# The evolution of the dust and gas content in galaxies

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# Galaxy scaling relations

Aim: investigating the scaling relations among galaxy fundamental physical parameters

- Star Formation Rate
- stellar mass
- dust mass
- gas mass

} Key physical properties to understand galaxy evolution, linked with each other through the processes responsible for mass build-up

and their evolution across cosmic time.

# Sample and basic ingredients of the analysis

Large statistics: GOODS–S + GOODS–N + COSMOS

- multiwavelength photometry from X-rays to FIR
- **Herschel** data from PEP (PACS survey, Lutz+11) and HerMES (SPIRE survey, Oliver+10)
- zspec or photo–z

Basic ingredients:

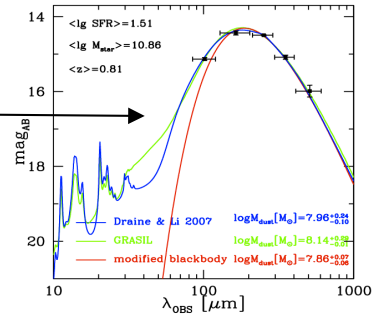
- **Star Formation Rate** → from 24 μm observations
- **stellar mass** → nearUV–to–nearIR multi–λ photometry

Selections: S/N > 10 in K band + AGNs removed + $\begin{cases} 0.05 < z < 2.5 \\ 9.75 < \log M_{star} < 12 \\ -0.75 < \log SFR < 3 \end{cases}$

~30000 galaxies in the final sample

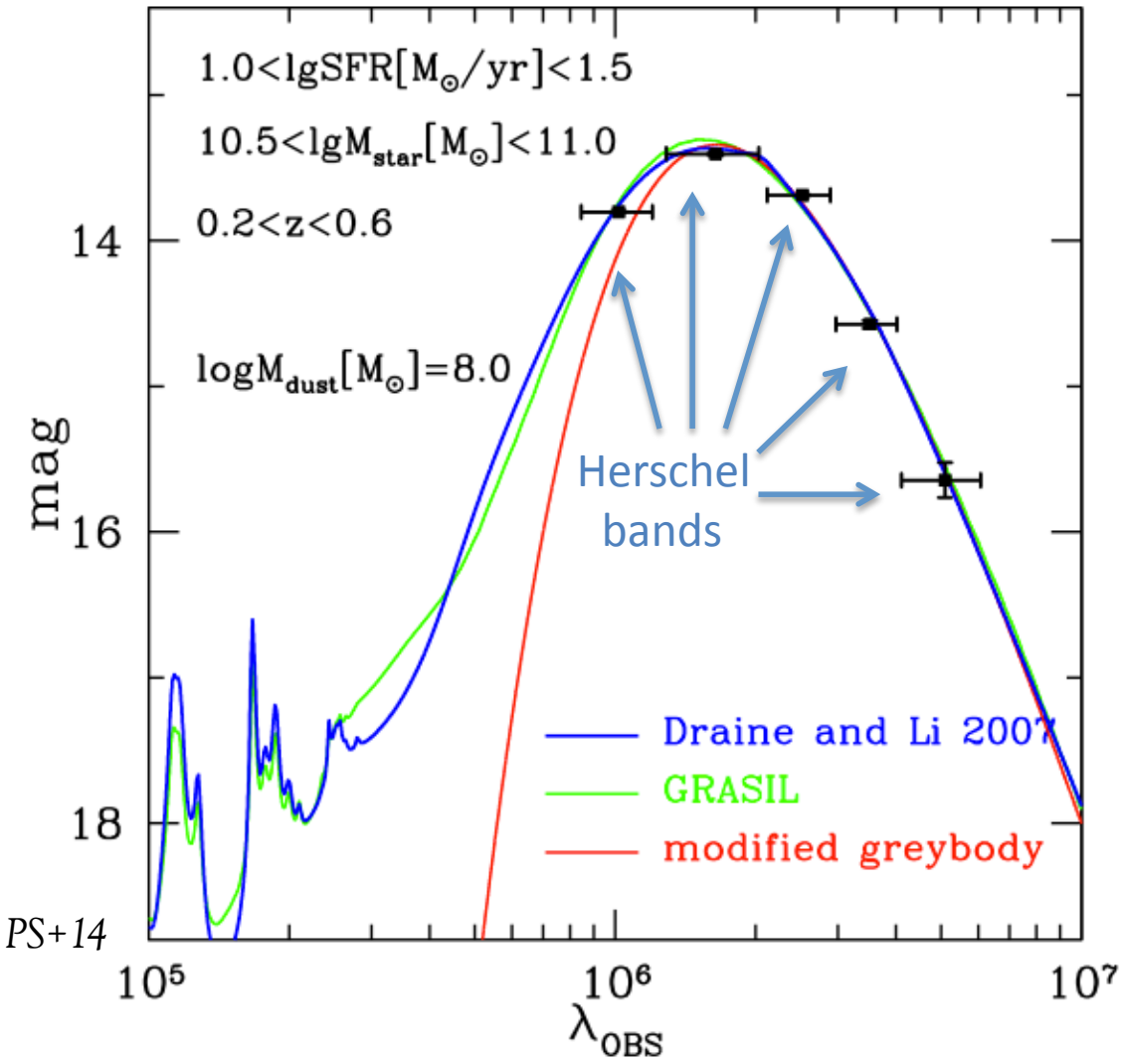
Average fluxes in Herschel bands by **stacking** on the maps at the positions of sources with similar properties (redshift, $M_{star}$, SFR)

