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Relic neutrino decay solution to the excess radio background

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Based on: JCAP 04 (2024) 046

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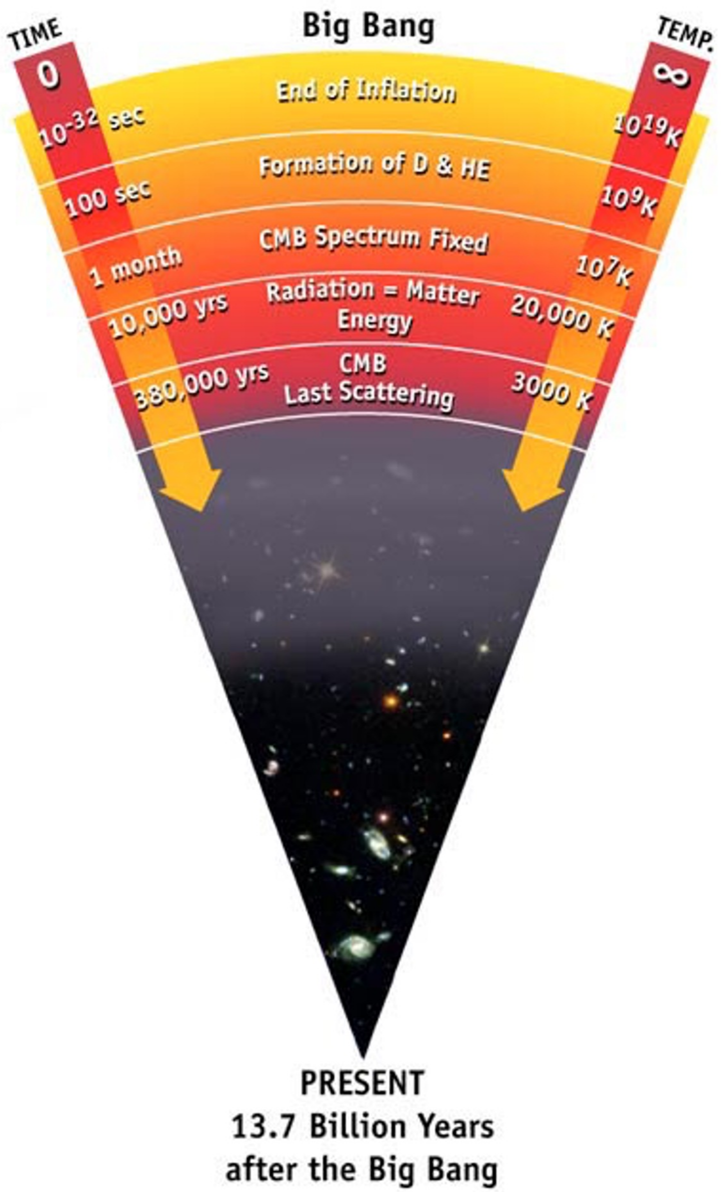
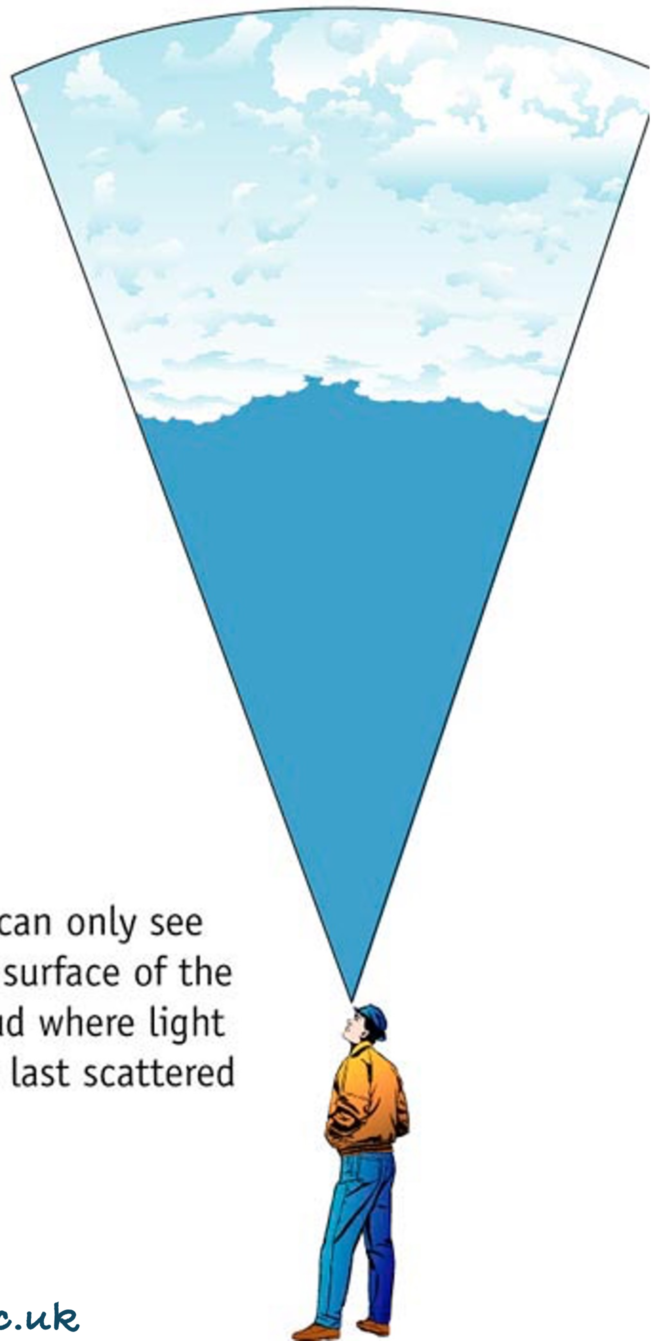
Our Universe

Cosmological tools:

Gravitational Waves
Cosmic Microwave Background
Cosmic Neutrinos



The cosmic microwave background Radiation's "surface of last scatter" is analogous to the light coming through the clouds to our eye on a cloudy day.



