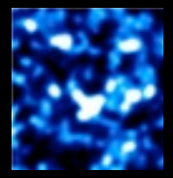
Mapping the EoR

Jonathan Pritchard
Imperial



Towards a full picture of EoR

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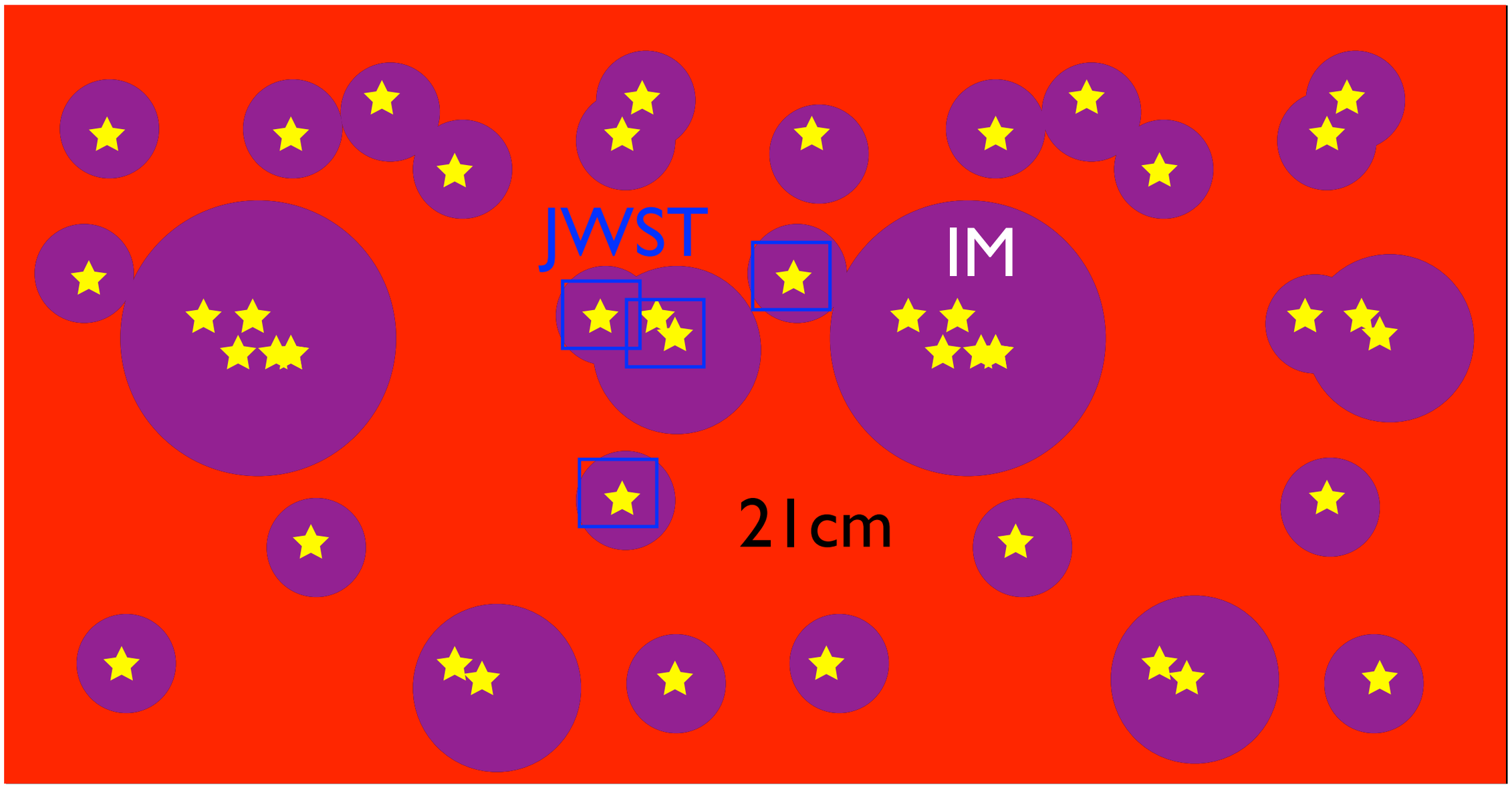
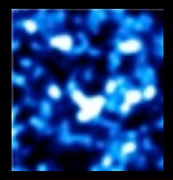


Galaxy surveys identify individual galaxies

21 cm determines properties of gas around galaxies

Intensity mapping probes gas in galaxies



Faint galaxies are important!

