~~Cold Disks Around Nearby Stars Explored by Herschel~~

~~Cool Stellar Disks~~

Debris Disks – Cool Herschel Results

IDSW 2013, Aranjuez, 19 November 2013

Göran Pilbratt, Herschel Project Scientist

– and the DUNES & Disk Evolution KP consortia

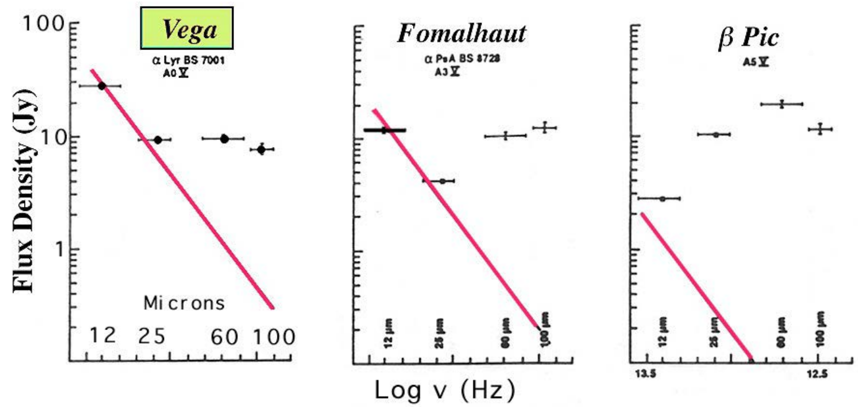
What are 'debris disks' & why interesting?

Discovery by IRAS: 'IR excess'

- Surprise discovery: ~15-20% of nearby A-K stars show larger IR flux than predicted from the stellar photosphere (e.g. Aumann 1985)
- 'Vega phenomenon' – 'Fab four':
  - Vega – A0V at 7.8 pc, ~350 Myr
  - β Pictoris – A5V at 19 pc, ~12 Myr
  - Fomalhout – A3V at 7.7 pc, ~200 Myr
  - ε Eridani – K2V at 3.2 pc, ~800 Myr

Confirmed by later studies

- ISO @60 μm (Habing et al. 2001):
  - 14 of 84 (17%) A-K stars at <25 pc
  - A stars over-represented
- Spitzer @70 μm (Trilling et al. 2006):
  - A stars: ~ (26 +10/-7) %
  - FGK stars: ~ (21 +7/-5) %
  - M stars: 0



Interpretation of observed IR excess

- **Dust grains** around stars
- Need to be **replenished**, on time-scales short compared to stellar ages
- Infer **planetesimals** (<10s of km), dust produced by **'collisional cascades'**
- Connection to planets 'unclear'

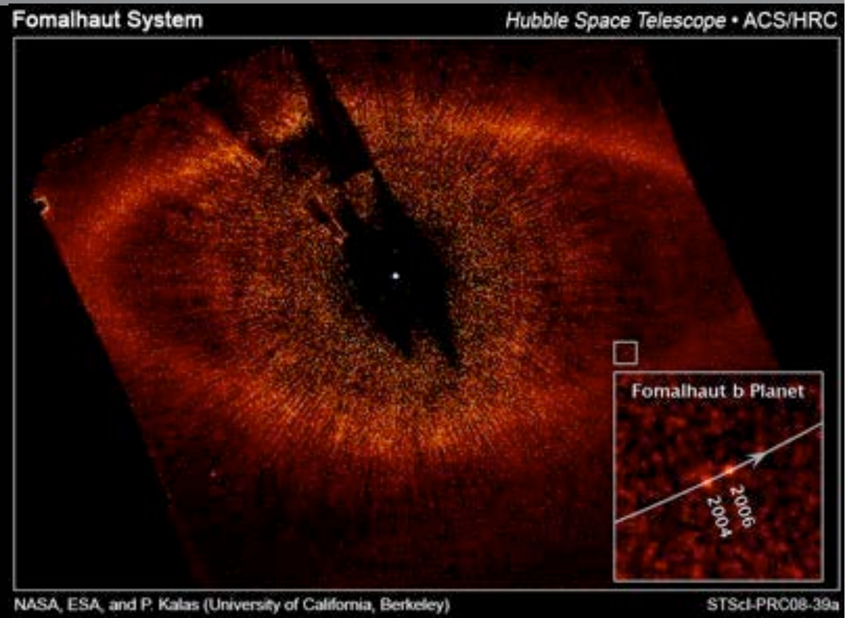
Our solar system

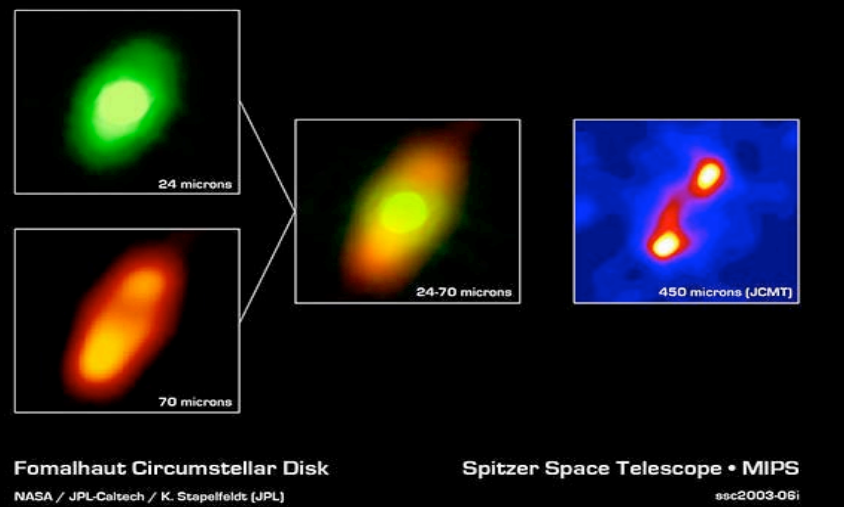
- Asteroid ('zodiacal') and EKB
- Could not be observed if at 10 pc!

