Radio telescope probes on the light scalar fields

Kenji Kadota, IBS Center for Theoretical Physics of the Universe (CTPU)

(1) Radio telescope search for the resonant conversion of cold dark matter axions from the magnetized astrophysical sources

Phys.Rev. D97 (2018) 1803.08230 [hep-ph]

In collaboration with: Fa Peng Huang, Toyokazu Sekiguchi, Hiroyuki Tashiro

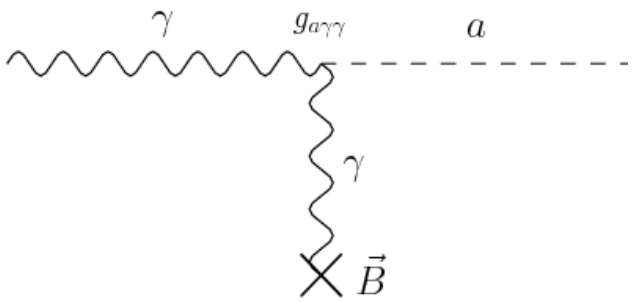
(2) Cross-correlation between 21-cm radiation and CMB B modes from the cosmic birefringence in the presence of a light scalar field

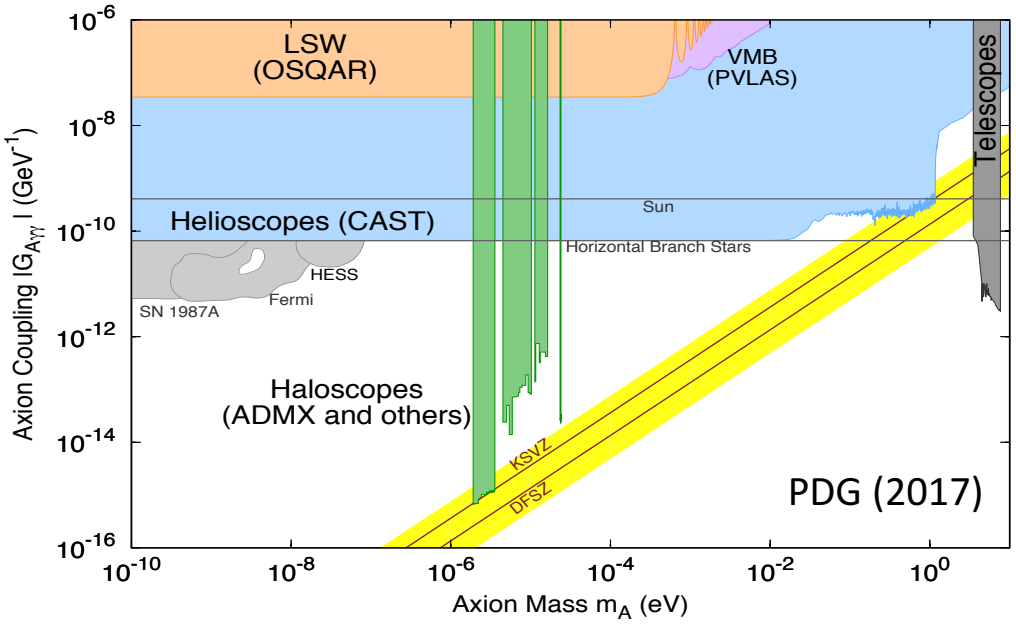
Phys.Rev.D100(2019) 1906.00721[astro-ph]

In collaboration with: Junpei Ooba, Hiroyuki Tashiro, Kiyotomo Ichiki, Guo-Chin Liu

Primakoff effect

$$\frac{g_{a\gamma\gamma}}{4} aF\tilde{F} = -g_{a\gamma\gamma} a\boldsymbol{E}\cdot\boldsymbol{B}$$





QCD axion as a CDM candidate : mass range μeV ~ meV(0.1GHz ~ 100GHz)

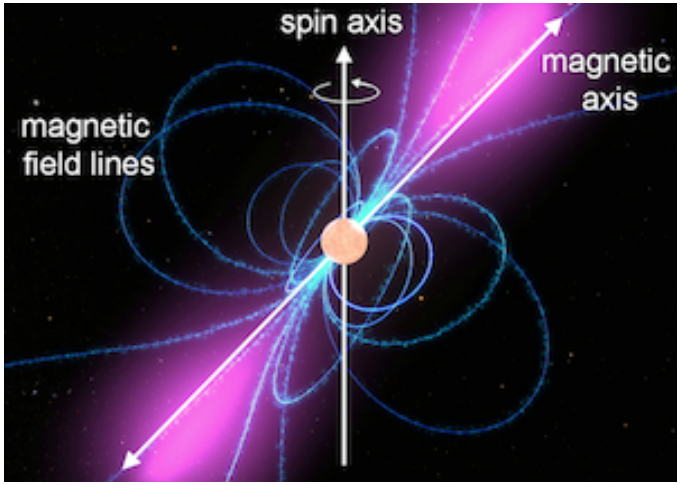
Previous works: CDM axions converted into photons in the labs.
Relativistic axion into photon around neutron stars (Yoshimura (88),Raffelt&Stdolsky(88))

New works: How about the astrophysically sourced magnetic fields?

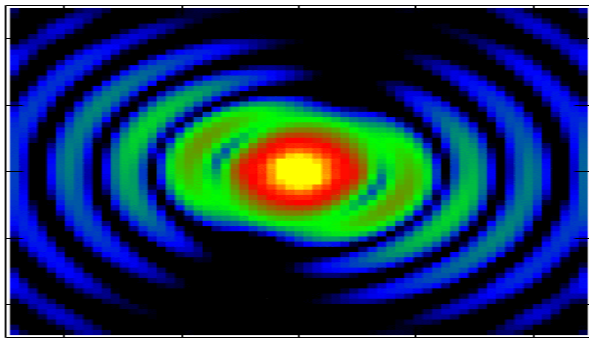
Non-resonant conversion: Kelley and Quinn (2017), Sigl (2017)

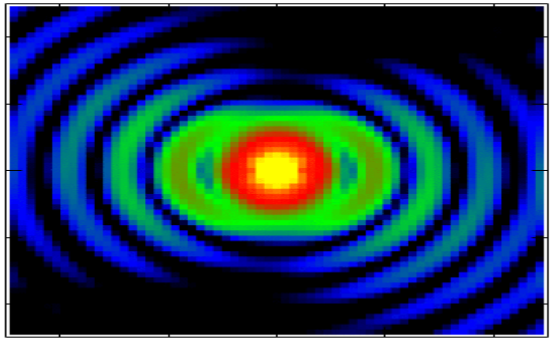
Resonant conversion: Huang, KK, Sekiguchi and Tashiro (2018), Hook,Kahn,Safdi and Sun(2018)

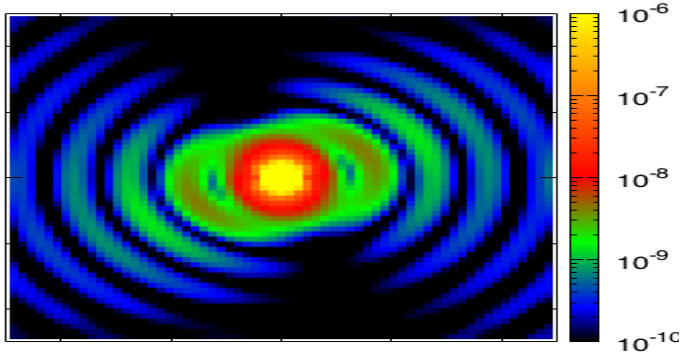
Line-like radio signal for non-relativistic axion conversion: $f \sim \frac{m_a}{2\pi} \sim 240 \left(\frac{m_a}{\mu eV}\right)$MHz

