Cosmological Parameter Sensitivity Forecasts for CHIME

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The Canadian Hydrogen Intensity Mapping Experiment

The largest volume survey of the universe

- Beyond half the sky at redshifts 0.8 - 2.5
- Intensity mapping of the 21 cm transition in neutral hydrogen traces large scale structure without resolving individual galaxies

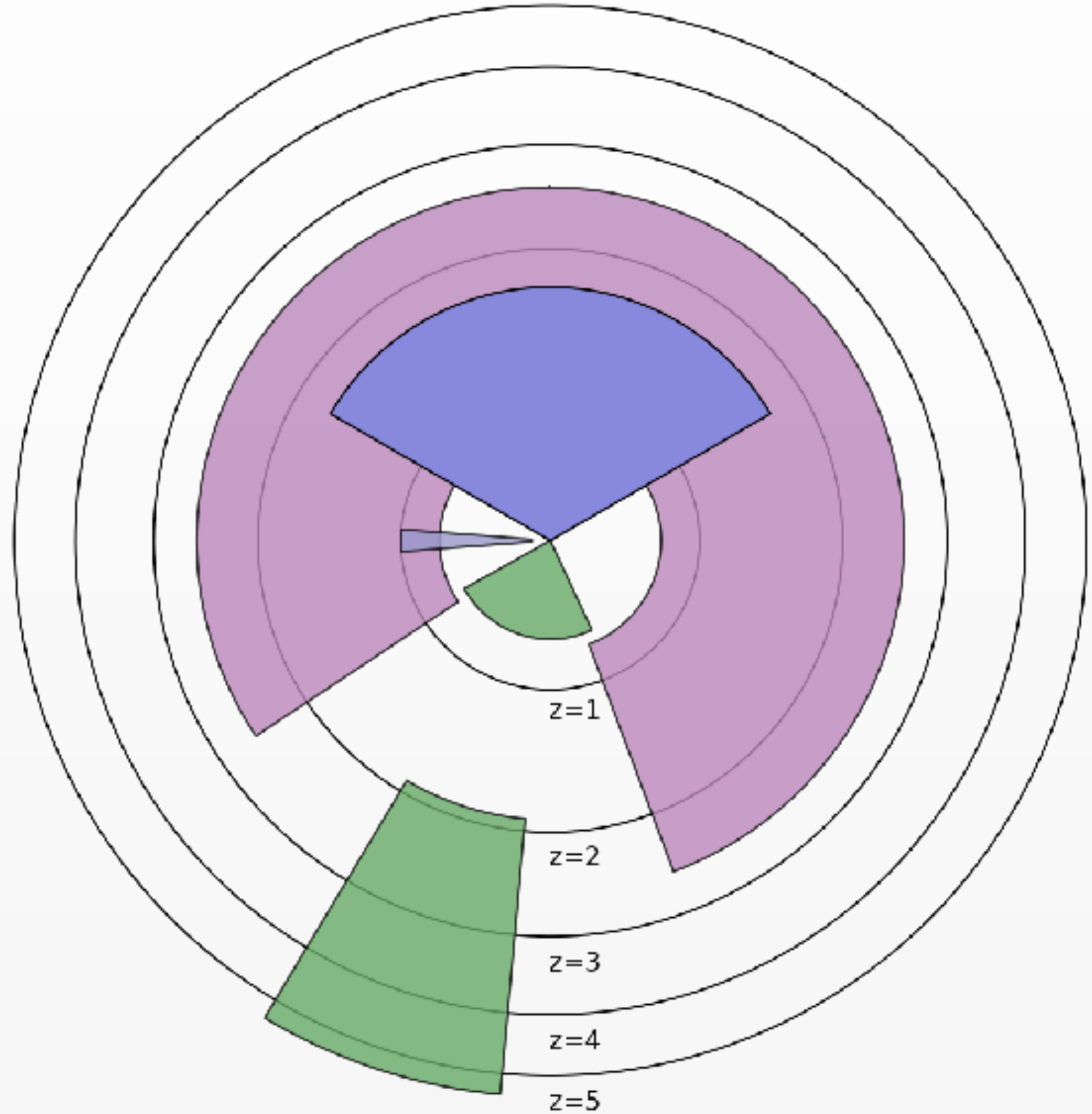
WiggleZ: 1.2 $(h^{-1}\ Gpc)^3$

BOSS

- LRG: 5.3 $(h^{-1}\ Gpc)^3$
- Lyα: 37 $(h^{-1}\ Gpc)^3$

CHIME: 203 $(h^{-1}\ Gpc)^3$

DESI ELG: 50 $(h^{-1}\ Gpc)^3$



Scale: Area = Survey volume

CHIME Signal-To-Noise Estimate

Neutral hydrogen power spectrum

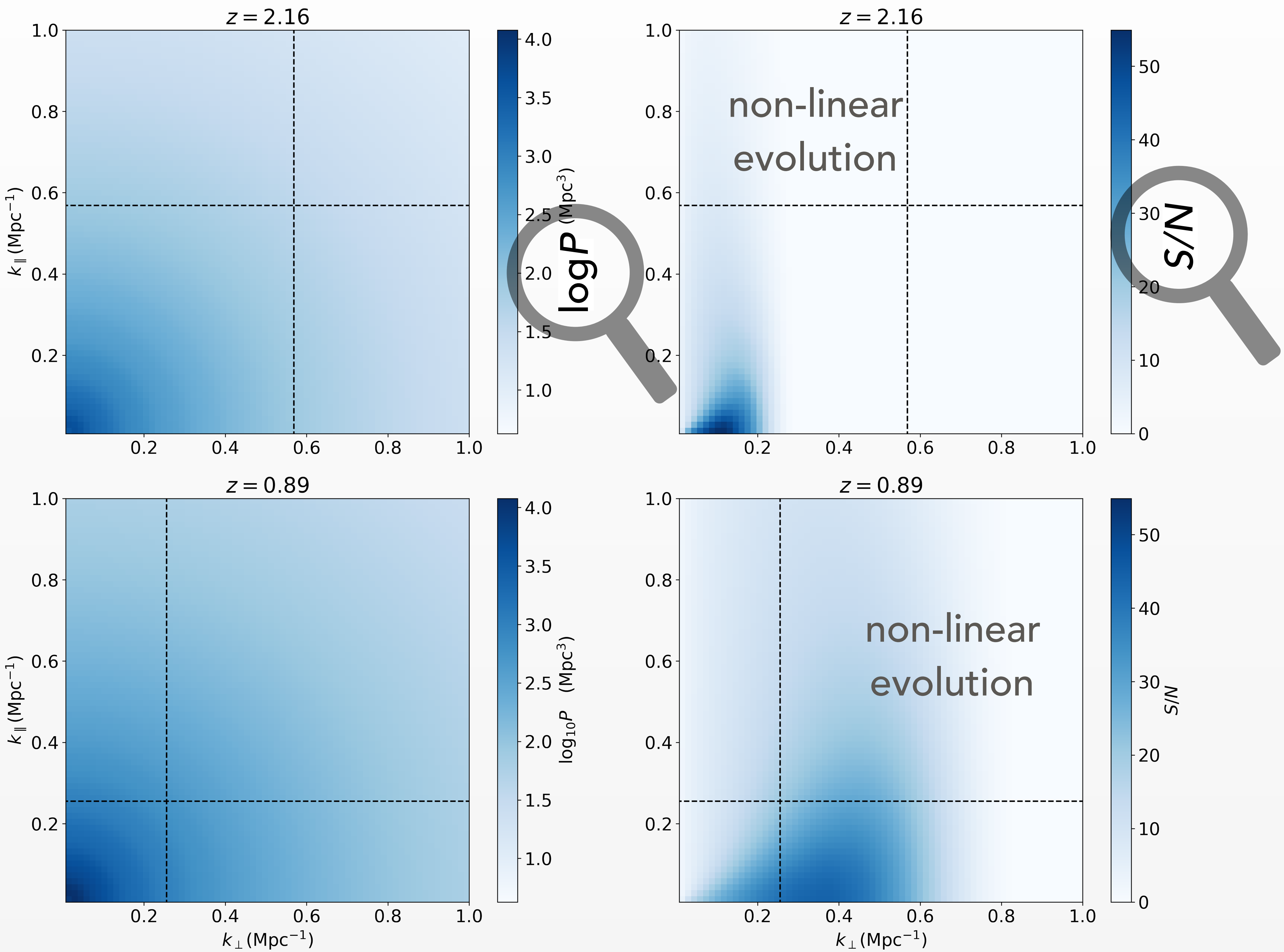
$$\frac{\mathrm{S}}{\mathrm{N}} = \sqrt{\frac{2\pi k_\perp dk_\perp dk_\parallel V_{sur}}{2(2\pi)^3}} \frac{P_{HI}(k_\perp, k_\parallel)\hat{W}^2}{P_{HI}(k_\perp, k_\parallel) + \left[\frac{g\bar{T}_{sky} + \bar{T}_a}{g\bar{T}_{sig}\sqrt{t_{int}\Delta f}}\right]^2 V_R + N_{shot}}$$

