Real time cosmology

GLOWSKA 2016 KIT

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Real time cosmological experiments

Idea measure the change of observables within 10 or 30 years

- angle – cosmological parallax less than μas / years
-

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THE CHANGE OF REDSHIFT AND APPARENT LUMINOSITY OF GALAXIES DUE TO THE DECELERATION OF SELECTED EXPANDING UNIVERSES

ALLAN SANDAGE

1. The foregoing considerations show that an "ideal" deceleration test exists between the exploding and the steady-state models in the sense that the *sign* of the effect is reversed. However, for the test to be useful, it would seem that a precision redshift catalogue must be stored away for the order of 10^7 years before an answer can be found because the decelerations are so small by terrestrial standards.

CODEX like experiment

Observational evidence from supernovae for an accelerating universe and a cosmological constant [Riess, et al., 1998, AJ 116]

Measurement of Ω and λ from 42 high-redshift supernovae [Perlmutter et al., 1999, ApJ 517]

KUNGL. VETENSKAPS-AKADEMIEN

THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Nobel Prize in Physics 2011

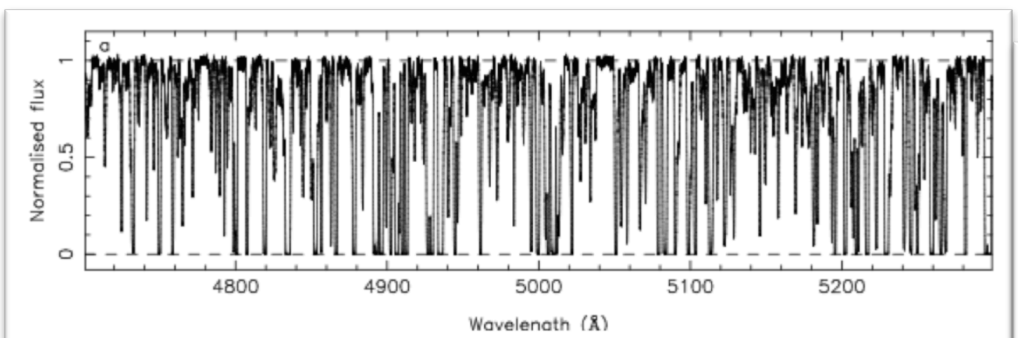
Saul Perlmutter, Brian P. Schmidt and Adam G. Riess

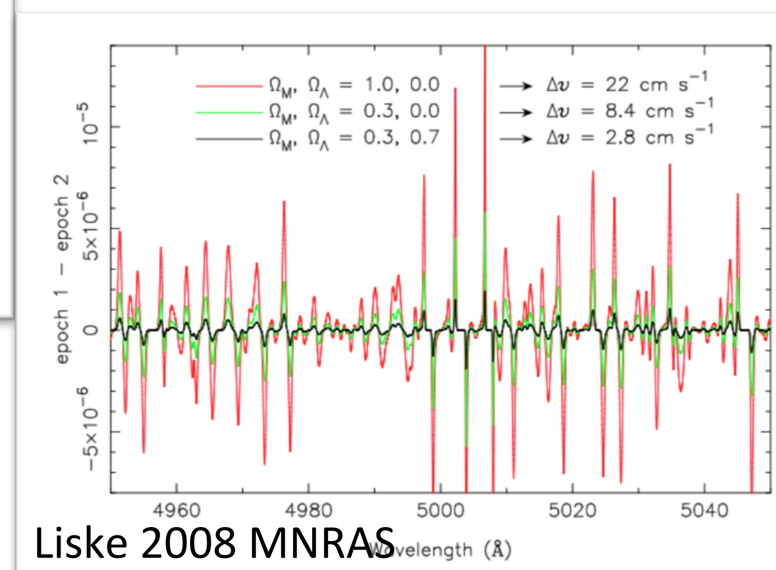
"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"

A. Loeb 1998

The cosmic signal can then be searched for through a cross-correlation analysis of the Lyα forest template in the spectrum of these quasars, taken at two different times with the HIRES instrument on the Keck 10 meter telescope.

