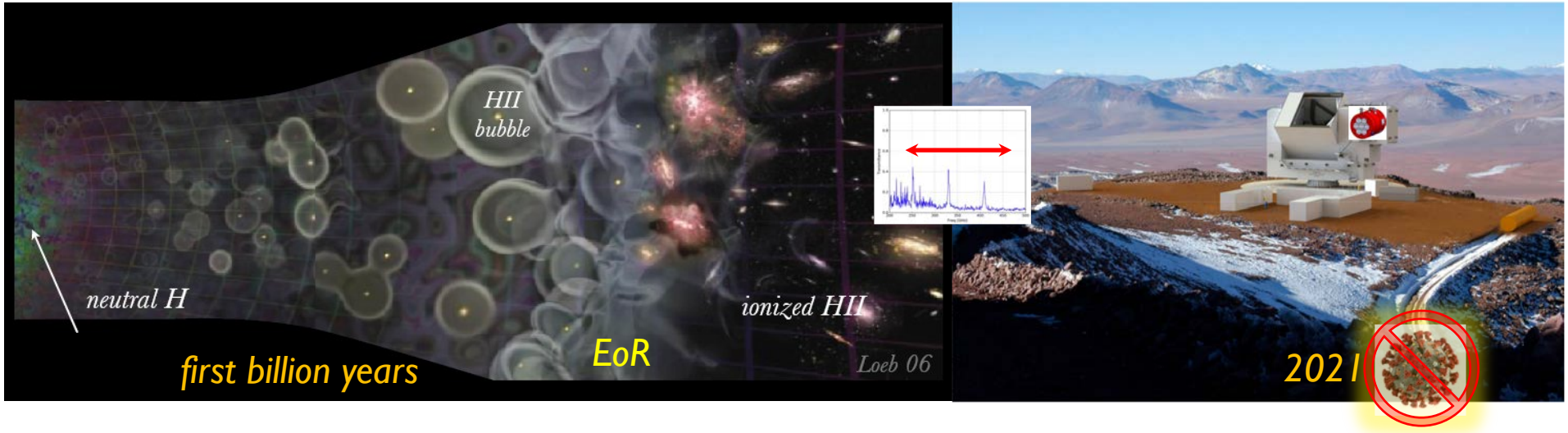
Line Intensity Mapping from Cosmic Noon to the Epoch of Reionization

CCAT-prime



Dominik Riechers (Cornell)

on behalf of the SWG

With thanks to:

P. Breysse, D. Chung, C. Karoumpis, B. Magnelli, G. Stacey, et al.

your name could be here!

Session Outline

CCAT-prime

- Overview (this presentation)
- [CII] Detectability Forecasts for CCAT-prime through Empirical Models *(Dongwoo Chung; Stanford)*
- CCAT-prime [CII] & [OIII] Intensity Mapping Predictions *(C. Karoumpis; AIfA Bonn)*
- More than foregrounds: AGN feedback with CO cross-correlations *(P. Breysse; CITA)*

