

Probing Dark Energy with the
Canadian Hydrogen Intensity
Mapping Experiment

Richard Shaw



a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

CANADA



bald eagle



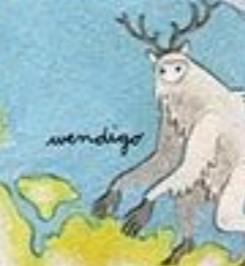
snowshoe hare



arctic fox



muskox



wendigo



narwhal



cougar



black bear



mountain goat



caribou



polar bear



harp seal



puffin



mink



moose



grey squirrel



wood duck



blue jay



lobster



robin



golden winged warbler



loon



beaver



bison



turtle



frog



bison



leopard frog



golden winged warbler



loon



beaver



bison



turtle



frog



golden winged warbler



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beaver



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golden winged warbler



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golden winged warbler



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beaver



bison



turtle



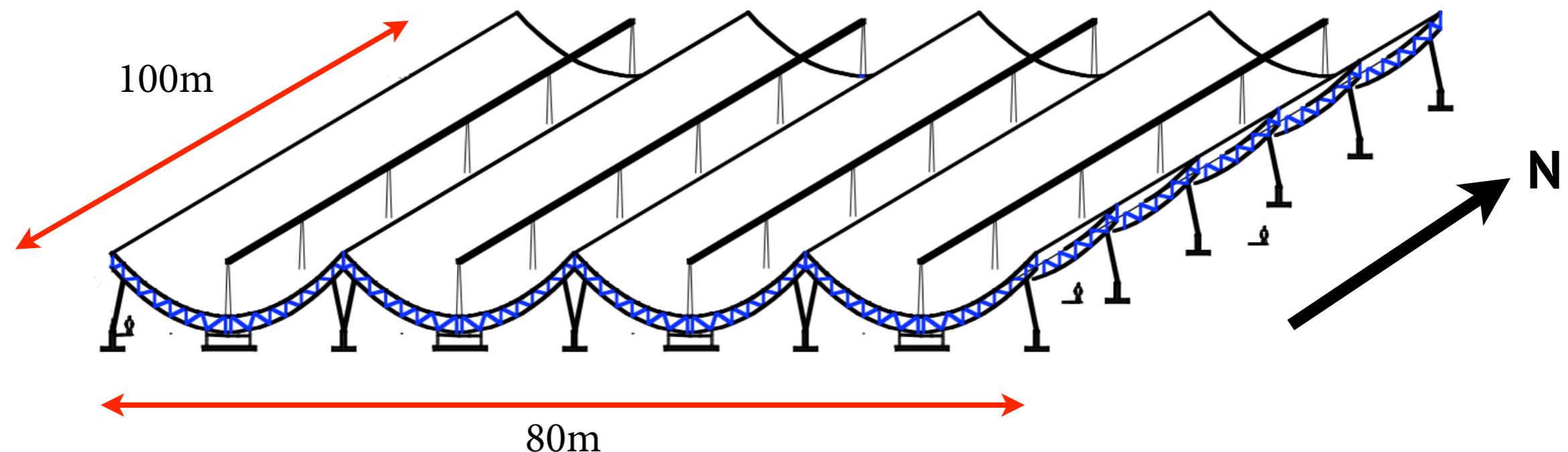
frog



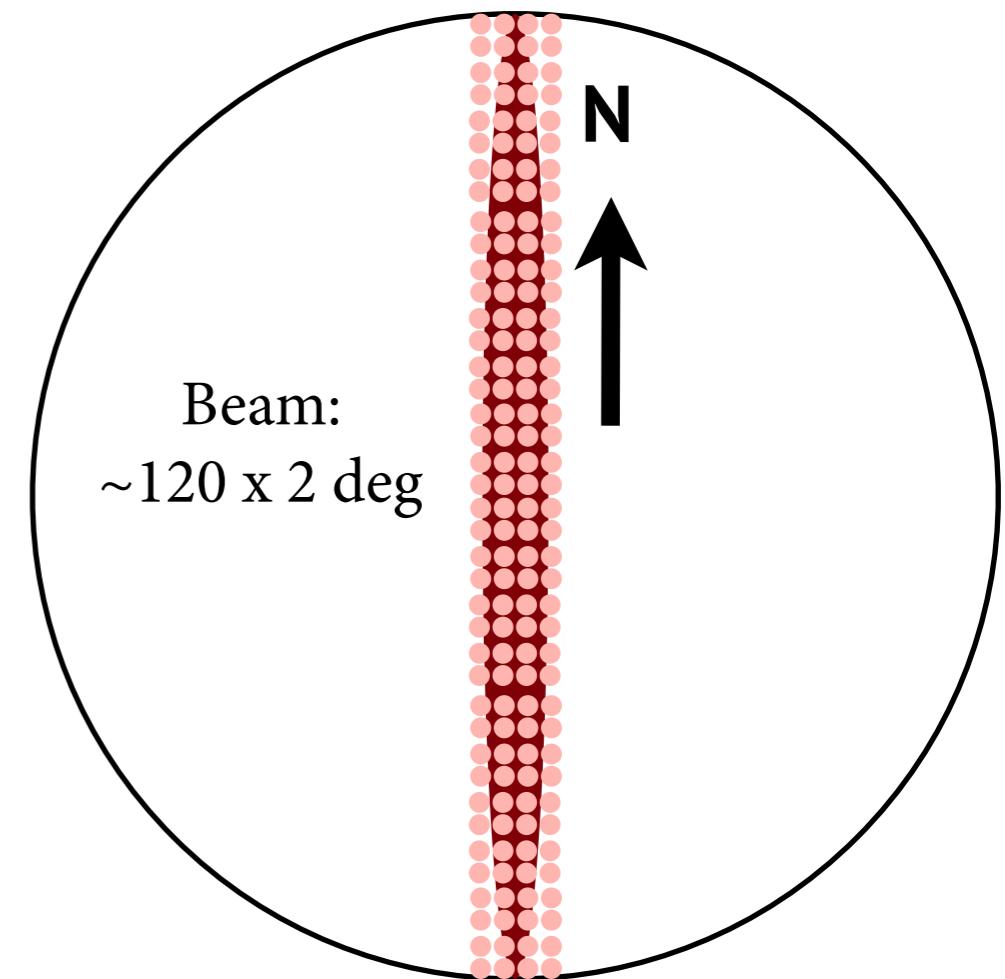
golden winged warbler



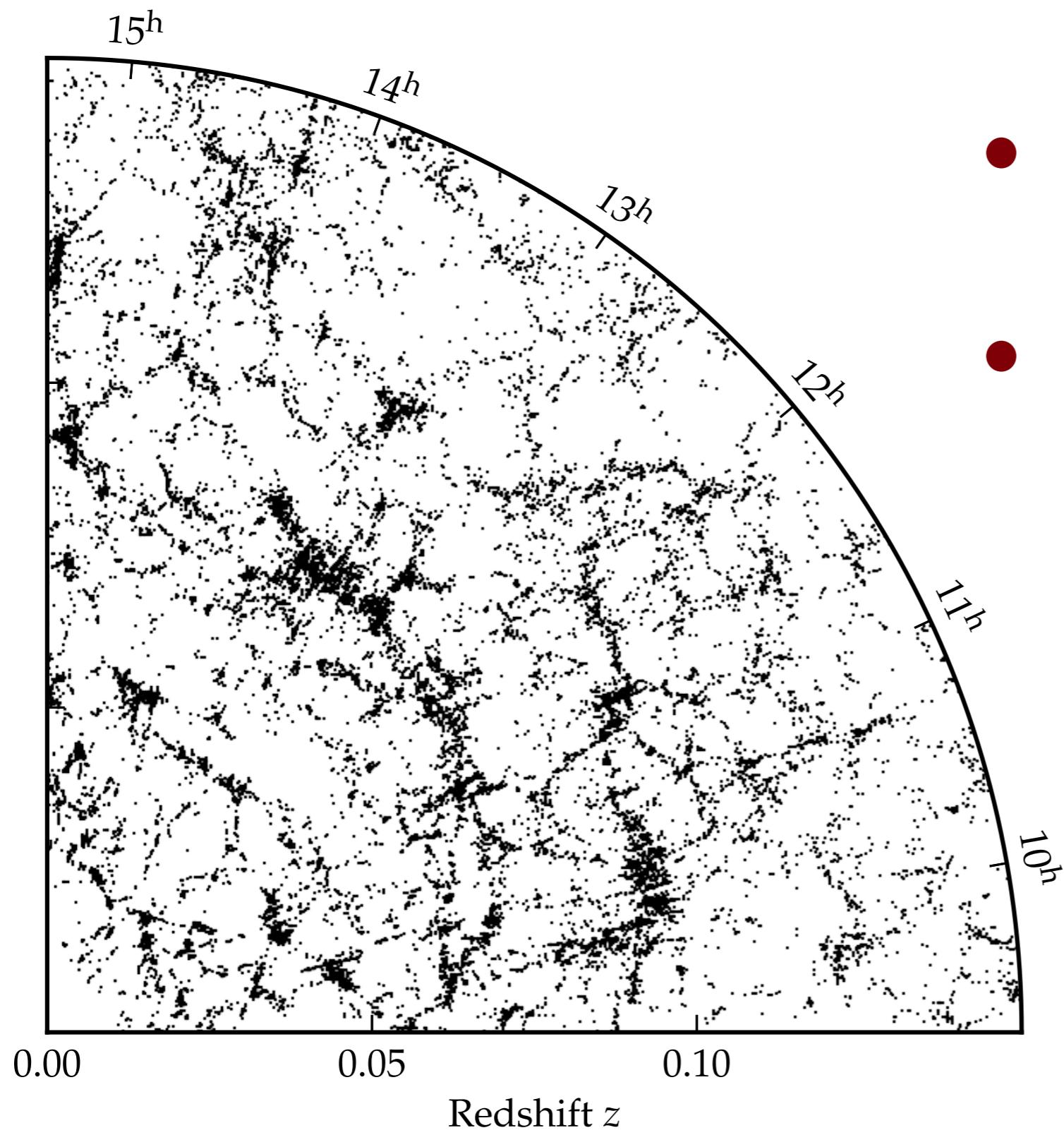
CHIME Overview



- Science Goals
 - ▶ Intensity mapping for BAOs
 - ▶ Pulsar observations
 - ▶ Radio transients
 - ▶ Fully funded!



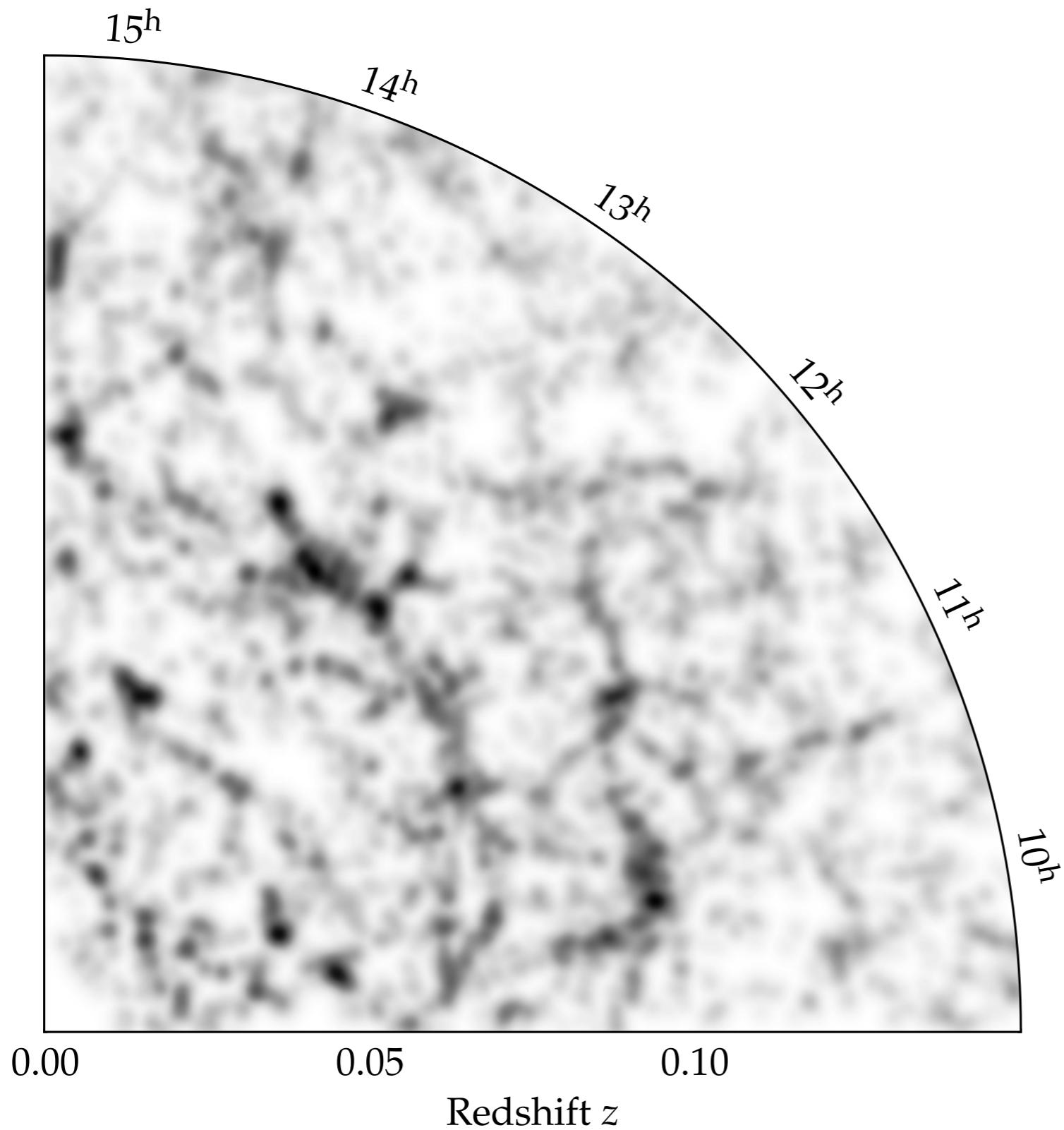
Galaxy Redshift Survey



- Detect all galaxies with high significance.
- Take spectra to determine redshift

