BLACK HOLES IN THE 21cm SIGNAL FROM COSMIC DAWN

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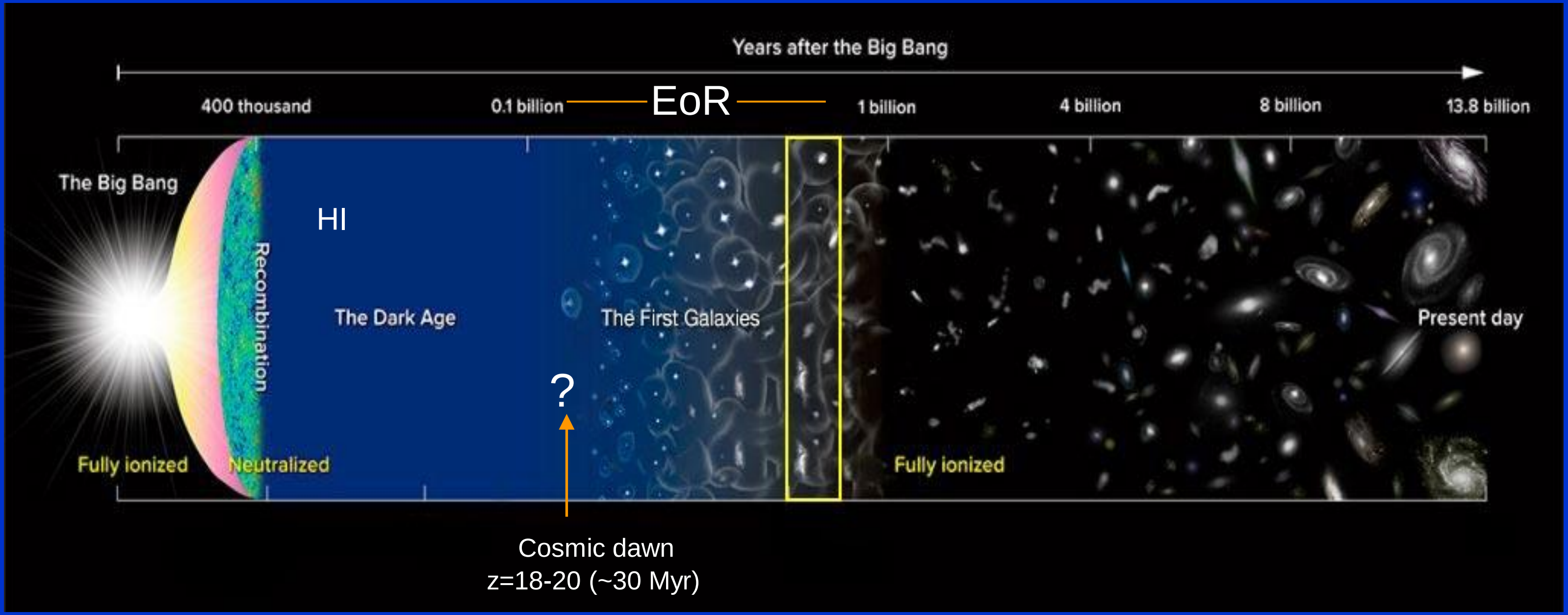


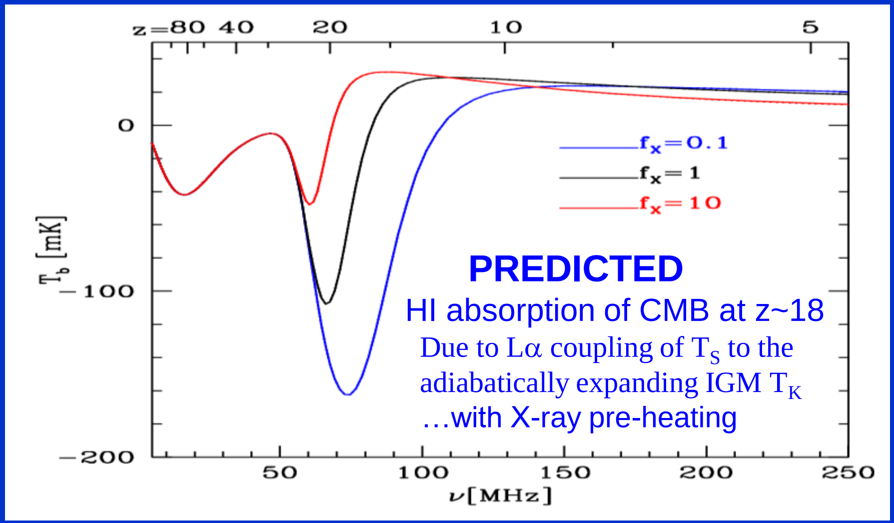
Cosmic dawn (CD) is one of the frontiers in cosmology