Outline of products

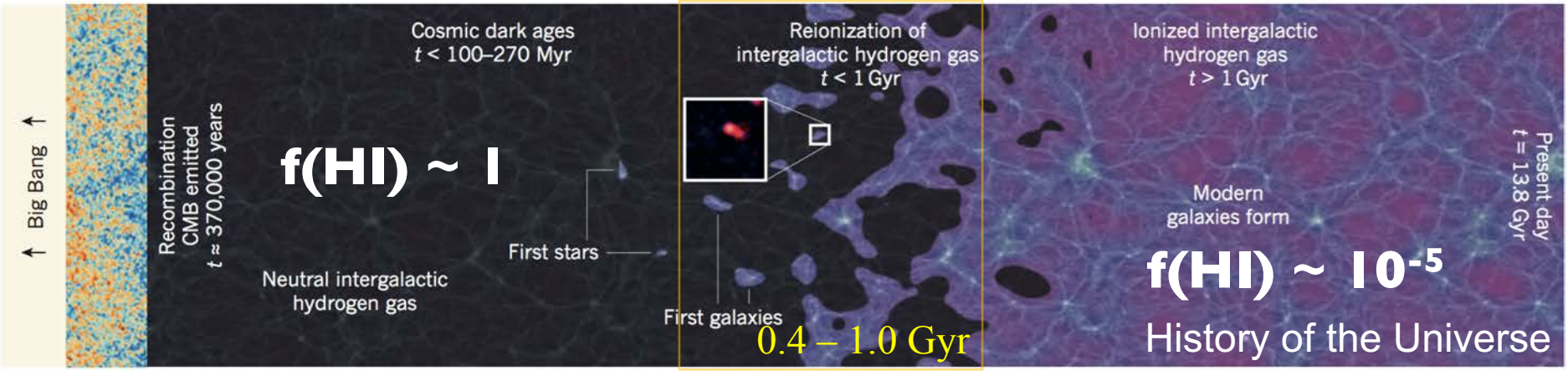
CCAT-prime

- Science Theme
- Science Goals
- First light science
- Baseline science
- Full Science
- Path to science
  - Observing requirements
  - Reduction plan and requirements (computing & such)
  - Model/simulations
  - Foreground removal
  - Data analysis schedule
  - Personnel needs/plans

Overall Project Title

CCAT-prime

- [CII], [OIII], CO intensity mapping to constrain clustering of star-forming galaxies at z=0-8
- Main goal of full survey: Topology and timescale of cosmic reionization at z>6



Robertson et al. (2010); Riechers (2013)

Simulations of Cosmic Reionization

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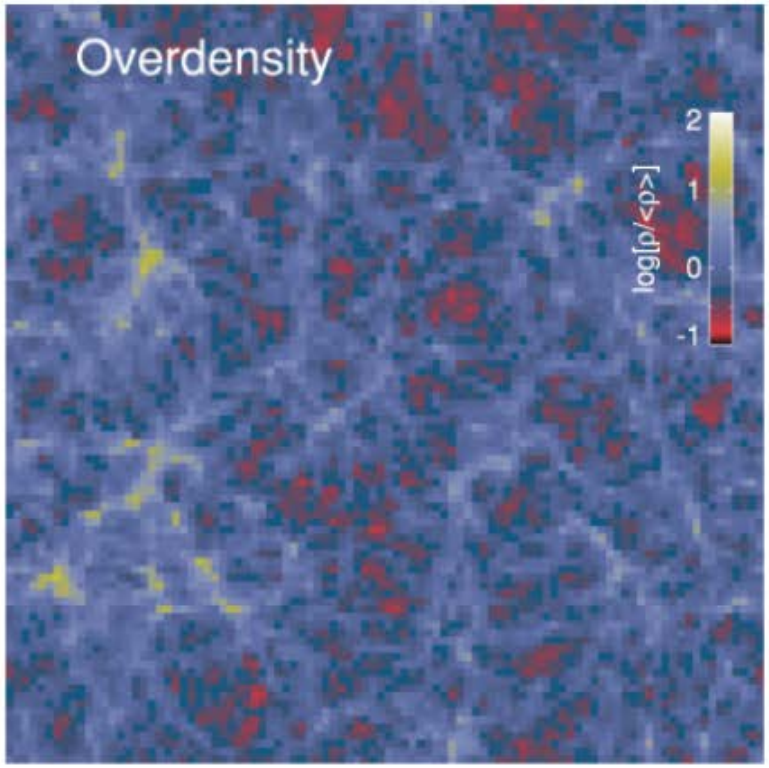
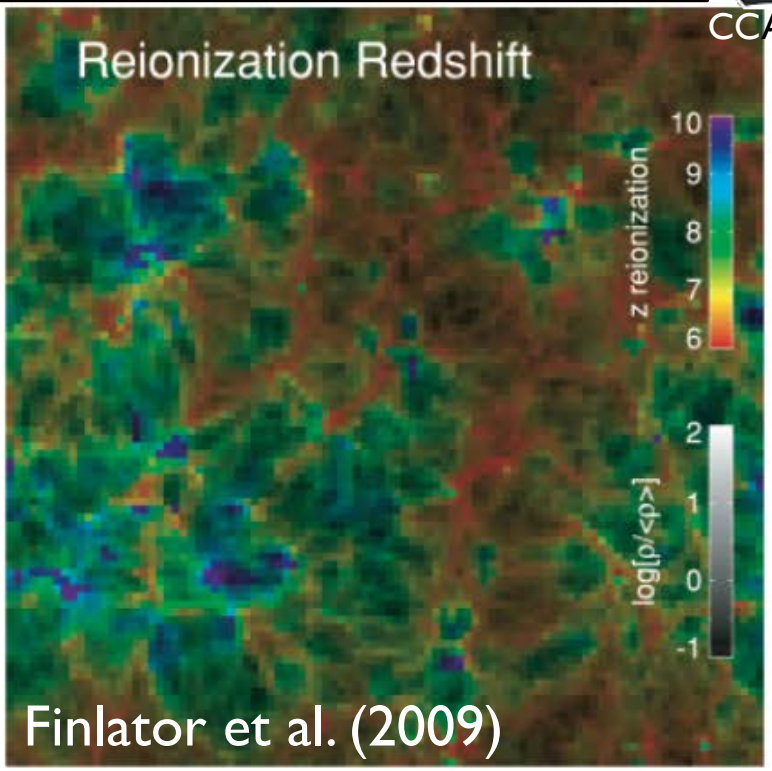


