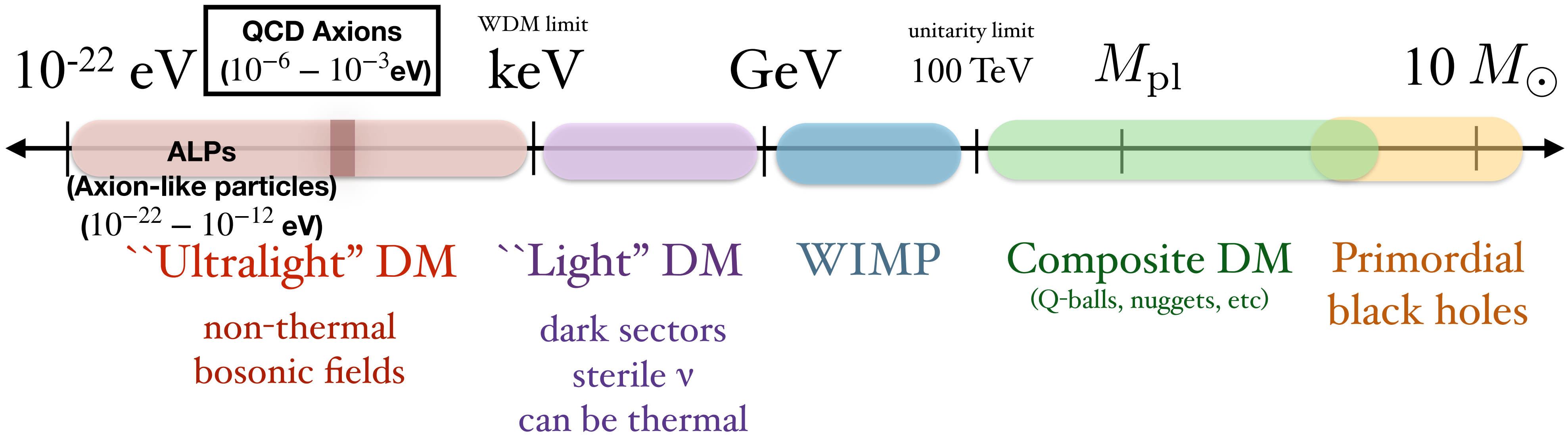
Radio telescope probes on Axion dark matter

Kenji Kadota (CTPU, IBS)

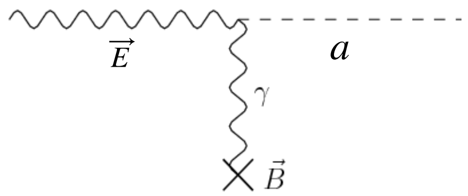
Based on the collaboration with
Fa-Peng Huang (Univ. of Washington), Kiyotomo Ichiki (Nagoya Univ), Toyokazu Sekiguchi (KEK),
Hayato Shimabukuro (Yunnann Univ), Hiroyuki Tashiro (Nagoya Univ)