INPRINT OF STARS & BHs OF Pop III IN THE λ21cm LINE OF HI

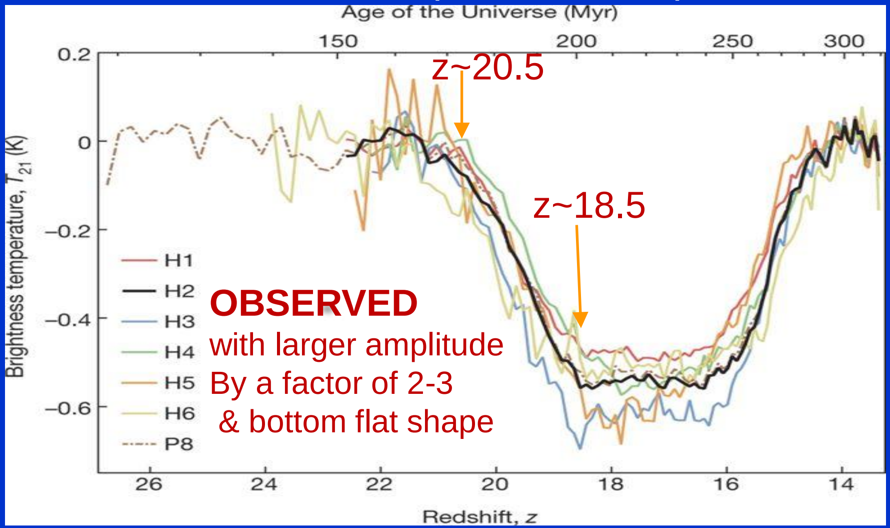
Hyperfine transition in the ground state of atomic hydrogen (HI)

Global signatures with **single dipoles** (e.g. EDGES) & Tomography with **interferometers** (e.g. SKA)

Furlanetto (2006); Mirabel, Diskra, Loeb+ (2011)



Bowman+ (Nature 2018)