(Seo et al. 2010)

- Survey parameters:
  - 5 years
  - 50 K receiver temperature
  - 400-800 MHz band masked based on measured RFI environment
- Partition band into 4 redshift bins

CHIME Signal-To-Noise Estimate

Neutral hydrogen power spectrum



Measurement Errors

Extracting the standard ruler

Fitting parameters:

$$D_A/r_s = \frac{1}{H_0 r_s (1+z)} \int_0^z \frac{dz'}{\sqrt{\Omega_\Lambda + \Omega_k (1+z')^2 + \Omega_m (1+z')^3 + \Omega_r (1+z')^4}}$$

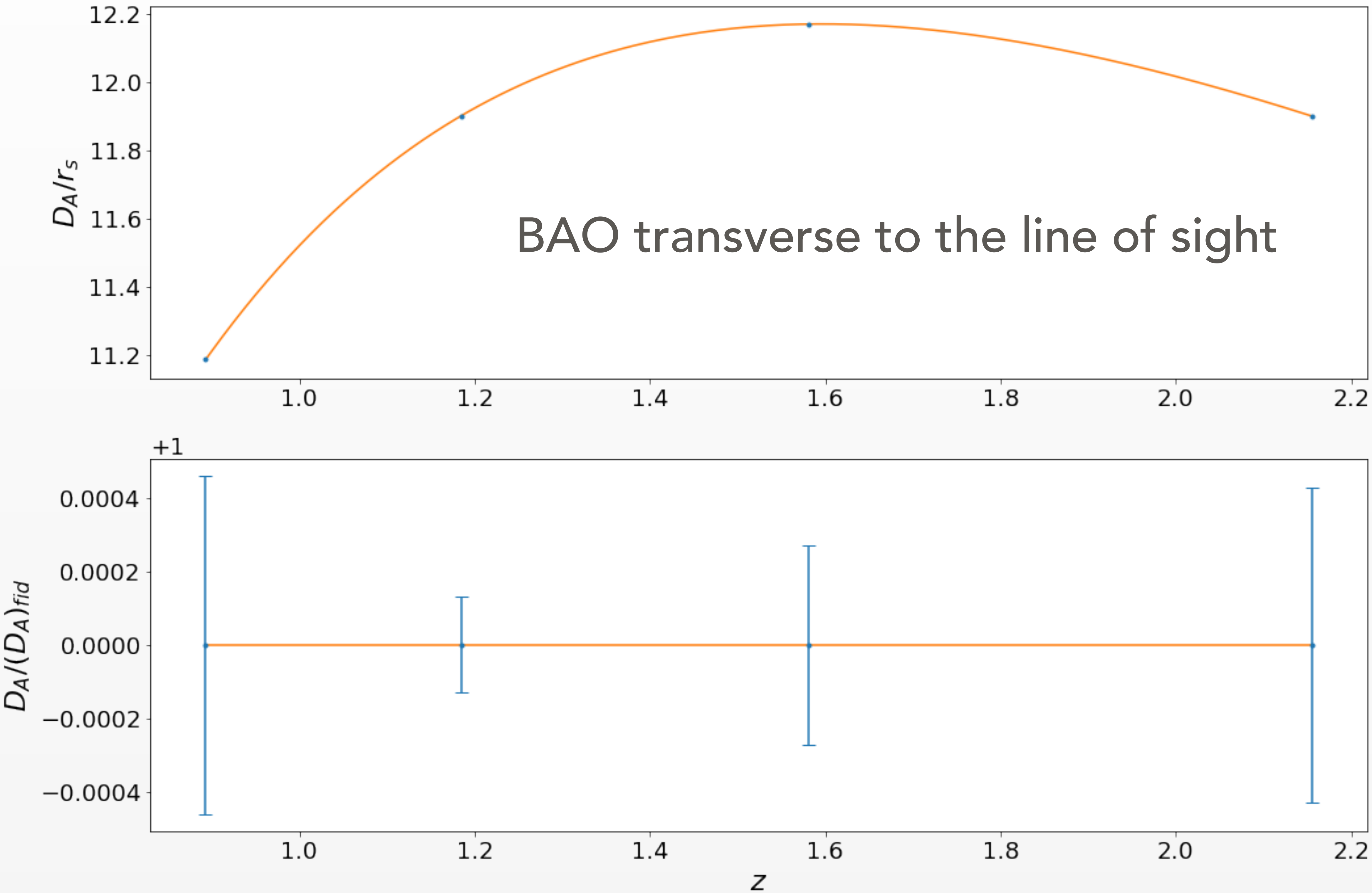
$$H(z) r_s = H_0 r_s \sqrt{\Omega_\Lambda + \Omega_k a^{-2} + \Omega_m a^{-3} + \Omega_r a^{-4}}$$

(… and nuisance parameters to remove dependence on broadband shape)

- Measurements are degenerate with r_s, the scale of the standard ruler
- Sensitive to cosmological parameters $H_0 r_s$, Ω_i; straightforward to extend to include w

