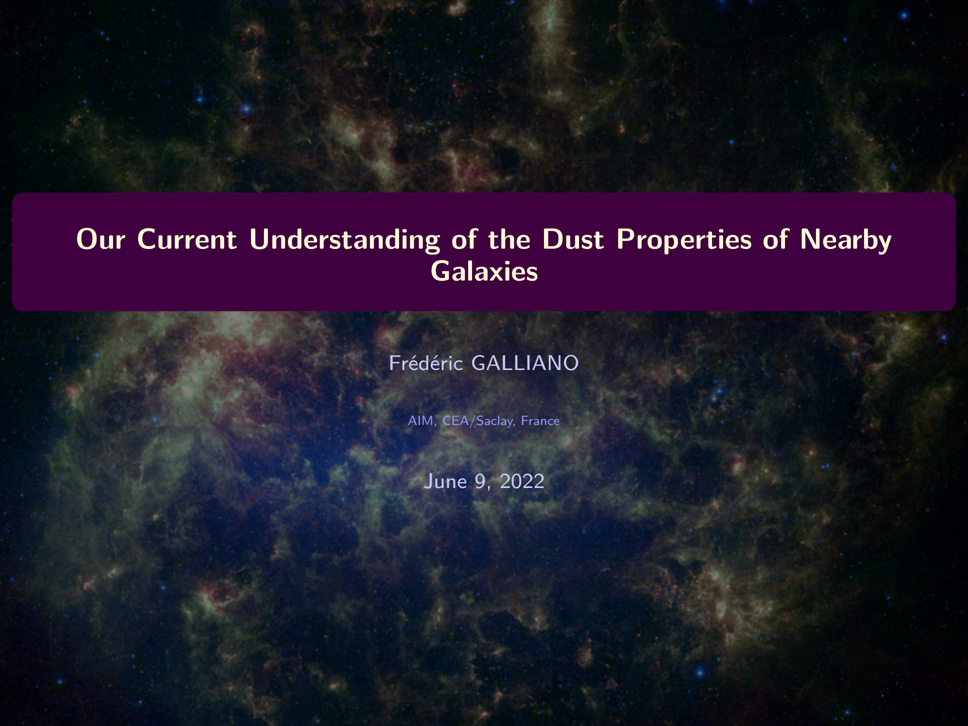

Our Current Understanding of the Dust Properties of Nearby Galaxies

Frédéric GALLIANO

AIM, CEA/Saclay, France

June 9, 2022

Outline of the Talk

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   - What constraints do they bring on dust?
   - The diversity of nearby galaxies

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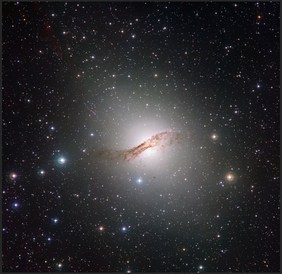

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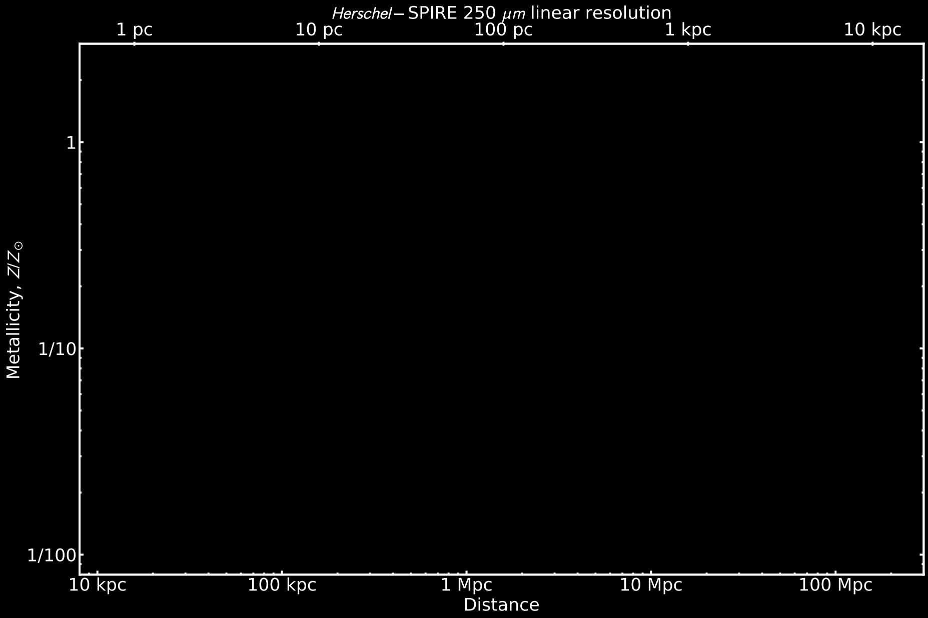

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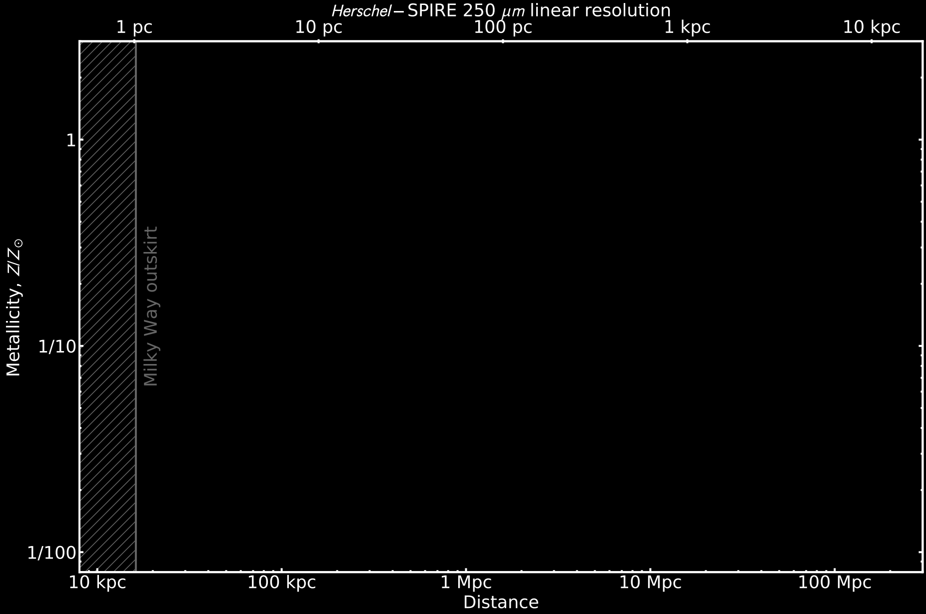

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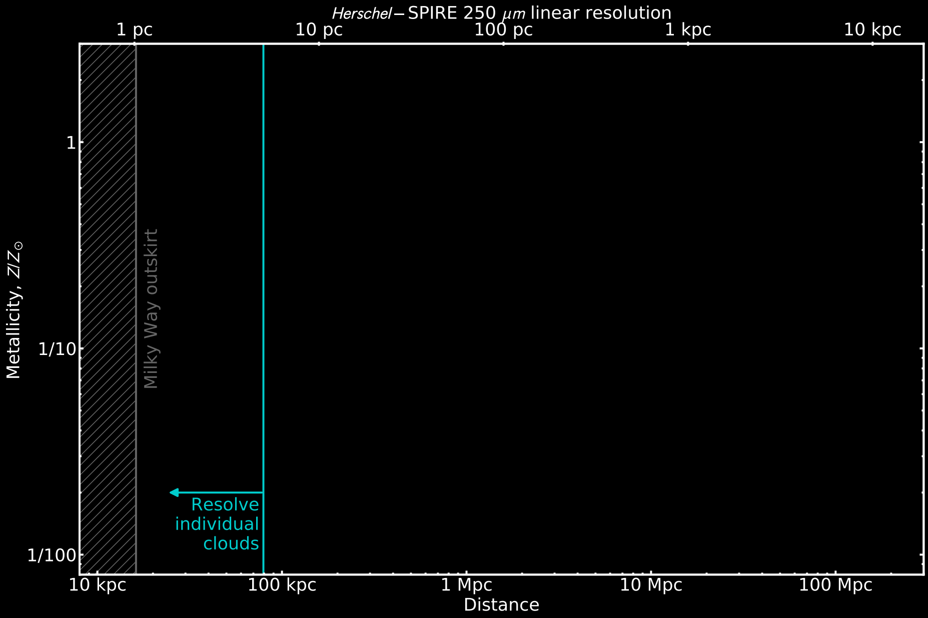

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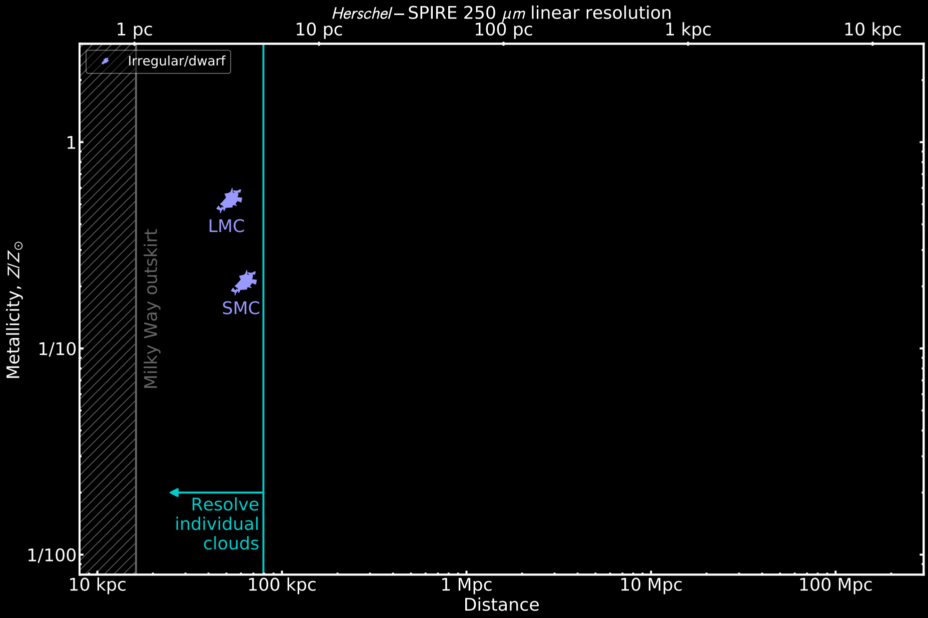

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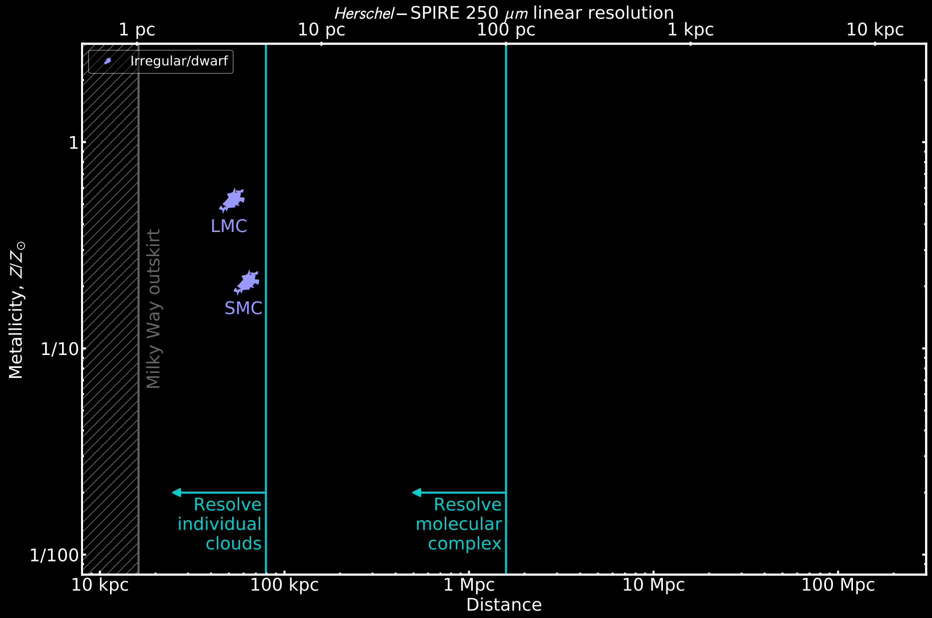

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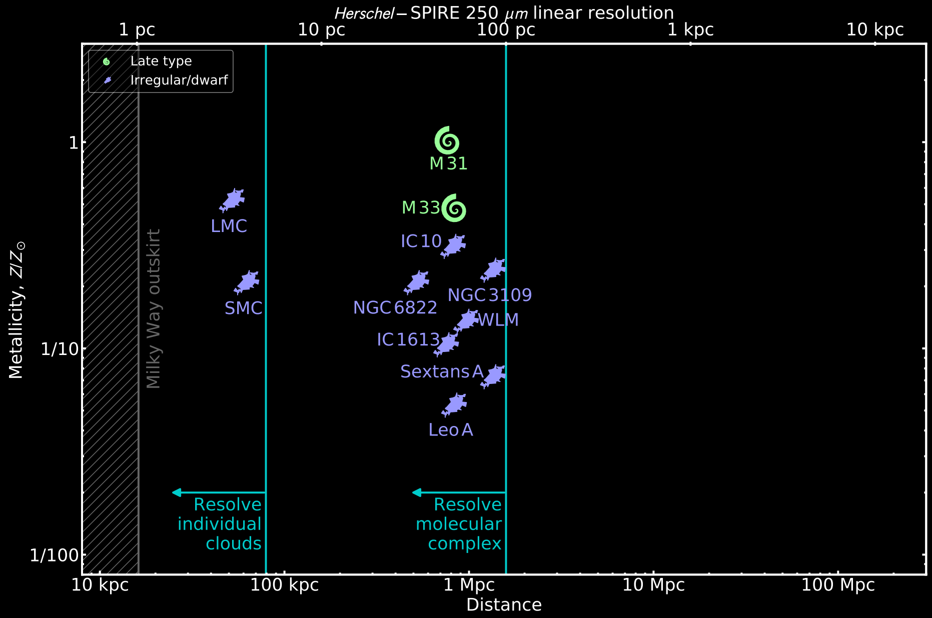

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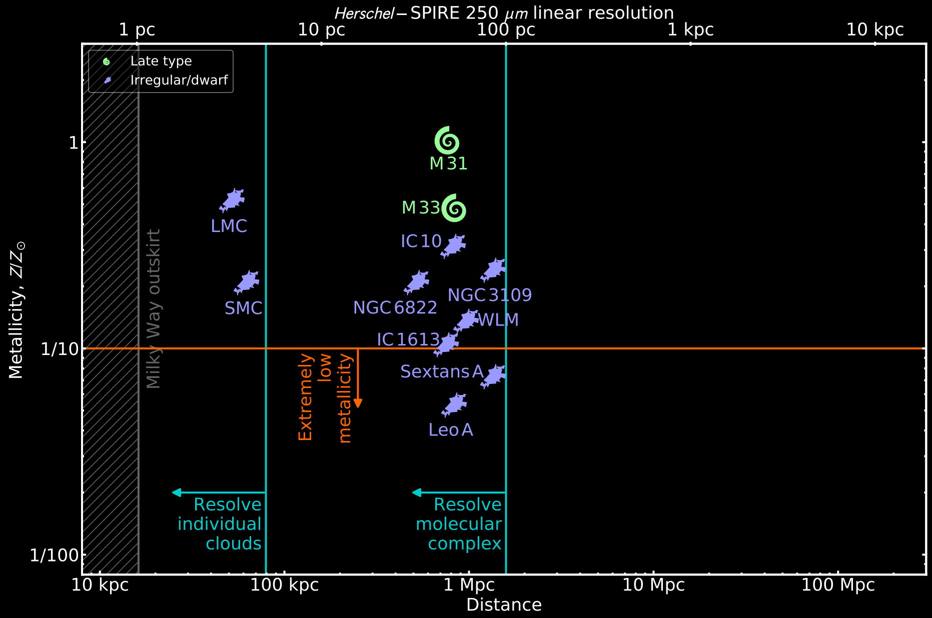

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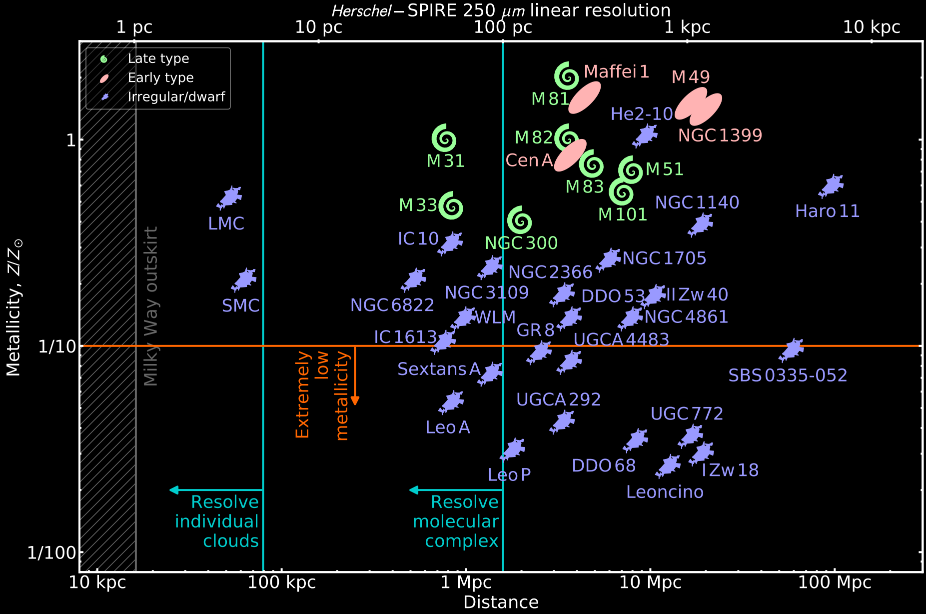

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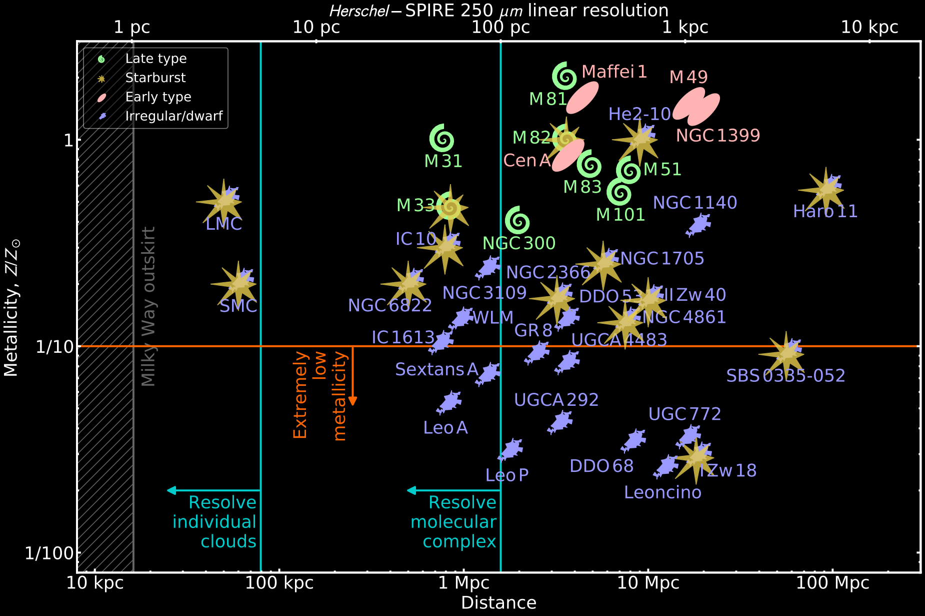

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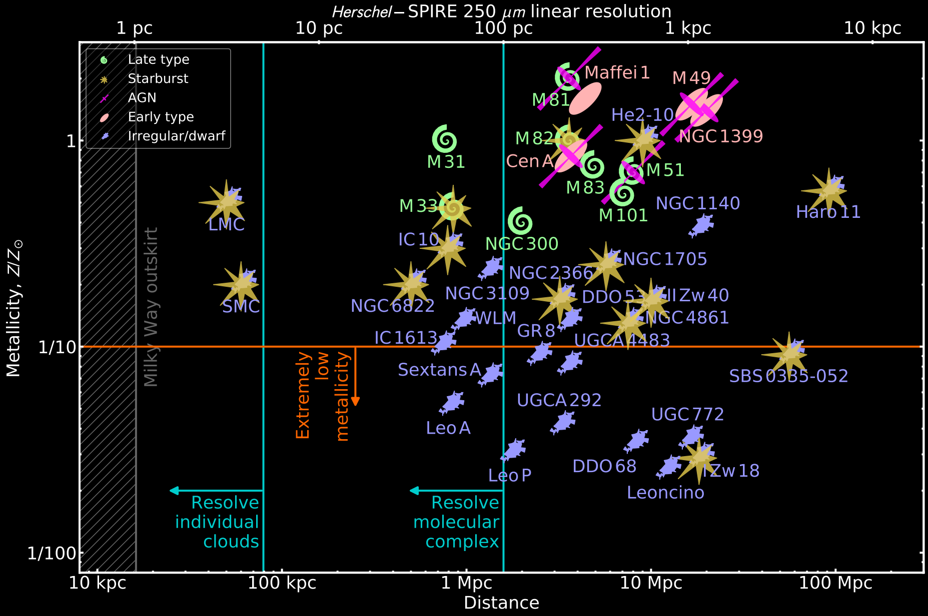