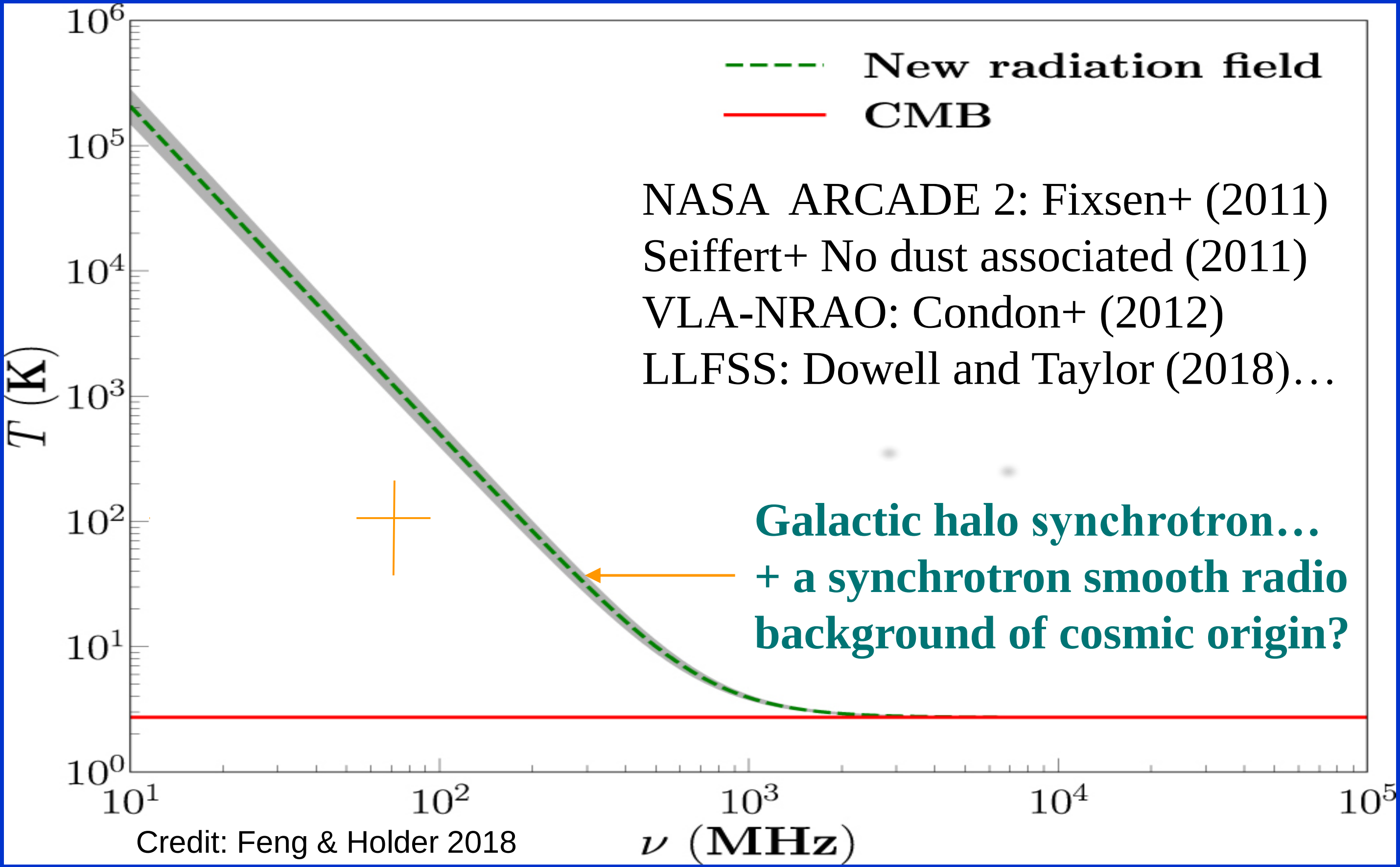


The absorption reported by EDGES needs confirmation…

- **New physics:** $\delta T_b \propto \{1 - (T_{CMB} / T_s)\}$; $T_s \rightarrow 0$ by interaction with DM (Barkana 2018…)
- **Astrophysics:** $\delta T_b \propto \{1 - (T_{CMB} + T_{CRB})/T_s)\}$ (Feng & Holder 2018; Ewall-Wice+ 2018)

Is there a Cosmic Radio Background (CRB)?

