Modelling the observed evolution of dust in galaxies

Aurélie Rémy-Ruyer

With: Suzanne Madden, Anthony Jones, Nathalie Ysard, Mélanie Köhler, Frédéric Galliano, Vianney Lebouteiller

Outline

Dust and galaxy evolution

- The ISM lifecycle
- Gas-to-dust mass ratios
- Dust-to-stellar mass ratios

A new description of dust

- Motivations for the new model
- Ingredients
- Validation on the diffuse ISM
- Impact on the dust evolution

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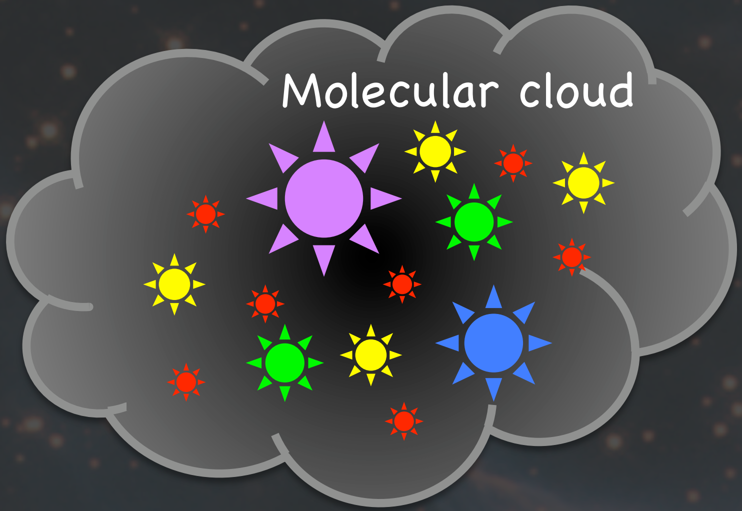
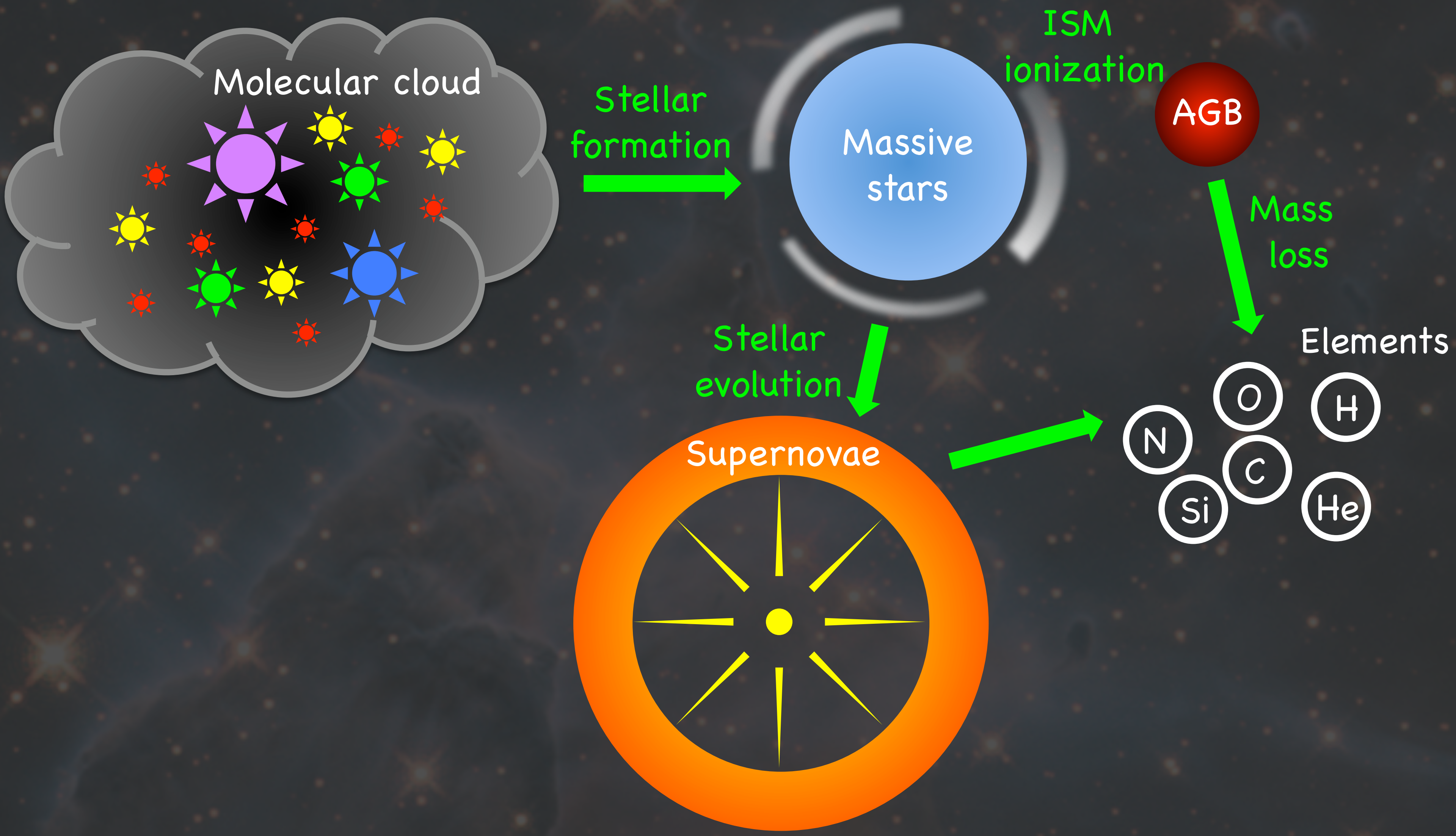
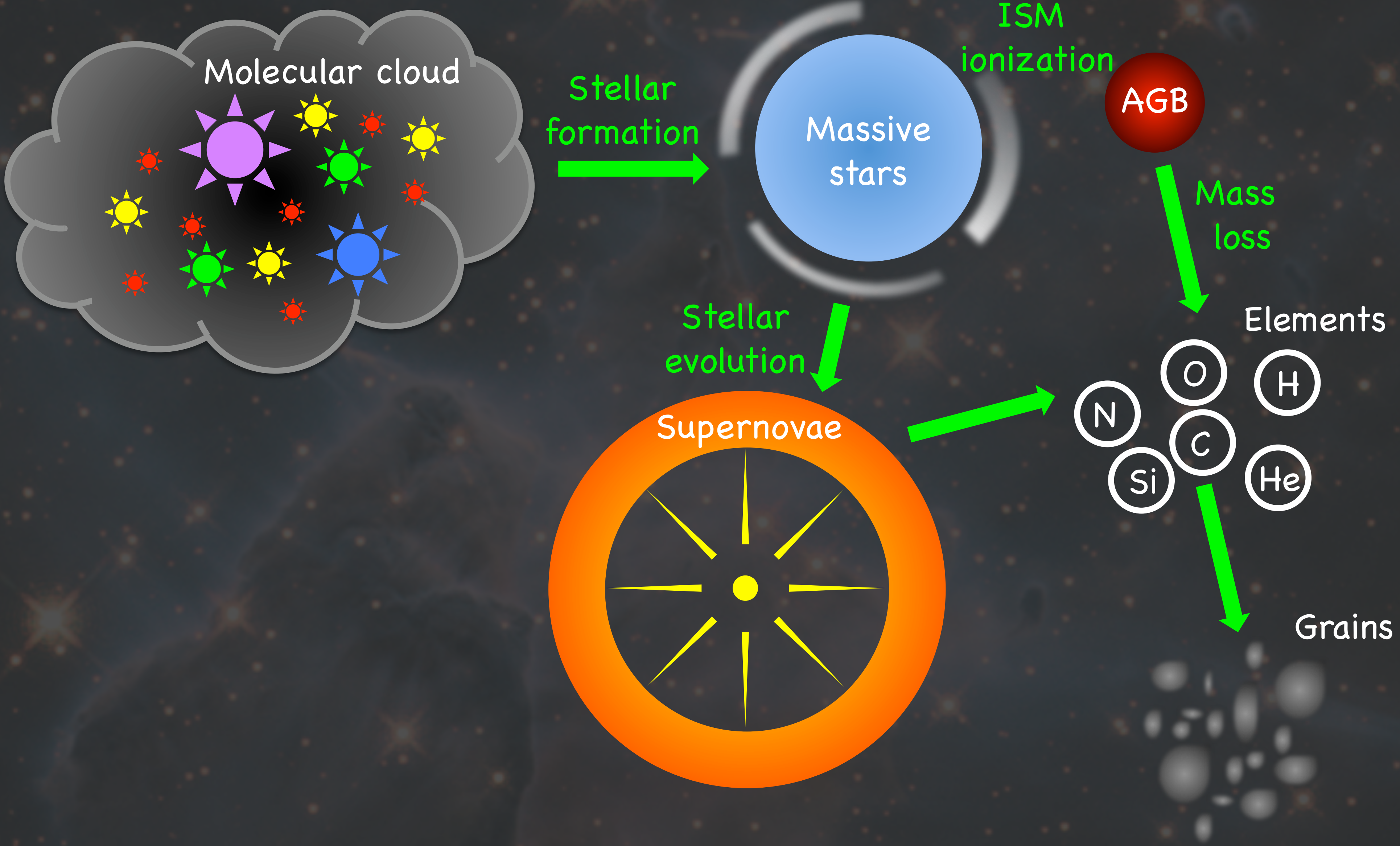
Dust and galaxy evolution: The ISM lifecycle



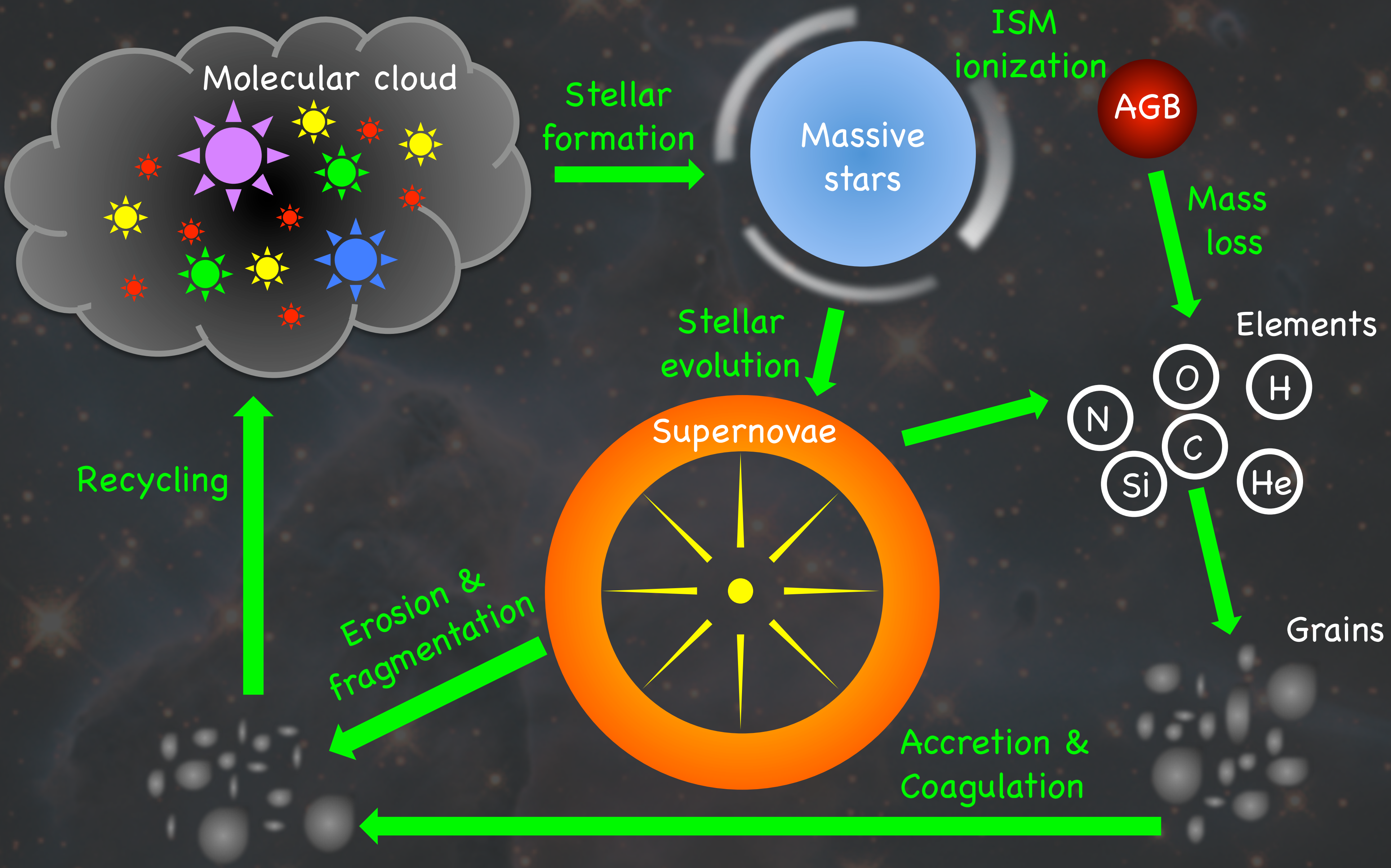
Dust and galaxy evolution: The ISM lifecycle



