Metallicity of solar-type stars with debris discs and planets

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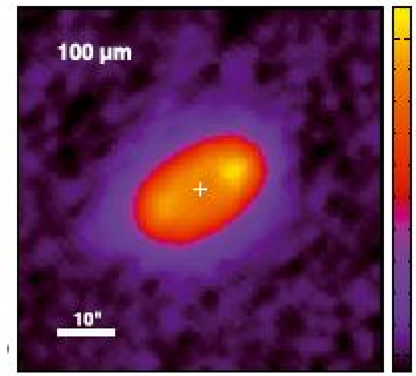
- Dust luminosity versus [Fe/H] and planet eccent.
- Conclusions

Introduction

Debris discs around MS stars are, strictly speaking, the signatures of planetesimal systems

- they are produced by collisions from such solid bodies



HD 207129 as seen with Herschel, Marshall et al. (2011), Löhne et al. (2012)

Spitzer: ~16% of solar-type stars host a debris disc (e.g. Trilling et al.2008)

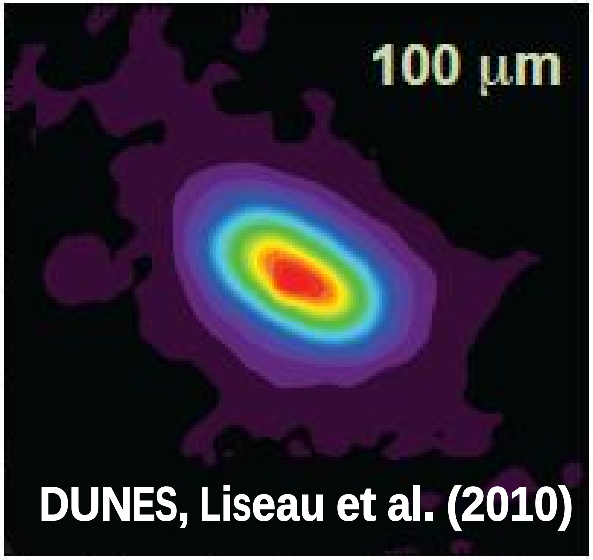
- Herschel: $\gtrsim$ 25 % (DUNES FGK stellar sample)

Concerning planets (Mayor et al. 2011):

- 50% of solar-type stars harbor at least one planet of any mass with periods up to ~ 100 days
- ~ 14% of this type of stars have planets with $M_P \gtrsim 50\ M_\oplus$ and P < 10 years

Introduction

If planetesimals are the raw material to form debris discs and are needed to form planets ("building blocks"),
it might be expected that their host stars have, somehow, similar properties



q[1] Eri: Herchel PACS image
- **Star: F8V, 1.2 $L_{\odot}$, [Fe/H] = -0.1, Age ~ 2 Gyr**
- **Planet: 0.9 M_J, a = 2 AU, e = 0.1**
- **Debris disc: 40 AU wide ring at ~ 85 AU, L_{dust}/L_{star} ~ 10^{-4}**

- **e.g. it is well known the trend of higher [Fe/H] of stars hosting gas giant planets, but no for low mass planets ($\lesssim$ 30-40 $M_{\oplus}$), what about stars with debris discs?**

Introduction

Several works dealing with this issue:

-Incidence of debris discs not higher around stars with planets than around stars with no (detected) planets

-There is no apparent trend of the incidence of discs with the stellar metallicity or any other stellar property.

- But results based on a small number of stars with both discs and planets
  - e.g. Kóspal et al. (2009) list 19 solar-type MS stars

Motivation

We have re-visited the analysis of the properties of stars with discs and planets because:

- 29 solar-type stars are now known with both debris discs and planet(s)

- **50% increase wrt previous analysis**
- **in particular, stars hosting low-mass planets**

(*) we do not include Herschel results

Sample

For the analysis, three categories of solar-type (F5-K3) stars are distinguished **(selected from works dealing with IR excesses from IRAS, ISO and SPITZER):**

- Stars with discs (SWDs) (no known planet): 107 stars

- Stars with planets (SWPs) (no known disc): 120 stars

- Stars with discs and planets (SWDPs): 29 stars

Control sample:

- Stars without discs and planets (SWODs): 145 stars

- **Discs with Ldust/Lstar < 10E-5 (~ Spitzer lower limit) could be included**
- **Planets not discovered yet**

Bias?

First aim: metallicity distribution of our samples

- **In particular, need of checking the SWDs and SWODs sample because of different age and distance ranges**

	SWDs			SWODs		
	Range	Mean	Median	Range	Mean	Median
Distance (pc)	3.6/134	32.0	24.6	5.8/53	24.1	20.6
log[Age (yr)]	7.2/9.9	9.0	9.0	7.6/9.9	9.2	9.6
SpType (%)	45.8 (F); 34.6 (G); 19.6 (K)			42.8 (F); 44.8 (G); 12.4 (K)		

- **We do not find any significant chemical evolution (Fe enrichment of the ISM) due to Type I and II supernovae for the age range of both samples which can affect the [Fe/H] distribution**