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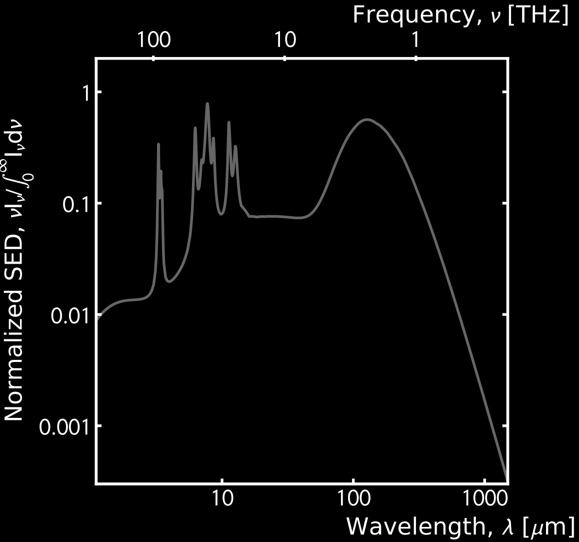

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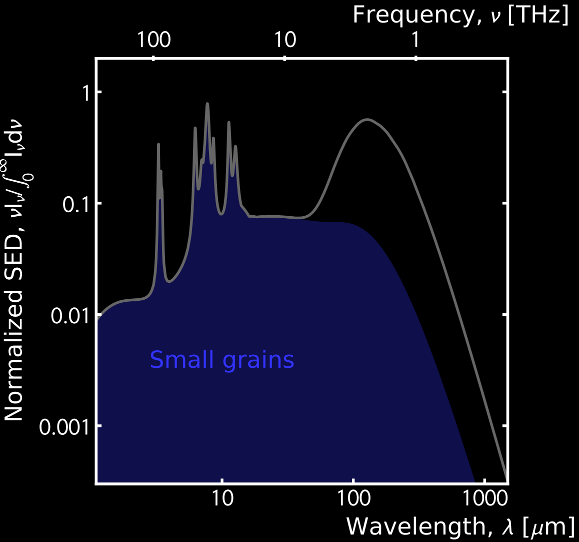

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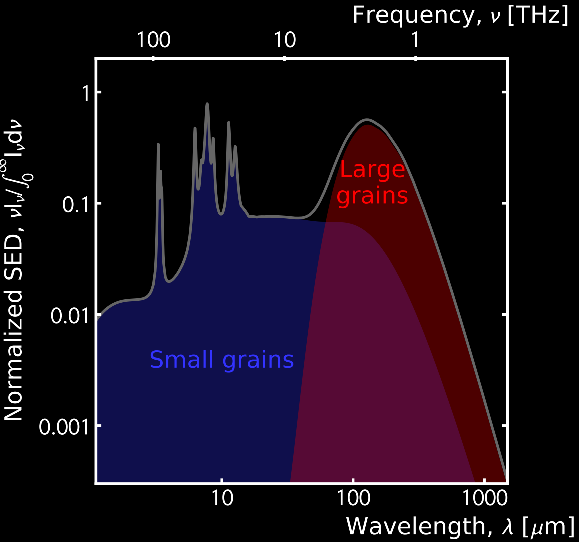

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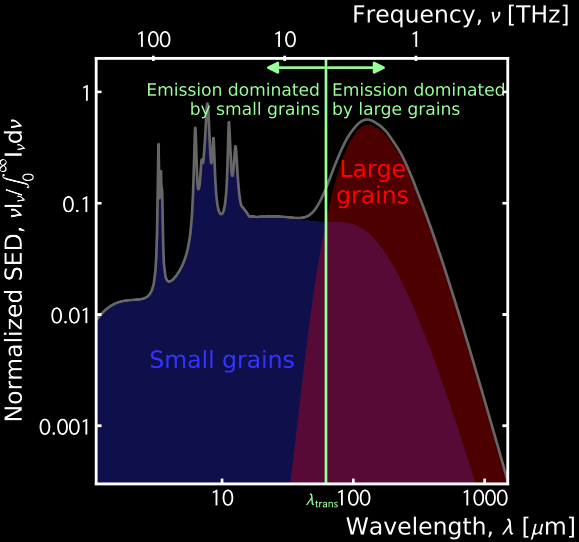

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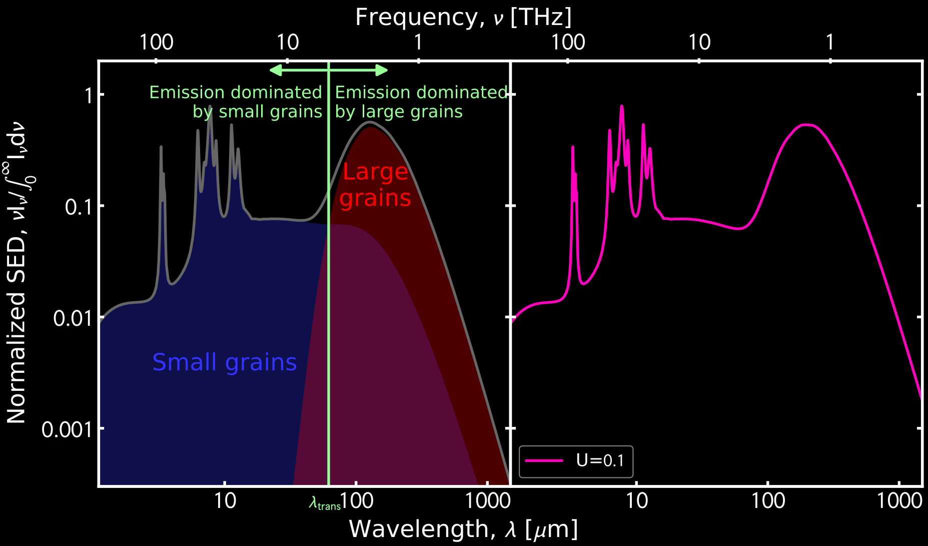

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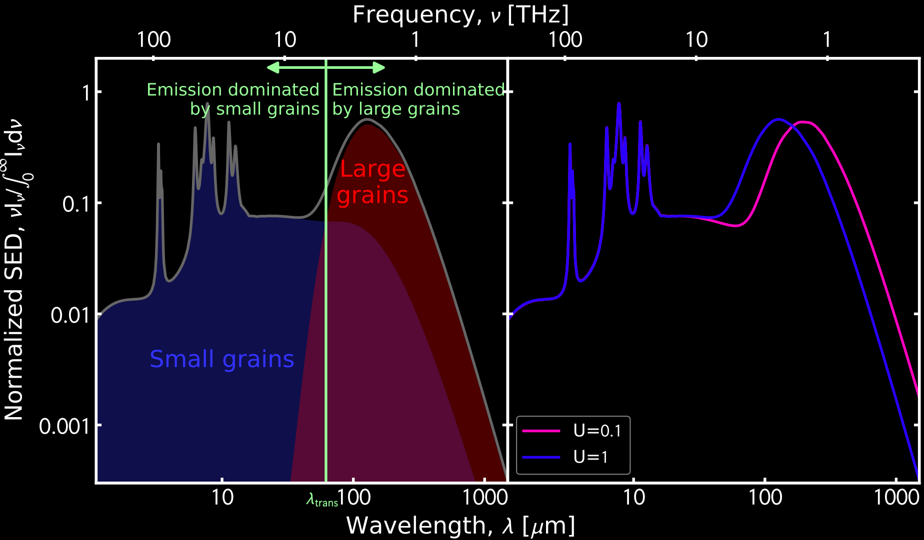

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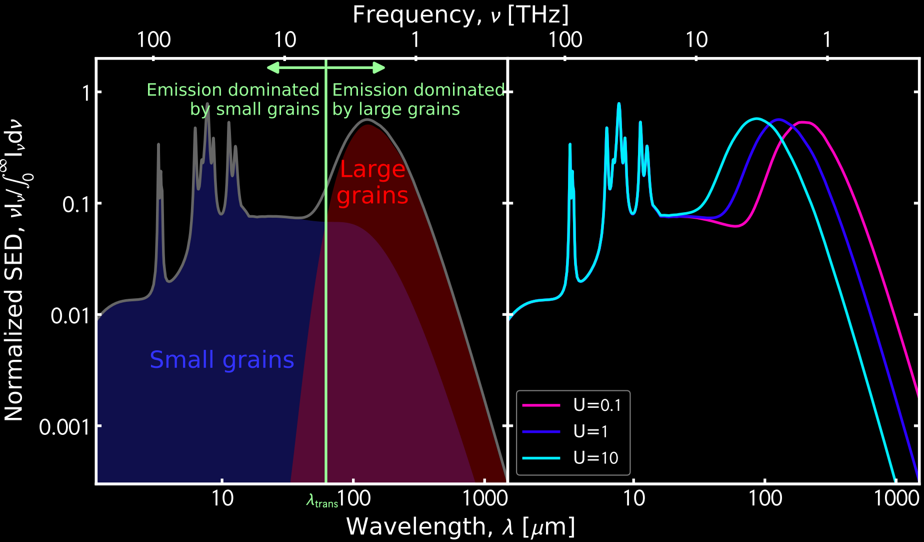

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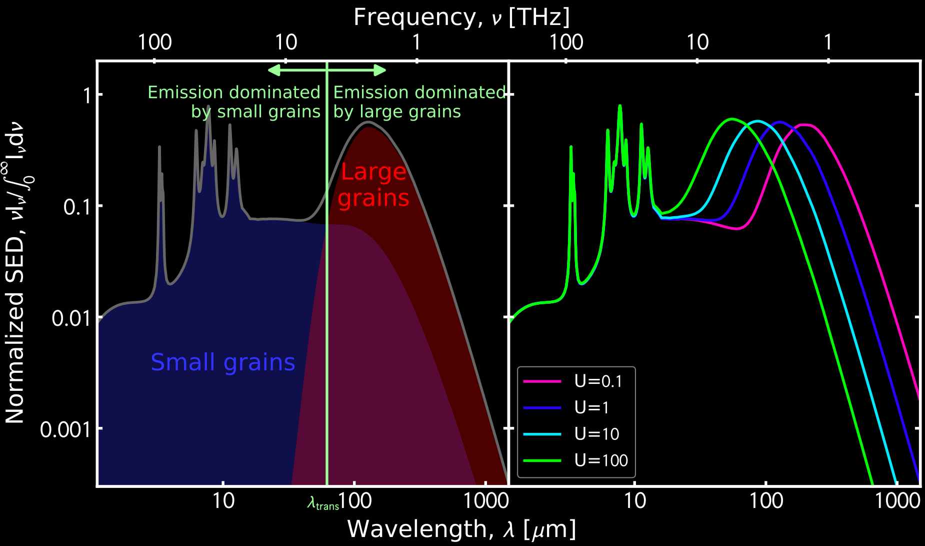

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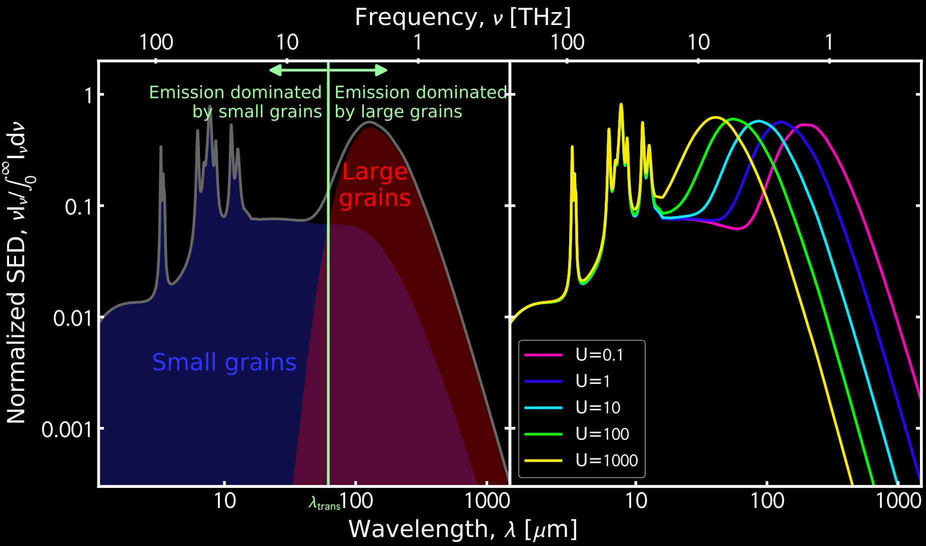

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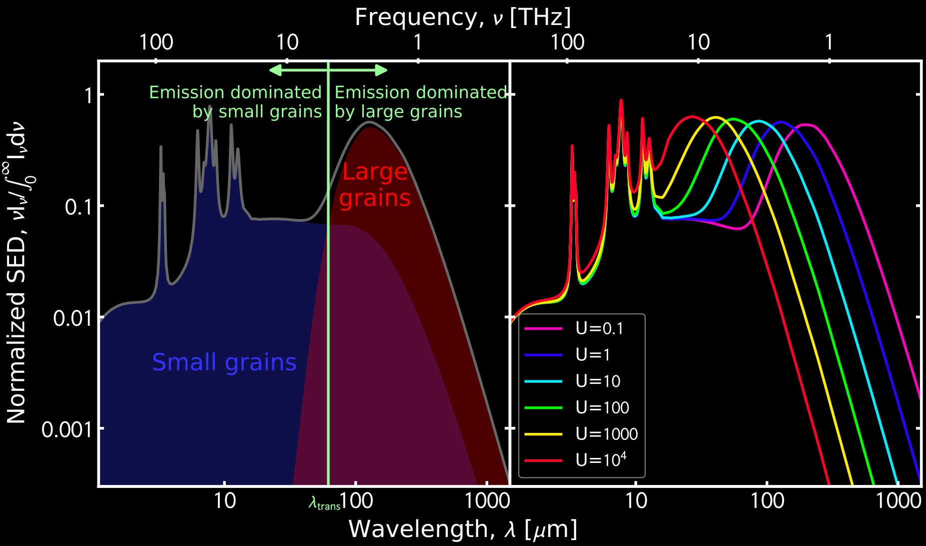

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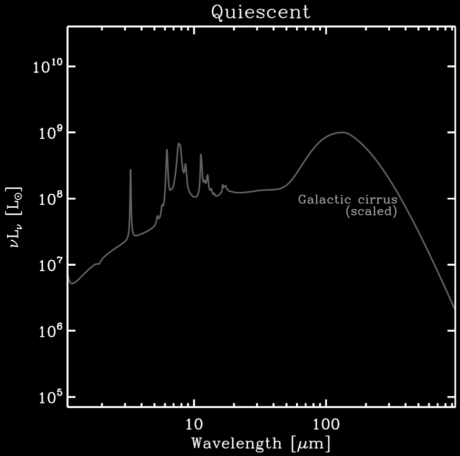

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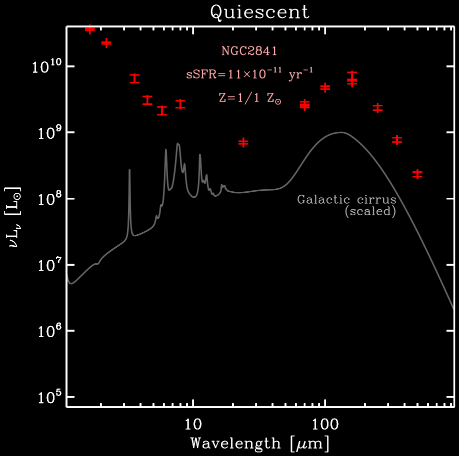

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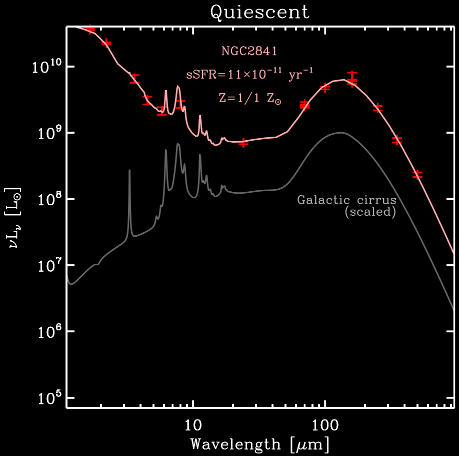

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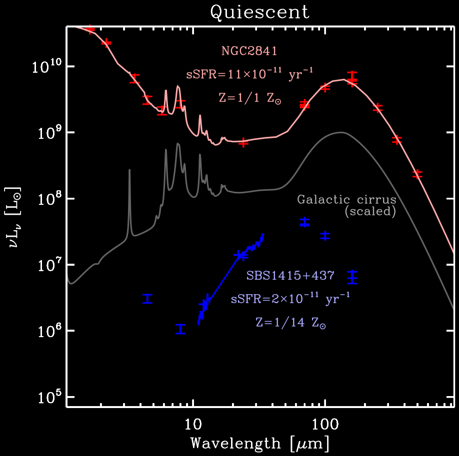

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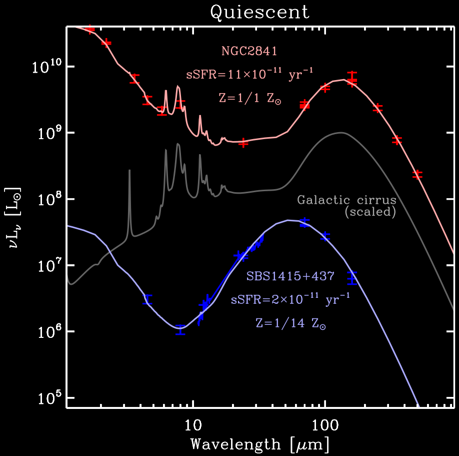

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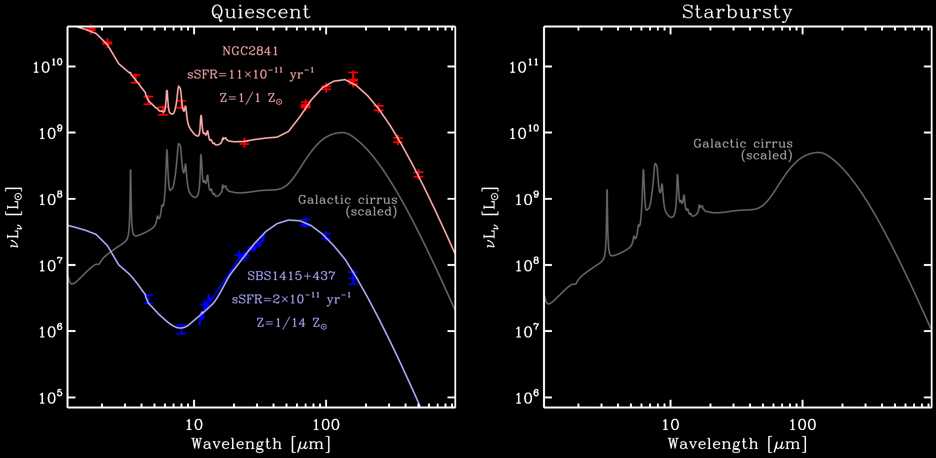

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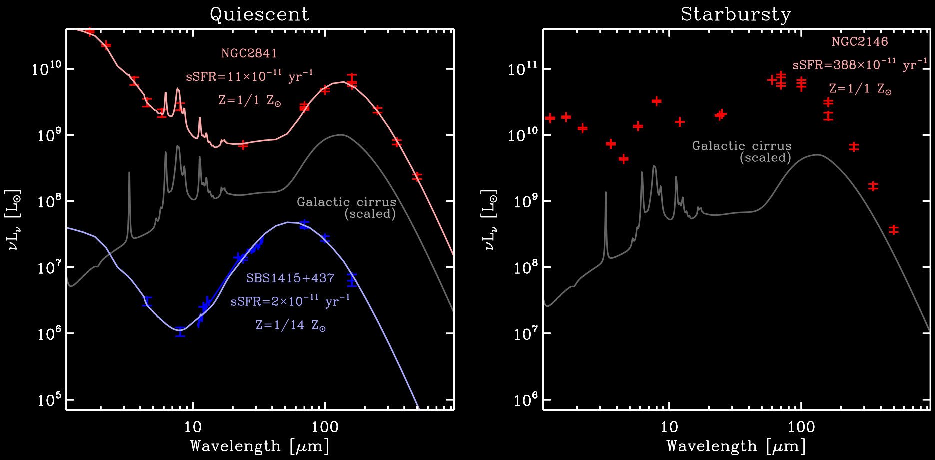

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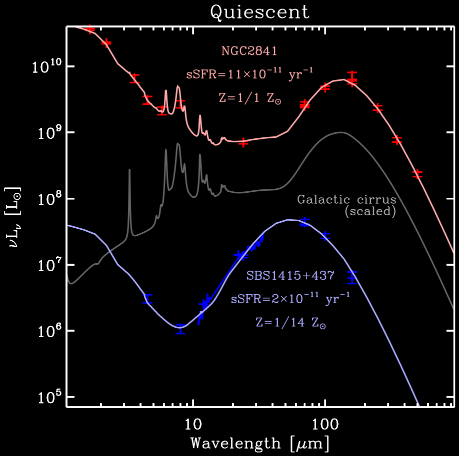