Dust and galaxy evolution: The ISM lifecycle



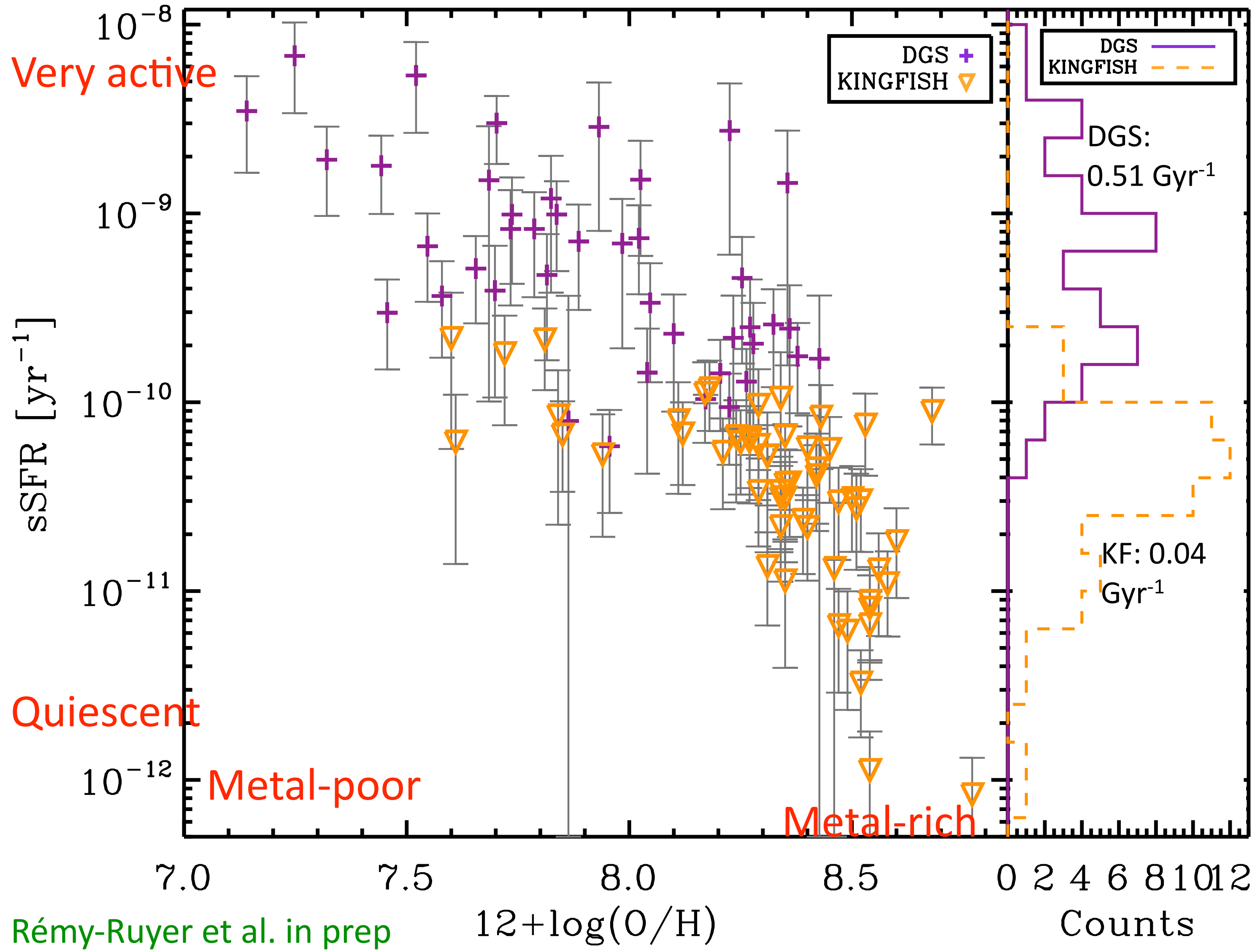
Dust and galaxy evolution: The ISM lifecycle



Dust and galaxy evolution: Sample

DGS : Dwarf Galaxy Survey
Madden+13, Rémy-Ruyer+13

KINGFISH
Kennicutt+11, Dale+12



Rémy-Ruyer et al. in prep

- Wide range of star-formation activity and metallicity
- ~100 sources

Dust and galaxy evolution: Ingredients

$\frac{G}{D}$ as a function of metallicity

See also:
Lisenfeld&Ferrara+98,
Hirashita+02, Draine+07,
Munoz-Mateos+09,
Galametz+11, Sandstrom
+13, Roman-Duval+14,
Grossi+15, etc.

Dust and galaxy evolution: Ingredients

Same « strong line » method for the whole sample

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Dust and galaxy evolution: Ingredients

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$\frac{G}{D}$ as a function of metallicity

Use Galliano+11 model:

- MW dust: silicates+graphite+PAHs (Zubko+04)
- ISRF from Mathis+83
- Power-law distribution for radiation field intensity (Dale+01)

See also:
Lisenfeld&Ferrara+98, Hirashita+02, Draine+07, Munoz-Mateos+09, Galametz+11, Sandstrom+13, Roman-Duval+14, Grossi+15, etc.

Dust and galaxy evolution: Ingredients

Atomic gas mass : HI

Molecular gas mass : H2, use $X_{CO,Z}$ from Schruba+12

Same « strong line » method for the whole sample

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Dust and galaxy evolution: Ingredients

From same dust model

$\frac{D}{S}$ as a function of SSFR

See also: Kauffmann +03, Brinchmann+04, Schiminovich+07, daCunha+10, Skibba +11, Cortese+12, etc.

Dust and galaxy evolution: Ingredients

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Empirical prescription from NIR bands (Eskew+12)

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Dust and galaxy evolution: Ingredients

From same dust model

SSFR = SFR/S
SFR from Hα measurements, corrected for dust attenuation with L_{TIR} (Kennicutt&Evans+12)

$\frac{D}{S}$ as a function of SSFR

See also: Kauffmann+03, Brinchmann+04, Schiminovich+07, daCunha+10, Skibba+11, Cortese+12, etc.

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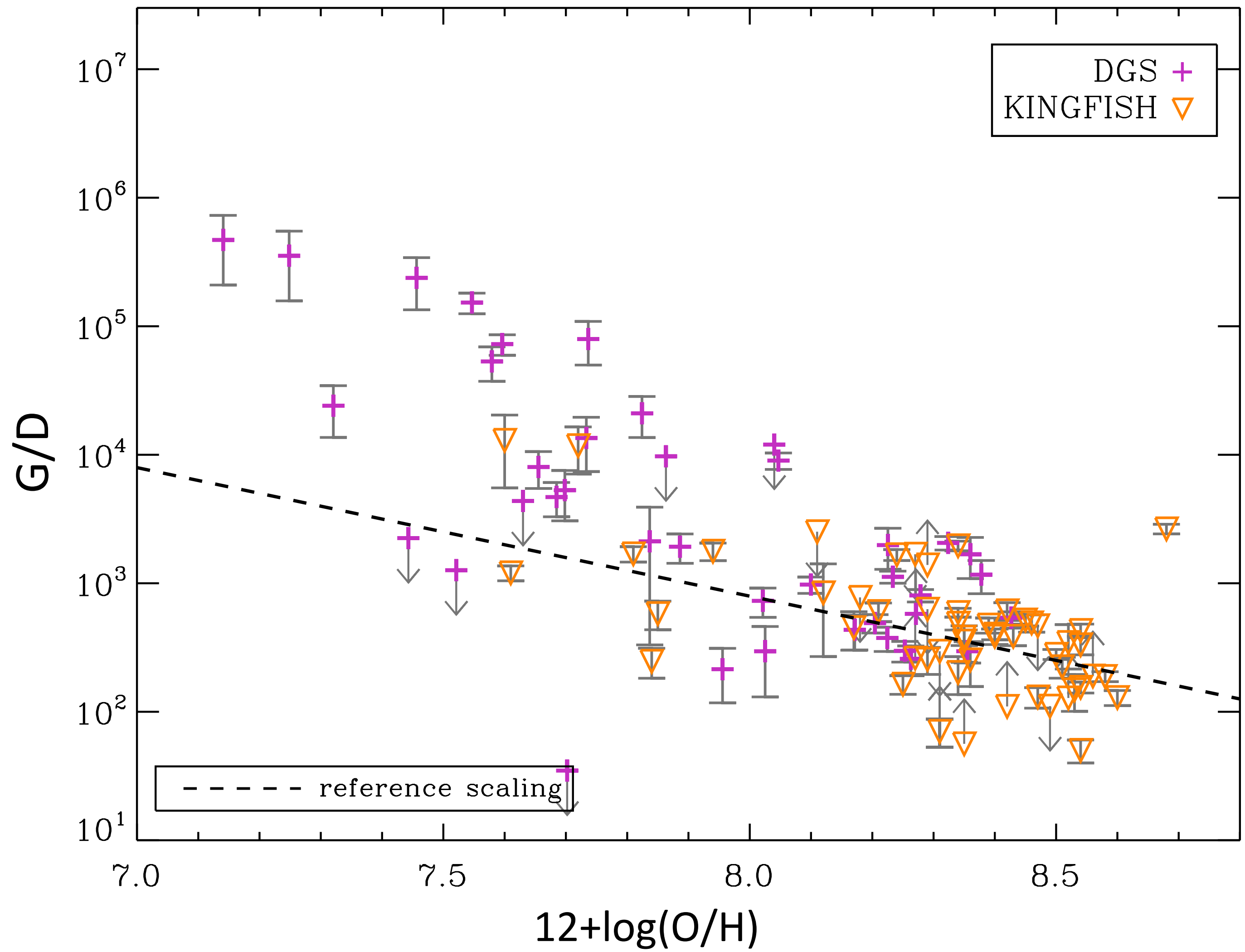
Dust and galaxy evolution: G/D and metallicity

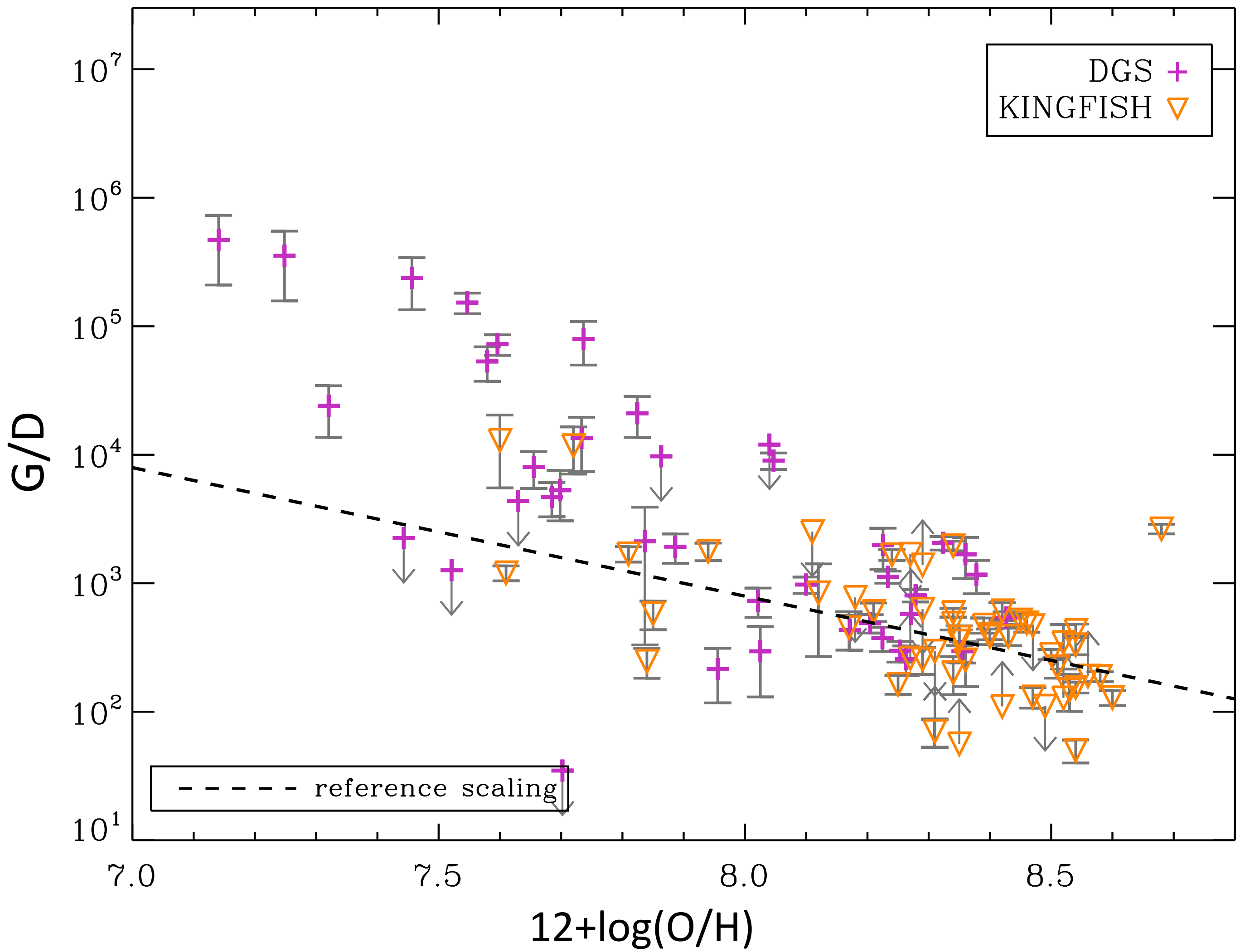
Rémy-Ruyer+14



- Large scatter

Dust and galaxy evolution: G/D and metallicity

Rémy-Ruyer+14

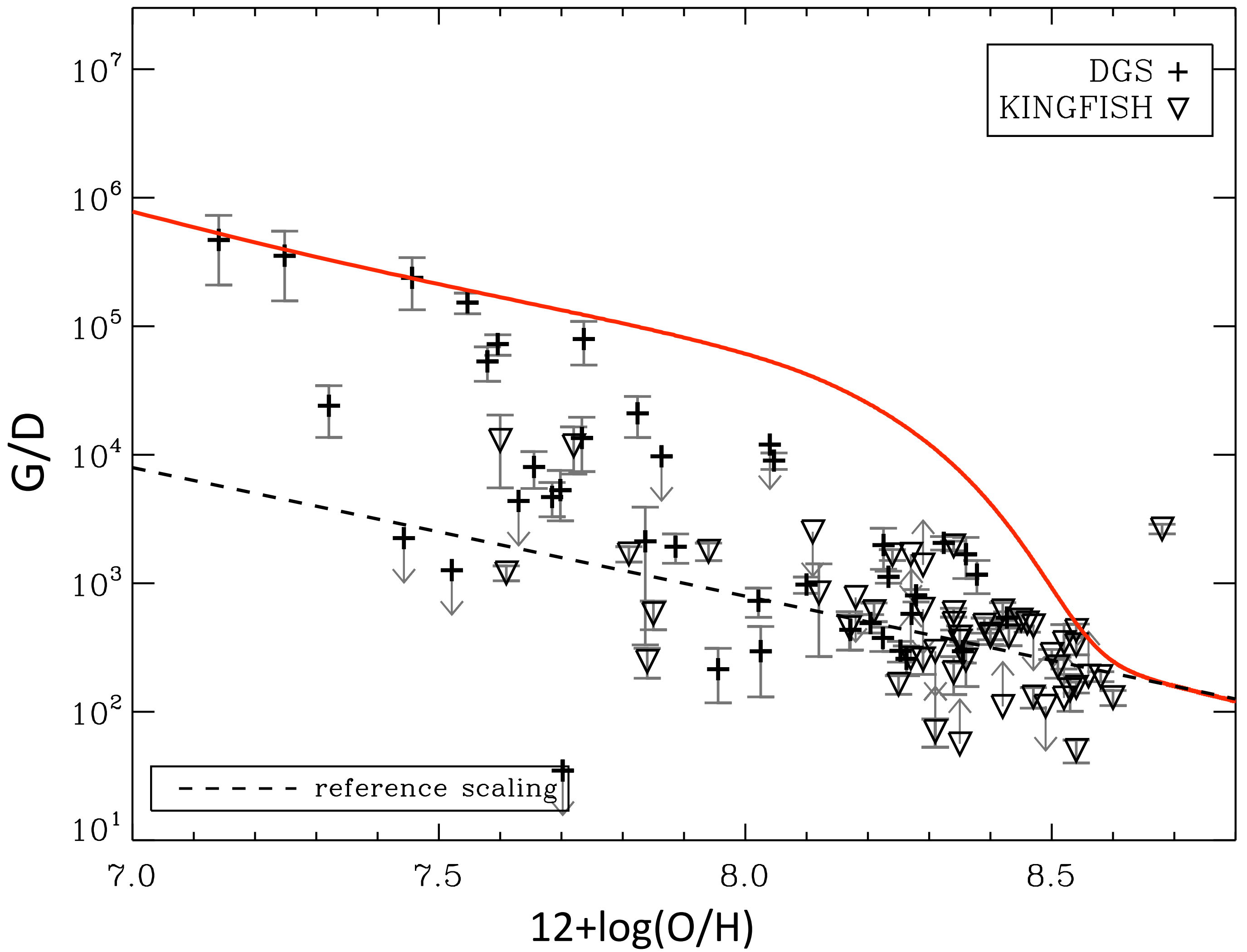


- Large scatter

- Not coherent at low metallicities with a simple description of dust evolution in the ISM

