The nature of the ISM during the star-formation activity peak of the Universe

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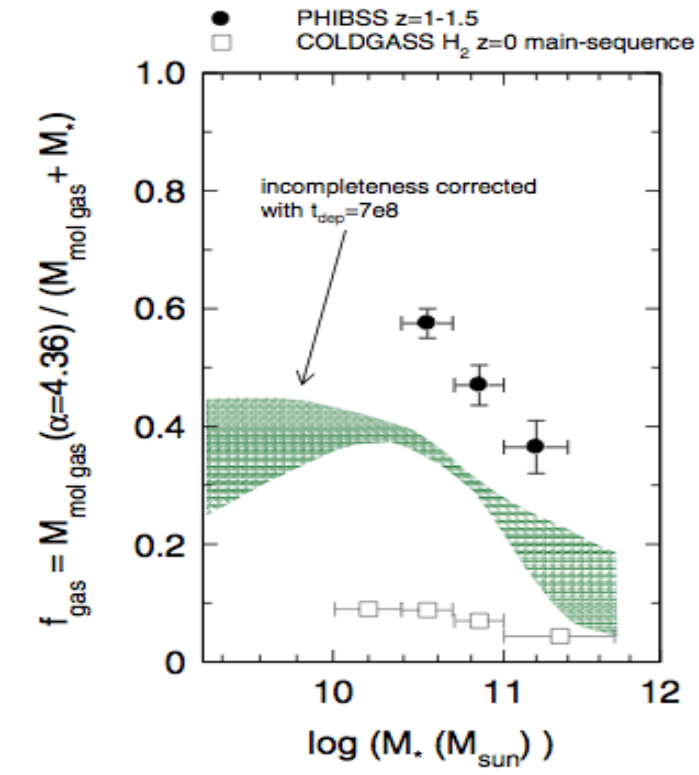
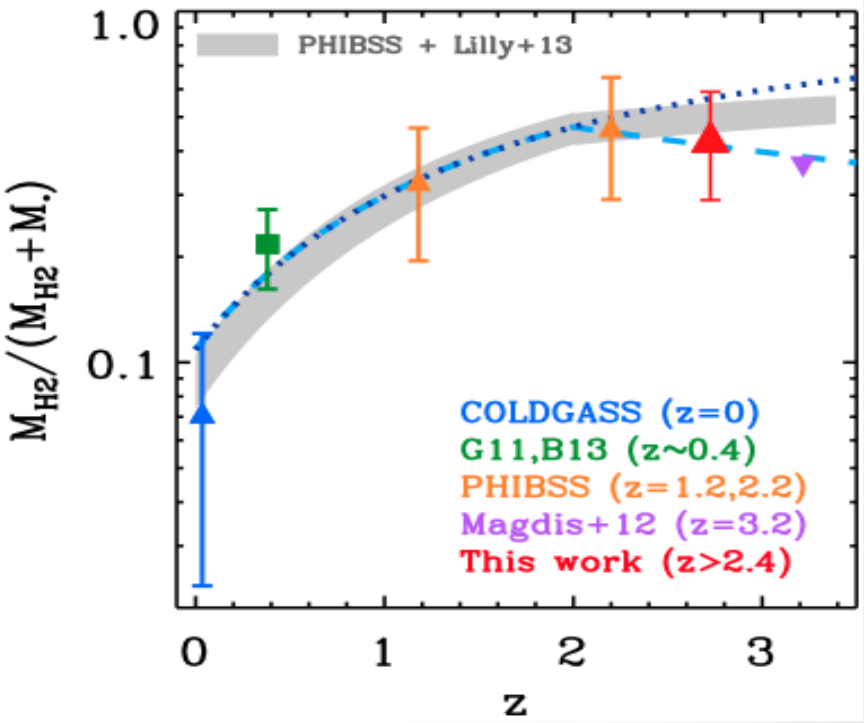
Gas properties of galaxies

