Detection of Cosmological 21cm Emission with CHIME

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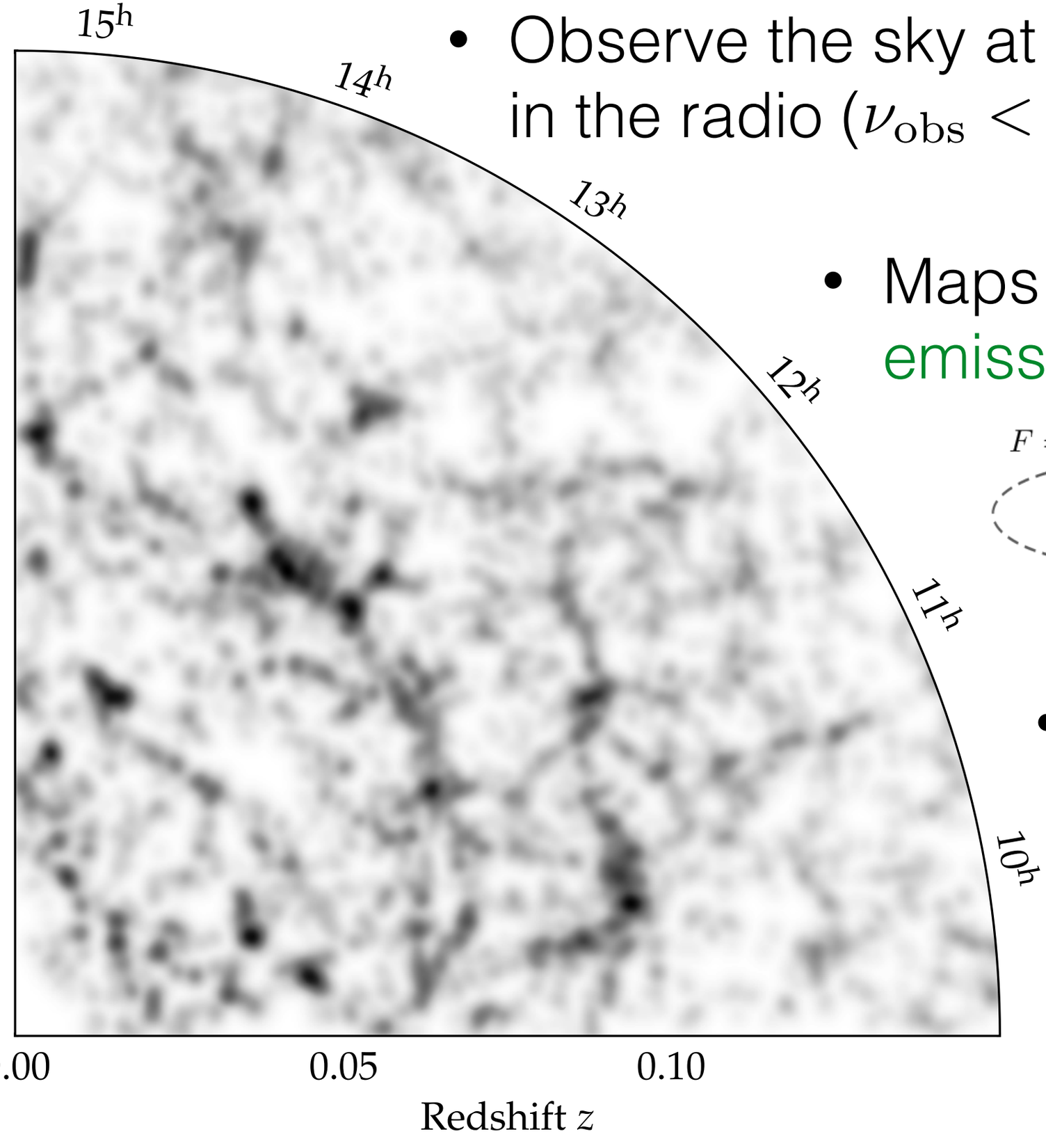
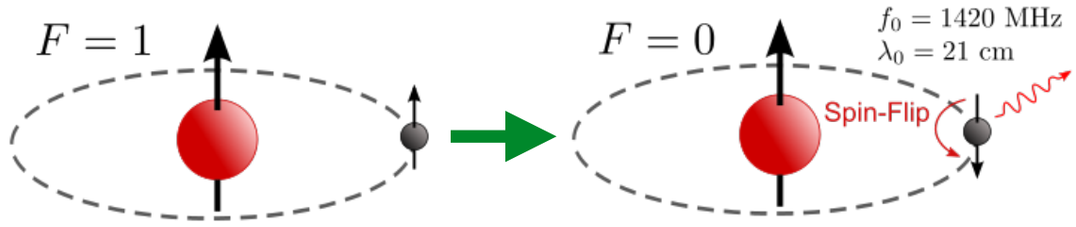
Large-scale structure with 21cm intensity mapping



- Observe the sky at low resolution in the radio ($\nu_{\rm obs} < 1420.4\,{\rm MHz}$)

- Maps contain 21cm line emission from spin flips in HI



- Observing frequency → redshift:

$$z = \frac{1420.4\,{\rm MHz}}{\nu_{\rm obs}} - 1$$

figure: Richard Shaw

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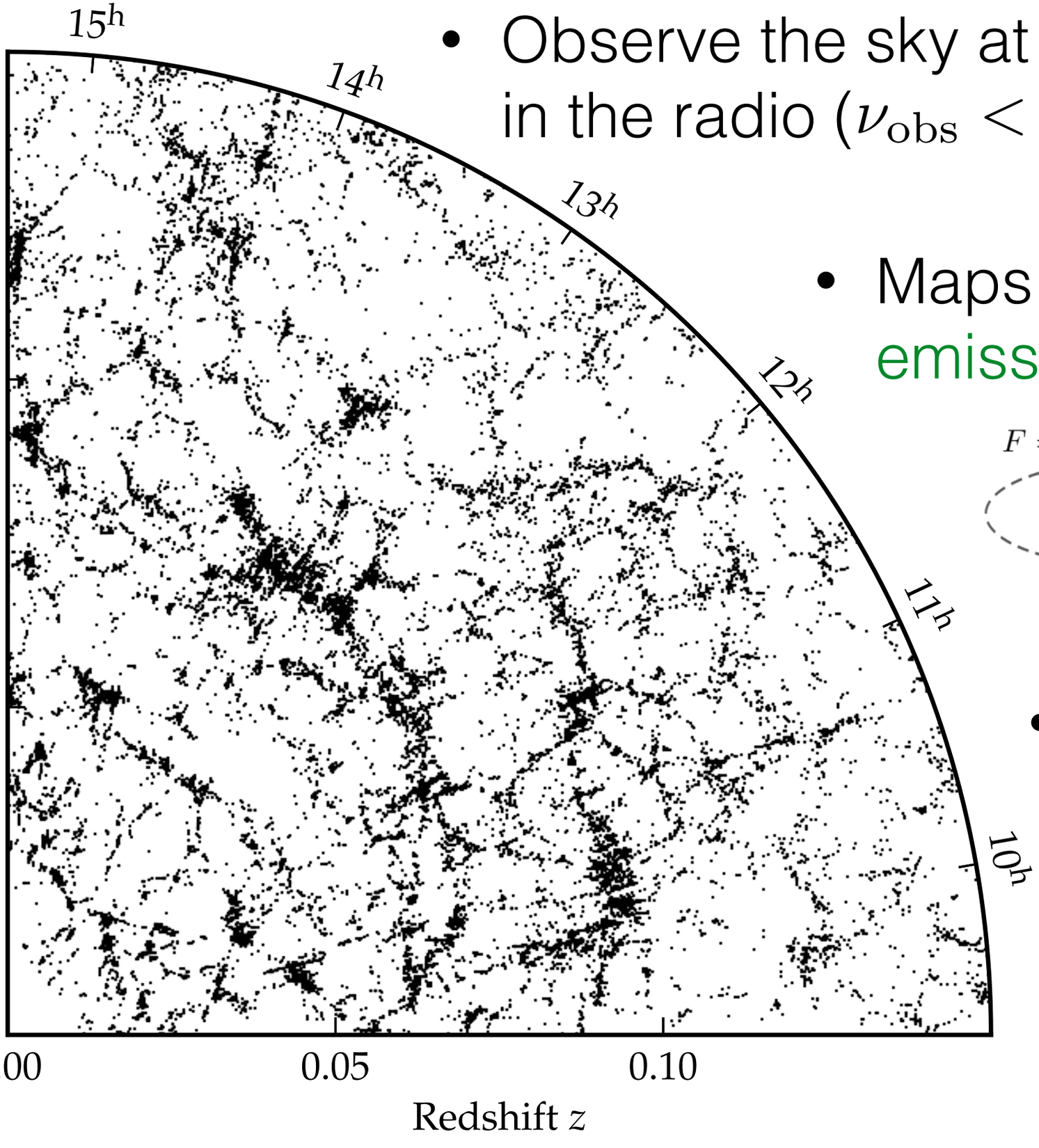