- **dust mass** → fit Herschel fluxes to Draine & Li 2007 model
- **gas mass** → conversion through the dust/gas ratio (metallicity from the FMR of Mannucci+10)



# Dust as gas tracer

**$M_{dust}$ from IR-submm SED** → **dust-to-gas ratio** → **$M_{gas}$**

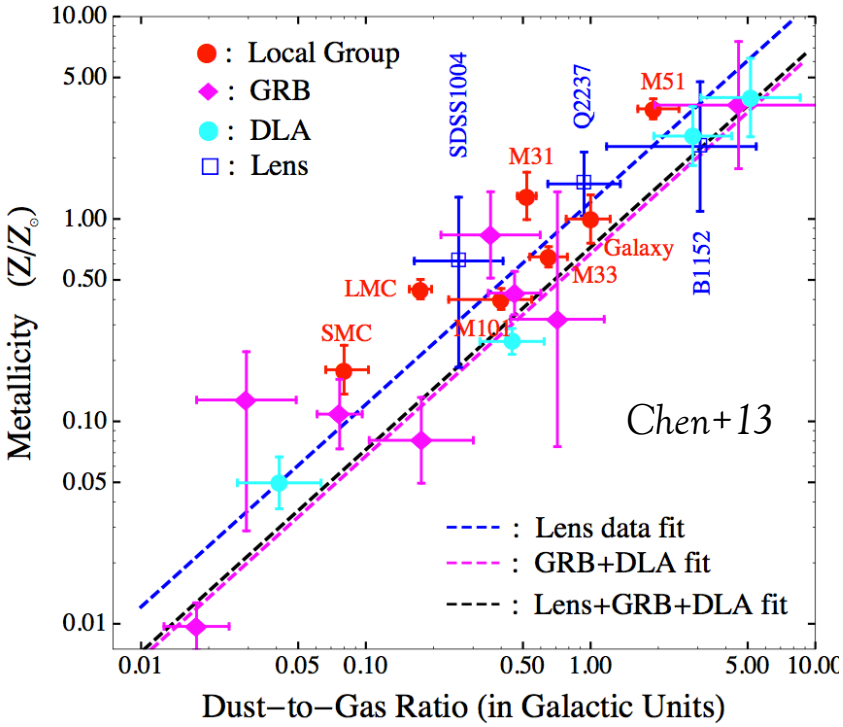



Eales+10, 12
Leroy+11
Magdis+11,12
Magnelli+12
Scoville+12,14
Bolatto+13
Bethermin+14

# Gas mass from dust

**Dust-to-Gas ratio ∝ metallicity**

(at Z>~0.1$Z_{sun}$, not true at lower metallicities)



