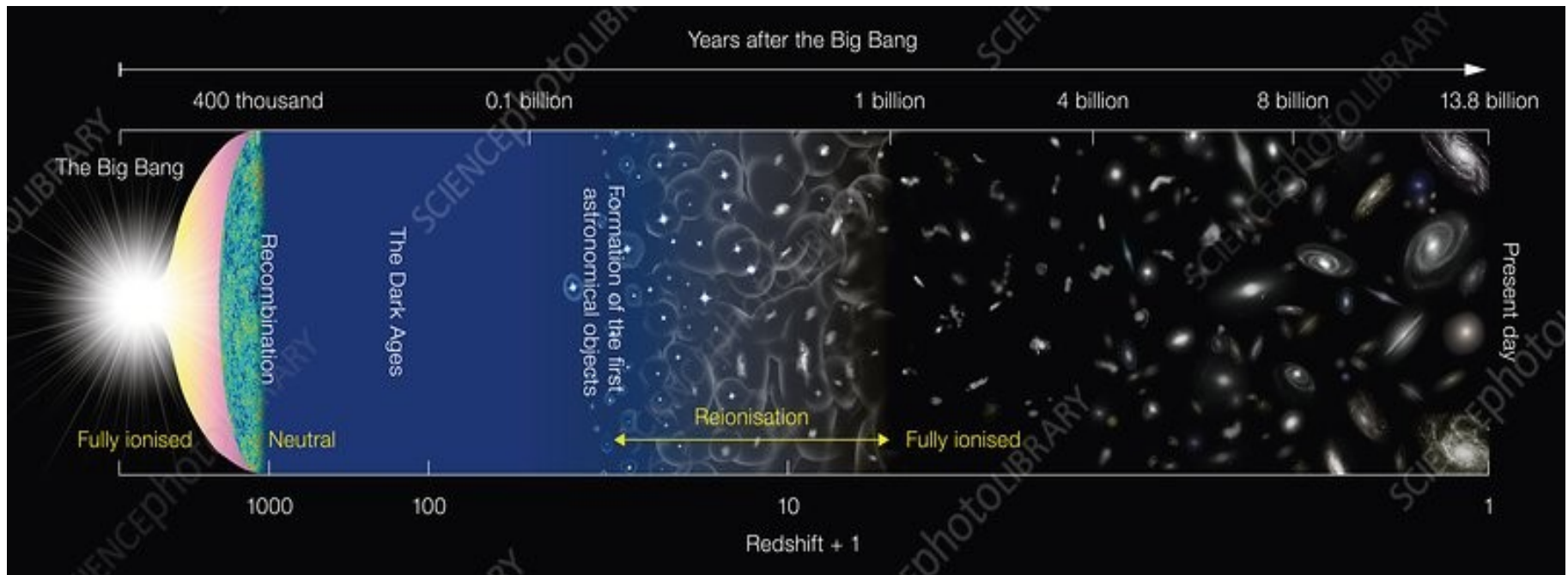




# Istraživanje korelacije između kinetičkog Sunyaev- Zel'dovich efekta i