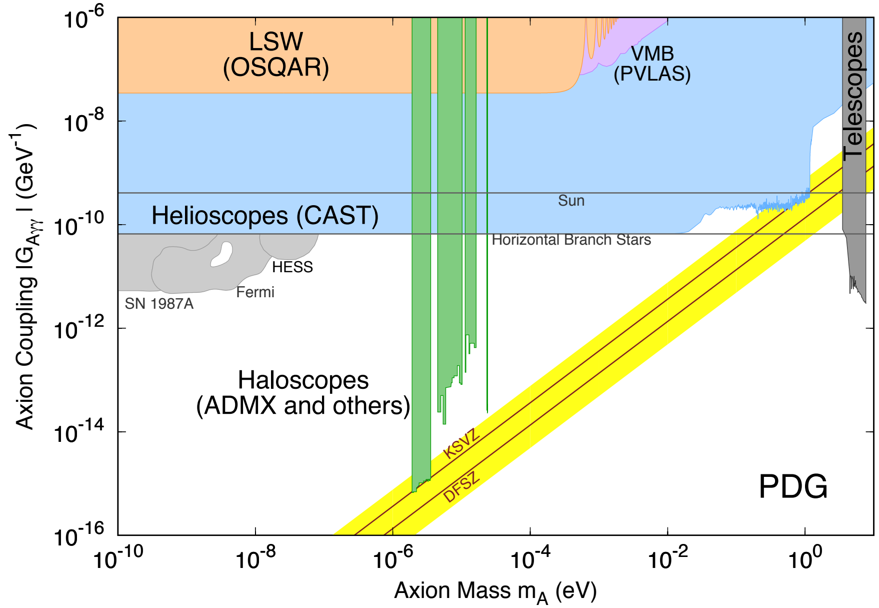
(1)Radio signals from the neutron stars

(2) 21cm probes on small scale structure evolutions

Primakoff effect $g_{a\gamma\gamma} a \mathbf{E} \cdot \mathbf{B}$



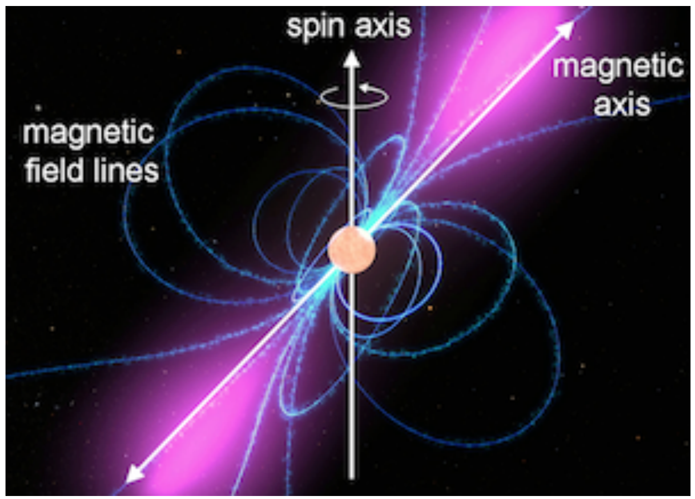
Axion Dark Matter



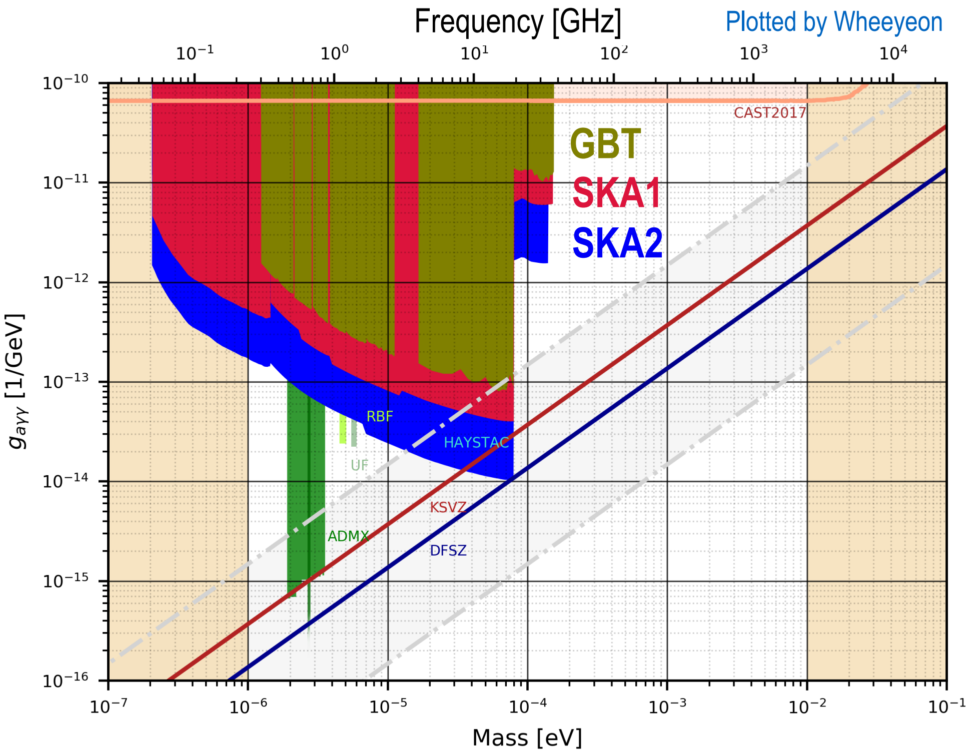
If QCD axion is CDM:
Target mass: $\mu eV - meV (0.1 GHz - 100 GHz)$

How about astrophysically sourced magnetic fields?

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

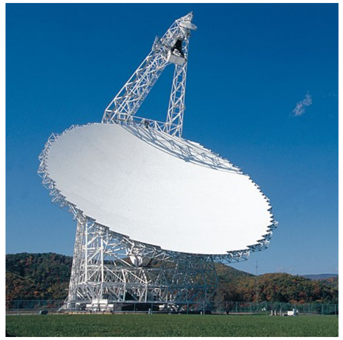


Radio Line signal $f \sim \frac{m_a}{2\pi} \sim 240 \left(\frac{m_a}{\mu eV}\right) MHz$

