A Brief History of Gastrophysics and Star Formation

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Outlook

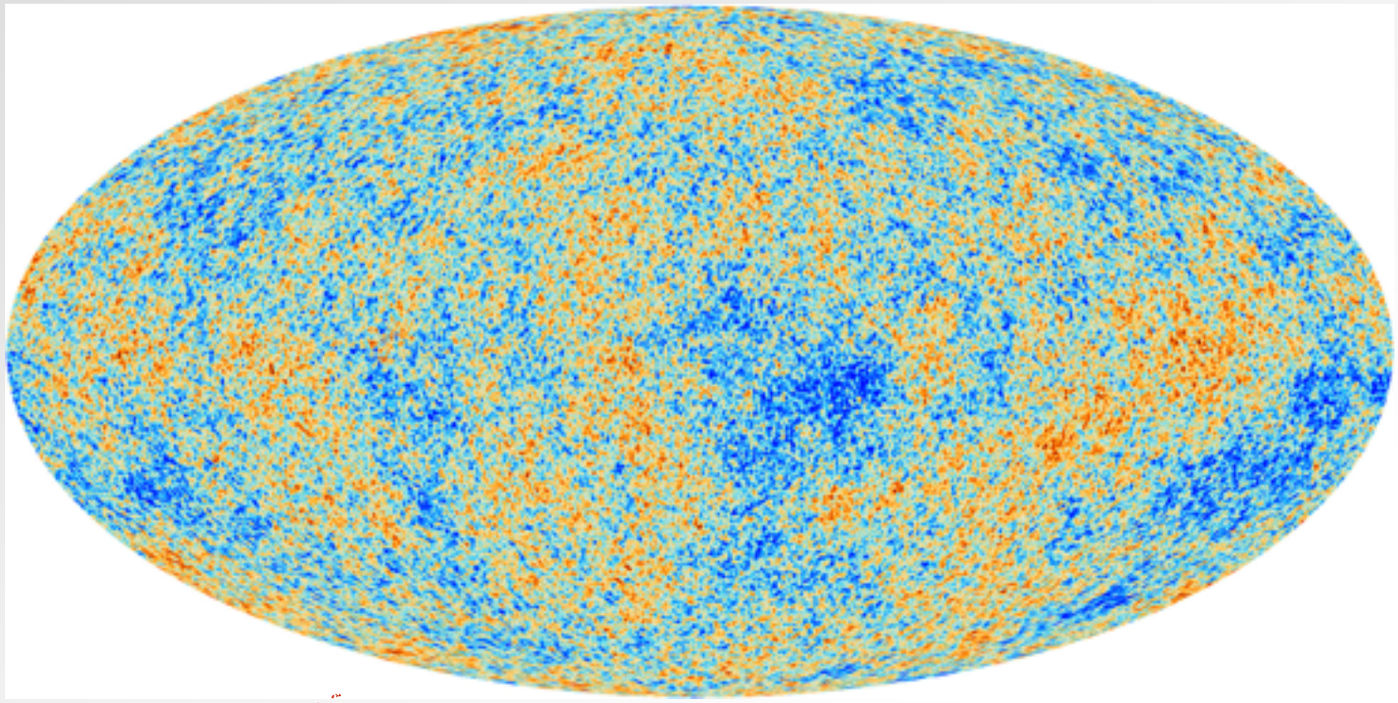
1. Galaxy formation: The classical view
2. High redshift: A different paradigm
3. Analogs at low redshift
4. Conclusions

Galaxy formation:

The classical view

Galaxy formation: The classical view

Planck collaboration



Formation of the large-scale structure

Illustris

Galaxy formation: The classical view

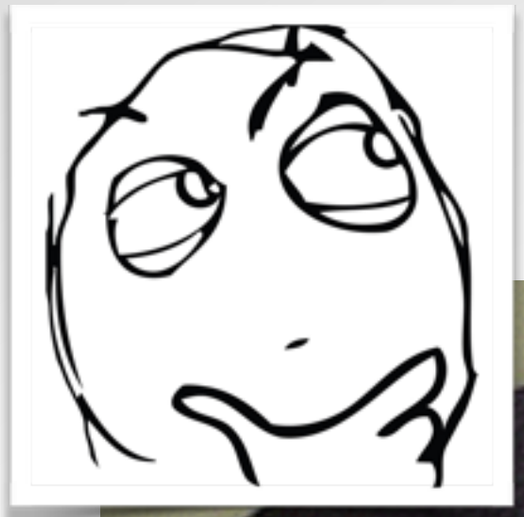
HST

The interstellar medium (ISM): gas and stars

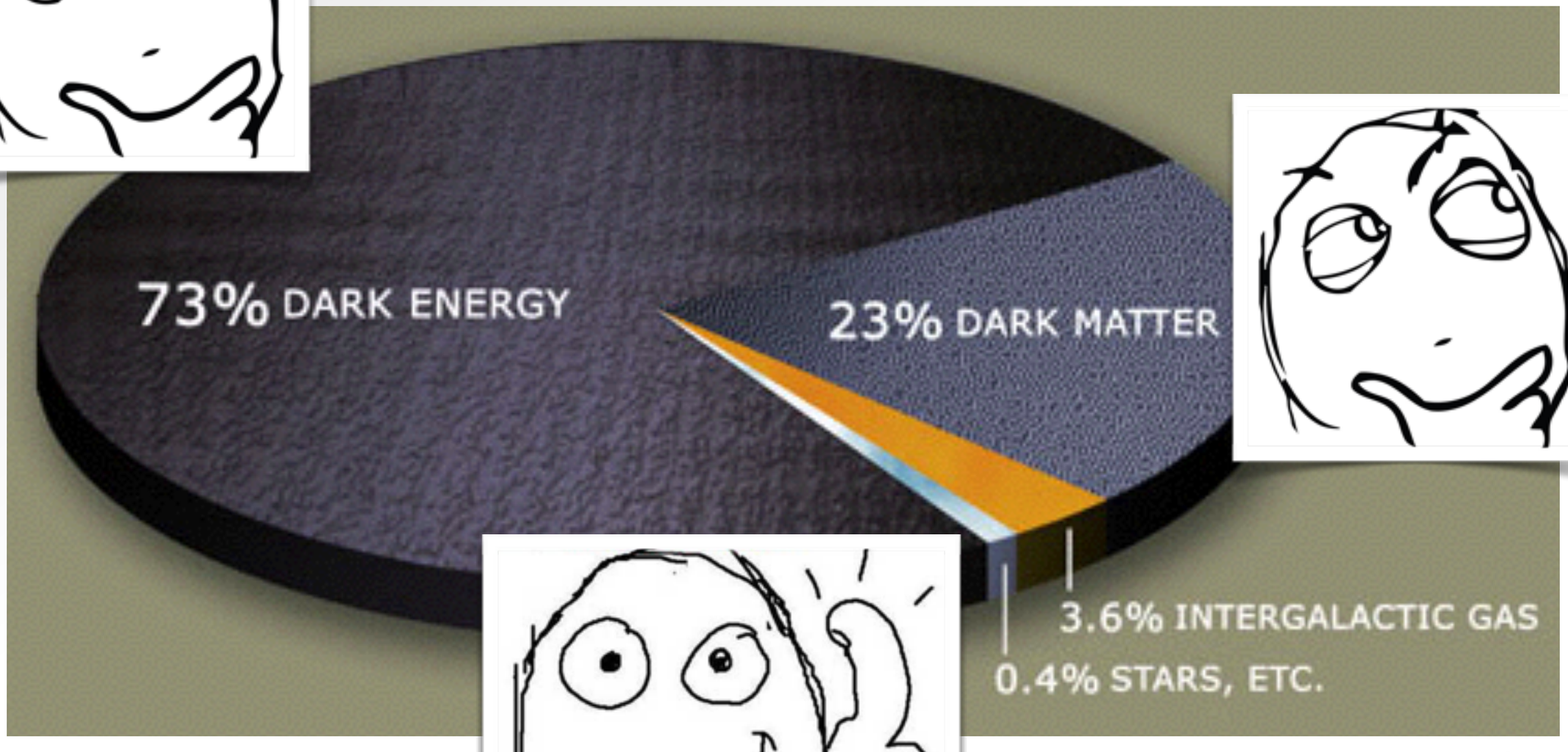
Non-linear processes: mechanical & radiative feedback, turbulence, magnetic fields

