Dark Energy constraints with future observations

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Center for Gravitation and Cosmology
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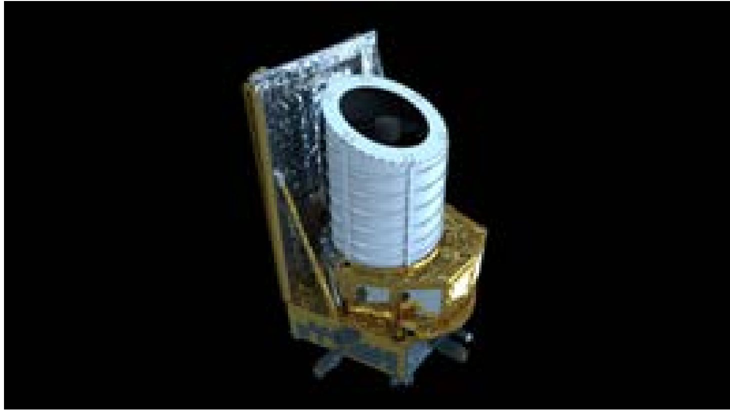
Optical

DESI



EUCLID

J-PAS

LSST

J-PAS

- J-PAS will be able to provide insights about the expansion of the Universe using the main four DETF strategies:
- SNIa
- BAO
- WL
- Galaxy Clusters

- Collaboration:Brazil/Spain
- Location: Teruel, Spain
- Main Telescope: 2.55 m
- FoV: 7 sq. deg
- Area: 8500 sq. deg.
- Redshift range: [0, 4]
- Filters: 59
- Photo-z error: 0.003(1 + z)

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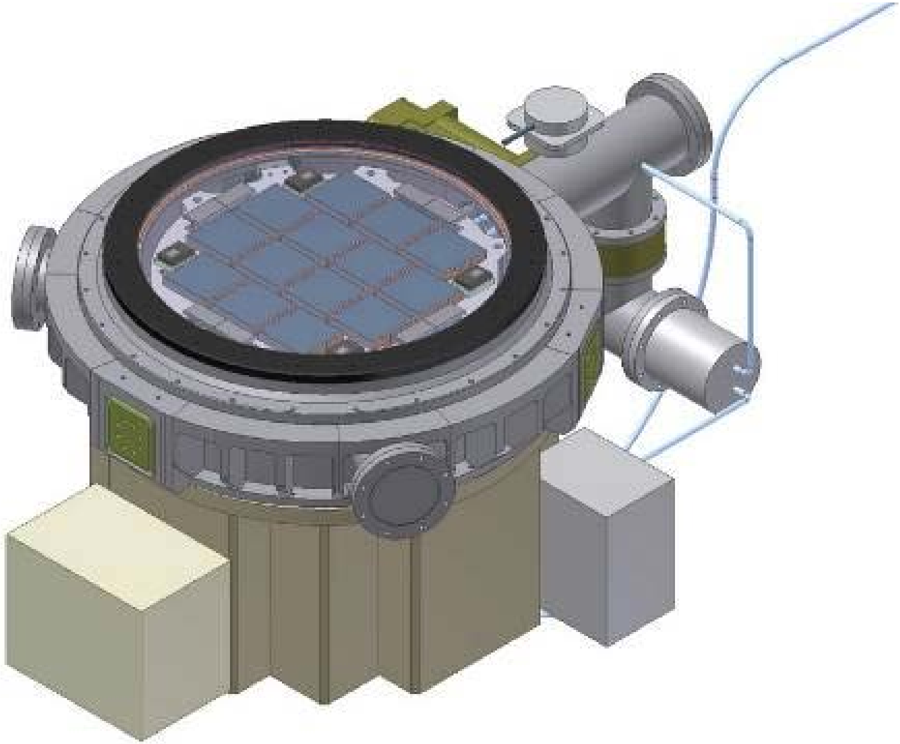
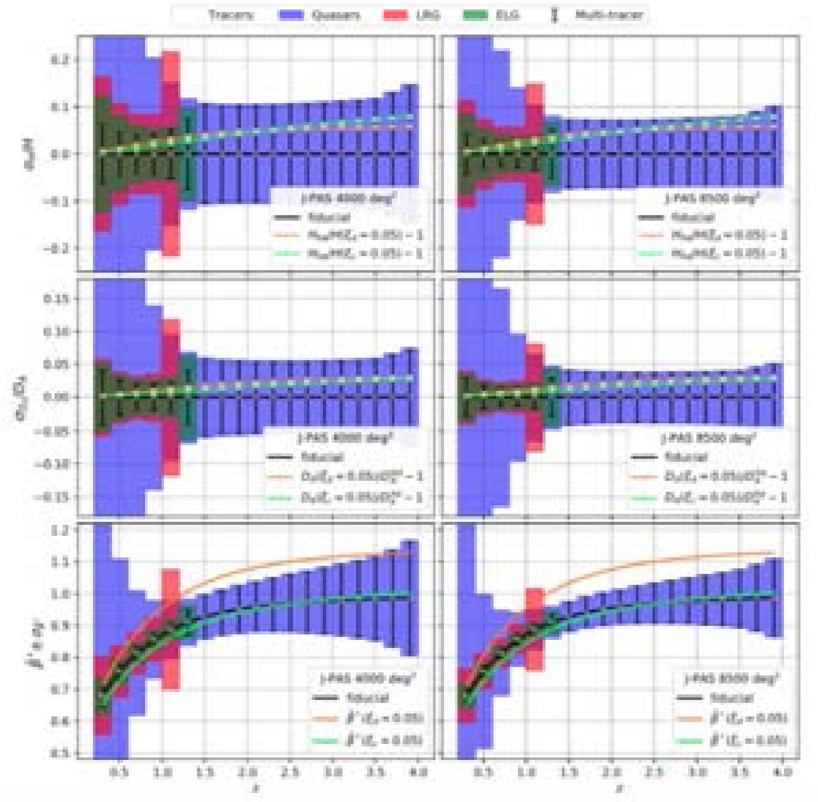


$$P(k_r, \hat{\mu}_r, z) = \frac{D_{A\,r}^2\, E}{D_A^2\, E_r} \left[b\, \sigma_8(z) + f\, \sigma_8(z)\, \hat{\mu}^2 \right]^2 \hat{P}(k) + P_{SHOT}$$

$$\nabla_\mu T^{\mu\nu}_{(i)} = Q^\nu_{(i)}$$

$$\dot{\rho}_c + 3H\rho_c = Q,$$
$$\dot{\rho}_d + 3H(1+w_d)\rho_d = -Q$$



Costa et al. (J-PAS Collaboration), 1901.02540.