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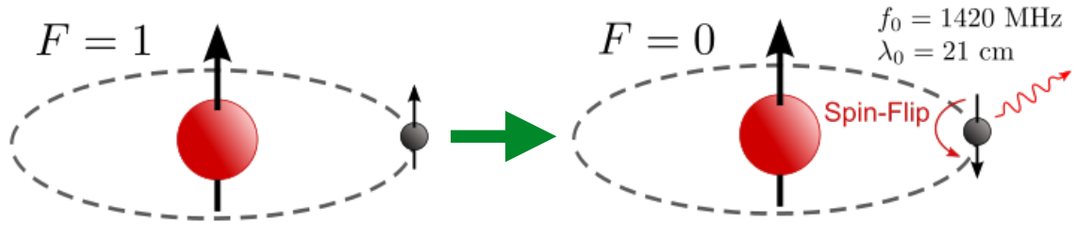

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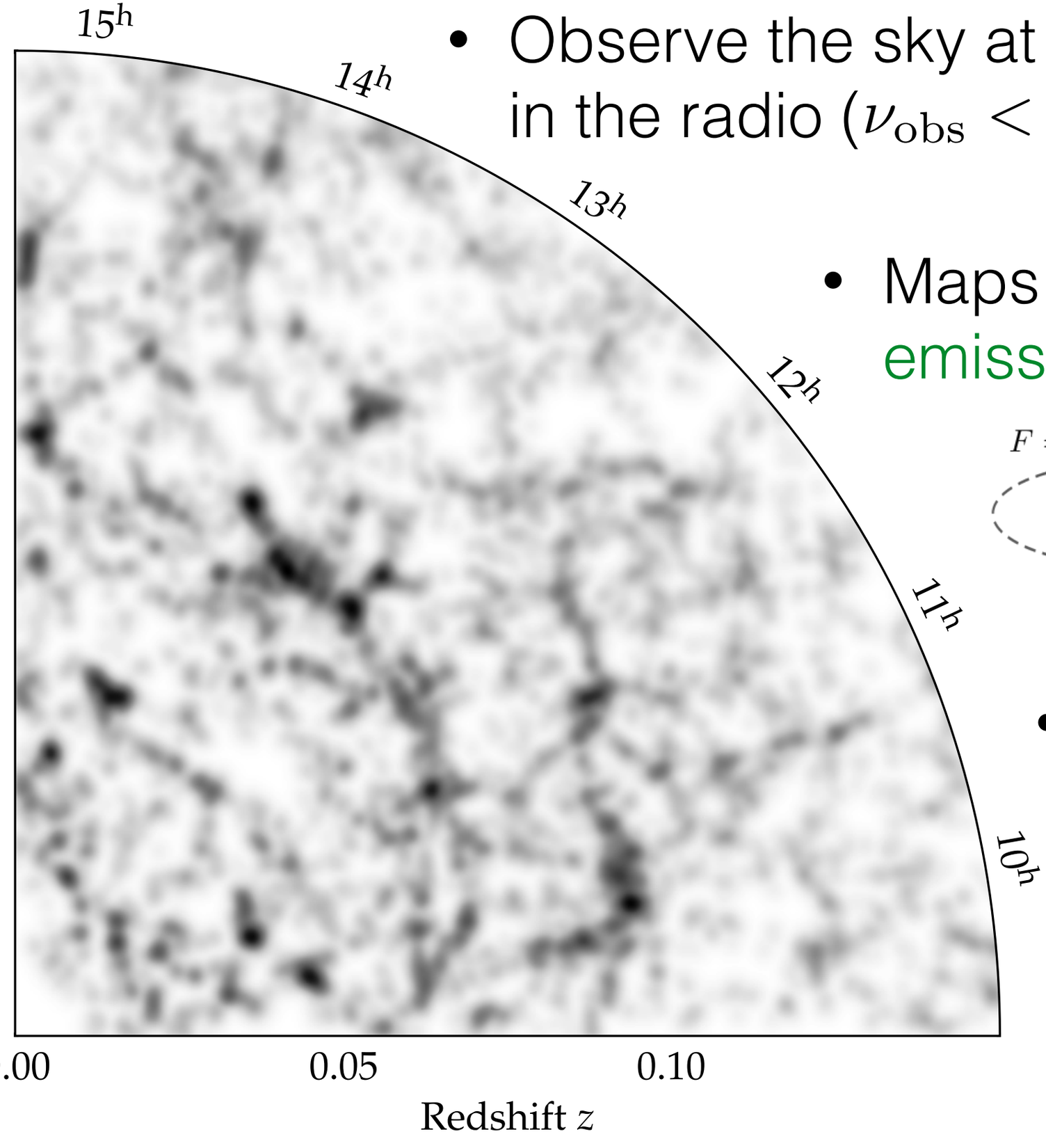

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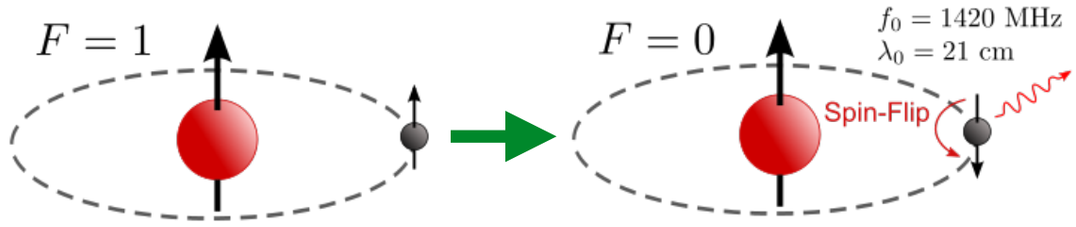