We can only see the surface of the cloud where light was last scattered

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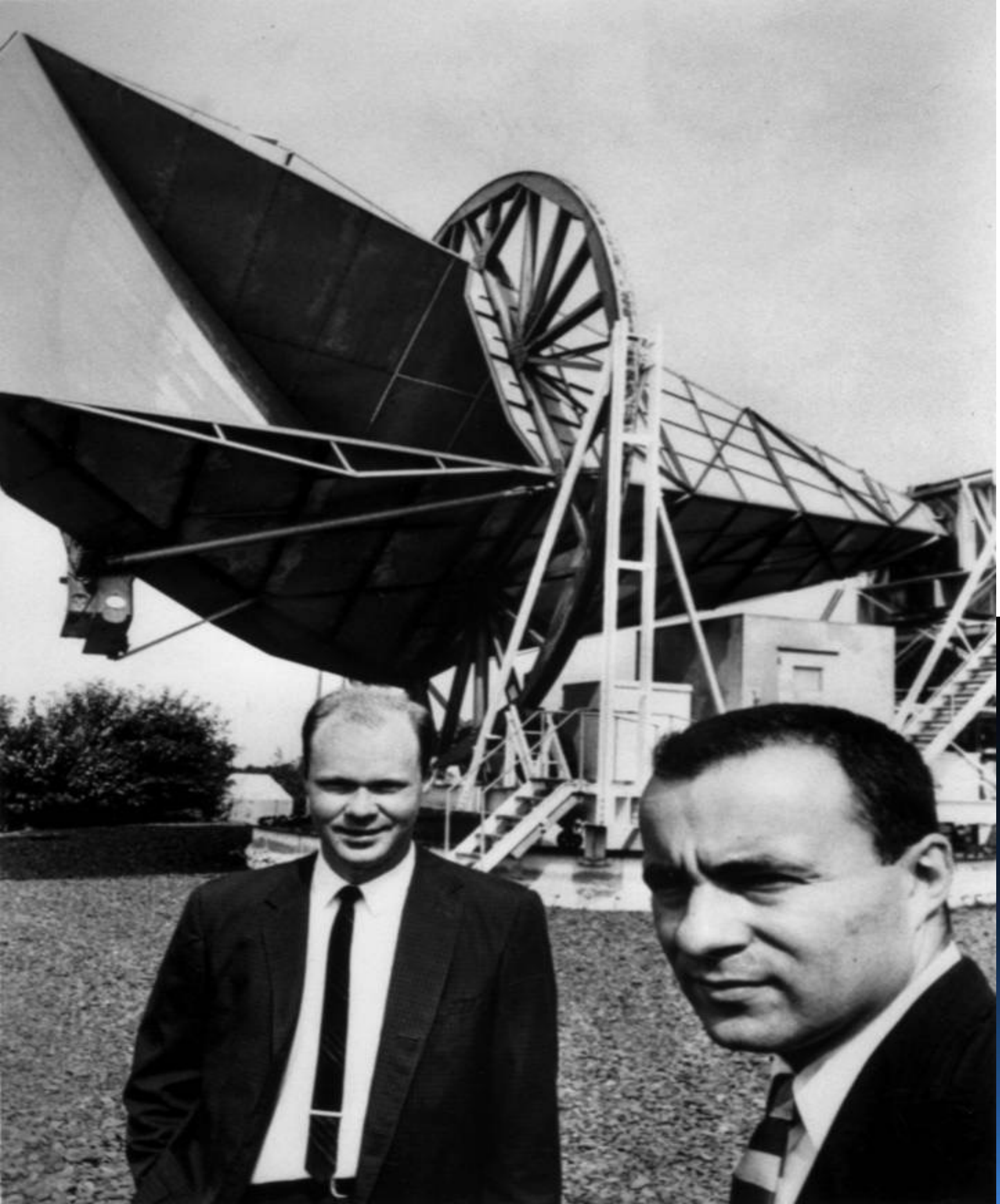
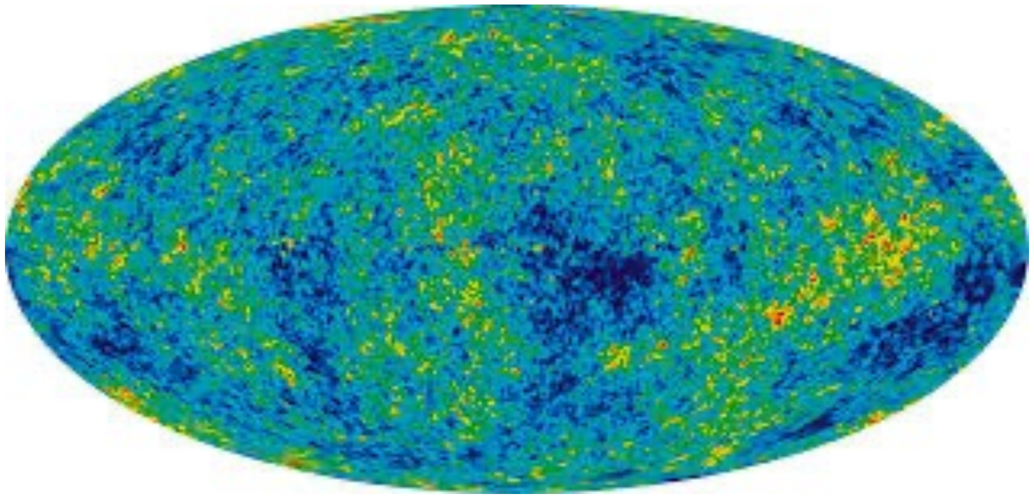
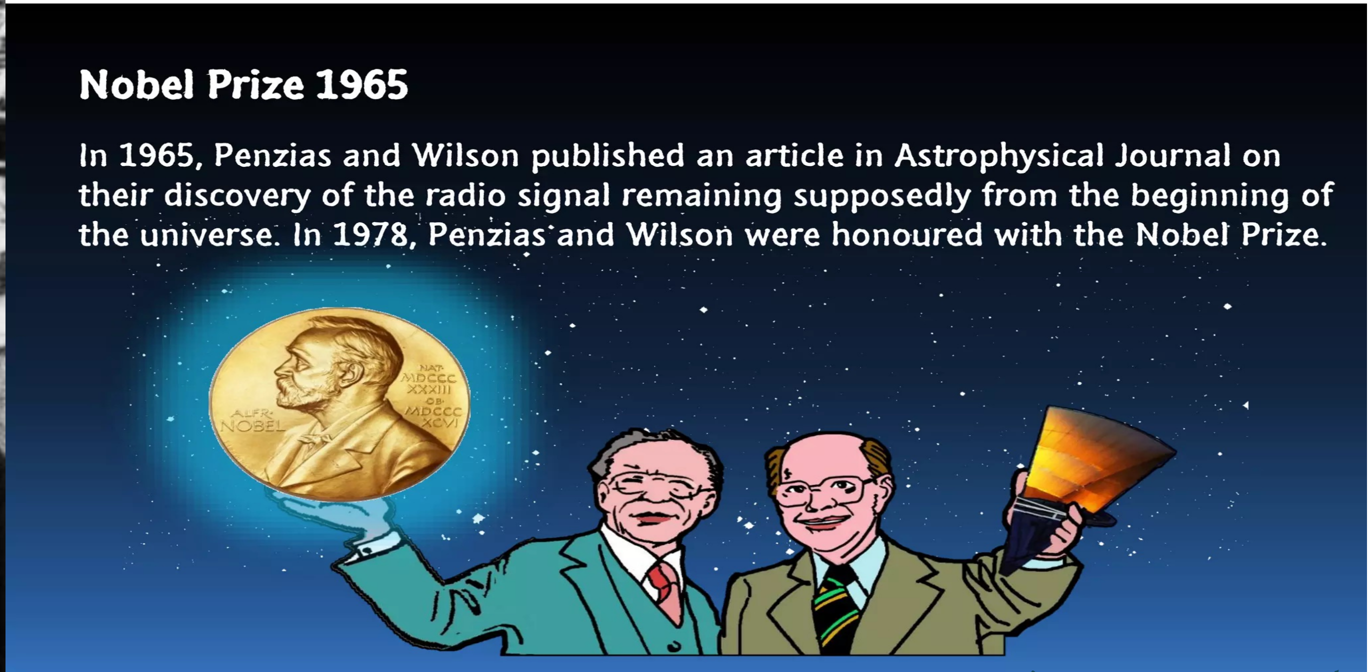
Cosmic Microwave Background
(Relic Radiation)







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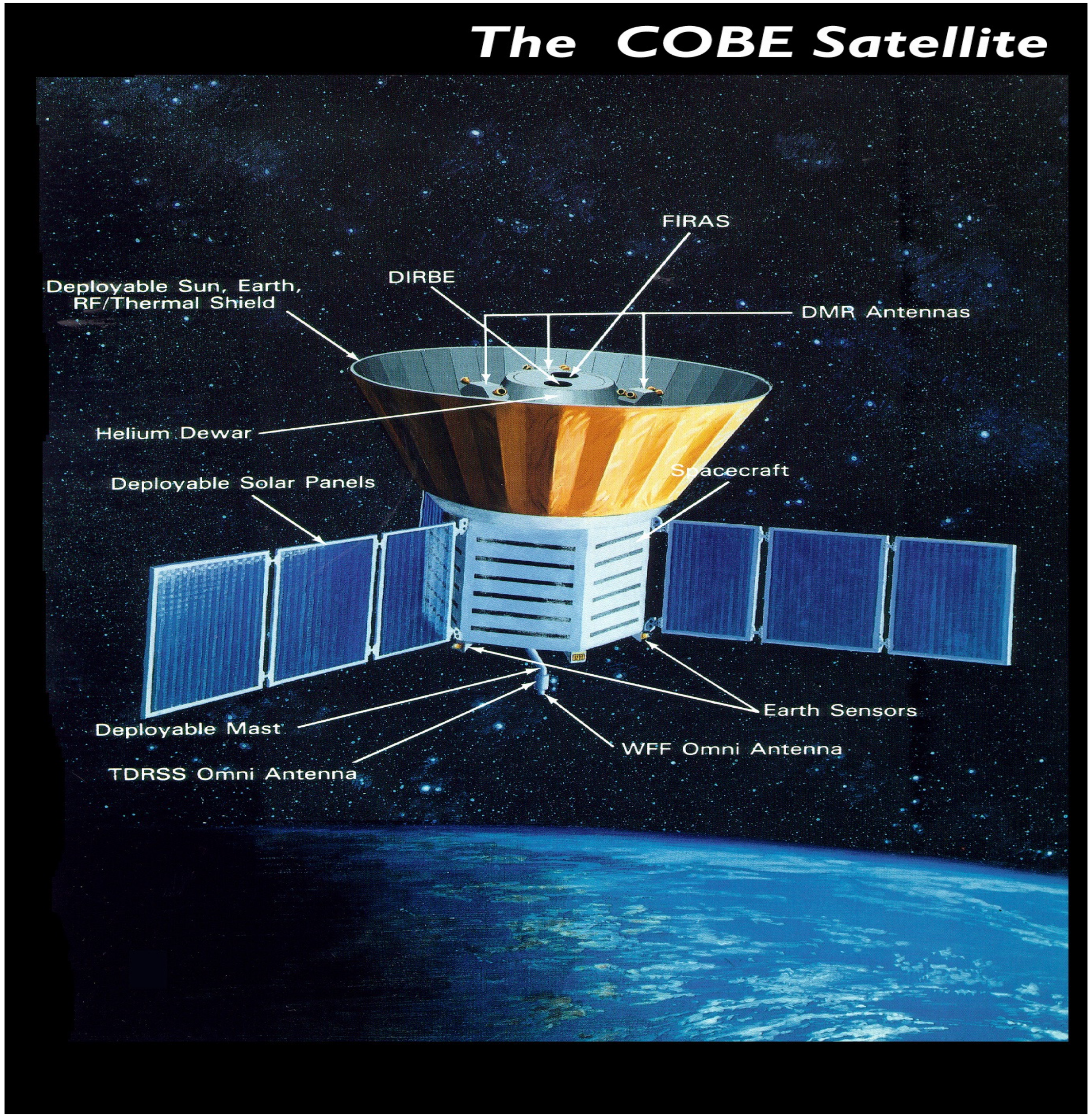
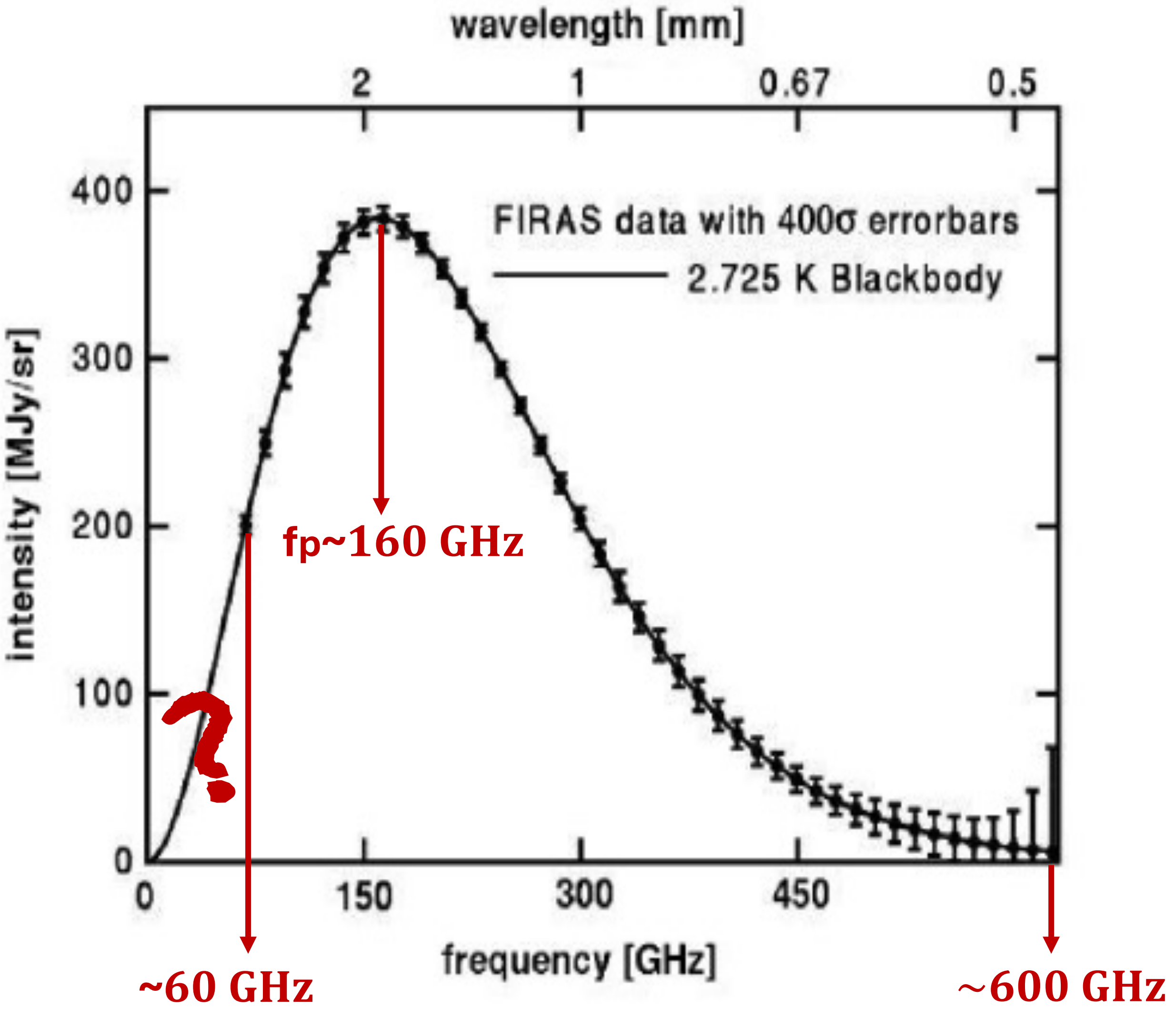
CMB Spectrum