Comet massacre around Fomalhaut

Herschel/PACS @70 μm

Acke et al. 2012
A&A 540, A125





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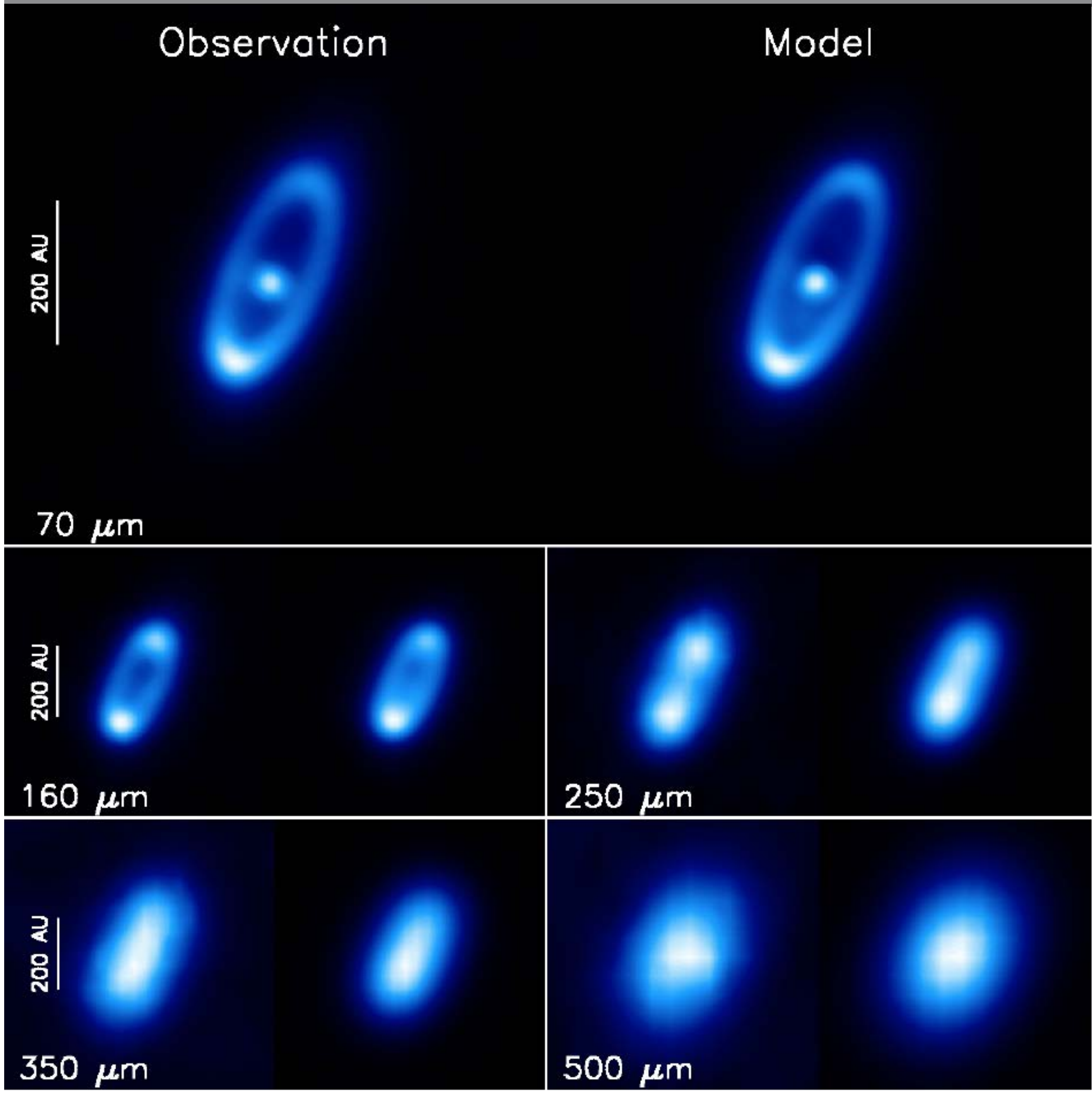

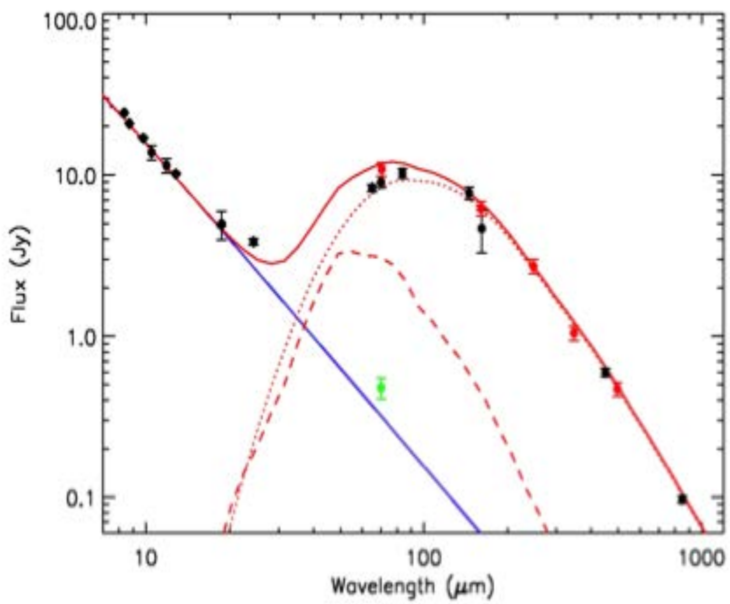

- Optically large >50 μm grains, thermal small (blow-out) grains => ‘fluffy aggregates’
- Replenishment time ~1700 yrs
- Mass loss (=production) rate ~2000 (1 km) comets per day
- Reservoir of ~10^{13} comets, with a total mass of ~100 M_{Earth}
- Currently a remarkably violent system!