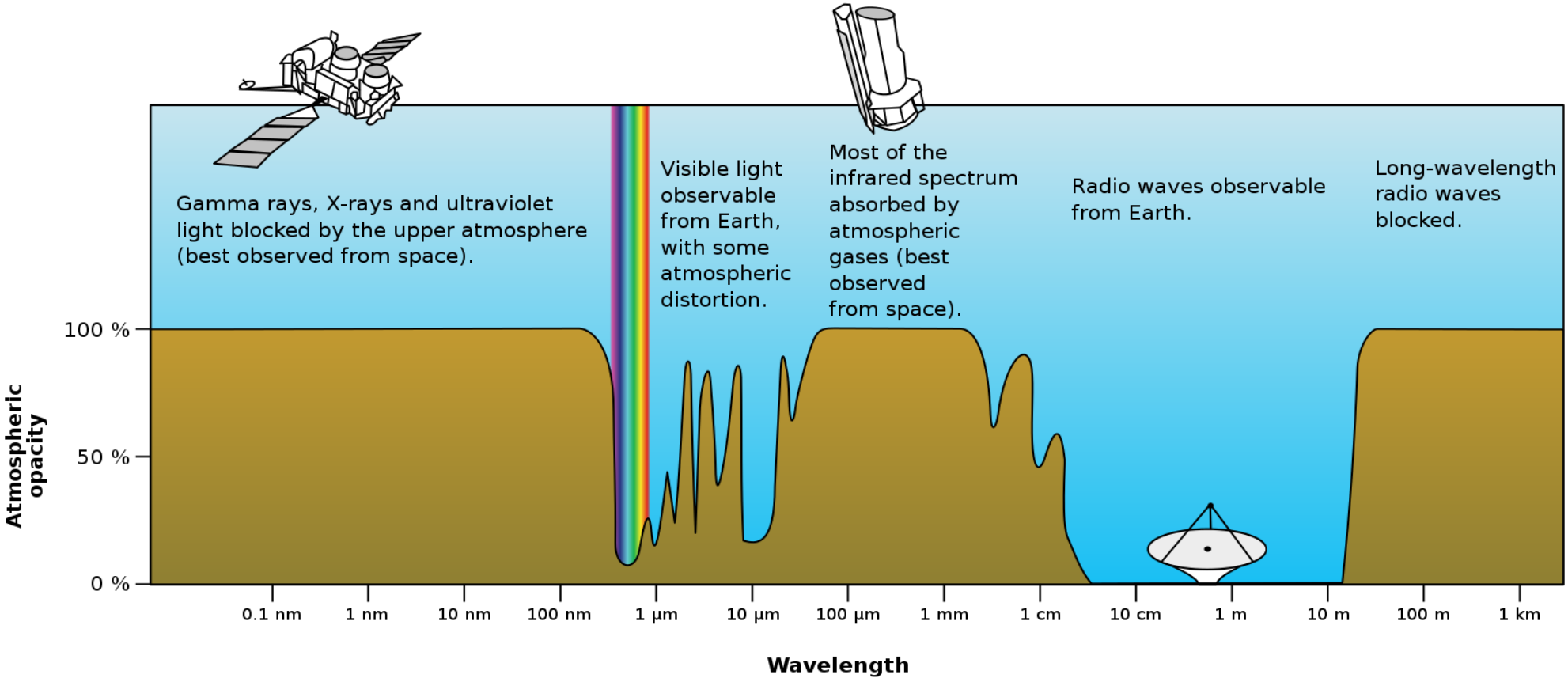


(KK & Kitajima, to appear)









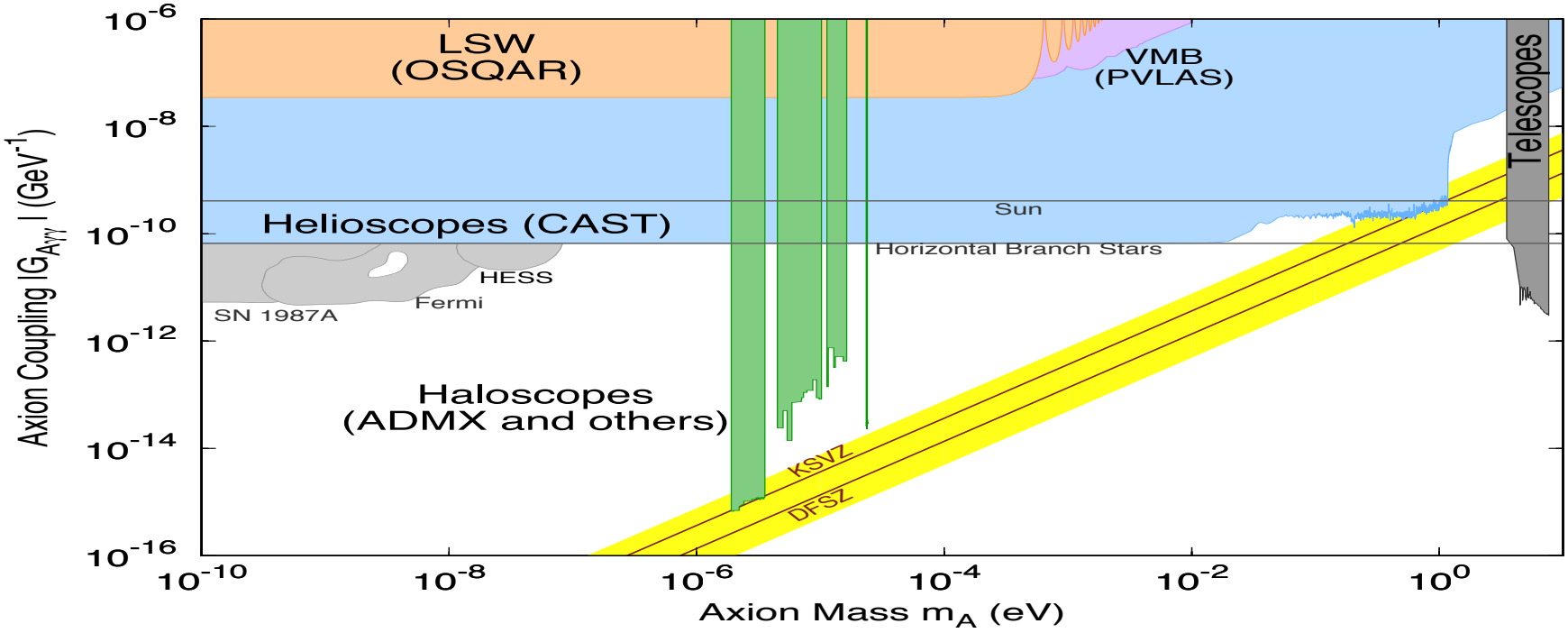
Australia: SKA low: 50-350 MHz

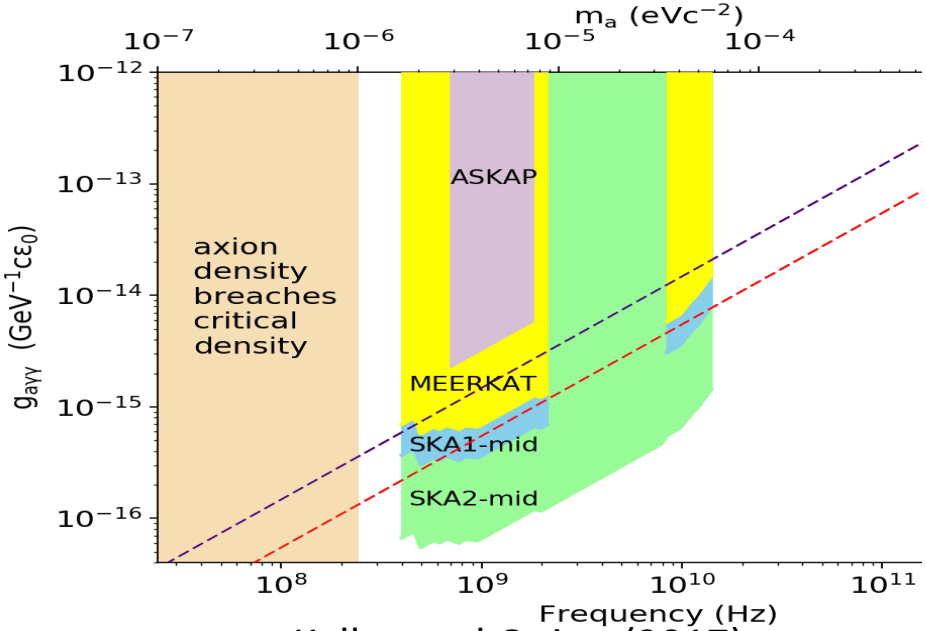
S. Africa: SKA mid: 350 MHz-14GHz

Axion mass: $0.2 \sim 60\ \mu eV$

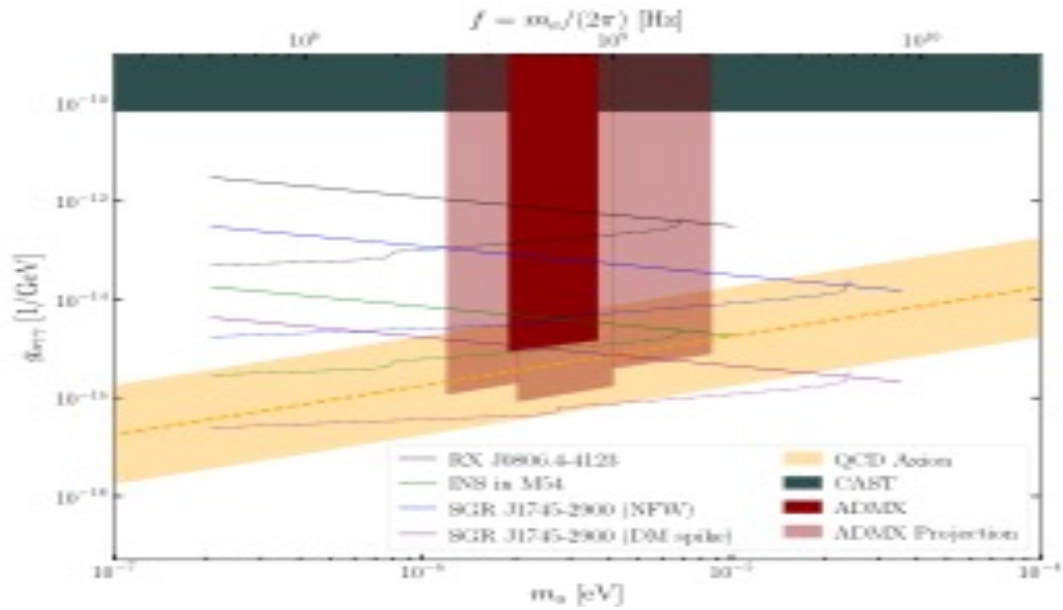
QCD axion as a CDM candidate :