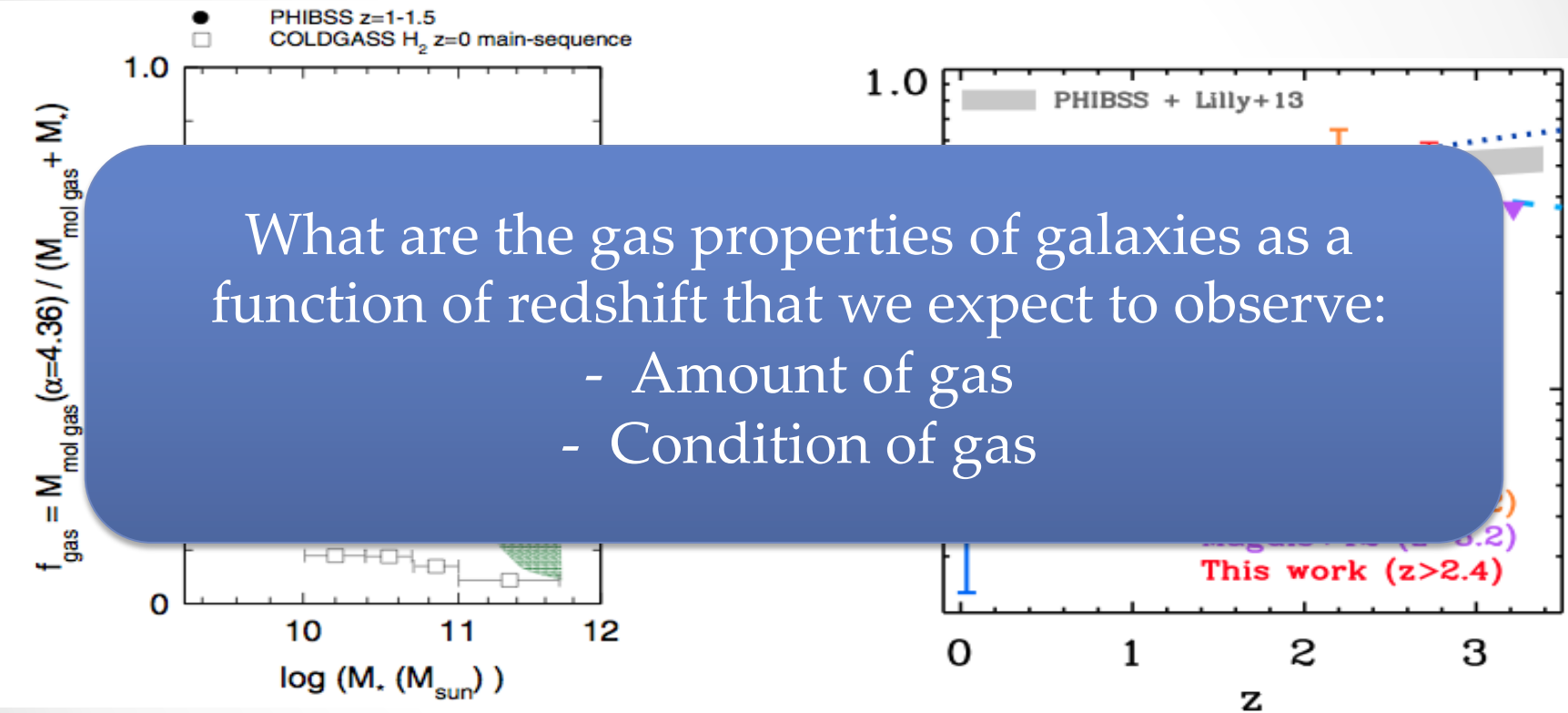




Gas fractions in galaxies decrease with time

Tacconi+2010, Popping+2012, Saintonge+2013, Tacconi+2013

Gas properties of galaxies



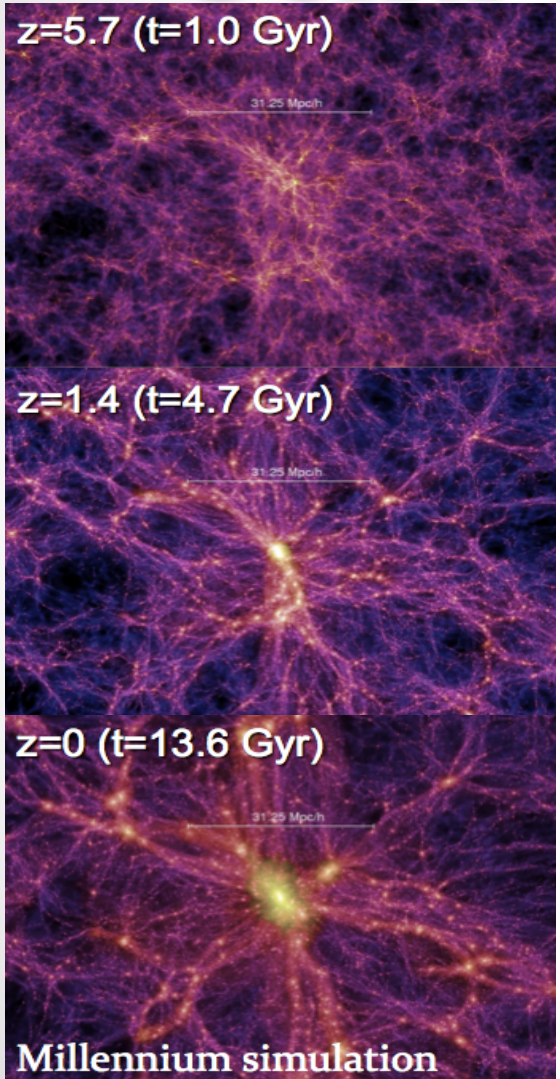
What are the gas properties of galaxies as a function of redshift that we expect to observe:

- Amount of gas
- Condition of gas

Gas fractions in galaxies decrease with time

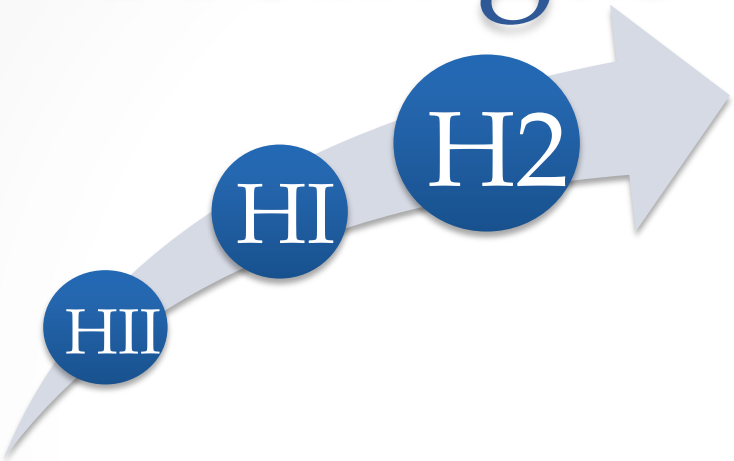
Tacconi+2010, Popping+2012, Saintonge+2013, Tacconi+2013

Semi-Analytic Model



- Gravitationally bound structures (halos) form as predicted by ΛCDM
- Gravity causes gas to accrete into halos and galaxies
- Accretion may be suppressed by presence of photoionizing background
- Sizes are determined based on angular momentum conservation
- Cold gas is heated and removed from galaxy by SN
- Metals produced by stars enrich cold gas

From gas to stars

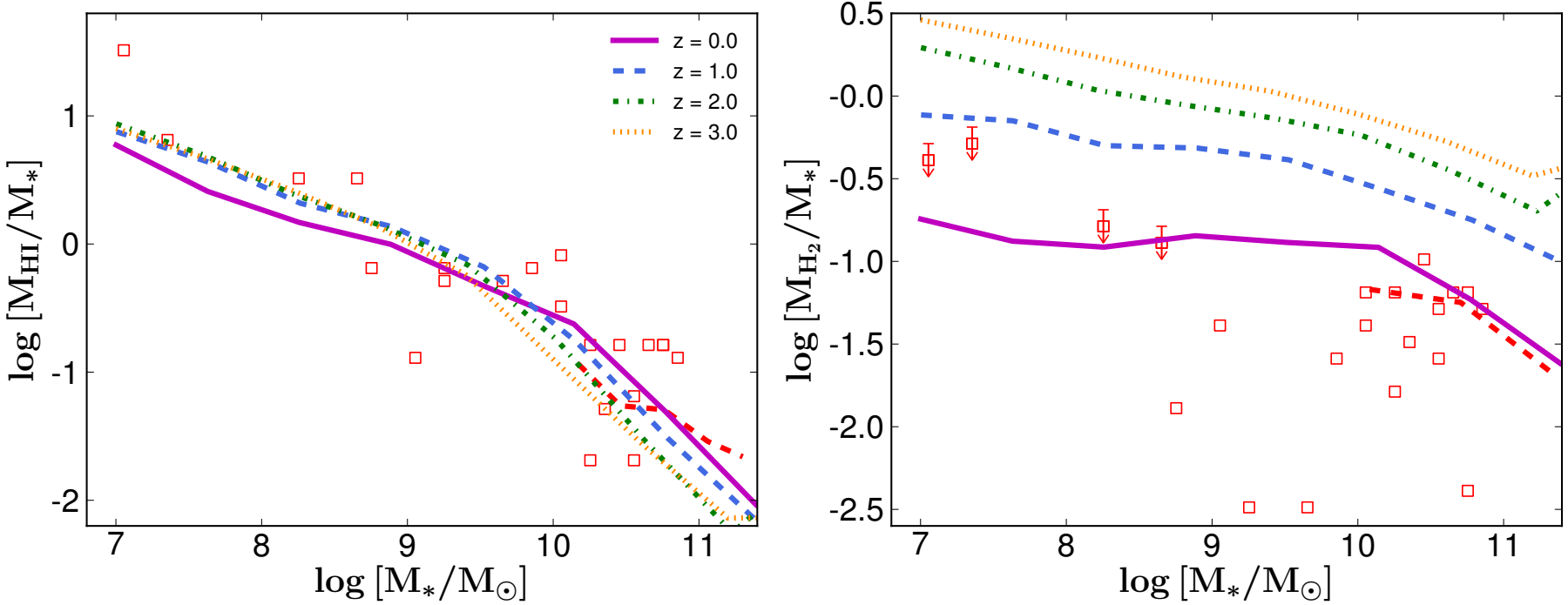


- Internal heating and external heating of low-column density gas -> Ionized gas (Gnedin 2012)
- Cold gas partitioned into atomic and molecular hydrogen (depends on metallicity, gas density, UV radiation field, Gnedin & Kravtsov 2011)
- Stars are formed out of molecular gas (Bigiel+ 2008)