(a) Overdensity $\rho/\bar{\rho}$ at $z = 6.49$.



(b) Redshift of reionization, defined as the redshift at which the hydrogen neutral fraction first dips below 10^{-3}.

Re-ionization does *not* occur instantaneously, because mean free path of ionizing photons depends on local IGM density structure. Overdense regions re-ionize first, then voids, then moderate-density structures

⇒ *galaxy clustering drives the evolution*

⇒ *need to map signal spatially and as f(redshift)*

Measurement: [CII] Power Spectrum

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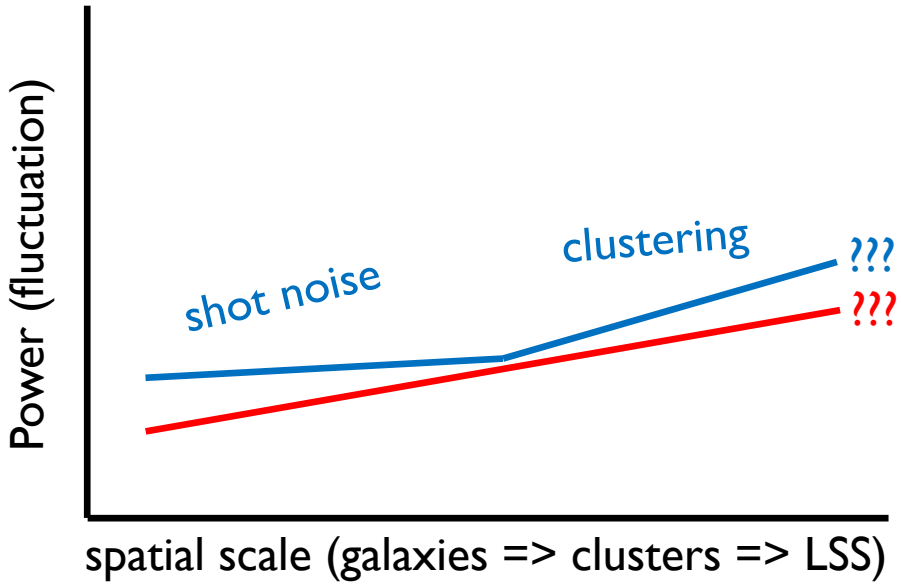

Use [CII] 158 μm line to trace locations/*density* of star-forming galaxies that cause cosmic reionization, trace with *time* (redshift range)

[CII] intensity/fluctuations on large scales measures *clustering* (=more/less intensity per beam)
[CII] intensity on small scales (galaxies) measures *luminosity function*
Cross-correlation with HI 21cm gives size/growth of *ionized bubbles*

actual predictions: talks to follow!

CO Foregrounds

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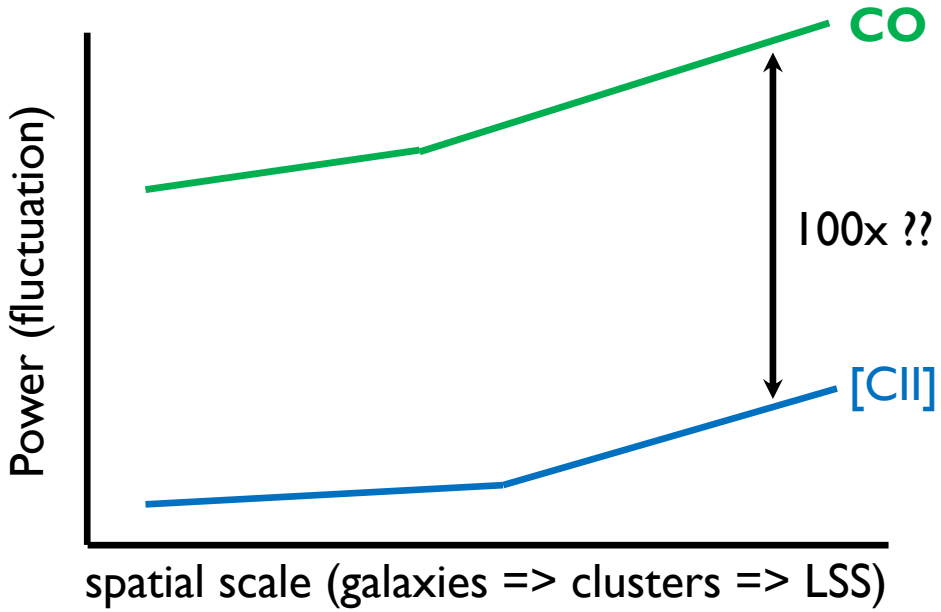