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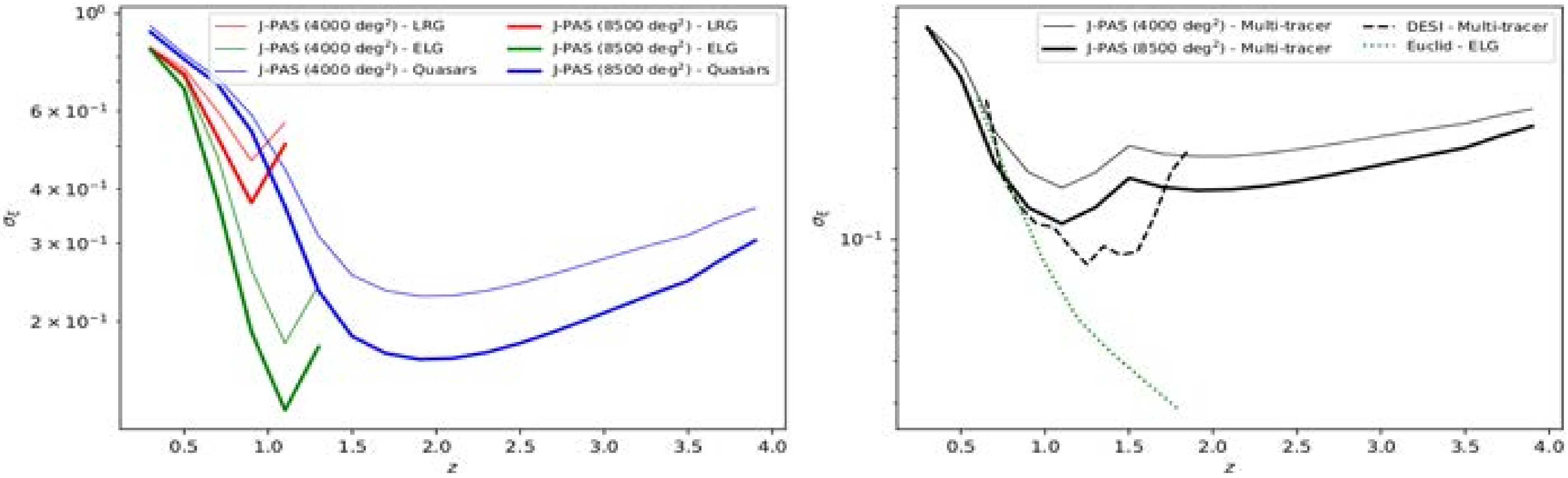

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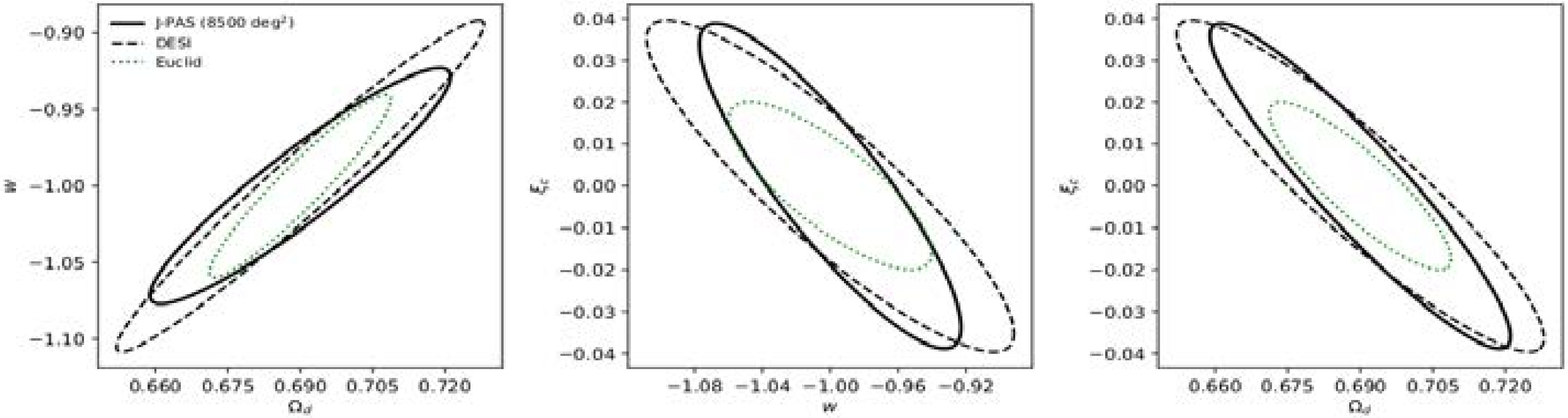


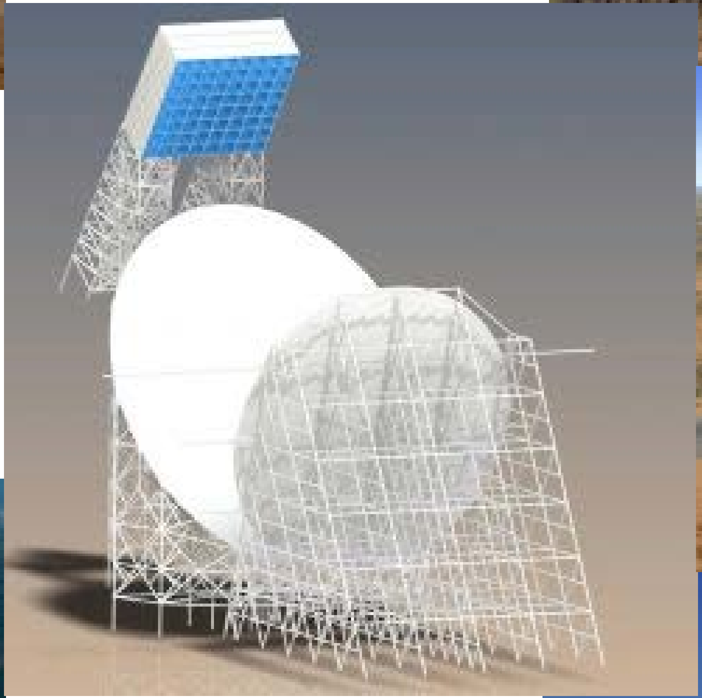
Costa et al. (J-PAS Collaboration), 1901.02540.