Only interested in large scales

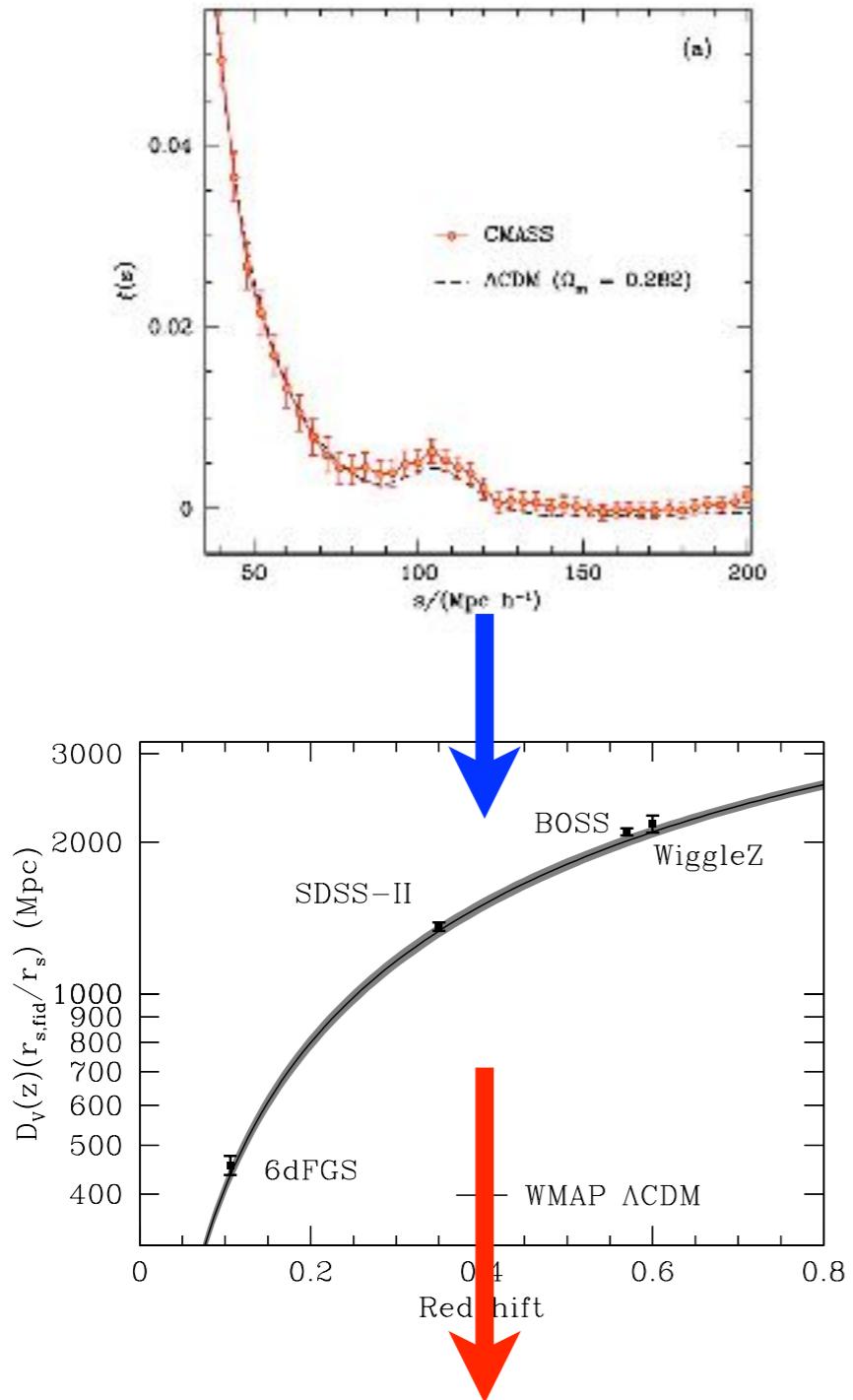
Intensity Mapping



- Observe galaxies with a line transition
- Automatically gives redshift

Don't need to resolve individual galaxies

Probing Dark Energy

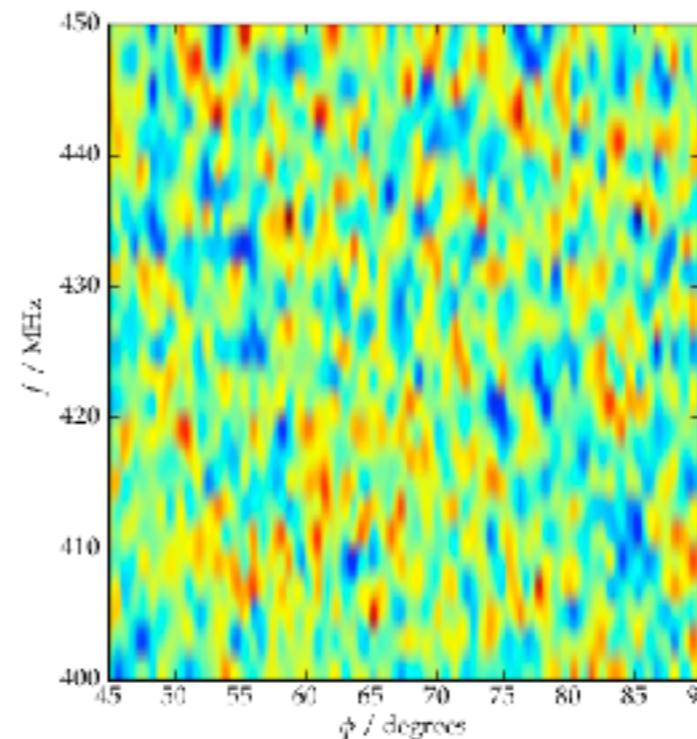
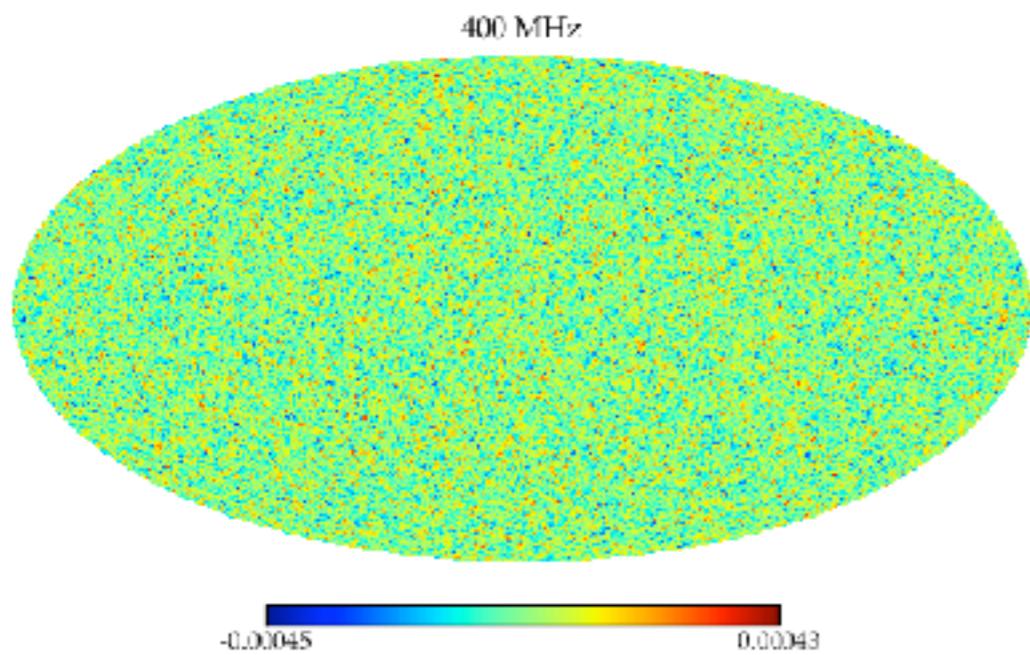