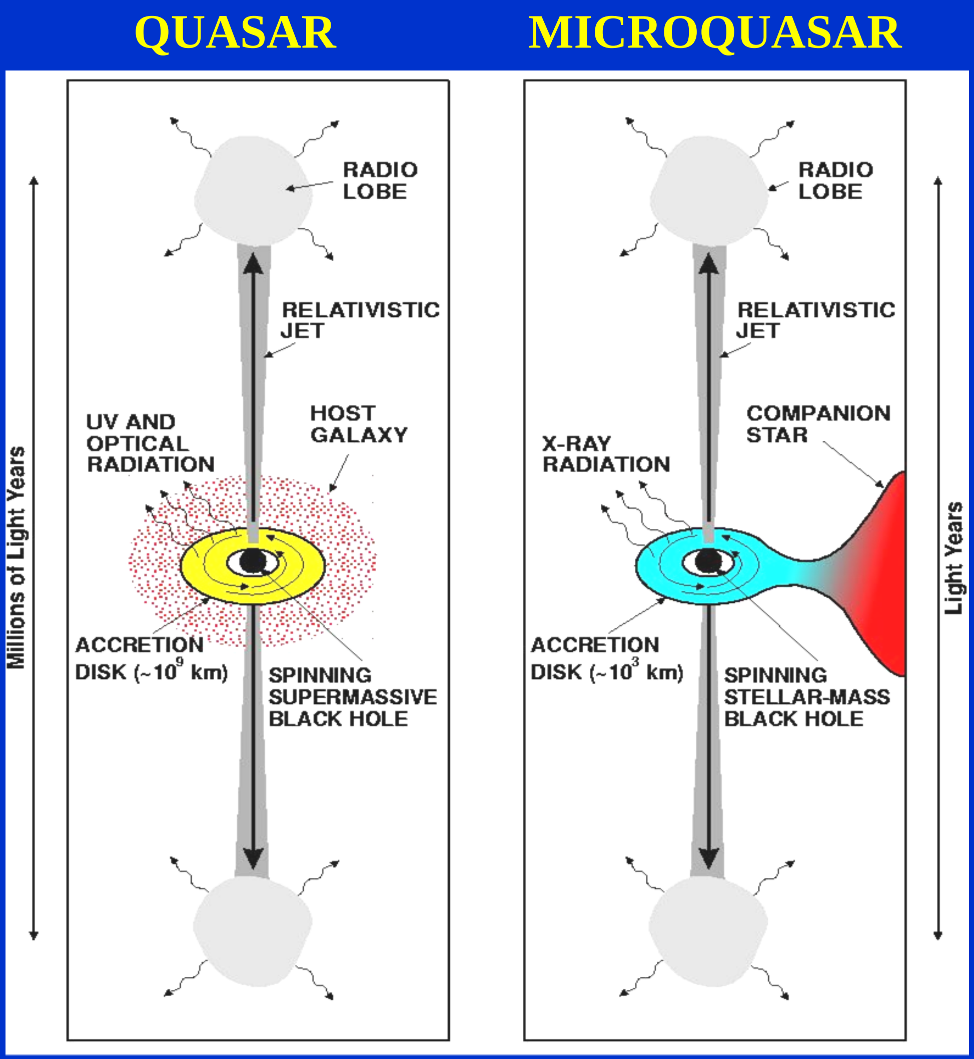
A low frequency synchrotron background radiation with a possible component of cosmic origin reported by the NASA ARCADE 2



- **A fraction of this synchrotron emission may be of unidentified cosmic origin** (Condon+ 2012; Ysard & Lagache 2012) now confirmed by Dowell and Taylor (2018)

- **What are the sources of this Cosmic Radio Background (CRB)**?