Dust and galaxy evolution: Chemical evolution

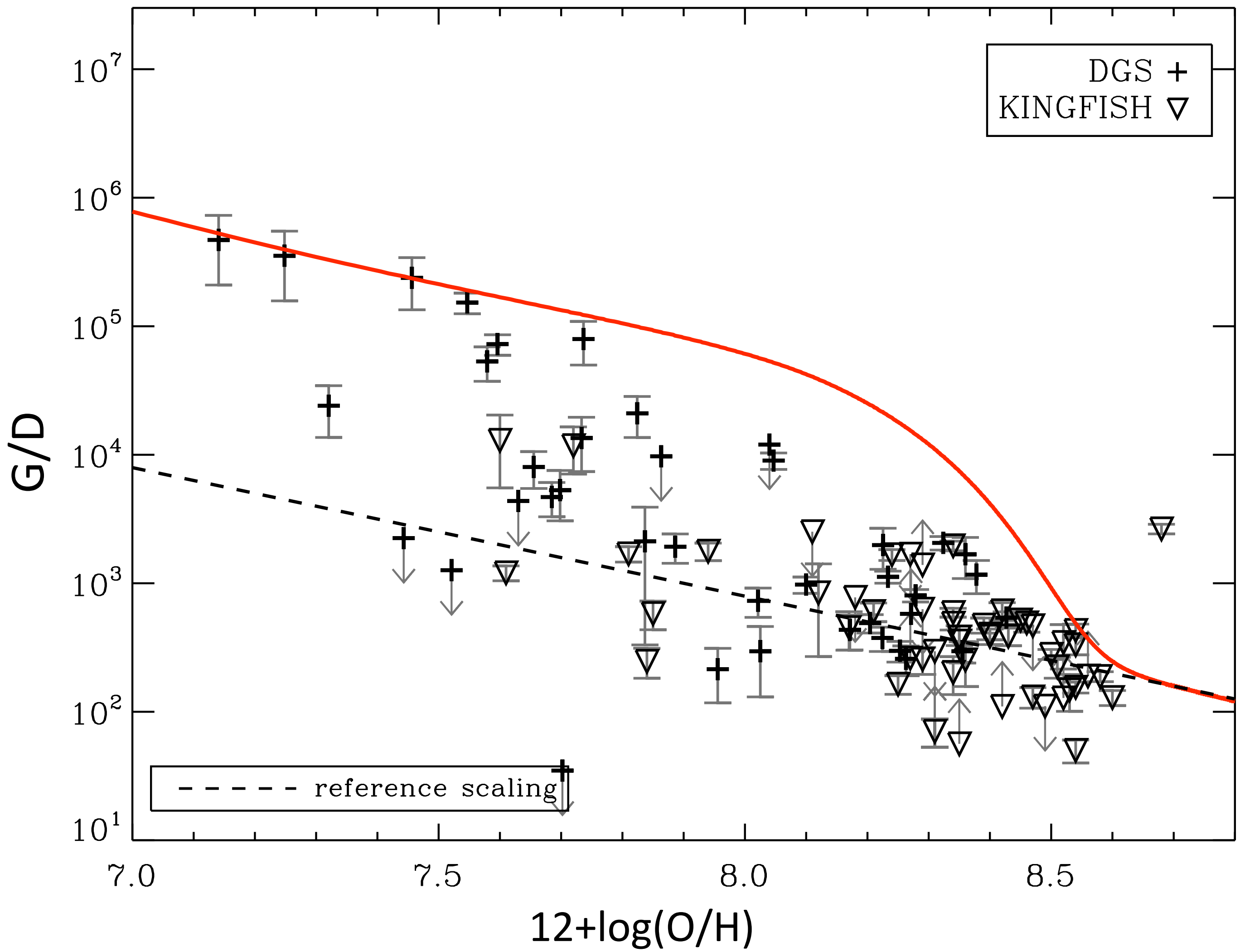
Rémy-Ruyer+14



- Chemical evolution model by Asano+13

Dust and galaxy evolution: Chemical evolution

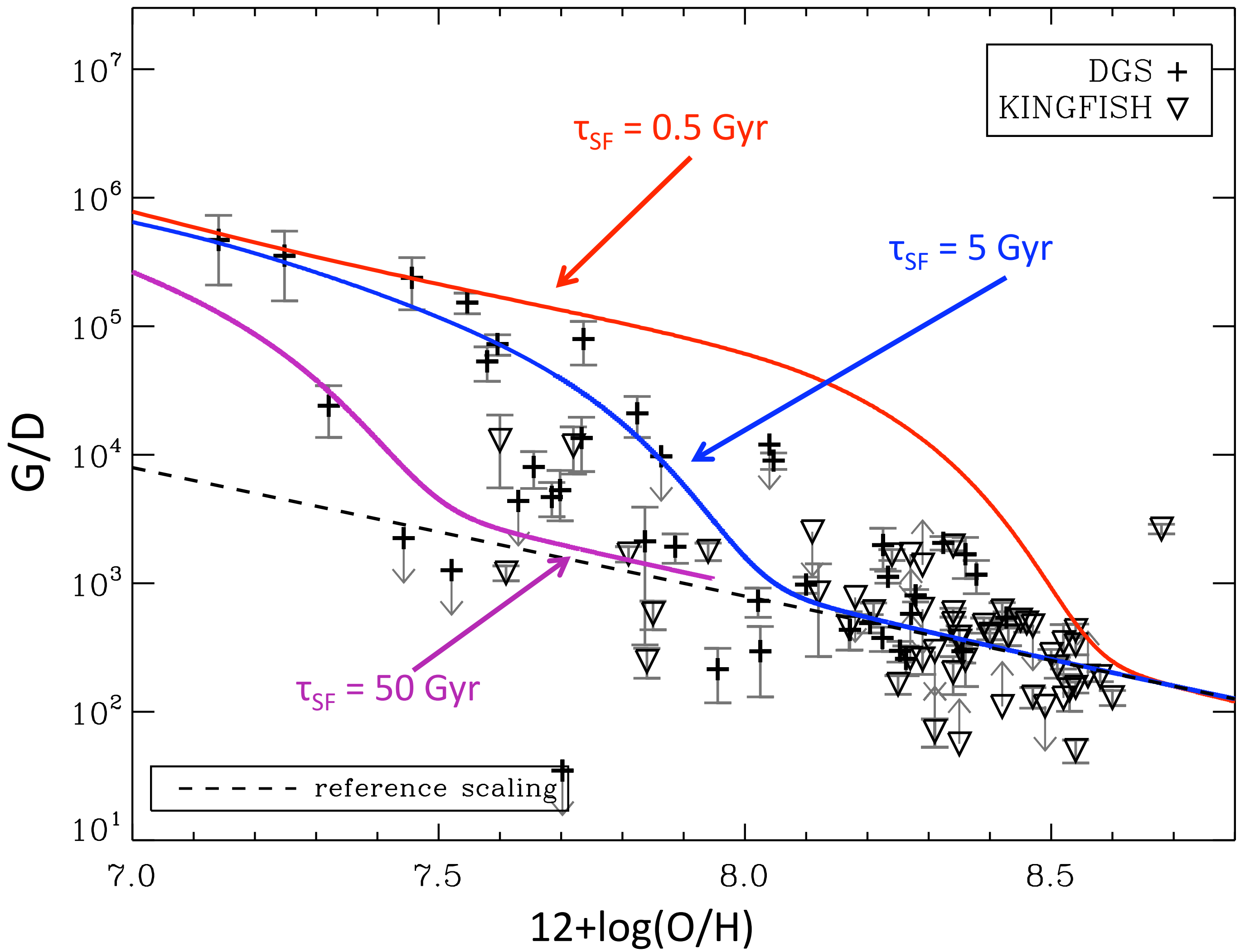
Rémy-Ruyer+14



- Chemical evolution model by Asano+13
- « Critical » metallicity over which dust growth is the main process in the dust mass evolution

Dust and galaxy evolution: Chemical evolution

Rémy-Ruyer+14



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- Depends on the star formation timescale

Dust and galaxy evolution: Chemical evolution

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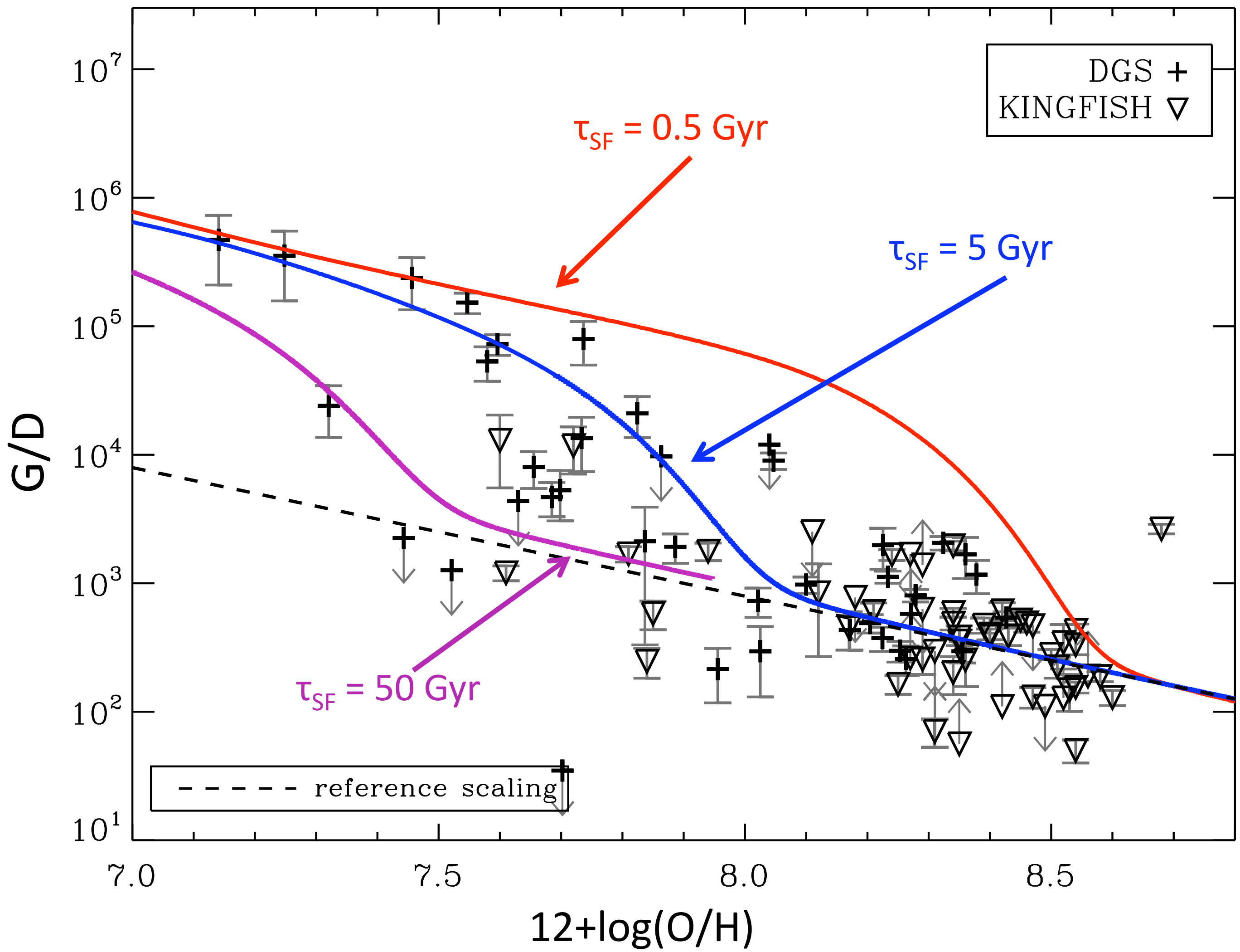
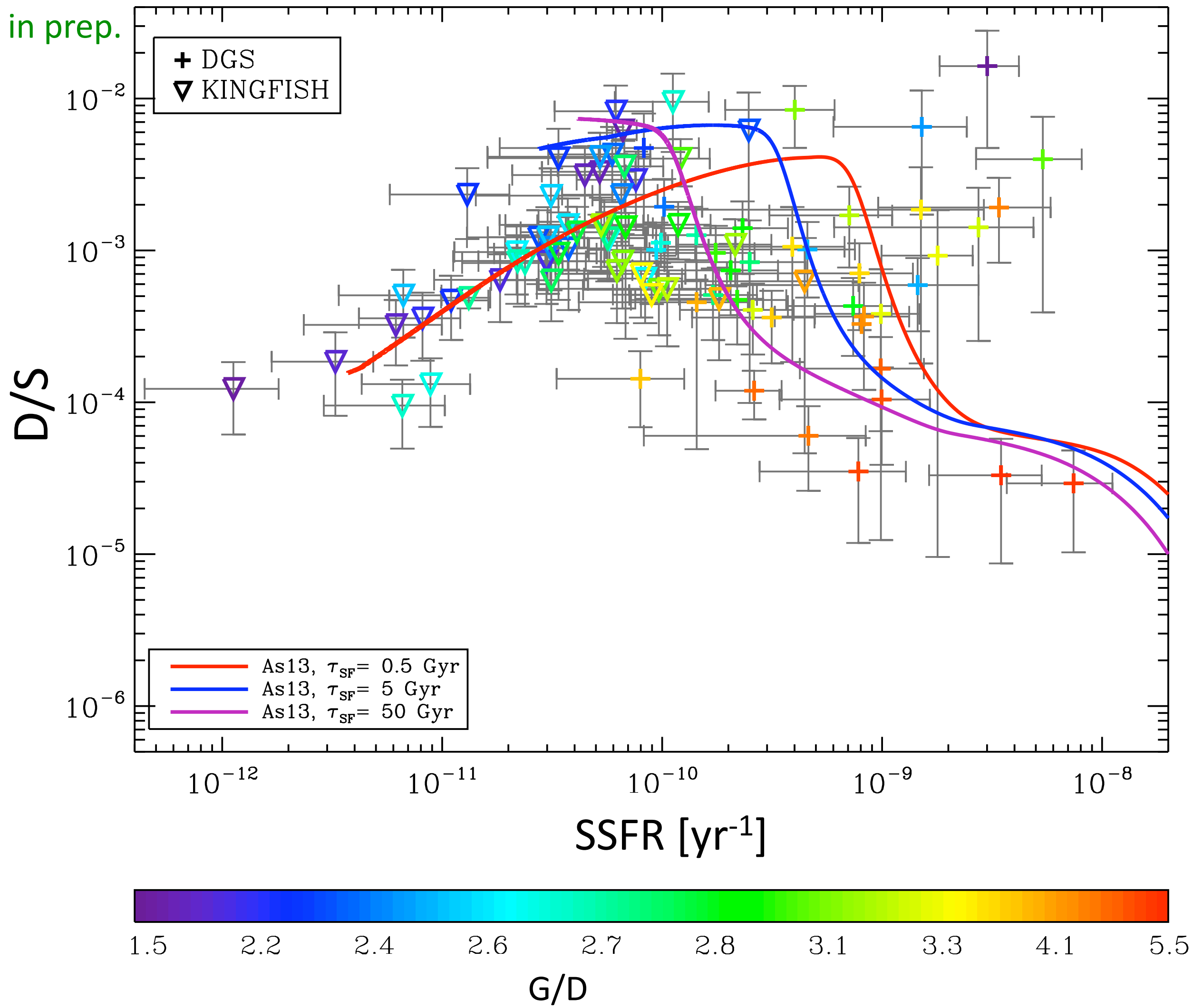


- Chemical evolution model by Asano+13
- « Critical » metallicity over which dust growth is the main process in the dust mass evolution
- Depends on the star formation timescale

➢Scatter can be explained if you account for the different star formation histories of the sources

Dust and galaxy evolution: D/S and SSFR

Rémy-Ruyer+15
in prep.