$$T_0 = (2.725 \pm 0.001)\mathrm{K}$$



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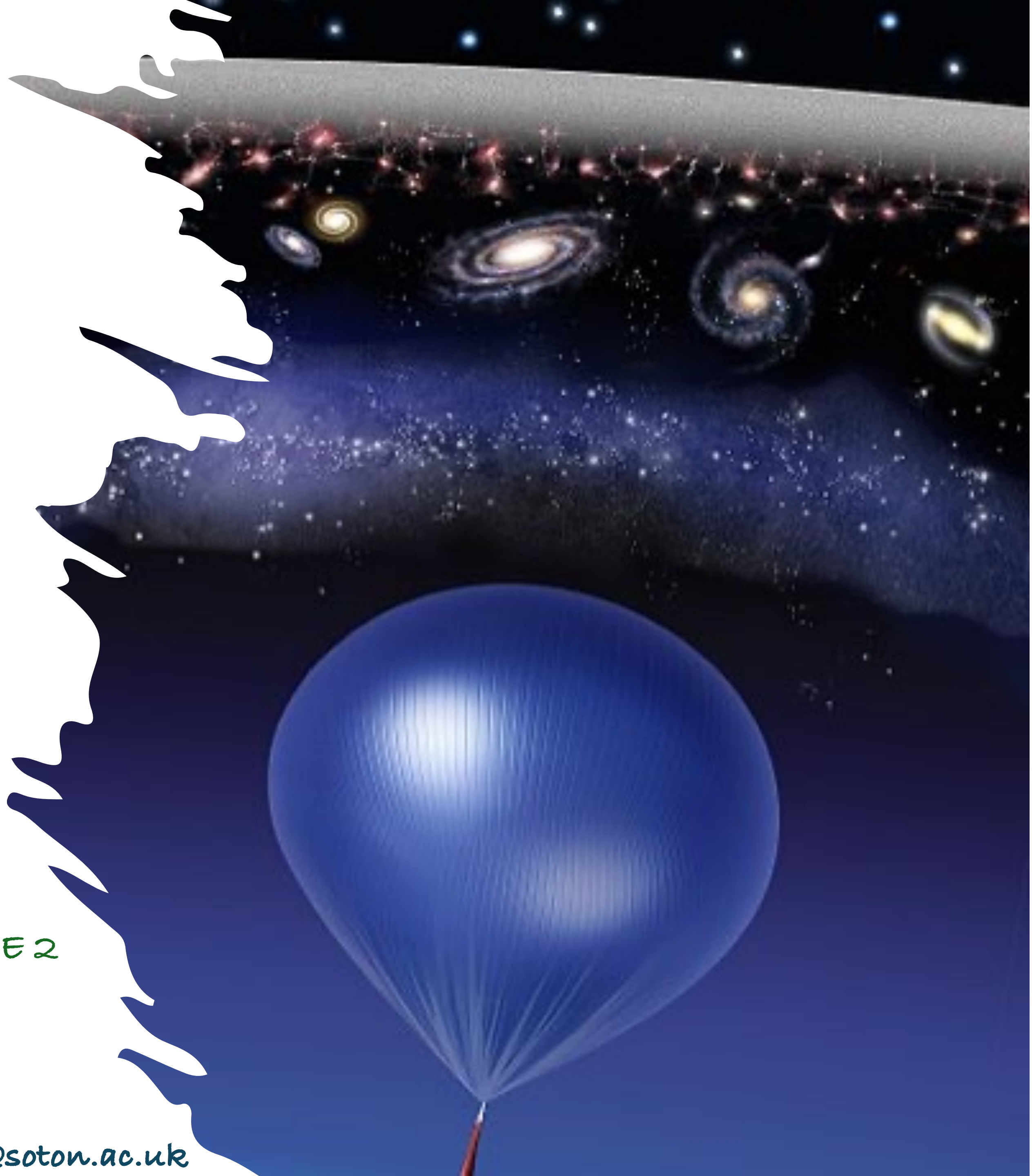
Absolute
Radiometer for
Cosmology,
Astrophysics and
Diffuse
Emission



With only two hours of balloon flight observations, ARCADE 2 approaches the absolute accuracy of long-duration space missions!