HIRES – EELT



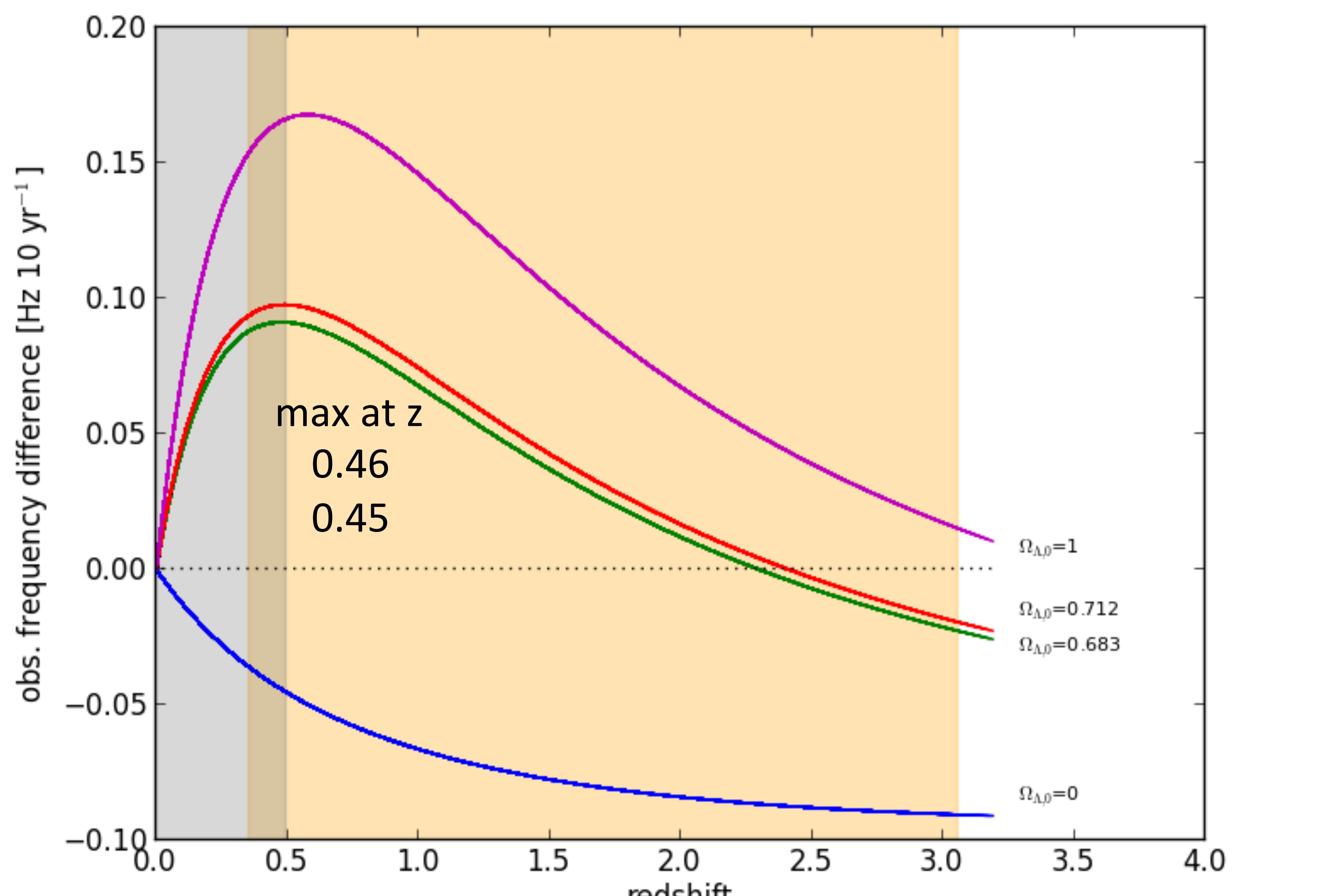


Liske 2008 MNRAS

Key figure in the frequency regime (10 yrs)

from theory $\dot{z} = H(z) - (1+z)H_0$

$$H(z) = H_0[\Omega_m \times (1+z)^3 + \Omega_\lambda + \Omega_k(1+z)^2]^{\frac{1}{2}}$$ LCDM



Klöckner et al. 2015; astro-ph: 1501.03822

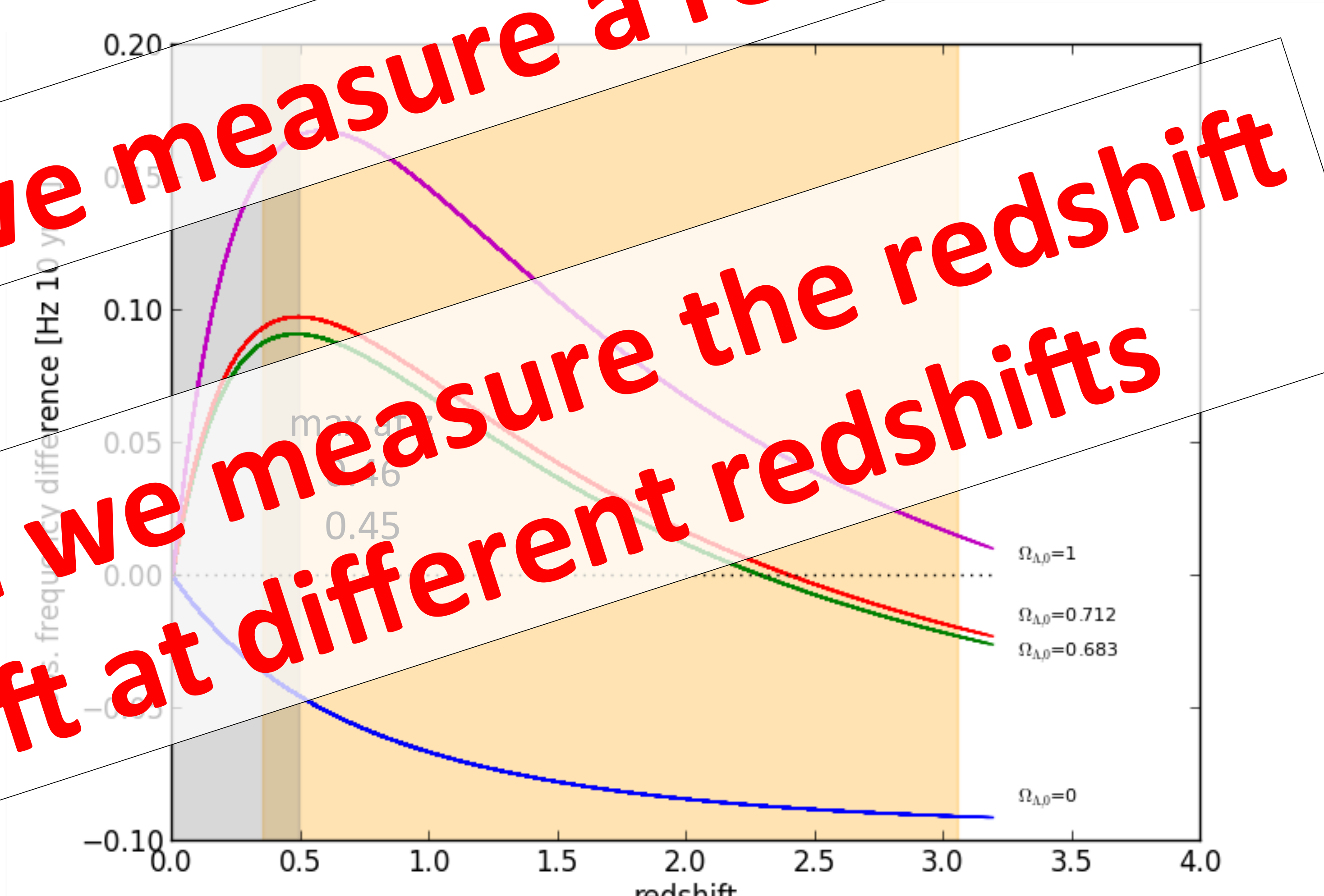
Key figure in the frequency regime

$$\dot{z} = \mathrm{H(z)} - (1+z)\mathrm{H}_0$$

$$\mathrm{H(z)} = H_0[\Omega_\mathrm{m} \times (1+z)^3 + \Omega_\lambda + \Omega_k(1+z) \ldots]$$ LCDM