kozmoškog signala neutralnog vodika.

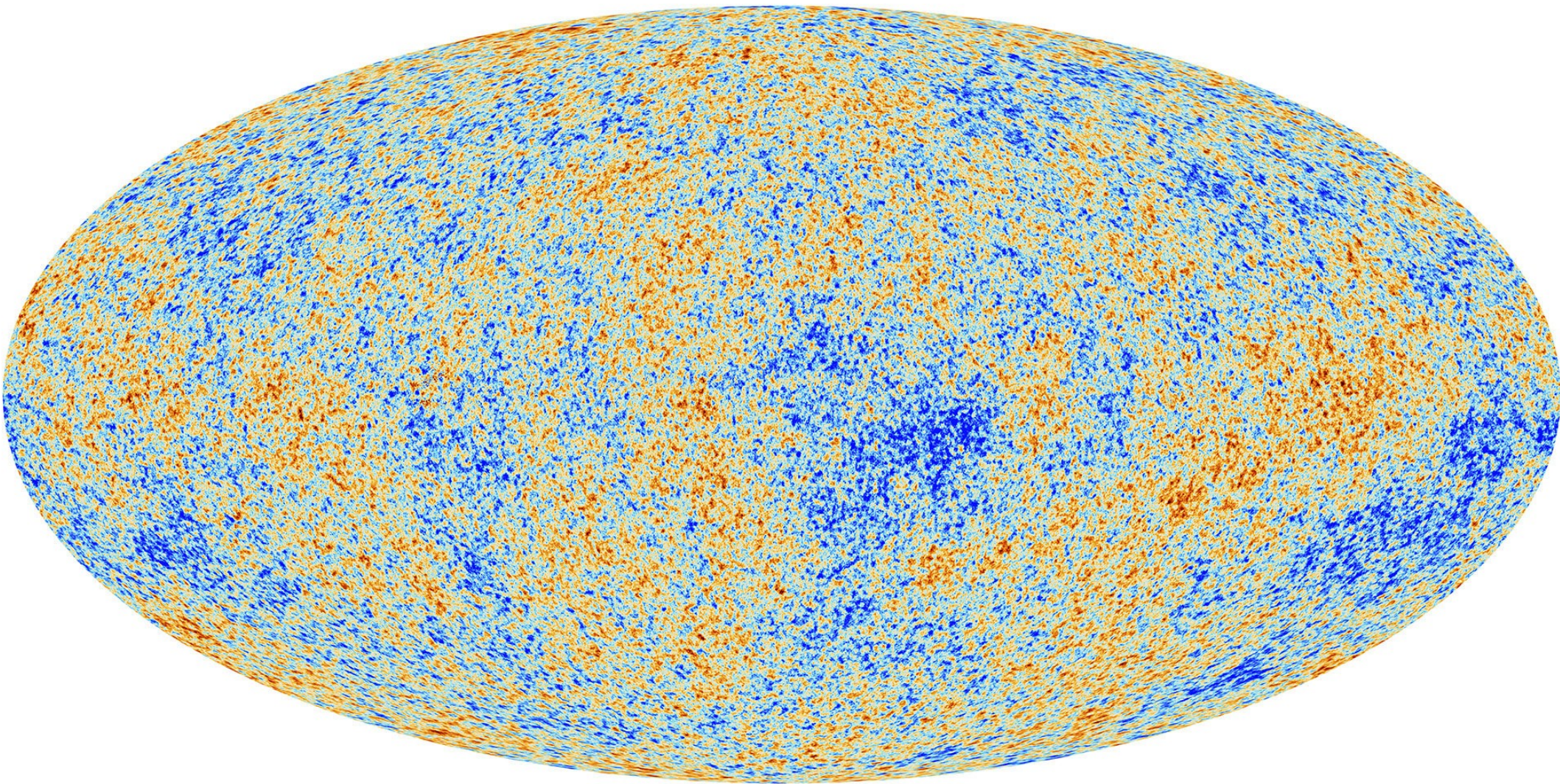
Ivan Nikolić  
Mentor: dr.sc. Vibor Jelić