Astrophys.J. 734 (2011) 5

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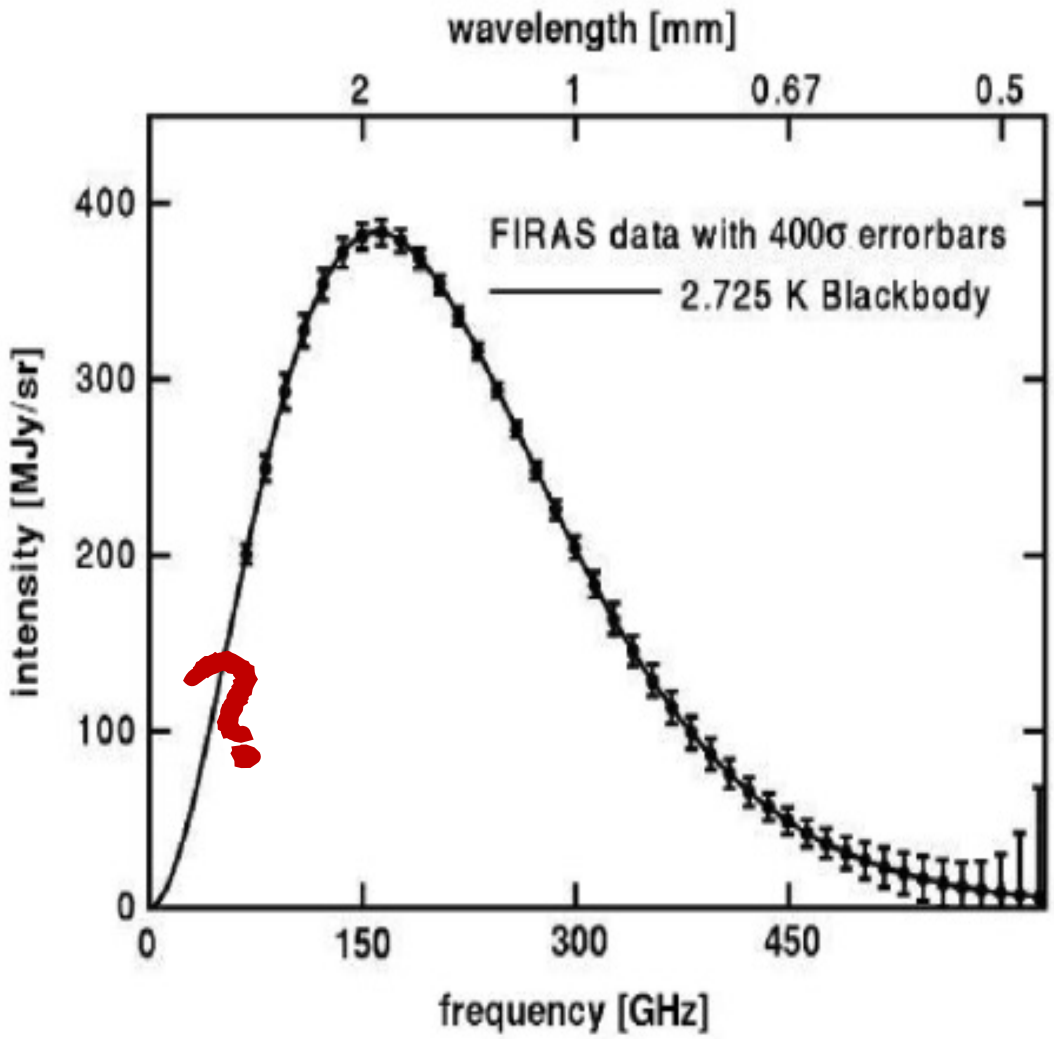
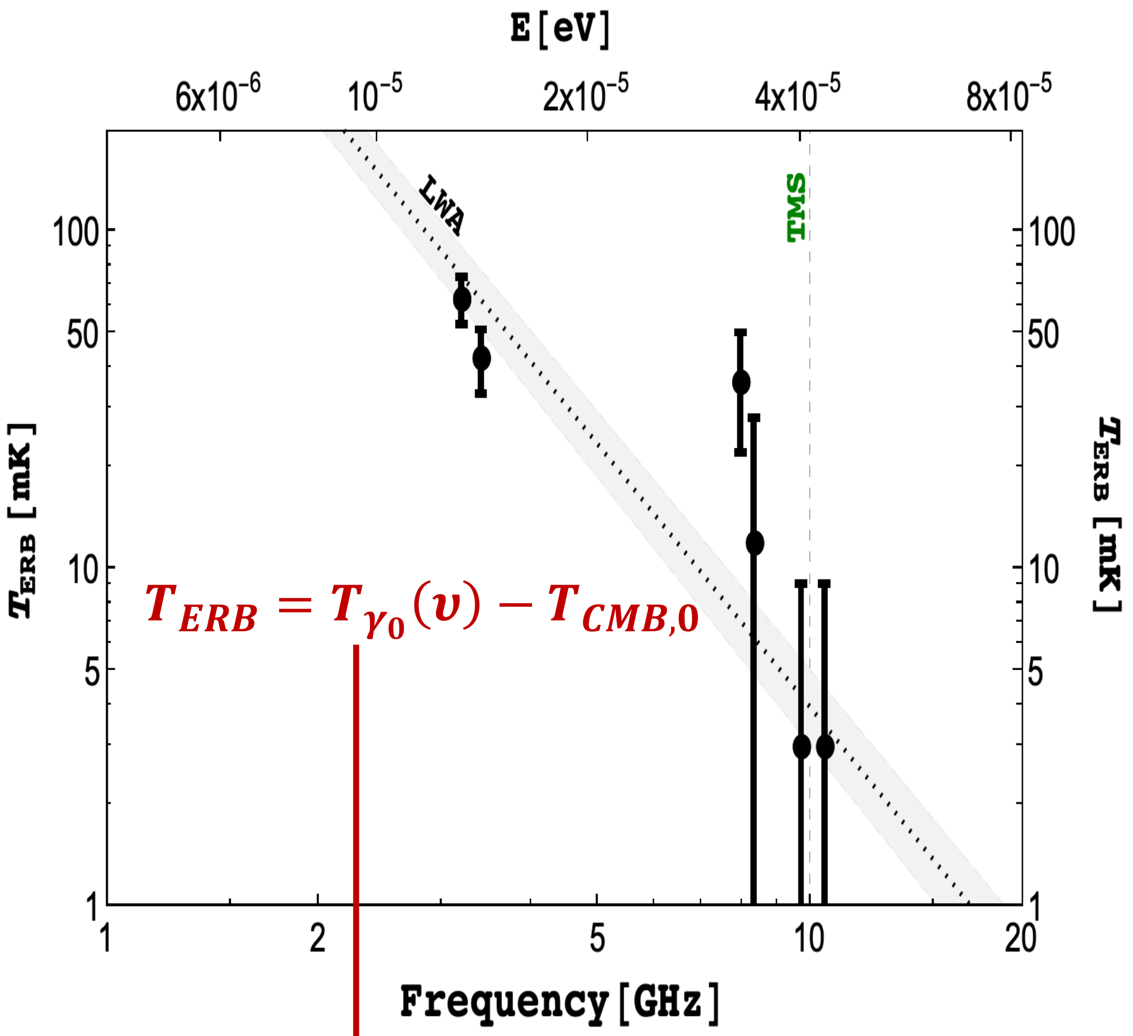
ARCADE 2: Results (Astrophys.J. 734 (2011) 5)





$$T_{ERB} = T_{\gamma_0}(\nu) - T_{CMB,0}$$

Radiometric Temp.
(Observed by ARCADE)

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Possible Explanations

1. Astrophysical sources: Contributes 3 to 10 times smaller than the measured temperature.

2. Primordial Black Holes: The ERB produced by Hawking radiation is extremely small (even in extreme cases: PBH as DM).

3. Accreting PBHs: Radio emission can explain ERB. (Mon.Not.Roy.Astron.Soc. 510 (2022) 4)

4. The issue: the expected ultraviolet photons from accreting PBHs will completely ionize the universe at $z>6$, this is in contrast with the CMB anisotropy observation (Mon.Not.Roy.Astron.Soc. 517 (2022) 2)

5. Dark Matter decay/Annihilations: faces difficulty in explaining the smoothness of ERB.

6. Superconducting Cosmic strings: can explain the ERB (Phys.Rev.D 109 (2024) 12)

7. Decay of Relic Neutrinos: provides a very good fit to ARCADE 2 data.

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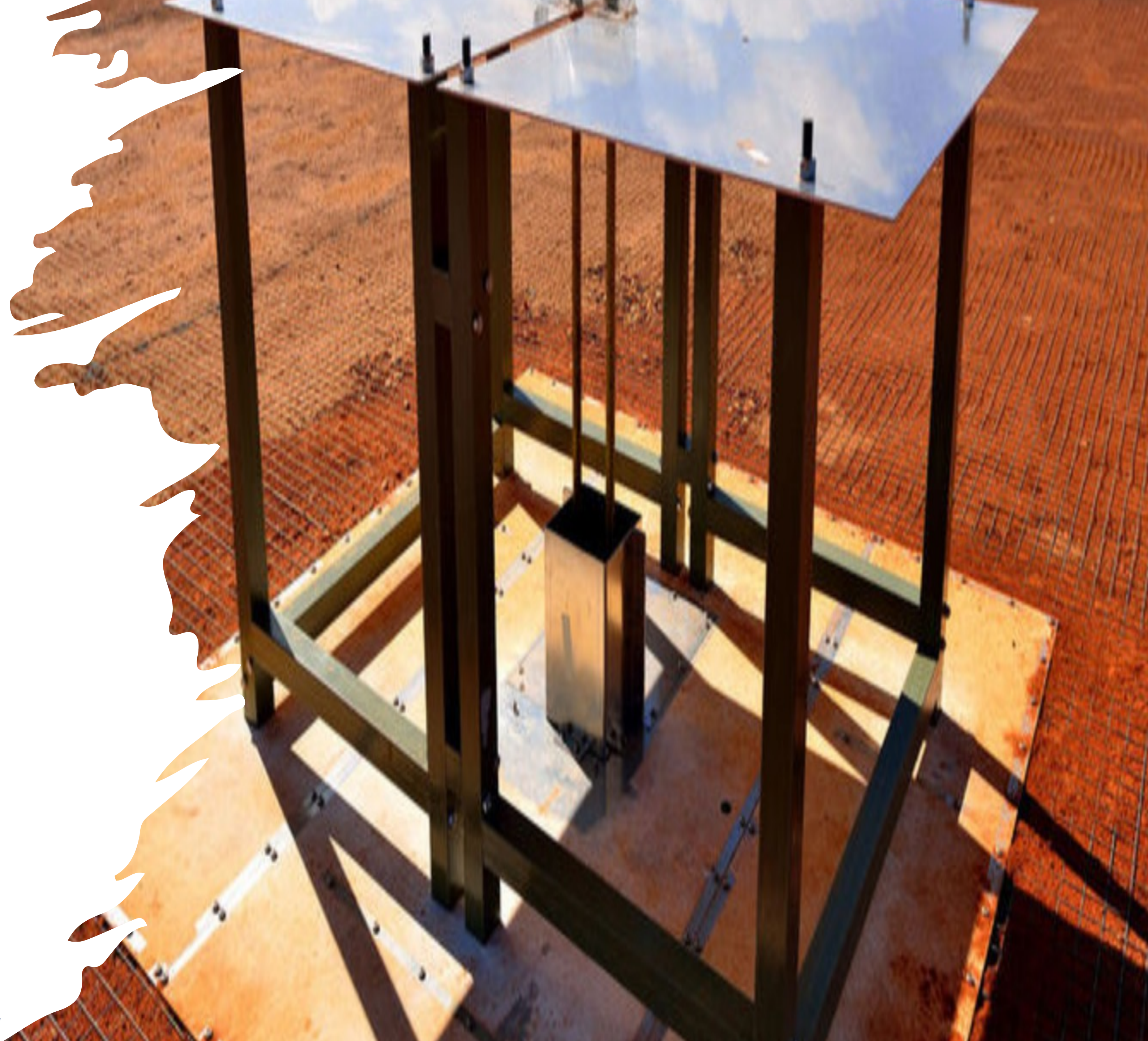
Experiment to
Detect the
Global
EoR
Signature