Popping+ 2014a

Bigiel+ 2008,2012, Gnedin & Kravtsov 2011, Gnedin 2012

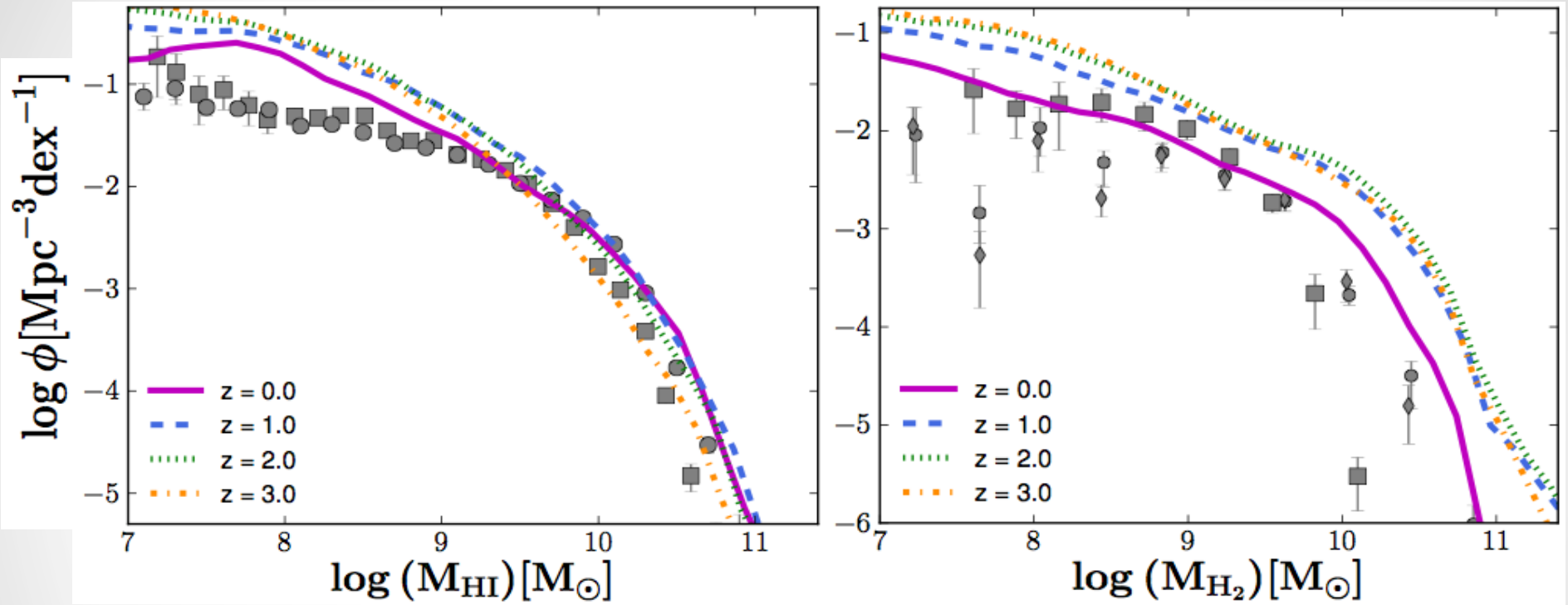
Gas fractions



- Relative H2 content of galaxies decreases with time
- HI content remains roughly constant