Mass µeV ~ meV(0.1GHz ~ 100GHz)





Kelley and Quinn (2017)



Hook,Kahn,Safdi and Sun(2018)

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Model: ALP (Axion-like particles) i.e. Ultra-light scalars

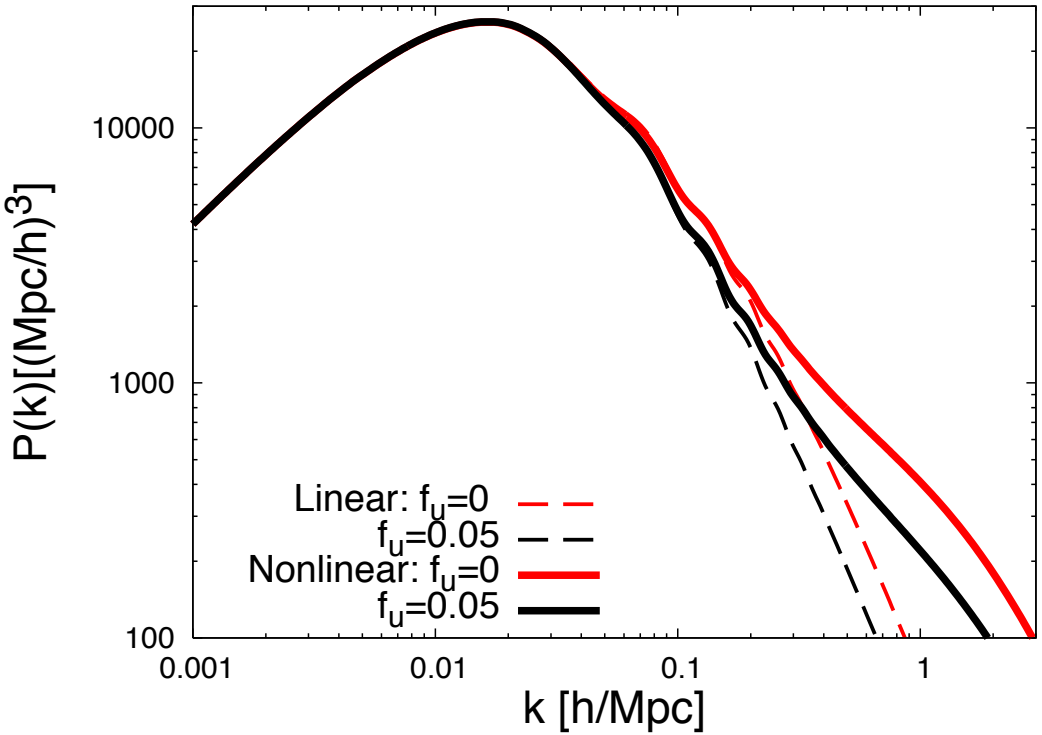
Ultra-light mass :

$m_u \sim H_0 \sim 10^{-33} eV$ DE (Barbieri et al (2005),…)

$m_u \sim \sim 10^{-22} eV$ Fuzzy DM (Hu (2000),…)

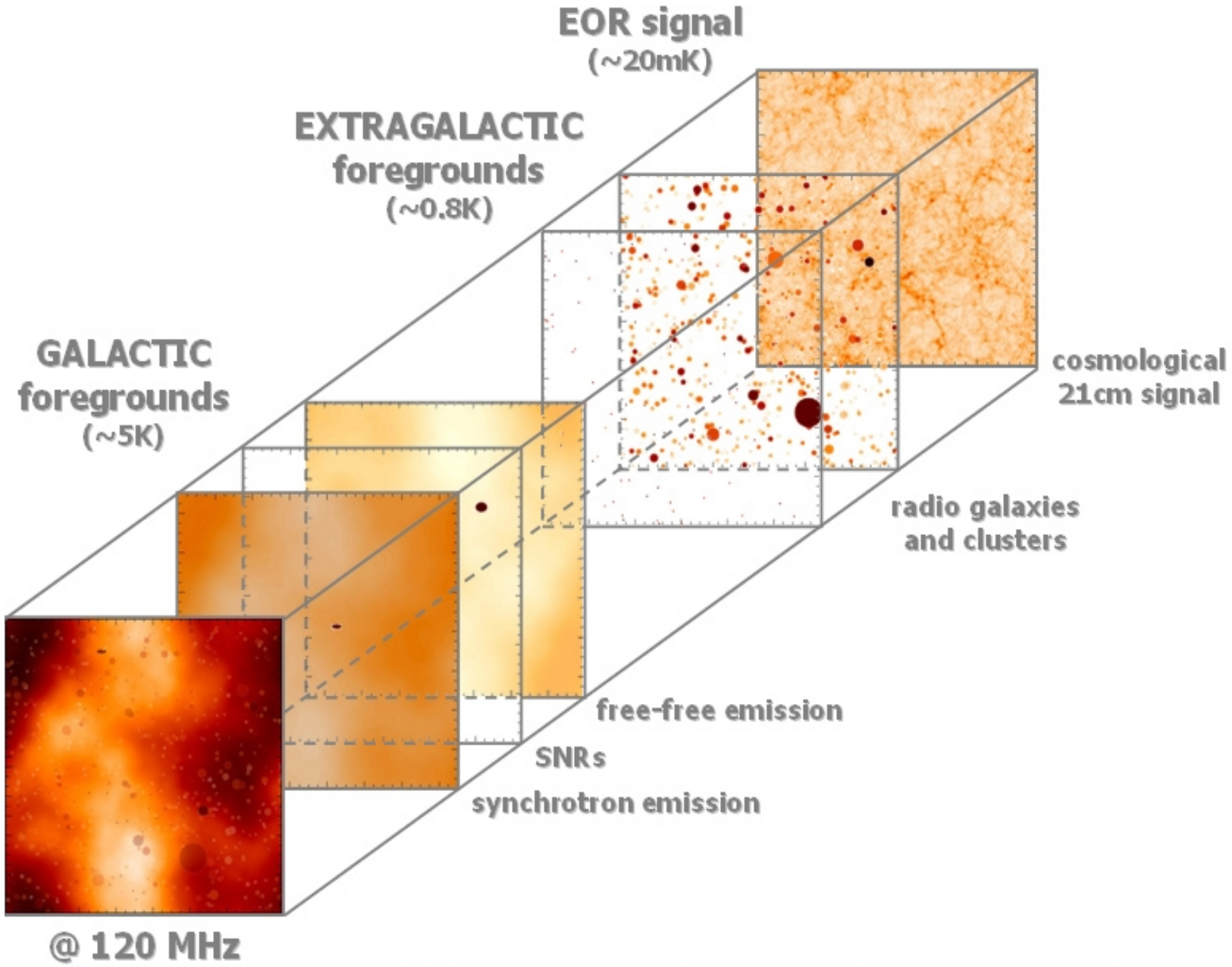
$m_u \sim \sim 10^{-22} eV - 10^{-10} eV$ String axiverse (Arvanitaki et al (2009),...)

KK, Yi Mao, Kiyomoto Ichiki, Joseph Silk (2014)
"Cosmologically probing ultra-light particle dark matter using 21 cm signals"