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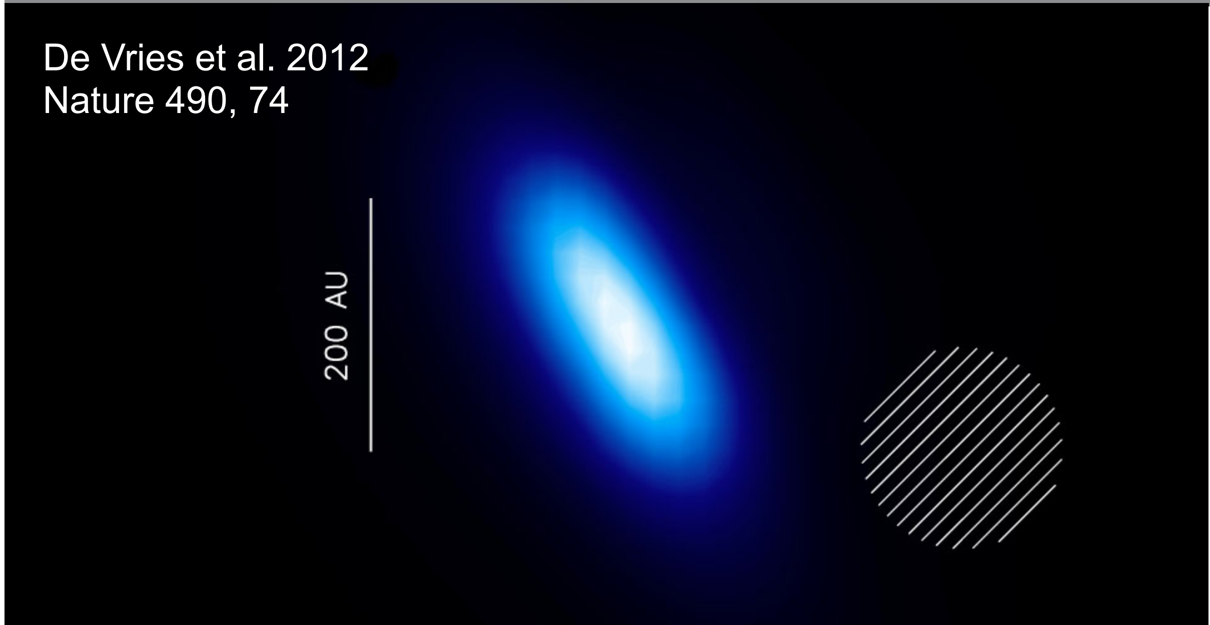
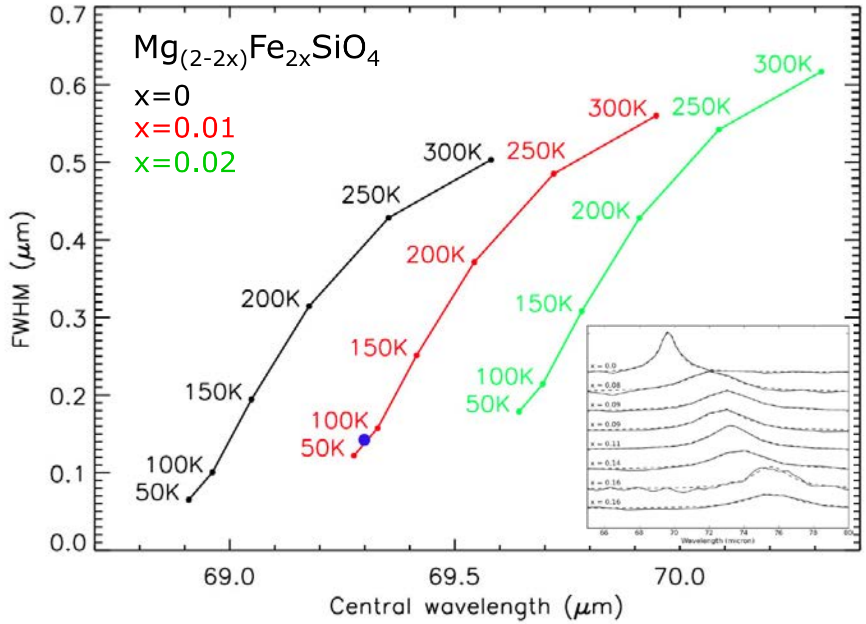
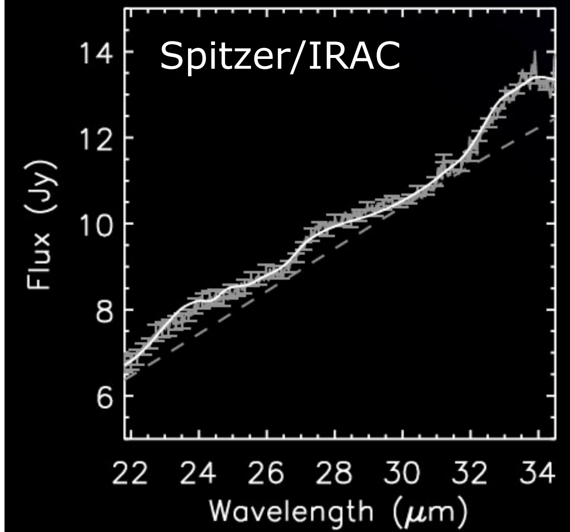
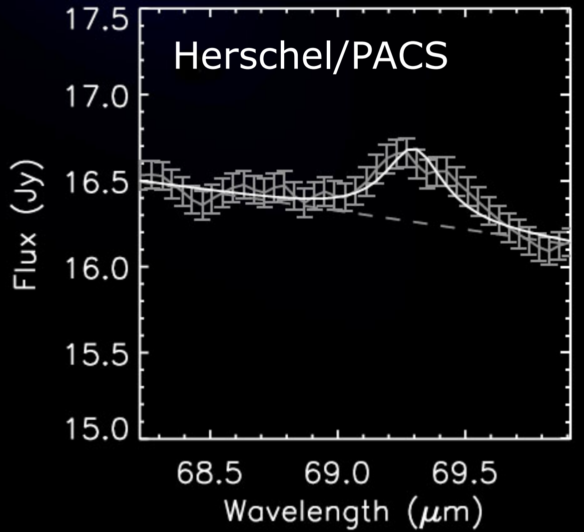
Pristine material around β Pictoris









- Spitzer/IRAC 22-34 um
- Herschel/PACS 69 um band => **Mg-rich crystalline olivine**
- Mg-rich => ‘pristine’
- Fe-rich => ‘processed’

Debris Disks and DUNES Open Time KP

esa

Overall objective: Detect and characterise faint exo-solar analogues to the solar system Edgeworth-Kuiper Belt (EKB)

- Direct proof of incidence of planetesimal systems (possible indirect one of planets)

Specifically, to evaluate the

- fraction of solar-type stars with faint, EKB-like, discs
- collisional and dynamical evolution of these EKB analogues
- dust properties and size distribution of these EKB analogues
- incidence of EKB-like discs versus host star properties, including the presence of planets

