Thermal bremsstrahlung emission from accretion disc in non-Kerr spacetime

Presented by
Subhankar Patra
IIT Guwahati, India

Collaboration with
Dr. Bibhas Ranjan Majhi
& Prof. Santabrata Das

Date: December 12, 2023
E-mail: psubhankar@iitg.ac.in

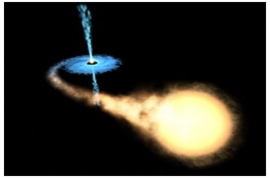
The 32nd Texas Symposium on Relativistic Astrophysics, December 11-15, 2023

Accretion process:

❖ Accreting astrophysical sources: AGN, BHXRBs and GRB, etc.

➢ Lost gravitational energy
→ Thermal energy

➢ Thermal energy
→ Radiation spectrum



https://en.wikipedia.org/wiki/Accretion_disk#/media/File:Accretion_disk.jpg)

Johannsen-Psaltis (JP) metric :

$$ds^2 = -\left(1-\frac{2M_{BH}}{r}\right)(1+h)dt^2 - \frac{4M_{BH}a_k}{r}(1+h)dt\,d\phi + \frac{r^2(1+h)}{\Delta + a_k^2 h}dr^2 + \left(r^2 + a_k^2(1+h)\left(1+\frac{2M_{BH}}{r}\right)\right)d\phi^2$$

$$\Delta = r^2 - 2r + a_k^2,\; h = \frac{\epsilon}{r^3}$$

$\epsilon =$ deformation parameter

❖ JP metric provides both the black hole (BH) and naked singularity (NS) solutions.

Model Equations:

❖ Radial momentum equation in CRF:

$$\gamma_v^2 v\frac{dv}{dr} + \frac{1}{e+p}\frac{dp}{dr} + \frac{d\Phi^{eff}}{dr} = 0$$

❖ Thermal bremsstrahlung emissivity:

$$\varepsilon_\nu^{ff} = \frac{32\pi e^6}{3m_e m_p^2 c^3}\sqrt{\frac{2\pi}{3m_e k_B}}\,\rho^2 T_e^{-\frac{1}{2}}(1+4.4\times10^{-10}T_e)\times e^{-h\nu/k_B T_e} g_B$$

❖ Monochromatic disc luminosity: $L_\nu = 2\int_{r_0}^{r_{edge}}\int_0^{2\pi} \varepsilon_\nu^{ff} H r\, dr\, d\phi$

Results:

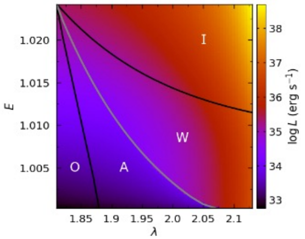


Fig. 1: Division of parameter space in $\lambda - E$ plane according to the nature of O, A, W and I-type flow topologies in the BH model. Colour bar indicates disc luminosity (L) in erg/sec.

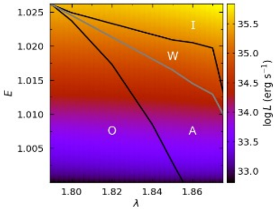


Fig. 2: Division of parameter space in $\lambda - E$ plane according to the behaviour of O, A, W and I-types flow topologies in the NS model.

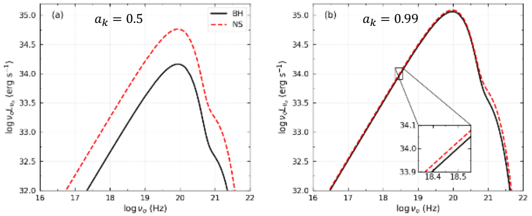


Fig. 3: Comparison of SEDs obtained from BH and NS models for different spins at a given flow parameters.

Conclusions:

❖ In both BH and NS models, disc luminosity is large for I-type flow topologies than other flow topologies.
❖ Luminosity distribution for the NS model is higher than the BH model.

References:

1. S. Patra, B. R. Majhi, and S. Das, Phys. Dark Univ. 37, 101120 (2022).
2. S. Patra, B. R. Majhi, and S. Das, 2308.12839 (2023).