Radio

CHIME

HIRAX

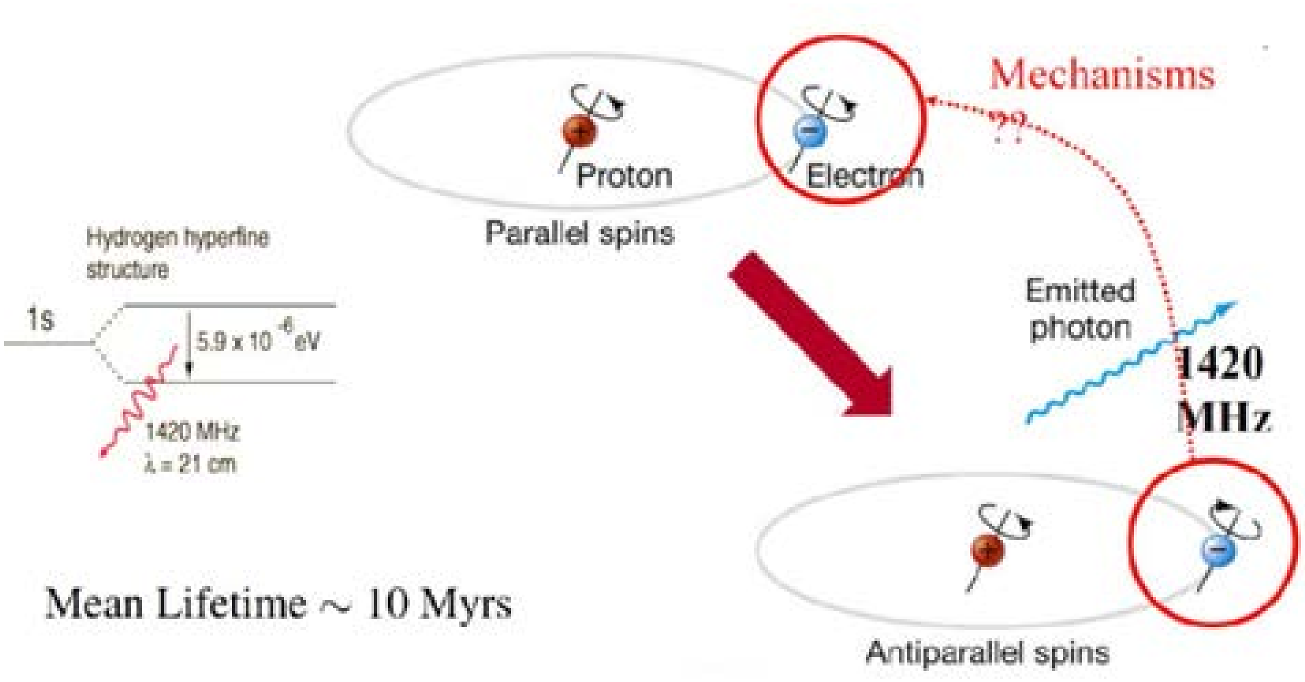
BINGO

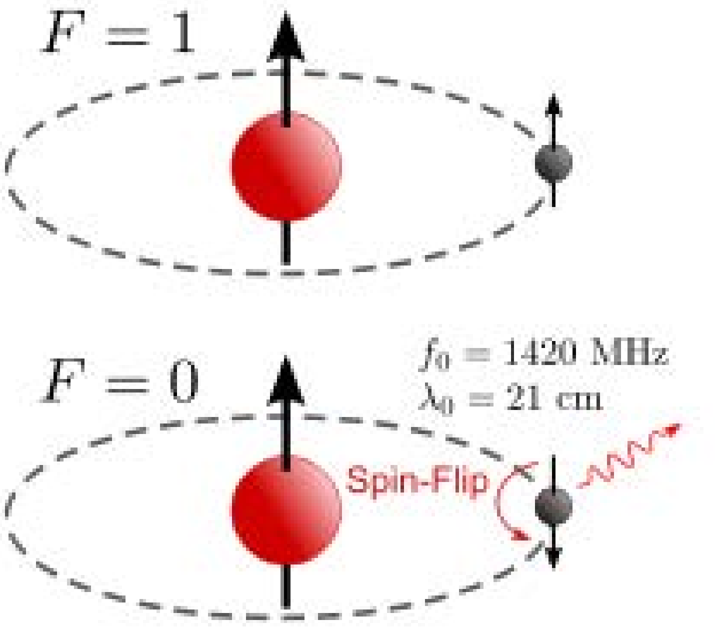


FAST

TIANLAI

21-cm Intensity Mapping



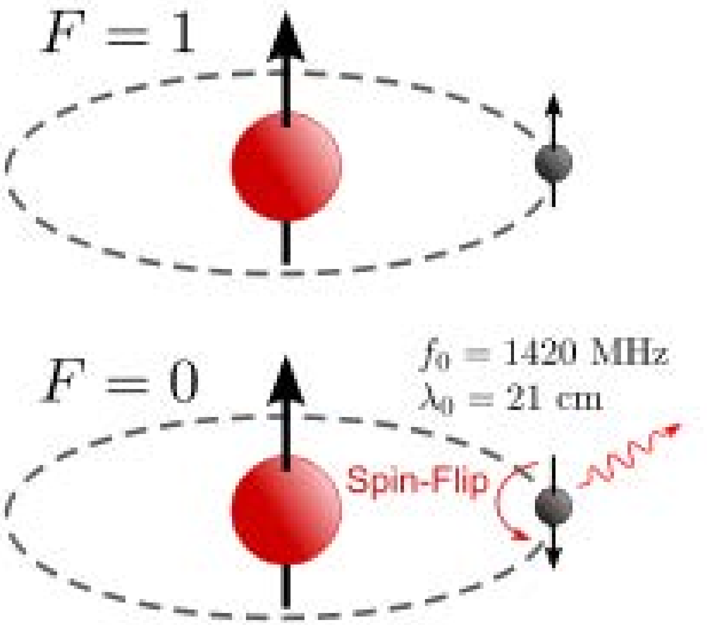


$$T_s^{-1} = \frac{T_{CMB}^{-1} + x_c T_k^{-1} + x_\alpha T_k^{-1}}{1 + x_c + x_\alpha}$$

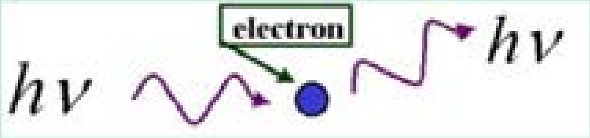
Field 1958
Madau et al. 1998
Ciardi & Madau 2003

$$\frac{n_1}{n_0} = \frac{g_1}{g_0} \exp\left(-T_{21cm}/T_S\right)$$

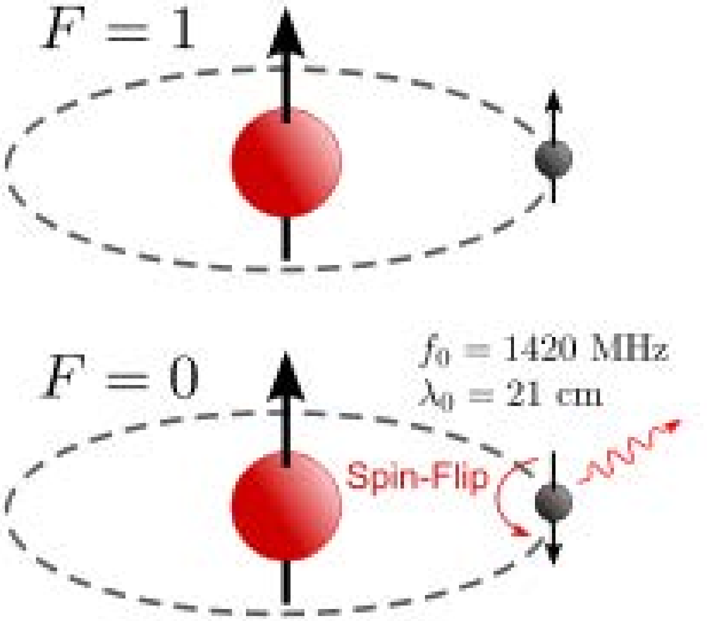
$$T_s^{-1} = \frac{T_{CMB}^{-1} + x_c T_k^{-1} + x_\alpha T_k^{-1}}{1 + x_c + x_\alpha}$$