Nature 555 (2018) 7694, 67-70

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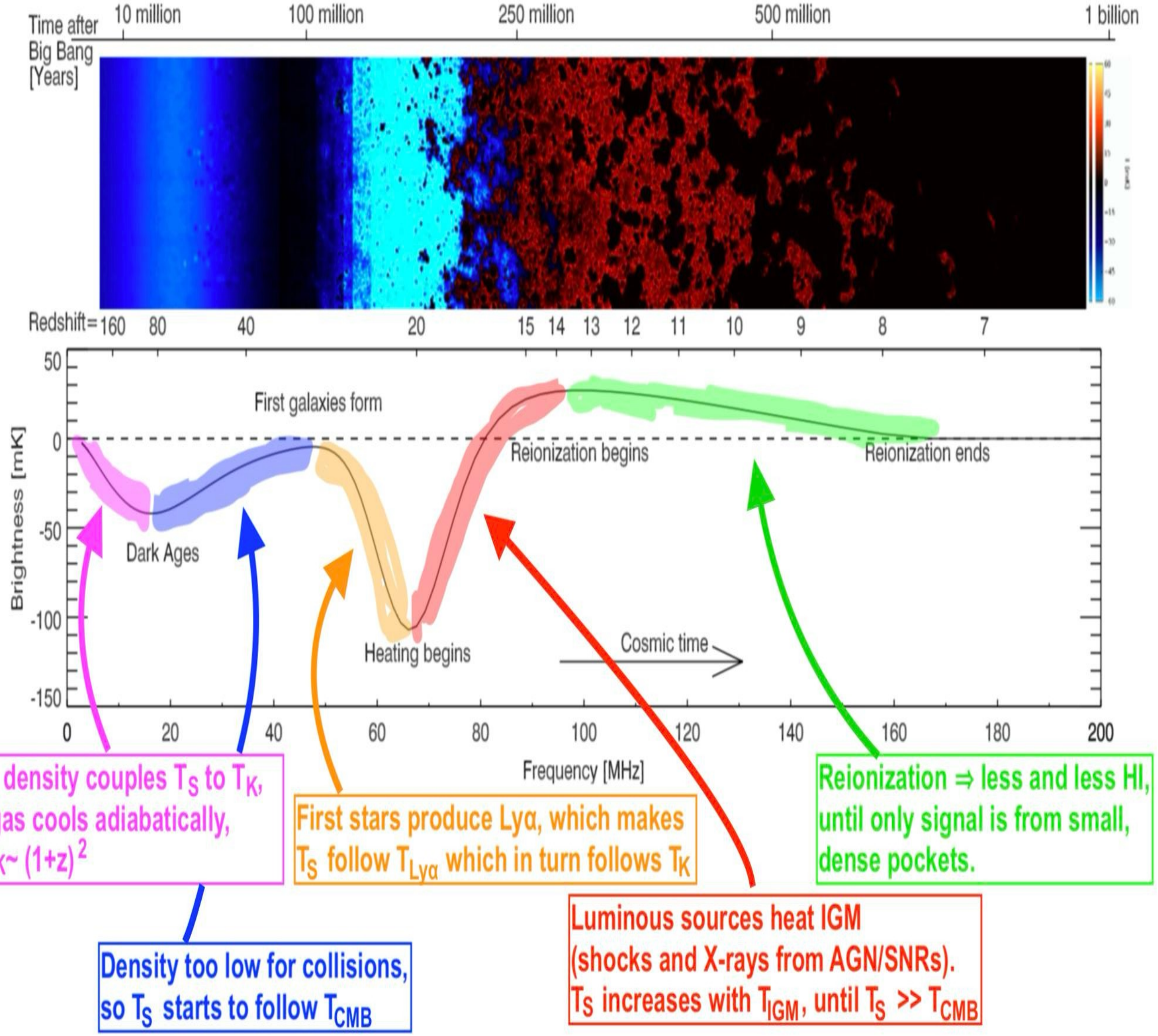
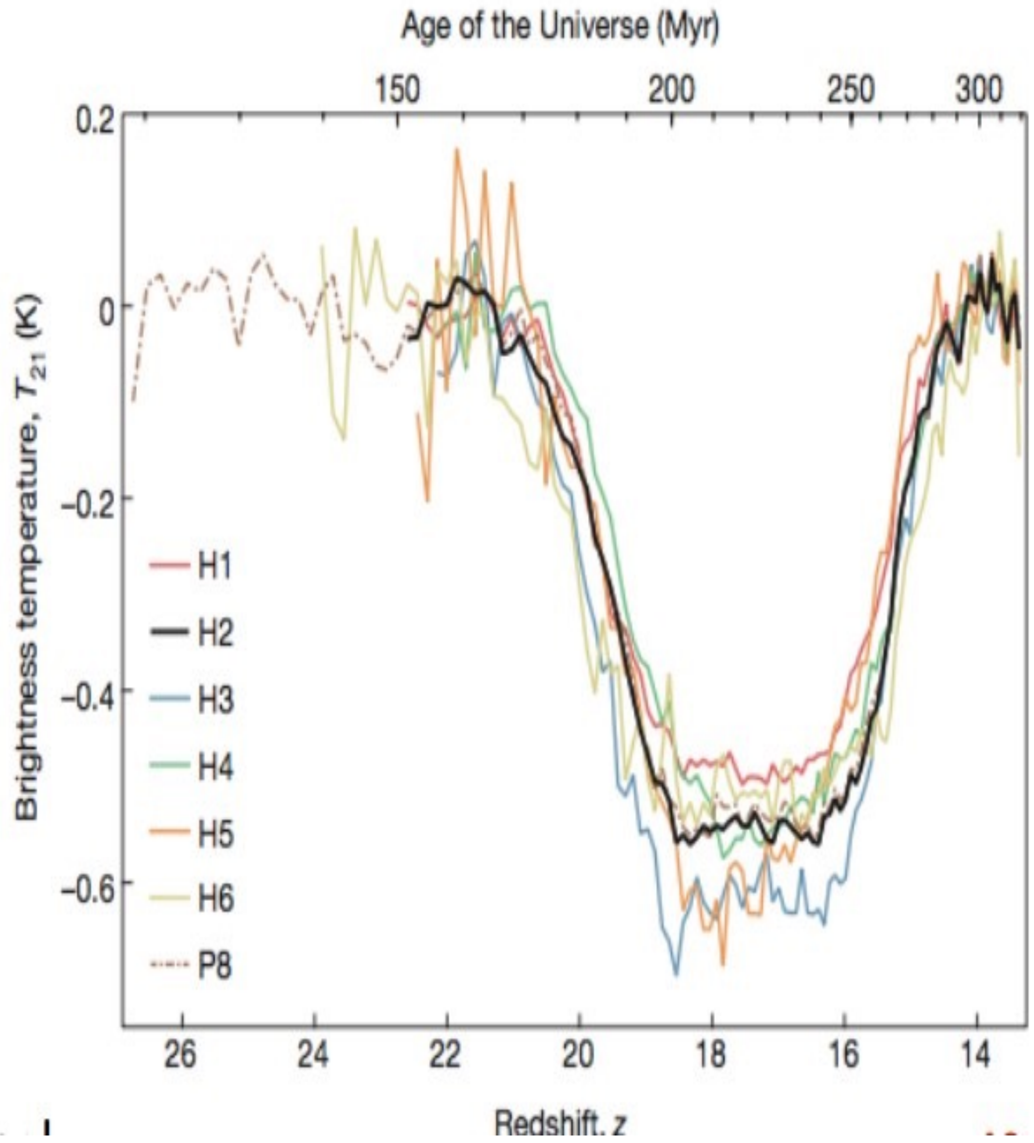
EDGES Anomaly



$$T_{21}(z) \simeq 23\,\mathrm{mK}\,(1+\delta_B)\,x_{H_I}(z)\left(\frac{\Omega_B h^2}{0.02}\right)\left[\left(\frac{0.15}{\Omega_m h^2}\right)\left(\frac{1+z}{10}\right)\right]^{1/2}\left[1-\frac{T_\gamma(z)}{T_S(z)}\right]$$



