Hablova konstanta i tenzije oko lokalnih i kosmoloških merenja

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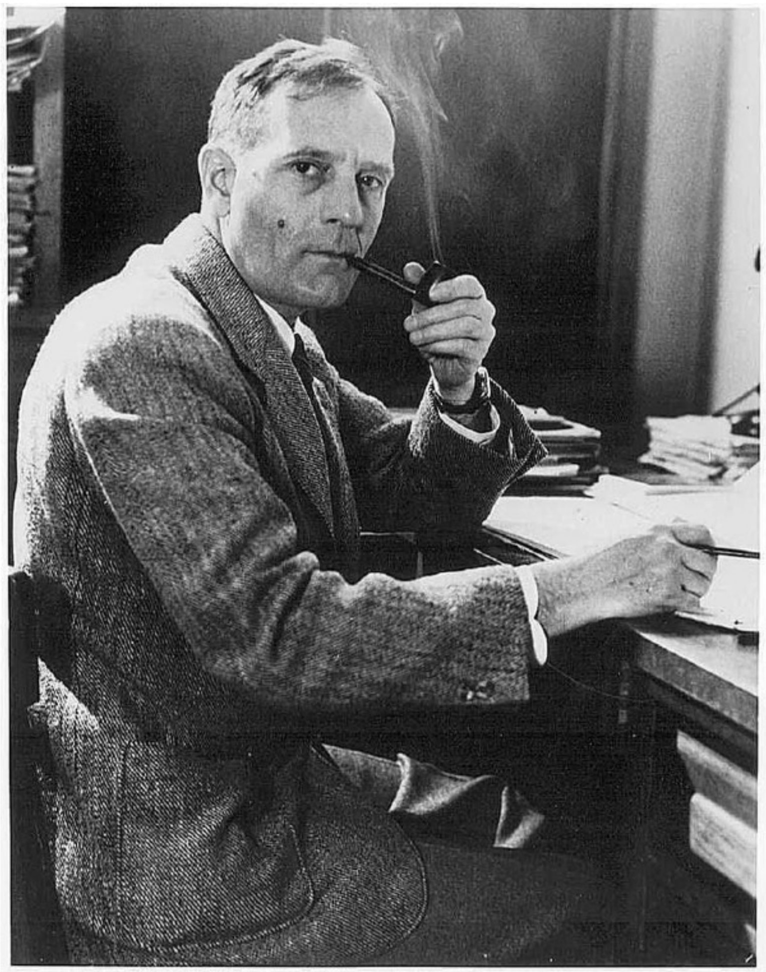
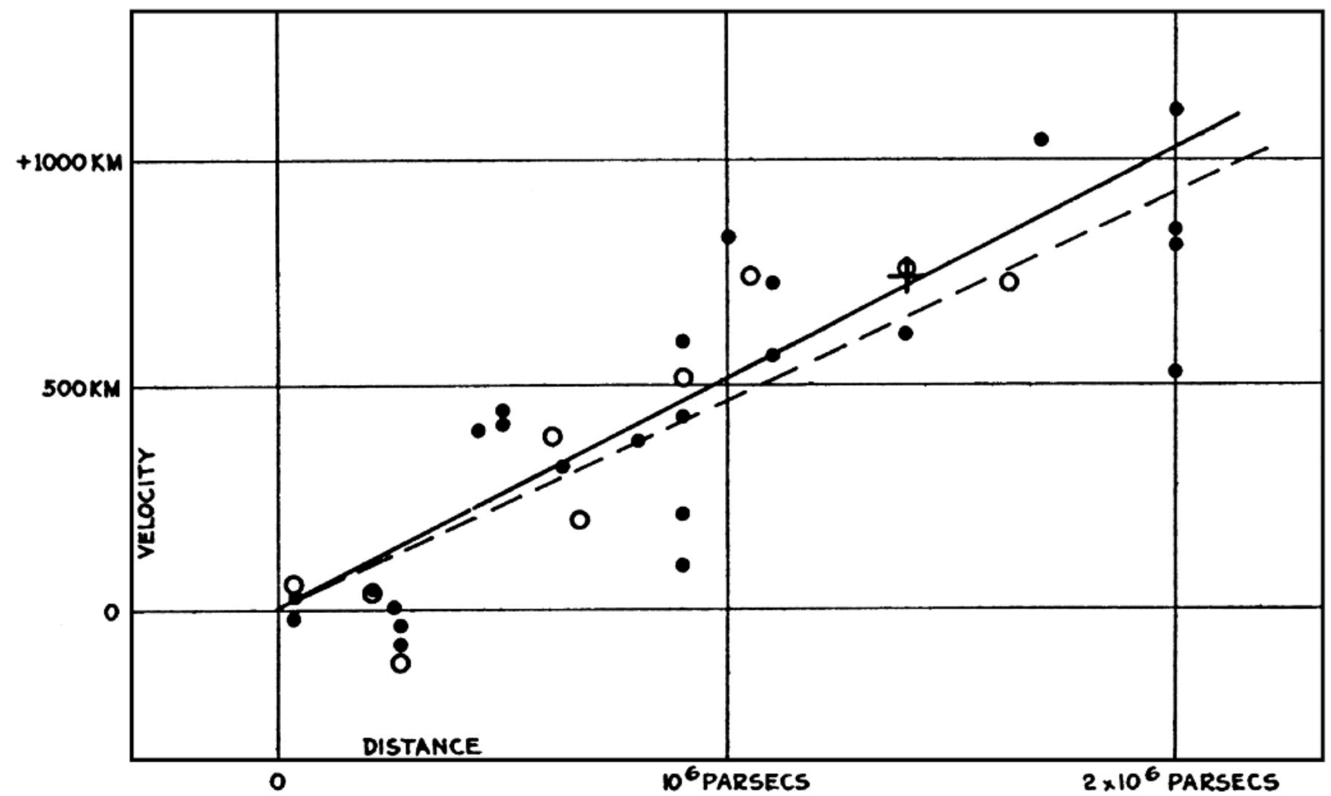
Seminar Katedre za astronomiju
24. decembar 2019.

Hablova konstanta



$$v = H_0 \, d$$



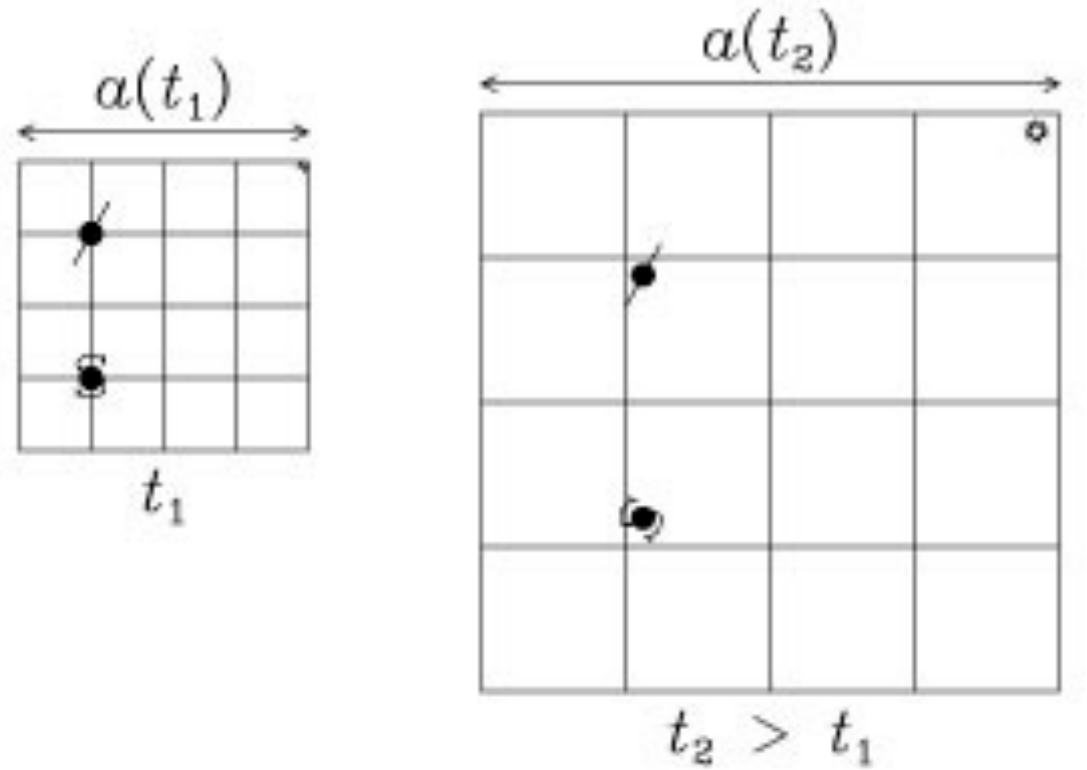
$$[H_0] = \mathrm{km/s/Mpc}$$

$$H_0 \equiv h \cdot 100 \, \mathrm{km/s/Mpc}$$

Hablova konstanta

$$ds^2 = -\,dt^2 + a^2(t)d\boldsymbol{x}^2$$

$$H(t) \equiv \frac{\dot{a}}{a} \qquad H_0 \equiv H(t=0)$$



Dinamika — Fridmanove jednačine

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}(\rho_r + \rho_m + \rho_\Lambda)$$

$$\rho_{\text{crit.}} \equiv \frac{3H_0}{8\pi G}$$

$$H^2(t) = H_0^2(\Omega_r + \Omega_m + \Omega_\Lambda)$$

$$\Omega_i \equiv \frac{\rho_i}{\rho_{\text{crit.}}}$$

↓

$$\omega_i \equiv \Omega_i h^2$$

Direktna (lokalna) merenja

Standardne sveće: SNIa

“Standardni lenjiri”: gravitaciona sočiva

SNIa

Standardne sveće su neophodne
za merenje rastojanja

Luminosity distance

$$F \equiv \frac{L}{4\pi D_L}$$

$$D_L(z) = (1+z)\int_0^z \frac{dz'}{H(z')}$$

Fizički Hablov dijagram je F(z), za datu luminoznost L

L i H0 potpuno degenerisani!