# Povijest Svemira





# CMB

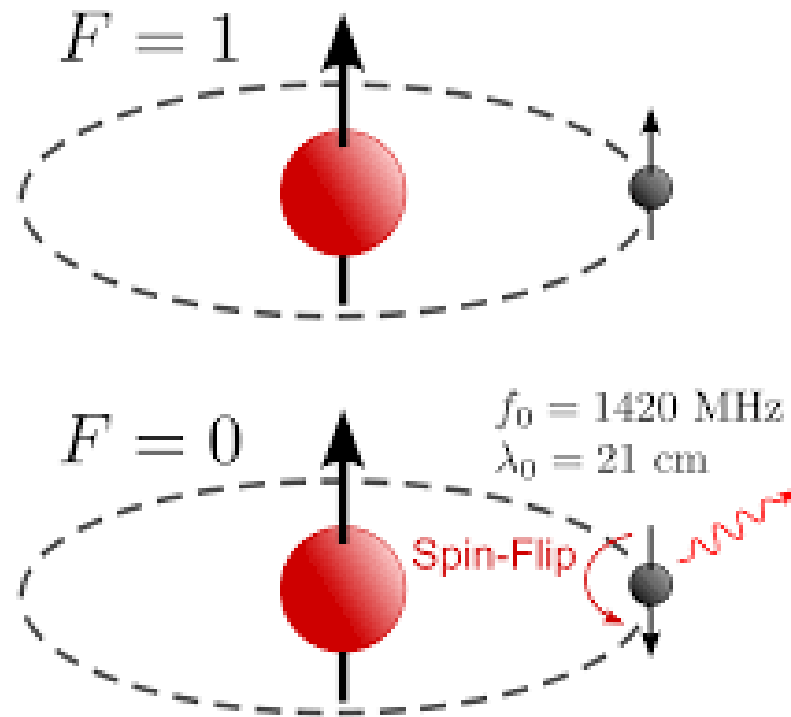




# Epoha reionizacija

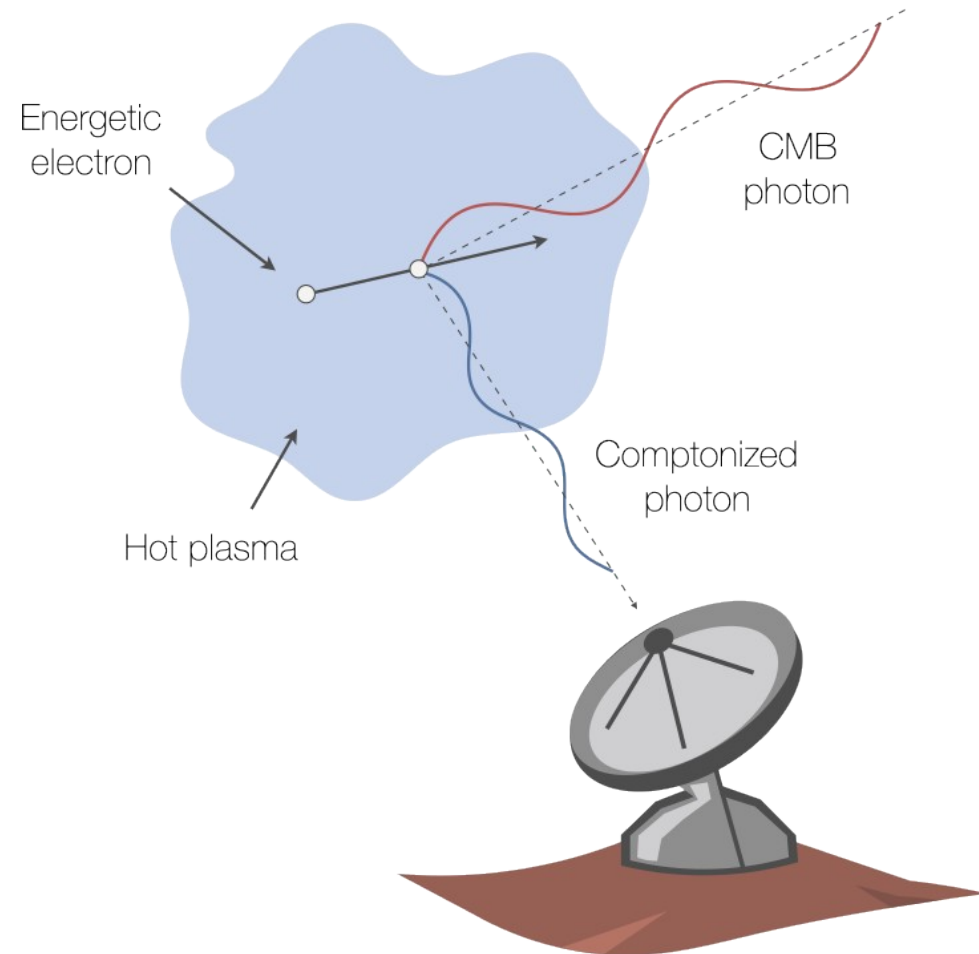
- Malo mjerenja koja ograničavaju reionizaciju
- Gunn-Petersonov jarak – kraj oko  $z = 6$
- Mjerenje ukupne optičke dubine – početak oko  $z = 11$