Dust and galaxy evolution: D/S and SSFR

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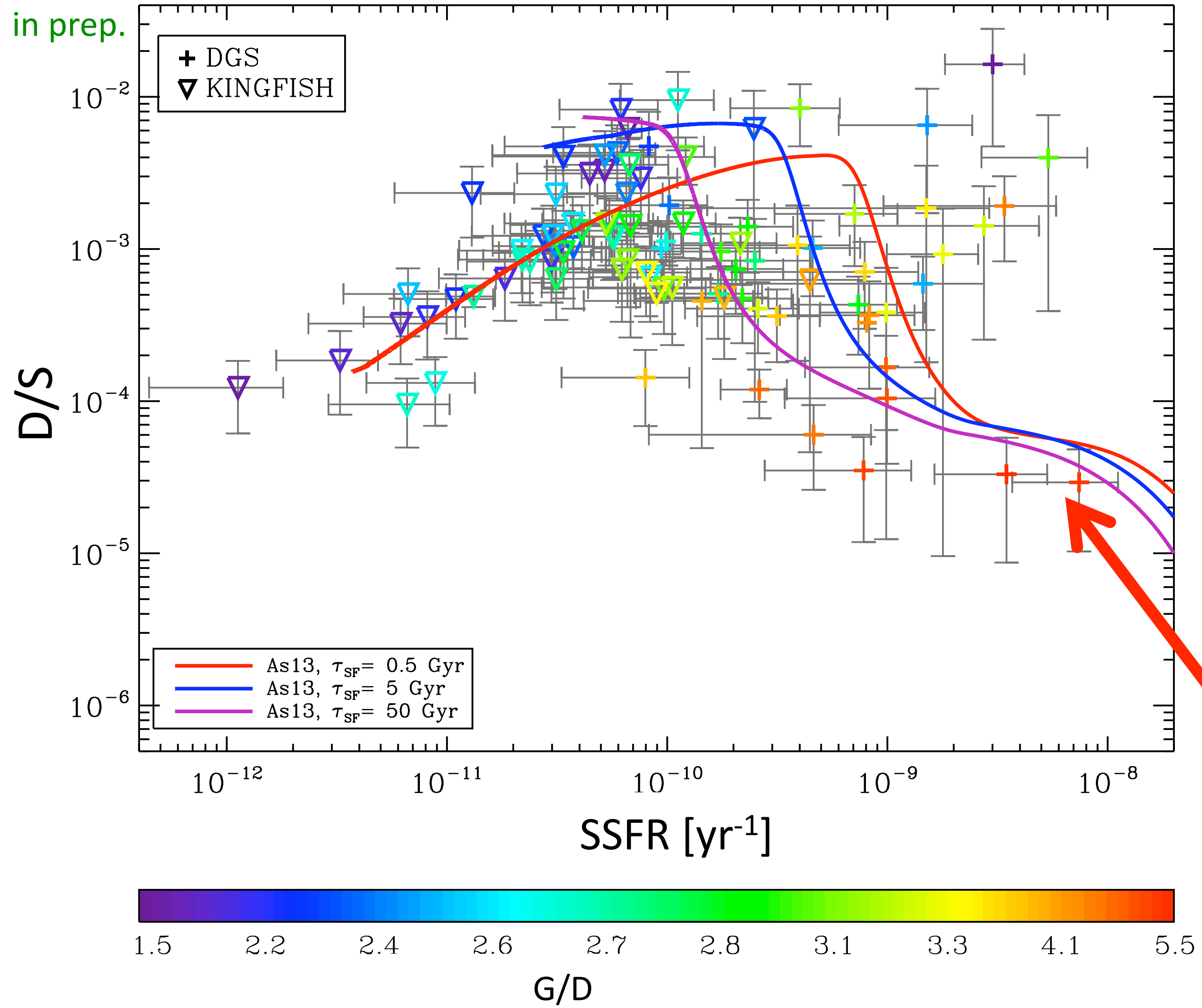

High SSFR, low Z ,low M_{star}, high G/D

Dust and galaxy evolution: D/S and SSFR

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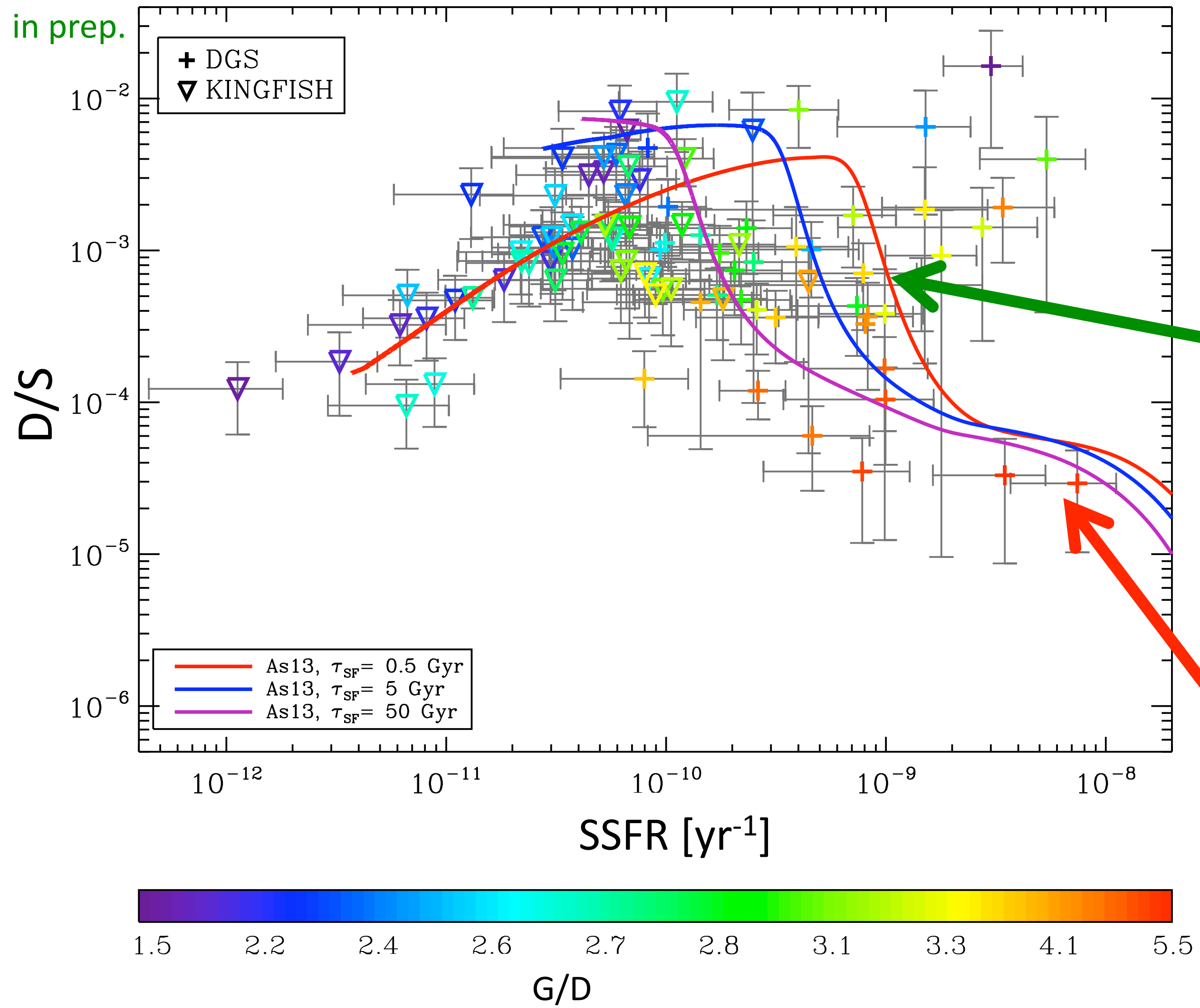

Dust growth: M_{dust} increases, scatter arises from different evolutionnay stages

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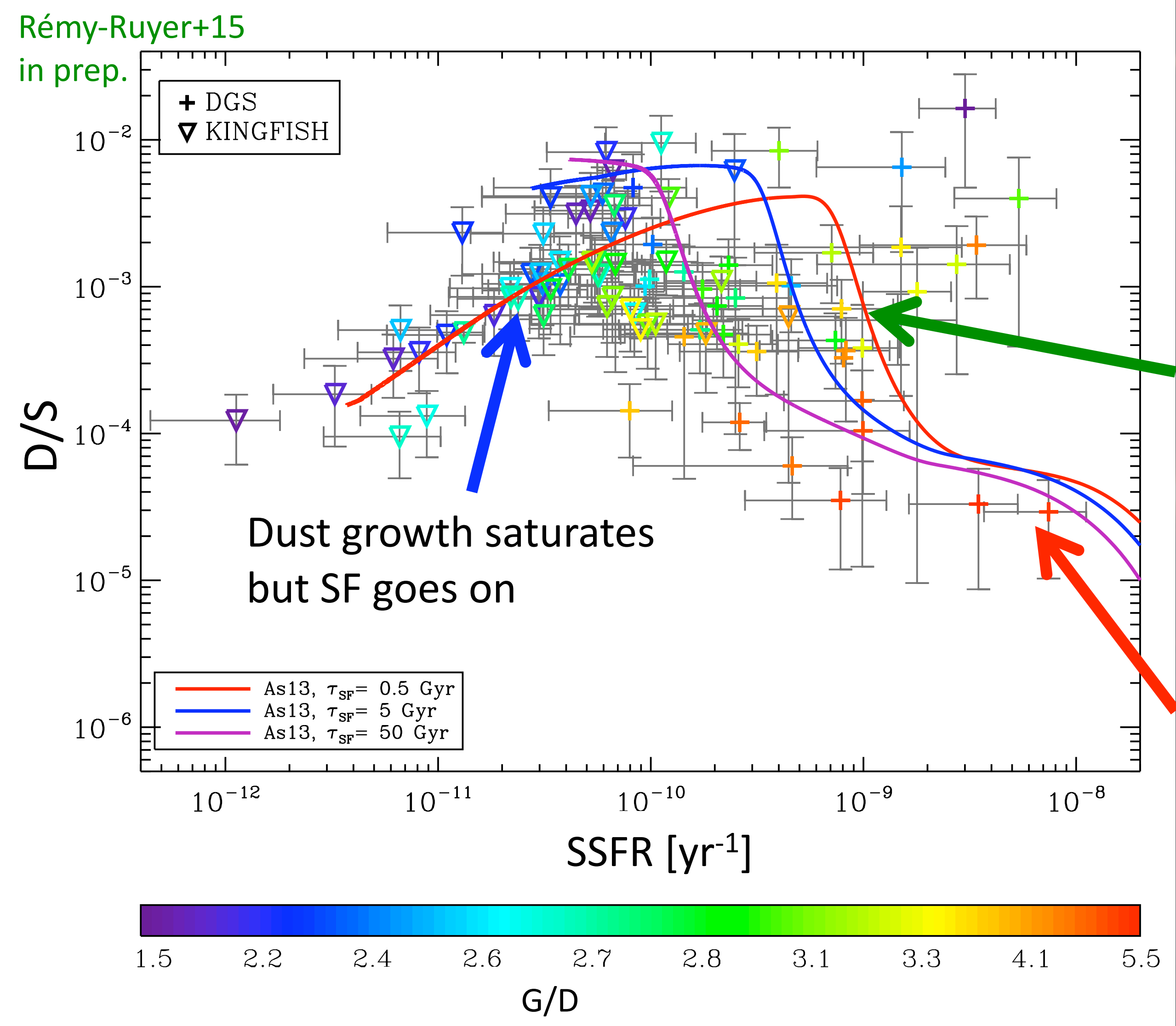

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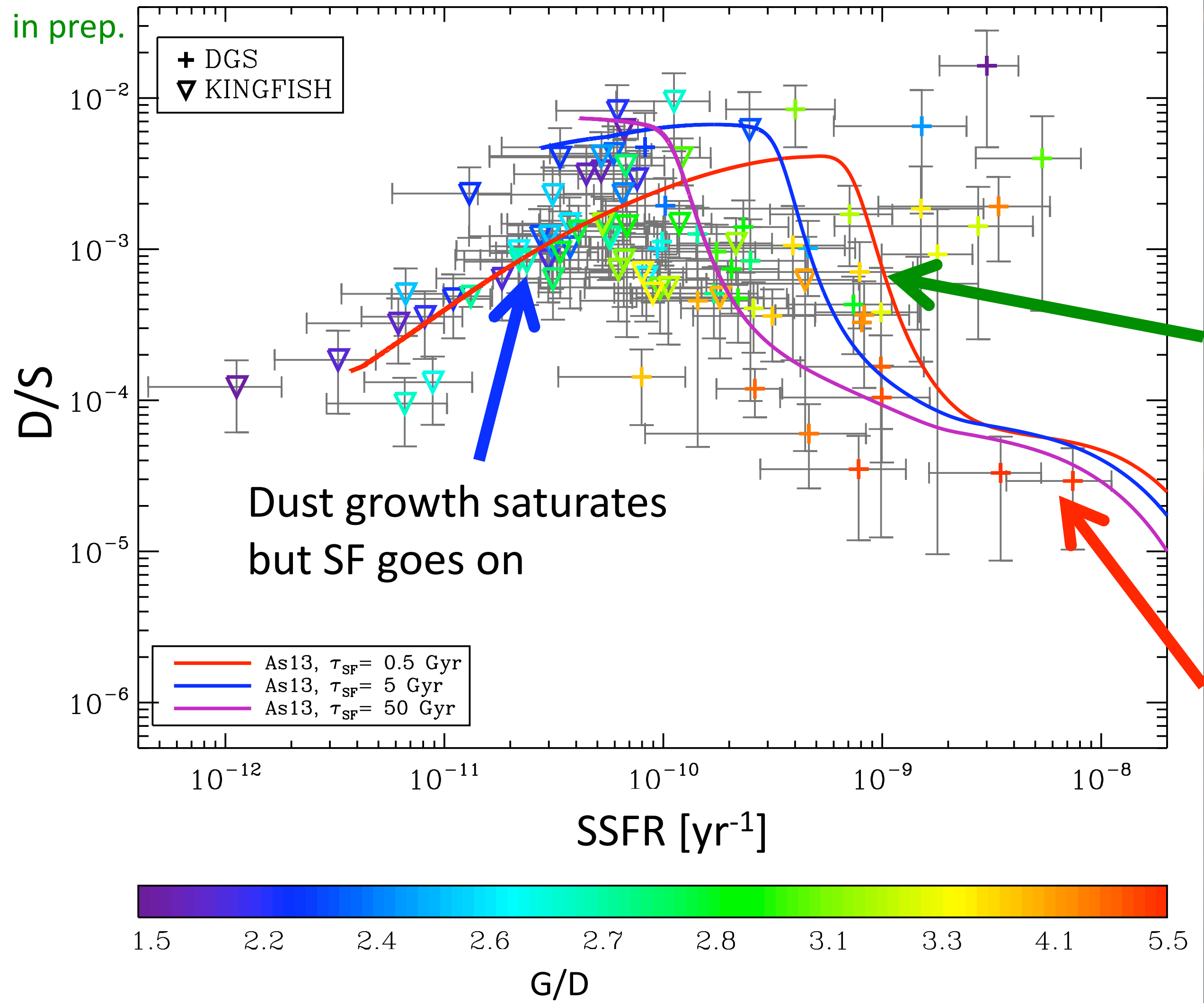