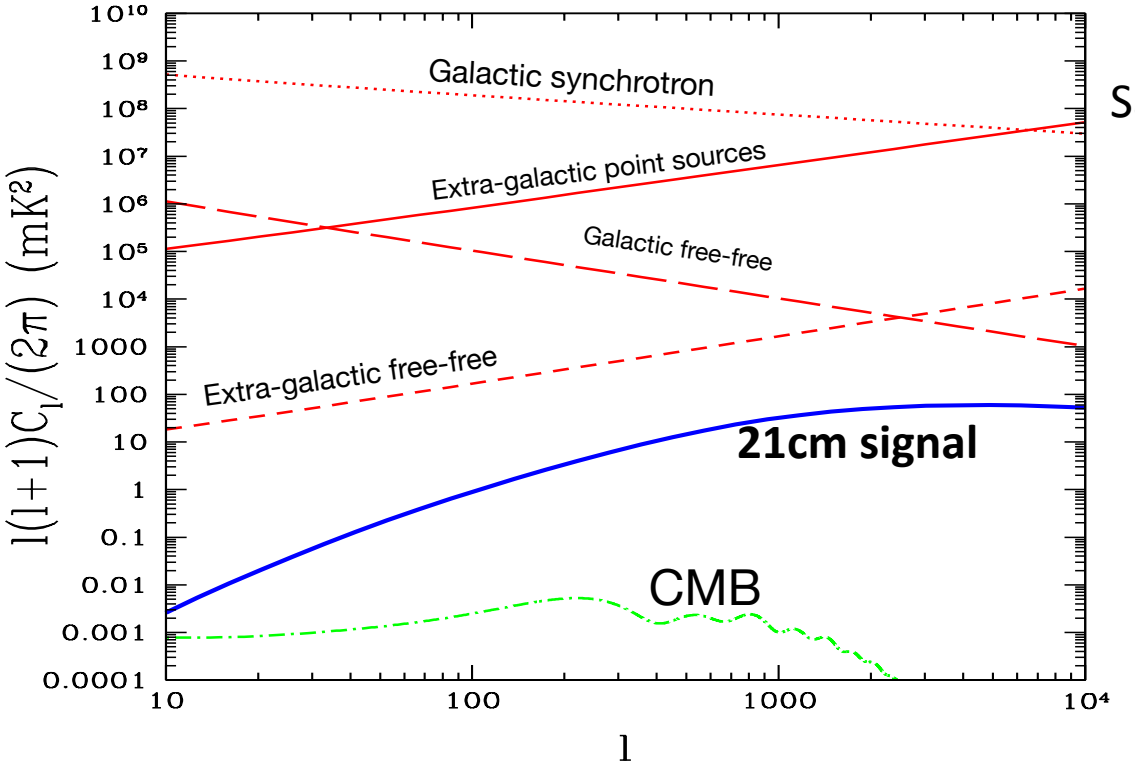


KK, Mao, Ichiiki, Silk (2014)

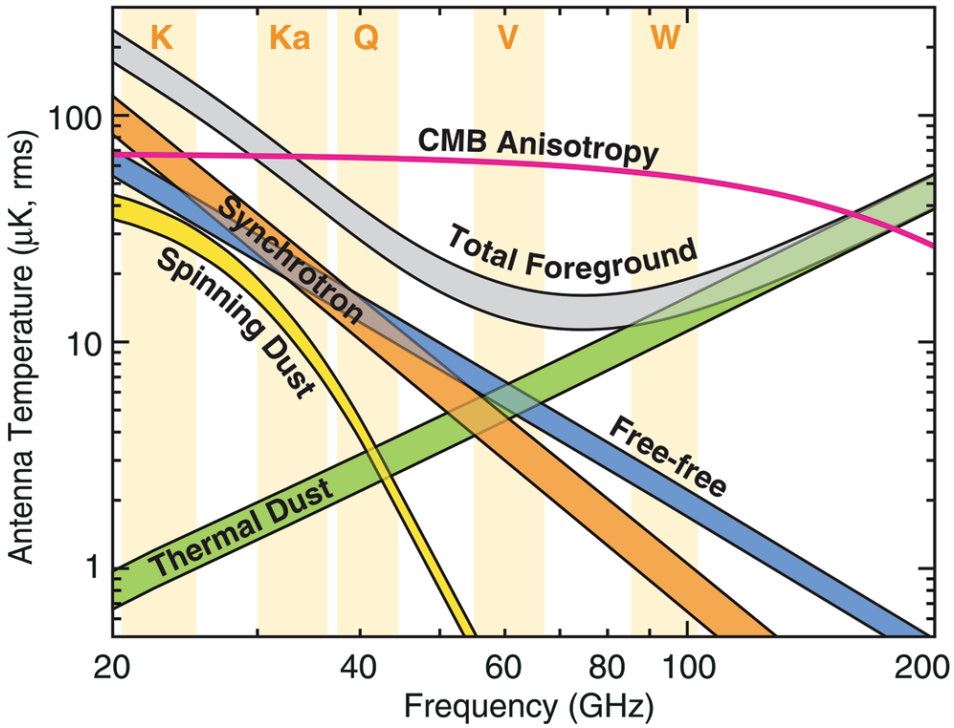
Also the talks by Julian Munoz, Yong Tang



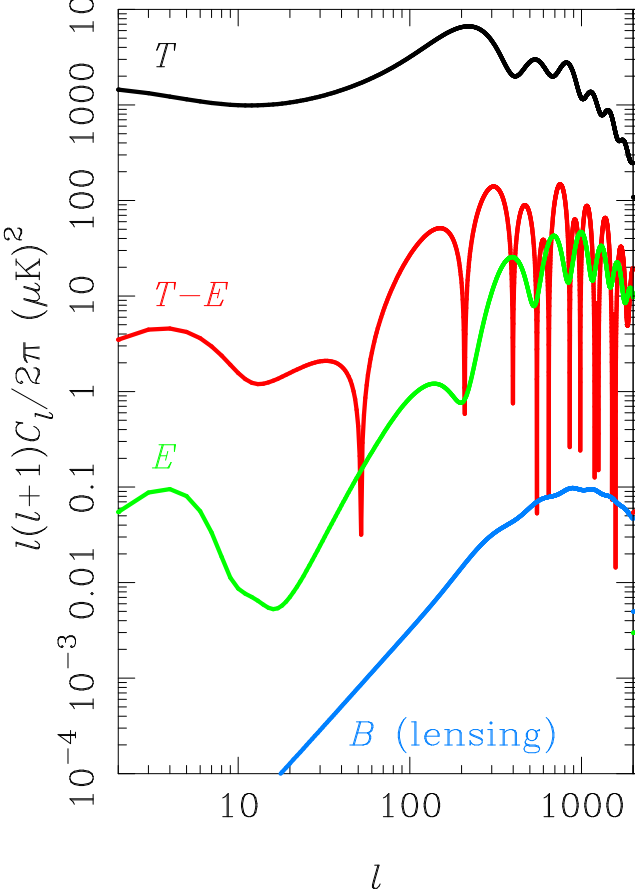
Jelic and Zaroubi



Santos et al (2014)



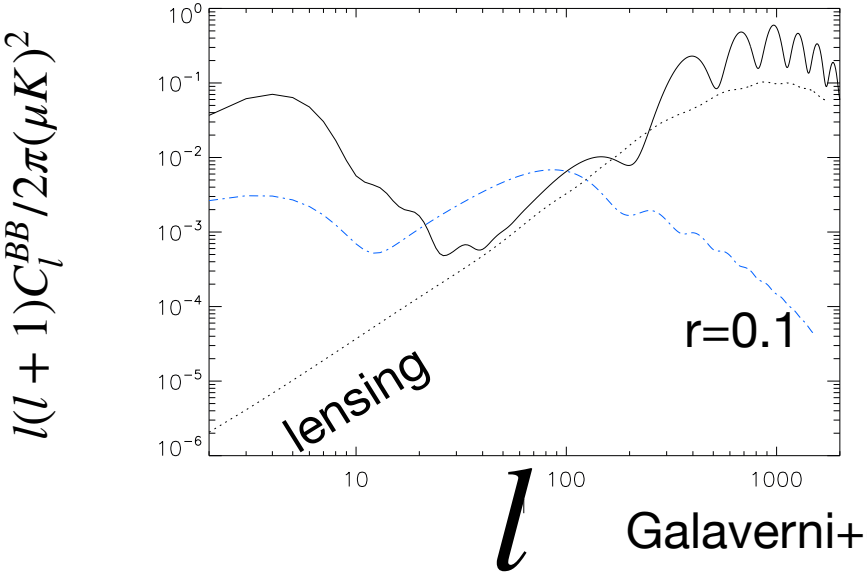
C.L. Bennett + (2013)