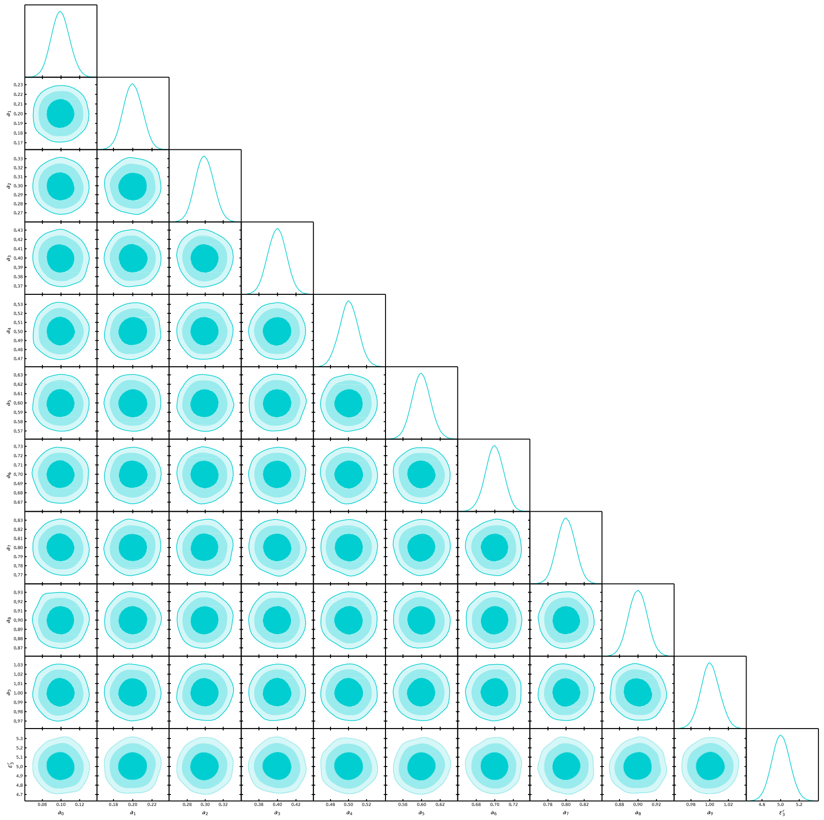
Testing The Kerr Paradigm Through Synchrotron Radiation

Masoumeh Ghasemi-Nodehi (XAO/CAS)

with Fatemeh Tabatabaei (IPM)

Summary

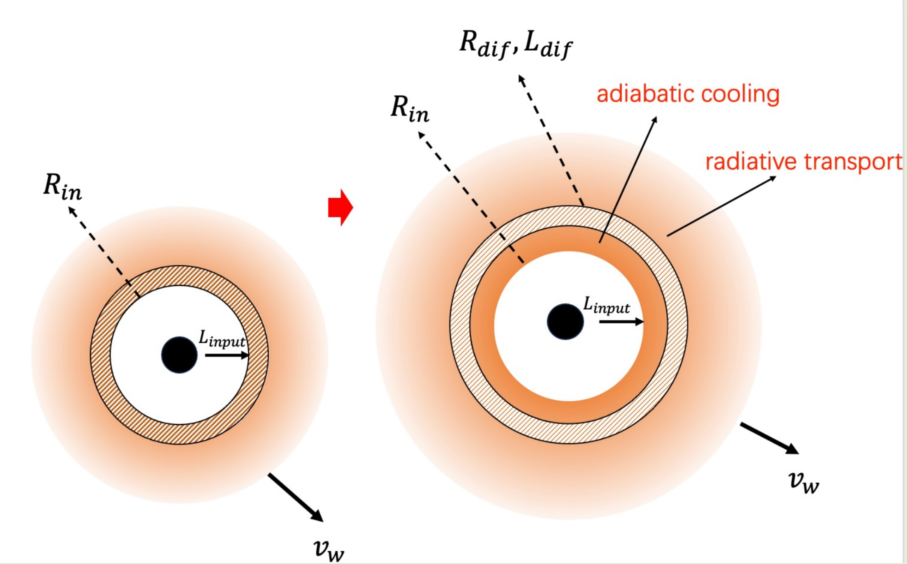
- **We are trying to test Kerr solution with electromagnetic radiation.**
- **We employed Synchrotron radiation to test. Using minimum total energy densities of cosmic rays and that of magnetic field, we generate synchrotron intensity.**
- **We mock synchrotron observations of 10 objects.**
- **We use MCMC method to fit model parameters.**
- **We use the Cardoso, Pani, Rico (CPR) deformed space time.**
- **Assuming uniform/gaussian prior, all parameters including spin and deformation parameters of CPR metric can be constrained. This means synchrotron radiation with bayesian approach using uniform/gaussian prior can distinguish Kerr and CPR space time.**
- **Assuming gaussian prior for spin parameter and uniform prior for metric deformation parameters, the spin parameter can be constrained but the deformation parameters can not be constrained. In this case, as deformation parameters can not be fitted, one cannot distinguish Kerr and CPR space time from synchrotron observation.**