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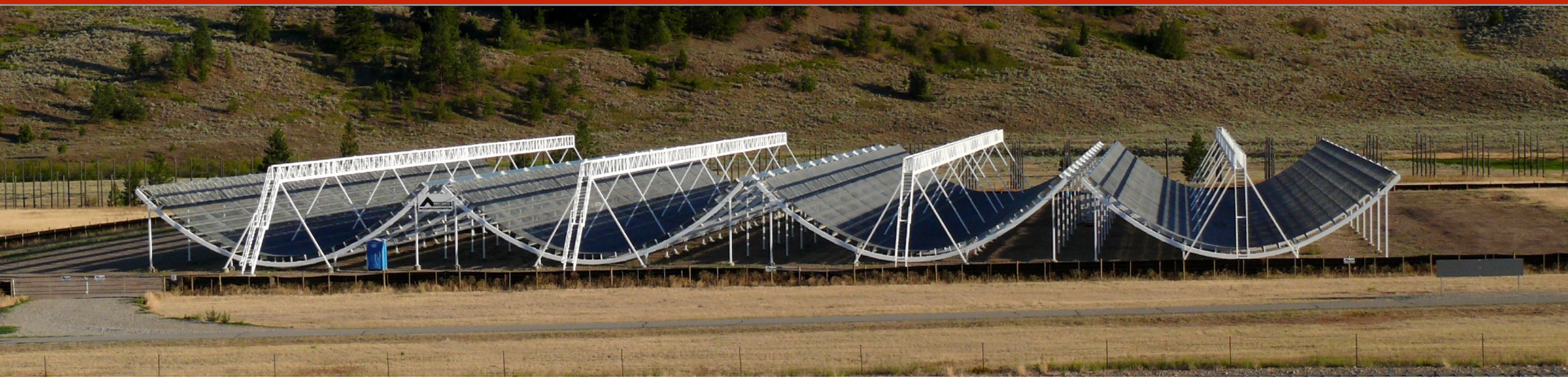
The Canadian Hydrogen Intensity Mapping Experiment



Transit radio interferometer (no moving parts)

1024 dual-polarized antennas

4 cylinders, 20m x 100m each

400 - 800 MHz ($2.5 > z > 0.8$)

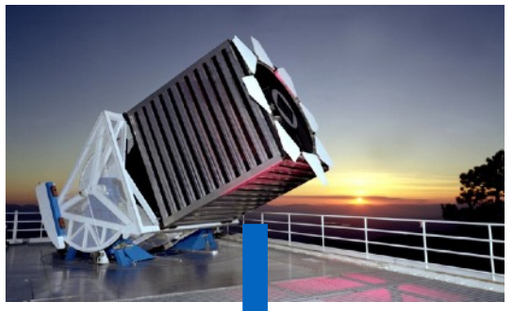
Location

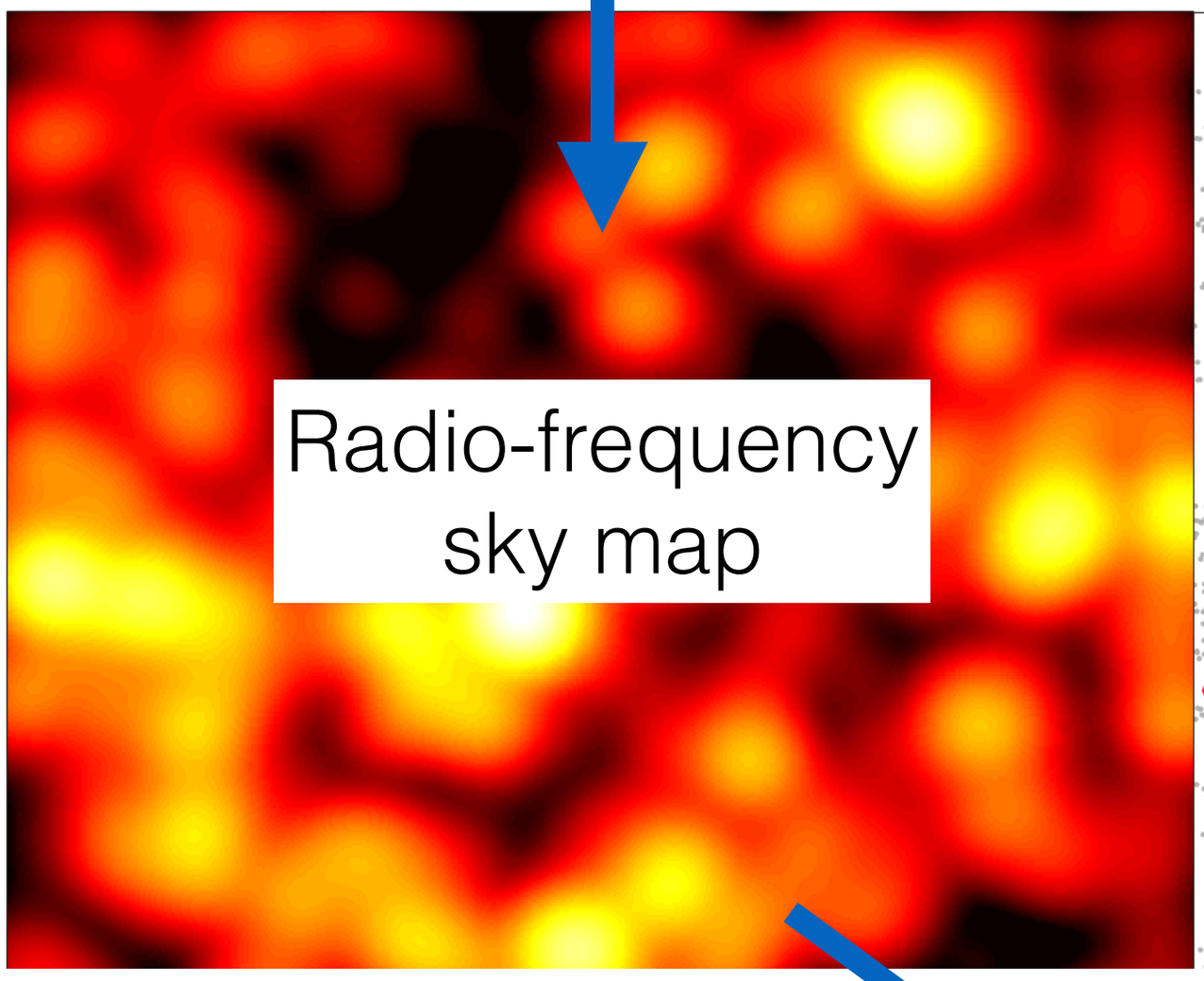

CANADA
GREENLAND
(Denmark)
GROENLAND
(Danemark)
N
W
E
S
Arctic Ocean
Océan Arctique
Baffin Bay
Baie de Baffin
UNITED STATES OF AMERICA
ÉTATS-UNIS D'AMÉRIQUE
Yukon Territory
Territoire-du-Yukon
Whitehorse
Northwest Territories
Territoires-du-Nord-Ouest
Yellowknife
Nunavut
Iqaluit
Labrador sea
Mer du Labrador
Newfoundland and Labrador
Terre-Neuve et Labrador
Hudson Bay
Baie d'Hudson
St. John's
Pacific Ocean
Océan Pacifique
British Columbia
Colombie-Britannique
Alberta
Edmonton
Calgary
Saskatchewan
Regina
Manitoba
Winnipeg
Ontario
Quebec
Québec
Québec
Prince Edward Island
Île du Prince-Édouard
Charlottetown
Nova Scotia
Nouvelle-Écosse
Fredericton
Halifax
New Brunswick
Nouveau-Brunswick
Montréal
Ottawa
Toronto
Victoria
chime
Ingenio Canada Map Floor Puzzle