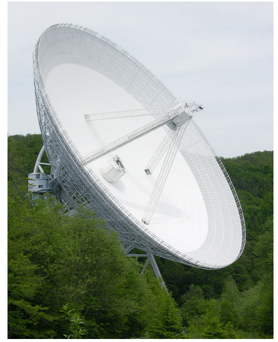


First results with actual data

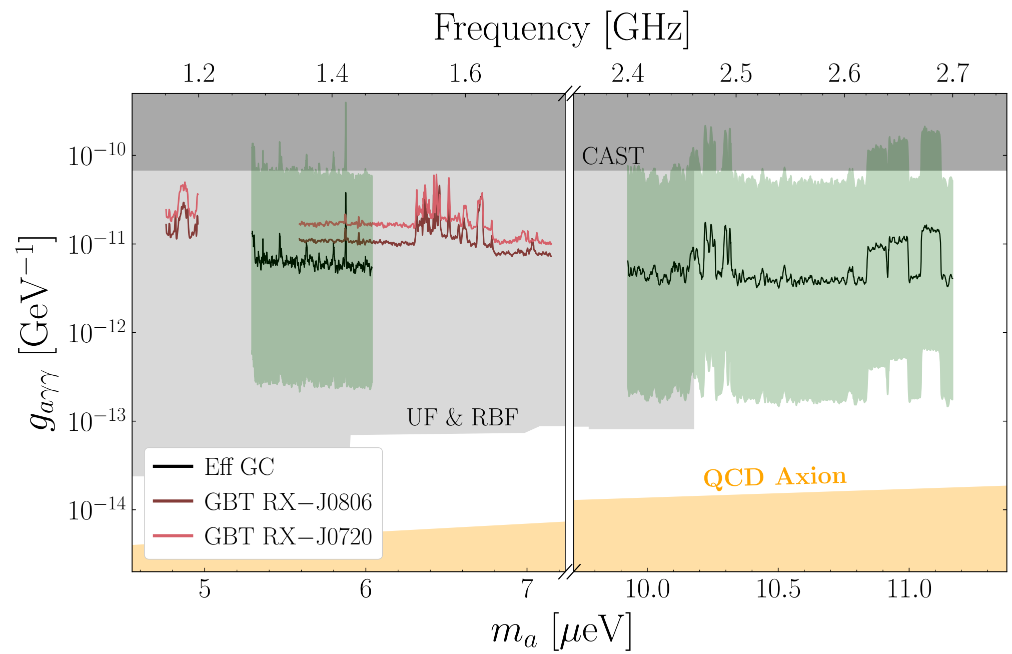
(Foster et al [2004.00011])



(Green Bank Telescope)



(Effelsberg Radio Telescope)



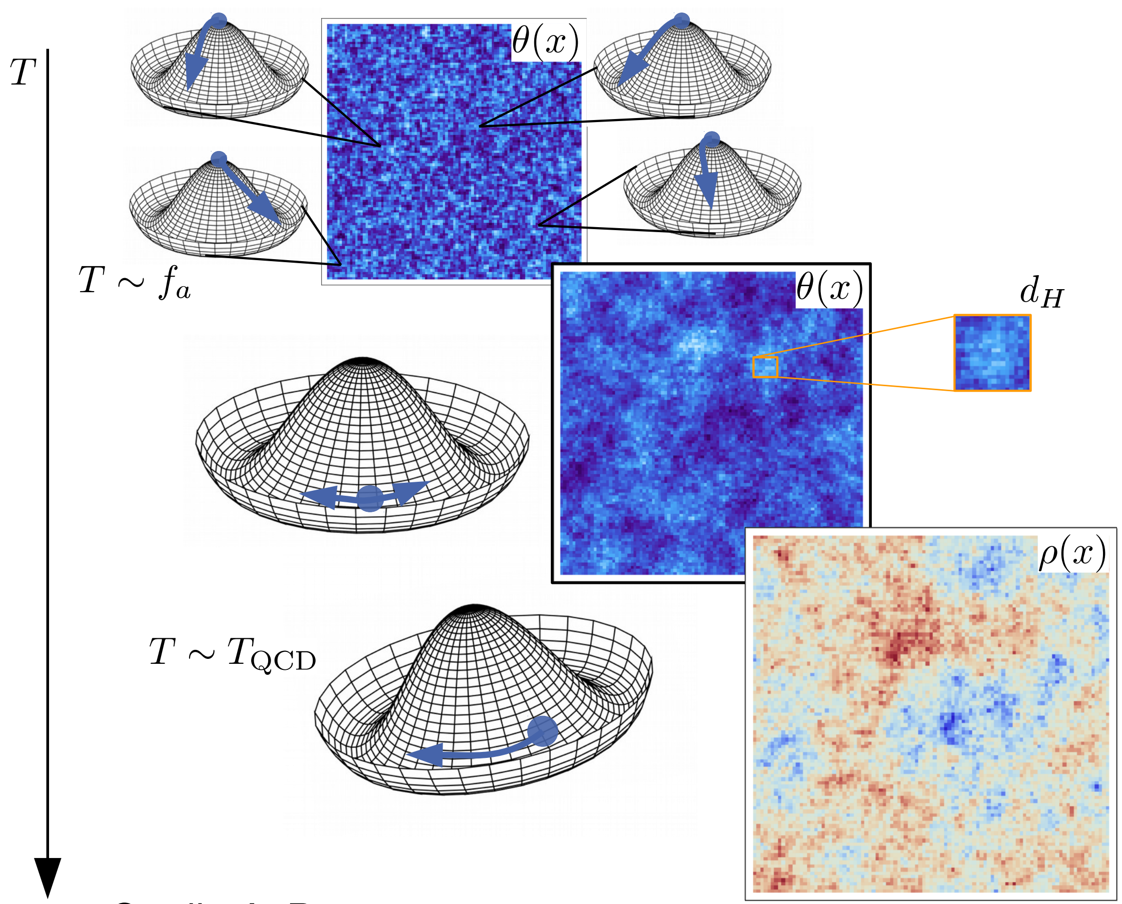
Radio telescope probes on Axion dark matter

