The gas-stars-dust chain
in star forming dwarf galaxies

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& the DustPedia team

Importance of studying star-forming dwarfs

- Structure in this ΛCDM universe:

  hierarchical structure formation

  → DM halos grow via merger and accretion

- Dwarf galaxies:

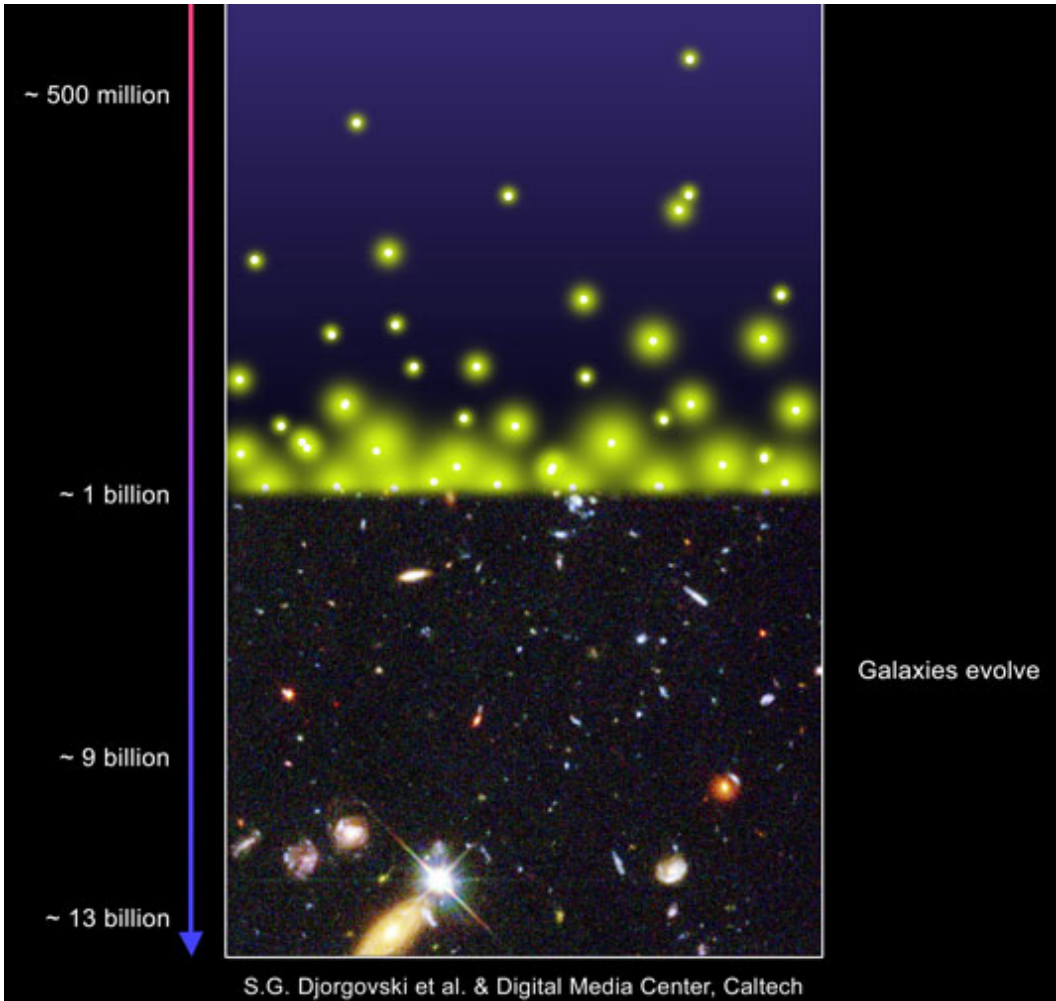
  appear at the beginning of

  the galaxy formation ladder

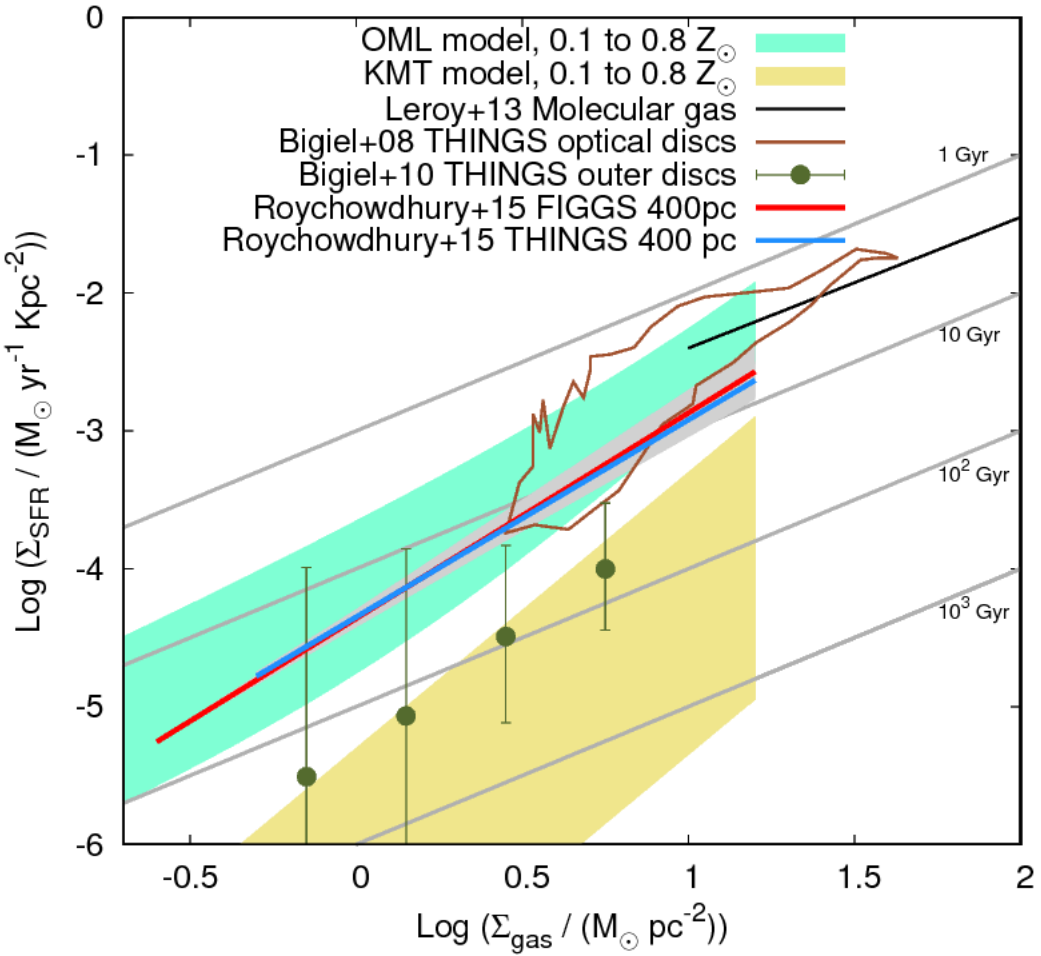
- *Nearby dwarfs are unique:*

  → understanding how stars form in low metallicity, low dust ISM

  → necessary to understand star formation in the first galaxies

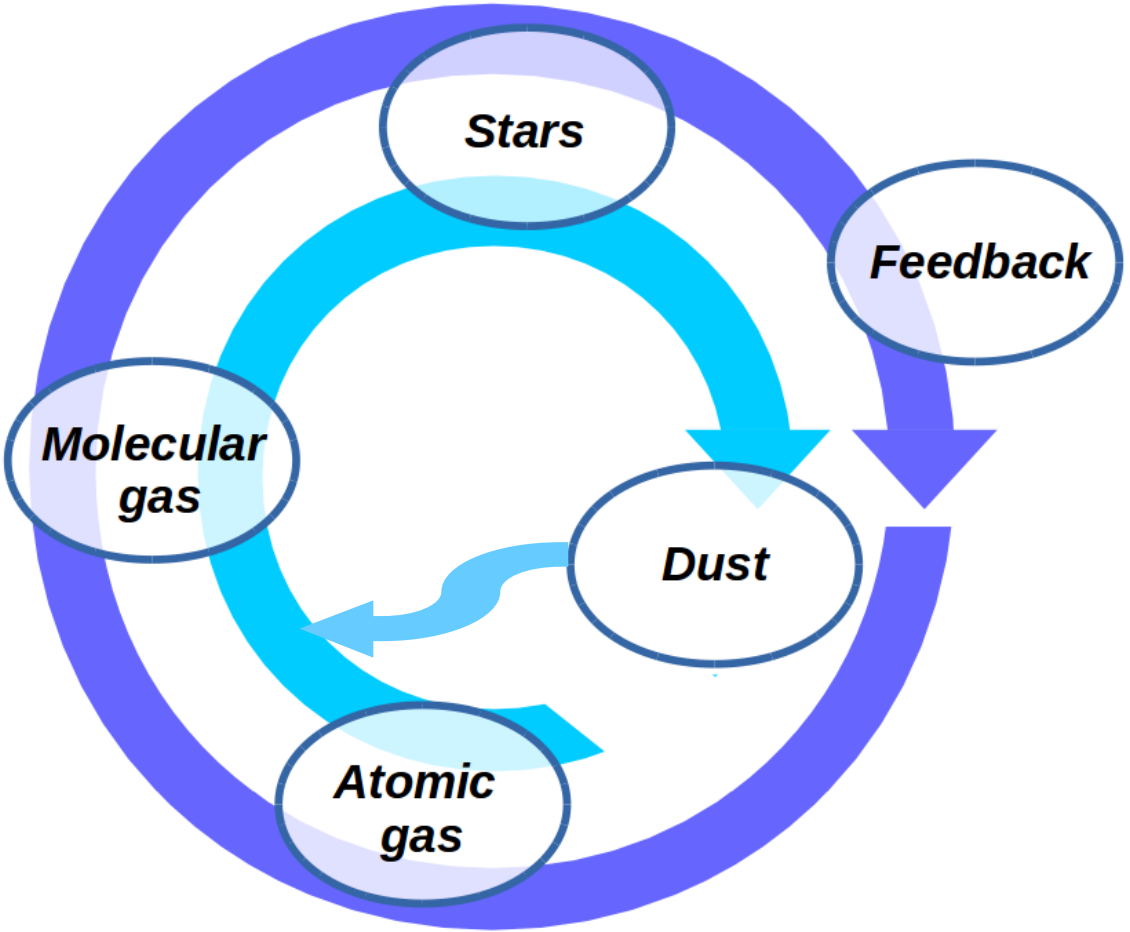


Baryon cycle and the importance of HI



- Our aim is to study how gas converts to stars → the baryon cycle
- Gas content of star-forming dwarfs dominated by atomic hydrogen (HI)
- Overall molecular hydrogen content low → also hard to detect due to high CO-to-H_2 conversion factor
- *Study of the Kennicutt-Schmidt relation using HI revealed importance of baryon cycle* (**Roychowdhury et al. 2015**)

Baryon cycle and the importance of HI



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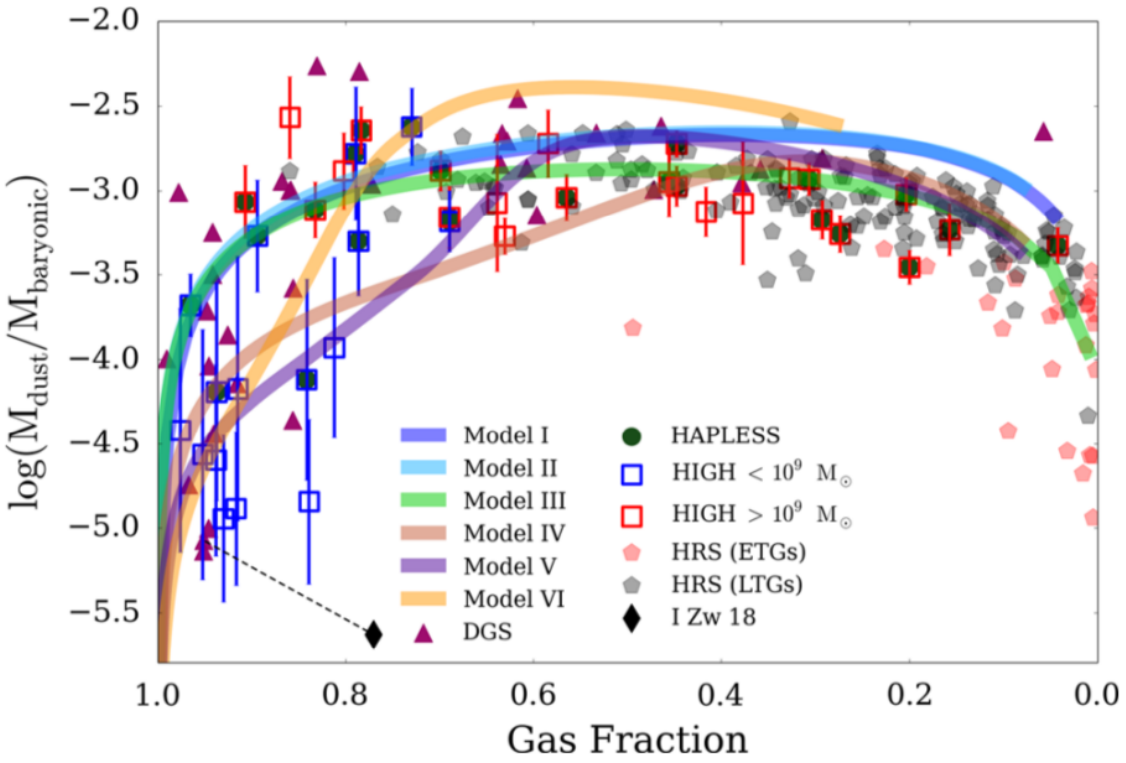
- *Study of the Kennicutt-Schmidt relation using HI revealed importance of baryon cycle* (**Roychowdhury et al. 2015**)
- Dust: by-product of stellar feedback
- Here we combine dust and gas properties → how the ISM evolves

Evolution of the ISM in dwarfs

- Dwarf galaxies, especially the ones at the lowest metallicities, need specialized models of chemical evolution to match their combined dust+gas properties
- e.g. different modes of formation and evolution of dust, outflow and inflow of gas



Model I
Model II
Model III

Closed box models with different SFHs
Model III: outflows

Model IV
Model V
Model VI

With dust destruction
Decreasing SN dust yields
Increasing grain growth
Increasing inflows+outflows

De Vis et al. (2017)

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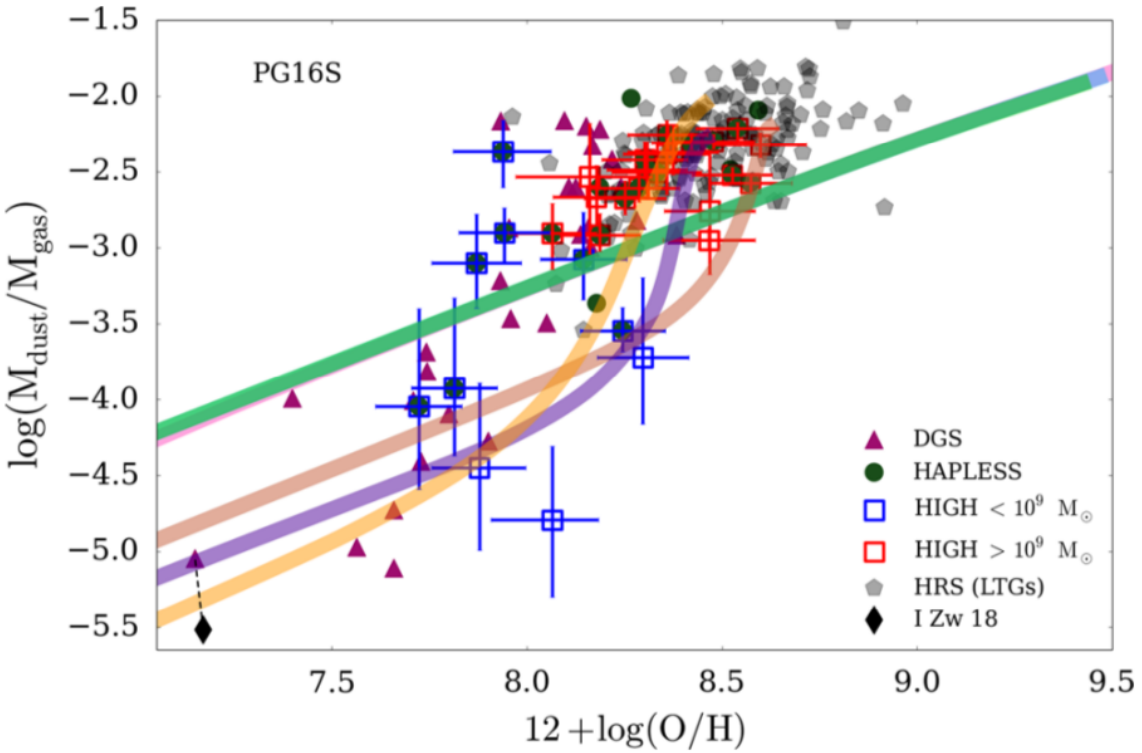

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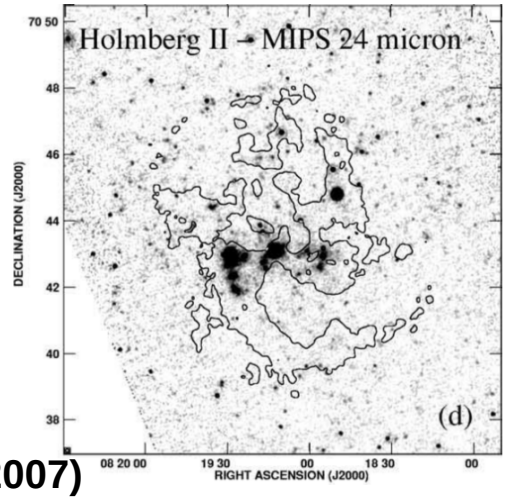
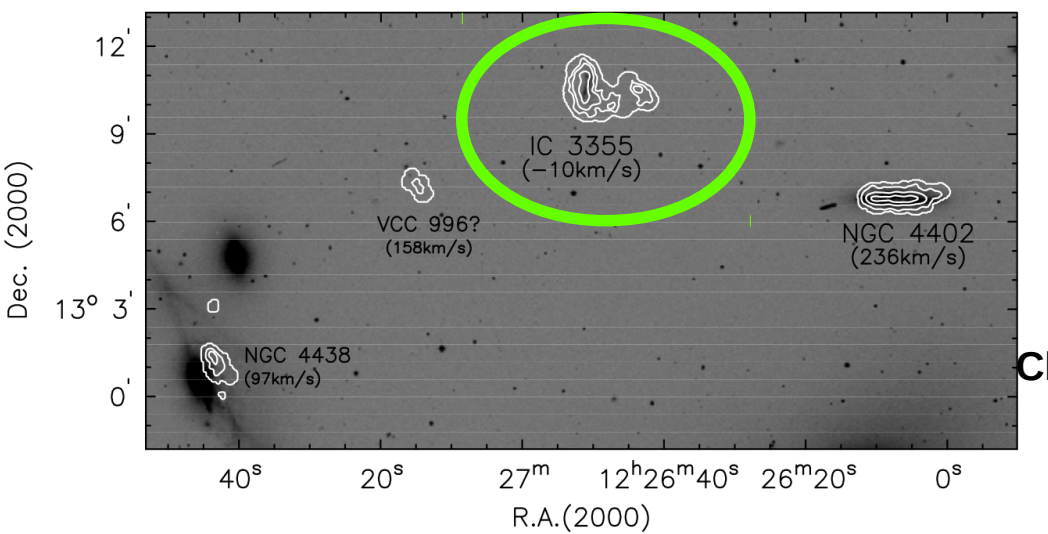
But … regarding gas in dwarfs ...

