Title: A new test of the concordance cosmology

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Abstract: A new test of the LCDM concordance cosmology is presented.

Reflections in an imperfect mirror

Spectral distortions of the CMB in a radially inhomogeneous universe

Robert Caldwell
Dartmouth College

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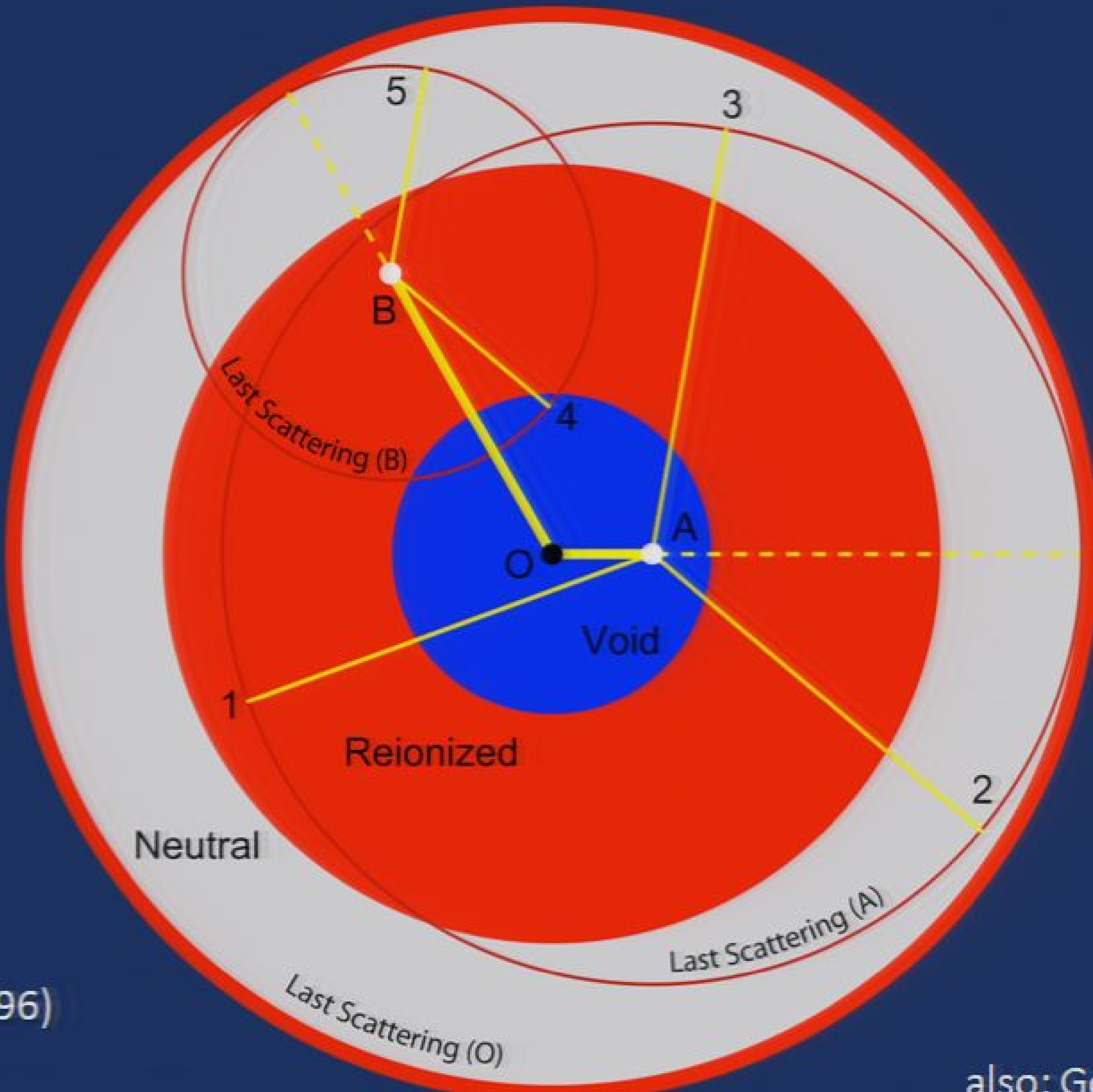
A Test of the Copernican Principle
Stebbins & RC, PRL 100, 191302 (2008)



