Astrophysical Hints For Magnetic BlackHoles

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Farman Ullah

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH PUNE, INDIA

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Authors: Diptimoy Ghosh, Arun Thalapillil, Farman Ullah

Reissner-Nordstrom black hole metric

$$ds^2 = -\left(1 - \frac{2M}{r} + \frac{\left(Q_E^2 + Q_B^2\right)}{r^2} - \frac{\Lambda r^2}{3}\right) dt^2 + \left(1 - \frac{2M}{r} + \frac{\left(Q_E^2 + Q_B^2\right)}{r^2} - \frac{\Lambda r^2}{3}\right)^{-1} dr^2 + r^2 d\Omega^2$$

In units where $c = 1,\ G_N = 1,\ 1/4\pi\epsilon_0 = \mu_0/4\pi = 1.$

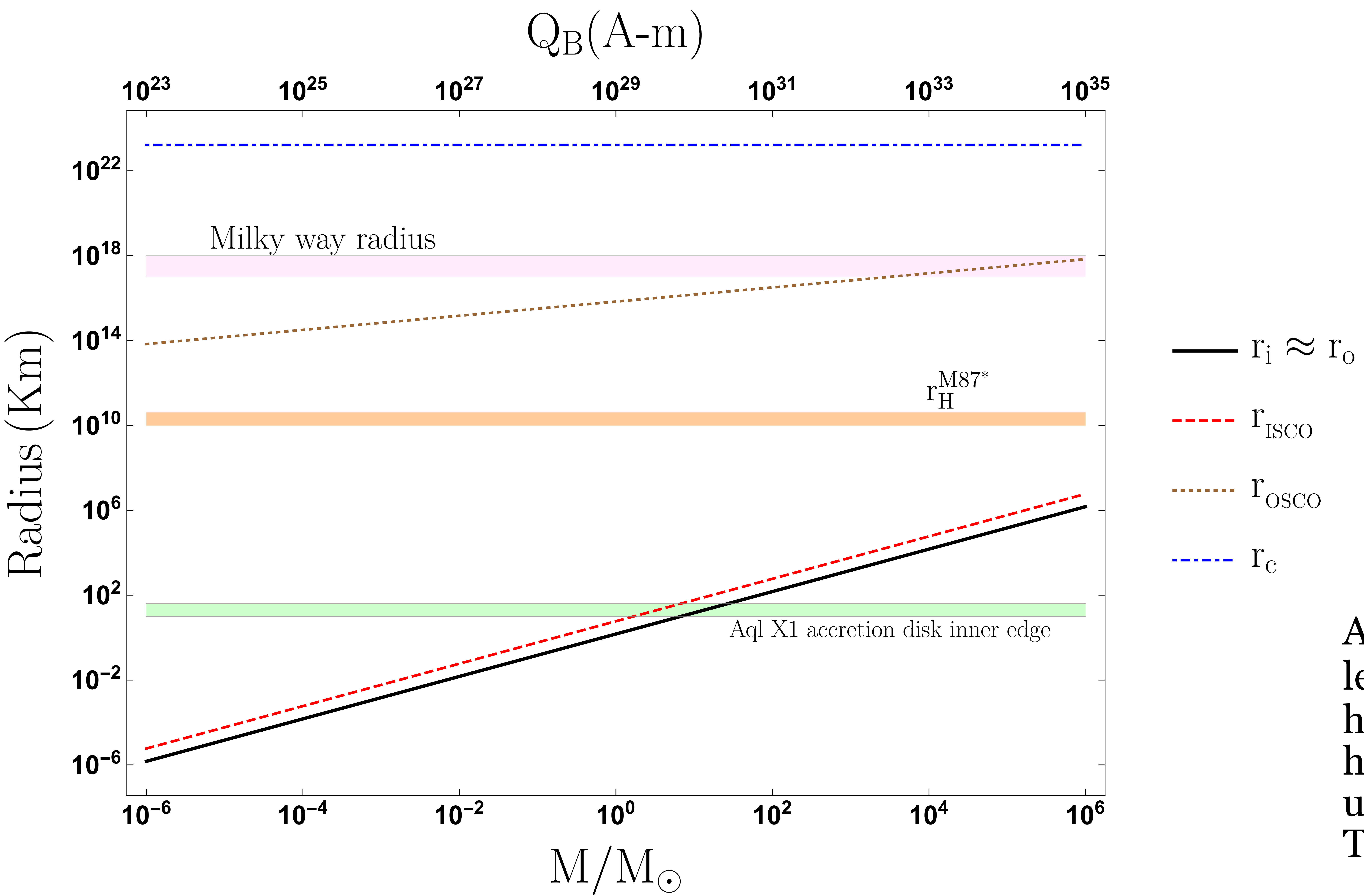
- M is the mass of the black hole, Λ is the cosmological constant which is positive for de Sitter space-time.