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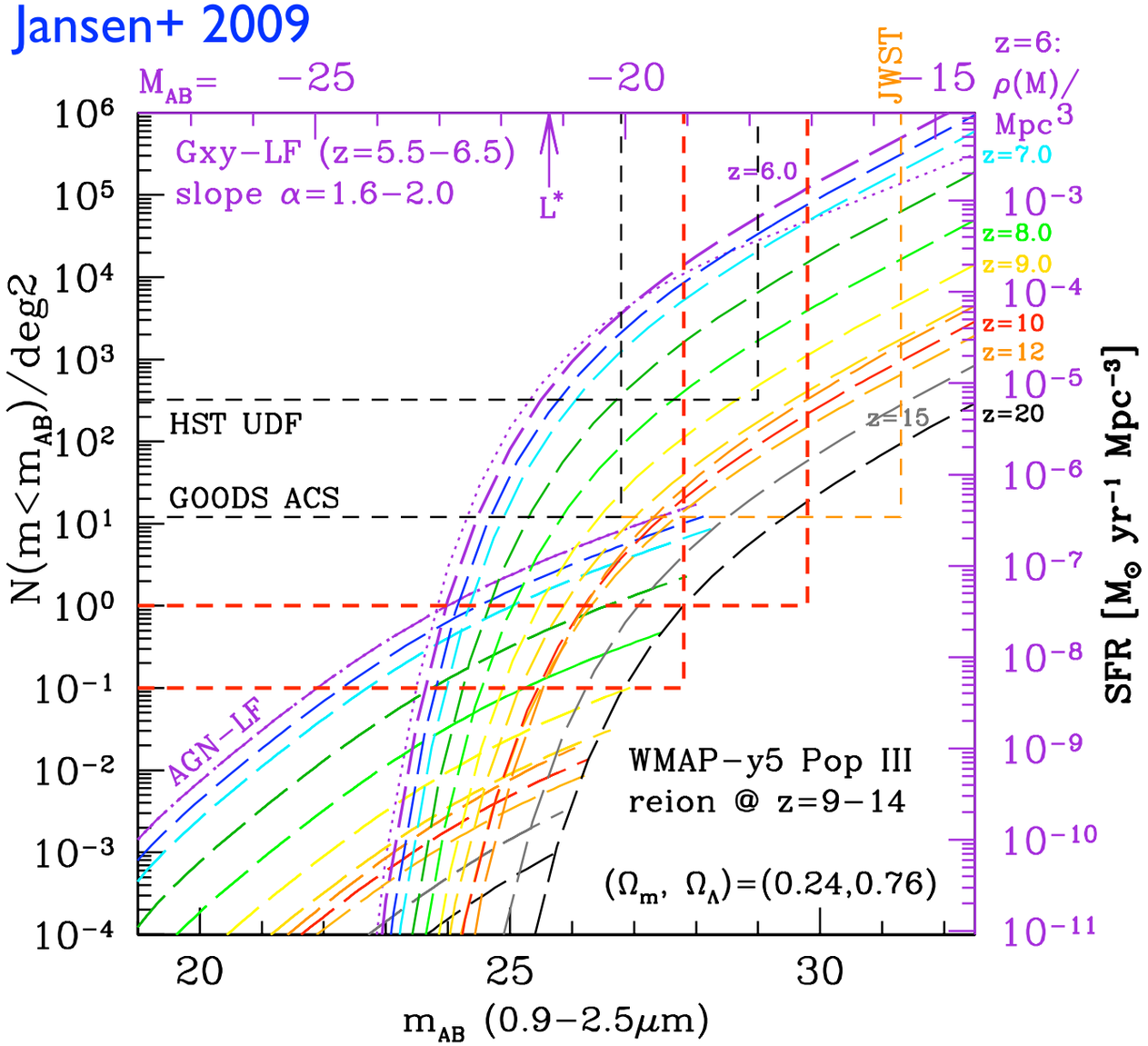
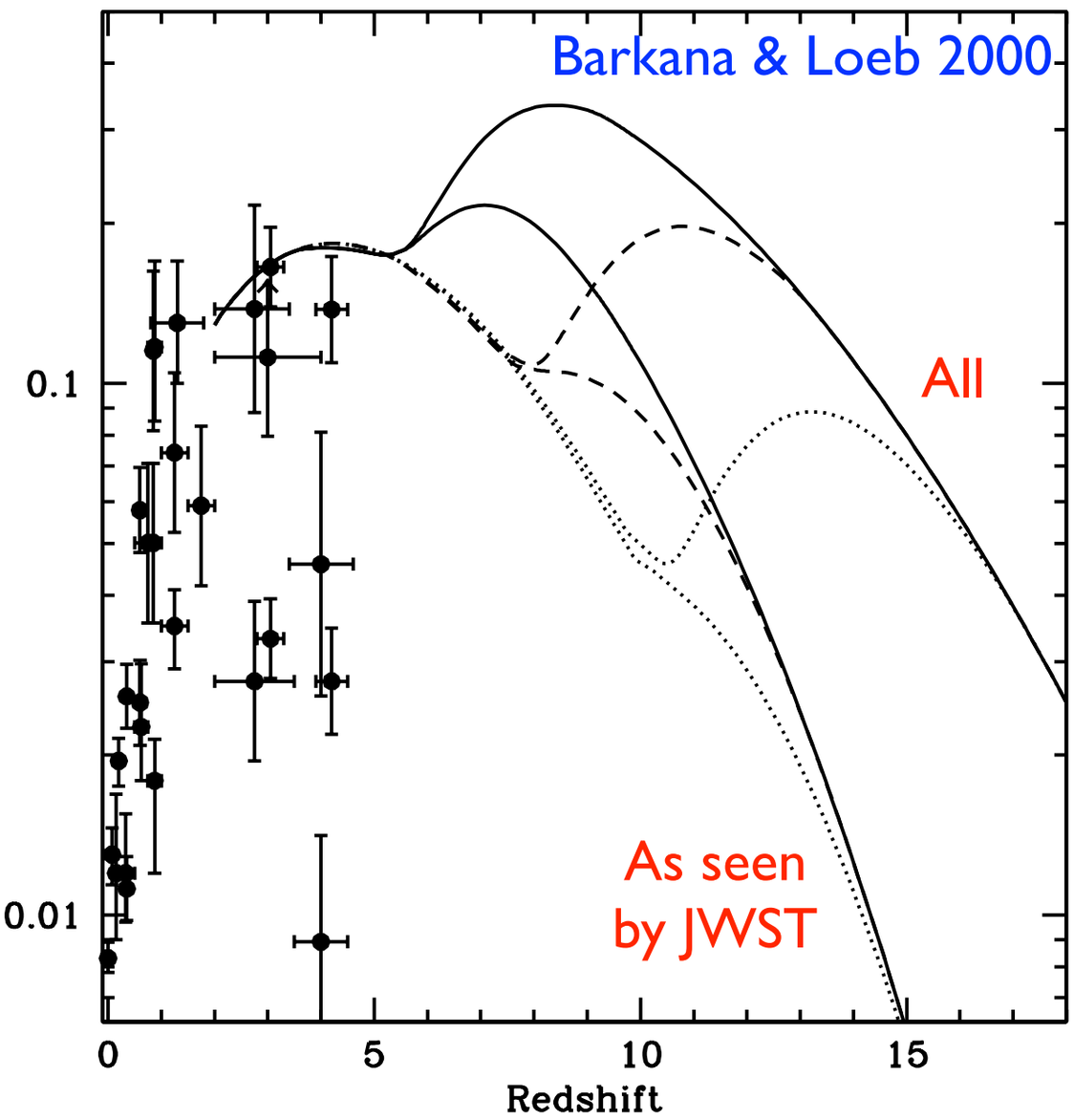
Jansen+ 2009



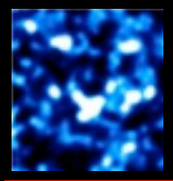
Barkana & Loeb 2000



JWST/TMT/E-ELT/ALMA will pin down galaxy luminosity function

JWST lacks sensitivity to see the faint end galaxies at high redshift

IM can probe the galaxies other surveys can not reach!