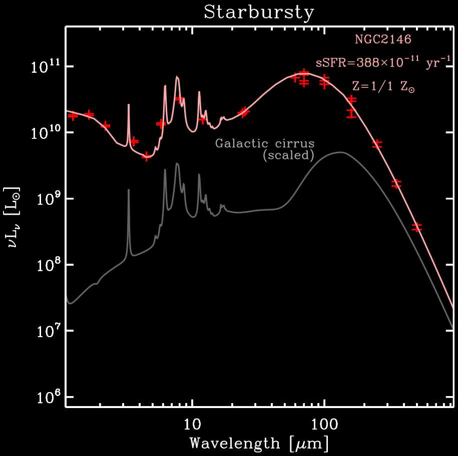

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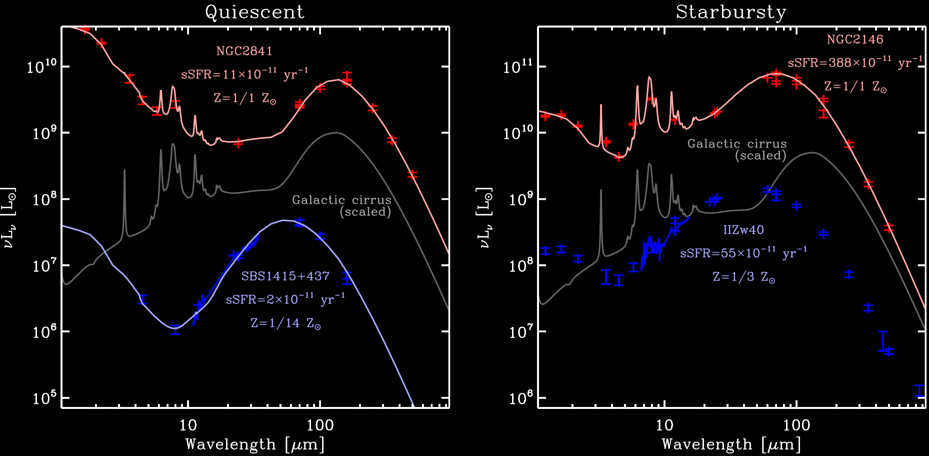

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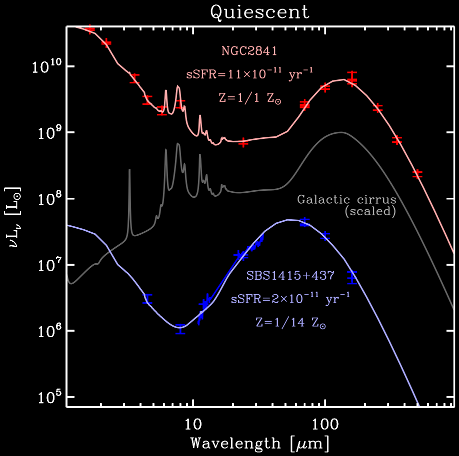

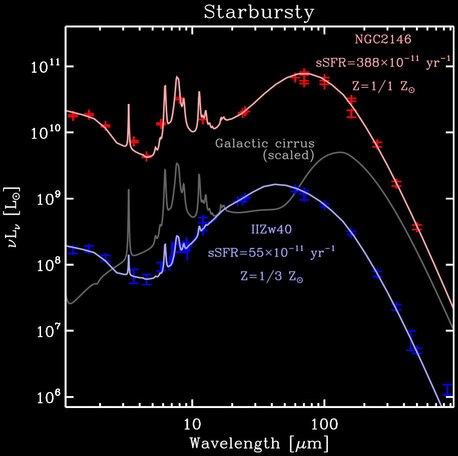

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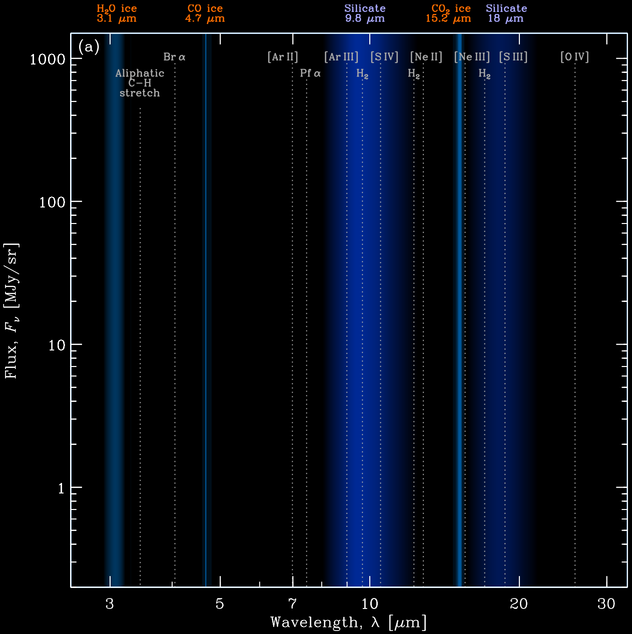

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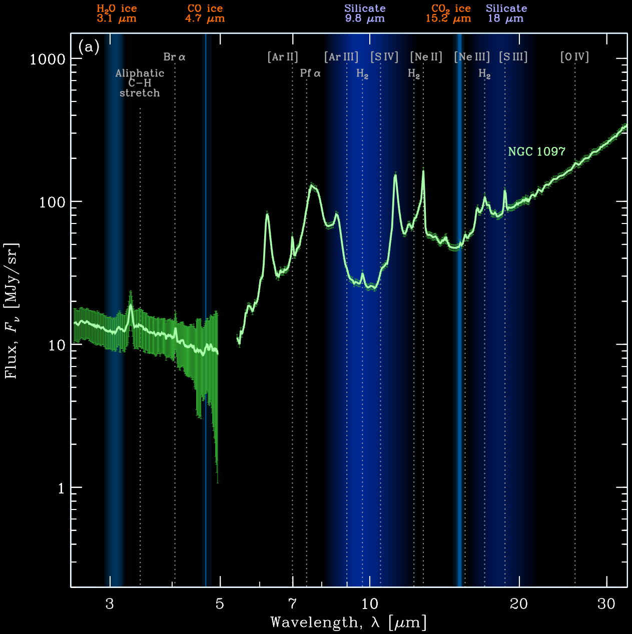

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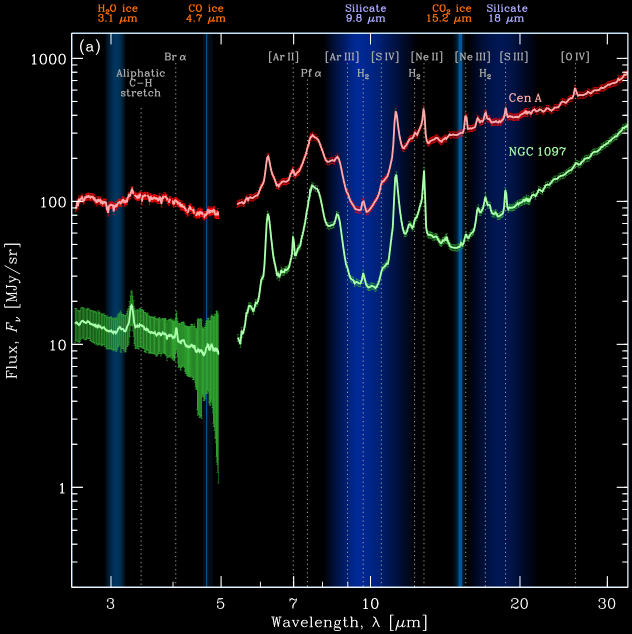

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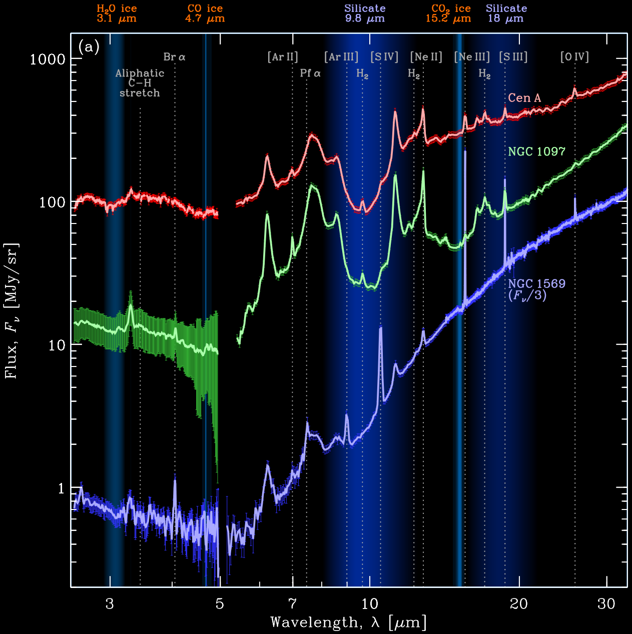

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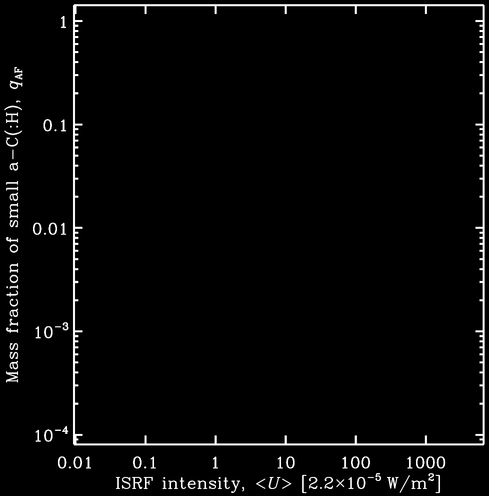

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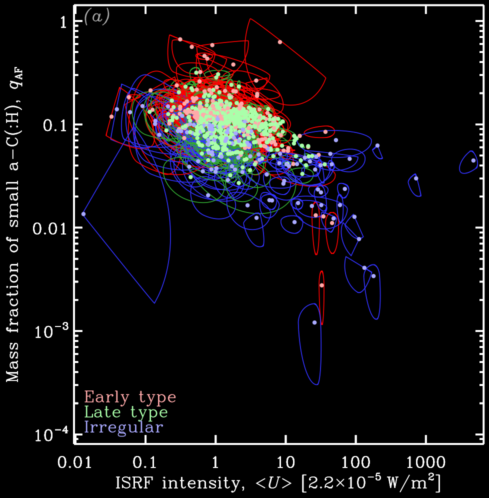

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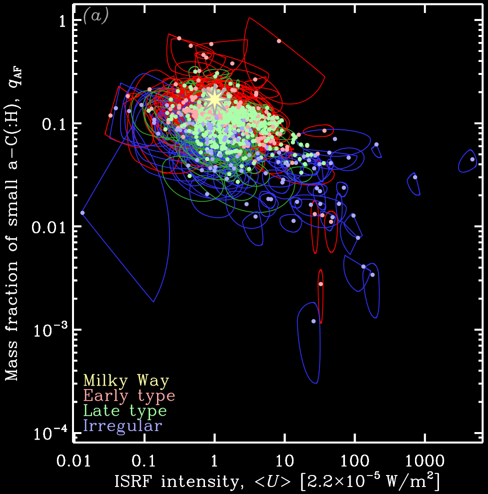

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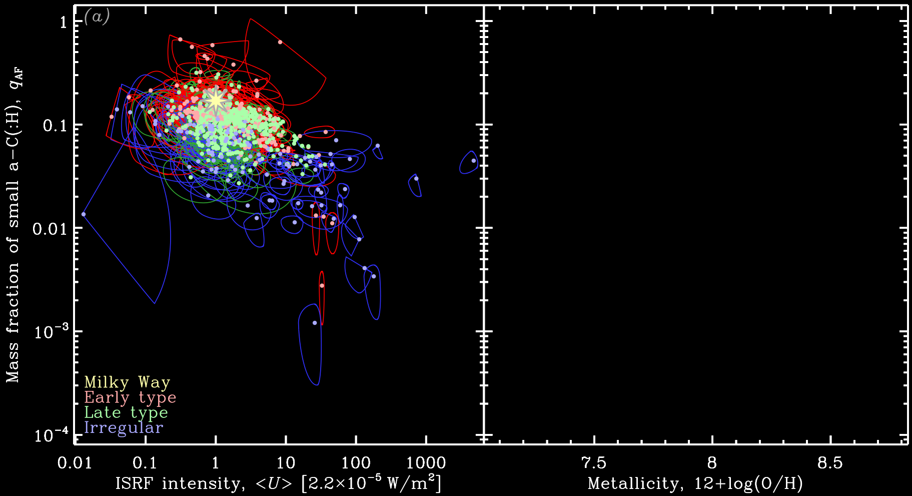

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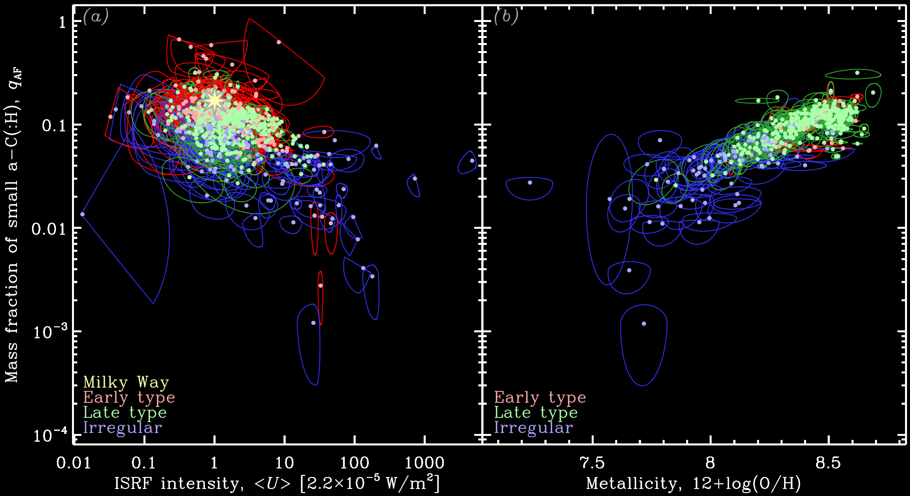

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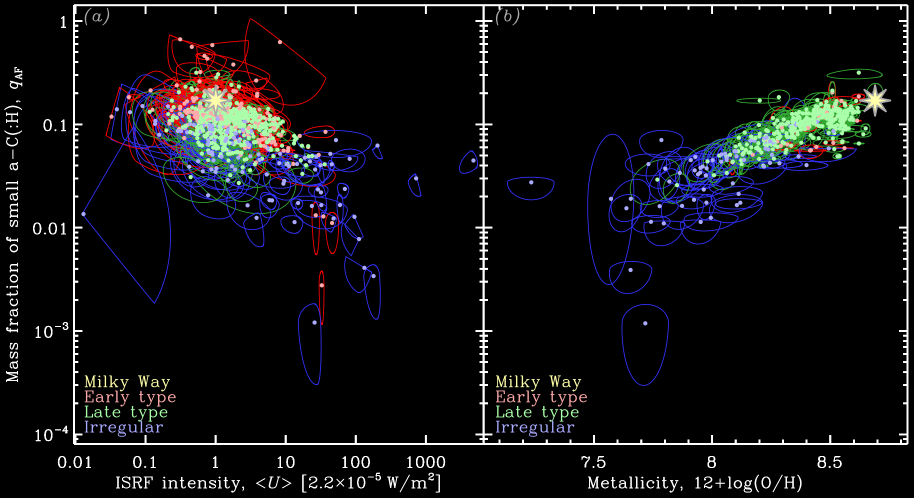

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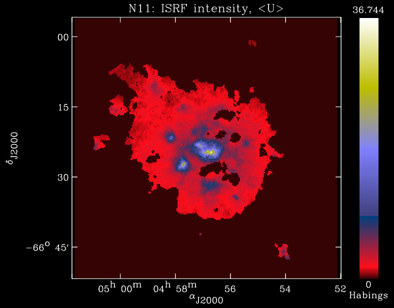

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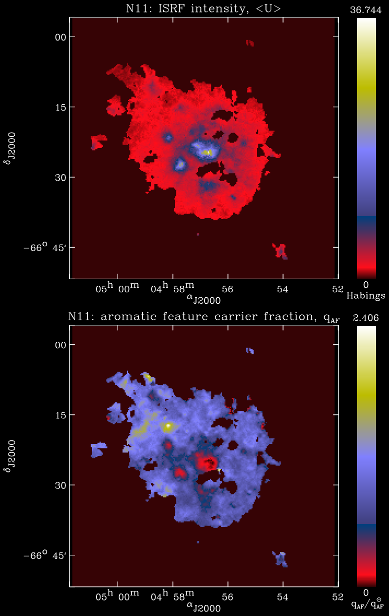

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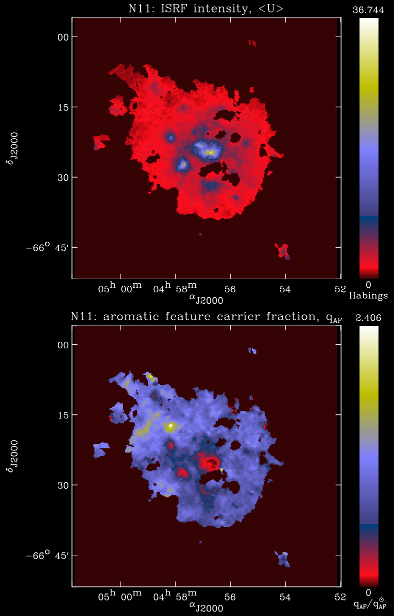

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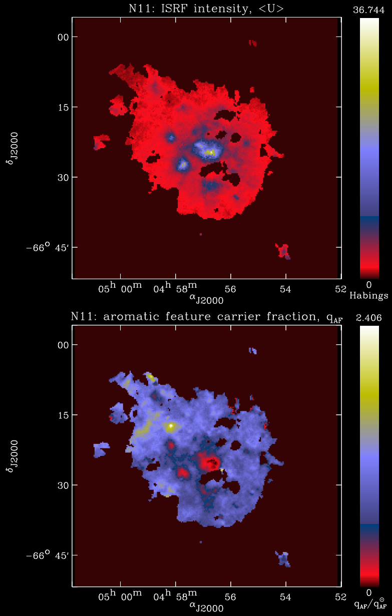

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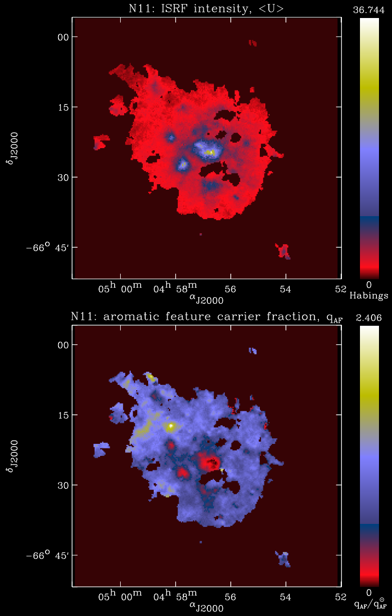

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The Diversity of Extinction Curves

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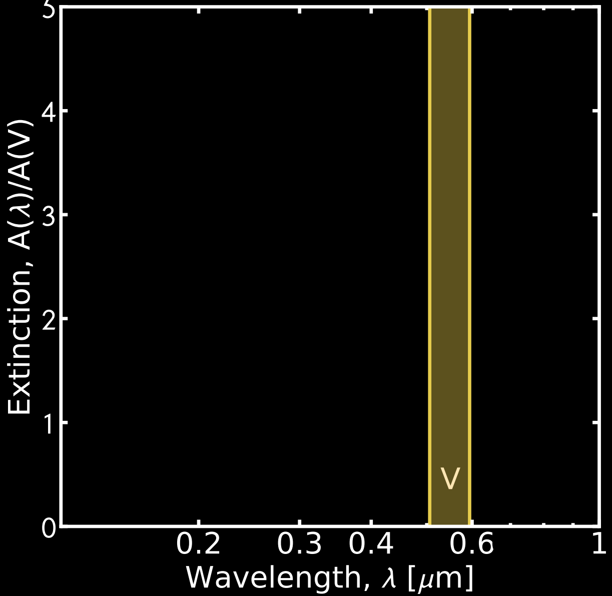

Milky Way: Fitzpatrick *et al.* (2019)

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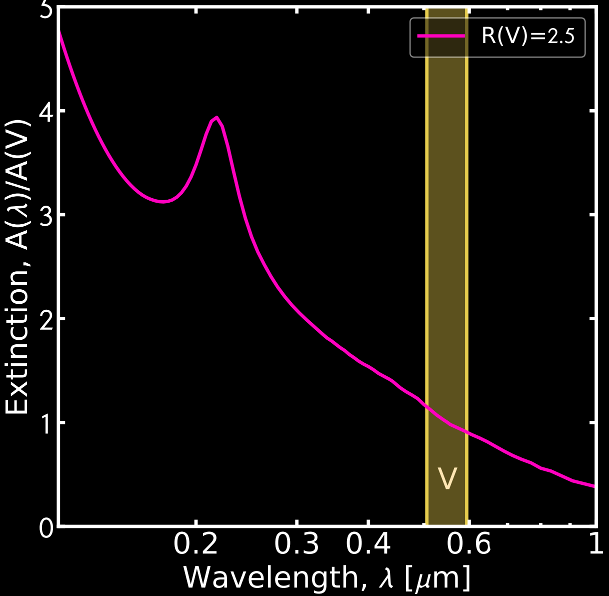