Obreschkow2009, Lagos2011, Fu2012, Popping 2014a

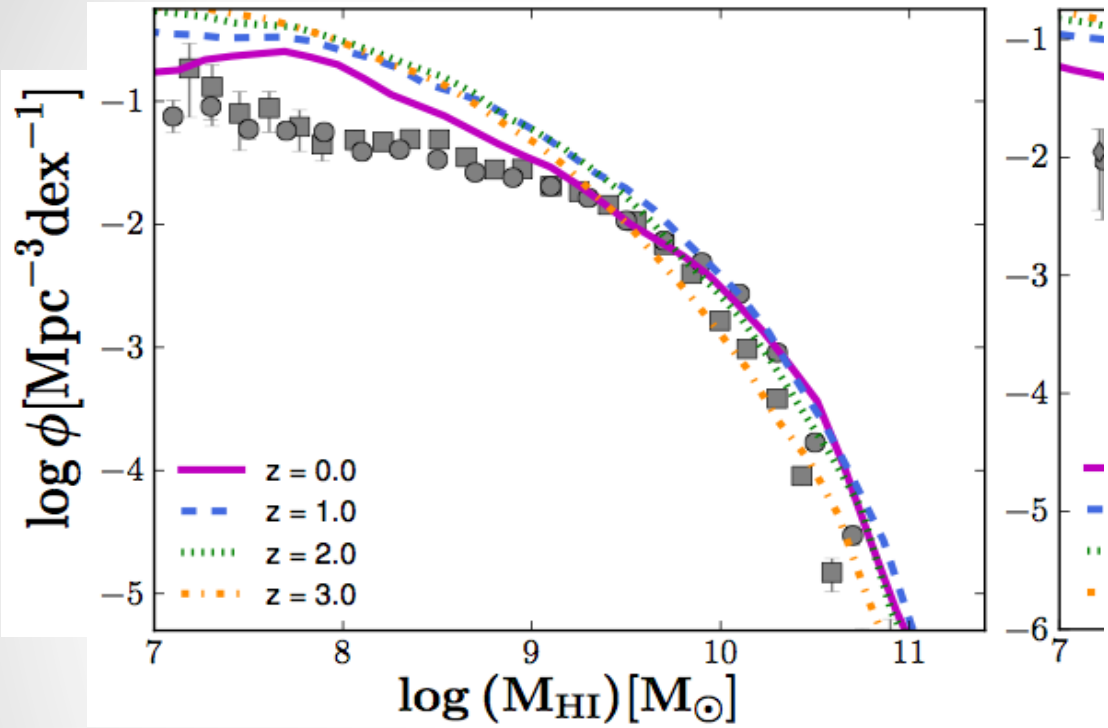
Mass functions

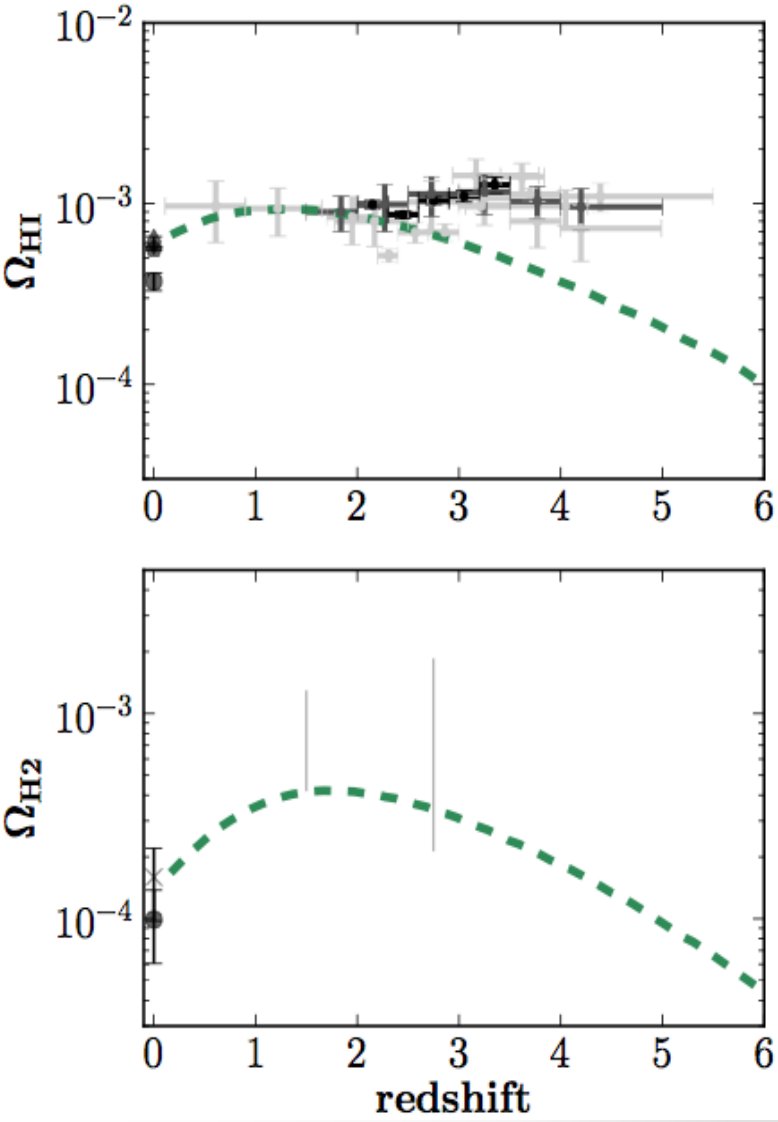


- Strong evolution in H2 at z < 1
- Weak evolution in HI -> self regulated equilibrium

Obreschkow2009, Lagos2011, Fu2012, Popping 2014a

Mass funct





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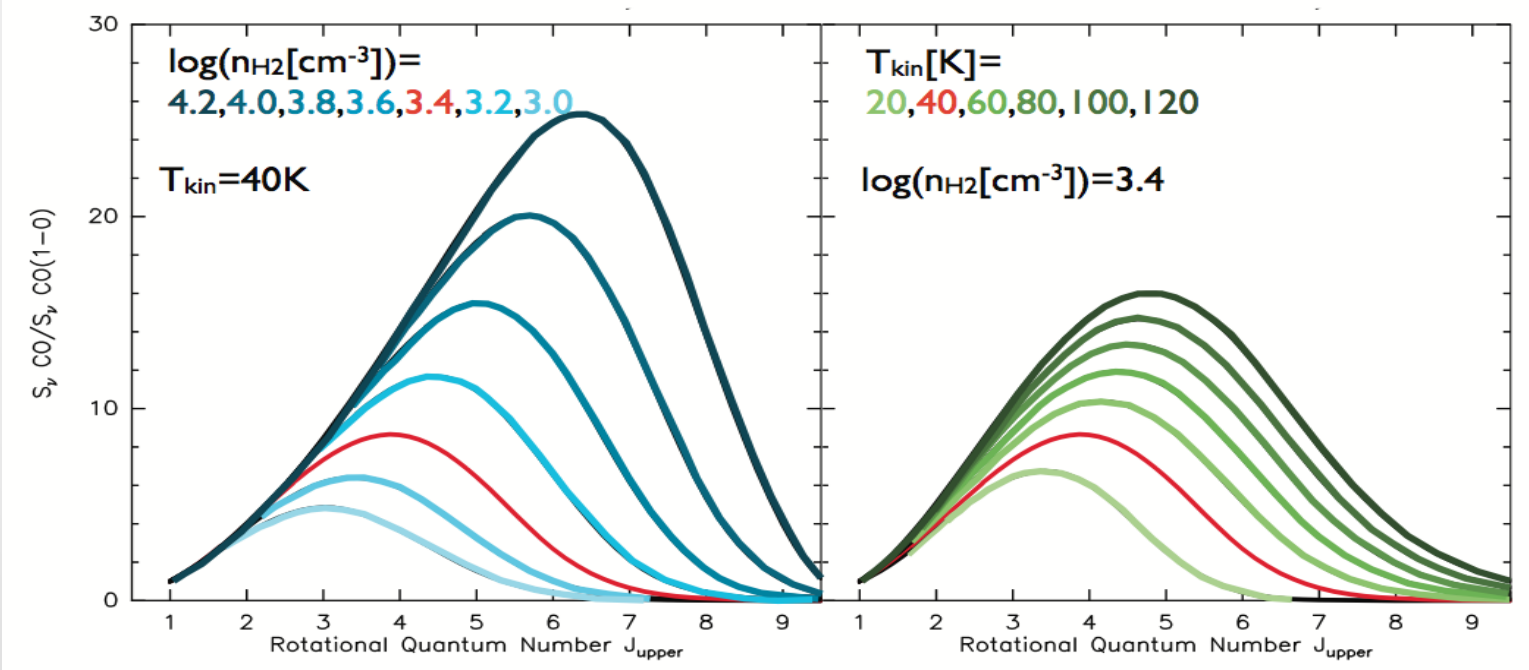
Sub-mm emission

- CO as a tracer of H2
- CO line ratios hold information on gas density/temperature/radiation field