Motivations for cross correlation

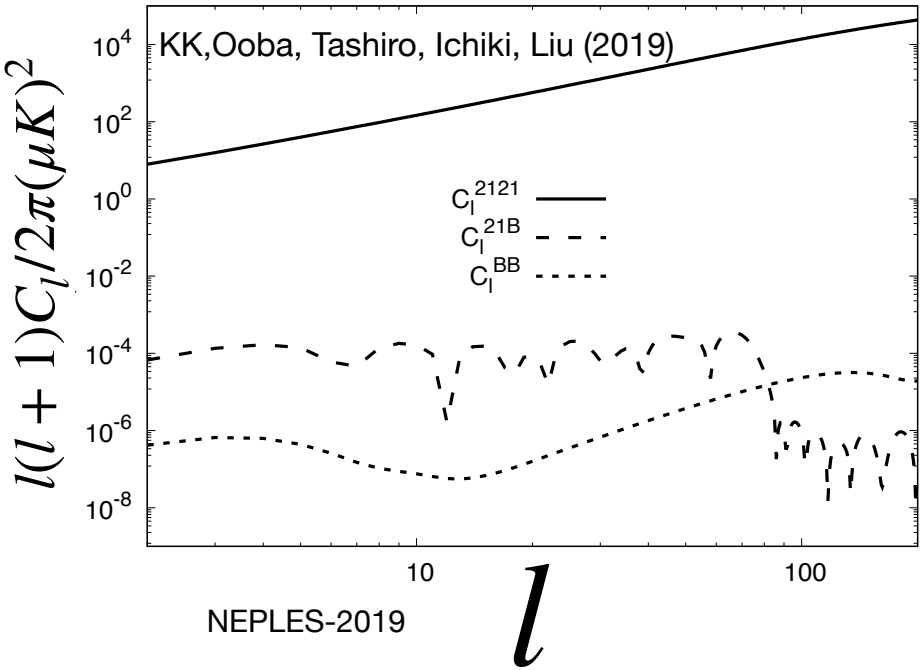
The different systematics

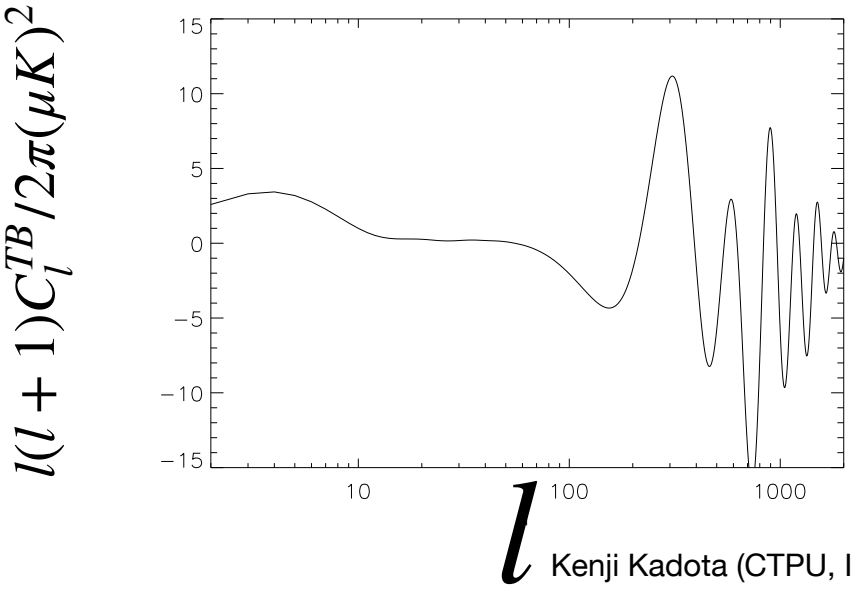
21cm fluctuations >> B mode fluctuations



Galaverni+(2008)

$m = 10^{-22}eV, \beta = 10^{-20}eV^{-1}$

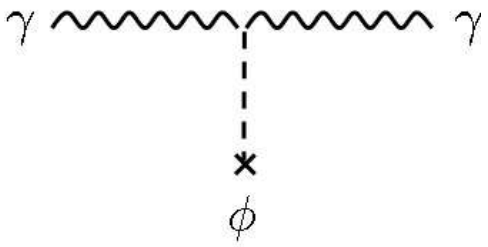




Cosmological Birefringence

(Carroll, Field, Jackiw (1990), Harari,Sikivie (1992),Lue, Wang,Kamionkowski (1999), …)

$$L_{\phi\gamma} = -\frac{\beta}{4}\phi F_{\mu\nu}\tilde{F}_{\mu\nu} = \beta\phi\mathbf{E}\cdot\mathbf{B}$$



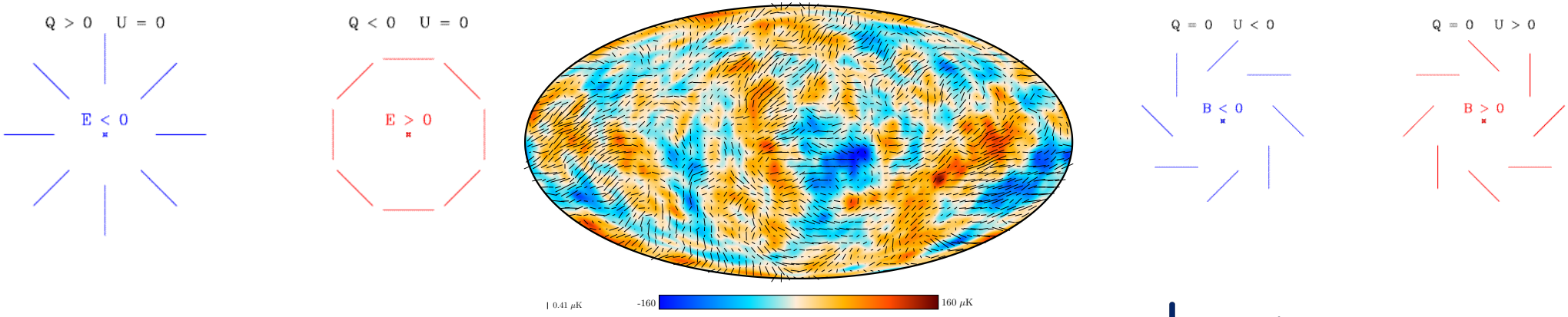
$$\omega_{\pm} \sim k \pm \frac{\beta}{2}\left(\frac{\partial\phi}{\partial t} + \nabla\phi\cdot\frac{\mathbf{k}}{k}\right)$$

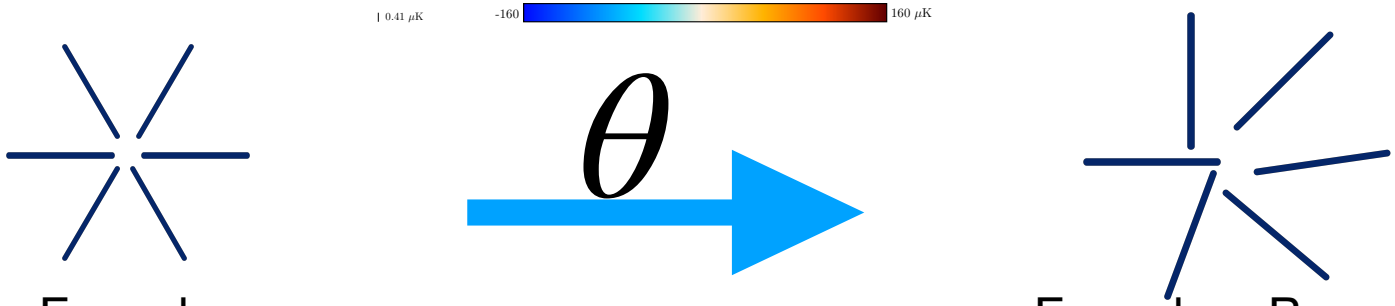
$$\theta(\eta) = \frac{1}{2}\int(\omega_+ - \omega_-)dt = -\frac{\beta}{2}\left(\phi(\eta_0) - \phi(\eta)\right)$$

$$\left(Q \pm iU\right) \to e^{\mp 2i\theta}\left(Q \pm iU\right)$$

e.g. For the time-indept constant rotation

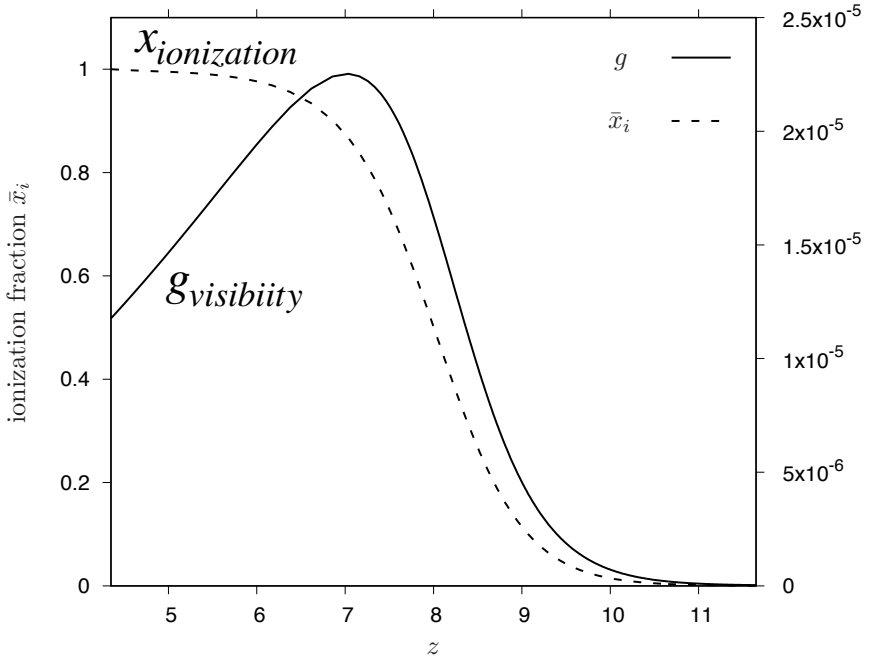
$$E^{observed} = E\cos(2\theta) - B\sin(2\theta)$$
$$B^{observed} = E\sin(2\theta) + E\sin(2\theta)$$