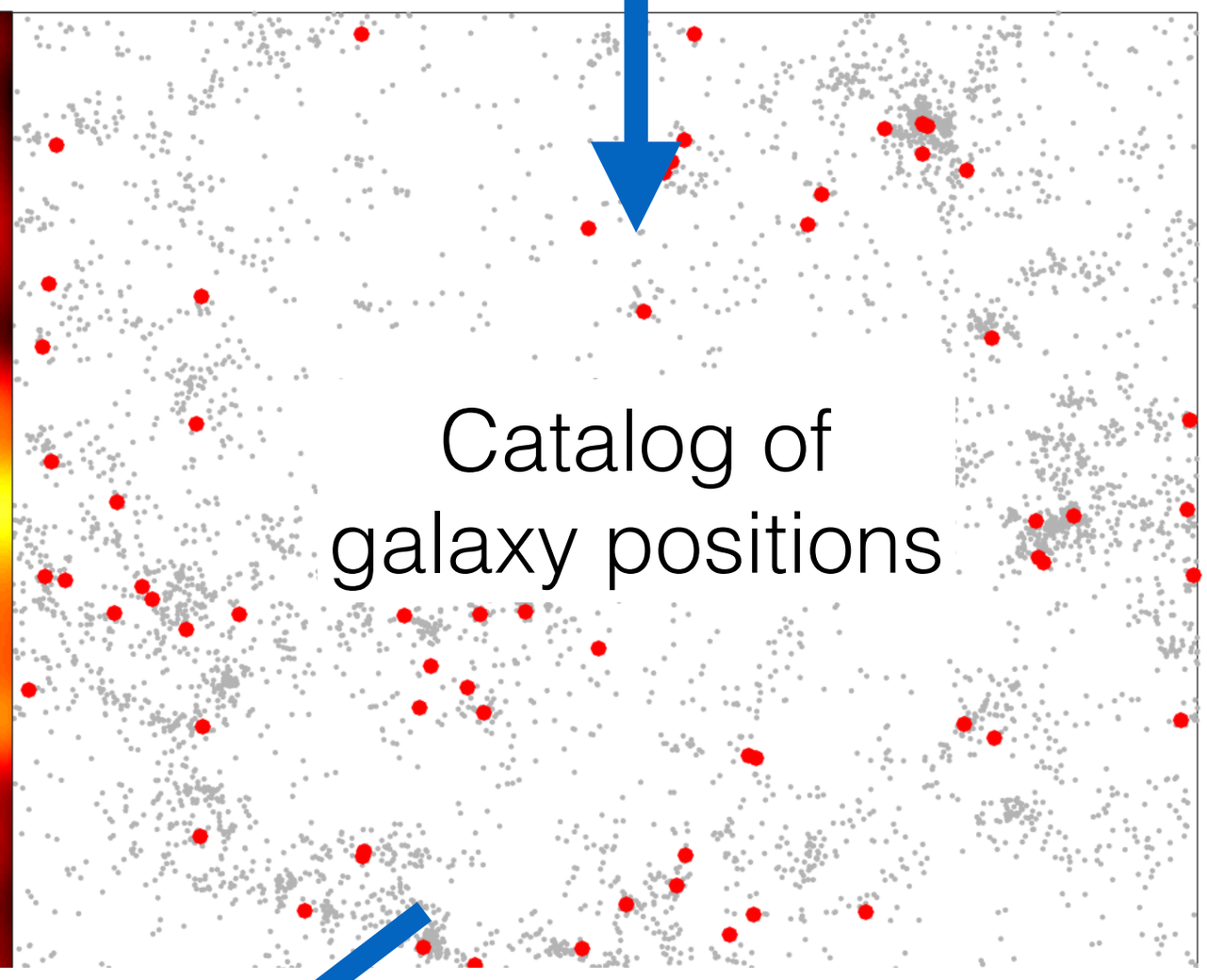
Location

We acknowledge that CHIME is located on the traditional, ancestral, and unceded territory of the Syilx Okanagan people.

First cosmology analysis

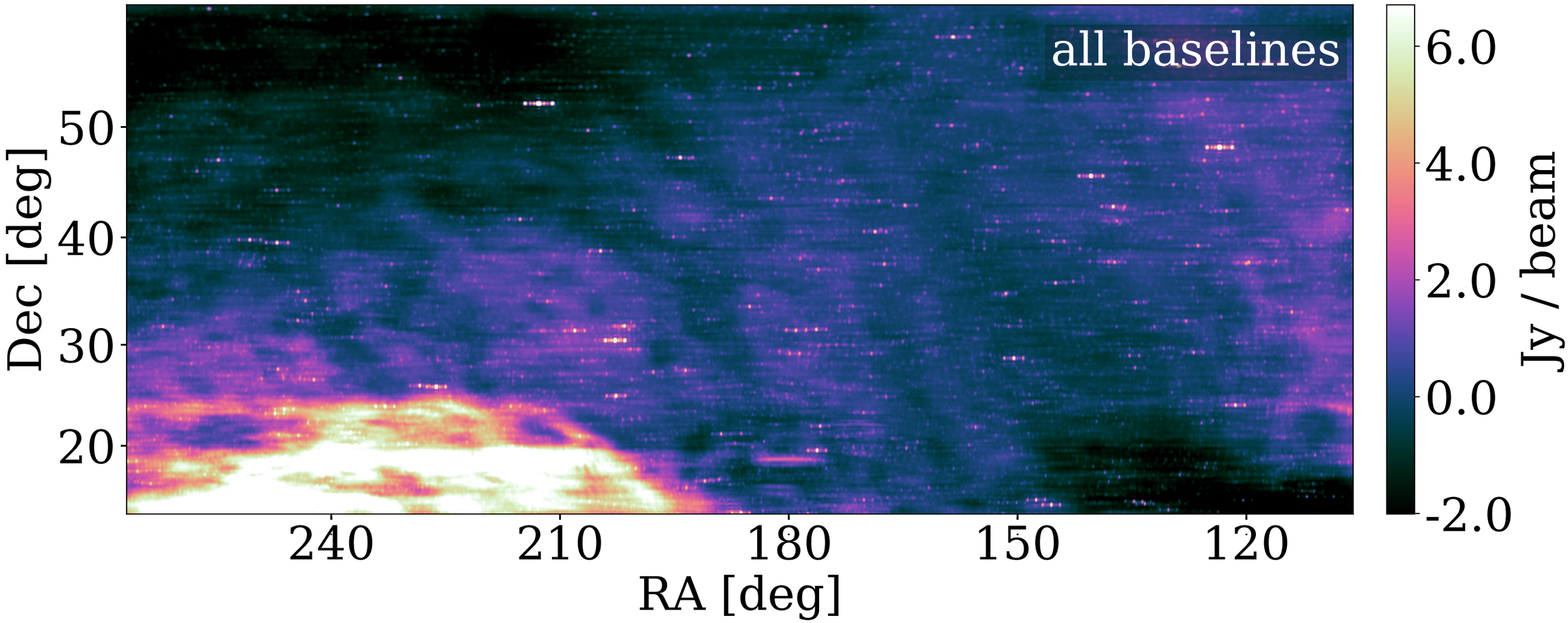






Measure **correlation**

CHIME sky map at 700MHz ($z \simeq 1$)



Roughly 500 hours (~22 days) of integration time

(Total collected so far: ~ 3 years)