Gastrophysics

Galaxy formation: The classical view

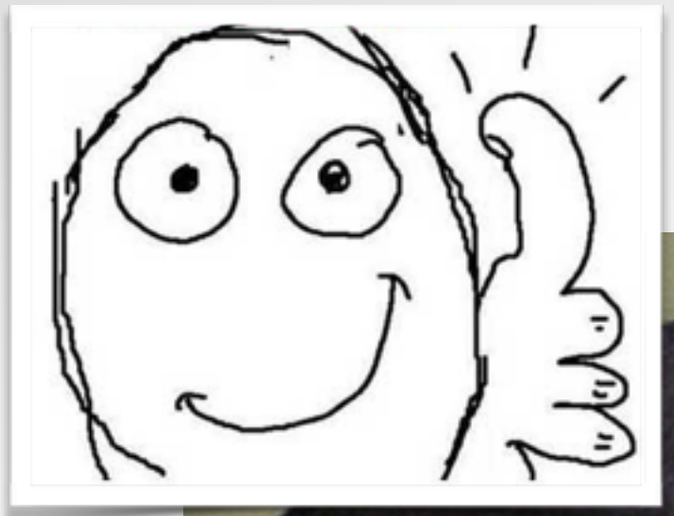


Cosmologists

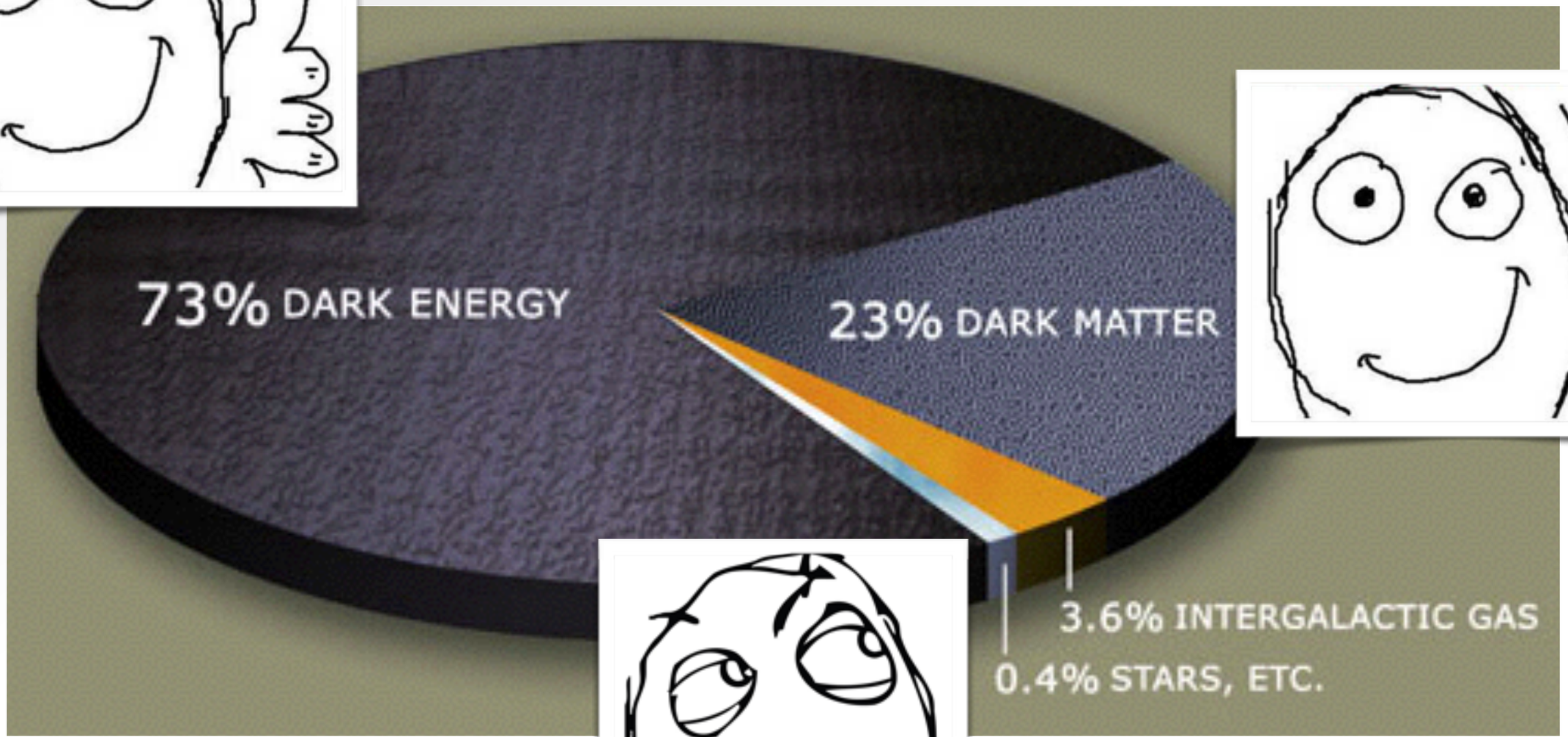


NASA

Galaxy formation: The classical view



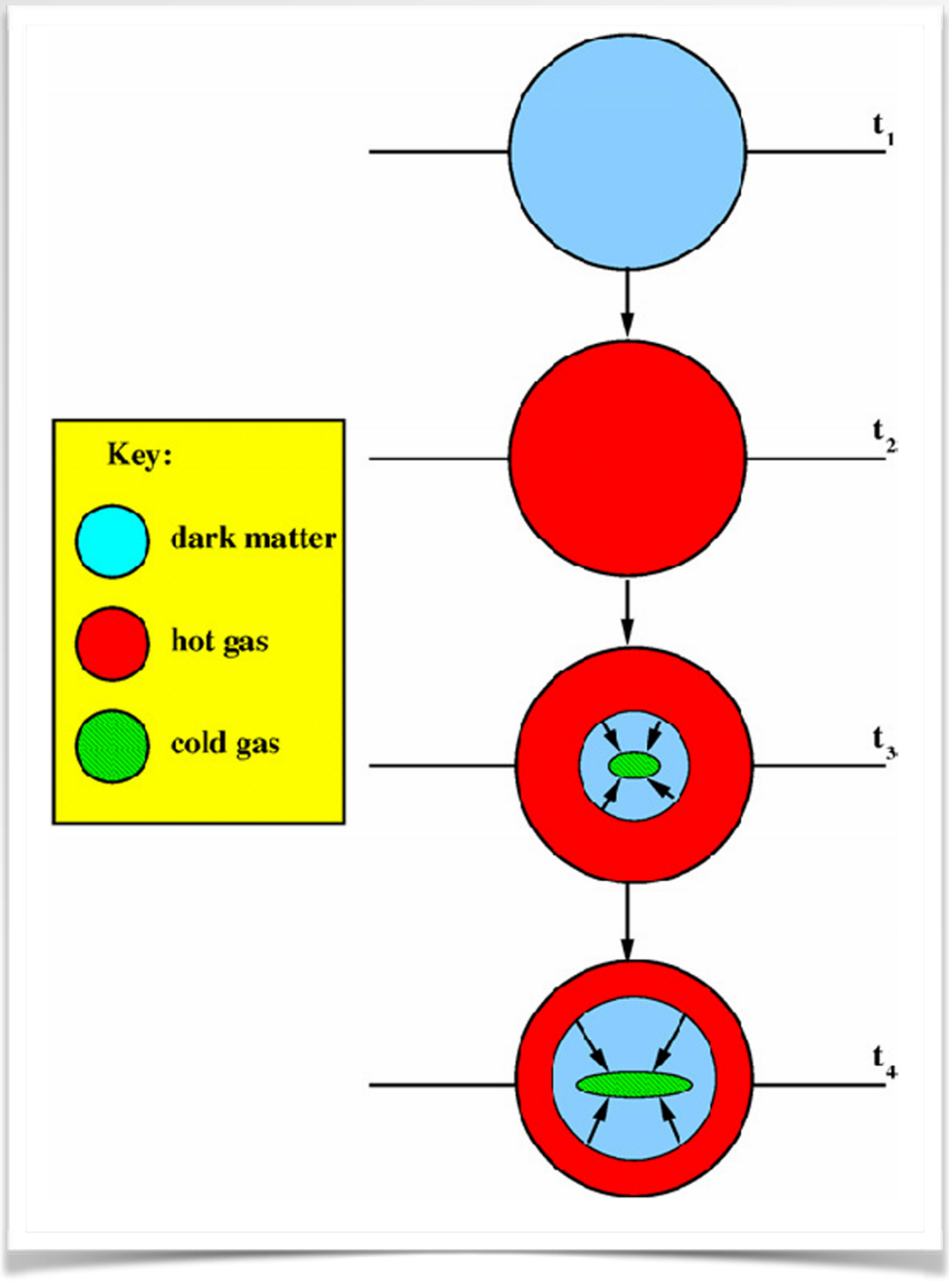
Extragalactic Astrophysicists



NASA

Galaxy formation: The classical view

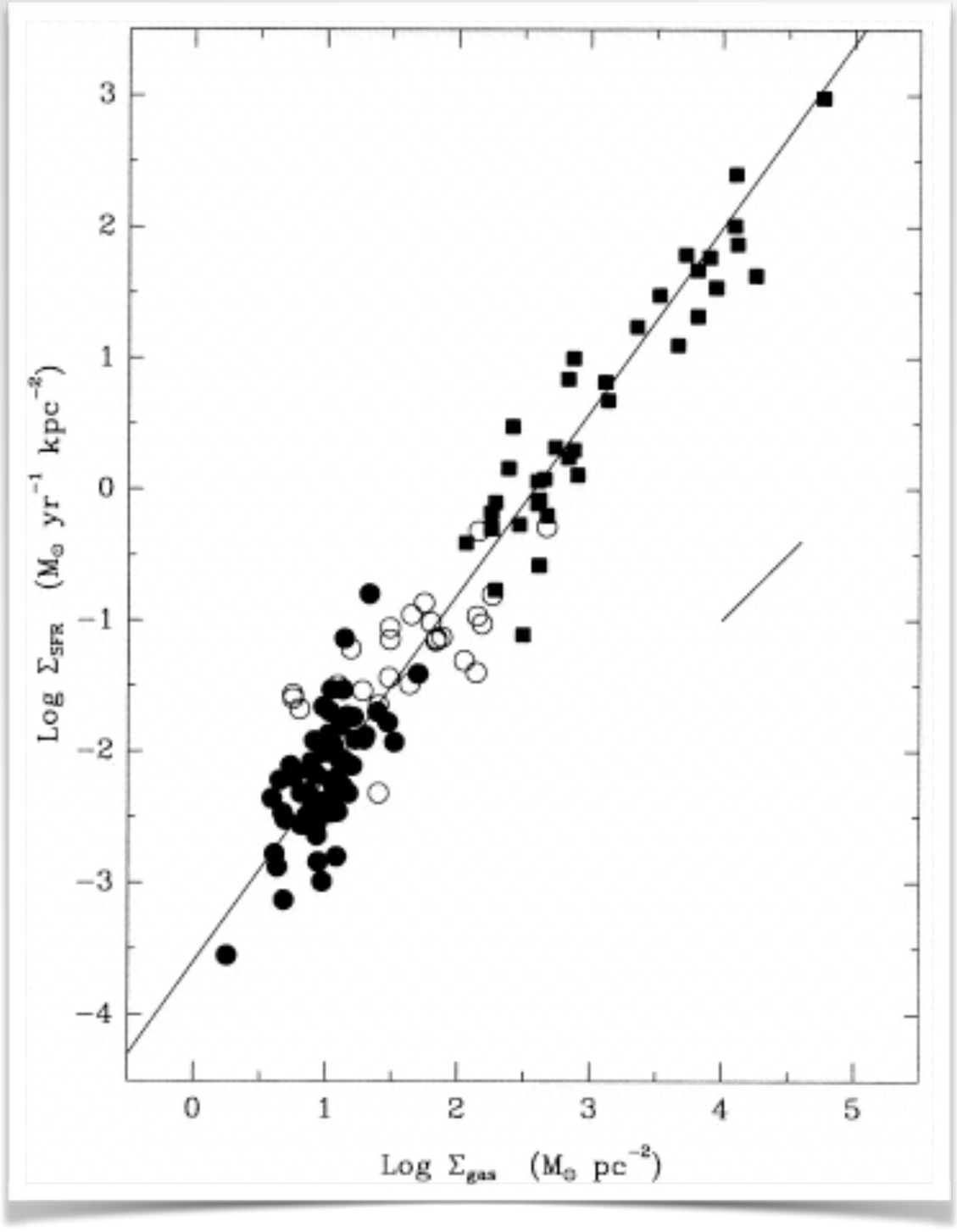
Baugh (2006)