Lower-redshift CO lines [$d\nu$=115GHz/(1+z); ~4 lines at most z] continuously redshift through spectral range

⇒ "flag" for [CII]

⇒ *But can do similar science + CO excitation at lower z*

⇒ *Also: [OIII] 88μm at higher z*

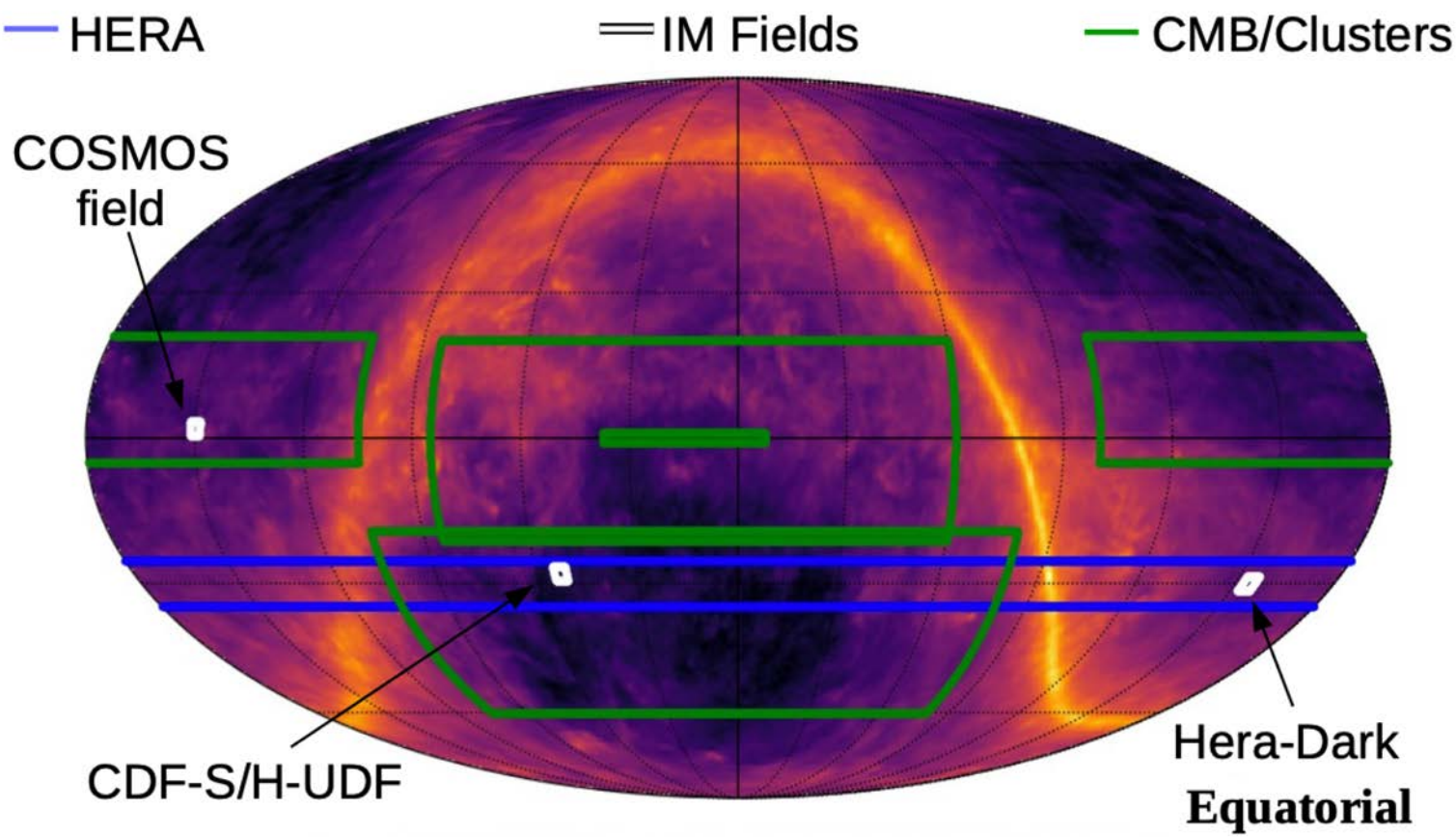
actual predictions: talks to follow!