Intensity mapping in outline

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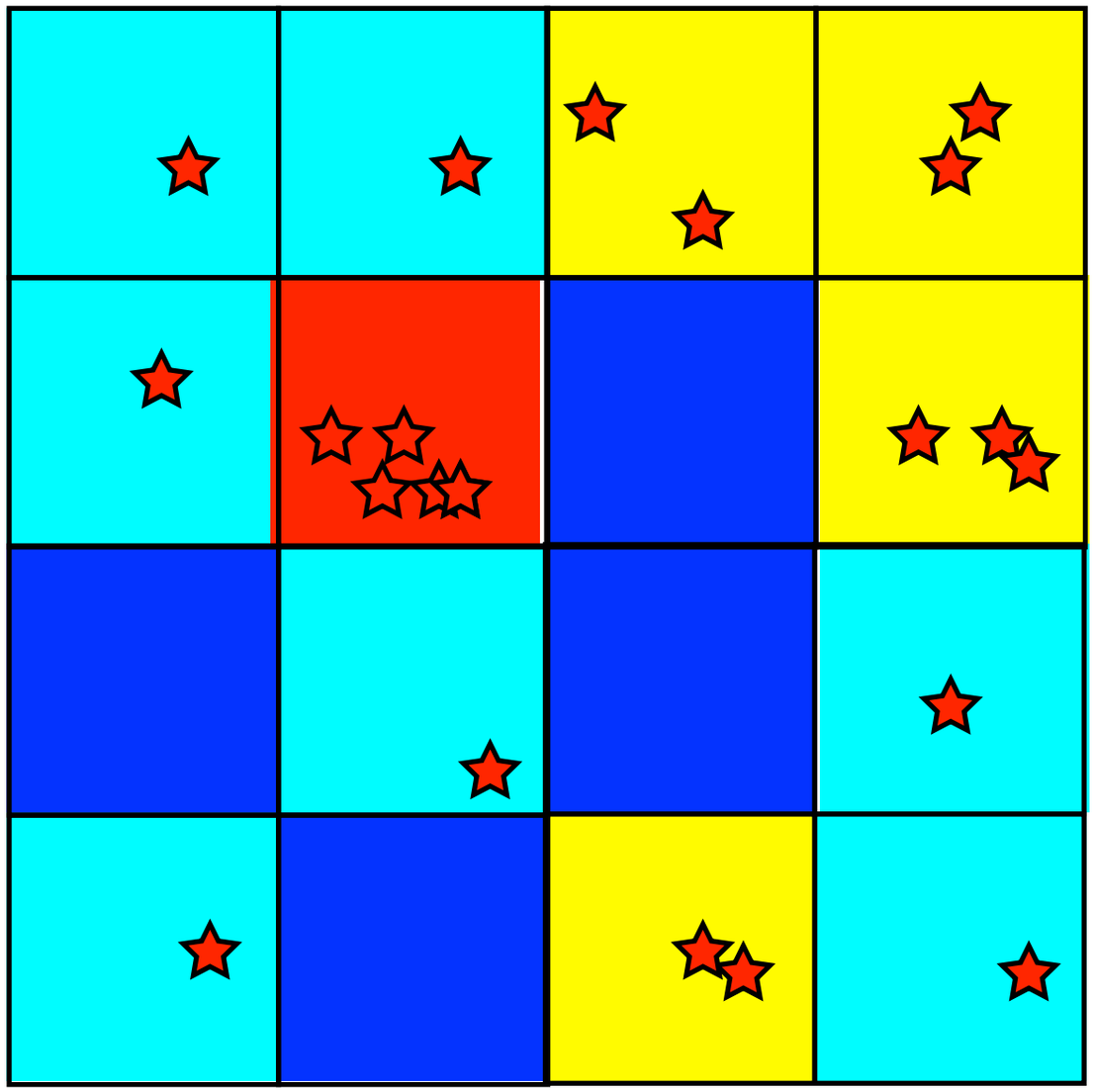
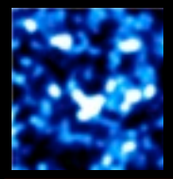


Traditional galaxy survey identifies individual galaxies

Bin galaxies to estimate density field

Intensity mapping integrates flux from all galaxies

Probing integrated population of galaxies - is that easier or harder to interpret than individual galaxies?



Which lines? Which redshifts?