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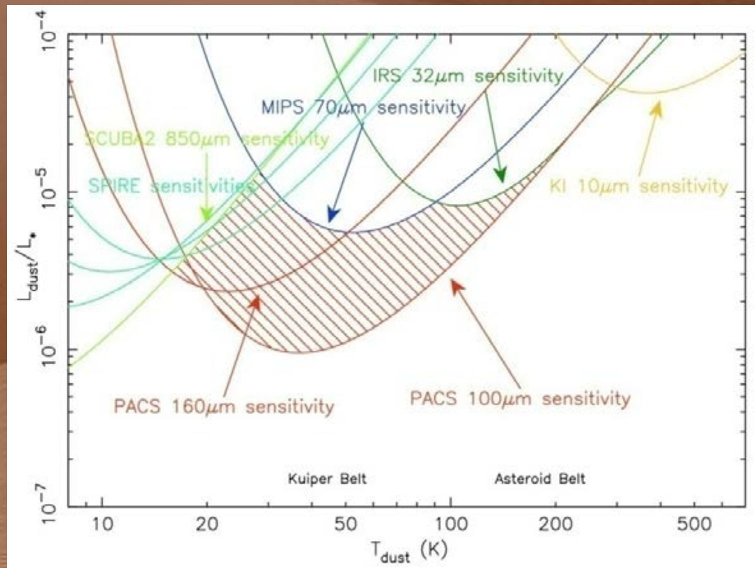
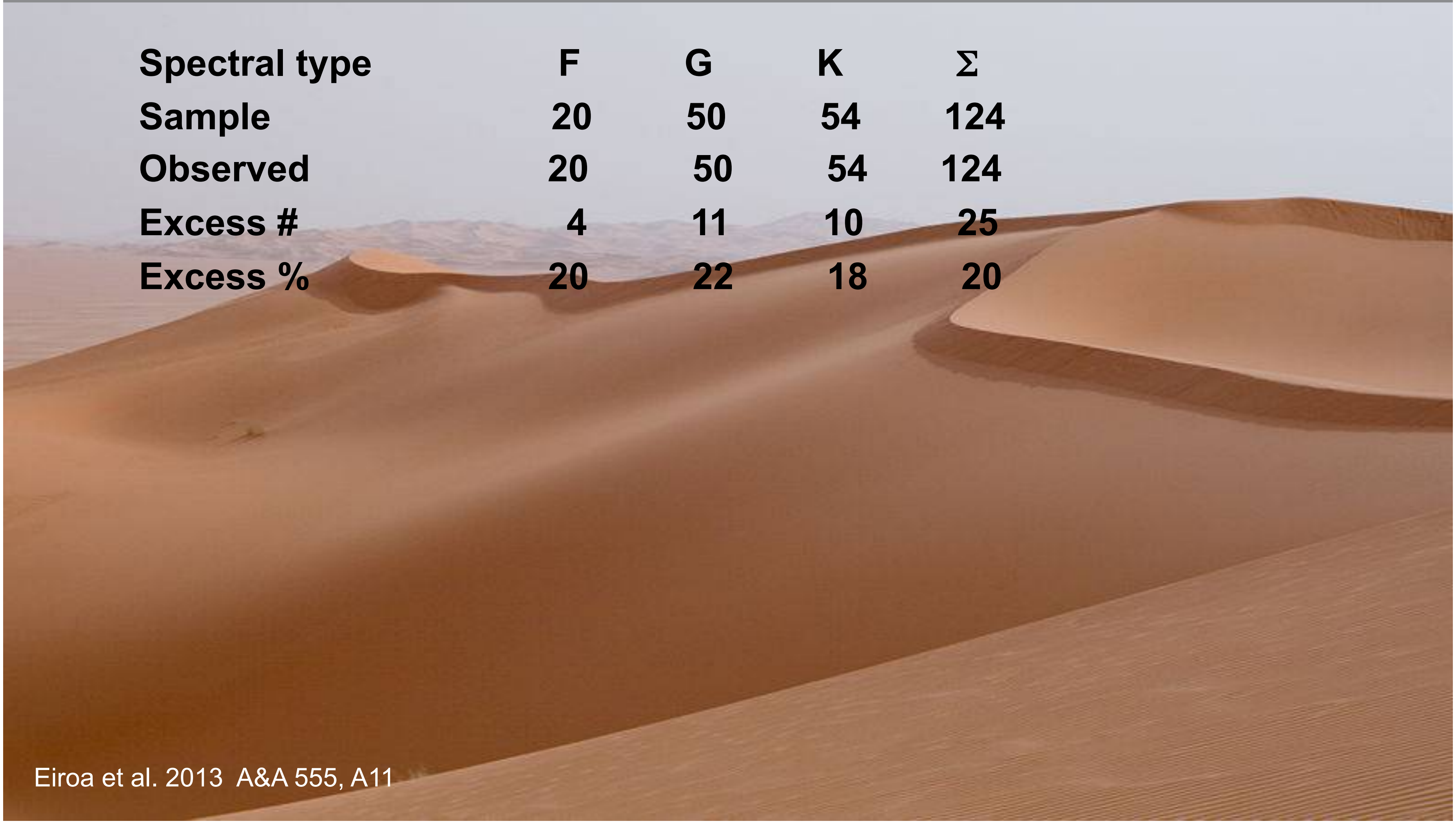
The DUNES sample

- FGK stars <20 pc (+known planet/disk stars <25 pc)
- Detect photosphere (L_{star}) with SNR >5 @100 μm, puts reqs on background => avoid galactic plane
- Time allocation: split & share with DEBRIS
- DUNES 20 pc sample: 20 F, 50 G, 54 K, Σ 120
- DEBRIS 20 pc sample: 32 F, 16 G, 8 K, Σ 56
- **Sun**: EKB peaks ~50 μm, PACS fluxes ~0.1-0.4 mJy, and ‘fractional luminosity’ $f_d = L_{disk}/L_{star}$ ~10^{-7}



DUNES 20 pc sample – obs results

Spectral type	F	G	K	Σ
Sample	20	50	54	124
Observed	20	50	54	124
Excess #	4	11	10	25
Excess %	20	22	18	20



Eiroa et al. 2013 A&A 555, A11

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Points noted:

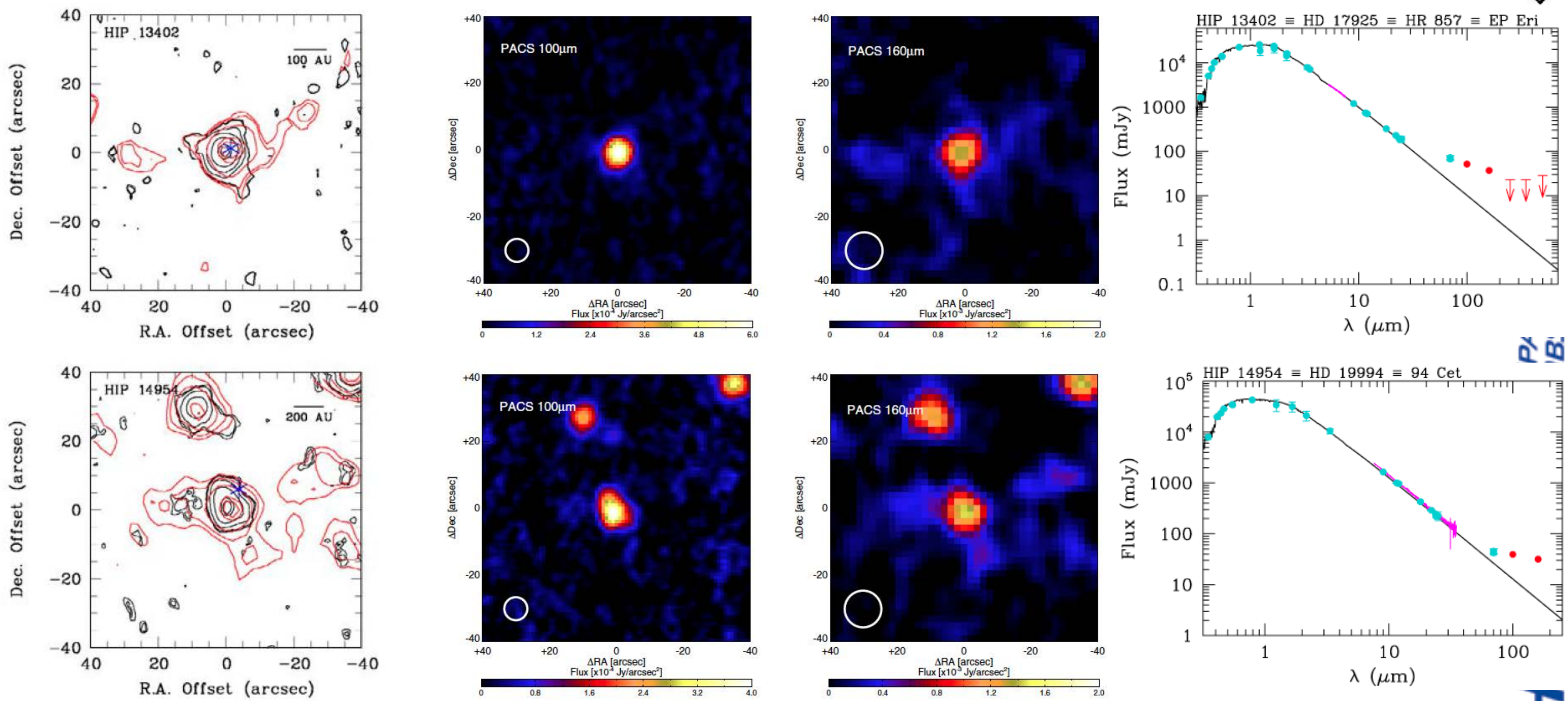
- Of these 124 stars 15 (12%) have Spitzer disk detections
- Herschel disk detection is a factor 25/15 (~1.7) higher
- Herschel has resolved many more disks
- Mean f_d values for 'new' & 'old' disks are $\sim 4\times10^{-6}$ & $\sim 4\times10^{-5}$
- Mean disk temp T_d for 'new' & 'old' disks are ~34 K & ~64 K
- Mean black body radius for 'new' & 'old' disks are ~82 AU & ~38 AU

Herschel has detected fainter, colder, larger disks – as expected

Eiroa et al. 2013 A&A 555, A11

Example observations

Top: HIP13402, PACS 100 µm, PACS 160 µm, SED; bottom HIP 14954



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What do we learn – correlations!?

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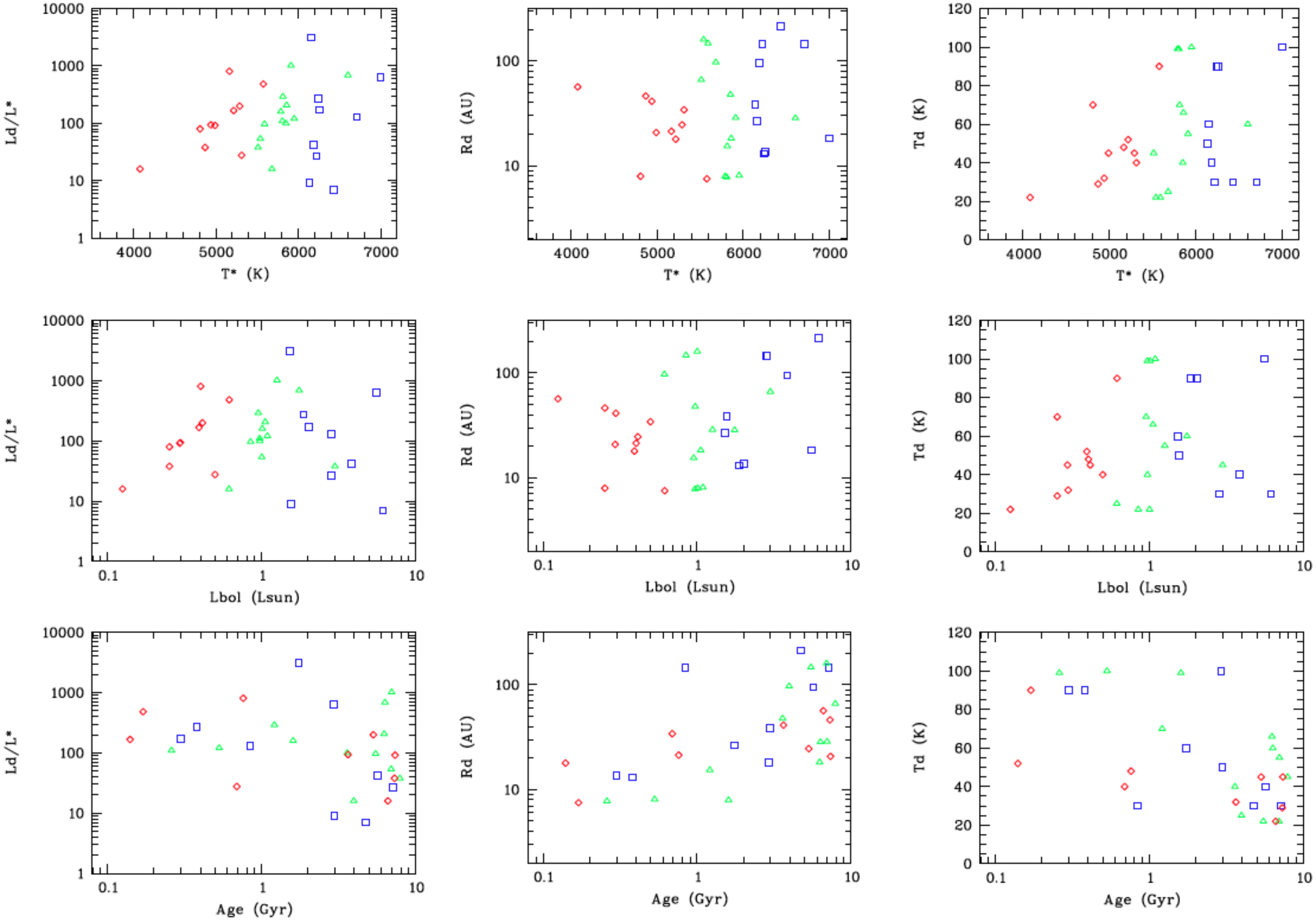
Legend