- Gas masses are based on single dish measurements
- Dwarf galaxies have extended gas disks
- Their gas disks are also vulnerable to disturbance due to tidal interactions or star formation feedback

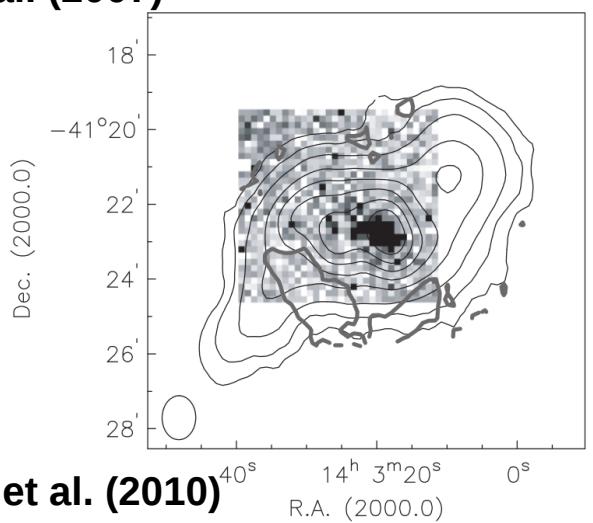
★ *A study with interferometric HI maps is needed*



Walter et al. (2007)



Chung et al. (2009)



Van Eymeren et al. (2010)

DustPedia → an ideal sample

- **DustPedia** : 875 galaxies → photometry in 42 bands from UV to sub-mm
- Legacy of *Herschel*, velocity < 3000 km/s, D_{25} > 1 arcmin
- ~ 150 dwarf galaxies
- Adding resolved HI 21 cm maps to the mix

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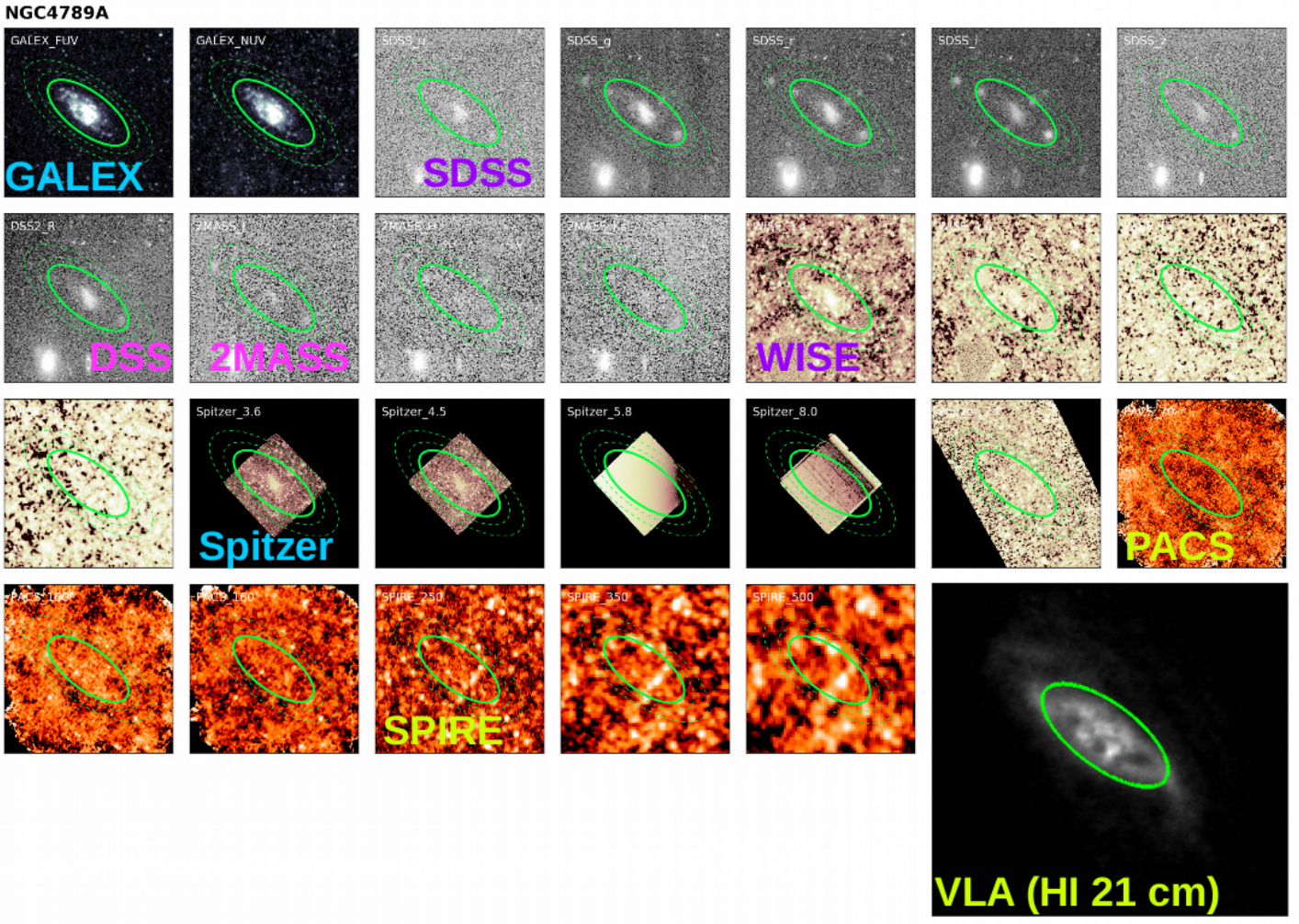

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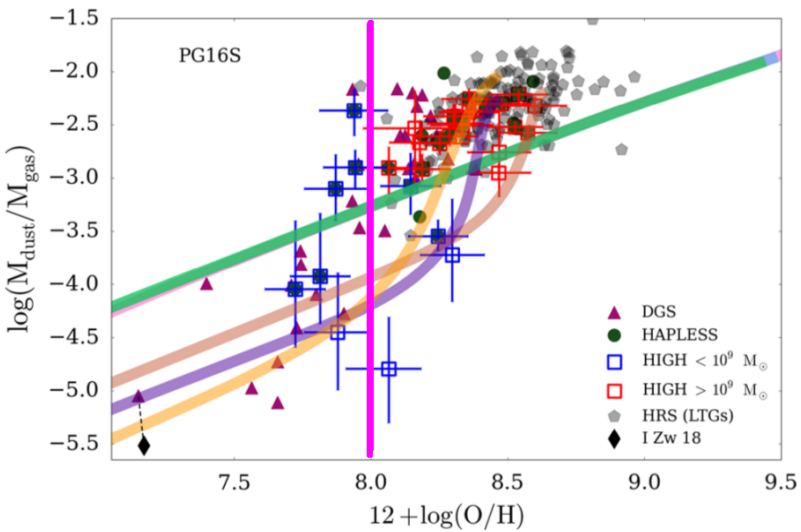
  → *at 0.4 r_{25} using metallicity gradients, Pilyugin & Grebel(2016) calibration*



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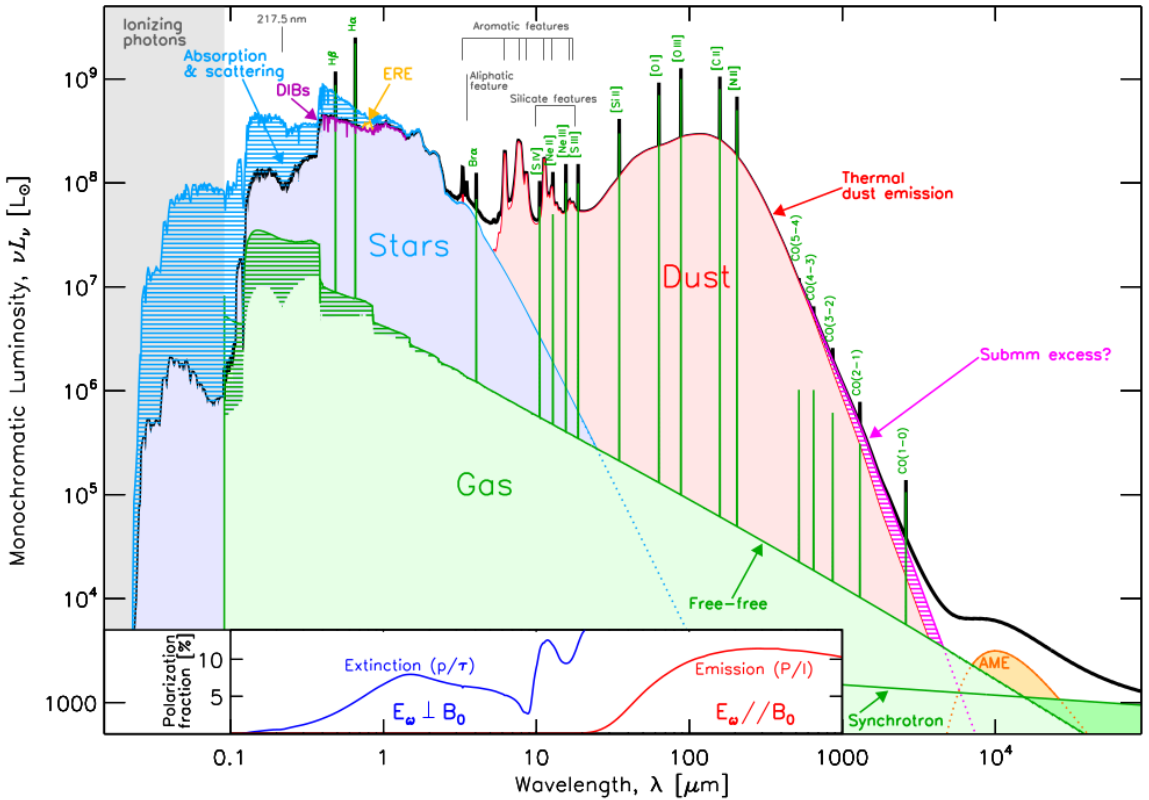
- **28** DustPedia dwarf galaxies (15 galaxies processed)

  + **19** from *Dwarf Galaxy Survey* → mostly BCDs (5 galaxies processed)

Determining dust properties

- Emission from dust dominates the Spectral Energy Distribution (SED) of late-type galaxies at infrared & sub-millimeter wavelengths → fitting measured SEDs with models



SED of a typical late-type galaxy from **Galliano, Galametz & Jones (2017)**

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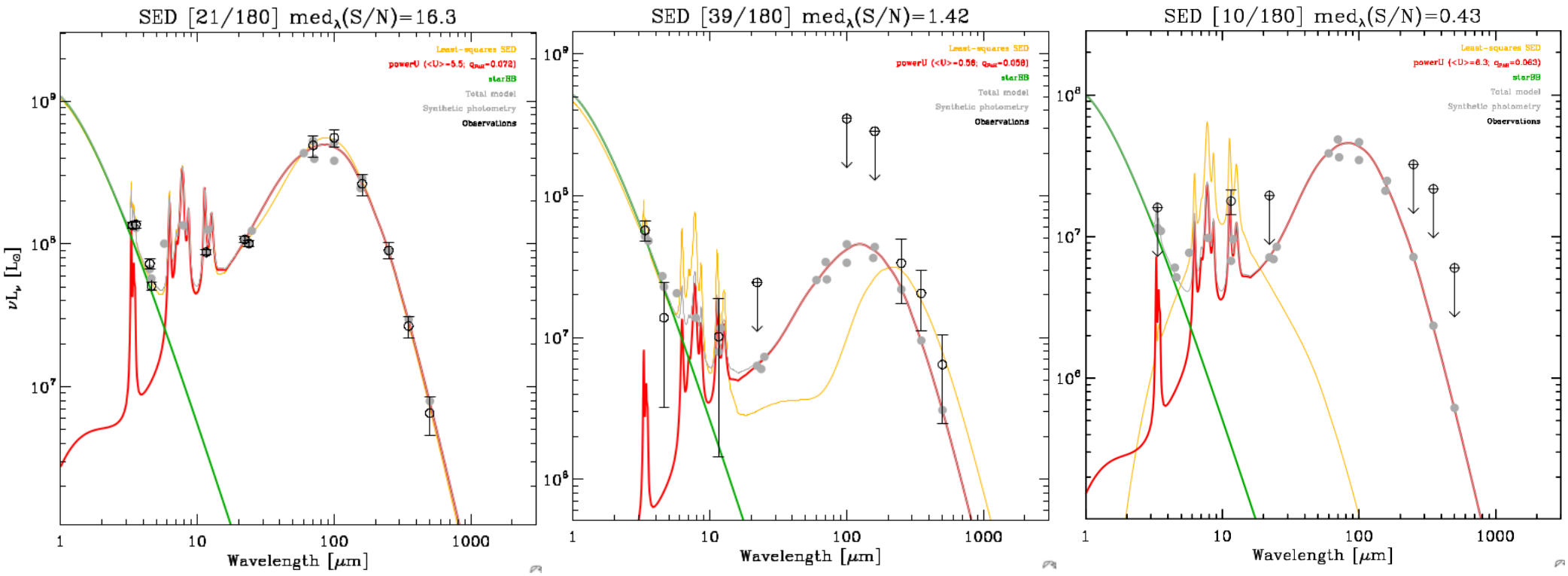
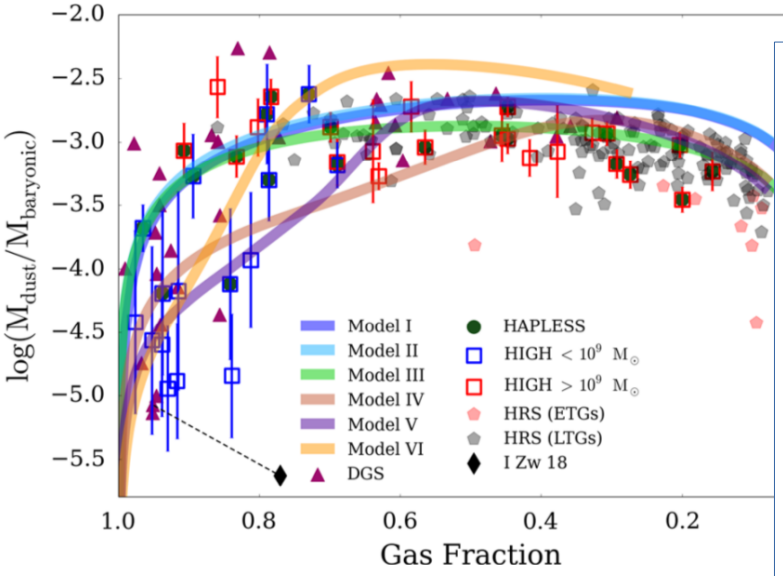
- **HerBIE**: dust SED modeling based on hierarchical Bayesian inference (Galliano et al. 2018) → using **THEMIS** dust modeling framework (Jones et al. 2017)
- Required for dwarf galaxy observations → to deal with non-detections

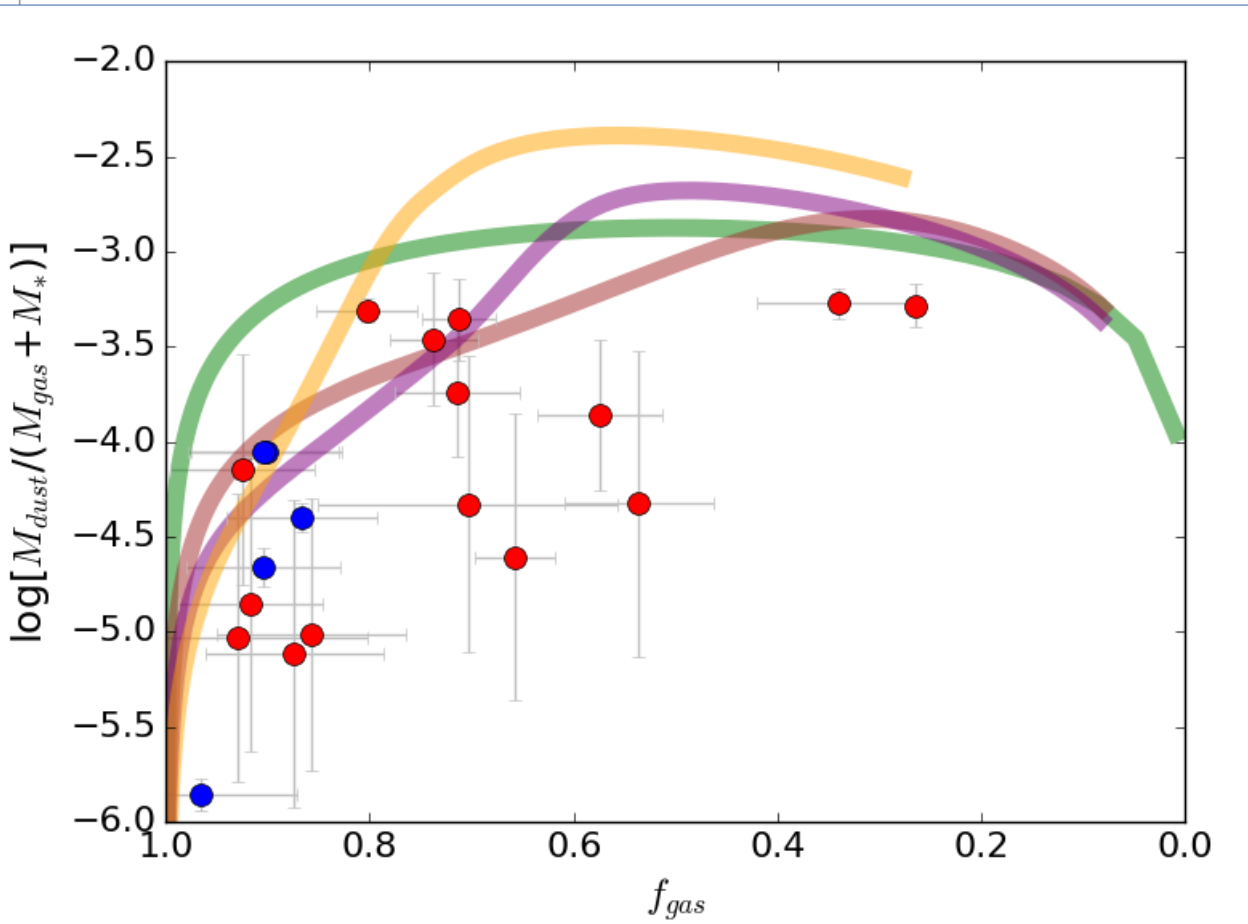
SEDs with HerBIE

- Run for DustPedia + DGS dwarf galaxies → should have similar prior



Disk-averaged results





- HI → *single dish* measurements
- Dust & stars → limited aperture
- Red points: DustPedia galaxies
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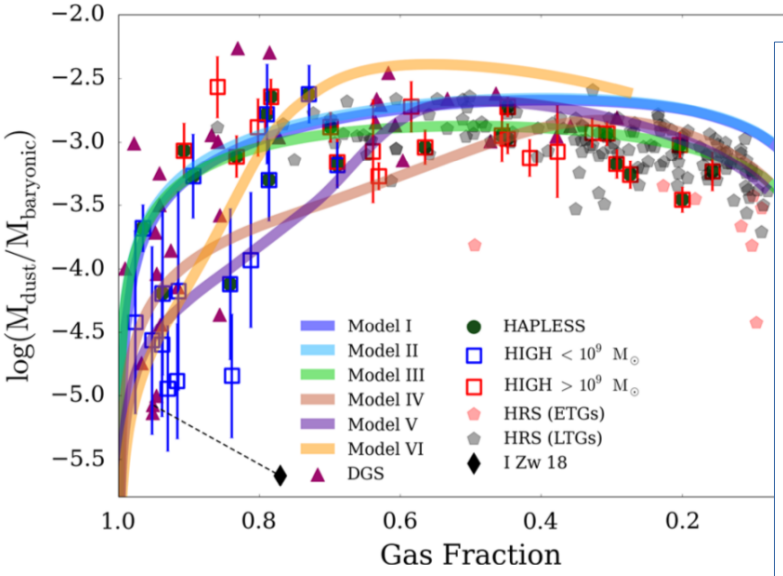