Spectra of the radiative reprocessing in an outflow

Chun Chen, Rong-feng Shen
School of Physics and Astronomy, Sun Yat-sen University
chench386@mail2.sysu.edu.cn;shenrf3@mail.sysu.edu.cn

Fig 1. Schematic



The density profile of the outflow: $\rho(r,t) = \frac{\dot{M}}{4\pi r^2 v}$.

The temperature profile:

(1) For $r < r_{dif}$, $T(r) \propto r^{-2/3}$, since the gas temperature is determined by the adiabatically cooling.

(2) For $r_{dif} < r < r_{out}$, $T(r) \propto r^{-3/4}$, since the temperature profile is determined by the radiative transport.

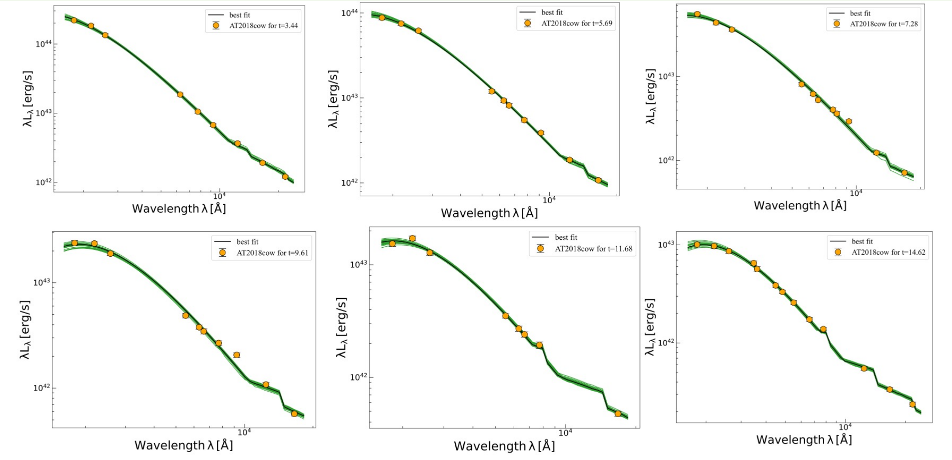


Fig 2 . Fitting of AT2018cow SED data.