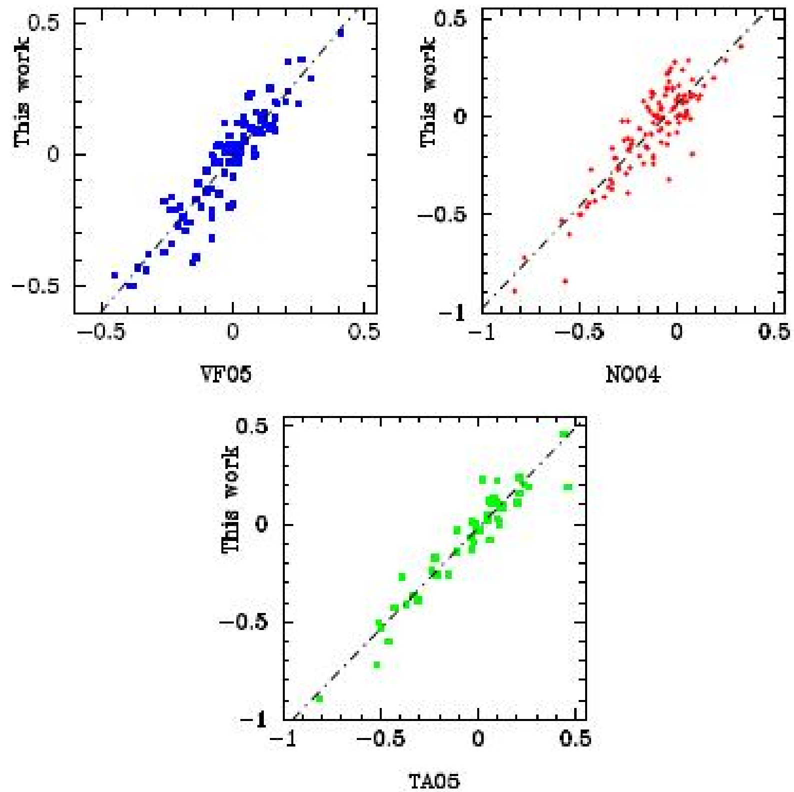
- **We do not find any bias introduced by the distance**

Spectroscopic Data

- **High resolution spectra of stars up to 25 pc from Maldonado et al. (2010):**
  - **FOCES (2.2 m, Calar Alto), SARG (TNG, La Palma), FIES (NOT, La Palma) + S^4N and ESO archives**

- **Stellar parameters using the code TVG (Takeda et al. 2002)**

- **Comparison with other works of our metallicity estimates to extend the analysis to the whole range of distances**

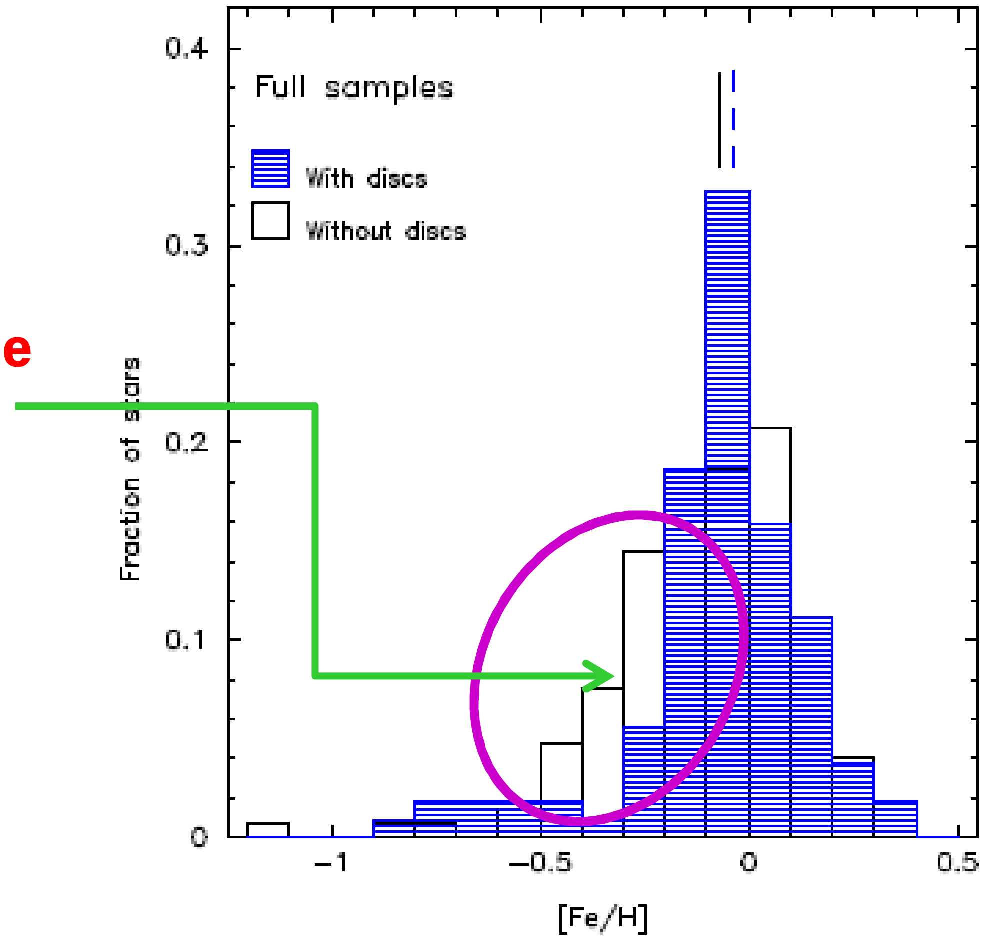


- **All metallicities values in the same metallicity scale**

[Fe/H] distribution: SWDs versus SWODs

- Similar [Fe/H] distributions (K-S tests)