Classical view: gas collapse and disk formation

Galaxy formation: The classical view

Kennicutt 98



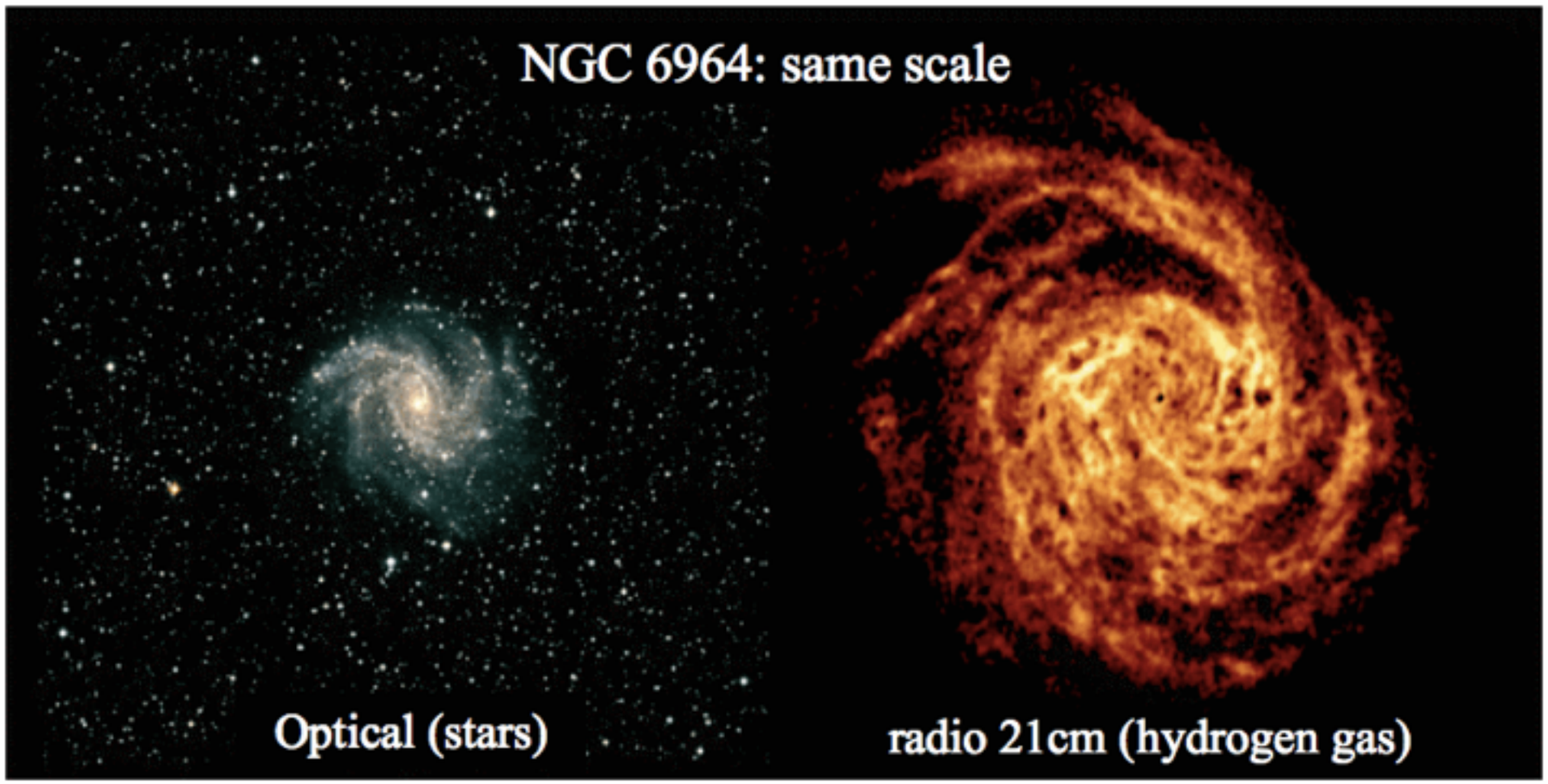
Gas → Stars

The Schmidt-Kennicutt relation

$$\Sigma_{SFR} = A\Sigma_{gas}^{n}$$

Galaxy formation: The classical view

What do we mean by “gas”?

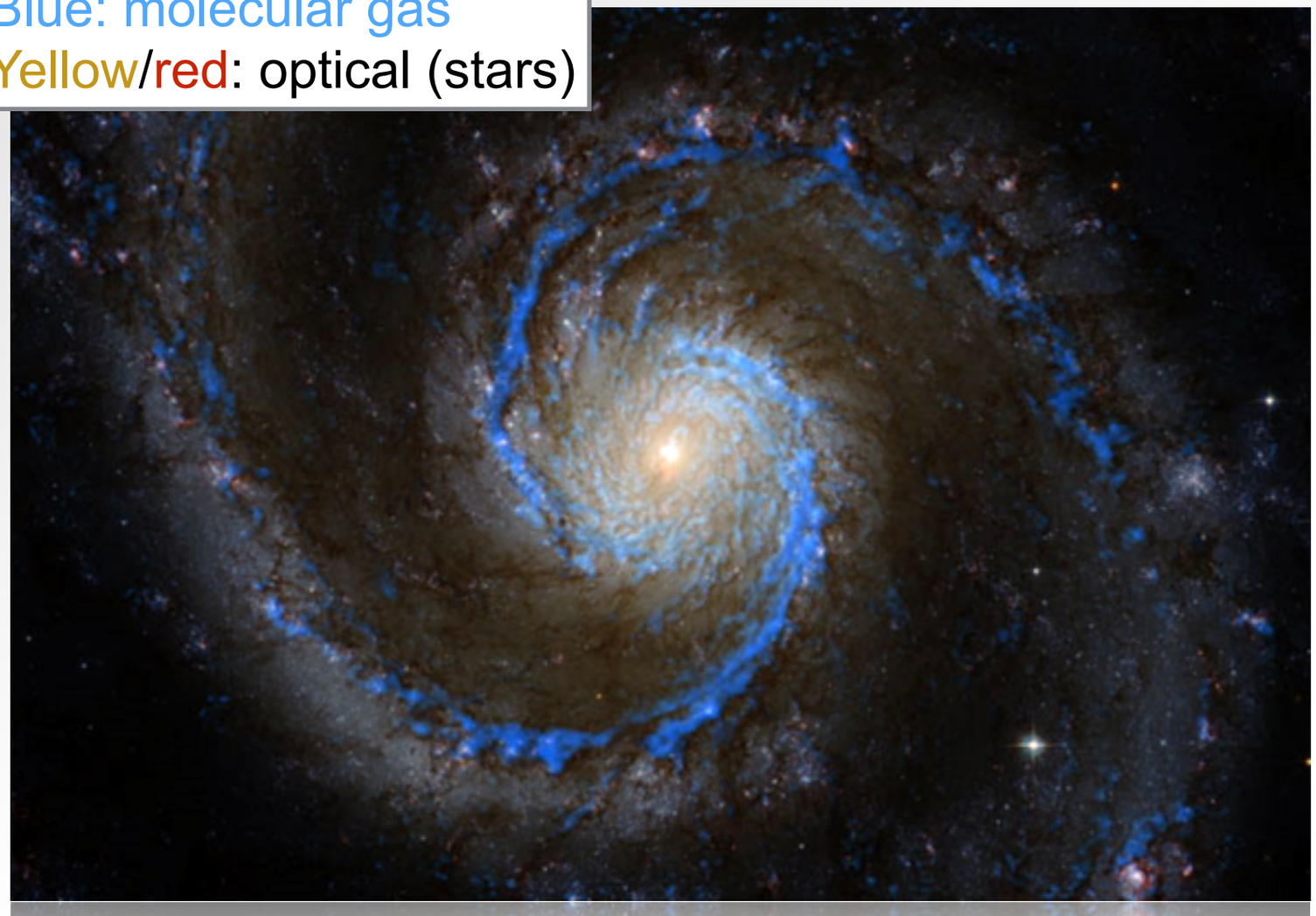


Atomic hydrogen does not form stars!

Galaxy formation: The classical view

PAWS Team/IRAM/NASA HST/T. A. Rector

Blue: molecular gas
Yellow/red: optical (stars)



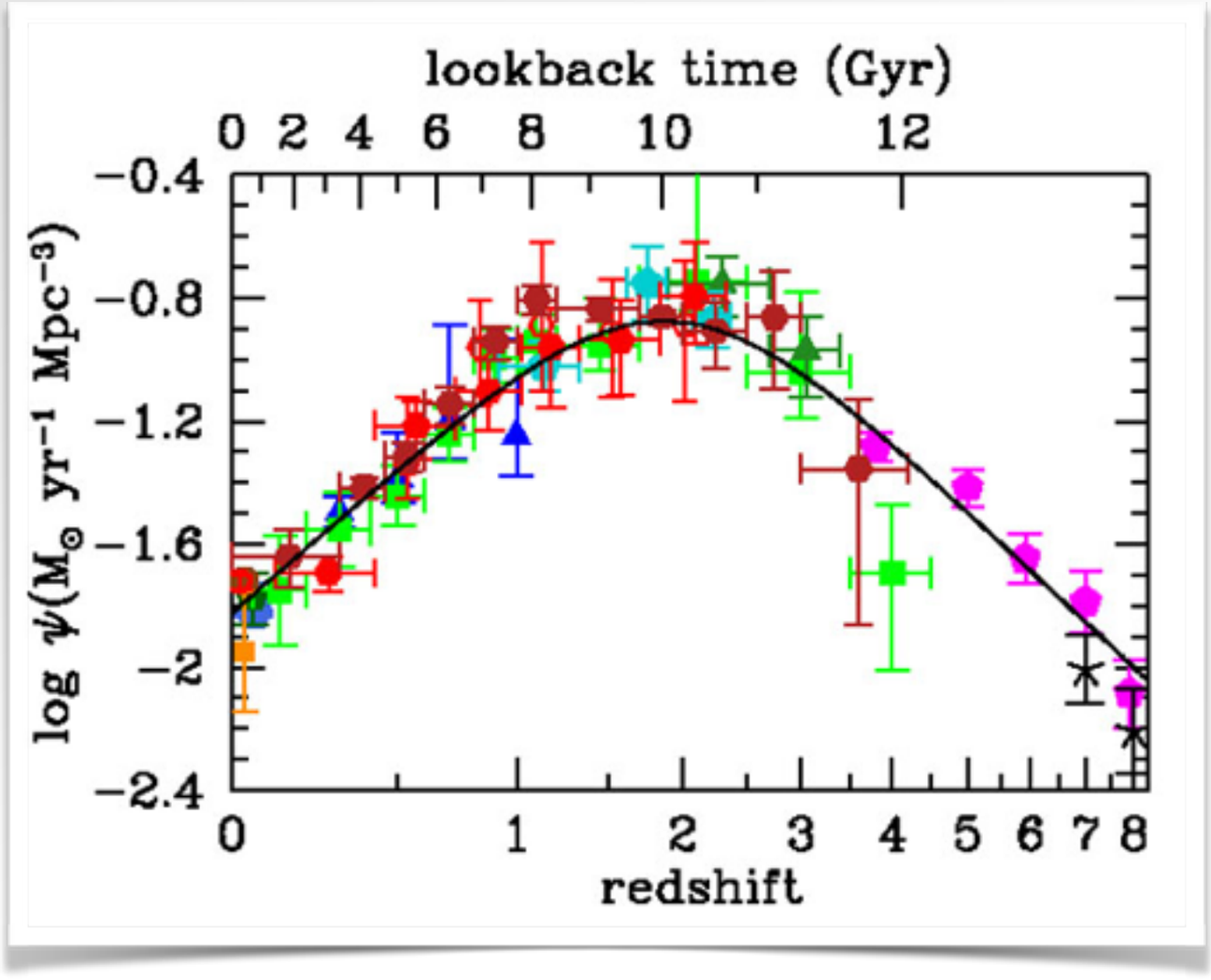
Cold molecular hydrogen DOES form stars!