Dust growth: M_{dust} increases, scatter arises from different evolutionnay stages

High SSFR, low Z ,low M_{star}, high G/D

- Dust growth in the ISM is fundamental

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DustPedia

A new dust model: Motivations

- Key is dust growth in the ISM…

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  … but previous model uses homogeneous grains

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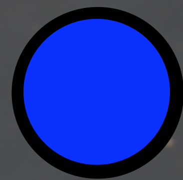
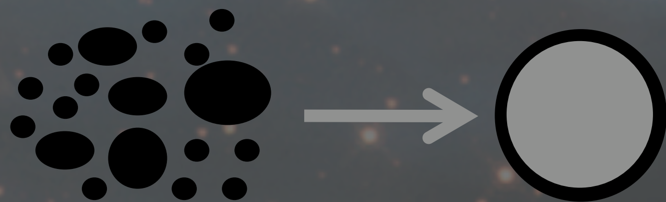
	Galliano+11 based on Zubko+04, but also Draine&Li+07 and others	
Silicates	« Astronomical silicates » Olivine-type ($MgFeSiO_4$)	Draine&Lee+84, Weingartner&Draine+01, Li&Draine+01 • Modified to fit the data
Carbons	Graphites + PAHs 	Laor&Draine+93, Draine&Malhotra+93, Li&Draine +01, Draine&Li+07 • No observational evidence of graphite or PAHs in the diffuse ISM

A new dust model: Ingredients

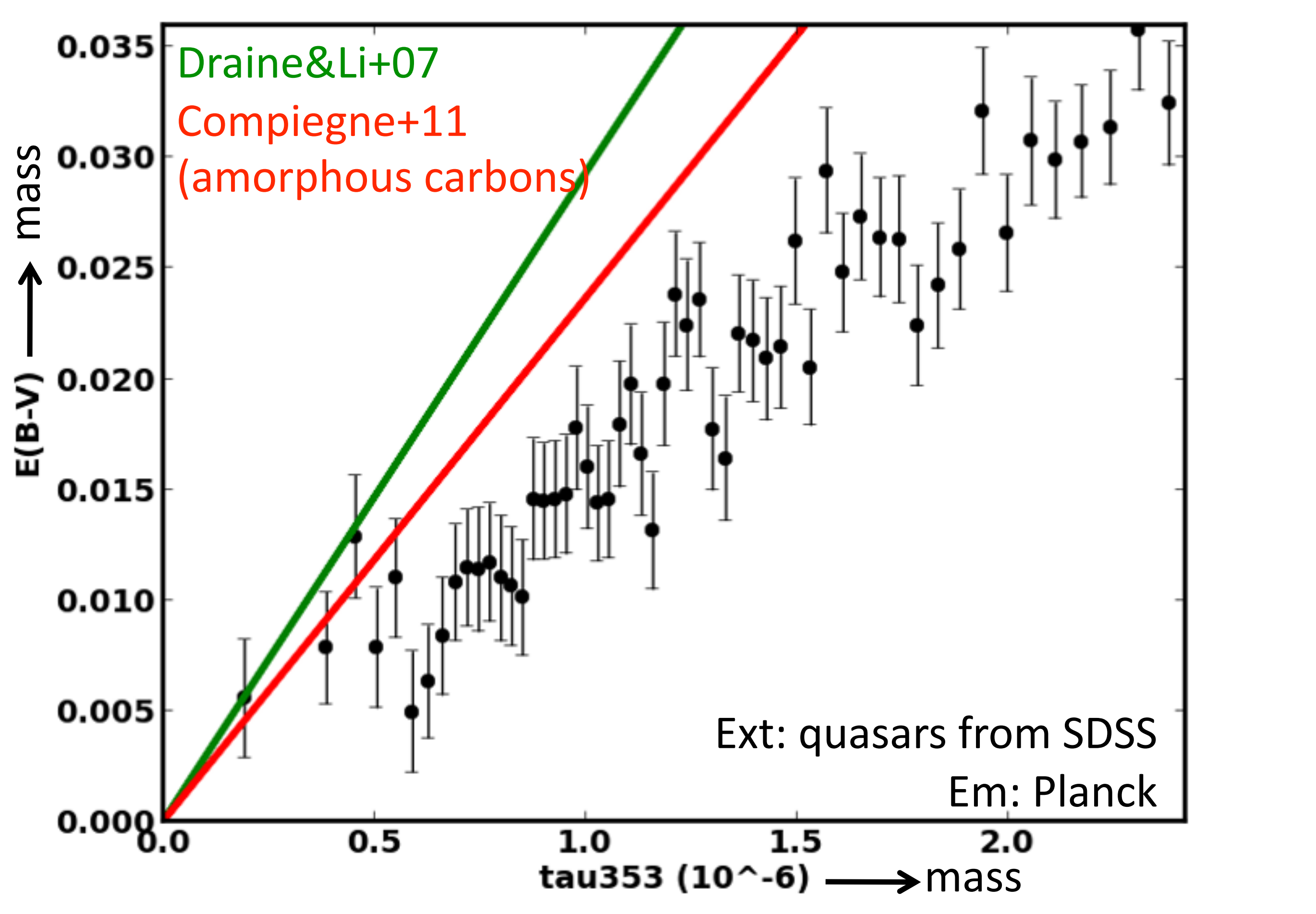
- New dust grains with a « core-mantle » structure
  - Optical properties derived from laboratory measurements
  - Consistent with elemental abundances

	Galliano+11 based on Zubko+04, but also Draine&Li+07 and others	Jones+13 & Köhler+14
Silicates	« Astronomical silicates » Olivine-type ($MgFeSiO_4$) 	Amorphous pyroxene & olivine with Fe/FeS inclusions 
Carbons	Graphites + PAHs 	Hydrogenated amorphous carbons 

A new dust model: Caveats of previous models

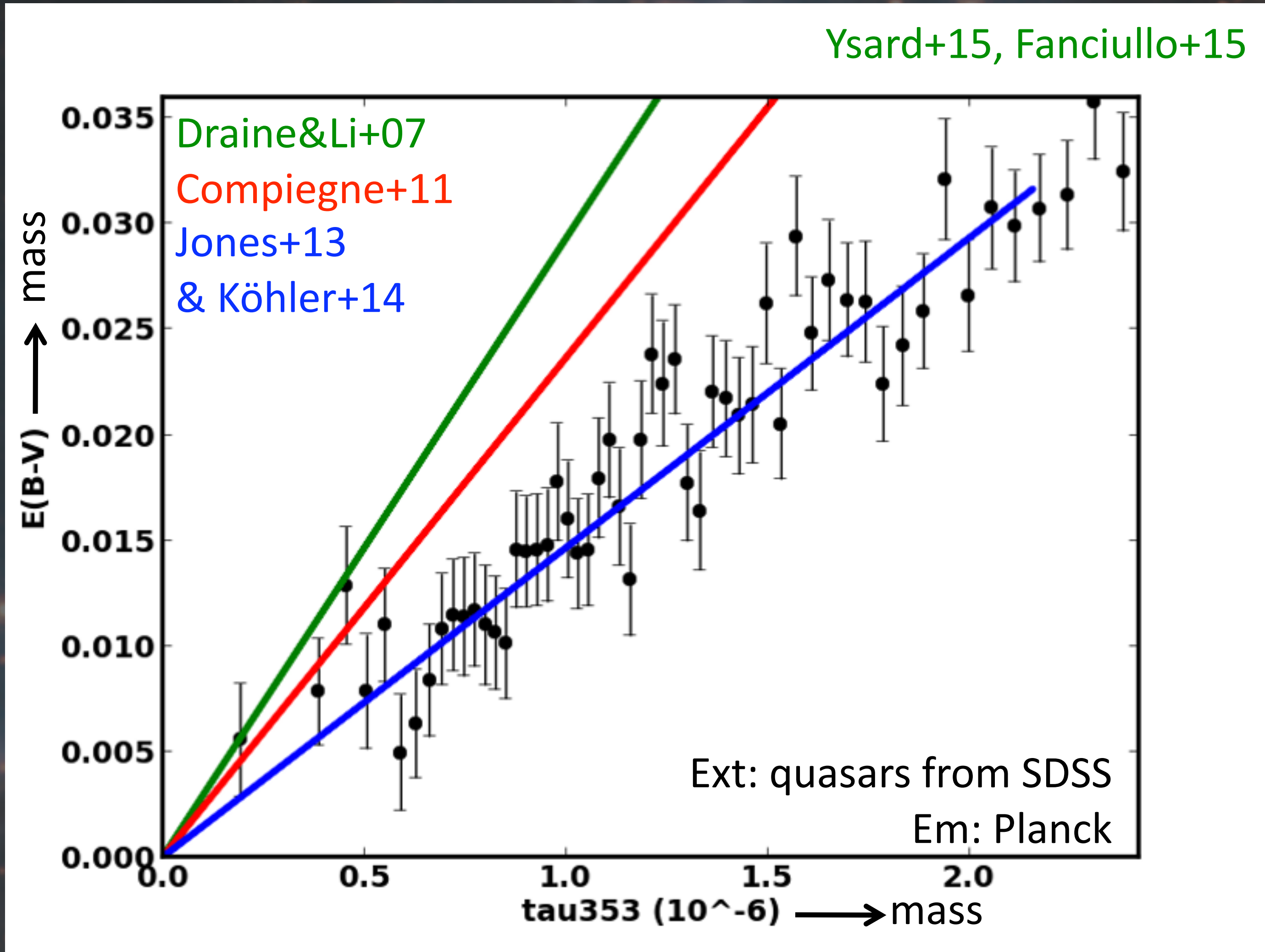
➢ Inconsistency between the emission and extinction measurements

Planck Collaboration XI (2014)