(1)Radio signals from the neutron stars

(First results with the actual data)

(2) 21cm probes on small scale structure evolutions

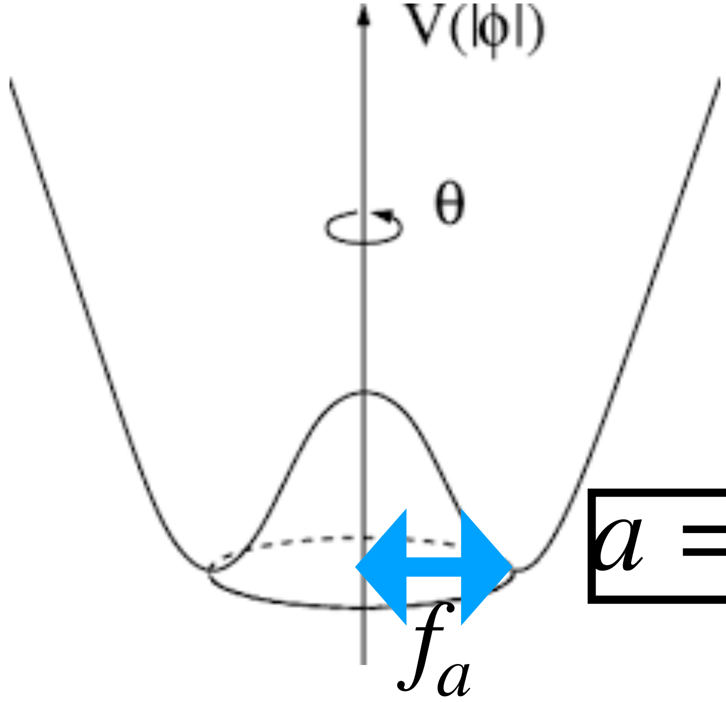
Axion-like particles in the **post-inflation** symmetry breaking scenarios



Credit: A. Pargner

$$\rho_a \sim m_a^2 a^2 \sim \theta^2$$

$$\delta_a \equiv (\rho_a - \bar{\rho}_a)/\bar{\rho}_a$$



$$a = f_a \theta$$

$$\sigma^2 \equiv \langle \delta_a^2 \rangle = (2\pi)^{-3} \int_0^{k_{osc}} d^3k P(k) = \frac{4}{5}$$