Carilli & Walter 2013

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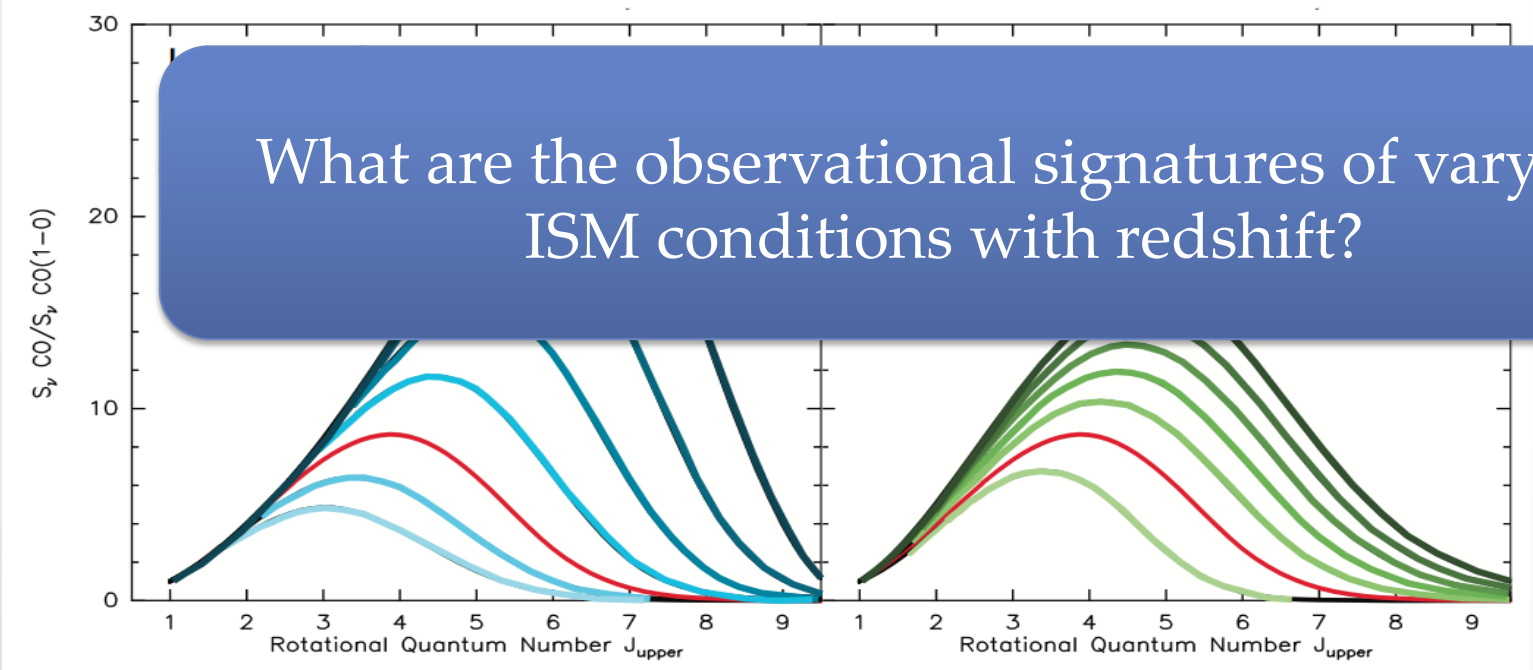
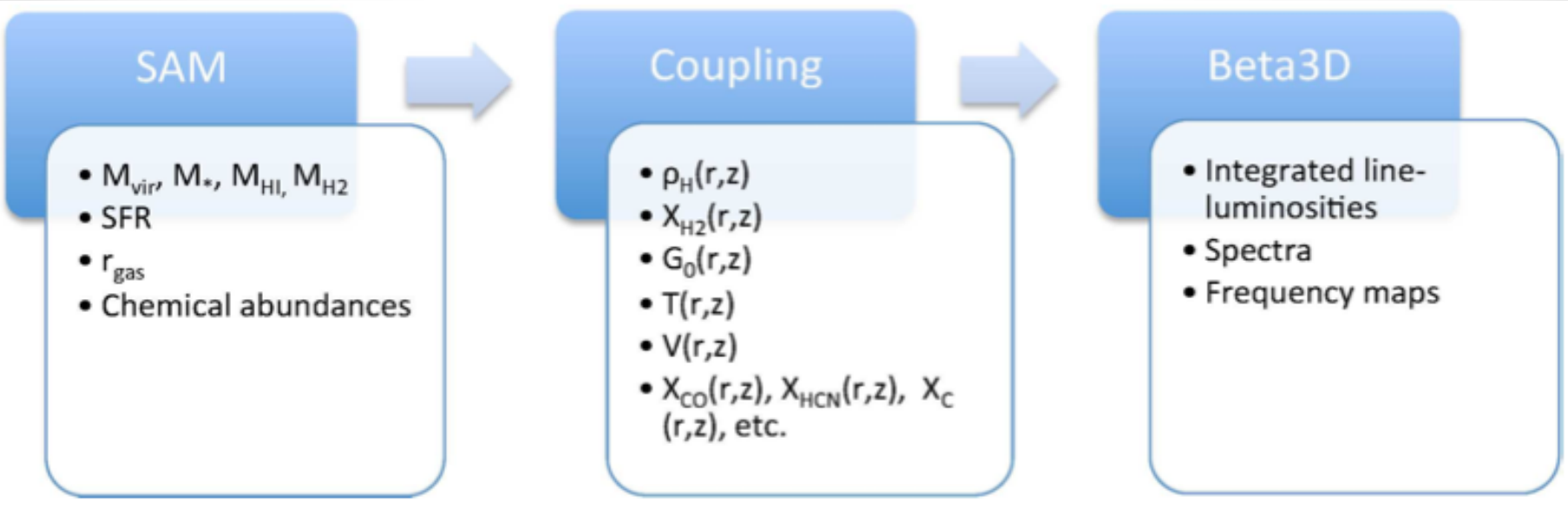


What are the observational signatures of varying ISM conditions with redshift?

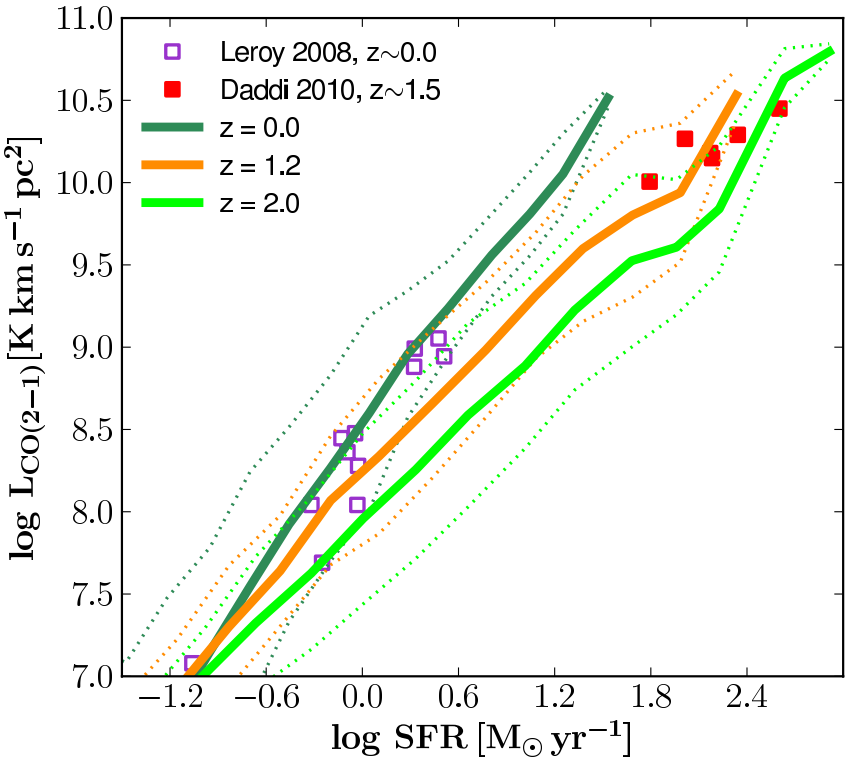
& 2013

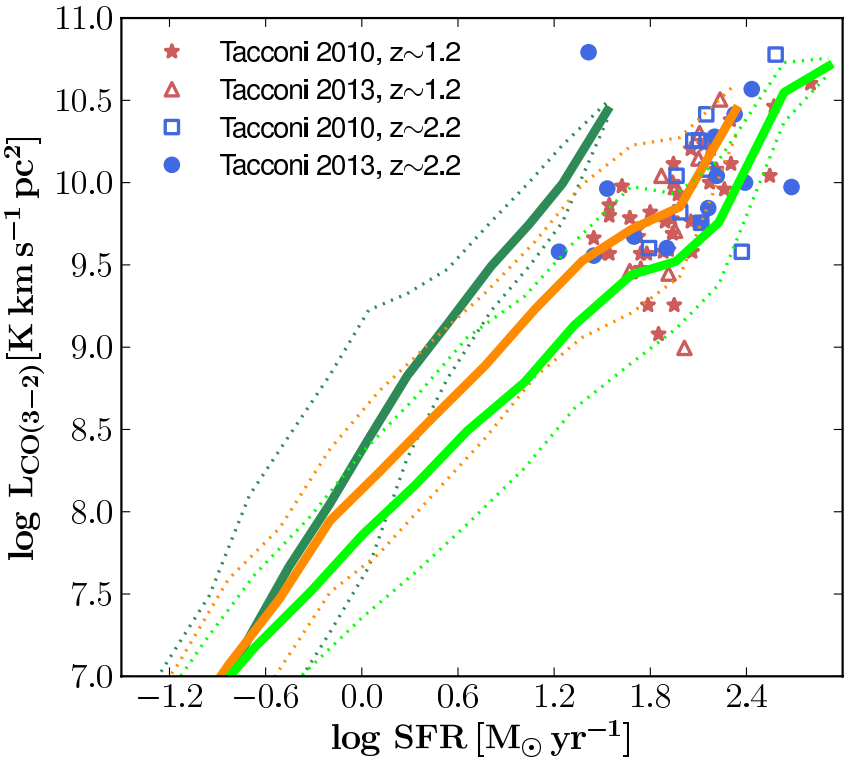
How to model sub-mm emission?