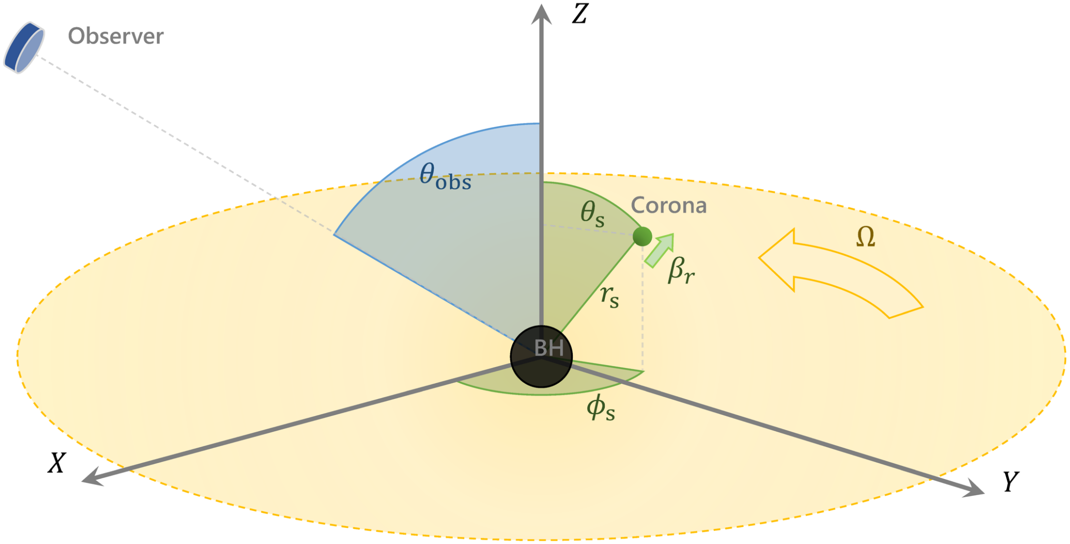
Conclusion

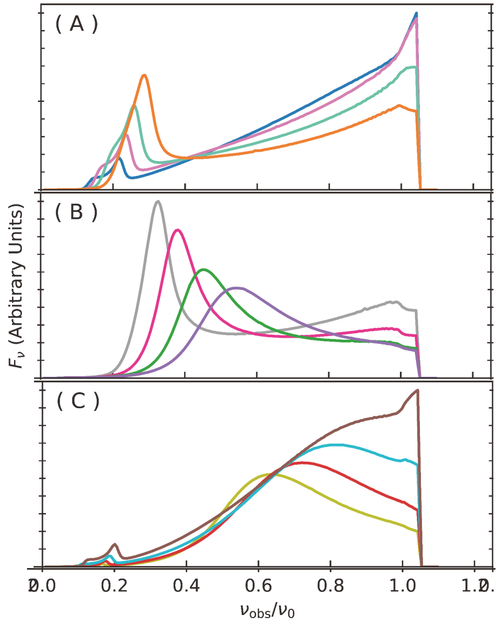
For AT2018cow, a supermassive star explosion event, the pre-SN mass $\gtrsim 8\ M_\odot$. The total mass of the outflow ~ $3\ M_\odot$, thus the residual compact object mass:$M_{obj} \gtrsim 8 - 3.046\ M_\odot \sim 5 M_\odot$. The compact object might be a stellar-mass BH.

Moving Corona and the Line Profile of the Relativistic Broad Iron Emission Line

Feng Yuan
University of Science and Technology of China

Collaborator: Yuan Y.-F. (USTC), Zhang S.-N. (IHEP)