- It seems to be a deficit of the SWDs in the low [Fe/H] range



SDWPs: characteristics

- **29 solar-type SWDPS:**

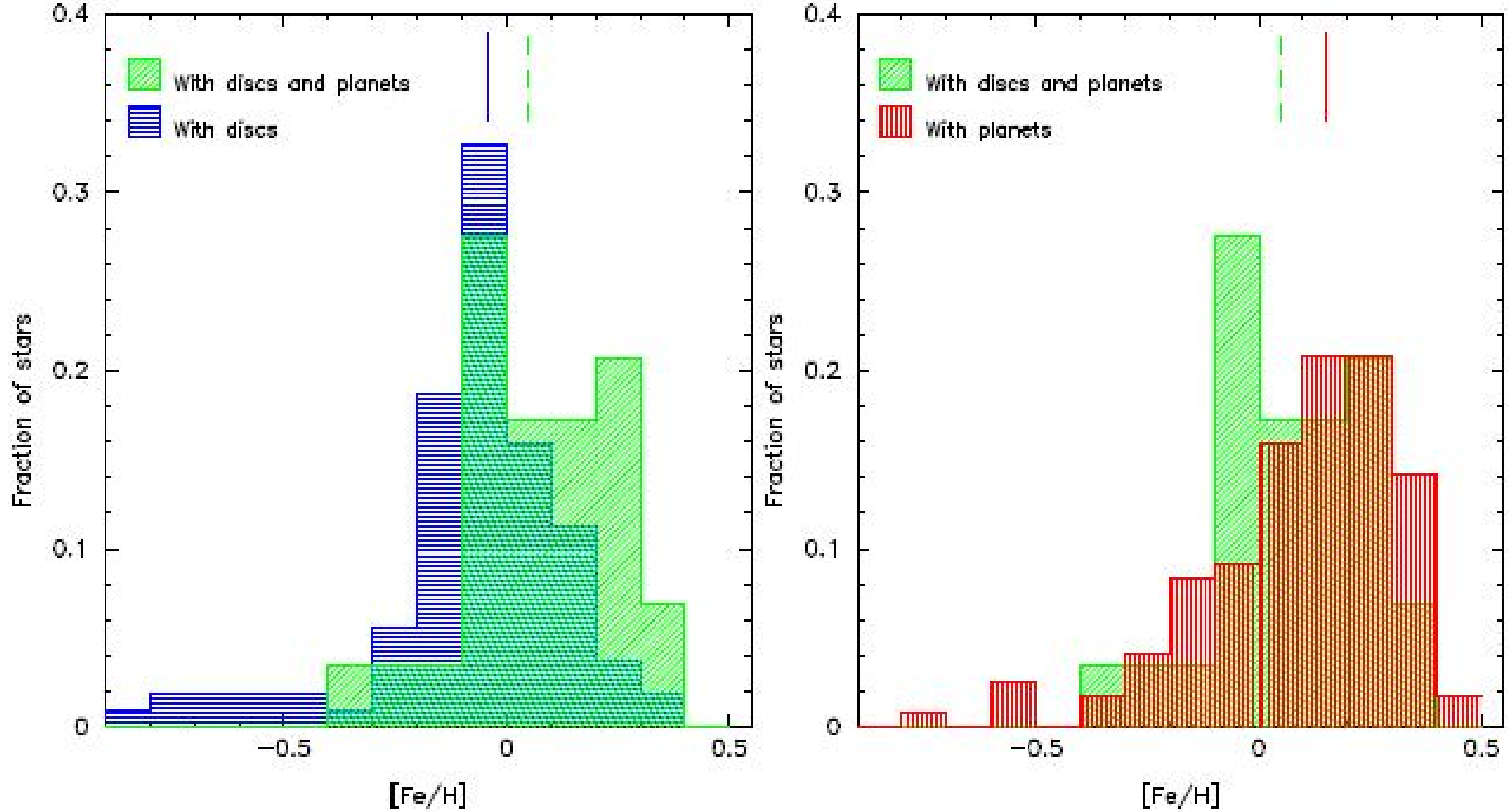
- **11 stars (38%) host multiplanet systems**
  - ➢ **14% (maybe up to 28%) for all stars with planets (Wright et al. 2009)**
  - ➢ **70% multiplanet systems in case of low-mass planets, $M_P < 30\ M_\oplus$ (Mayor et al. 2011)**

    (in our case, 5 stars with low-mass multiplanet systems)

- **22 stars host only gas-giant planets**
  - **Most of them are cool Jupiters**
  - **2 systems with a < 0.1 AU**
  - **5 systems with a < 0.5 AU**
- **7 stars host at least one low-mass planet**
  - **All but 2 with a < 0.1 AU**
  - **All but one with [Fe/H] ≤ 0.0**
    - ➢ **consistent with e.g. Mayor et al. 2011, Sousa et al. 2011**