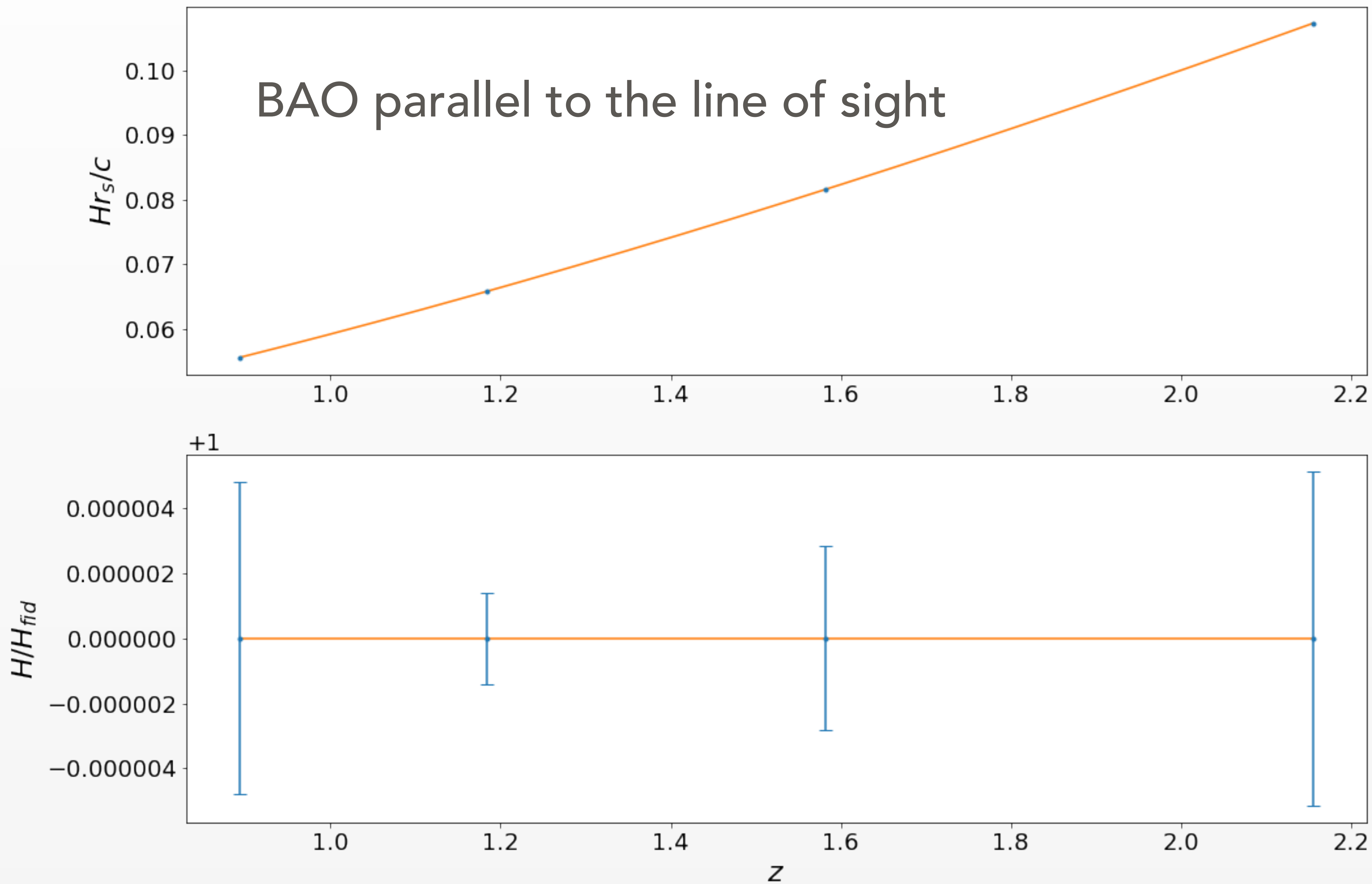
Measurement Errors

Fischer matrix forecasts



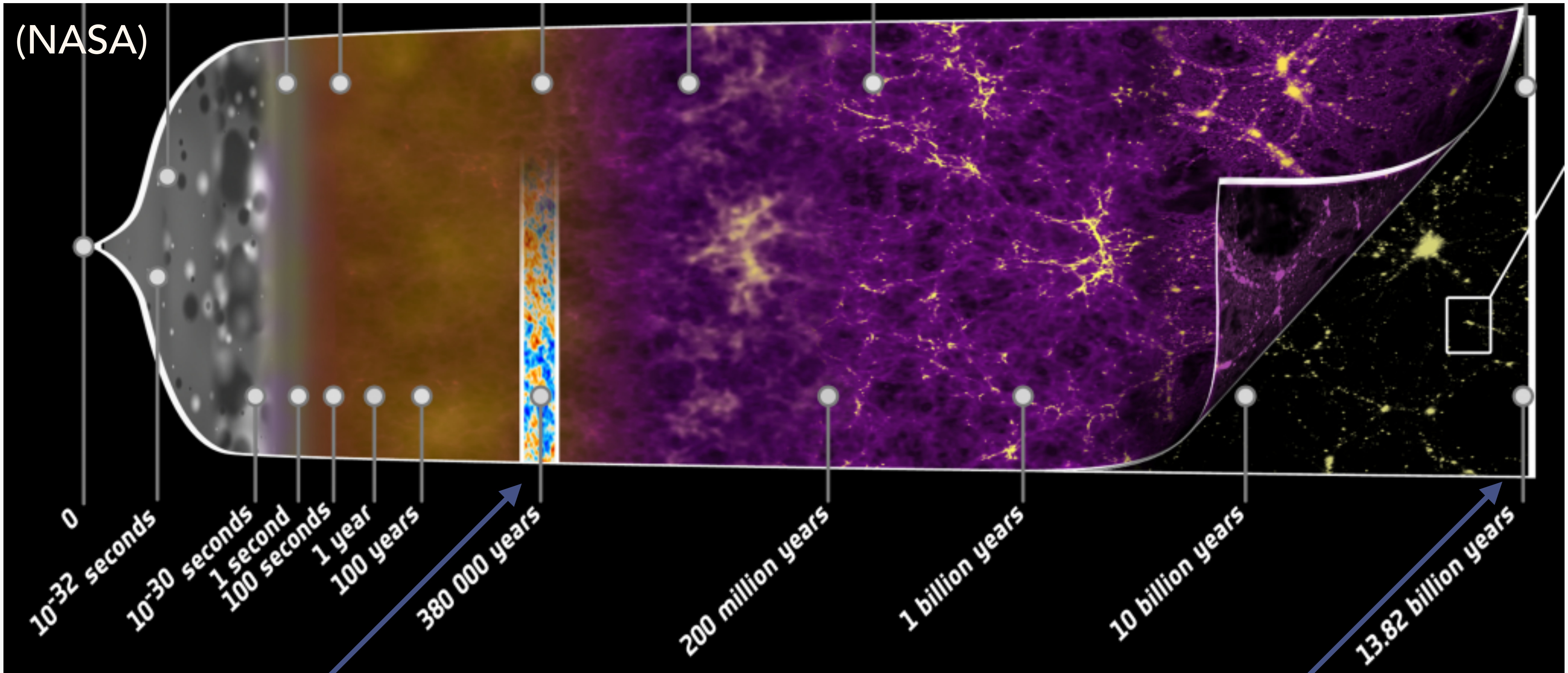
Measurement Errors

Fischer matrix forecasts



The Hubble Constant

Apparent tension between measurements



CMB

67.51 ± 0.64

km/s/Mpc

(Planck 2015)