  Q_E & Q_B are electric and magnetic charges respectively.

  We will focus on the case where $Q_E = 0, Q_B \neq 0$, since electric charges can very quickly neutralise owing to plasma accretion, Schwinger pair production etc. The paucity and heaviness of magnetic charges makes magnetically charged blackholes more stable. We further specialise to Extremal Blackholes i.e $Q_B = M$.

Stable Circular Orbits

Asymptotically de Sitter Spacetime



$$r_{ISCO} \approx 4|Q_B|\left[1 + \frac{64\epsilon^2}{9} + O(\epsilon^4)\right]$$

$$r_{OSCO} \leq 2max\left(\left|\frac{3Q_B}{\Lambda}\right|^{1/3}, \left|\frac{3Q_B^2}{\Lambda}\right|^{1/4}\right)$$

$$r_i = |Q_B|\left(1 - \frac{\epsilon}{4} + O(\epsilon^2)\right)$$

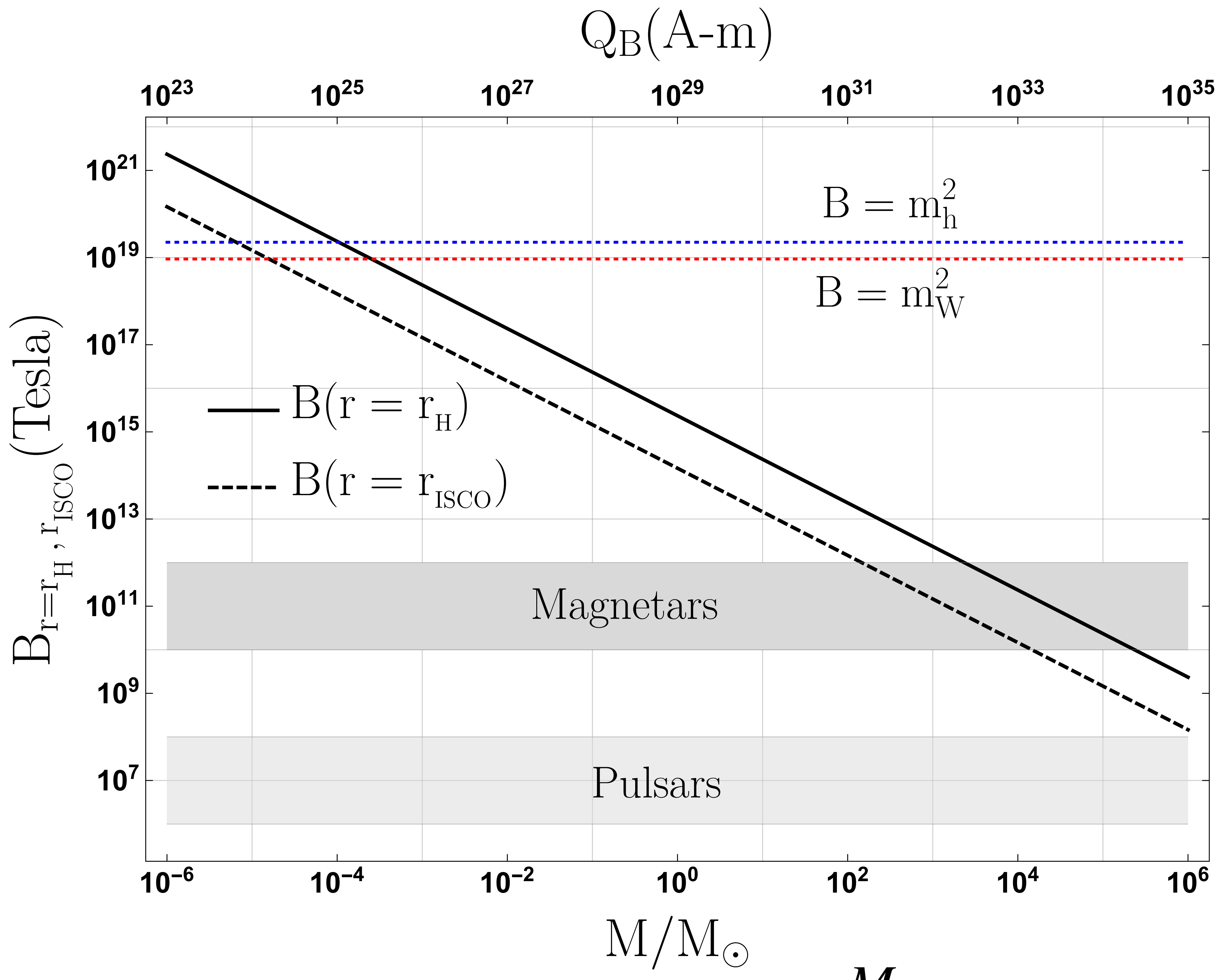
$$r_o = |Q_B|\left(1 + \frac{\epsilon}{4} + O(\epsilon^2)\right)$$

