On the age of debris disk host stars of the TUPURI project

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and, from INAOE,

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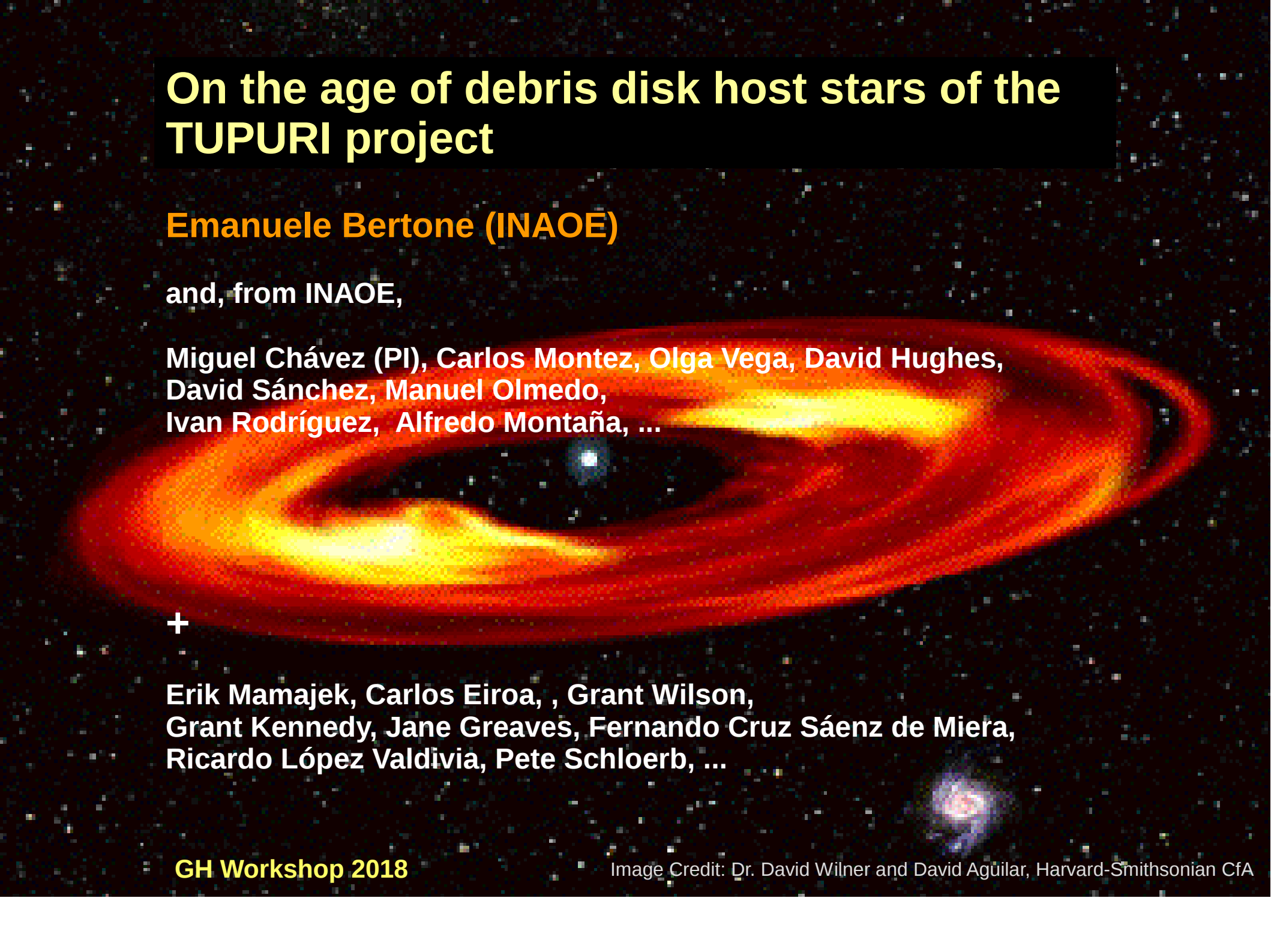
+

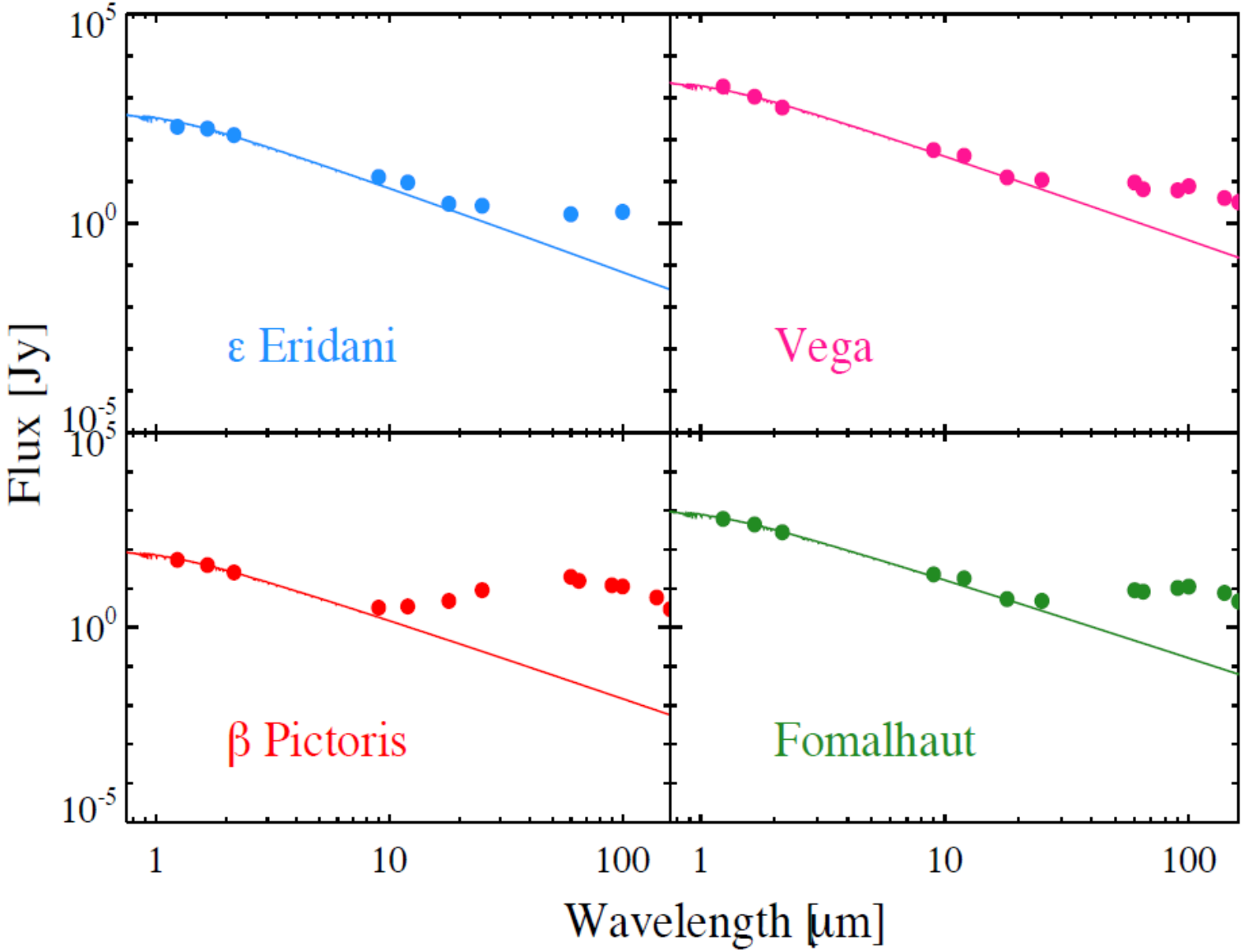
Erik Mamajek, Carlos Eiroa, , Grant Wilson, Grant Kennedy, Jane Greaves, Fernando Cruz Sáenz de Miera, Ricardo López Valdivia, Pete Schloerb, ...