SNIa

SNIa dobre standardne sveće

Kako ih kalibrisati?

Direct distance ladder

paralakse

↓

MW cefeide

↓

lokalne galaksije

↓

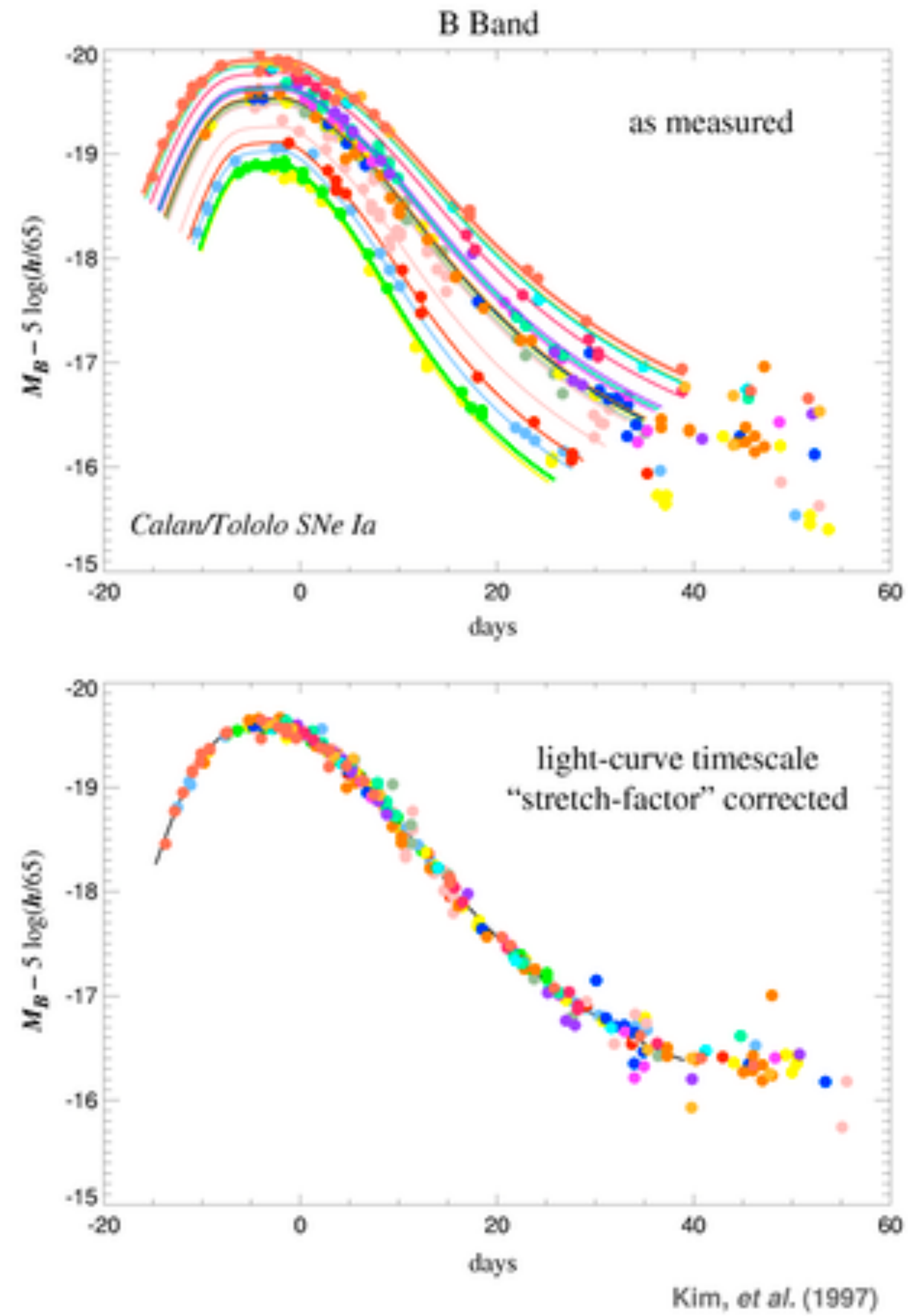
lokalne SNIa

↓

kosmološke SNIa

↓

H0

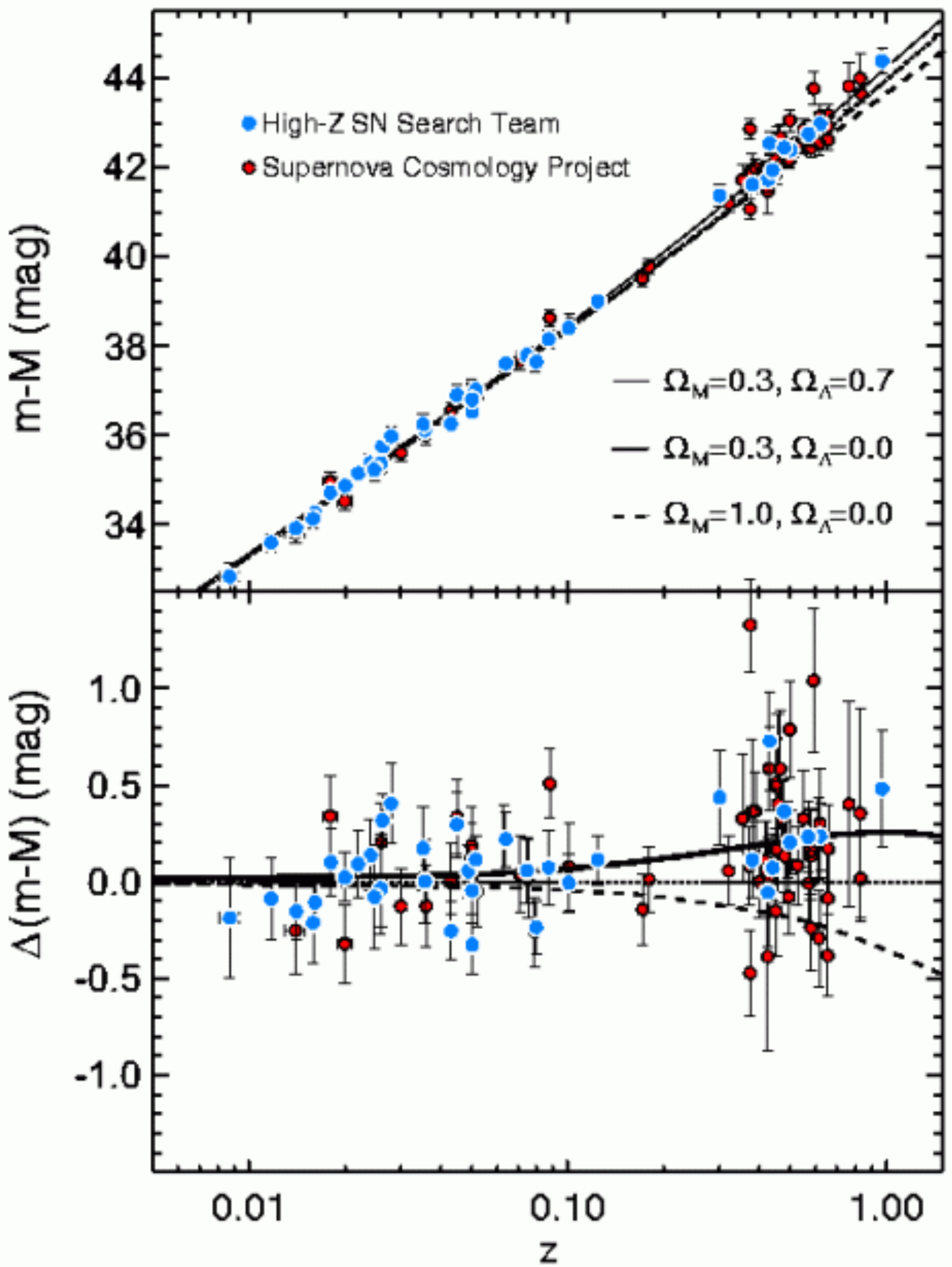


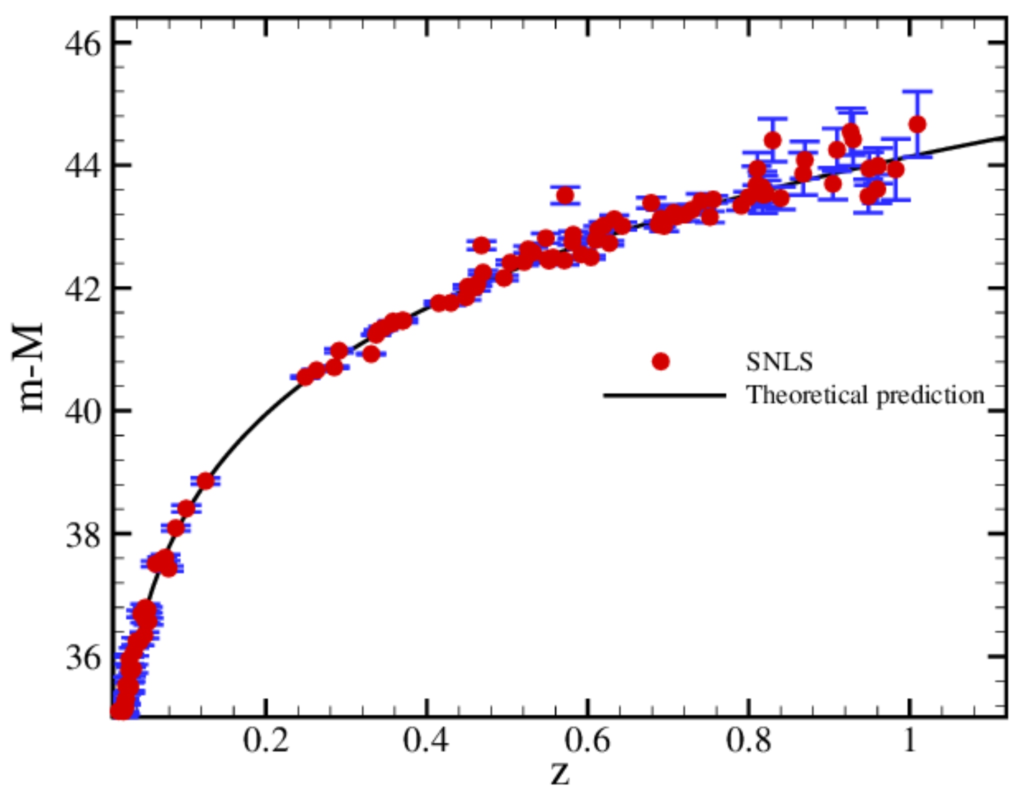
SNIa

Otkriće kosmološke konstante

Normalizacija nije važna

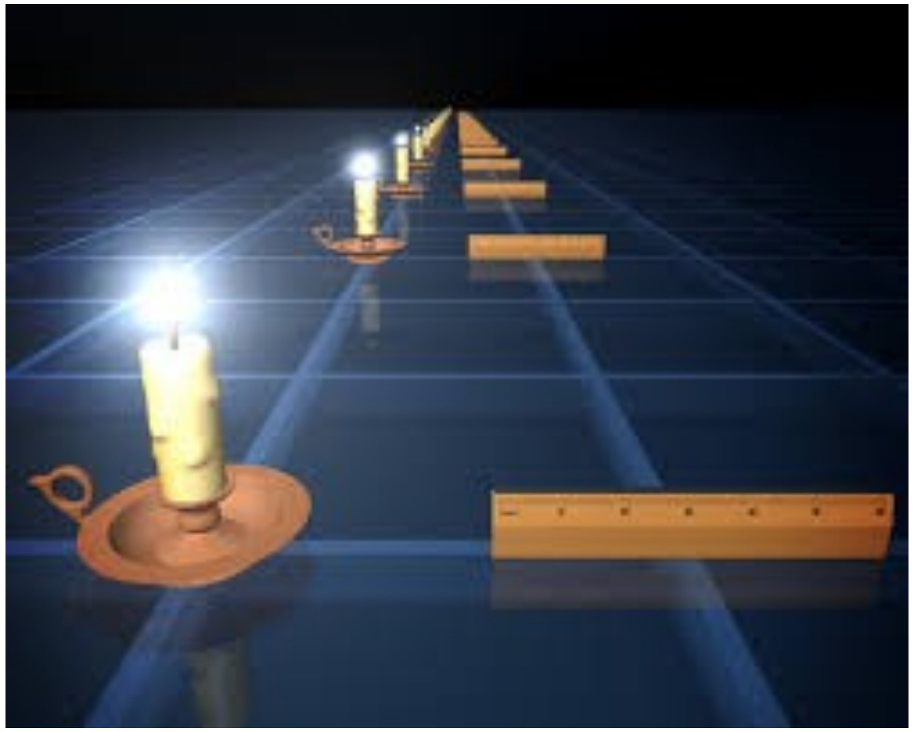