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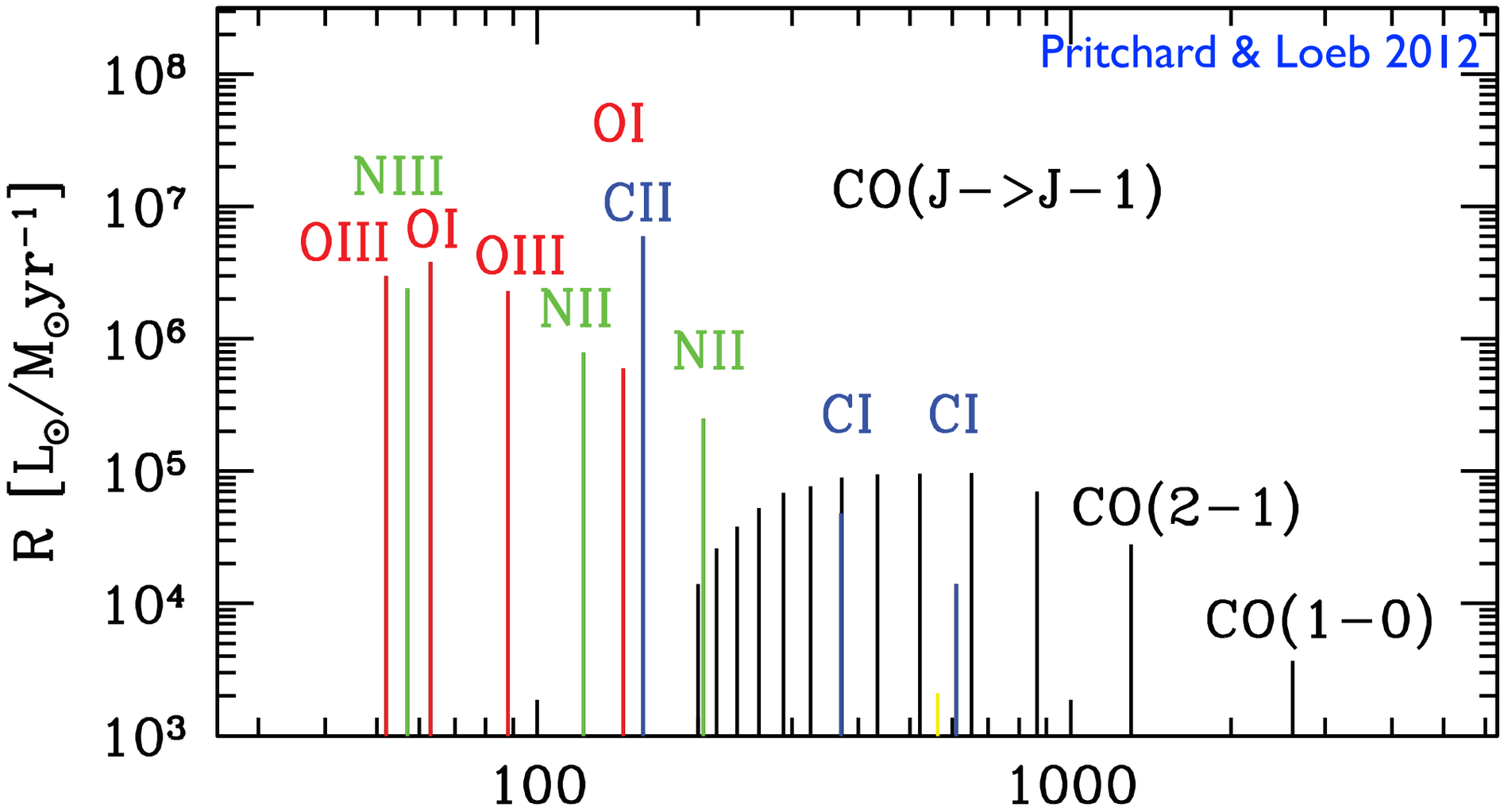
Different lines probe different elements of galaxy ISM

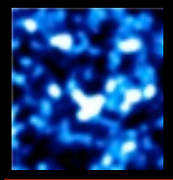


Righi+ 2008,
Visbal & Loeb 2010
Carilli 2011,
Gong+ 2011, 2012
Lidz+ 2011

Also: Lya: lambda= 0.1215 um
21cm: lambda=0.21 *10^6 um

Meiksin+ 2011
Silva+ 2012

Chang+2008,
Loeb+2008



IM science

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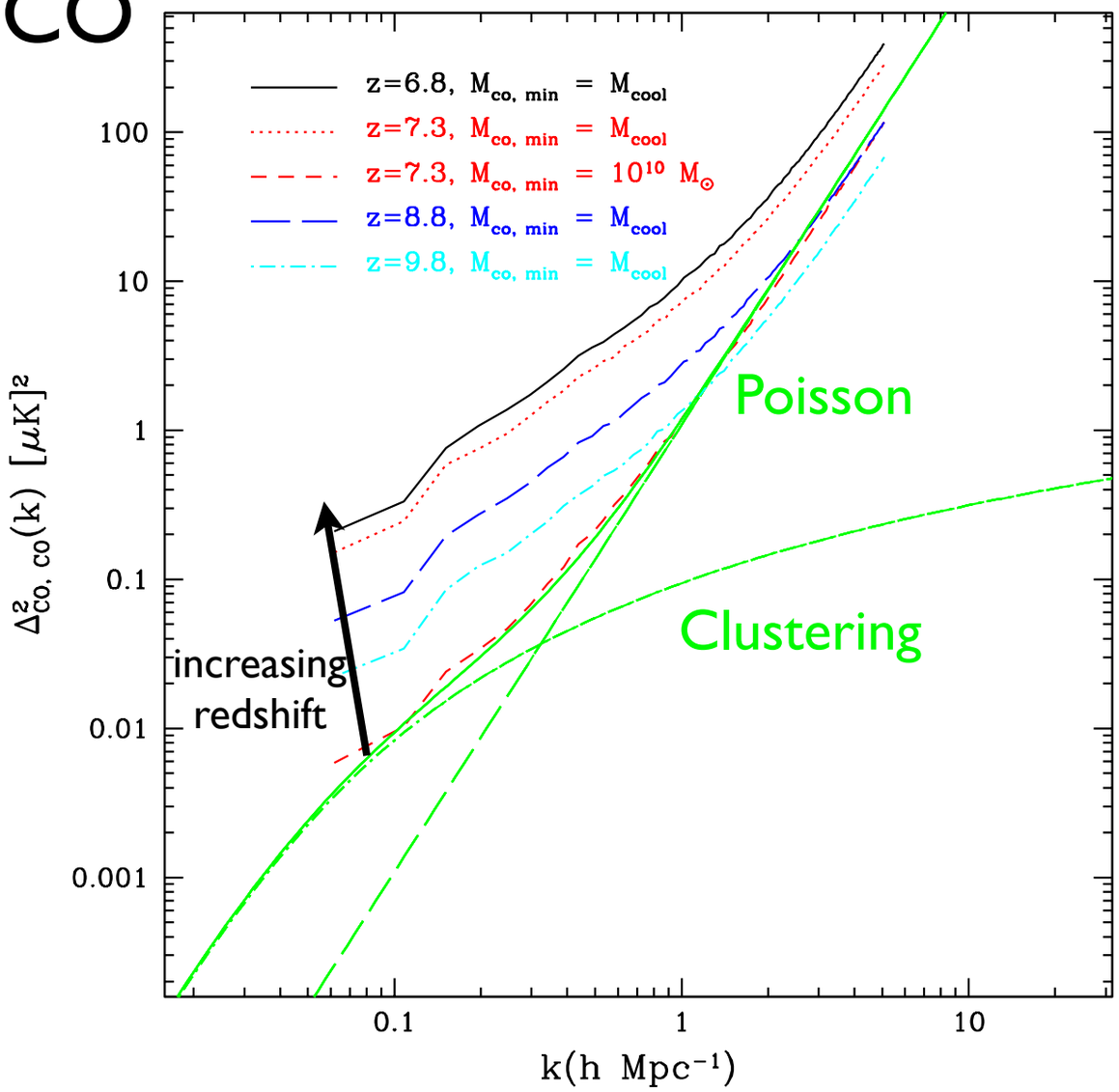
Basic expectation is that IM follows underlying galaxy distribution - clustering + poisson