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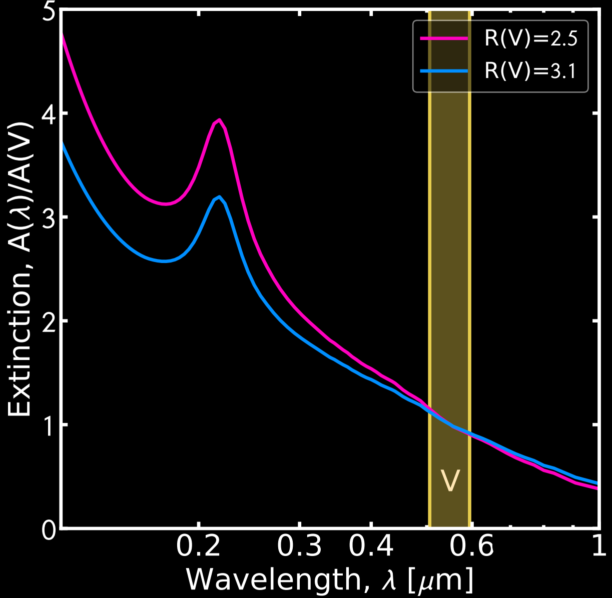

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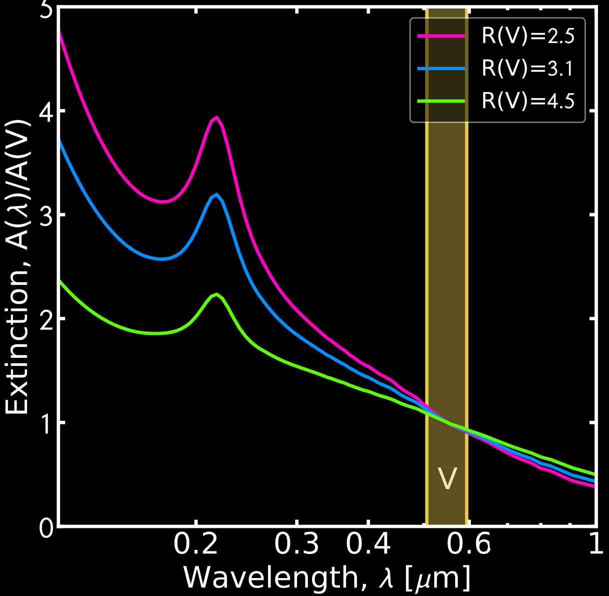

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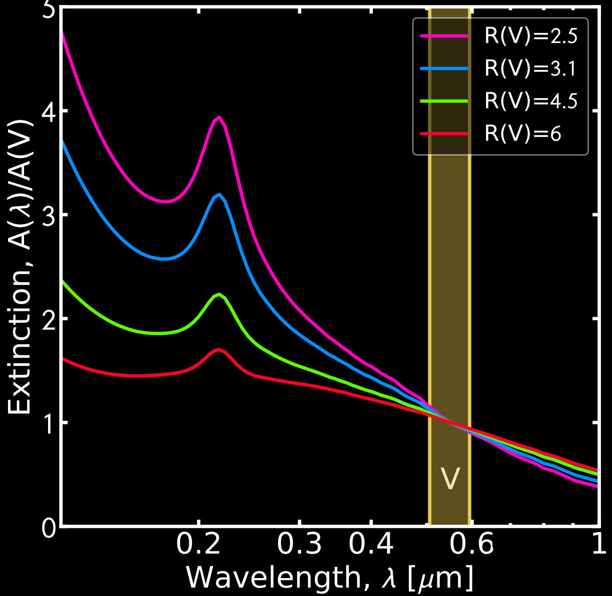

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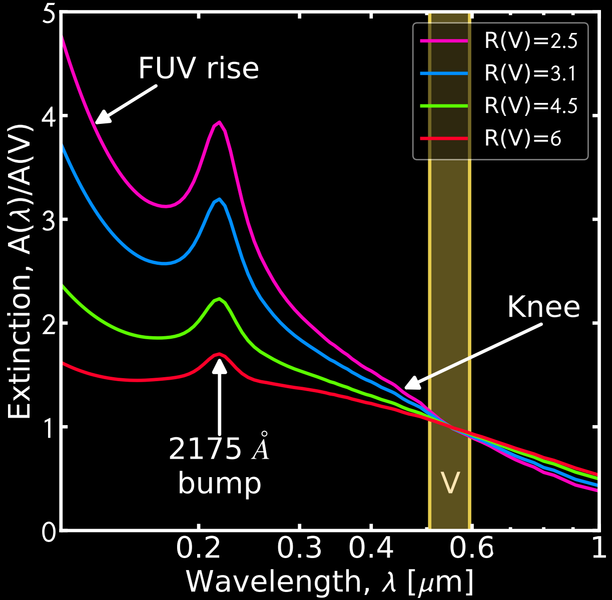

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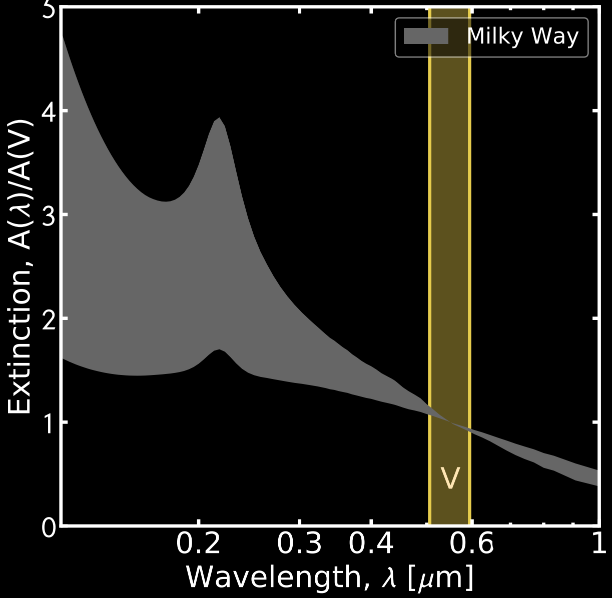

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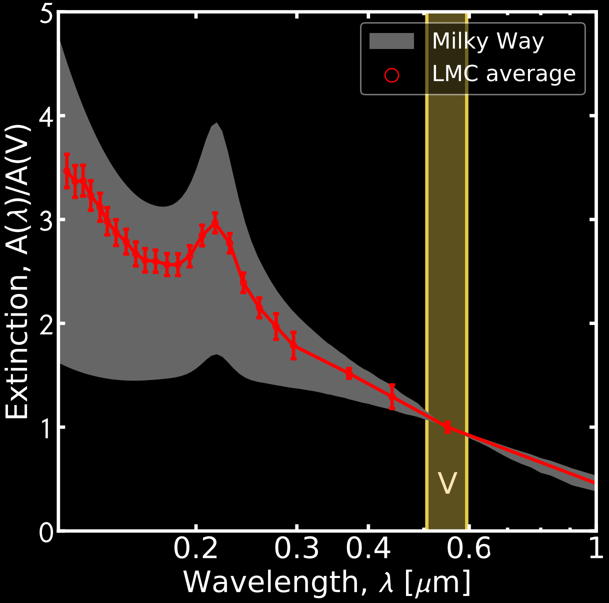

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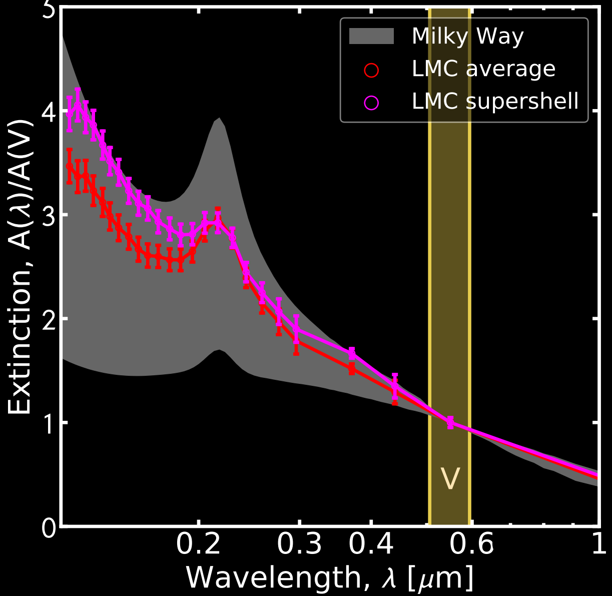

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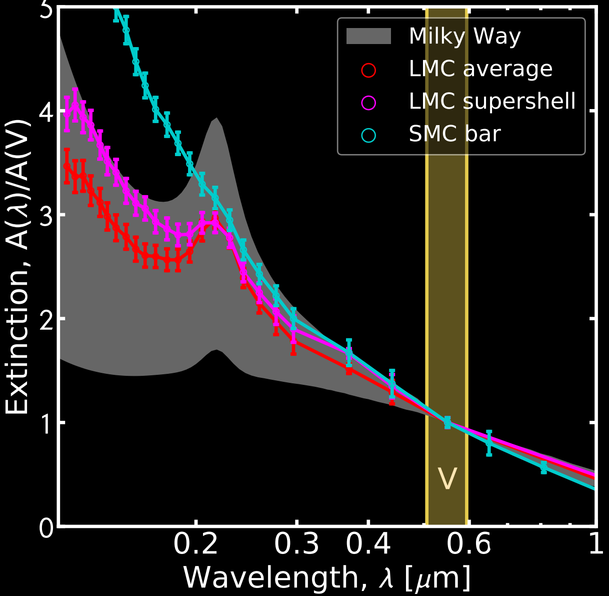

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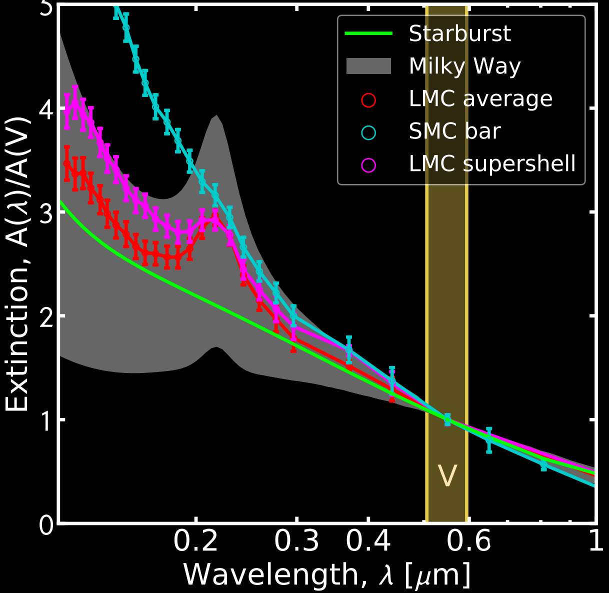

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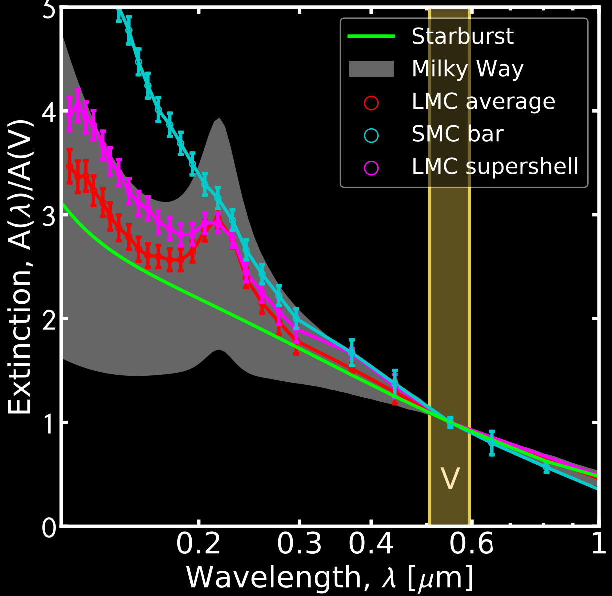

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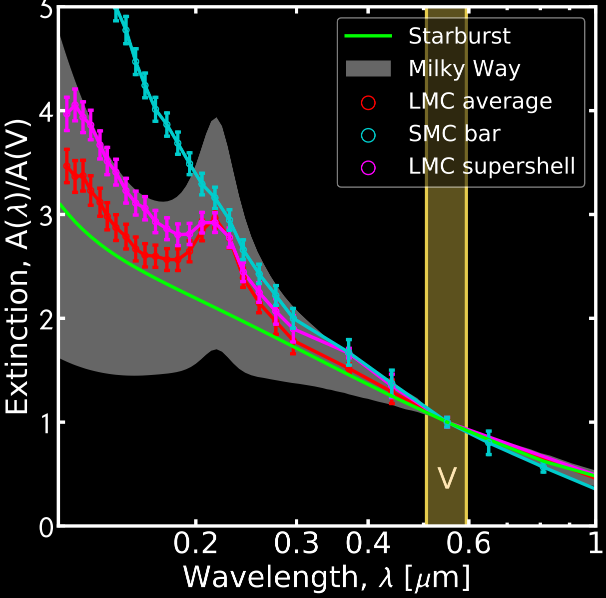

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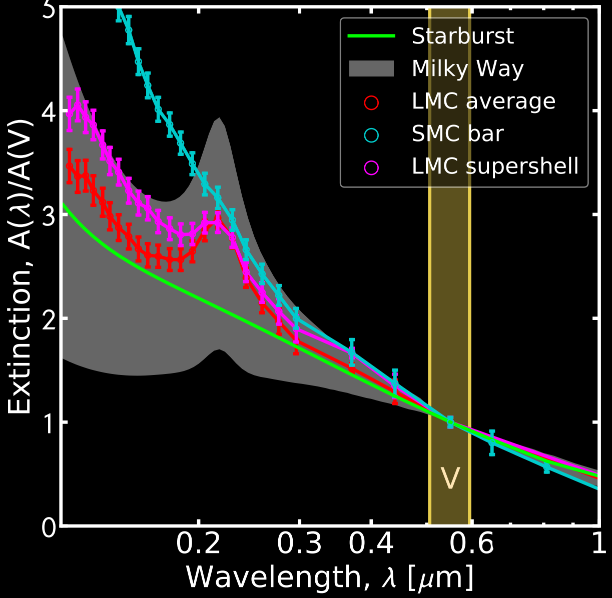

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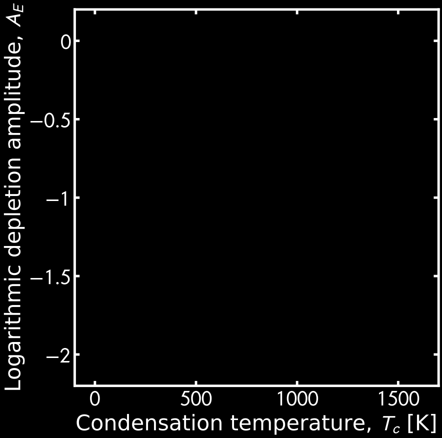

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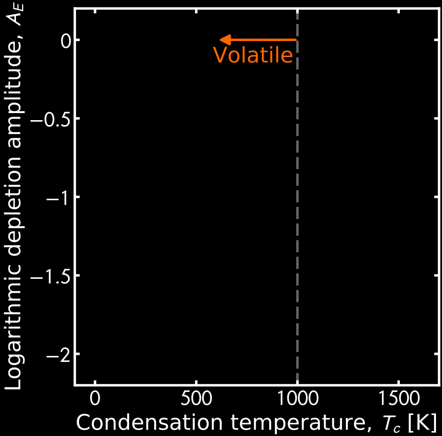

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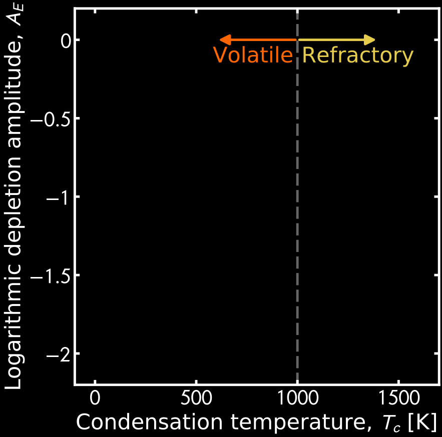

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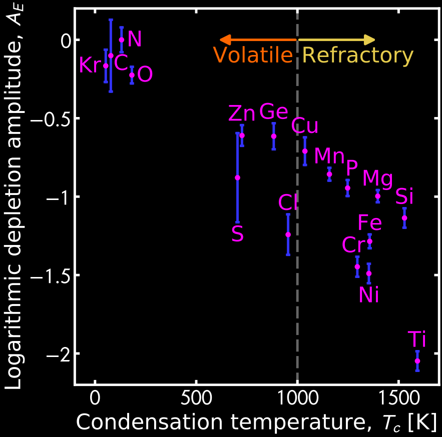

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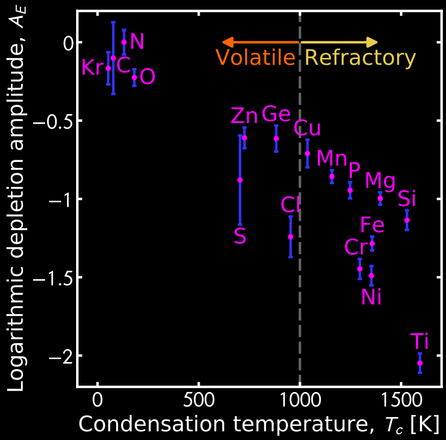

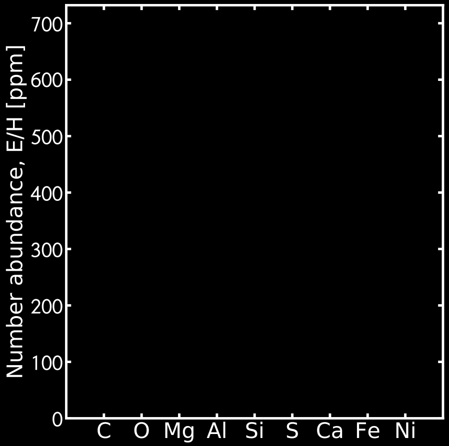

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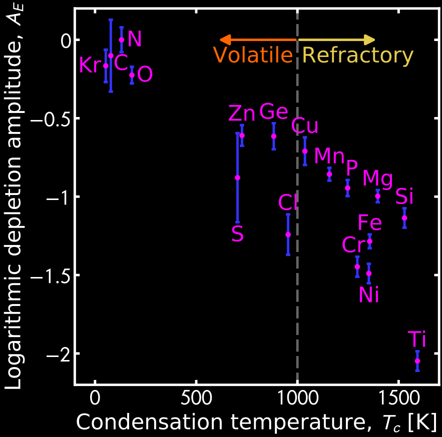

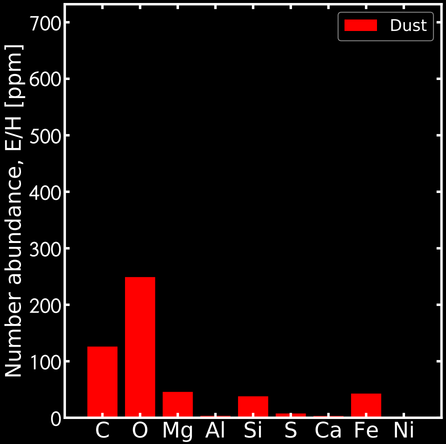

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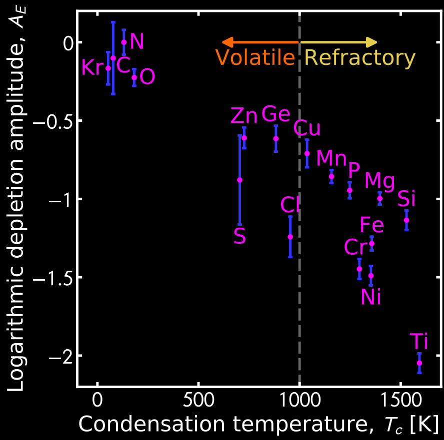

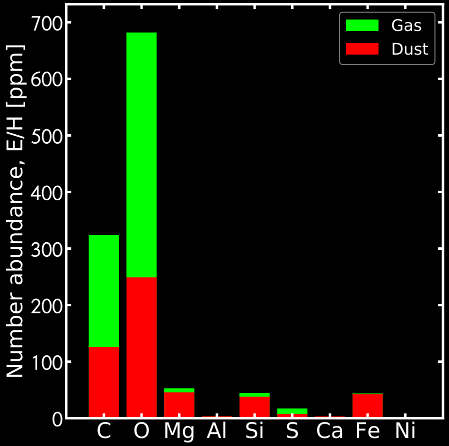

Evolution with Column Density in the Milky Way

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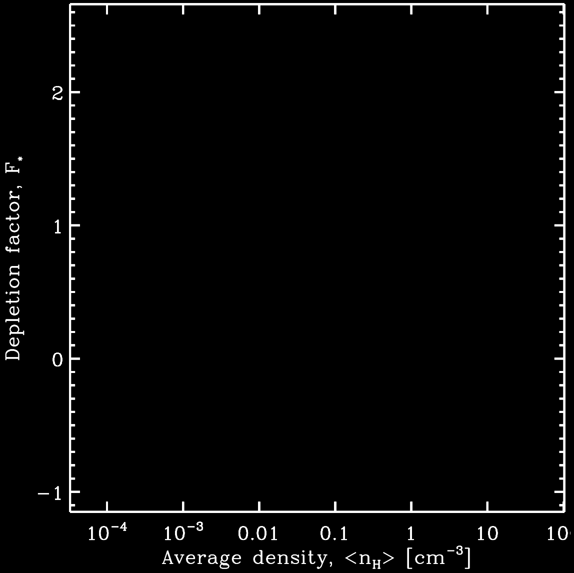