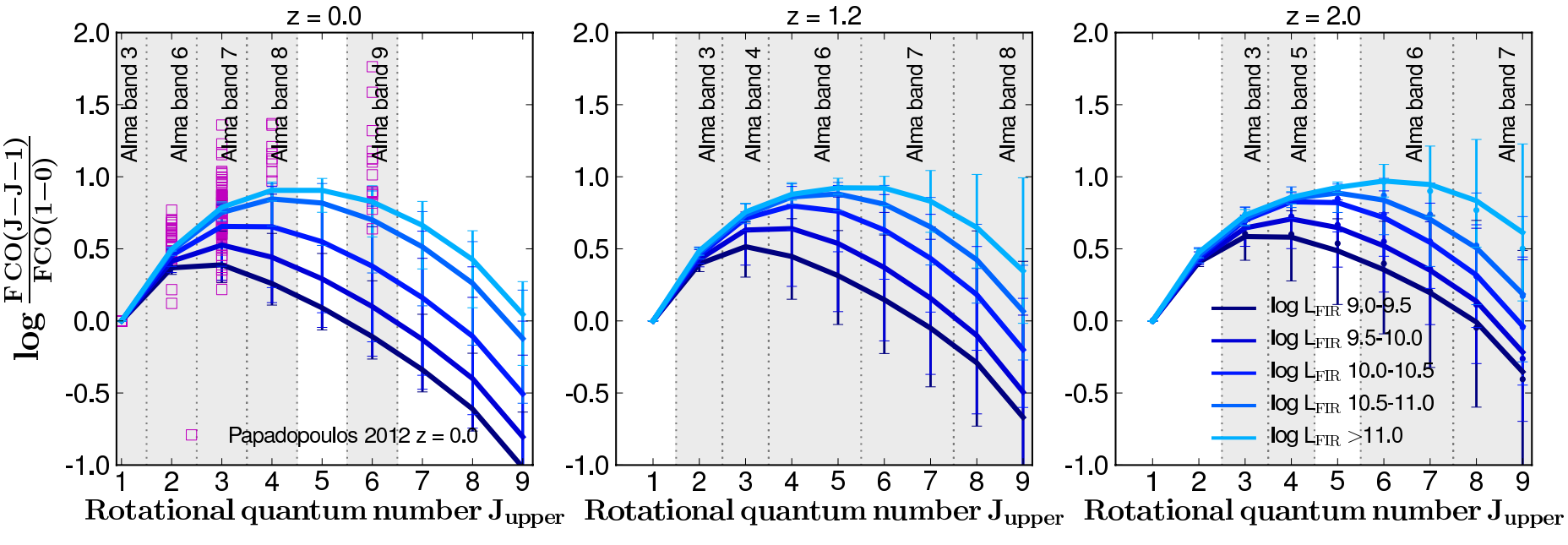
- Exponential discs
- Lognormal density distribution of gas
- Metallicity dependent abundances