Measure BAO scale from clustering
and turn into dark energy constraints

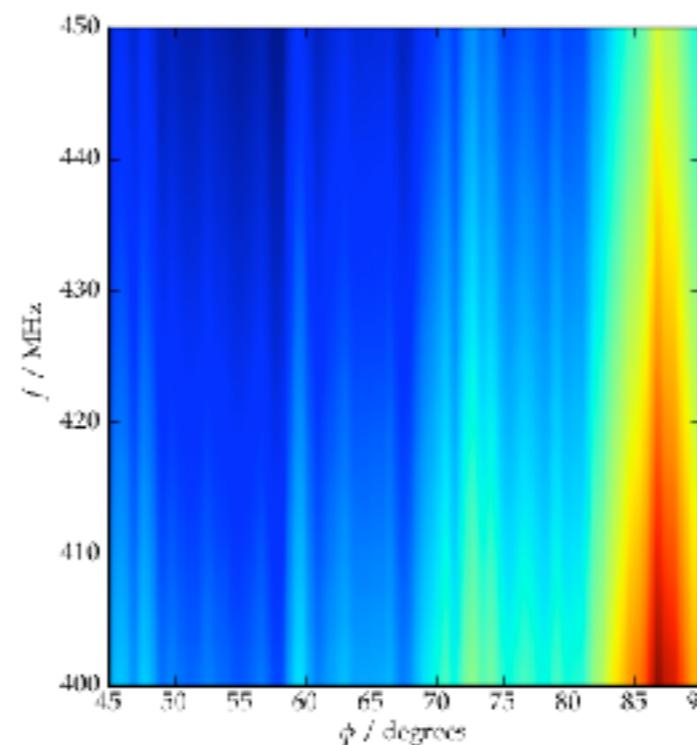
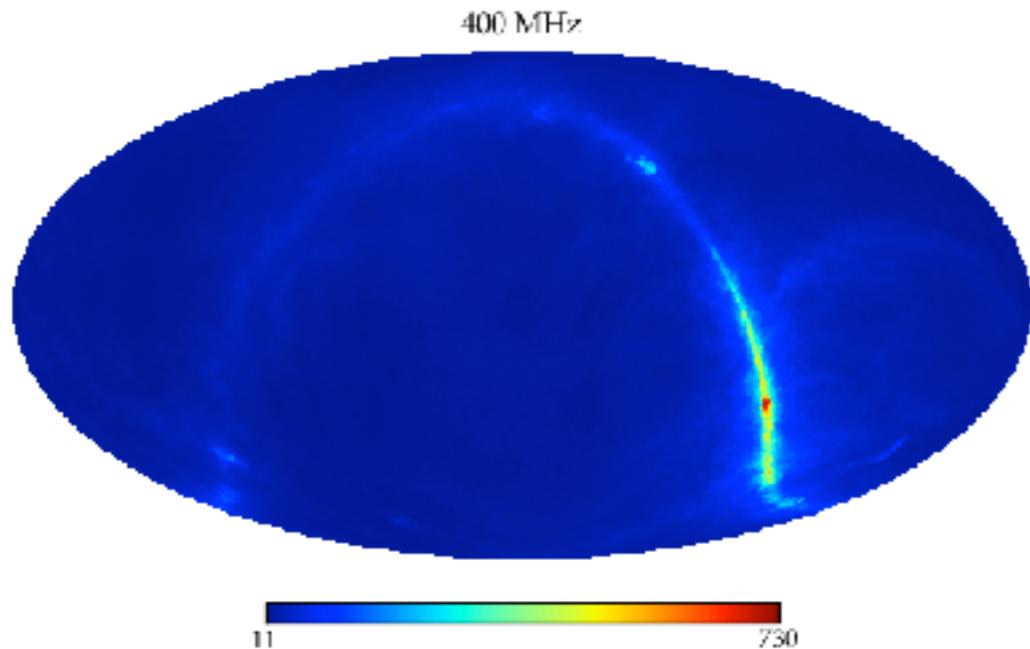
Constraints on
theory of dark
energy

$$H(z)^2 \approx \Omega_m(1+z)^3 + \Omega_{DE} \exp \left[\int_0^z (1+w(z)) \frac{dz}{1+z} \right]$$

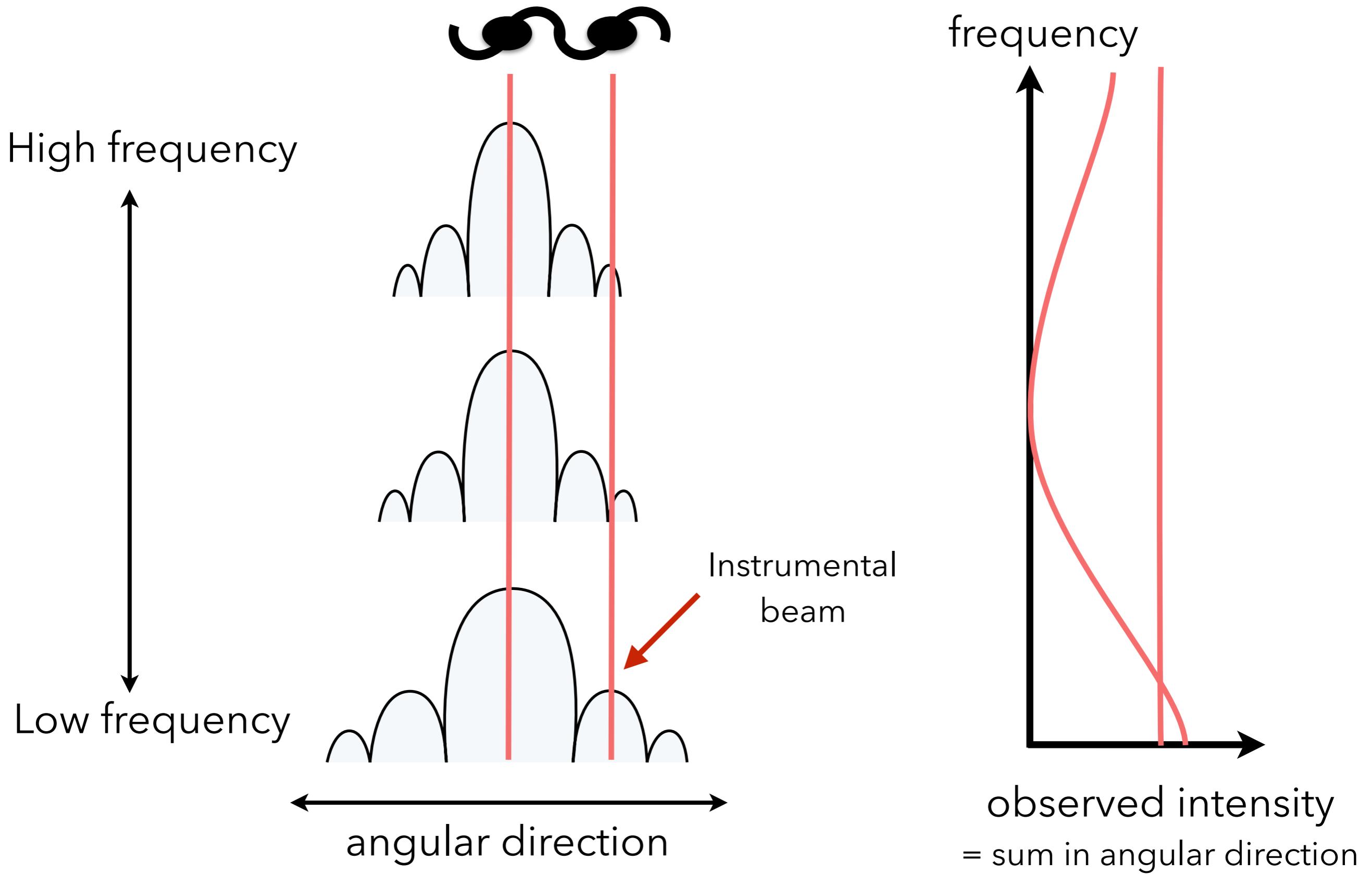
Foreground challenges?