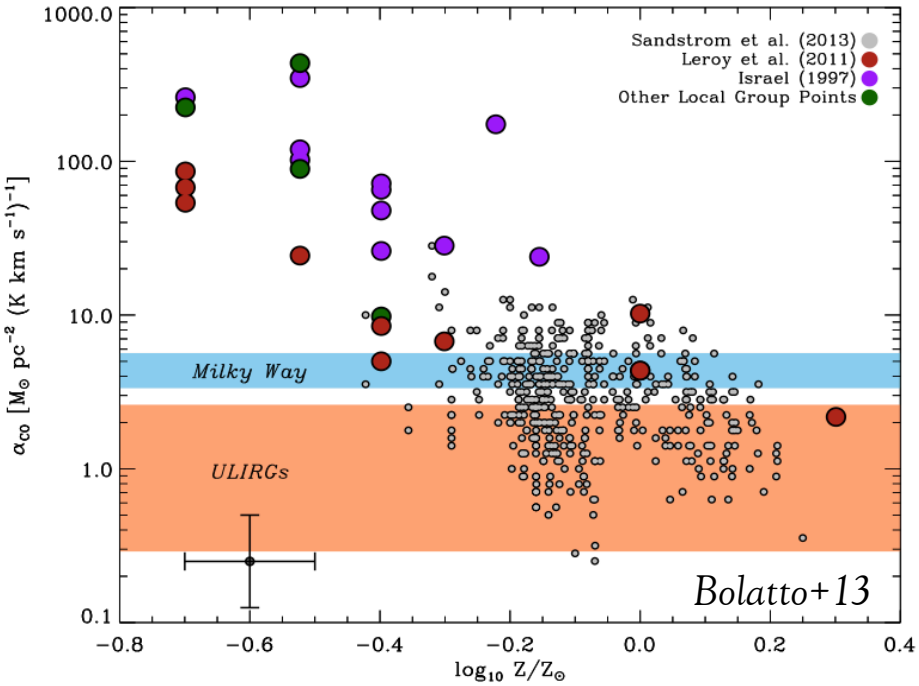

- Photometric redshifts good enough
- Fast method: can quickly deliver gas masses for thousands of galaxies

*James+02; Draine+07; Leroy+11; Smith+12; Corbelli +12; Sandstrom+13; Zafar & Watson 13; Chen+13; Remy-Ruyer+14*

# Gas mass from CO

**CO-to-$H_2$ conv. factor ∝ metallicity$^{\sim -1.5}$**

(with larger spread)




- **At high-z generally high-J CO transitions observed** → need to correct for excitation
- **Different for ULIRGs, SMGs, and "normal galaxies"(?)**
- Needs accurate spectroscopic redshifts
- Time demanding

*Bolatto+13; Genzel+12; Leroy+11; Papadopulos+12; Sandstrom+13; Lee+14; Dannerbauer+09; Ivison+11; Carilli & Walter 13*