# 21 cm linija



# Sunyaev-Zel'dovich efekt

- Sekundarna anizotropija mikrovalnog pozadinskog zračenja
- Termalni Sunyaev-Zel'dovich efekt (tSZ)
- Kinetički Sunyaev-Zel'dovich efekt (kSZ)



# Problemi detekcije signala neutralnog vodika

- Emisija iz prednjeg plana
- Ionosfera
- Odgovor instrumeta
  
- Rješenje: promatranje korelacije s kSZ signalom.

# 21 cm signal

- Temperatura spina:  $\frac{n_1}{n_0} = 3 \exp(-T_*/T_{spin})$ .

$$T_b(\nu) = T_{spin}(1 - e^{-\tau_\nu}) + T_{CMB}(\nu)e^{-\tau_\nu}$$

- Veličina koju mjerimo:  $\delta T_b = 28mK(1 + \delta)x_{HI} \left(1 - \frac{T_{CMB}}{T_{spin}}\right) \left(\frac{\Omega_b h^2}{0.0223}\right) \sqrt{\left(\frac{1+z}{10}\right) \left(\frac{0.24}{\Omega_m}\right)}$ .

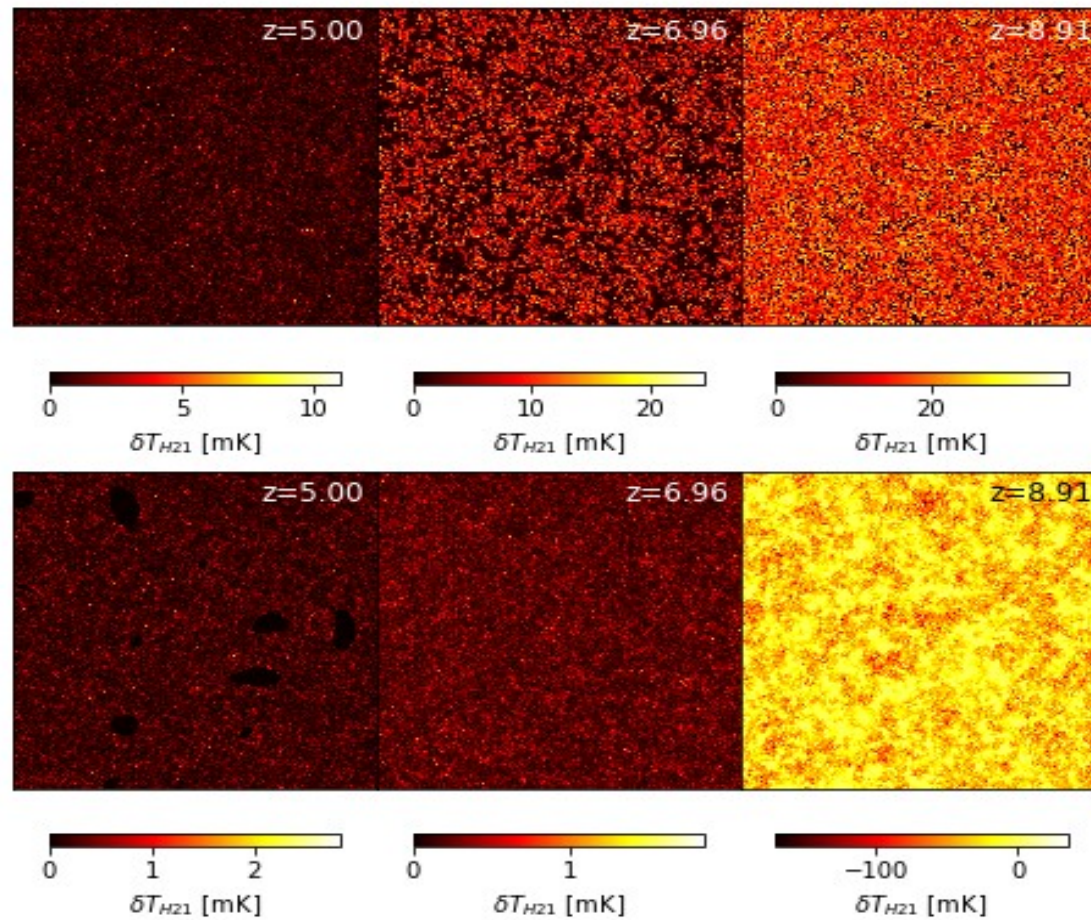
- $T_{spin} = \frac{T_{CMB} + y_{kin}T_{kin} + y_\alpha T_\alpha}{1 + y_{kin} + y_\alpha}$



