BADGRS

Submillimeter galaxies in the local universe

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Sub-mm selection of local galaxies

- dust fraction increases rapidly as stars form
- then declines as star-formation stops
- different selections favour different stages

de Vis et al 2017
HAPLESS and BADGRS

- Local volume-limited sample from phase 1 H-ATLAS, 15<D<46Mpc

- found >50% of galaxies were:
  - very blue (FUV-K)<3.5
  - intermediate mass $(10^8 < M_* < 10^{10} \, M_\odot)$
  - flocculent or irregular morphologies
  - high gas fractions in terms of HI.

- **Blue And Dusty Gas Rich Sources** – BADGRS

- only 6% of stellar mass, 30% of dust mass density, 20% of the star formation rate

Clark et al 2015
Dust Temperatures and Radiation field

- Diffuse dust temperature in the BADGRS is 13–14 K (cf 18–31 K for normal spirals)
- For the same dust properties, this would require an ISRF 10–20 times lower than the local Galactic value.
- The measured radiation surface densities are similar to local Galactic value.
- Need either
  - different dust geometry (clumpier)
  - different dust properties (size distribution, composition, opacity)
Sample of 4 BADGRS for detailed follow-up

• Range of gas fractions
• Higher dust mass per stellar mass
• Very blue: FUV-K < 2.7

• Follow-up observations
  – CO lines (IRAM + APEX)
  – HI maps (VLA + GMRT)
  – optical IFU spectra (AAT)
  – CO maps (ALMA)
4 BADGRS

- yellow – IRAM CO pointings
- green – KOALA IFU and ALMA coverage
CO in BADGRS
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• Low CO flux (Peak $T_{MB} \sim 5 - 30$ mK)

• Narrow Line widths (FWHM 30 – 100 km/s)

• Wide range of excitations ($r_{31} = 0.25 – 0.6$)
A lack of molecular gas?

- Deficient in CO emission cf 250 flux by factor 2 to 7 (average 4.2)

- $M_{\text{H}_2}/M_{\text{dust}} \sim 10$ times lower than seen in local spirals ($M_{\text{H}_2}/M_{\text{dust}} \sim 10$ vs $\sim 100$)
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Grossi et al 2016
Reasons CO may be low

- ISM conditions unfavourable for HI $\rightarrow$ $H_2$ conversion, so very little molecular gas.

- Low metallicity, so CO is destroyed.

- Is either possibility correct?
Low Molecular gas

- If most gas is HI, then dust would trace HI
- Compare HI to dust distribution
- HI peaks don’t trace dust
- The deficiency in CO does not appear to be due to a lack of H$_2$
- Also estimates of the ISM pressure suggest that >50% of the gas should be molecular
Metallicity

- Low metallicity can lead to low CO:
  - Low Z $\Rightarrow$ low dust $\Rightarrow$ reduces the shielding of CO in molecular clouds
  - CO is strongly photo-dissociated at $Z < 0.5 \ Z_\odot$

- But measured metallicities are \textbf{not} low (O/H abundance $\sim$8.4)
- And we can see plenty of dust
Paradoxical properties

- Very dusty, but very blue
- Low temperature dust, but strong ISRF
- Low CO but metal rich

- to make progress need
  - high resolution CO and dust measurements from ALMA
  - optical IFU data to measure gas surface densities, kinematics, line ratios, metallicities, star formation histories, and dust attenuation
  - resolved SED fitting (including radiative transfer modelling)
IFU Koala Observations

- optical spectra
  - blue 3600A to 5700 with 1A resolution
  - red 6100A to 7300A with 0.6 A resolution
- O[I], O[II], O[III], N[II], S[II], Hα, Hβ, Hγ, Hδ
Koala IFU Observations

• Analysis of line strengths from spectral cubes underway
• Measure kinematics of both gas and stars
  – rotation
  – velocity dispersion
  – Toomre Q value
• Spatially resolved measurements of:
  – dust reddening
  – O and N abundances
  – excitation temperatures
Summary

• Dust selection favours high gas fraction galaxies
• About half are very blue, flocculent, intermediate mass galaxies
• BADGRS – contain only 6% of stellar mass, but have 30% of dust mass density and 20% of the star formation rate

• Unusual ISM properties:
  – low $T_{\text{dust}}$ but high IS radiation field
  – should be $H_2$ rich but are found to be CO poor

• In order to explain this discrepancy there must be either:
  – a radically different dust geometry (clumpier)
  – different dust properties (size distribution, composition, opacity) compared to the Milky Way and other local galaxies