(see also Bigiel+08, Schruba+11)

High redshift:

A different paradigm

High-redshift: a different paradigm



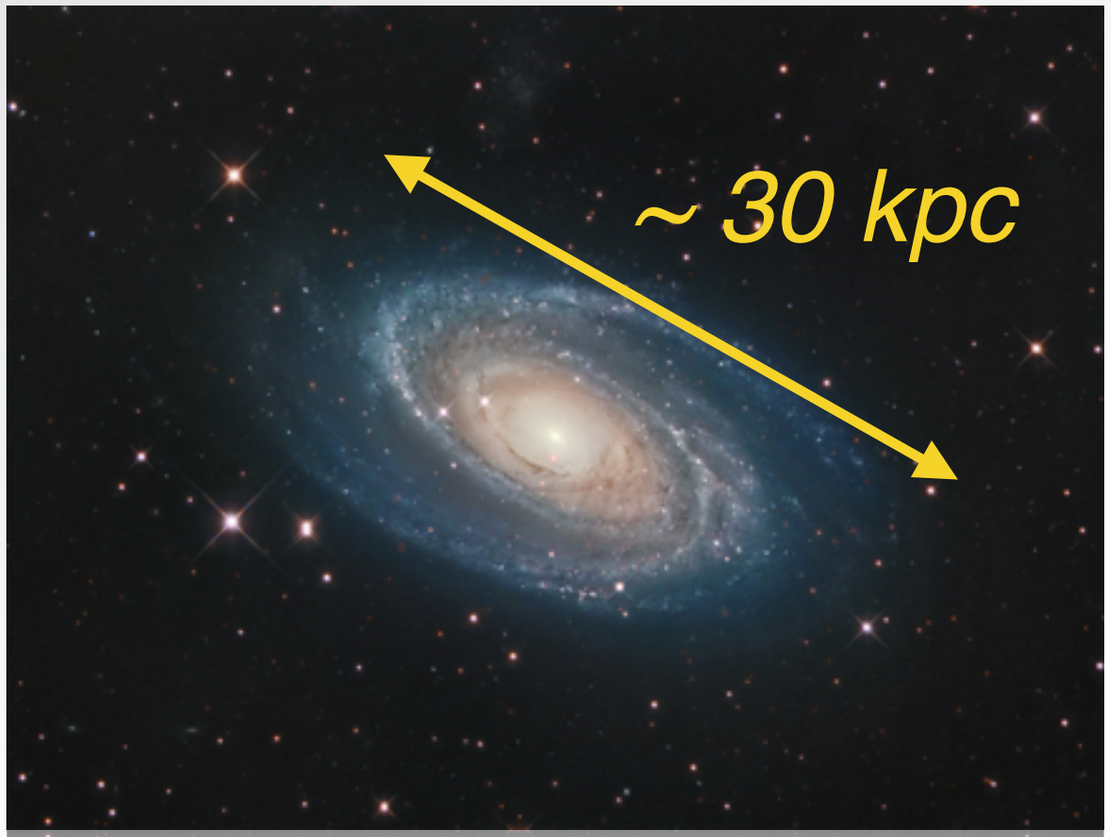
Madau & Dickinson 14

The universe was forming stars more rapidly in the past

High-redshift: a different paradigm

Galaxies were different back then…

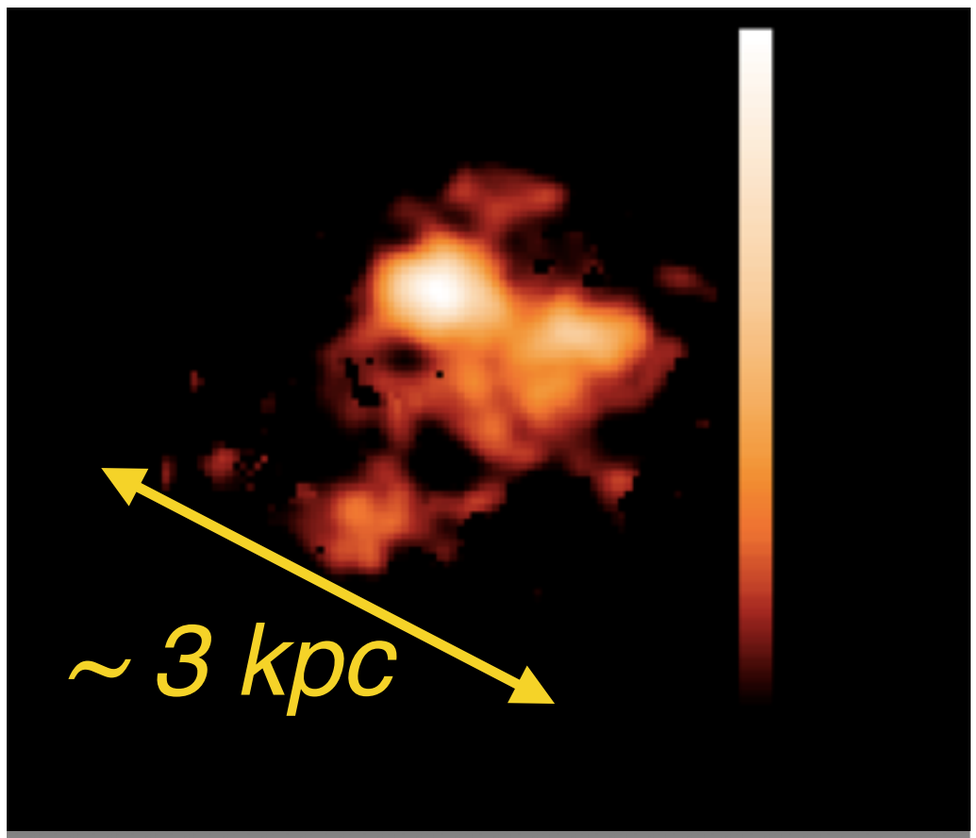
HST



Local universe

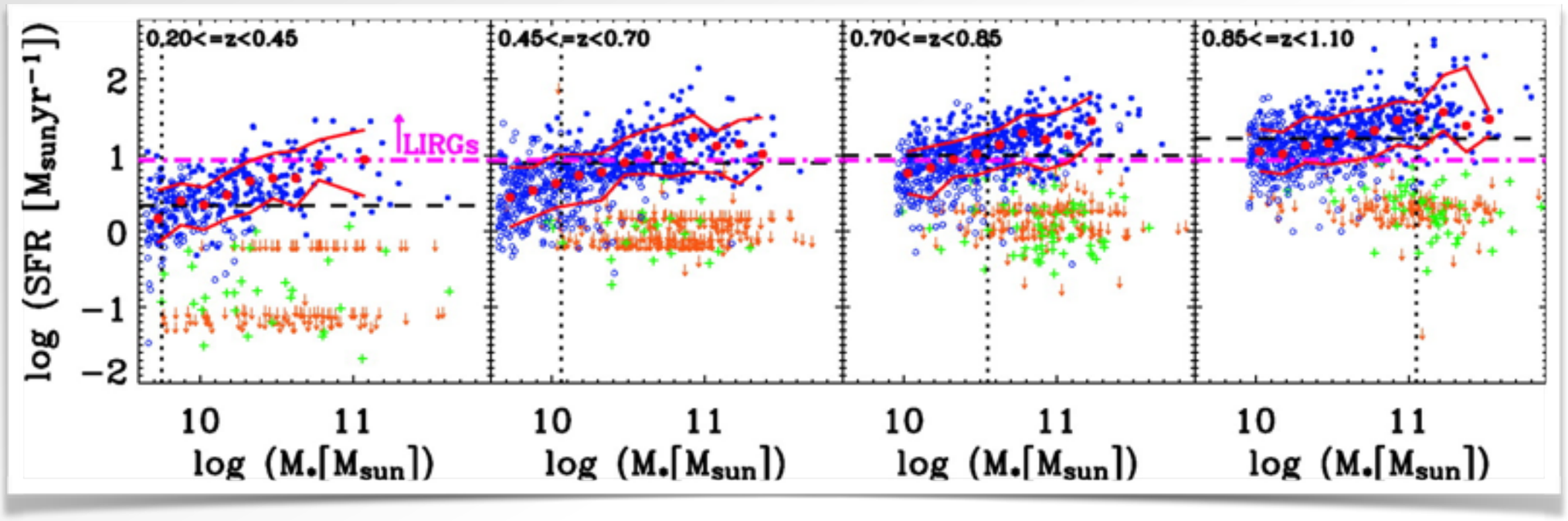
High redshift

Gonçalves+10



High-redshift: a different paradigm

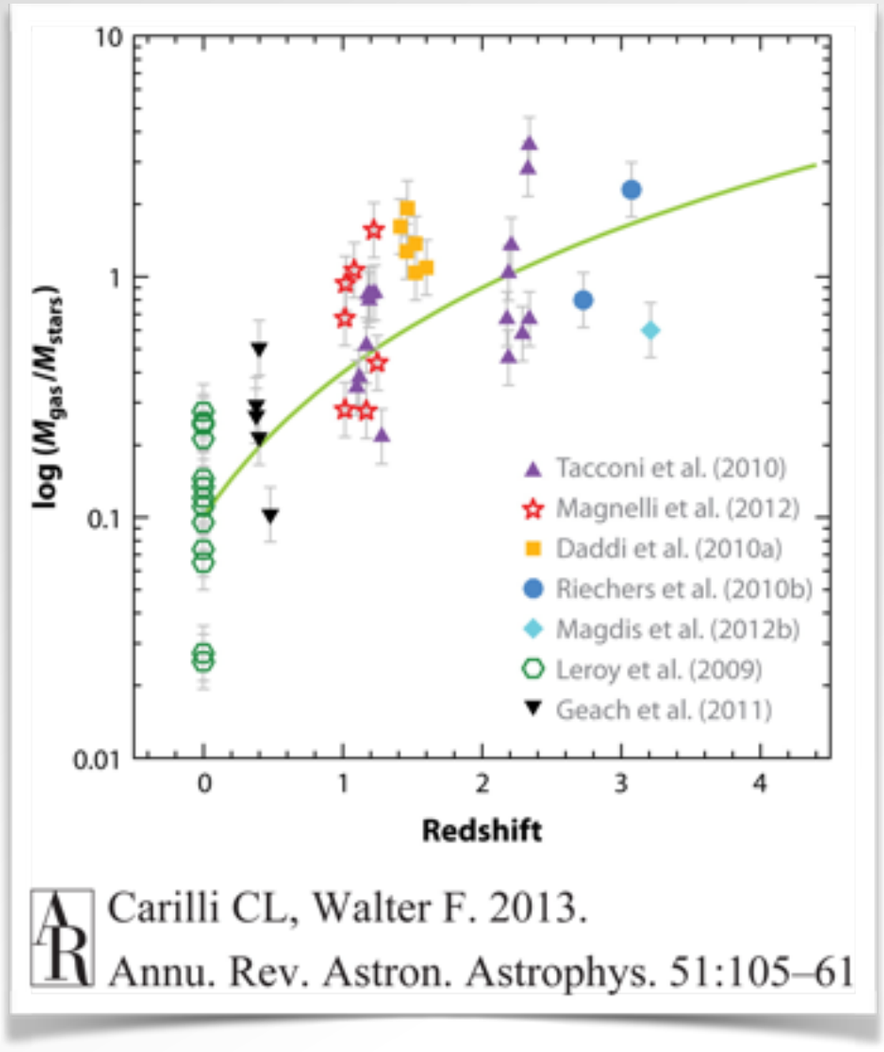
Noeske+07



The “main sequence” of galaxies: relation between stellar mass and star formation

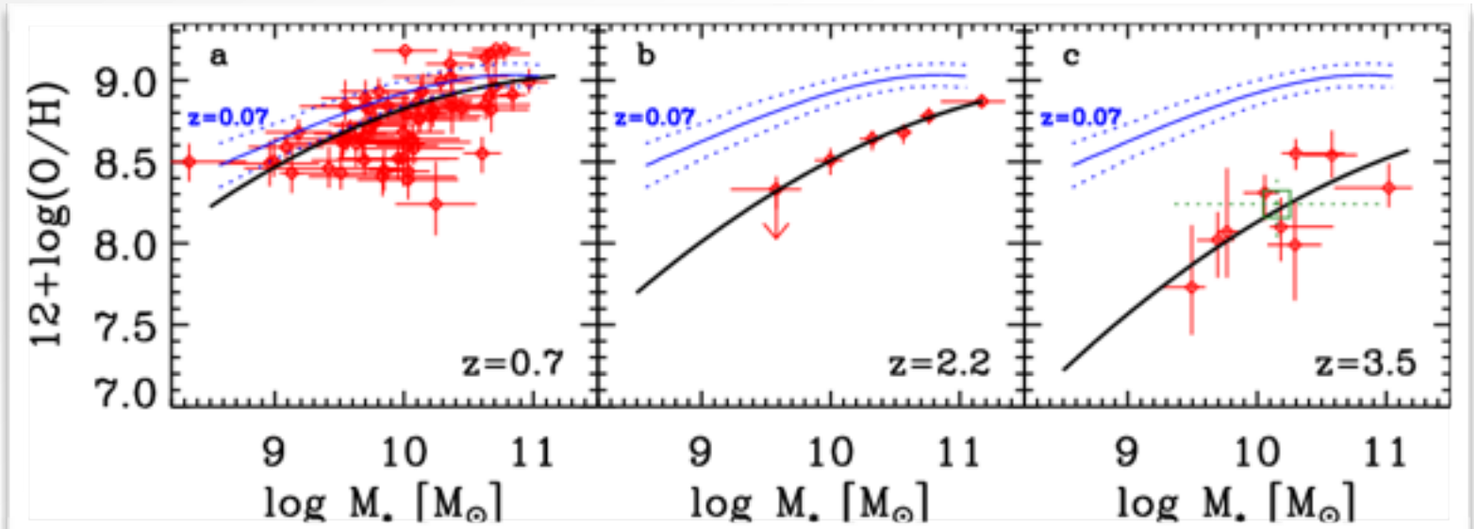
