On particle acceleration

near

magnetized rotating black hole

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`in collaboration with`

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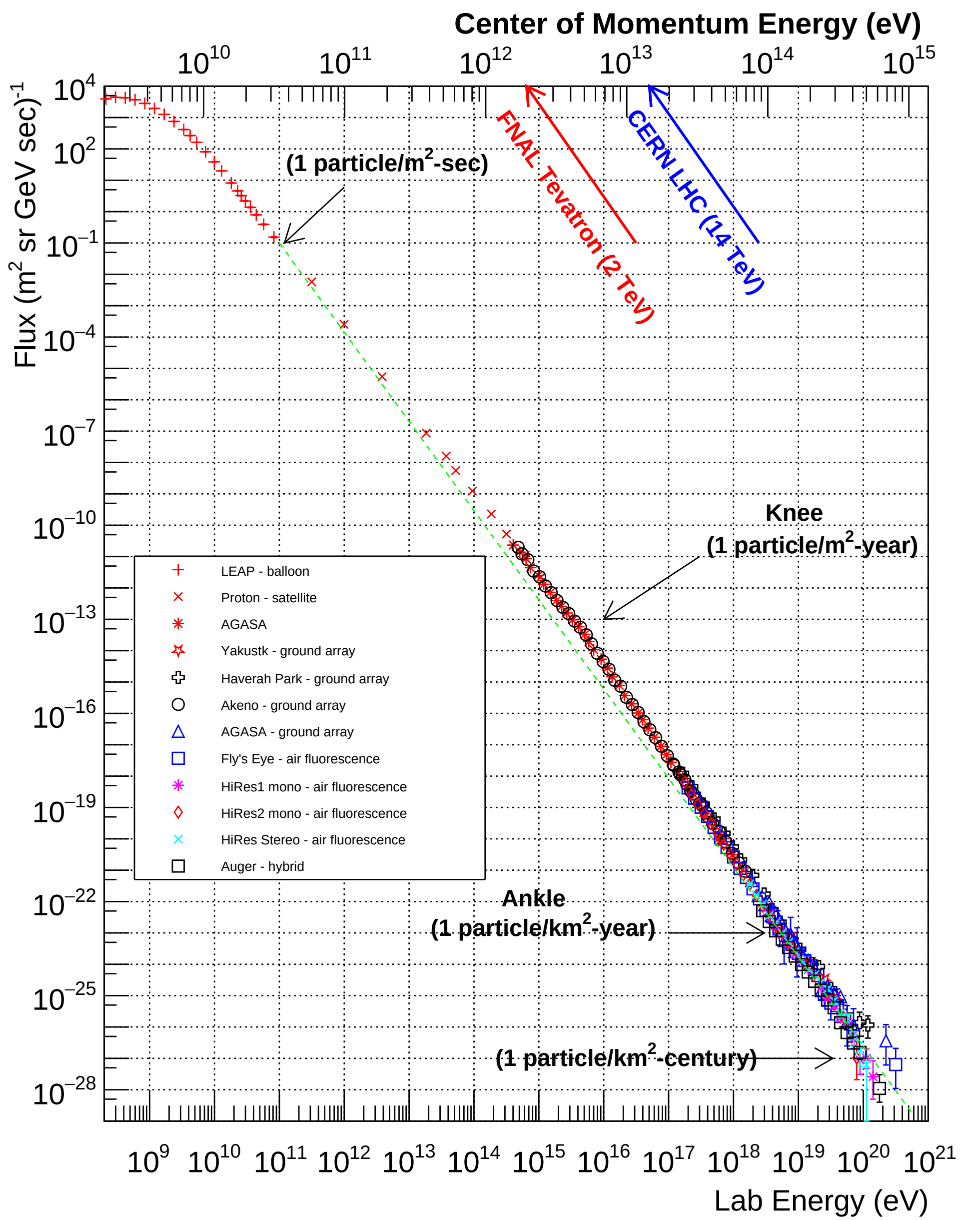
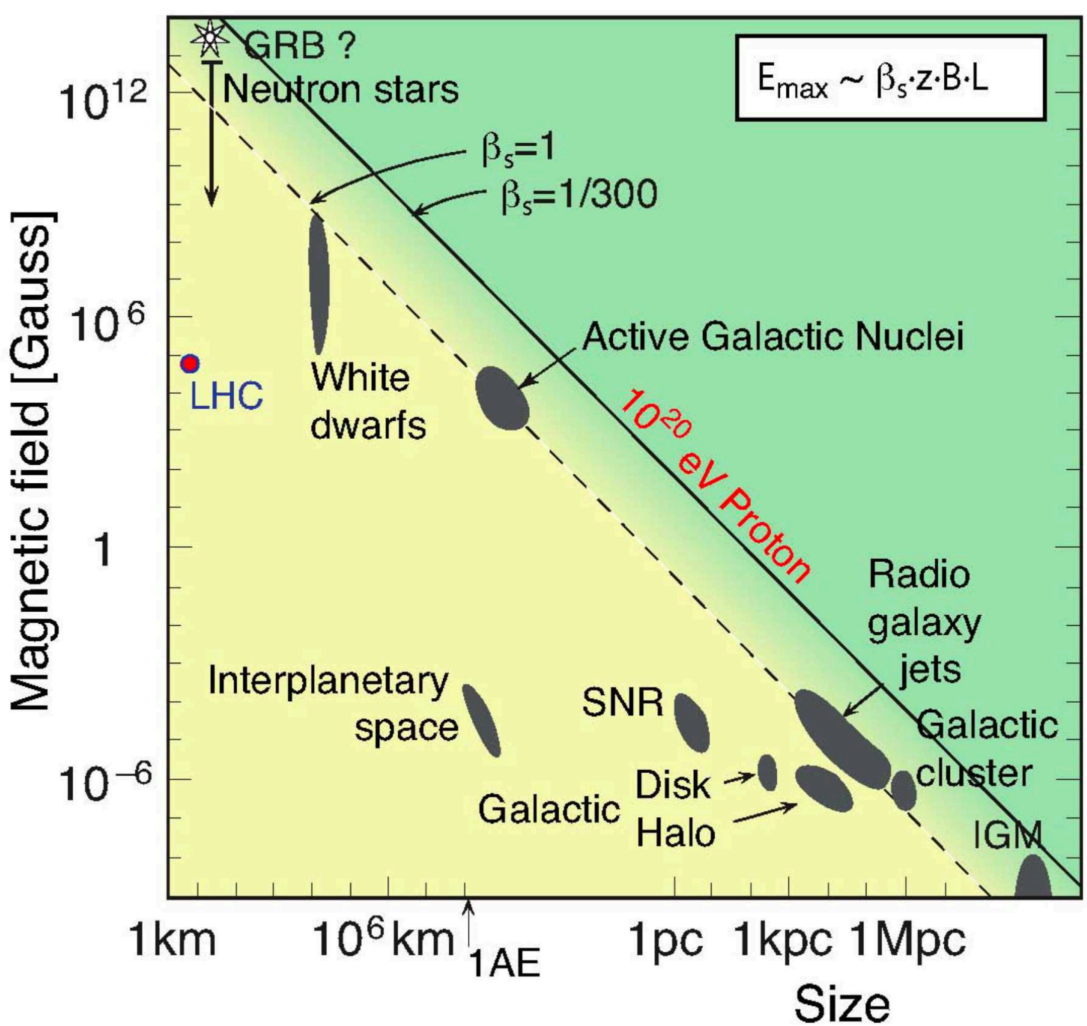
Motivation: Spectrum of cosmic ray particles