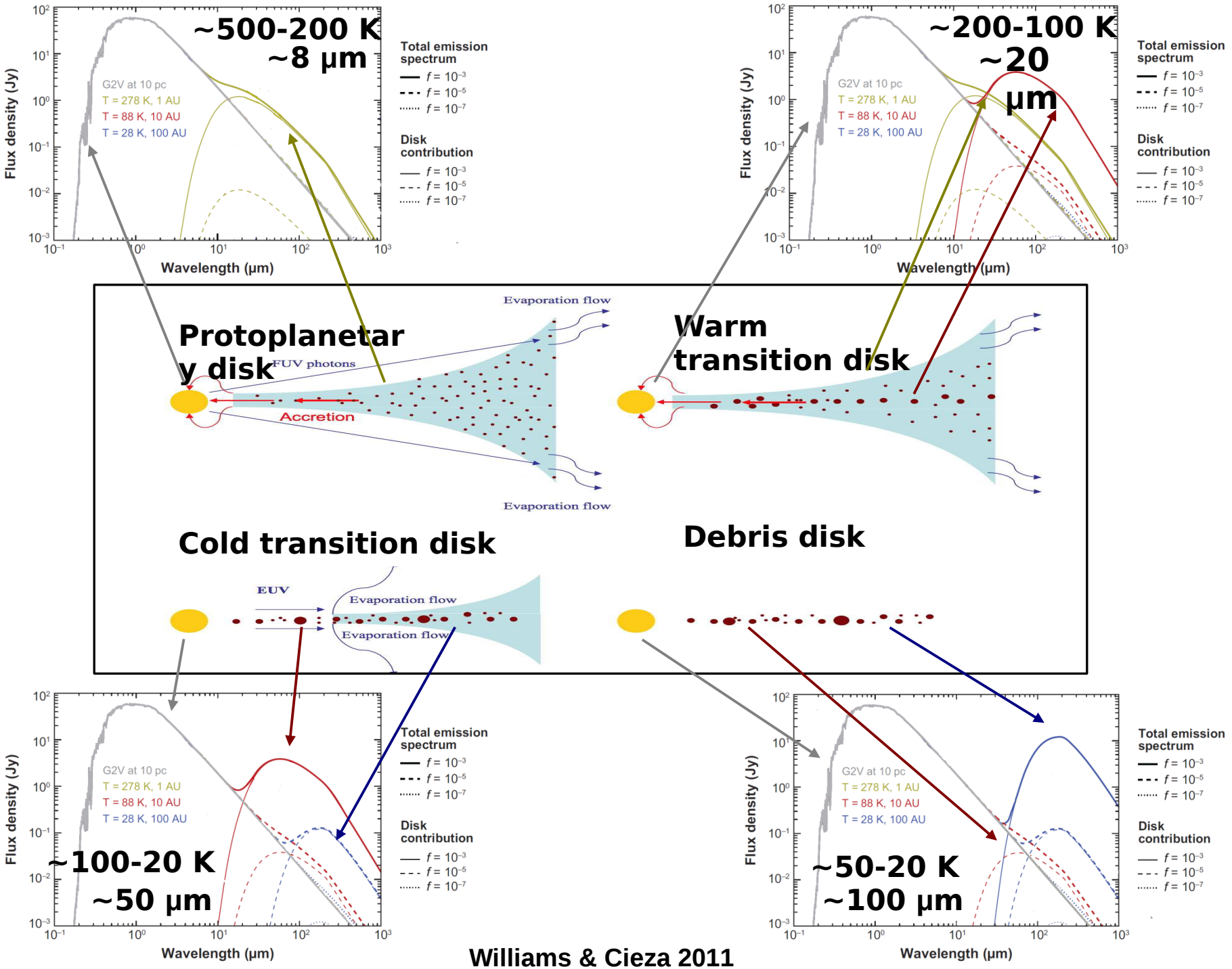


GH Workshop 2018

Image Credit: Dr. David Wilner and David Aguilar, Harvard-Smithsonian CfA

Debris disks
The “Fab four”





Williams & Cieza 2011
Wyatt 2008

The TUPURI project

Studying debris disks and stellar hosts with the LMT 50m

The sample:

- **DUNES** + **DEBRIS** sources from **Herschel**
- **SONS** sources from **JCMT / SCUBA2**
- Stars @ photospheric level (including nearby M stars)

The LMT observations:

- 3 band (1.1, 1.4, 2.0 mm) continuum images with TOLTEC (+ MUSCAT @ 850 μm ?) for characterizing the dust and stellar emission

- Spectroscopic follow-up with SEQUOIA + B4R (+ B45R ?) for detecting possible gas content in the disk

Known debris disks with gas

Table 1. List of all known debris discs with gas.

Star's name	Atoms and molecules observed	L_* ($L_\odot$)	d (pc)	M_{CO} ($M_\oplus$)[a]	R_0 (au)	M_{dust} ($M_\oplus$)	L_{IR}/L_*	Star's age (Myr)
β Pic (1)	CO, C I, C II, O I, ...	8.7	19.4	2.8×10^{-5}	85	7.8×10^{-2}	1.7×10^{-3}	23
49 Ceti (2)	CO, C I, C II, O I[b]	15.5	59.4	1.4×10^{-4}	100	0.27	1.1×10^{-3}	40
η Tel (3)	C II	22	48.2	–	24	1.3×10^{-2}	7.6×10^{-4}	23
HD 21997 (4)	CO	14.4	71.9	6×10^{-2}	60	0.16	5.9×10^{-4}	45
HD 32297 (5)	CO, C II	5.6	112	1.3×10^{-3}	110	0.37	5.4×10^{-3}	30
HD 110058 (6)	CO	5.9	107	2.1×10^{-5}	50	3×10^{-3}	1.9×10^{-3}	10
HD 131835 (7)	CO	9.2	122	6×10^{-2}	50	0.47	1.5×10^{-3}	16
HD 138813 (6)	CO	24.5	150.8	7.4×10^{-4}	100	7.6×10^{-3}	1.5×10^{-3}	10
HD 146897 (6)	CO	3.1	122.7	2.1×10^{-4}	100	2×10^{-2}	5.4×10^{-3}	10
HD 156623 (6)	CO	14.8	118	2.0×10^{-3}	75	2.4×10^{-4}	5.5×10^{-3}	10
HD 172555 (8)	O I	7.8	29	–	6	4.8×10^{-4}	7.8×10^{-4}	23
HD 181327 (9)	CO	3.1	51.8	1.8×10^{-6}	85	0.44	2×10^{-3}	23

[a]We computed these masses in NLTE from the most recent ^{12}CO integrated line fluxes cited in papers below (assuming that it is optically thin), except for HD 21997 and HD 131835 where it is based on C^{18}O observations (see also Table 2).

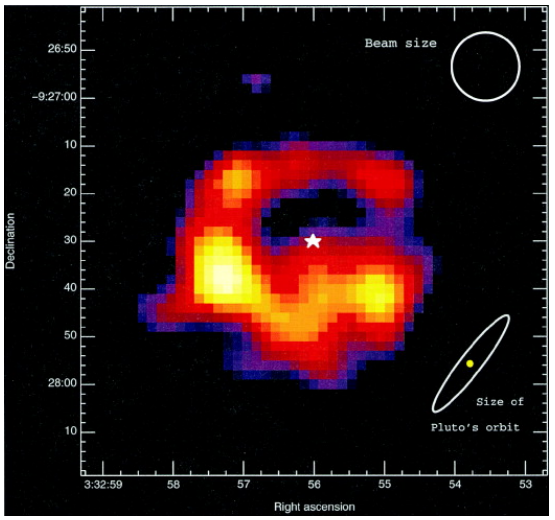
[b]C I and O I are detected via absorption lines in the UV for 49 Ceti and their abundances are not well quantified (Roberge et al. 2014).

(1) Kral et al. (2016), (2) Hughes et al. (2008), (3) Riviere-Marichalar et al. (2014), (4) Kóspál et al. (2013), (5) Greaves et al. (2016), (6) Lieman-Sifry et al. (2016), (7) Moór et al. (2015, 2016), (8) Riviere-Marichalar et al. (2012), (9) Marino et al. (2016).