CO emission of galaxies



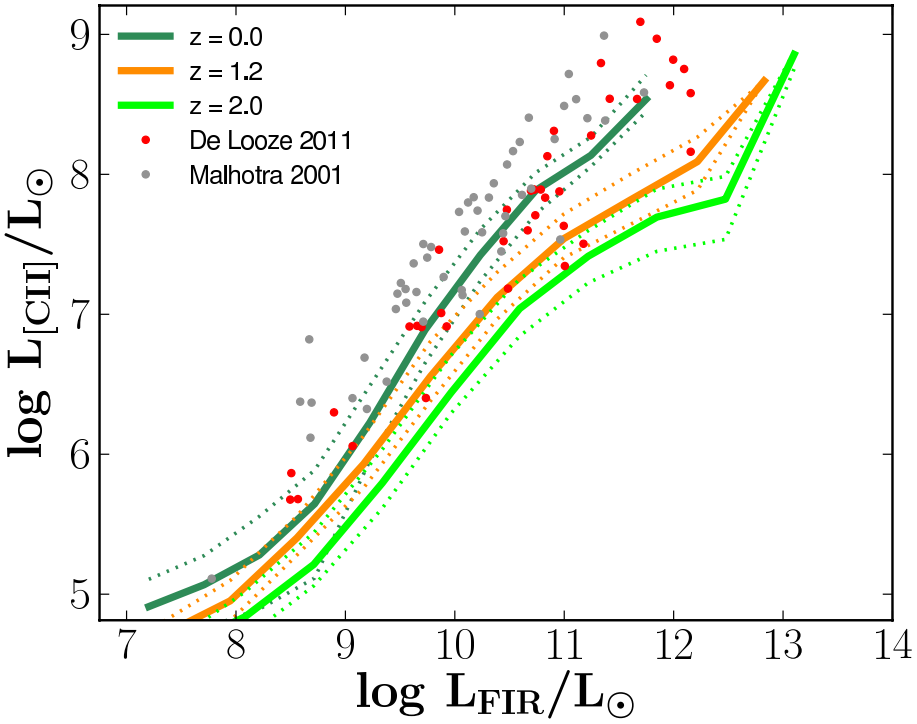


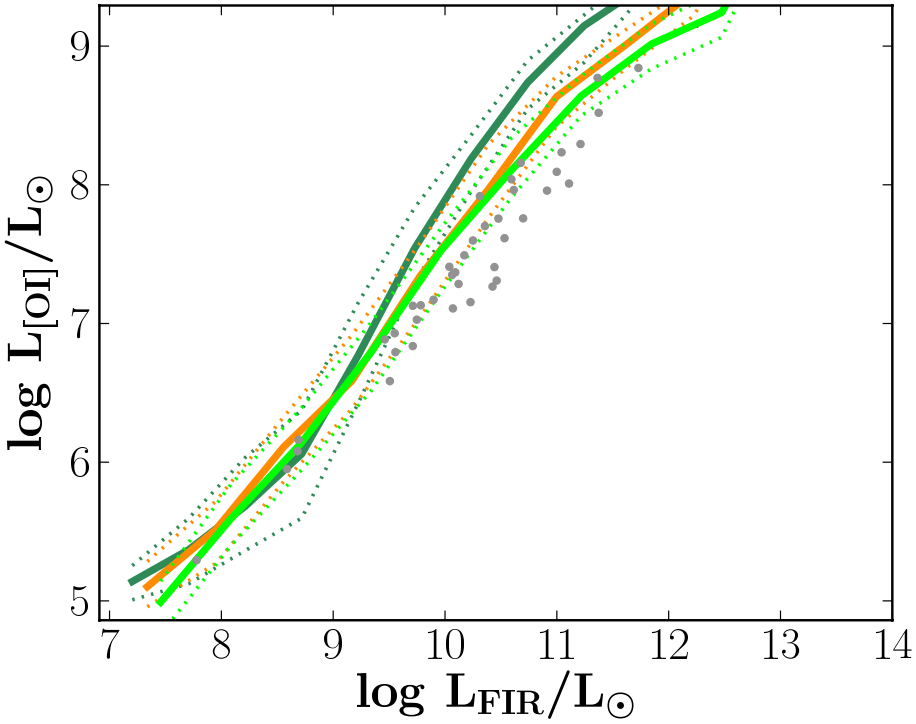
CO SLEDs



SLEDs peak at higher J-transitions: indicative of *denser* and *warmer* ISM

Cooling lines





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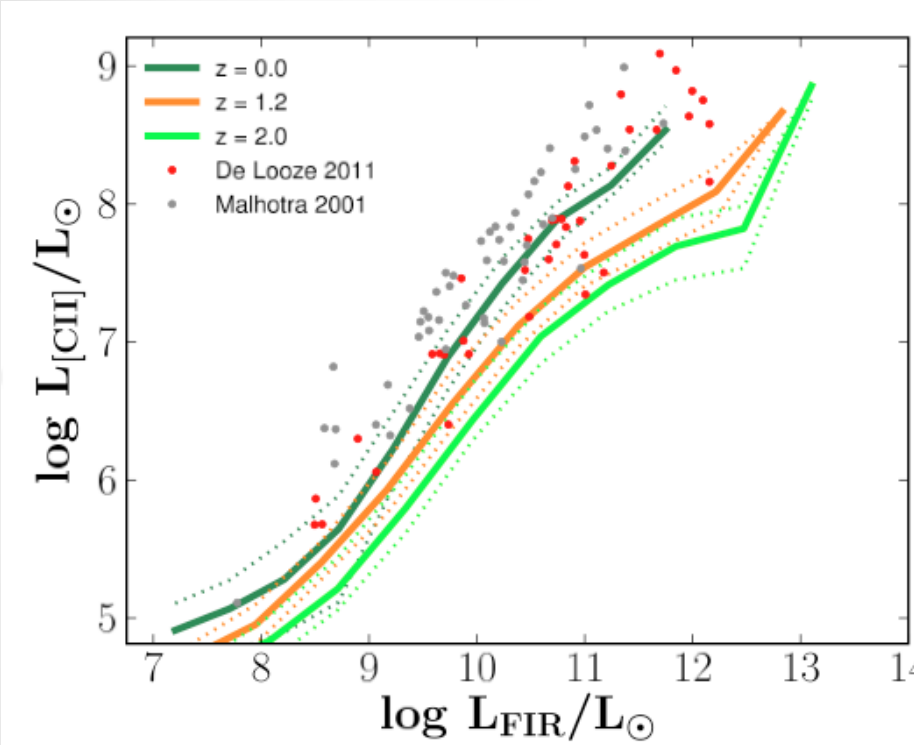
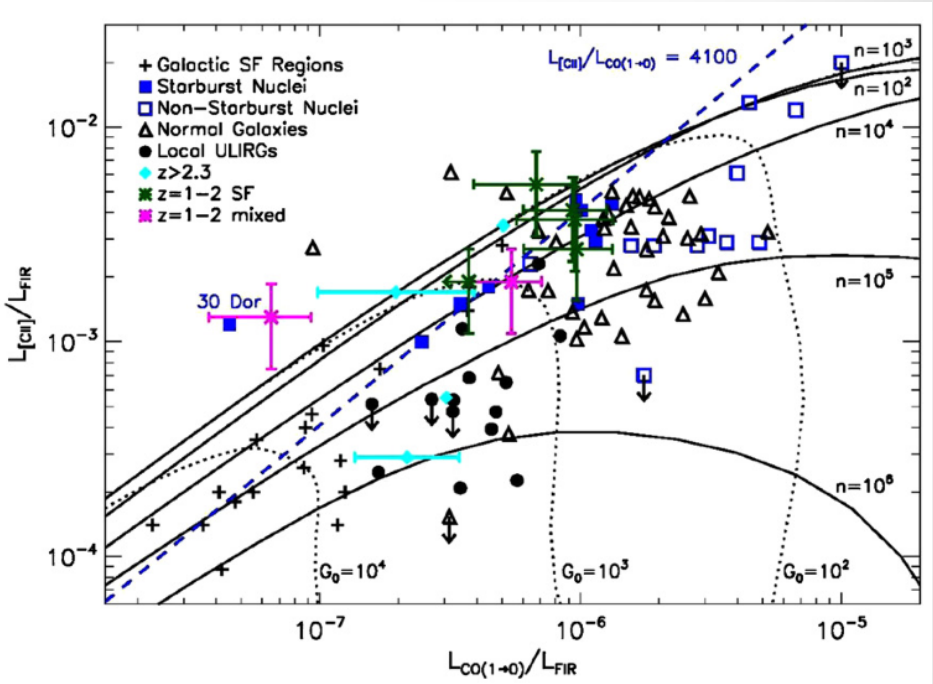
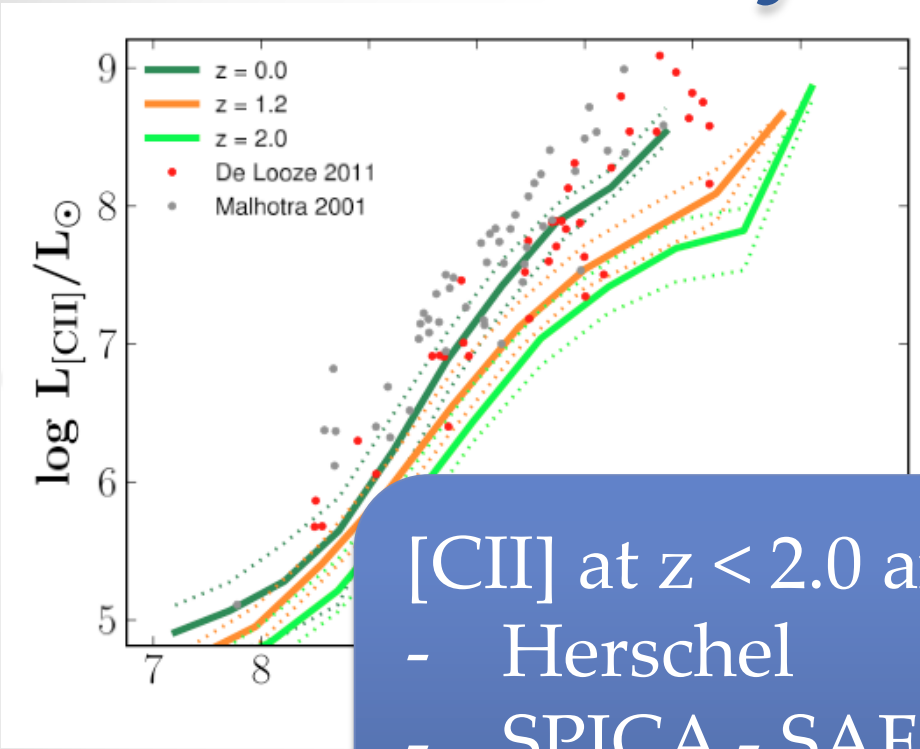