$$P_{iso} \propto \frac{1}{k_{osc}^3} \Theta(k_{osc} - k)$$

$$k_{osc} \leftrightarrow m_a (k_{osci} \sim H_{osc}^{-1} \sim m_a^{-1})$$

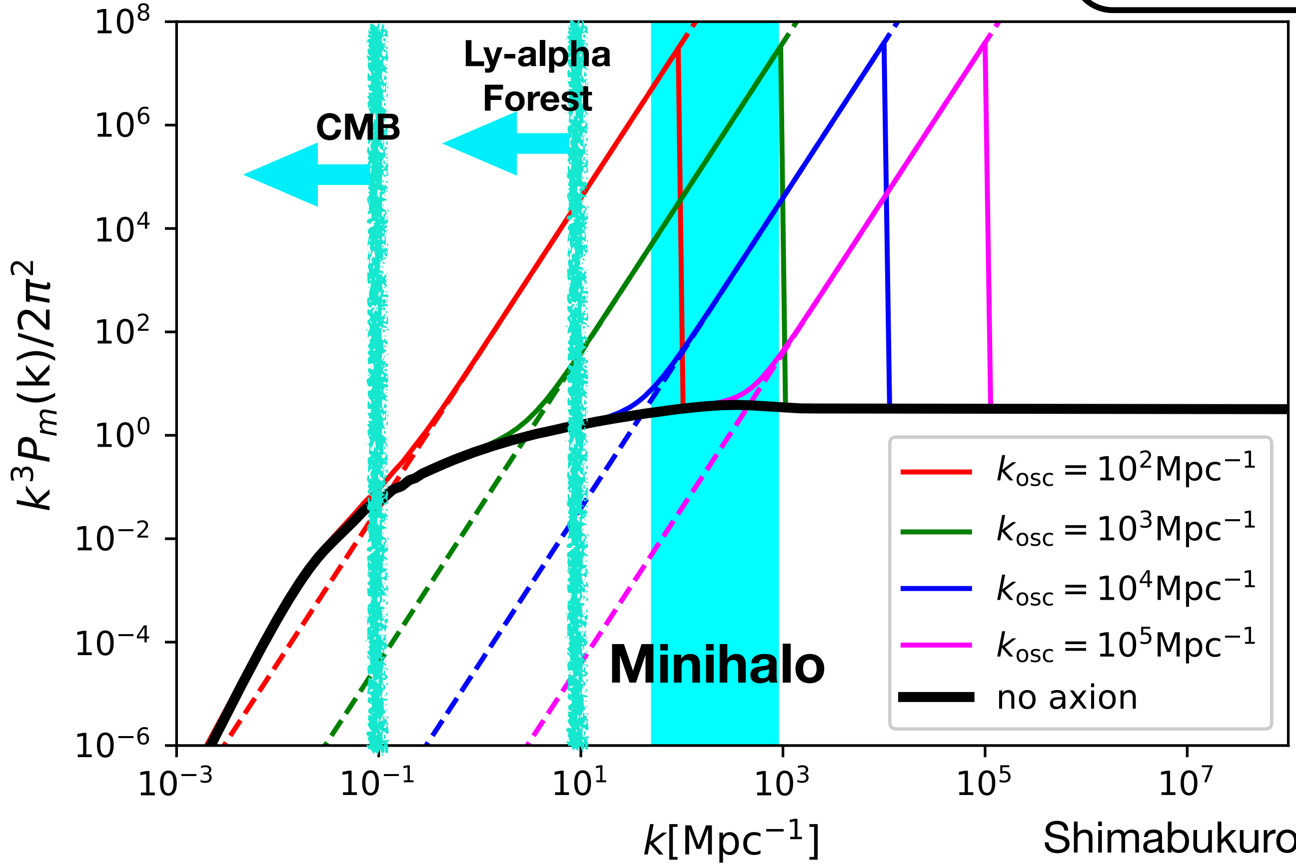
Enhancement of minihalo abundance

$$P_{total} = P_{adi} + P_{iso} \; (P_{iso} \propto 1/k_{osc}^3)$$

Baryon Jeans mass