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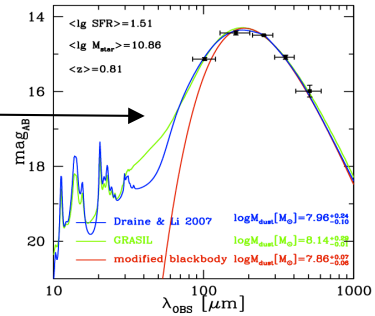
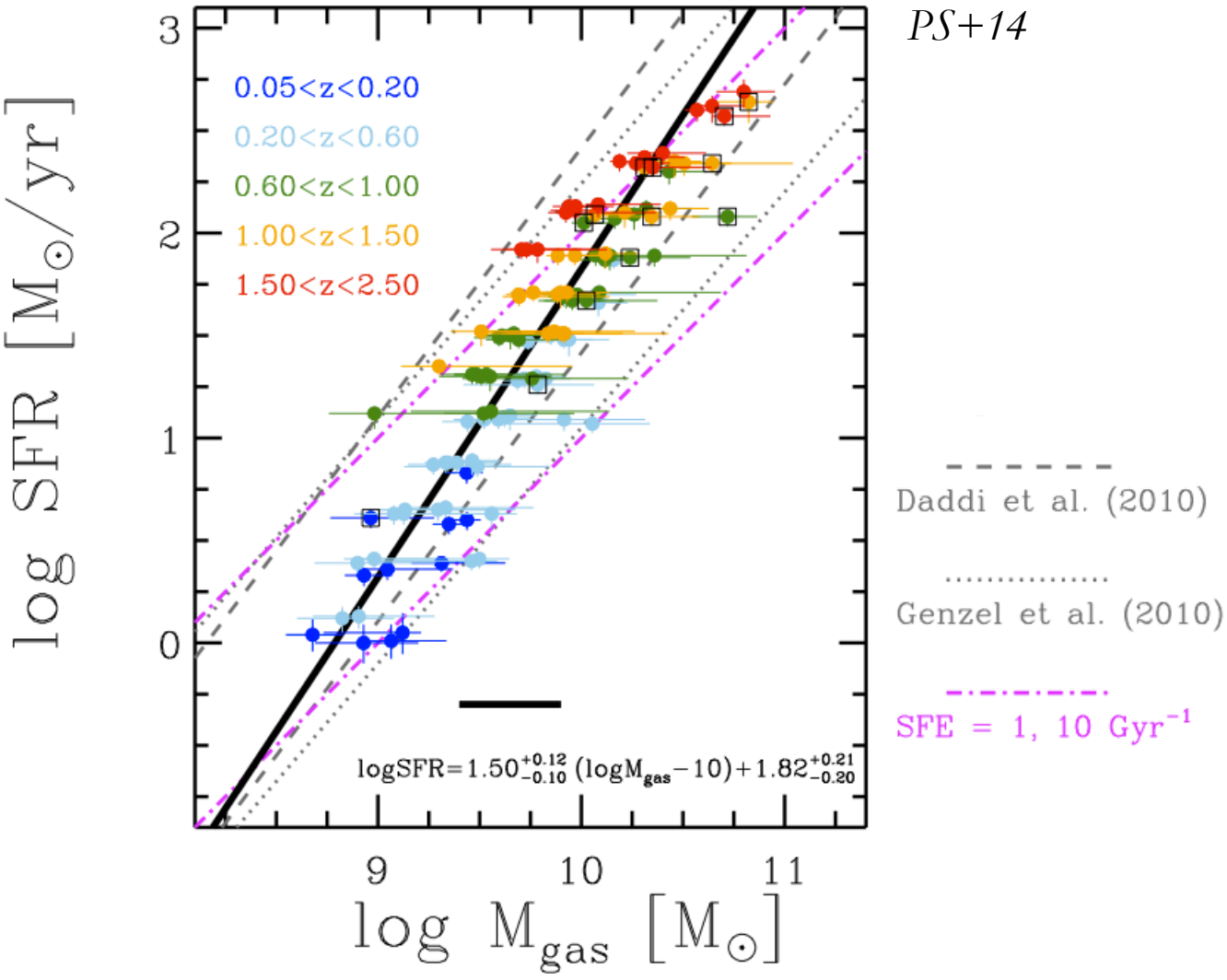