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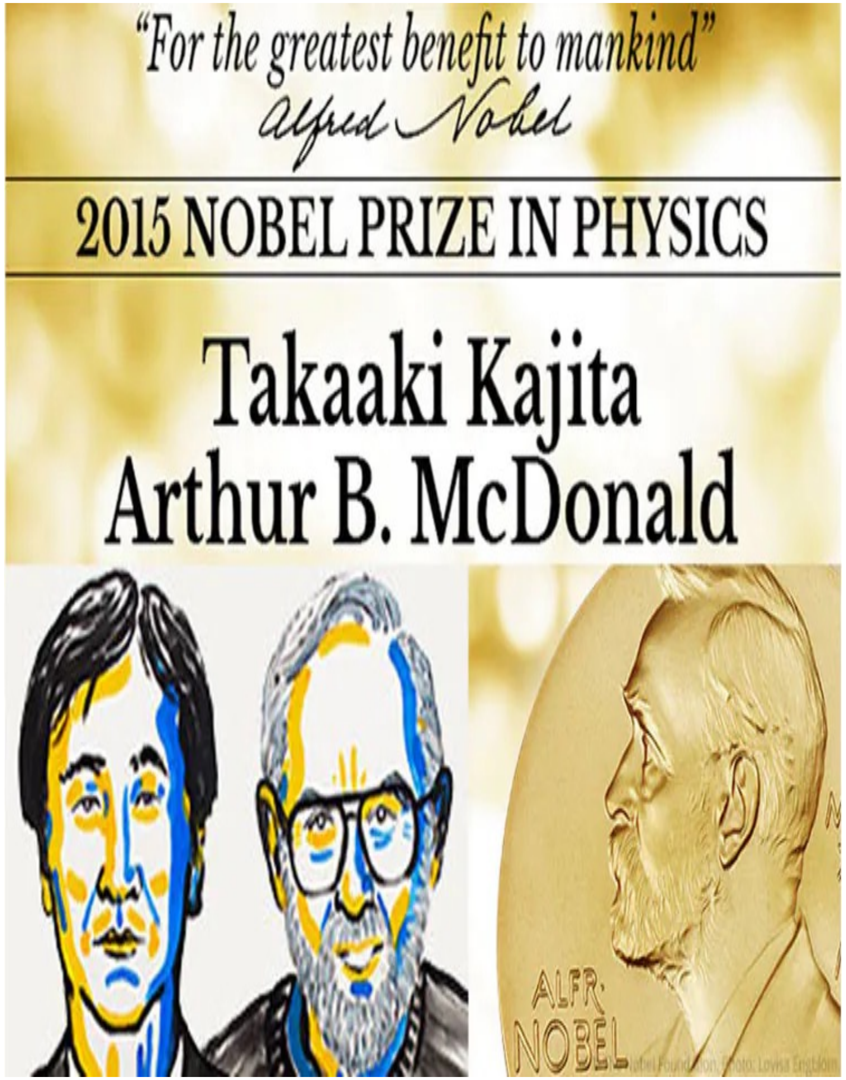
Neutrino, an elusive particle!

4th December 1930

Dear Radioactive Ladies and Gentlemen,

As the bearer of these lines, to whom I graciously ask you to listen, will explain to you in more detail, how because of the "wrong" statistics of the N and Li^6 nuclei and the continuous beta spectrum, I have hit upon a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. Namely, the possibility that there could exist in the nuclei electrically neutral particles, that I wish to call neutrons, which have spin 1/2 and obey the exclusion principle and which further differ from light quanta in that they do not travel with the velocity of light. The mass of the neutrons should be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton masses. The continuous beta spectrum would then become understandable by the assumption that in beta decay a neutron is emitted in addition to the electron such that the sum of the energies of the neutron and the electron is constant...



Can relic neutrinos solve these anomalies?

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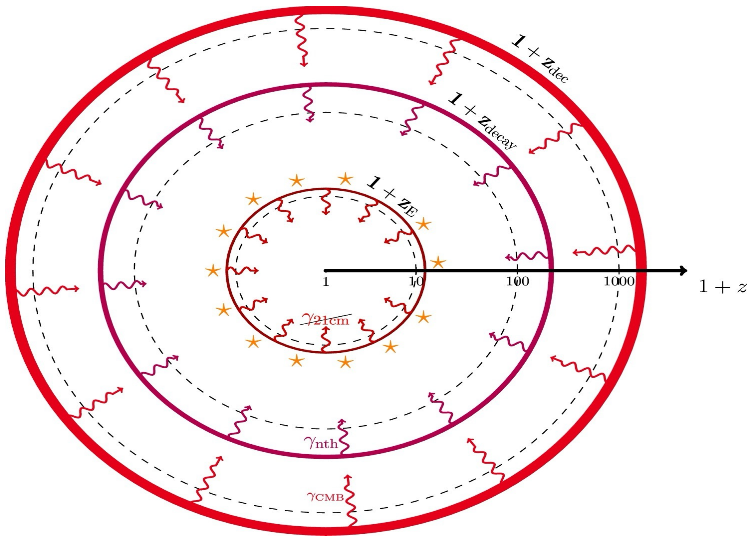
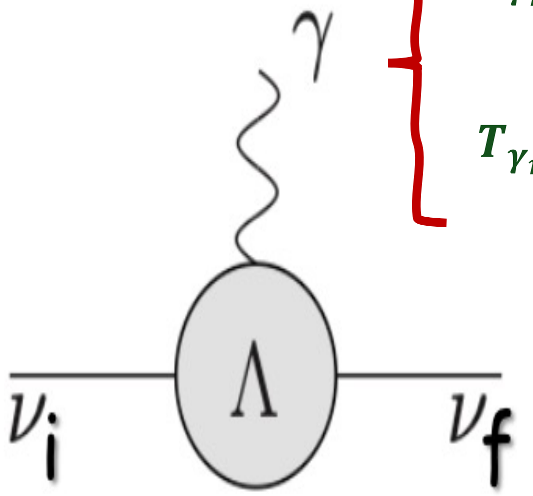
Relic neutrino decays

Phys.Lett.B 790 (2019) 64-70

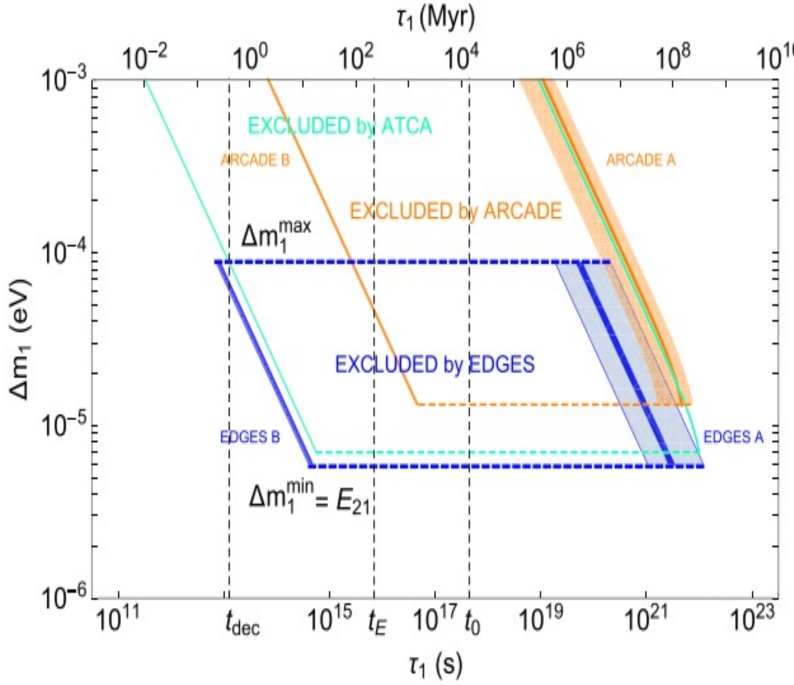


Relic neutrino decay can produce non-thermal photons



$$I_{\gamma_{nth}}(E,z) = \frac{n^{\infty}_{\nu 1}(z)}{4\pi}\frac{e^{-t(a_D)/\tau_1}}{H(a_D)\tau_1}$$

$$T_{\gamma_{nth}} \cong \frac{4\pi^3}{E^2} I_{\gamma_{nth}}(E,z)$$



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Relic neutrino decay: solution to ARCADE 2 anomaly

ARCADE measurements: z=0

$$I_{\gamma nth}(E,0) = \frac{n^{\infty}_{\nu 1}(0)}{4\pi}\,\frac{e^{-t(a_D)/\tau_1}}{H(a_D)\tau_1}$$

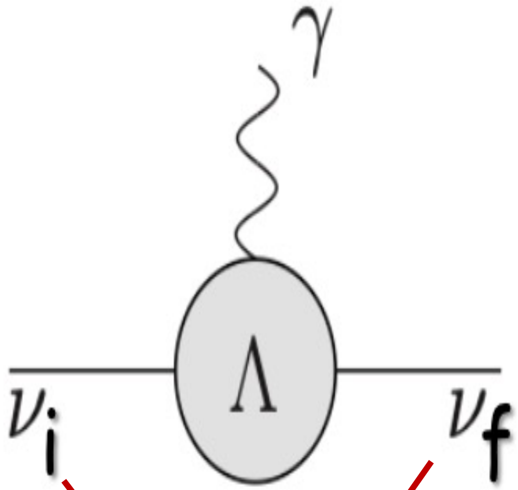
$$T_{\gamma nth}(E,0) \cong \frac{4\pi^3}{E^2}\, I_{\gamma nth}(E,0)$$

We work in the regime: $E \ll T_\gamma$ and under the assumption $\tau_1 >> t_0$.

$$T_{\gamma_{\rm nth}}(E,0) \simeq \frac{6\,\zeta(3)}{11\,\sqrt{\Omega_{M0}}}\,\frac{T_0^3}{E^{1/2}\,\Delta m_1^{3/2}}\,\frac{t_0}{\tau_1}\left(1+\frac{a_D^3}{a_{eq}^3}\right)^{-\frac{1}{2}}$$