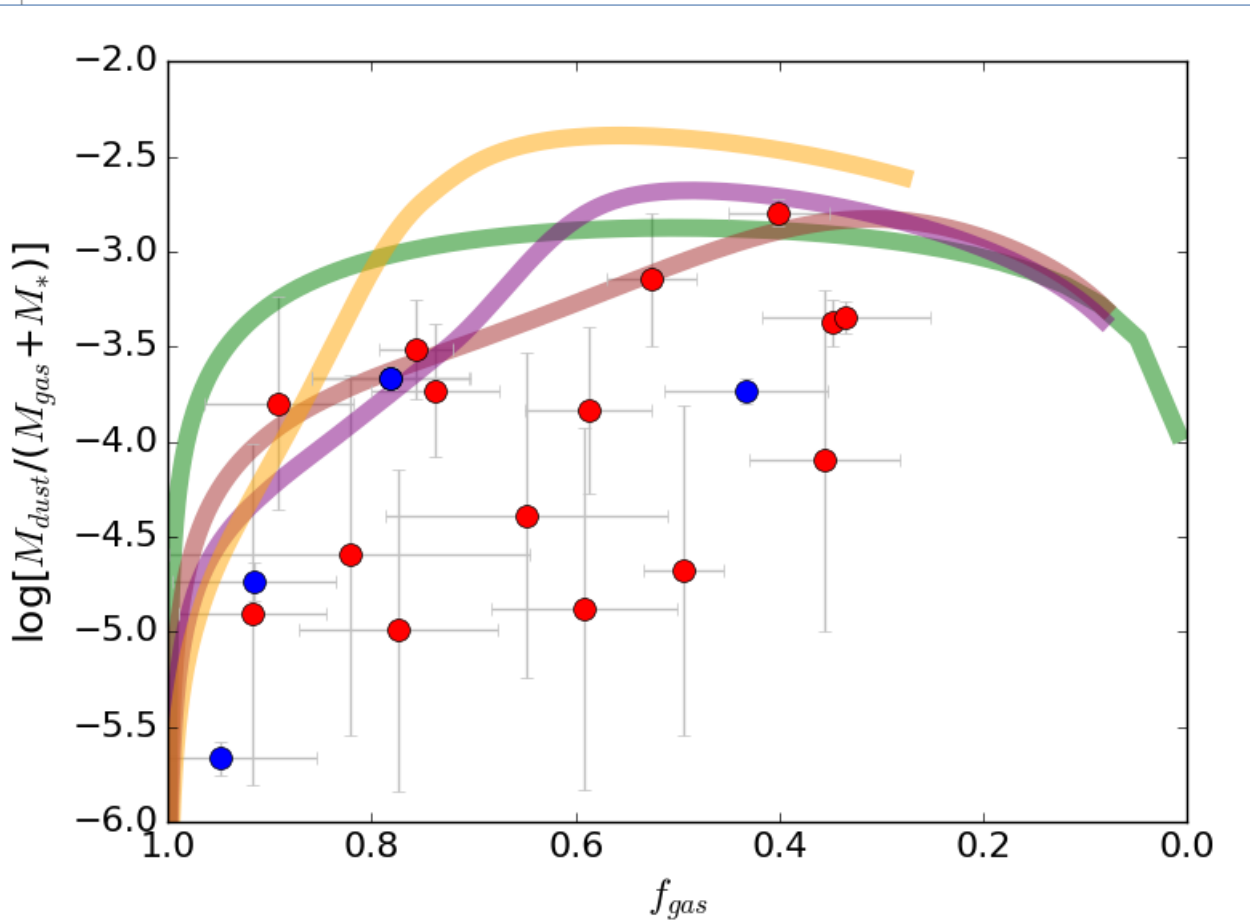

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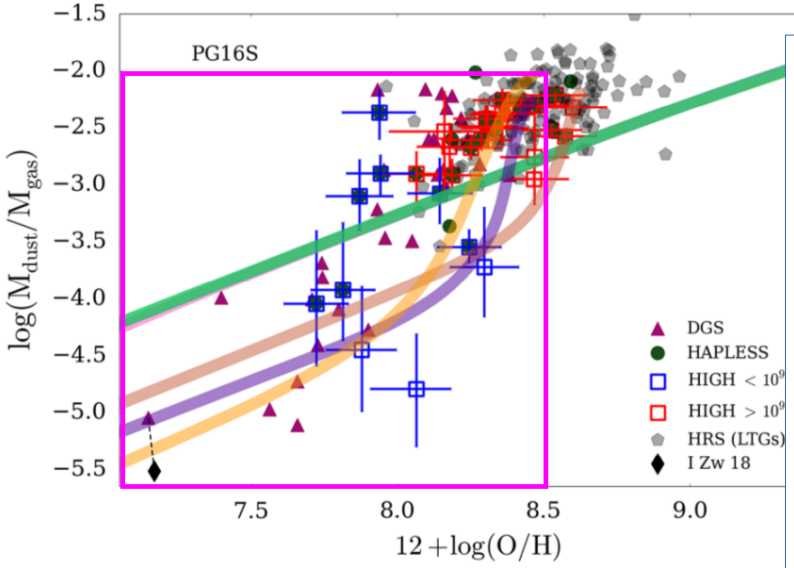

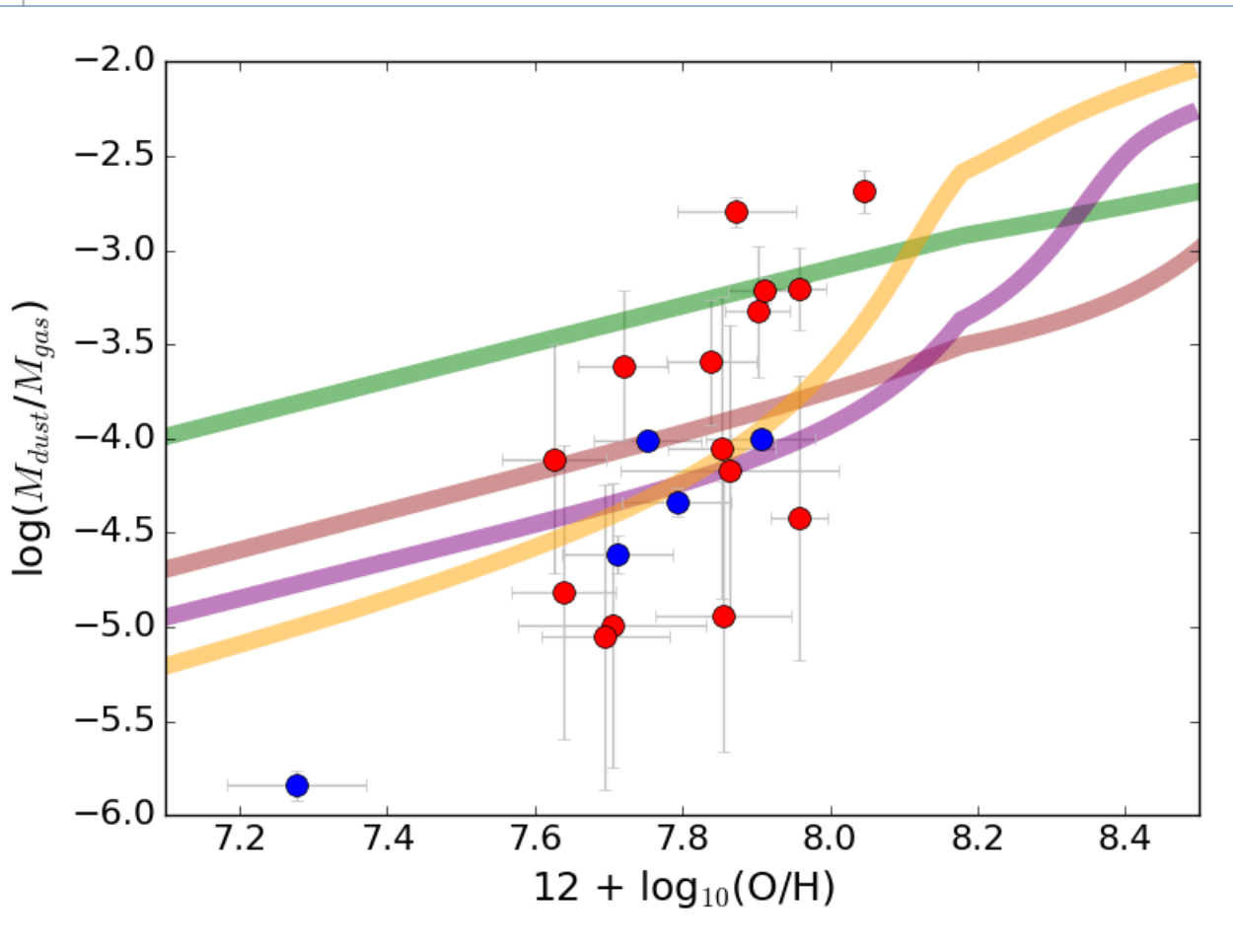

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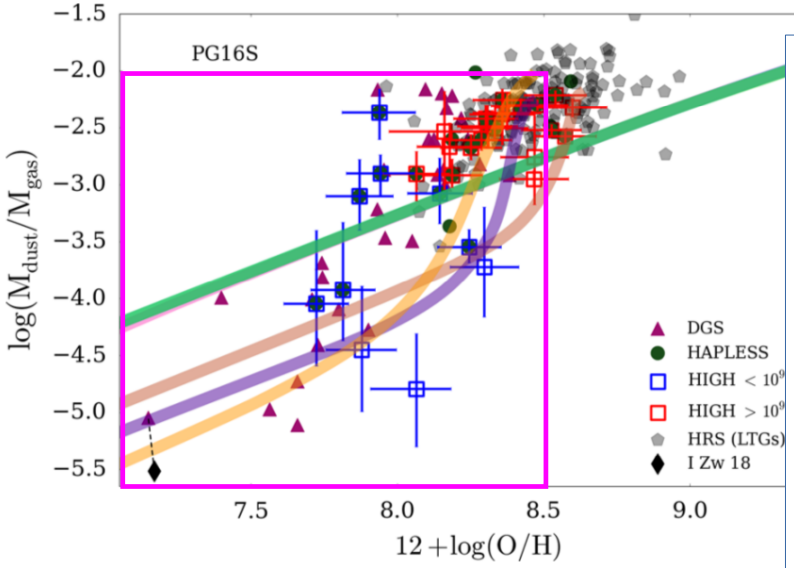

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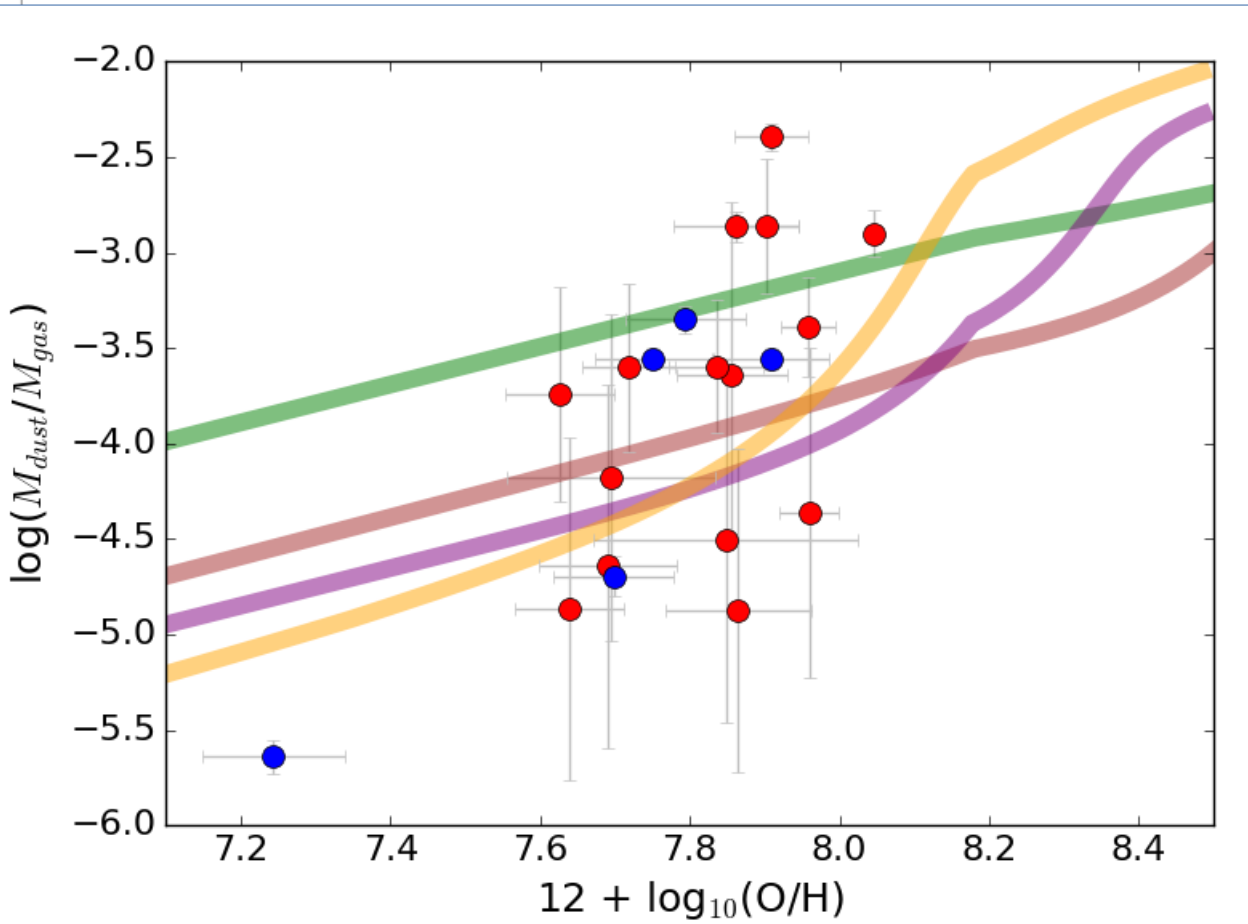
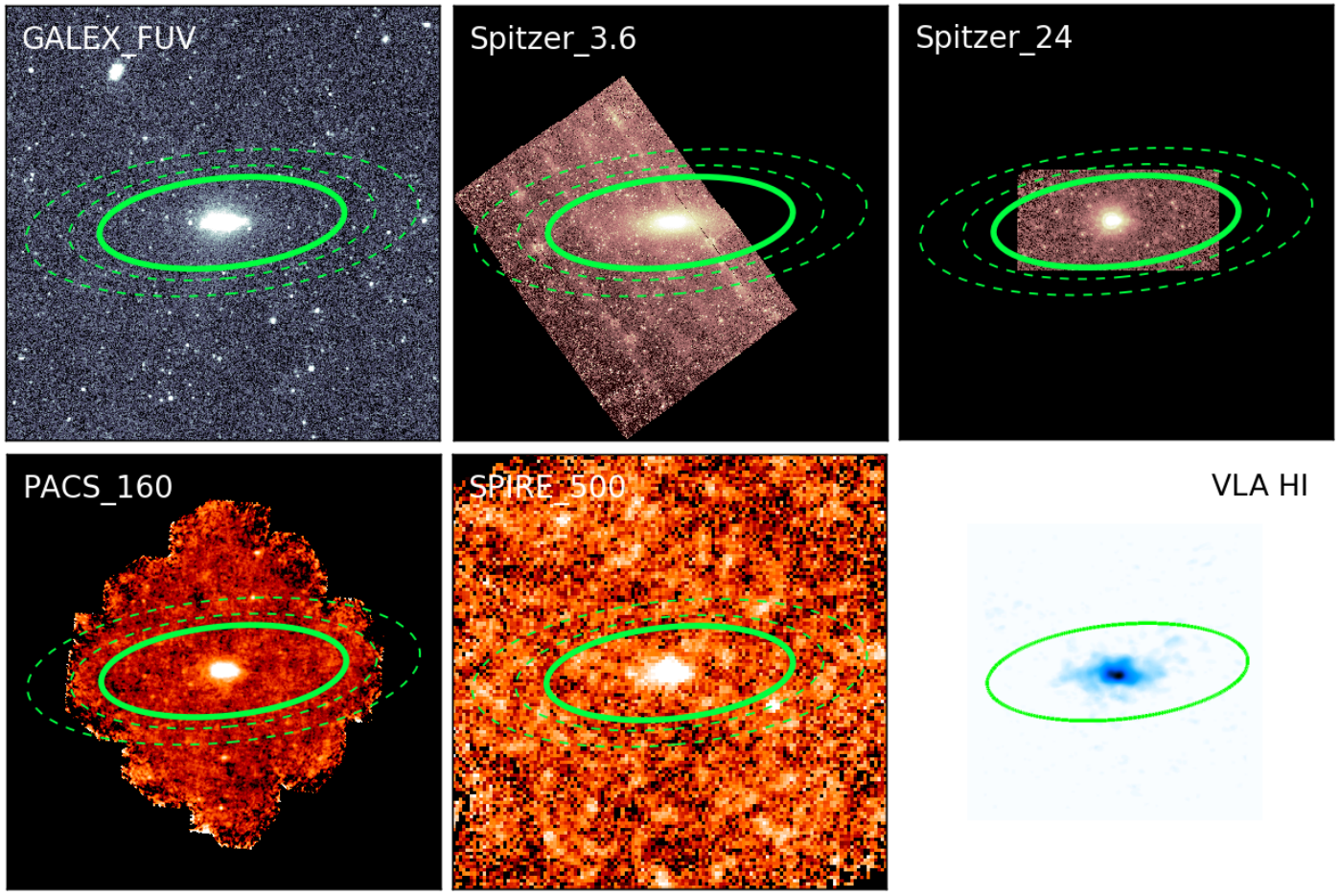
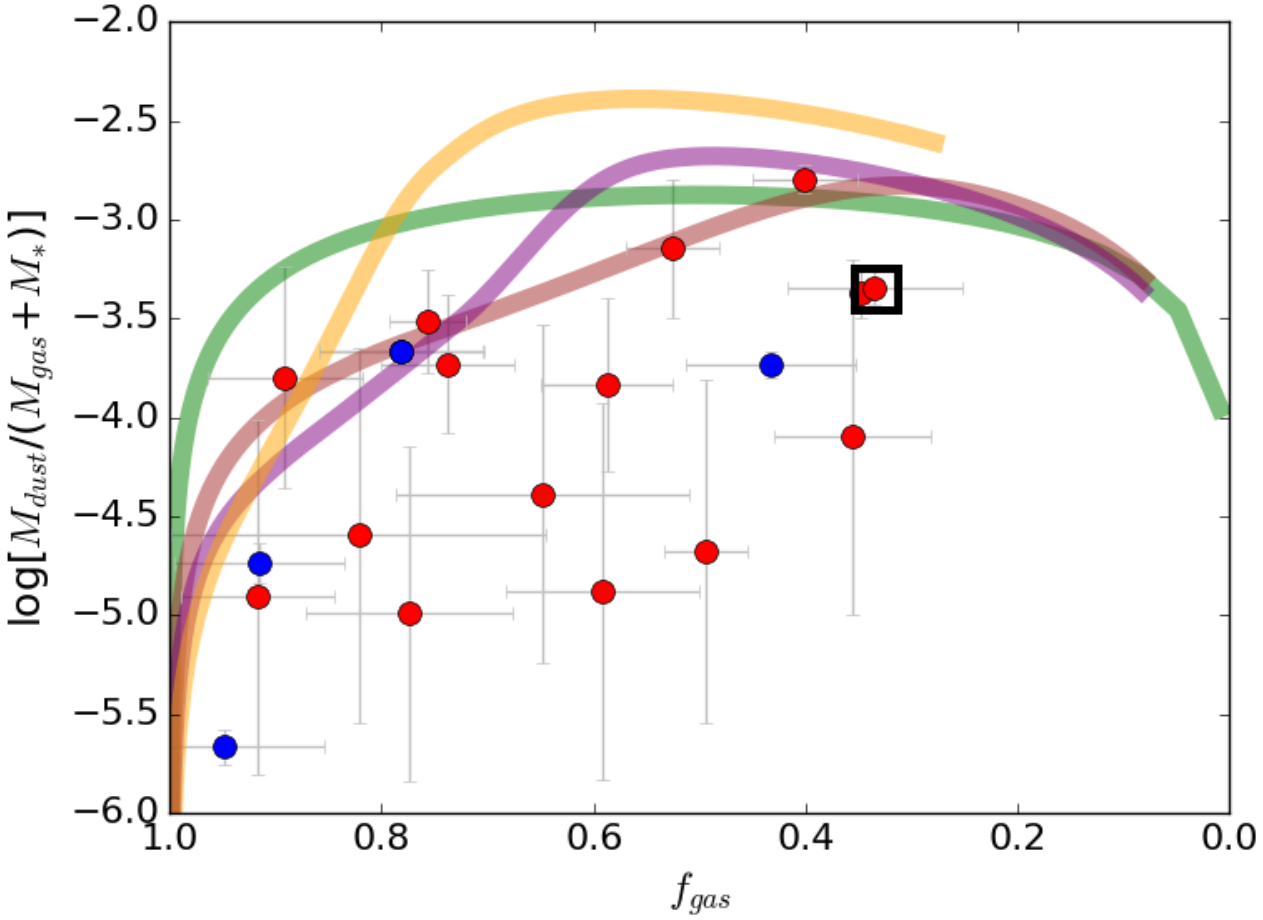