H0 menja normalizaciju





Jaka gravitaciona sočiva

Velicinu x nekog objekta možemo koristiti za merenje rastojanja



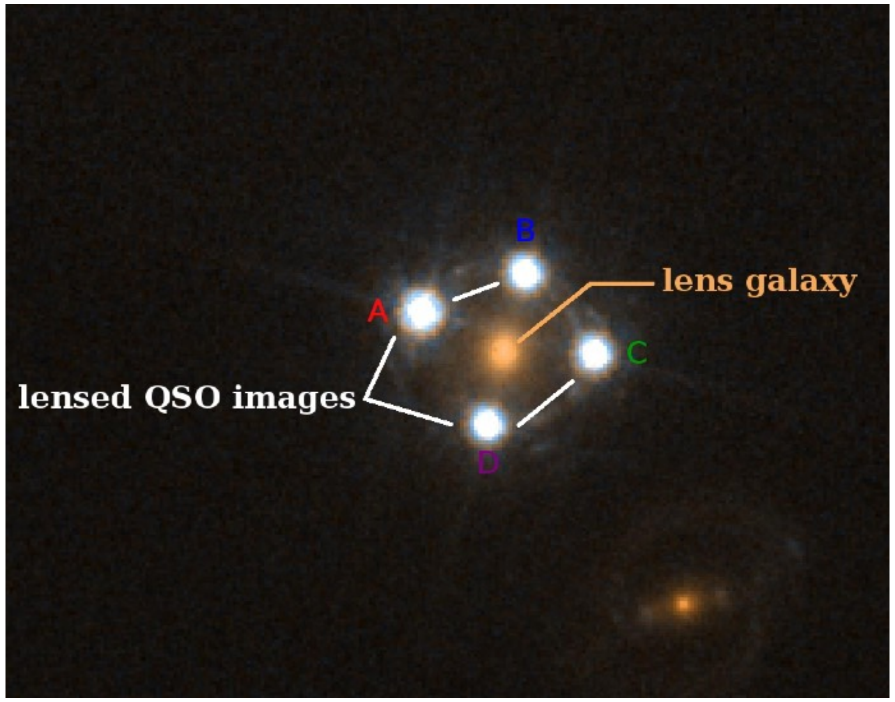
$$\theta \equiv \frac{x}{D_A}$$

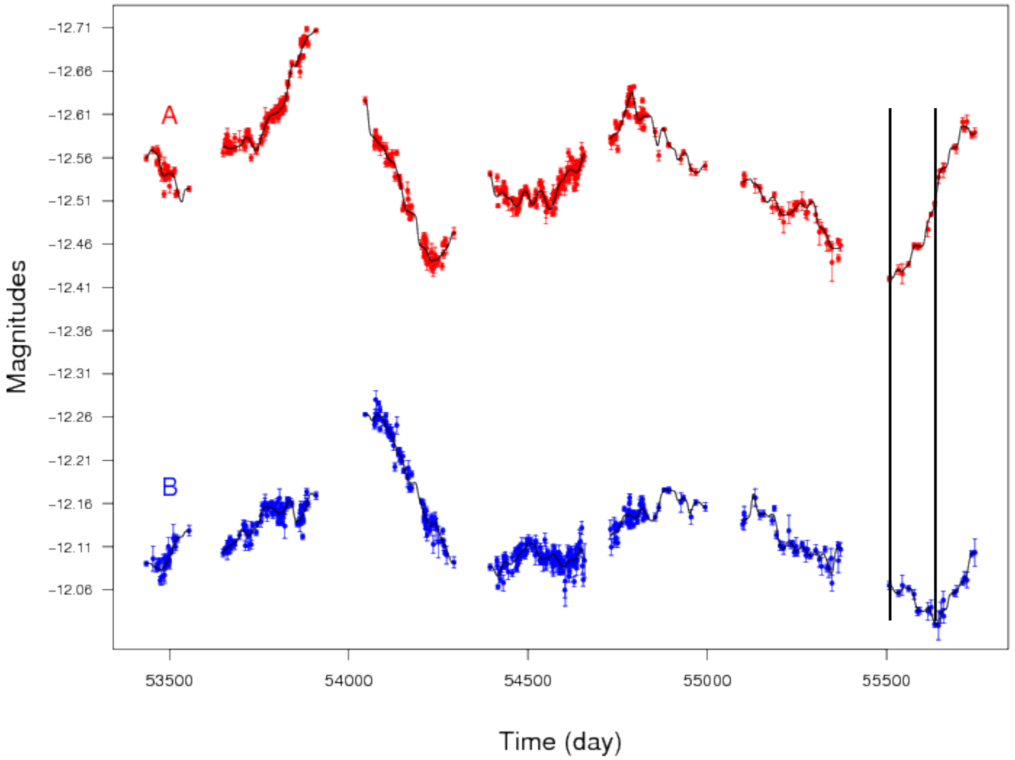
$$D_A(z) = \frac{1}{(1+z)} \int_0^z \frac{dz'}{H(z')}$$

Fizički Hablov dijagram je theta(z), za datu veličinu x

x i H0 potpuno degenerisani!

