Dust attenuation in the universe: the UV and the IR points of view

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And many other collaborators from Herschel and AKARI surveys teams

Sendai-november 7th 2014
Both UV and IR emissions are related to recent star formation and to dust attenuation.
Three different measurements of dust attenuation in the universe

- A global point of view:
  UV and IR luminosity densities
- UV emitting galaxies:
  $Z=1.5$, 3 & 4 COSMOS field with Herschel (HERMeS data)
- IR selected galaxies
  NEP-AKARI field, 0$<z<2$
A work based on several Herschel surveys

- HerMES (P.I.: S. Oliver),
- GOODS-Herschel (P.I.: D. Elbaz)
- + PEP (P.I.: D. Lutz)

**COSMOS and CDFS fields**  
*HerMES Data Release 2 Field Positions*

GOODS-H-CDFS field at 24-100-160 μm

IRAS dust map (Schlegel et al, 1998)  
Equatorial coordinates
The NEP-AKARI deep survey
Three different measurements to be compared

• **A global point of view:**
  UV and IR luminosity densities
Takeuchi, Buat & Burgarella+06
GALEX & SPITZER

Burgarella, Buat +13
Herschel and optical surveys

Attenuation increases up to $z=1$ and then decreases $A_{\text{UV}}(z=0) \sim A_{\text{UV}}(z=4)$
Three different measurements to be compared

• A global point of view:
  UV and IR luminosity densities

• UV emitting galaxies:
  $Z=1.5, 3 \& 4$ COSMOS field with Herschel (HERMeS data)
Study of UV selected galaxies in the COSMOS field @ z=1.5, 3 & 4
Heinis+13,+14

UV selected Samples

Based on photometric redshifts (Ilbert+13)

- FUV restframe selections
  - \( z \sim 1.5 \): u-band selection \((1.2 < z < 1.7)\), 41,102 galaxies
  - \( z \sim 3 \): r-band selection \((2.75 < z < 3.25)\), 23,774 galaxies
  - \( z \sim 4 \): i-band selection \((3.5 < z < 4)\), 7,713 galaxies
Adding the IR to the UV:
Almost no counterpart of UV selected sources in Herschel images!!

Less than 1% of galaxies are detected ⇒ stacking
Stacking per bin of $L_{\text{FUV}}$

$L_{\text{IR}}$ measured by fitting Dale & Helou (2002) templates on SPIRE data

$A_{\text{FUV}} = f(L_{\text{IR}}/L_{\text{FUV}})$ (Buat+05)

→ LIRGs and sub-LIRGs

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Dust attenuation $L_{\text{IR}}/L_{\text{FUV}}=\text{IRX}$ versus $M_*$ for UV selected galaxies and LBGs

$L_{\text{IR}}$ measured by fitting Dale & Helou (2002) templates on SPIRE data

$A_{\text{FUV}} = f(L_{\text{IR}}/L_{\text{FUV}})$ (Buat+05)

Consistent results found by Panella+14 for a mass selection

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Three different measurements to be compared

- **A global point of view:**
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- **UV emitting galaxies:**
  \(Z=1.5, 3 \& 4\) COSMOS field with Herschel (HERMeS data)

- **IR selected galaxies:**
  NEP-AKARI field, \(0<z<2\)

*Buat et al. In prep (submitted end of nov)*

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Definition of the 8 µm rest-frame selection in the NEP-AKARI deep field

PAH Feature @ 7.7 µm

• **S11** λ(cent) → z=0.38
  With trans > 0.8 (right) & 0.9 (left) 0.15<z<0.49

• **L15** λ(cent) → z=1.08
  With trans > 0.8 0.75<z<1.34

• **L18** λ(cent) → z=1.55
  With trans > 0.8 1.34<z<1.85

• **L24** λ(cent) → z=2
  With trans > 0.8 1.7<z<2.05

Similar selection as in Goto+10

Photo-z from Oi+14
AKARI sources from Murata+13
PACS data for 599 sources
Fitting the full SED with Cigale

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of dust attenuation $E(B-V)$</td>
<td>0.1-1 mag</td>
</tr>
<tr>
<td>Attenuation curve</td>
<td>B12,C00, SMC-like</td>
</tr>
<tr>
<td>IR templates, $\alpha$</td>
<td>1-3</td>
</tr>
<tr>
<td>AGN fraction, $\text{frac}_{\text{AGN}}$</td>
<td>0-0.5</td>
</tr>
</tbody>
</table>