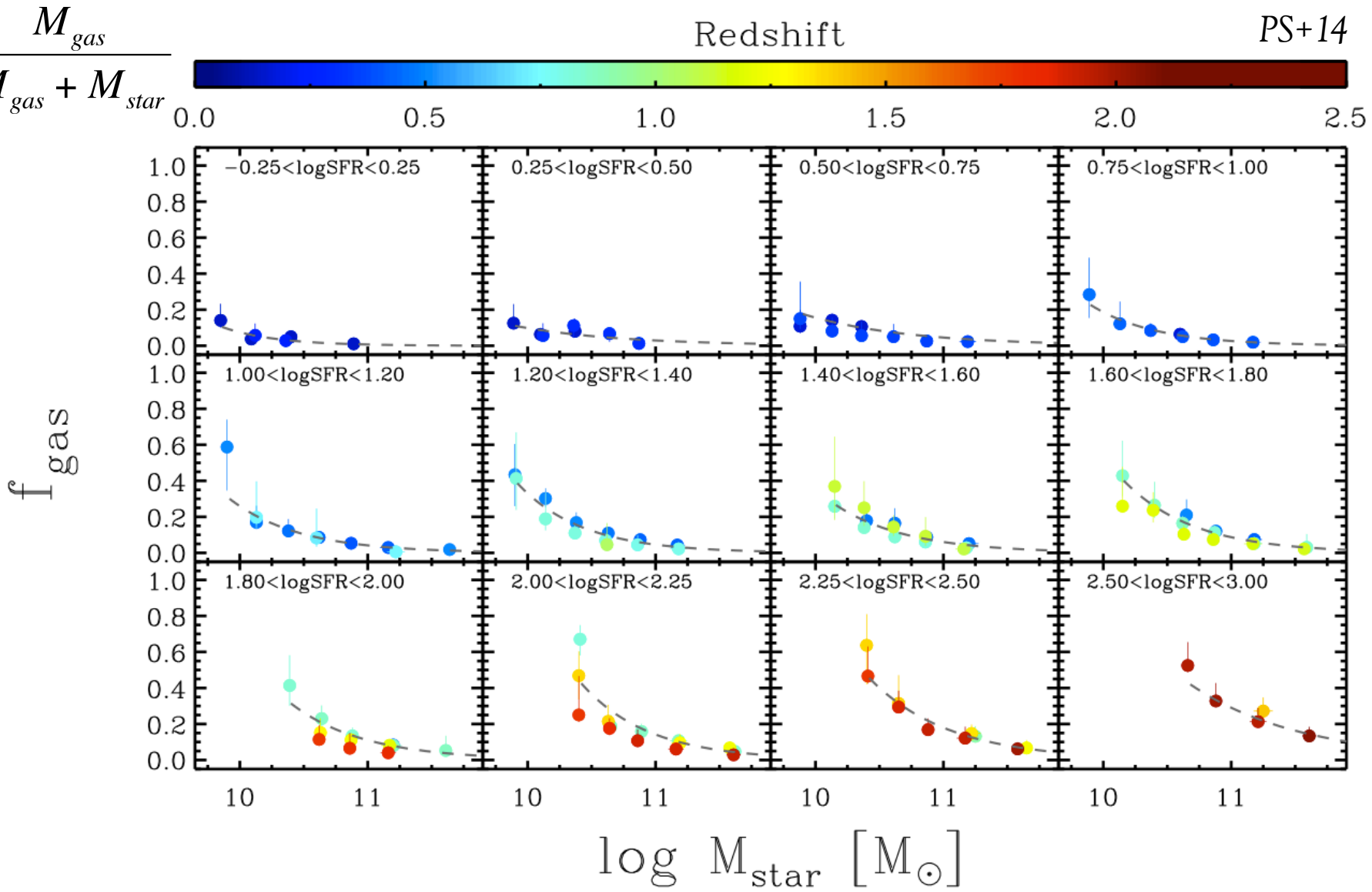
# The "dust-based" integrated Schmidt-Kennicutt law




- consistent with a single power law of slope 1.5 (original S-K slope, Kennicutt+98)
- broadly consistent with previous CO–based works for the majority of galaxies