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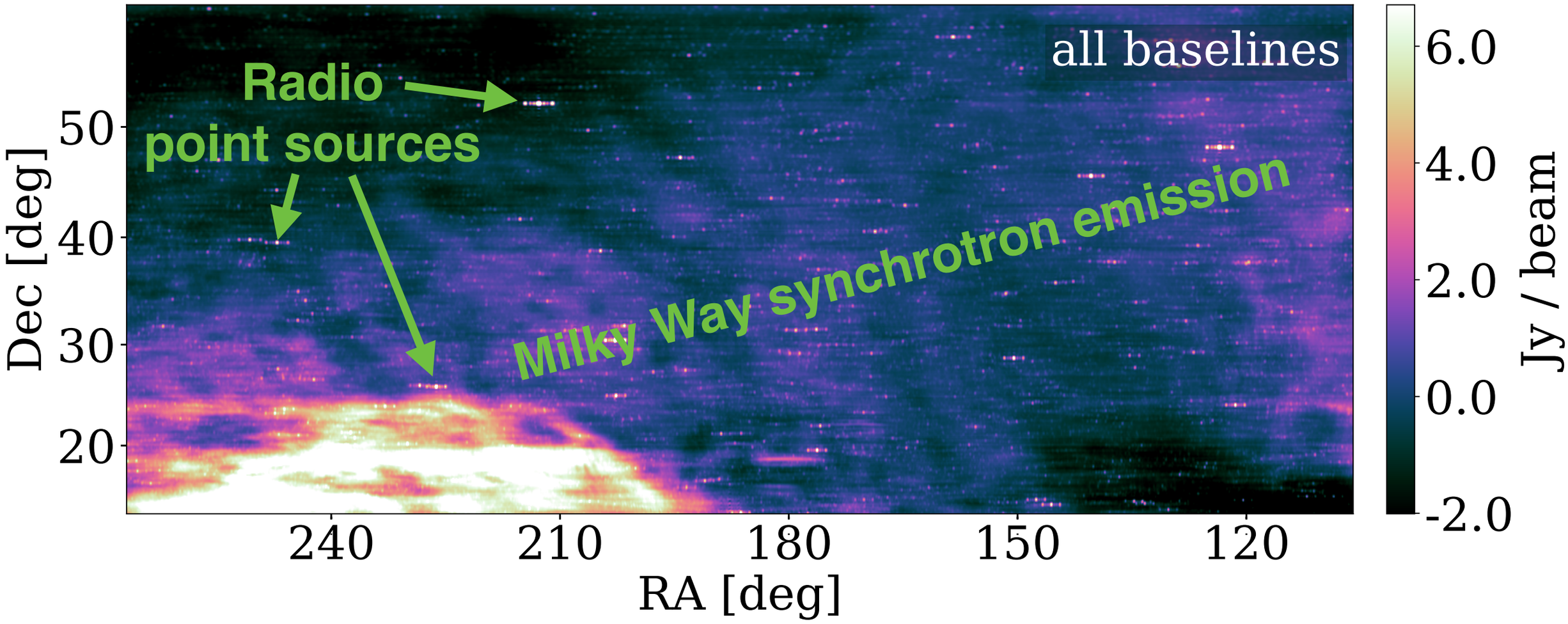

Roughly 500 hours (~22 days) of integration time

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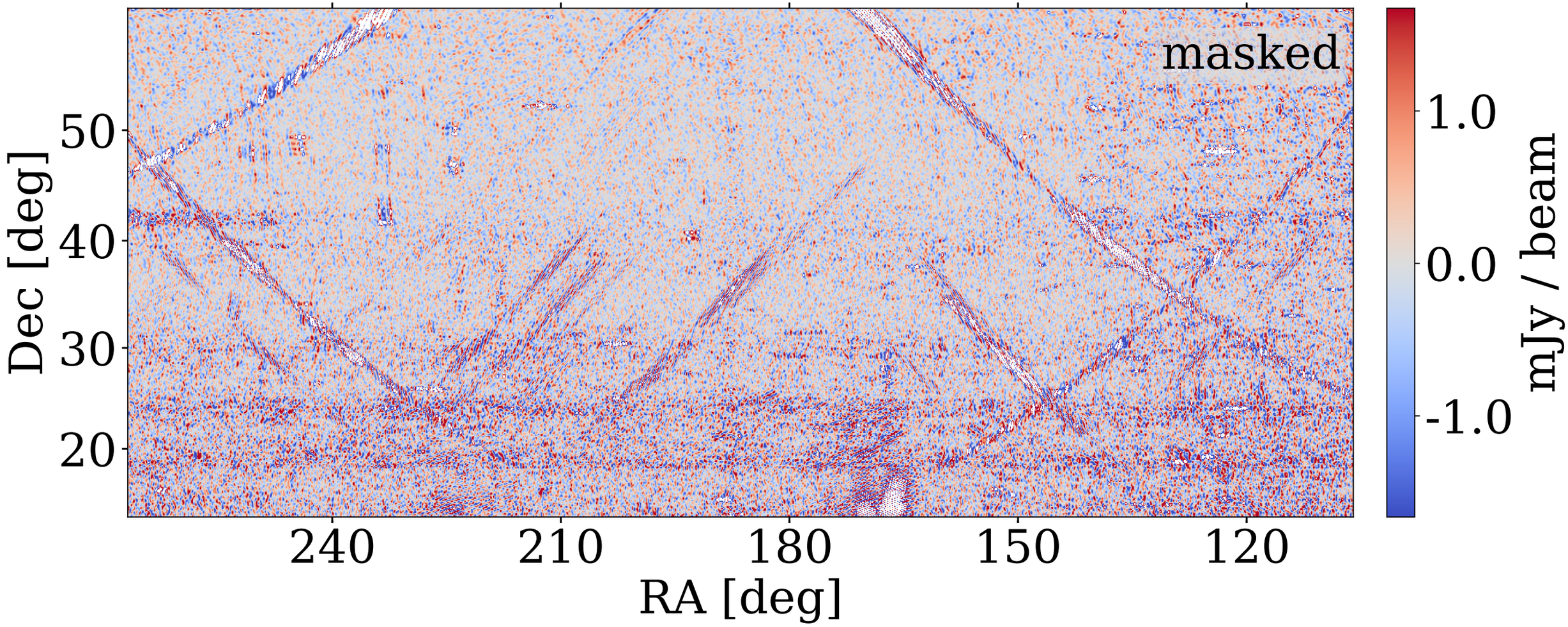
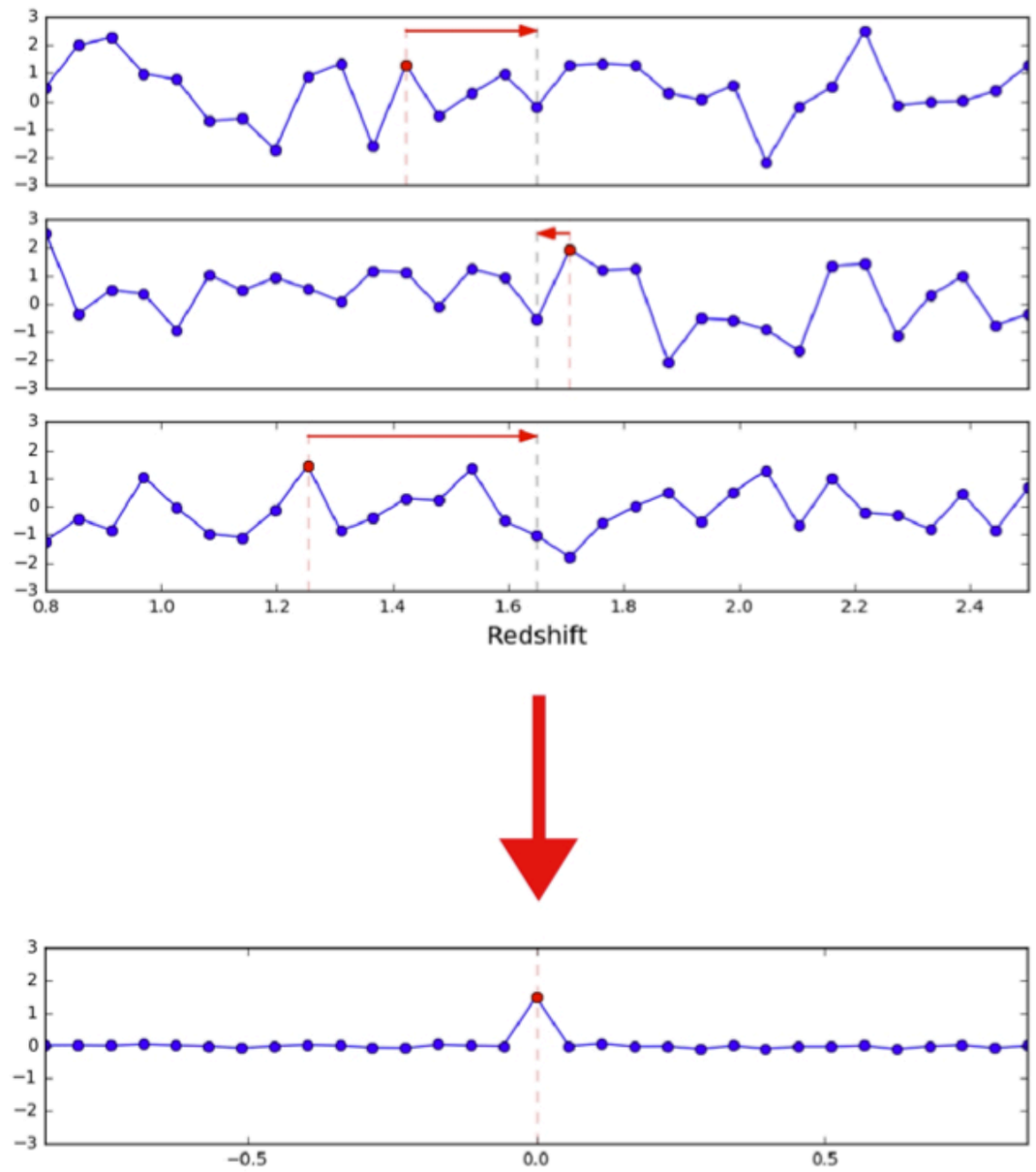
CHIME sky map at 700MHz ($z \simeq 1$): filtered