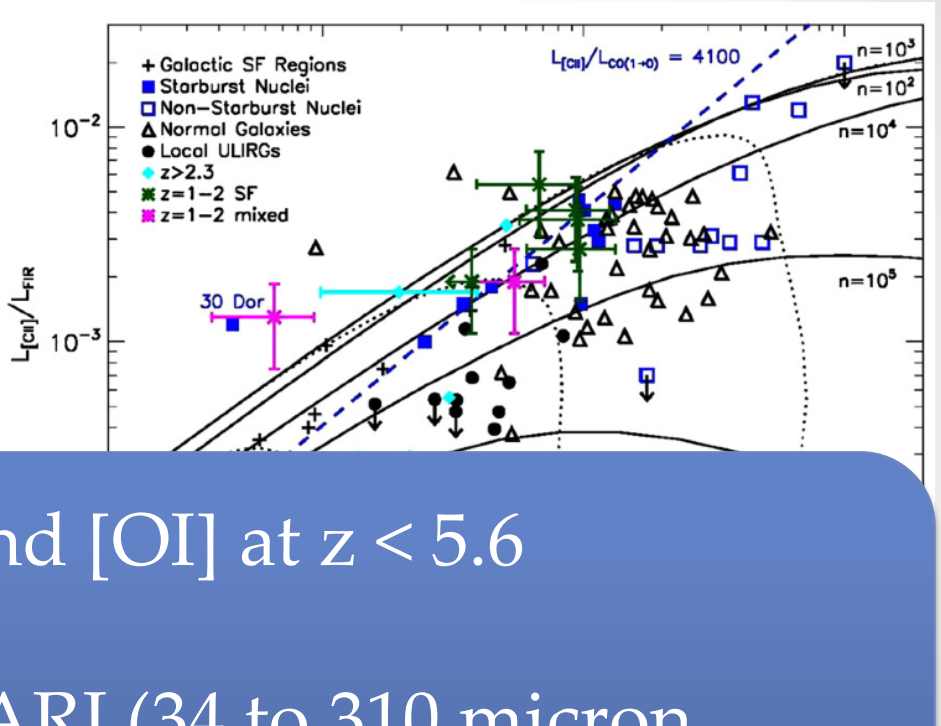


[CII] and [OI] as a proxy for the gas conditions

Stacey 2010

Summary and Synergy





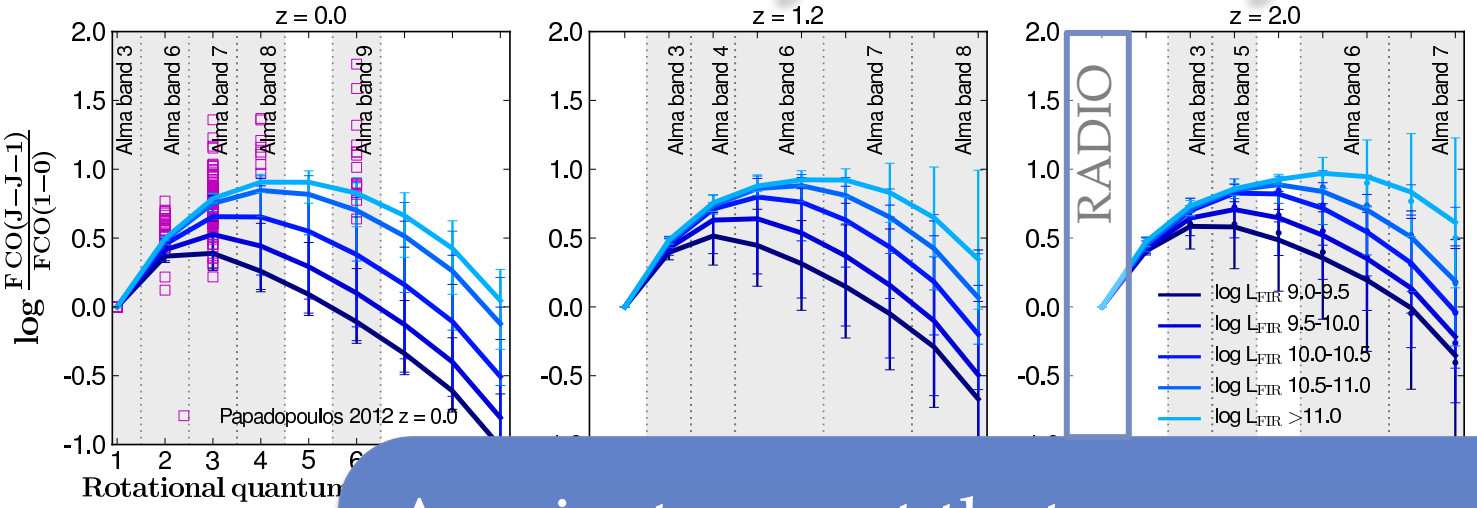
[CII] and [

[CII] at z < 2.0 and [OI] at z < 5.6

- Herschel
- SPICA - SAFARI (34 to 310 micron spectrograph; 2025)

Stacey 2010

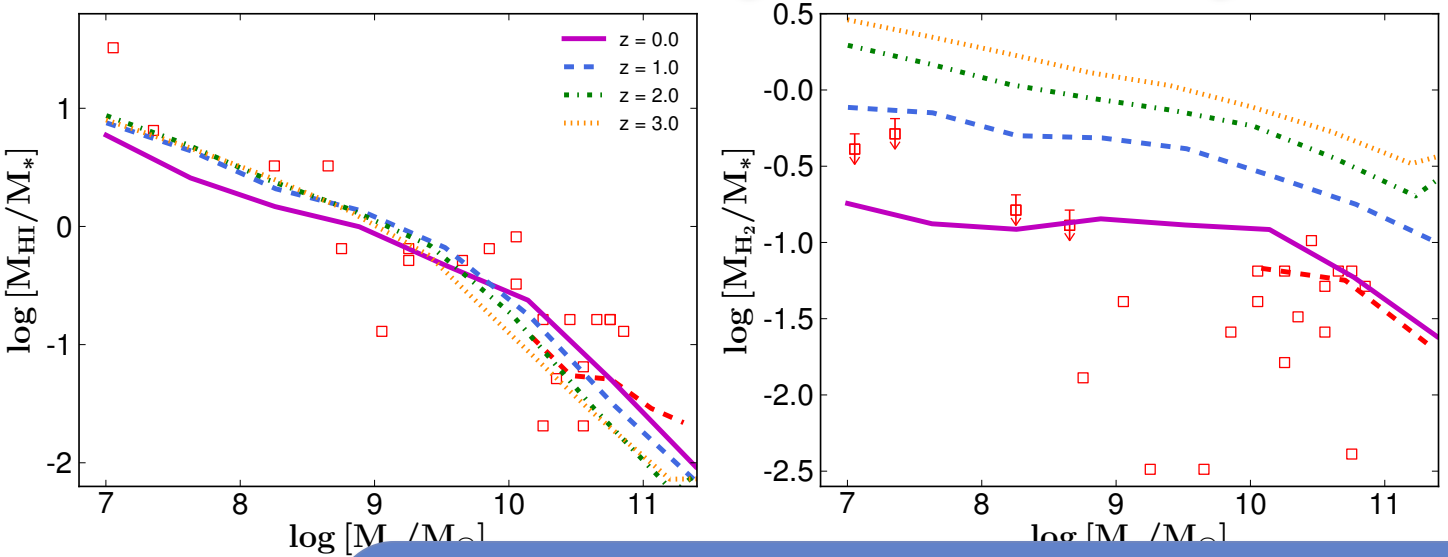
Summary and Synergy



Any instrument that can measure CO lines

At z > 2 radio instruments can observe CO 1-0

Summary and Synergy



WSRT, JVLA, SKA and SKA pathfinders are very complementary to ALMA

Summary

- SAM to model HI and H2 in galaxies and sub-mm emission from galaxies
- We predict a weak evolution in HI mass at $z < 2.0$
- H2 mass evolves over an order of magnitude during the same cosmic epoch
- CO SLEDs suggest that gas in high-z galaxies is warmer and denser than in local counterparts
- Atomic carbon and cooling lines as a proxy for temperature, density, and impinging radiation