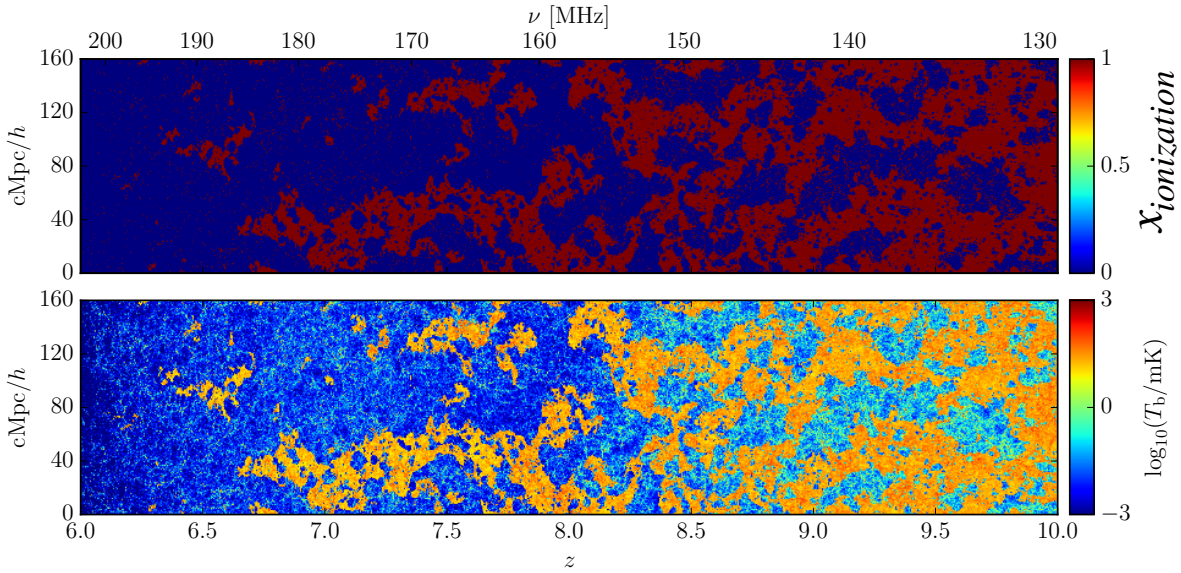


E-mode

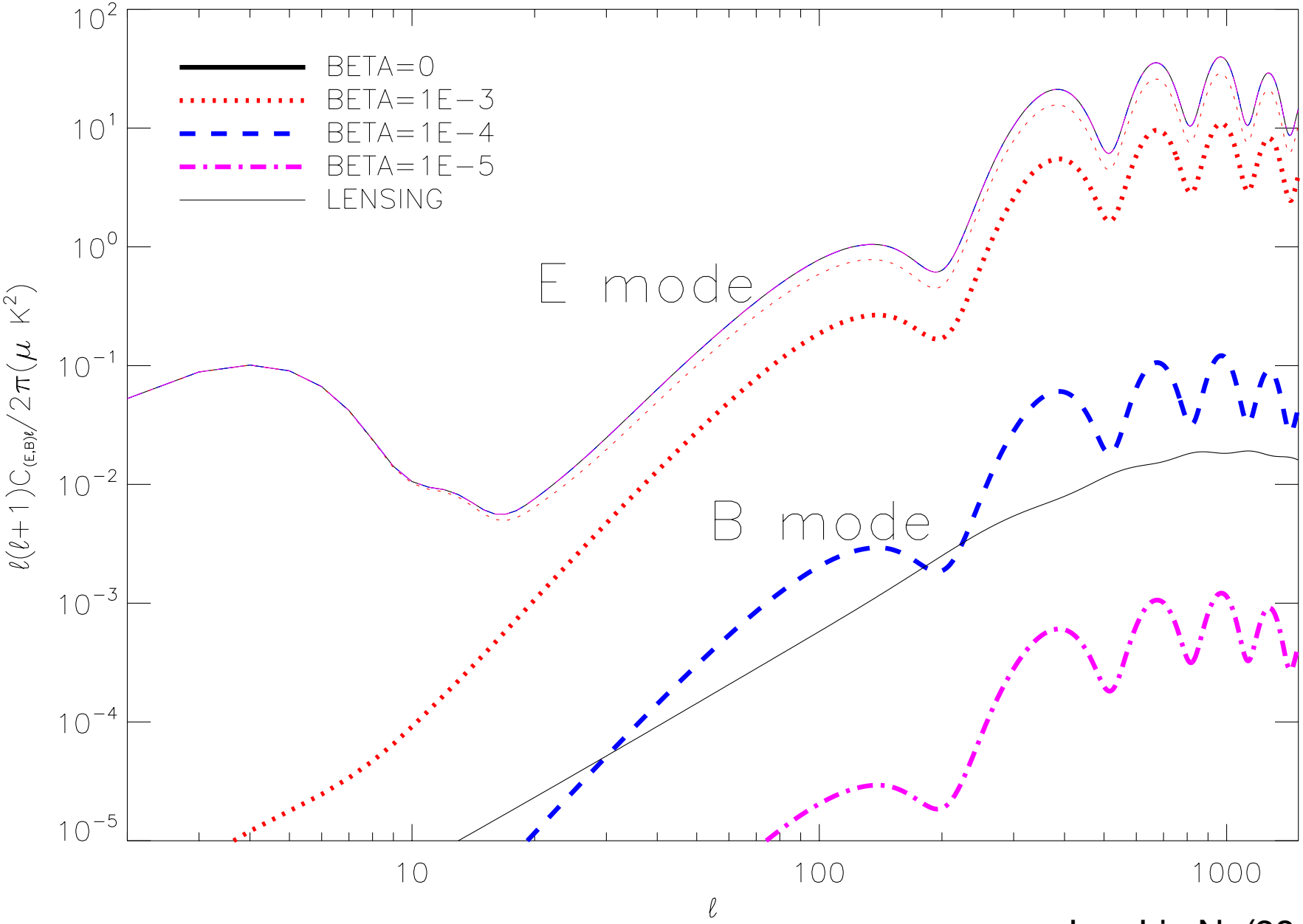
E-mode + B-mode



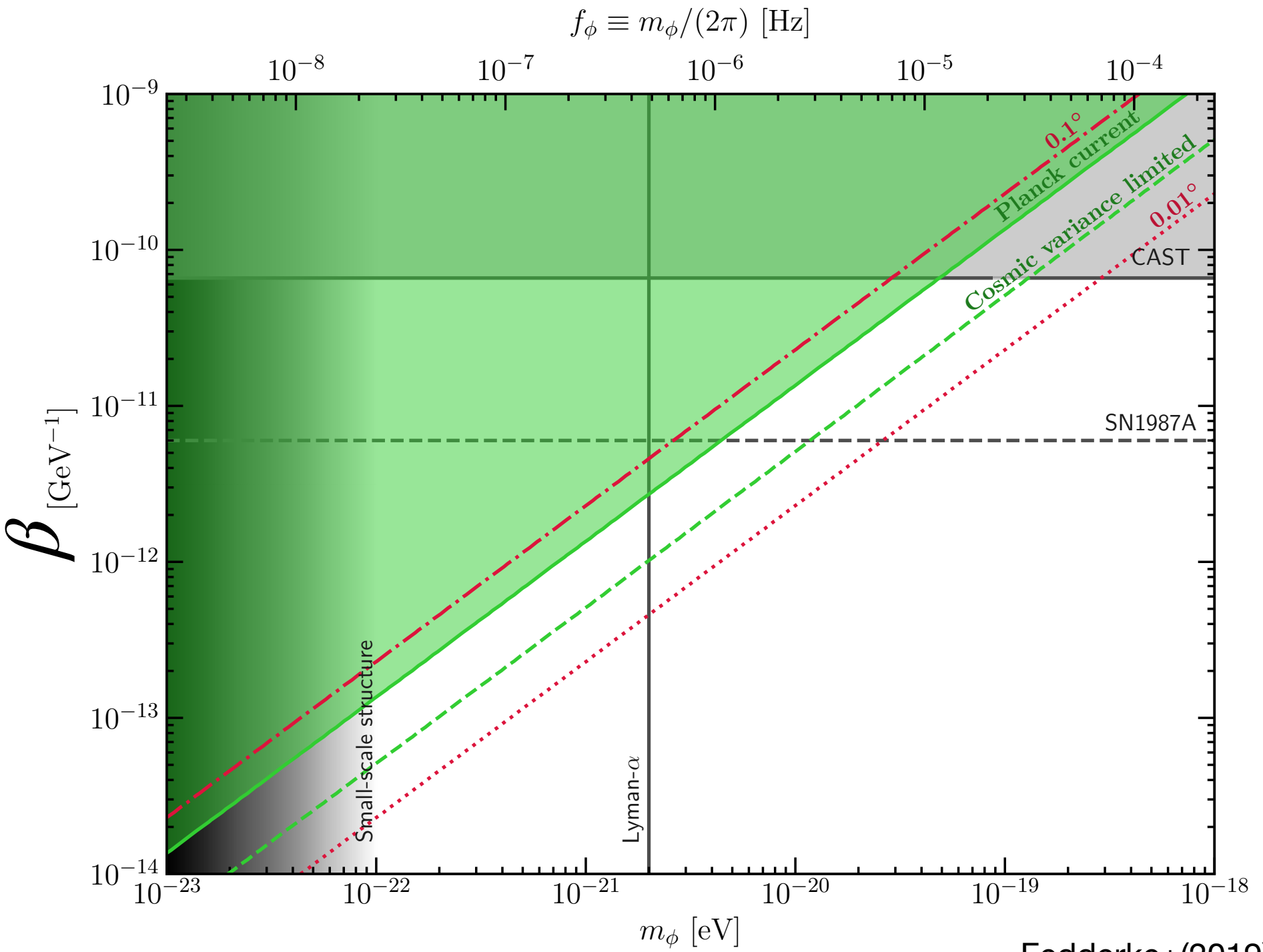
KK, Ooba, Tashiro, Ichiki, Liu (2019)