HD	SpType	[Fe/H][†] (dex)	Ref[‡]	Planet'
142	F7V	0.09 (b)	9:	gc
1461	G0V	0.18 (b)	11	mlh
10647	F8V	-0.09 (a)	3	gc
19994	F8V	0.19 (a)	8	gc
20794	G8V	-0.34 (a)	10	mlc
22049	K2V	-0.08 (a)	1	gc
38529	G4V	0.31 (b)	6	mgc
38858	G4V	-0.27 (a)	4	lc
40979	F8	0.13 (b)	10:	gc
45184	G2V	0.03 (b)	11	lh
46375	K1IV	0.23 (b)	10:	gh
50499	G1V	0.29 (b)	10:	gc
50554	F8	-0.09 (b)	8	gc
52265	G0V	0.18 (b)	8	gc
69830	K0V	0.00 (a)	2	mlh
73526	G6V	0.22 (b)	10:	mgc
82943	G0	0.23 (b)	8	mgc
104067	K2V	0.04 (b)	11	gc
108874	G5	0.17 (b)	12	mgc
115617	G5V	0.00 (a)	8	mlh
117176	G5V	-0.03 (a)	8	gc
128311	K0	0.04 (a)	8	mgc
130322	K0V	-0.07 (b)	12	gh
178911B	G5	0.29 (b)	10:	gc
187085	G0V	0.05 (b)	10:	gc
192263	K2	-0.01 (a)	5	gc
202206	G6V	0.36 (b)	10	mgc
215152	K0	-0.10 (c)	11	mlh
216435	G3IV	0.24 (b)	10	gc

SWDPs: [Fe/H] distribution

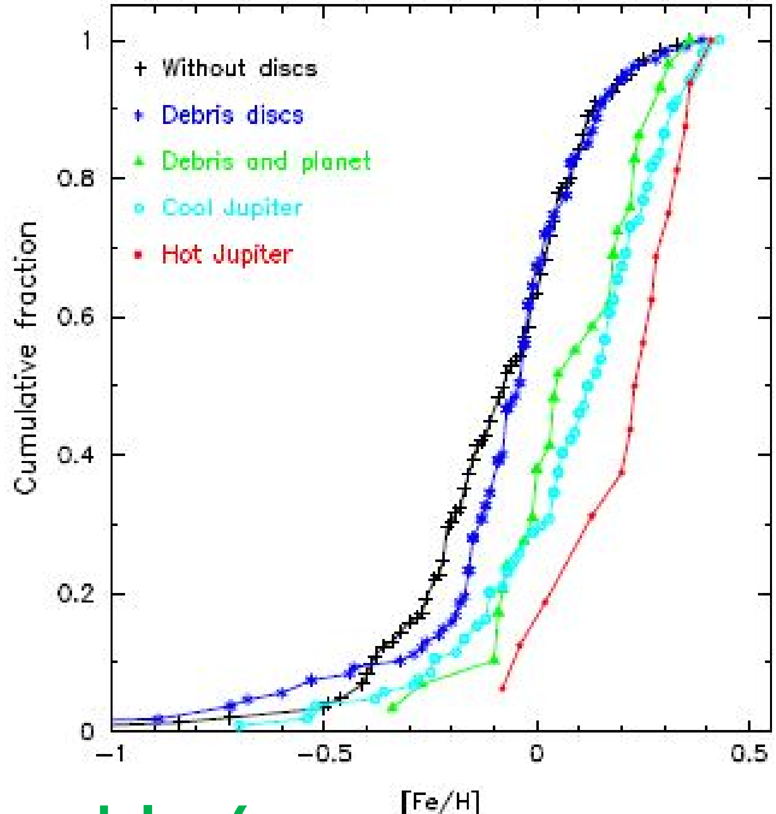


[Fe/H] distribution: Summary

- Transition toward higher metallicity from SWDOs to SWPS

- SWODs and SWDs similar [Fe/H] distribution, but a "deficit" of SWDs at low [Fe/H]

- SWDPs clearly distinct from SWDs but similar to SWPs
  - planets is the key ingredient conforming the [Fe/H] behaviour of the SWDPs