We have to fit 6 values of effective temperature measured by ARCADE 2

i	ν_i (GHz)	E_i (10^{-5} eV)	$T^i_{\gamma 0}$ (K)	$\overline{T}^i_{\rm ERB}$ (mK)	$\delta T^i_{\rm ERB}$ (mK)
1	3.20	1.36	2.792	63	10
2	3.41	1.41	2.771	42	9
3	7.97	3.30	2.765	36	14
4	8.33	3.44	2.741	12	16
5	9.72	4.02	2.732	3	6
6	10.49	4.34	2.732	3	6



$\Delta m_1 = m_1 - m_S \ll m_1$

Quasi-degenerate

$$E \leq \Delta m_1$$

Existence of an endpoint!
(Model prediction)

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Fitting the ARCADE 2 ERB

χ^2

Input

i	ν_i (GHz)	E_i (10^{-5} eV)	$T^i_{\gamma 0}$ (K)	$\overline{T}^i_{\rm ERB}$ (mK)	$\delta T^i_{\rm ERB}$ (mK)
1	3.20	1.36	2.792	63	10
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3	7.97	3.30	2.765	36	14
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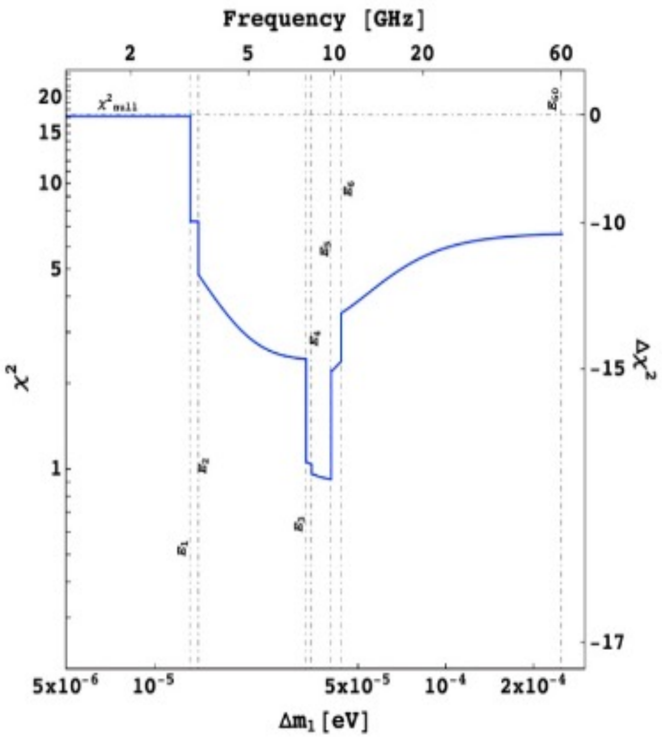
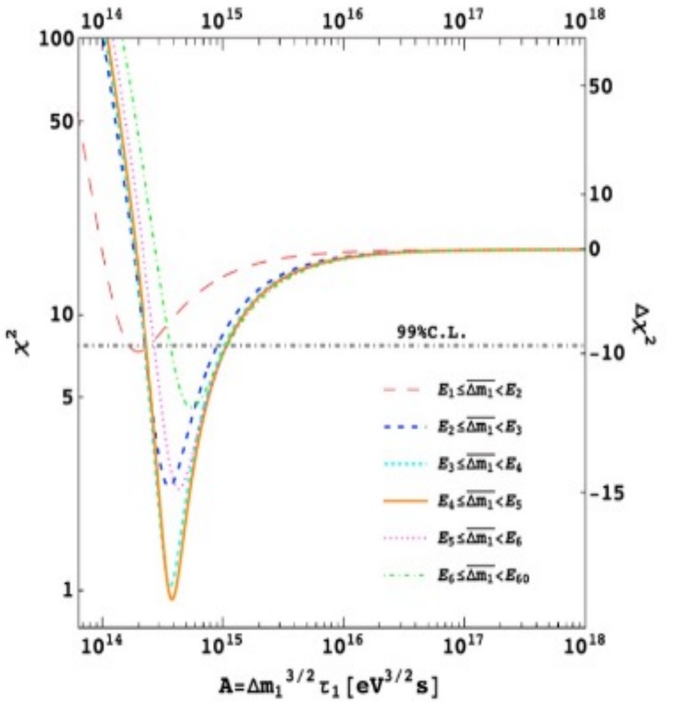
6	10.49	4.34	2.732	3	6





Result

Interval	$\overline{A}$ (eV$^{3/2}$ s)	$\overline{\Delta m_1}$ (eV)	$\overline{\tau}_1$ (s)	$\chi^2_{\rm min}$	$\Delta\chi^2_{\rm min}$
$E_1 \le \Delta m_1 < E_2$	1.9×10^{14}	1.4×10^{-5}	3.6×10^{21}	7.36	-9.87
$E_2 \le \Delta m_1 < E_3$	2.3×10^{14}	2.7×10^{-5}	1.6×10^{21}	2.28	-14.95
$E_3 \le \Delta m_1 < E_4$	3.6×10^{14}	3.4×10^{-5}	1.8×10^{21}	1.06	-16.17
$E_4 \le \Delta m_1 < E_5$	3.8×10^{14}	4.0×10^{-5}	1.46×10^{21}	0.96	-16.27
$E_5 \le \Delta m_1 < E_6$	4.2×10^{14}	4.3×10^{-5}	1.49×10^{21}	2.19	-15.04
$E_6 \le \Delta m_1 < E_{60}$	4.7×10^{14}	2.0×10^{-4}	1.66×10^{20}	3.23	-14.00

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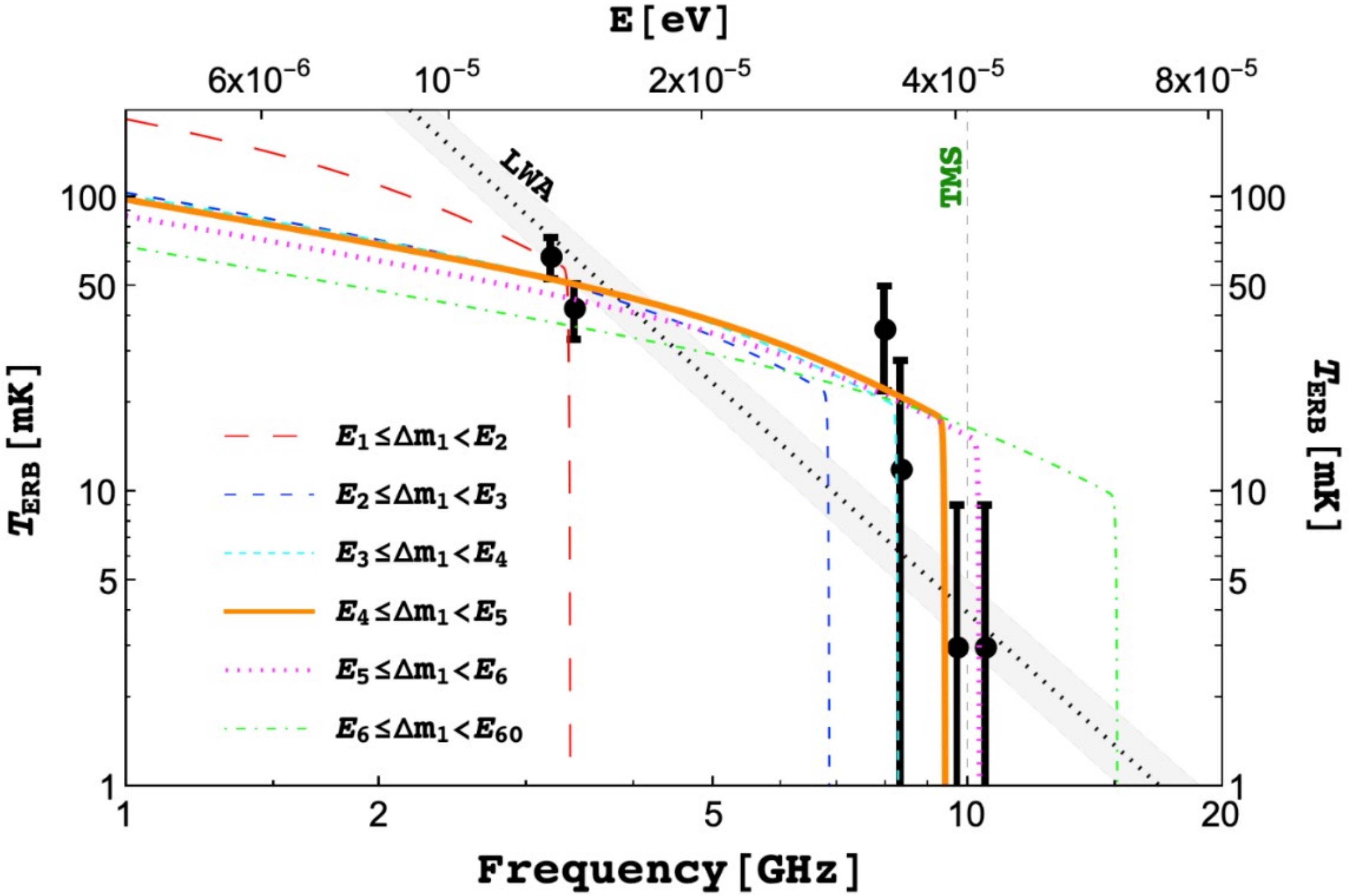
Fitting the ARCADE 2 ERB



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Can relic neutrino decay also solve EDGES?