Coupling to the CMB



Thomson scattering of CMB photons (low energy photons) by free electrons



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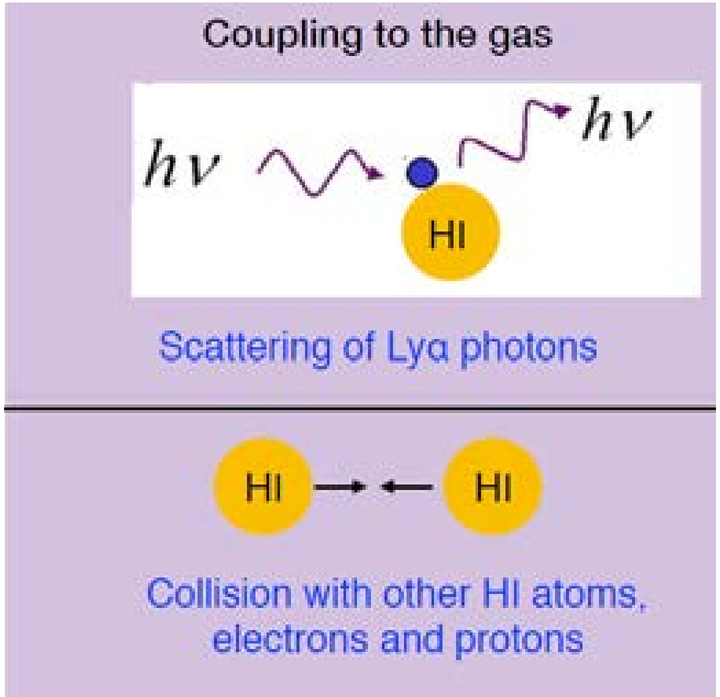
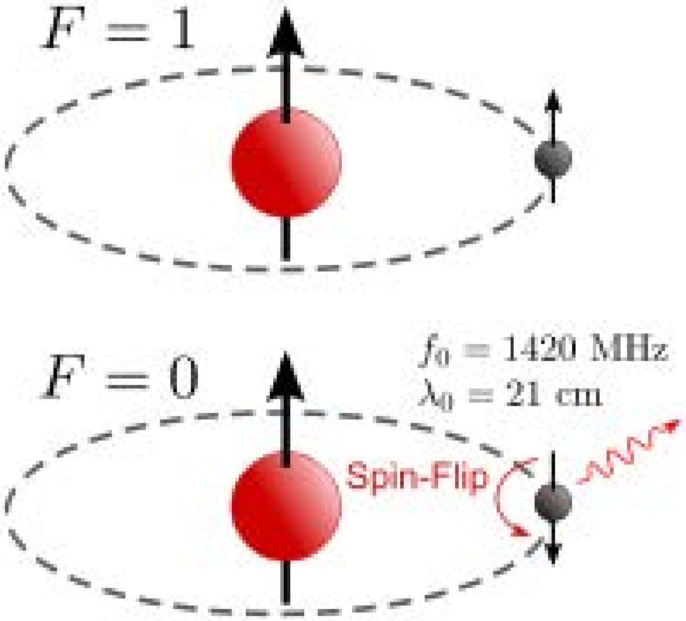
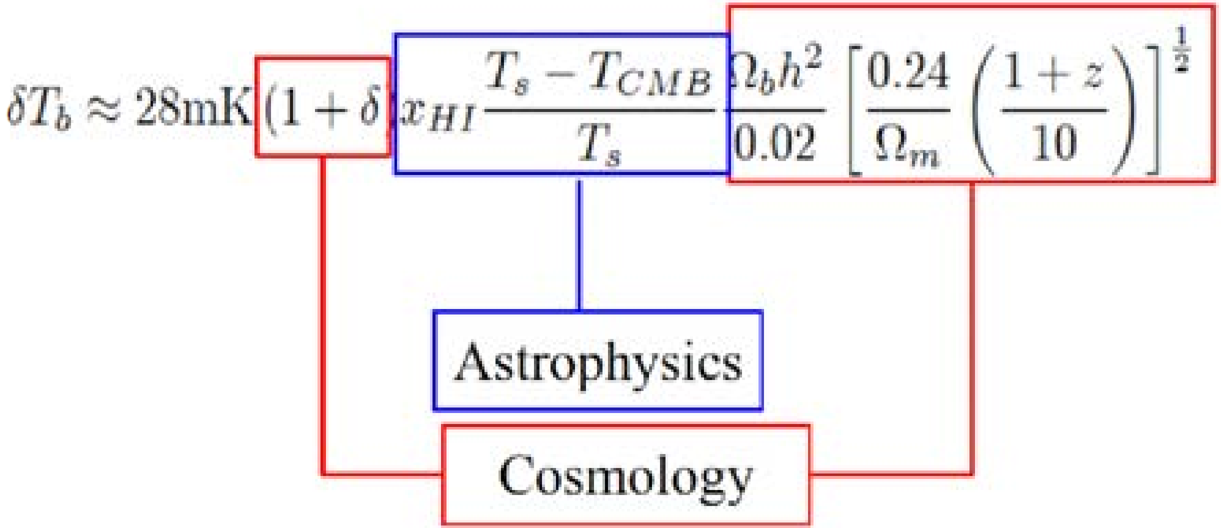
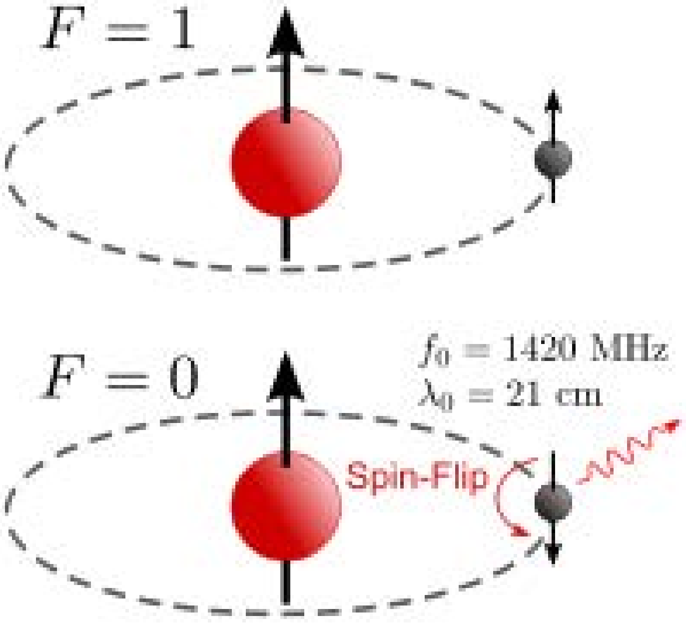