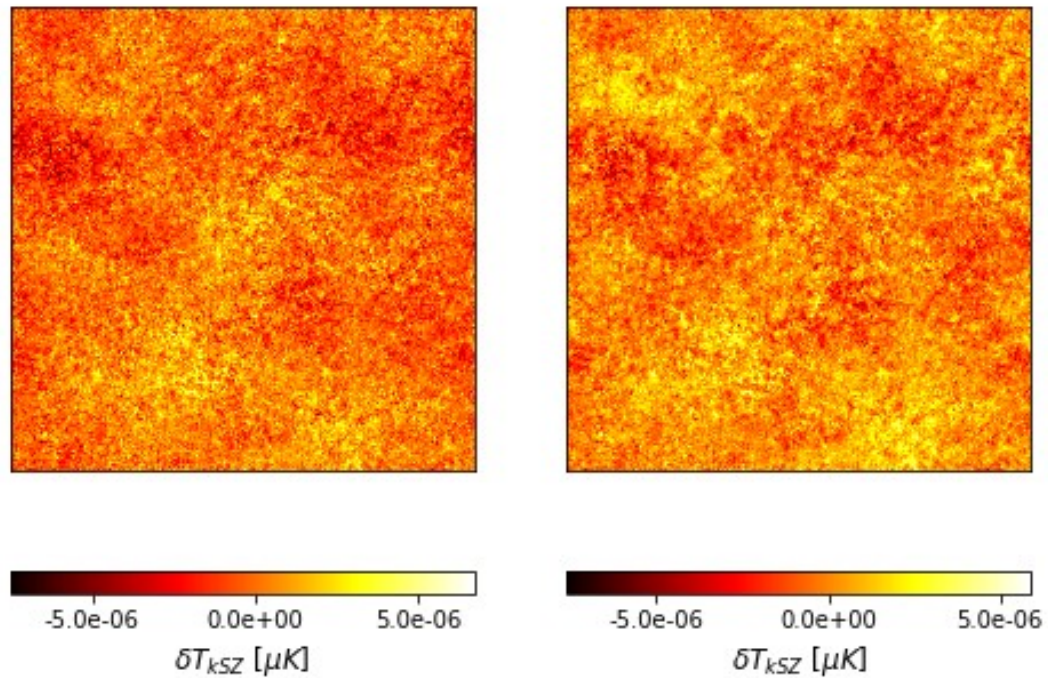
# KSZ efekt

- ksz efekt: 
$$\left(\frac{\delta T}{T}\right)_{kSZ} = -\sigma_T \int_{t_r}^{t_0} e^{-\tau} n_e(\hat{r} \cdot \vec{v}) dt$$
- Koncentracija elektrona: 
$$n_e = \bar{n}_n \bar{x}_e (1 + \delta + \delta_{x_e} + \delta\delta_{x_e})$$
- $$\left(\frac{\delta T}{T}\right)_{kSZ} = -\sigma_T \bar{n}_{\text{HI}(0)} \int_{z_r}^{z_0} \frac{(1+z)^2}{H} e^{-\tau} \bar{x}_e (1 + \delta) v_r dz.$$
- Optička dubina: 
$$\tau = c\sigma_T \int_0^z n_e \frac{(1+z)^2}{H(z)} dz.$$