Spatially resolved study

NGC0625



Spatially resolved study of NGC 625



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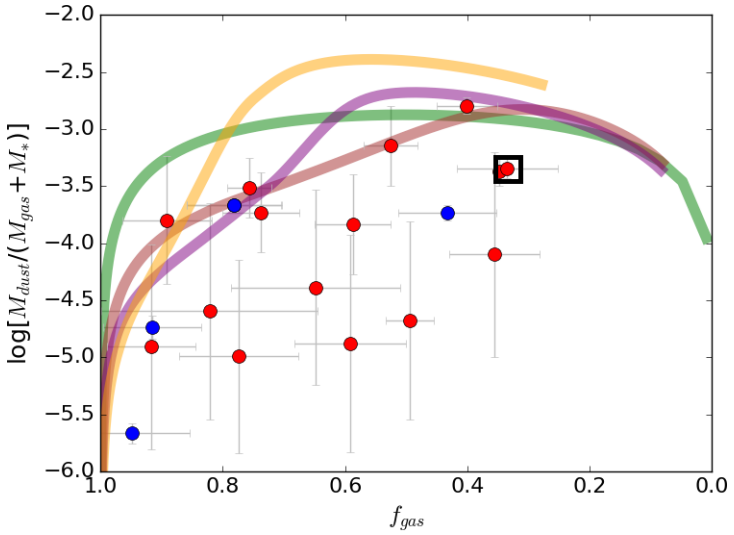

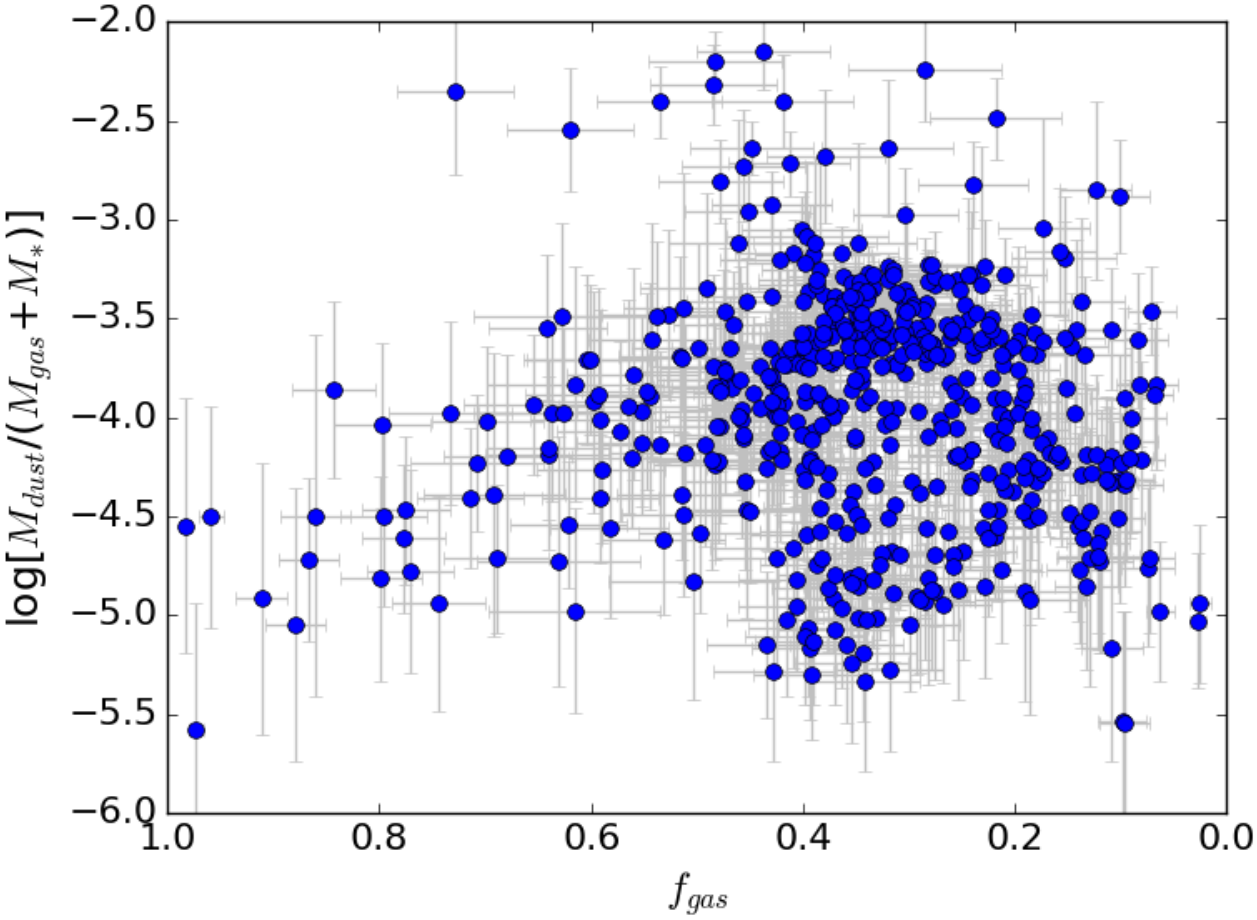

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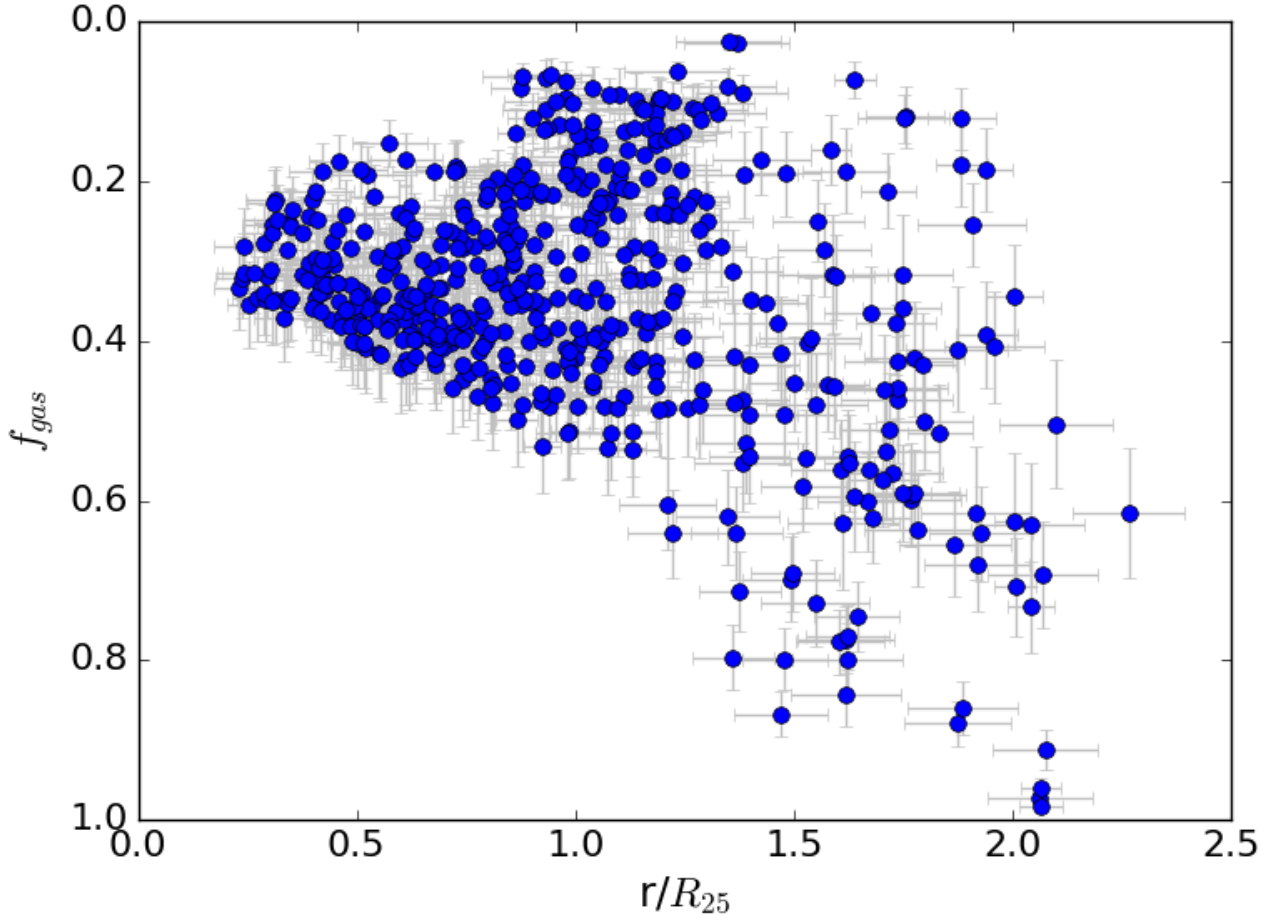

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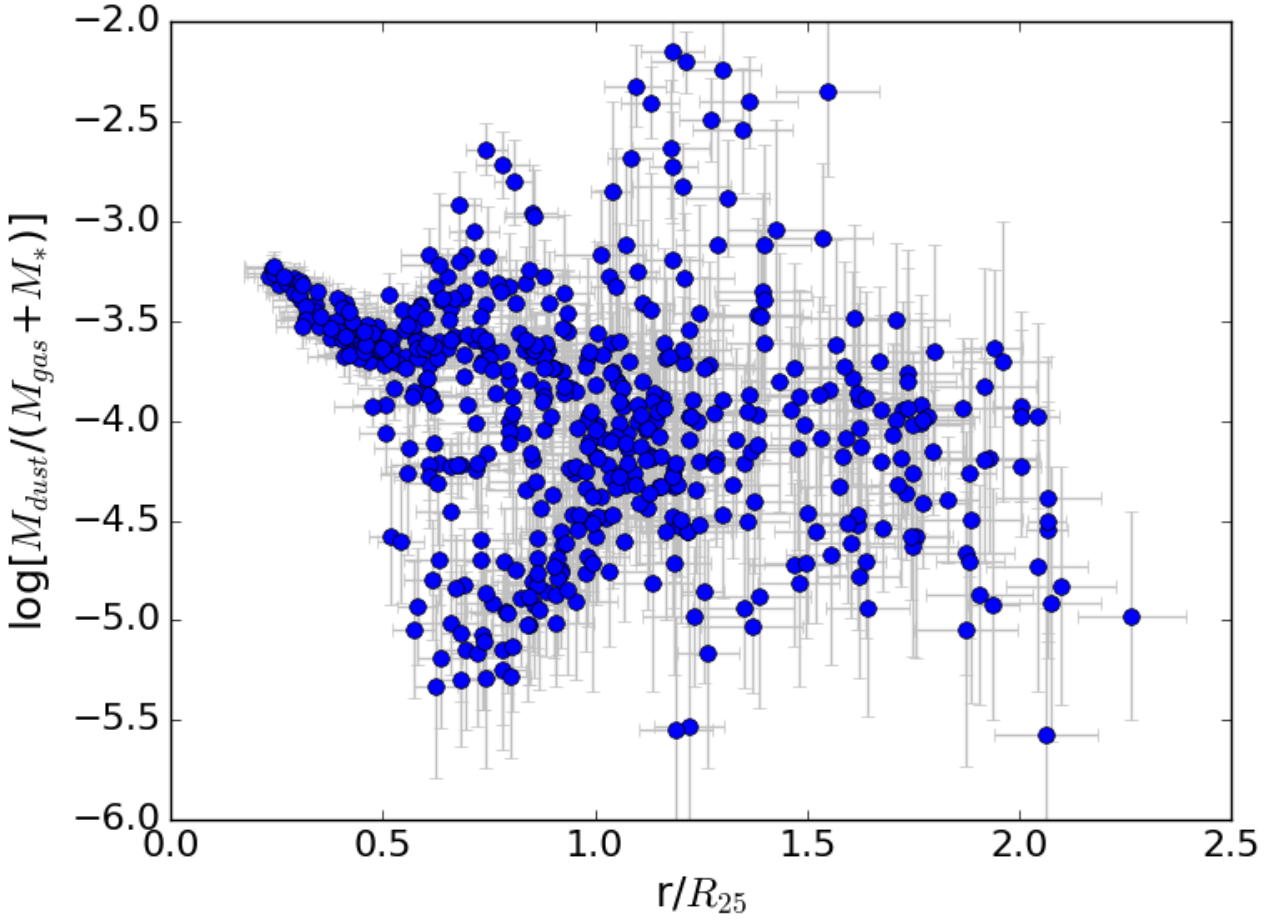

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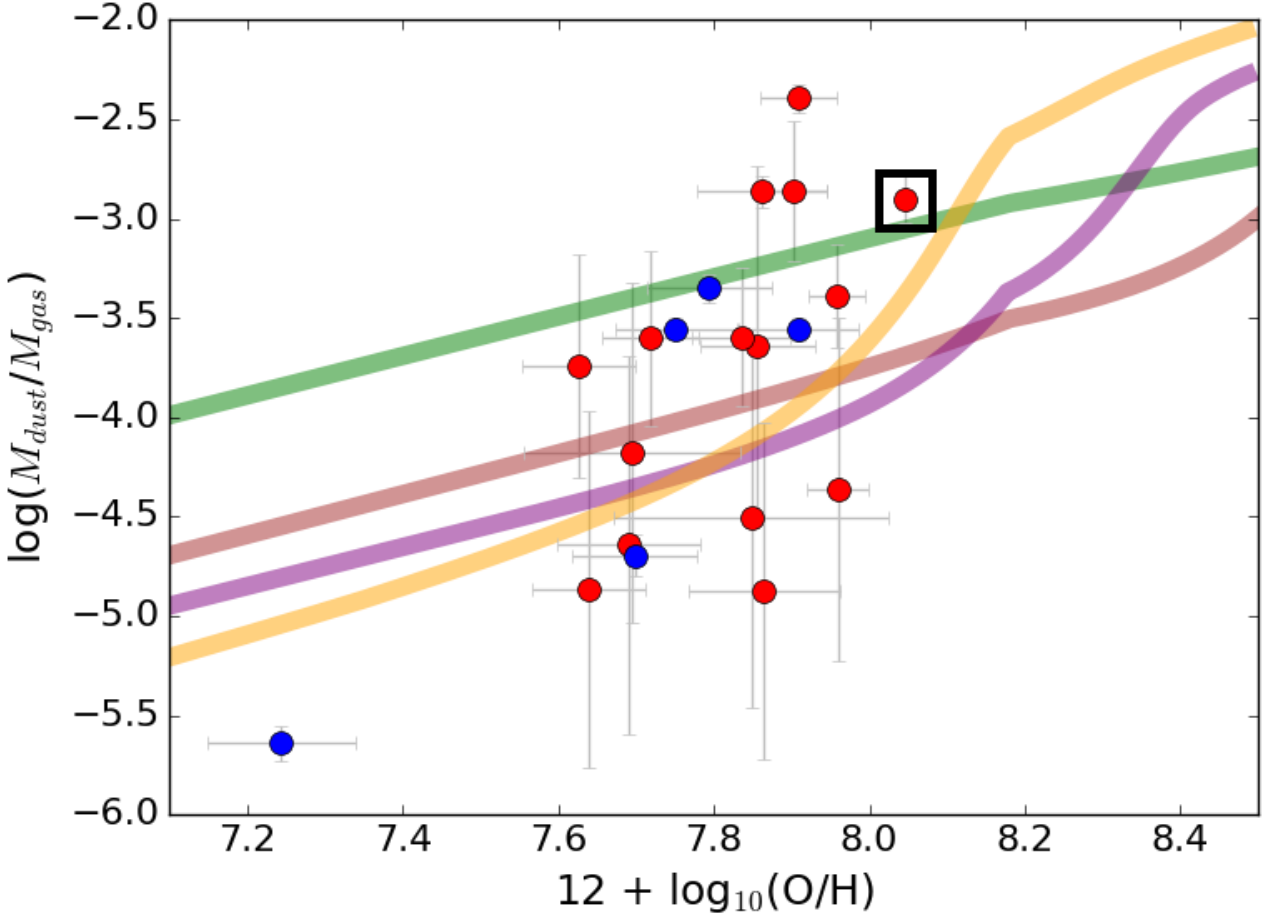