$$r_c = \sqrt{\frac{3}{\Lambda}}\left(1 - \frac{\epsilon}{4} + O(\epsilon^2)\right)$$

$$\epsilon = 4M\sqrt{\frac{\Lambda}{3}}$$

As shown in the figure on the left, r_{ISCO} is very close to the horizon radius and will have huge magnetic fields which help us probe Quantum Field Theoretic phenomena.

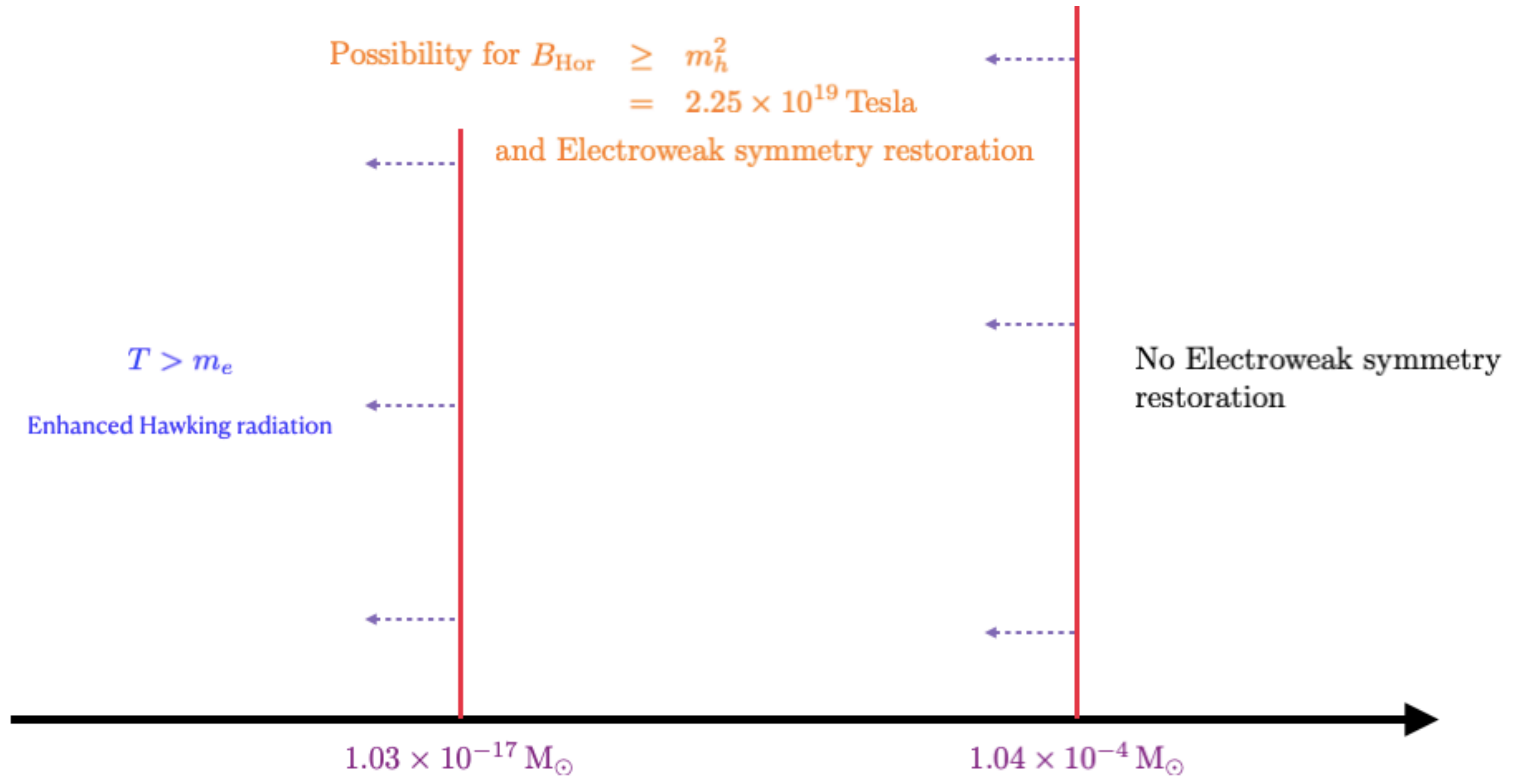
Quantum Field Theoretic Aspects of MBHs



$$B_{ext}(r_H) = 2.34 * 10^{15} Tesla \frac{M_\odot}{M}$$