Minihalo: $10^4 M_{sun} \lesssim M \lesssim 10^8 M_{sun}$

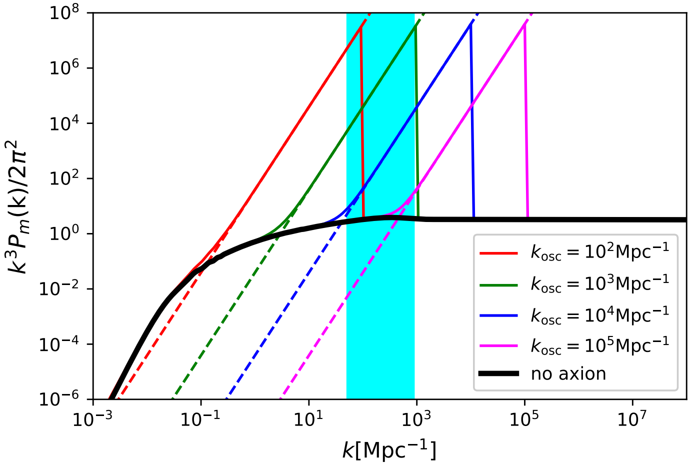
$T_{gas} < 10^4 K$



◆Minihalos: too small to host stars

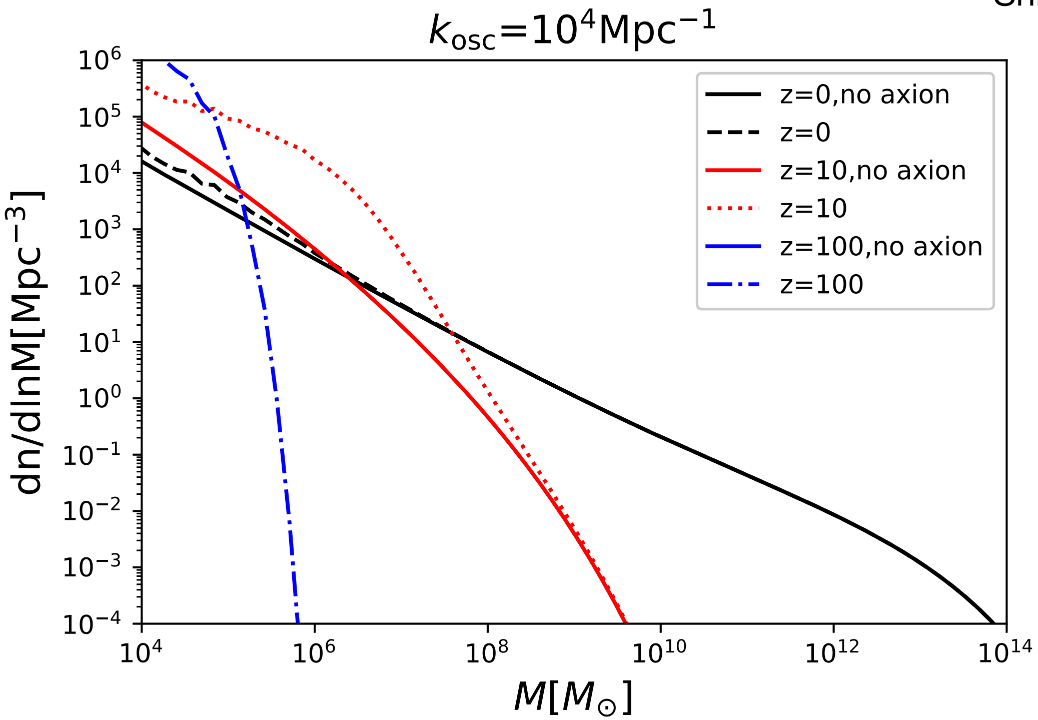
Starless Halos

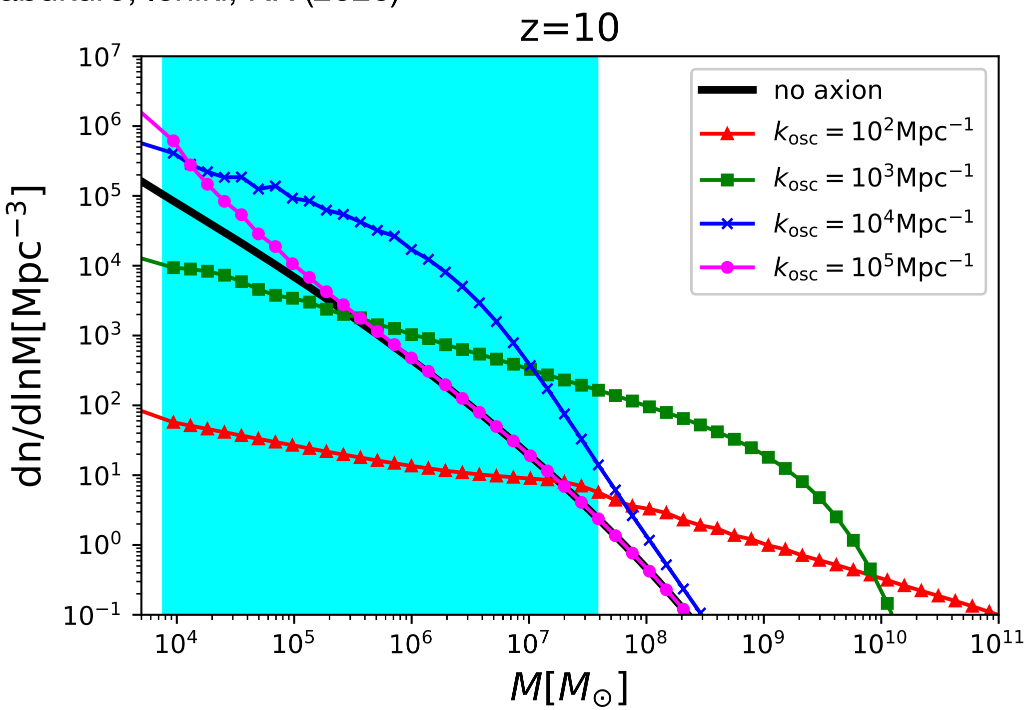
Shimabukuro, Ichiki, KK (2020)



$$(P_{iso} \propto 1/k_{osc}^3)$$

Shimabukuro, Ichiki, KK (2020)