- F stars
- G stars
- K stars
- f_d units of 10^{-7}

Correlations?

- f_d vs age?
  - no
  - **surprise!?**
- R_d vs age?
  - weak?
- T_d vs age?
  - weak anti?

Eiroa et al. 2013
A&A 555, A11



Compare 37 RV-planet & DUNES/DEBRIS stars

Comparison of 37 stars known to host RV planets with 11 DUNES/DEBRIS cold debris disks – disk incidence ~30%

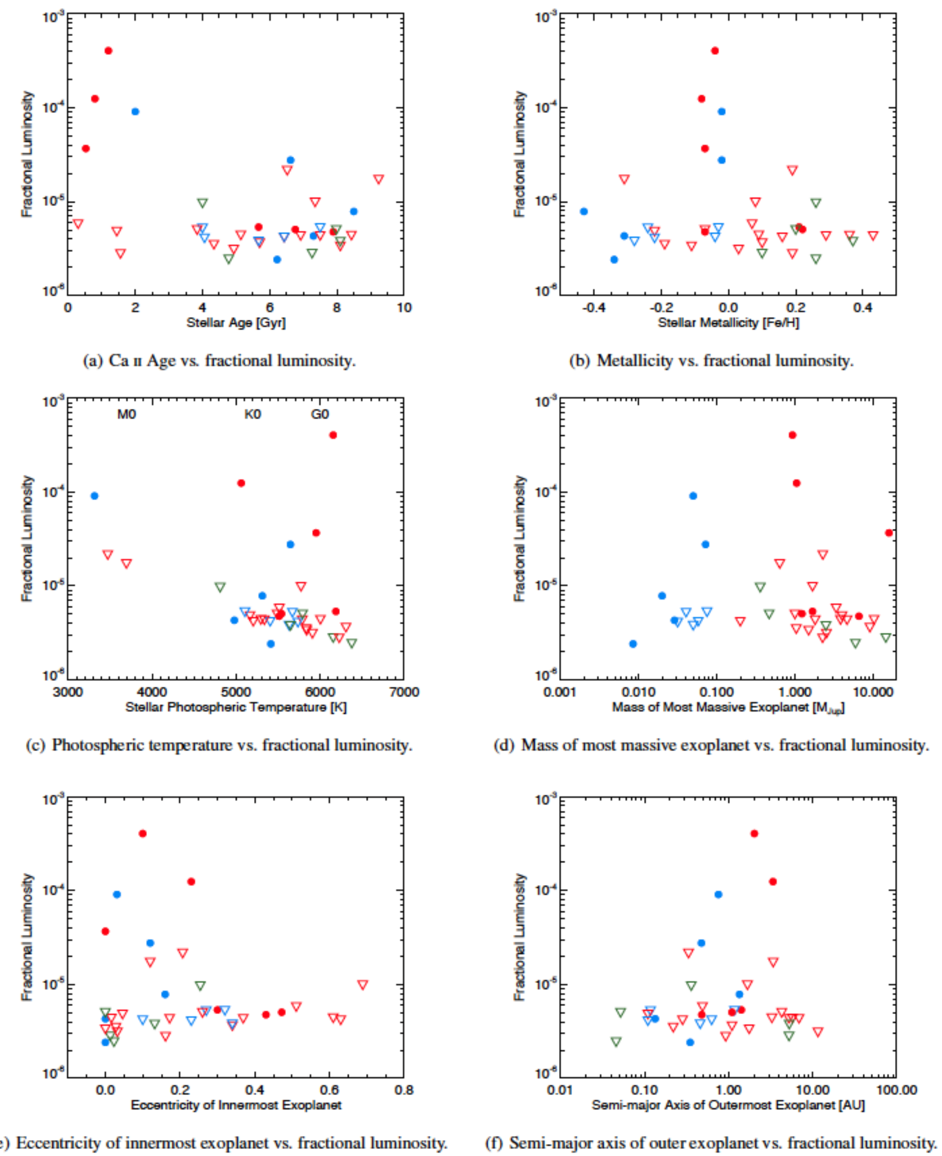
Legend

- Disks: debris disks, triangles: upper limits
- Data points:
  - Blue – low mass planet (<30 M_{Earth}~0.1 M_{Jup})
  - Green – hot giant planet (>0.1 M_{Jup}, R_P<0.1 AU)
  - Red – cold giant planet (>0.1 M_{Jup})

Correlations?

- Fract luminosity f_d vs stellar age – no
- Metallicity [Fe/H] vs f_d – ?
- Photospheric temp vs f_d – no
- Mass of most massive planet vs f_d – ?
- Orbit eccentricity of innermost planet vs f_d – no
- Orbit semi-major axis of outer exopl vs f_d – no

Marshall et al. 2013 A&A subm



(a) Ca II Age vs. fractional luminosity.

(b) Metallicity vs. fractional luminosity.

(c) Photospheric temperature vs. fractional luminosity.

(d) Mass of most massive exoplanet vs. fractional luminosity.

(e) Eccentricity of innermost exoplanet vs. fractional luminosity.

(f) Semi-major axis of outer exoplanet vs. fractional luminosity.

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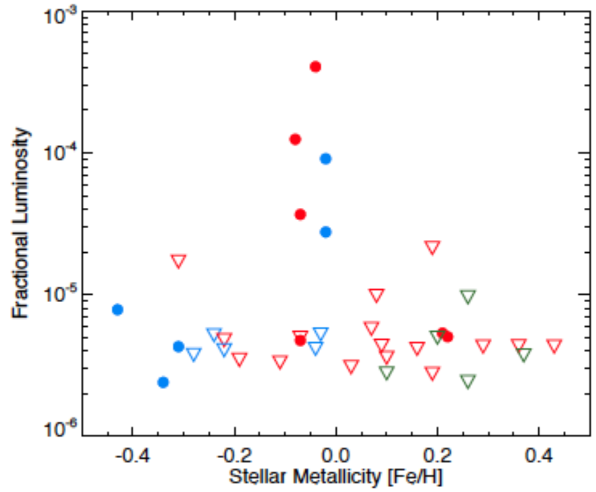
Correlations?

