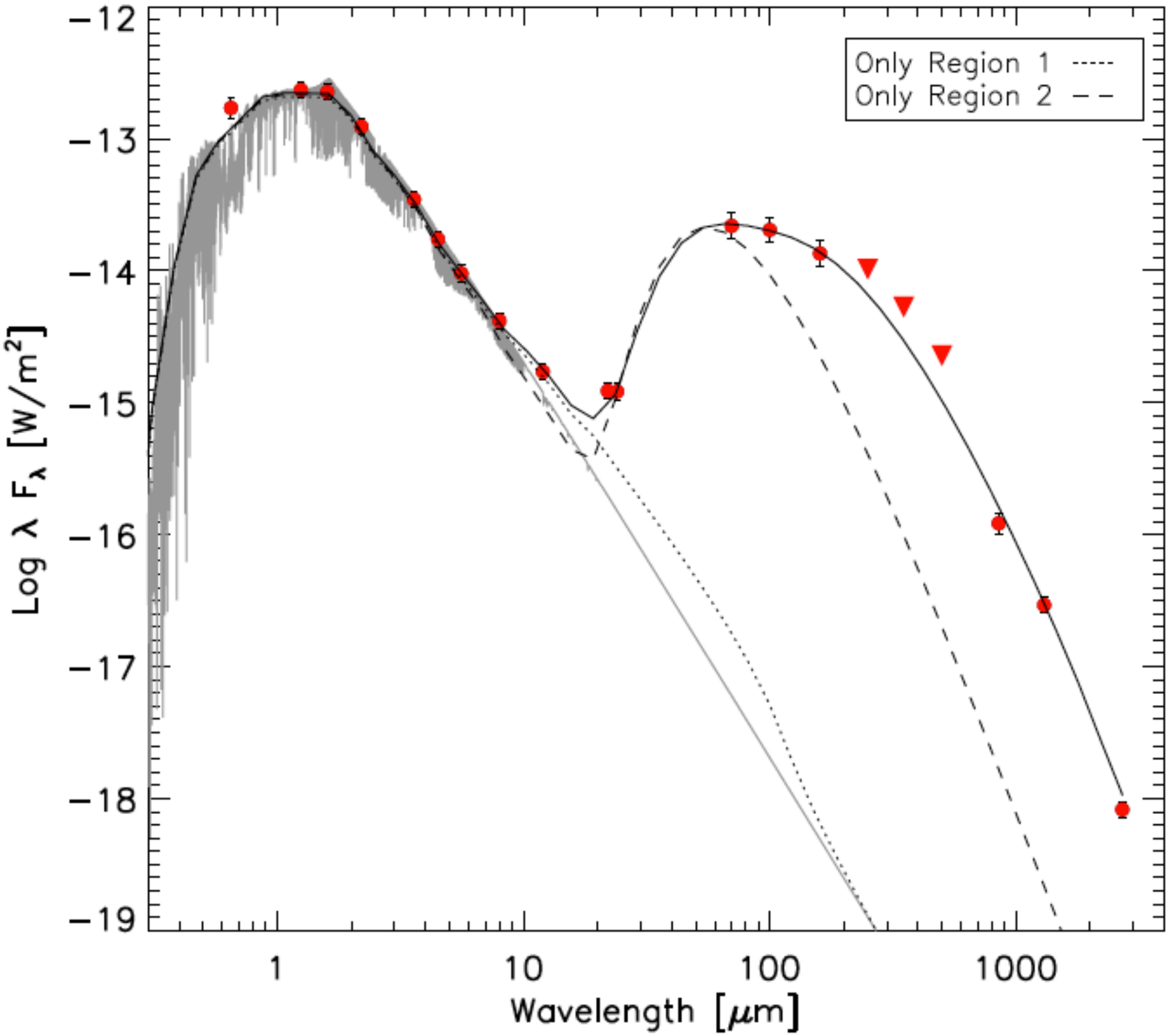


Radiative Transfer results: cavity structure



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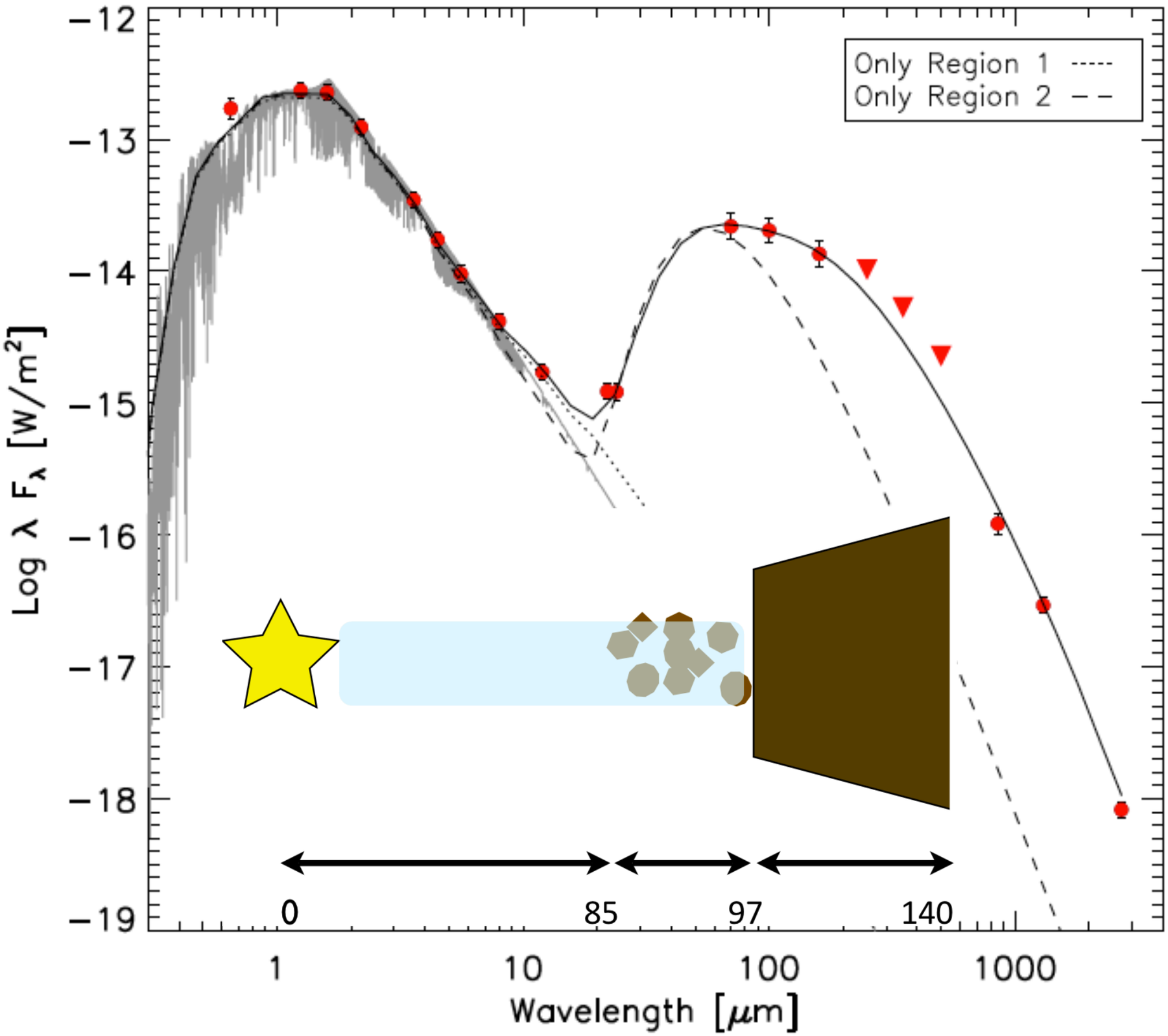

summarizing

- 97 au cavity: largest cavity around <1 $M_\odot$ stars! (average r to Pluto: 39.5 au)
- Cavity divided in 2 sub-zones
- CO inside the cavity
- Compact outer disk

Andrews et al. 2012

summarizing

Name	M_d ($M_\odot$)	R_{cav} (AU)	M_* ($M_\odot$)
(1)	(2)	(6)	(8)
MWC 758	0.008	73	1.8
SAO 206462	0.026	46	1.6
LkHα 330	0.024	68	2.2
SR 21	0.006	36	2.0
UX Tau	0.007	25	1.5
SR 24 S	0.045	29	2.0
DoAr 44	0.007	30	1.3
LkCa 15	0.055	50	1.01
RX J1615−3255	0.128	30	1.1
GM Aur	0.070	28	0.84
DM Tau	0.040	19	0.53
WSB 60	0.028	15	0.25

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WHY SZ 91 IS A STRONG PLANET FORMING CANDIDATE(s)? (I)

Current explanations for inner cavities in TD's:

- Photoevaporation
- Grain Growth
- Binarity
- Planet Formation

Owen et al. 2012, , Birnstiel et al. 2012, and several others

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Model's predictions:

- Dust "filtration/size segregation"
- Compact Outer Disk
- Large Cavity
- Gas inside the cavity
- Small (but detectable) accretion

Lubow et al. 2006, Pinilla et al. 2012, Birnstiel et al. 2012, Dodson-Robinson & Salyck 2012, and many others

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- ALMA Cycle 2 data (next month? - please!)