QSO & MQ RELATIVISTIC COMPACT JETS

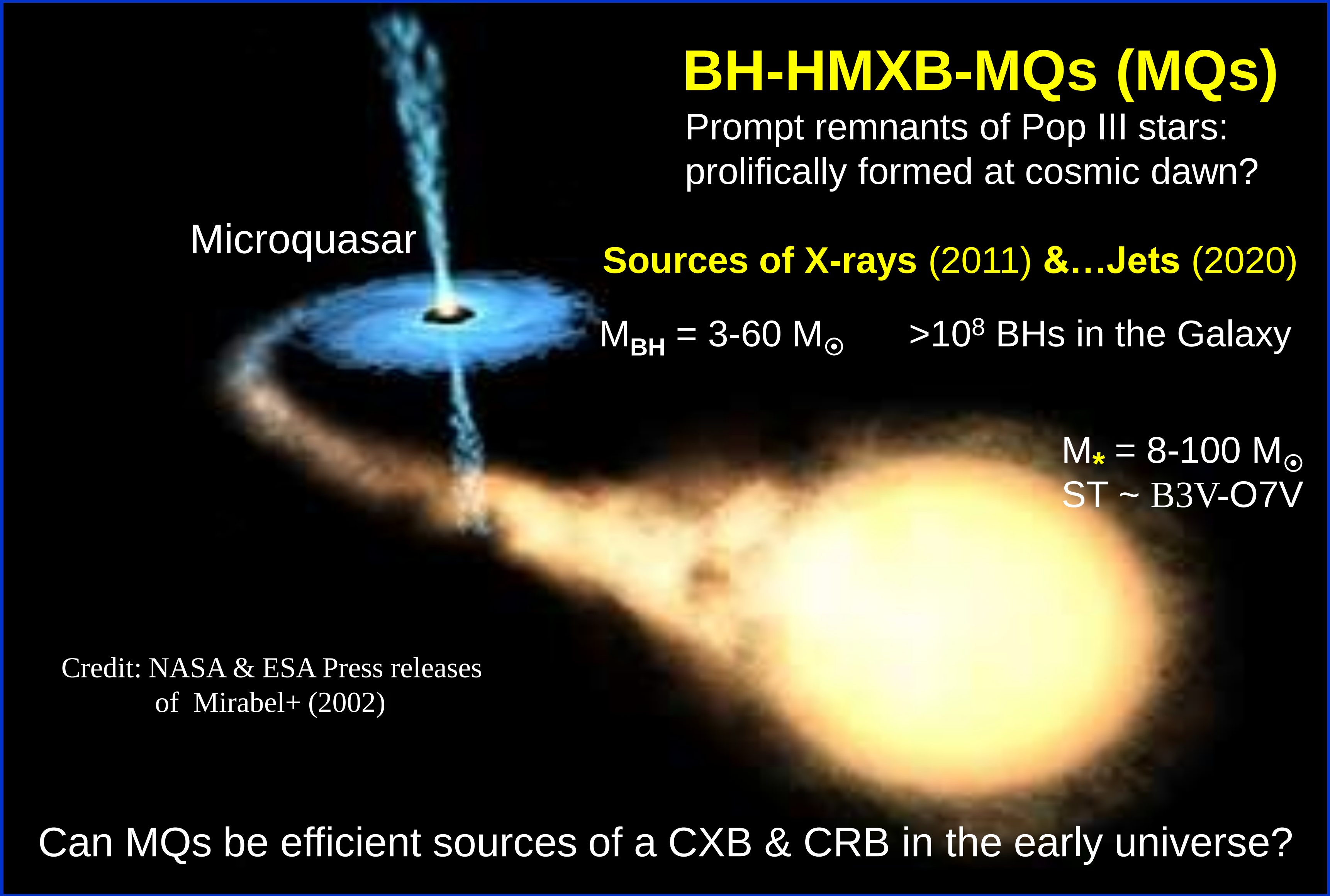


Mirabel & Rodríguez
(Nature 1998)

The scales of length and time are proportional to M_{BH}

$$R_{sh} = 2GM_{BH}/c^2 \; ; \;\; \Delta T \; \alpha \; M_{BH}$$

STELLAR BLACK HOLES IN HMXBs



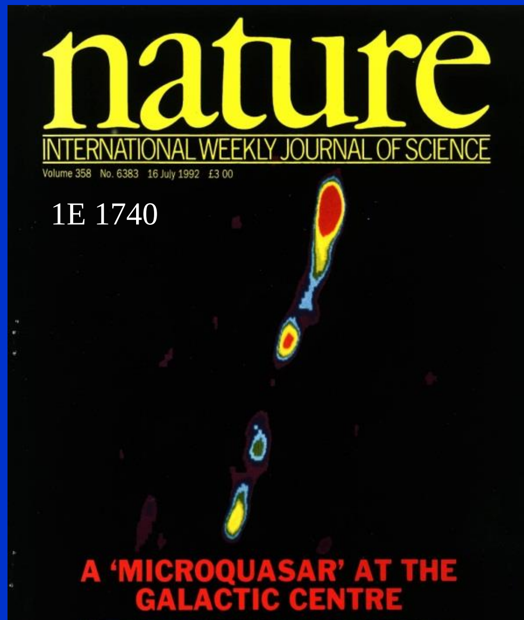
ARE MQs OF POP III THE SOURCES OF A CRB?