- Metallicity [Fe/H] vs f_d – **?** (19 sub- & 18 supra-solar Z)
- 9 disks low Z stars & 2 disks high Z stars
- **Low mass planets – all 10 low Z stars, many (5/10) disks**
- Cold giant planets – all stars, some (6/22) disks
- **Hot giant planets – all 5 high Z stars, no (0/5) disks**



(b) Metallicity vs. fractional luminosity.

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Correlations?

- Mass of most massive planet vs f_d – **?**
- Low mass planets – w/wo disks
- Cold giant planets – w/wo disks
- **Hot giant planets – no disks!**

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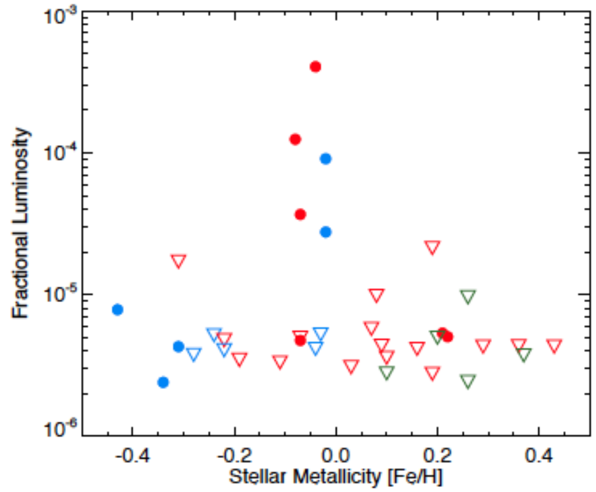

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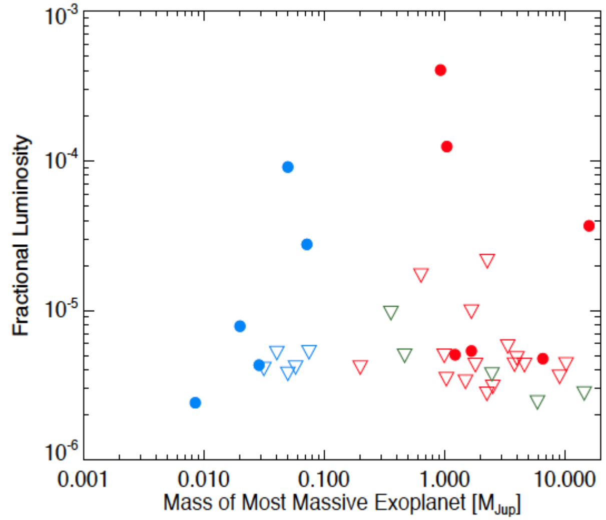
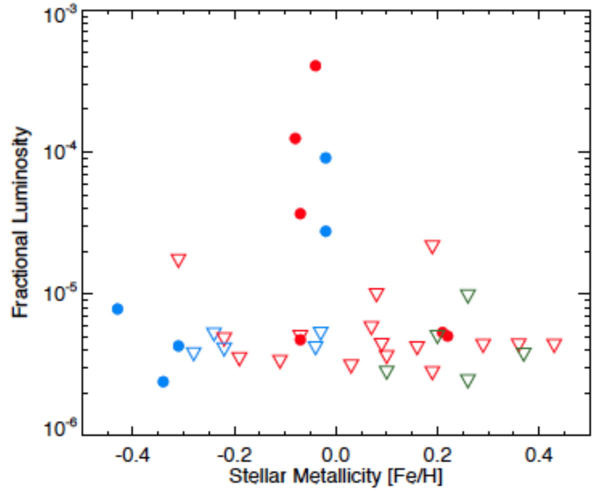


Göran Pi (d) Mass of most massive exoplanet vs. fractional luminosity.

Compare 37 RV-planet & DUNES/DEBRIS stars

In summary, what we observe:

- **All 10 low mass planets** with **low Z** stars (10/19 vs 0/18), **many (5/10) with disks**
- Cold giant planets – with low (9/19) & high Z (13/18) stars, some (6/22) disks, (4/9) low Z & (2/13) high Z stars
- **All 5 hot giant planets** with **high Z** stars (5/18 vs 0/19), **none (0/5) with disks**



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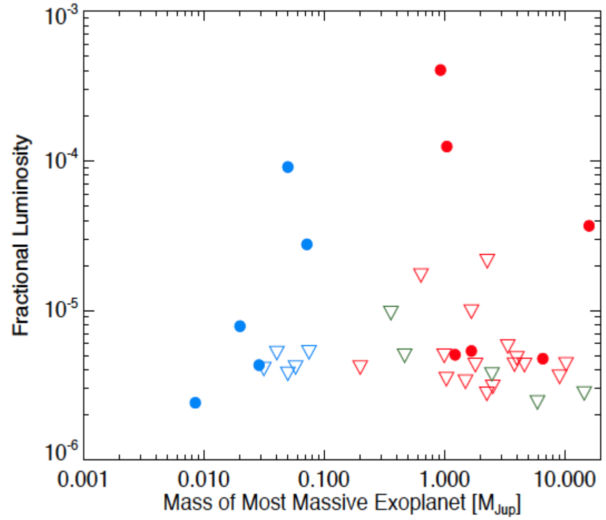

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- **All** **5 hot giant planets** with **high Z** stars (5/18 vs 0/19), **none (0/5) with disks**

Correlations

- Exoplanet host star sample is **not** significantly different from the (larger and unbiased wrt to planets) DUNES sample
- **No trend** wrt **disks** and **spectral type** of FGK stars
- **Hot giant planets** and other planets do **not** come from same underlying distribution of stars, and have **no disks**
- **Low Z** stars are more likely to have **low mass planets,** and to have **detectable debris disks**
- **Low mass planets** are more likely to be **associated with debris disks**