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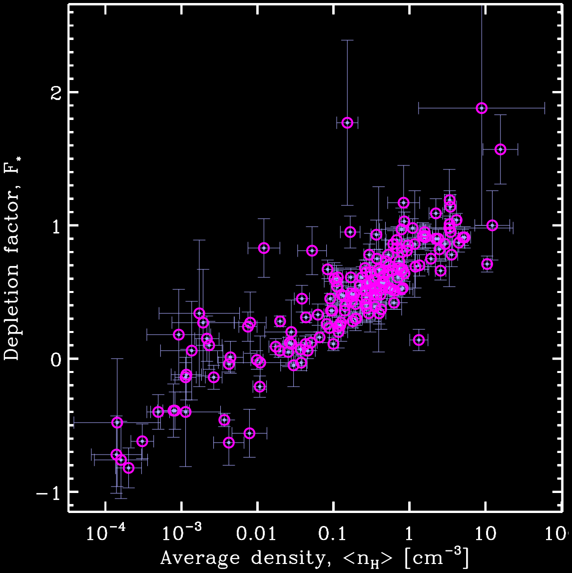

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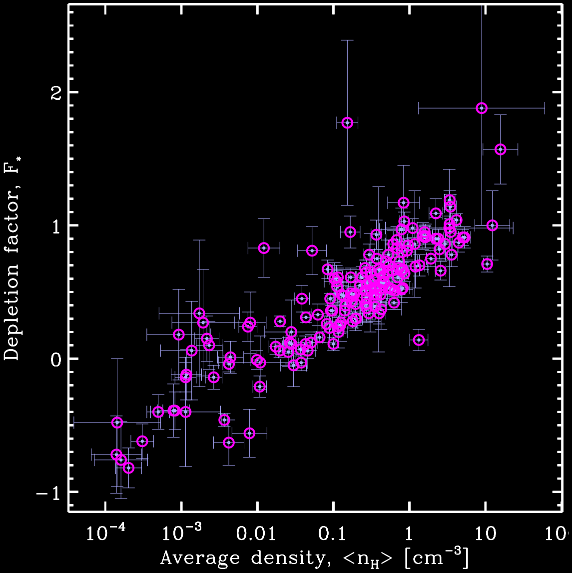

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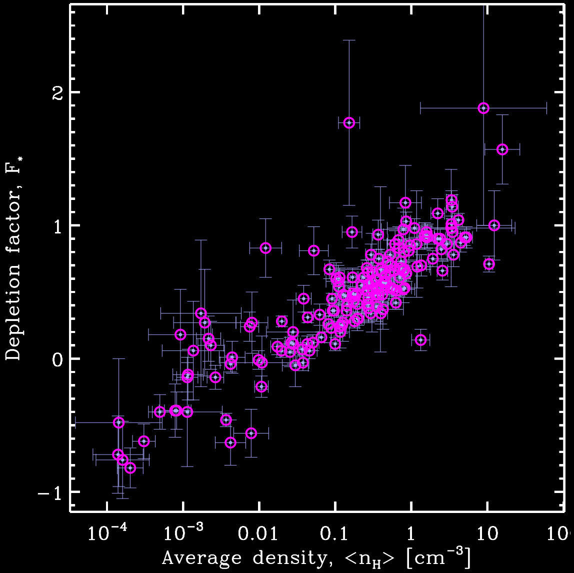

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Evolution with Column Density in the Milky Way

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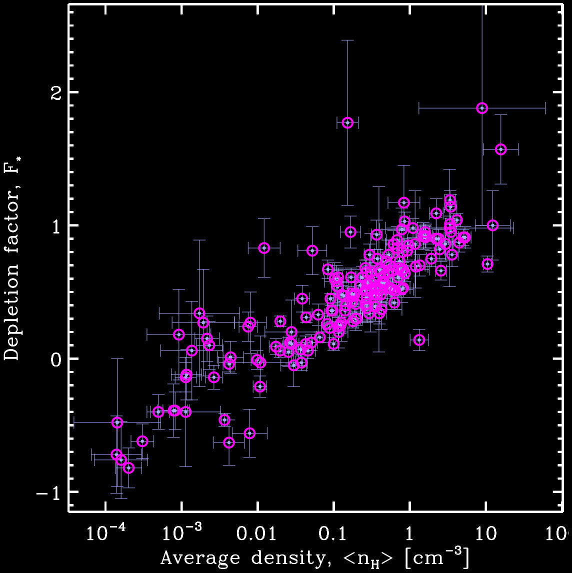
- ⇒ rapid grain growth in ISM & destruction by shocks
- ⇒ most grains were formed in the ISM (*e.g.* Tielens, 1998; Draine, 2009)



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Depletions in the Magellanic Clouds

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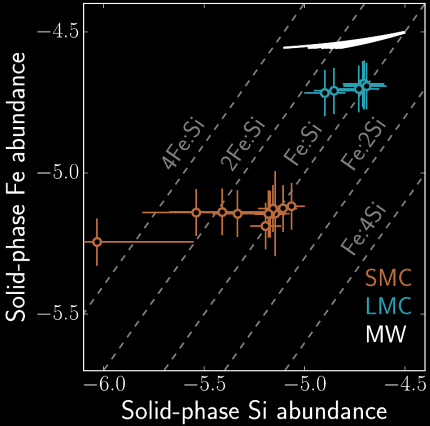

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- SMC: δ(Si) consistent with 0, but δ(Fe) significant

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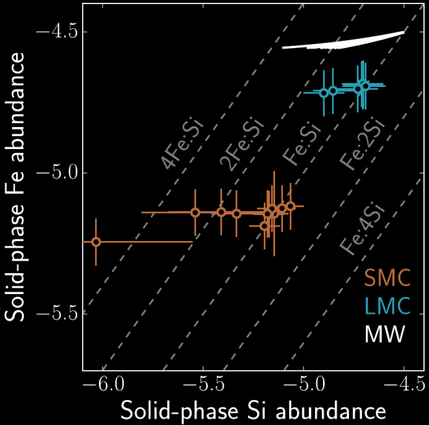

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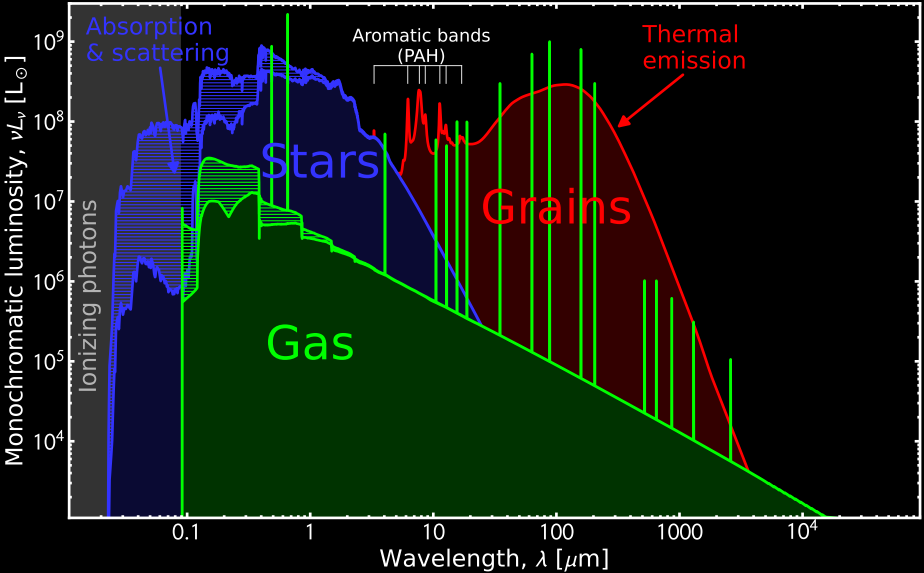

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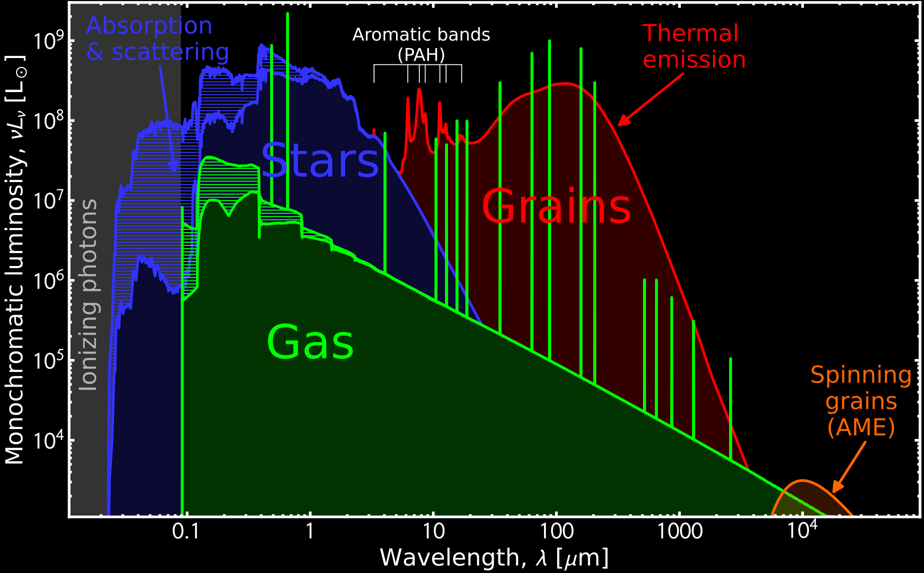

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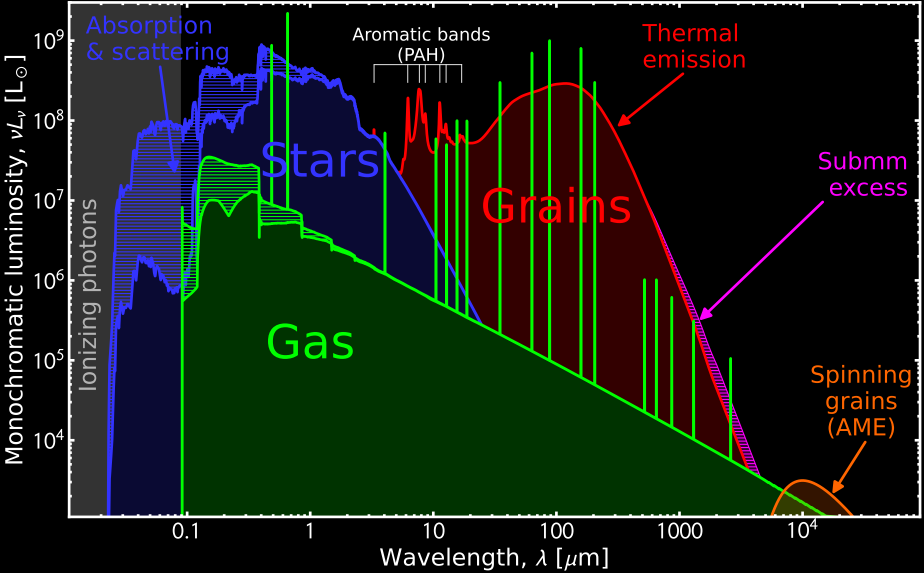

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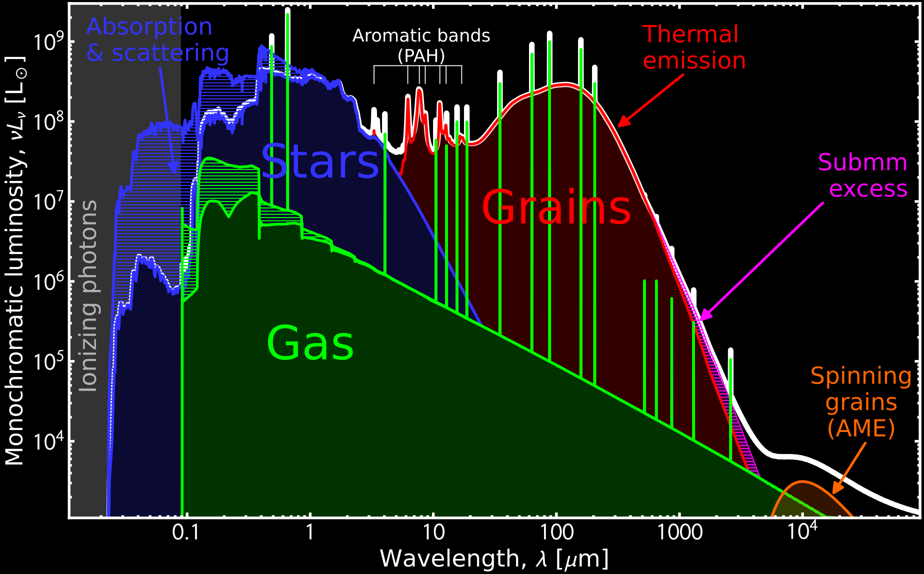

The Puzzling Submillimeter Excess

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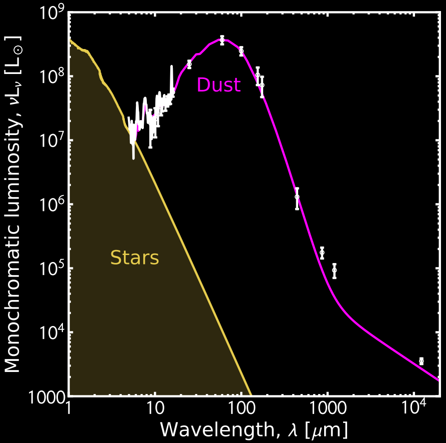
NGC 1569 (blue compact dwarf galaxy)
(Galliano *et al.*, 2003)



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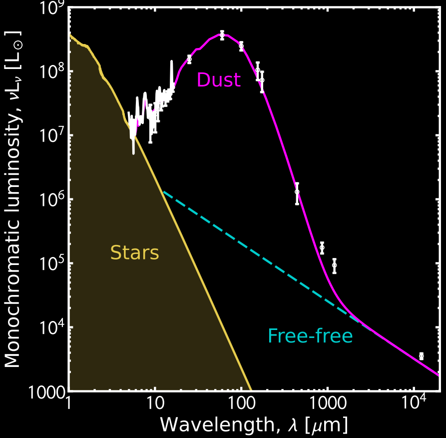

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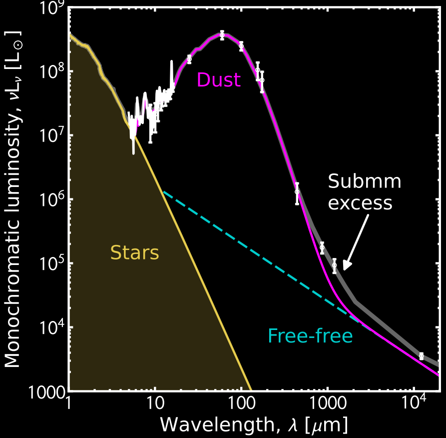

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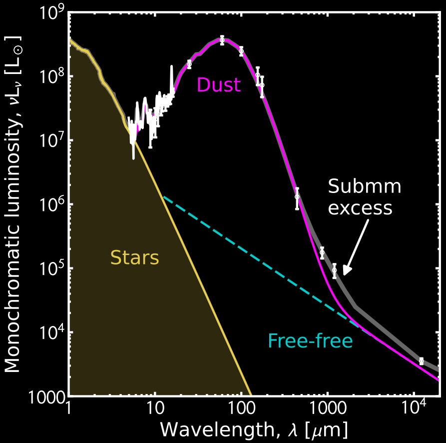

Observations corrected for
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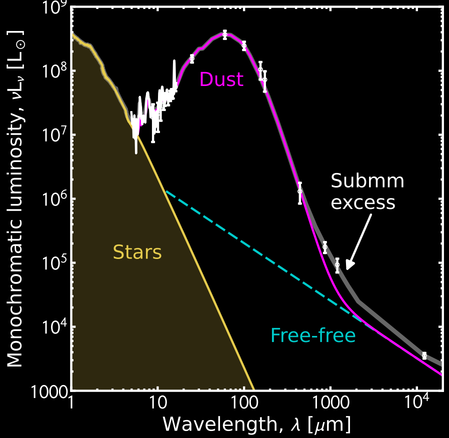

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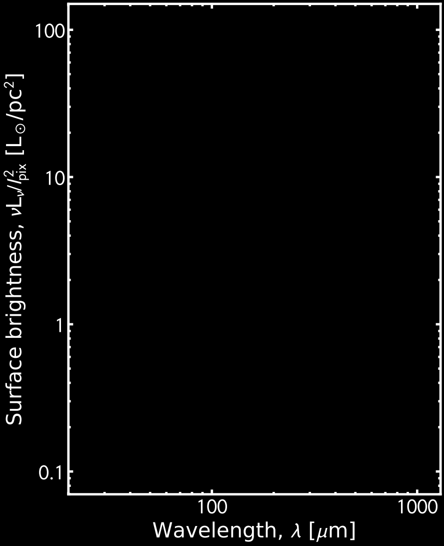
LMC (Galliano *et al.*, 2011)



The Puzzling Submillimeter Excess

NGC 1569 (blue compact dwarf galaxy)
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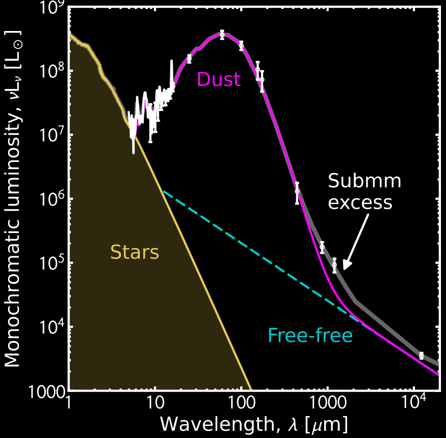

Observations corrected for $^{12}CO(J{=}2\rightarrow1)_{1.3\text{mm}}$ & $^{12}CO(J{=}3\rightarrow2)_{867\mu\text{m}}$.

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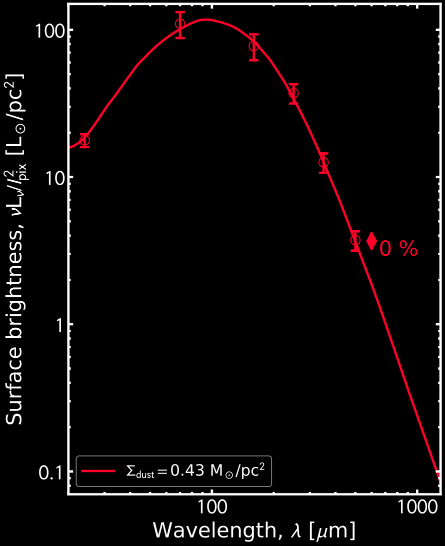

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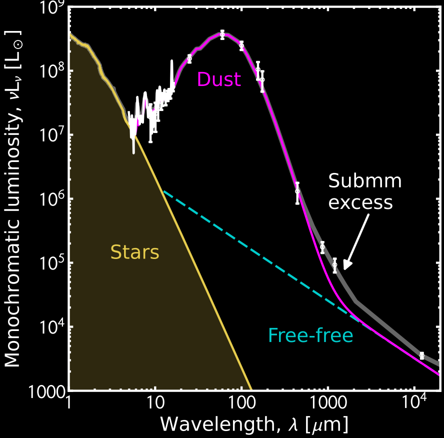

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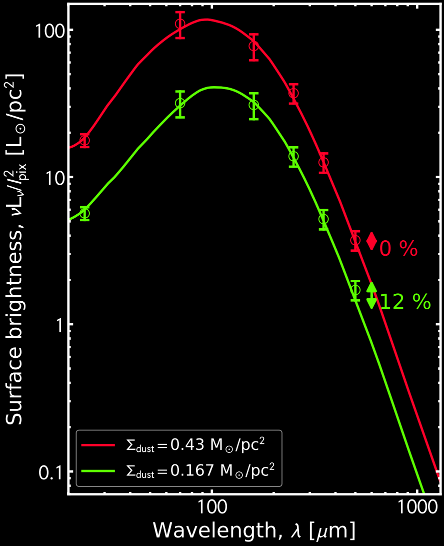

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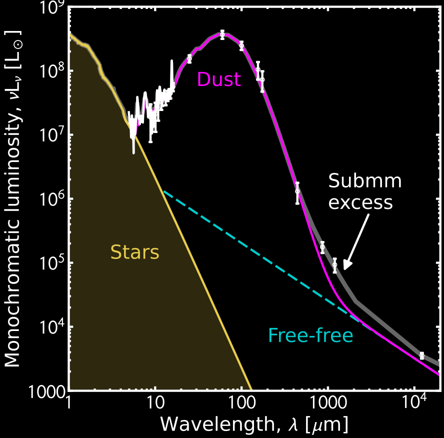

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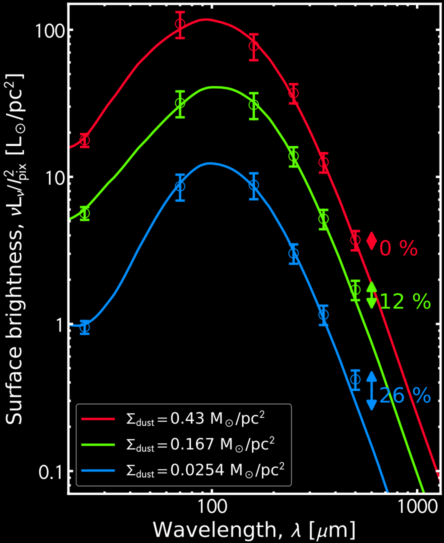

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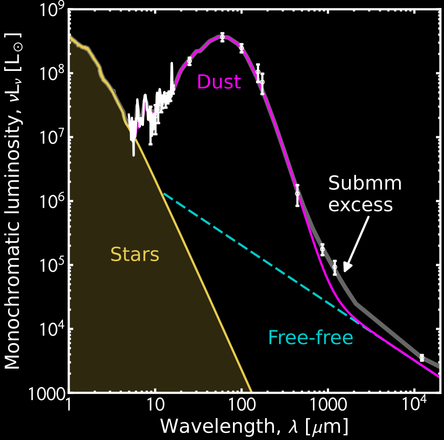

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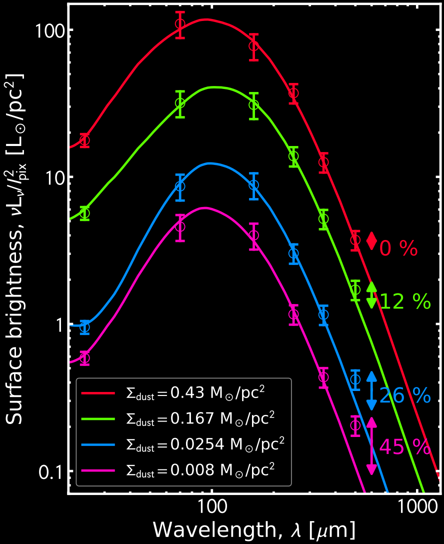

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Outline of the Talk

1. **MOTIVATIONS**
    - What constraints do they bring on dust?
    - The diversity of nearby galaxies
2. **THE DUST PROPERTIES OF NEARBY GALAXIES**
    - Thermal IR emission
    - UV-visible extinction
    - Elemental depletions
    - Long-wavelength properties
3. **CONTRAINTS ON COSMIC DUST EVOLUTION**
    - Cosmic dust evolution models
    - Dust-related scaling relations
    - What local galaxies tell us about cosmic dust evolution
4. **SUMMARY & PROSPECTIVES**
    - What have we learned so far?
    - What are the next challenges & opportunities?