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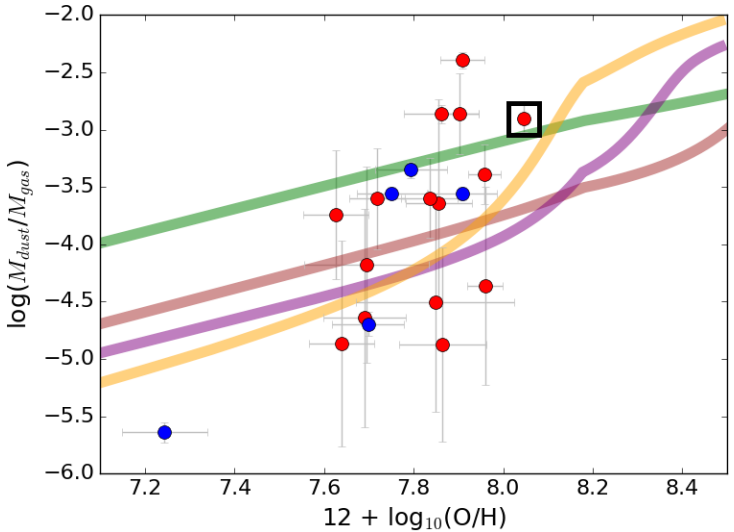

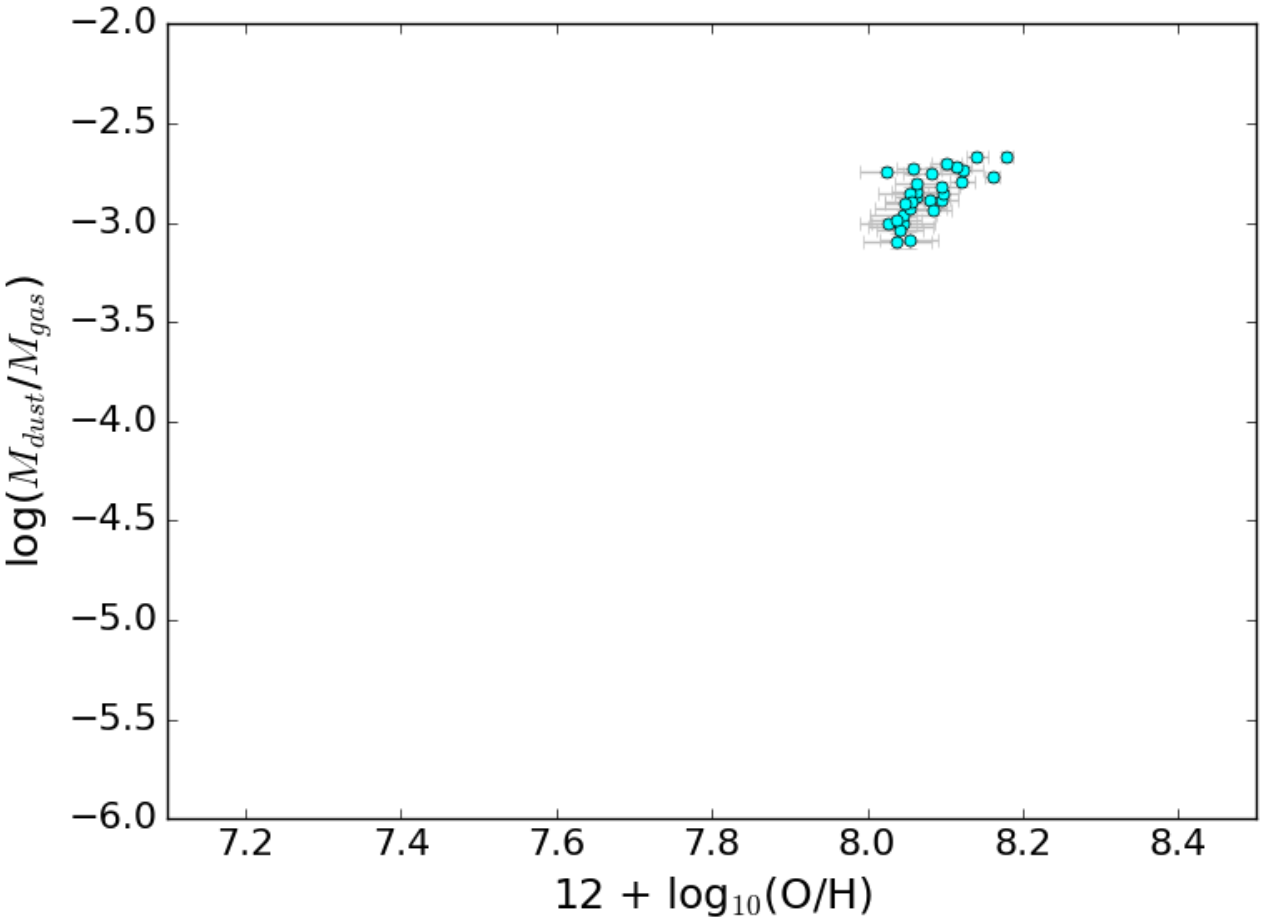

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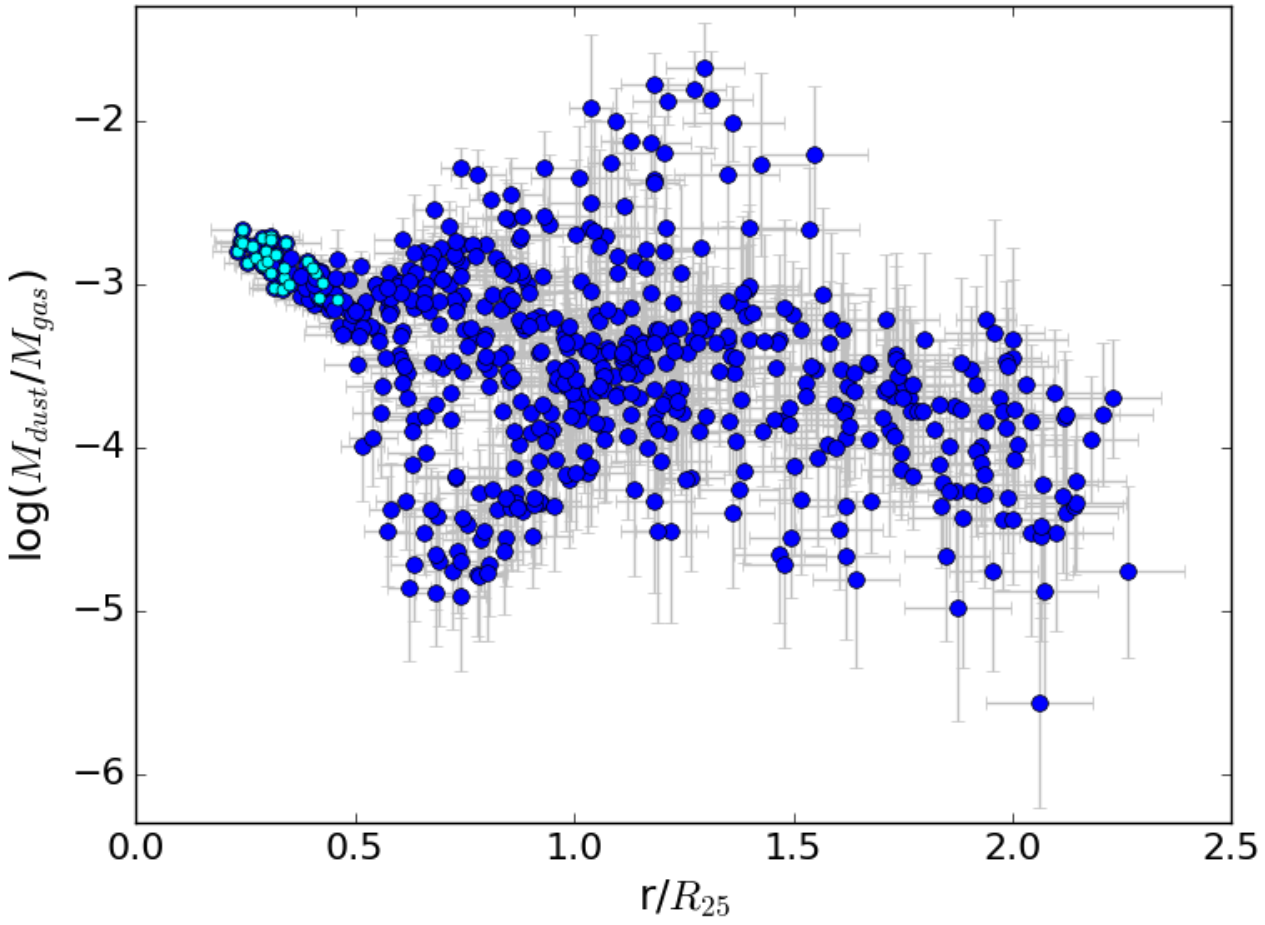

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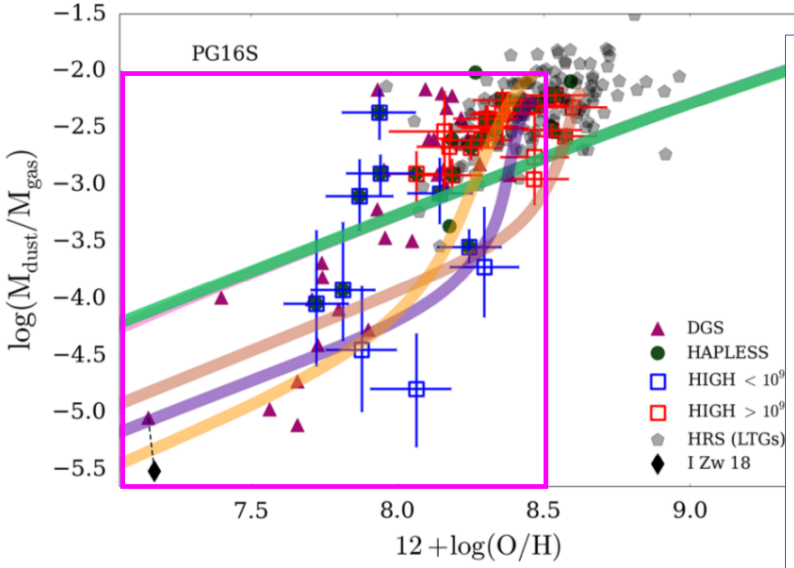

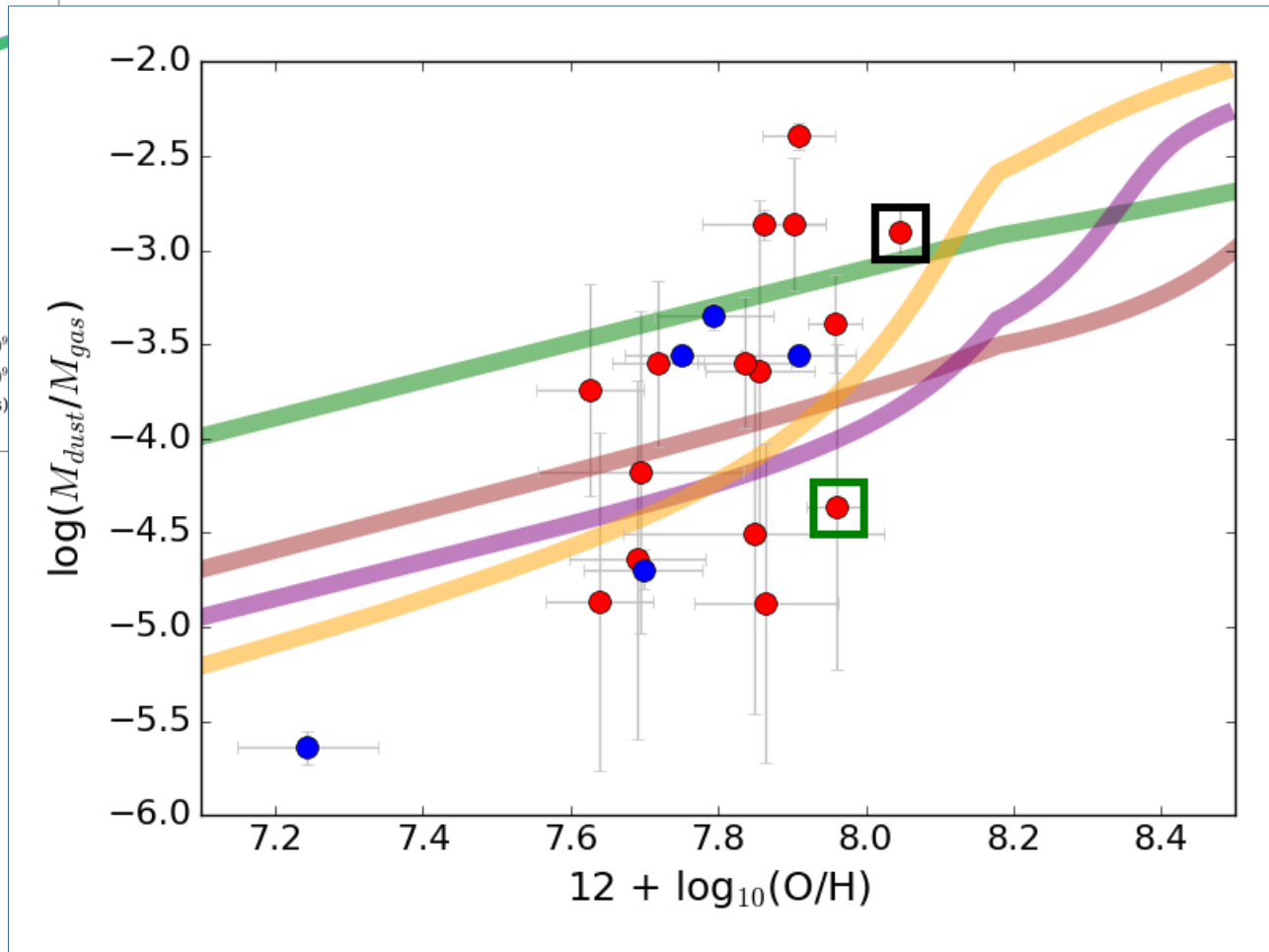

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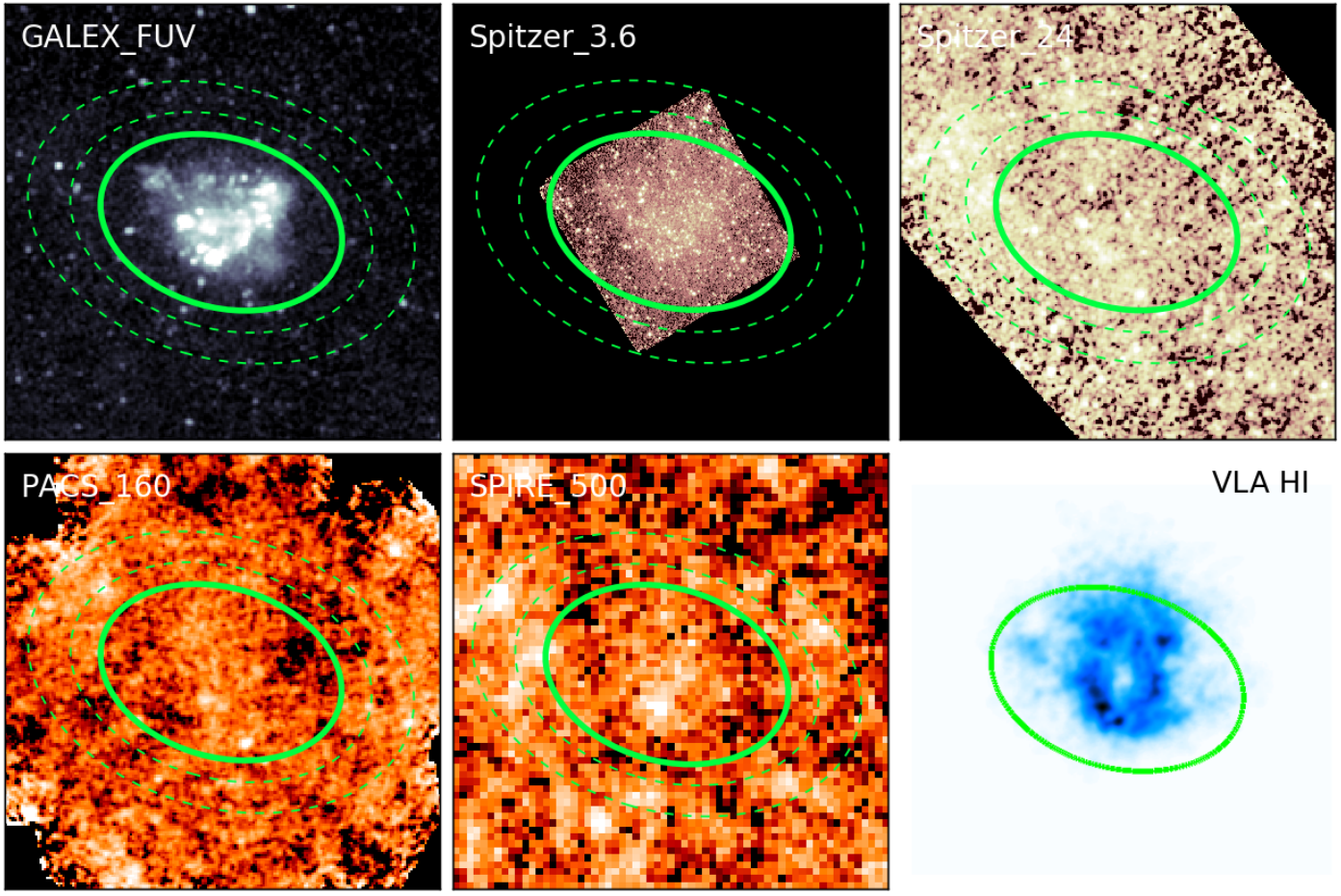