A new dust model: Consistent extinction & emission

- Explain self-consistently emission and extinction measurements



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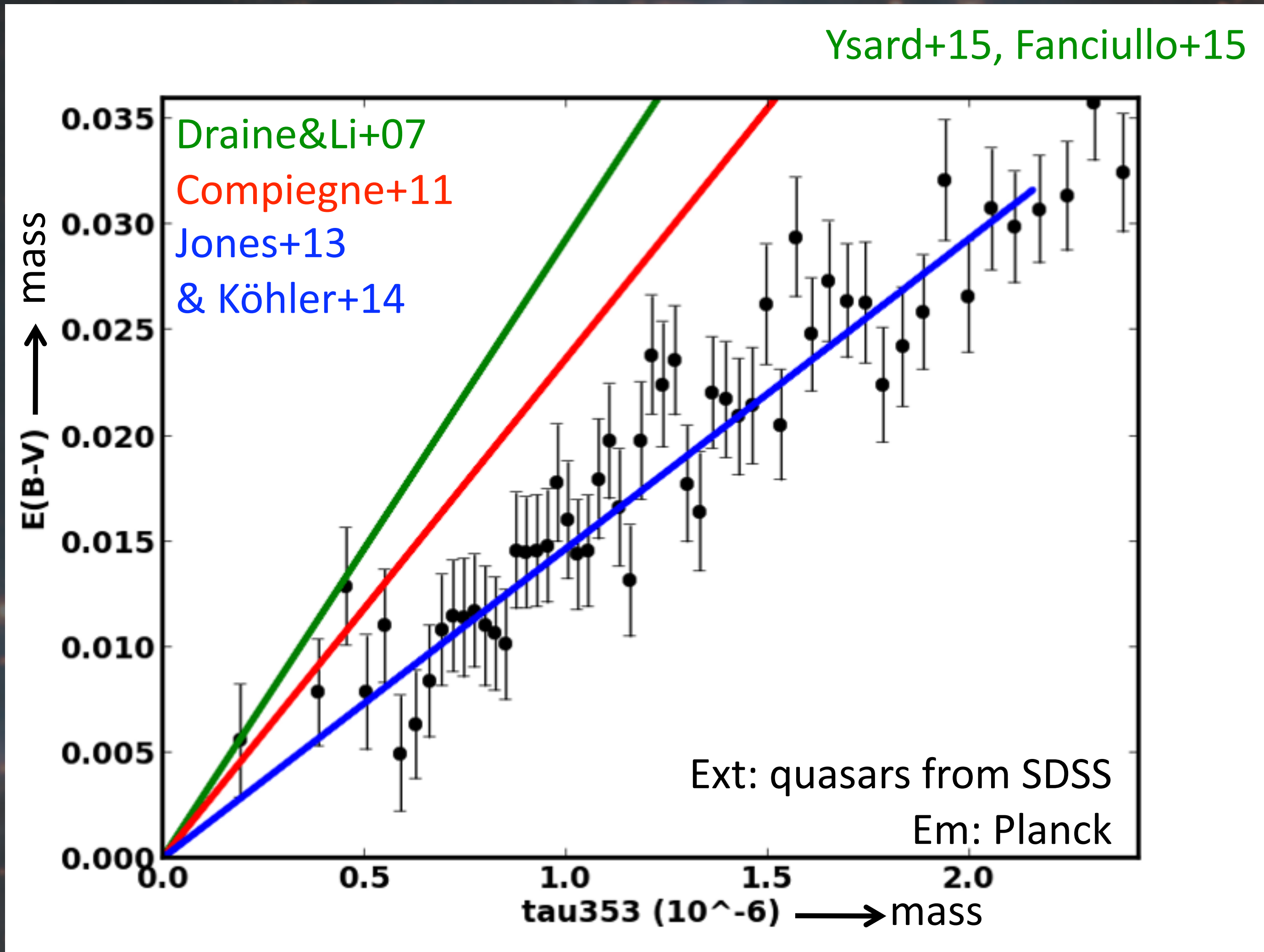
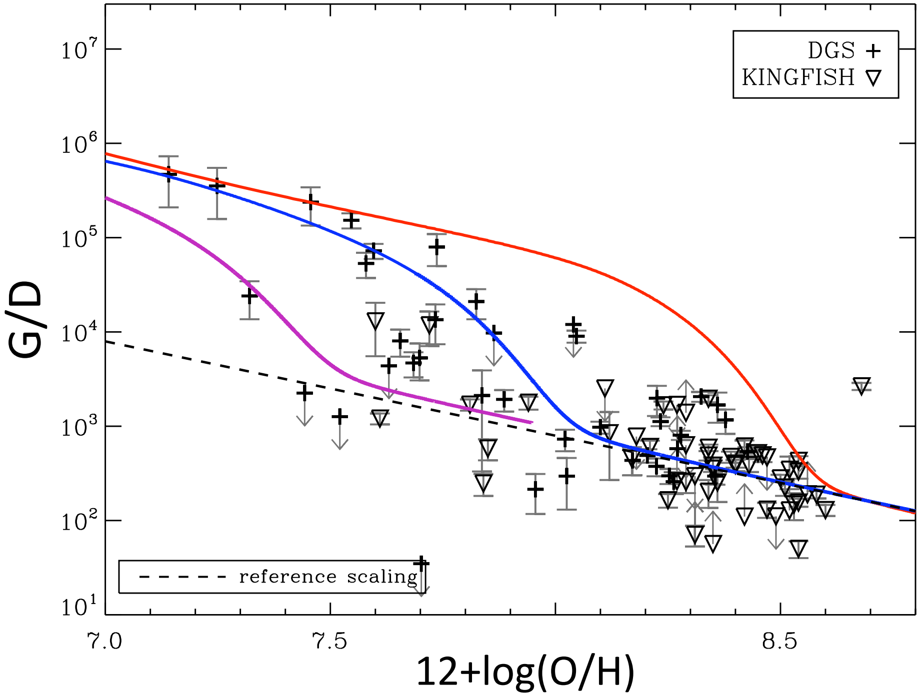
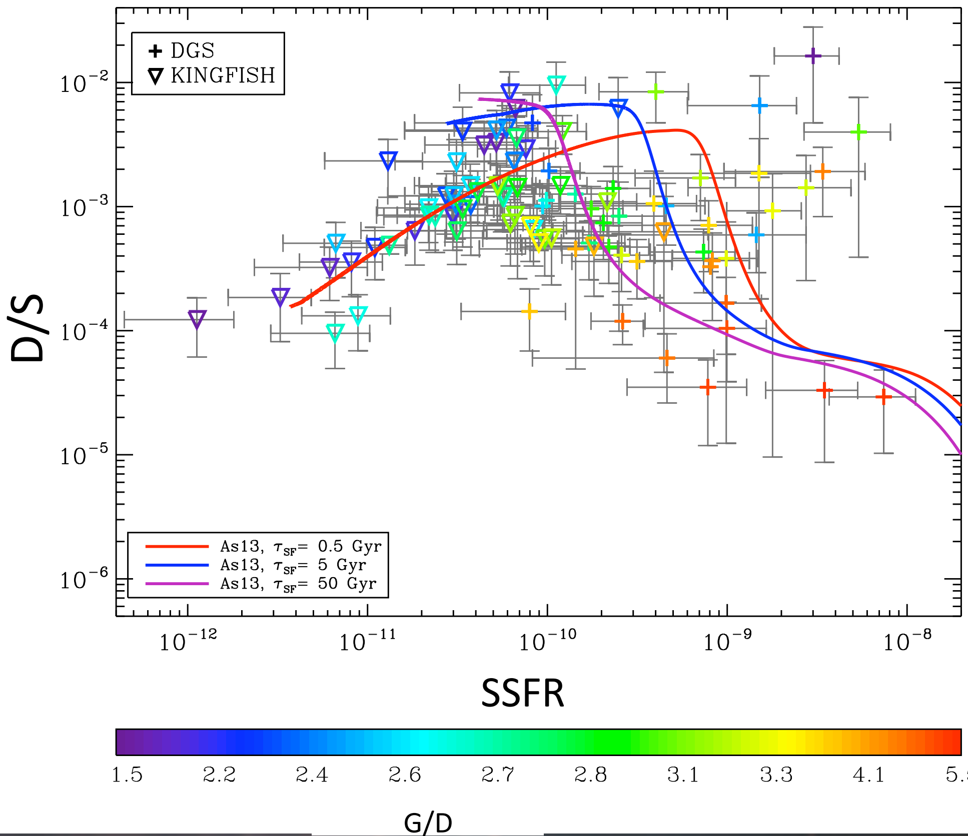


- Tested and validated in the diffuse ISM (Jones+13, Köhler+14, Ysard+15)
- Tested and validated in the dense ISM (Köhler+15)

Impact on G/D and D/S





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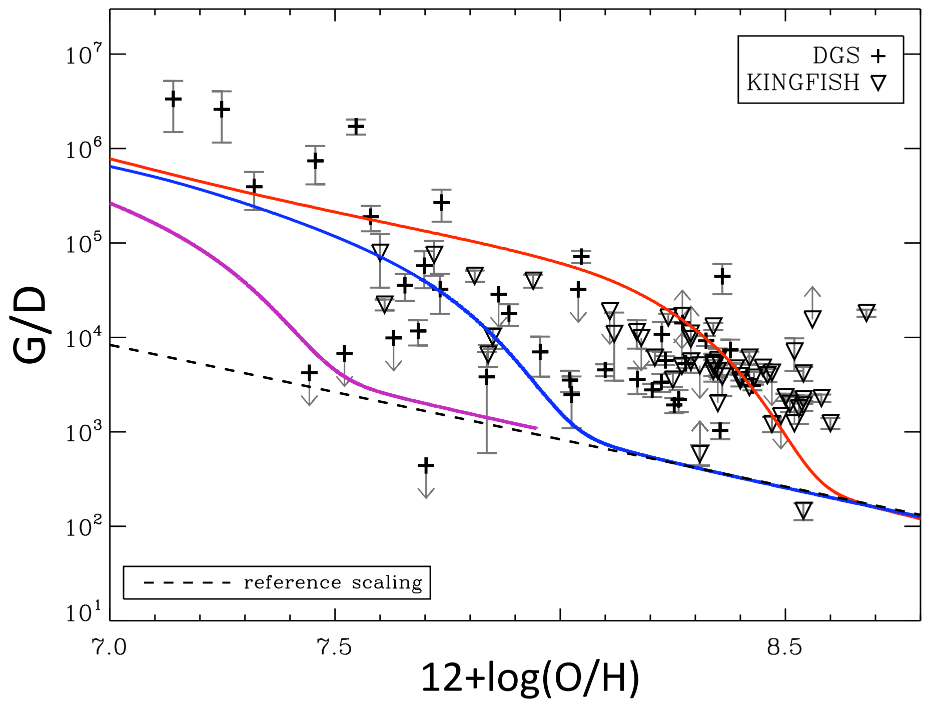

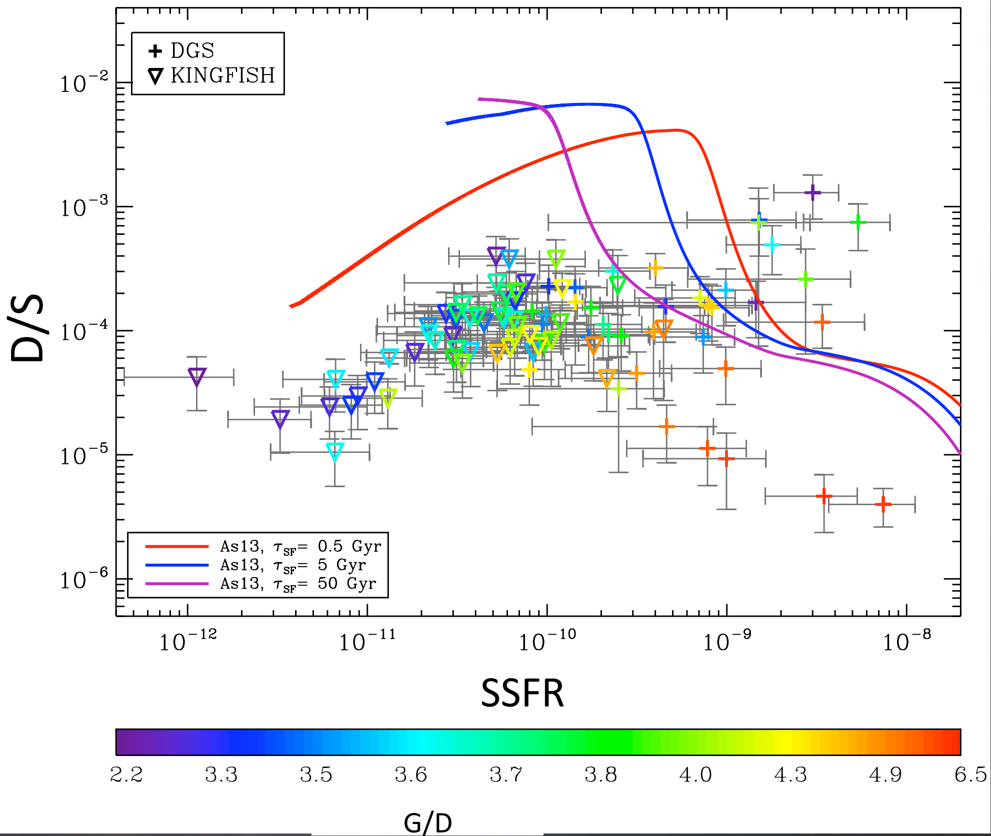

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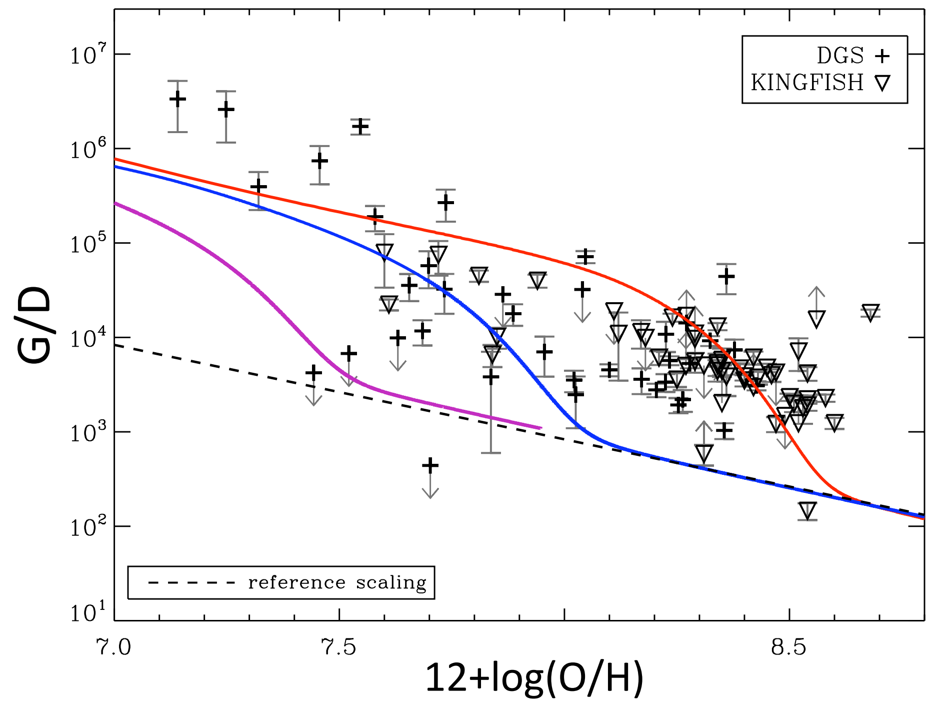
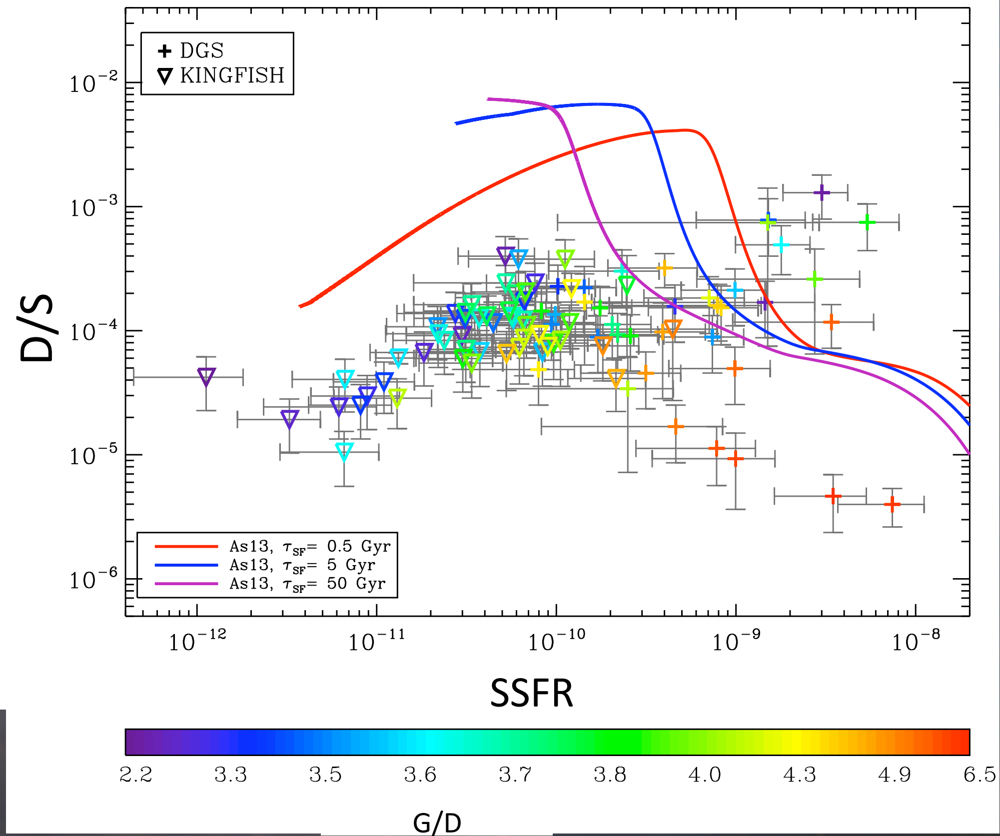
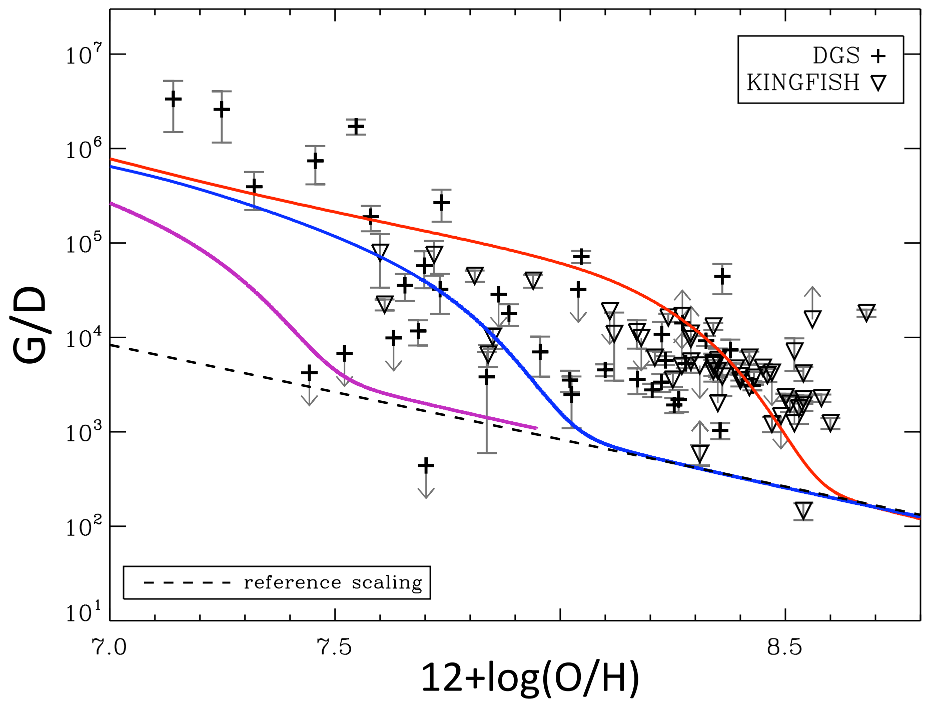
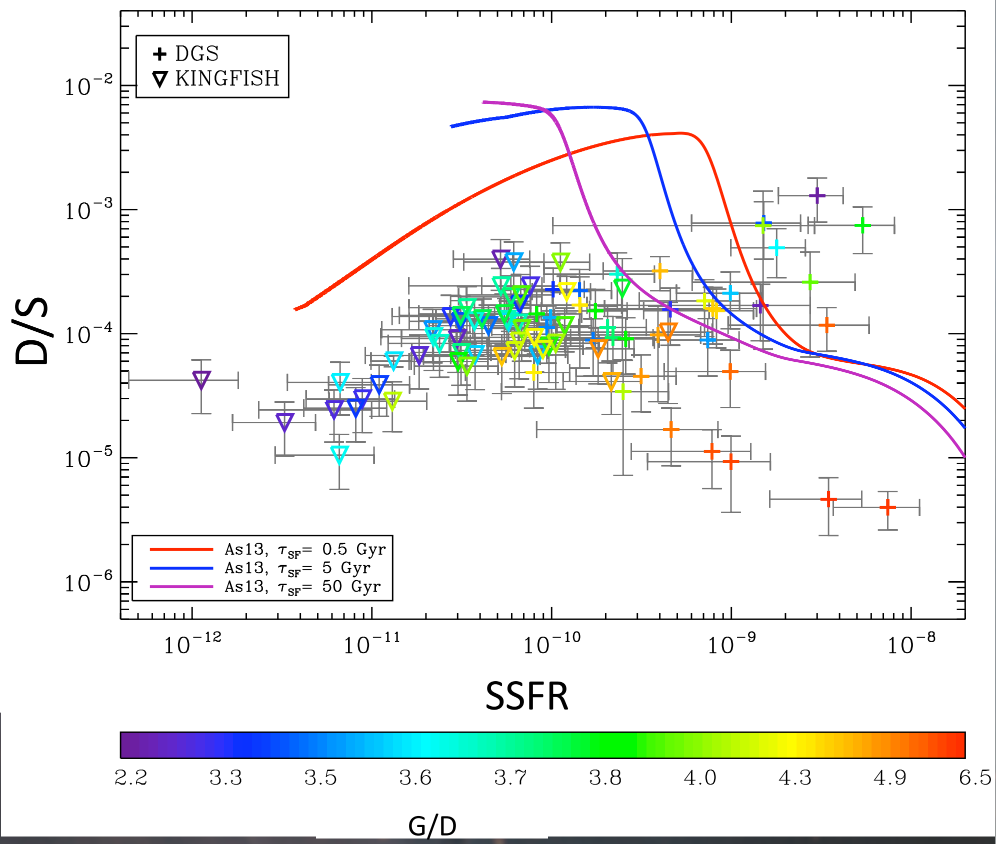