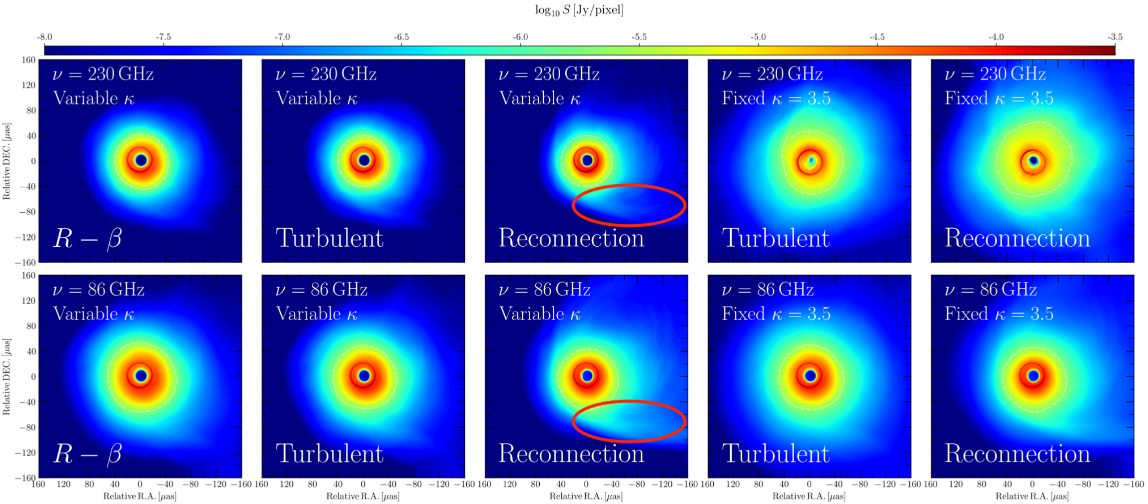


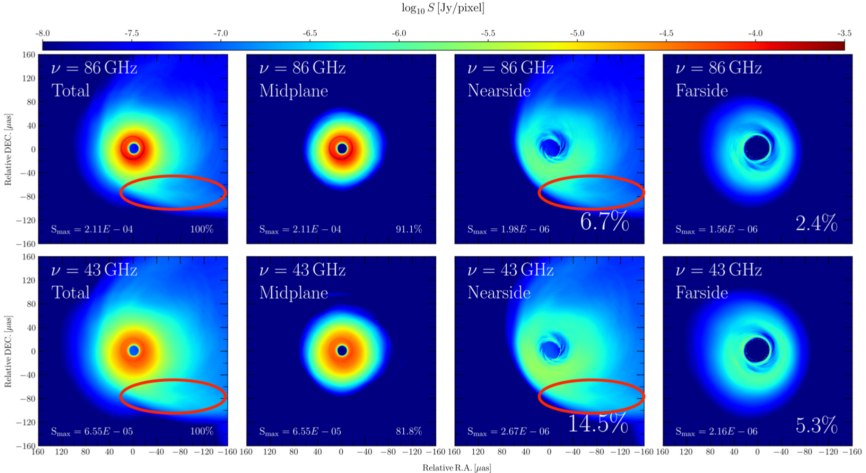


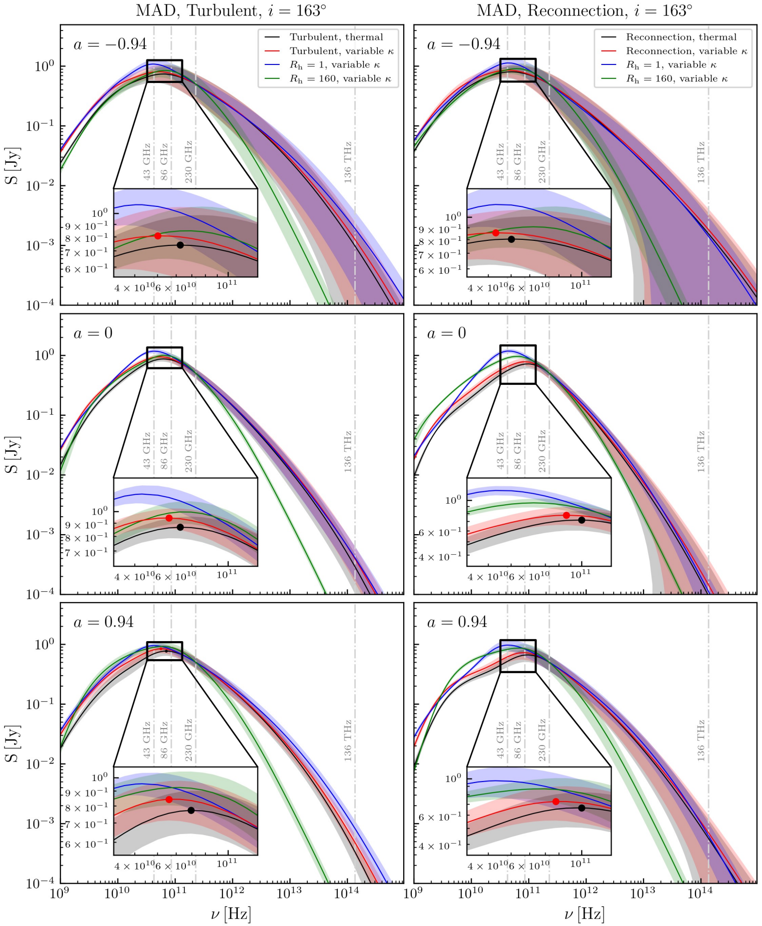
TSUNG-DAO LEE INSTITUTE 李政道研究所

Impacts of non-thermal emission on the images of black hole shadow and extended jets in two-temperature GRMHD simulations

Mingyuan Zhang, Yosuke Mizuno, Christian M. Fromm, Ziri Younsi and Alejandro Cruz-Osorio