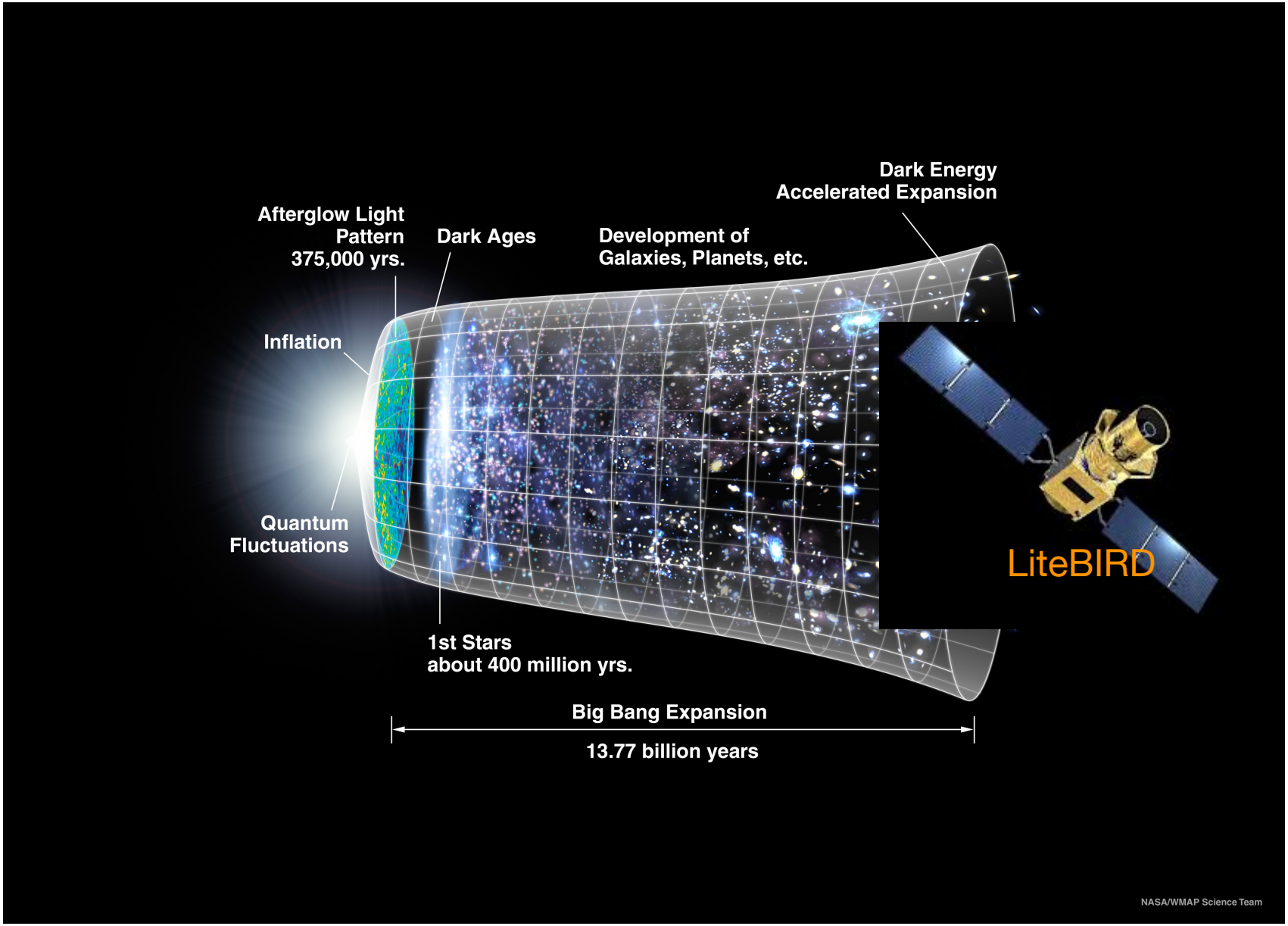
Kulkarni+(2016)



Lee,Liu,Ng(2016)



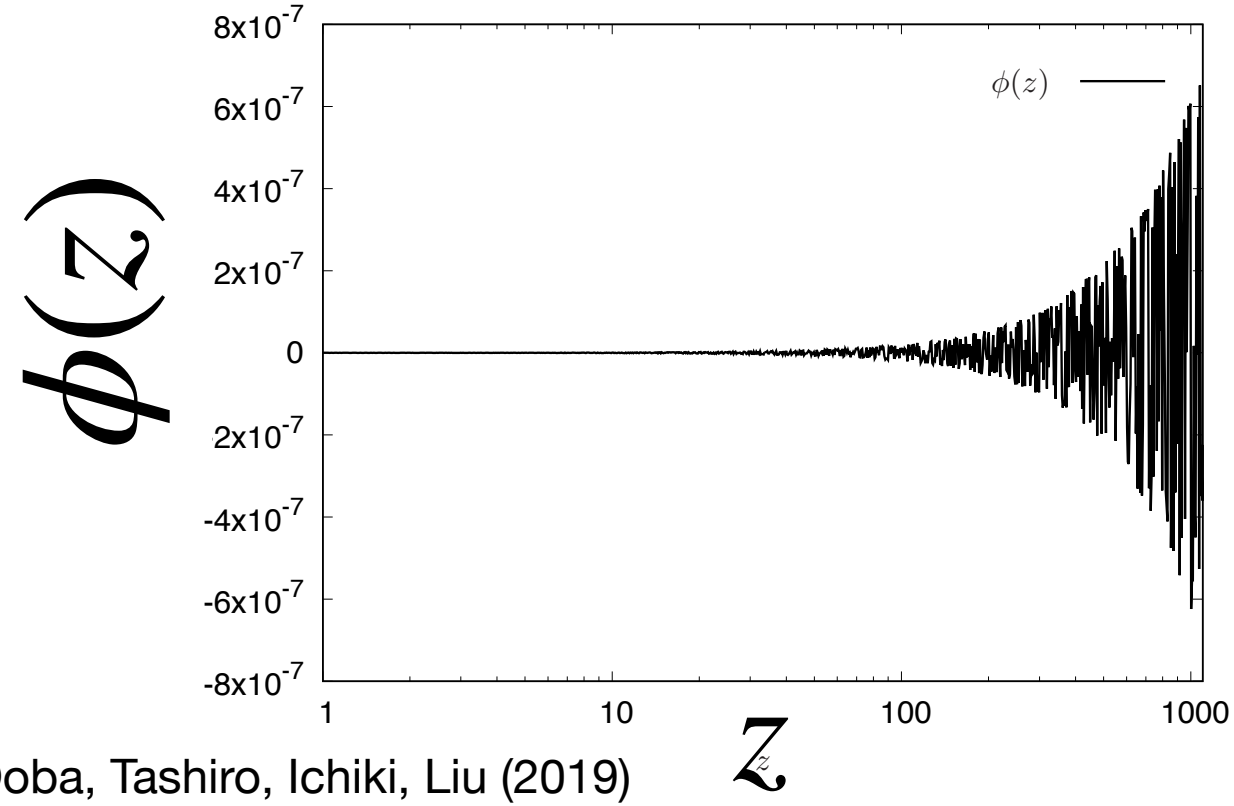
Fedderke+(2019)