Remove smooth frequency modes

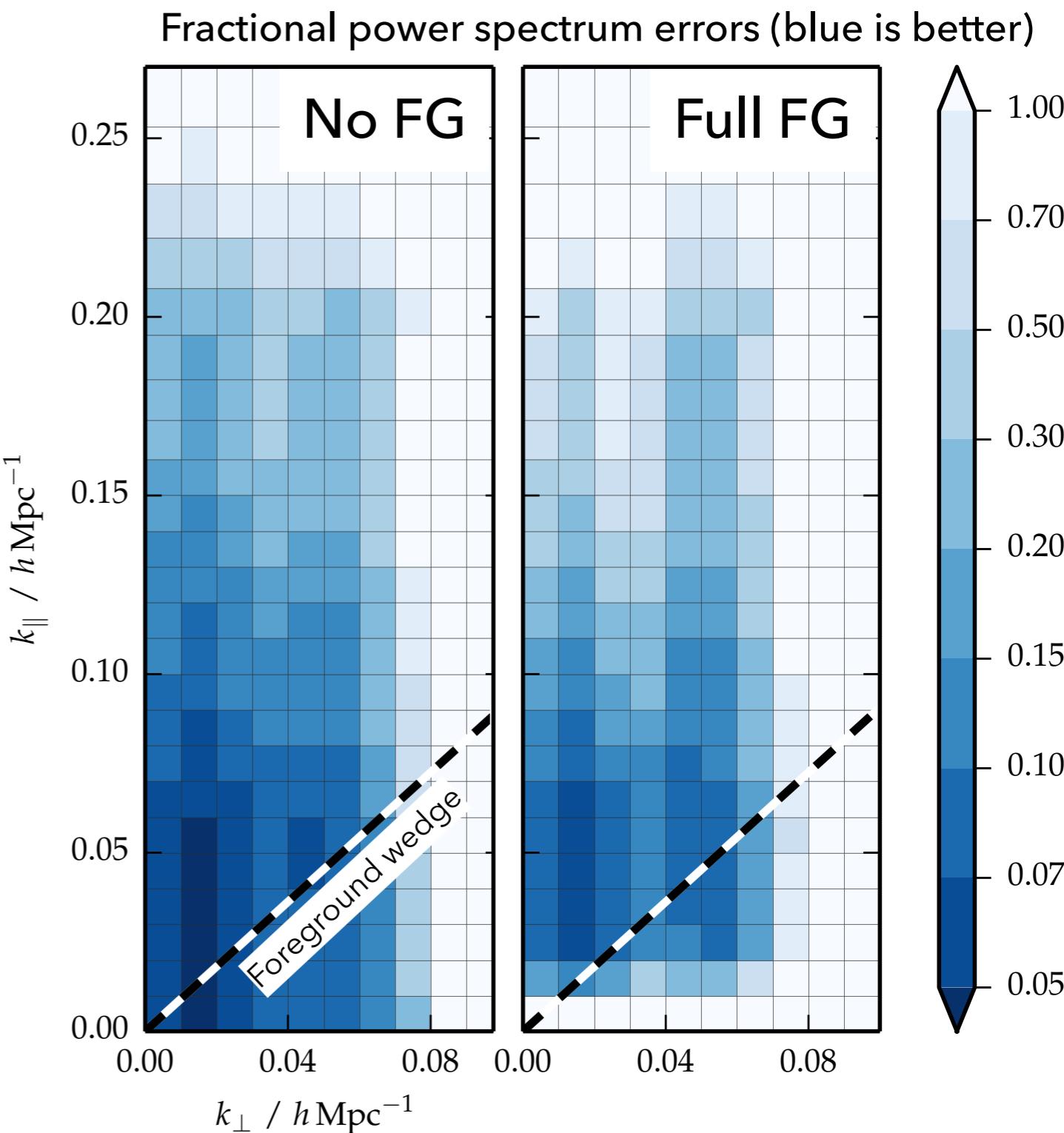


Issue: Mode mixing



Foreground Cleaning

- Foreground problem is tractable
- Lots of active research (KL-filtering: JRS+ 2014, 2015, Delay spectrum: Parsons 2012 ...)
- Level of success depends on instrumental knowledge (beams, gains...)
- Don't see every mode in volume (missing large scale radial modes)





 McGill



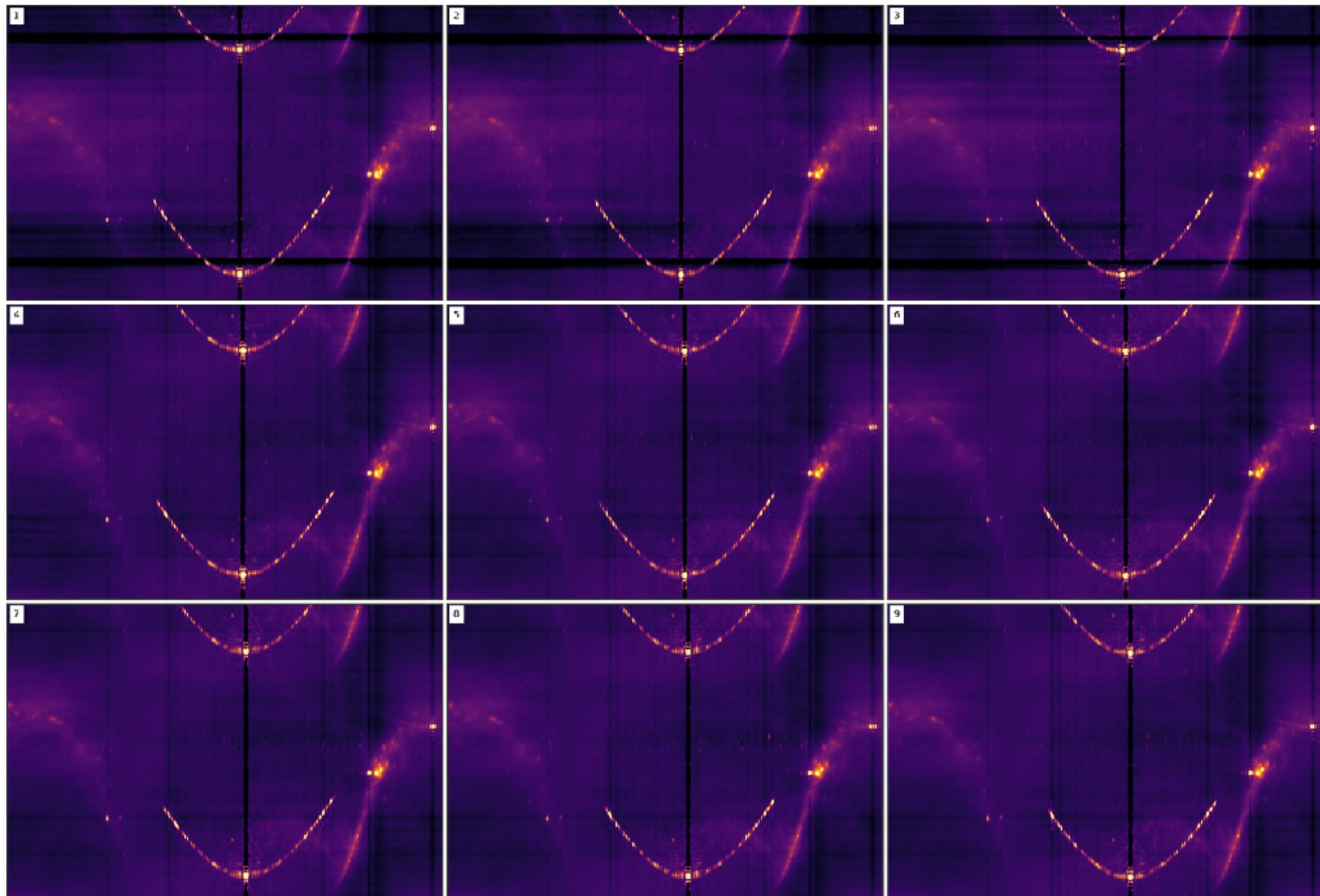
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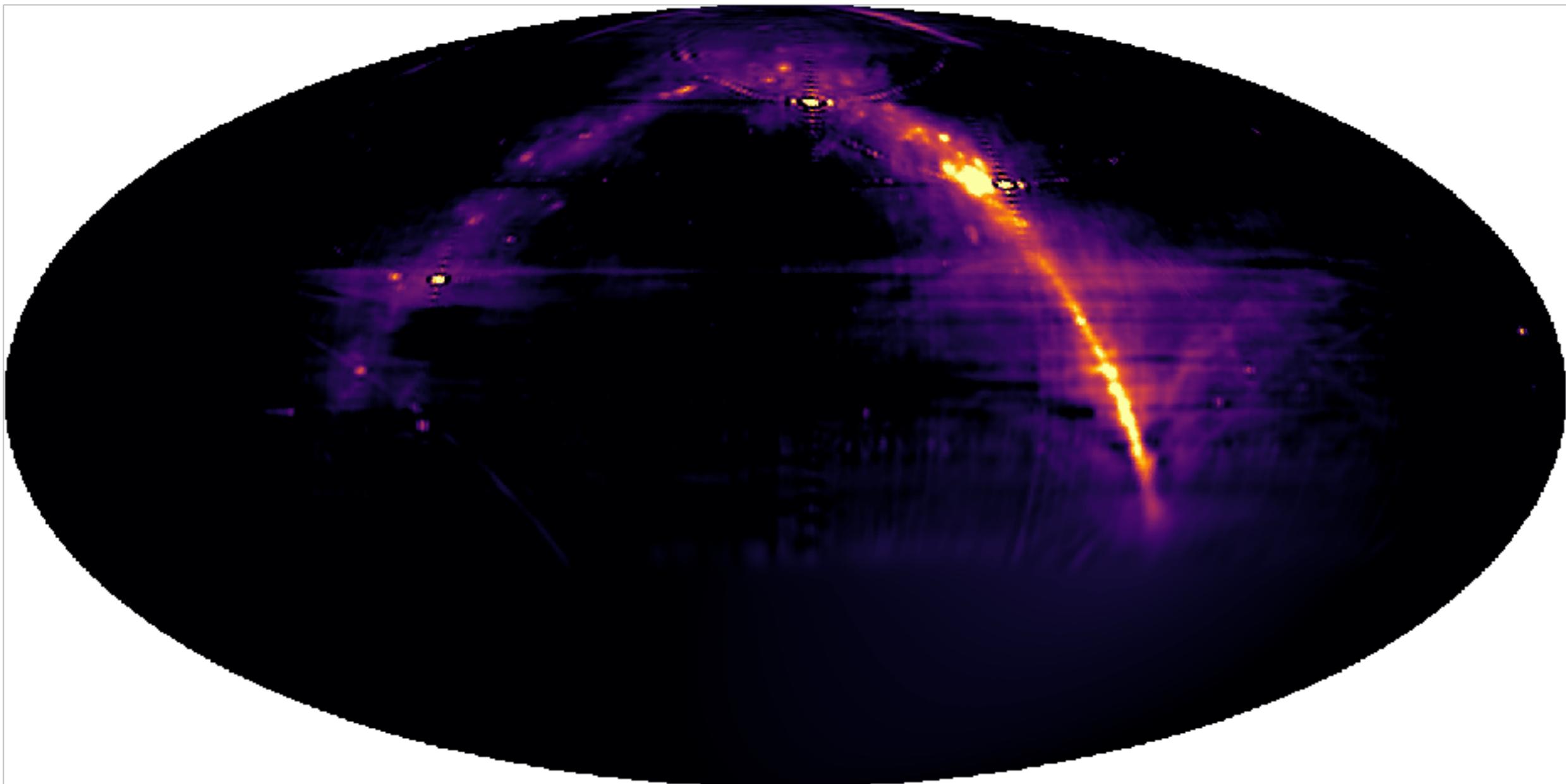
 chime