- Global trend is still the same
- Absolute scale is changing: variation of a factor of ~4 -5 in the dust mass

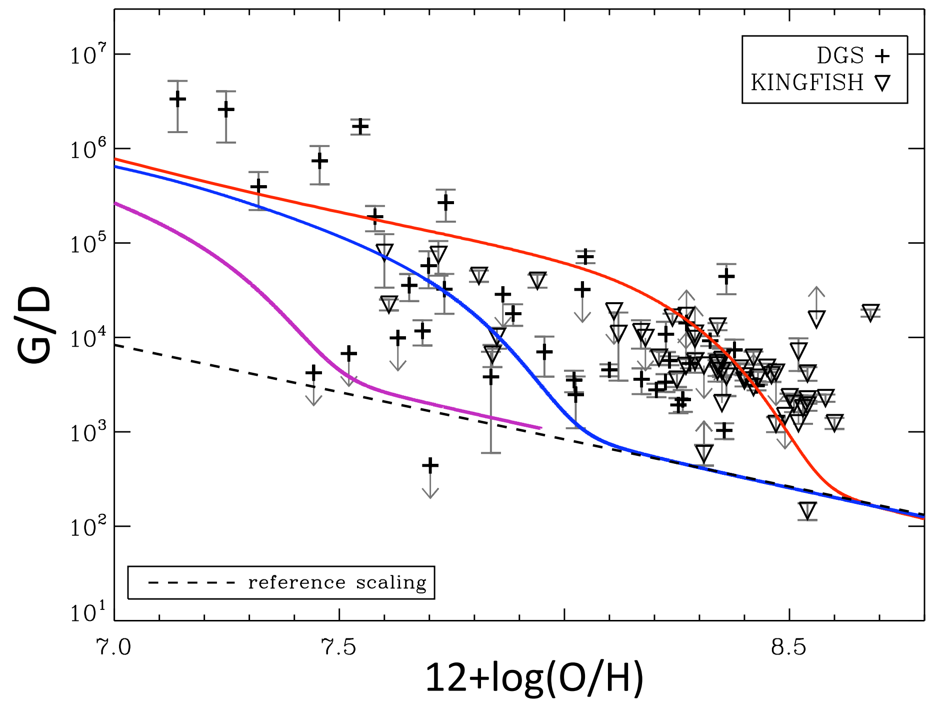
Impact on G/D and D/S

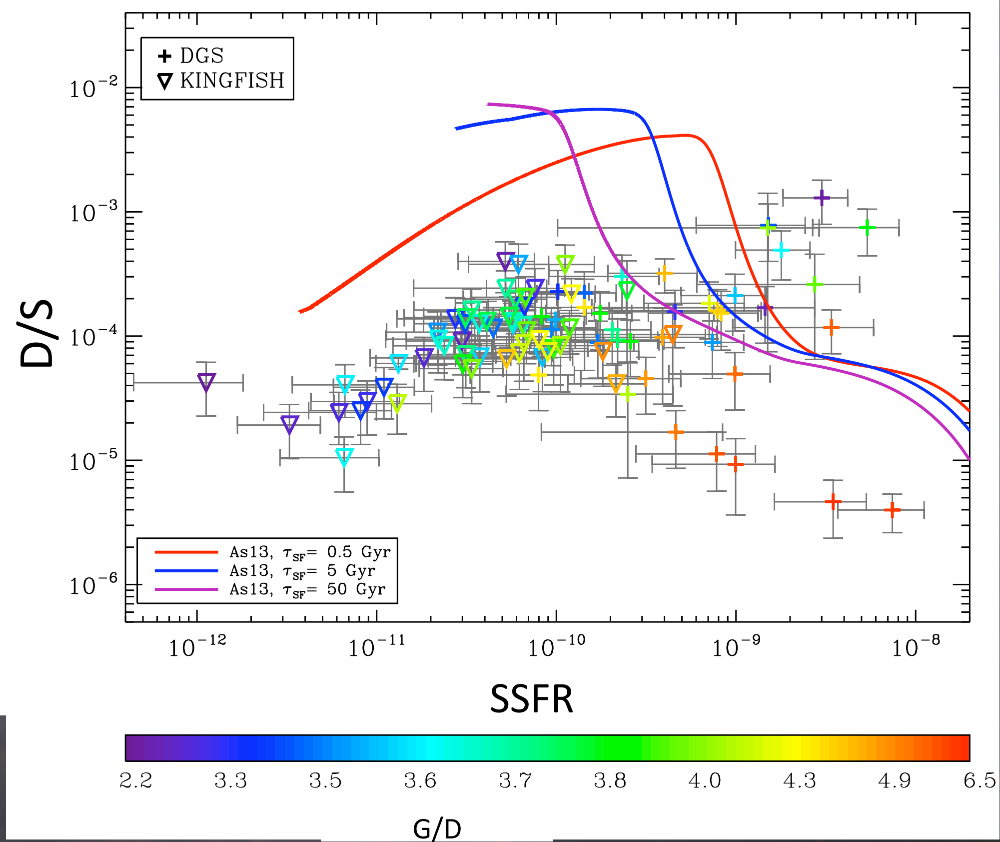




- Global trend is still the same
- Absolute scale is changing: variation of a factor of ~4 -5 in the dust mass
  - Graphite -> Amorphous carbons: ~2 - 2.5
  - « Astronomical » silicates -> new amorphous silicates: ~2 - 2.5 (mass density)

Impact on G/D and D/S





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➢ Important consequences for estimating D or G from G/D and metallicity

Summary: Take away messages

- Dust growth is the key to explain G/D and D/S
    - Large scatter can be explained with different star formation histories and different evolutionary stages

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Rémy-Ruyer+14, Jones+13, Köhler+14, Ysard+15
Rémy-Ruyer et al., in prep.

- A more physically consistent description of dust
    - No Graphite, No PAHs, No « Astronomical » Silicates !

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- Dust growth is the key to explain G/D and D/S
  - Large scatter can be explained with different star formation histories and different evolutionary stages

Rémy-Ruyer+14, Jones+13, Köhler+14, Ysard+15
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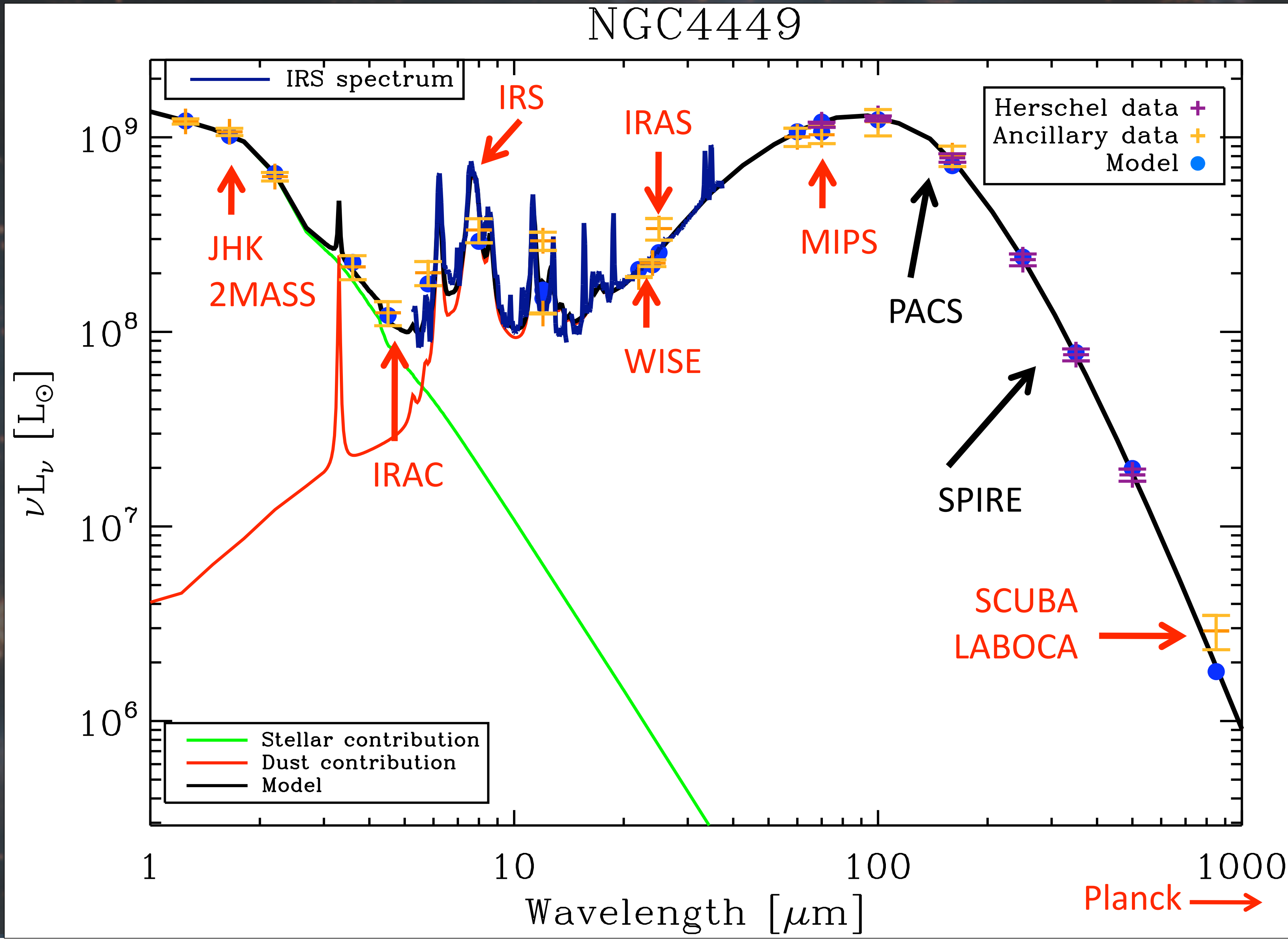
- A more physically consistent description of dust
  - No Graphite, No PAHs, No « Astronomical » Silicates !
  - Core-mantle structure : amorphous silicates and amorphous carbons
  - Optical properties derived from laboratory measurements
  - Consistent in size : from small to big carbon in one grain family
  - Consistent with both extinction and emission *together*
  - Tested and validated in the diffuse and dense ISM
  - Imply *significant* change in the derived dust mass !