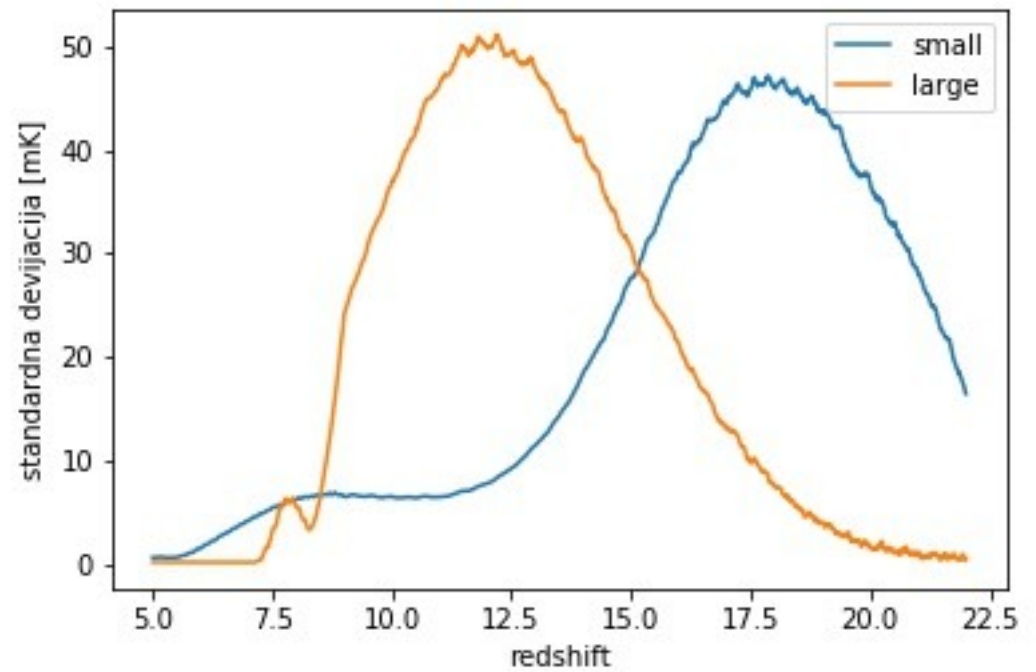
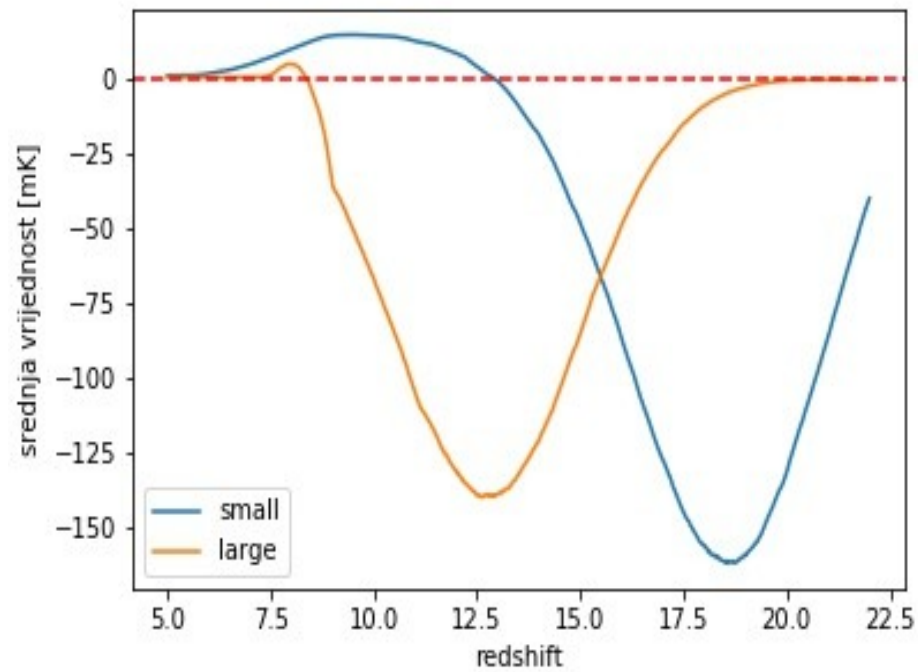
# 21cmFast - 21 cm signal