CHIME Pathfinder





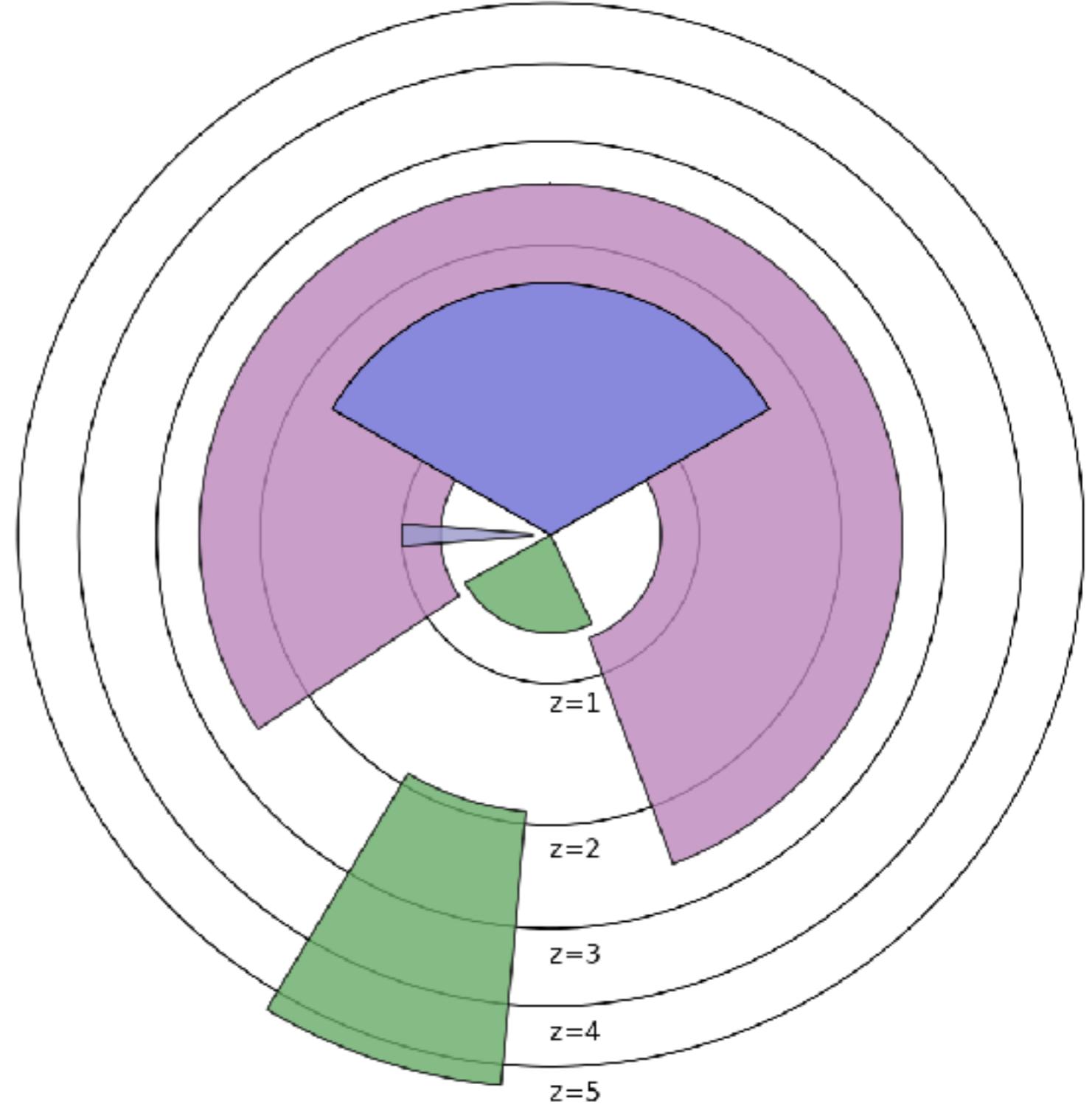
Deconvolved Map



711 MHz

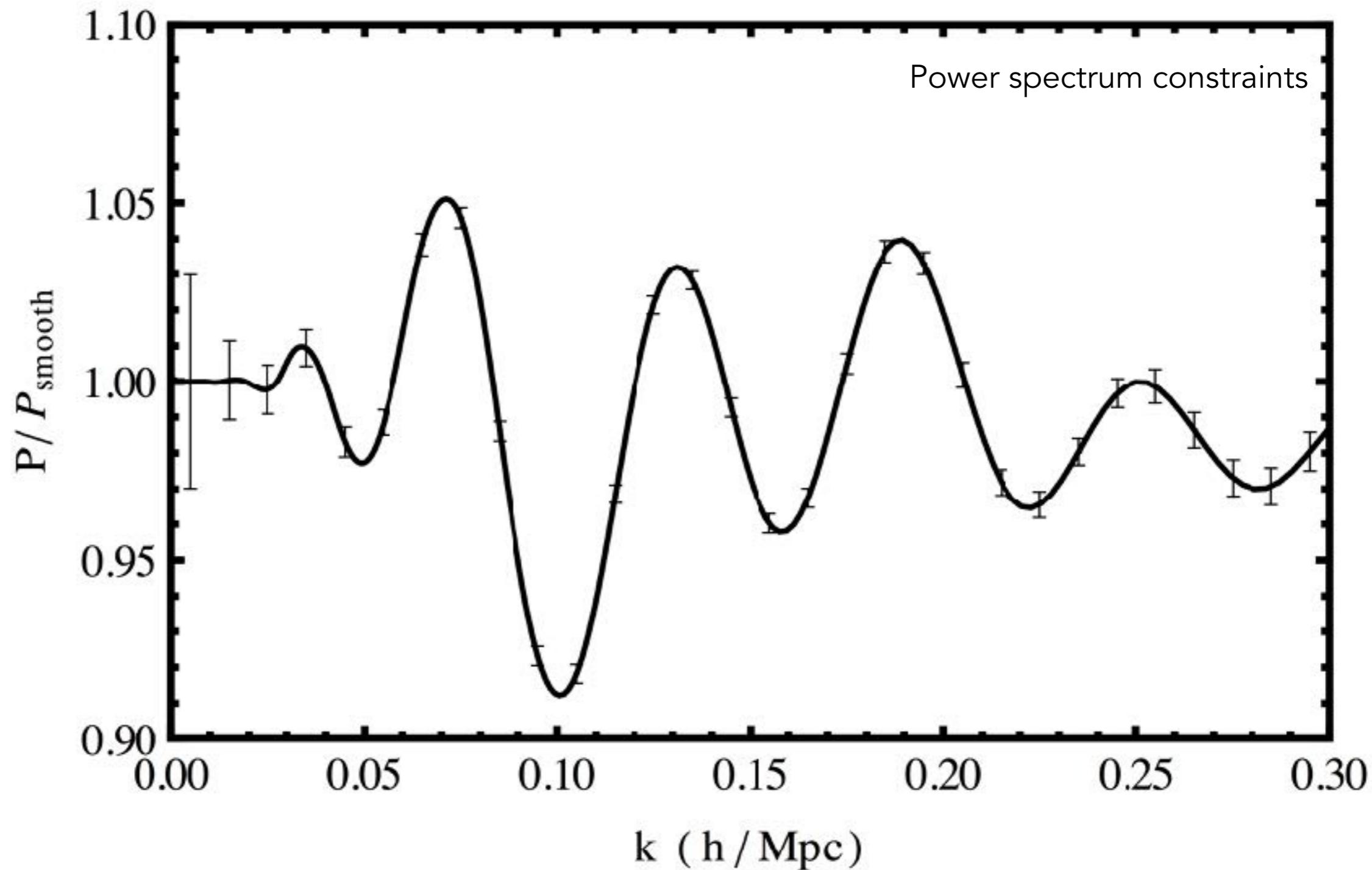
Survey Volume

- WiggleZ: $1.2 (h^{-1} \text{ Gpc})^3$
- BOSS
 - LRG: $5.3 (h^{-1} \text{ Gpc})^3$
 - Ly α : $37 (h^{-1} \text{ Gpc})^3$
- CHIME: $203 (h^{-1} \text{ Gpc})^3$
- DESI ELG: $50 (h^{-1} \text{ Gpc})^3$