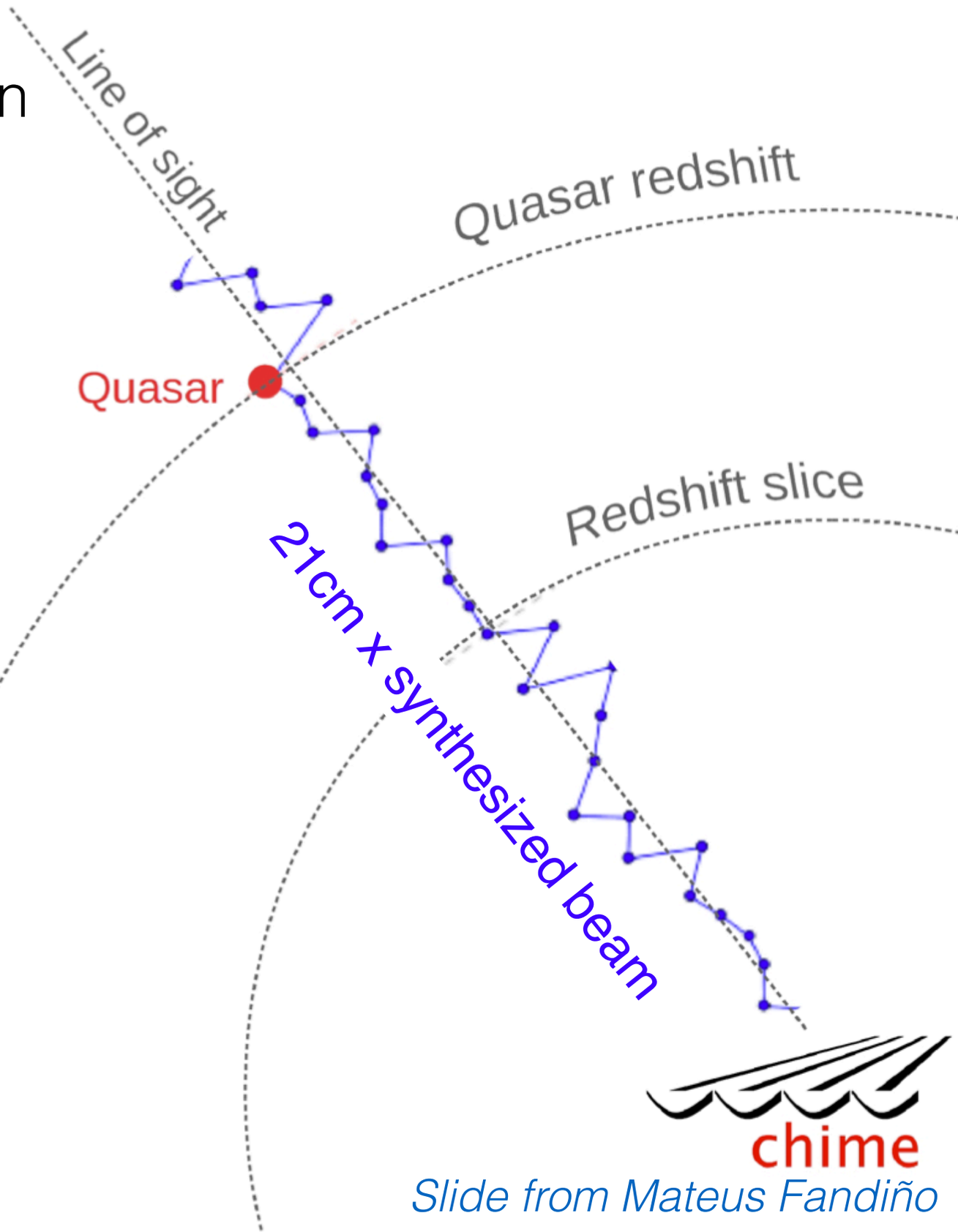


- Apply **high-pass spatial filter**: resolve out diffuse MW emission
- Apply **high-pass filter along frequency axis**:
  remove spectrally-smooth point sources
- **Mask pixels** >6 times expected noise level:
  mitigate residuals from bright point sources

Cross correlations: method

- Extract 1d “pencil beam” from map, at angular location of each catalog object
- Shift ν axis and stack