The main sequence evolves!

High-redshift: a different paradigm



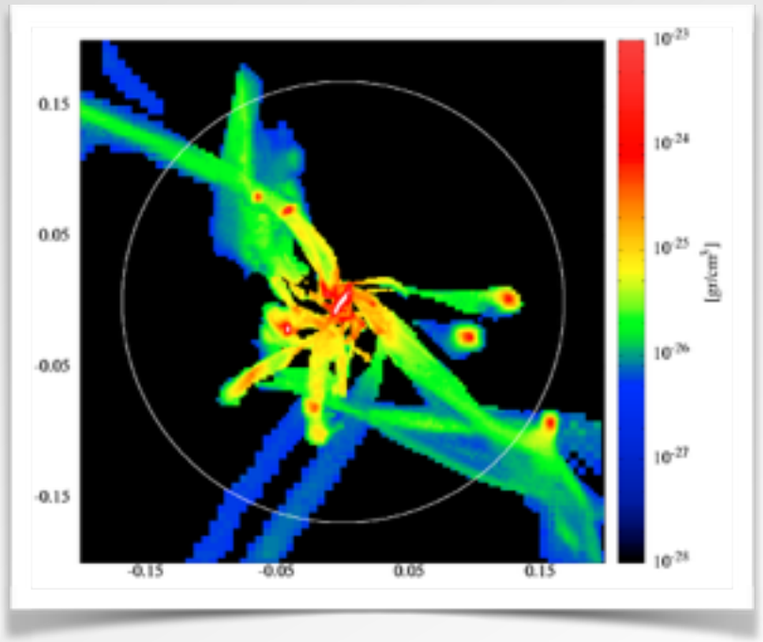
Carilli CL, Walter F. 2013.
Annu. Rev. Astron. Astrophys. 51:105–61

Maiolino+08



Galaxies had more gas and lower metallicity in the past!

High-redshift: a different paradigm



Dekel & Birnboim 06

Cold flows?

Mergers and interactions?

HST

High-redshift: a different paradigm

BUT: studies at high-z are hard!!

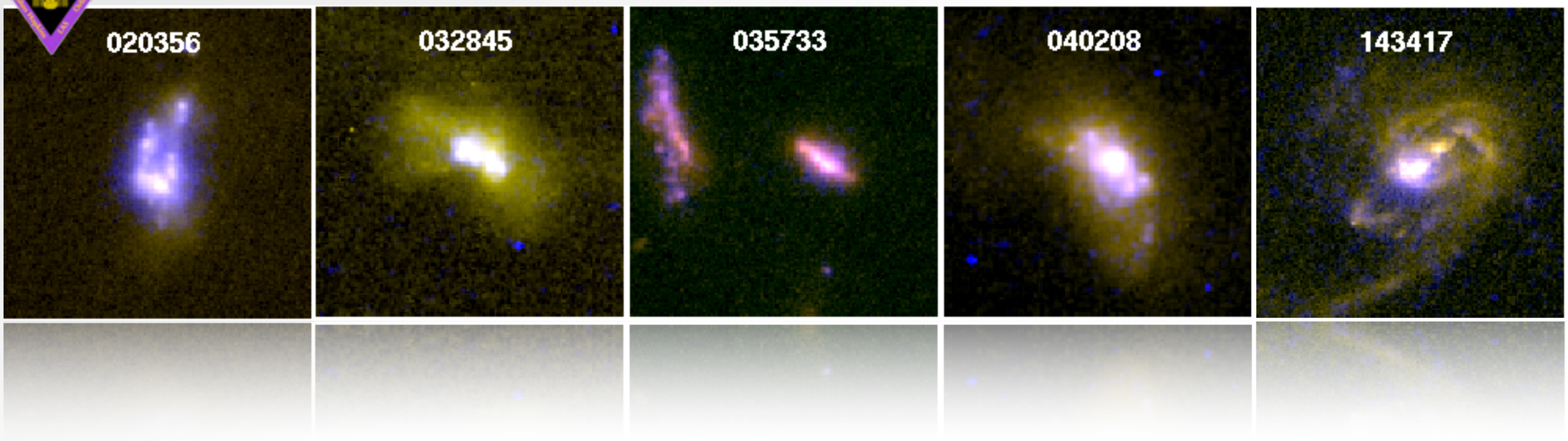
- Luminosity distances are large
- Cosmic surface brightness dimming

Wouldn't it be great to have local galaxies that resembled the ones at high-z?