Officially approved May 2019

Launch in 2027

Sensitivity $r \sim 10^{-3}$

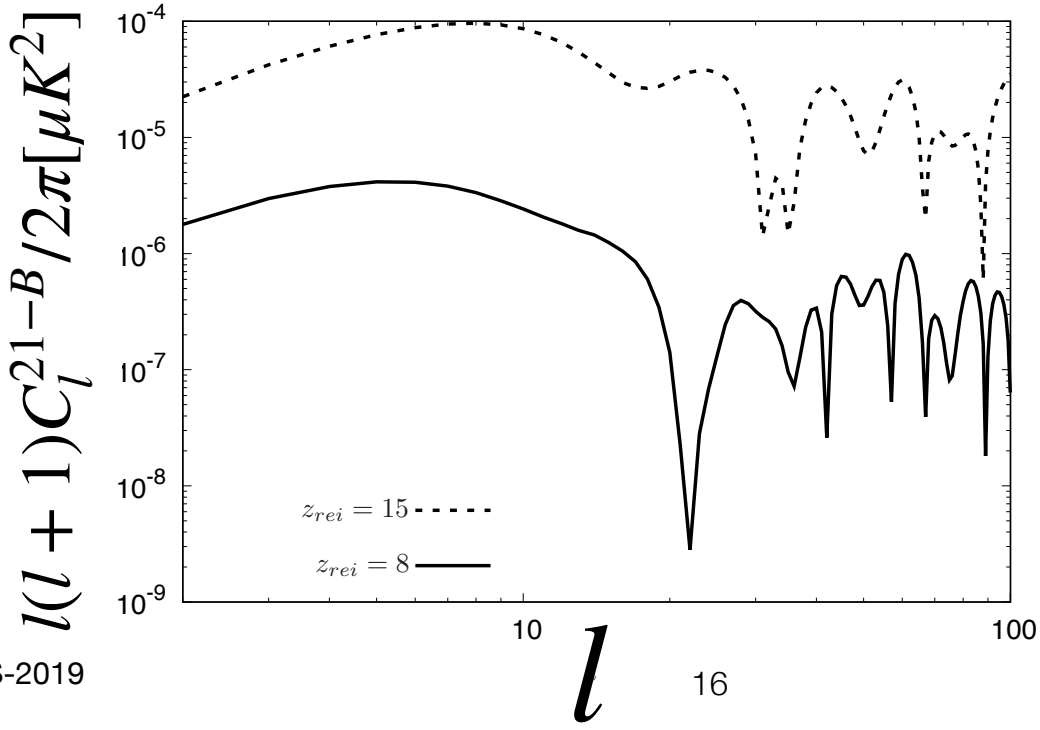


$$V = m^2\phi^2$$

$$m_\phi = 10^{-22}eV$$

$$\beta = (10^{13}GeV)^{-1}$$

KK,Ooba, Tashiro, Ichiki, Liu (2019)

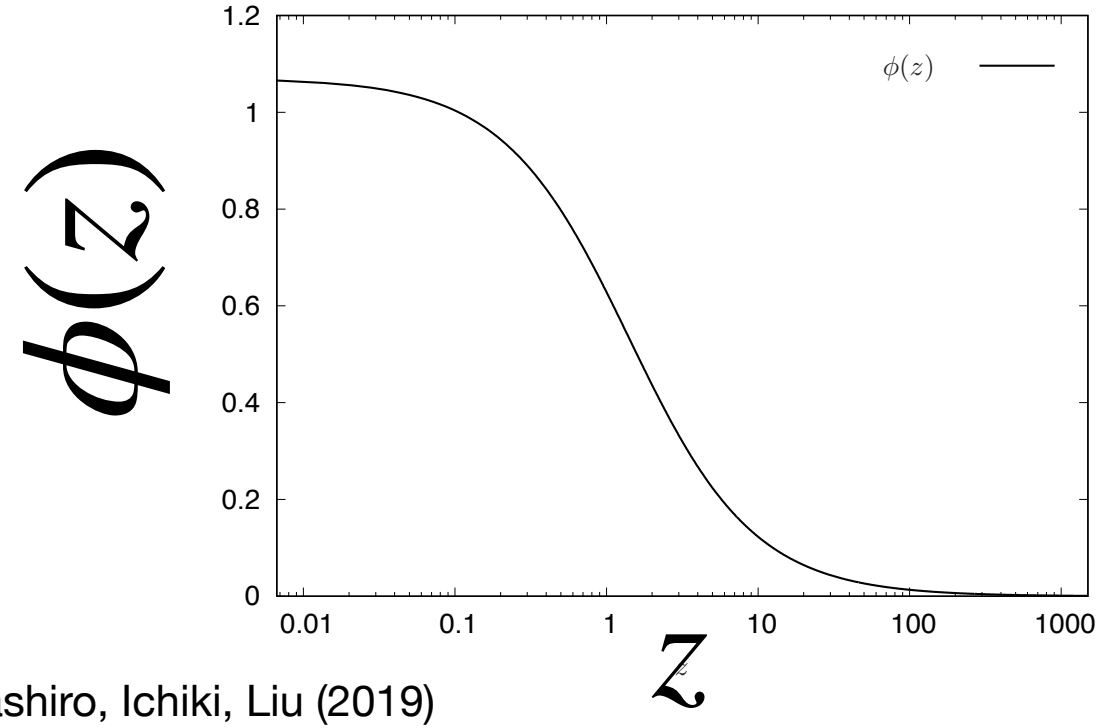


Ratra-Peebles Quintessence model

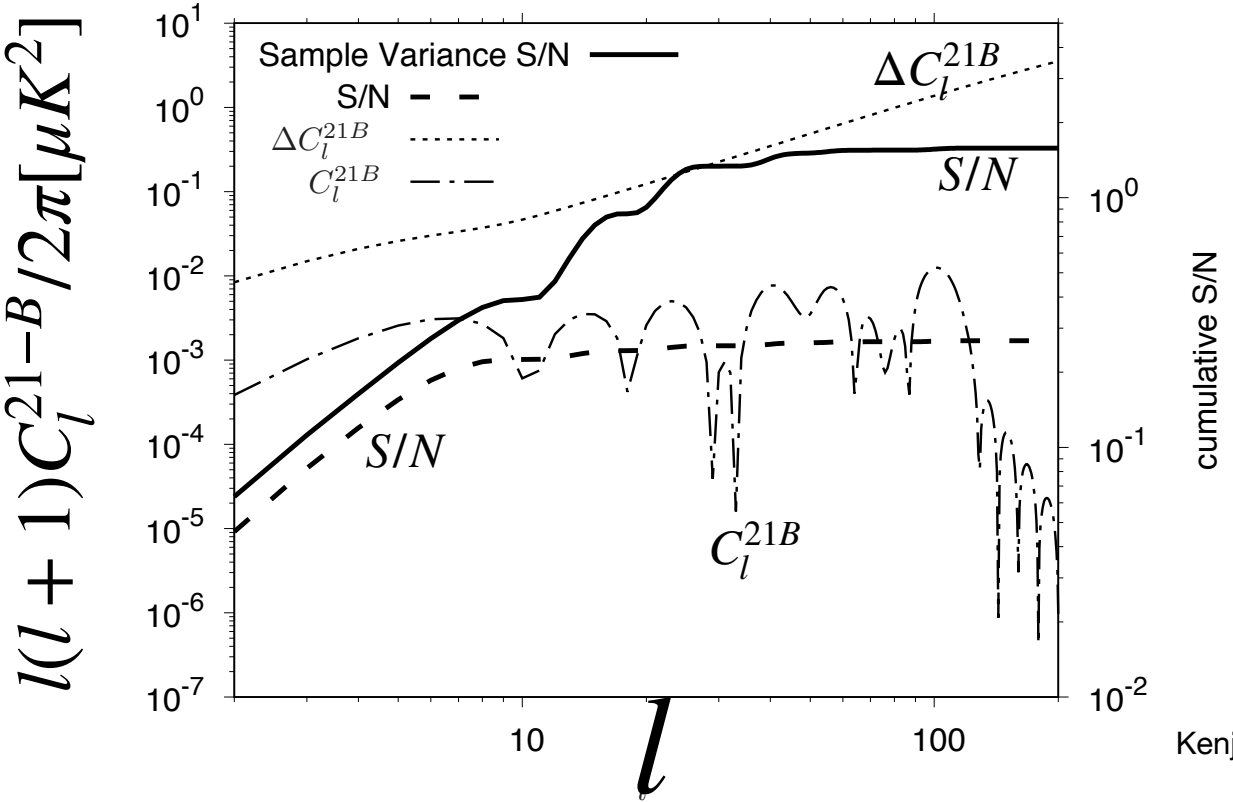
$$V(\phi) = \Lambda^{4+\alpha}\phi^{-\alpha}$$

$$\alpha = 1$$

$$\beta = 0.01/M_p$$



KK,Ooba, Tashiro, Ichiki, Liu (2019)



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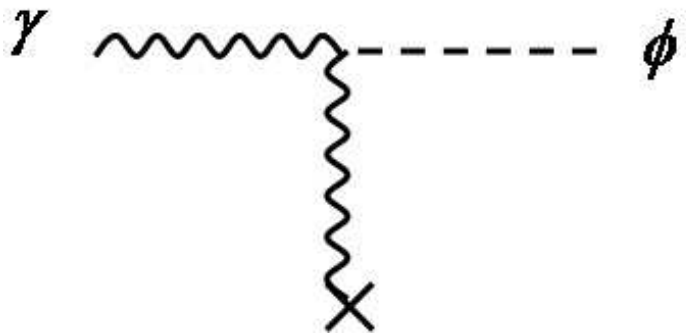

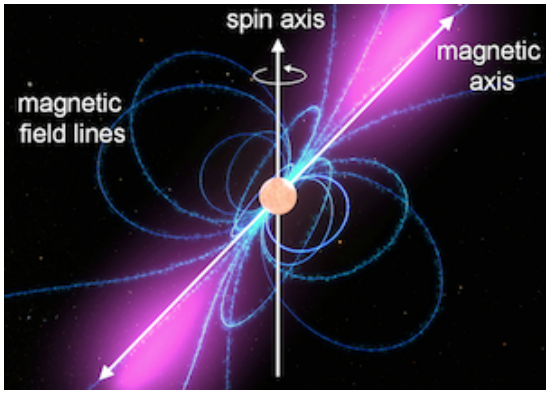

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