3.6 σ tension

Local distance ladder

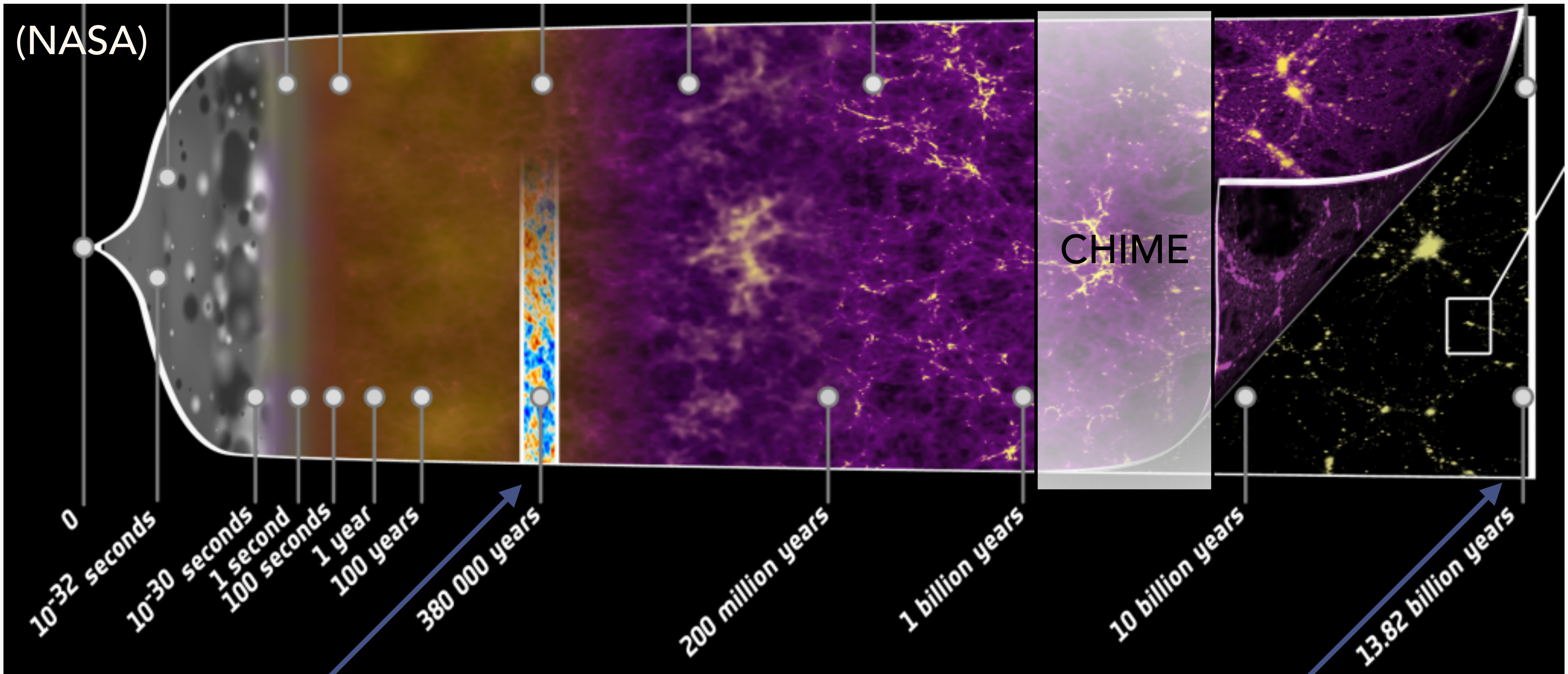
73.48 ± 1.66

km/s/Mpc

(Riess et al. 2015)

The Hubble Constant

Apparent tension between measurements



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Breaking r_s Degeneracy

Primordial deuterium abundance

- BAO can only constrain combination $H_0 r_s$
- r_s is determined by $\Omega_b h^2$ and $\Omega_m h^2$ – well measured by the CMB

$$r_s \approx \frac{55.154}{(\Omega_m h^2)^{0.25351}(\Omega_b h^2)^{0.12807}} \ \mathrm{Mpc}$$ (Aubourg et al.)

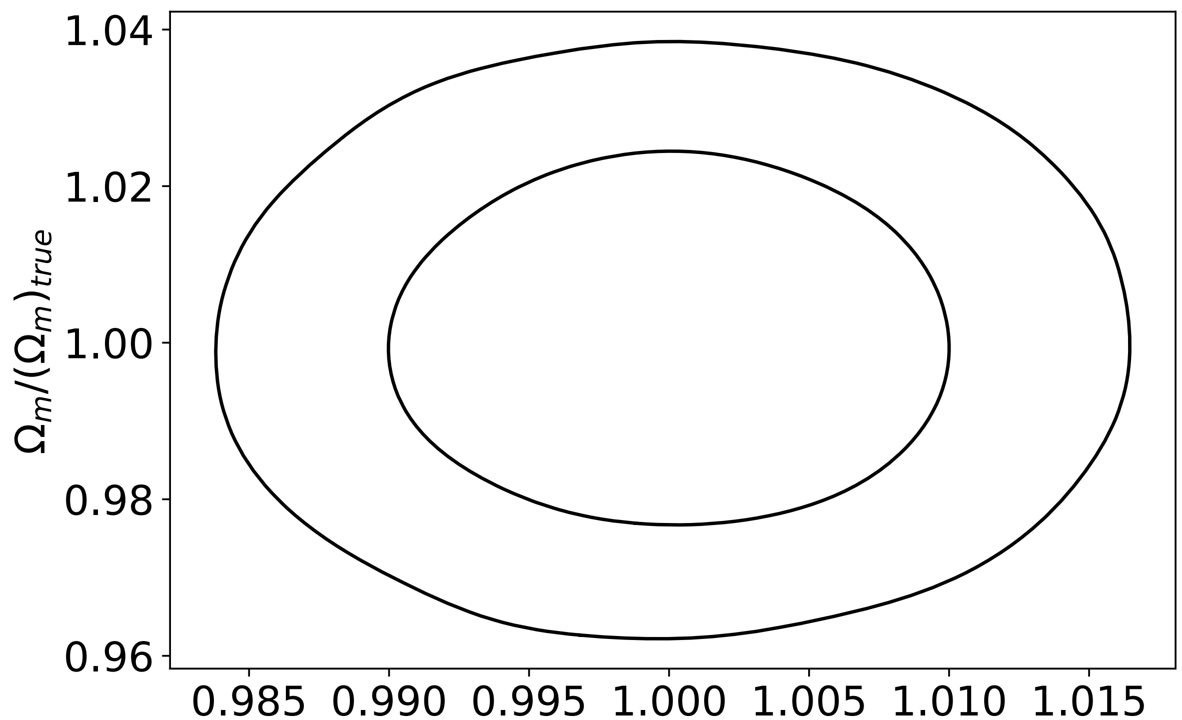
- For a measurement independent of the CMB, observations of primordial deuterium abundance provide a constraint on $\Omega_b h^2$

$$\Omega_b h^2 = 0.02235 \pm 0.00037$$

(Cooke et al.)