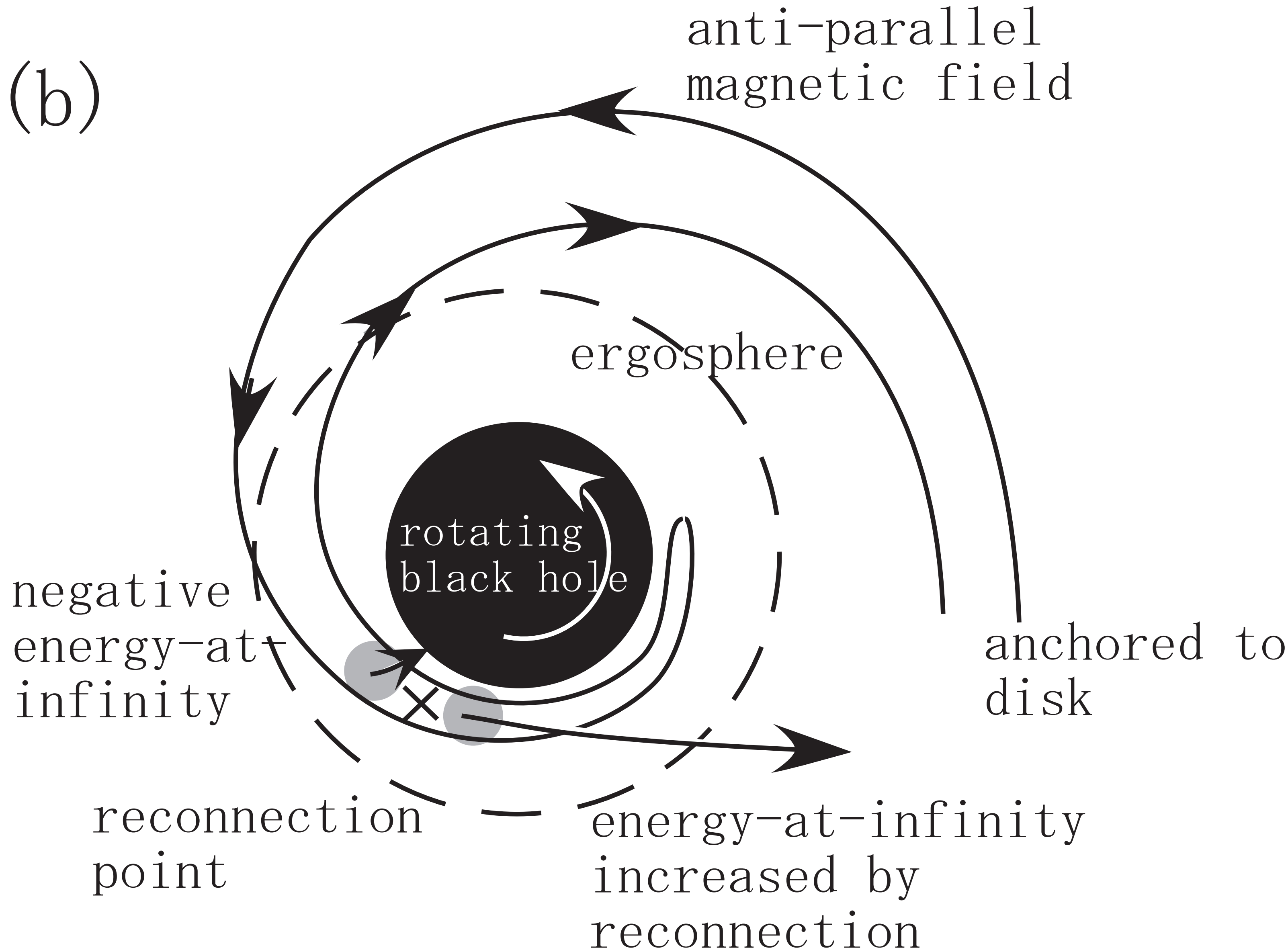
Different constituents are plotted against several limits of particle accelerator experiments (figure from Hanlon 2021).

