Interplay between metallicity and properties of galaxies

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The plan

- Describe a survey of a large variety of local universe galaxies
  SF activity, metallicity, morphology....

- Detailed SED model applied systematically to all galaxies

- SED model parameters -> physical properties of galaxies

- Gas-to-dust mass ratio (G/D): a powerful tracer of evolutionary
  stage of a galaxy

Local Universe - a zoo of galaxies, including low metallicity dwarf
galaxies - convenient labs to study of the evolution of the
dust and gas properties
Survey of Dust properties in galaxies: The Sample

DGS: Dwarf Galaxy Survey
Madden et al. +13
Remy-Ruyer et al. 2013; 2014
48 galaxies

- Low metallicity, star forming, gas-rich dwarf galaxies

KINGFISH
Kennicutt+11, Dale+12
61 galaxies

- More metal-rich systems

Observed with *Herschel & Spitzer*
PACS: 70/100/160 µm + spectro
SPIRE: 250/350/500 µm

Diane Cormier’s talk
Kingfish (Key Insights on Nearby Galaxies: a Far-Infrared Survey with Herschel)

D = 3 to 33 Mpc

Elliptical

SO

SBa

SBb

SBc

SBd

Irregular
Detailed SED modeling of 109 galaxies - systematic.

full IR-submm wavelength range

- Dust SED Model of Galliano+11
- Grain size distribution Zubko+04
- MW dust: graphite, Silicate and PAHs
  Remy-Ruyer et al. in prep
SED characterization to galactic properties

- Position of the peak given by the average starlight intensity $<U>$

- Width of the peak given by $\sigma^2 U$

- $U_{\text{max}} = 409$
- $U_{\text{min}} = 0.4$

Can get high $\sigma^2 U$
With wide range of clumps in beam, for example

Figure from Galliano+11
Dust temperature distribution: Metallicity

Dwarf galaxies have warmer dust and a broader range in dust temperature.

KINFGISH galaxies have a colder and narrower SEDs.

\[ <U> \text{ can be transformed into a characteristic dust grain temperature } \]

\[ <T_{DGS}> \sim 30 \text{ K} \]

\[ <T_{KF}> \sim 20 \text{ K} \]
SFR and sSFR and Metallicity

SFR Composite: Halpha corrected for attenuation with $L_{TIR}$, Kennicutt et al. (2009)

sSFR
M* Eskew + (2012)
irac 3.6 + 4.5 mu

Correlation sSFR & Z
Speafman rank c
Correlation coeff : -0.77

Remy-Ruyer et al. In prep
What is controlling the SED shape?

\(<U>\) (position of peak) and \(\sigma^2 U\) (peak width)

<table>
<thead>
<tr>
<th>Param</th>
<th>12+log(O/H)</th>
<th>(&lt;U&gt;)</th>
<th>(\sigma^2 U)</th>
<th>sSFR</th>
<th>(M_{\text{star}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M_{\text{dust}})</td>
<td>0.76</td>
<td>-0.53</td>
<td>-0.56</td>
<td>-0.70</td>
<td>0.91</td>
</tr>
<tr>
<td>(M_{\text{dust}}/M_{\text{star}})</td>
<td>-0.004</td>
<td>-0.60</td>
<td>-0.39</td>
<td>-0.03</td>
<td>-0.10</td>
</tr>
<tr>
<td>(L_{\text{TIR}})</td>
<td>0.63</td>
<td>-0.02</td>
<td>-0.10</td>
<td>-0.40</td>
<td>0.86</td>
</tr>
<tr>
<td>(f_{\text{PAH}})</td>
<td>0.61</td>
<td>-0.41</td>
<td>-0.50</td>
<td>-0.75</td>
<td>0.68</td>
</tr>
<tr>
<td>(&lt;U&gt;)</td>
<td>-0.46</td>
<td>1.00</td>
<td>0.87</td>
<td>0.68</td>
<td>-0.34</td>
</tr>
<tr>
<td>(\sigma^2 U)</td>
<td>-0.54</td>
<td>0.87</td>
<td>1.00</td>
<td>0.76</td>
<td>-0.46</td>
</tr>
<tr>
<td>SFR</td>
<td>0.46</td>
<td>0.11</td>
<td>0.05</td>
<td>-0.14</td>
<td>0.70</td>
</tr>
<tr>
<td>sSFR</td>
<td>-0.77</td>
<td>0.68</td>
<td>0.76</td>
<td>1.00</td>
<td>-0.76</td>
</tr>
<tr>
<td>(M_{\text{star}})</td>
<td>0.83</td>
<td>-0.34</td>
<td>-0.46</td>
<td>-0.76</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Rémy-Ruyer et al. in prep