Can we measure a redshift drift

Can we measure the redshift drift at different redshifts

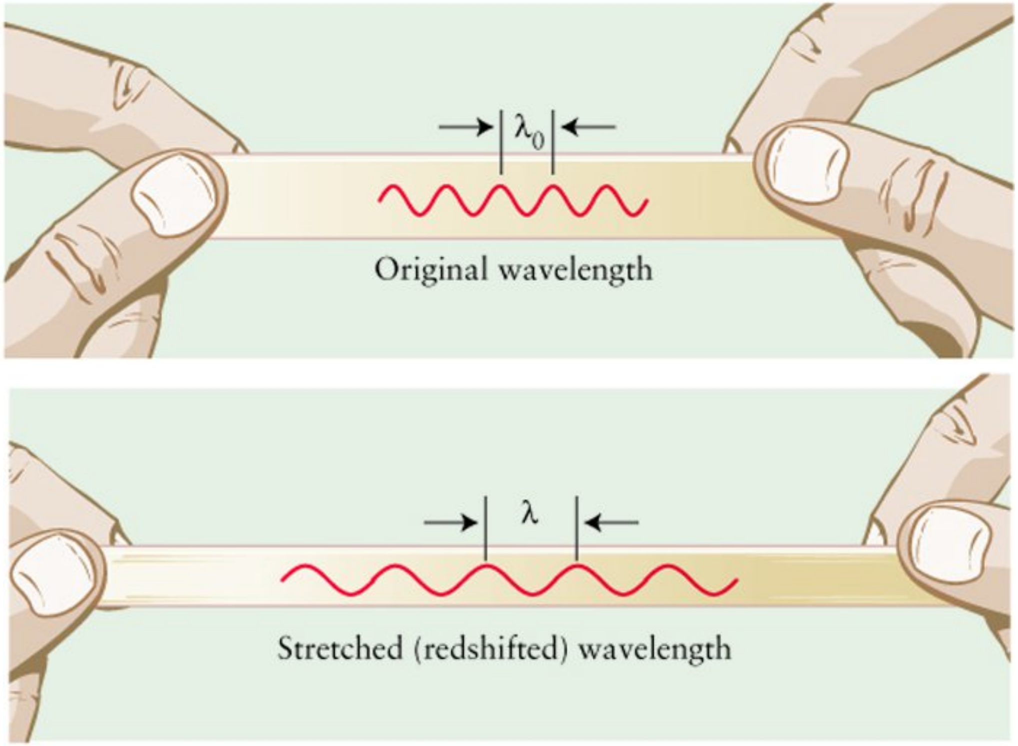


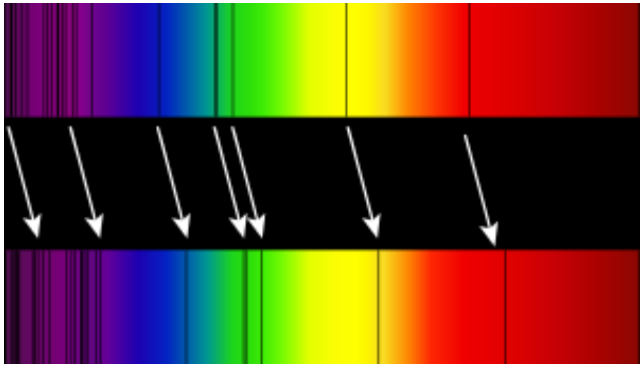
Klöckner et al. 2015; astro-ph: 1501.03822

cosmological redshift

$$\frac{R(t_0)}{R(t_e)} = (1+z)$$

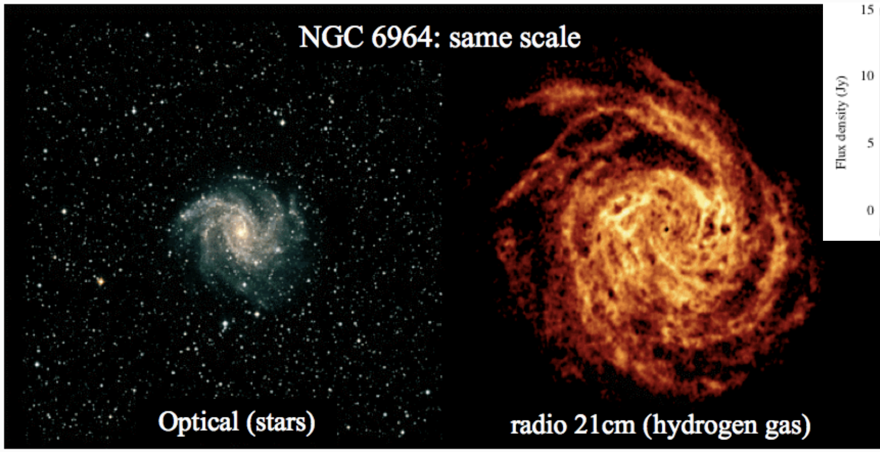
$$ds^2 = (c\ dt)^2 - R^2(t)\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + \sin^2\theta d\phi^2)\right]$$

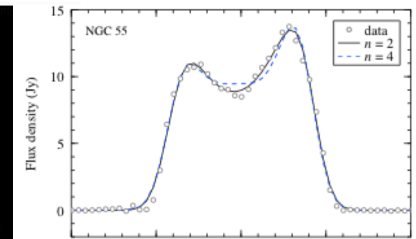




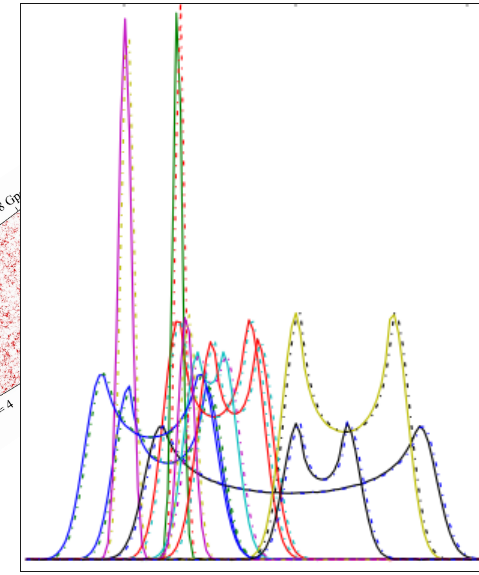
$$z = \frac{\nu_{\mathrm{restframe}} - \nu_{\mathrm{obs}}}{\nu_{\mathrm{obs}}}$$