Analogs at low redshift

Analogs at low redshift

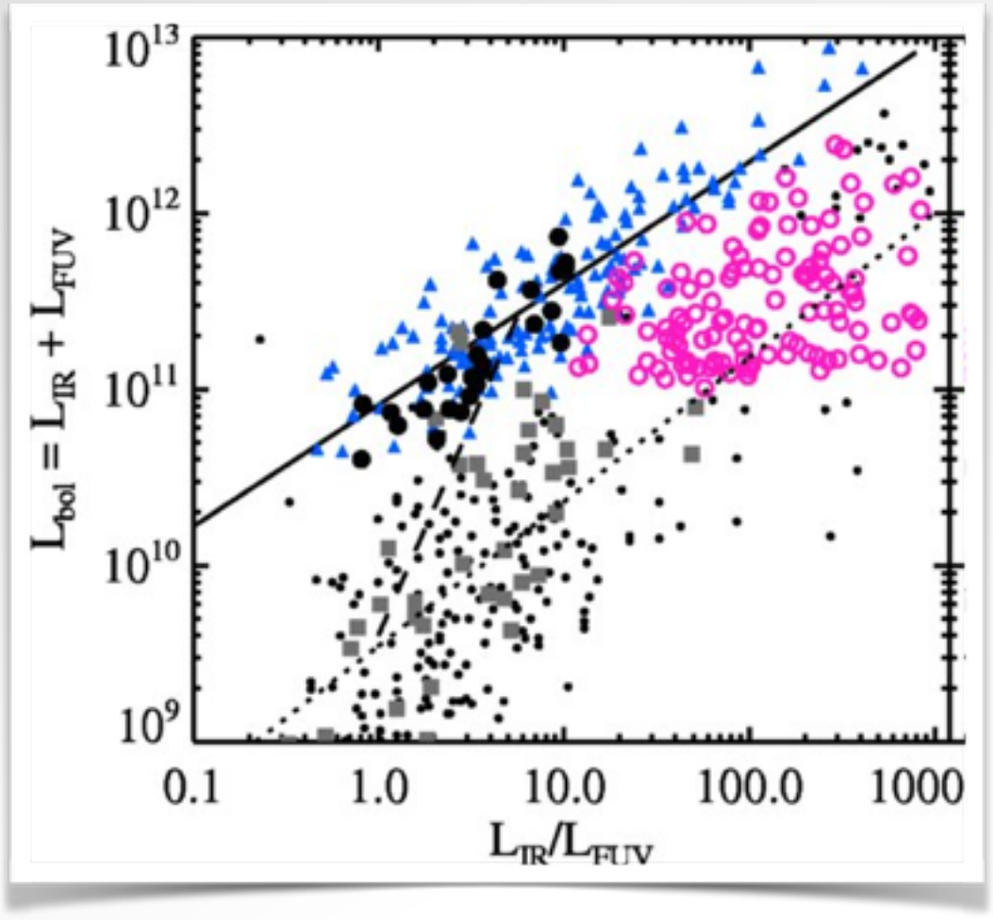
Hoopes+07
Overzier+09



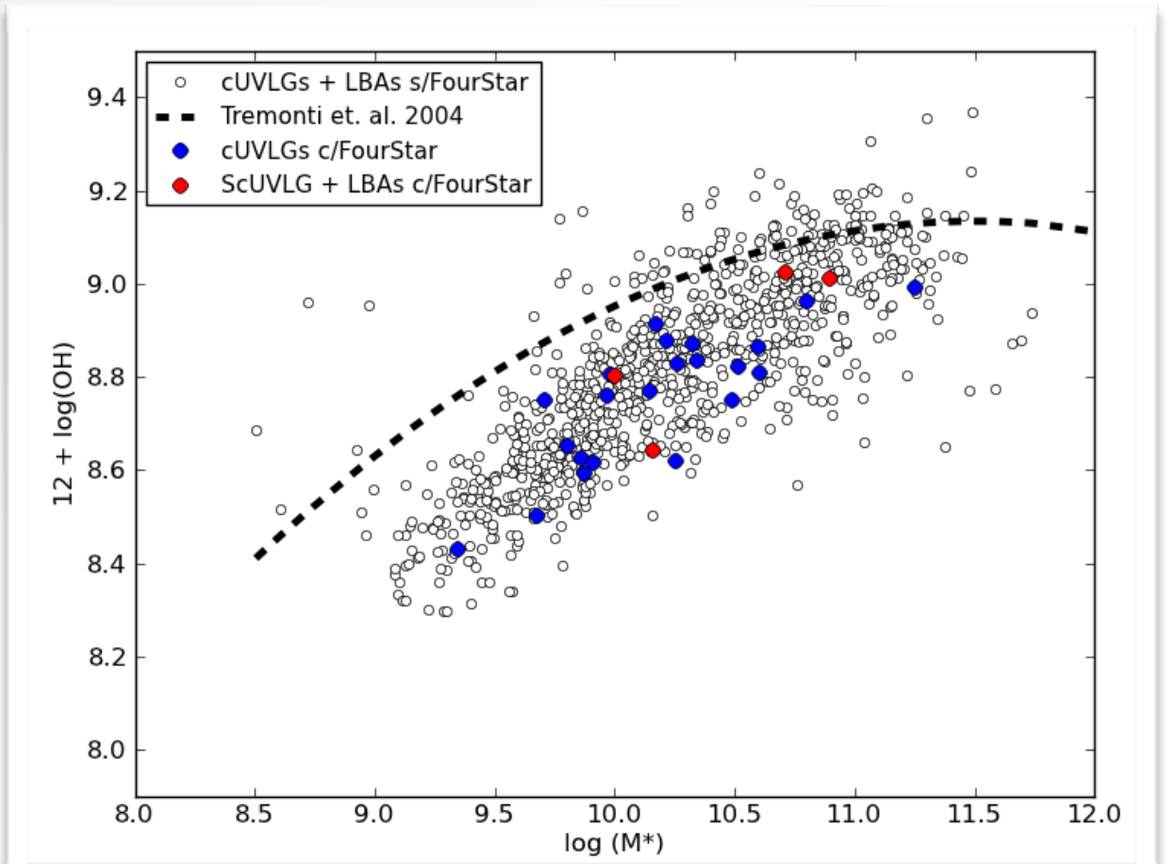
- z ~ 0.2
- Selected by ultraviolet luminosity and surface brightness

Analogs at low redshift

Overzier+11



Santos-de-Oliveira+ in prep



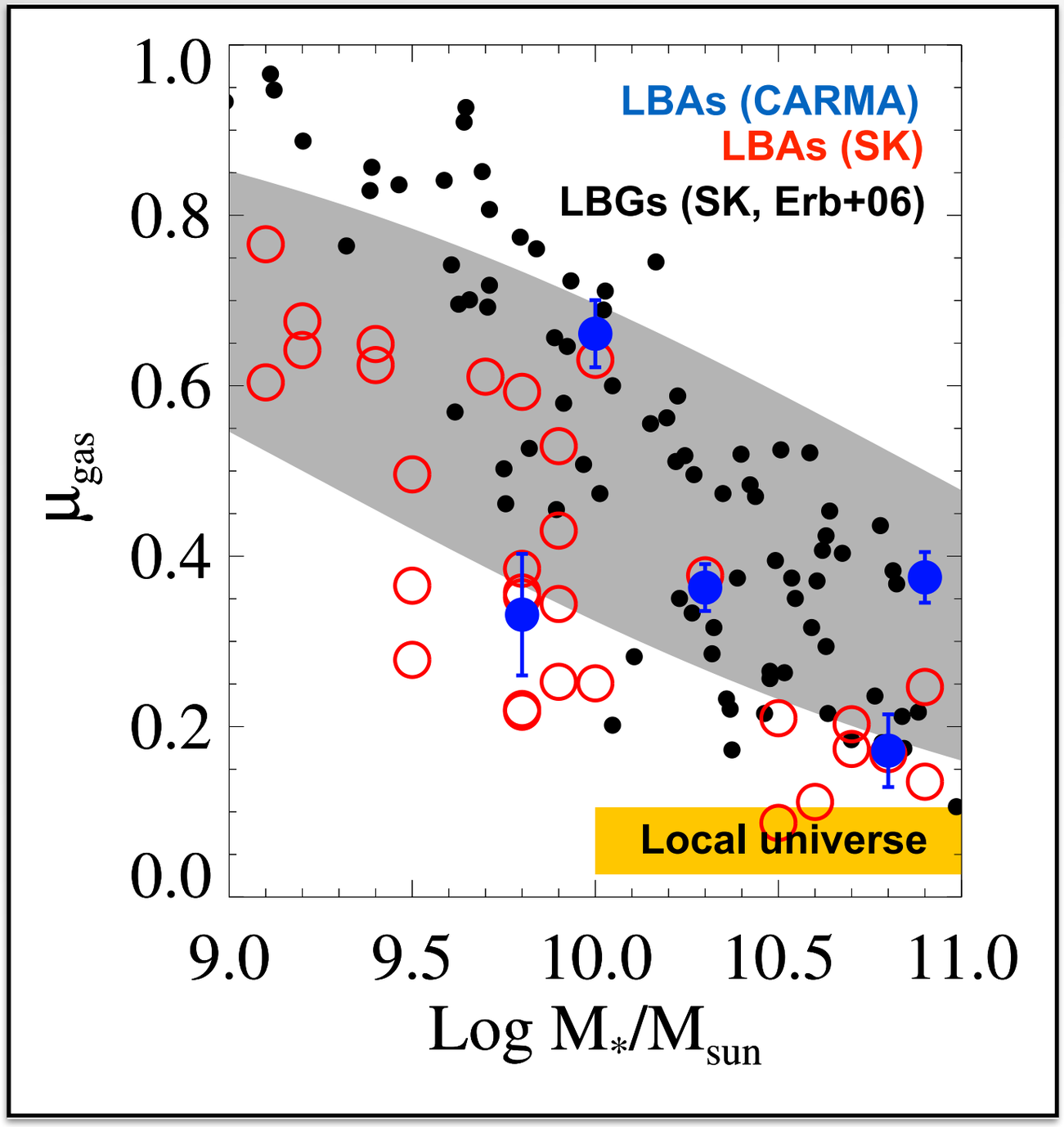
Low extinction

Low metallicities

Lyman break analogs (LBAs)