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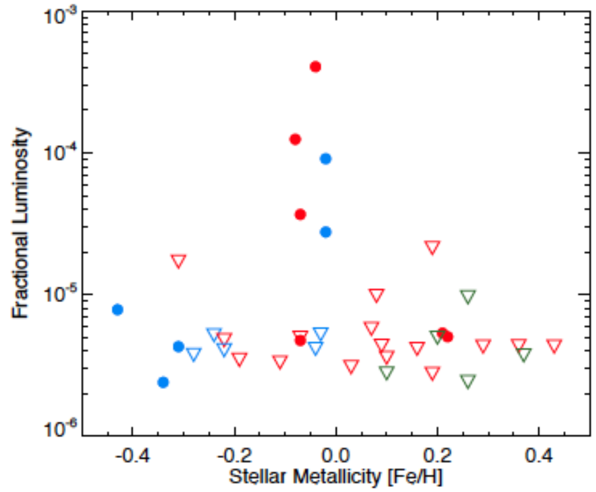

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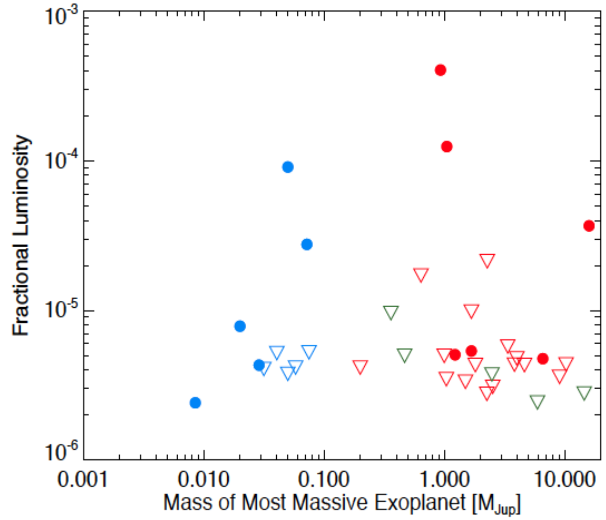

Göran Pi (d) Mass of most massive exoplanet vs. fractional luminosity.

Some thoughts

It must not be forgotten:

- We are talking relatively small number statistics
- We define ‘stars with debris disks’ (SDD) and ‘stars with planets’ (SP), but we must not forget that
    - SDD have disks of certain f_d, but possibly all (FGK) stars have DDs at some level)

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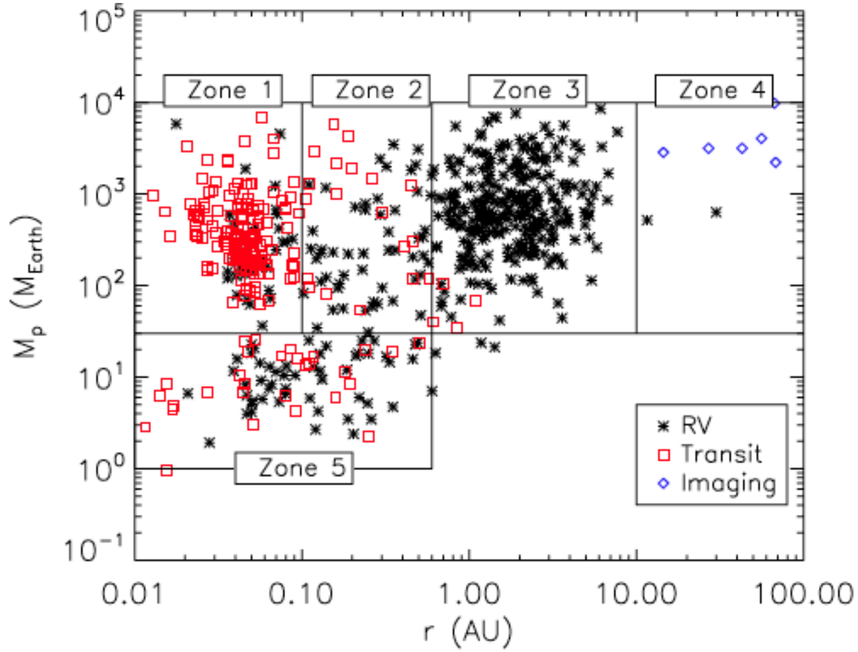
  - The sun is neither SDD nor SP!
- When talking about SDD and/or SP you need to state clearly what you mean!



Hasegawa & Pudritz 2013 ApJ 778, 78

Marshall et al. 2013 A&A subm

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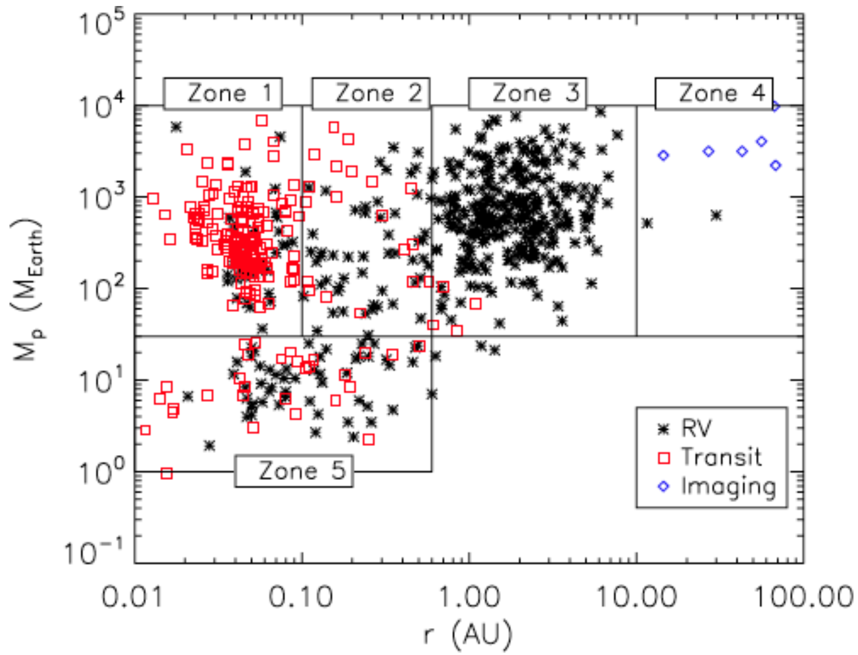

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‘Scenario’: low Z stars, low mass planets, and debris disks

- A star forms surrounded by a protoplanetary disk of gas and dust
- Gas is lost/stripped from the disk too quickly for gas giants to form
- Low mass planets form, but do not scatter planetesimals strongly enough
- Speculative – time will tell!

Marshall et al. 2013 A&A subm


THANK
YOU !