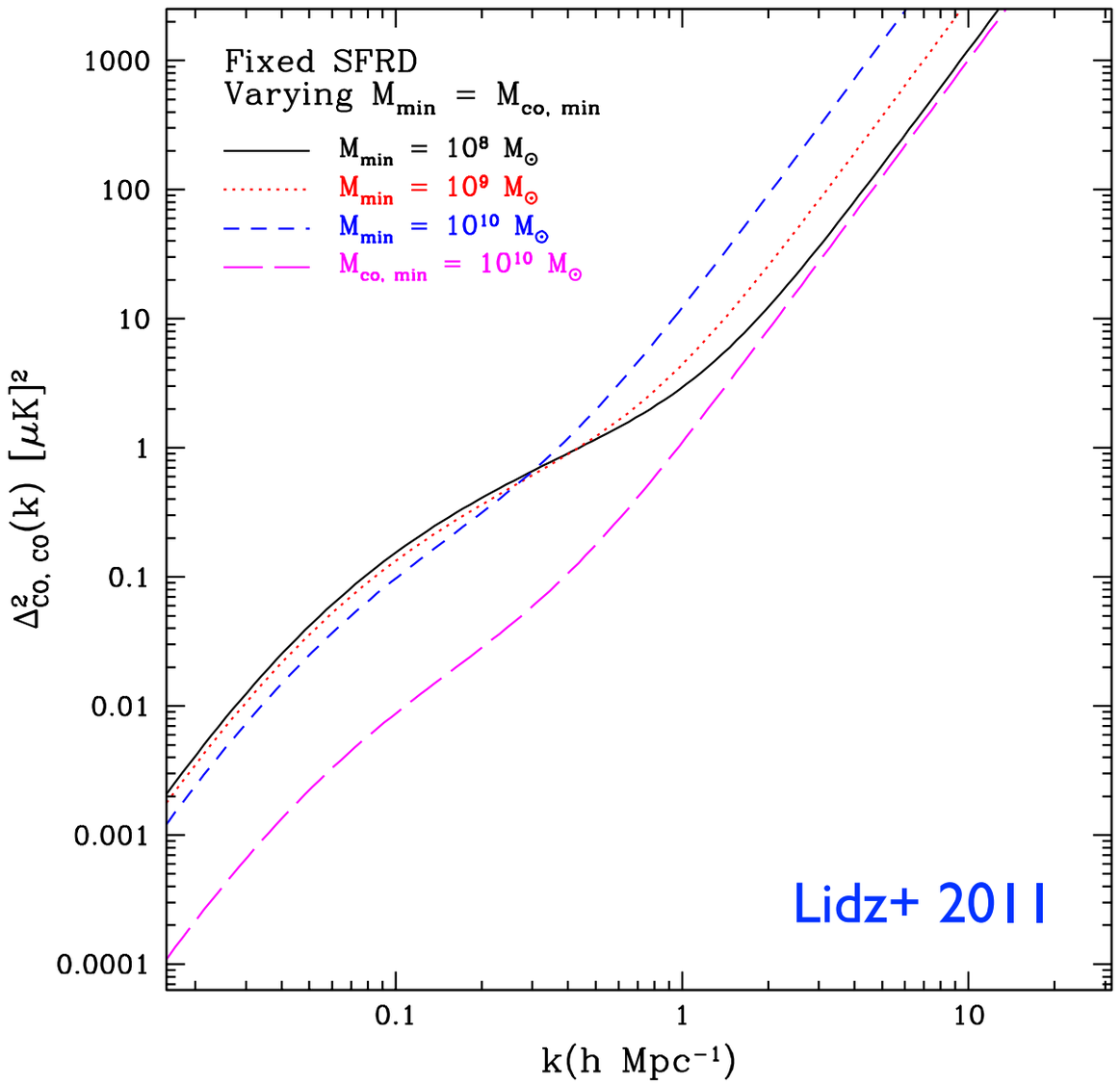
Details determined by complicated ISM physics - metalicity, stellar/AGN heating, chemistry,...