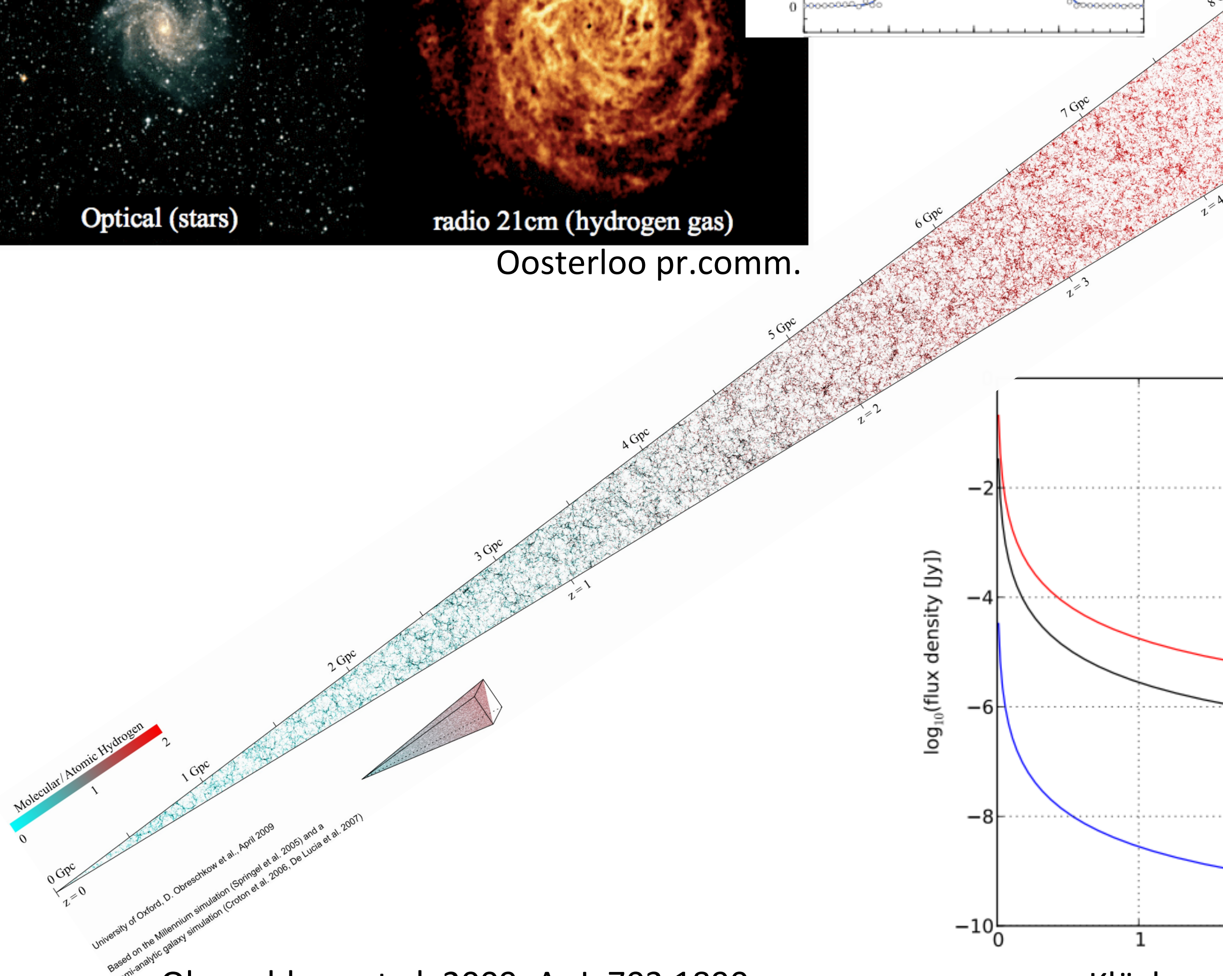
finding the right tracer



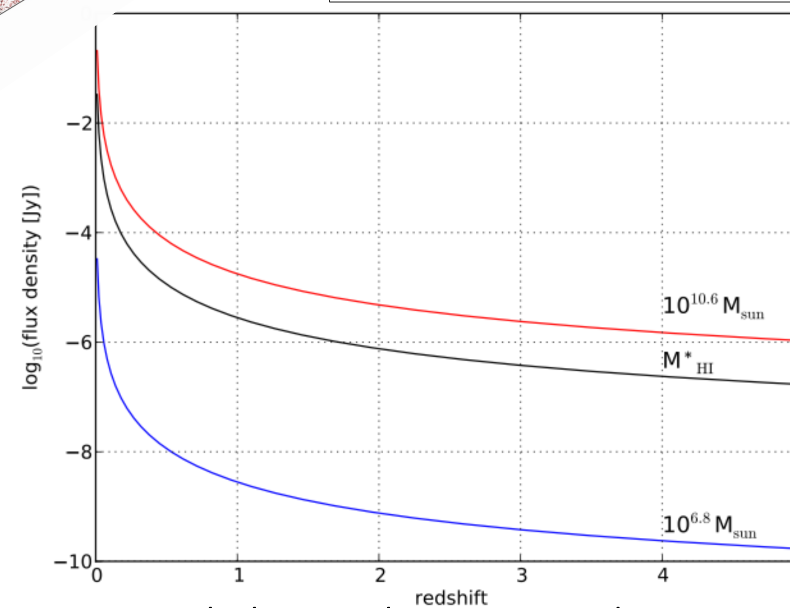


Oosterloo pr.comm.