chime

Slide from Mateus Fandiño

Stacking signal for all eBOSS catalogs

ELG

31k objects, z_{eff} = 0.96

S/N ~ 5.7

LRG

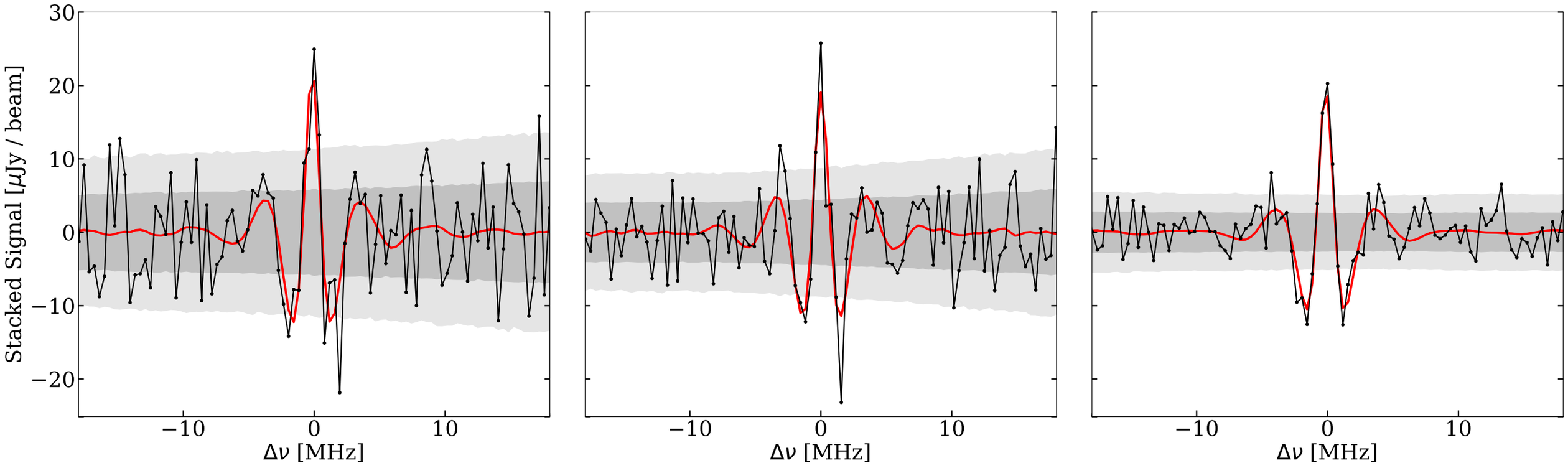
22k objects, z_{eff} = 0.84

S/N ~ 7.1

QSO

48k objects, z_{eff} = 1.20

S/N ~ 11.1

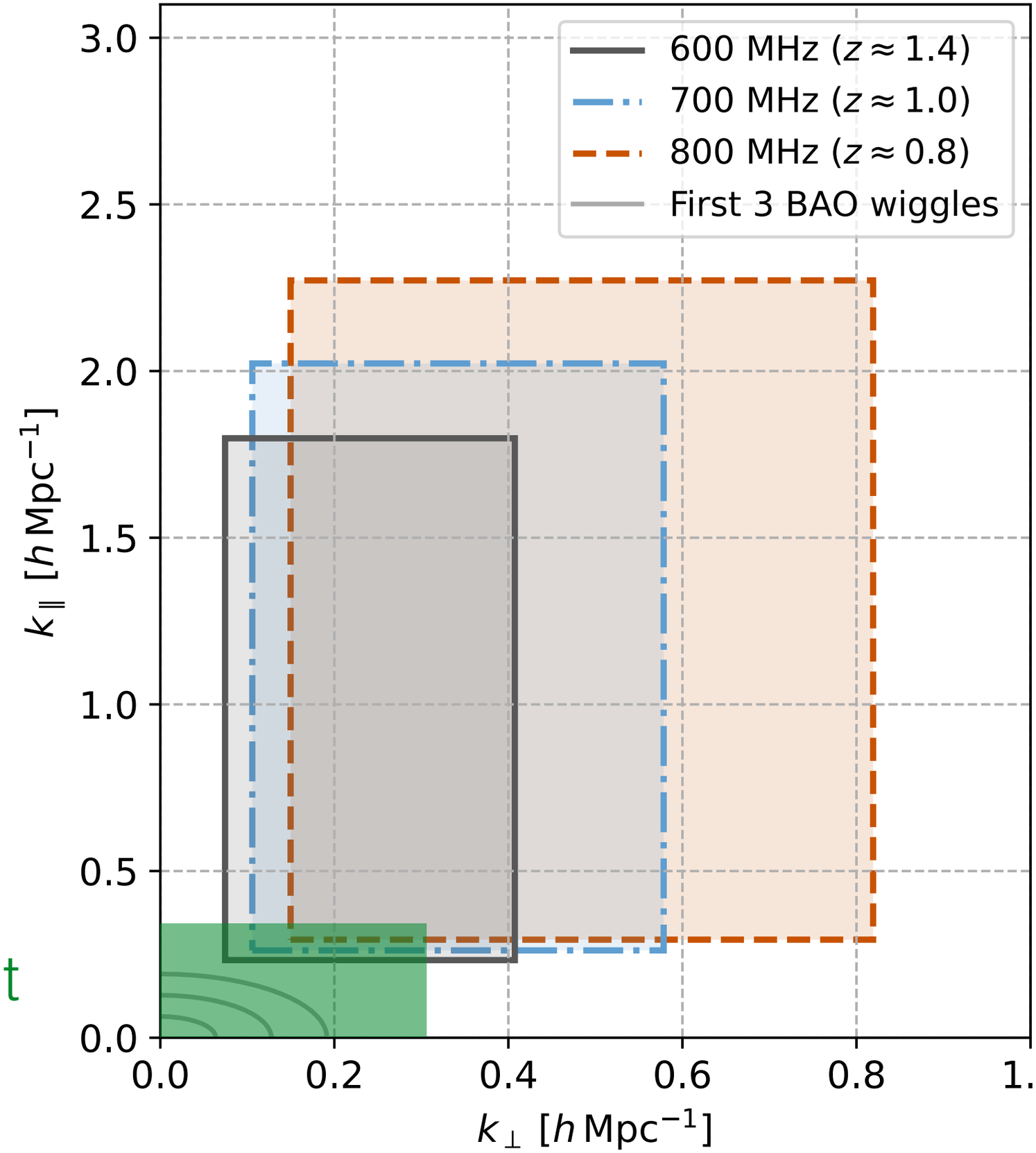


First 21cm IM measurement:

- With custom-built instrument
- With interferometric telescope
- At redshifts > 1.2