Motivation: Hillas diagram



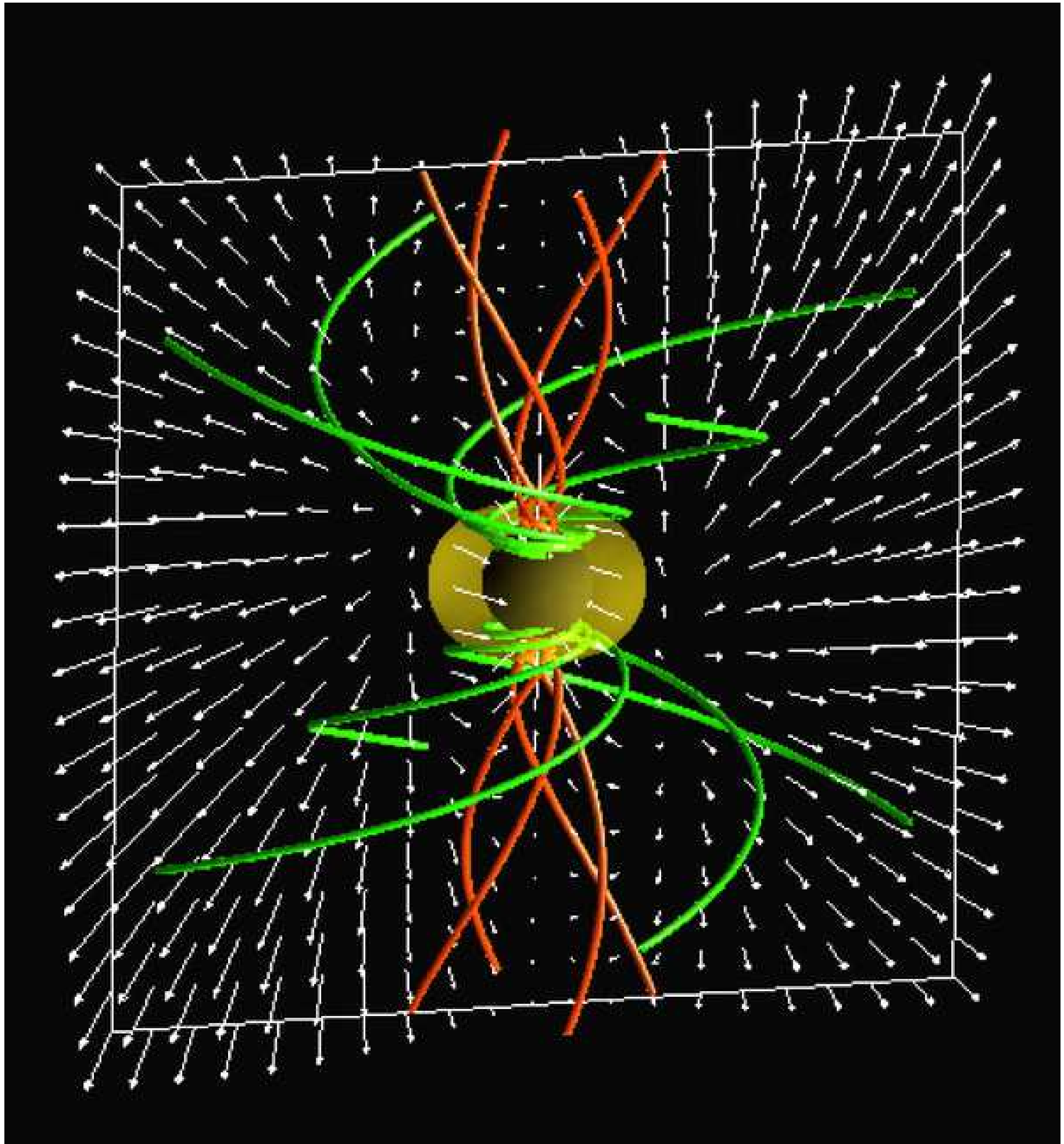
Sites of cosmic rays depending on the size of the source and the magnetic field intensity. Objects located below the diagonal line are unable to accelerate cosmic rays to the given energy of 10^{20} eV. Position of the ground based Large Hadronic Collider (LHC) is also shown. Various cosmic sources can produce cosmic rays above the limits of what laboratory accelerators achieve (De Angelis et al. 2015; Piran & Beniamini 2023).

Magnetic reconnection in ergosphere



Koide & Arai (ApJ, 2008); Lyutikov (PRD, 2011); Morozova et al. (2014)