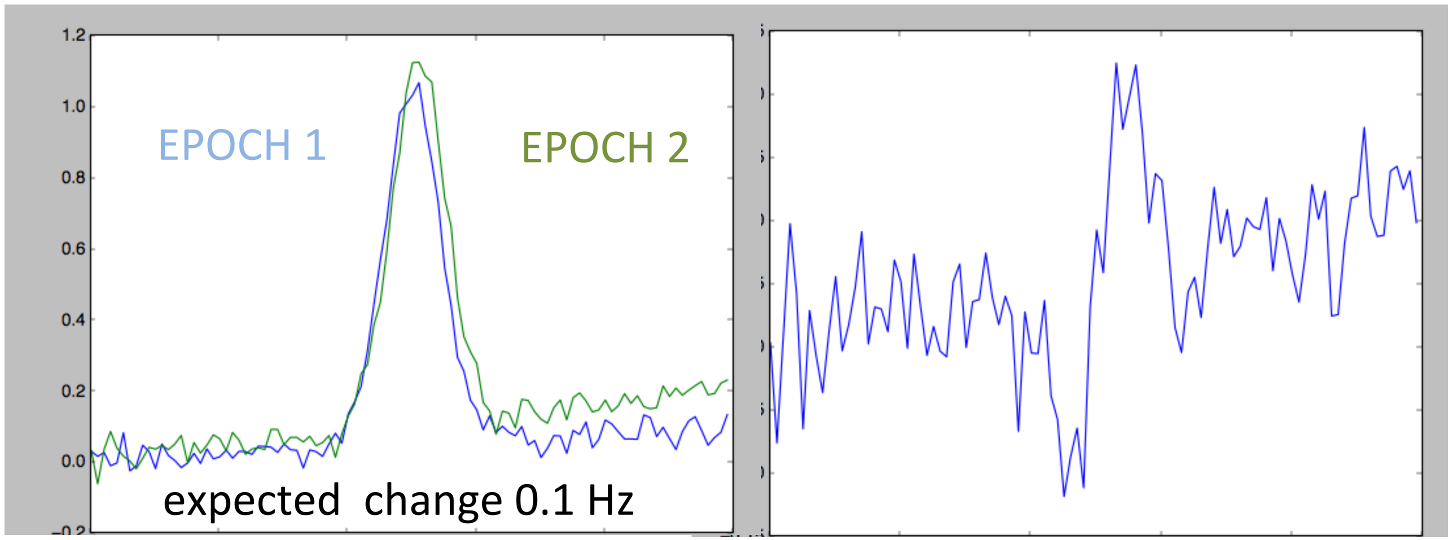
Obreschkow et al. 2009; ApJ, 703,1890



Klöckner et al. 2010; astro-ph: 1002.0502

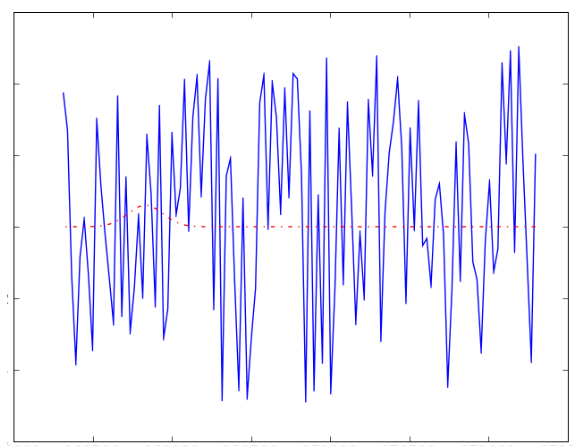
The basics - measure acceleration

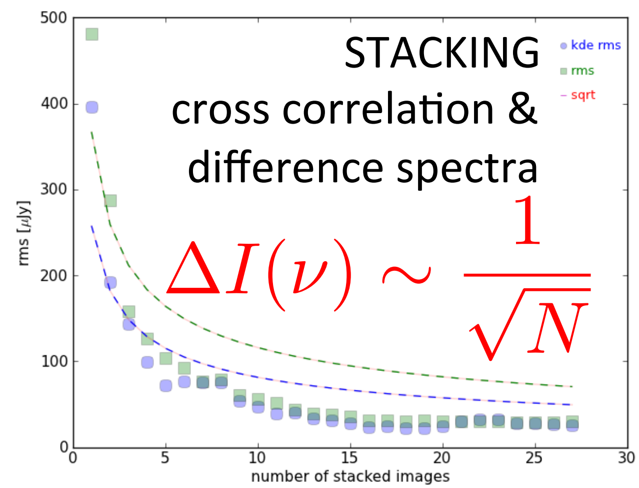
back to the roots re-visiting Sandage idea in the radio regime



$$\Delta I = \frac{SEFD}{\eta_s \sqrt{t \Delta \nu}}$$

$$SEFD = \frac{2kT_{sys}}{A_{eff}}$$



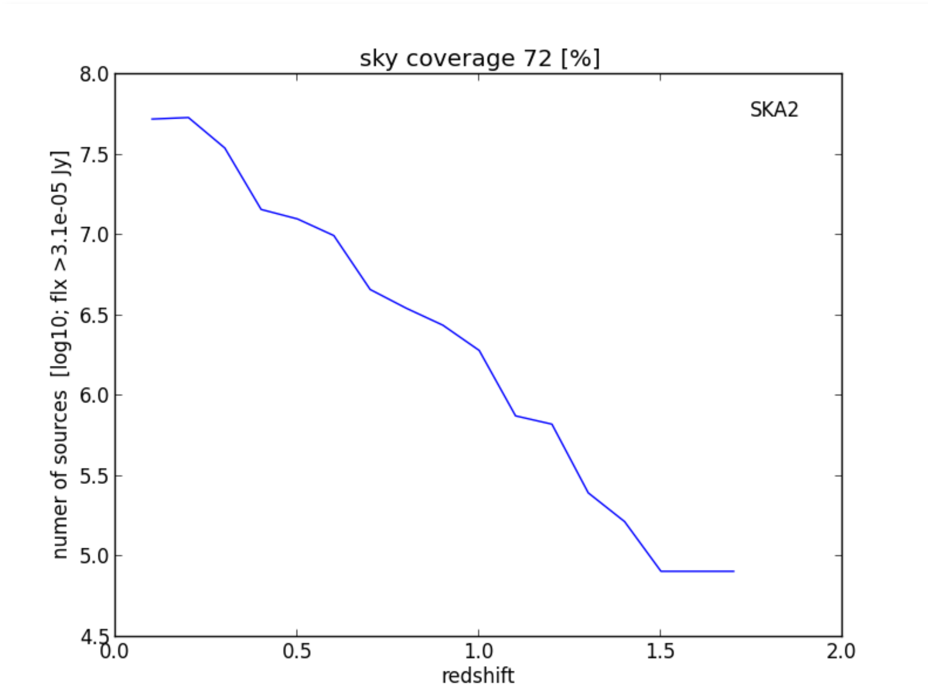


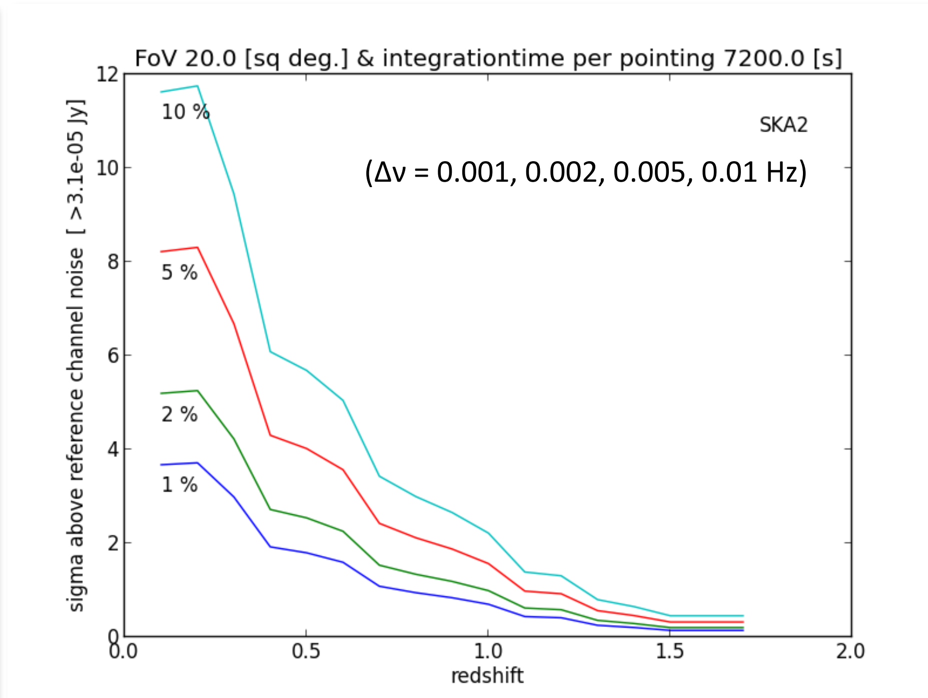
SKA baseline design 3.9 kHz → 0.01 Hz
simulation are currently on its way