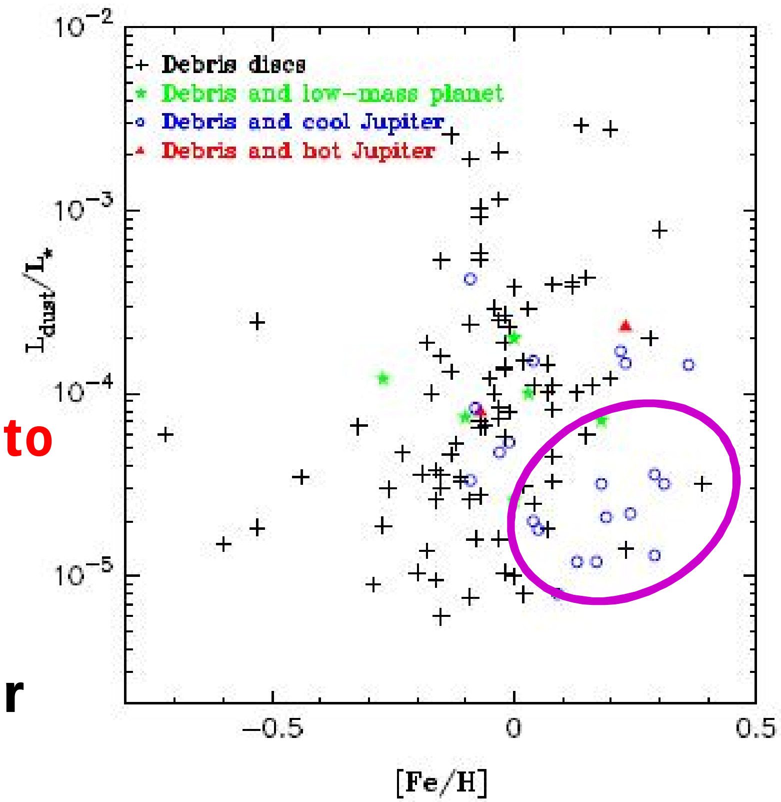
- Trends consistent with core-accretion models (e.g Pollack et al. 1996) and with the view that the mass of solids in proto-planetary discs is the main factor determining the formation of planets and planetesimals (e.g. Moro Martín et al. 2007, Greaves et al. 2007)

Dust luminosity versus [Fe/H]

- **SWDPs span ~ 2 orders of magnitude in L_{dust}/L_{star} and are well mixed with SWDs**

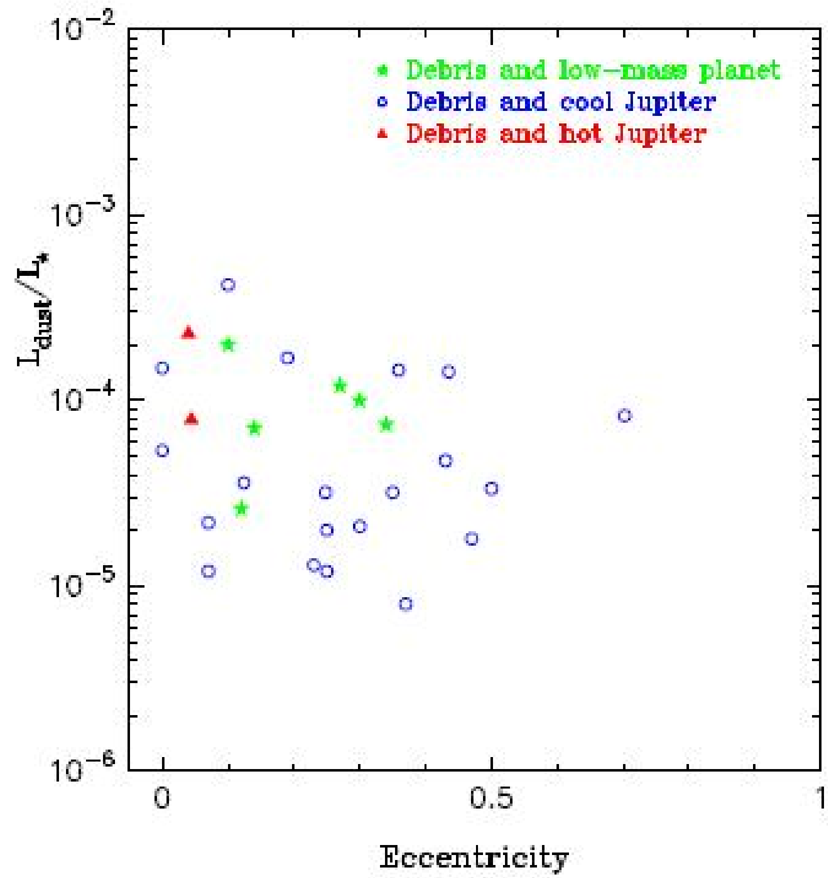
- **SWDPs hosting cool giant planets tend to have low L_{dust}/L_{star} ($< 10^{-4}$)**