FIRAS
Fixsen et al (1996)

also: Goodman (1995)

[redacted]

A Test of the Copernican Principle

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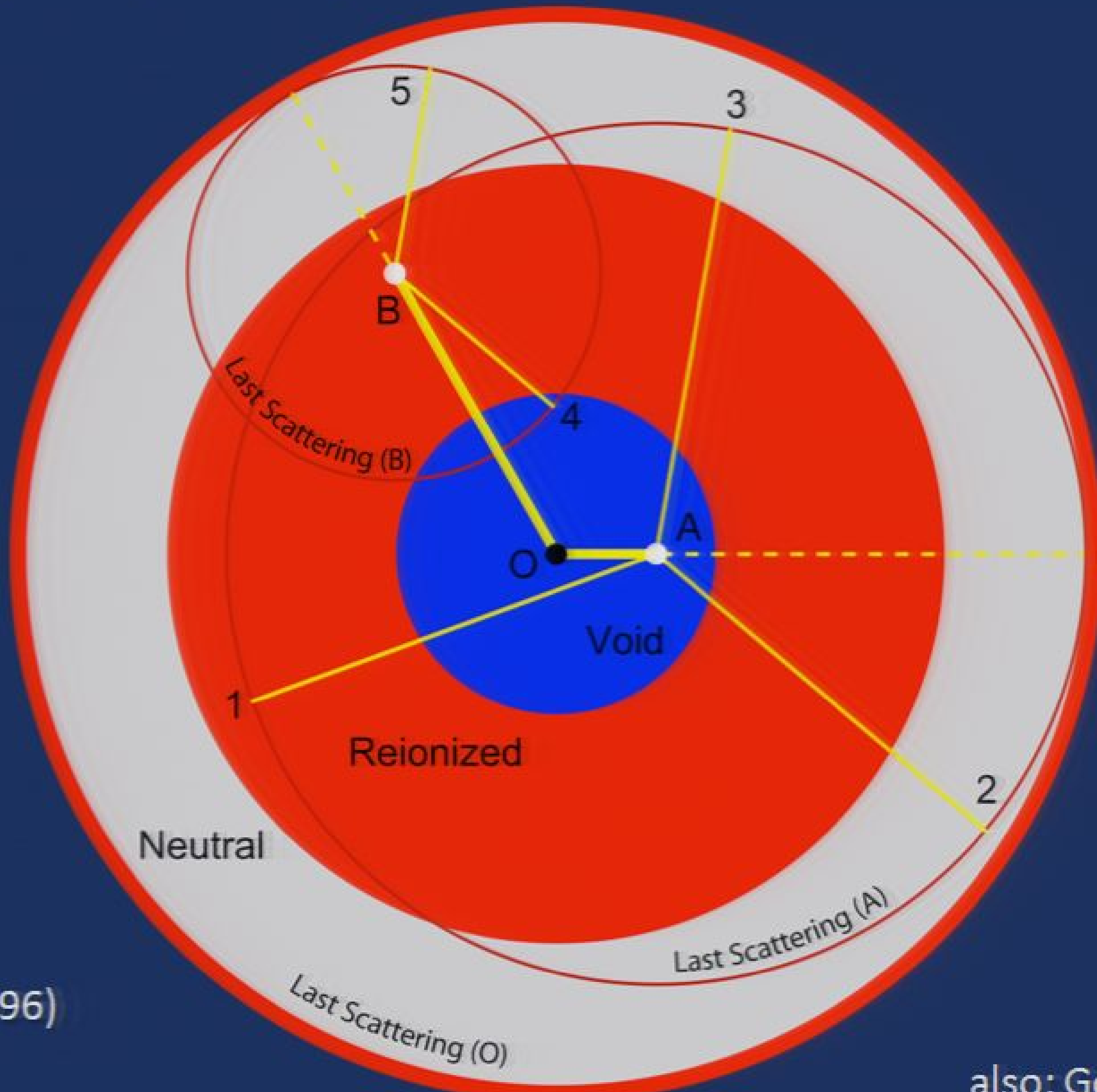

FIRAS

Fixsen et al (1996)

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Evidence for our Robertson-Walker spacetime

Copernican Principle: *We are not at the center of the universe*

Bondi (1960)

Location Principle: *We are not at a special location, should one exist*

Harrison (1981)