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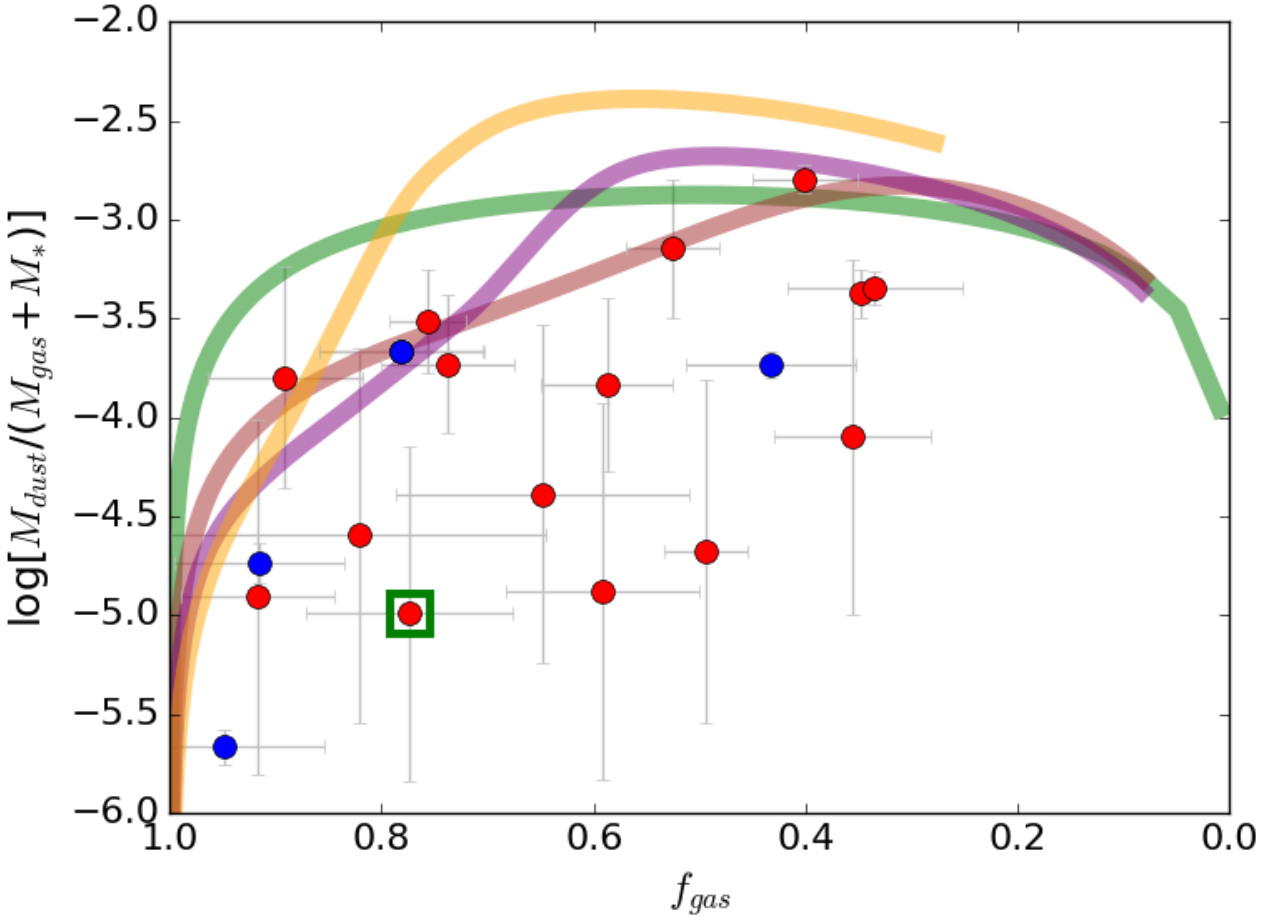

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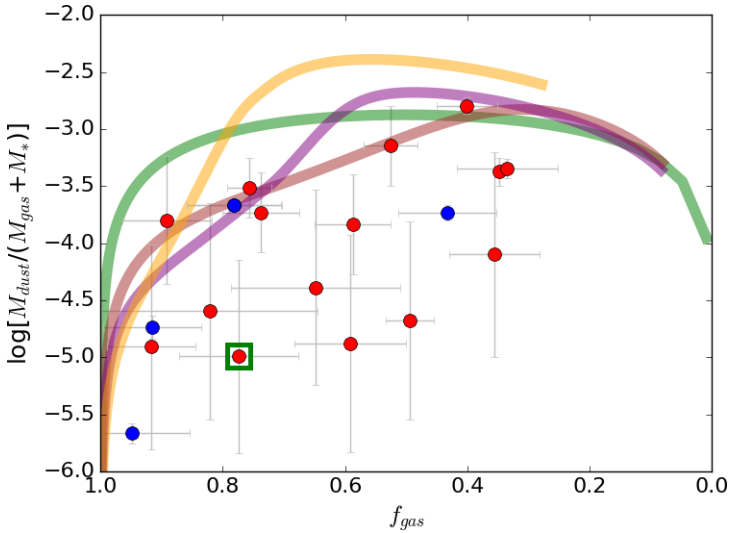

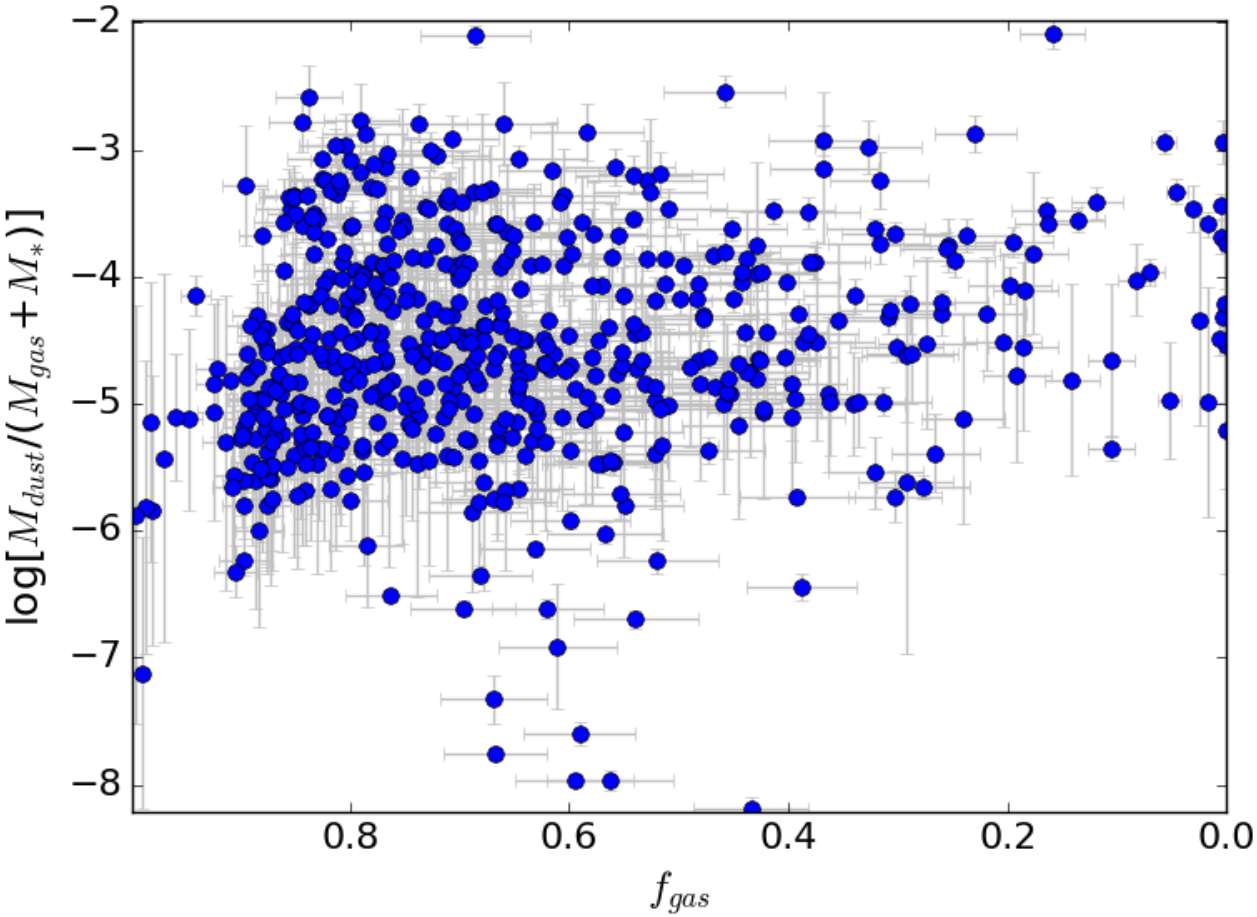

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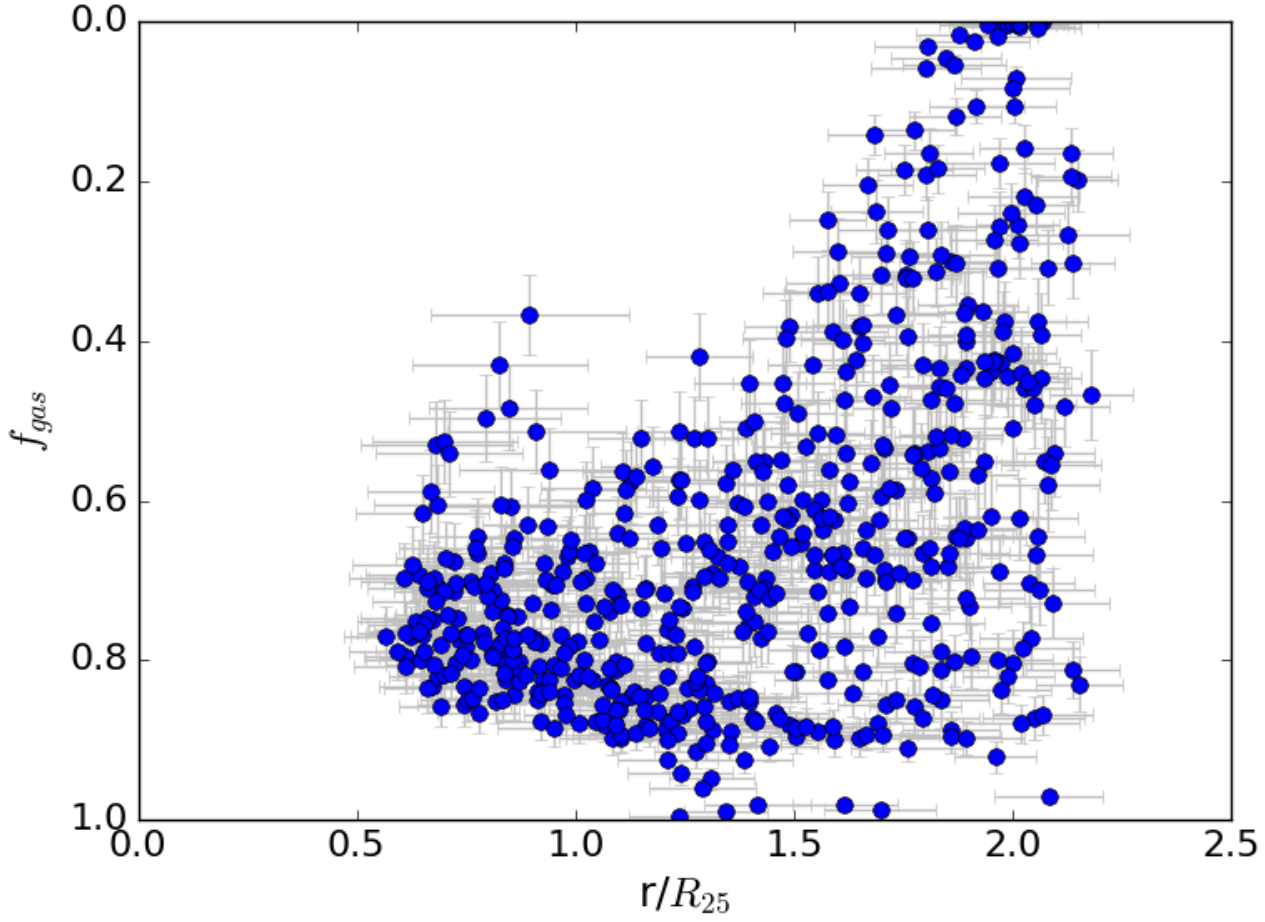

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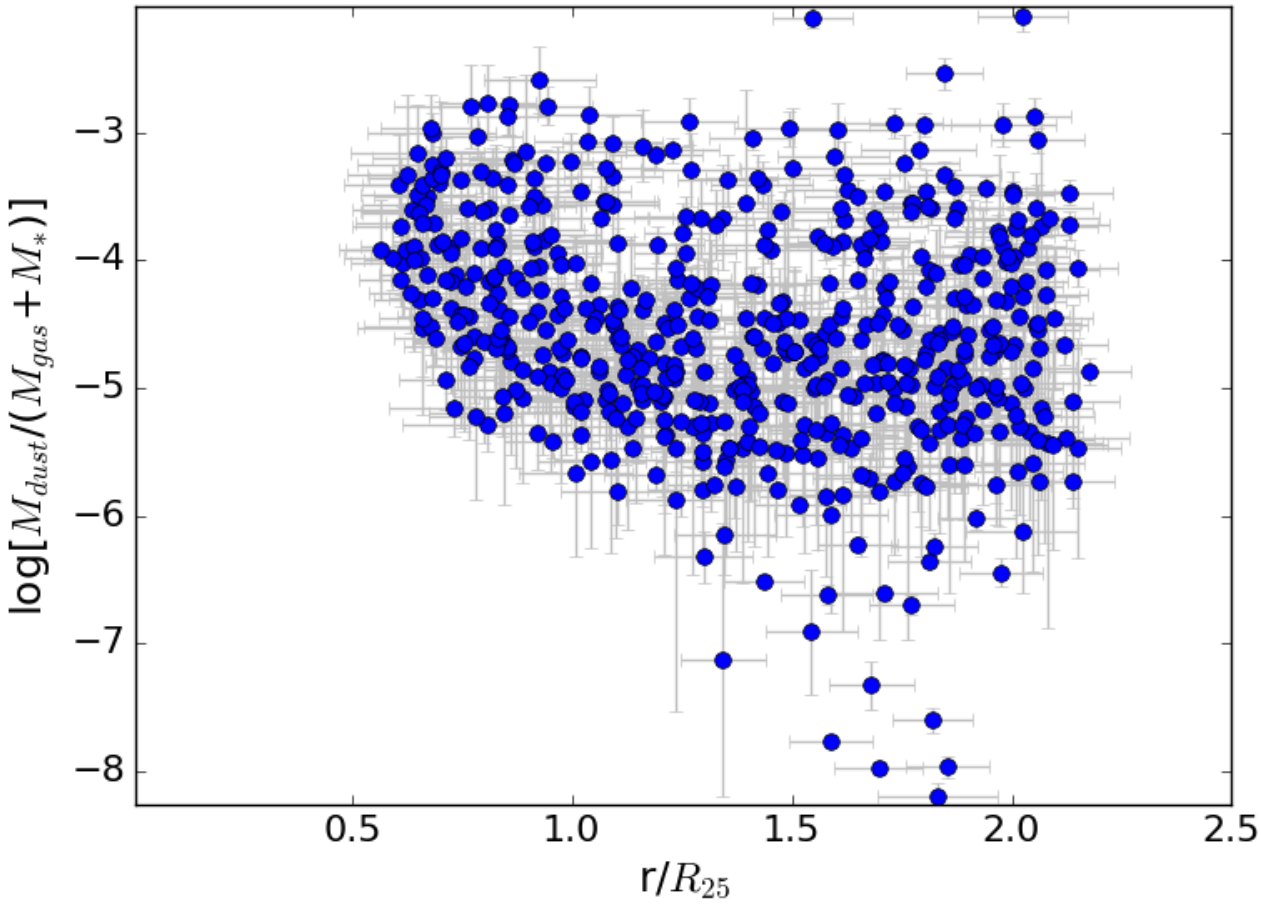

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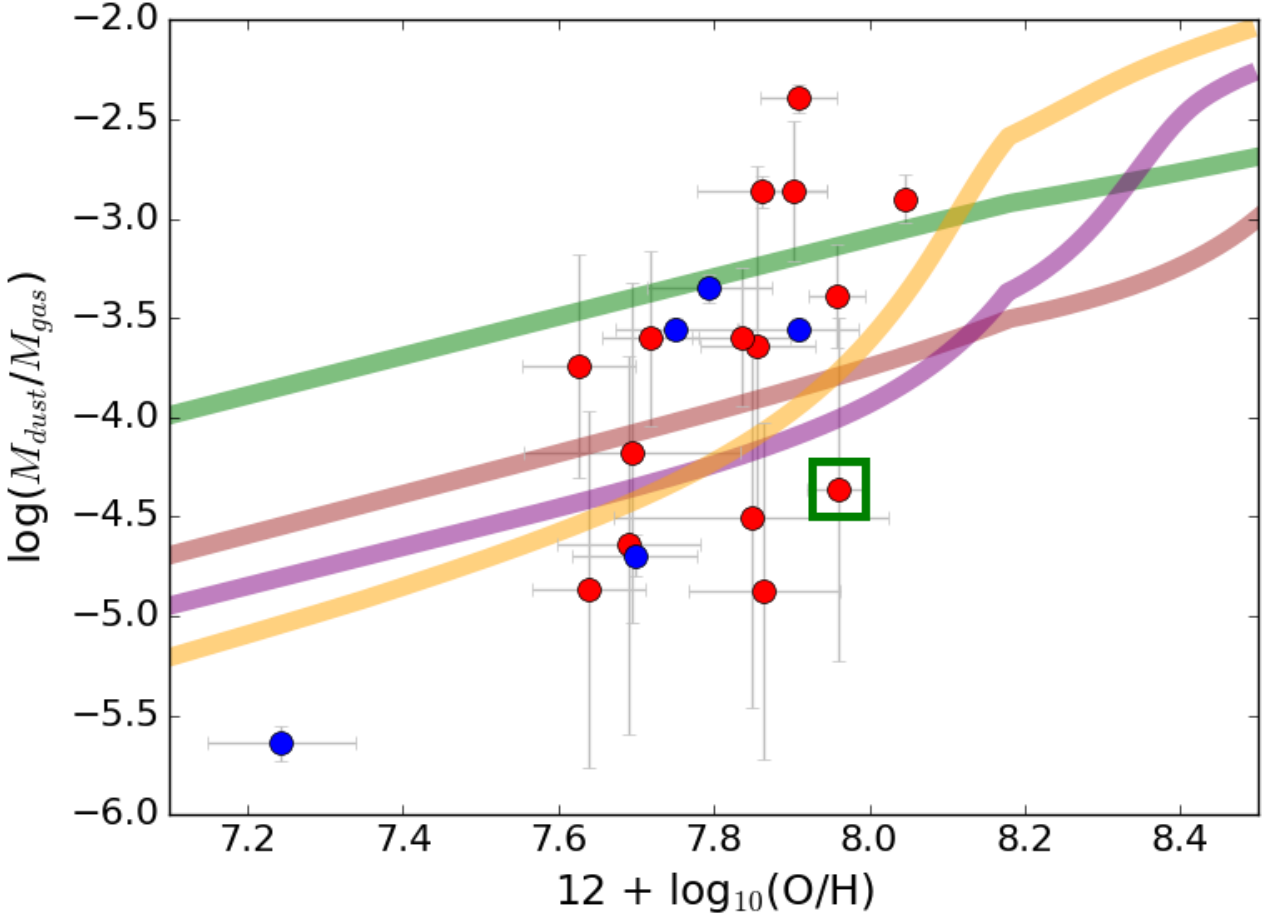