  - **>50% concentrated in the low L_{dust}/L_{star} - high [Fe/H] corner**



Dust luminosity versus planet eccentricity

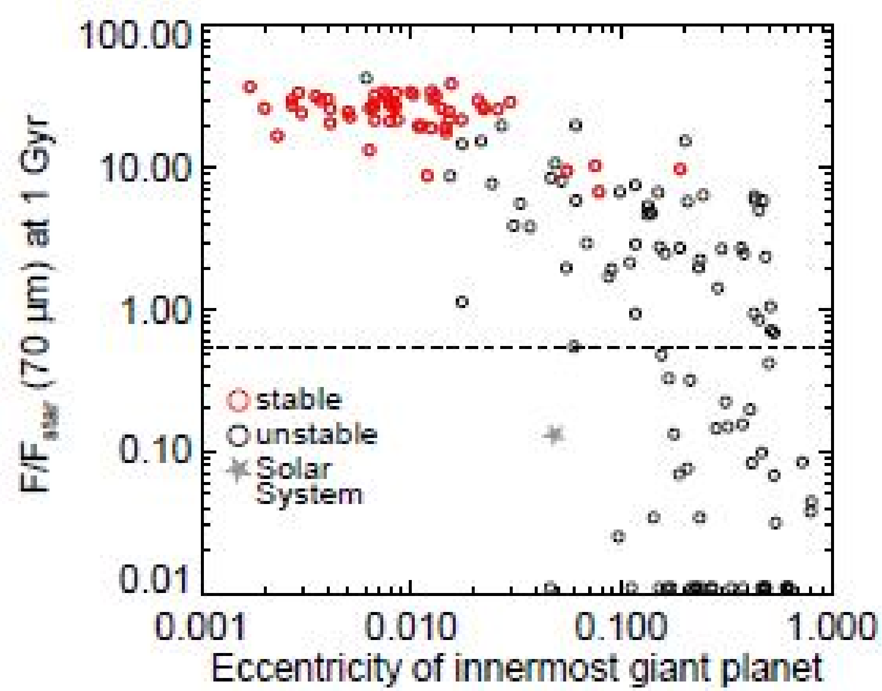
- There seems to be an anticorrelation between the (innermost) planet eccentricities and the luminosity of the debris discs
    - (although with a large scatter)



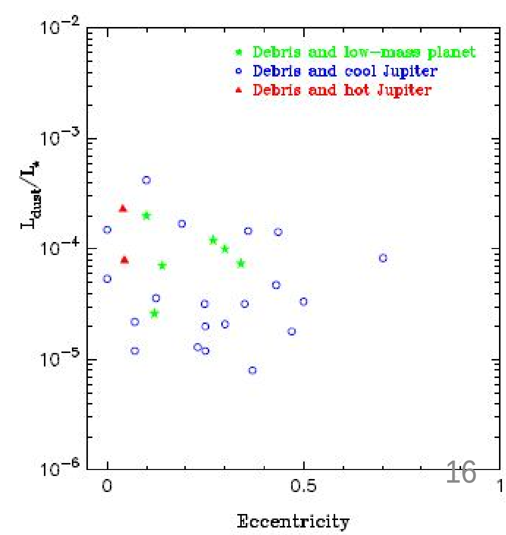
- No other correlation/trends between planets and debris discs are apparent

L_{dust}/L_{star} – eccentricity

-**Simulations of dynamical instabilities in a disc produced by eccentric giant planets, which clear out the inner and outer regions of the planetary discs, result in an anticorrelation between the disc luminosities and the planet eccentricities (Raymond et al. 2011)**



- **Such scenario is very attractive to explain the observed apparent behaviour between the disc luminosities versus both the stellar [Fe/H] and the planet eccentricities**



Conclusions

- We find a transition toward higher [Fe/H] from SWODs to SWPs
  - SWDs have similar [Fe/H] as SWDOs, but there might be a deficit of SWDs at low metallicities
  - SWDPs behave as SWPs, irrespective if the planets are low-mass or gas giants

- SWDPs show a high rate of multiplanet systems

- Most of the known SWDPs host cool Jupiters
  - (bias against low-mass planet detections?)

- SWDPs hosting cool giant planets tend to have low L_{dust}/L_{star}

- There might exist an anticorrelation between the L_{dust}/L_{star} and the planet eccentricity

- These conclusions might change/be modulated by Herschel and further detections of planets

Biases?

	SWDs			SWODs		
	Range	Mean	Median	Range	Mean	Median
Distance (pc)	3.6/134	32.0	24.6	5.8/53	24.1	20.6
log[Age (yr)]	7.2/9.9	9.0	9.0	7.6/9.9	9.2	9.6
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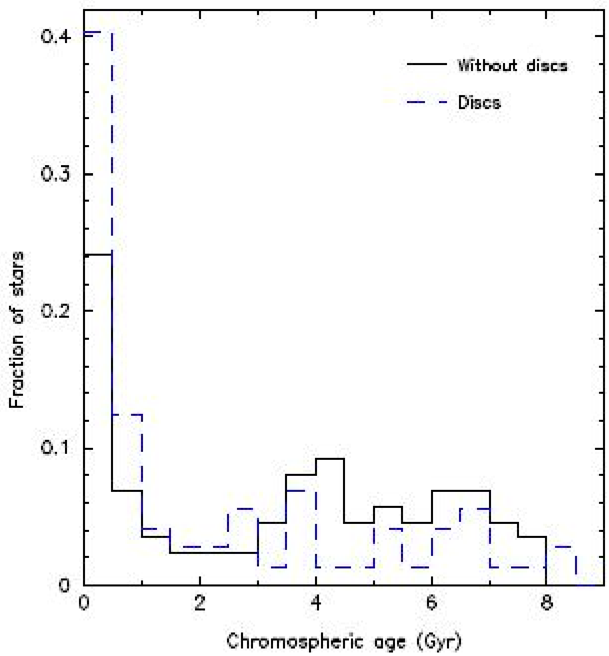


Fig. 1. Age distribution for stars in the SWODs (continuous-black line) and the SWDs (dotted-blue line) samples.