We see that the magnetic fields at the horizon and at ISCO are extremely large (for most of the parameter space) , even larger than Magnetars i.e Neutron stars with extremely high magnetic fields.

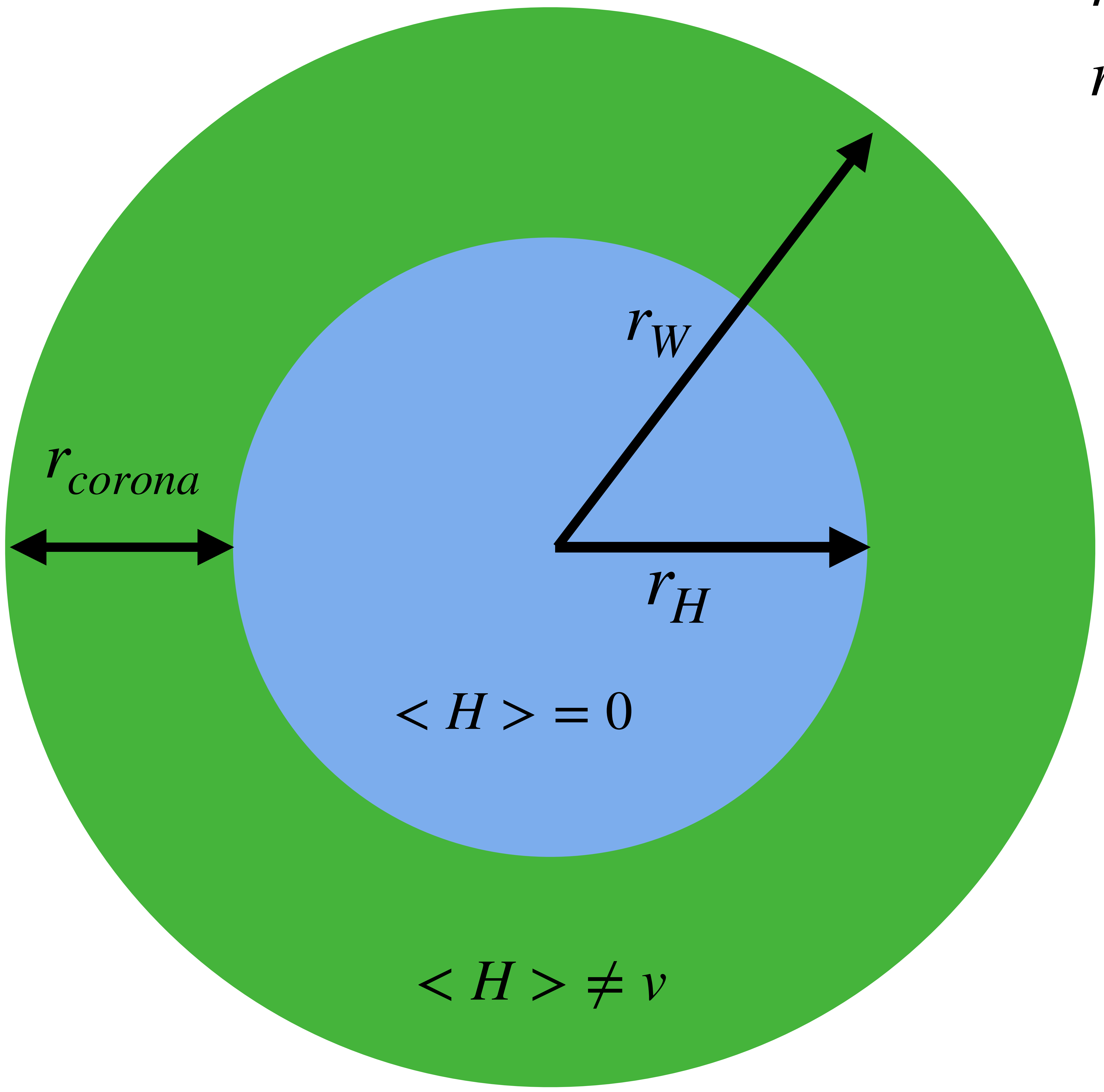
Regions where $B \geq m_H^2$ will restore the electroweak symmetry until $B \leq m_W^2$ forming an electroweak corona in-between where VEV of Higgs is less than 246 GeV.[Amjorn & Olesen, arXiv:hep-ph/9304220]