Observed Isotropy + Copernican/Location Principle = *Homogeneity*

Cosmological Principle: *All places in the universe are alike, homogeneous and isotropic*

Milne (1933)

$$ds^2 = -dt^2 + a^2(t)\left(\frac{dr^2}{1+kr^2} + r^2 d\Omega^2\right)$$

Evidence for our Robertson-Walker spacetime

Proving Homogeneity

If all observers in an expanding universe see isotropic radiation, then the spacetime is homogeneous and isotropic

Ehlers, Geren, Sachs (1968)

"Limits on Anisotropy and Inhomogeneity from the CMB,"

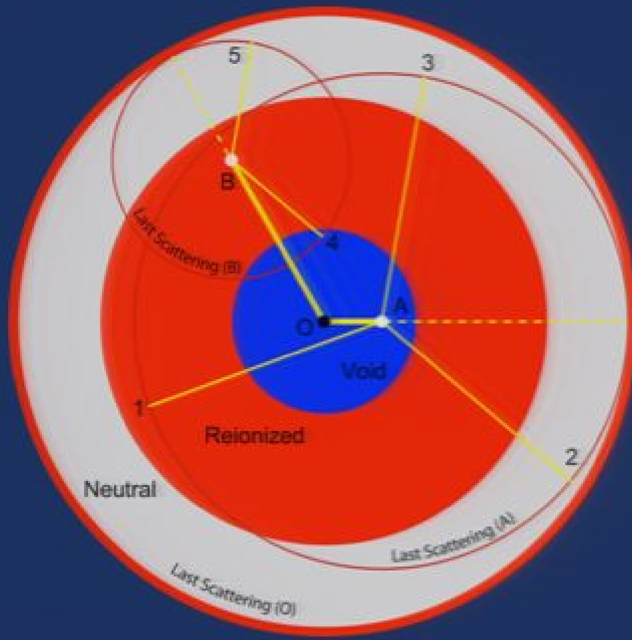
Maartens et al (1995)

"Cosmic Homogeneity Demonstrated with LRGs,"

Hogg et al (2005)

$$ds^2 = -dt^2 + a^2(t)\left(\frac{dr^2}{1+kr^2} + r^2 d\Omega^2\right)$$

u-distortion



$$u[\hat{n}] = \frac{3}{16\pi}\int_0^\infty dz' \frac{d\tau}{dz'} \int d\hat{n}'(1+(\hat{n}\cdot\hat{n}')^2) \times \left(\frac{\Delta T}{T}[\hat{n},\hat{n},z] - \frac{\Delta T}{T}[\hat{n}',\hat{n},z]\right)^2$$

degenerate with Compton y-distortion parameter: u = 2y

[see Stebbins (2008), Chluba&Sunyaev (2003)]

$$\frac{\Delta T}{T}|_{SW} = \frac{1}{3}(\Phi[\vec{x}_{rec}] - \Phi[\vec{x}_{sc}])$$