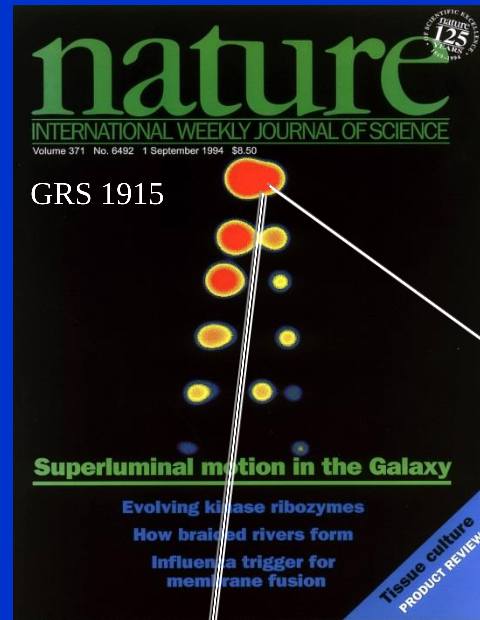
Mirabel, Rodríguez+1992

Mirabel & Rodríguez 1994

Luis F. Rodríguez

VLA λ3.6 cm





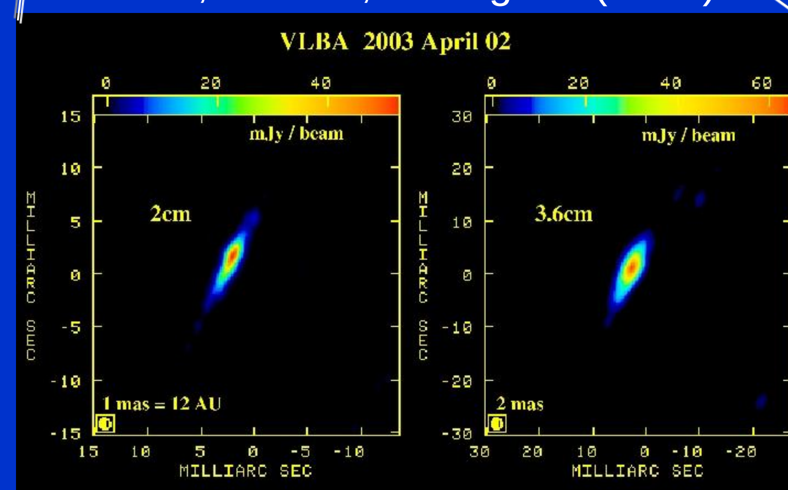
STEADY

JETS

TRANSIENT

JETS

Dhawan, Mirabel, Rodríguez (2000)



SYNCHROTRON COMPACT JETS

Because the magnetic fields $B = 10^2 - 10^4$ G

Cygnus X-1 is the best studied BH-HMXB-MQ

NUMBER OF BHs NEEDED TO EXPLAIN EDGES

$S_{CRB} = 2.4\, S_{CMB}$ between z=20.5 and z=18.5 or 174 and 202 Myr

$N = 6.67 \times 10^{20} \left[\frac{S_{1.4}}{Jy}\right]^{-1}$ *(eq. 1)* where $\frac{S_{1.4}}{Jy}$ is the flux at 1 kpc in Jy

Table 1. Number of sources needed to explain the onset of HI absorption reported by EDGES

Source	$S_{1.4}$ (observed) (Jy)	d (kpc/Mpc)	$S_{1.4}$ (corrected to d=1 kpc) (Jy)	BH Mass ($M_\odot$)	Number of Sources
Cyg X-1	0.015	1.9 kpc	0.060	14.8	1.1×10^{22}
Sgr A*	1	8.5 kpc	73	4×10^{6}	9.3×10^{18}
Cen A	0.8	3.8 Mpc	1.2×10^{7}	1×10^{8}	5.6×10^{13}
M87	3	16.4 Mpc	8.1×10^{8}	6.5×10^{9}	8.2×10^{11}
3C273	32	749 Mpc	1.8×10^{13}	6.6×10^{9}	3.7×10^{7}

CAN BH-MQs EXPLAIN THE ONSET OF THE EDGES ABSORPTION?