$F=1$
$F=0$
$f_0 = 1420$ MHz
$\lambda_0 = 21$ cm
Spin-Flip


$\delta T_b \approx 28\text{mK}(1+\delta)x_{HI}\frac{T_s - T_{CMB}}{T_s}\frac{\Omega_b h^2}{0.02}\left[\frac{0.24}{\Omega_m}\left(\frac{1+z}{10}\right)\right]^{\frac{1}{2}}$
Astrophysics
Cosmology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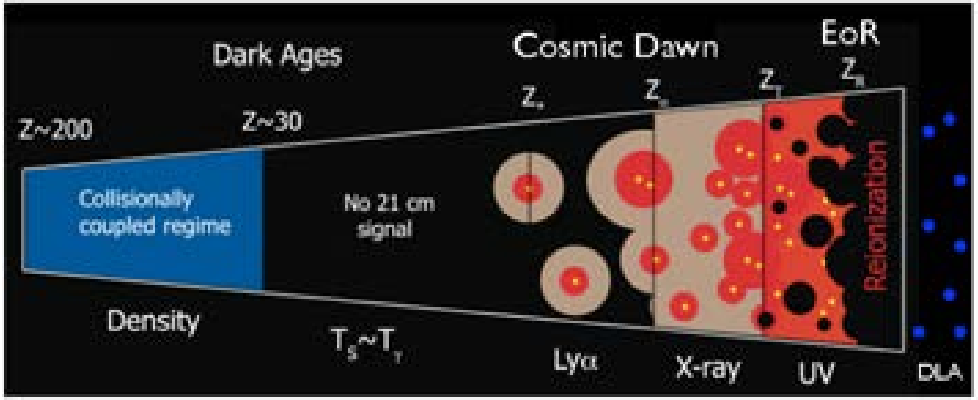
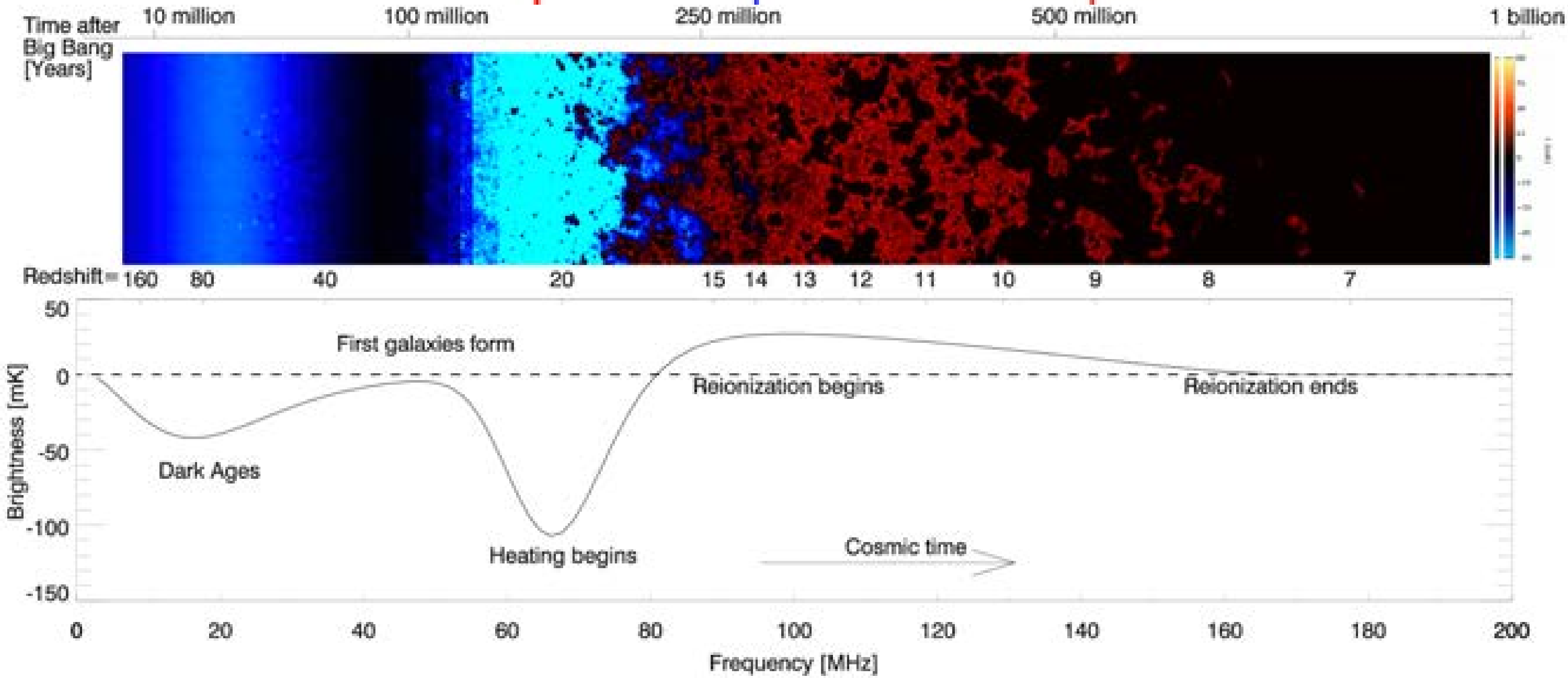
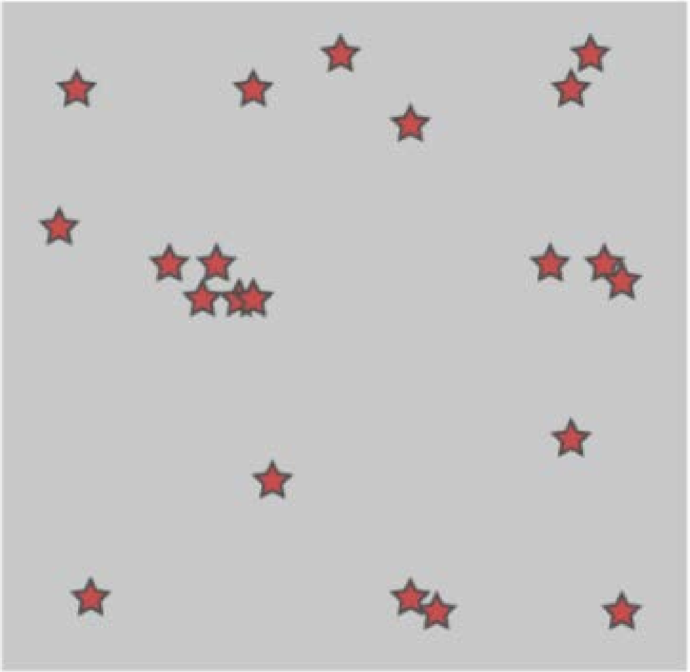
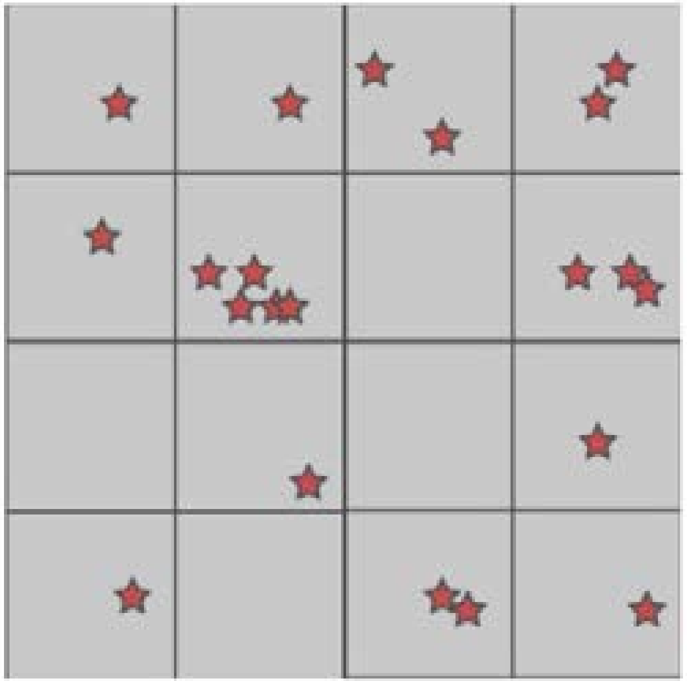
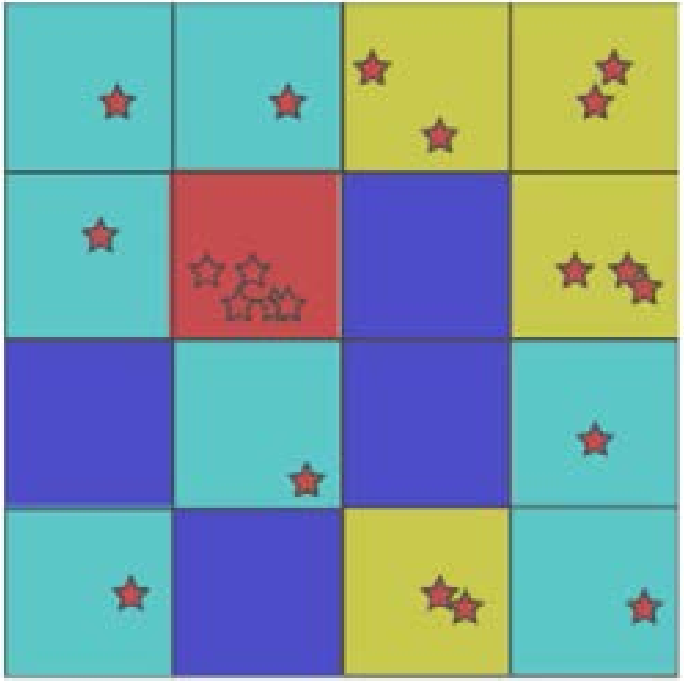