CHIME Likelihood Forecasts

CHIME and deuterium

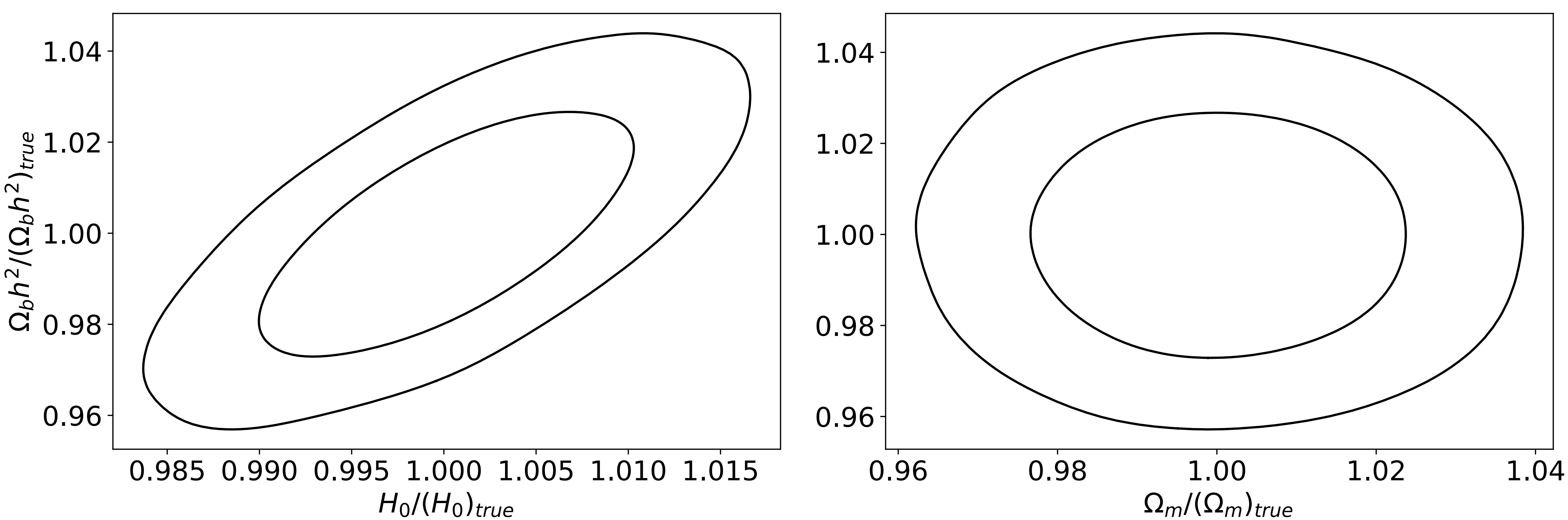


Priors:

$\Omega_b h^2 = 0.02235 \pm 0.00037$

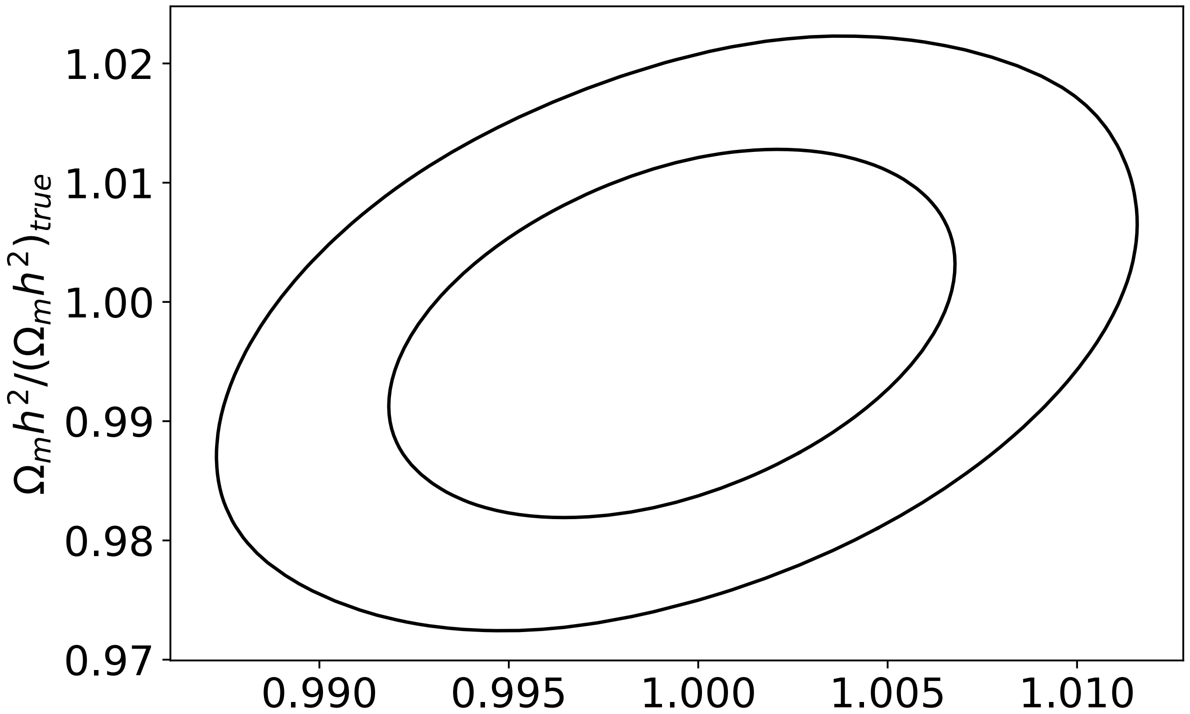
H_0 constraint:

0.61%



CHIME Likelihood Forecasts

CHIME and CMB (Planck 2015)



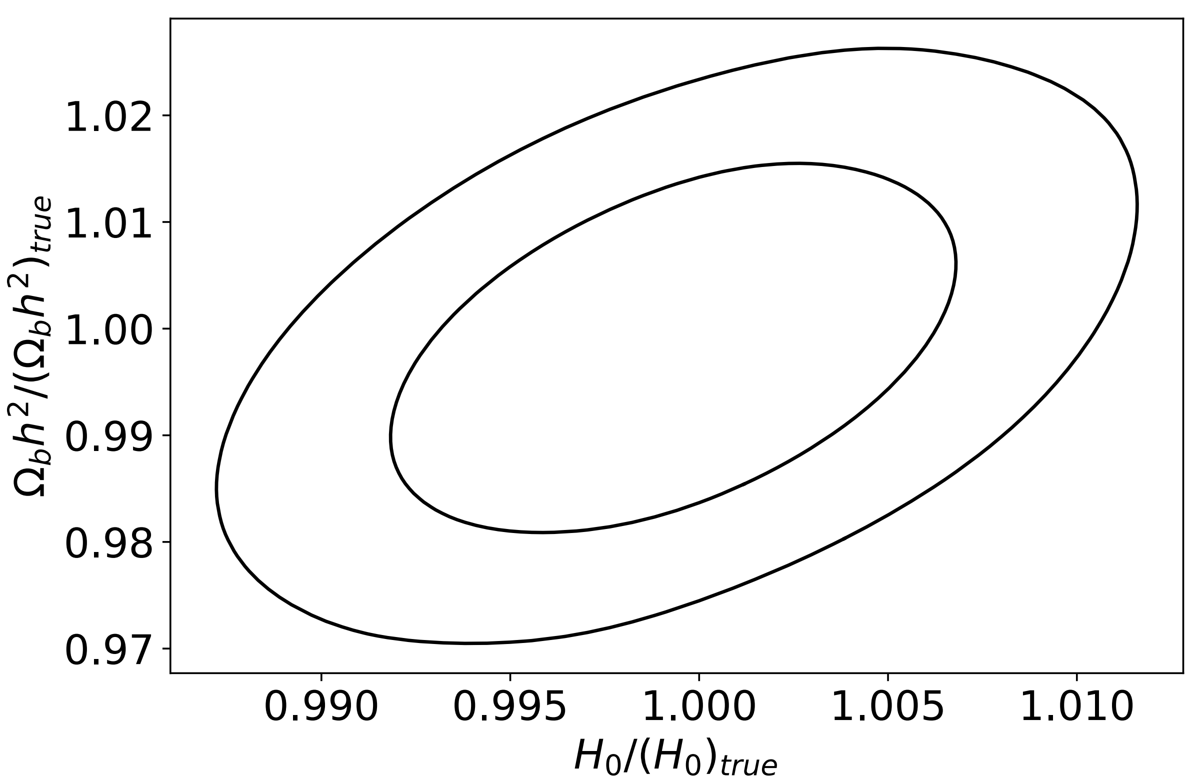
Priors:

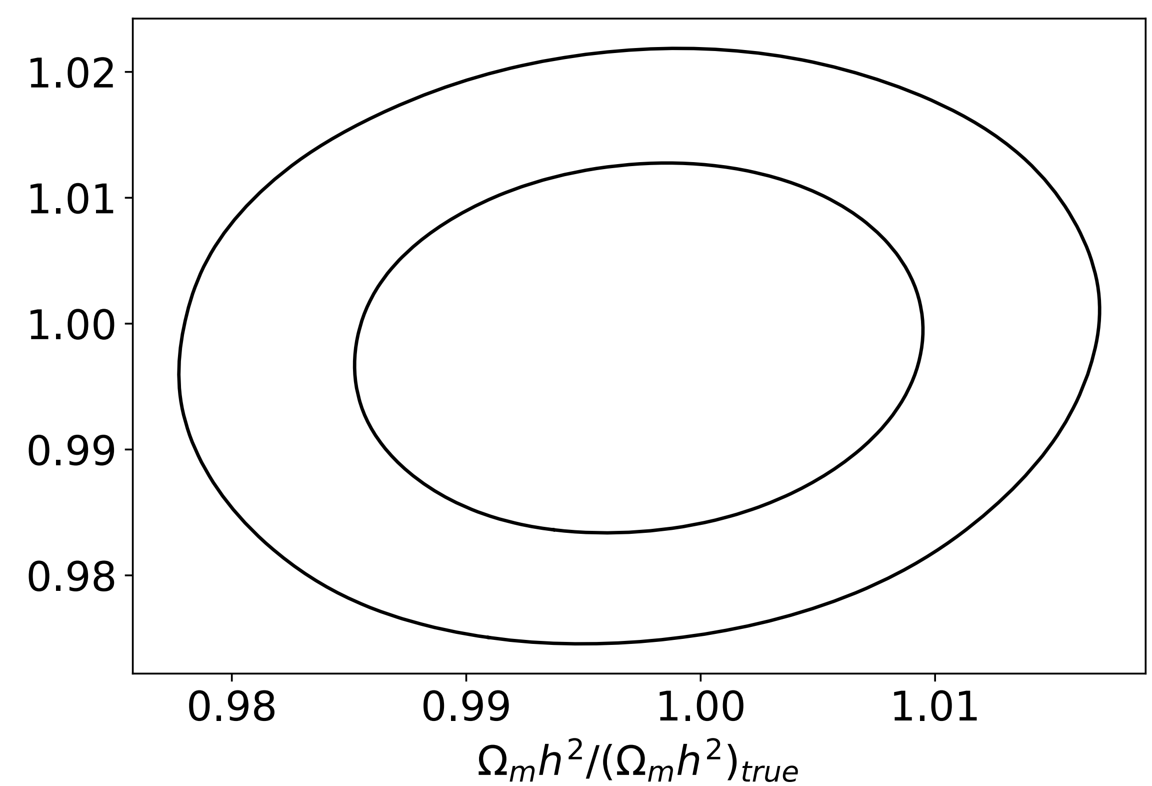
$\Omega_b h^2 = 0.02230 \pm 0.00014$

$\Omega_m h^2 = 0.14110 \pm 0.00097$

H_0 constraint:

0.44%





CHIME Likelihood Forecasts

CHIME and deuterium for *w*CDM

Priors:

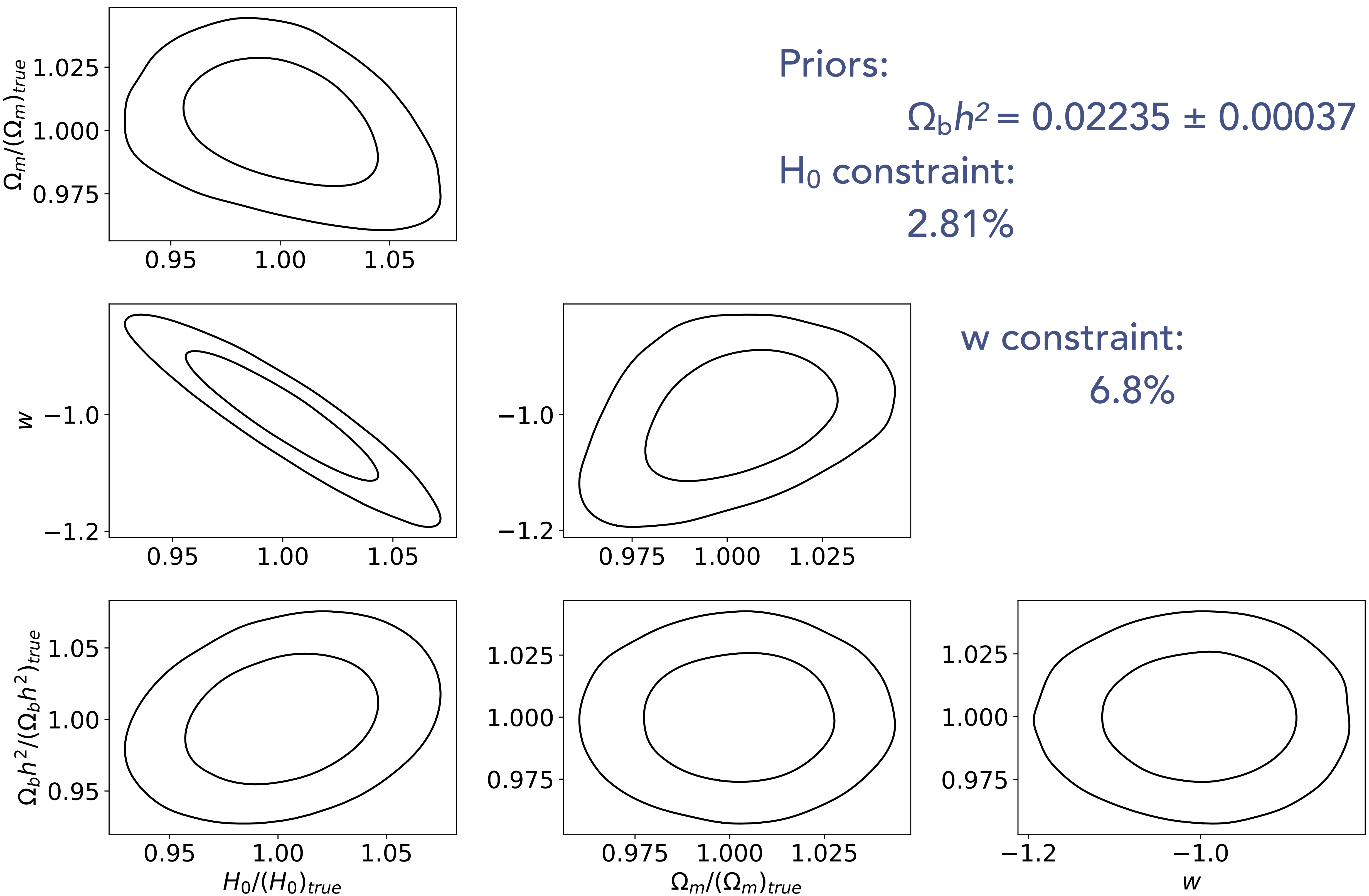
$\Omega_b h^2 = 0.02235 \pm 0.00037$

H_0 constraint:

2.81%

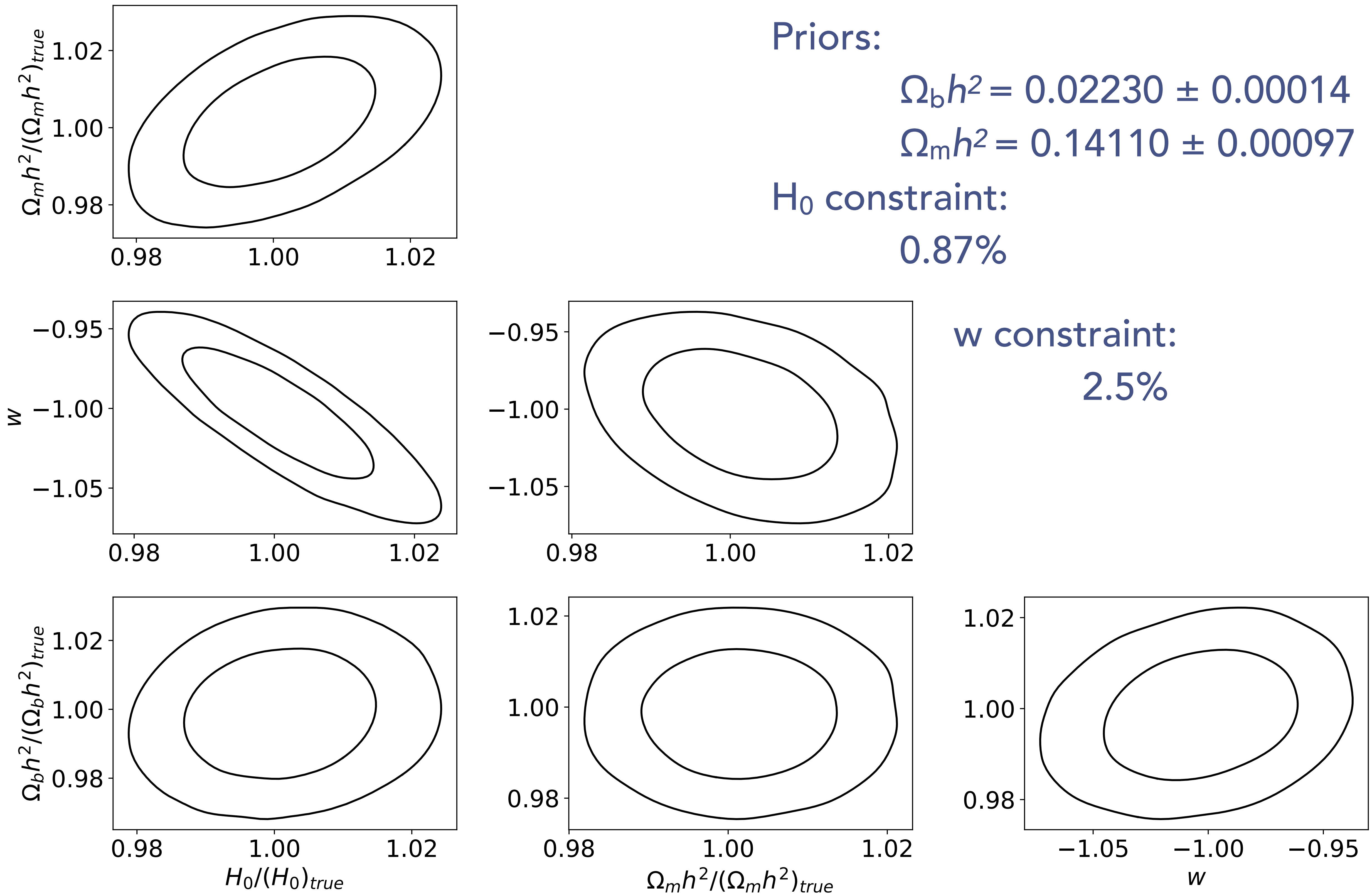
w constraint:

6.8%



CHIME Likelihood Forecasts

CHIME and CMB (Planck 2015) for wCDM



Priors:

$\Omega_b h^2 = 0.02230 \pm 0.00014$

$\Omega_m h^2 = 0.14110 \pm 0.00097$

H_0 constraint:

0.87%

w constraint:

2.5%

In Conclusion

Marginalized 68% CI from RMS over the parameter chains for H0

CHIME + D/H	CHIME + CMB	CHIME + D/H + w	CHIME + CMB + w
0.61%	0.44%	2.81%	0.87%

- Using observations of primordial deuterium abundance to break the r_s degeneracy, measurements of the BAO provide an independent probe of H_0, subject to different systematic effects

- The CHIME survey will have the sensitivity to produce constraints on H_0 precise enough to distinguish between CMB and distance ladder measurements

- Reconstruction of non-linear evolution has the potential to significantly improve the signal to noise

Some References

- H.-J. Seo, S. Dodelson, J. Marriner, D. Mcginnis, A. Stebbins, C. Stoughton, and A. Vallinotto. A Ground-based 21 cm Baryon Acoustic Oscillation Survey. ApJ, 721: 164–173, September 2010. doi: 10.1088/0004-637X/721/1/164.

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- Planck Collaboration, P. A. R. Ade, N. Aghanim, M. Arnaud, M. Ashdown, J. Aumont, C. Baccigalupi, A. J. Banday, R. B. Barreiro, J. G. Bartlett, and et al. Planck 2015 results. XIII. Cosmological parameters. A&A, 594:A13, Sept. 2016. doi: 10.1051/0004-6361/201525830