Z not strong correlation \(<U>\) (position of peak) and \(\sigma^2 U\) (peak width)
sSFR correlates with \(<U>\) (position of peak) and \(\sigma^2 U\) (peak width)
The lowest metallicity galaxies in local universe

**SBS0335-052**
- $Z \sim 2.3\%$ Zsolar
- $D = 58 \text{ Mpc}$
- $>10,000$ stars in
  - $6 (<50 \text{ pc})$ SSCs
- $n_e \sim 600-2000 \text{ cm}^{-3}$
- SFR $\sim 1 \text{ Mo/yr}$

*Diffuse, compact, More active SF regions*

**IZw18**
- $Z \sim 2\%$ Zsolar
- $D = 10 \text{ Mpc}$
- 1100 stars in 2 clusters
- No SSCs
- $n_e \sim 100 \text{ cm}^{-3}$
- SFR $\sim 0.4-0.1 \text{ Mo/yr}$

*Diffuse, passive, low n SF regions*
The lowest metallicity galaxies in local universe

**SBS0335-052**
- Z~ 2.3% Zsolar
- D=58 Mpc
- >10 000 stars in 6 (<50 pc) SSCs
- \(n_e\) ~600 – 2000 cm\(^{-3}\)
- SFR~ 1 Mo/yr
- Dense, compact,
  More active SF regions

\[L_{\text{FIR}} = 1.3 \times 10^9 L_{\odot}\]

**IZw18**
- Z~ 2% Zsolar
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- >1100 stars in 2 clusters
- No SSCs
- \(n_e\) ~100 cm\(^{-3}\)
- SFR ~ 0.4-0.1 Mo/yr
- Diffuse, passive, low n SF regions

\[L_{\text{FIR}} = 3.5 \times 10^7 L_{\odot}\]

Not only metallicity that matters
Submm excess?

- Include (or not) 500μm point?

Conclusion:
- 8 galaxies show excess when using the 500μm point & dust masses are not effected with or without 500μm.

Rémy-Ruyer et al. 2014
$G/D$ vs $Z$: Observed relation

Atomic gas mass: HI

Molecular gas mass: H$_2$, use $X_{\text{CO},Z}$ from Schruba+12

Same "strong line" method for the whole sample

$G/D$ as a function of metallicity

From dust model

Sample: DGS, KINGFISH, and Galametz+11
G/D vs Z: Empirical relations

- Power law: $G/D$ as $Z^{-\alpha}$
  - Get $\alpha = 2.0 \pm 0.3$
- 2 power laws: $G/D$ as $Z^{-\alpha_L}$ at low metallicities
  - Get $\alpha_L = 3.1 \pm 1.3$
- Transition at $12+\log(O/H) = 8.10$

Less dust from the available metals in low-Z ISMs
  - why is grain formation less efficient?

Rémy-Ruyer et al. 2014
Chemical evolution models

- Chemical evolution model by Asano+13

- « Critical » metallicity over which dust growth is the main process in the dust mass evolution

- Depend on the star formation timescale

- Dust growth in the ISM is fundamental (also Zhukovska et al 2014)

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

Rémy-Ruyer+14

Rémy-Ruyer et al. 2014
Summary

- **Dust temperature, SF, metallicities:**
  - Warmer dust, larger range of dust temperatures in low Z
  - Joint effect of low-metallicity and high star-formation activity
  - Wide spread in SFR but sSFR anticorrelated with Z - high in low metallicity galaxies

- **Dust Mass and Gas/Dust mass ratios**
  - Strong NON LINEAR metallicity evolution
  - Metals incorporated into dust less efficiently until grain-growth has improved efficiency ($Z \sim 1/4$)
  - Large scatter can be explained with different star formation histories
  - New empirical relation to estimate the G/D from metallicities

*Caution going from dust mass to total gas mass – large variations.*