Measuring acceleration with the SKA

KEY is number density and channel resolution

need to detect $\Delta\nu$ = 0.1 Hz





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Measuring acceleration with the SKA

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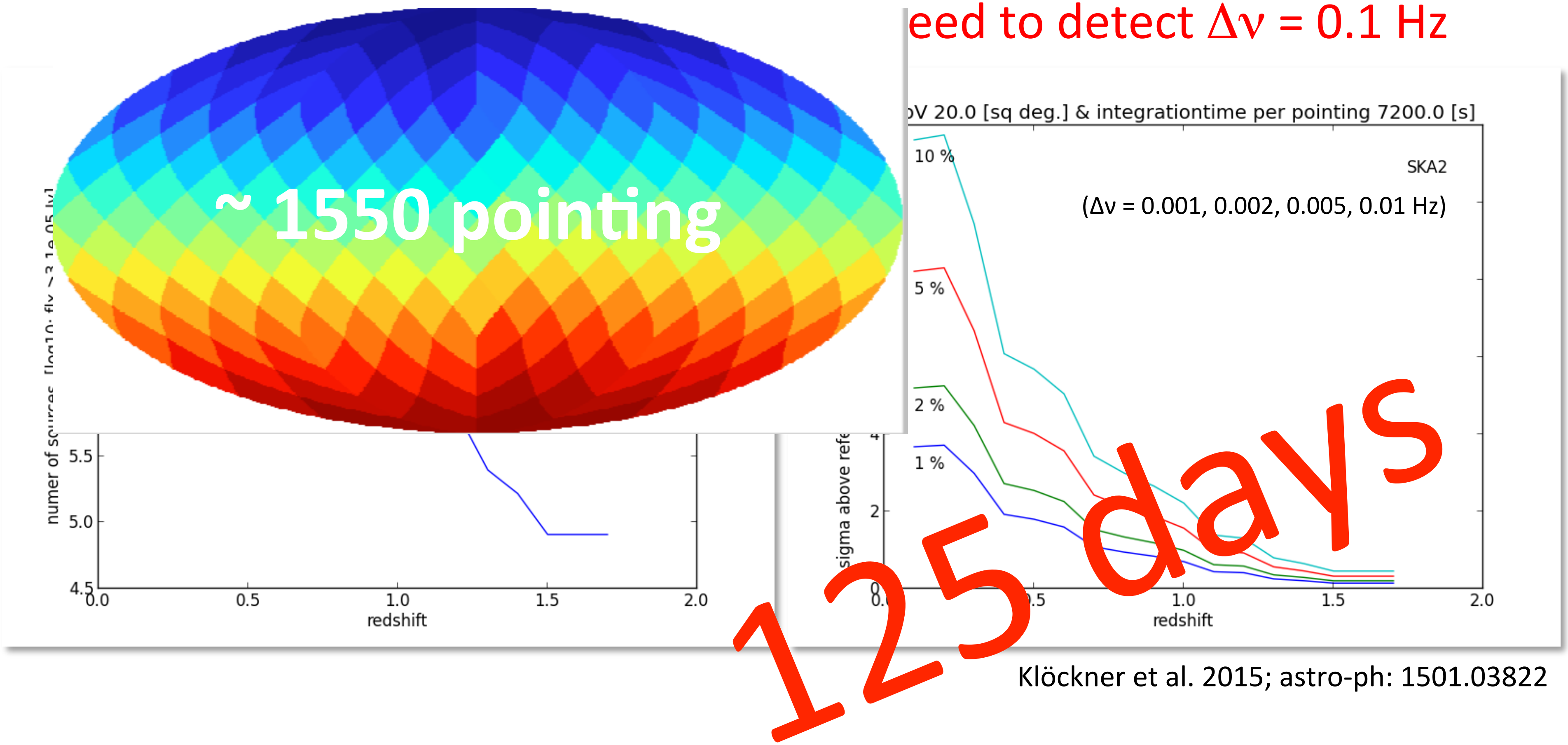
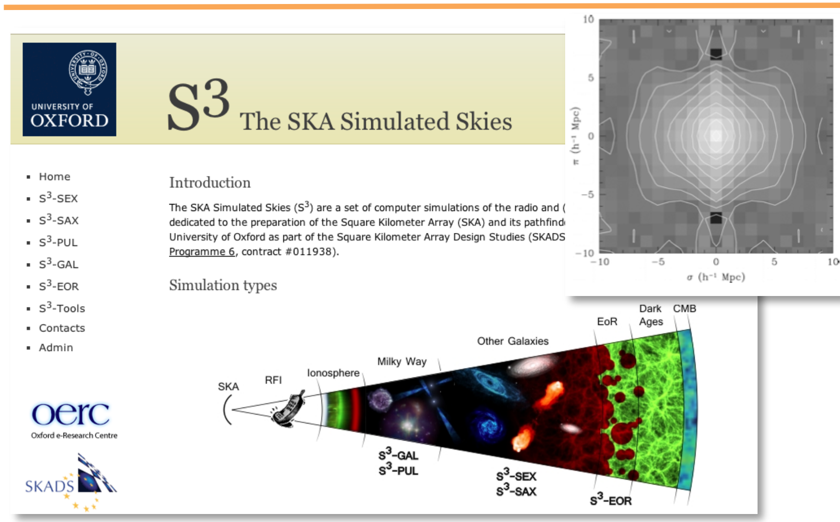