Calculation: for z=20.5 to z=18.5 are 28 x10^{6} yr and 2.7 x 10^{11} Mpc^{3} respectively.

From N_{tot} = 1.1 x 10^{22} MQs as Cygnus X-1 the MQFRD = 1.3 x 10^{3} MQs Mpc^{-3} yr^{-1}

For a flat, top heavy IMF between 30 $M_{\odot}$ and 110 $M_{\odot}$ results in 9.1 x 10^{4} $M_{\odot}$ Mpc^{-3} yr^{-1} which is ~6 orders of magnitude larger than the log SFRD ($M_{\odot}$ Mpc^{-3} yr^{-1})=-1 at z~1, and 8-9 orders of magnitude larger than the expected log SFRD at z ~ 20.

From recent astrophysics results: The large majority of massive stellar binaries are born with large orbital periods, and stars of Pop III are more compact and lose less mass compared to metallicity enriched stars of the same mass. Therefore, the large majority of stellar BHs with high mass companions of Pop III stars are silent in the X-rays and radio waves.

Conclusion: BH-MQs are not the sources of a CRB that can explain the onset of the EDGES HI absorption signal

Can solitary BHs be the sources that explain the EDGES absorption?

BHs typically radiate 1% the Eddington luminosity $L_{Edd} = 1.26 \times 10^{38} \left[\frac{M}{M_\odot}\right] erg\ s^{-1}$

The radio luminosity of BHs radiating at the Eddington luminosity is given by

Ho (2002) & Merloni et al. (2003): $L_{Edd} \simeq 10^{33} \left[\frac{M}{M_\odot}\right] erg\ s^{-1}$ $\quad eq\ (2)$

That is, only 10^{-5} of the radiated energy comes out in the radio regime.

we have that approximately (Gallo et al. 2014)

$L_R \approx L_5 \times 5\ GHz, \quad or \quad S_5\, 4\pi\, d^2 = L_5 = \frac{L_R}{5\ GHz}$, eq. (3)

where L_5 is the luminosity at 5 GHz per frequency unit. Assuming a flat spectrum:

$$S_{1.4} = S_5 \qquad eq.(4)$$

Substituting eq. (4) in (3) and then in (2) and evaluating for $d = 1$ kpc, we obtain that:

$$\left[\frac{S_{1.4}}{Jy}\right] \approx 167 \left[\frac{M}{M_\odot}\right], \qquad eq.\ (5)$$

where $S_{1.4}$ is the flux of the source at 1.4 GHz measured at a distance of 1 kpc in Jy.

Substituting eqn. (5) in eq. (1), $N = 6.67 \times 10^{20} \left[\frac{S_{1.4}}{Jy}\right]^{-1}$ *(eq. 1)*

we find that the total mass that we have to invest in BHs (of any masses) is:

$$\boldsymbol{Total\ mass\ in\ BHs \approx 4.0 \times 10^{18}\, M_\odot}$$

If in the interval of z = 20.5 to z = 18.5 (28×10^6 yr) and volume of 2.7×10^{11} Mpc^{-3} the SFRD ~ 10^{-4} $M_{\odot}$ yr^{-1} Mpc^{-3} (Mirocha and Furlanetto 2019; Finkelstein et al. 2019; Jaacks et al. 2019), the total stellar mass formed in that interval would be 7.6×10^{14} $M_{\odot}$, about 5000 times less than the required mass in BHs of 4.0×10^{18} $M_{\odot}$.

Even assuming that all the star formation at cosmic dawn goes into BHs radiating at the Eddington limit, the absorption reported by EDGES cannot be explained by the expected star formation.

CONCLUSION

- **The reported absorption by EDGES may not be of cosmic origin**

- **But if confirmed as of cosmic origin, it may be the signal of massive BHs of non-stellar origin, as suggested by the SMBHs of $10^{8\text{-}9}$ $M_{\odot}$ in QSQs at z = 7.5, probably grown by super-Eddington accretion from BH seeds of $10^{3\text{-}4}$ $M_{\odot}$, formed by direct collapse in pre-galactic dark matter haloes at z > 30, when the Universe was less than 100 Myr old.**