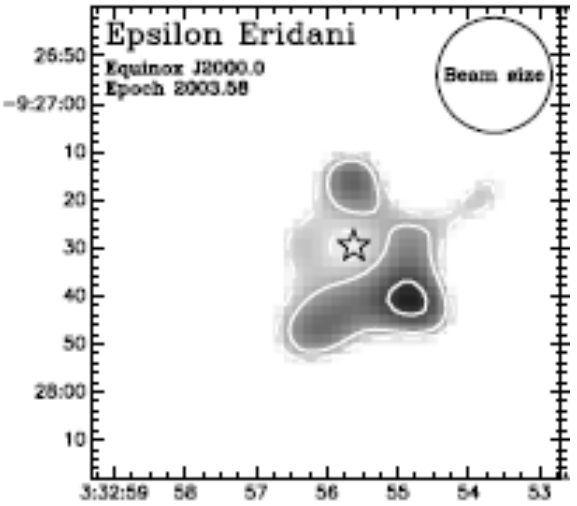
from **Kral et al. 2017**

Epsilon Eridani

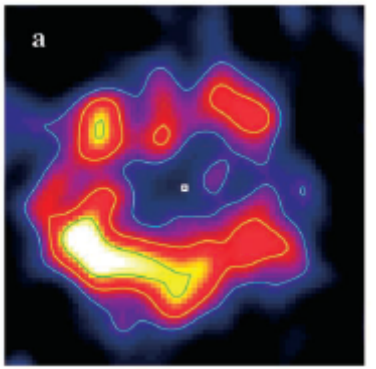
Previous (sub-)mm observations



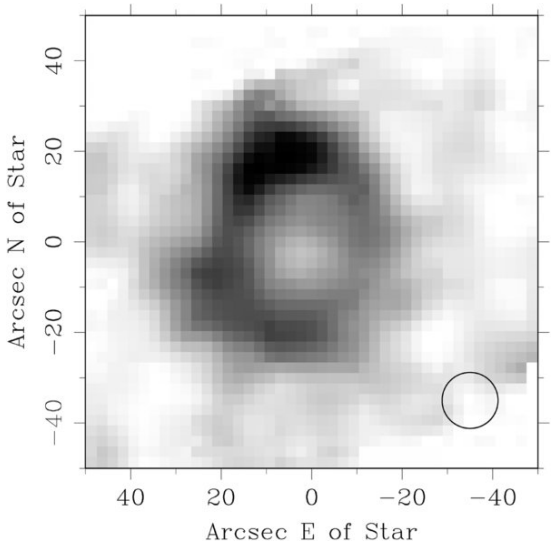
SCUBA 850 µm Greaves+1998



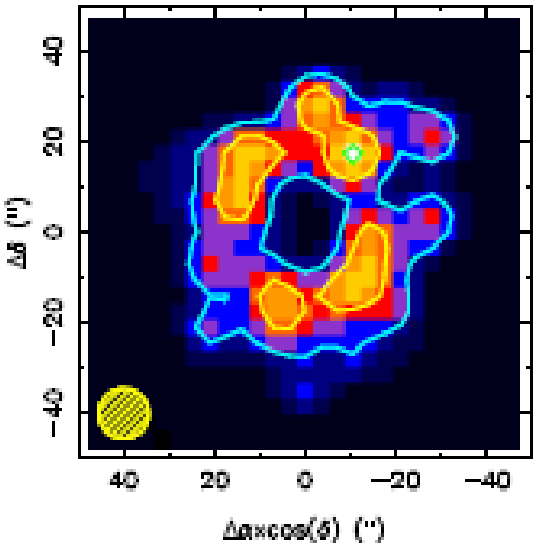
SIMBA 1.2 mm Schutz+2004



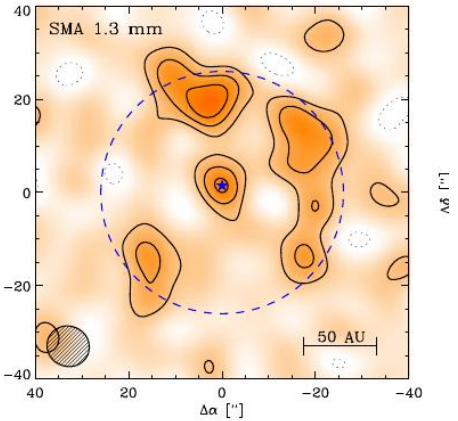
SCUBA 850 µm Greaves+2005



SHARC II 350 µm Backman+2009



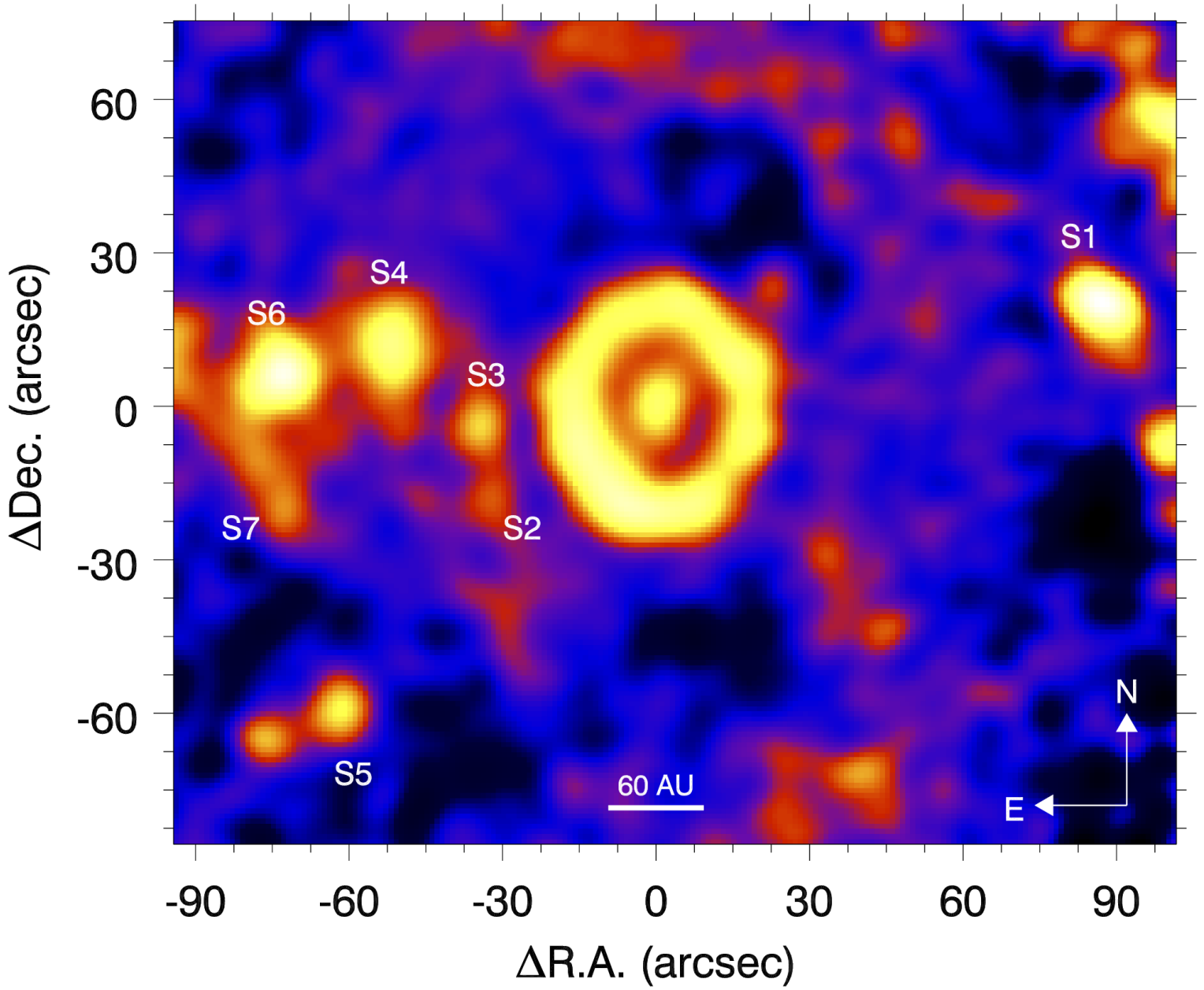
MAMBO 1.2 mm Lestrade & Thilliez 2015

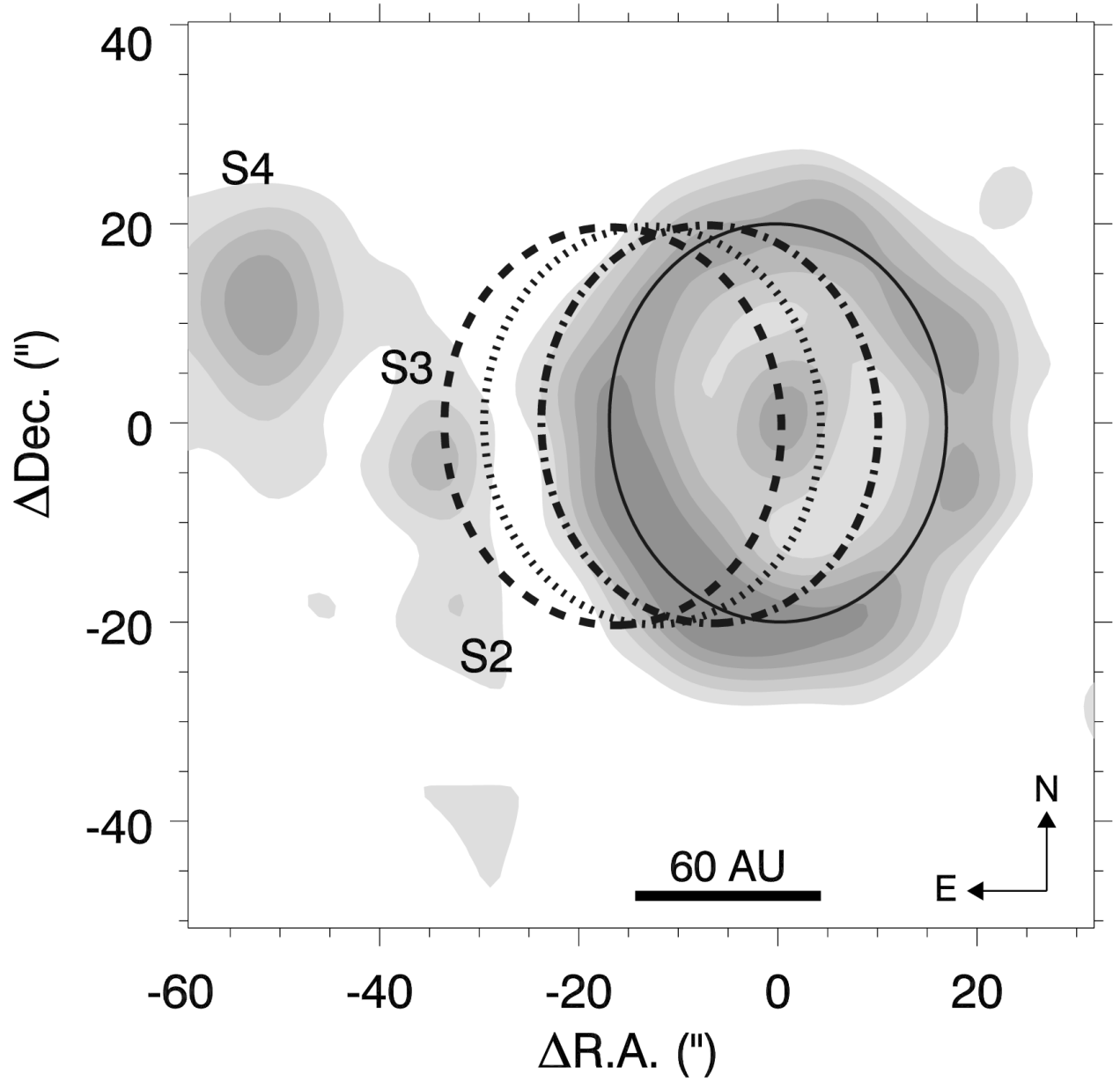


SMA 1.3 mm MacGregor et al 2015

Epsilon Eridani

AzTEC / LMT image

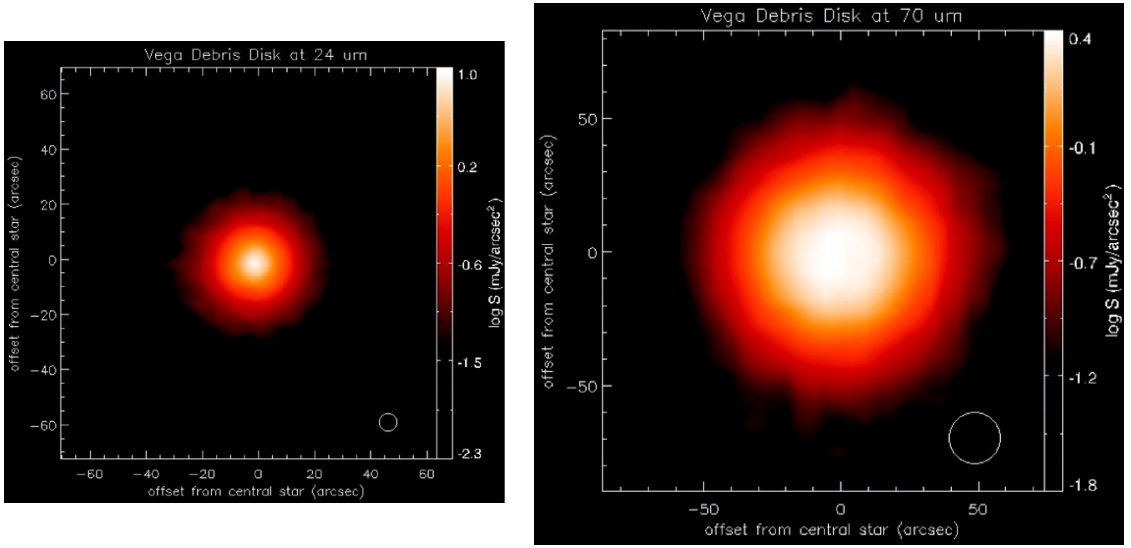



40
20
0
-20
-40
ΔDec. (")
S4
S3
S2
60 AU
N
E
-60
-40
-20
0
20
ΔR.A. (")