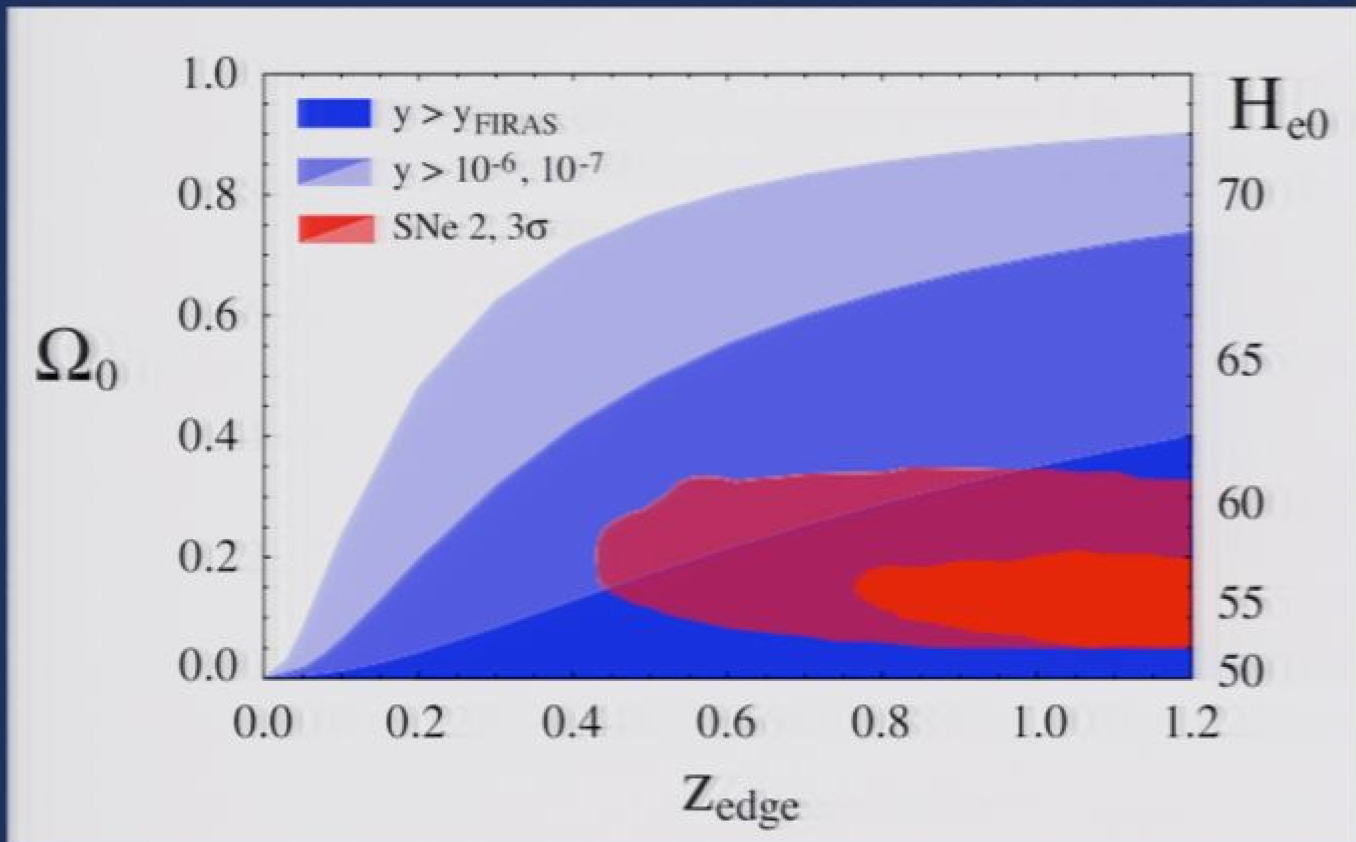
$$\frac{\Delta T}{T}|_{Doppler} = \frac{2}{3}\frac{H_0^{-1}}{\sqrt{1+z}}\hat{n}'\cdot\vec{\nabla}\Phi[\vec{x}_{sc}]$$

Hubble Bubble: $\Phi[r] = \Phi_0\left(1 - r^2/r_V^2\right)\Theta[r_V - r]$

RC & AS 2007/8

u-distortion

COBE-FIRAS: $y < 15 \times 10^{-6} (95\%)$
Mather et al (1994), Fixsen et al (1996)



future: see Fixsen& Mather (2002), Kogut (2006)

Nonlinear Inhomogeneous Spacetime

$$ds^2 = -dt^2 + \frac{(\partial_r R)^2}{1+k(r)r^2} dr^2 + R^2(t,r) d\Omega^2$$

Lemaitre (1933), Tolman (1934), Bondi (1947)

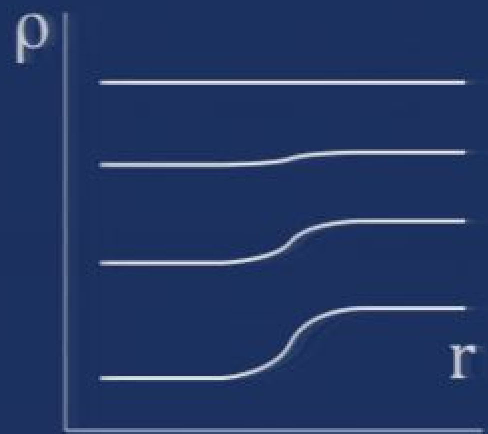
(See Krasinski (1997) for more general inhomogeneous, perfect fluid models)

k(r): curvature function fixes the mass density profile

R(t,r): solve for the radially-dependent scale factor

Instructions: see Garfinkle (2006), Garcia-Bellido&Haugbolle (2008)