Jaka gravitaciona sočiva — H0LiCOW kolaboracija



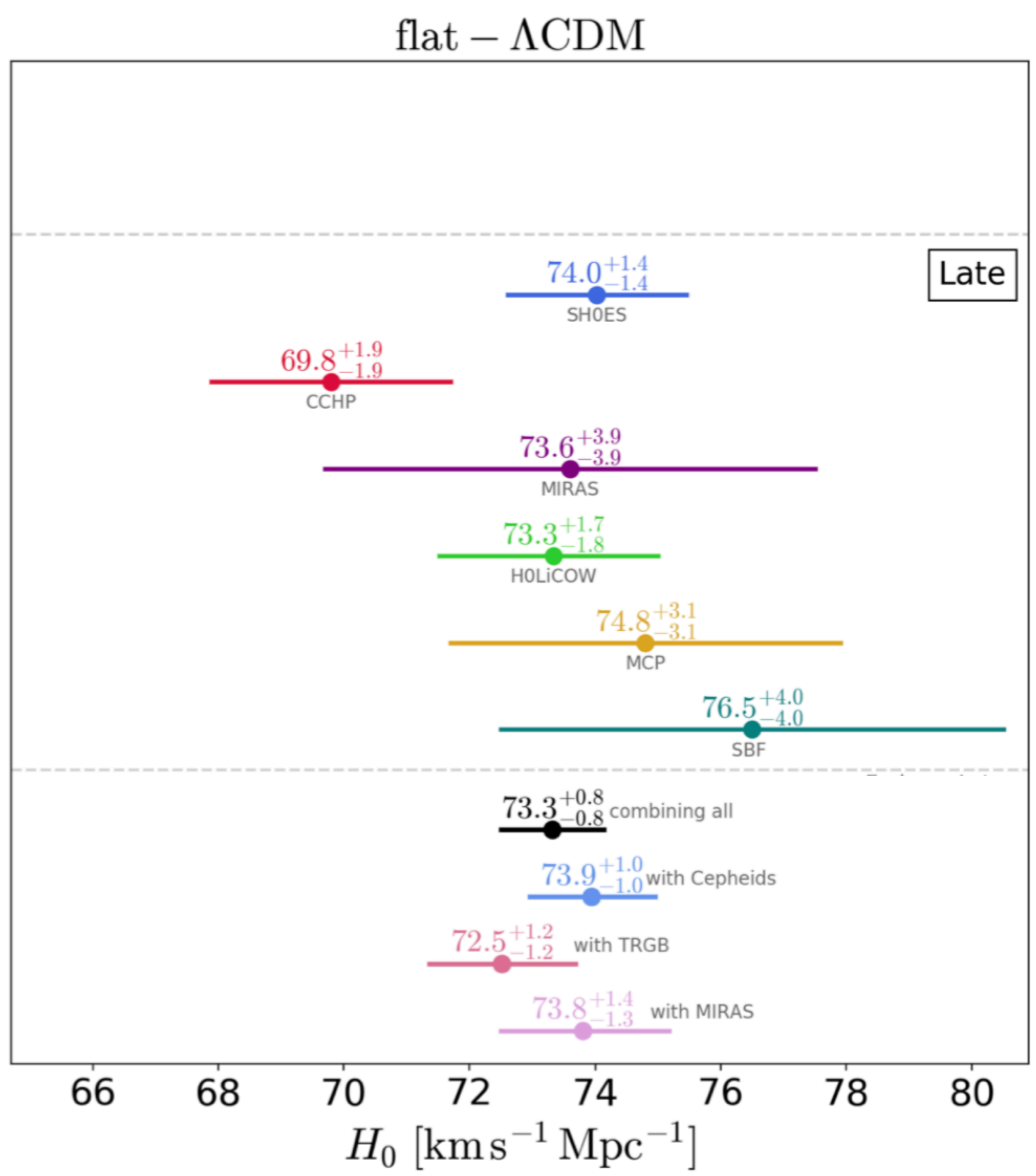


Kašnjenje daje veličinu sočiva!

Veličina sočiva omogućava merenje ugaonog rastojanja

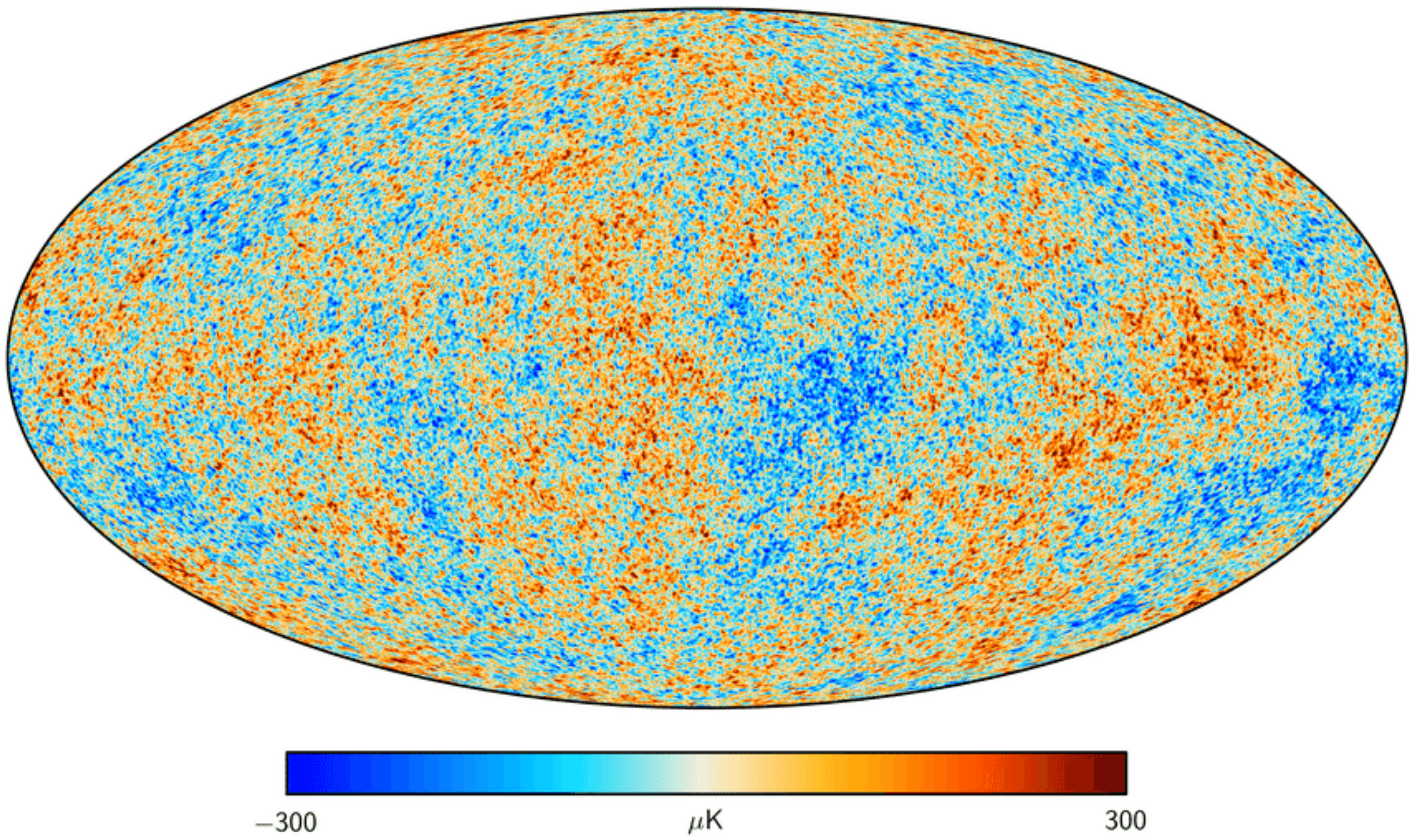
I ovde postoji problem kalibracije (modelovanje sočiva)

