The Far-Infrared Emission of the First Massive Galaxies


- Dust will be silicate-rich for first 400 Myr of evolution of a galaxy
  - Large carbon yields only for AGM stars below 3.5 M_☉

- Far infrared emission of silicate-rich dust is “warmer” than for 50/50 silicate/carbon
  - Poor emission efficiency of silicate dust outside 8 – 60 µm

- High energy density of early galaxies also favors “warm” far infrared SEDs

- Haro 11 spectral energy distribution is a good surrogate for very high redshift IR galaxies
  - Dominated by very recent star formation, similar energy density

- Haro 11 SED fits the composite SED for 5 < z < 7 galaxies well
  - Fit with local templates is much worse

- Haro 11 template fit implies much higher star formation rates needed for a given flux density at 1mm, compared with local or blackbody templates
• Dust will be silicate-rich for first 400 Myr* of evolution of a galaxy
  • Large carbon yields only for AGB stars below 3.5 $M_\odot$

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* 400 Myr corresponds to going from $z = 9$ to $z = 6$
Theoretical SEDs for these young galaxies peak between 15 & 100 µm
Theoretical SEDs for these young galaxies peak between 20 & 100 µm

Will show again soon
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  • Dominated by very recent star formation, similar energy density
Haro 11

- Black beam is infrared source – unresolved with Spitzer \[ \Rightarrow \leq 150 \text{ pc}, \text{ SFR} = 30 \text{ M}_\odot/\text{yr} \]
- SF surface density $500 \text{ M}_\odot/\text{yr pc}^{-2}$, mass $2 \times 10^9 \text{ M}_\odot$, sSFR = $15 \text{ Gyr}^{-1}$, $12 + \log(O/H) \sim 8.3$
Haro 11

- Red circle is infrared source – unresolved with Spitzer \( \Rightarrow \) \( \leq 150 \) pc, SFR = 30 \( M_\odot \) /yr
- SF surface density 500 \( M_\odot \) /yr pc\(^{-2}\), mass 2 \( \times 10^9 M_\odot \), sSFR = 15 Gyr\(^{-1}\), 12 + log(O/H) \( \sim \) 8.3
Haro 11

- Red circle is infrared source – unresolved with Spitzer ⇒ ≤ 150 pc, SFR = 30 M_☉ /yr
- SF surface density 500 M_☉ /yr pc⁻², mass 2 × 10^9 M_☉, sSFR = 15 Gyr⁻¹, 12 + log(O/H) ~ 8.3
The pure silicate SEDs do not fit the Haro 11 one well.
But just a little carbon makes a big improvement

- 156µm line shows there is some carbon and small yields are predicted theoretically.
• “Local” templates fit SEDs well at $z \sim 3$
• Haro 11 SED fits the composite SED for $5 < z < 7$ galaxies well
  • Fit with local templates is much worse
“Local” template fits well at $z \sim 3$

- Measured points have been shifted to rest frame and normalized over $50 < \lambda < 200 \mu m$
but not at \( z \sim 6 \)
Haro 11 based template is much better at z ∼ 6

$5 < z < 7$
• Haro 11 template fit implies much higher star formation rates needed for a given flux density at 1mm, compared with local or blackbody templates
Conversion factor for mJy @ 1mm to L(TIR), as predicted by different templates.
Summary

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