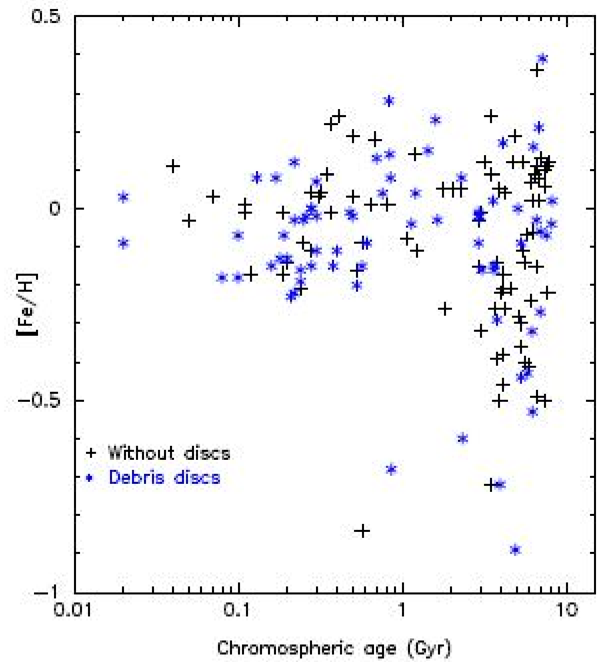
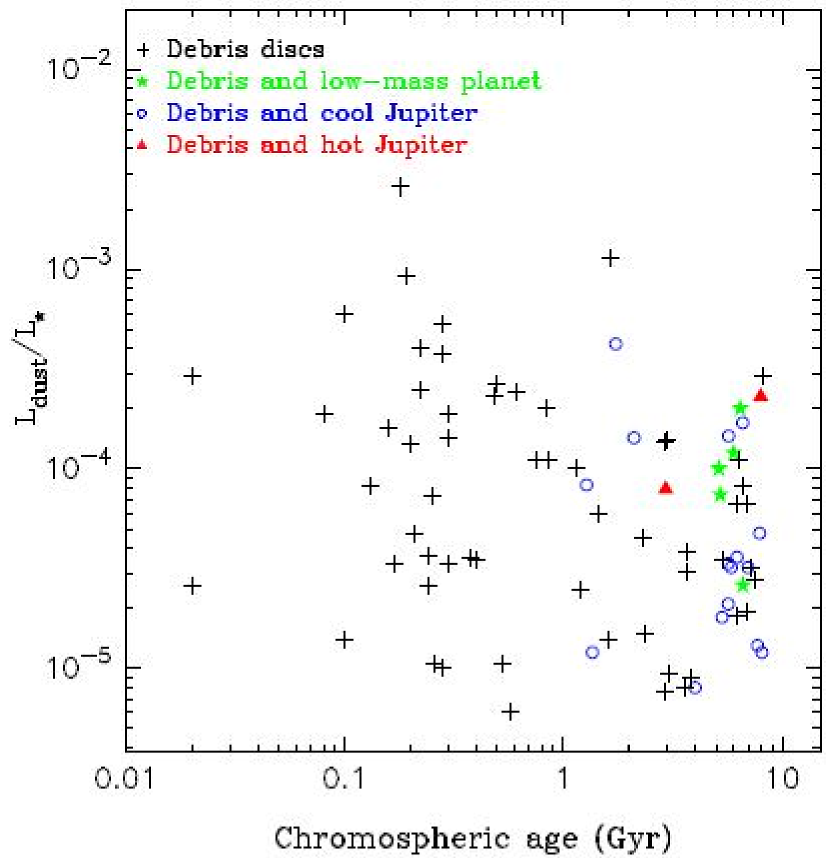
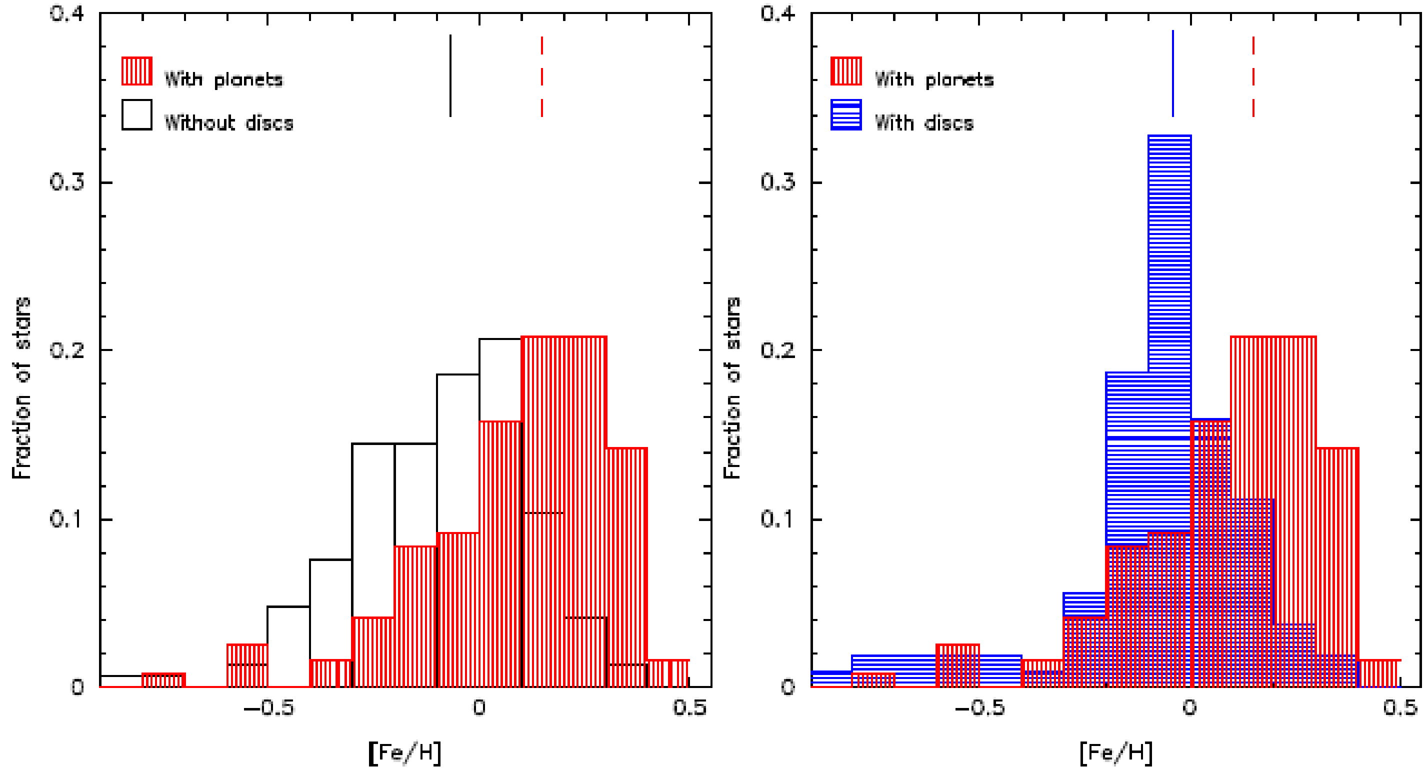