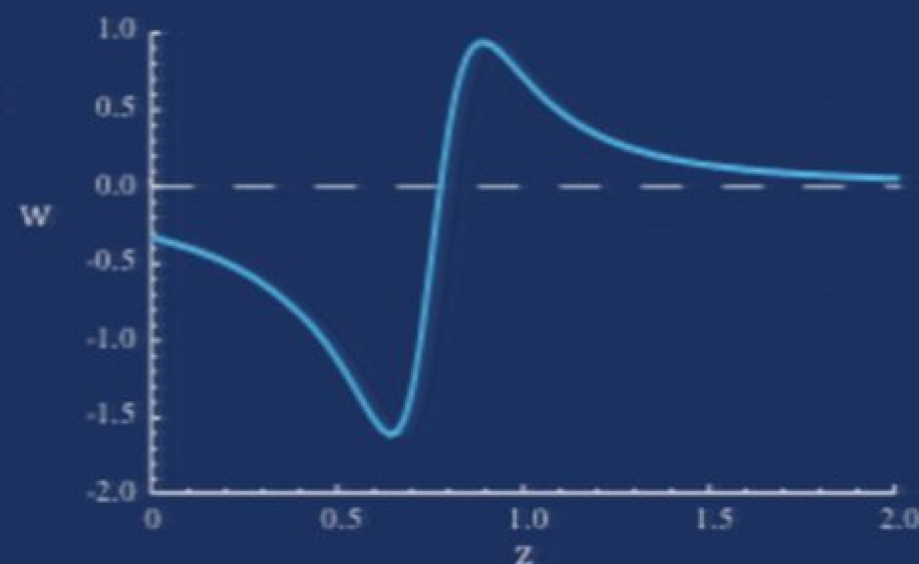
Nonlinear Inhomogeneous Spacetime



$$\frac{k(r)}{H_0^2} = \frac{1-\Omega_0}{1+(r/r_o)^n}$$

Cosmological Considerations:

- Distances (SN): w vs. z
- Angles (CMB): Ω, θ
- Rates: (H) Local vs. Global



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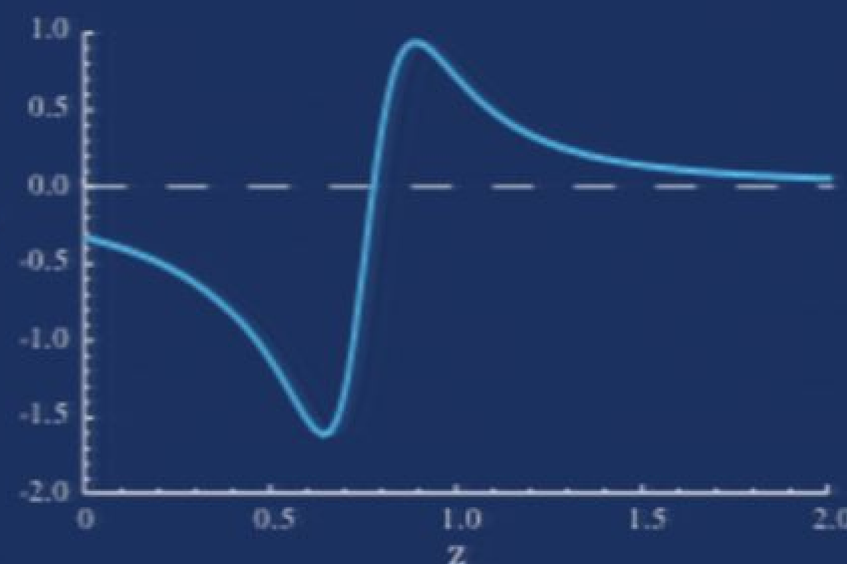

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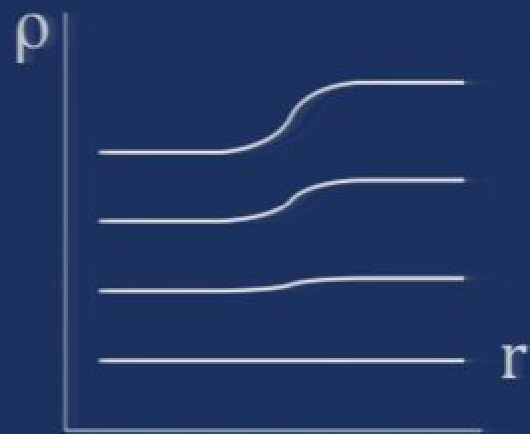