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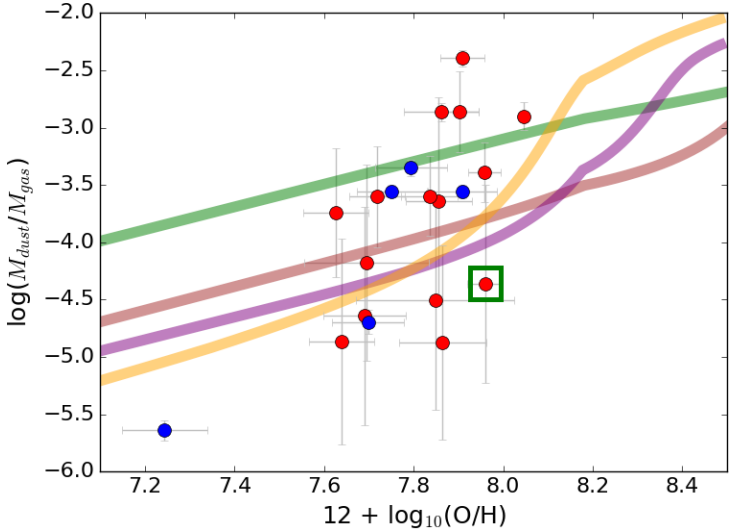

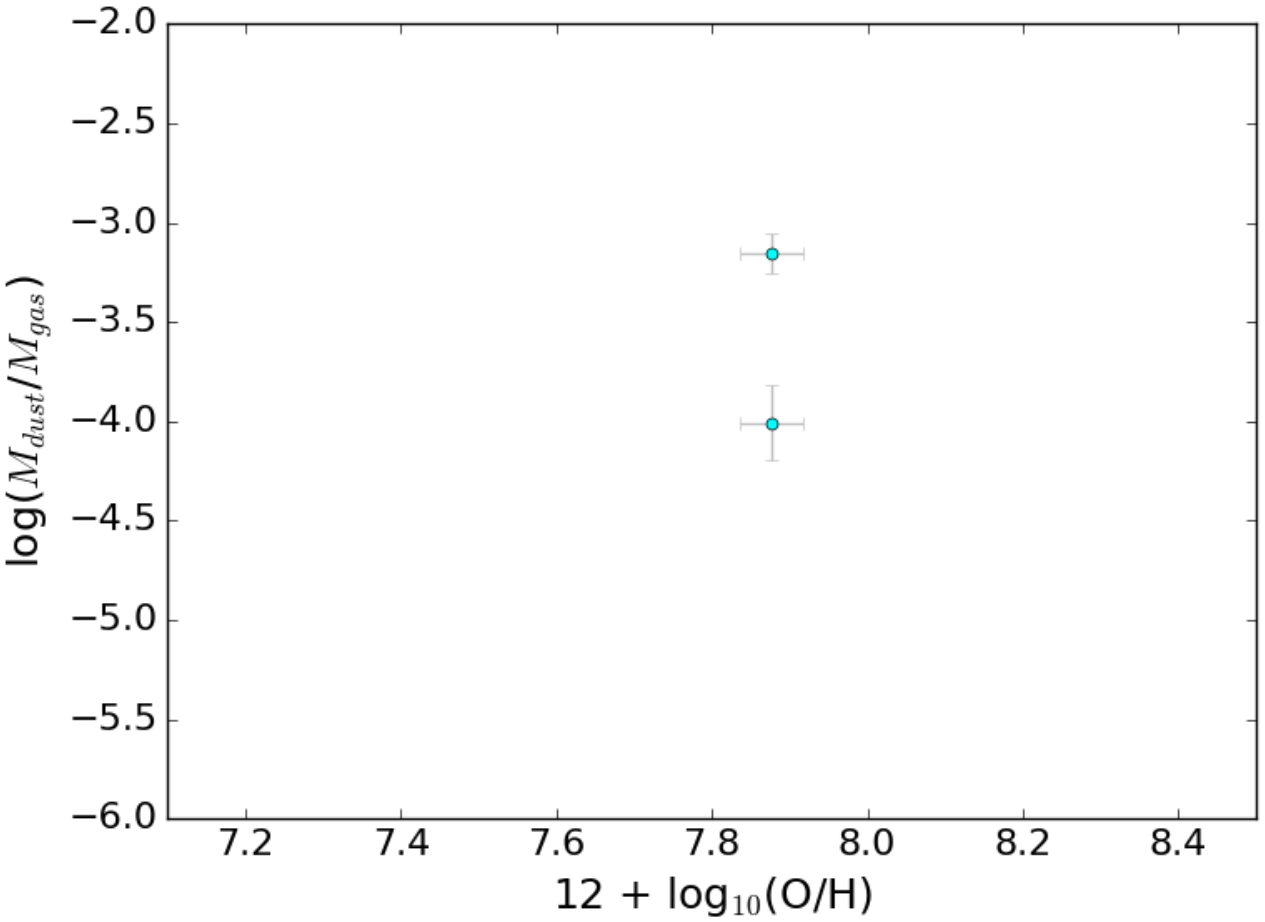

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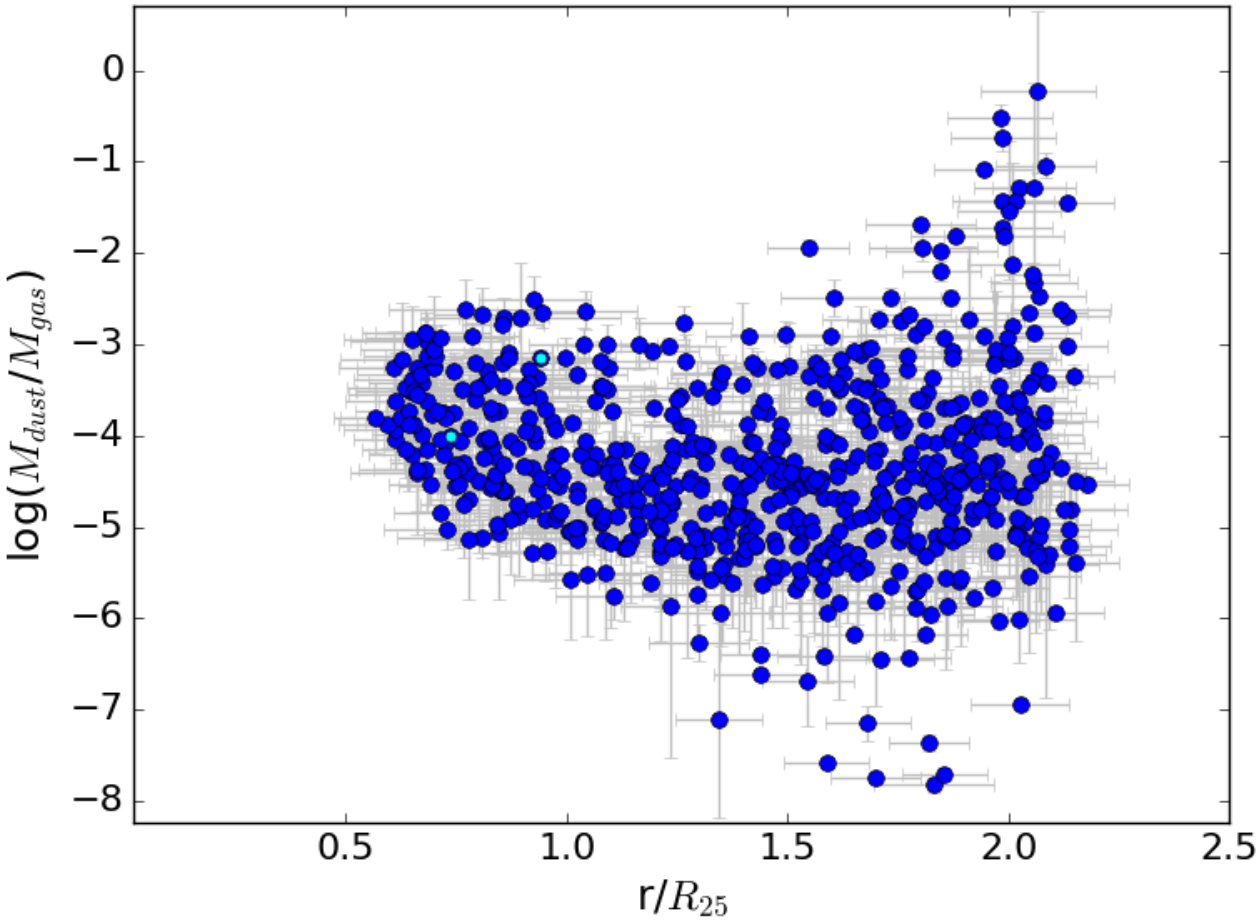

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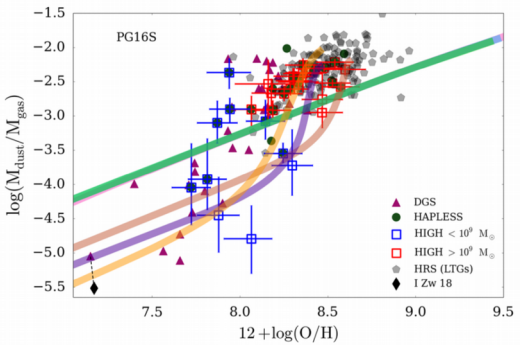
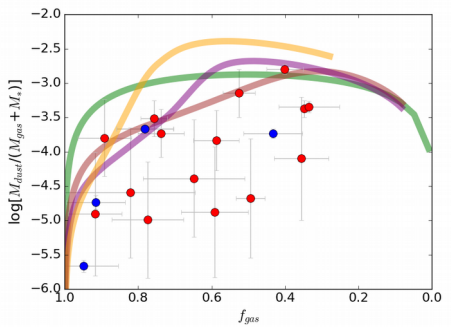
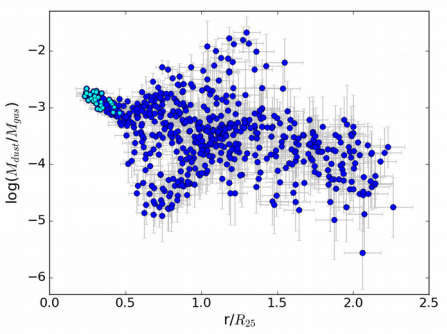
- Need to use interferometric HI data
- Low (less than SMC) metallicity dwarfs from the well defined DustPedia sample (& from DGS sample)

  Dust properties from SED fits using HerBIE with THEMIS
- Disk-averaged results using interferometric data - appear to move results to unexplainable(?) areas of parameter space
- Spatially resolved studies of individual dwarf galaxies reveal the rich variation in dust-gas properties within galaxies
- → Disk-averaged values can be misleading
- A comprehensive picture is being built using resolved studies ...







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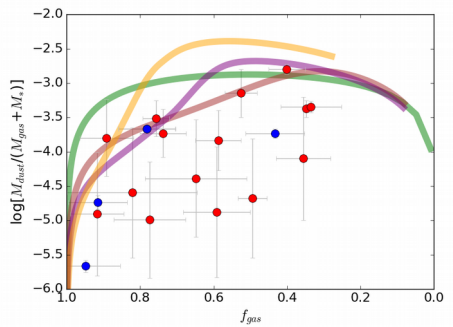
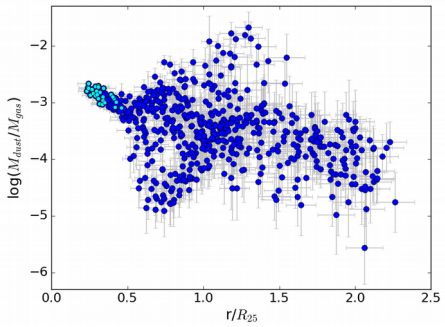
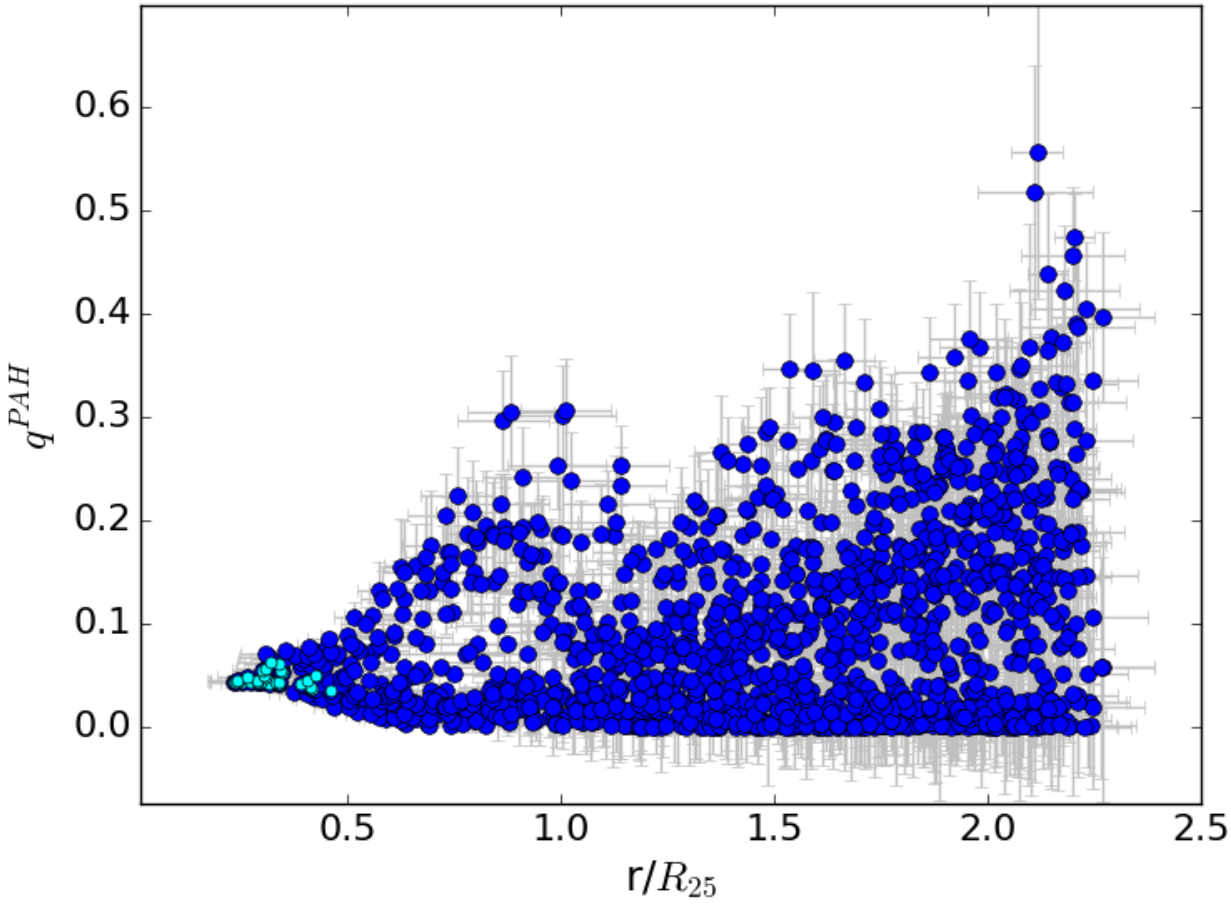
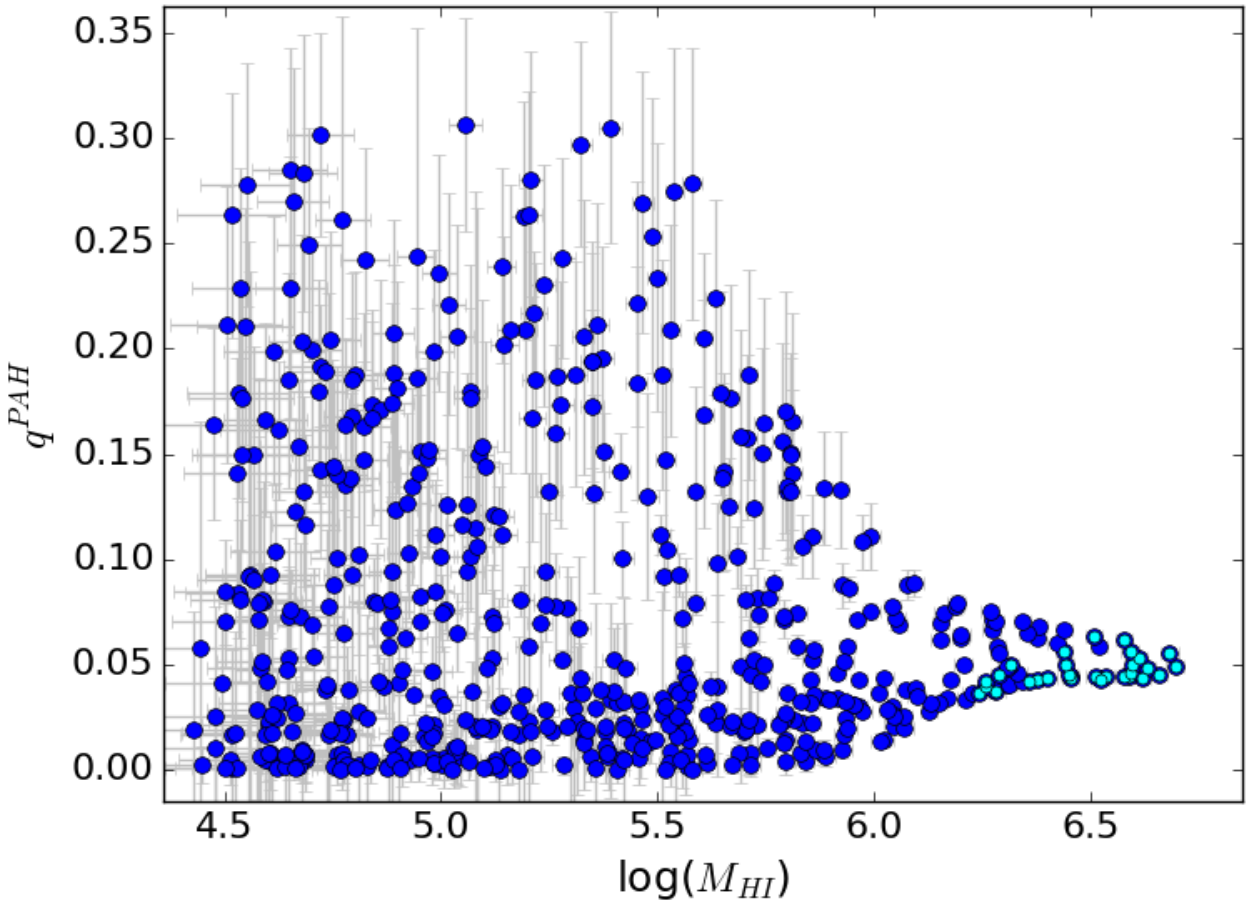