Dark Ages
Cosmic Dawn
EoR
Z~200
Z~30
Collisionally coupled regime
No 21 cm signal
Reionization
Density
$T_S \sim T_\gamma$
Lyα
X-ray
UV
DLA

$$\delta T_b \approx 28\mathrm{mK}\,(1+\delta)\,x_{HI}\,\frac{T_s - T_{CMB}}{T_s}\,\frac{\Omega_b h^2}{0.02}\left[\frac{0.24}{\Omega_m}\left(\frac{1+z}{10}\right)\right]^{\frac{1}{2}}$$







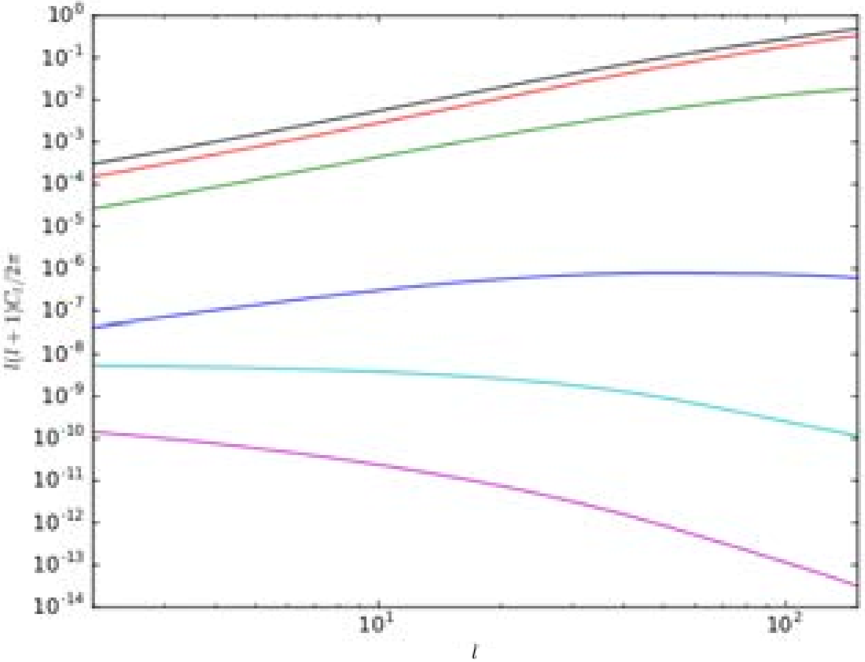


21-cm Intensity Mapping

- Following the same procedure used for CMB, we expand the brightness temperature in spherical harmonics

$$\Delta T_b(z,\hat{n}) = \sum_{lm} \Delta T_{b,lm}(z) Y_{lm}(\hat{n})$$

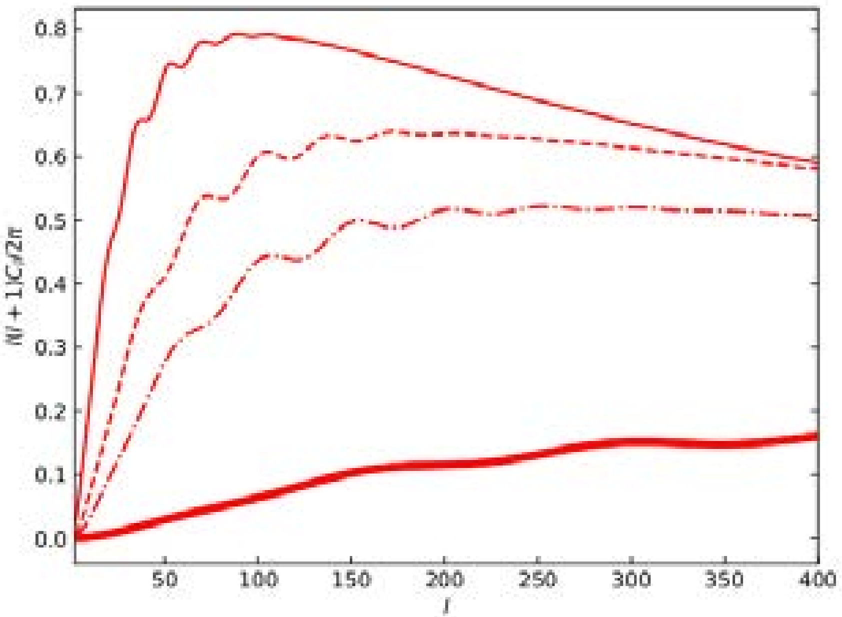
$$C_l^{WW'} = 4\pi \int d\ln k\,\mathcal{P}_{\mathcal{R}}(k)\,\Delta^{W}_{T_b,l}(\mathbf{k})\,\Delta^{W'}_{T_b,l}(\mathbf{k})$$