Model either empirically or based on some first principle prescription

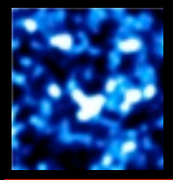
CO



Amplitude evolves with $\langle T_{CO} \rangle$ and determined by SFR



For fixed SFR, shape determined by minimum mass for CO bright galaxies



Multiple lines isolates redshift slice

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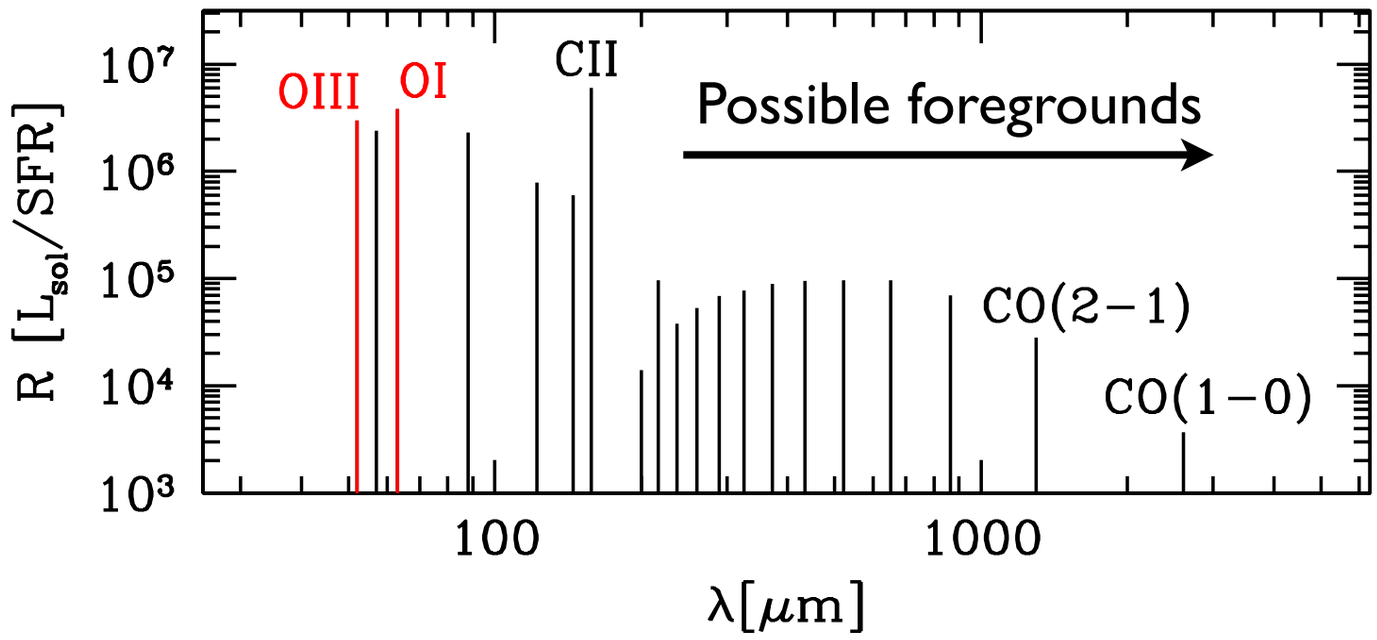
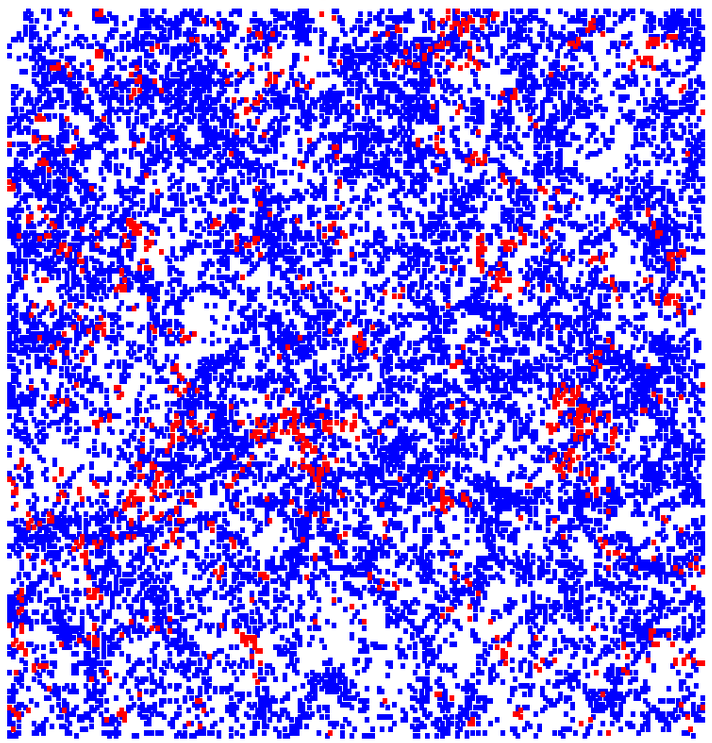
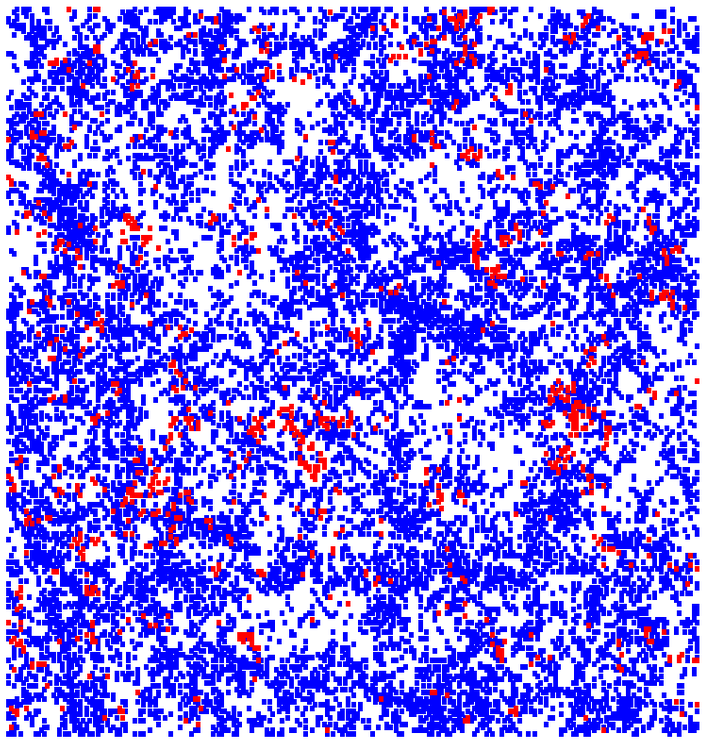


441μm map=> OI(63μm)



364μm map => OIII(52μm)



Visbal & Loeb 2010
Visbal, Trac, Loeb 2011

z=6

blue=other lines

Cross-correlation of two maps cleaning picks out galaxy distribution at fixed redshift