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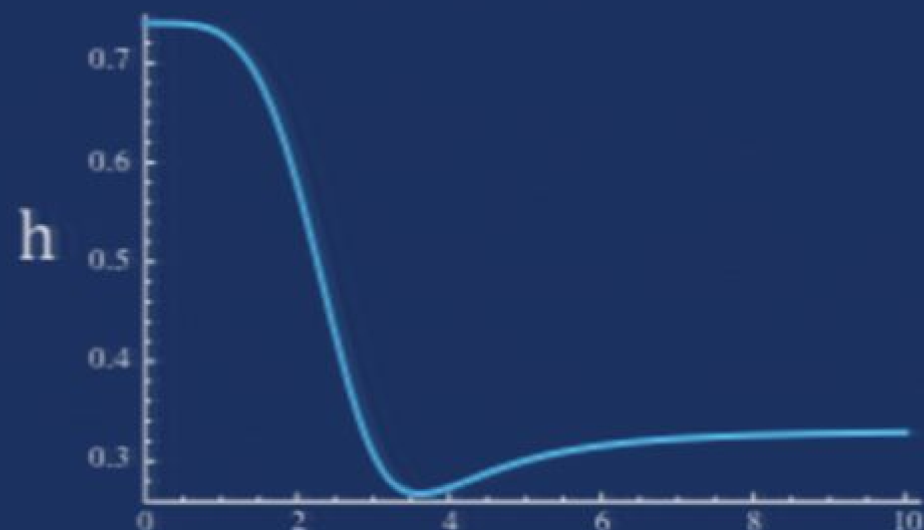

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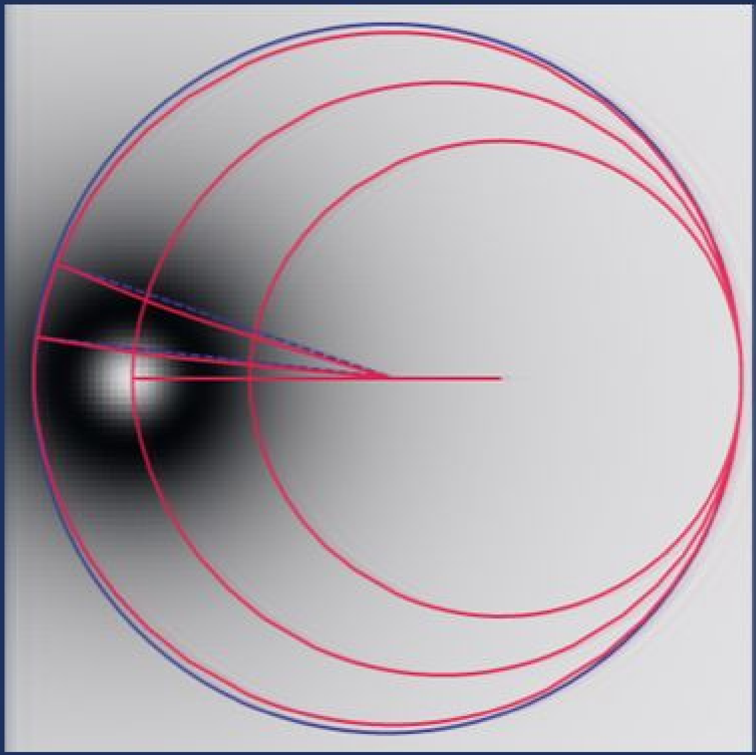


- Integrate the photon geodesic radially outward to the scattering site

- Change direction and follow the photon to the last scattering surface

- All gravitational effects are included – SW, ISW, Doppler, lensing deflection.