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⇒ Parameters empirically inferred (*e.g.*: De Looze *et al.*, 2020; Nanni *et al.*, 2020; Galliano *et al.*, 2021; De Vis *et al.*, 2021)

Dust Evolution Tracks

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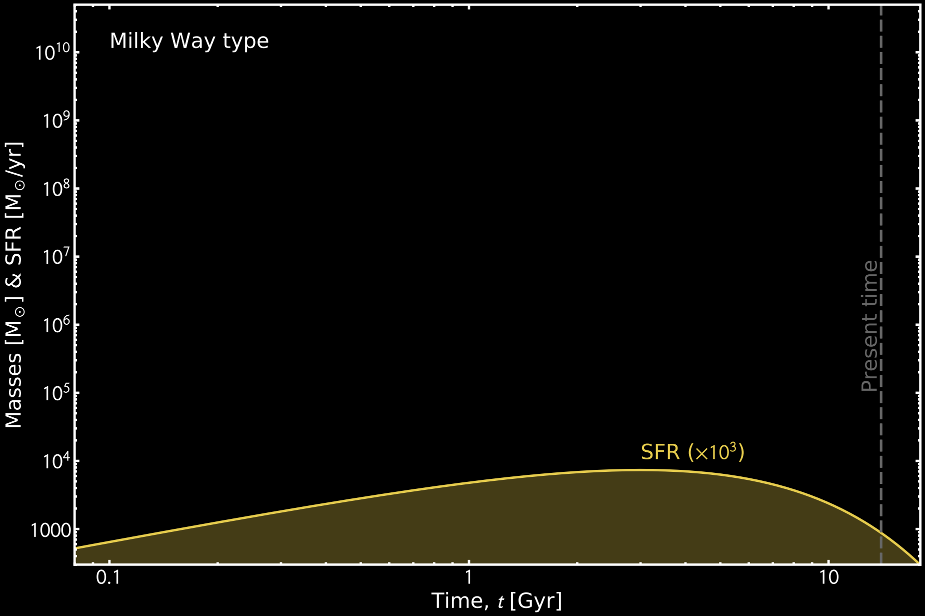

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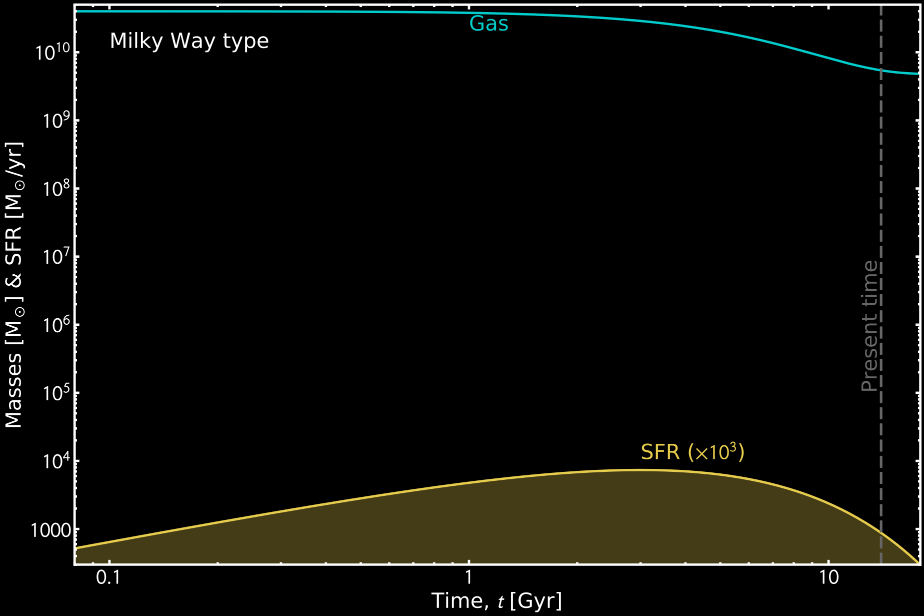

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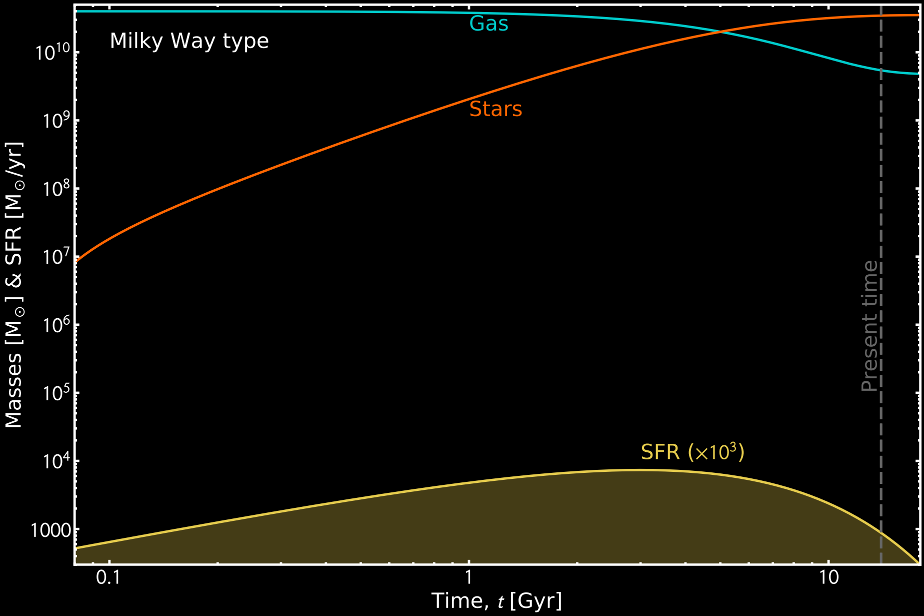

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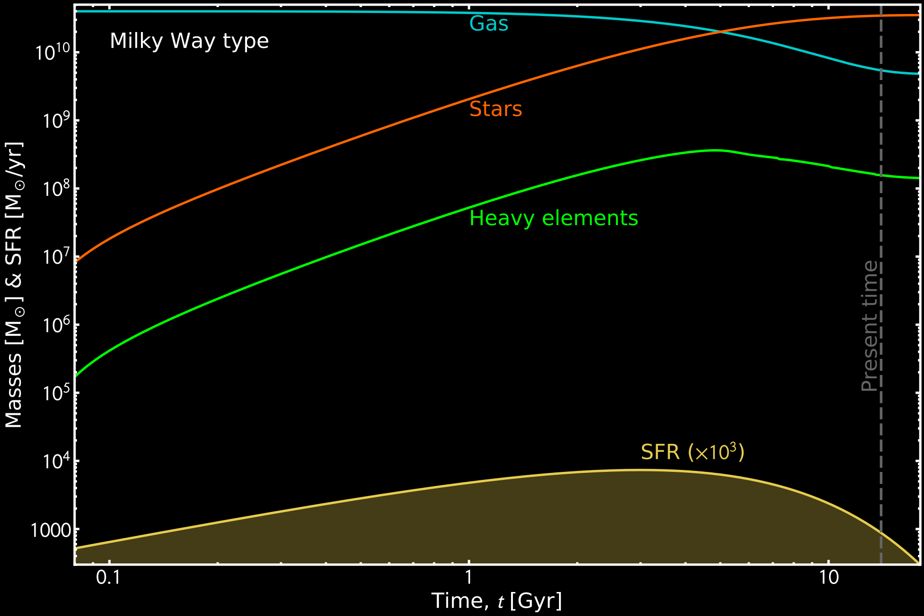

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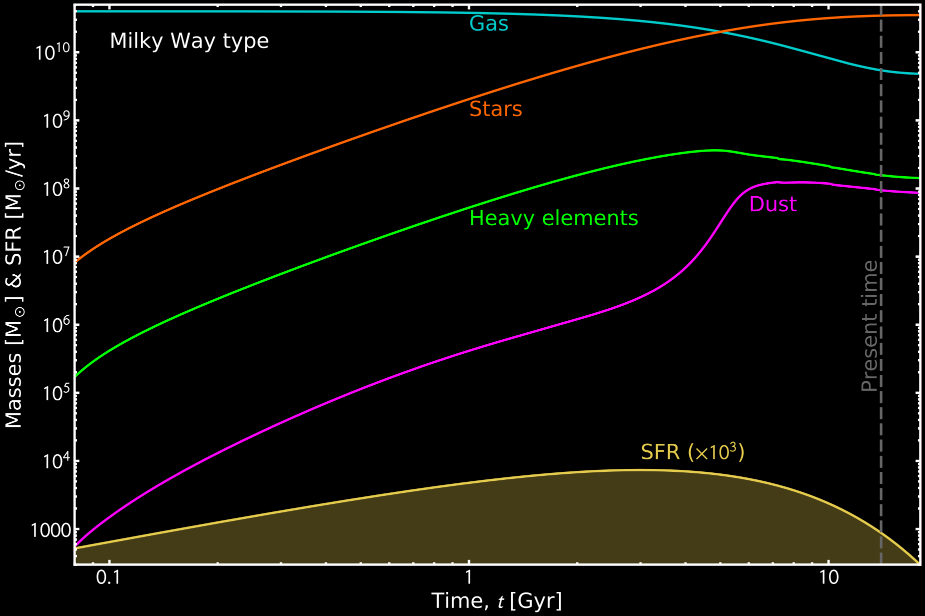

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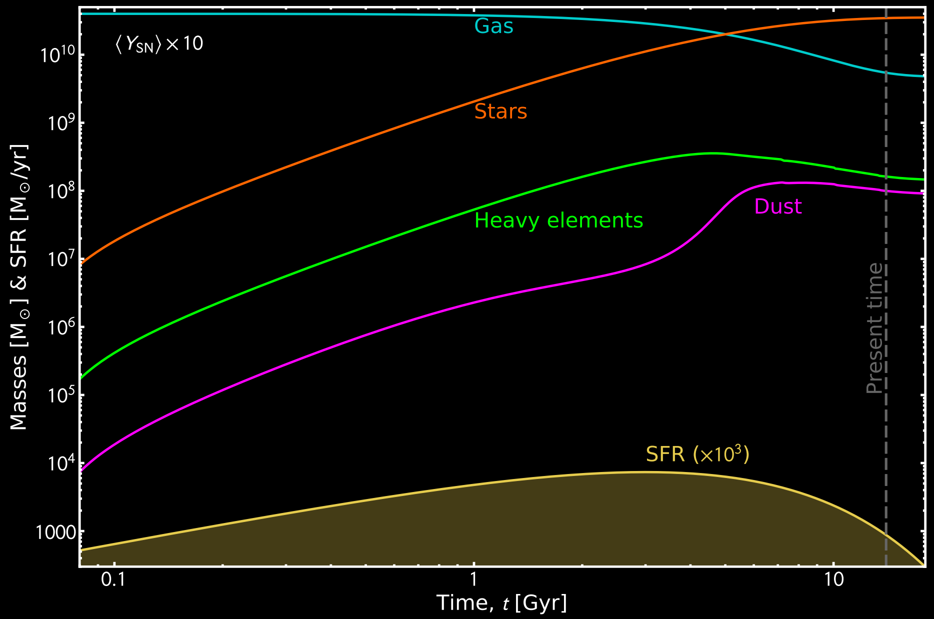

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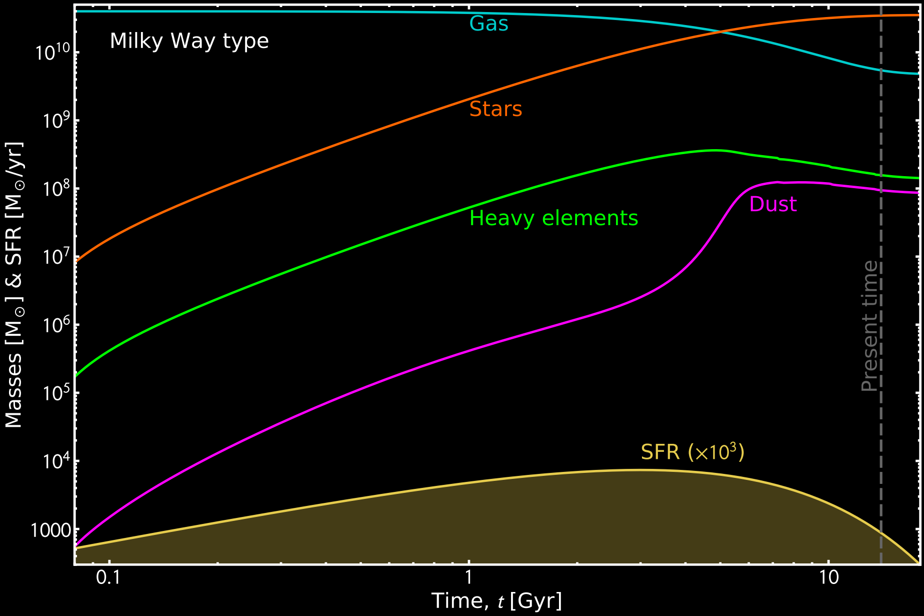

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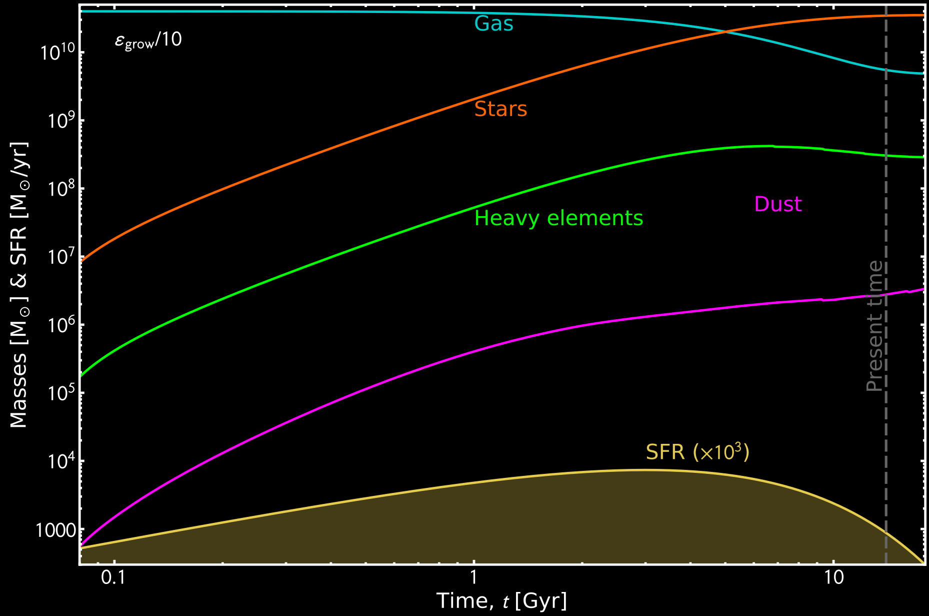

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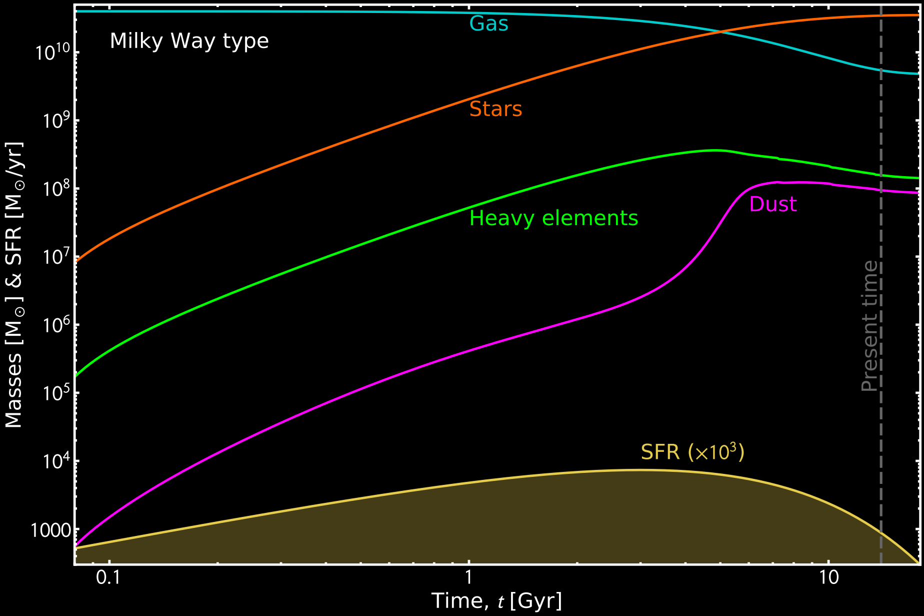

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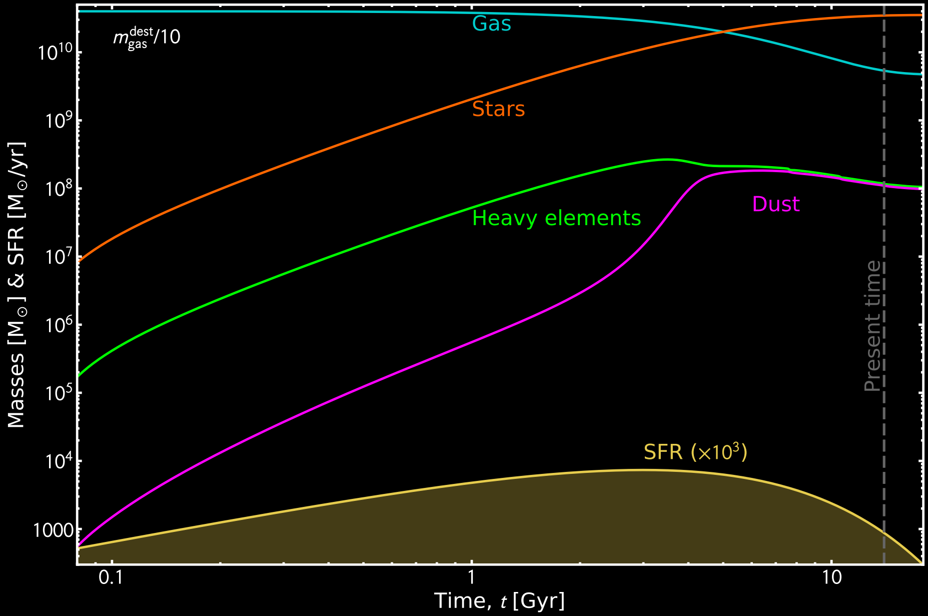

Dust-Related Scaling Relations

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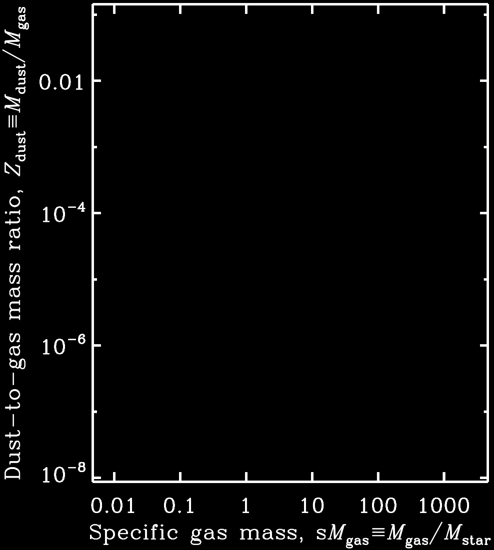

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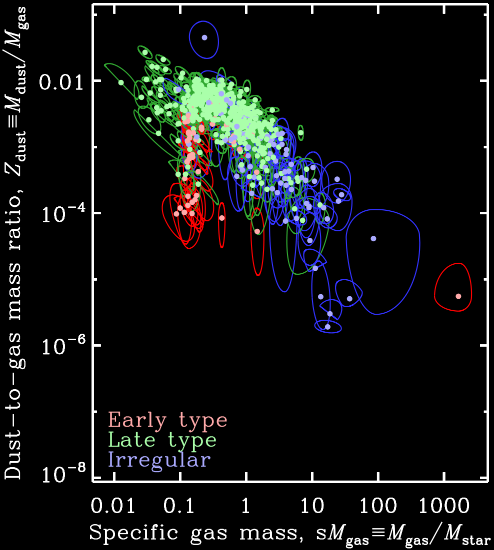