EDGES measurements: zE=17.2

$$I_{\gamma nth}(E_{21},z_E) = \frac{n_{\nu 1}^{\infty}(z_E)}{4\pi}\frac{e^{-t(a_D)/\tau_1}}{H(a_D)\tau_1}$$

$$T_{\gamma nth}(E_{21},z_E) \cong \frac{4\pi^3}{E^2} I_{\gamma nth}(E_{21},z_E)$$

⇓

$$T_{\gamma_{\rm nth}}(E_{21},z_E) \simeq \frac{6\,\zeta(3)}{11\sqrt{\Omega_{\rm M0}}}\frac{T_0^3\,(1+z_E)^{3/2}}{E_{21}^{1/2}\,\Delta m_1^{3/2}}\frac{t_0}{\tau_1}$$

Interval	$\overline{A}\,({\rm eV}^{3/2}\,{\rm s})$	$\overline{\Delta m_1}$ (eV)	$\overline{\tau}_1$ (s)	$\chi^2_{\rm min}$	$\Delta\chi^2_{\rm min}$
$E_1 \le \Delta m_1 < E_2$	1.9×10^{14}	1.4×10^{-5}	3.6×10^{21}	7.36	−9.87
$E_2 \le \Delta m_1 < E_3$	2.3×10^{14}	2.7×10^{-5}	1.6×10^{21}	2.28	−14.95
$E_3 \le \Delta m_1 < E_4$	3.6×10^{14}	3.4×10^{-5}	1.8×10^{21}	1.06	−16.17
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$E_5 \le \Delta m_1 < E_6$	4.2×10^{14}	4.3×10^{-5}	1.49×10^{21}	2.19	−15.04
$E_6 \le \Delta m_1 < E_{60}$	4.7×10^{14}	2.0×10^{-4}	1.66×10^{20}	3.23	−14.00

Substituting the best-fit value obtained from the last analysis,

we predict: $T_{21} = -238^{+21}_{-20} mK$

Prediction of EDGES: $T_{21} = -500^{+200}_{-500} mK$

Prediction of ΛCDM: $T_{21} = -200\ mK$

Our solution predicts a much smaller deviation from ΛCDM in comparison to EDGES!

However, this should still be measured by lunar-based future experiments.

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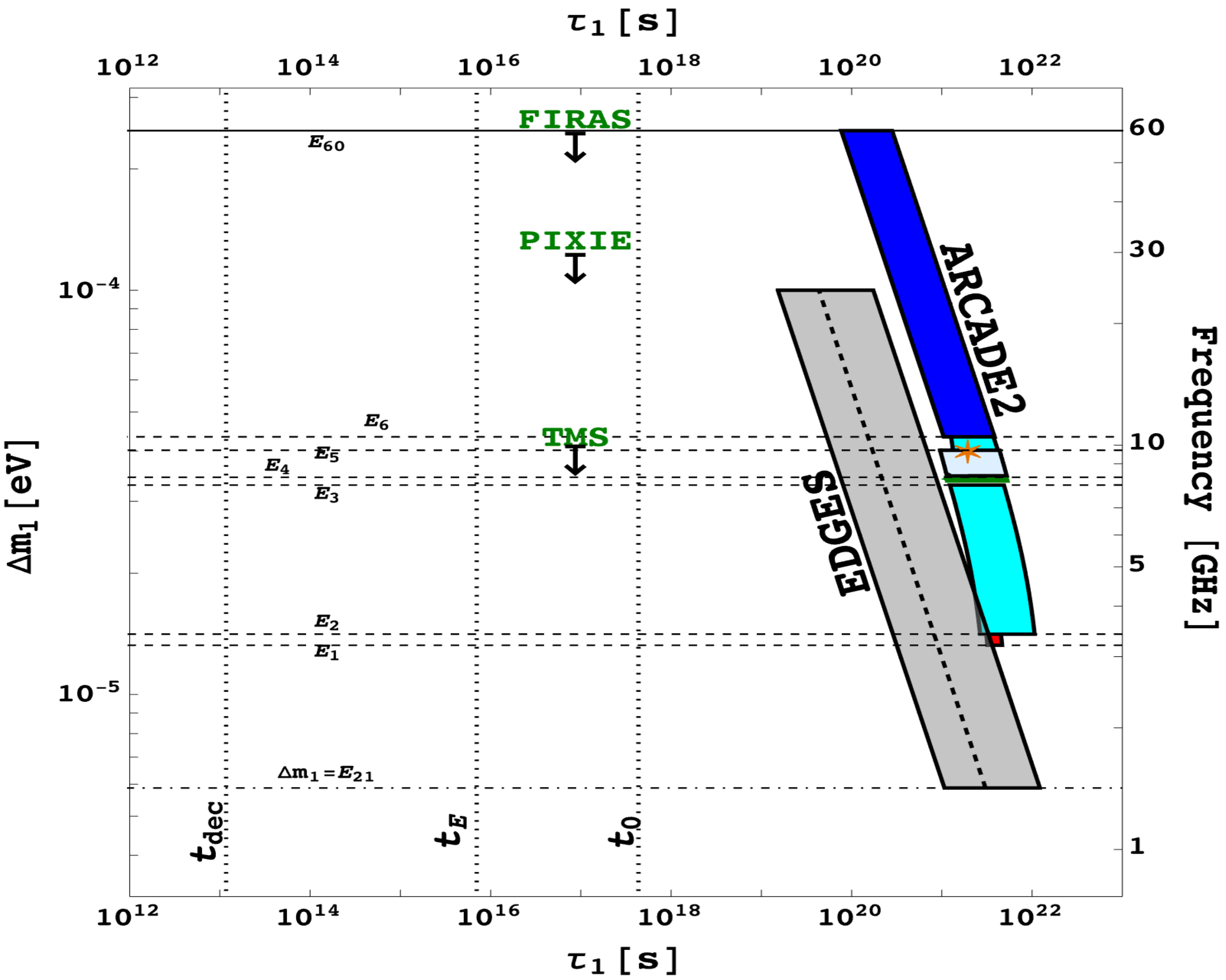
Allowed region (99% C.L.)



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There is some tension with the solution fitting ARCADE and EDGES

Final Remarks

1. The **ERB observed by ARCADE 2** is currently **unexplained**.

2. **The excess cannot** be explained by a **known (or even unknown)** population of **astrophysical sources**.

3. **Relic neutrino decays** provide an **intriguing solution** that **fits quite well with the ARCADE 2**.
   More results are needed: **Tenerife Microwave Spectrometer is on the way**!

4. **The solution** also **predicts** a **stronger 21cm absorption global signal** than in ΛCDM....though **not as strong as the EDGES** anomalous signal

5. Relic neutrino decays **require new physics**, so this solution represents a very exciting opportunity to **finally crack the SM of particle physics**.

6. Finally, **neutrinos in Cosmology** is not just a topic with important historical results, but it is still **one of the best-motivated routes to understand the cosmological puzzles!**

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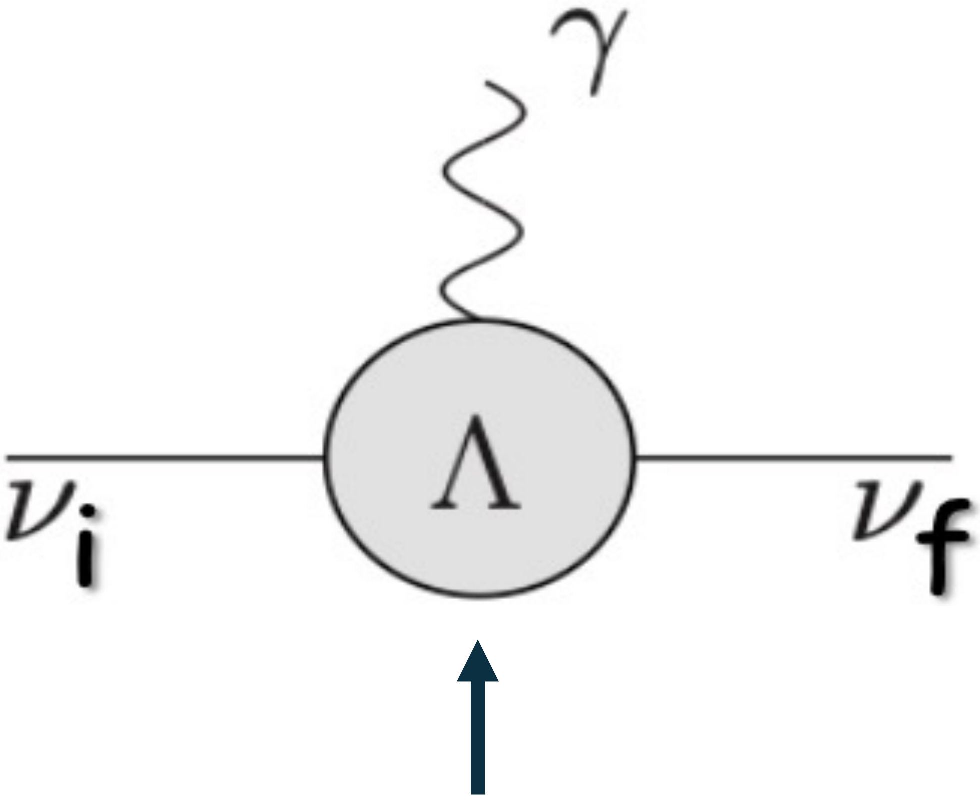

What is hidden inside?

Coming Soon, stay tuned!

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Ευχαριστώ