Vega

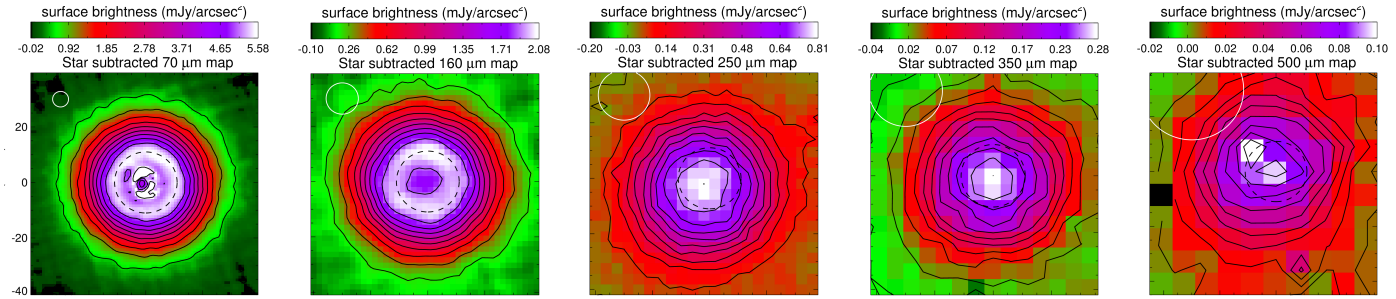
Previous IR and sub-mm observations

Spitzer 24 µm 70 µm



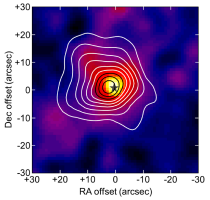
Su et al. 2005

Herschel 70 µm 160 µm 250 µm 350 µm 500 µm



Sibthorpe et al. 2010

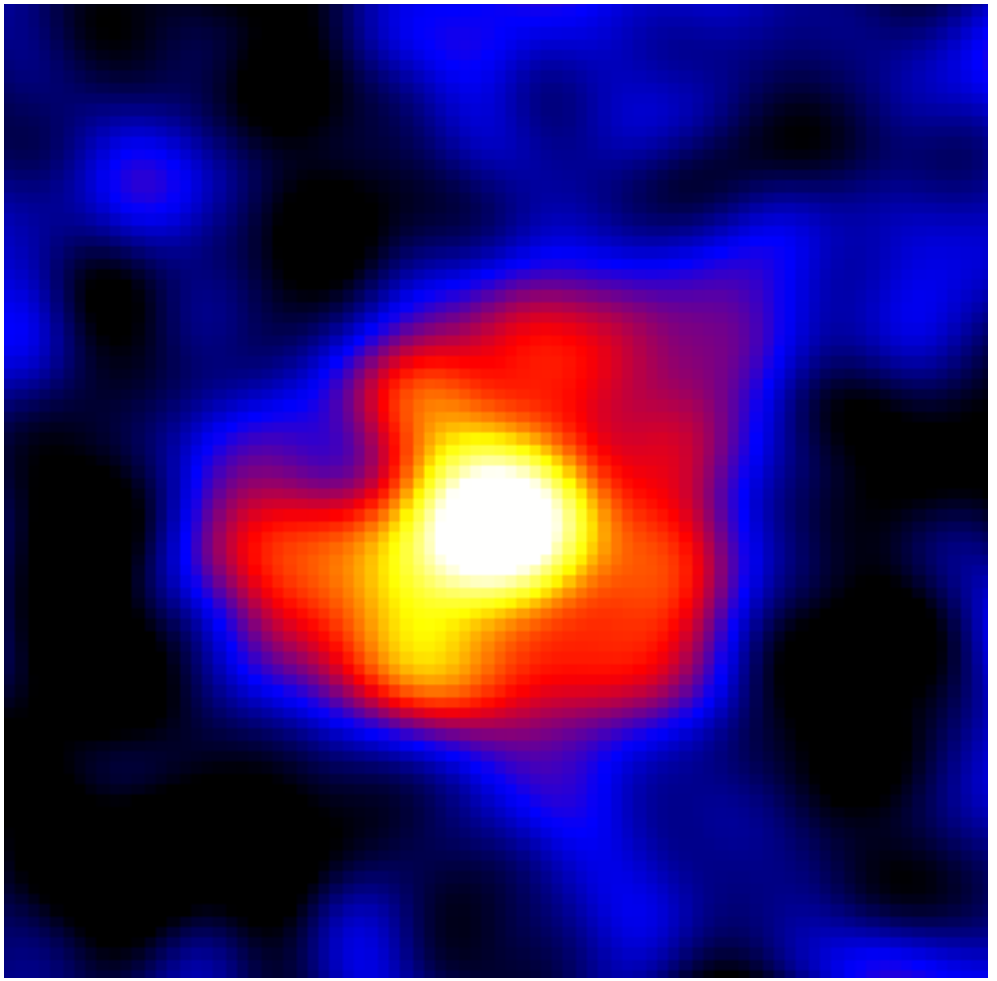
SCUBA2/JCMT 450 y 850 µm



Holland et al. 2017

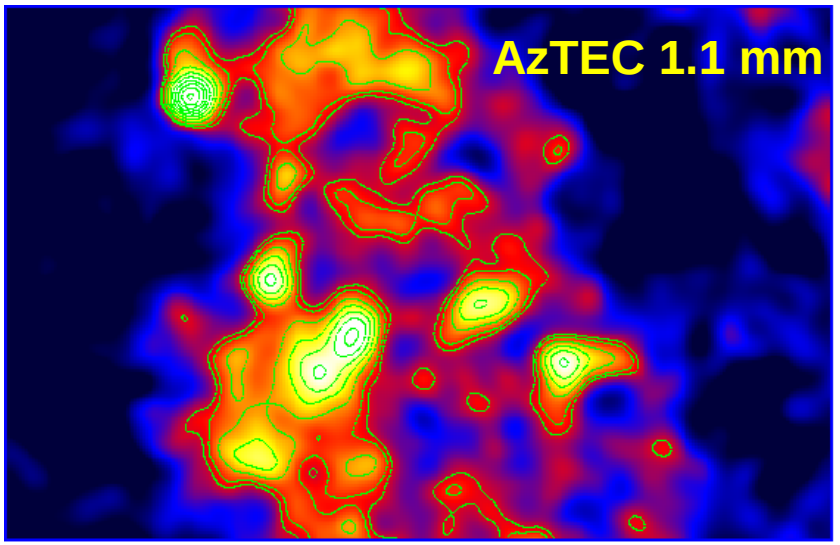