Different lines probe different physics

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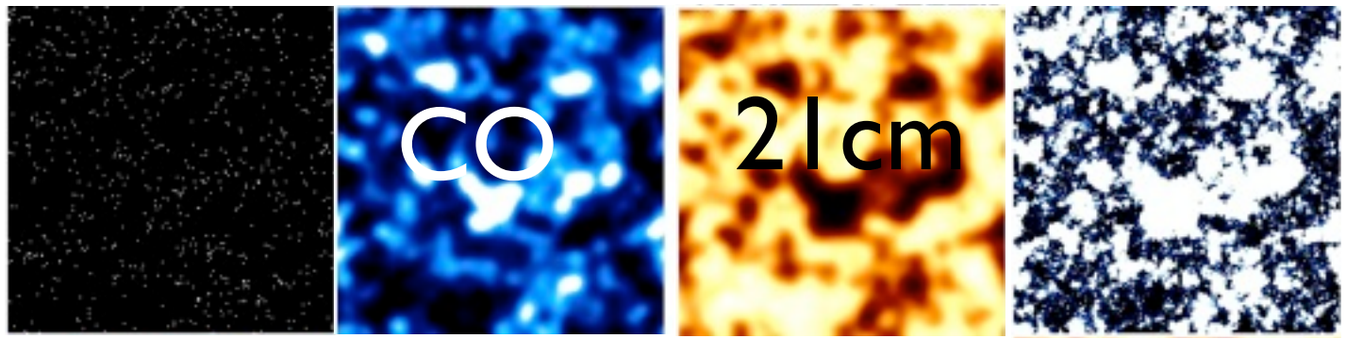
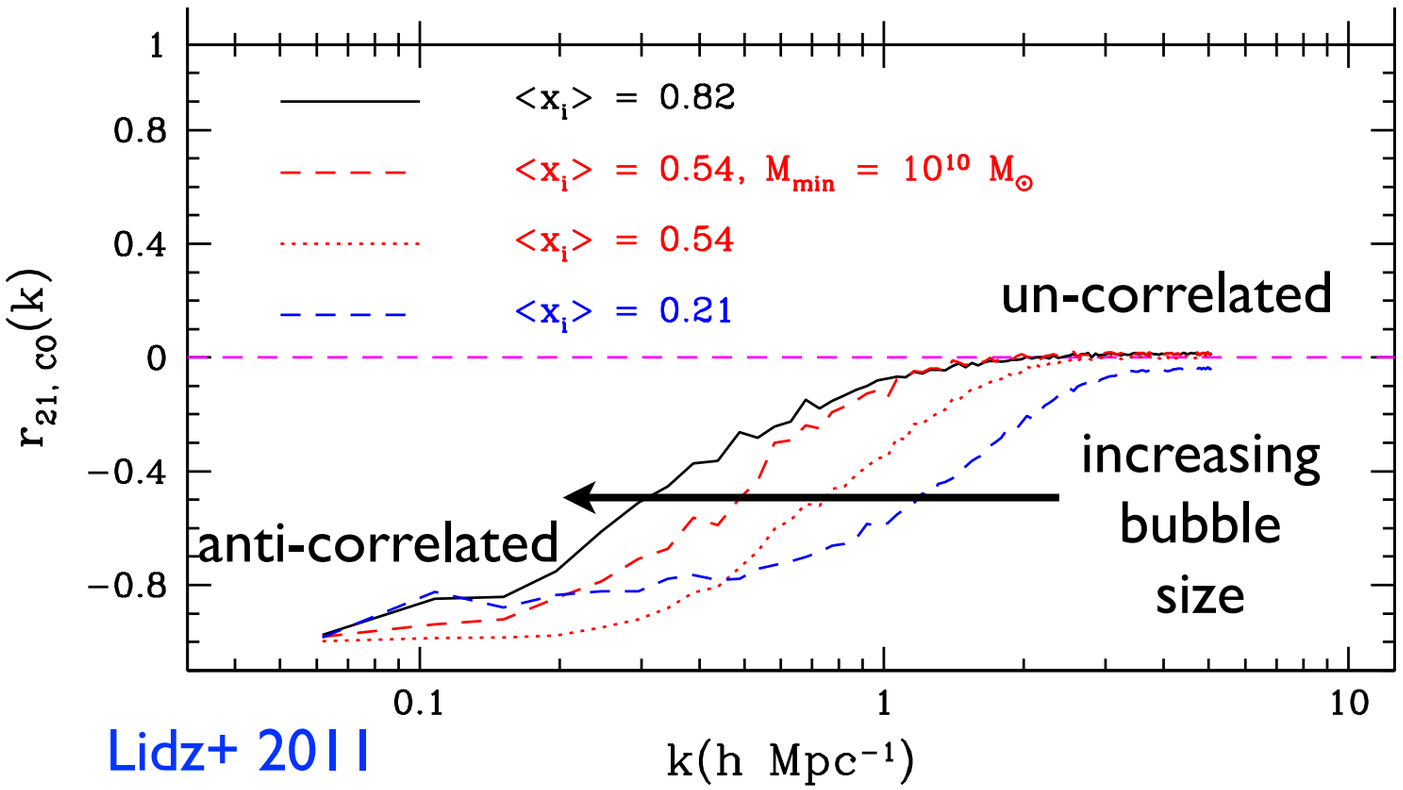
ISM versus IGM