Rezultati lokalnih merenja



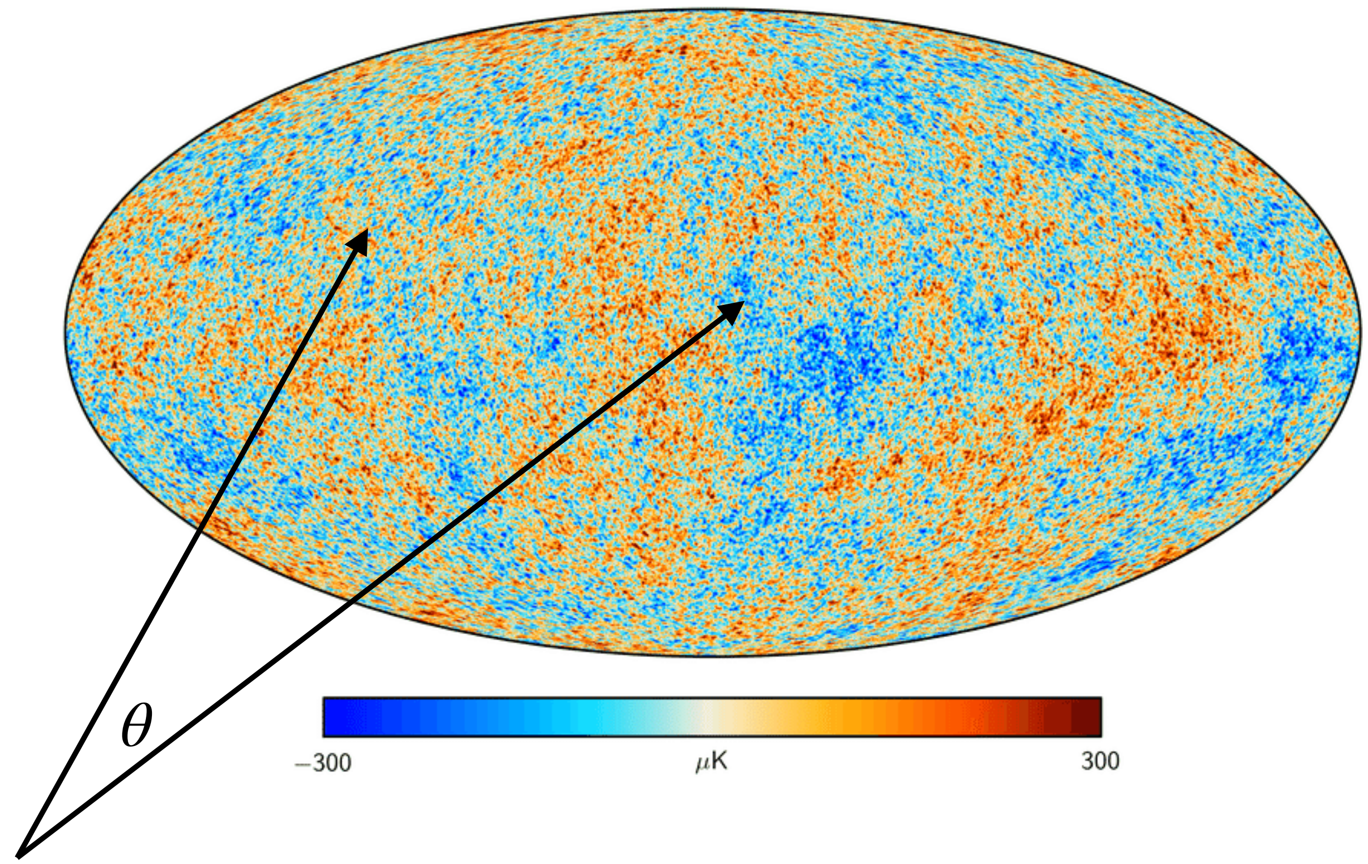
$$h = 0.733 \pm 0.008$$

Kosmološka merenja



Šta možemo da dobijemo iz fluktuacija?