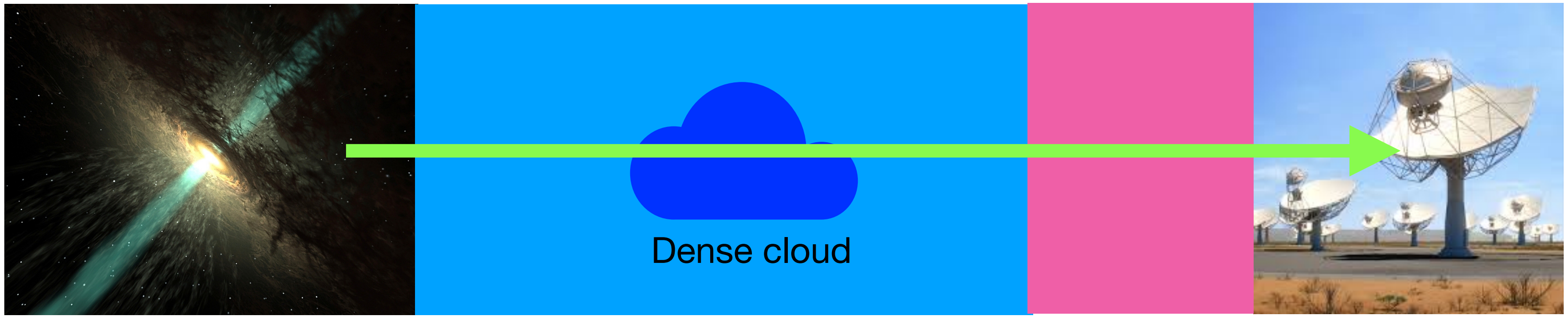




21cm forest

Diffuse sea of neutral hydrogen

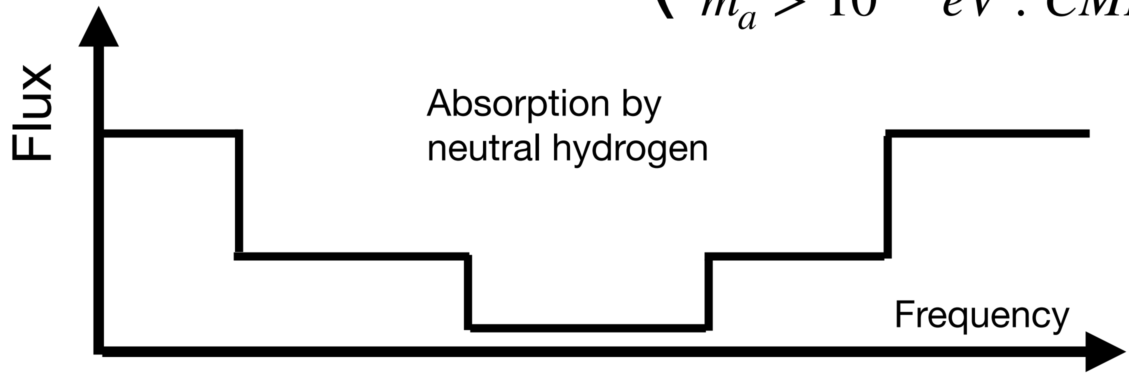
Hydrogen Ionized



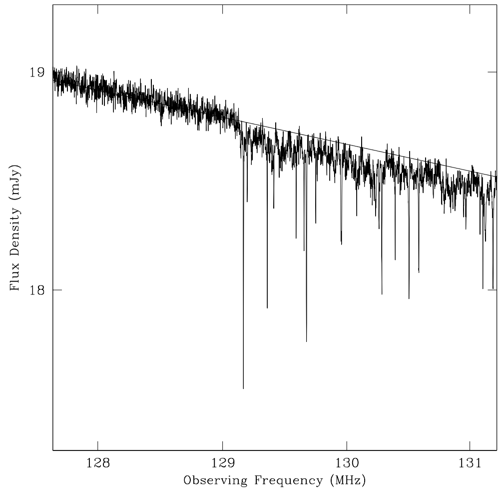
21cm signals from minihalo:
1) Radio background: Shimabukuro, Ichiki, KK (2020)
2) CMB background: KK, Sekiguchi, Tashiro (2020)

21cm: $m_a > 10^{-13} eV$

($m_a > 10^{-17} eV : Ly\alpha$ Irsic, Xiao, McQuinn (2019)
$m_a > 10^{-20} eV : CMB$ Feix et al (2020))



$$\frac{1420MHz(=21cm)}{1+z_{CLOUD}}$$



(Carilli+ 2002)