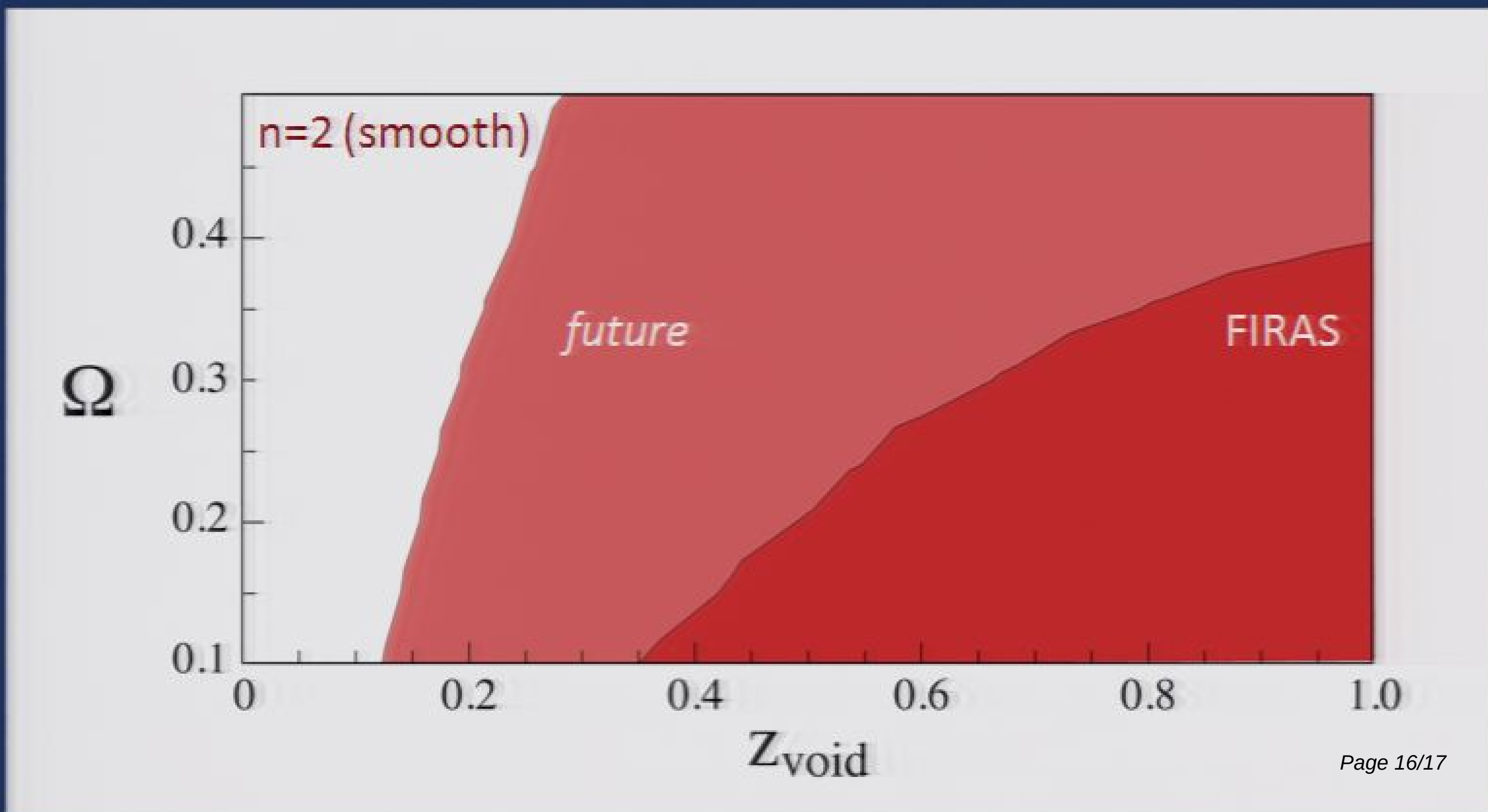
Just a taste:

$$\frac{dR}{dz} = \frac{R'}{\dot{R}'} \frac{\sqrt{1+k(r)r^2} - \dot{R}}{(1+z)}$$

$$R(t,r) = a(t,r)r \qquad \frac{da}{dz} = \frac{a'\sqrt{1+k(r)r^2} - \dot{a}R'}{\dot{R}'(1+z)}$$

Nonlinear Inhomogeneous Spacetime

U-distortion rules out a wide range of parameters describing anti-Copernican, inhomogeneous cosmological models



Nonlinear Inhomogeneous Spacetime

U-distortion rules out a wide range of parameters describing anti-Copernican alternatives to Dark Energy