Kosmološka merenja



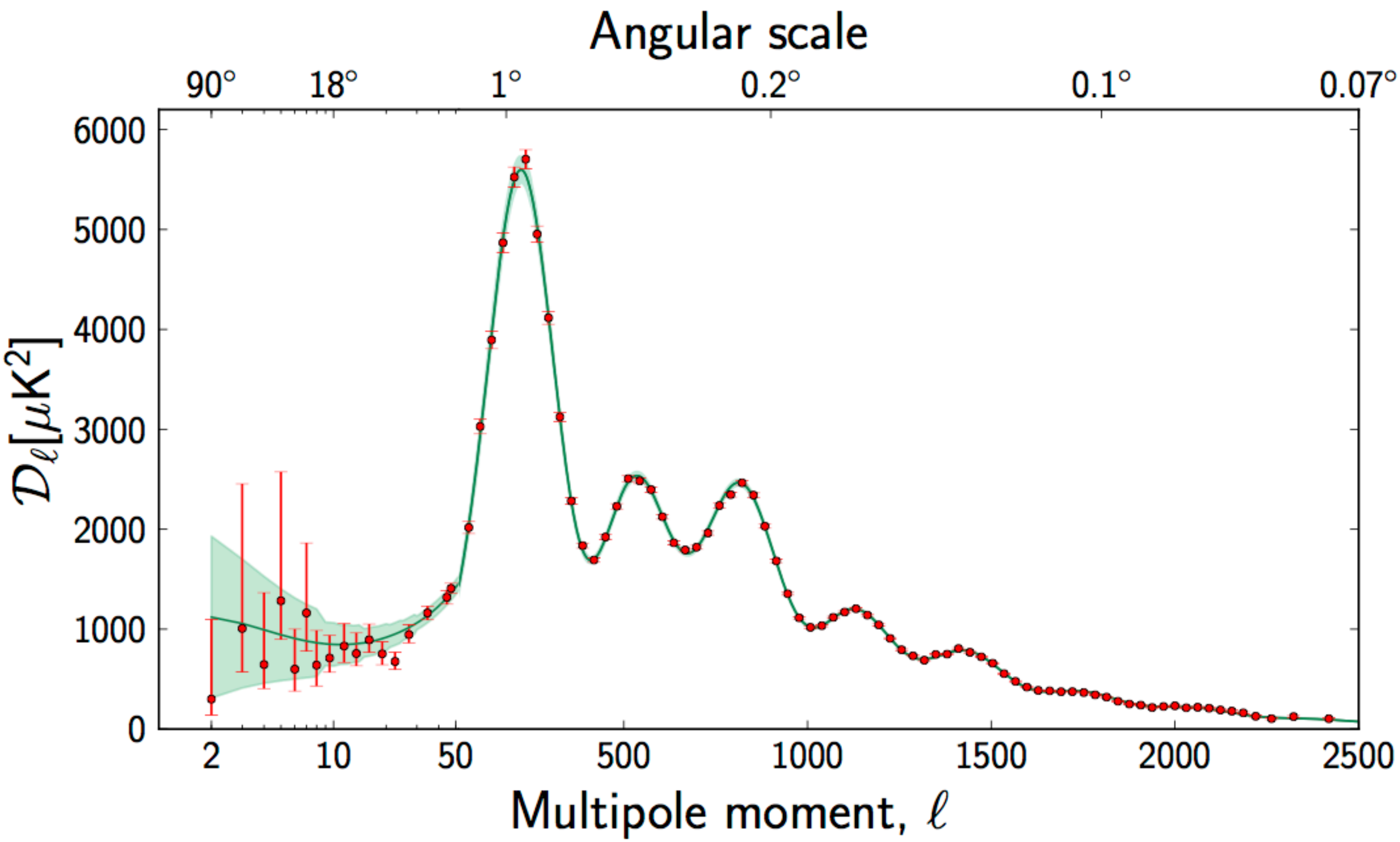
korelaciona funkcija

$\xi_{\mathrm{CMB}}(\theta)$

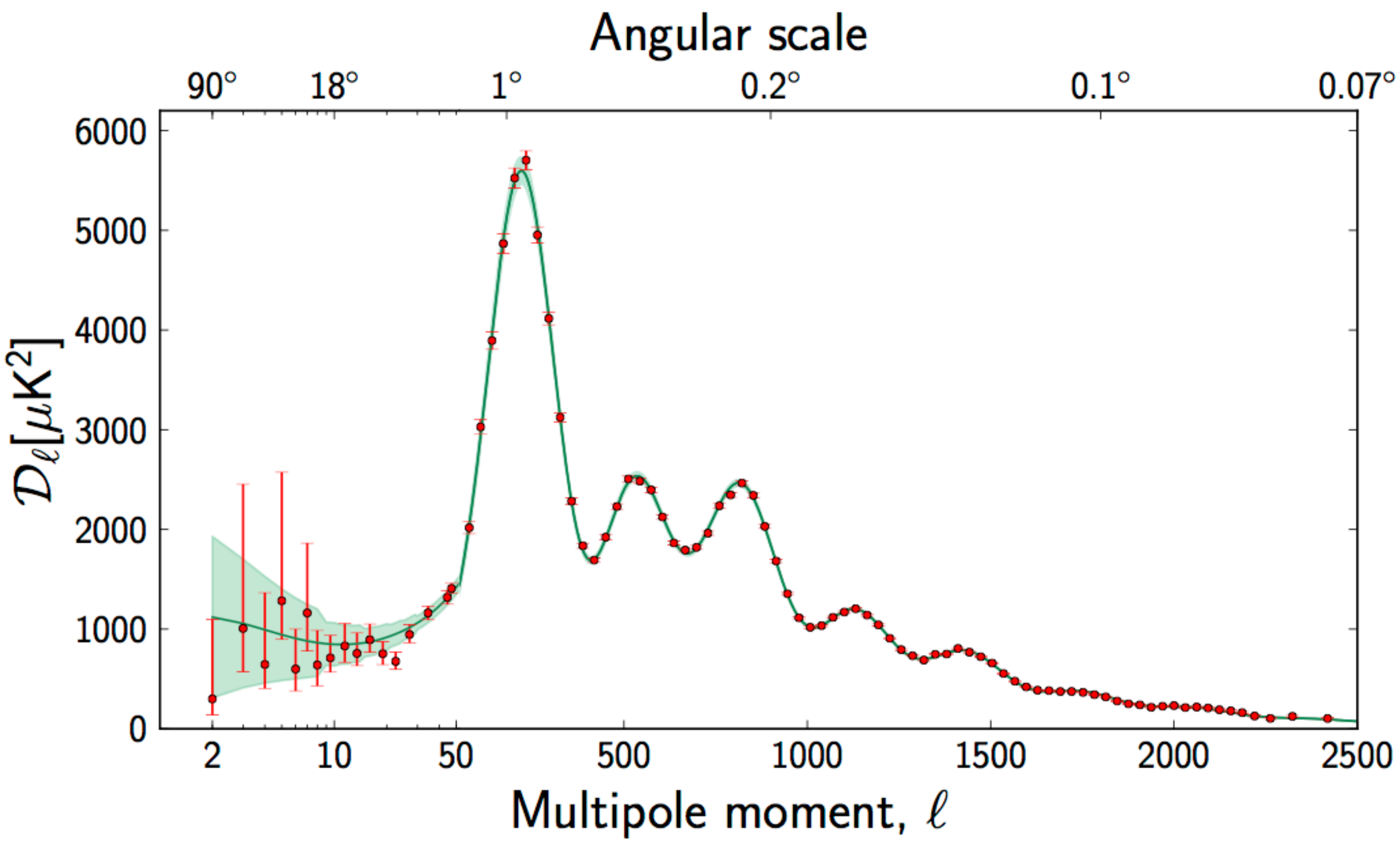
spektar fluktuacija

C_ℓ “Furije transform” korelacione funkcije

Kosmološka merenja



Kosmološka merenja



automatska kalibracija

$$\omega_i \equiv \Omega_i h^2$$

$$\omega_b, \omega_{cdm}$$

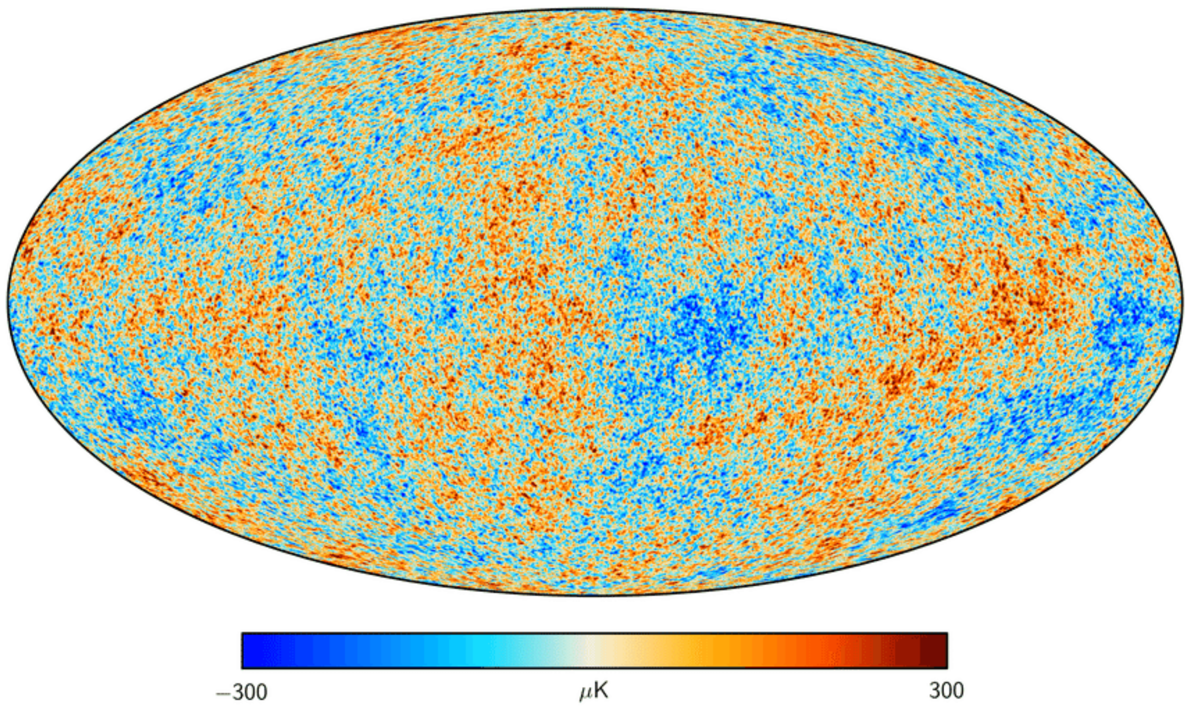
$$r_d = f(\omega_b, \omega_{cdm})$$

LCDM

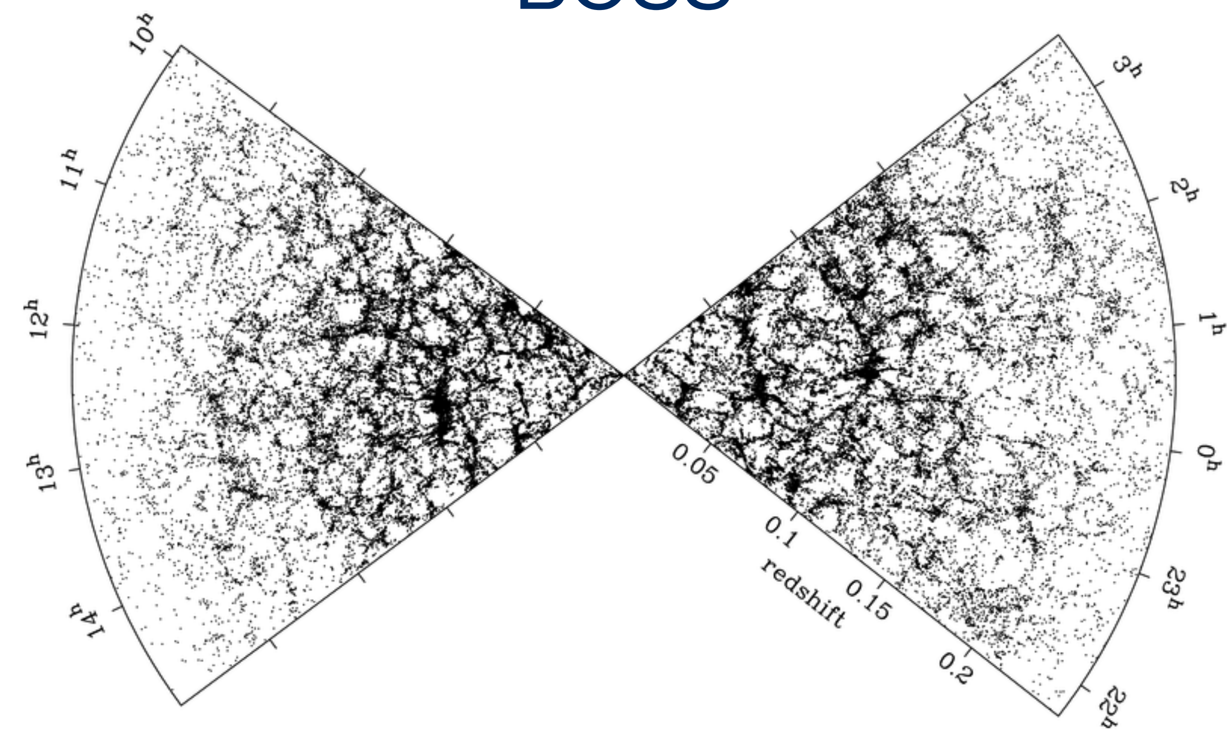
$$D_A(z) = \frac{1}{(1+z)} \int_0^z \frac{dz'}{H(z')}$$