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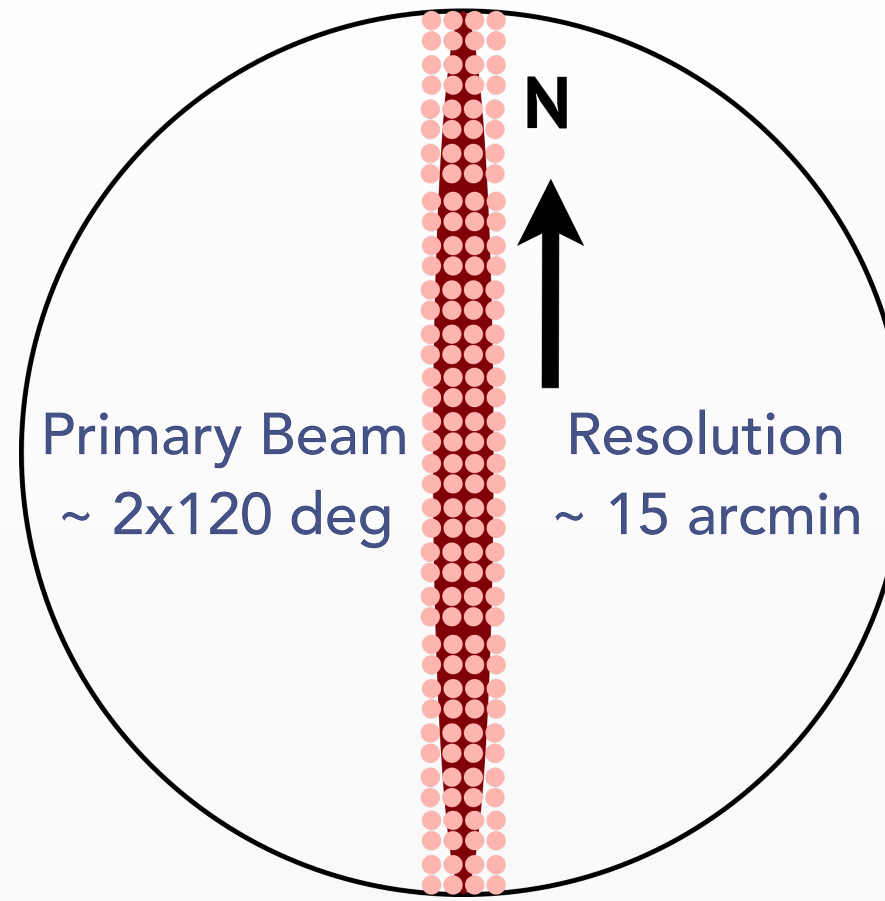
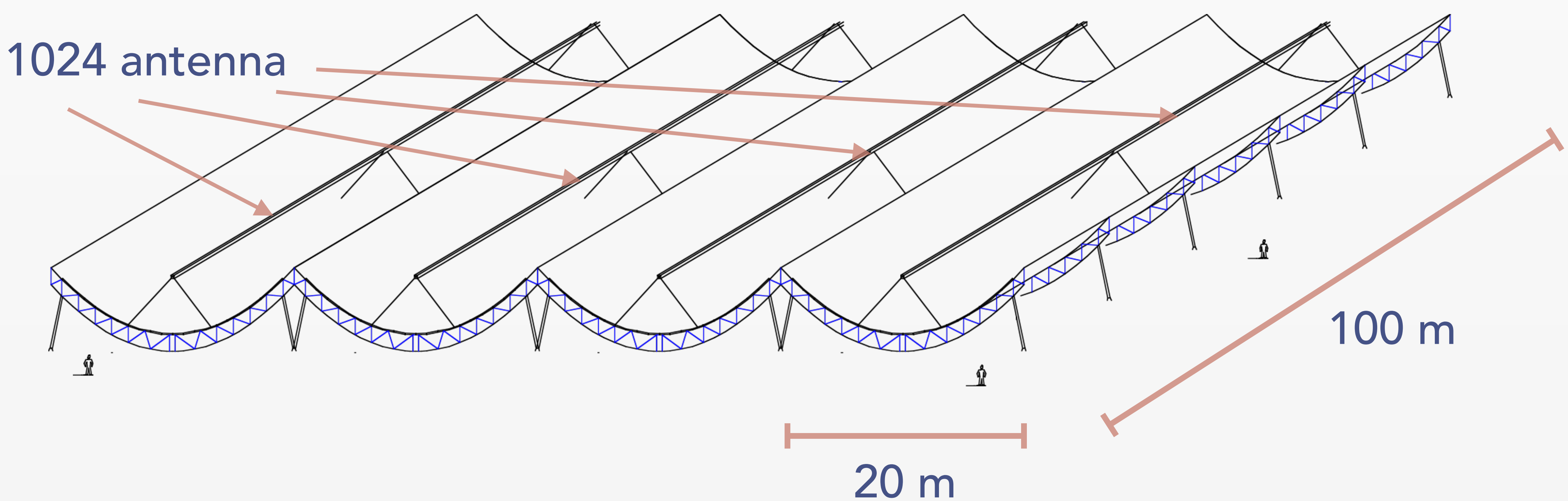
- R. J. Cooke, M. Pettini, and C. C. Steidel. One Percent Determination of the Primordial Deuterium Abundance. ApJ, 855:102, Mar. 2018. doi:10.3847/1538-4357/aaab53.

The Canadian Hydrogen Intensity Mapping Experiment

A cylindrical transit interferometer

- No moving parts
- Exposed to the entire northern sky every day
- 1024 antennas, two polarizations
- 400-800 MHz band divided into 1024 channels
- At a 10 s cadence, data rate is 135 TB / day



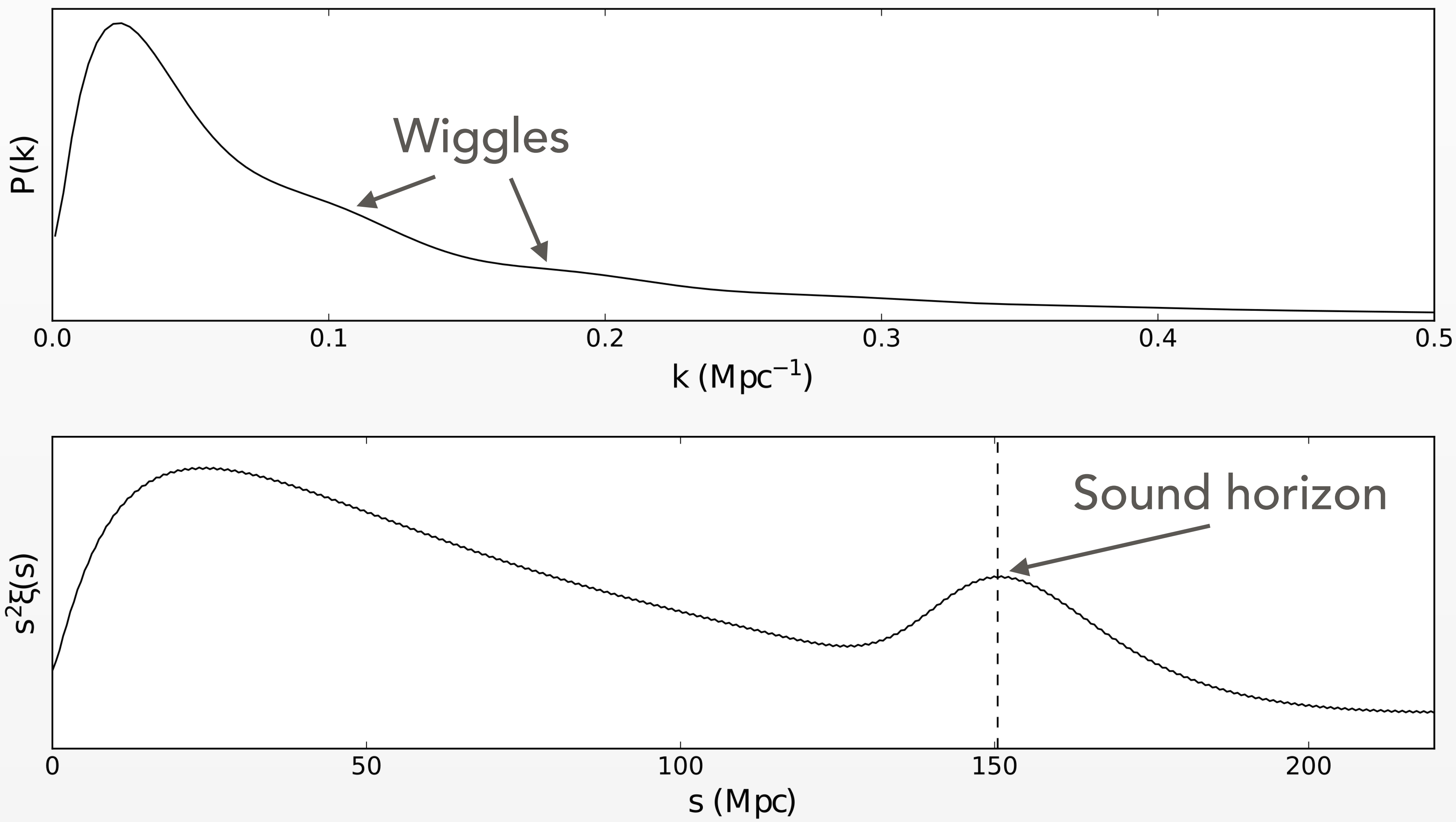


The Canadian Hydrogen Intensity Mapping Experiment

Measuring the Baryonic Acoustic Oscillations (BAO)

- CHIME will measure the power spectrum of HI density perturbations for a number of redshifts 0.8 < z < 2.5

- The BAO feature is a bump in the correlation function / wiggles in the power spectrum



Measurement Errors

Extracting the standard ruler

- Fit the power spectrum to a fiducial model by rescaling the *k* axis
- Rescaling of the wiggles at each redshift measures the deviation from the fiducial model of parameters describing the expansion history of the universe