$$\Delta_{T_b,l}(\mathbf{k},z) = \delta_n j_l(k\chi) + \frac{kv}{\mathcal{H}} j_l''(k\chi) + \left(\frac{1}{\mathcal{H}}\dot{\Phi} + \Psi\right) j_l(k\chi)$$

$$- \left[\frac{1}{\mathcal{H}} \frac{d\ln\left(a^3 \bar{n}_{HI}\right)}{d\eta} - \frac{\dot{\mathcal{H}}}{\mathcal{H}^2} - 2\right] \left[\Psi j_l(k\chi) + v j_l'(k\chi) + \int_0^{\chi} (\dot{\Psi} + \dot{\Psi}) j_l(k\chi') d\chi'\right]$$

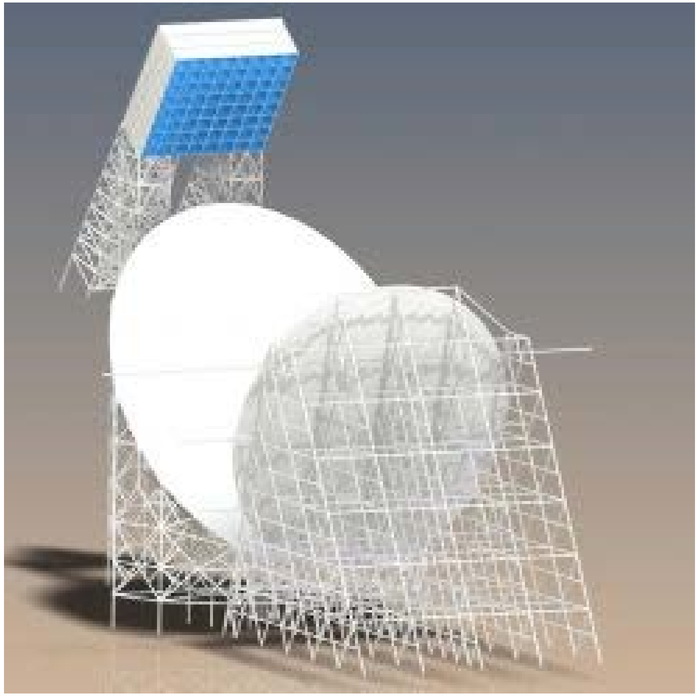
$$C_l^{WW'} = 4\pi \int d\ln k\,\mathcal{P}_{\mathcal{R}}(k)\,\Delta^{W}_{T_b,l}(\mathbf{k})\,\Delta^{W'}_{T_b,l}(\mathbf{k})$$



$$\Delta_{T_b,l}(\mathbf{k},z) = \delta_n j_l(k\chi) + \frac{kv}{\mathcal{H}} j_l''(k\chi) + \left(\frac{1}{\mathcal{H}}\dot{\Phi} + \Psi\right) j_l(k\chi) - \left[\frac{1}{\mathcal{H}}\frac{d\ln\left(a^3\bar{n}_{HI}\right)}{d\eta} - \frac{\dot{\mathcal{H}}}{\mathcal{H}^2} - 2\right]\left[\Psi j_l(k\chi) + v j_l'(k\chi) + \int_0^{\chi} (\dot{\Psi} + \dot{\Psi}) j_l(k\chi')\,d\chi'\right]$$

BINGO

- Collaboration: Brazil, UK, Uruguai, China
- Dishes diameters: 45, 38 m
- Num. feed horns: 50 (2 pol.)
- Freq. range: 960 – 1260 Mhz
- Redshift range: [0.13, 0.48]
- Area: ~ 5000 sq. deg.



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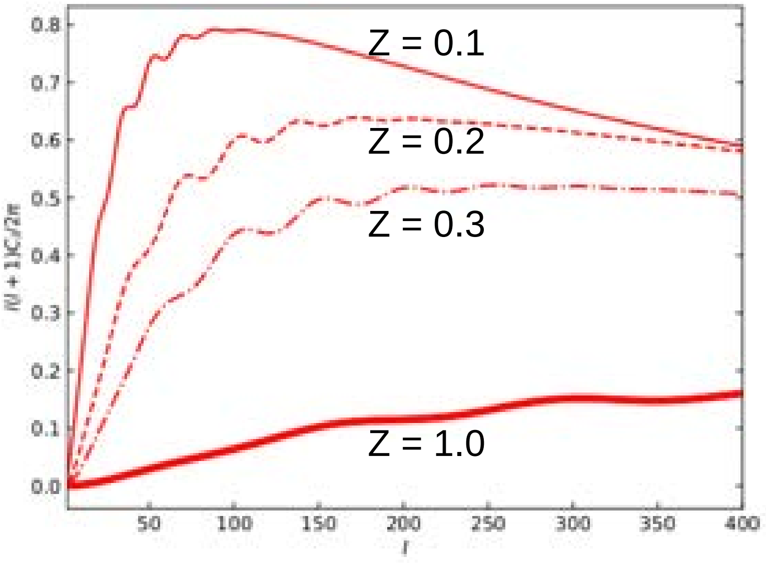
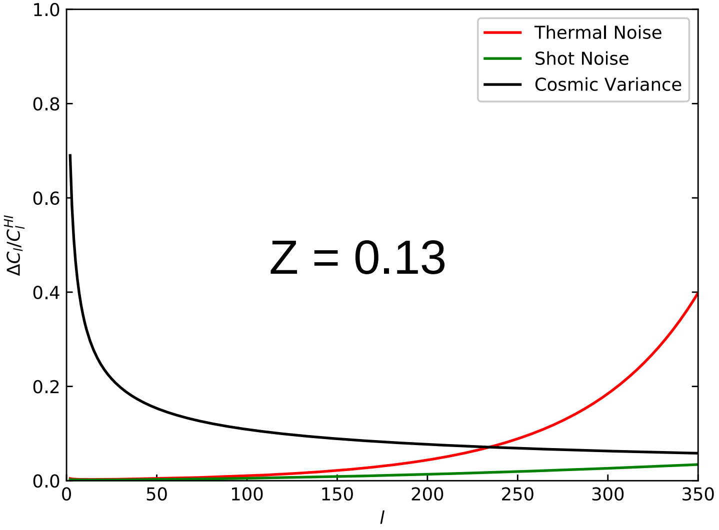
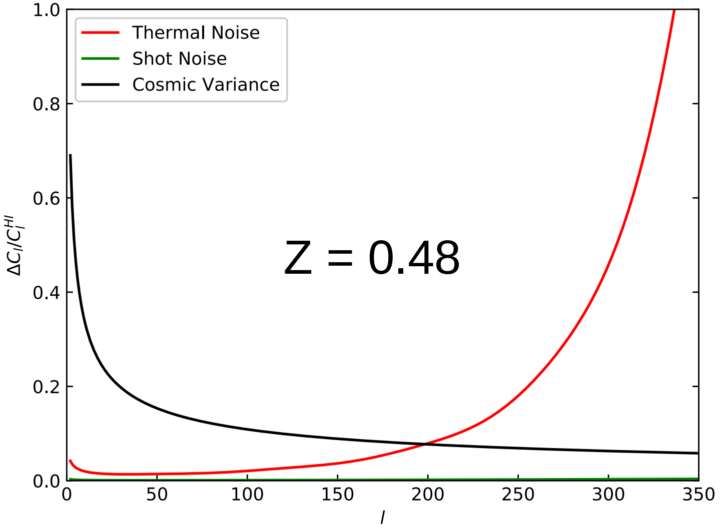