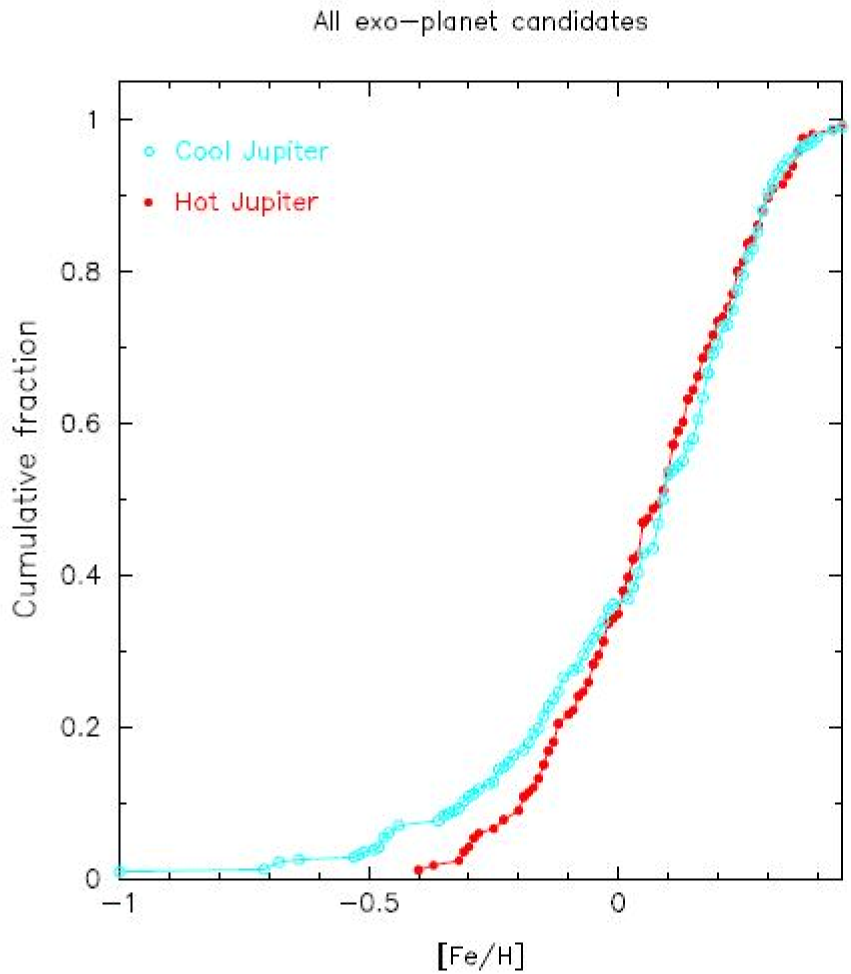
Fig. 2. [Fe/H] versus age for the stars in the SWODs (black crosses) and in the SWDs (blue asterisks) samples.



Debris discs
Debris and low−mass planet
Debris and cool Jupiter
Debris and hot Jupiter
$L_{dust}/L_{\star}$
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.01
0.1
1
10
Chromospheric age (Gyr)



With planets
Without discs
Fraction of stars
[Fe/H]
With planets
With discs
Fraction of stars
[Fe/H]


All exo-planet candidates
Cool Jupiter
Hot Jupiter
Cumulative fraction
0
0.2
0.4
0.6
0.8
1
−1
−0.5
0
[Fe/H]