Vega

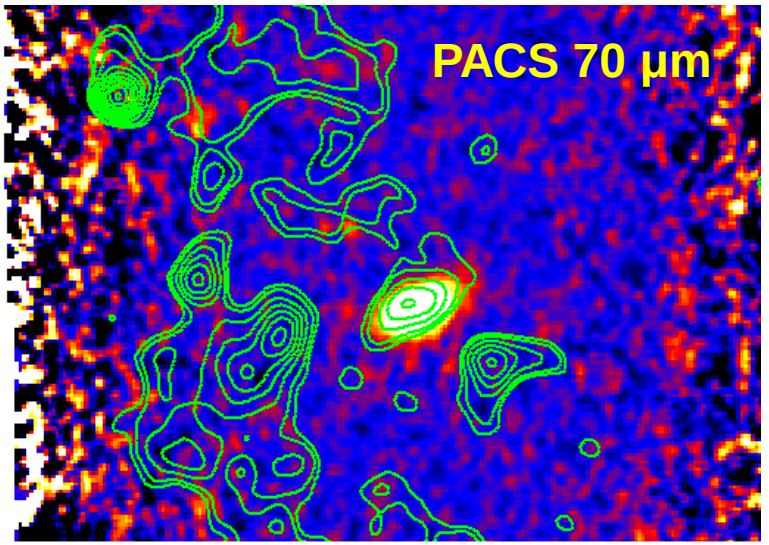
AzTEC / LMT image: preliminary reduction

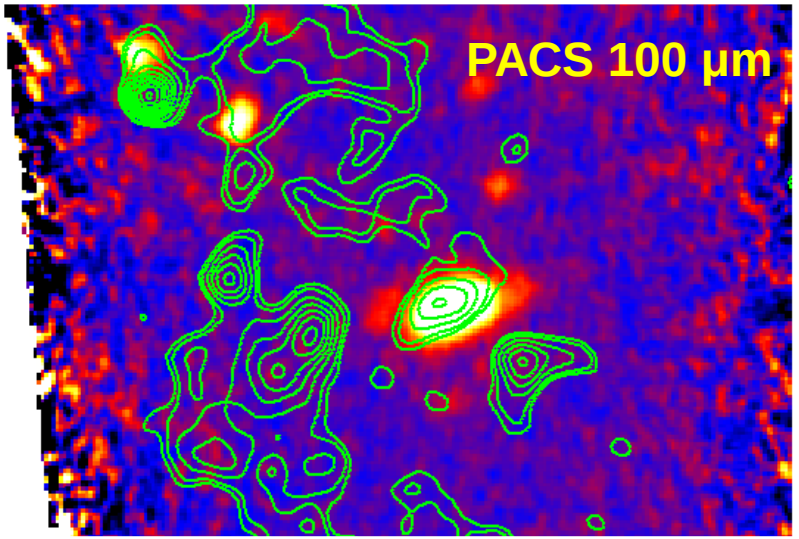


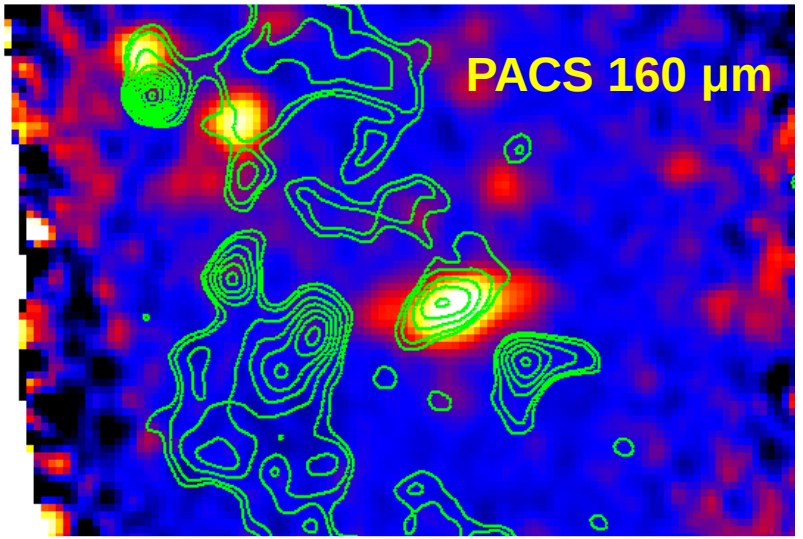
HD 48682

AzTEC / LMT and PACS / HERSCHEL images

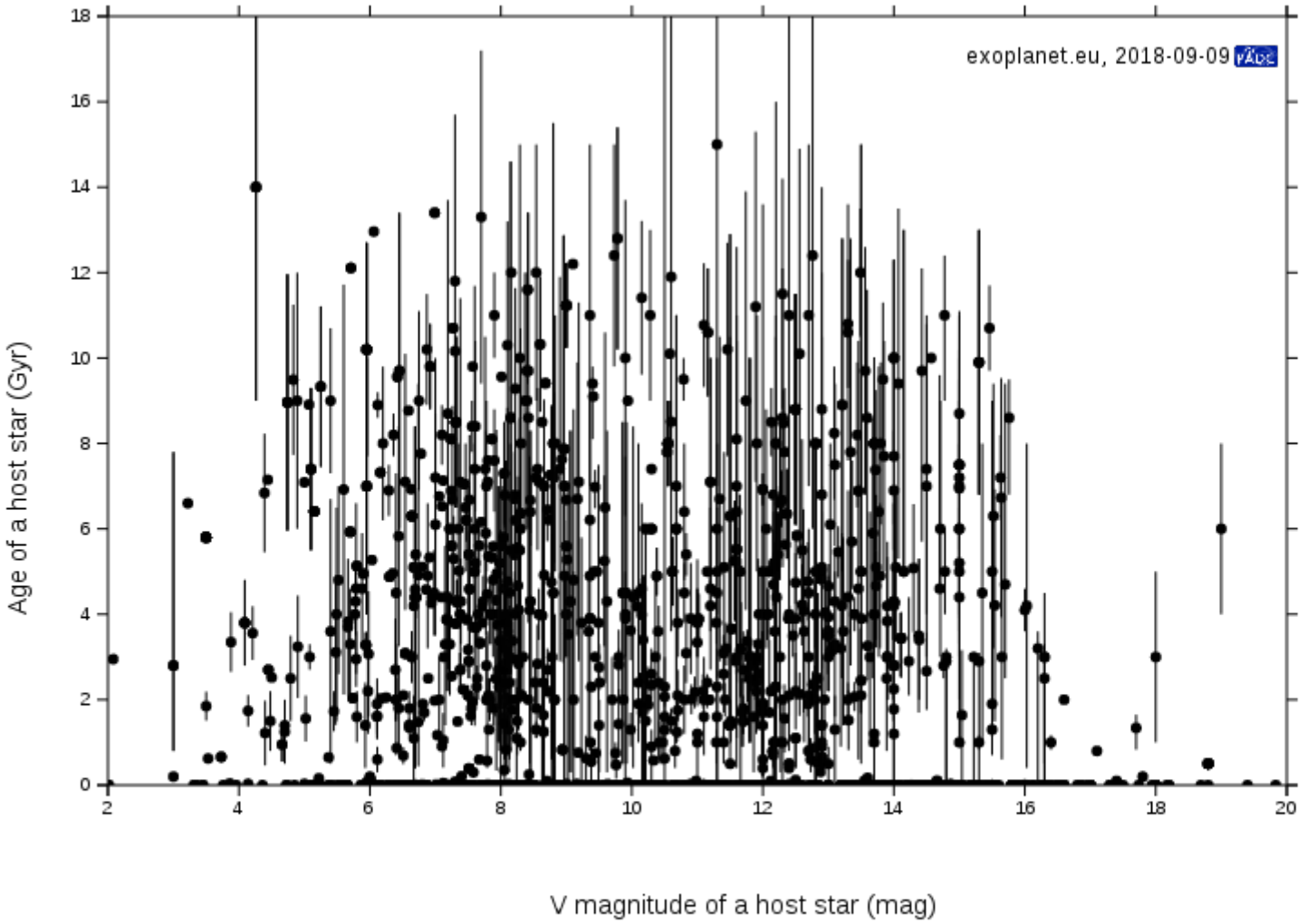








Age of exoplanet host stars



Age estimators for individual stars

Semi-fundamental:

- **Nucleocosmochronology** (U and Th decay)

Model dependent:

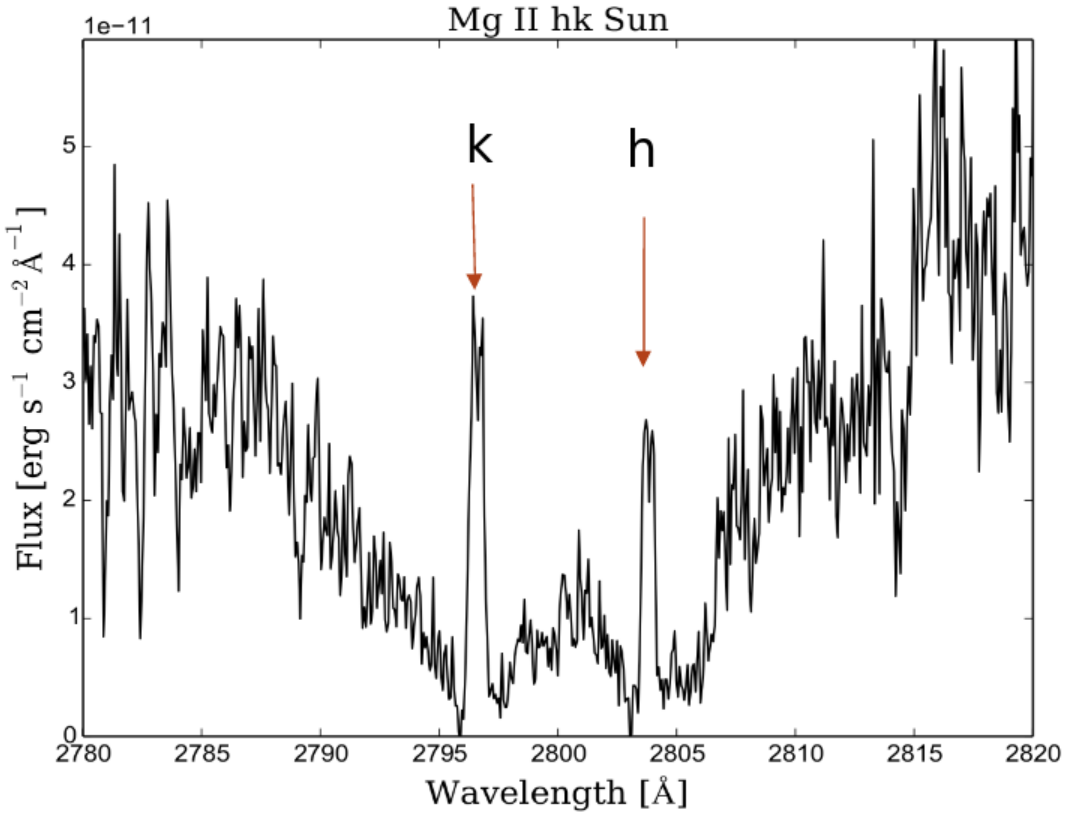
- **Isochrone placement** (very precise $T_{\rm eff}$, L, [M/H] are needed)
- **Asteroseismology** ($T_{\rm eff}$, L, [M/H] and detailed models are needed)

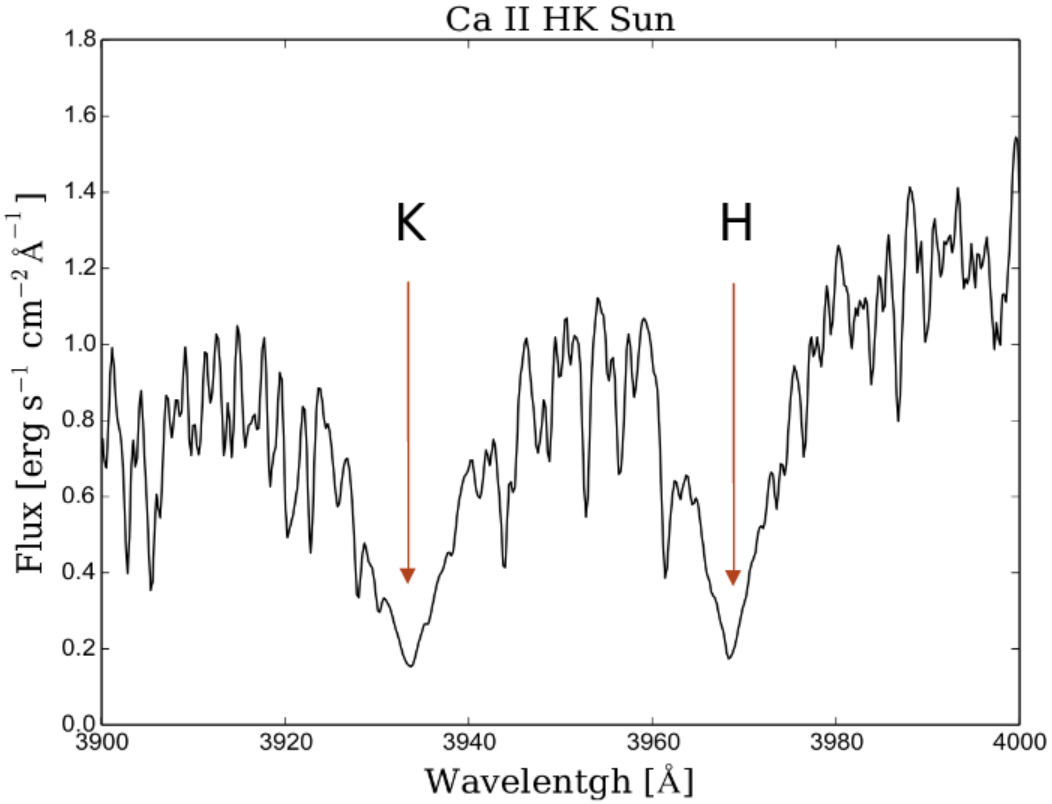
Empirical:

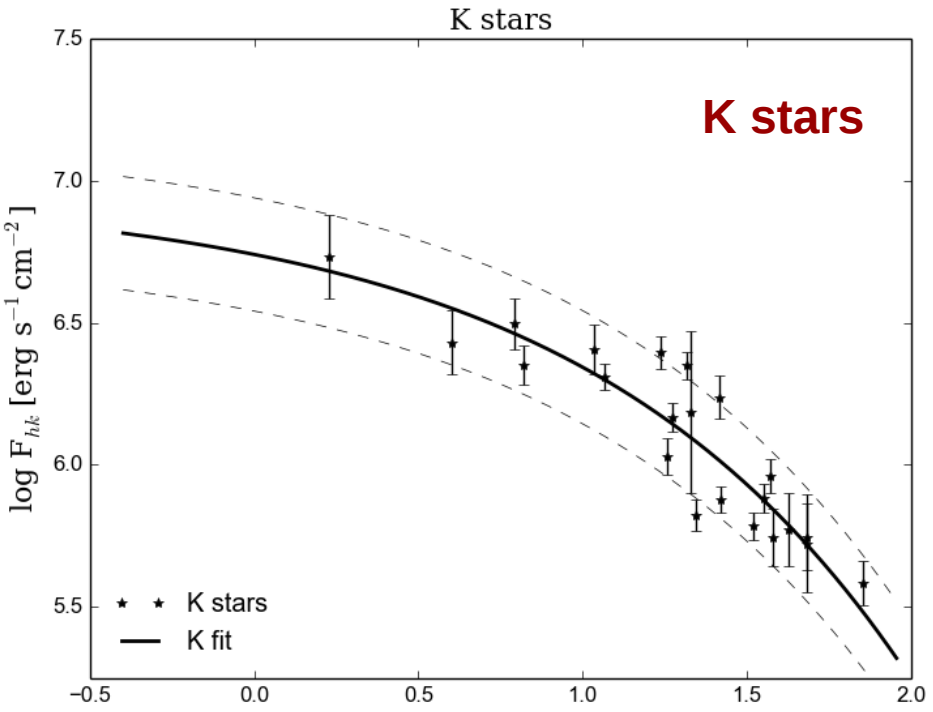
- **Gyrochronology**

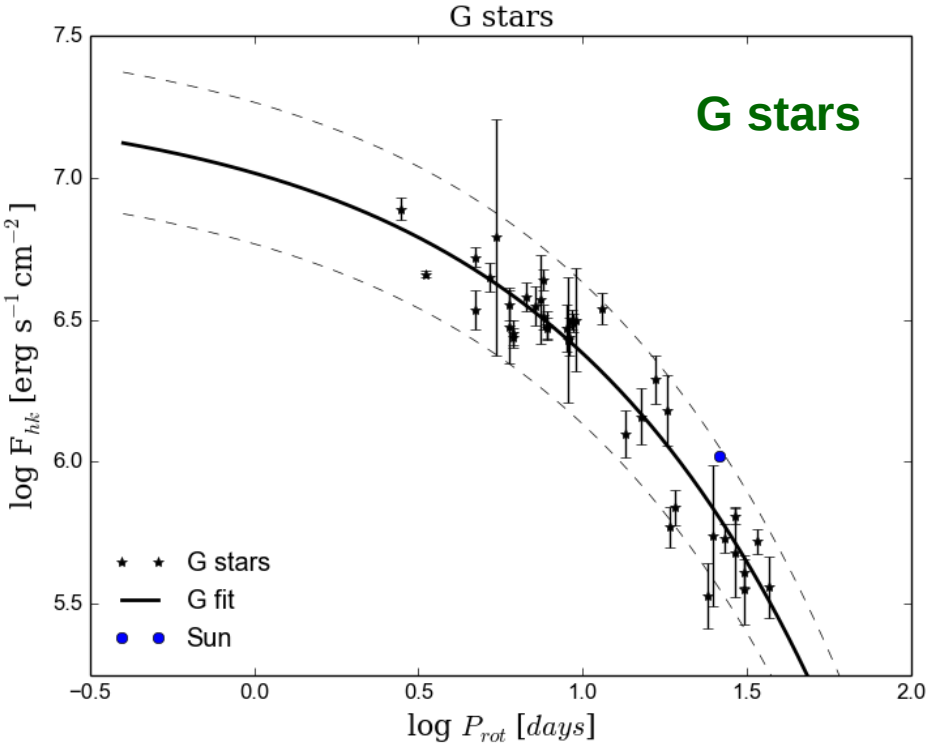
Rotation + convection $\Rightarrow$ B field through dynamo
Magnetic field + stellar wind $\Rightarrow$ angular momentum loss $\Rightarrow$ spindown
Magnetic fields $\Rightarrow$ stellar activity (emission lines: **Ca II HK**, **Mg II hk**, Hα; x-rays, ...)

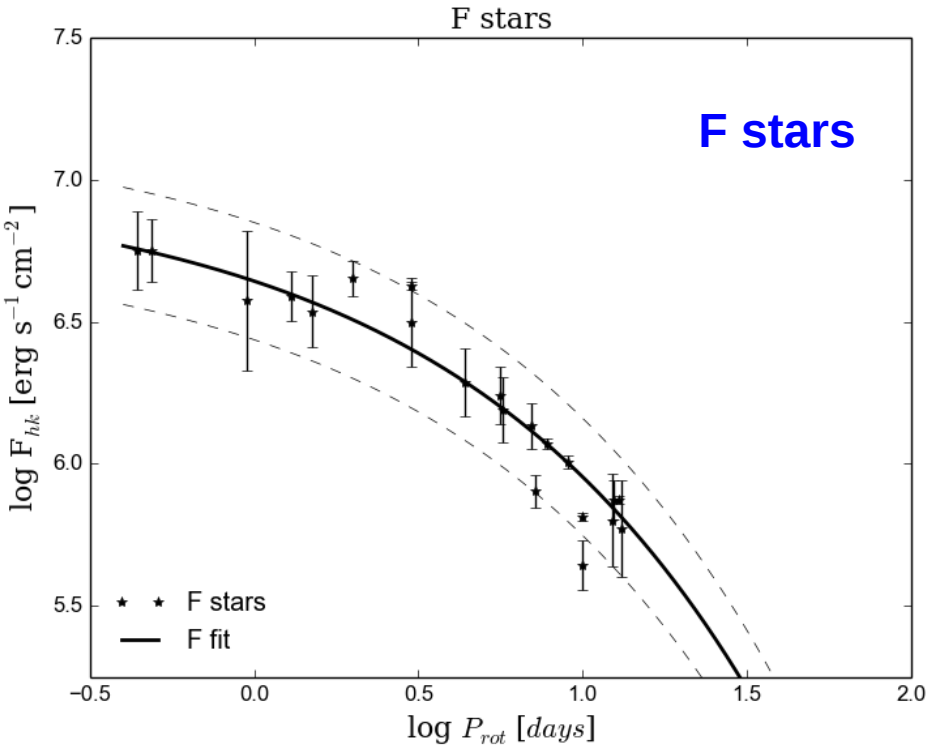
Mg II hk vs. Ca II HK









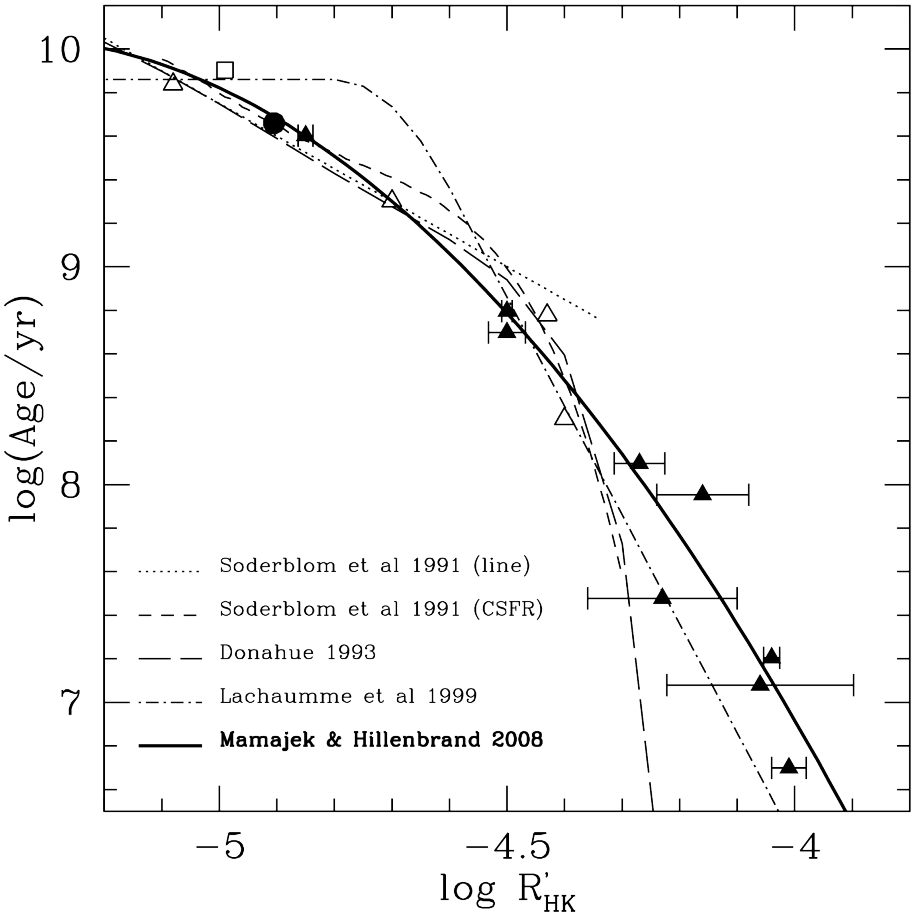


91 stars (22 K, 43 G, 26 F) from HST and IUE

Montez et al. in preparation

*F*hk-*P*rot calib. + Barnes (2007) ⇒ age

Age – activity calibration



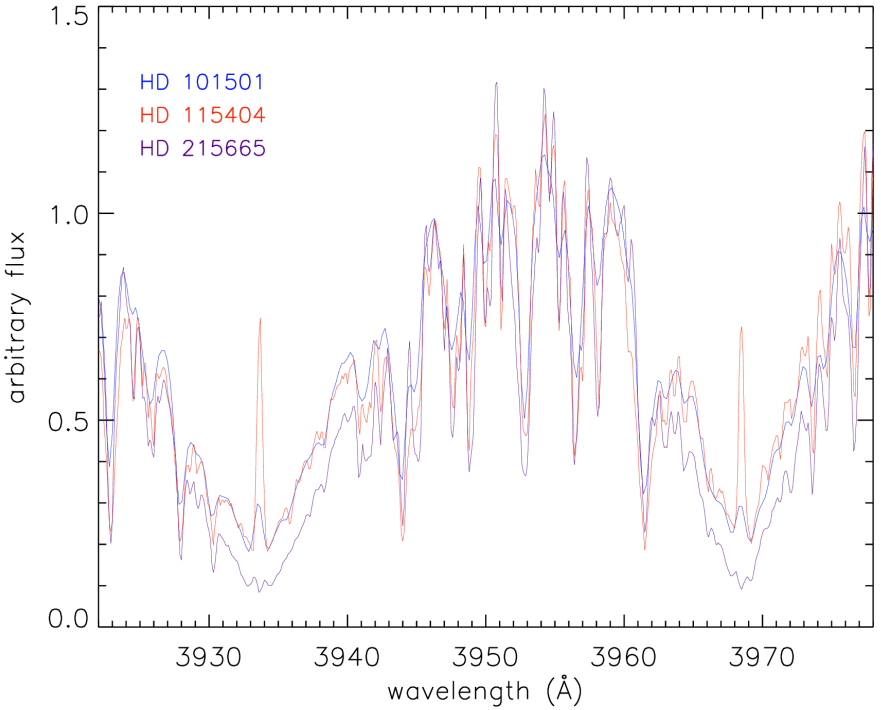
Mamajek & Hillenbrand 2008

- 206 stars in 9 open clusters +
- mean R'HK value for 4 cluster +
- 57 stars from Valenti & Fisher (2005) with $\sigma_{age}<20\%$