$$H_0$$

Kosmološka merenja



BOSS



$N \sim 10^7$

$N \sim 10^9$

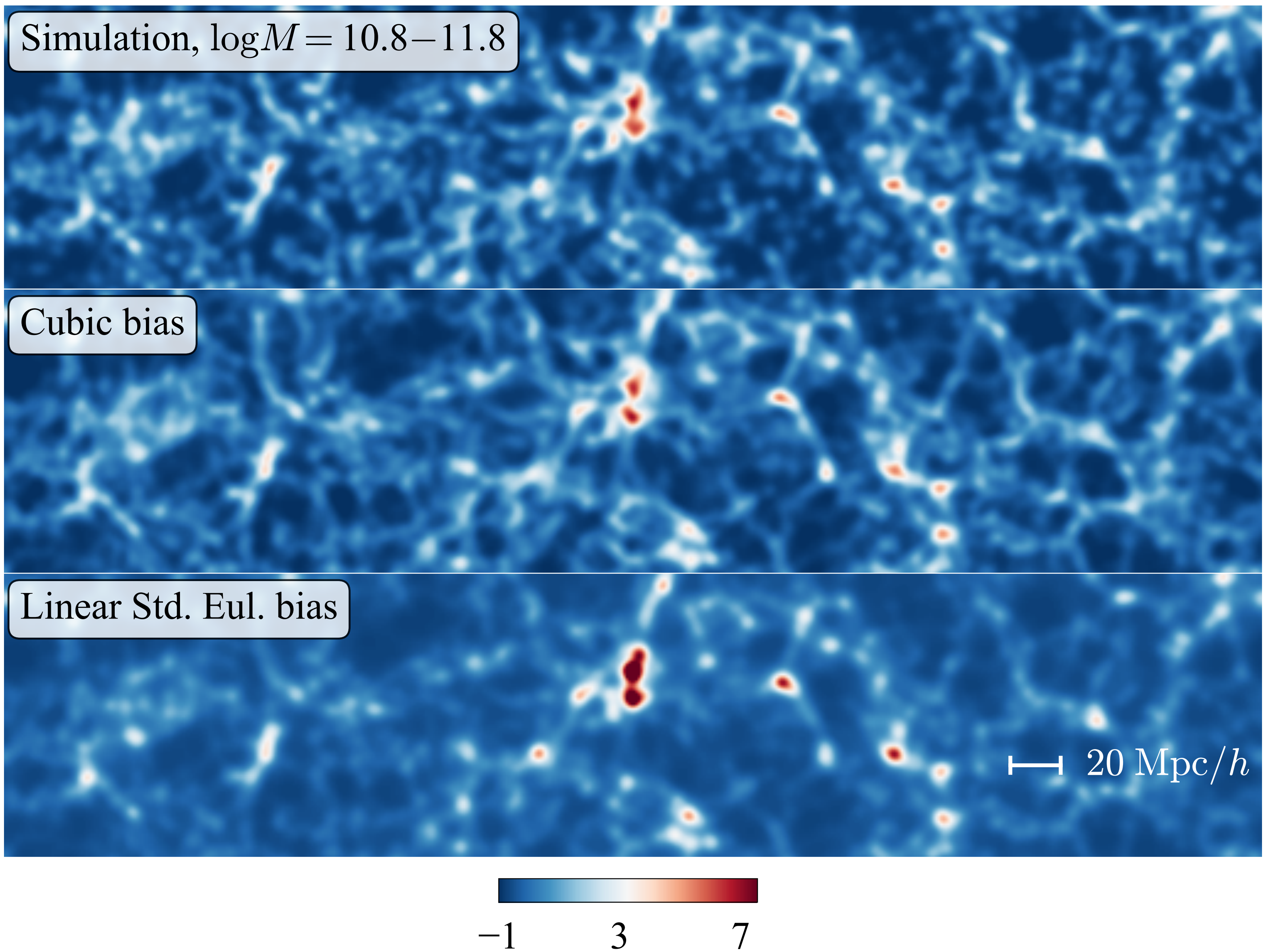
Postoji i drugi način — velike strukture

U perspektivi mnogo više informacija

Kosmološka merenja

Glavni izazov je nelinearna evolucija

Schmittfull, MS, Assassi, Zaldarriaga (2018)

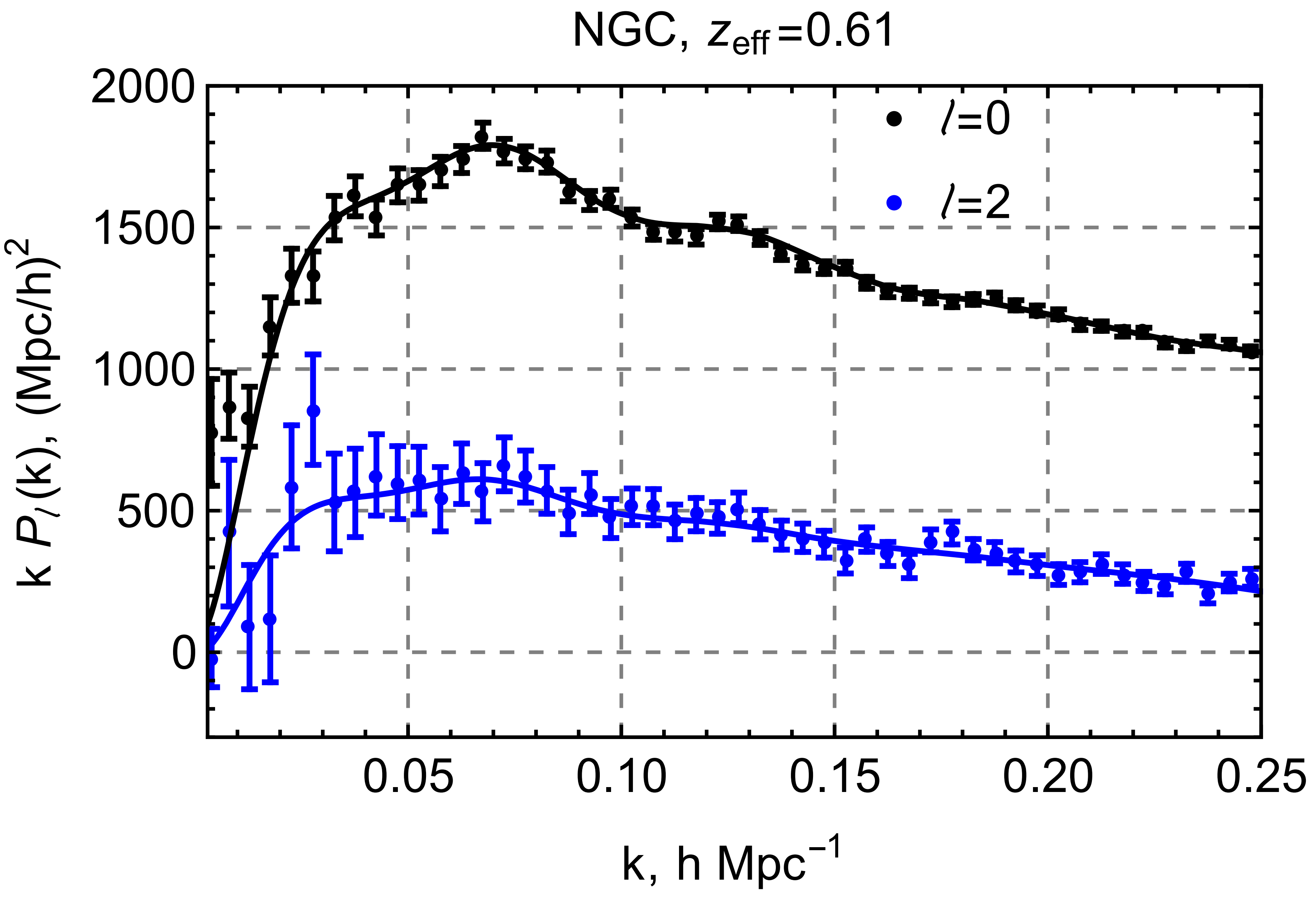


← simulacije

← teorijski model

Kosmološka merenja

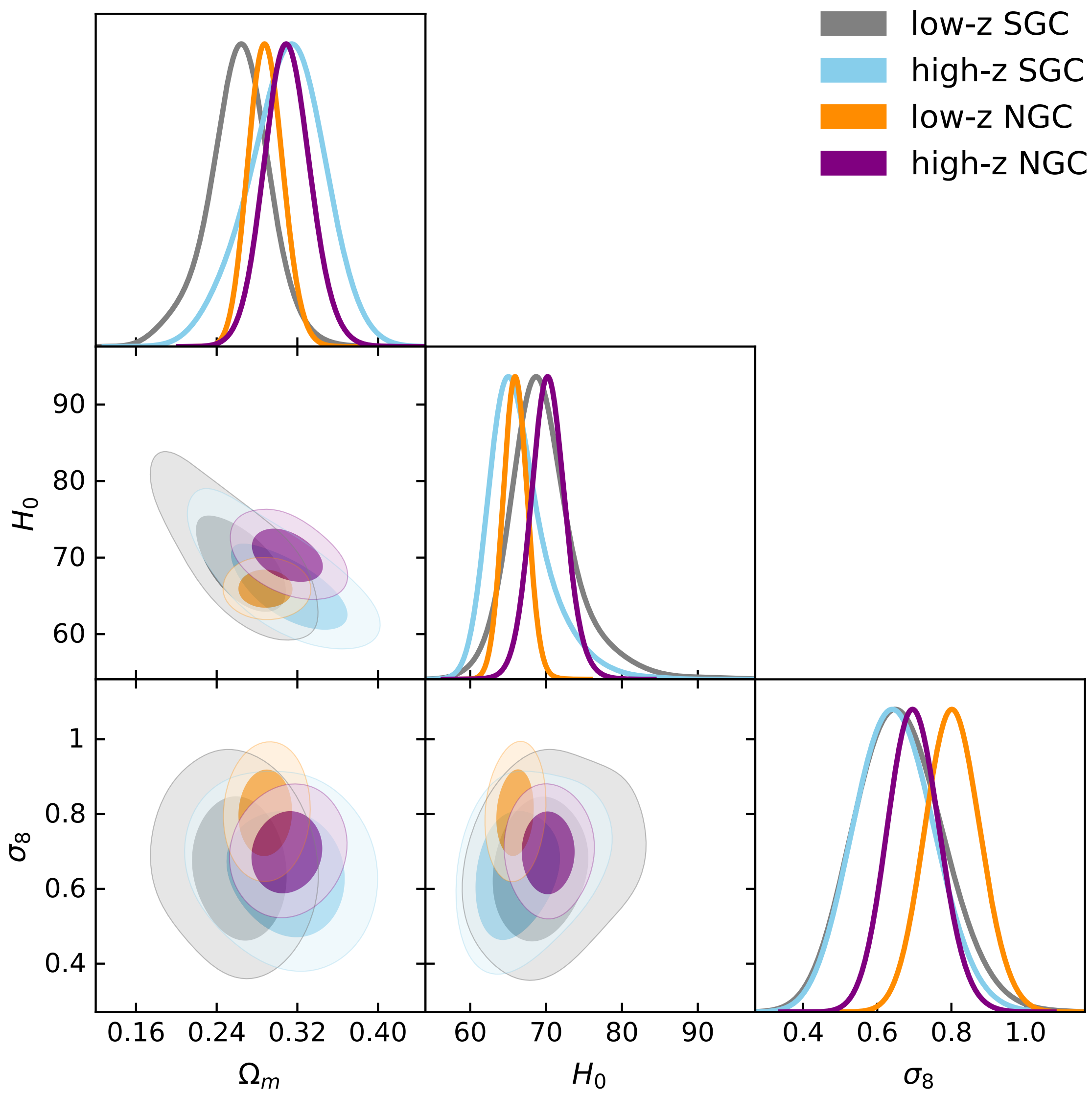
Spektar fluktuacija gustine galaksija za BOSS