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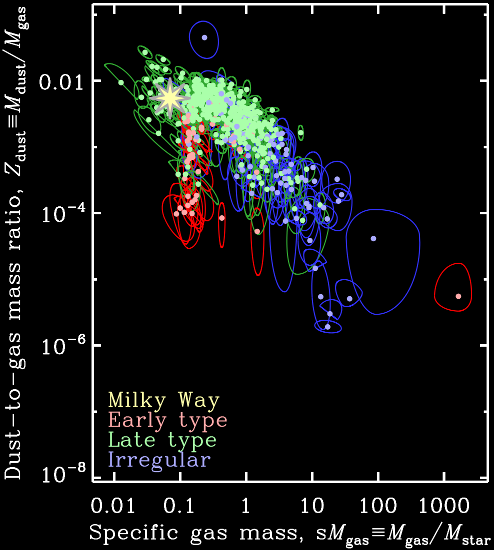

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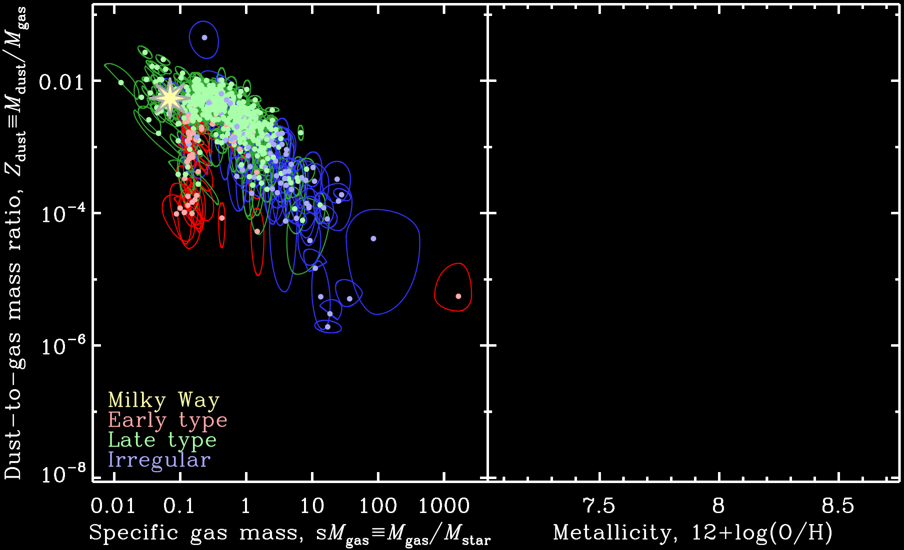

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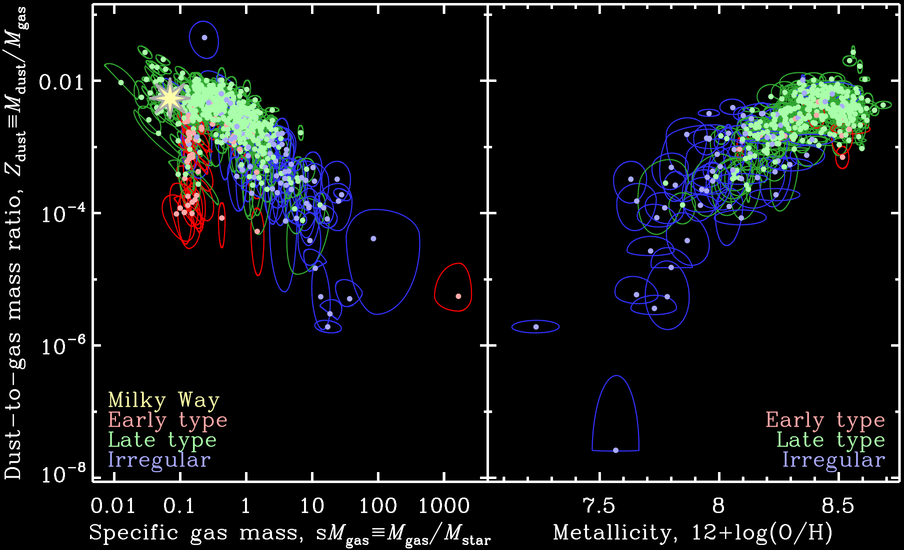

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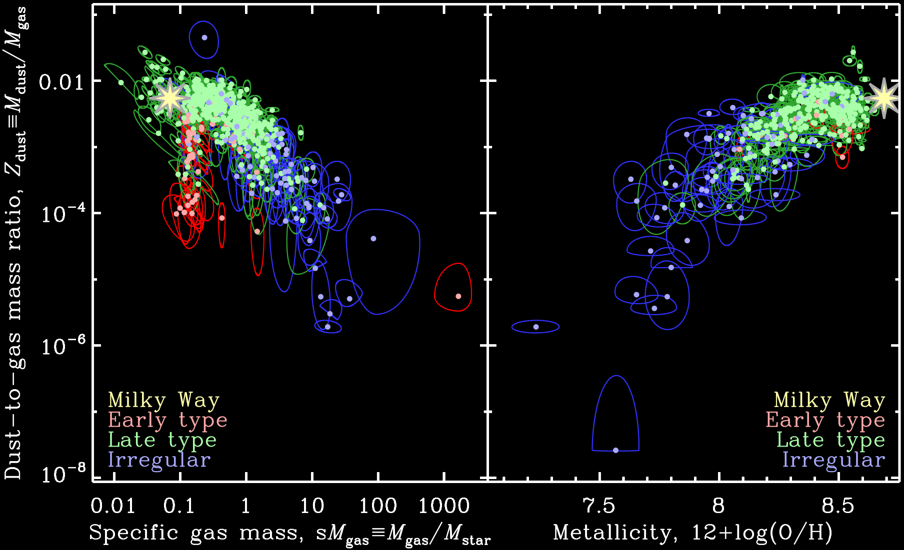

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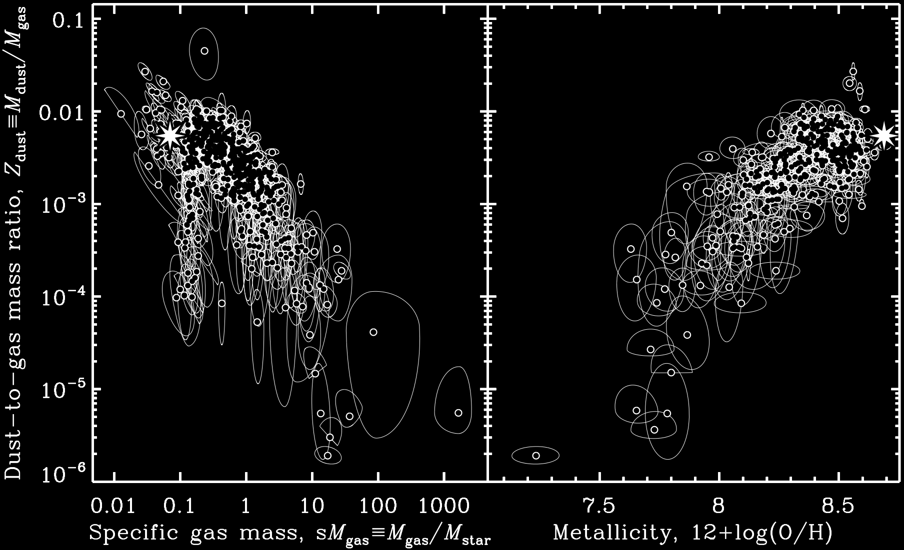
Fitting Dust Evolution Tracks



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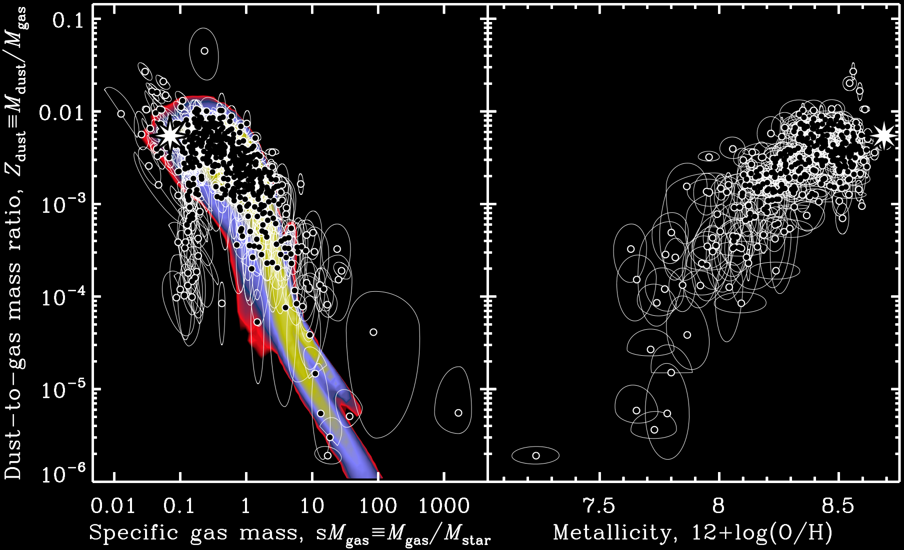

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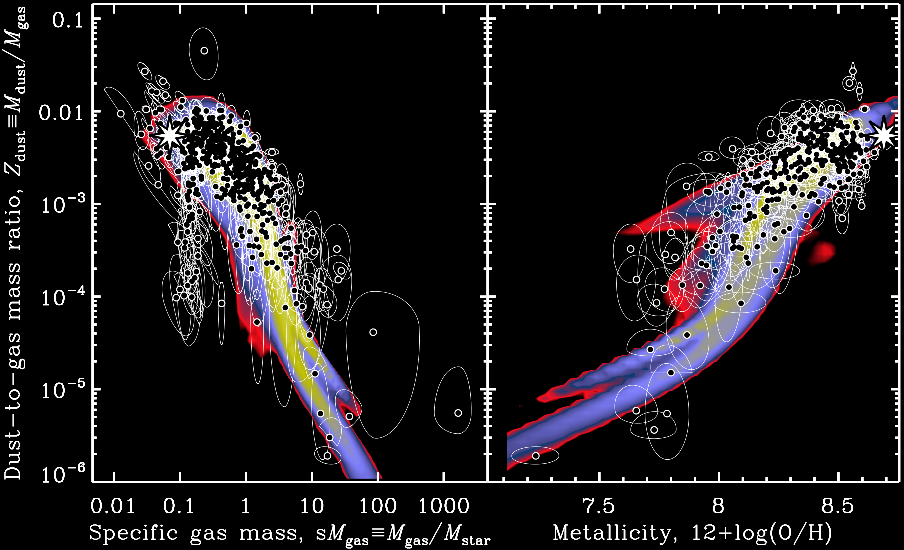

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The Three Dust Build-Up Regimes

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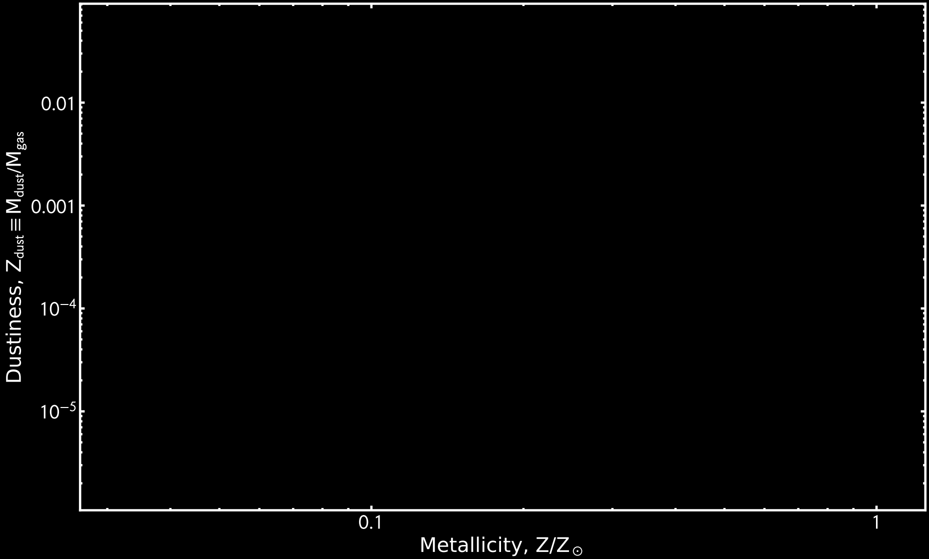

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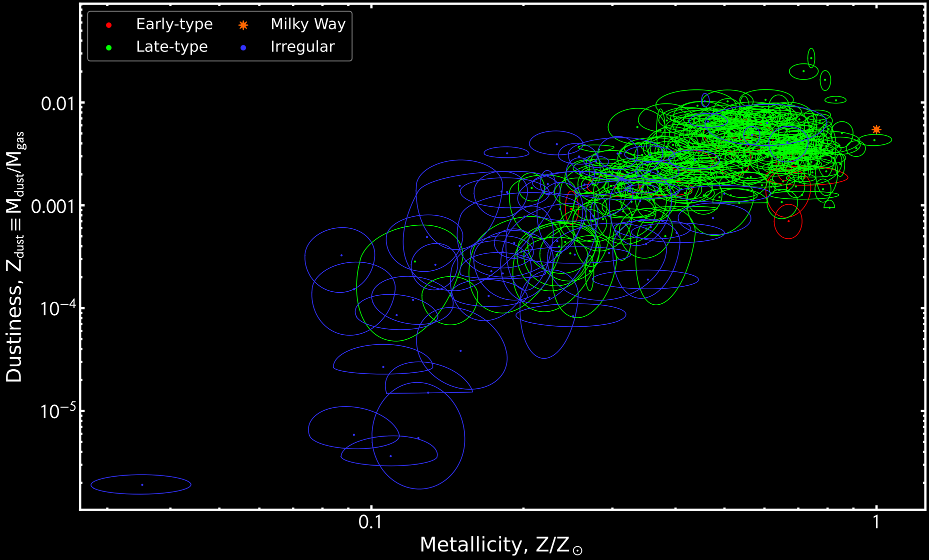

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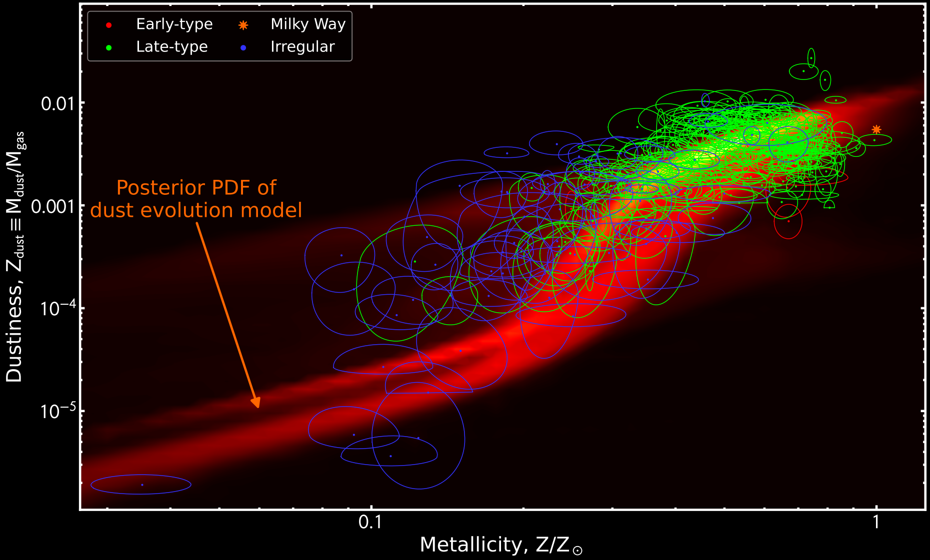

Posterior PDF of dust evolution model

(Galliano *et al.*, 2021)

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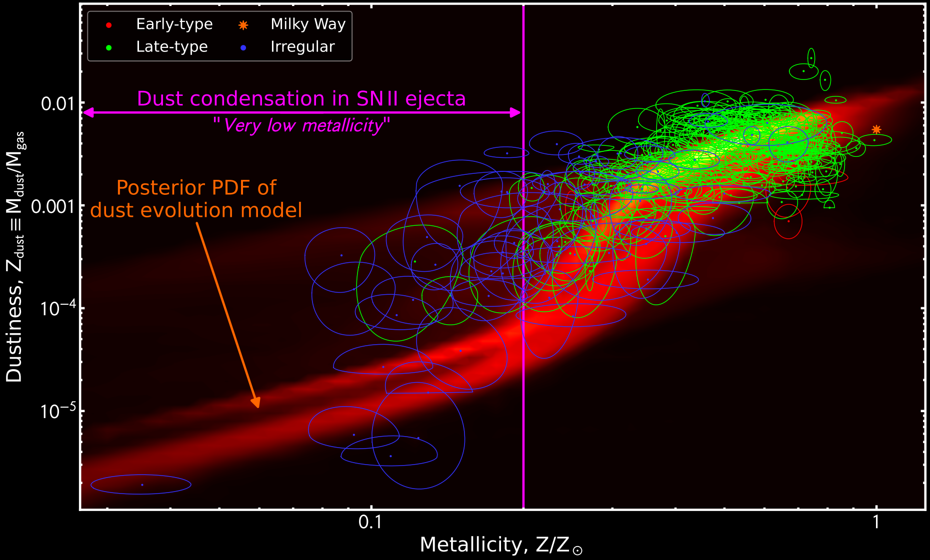

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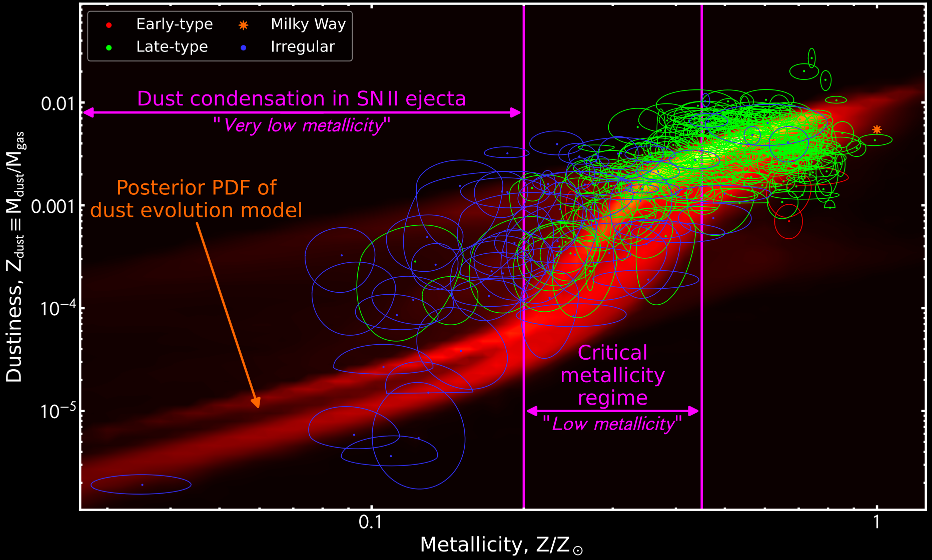

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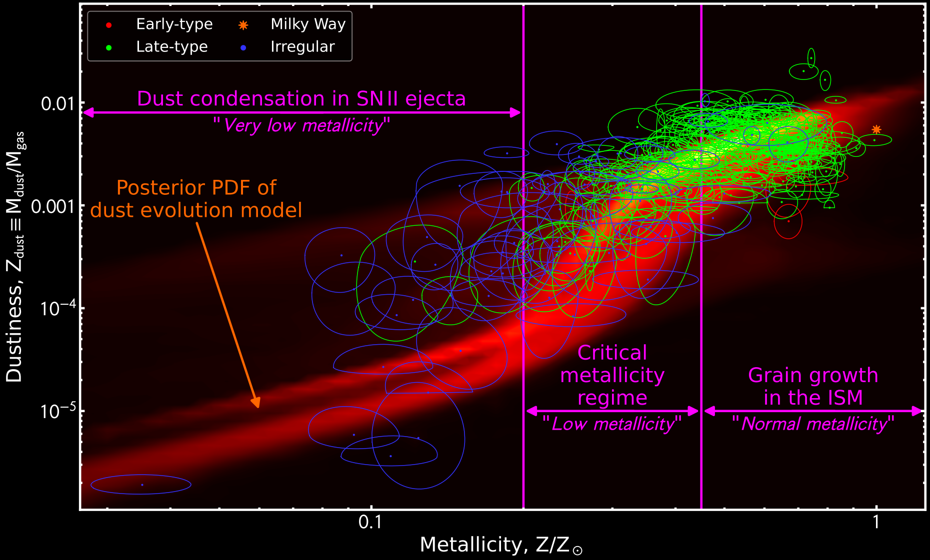

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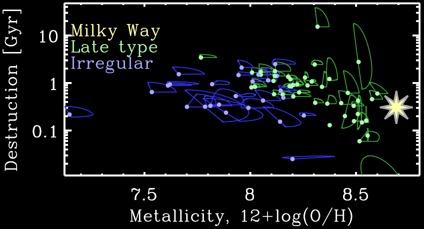