- Planet Hunting

15	2015-01-20	2015-01-27	ES (Observing Report)	124.0	37.3	C34-2/1	12.8 - 356.3	2.19	28.9
16	2015-01-27	2015-02-02	ES (Observing Report)	119.2	37.2	C34-2/1	12.8 - 356.3	2.19	28.9
			Engineering/Software Time						
17	2015-03-31	2015-04-07	ES (Observing Report)	TBD	TBD	C34-1/(2)	14 - 356.3	2.16	28.9
18	2015-04-07	2015-04-14	ES (Observing Report)	TBD	TBD	C34-1/(2)	13 - 356.3	2.19	25.3
19	2015-04-21	2015-04-28				C34-1/(2)	14 - 356.3	2-4	28.9
20	2015-04-28	2015-05-05				C34-1/(2)	14 - 356.3	2-4	28.9
21	2015-05-12	2015-05-19				C34-3/(4)	20-550	1.1-1.4	18
22	2015-05-19	2015-05-26				C34-3/(4)	20-550	1.1-1.4	18
23	2015-06-02	2015-06-09				C34-5	25-820	0.75	14
24	2015-06-09	2015-06-16				C34-5	25-820	0.75	14
25	2015-06-23	2015-06-30				C34-7	40-1500	0.4	9
26	2015-06-30	2015-07-07				C34-7	40-1500	0.4	9

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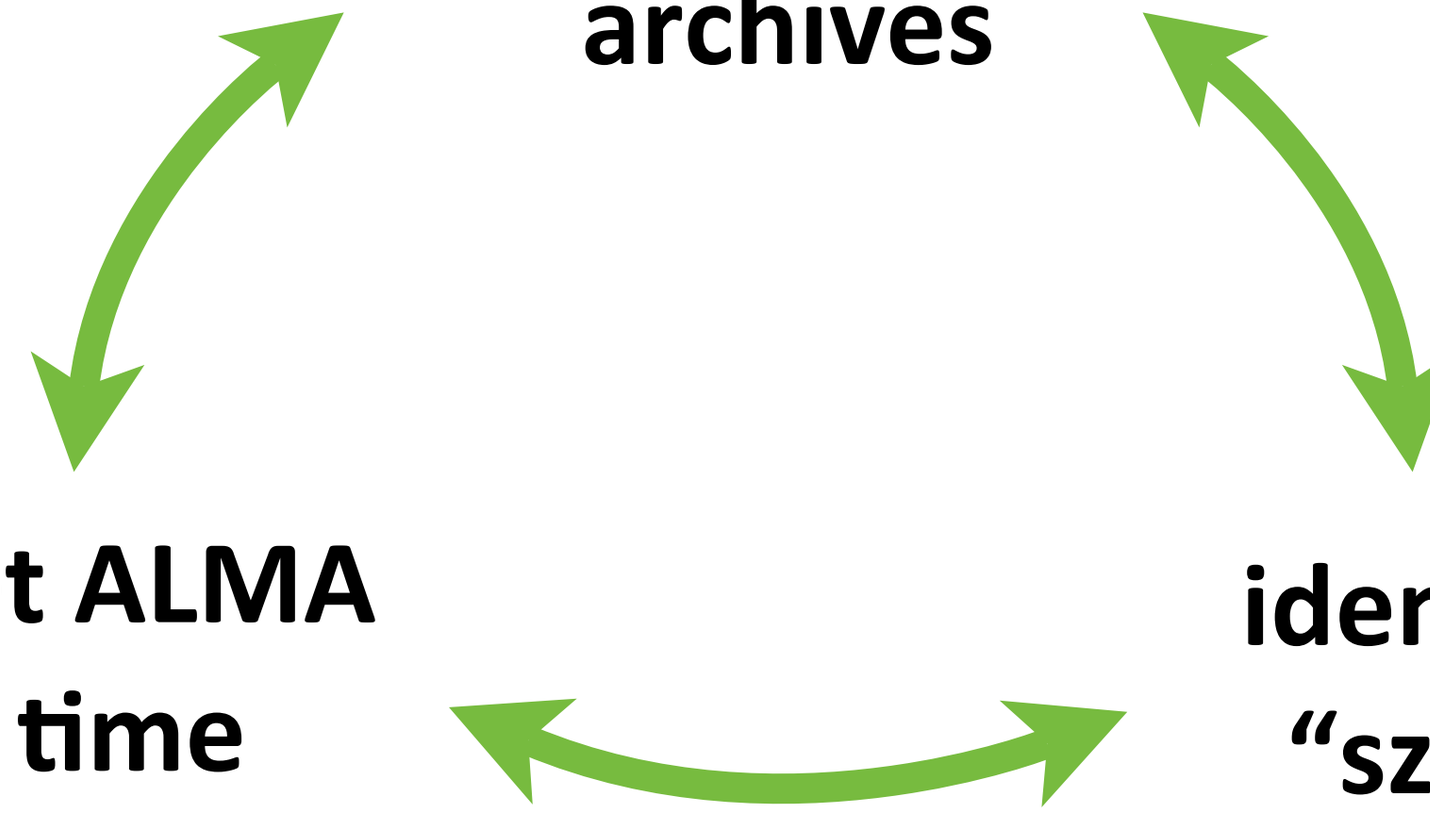
24	2015-06-09	2015-06-16				C34-5	25-820	0.75	14
25	2015-06-23	2015-06-30				C34-7	40-1500	0.4	9
26	2015-06-30	2015-07-07				C34-7	40-1500	0.4	9

The synergy MUST go on:

SPITZER & HERSCHEL archives



get ALMA time

identify new “sz91-like” objects

The synergy MUST go on:

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THANKS