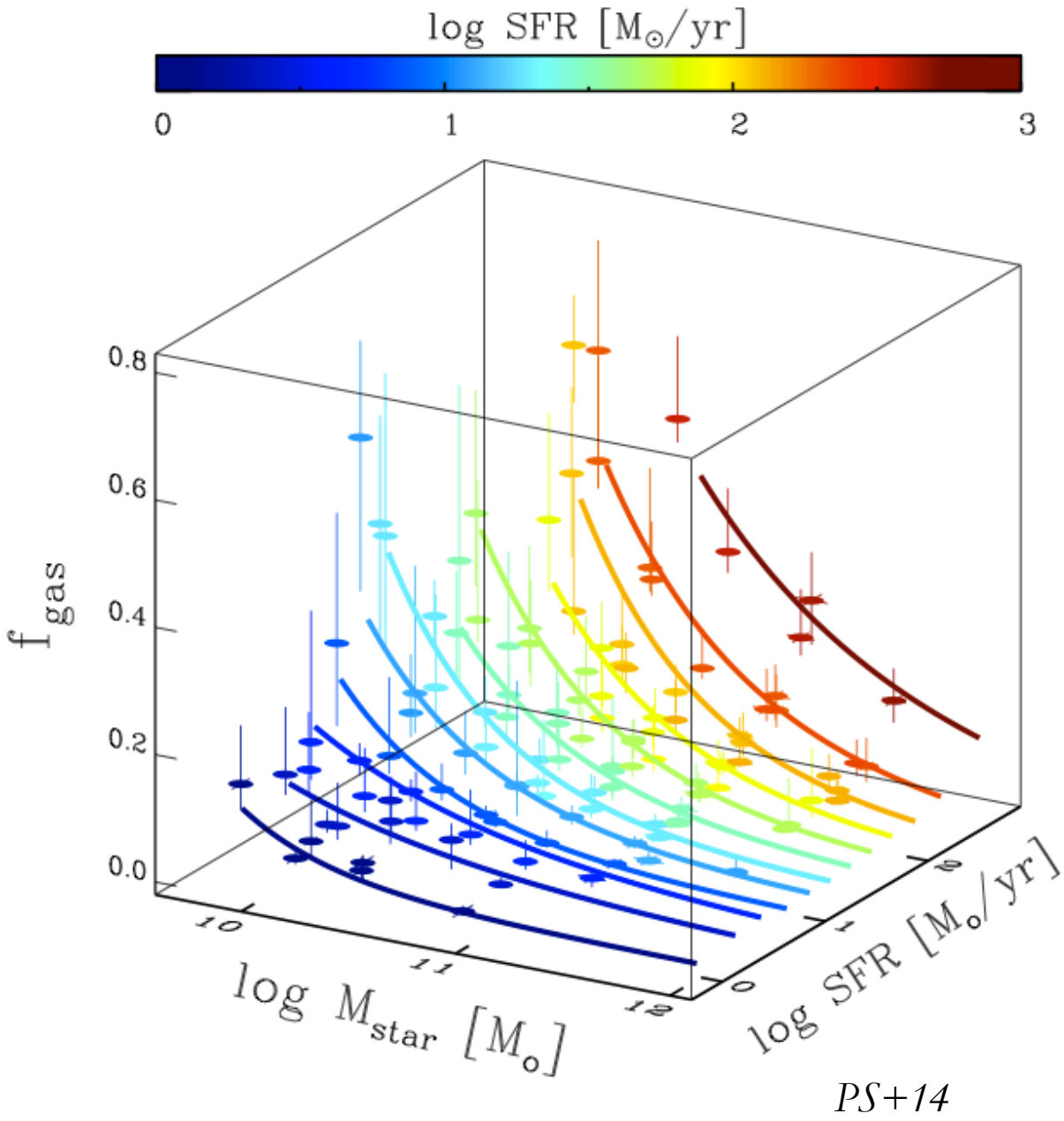
# The evolution of the gas fraction

$$f_{gas} = \frac{M_{gas}}{M_{gas} + M_{star}}$$




- $f_{gas}$ decreases with $M_{star}$ and increases with SFR
- no redshift evolution at fixed $M_{star}$ *and* SFR (at least out to z~2.5)