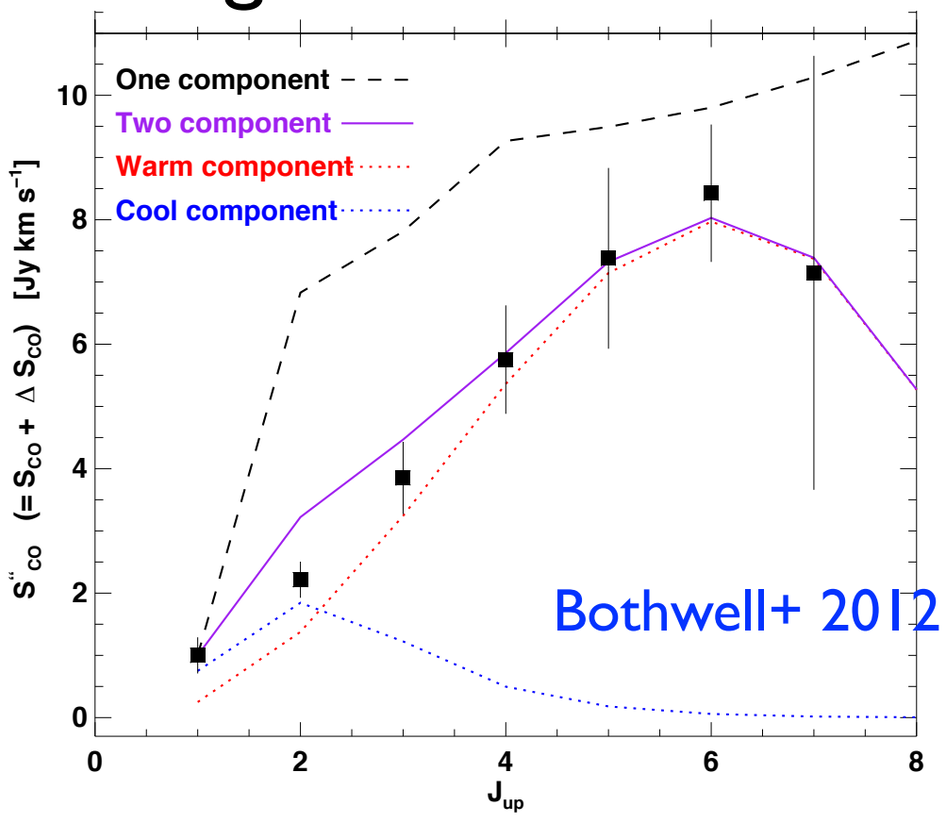




Lidz+ 2011

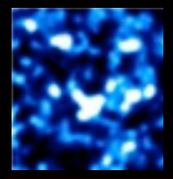
Parts of ISM

e.g. CO excitation



Bothwell+ 2012

increasing CO rotational levels →



How do you observe this stuff?

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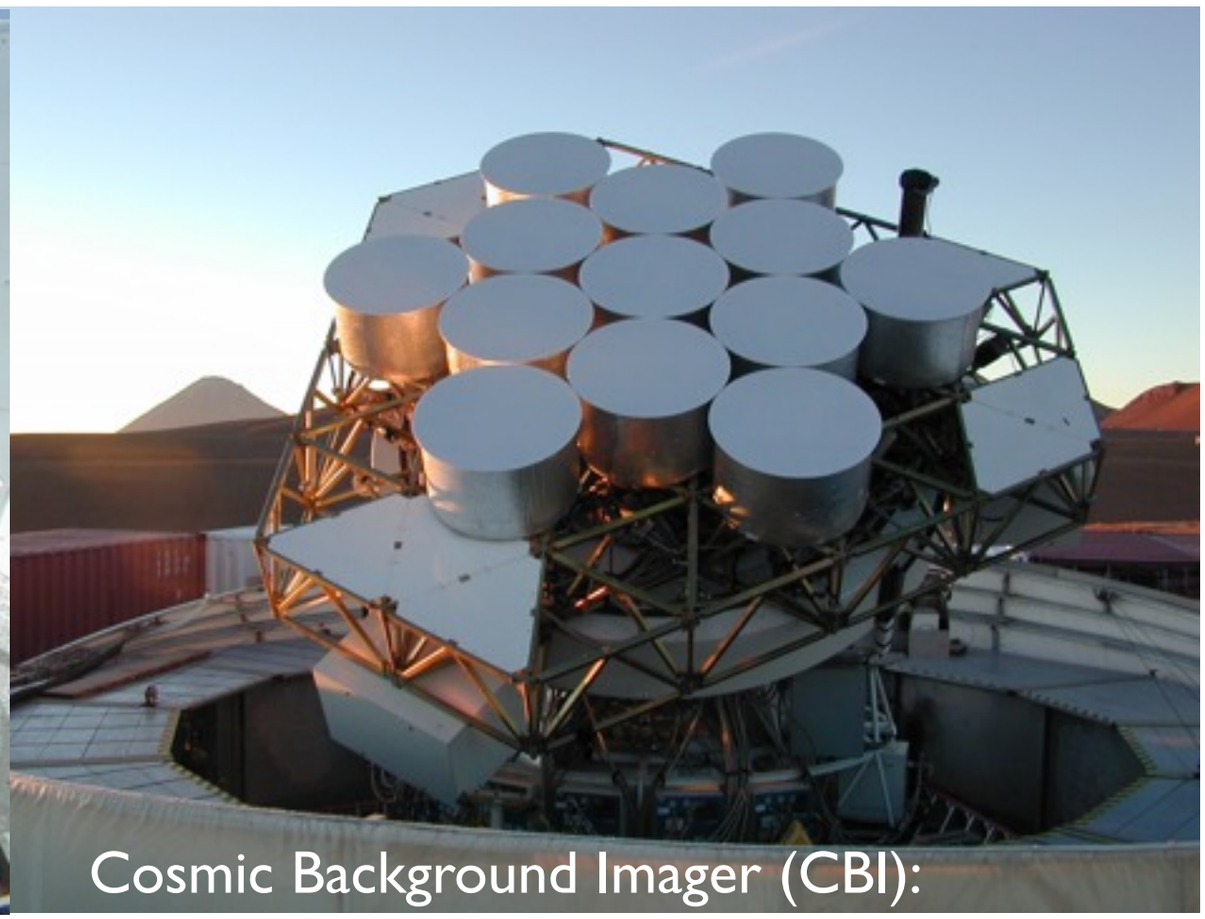
Desiderata: To match 21cm: ~25deg^2 survey, ~6 arcmin resolution
For CO: $d\nu/\nu$~0.003, noise ~0.1-1μK

For CO(2-1) at z=7, ν_{obs}~30GHz, λ_{obs}=1cm,
=> $D_{antennae}$~12cm, D_{max}~6m

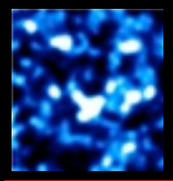
=> need filled array with ~900 antennaes to get 1μK noise (~80 times VSA/CBI)

Very Small Array (VSA)



Cosmic Background Imager (CBI):

Best technology? e.g. dishes+focal plane array, interferometer,...



EoR Intensity mapping questions

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- IM plays two roles in EoR:
  (1) Tracer of galaxies for cross-correlation with 21 cm
  (2) Probe properties of faint galaxies and ISM

- What aspects of galaxy population can IM constrain?
e.g. clustering, star formation history, excitation, metalicity,...

- Which lines and which combinations of lines are most interesting for understanding ISM of early galaxies?

- How well can the signal be predicted/interpreted? How well can it be measured?

- What experimental techniques get you to the sensitivity?