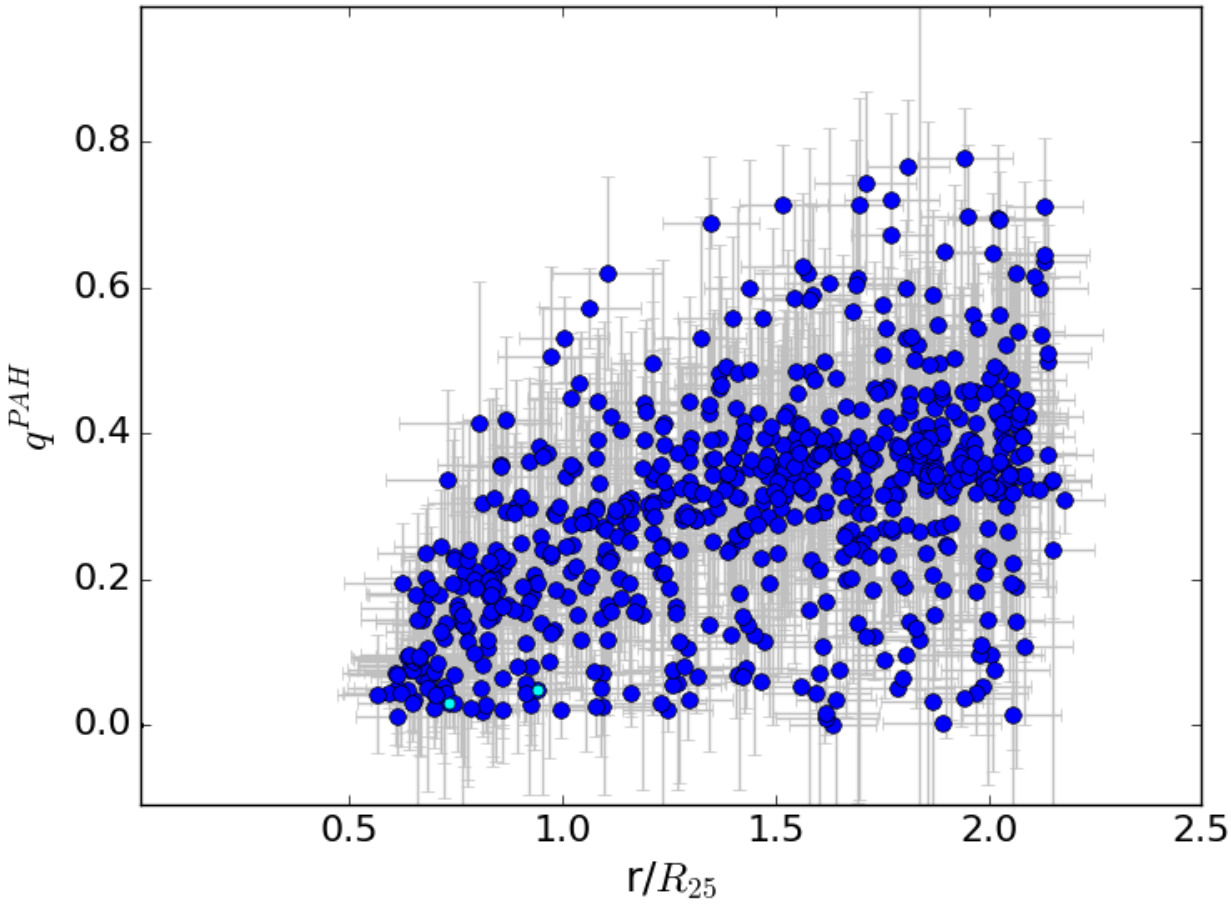
Spatially resolved study of NGC 625



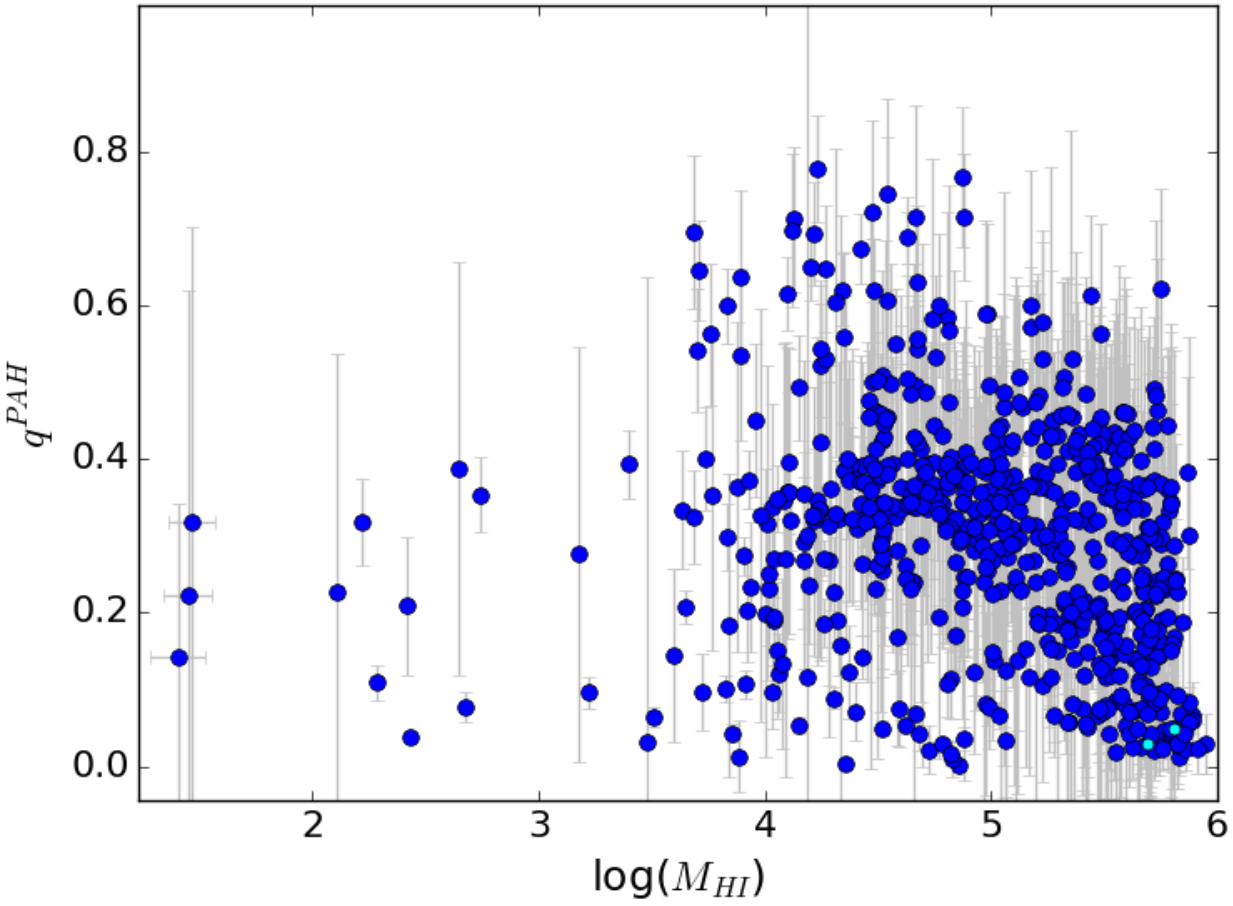
Spatially resolved study of NGC 625



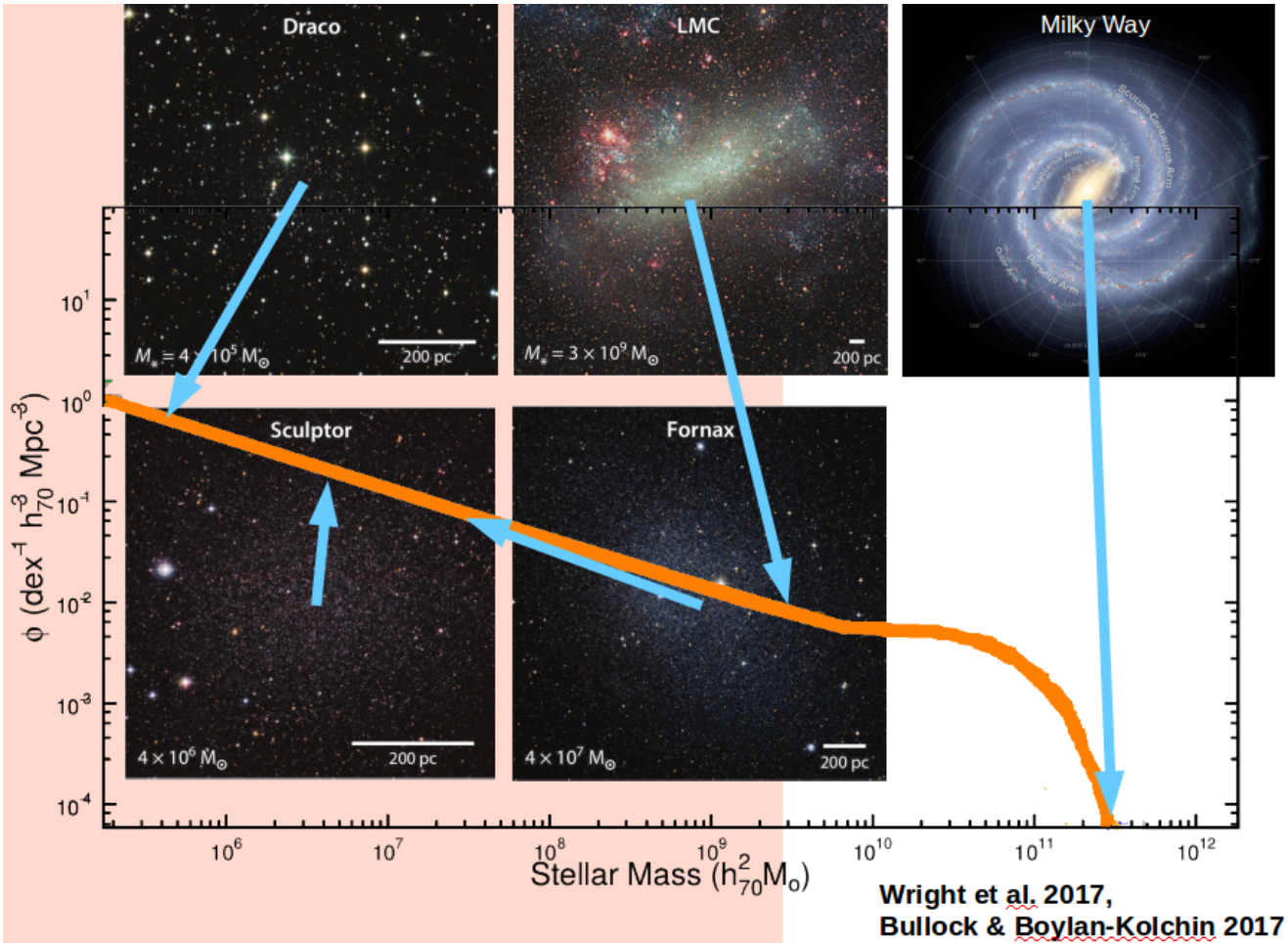
Spatially resolved study of Holmberg I



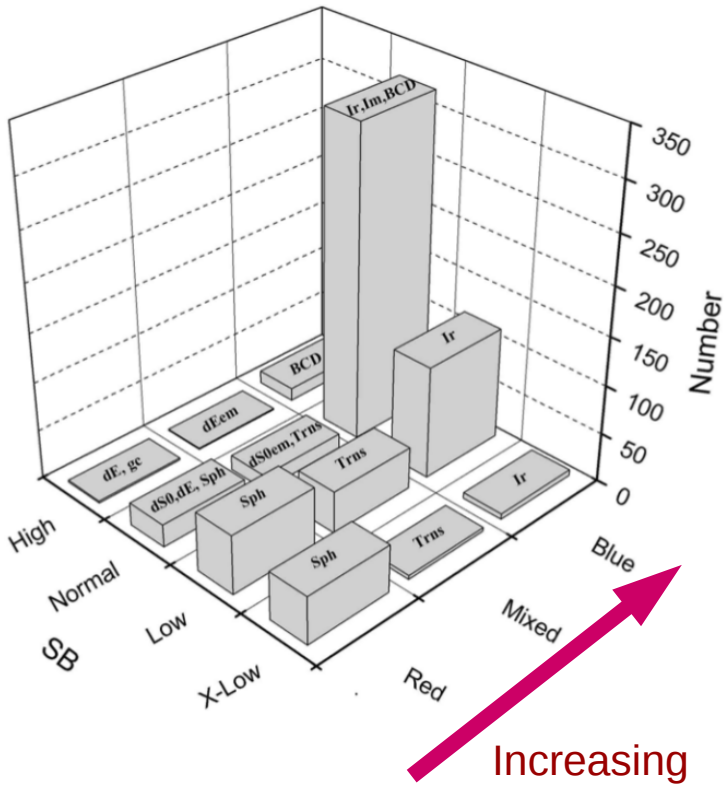
Spatially resolved study of Holmberg I



Star-forming gas-rich dwarf galaxies

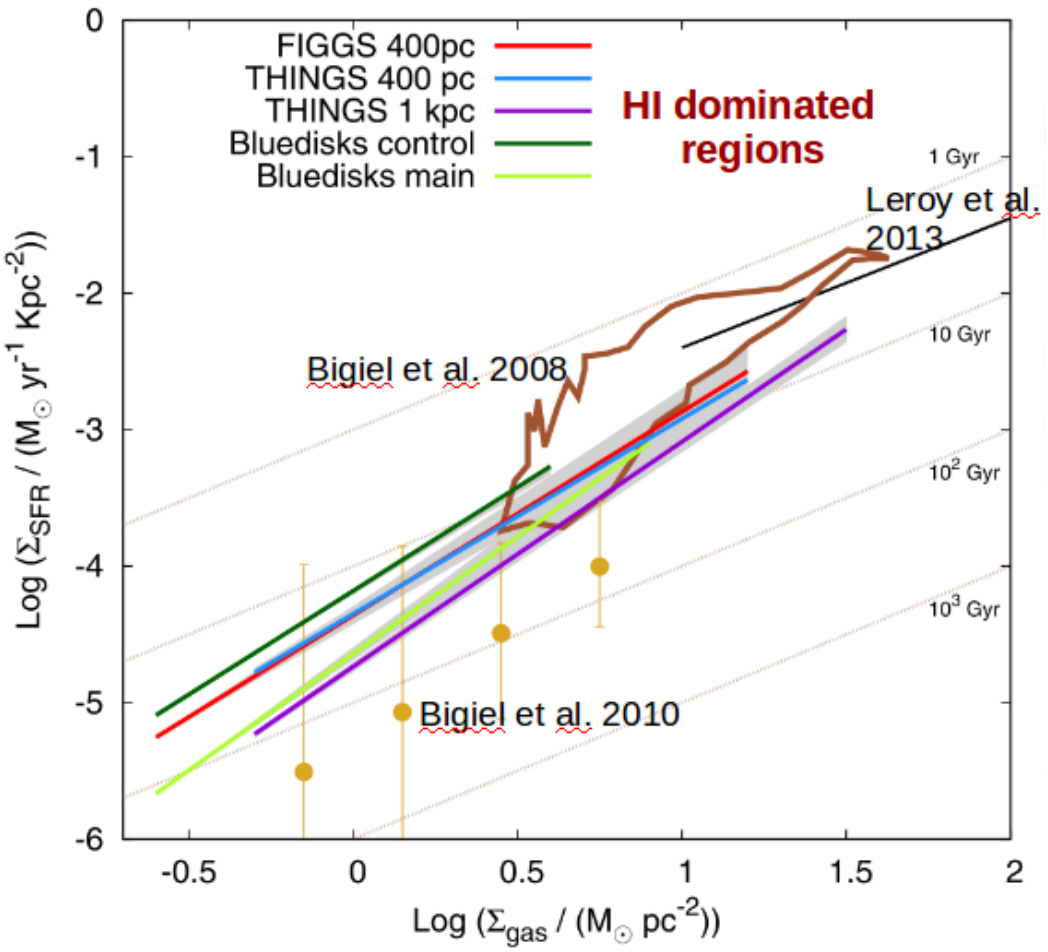


Wright et al. 2017,
Bullock & Boylan-Kolchin 2017



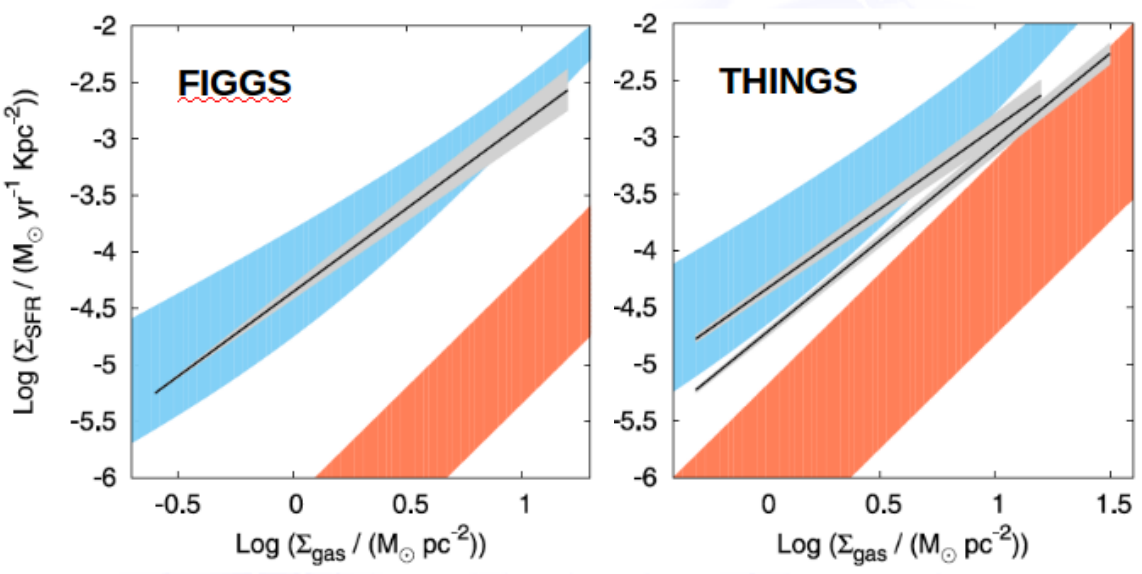
Karachentsev et al. 2013

Baryon cycle and the importance of HI



- Our aim is to study how gas converts to stars → the baryon cycle
- Gas content of star-forming dwarfs dominated by atomic hydrogen (HI)
- Overall molecular hydrogen content low → also hard to detect due to high CO-to-H_2 conversion factor
- *Study of the Kennicutt-Schmidt relation using HI revealed importance of baryon cycle* (**Roychowdhury et al. 2015**)

Baryon cycle and the importance of HI



- Blue: Ostriker, McKee & Leroy 2010 model for outer disks
- Red: Krumholz 2013 model
- Metallicity: 0.1 $Z_\odot$ for FIGGS, varied between 0.4 and 1 $Z_\odot$ for spirals

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