Klöckner et al. 2015; astro-ph: 1501.03822

The small print – handling the systematics

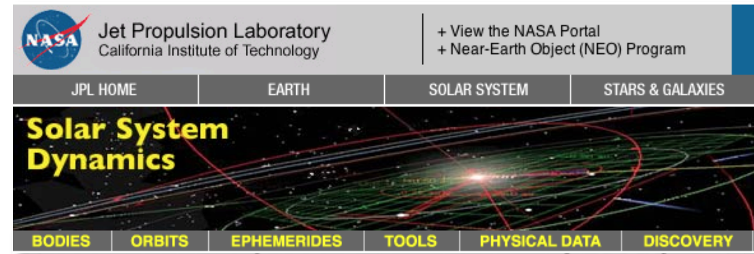


SAX simulation - Obreschkow et al. 2009

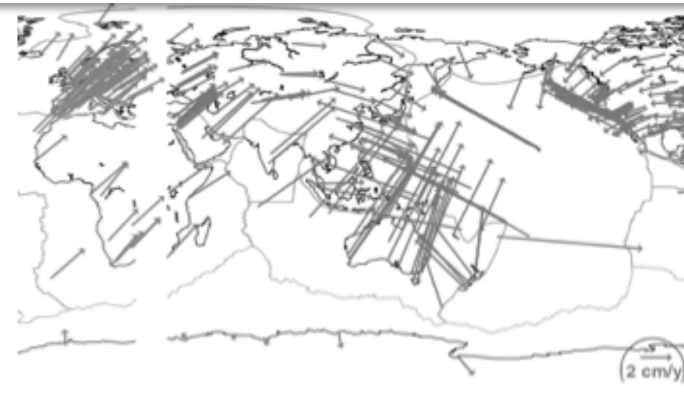
- Station / Source positions: different frames (ITRF, ICRF), motions
- Times: UTC; TAI, TT; UT1; TDB/TCB/TCG
- Orientation: Precession (50″/yr), Nutation (9.6″, 18yr), Polar Motion (0.6″, 1yr)
- Diurnal Spin: Oceanic friction (2ms/cy), CMB (5ms, dcds), AAM (2ms, yrs)
- Tides: Solid-earth (30cm), Pole (2cm)
- Loading: Ocean (2cm), Hydrologic (8mm), Atmospheric (2cm), PGR (mm's/yr)
- Antennas: Axis offset, Tilt, Thermal expansion
- Propagation: Troposphere (dry [7ns], wet [0.3ns]), Ionosphere
- Relativistic $\tau(t)$ calculation: Gravitational delay, Frame choice/consistency

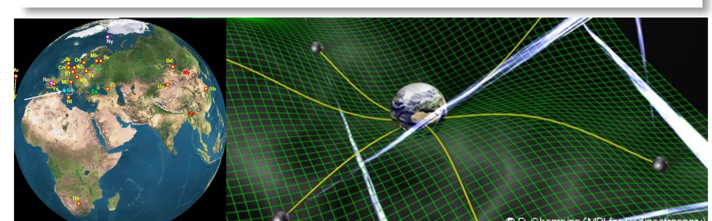
stolen from B. Campbell

mm < 3 cm/s 10/yrs



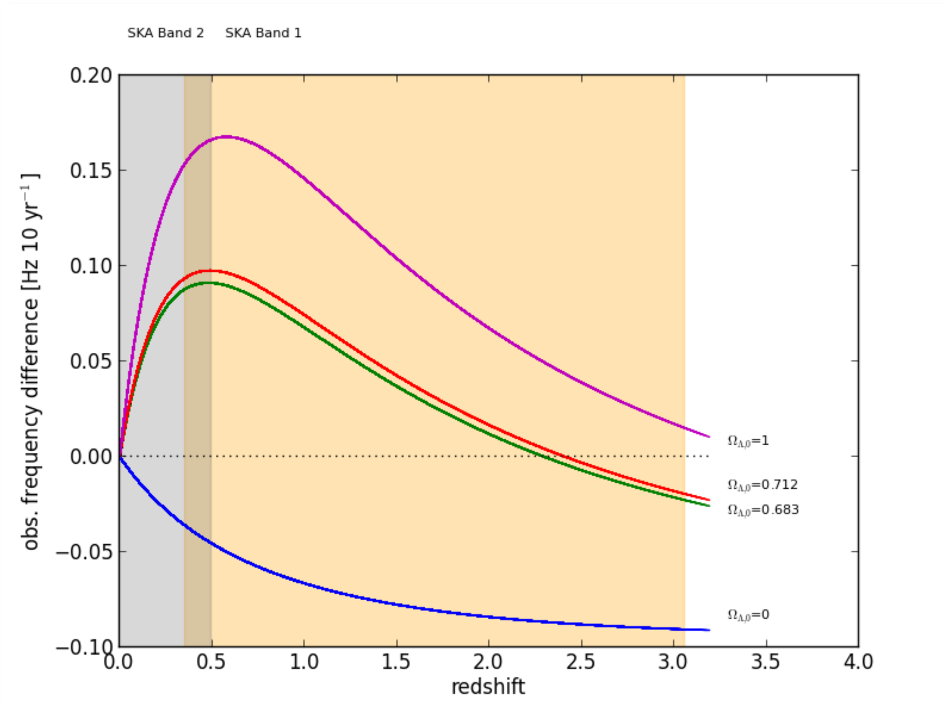
Rest Frame	Corrected for	Amplitude of Correction, km s^{-1}
Geocentric	Earth rotation	0.5
Earth-Moon Barycentric	Effect of the Moon on the Earth	0.013
Heliocentric	Earth's orbital motion	30
Solar System Barycentric	Effect of planets on the Sun	0.012
Local Standard of Rest	Solar motion	20
Galactocentric	Milky Way rotation	230
Local Group Barycentric	Milky Way motion	~100
Virgocentric	Local Group motion	~300
Microwave Background	Local Supercluster motion	~600

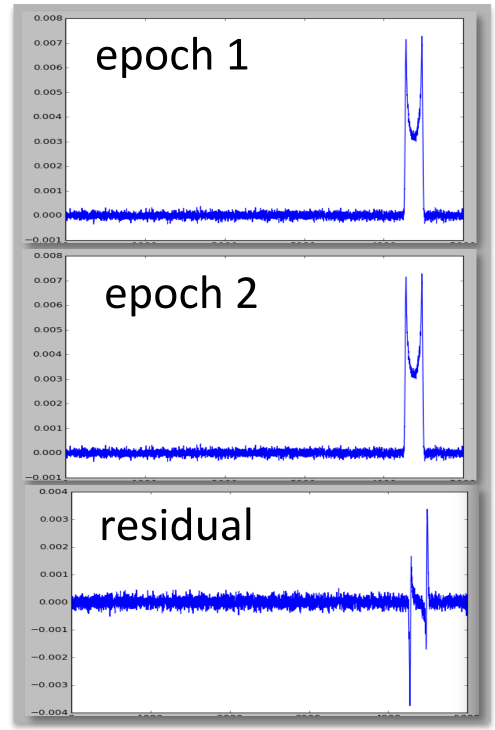




Real time cosmology - summary

- Cosmic acceleration, a test of dark energy, will change the redshift of individual galaxies within 10 years by dz/dt ~ 10^{-10}. Stacking the residual or cross-correlated spectra of 10^{7-9} individual galaxies can measure this offset of ~0.1 Hz.