Conclusion/Possible discussions

1) Axion search from the magnetosphere around the neutron stars

So far, done only for Greenbank and Effelsberg radio telescope data (a total observation of 2 hours)

2) Axion-like dark matter bounds:

$$m_a \gtrsim 10^{-20} eV : CMB$$

$$m_a \gtrsim 10^{-17} eV : Ly\alpha$$

$$m_a \gtrsim 10^{-13} eV : 21cm$$

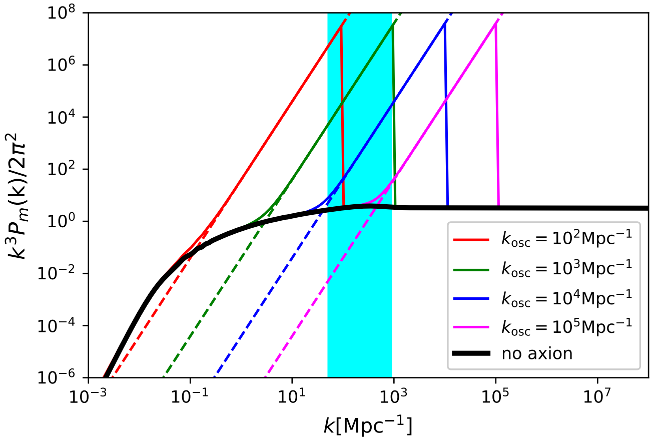
Axion-like particle in post-inflation symmetry breaking scenarios

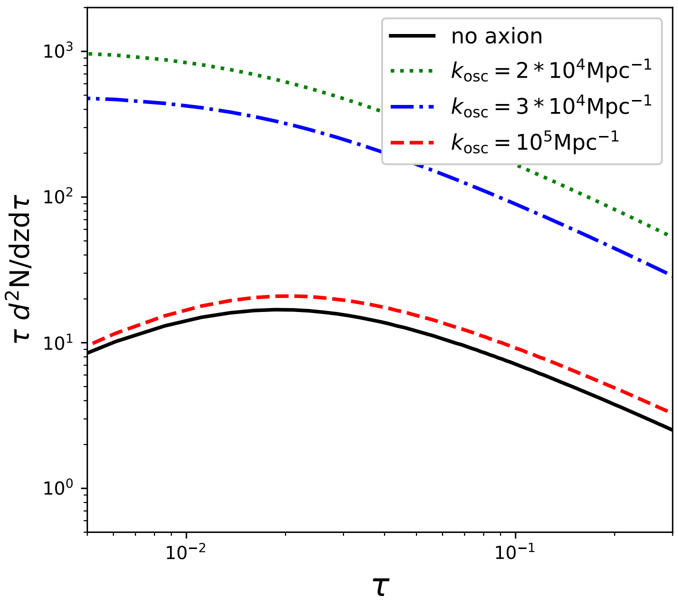
$$P_{total} = P_{adi} + P_{iso}$$
$$(P_{iso} \propto 1/k_{osc}^3)$$

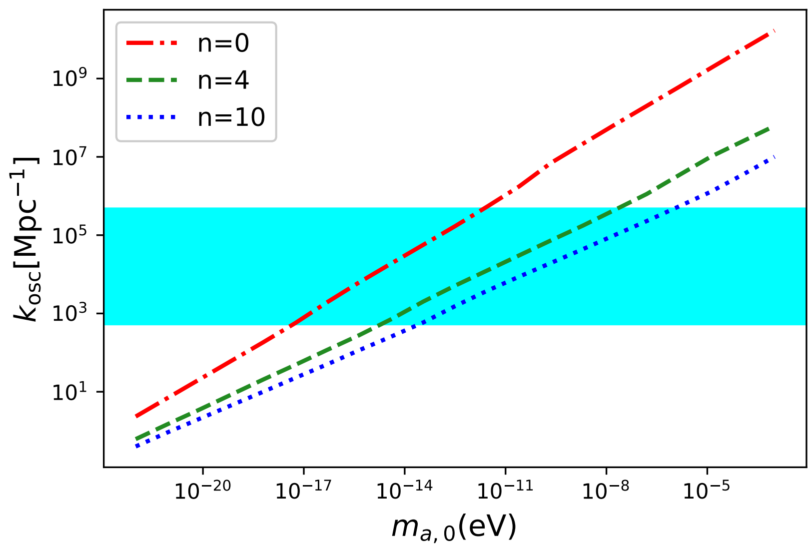
21cm: $m_a > 10^{-12} eV$

Ly-alpha: $m_a > 10^{-17} eV$

CMB: $m_a > 10^{-20} eV$







Shimabukuro, Ichiki, KK (2020)

$$m_a = m_{a0}(T/\mu)^{-n}$$