An improved Age-Stellar Activity Calibration with MEGARA/GTC

Cluster name	RA (J2000)	Dec (J2000)	U (mag)	exp.time (s)	Cluster name	RA (J2000)	Dec (J2000)	U (mag)	exp.time (s)
Berkeley 104	00 03 12.0	+63 33 30	20.2	7200	Berkeley 15	05 01 52.0	+44 28 00	17.3	1080
NGC 381	01 07 54.0	+61 34 30	17.0	720	NGC 1798	05 11 28.0	+47 40 00	20.2	7200
Berkeley 62	01 00 52.0	+63 53 30	19.4	3600	Berkeley 23	06 33 08.0	+20 30 30	20.2	7200
NGC 581	01 32 58.0	+60 38 30	18.3	1440	NGC 2355	07 16 52.0	+13 44 00	17.8	1200
Trumpler 1	01 35 04.0	+61 16 60	17.3	1080	Haffner 8	07 22 54.0	-12 19 60	16.1	400
NGC 654	01 43 44.0	+61 51 60	19.2	3600	NGC 2425	07 38 18.0	-14 55 00	19.4	3600
Berkeley 7	01 53 50.0	+62 19 60	20.1	7200	Berkeley 80	18 54 16.0	-01 15 00	20.1	7200
NGC 1348	03 33 56.0	+51 20 60	19.5	3600	NGC 6819	19 40 52.0	+40 09 30	18.2	1440
NGC 1545	04 20 28.0	+50 20 60	16.4	480	NGC 7235	22 12 06.0	+57 15 00	20.6	8000
Berkeley 12	04 44 12.0	+42 40 00	20.3	7600	NGC 7790	23 58 14.0	+61 11 00	19.6	3600

An improved Age-Stellar Activity Calibration with MEGARA/GTC



Montes et al. 1997

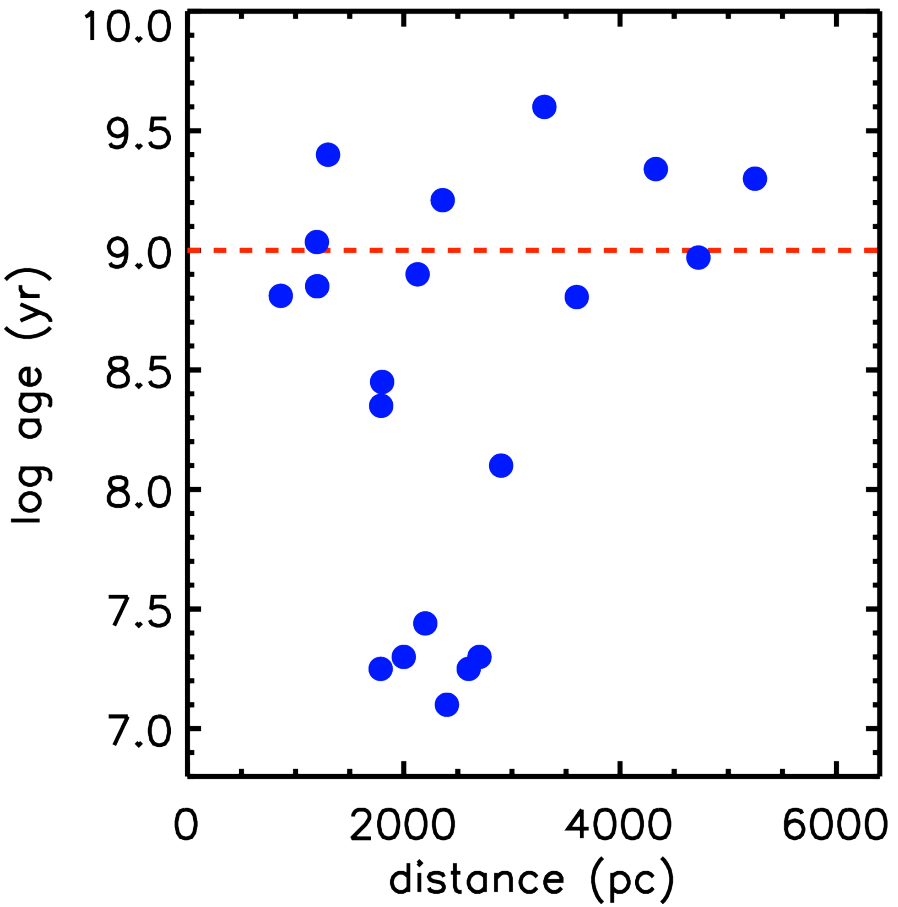
MEGARA/GTC setup:

- ► MOS mode;
- ► VPH410-MR MR-U

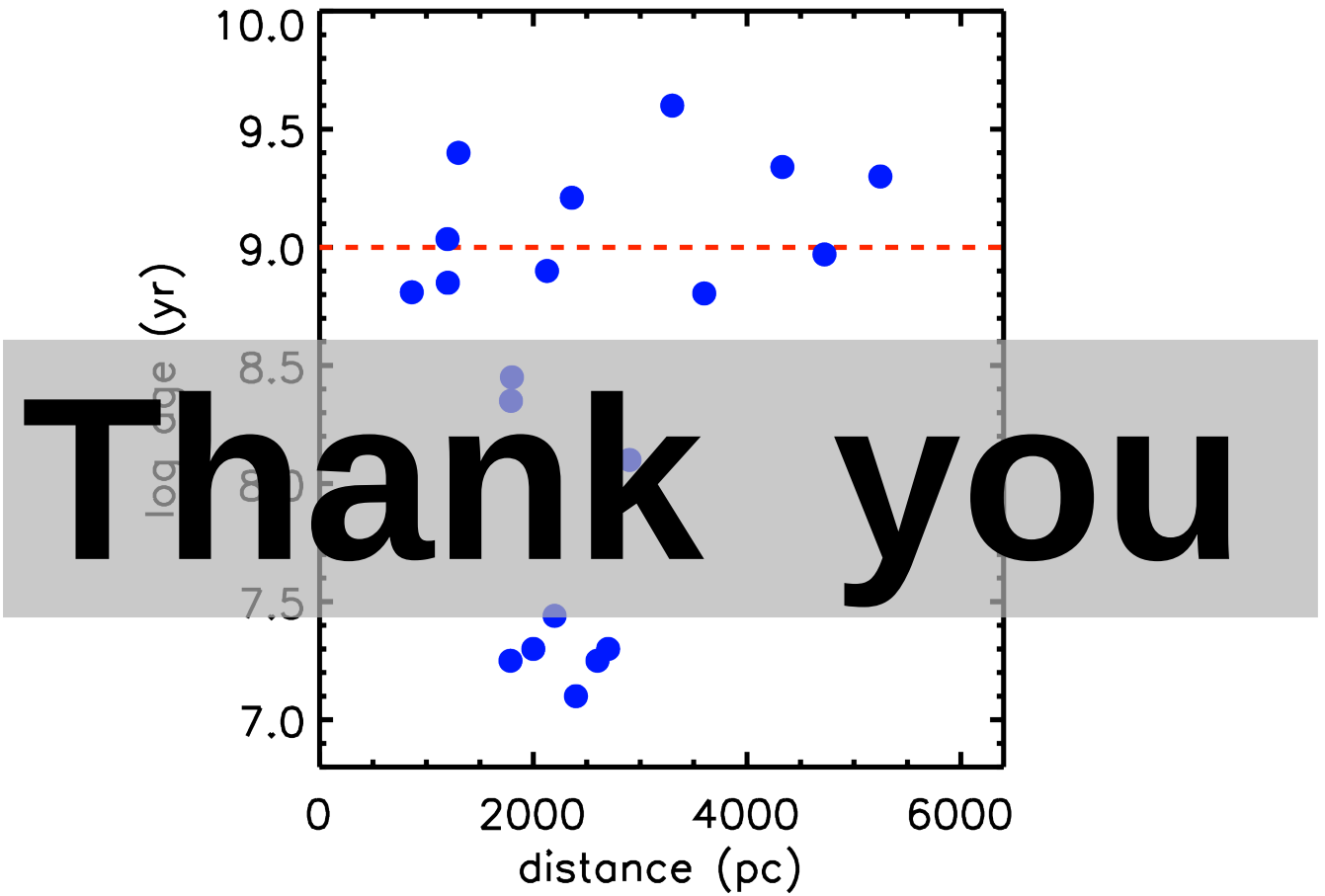
(3917–4227 Å @ R~12600)

~1500-2000 targets (1 pointing for cluster)

An improved Age-Stellar Activity Calibration with MEGARA/GTC



An improved Age-Stellar Activity Calibration with MEGARA/GTC



Thank you