"Nominal" survey

CCAT-prime

Table 1: Overview of planned survey regions (Fig. 4) and observing parameters.

Survey	Field ID	LST range [h]	Area [deg^2]	Time [hr]	Sensitivity (@ representative $\nu_{\rm obs}$[GHz])	Supporting Surveys[b]
EoR[a]	E-COSMOS	7.0-13.0	4	2000	0.02 MJy sr^{-1} bin^{-1} @ 220	1
	E-CDFS	23.5-7.0	4	2000	0.02 MJy sr^{-1} bin^{-1} @ 220	2
	HERA-Dark	13.0-23.5	4	*(filler)*	0.02 MJy sr^{-1} bin^{-1} @ 220	3



"First Light Science"

Assume: 100-400 hours, using 1-2 modules including 270/350/860 GHz + EoR modules and CHAI

- Notional titles of paper(s)
  - *z~3-4 detection of [CII] IM signal [Chung & Karoumpis talks]*
  - *[CII]-Ly-α cross-correlation in COSMOS at z~5.7*
  - *CO-AGN cross-correlation [Breysse talk]*
  - *CO Luminosity function and cosmic gas density at z=0-3*
  - *(calibration data) wide-band spectroscopy of Arp 220 & NGC 253*
- Observing Requirements:
  - Wavelength/frequency bands: *EoR-Spec, 1 module [350 GHz only?]*
  - Sensitivity: *(next talks)*
  - Mapping area – size and location: *COSMOS, 2-4 deg^2*
  - Observational cadence: *any*
  - Other requirements

Baseline Science

Assume: ~4000 hours, 2 broadband modules + EoR-spec & CHAI

- Notional titles of paper(s)
  - *z~6 detection of [CII] IM signal [Chung & Karoumpis]*
  - *z>7 constraints on [OIII] [Karoumpis]*
  - *Precise CO luminosity function constraints at z=1-3*

- Observing Requirements:
  - Wavelength/frequency bands: *EoR-Spec, 1 full module*
  - Sensitivity: $\frac{(@\ \text{representative}\ \nu_{\rm obs}[\rm GHz])}{0.02\,\rm MJy\,sr^{-1}\,bin^{-1}\ @\ 220}$ *(next talks)*
  - Mapping area – size and location: *COSMOS, CDF-S, HERA; 4-8 deg^2*
  - Observational cadence: *any*
  - Other requirements
- How do these requirements compare to baseline design?
  Needs full frequency range, sensitivity

Full Science

Assume: ~4000 hours, up to Choi et al. Instrument or variations (e.g. more EoR modules), & CHAI

- Notional titles of paper(s)
  - *z>7-8 detection of [CII] & [OIII] IM signal [Chung & Karoumpis]*
- Observing Requirements:
  - Wavelength/frequency bands: *EoR-Spec, 2 modules*
  - Sensitivity: *(next talks)*
  - Mapping area – size and location: *COSMOS, CDF-S, HERA; 8-16 deg^2*
  - Observational cadence: *any*
  - Other requirements
- Trade-offs
  - *Less modules/arrays impacts time required, no loss of science (potentially impacts largest-scale modes?)*

Path to Science

CCAT-prime

- Observing requirements:

  750 μm weather, EoR-Spec 24/7
- Reduction plan and requirements (computing & such): *TBD* ***[need predictions of data volumes]***
- Model/simulations: *talks to follow, need to map to "realistic" simulated Prime-Cam survey* ***[need personnel to create]***
- Foreground removal: *galaxy catalogs, CO frequency cross-correlation, anisotropic shape of CO vs [CII] power spectra* ***[personnel needed to develop further]***
- Data analysis schedule: *TBD [depends on above + "products"]*
- Personnel needs/plans: ***25 postdoc years for observations, data analysis, and modeling***