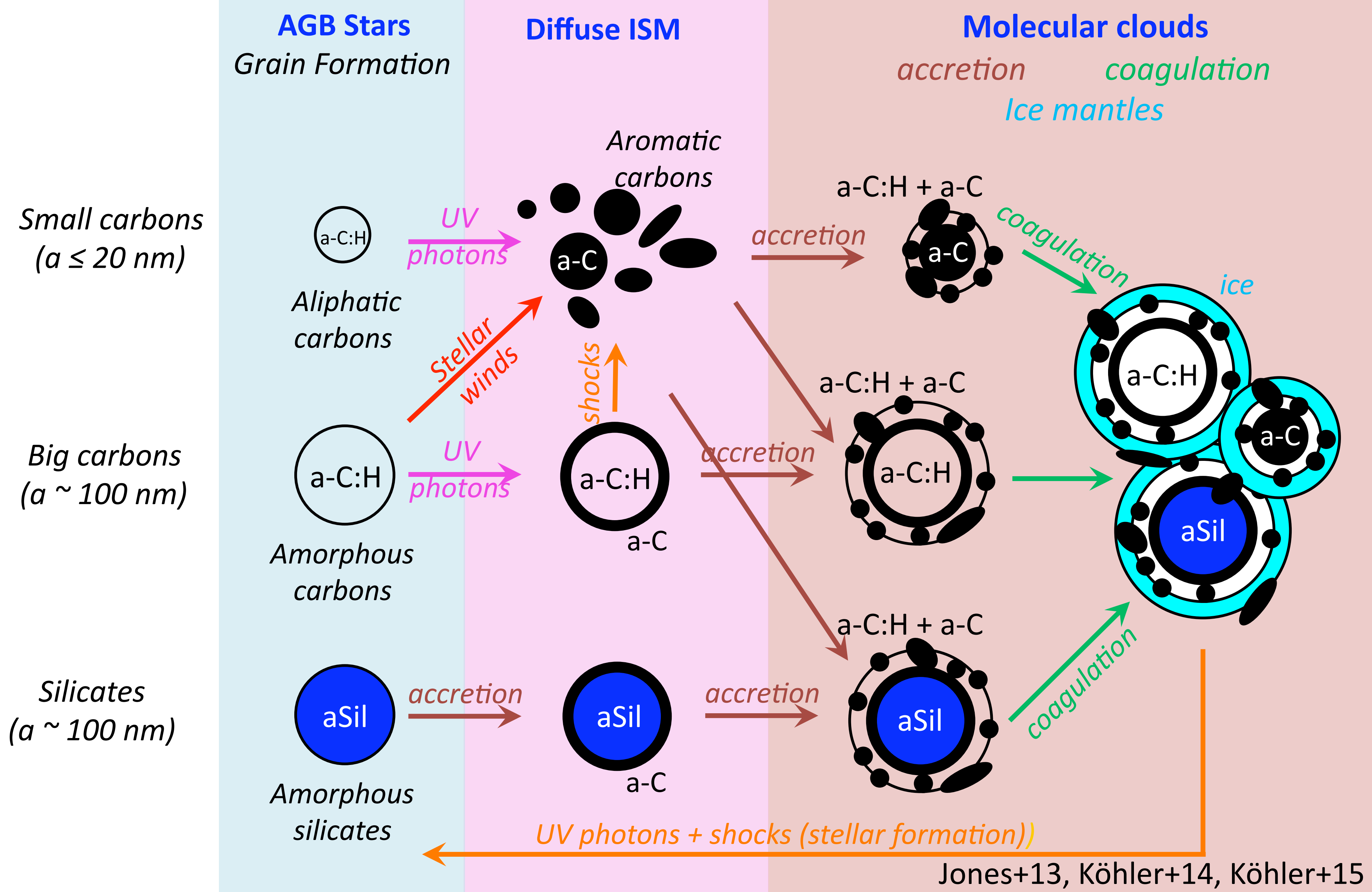
Thank you !

Dust and galaxy evolution: IR wavelength coverage

Rémy-Ruyer et al. in prep



Dust evolution within the ISM

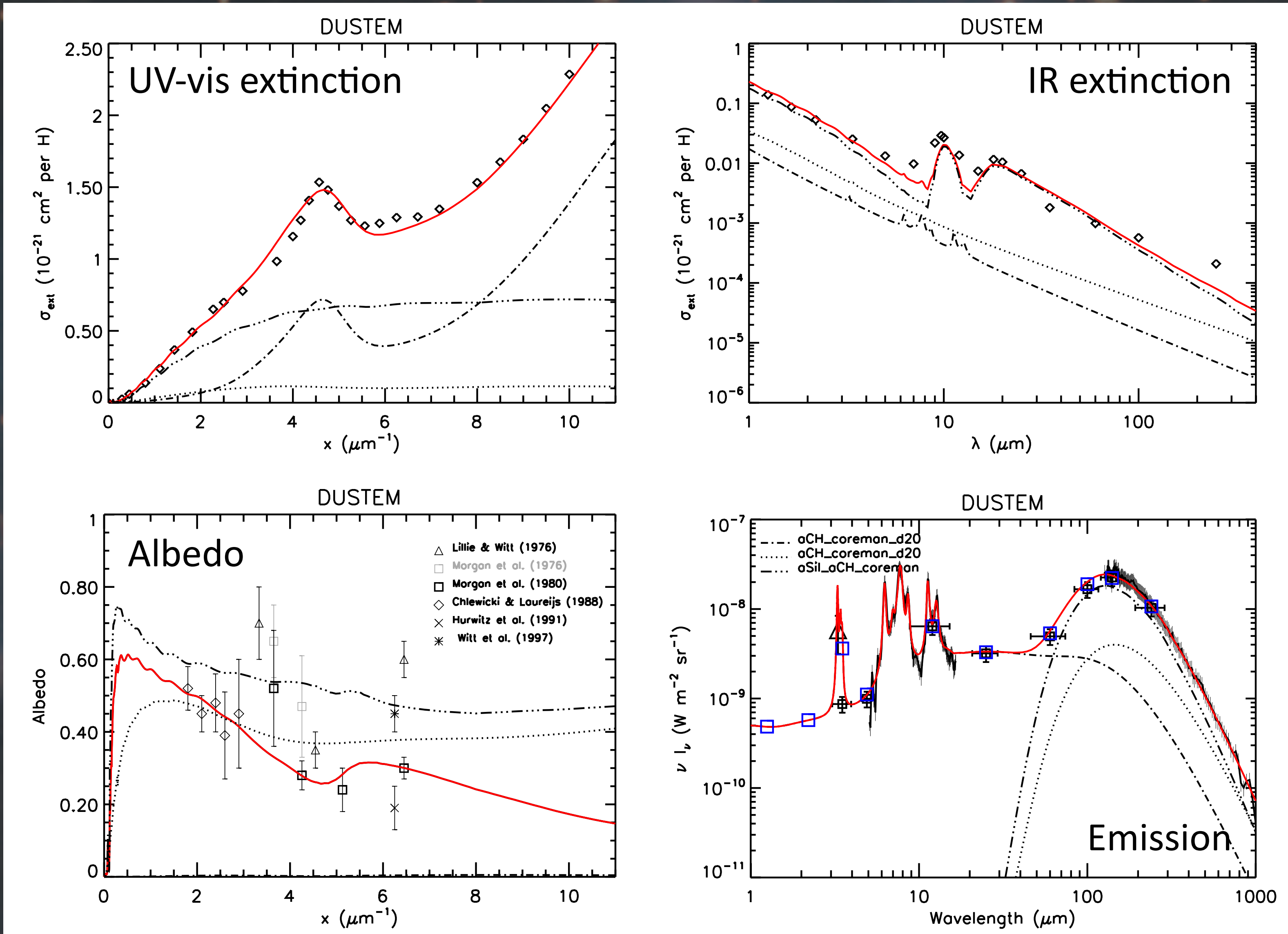


Jones+13, Köhler+14, Köhler+15

A new dust model: Validated on the diffuse ISM

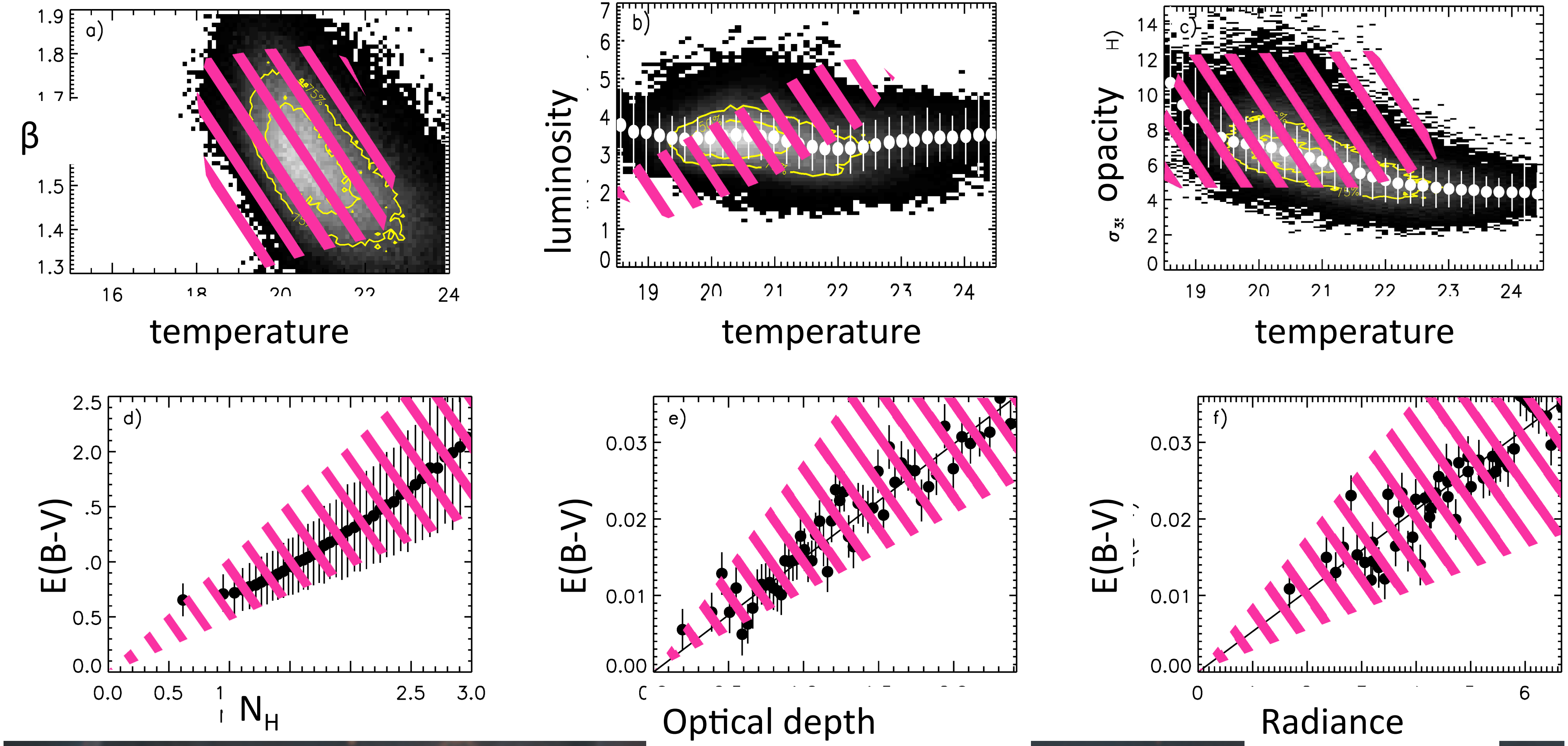
- Consistent with emission and extinction
- Consistent with elemental abundance constraints

Jones+13
Köhler+14

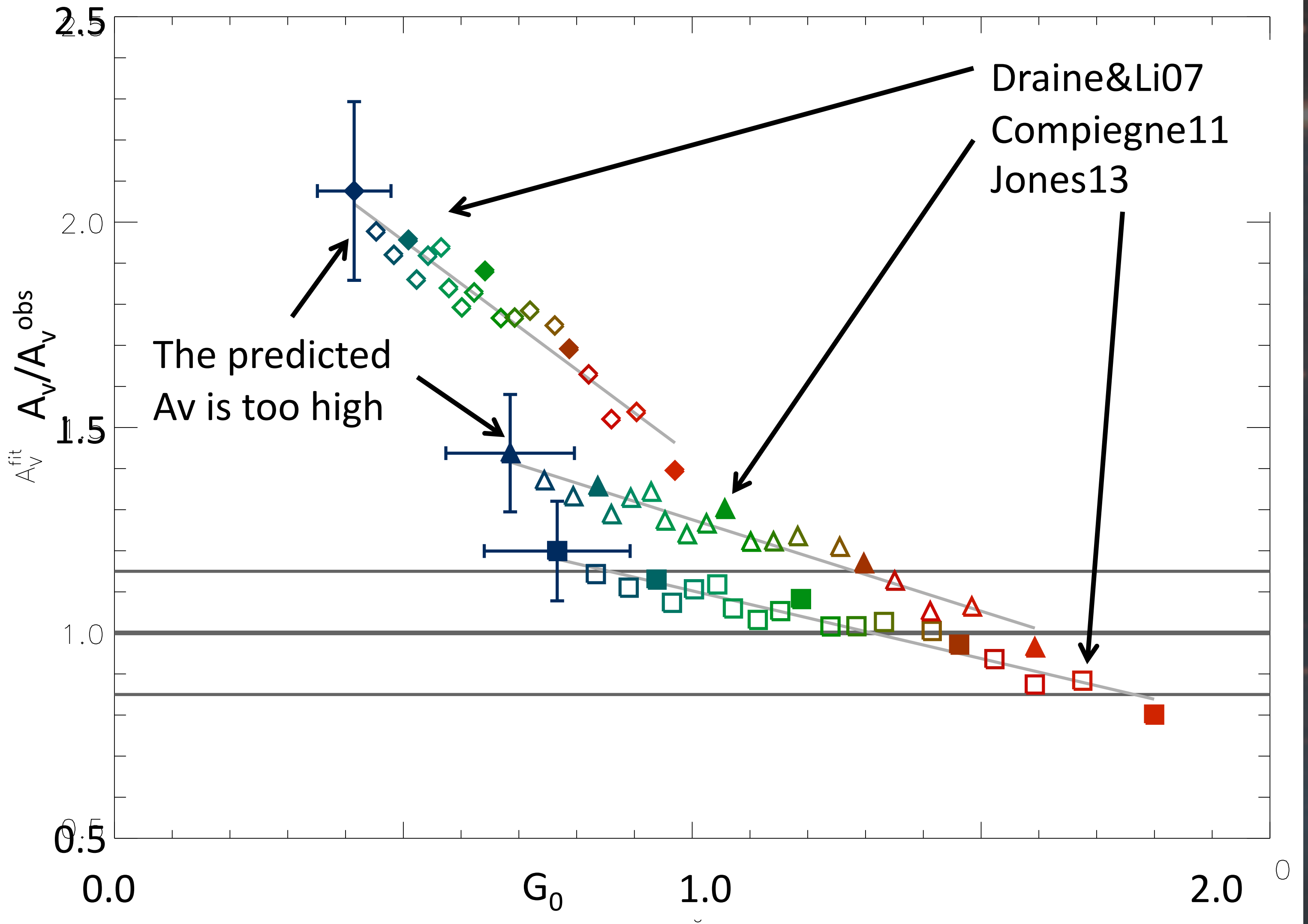


New model validated on the diffuse ISM

Ysard+15



Caveats of previous models



A_V^{obs} :
Measured on QSO lines of sight

Fanciullo+15