Stellar populations

- age (old stellar population) $t_f$: 2-11 Gyr
- e-folding rate (old stellar population) $\tau$: 1-5 Gyr
- age (young stellar population) $t_{\text{ySP}}$: 50-500 Myr
- stellar mass fraction $f_{\text{ySP}}$: 0.01-0.2

Dale+14 templates
Fritz+06 templates

2 stellar populations

One output parameter: $A_{\text{UV}}$
Mainly constrained by $L_{\text{IR}}/L_{\text{UV}}$

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Examples of best fits

Best model for 61010841 at z = 1.1. Reduced $\chi^2 = 0.97$

- SFR = 89 +/- 13 M$_{\odot}$/yr
- $M_* = (4.2 +/- 1.2) \times 10^{10}$ M$_{\odot}$
- Type 2
- Frac(AGN) = 0.1

Best model for 61013396 at z = 0.3. Reduced $\chi^2 = 2.73$

- SFR = 3 +/- 0.6 M$_{\odot}$/yr
- $M_* = (8.5 +/- 3.8) \times 10^{9}$ M$_{\odot}$
- Type 2
- Frac(AGN) = 0.05

Best model for 61011647 at z = 0.7. Reduced $\chi^2 = 1.06$

- SFR = 75 +/- 10 M$_{\odot}$/yr
- $M_* = (8 +/- 4) \times 10^{10}$ M$_{\odot}$
- Type 1
- Frac(AGN) = 0.25

AGN contribution to $L_{IR}$

$<\text{AGN fraction}> = 0.08 \pm 0.08$

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Evolution of dust attenuation $A_{UV}(\text{@ 150 nm})$ with $z$

- Global attenuation from luminosity densities (Burgarella+13)
- Attenuation in IR selected galaxies ~2 mag higher than the average of the universe

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Evolution of dust attenuation with $z$

IR selected samples: this work and literature
Good agreement in the measurements:

$\rightarrow$ Dust attenuation increases up to $z \sim 1$ and then remains $\sim$constant
Evolution of dust attenuation with $z$

**IR selected samples** (this work and literature):
Slight increase of the attenuation with redshift for galaxies producing the bulk of the IR energy ($L_{\text{IR}}^*$ galaxies)

**UV selected samples**: much lower attenuation, similar to the global one measured with $\rho_{\text{IR}}/\rho_{\text{UV}}$

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Heinis+13

No trend of $L_{IR}/L_{UV}$ with $L_{UV}$

→ The same average $L_{IR}/L_{UV}$ is measured for any cut in $L_{IR}$

$\langle A_{UV} \rangle$ in a UV selection is similar to the average attenuation
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(L_{IR}^*\ galaxies)
UV
selected
samples:
much
lower
attenuation,
similar
to
the
global
one
measured
with
\rho_{IR}/\rho_{UV}
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2014
Dust attenuation increases with $M_*$ in a UV selected sample

*Heinis*+14
Evolv
do of dust attenuation with \( z \)

If we select galaxies with the same stellar mass as in the IR selection \( \rightarrow \) Similar attenuation

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Towards a consistent model?
Bernhard, Béthermin et al. 2014
For each $M_{\text{star}}$ at any $z$

- $\text{SFR} = \text{SFR}(\text{IR}) + \text{SFR}(\text{UV})$
- $L_{\text{IR}}/L_{\text{UV}} = k_{\text{IR}} L_{\text{IR}} + K_{\text{UV}} L_{\text{UV}}$

$\rightarrow L_{\text{IR}}$ & $L_{\text{UV}}$
Evolution of dust attenuation with $z$

Model of Bernhard+14

#A_{UV}(mag) vs redshift

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To (quickly) conclude:

We have compared the evolution of dust attenuation globally in the universe, in UV and IR selected samples from z=0 to z~2

→ Dust attenuation is ~2 mag higher in IR selected galaxies than in average or in a UV selection
→ The stellar mass appears as the main driver for dust attenuation: universal relation between attenuation and stellar mass

IR selected galaxies, dominate the SFR density, they are massive galaxies & more attenuated than the average universe
UV selected galaxies exhibit a large range in stellar mass and exhibit an attenuation similar to that found in average for the universe

ありがとうございます

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Higher IR luminosities are reached when the stacking is performed by bins of $M_*$.

$\Rightarrow$ $M_*$ crucial parameter:

$\Rightarrow$ Stacking per bin of $(L_{\text{FUV}}, M_*)$
• In a bin of $L_{\text{UV}}$: large range of $M_*$
• Dust attenuation increases with $M_*$ for a given $L_{\text{FUV}}$
• Dust attenuation decreases with $L_{\text{FUV}}$ for a given $M_*$