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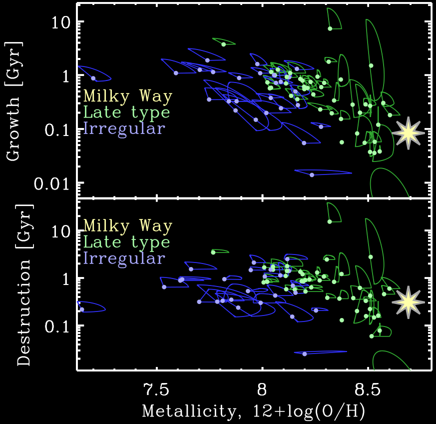

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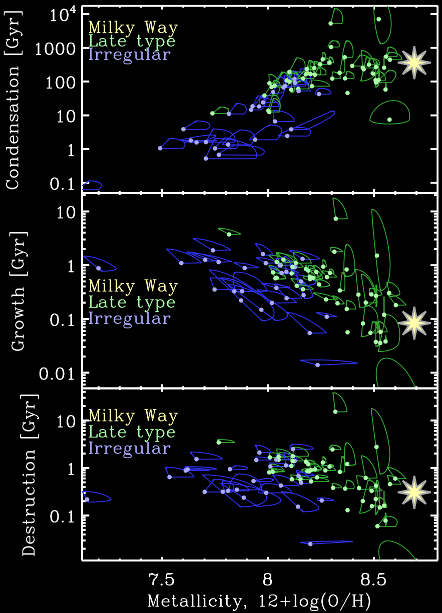

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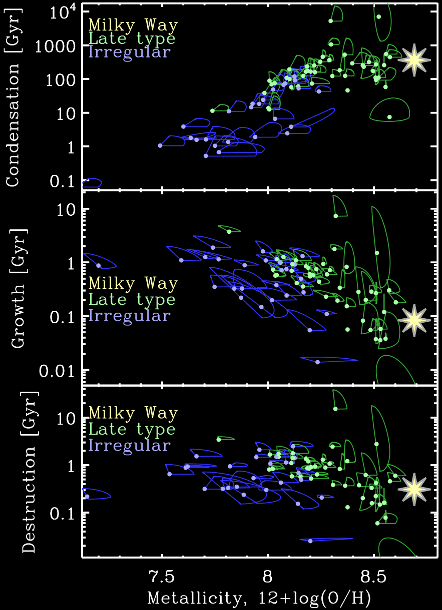

Dust evolution balance:

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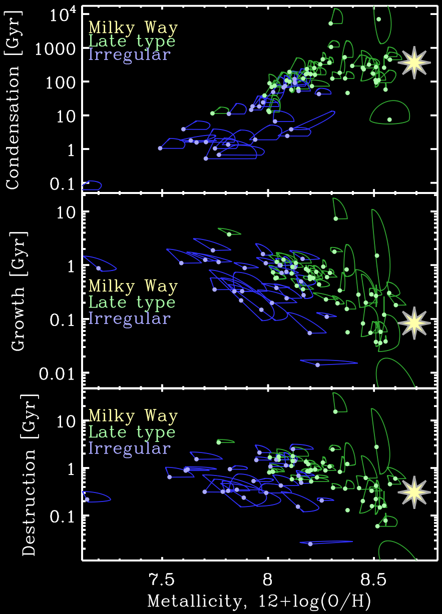

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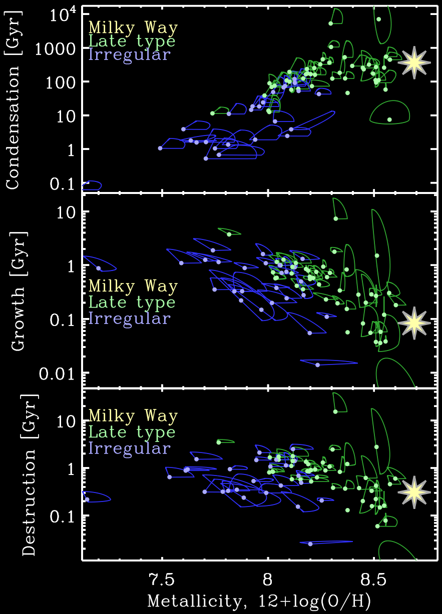

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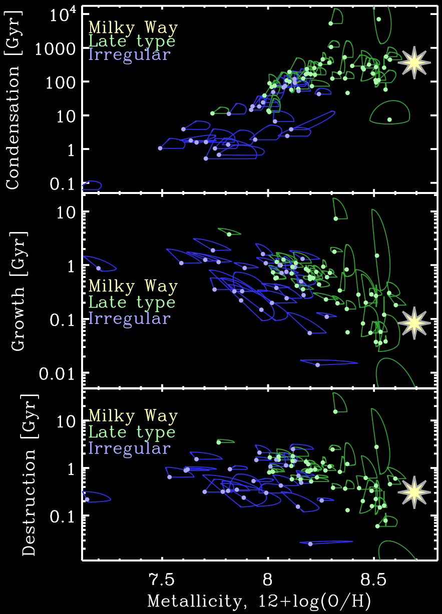

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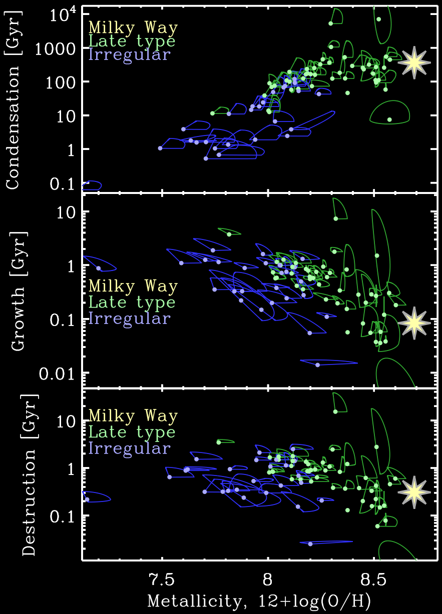

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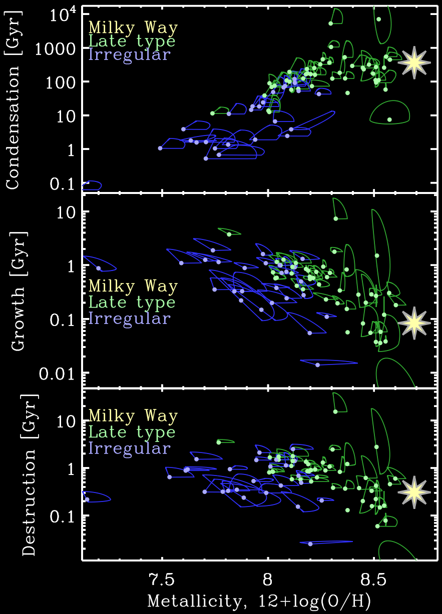

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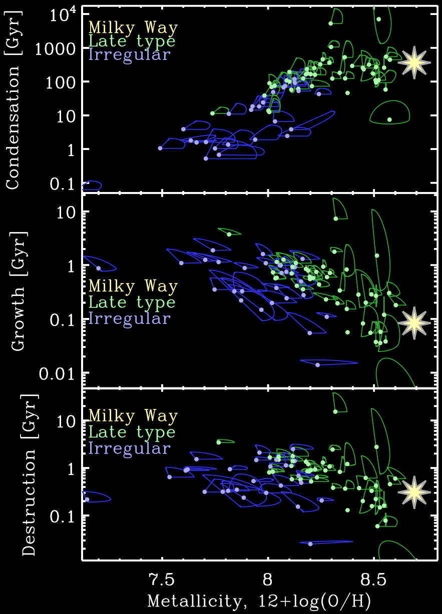

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Take away points:

- Important to fit dust evolution models (not only overlay) $\Rightarrow$ consistency & eliminate bad solutions;
- Need both low- & high-Z sources $\Rightarrow$ constrain both production regimes;
- Grain growth realistic for dust at high z $\Rightarrow$ simply need $Z \gtrsim 1/5\ Z_\odot$.

(Galliano *et al.*, 2021)

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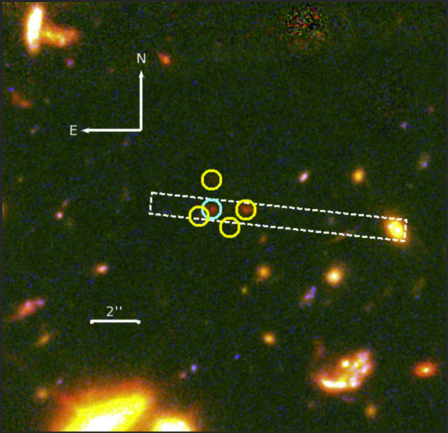
The example of A2744_YD4 ($z \simeq 8.38$; age $\lesssim 200$ Myr)



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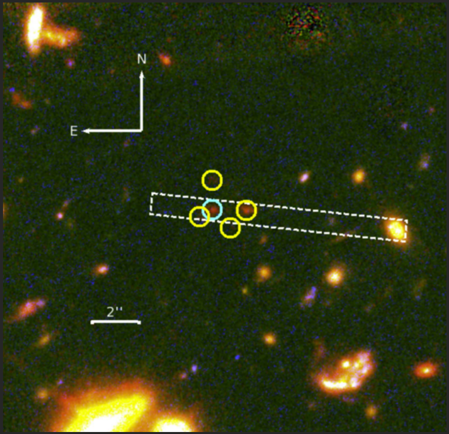

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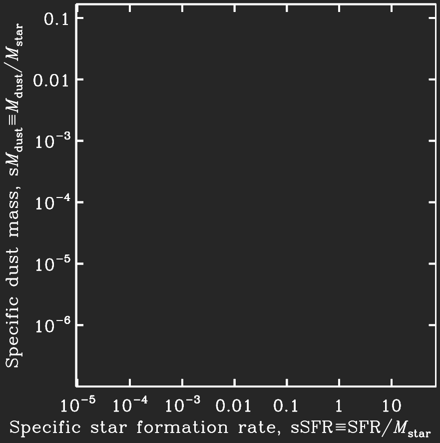

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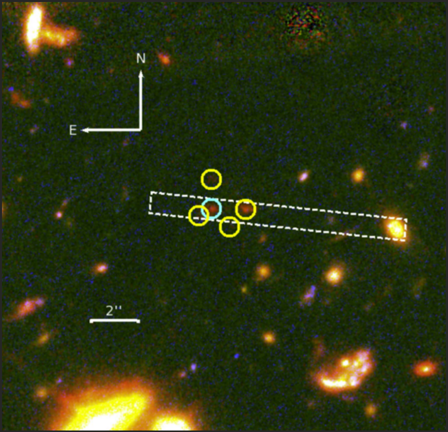

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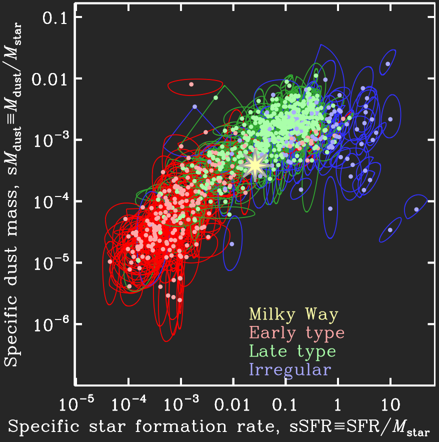

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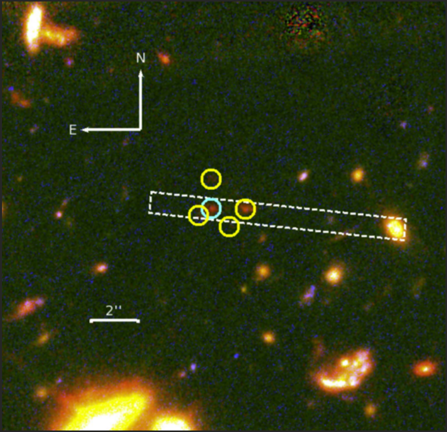

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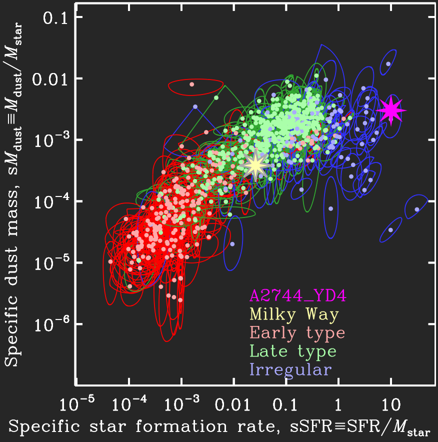

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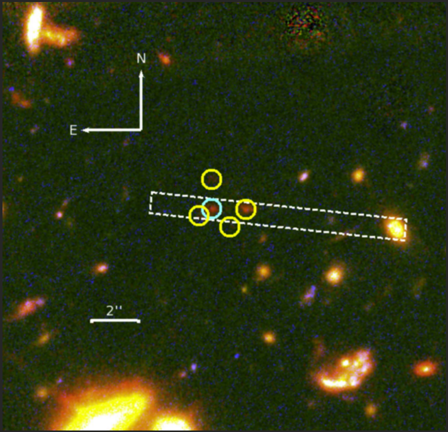

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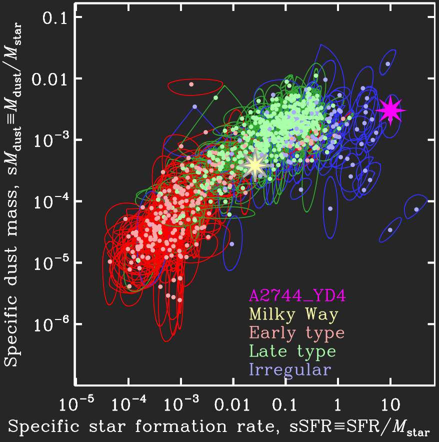

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Comparison: consistent with dwarfs around critical metallicity

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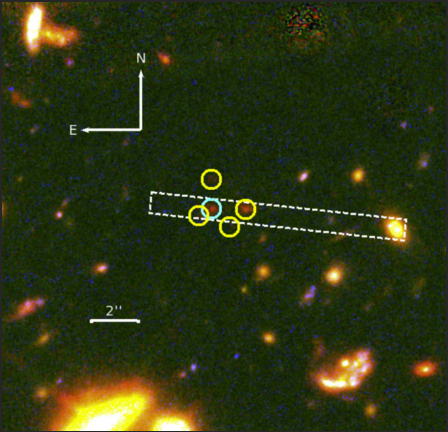

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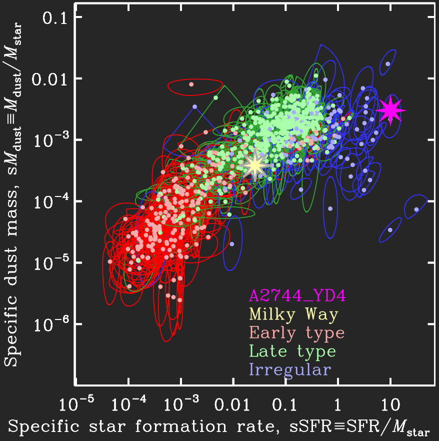

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Comparison: consistent with dwarfs around critical metallicity ⇒ grain growth kicks in

Outline of the Talk

1. **MOTIVATIONS**
   - What constraints do they bring on dust?
   - The diversity of nearby galaxies
2. **THE DUST PROPERTIES OF NEARBY GALAXIES**
   - Thermal IR emission
   - UV-visible extinction
   - Elemental depletions
   - Long-wavelength properties
3. **CONTRAINTS ON COSMIC DUST EVOLUTION**
   - Cosmic dust evolution models
   - Dust-related scaling relations
   - What local galaxies tell us about cosmic dust evolution
4. **SUMMARY & PROSPECTIVES**
   - What have we learned so far?
   - What are the next challenges & opportunities?

The Hierarchy of Dust Studies

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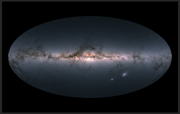
Milky Way studies



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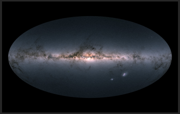

- Best linear resolution

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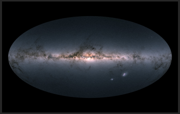

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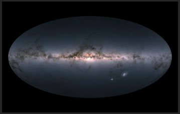

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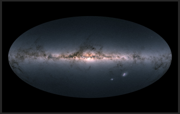

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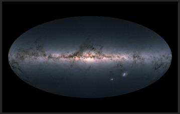

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Nearby galaxy studies

- Understand the effects of Z & SFR

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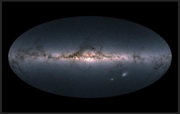

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- Understand the effects of Z & SFR
- Statistical sample

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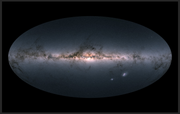

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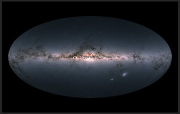

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Distant galaxy studies

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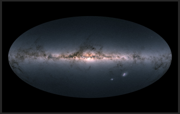

- Best linear resolution
- Comprehensive observables

⇒ Develop dust models

Nearby galaxy studies

- Understand the effects of Z & SFR
- Statistical sample

⇒ Constrain cosmic dust evolution

Distant galaxy studies

- Allow to understand galaxy evolution

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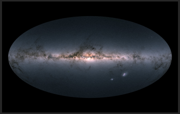

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- Give access to truly primordial systems (effects of pop. III)

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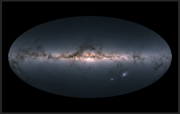

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Nearby galaxy studies

- Understand the effects of Z & SFR
- Statistical sample

⇒ Constrain cosmic dust evolution

Distant galaxy studies

- Allow to understand galaxy evolution
- Give access to truly primordial systems (effects of pop. III)

⇒ Better understanding of early evolution

Summary: What Have We Learned So Far from Nearby Galaxies?

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ALMA (2009-; submm/mm)

$\theta \lesssim 1''$

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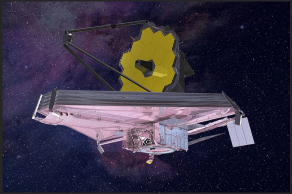

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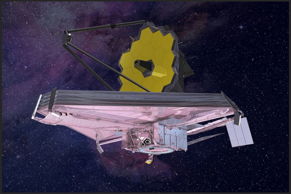

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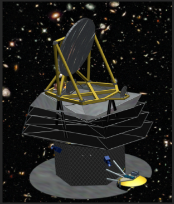

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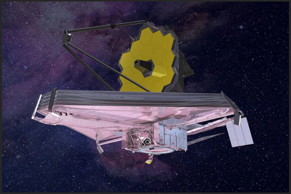

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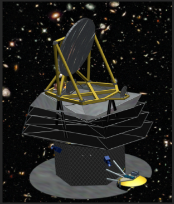

$\theta \lesssim 1'$

⇒ need a high angular resolution FIR project

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Recommended Reading

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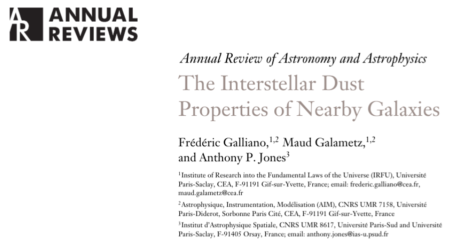
Galliano, Galametz & Jones (2018, ARA&A)



ANNUAL REVIEWS

Annual Review of Astronomy and Astrophysics

The Interstellar Dust Properties of Nearby Galaxies

Frédéric Galliano,[1,2] Maud Galametz,[1,2]
and Anthony P. Jones[3]

[1] Institute of Research into the Fundamental Laws of the Universe (IRFU), Université Paris-Saclay, CEA, F-91191 Gif-sur-Yvette, France; email: frederic.galliano@cea.fr, maud.galametz@cea.fr

[2] Astrophysique, Instrumentation, Modélisation (AIM), CNRS UMR 7158, Université Paris-Diderot, Sorbonne Paris Cité, CEA, F-91191 Gif-sur-Yvette, France

[3] Institut d'Astrophysique Spatiale, CNRS UMR 8617, Université Paris-Sud and Université Paris-Saclay, F-91405 Orsay, France; email: anthony.jones@ias-u.psud.fr

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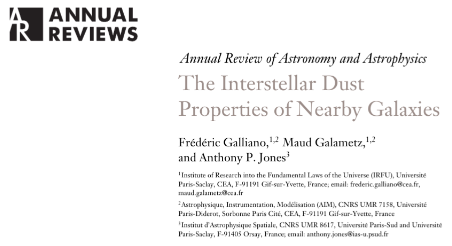

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Galliano (2022, HDR)

- Open source on ArXiv & HAL
- Written as a textbook
- 353 pages
- 165 figures
- 31 tables
- 796 references

Habilitation à diriger des recherches

université
PARIS-SACLAY

A Nearby Galaxy Perspective on Interstellar Dust Properties and their Evolution

Habilitation à diriger des recherches de l'Université Paris-Saclay

Habilitation présentée et soutenue à Gif-sur-Yvette, le vendredi 14 janvier 2022, par

Frédéric GALLIANO
Département d'Astrophysique, CEA Paris-Saclay

Composition du jury:

Véronique BUAT Professeure, Laboratoire d'Astrophysique de Marseille	Rapportrice
Stéphane CHARLOT Directeur de recherche, Institut d'Astrophysique de Paris	Examinateur
Vassilis CHARMANDARIS Professeur, Université de Crète, Grèce	Rapporteur
François-Xavier DÉSERT Astronome, Institut de Planétologie et d'Astrophysique de Grenoble	Examinateur
Thomas HENNING Professeur, Institut Max Planck d'Astronomie, Heidelberg, Allemagne	Rapporteur
Laurent VERSTRAETE Professeur, Institut d'Astrophysique Spatiale, Orsay	Président