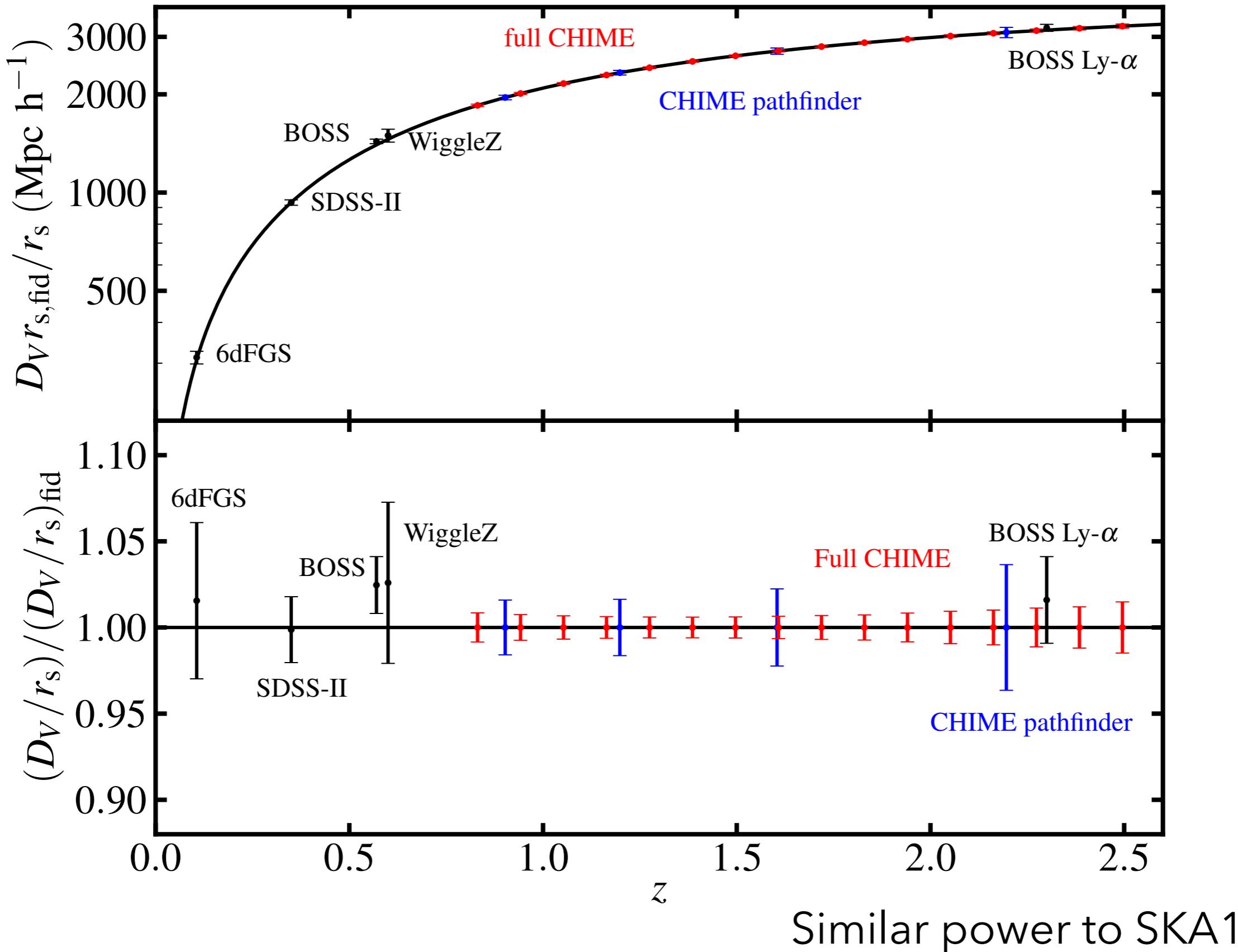


Scaled such that:
area of patch=volume of survey

BAO Forecasts



BAO Forecasts



Probing Gravity: Growth Rate

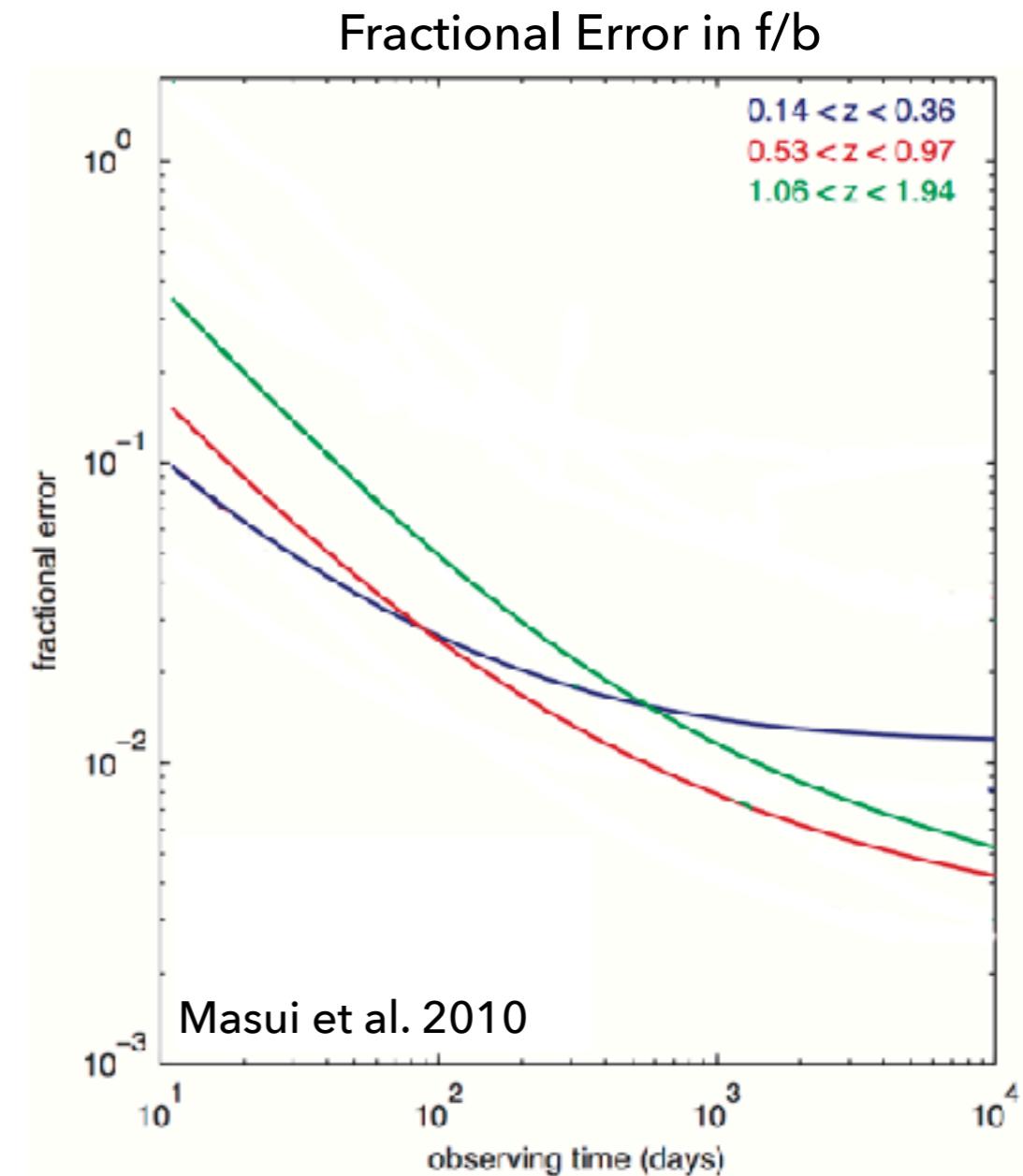
- Can use redshift space distortions to get access to the growth index $f = \Omega_m^\gamma$
- Problem, we have no direct measurement of the 21cm brightness temperature

$$P_{21}(\mathbf{k}) = \bar{T}_b^2 (b + f\mu^2)^2 P(k)$$

- Intensity mapping can only measure degenerate combinations:

$$f/b \quad \bar{T}_b f \sigma_8$$

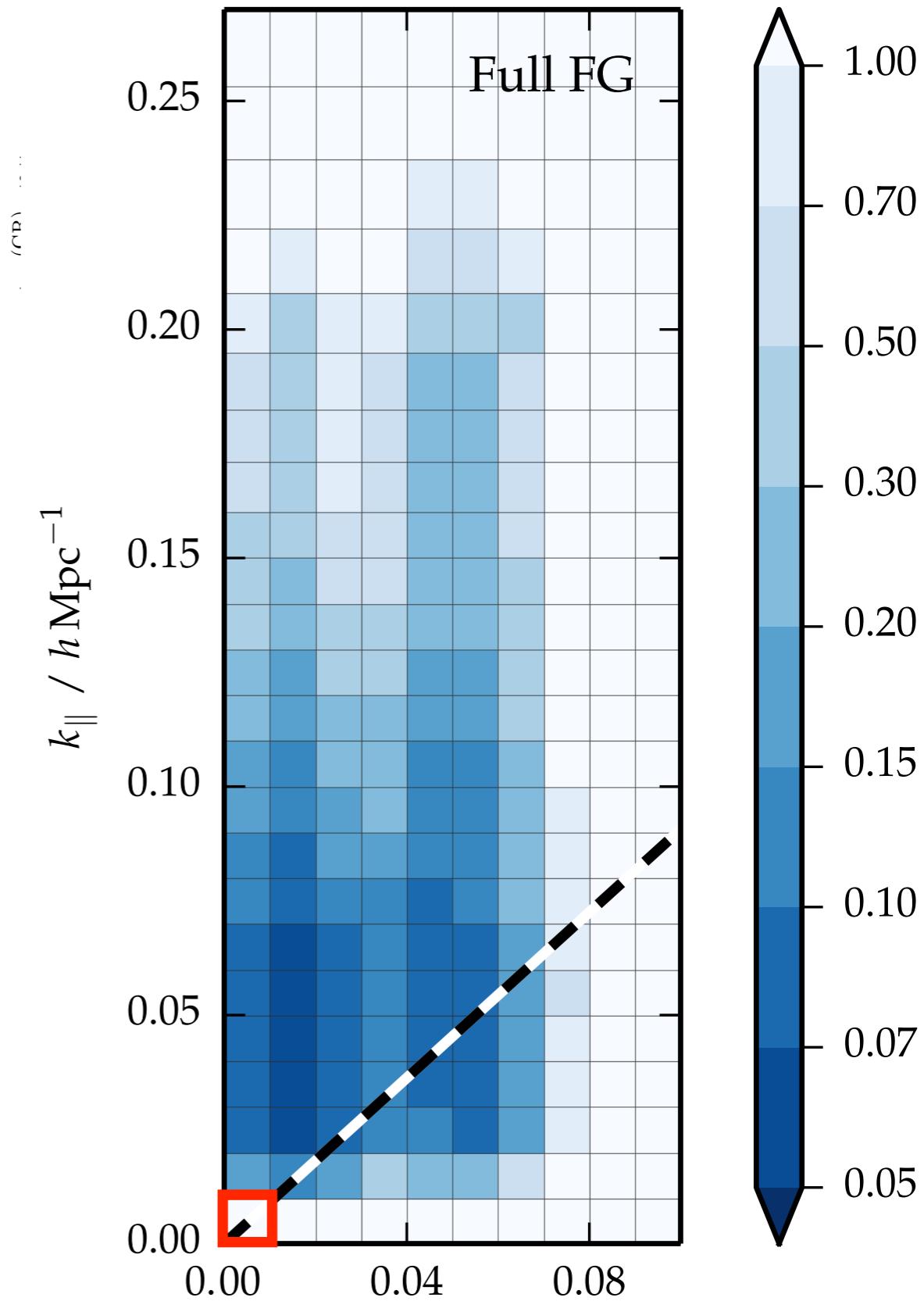
- Can we learn these any other way?
Sims, global sky experiments, 21cm galaxy surveys?



Probing Gravity: Large Scales

- Ultra-large scales are a promising regime for tests of gravity
- However foregrounds give a huge barrier to exploiting this regime
- Likely to remain a problem even for cross correlation/multi-tracer methods
 - ▶ Looks like an enhanced noise contribution to the cross correlation

$$\text{Var} \left(C_{\ell}^{\text{gal},21} \right) \sim \frac{1}{N} C_{\ell}^{\text{gal}} C_{\ell}^{21}$$



Summary

- CHIME is an interferometer designed to survey the Universe between redshift 0.8 and 2.5
 - ▶ Pathfinder is operating
 - ▶ Full instrument construction finishing in 2017
- Foregrounds are a hard, but surmountable problem for IM
- Nature of 21cm intensity mapping means many probes of gravity are hard
 - ▶ Look for synergies with other surveys