# 21cmFast - kSZ efekt

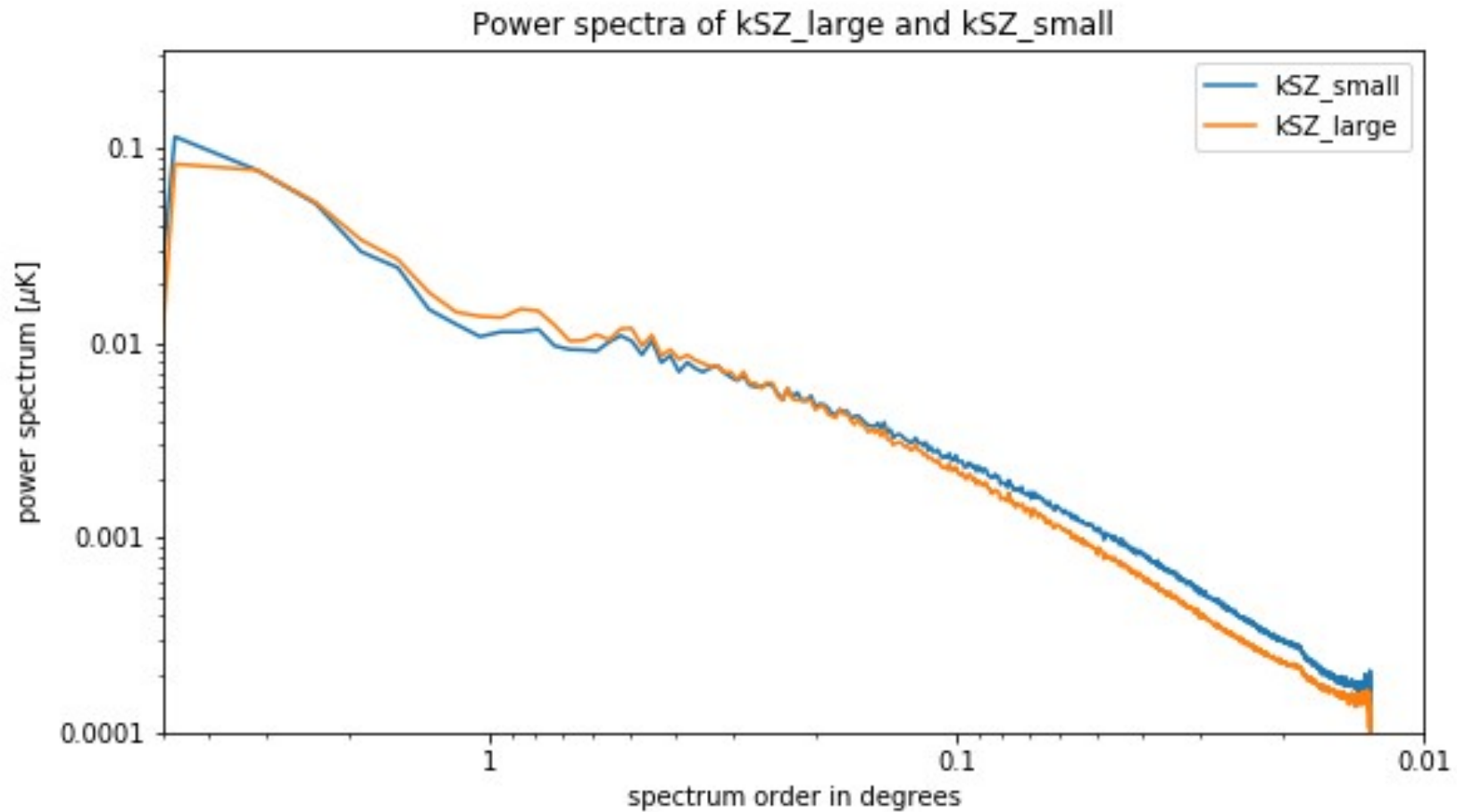


# 21 cm signal

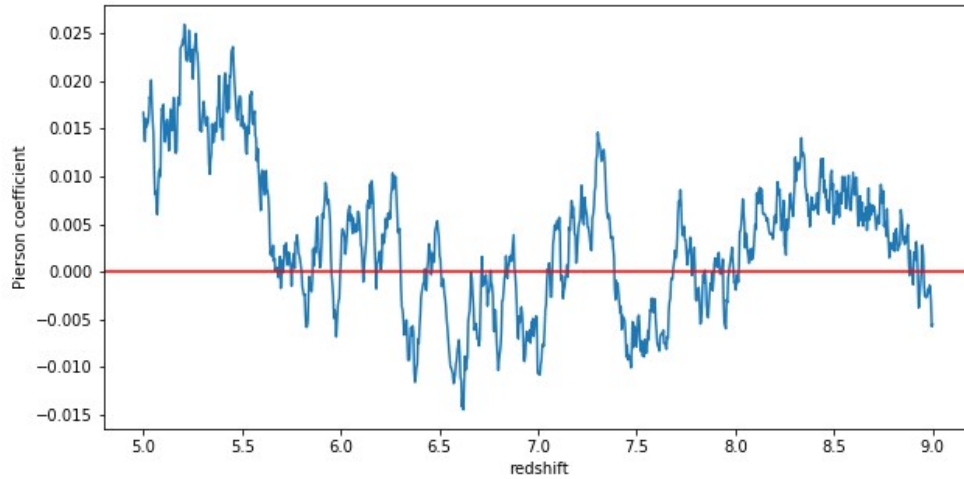




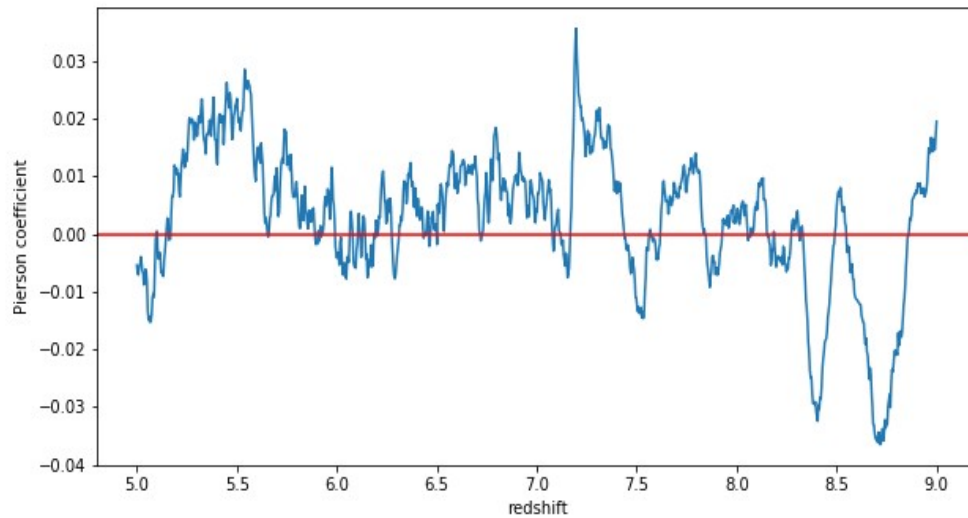
# kSZ spektral snage



# Korelacija



$$\rho_{X,Y} = \frac{\text{cov}(X, Y)}{\sigma_X \sigma_Y}$$



	SMALL		LARGE		
	emisija	apsorpcija	slabi signal	emisija	apsorpcija
kSZ , EOR	0.01817	0.01867	0.0496	0.00537	0.08178

# Zaključak

- Dobivena evolucija 21 cm signala i spektar snage kSZ efekta
- Rezultat istraživanja korelacije se razlikuje ovisno o mehanizmu reionizacije
- Malen koeficijent korelacije – potrebno je daljnje istraživanje



**Hvala na pažnji!**