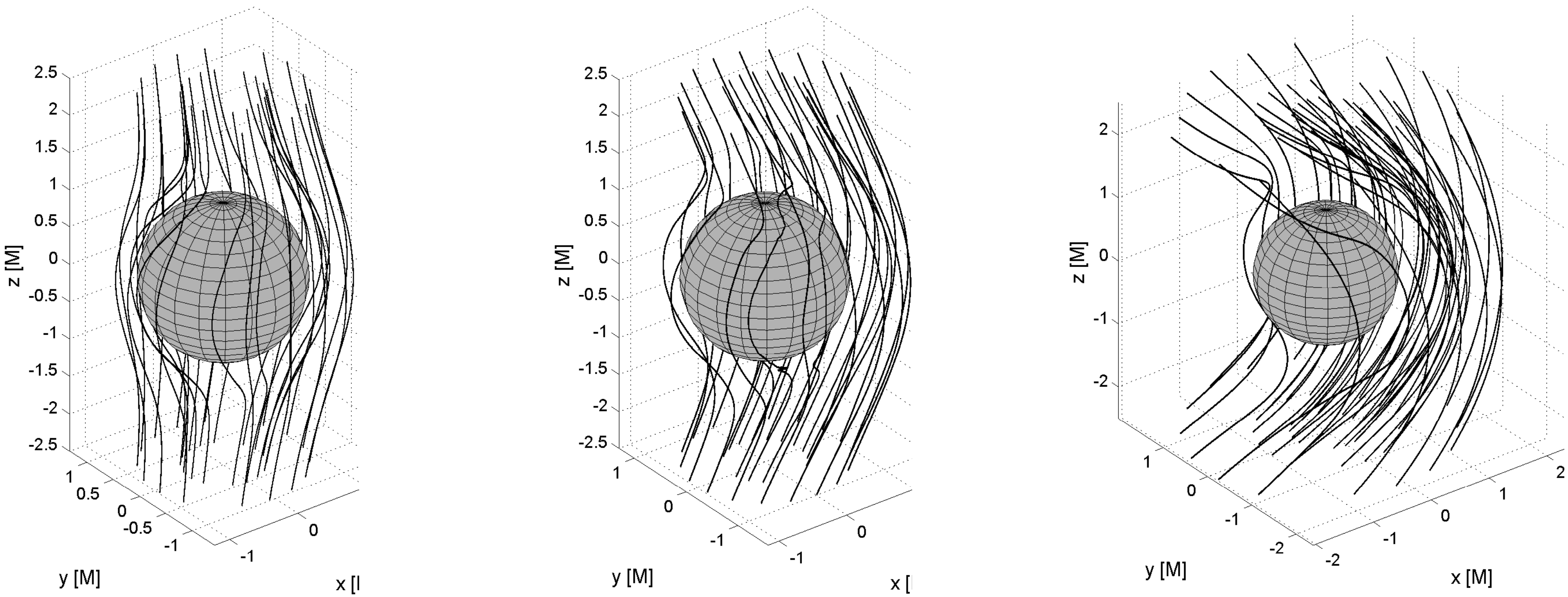
Relativistic particles from BH ergosphere?



Koide (ApJ, 2004)