Cosmological scales probed

Small spectral scales

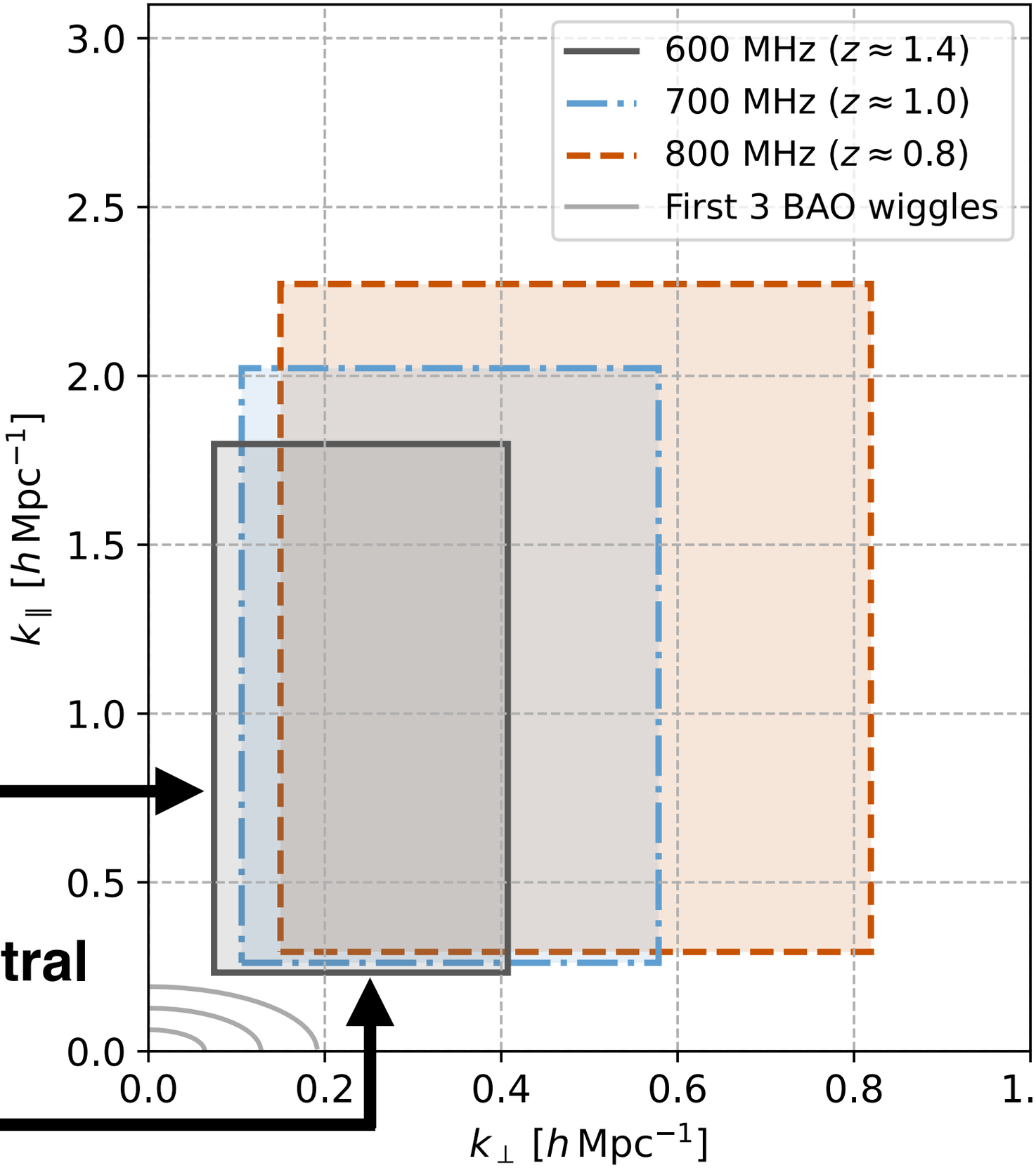


Main target

Small angular scales

Cosmological scales probed

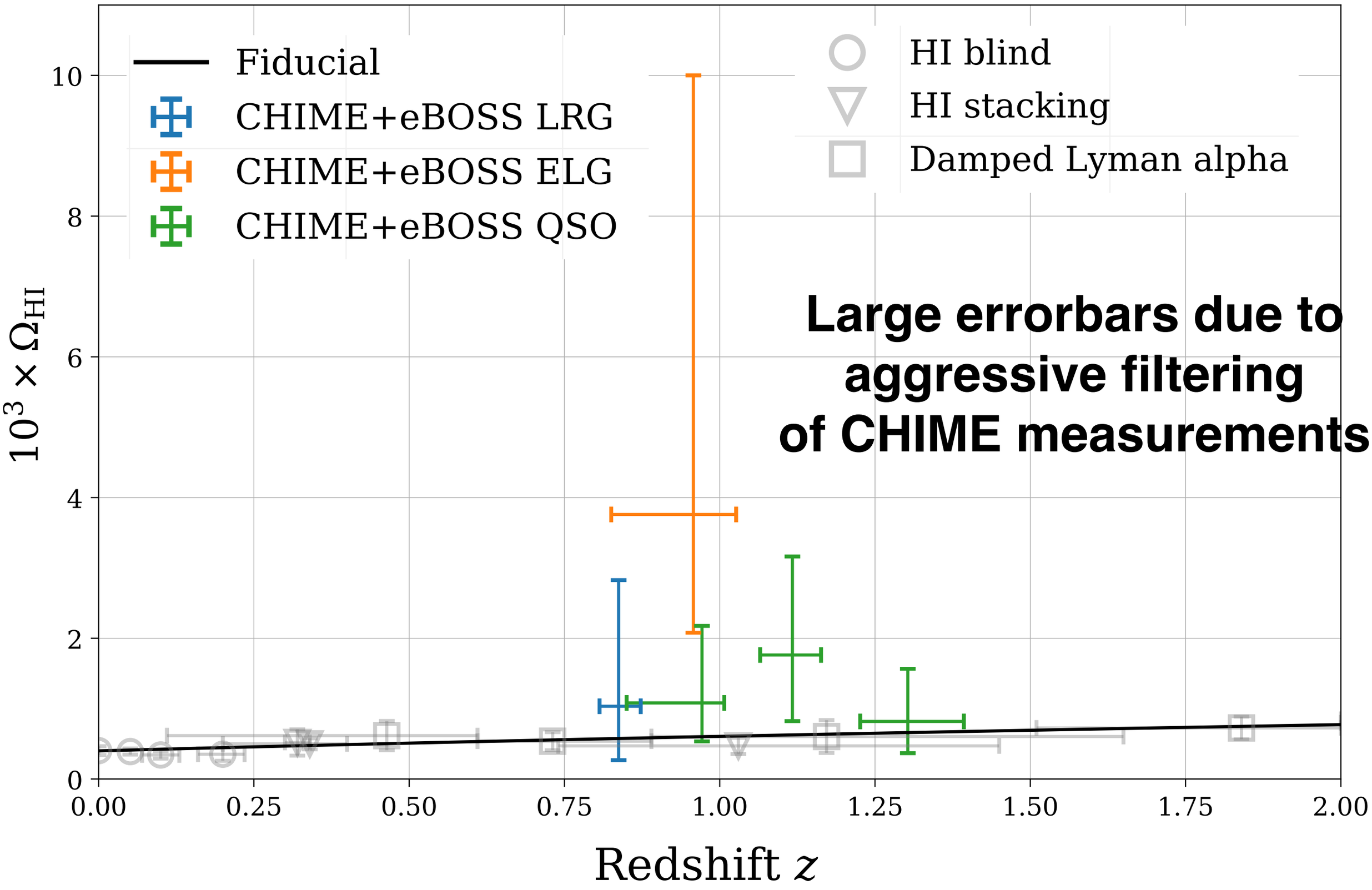
Small spectral scales



Set by spatial + spectral filtering

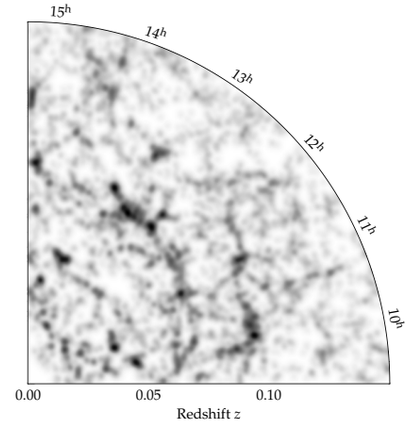
Small angular scales

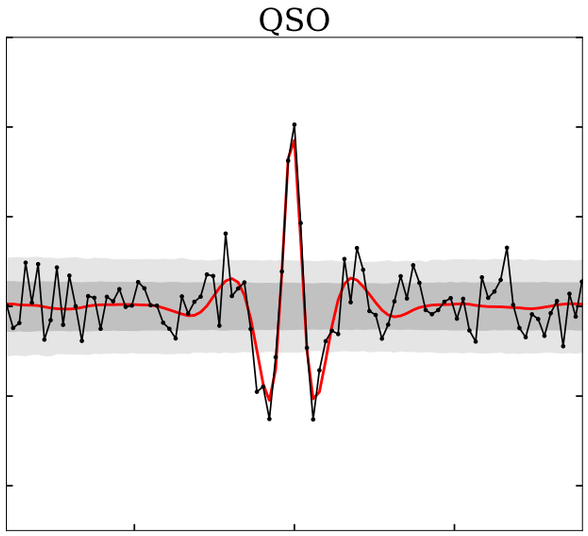
Constraints on mean HI density



Summary

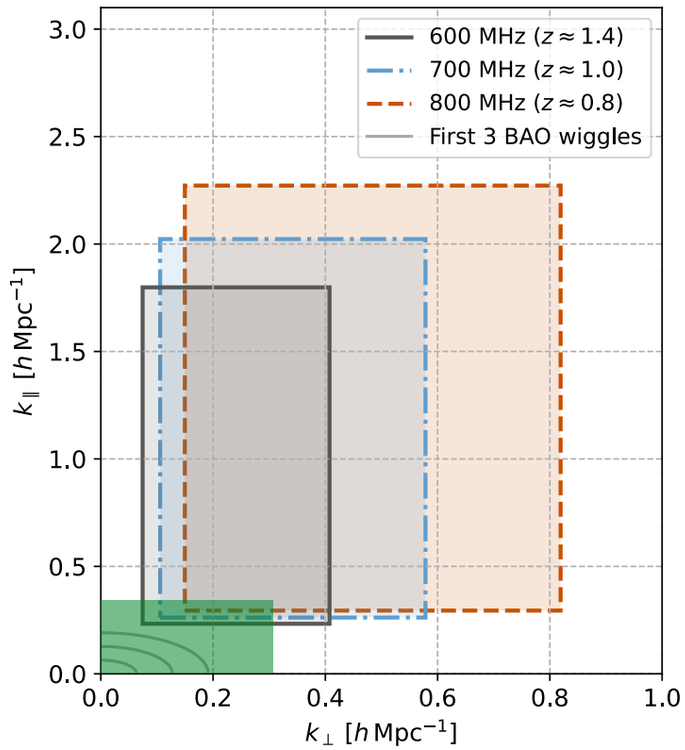
- CHIME is mapping large-scale structure from $z = 0.8$ to 2.5 using 21cm intensity mapping





- We have measured cross-correlations between CHIME sky maps and 3 galaxy/QSO catalogs from eBOSS, at >5σ

- Future analyses will push into regime where modelling is cleaner



CHIME overview paper: arXiv:2201.07869

Detection paper: arXiv:2202.01242