Analogs at low redshift

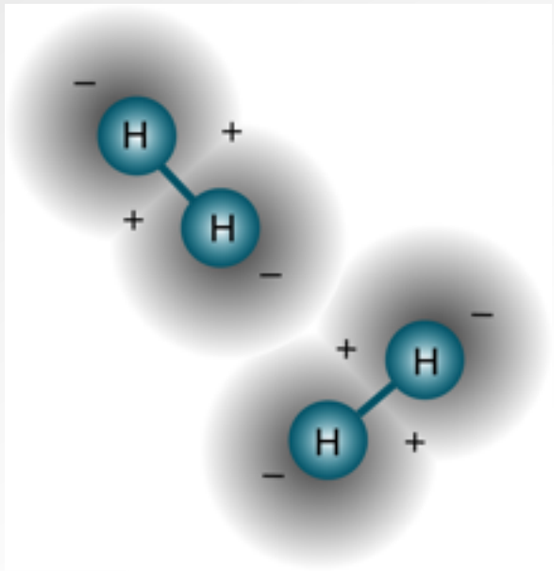
Gonçalves+14



Lots of gas, similar to high-z galaxies

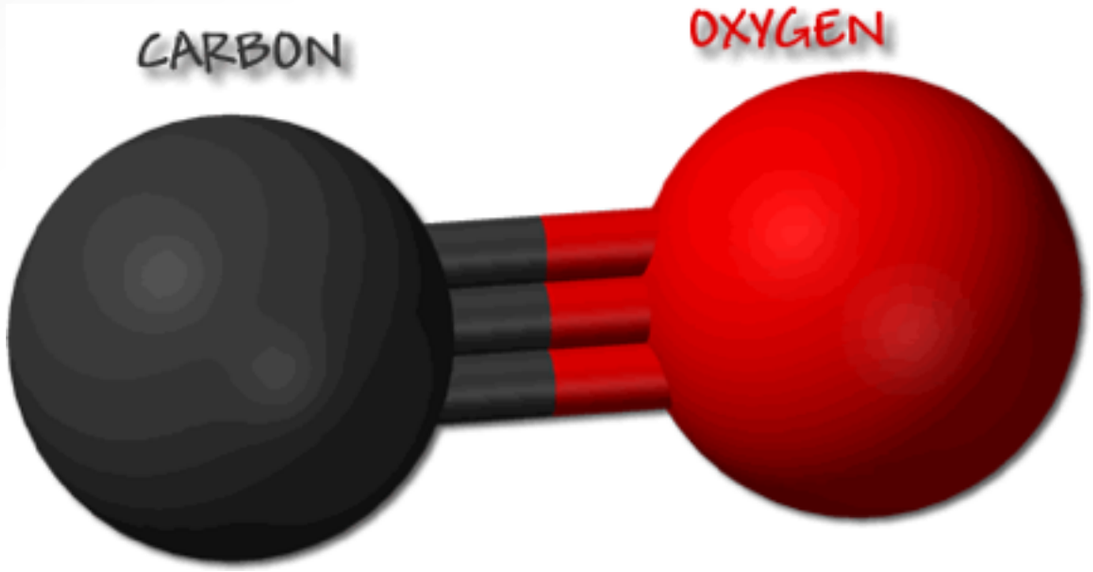
Analogs at low redshift

Observing molecular gas



H2, invisible

X



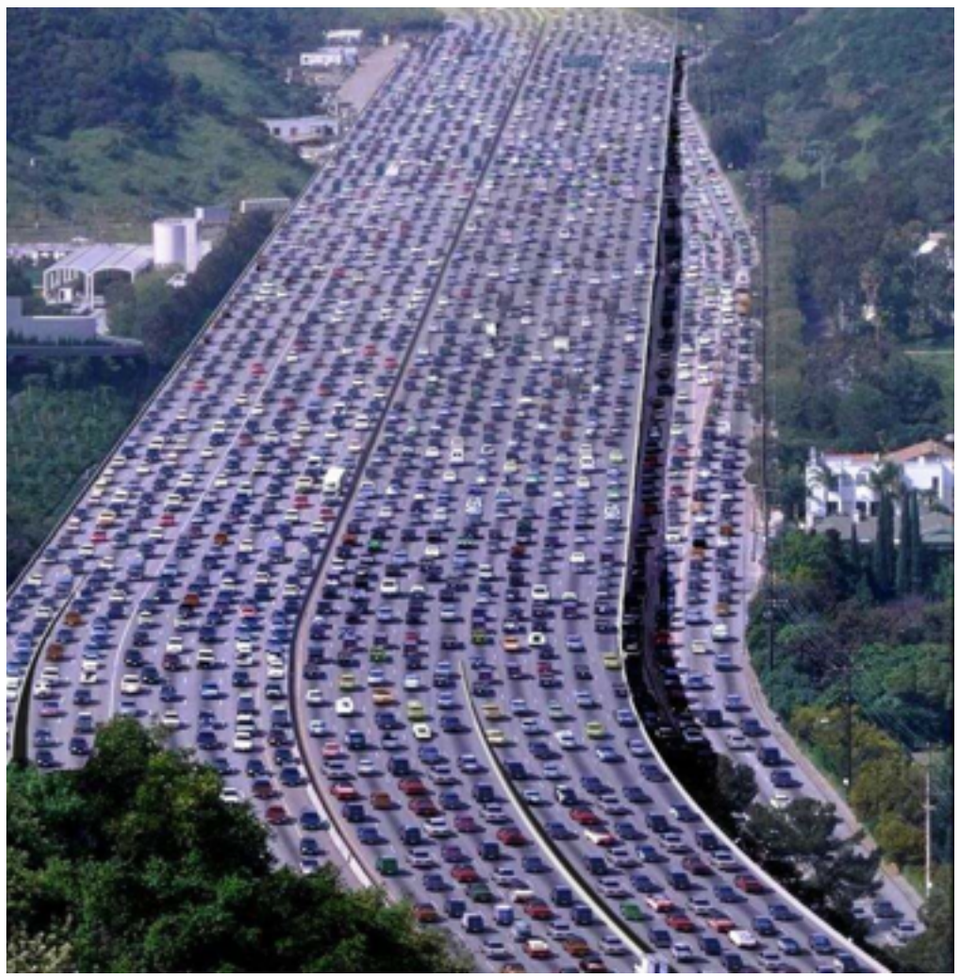
CO, visible

Analogs at low redshift

$$M_{mol} = \alpha_{\rm CO} L_{\rm CO}$$

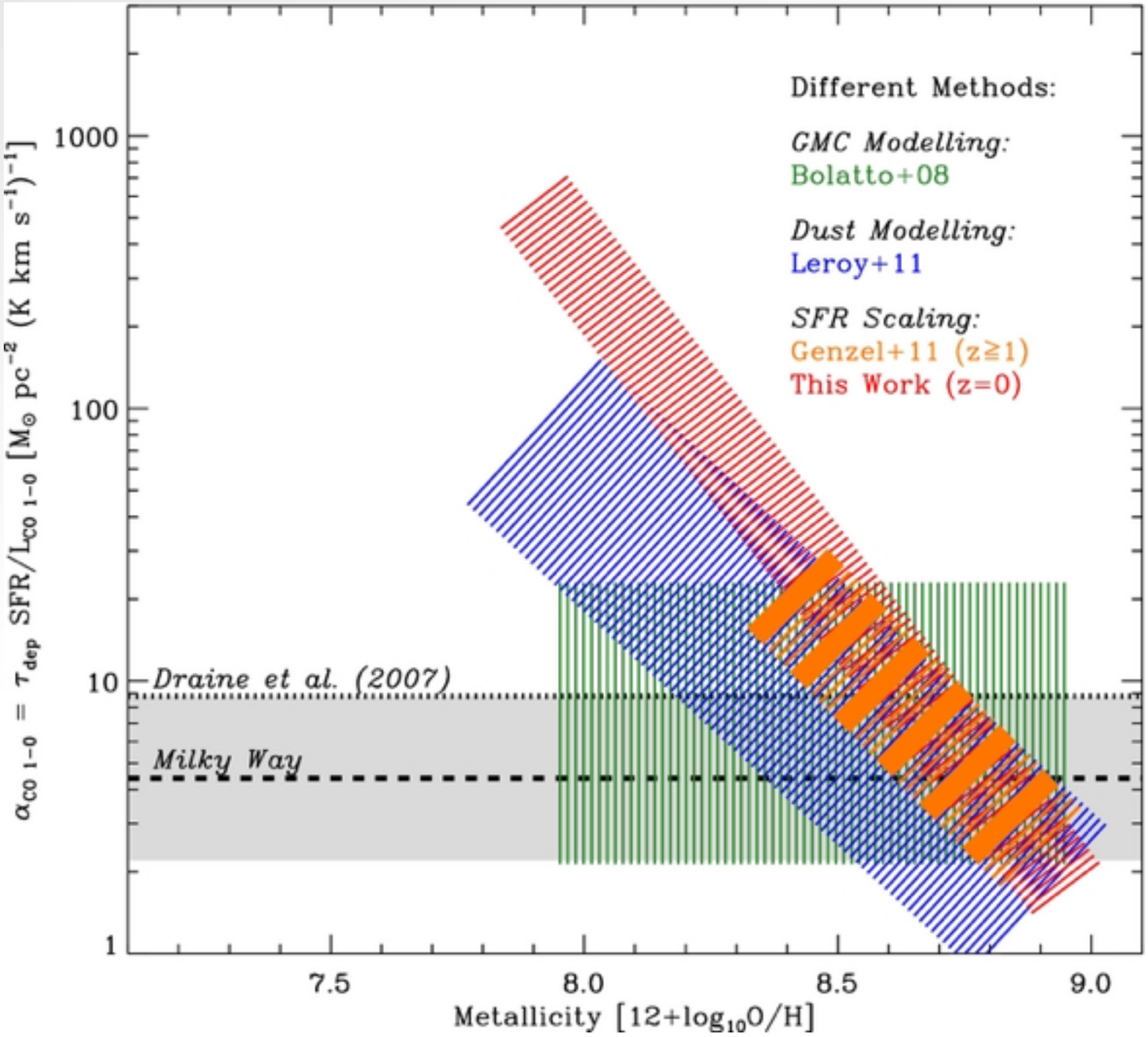
CO abundance: 1:10^4

X



Analogs at low redshift

The conversion factor?