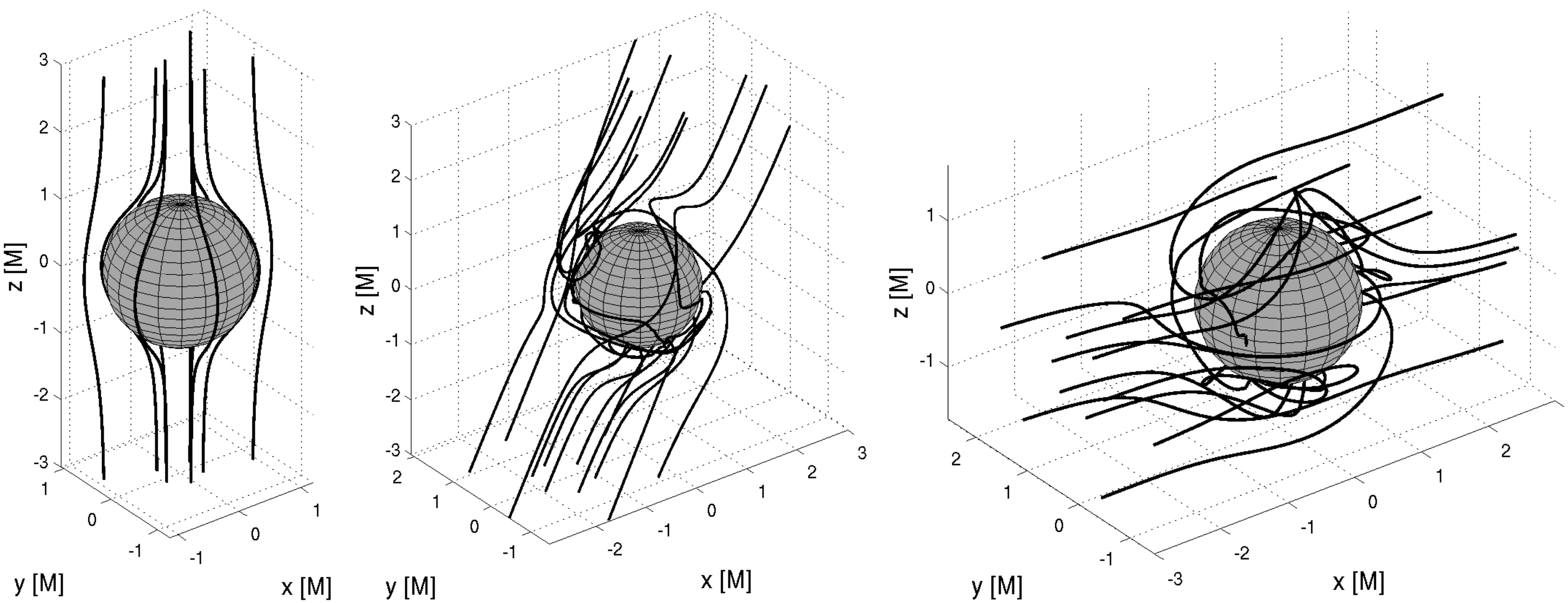
Rotating black hole + linear boost

$v = 0.1$ $\qquad$ $v = 0.3$ $\qquad$ $v = 0.7$



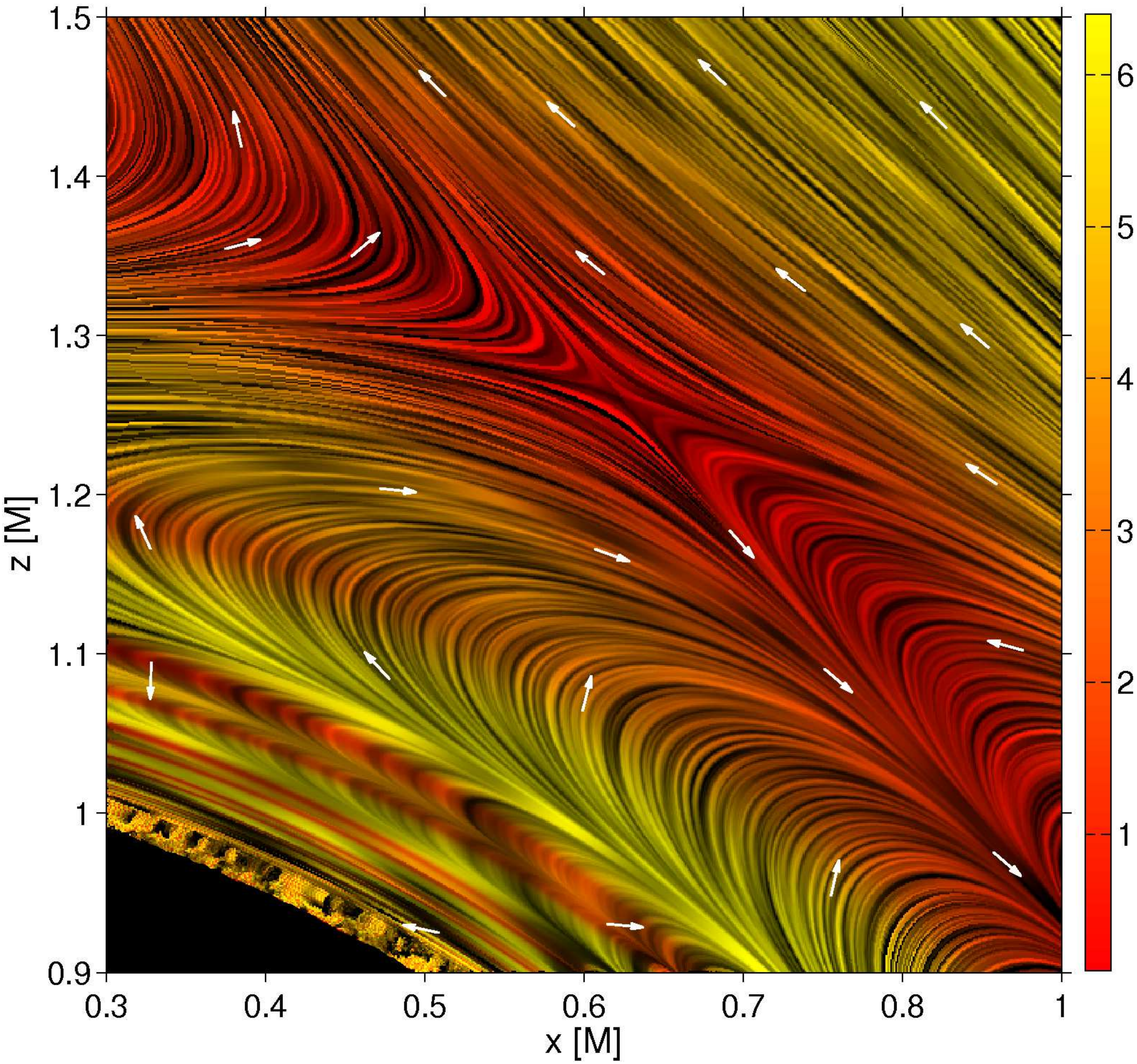
Effect of translatory motion (linear boost).