Z = 0.1
Z = 0.2
Z = 0.3
Z = 1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
50
100
150
200
250
300
350
400
l


Thermal Noise
Shot Noise
Cosmic Variance
Z = 0.13
ΔC_l/C_l^HI
l
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
300
350


Thermal Noise
Shot Noise
Cosmic Variance
Z = 0.48
ΔC_l/C_l^HI
l
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
300
350

Cosmological parameter forecasts for HI intensity mapping experiments using the angular power spectrum

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[1] *Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics & Astronomy, The University of Manchester, Oxford Road, Manchester, M13 9PL, U.K.*

[2] *School of Chemistry and Physics, University of KwaZulu-Natal, Westville Campus, Private Bag X54001, Durban 4000, South Africa*

[3] *Instituto de Física, Universidade de São Paulo, C.P. 66318, 05315-970, São Paulo, SP, Brazil*

ABSTRACT

HI intensity mapping is a new observational technique to survey the large-scale structure of matter using the 21 cm emission line of atomic hydrogen (HI). In this work, we simulate BINGO (BAO from Integrated Neutral Gas Observations) and SKA (Square Kilometre Array) phase-1 dish array operating in auto-correlation mode. For the optimal case of BINGO with no foregrounds, the combination of the HI angular power spectra with *Planck* results allows w to be measured with a precision of 4%, while the combination of the BAO acoustic scale with *Planck* gives a precision of 7%. We consider a number of potentially complicating effects, including foregrounds and redshift dependent bias, which increase the uncertainty on w but not dramatically; in all cases the final uncertainty is found to be $\Delta w < 8\%$ for BINGO. For the combination

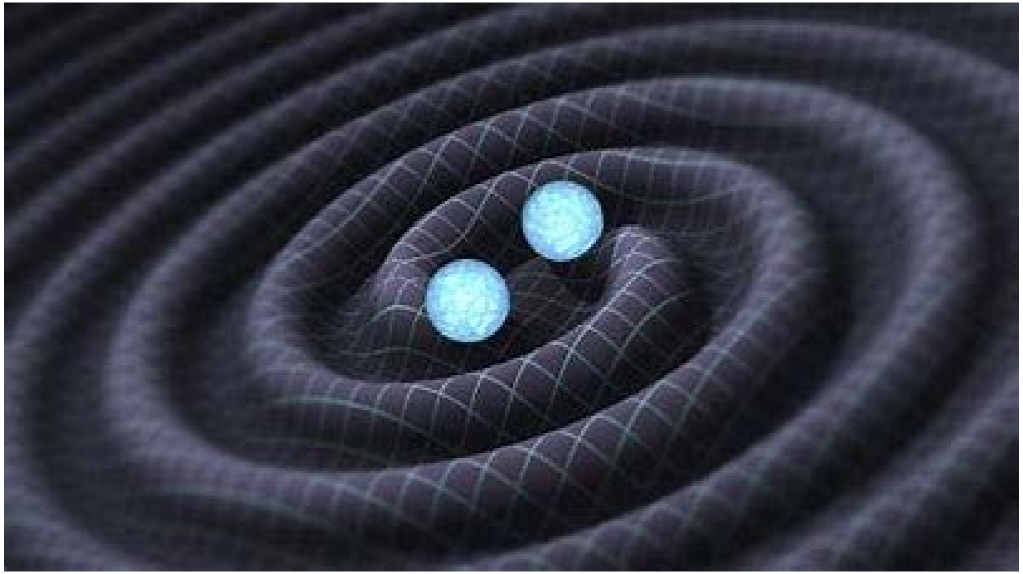
Gravitational Waves

$$L_{\mathrm{GW}} = \frac{32G^4\mu^2M^3}{5c^5a^5}$$

$$\omega = \sqrt{GM/a^3}$$

$$\dot{\omega}/\omega = 96G^3\mu M^2/5c^5a^4$$

$$v = \sqrt{GM/a}$$



A GRAVITATIONAL-WAVE STANDARD SIREN MEASUREMENT OF THE HUBBLE CONSTANT

THE LIGO SCIENTIFIC COLLABORATION AND THE VIRGO COLLABORATION, THE 1M2H COLLABORATION,
THE DARK ENERGY CAMERA GW-EM COLLABORATION AND THE DES COLLABORATION,
THE DLT40 COLLABORATION, THE LAS CUMBRES OBSERVATORY COLLABORATION,
THE VINROUGE COLLABORATION, THE MASTER COLLABORATION, et al.

The detection of GW170817 (Abbott et al. 2017a) in both gravitational waves and electromagnetic waves heralds the age of gravitational-wave multi-messenger astronomy.

$$H_0 = 70.0^{+12.0}_{-8.0}\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$$

First measurement of the Hubble constant from a dark standard siren using the Dark Energy Survey galaxies and the LIGO/Virgo binary–black–hole merger GW170814

We present a multi–messenger measurement of the Hubble constant H_0 using the binary–black–hole merger GW170814 as a standard siren, combined with a photometric redshift catalog from the Dark Energy Survey

$$H_0 = 75^{+40}_{-32}\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$$

Summary

- Several new experiments will improve our knowledge of the late-time expansion in the near future.
- They will survey the Universe and provide information using different observables and techniques in the optical, radio and gravitational wave domain.
- The constraints may reach percent or subpercent level.
- J-PAS (photometric) and BINGO (21-cm IM) will contribute with this effort.