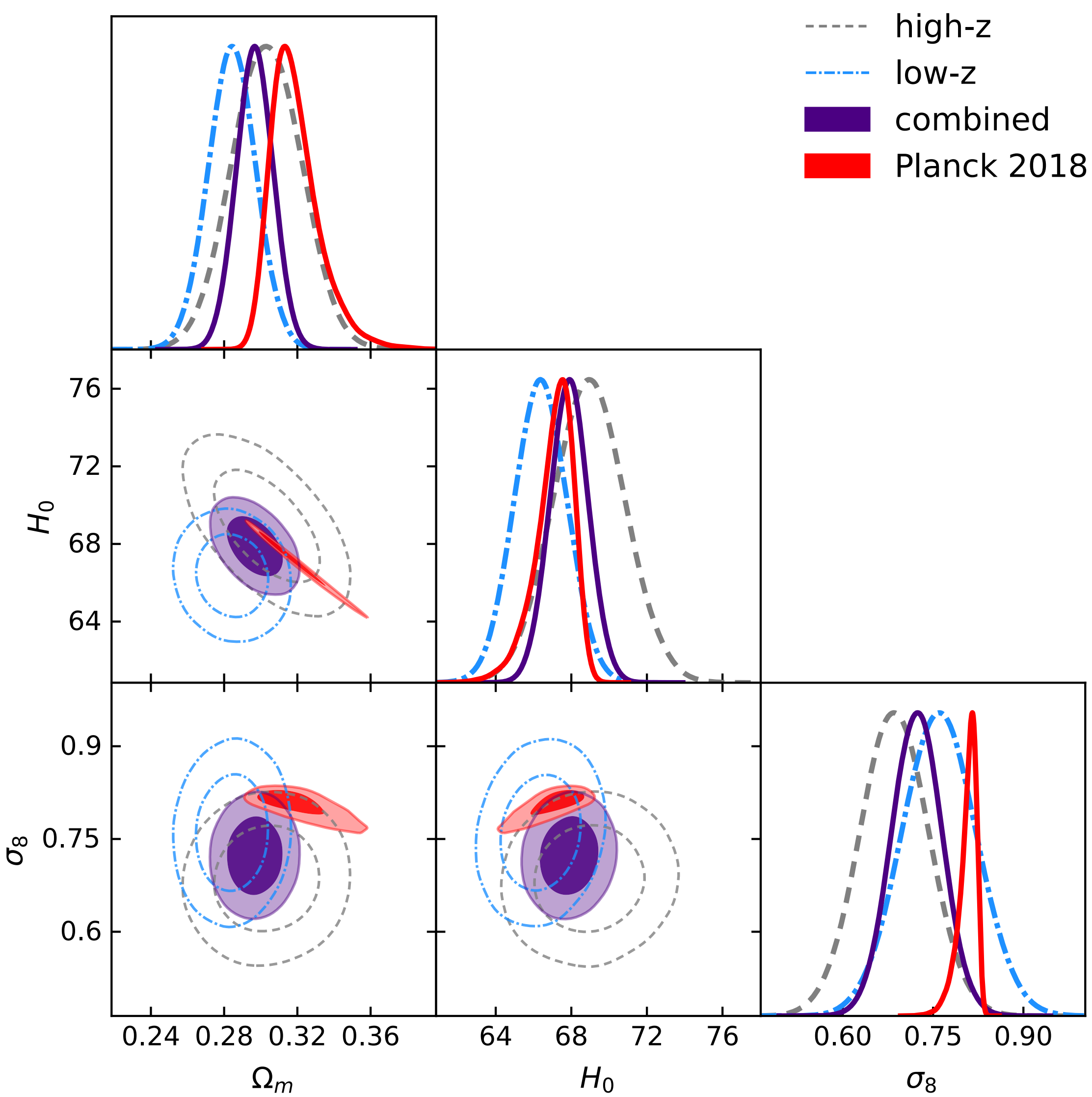


Kosmološka merenja

Ivanov, MS, Zaldarriaga (2019)

nezavisno od CMB

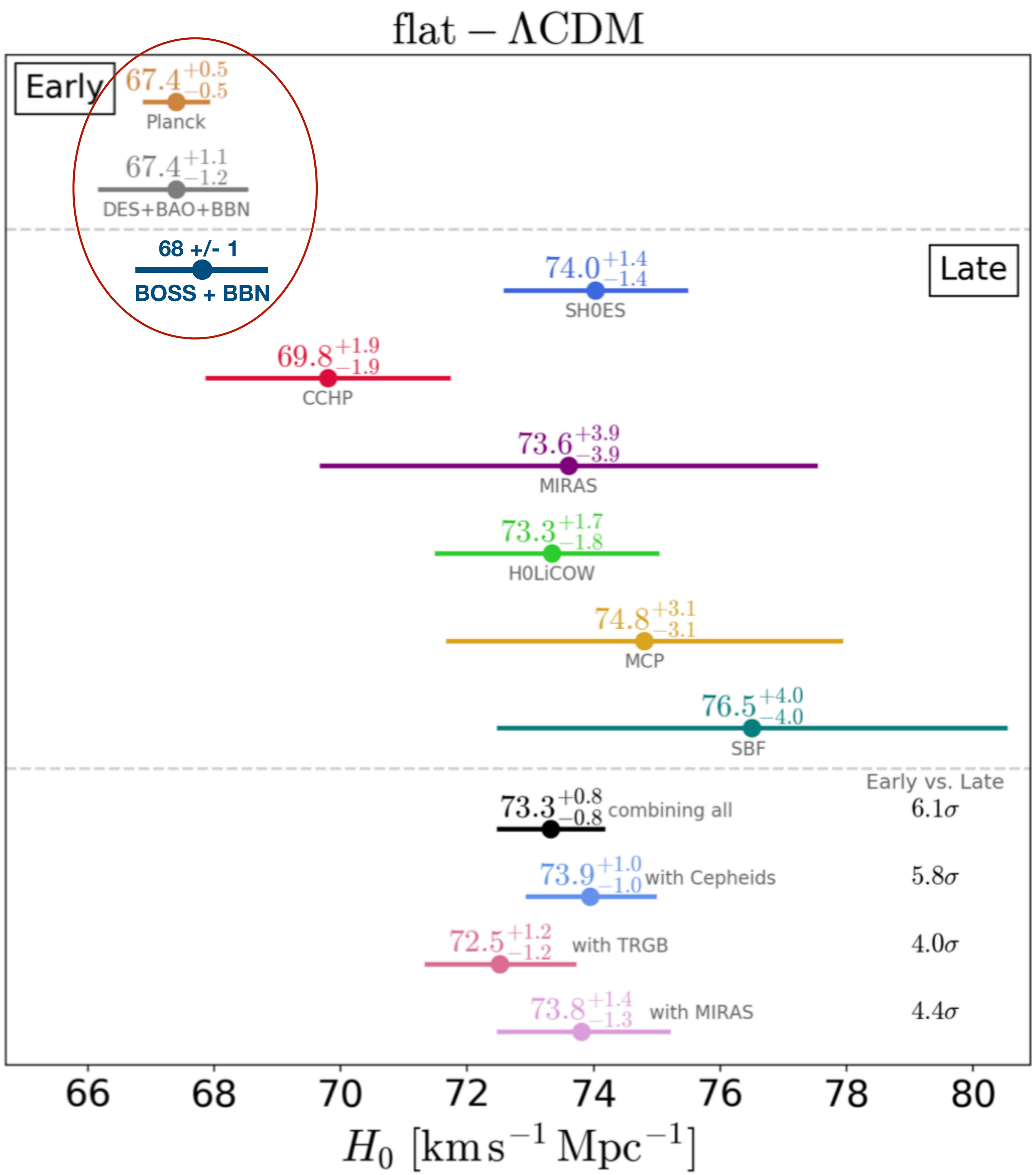




Rezultati kosmoloških merenja

$$h = 0.679 \pm 0.005$$

$$h = 0.733 \pm 0.008$$



U čemu je problem?

Lokalna merenja jako osetljiva na kalibraciju

Nepoznate sistematske greške

Kosmološka merenja su globalni fit, ne mere H0 direktno

Fizika ranog svemira je fiksirana

Nova merenja u narednih par godina!

Hvala na pažnji!