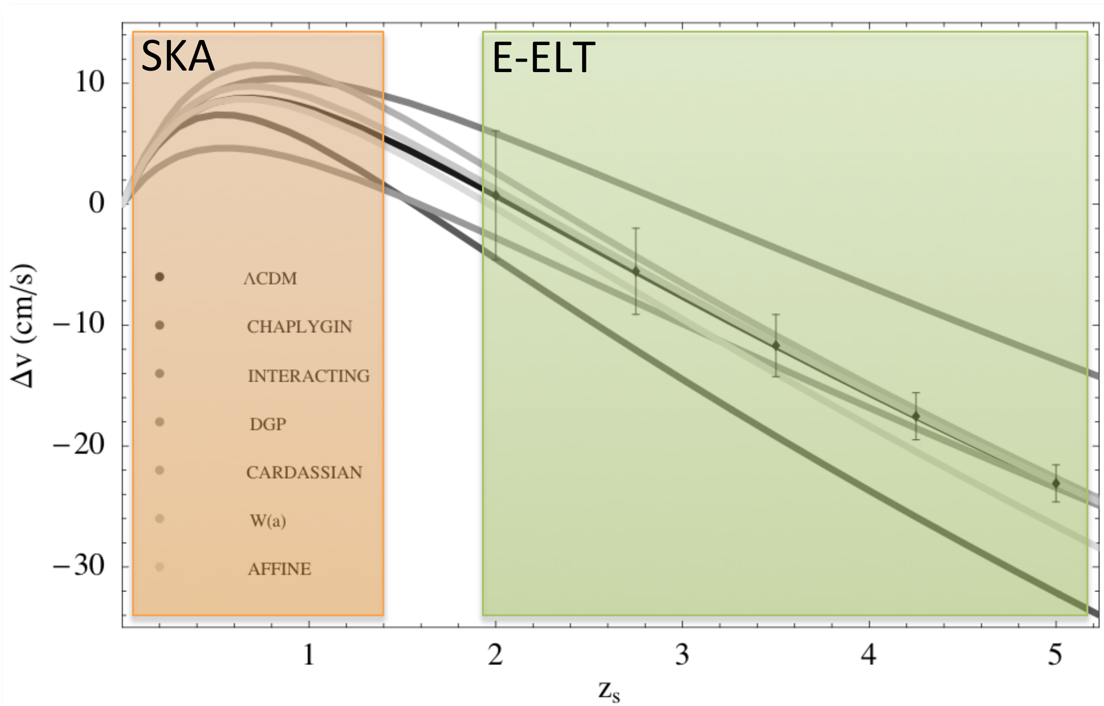




- This real time cosmology experiment does require some changes to the baseline design (e.g. channel resolution of ~0.001 Hz) and will challenge the overall system stability. Need at least 10^8 channels to cover HI line width (fan-out mode of sub-bands).

Real time cosmology - summary

- The SKA provides us with a model independent measure of the dynamics of the cosmic expansion within 10 years.
- The SKA will be the **only** observatory probing the cosmic acceleration and its dependency on redshift by facilitating a 3 π HI galaxy survey.
- The SKA will break degeneracy with other probes allowing to check



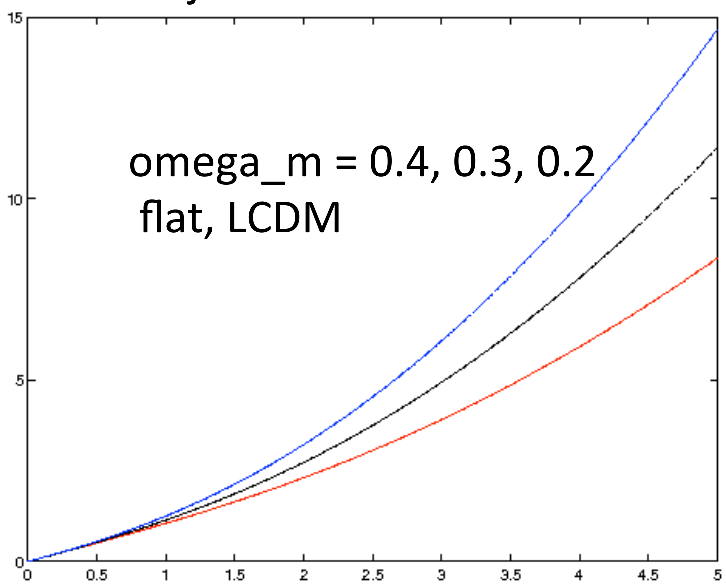
cosmic models e.g. 2 epoch 30 yrs [Balbi & Quercellini 2007 MNRAS 382]

Real time cosmology - summary

- SKA lifetime will be 50 year, e.g. redshift drifts and its evolution in time, alone and in combination with other experiments enables us to constrain cosmological models.

impact on the equation of state

cosmic jerk – term versus redshift



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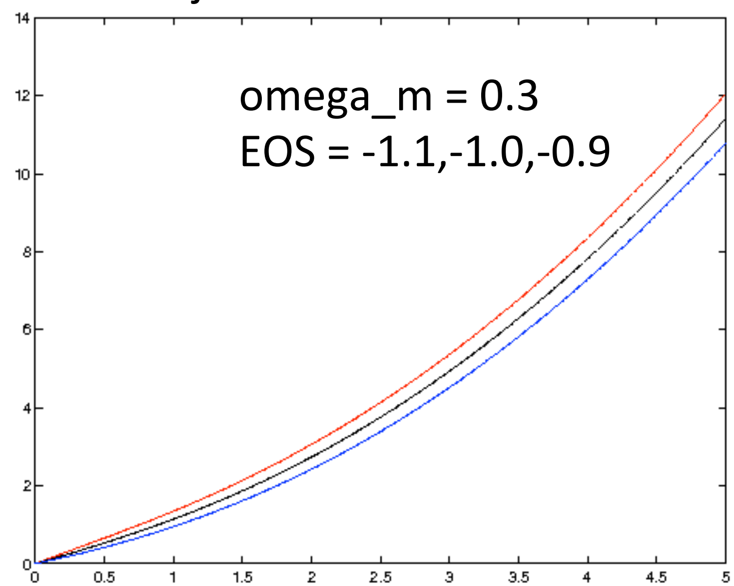

test for modified cosmological