Rotating black hole in vacuum, oblique magnetic field



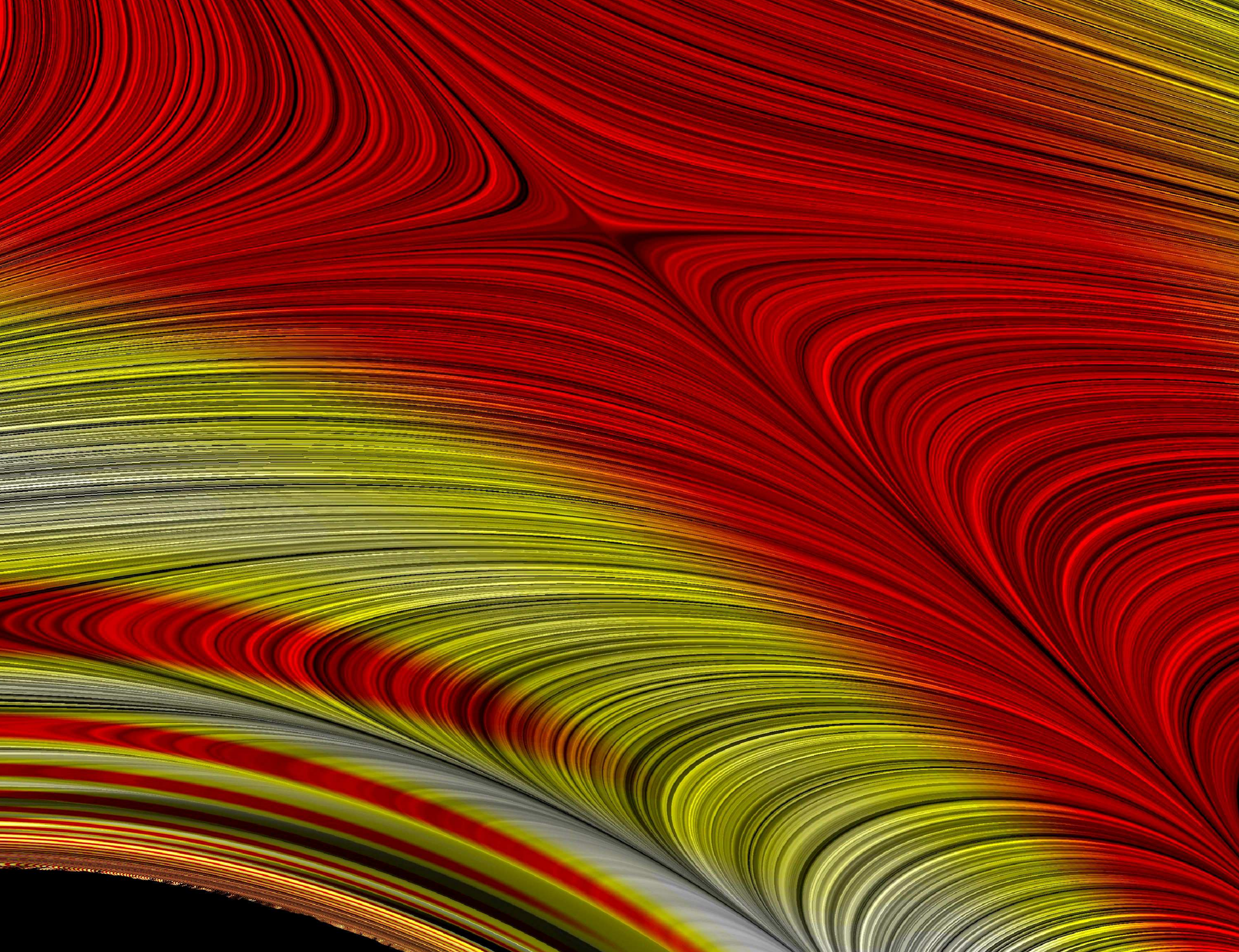
Effect of misalignement.