# The fundamental $f_{gas}$-$M_{star}$-SFR relation

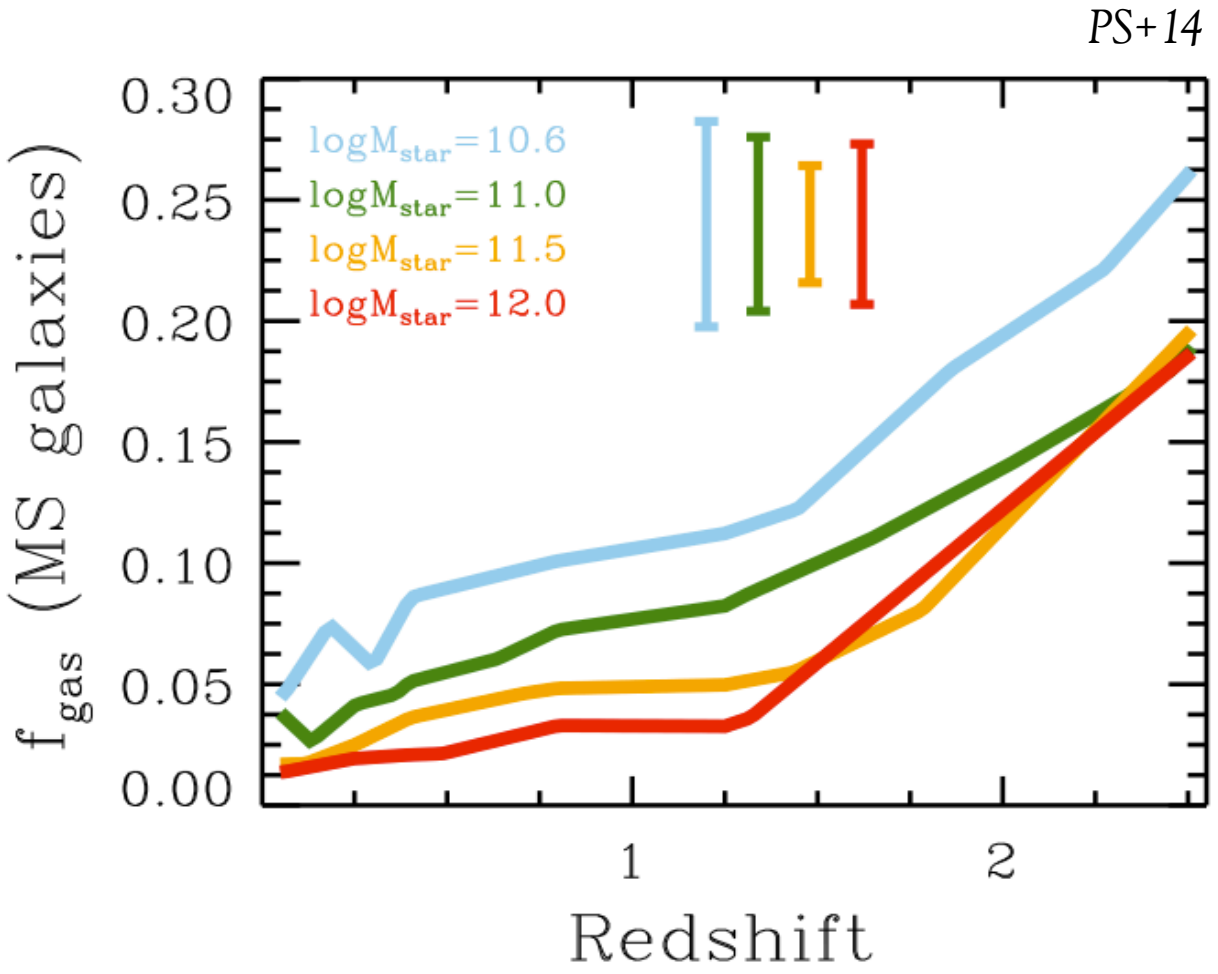



*PS+14*

- redshift–independent (➔ fundamental) 3D relation ➔ the physics of SF is independent of redshift

- does not imply lack of evolution: the majority of galaxies populate different regions of this surface at different epochs

# The evolution of the gas fraction in Main Sequence galaxies




Evidence of downsizing: massive galaxies have consumed their gas earlier and more rapidly than low mass galaxies

# Summary

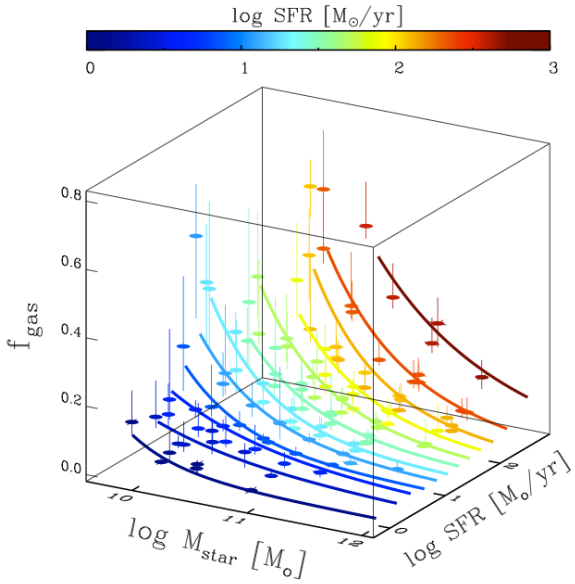
❑ **Dust is a powerful gas proxy**

It is possible to extend gas studies to much larger samples of galaxies, save much time and get rid of many systematics

❑ **The physics of star formation is independent of redshift** (at least out to z~2.5)

At fixed $M_{star}$ *and* SFR, gas and dust masses are consistent with no evolution with redshift (within uncertainties)

BUT the global gas and dust content does evolve since the majority of galaxies populate different regions of the fundamental $f_{gas}$-$M_{star}$-SFR relation across cosmic epochs




Thanks