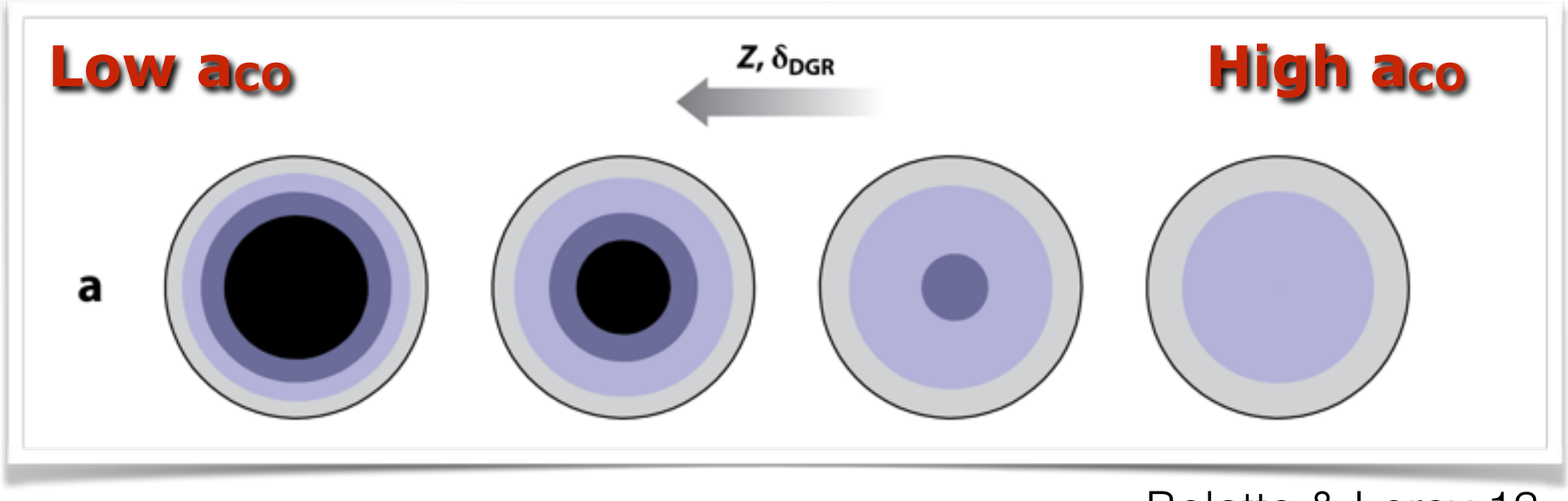
Schruba+12

Analogs at low redshift

The conversion factor in turbulent, hot galaxies: excited molecules, high CO luminosities

Downes & Solomon 98, Narayanan+11

Metal poor galaxies: destruction of CO molecules

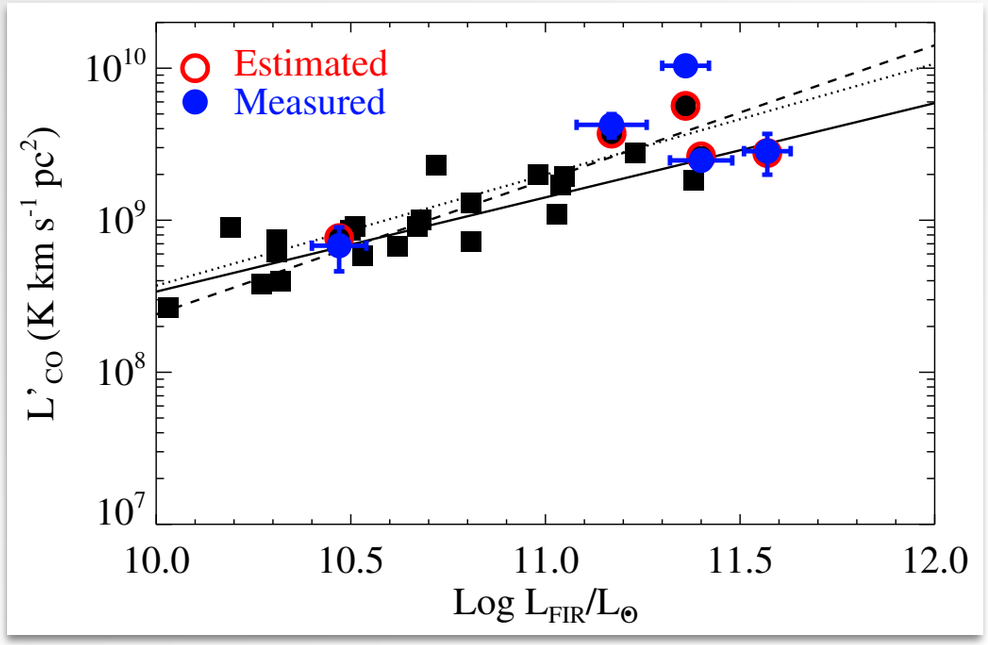


Bolatto & Leroy 13

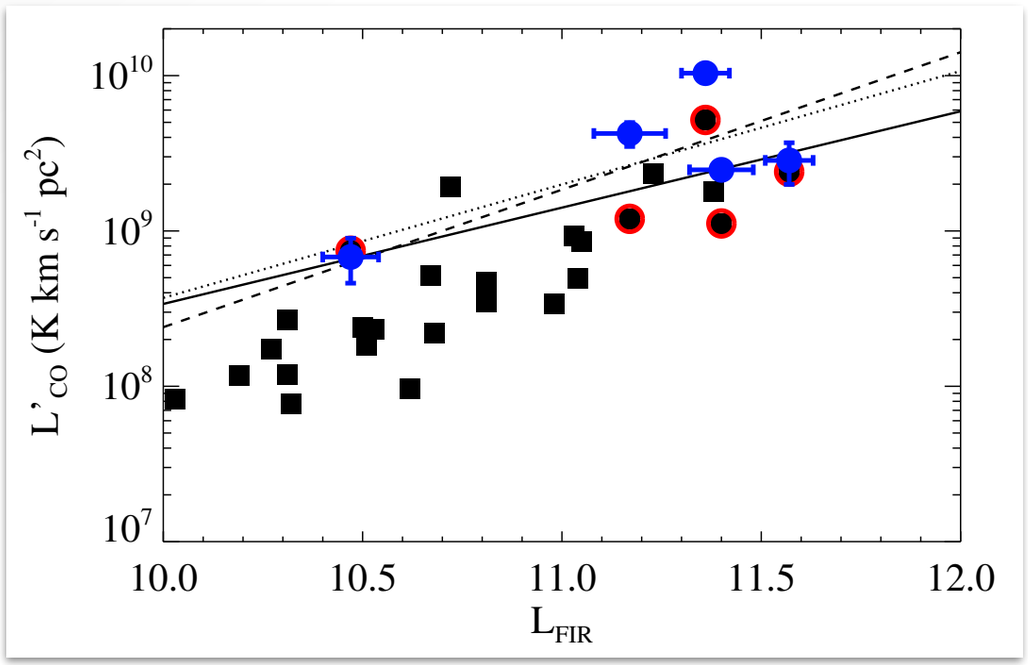
Analogs at low redshift

What if a galaxy is turbulent AND metal-poor?

Gonçalves+14



Constant conversion factor

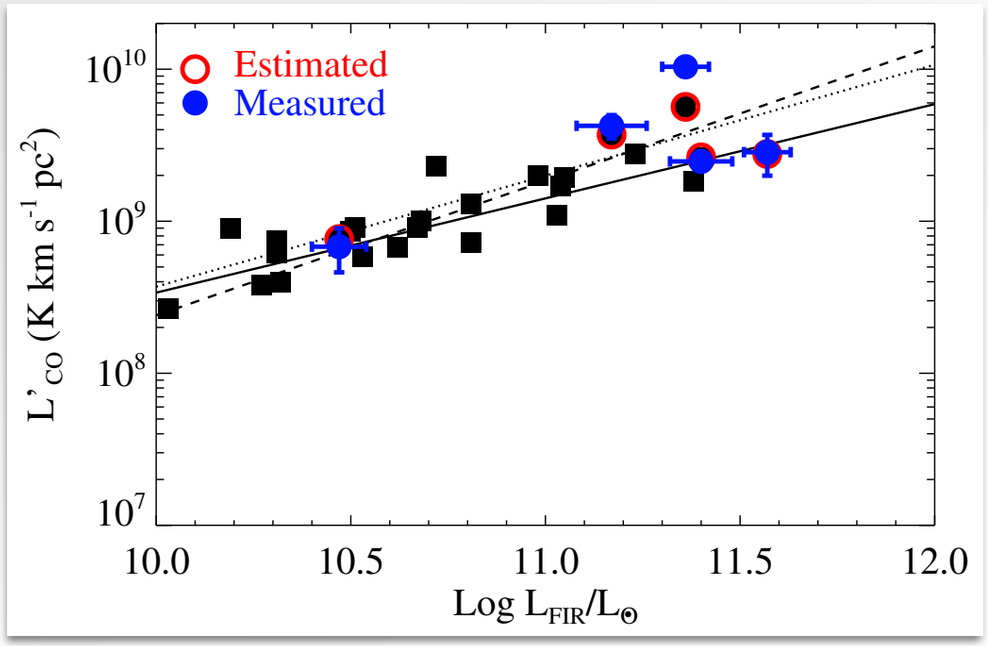


Metallicity-dependent conversion factor

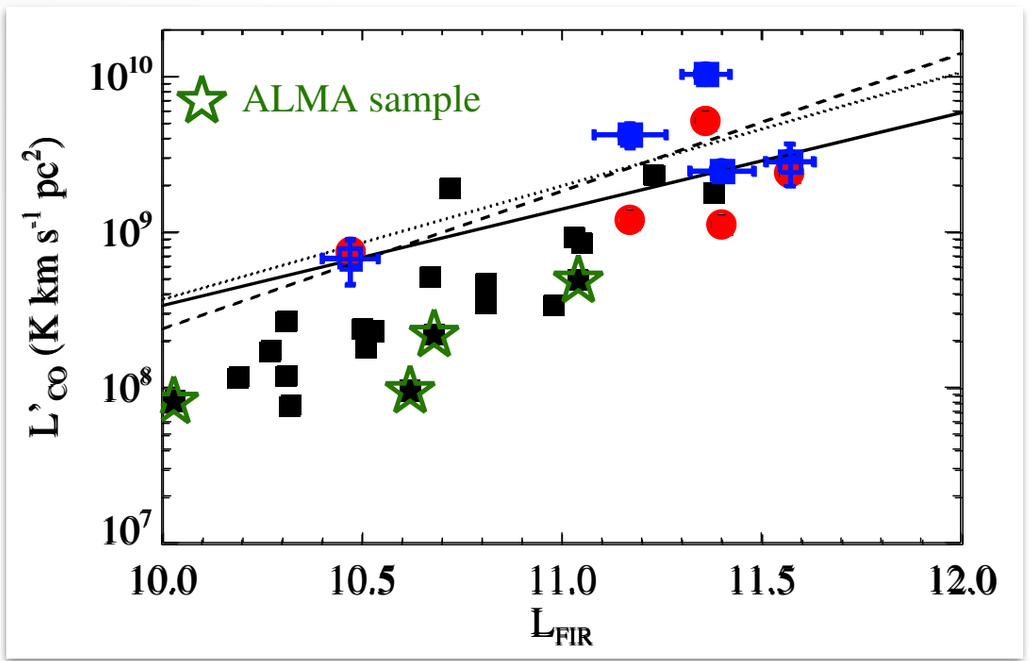
Analogs at low redshift

Analogs at low redshift

What if a galaxy is
turbulent AND metal-poor?



Constant
conversion factor



Metallicity-dependent
conversion factor

Conclusions

Conclusions

- Stars form in galaxies from cold, molecular gas
- ISM at high redshift is complicated: dense and turbulent, low extinction and metal-poor
- Lyman break analogs can help clarify some questions regarding star formation in extreme conditions
- Can we reliably measure gas reservoirs at high redshift? How is gas converted into stars under these conditions?