Magnetic null points

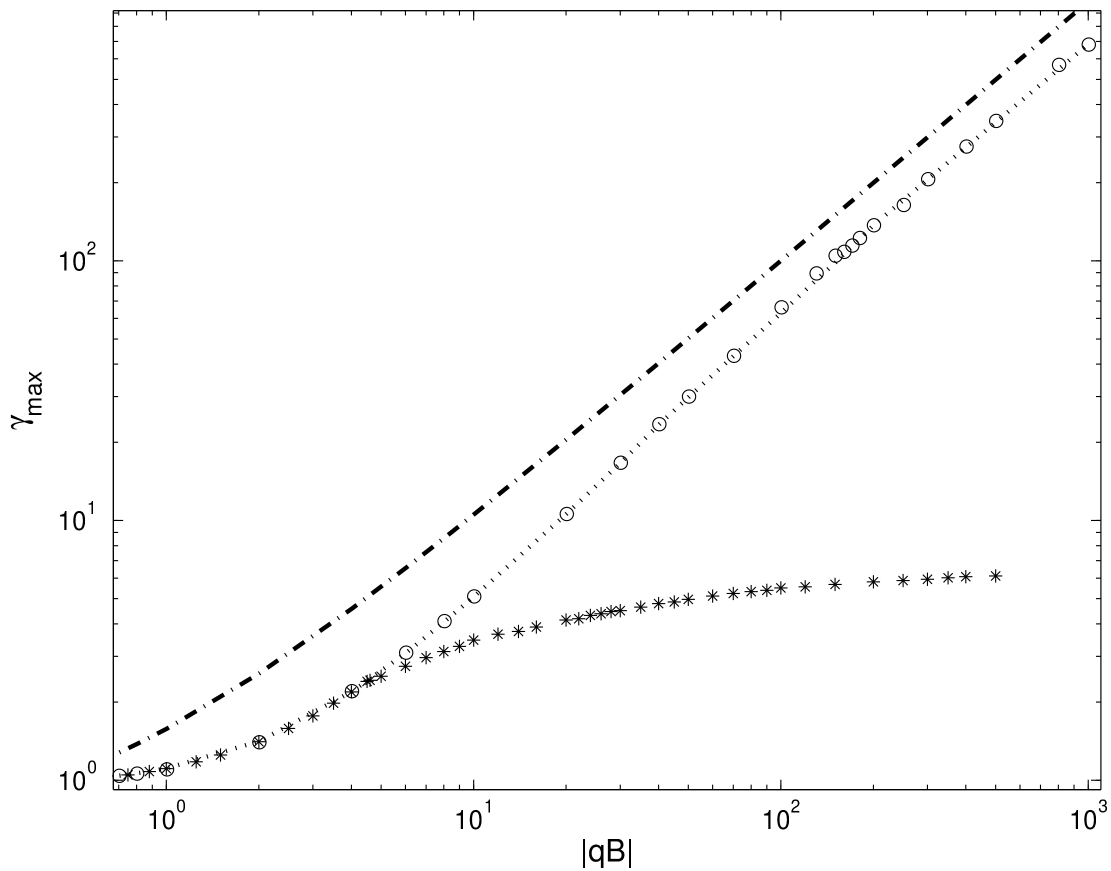


Field lines in equatorial plane

Karas et al. (2009, 2020)



Terminal Lorentz factor



Maximal value of the final Lorentz factor of escaping particles as a function of magnetization parameter $|qB|$. Circles denote the values obtained numerically for trajectories in the inclined magnetosphere ($B_x/B_z = 0.1$, i.e., $\alpha \approx 6^{\rm deg}$ with $\varphi_0 = \pi/2$); asterisks show the aligned case ($B_x = 0$); the dashed–dotted line is the theoretical maximum for $r_0 = r_+ = 1$.

Conclusions

Because of the combined effect of frame dragging and boost, a rotating BH forms magnetic null points.

Charged particles can be efficiently accelerated by electric field passing through magnetic nulls.

Karas, Kopáček, & Kunneriath (2012), Classical and Quantum Gravity, 29, id. 035010
Kopáček, Tahamtan, & Karas (2018), Physical Review D, 98, id.084055
Kopáček, & Karas (2020), Astrophysical Journal, 900, id.119
— (2023), in prep.

Selected Chapters on Active Galactic Nuclei as Relativistic Systems
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