Due to near horizon EWS hawking radiation is modified. We have 1+1 dim massless chiral fermions which enhance the hawking radiation by a factor of qQ_B/q_B.given that $T > m_e$ otherwise there will be a suppression due to the Boltzmann factor. The BB radiation in d+1 dimensions is proportional to T^{d+1}, which in this case becomes T^2.

r_H is the radius at which $B = m_H^2$

r_w is the radius at which $B = m_W^2$



$< H > = v = 246 GeV$

Phenomenological Aspects of MBHs

MBHs as a component of dark matter

We use Parker bound to evaluate the fraction of dark matter constituted by MBHs in our galaxy. This requires them to be virialised i.e $v \sim 10^{-3}$c.

The Parker bound is obtained by demanding that average energy gained by the MBHs during the regeneration time t_{reg} of the galactic magnetic field, be smaller than energy stored in the magnetic field. This gives the dark matter fraction as

$$f_{DM} \leq 1.5 * 10^{-6}\left(\frac{M}{Kg}\right)^2\left(\frac{A-m}{Q_B}\right)^2\left(\frac{v}{10^{-3}c}\right)\left(\frac{0.4GeV/cm^3}{\rho_{DM}}\right)\left(\frac{10kpc}{l_c}\right)\left(\frac{10Gyr}{t_{reg}}\right).$$

For typical astrophysical parmeter values,

$$f_{DM} \leq 1.5 * 10^{-6}\left(\frac{M/Kg}{Q_B/A-m}\right)^2$$

For extremal case

$$f_{DM} \leq 1.7 * 10^{-3}$$

Therefore, extremal blackholes cannot constitute a large fraction of dark matter but they have other interesting astrophysical aspects like electromagnetic and gravitational emissions during inspiral.

Gravity waves from oppositely charged MBH inspiral

The complete waveform is given by,

$$h_+(t) = \frac{G_N M a^2 \omega^2}{c^4 r}(1 + cos^2\theta)cos(2\omega t)$$

$$h_x(t) = \frac{2G_N M a^2 \omega^2}{c^4 r} cos\theta sin(2\omega t)$$