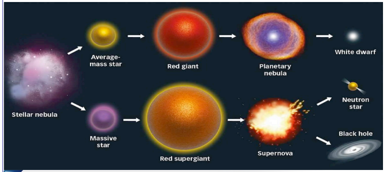


2023-12-12

Physical Analysis of Rastall PFRF Black Hole through Accretion Process

H. Rehman[1], G. Abbas[1,2] Abdul Jawad[3,4], Rong-Jia Yang[5], G. Mustafa[6,7]
1 Department of Mathematics, The Islamia University of Bahawalpur, Bahawalpur, Pakistan
2 National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, People's Republic of China
3 Institute for Theoretical Physics and Cosmology, Zhejiang University of Technology, Hangzhou 310023, People's Republic of Chi
4 Department of Mathematics, COMSATS University Islamabad, Lahore-Campus, Lahore 54000, Pakistan
5 College of Physics Science and Technology, Hebei University, Baoding 071002, People's Republic of China
6 Department of Physics, Zhejiang Normal University, Jinhua 321004, People's Republic of China
7 New Uzbekistan University, Mustaqillik Ave. 54, Tashkent 100007, Uzbekistan

The Islamia University of Bahawalpur



Introduction

- The adiabatic accretion onto the charged black hole surrounded by perfect fluid radiation field (PFRF) in Rastall gravity is addressed.
- One of the most interesting theories for describing the active galactic nuclei (AGNs) and quasars is matter accretion onto BHs.
- The increase in luminosity is linked to an increase in the accretion rate.
- In Rastall theory, the conservation is modified as follows

$$T^{\mu\nu}_{;\mu} = \lambda R^{\nu},$$

- where R is Ricci scalar and λ indicates the deviation of the Rastall theory from GR.
- The Field equations in Rastall theory are

$$G_{\mu\nu} + \kappa\lambda g_{\mu\nu} R = \kappa T_{\mu\nu},$$

- where κ is the Rastall gravitational coupling constant.

Charged Rastall Black Hole

$$ds^2 = -\Big(1 - \frac{2M}{r} + \frac{Q^2 - N_r}{r^2}\Big)dt^2 + \Big(1 - \frac{2M}{r} + \frac{Q^2 - N_r}{r^2}\Big)^{-1}(r)dr^2 + r^2(d\theta^2 + sin^2\theta d\phi^2)$$

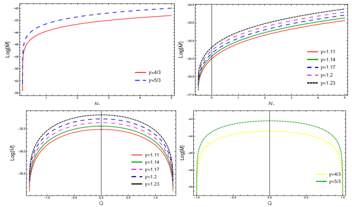
where M is the mass, Q is the charge and N_r is the Rastall parameter.

Mass Accretion Rate:

$$\dot{M} = M^2 m_b \pi n_\infty \Big(\big(5-3\gamma\big) + 6a_\infty^2\Big)^2 \Big(\frac{1}{2}\Big)^{\frac{3\gamma-4}{\gamma-1}} (5-3\gamma)^{\frac{1+\gamma}{2(\gamma-1)}} a_\infty^{-3} f(e),$$

where

$$f(e) = \Big[1 + \Big(\frac{\big(5-3\gamma\big) + 4\Big(3 - 4\Big(\frac{Q^2-N_r}{M^2}\Big)\Big)a_\infty^2}{\big(5 - 3\gamma + 12a_\infty^2\big)}\Big)^{\frac{1}{2}}\Big]^{\frac{3}{2}}.$$



Critical Radius and Velocity:

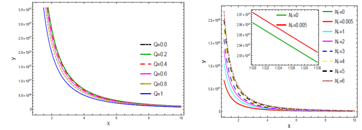
$$r_c \approx \frac{M(5-3\gamma) + 6a_\infty^2}{8a_\infty^2}\Big[1 + \Big(\frac{\big(5-3\gamma\big) + 4\Big(3 - 4\Big(\frac{Q^2-N_r}{M^2}\Big)\Big)a_\infty^2}{\big(5-3\gamma+12a_\infty^2\big)}\Big)^{\frac{1}{2}}\Big], \quad \gamma \neq \frac{5}{3},$$

$$r_c \approx \frac{3M\big(1+2a_\infty\big)}{8a_\infty}\Big[1 + \sqrt{3 - 16a_\infty\Big(\frac{Q^2-N_r}{3M^2}\Big)}\Big], \quad \gamma = \frac{5}{3},$$

$$u_c \approx \sqrt{\frac{4}{5-3\gamma}}a_\infty\Big[1 + \Big(\frac{5-3\gamma+4\Big(3-4\Big(\frac{Q^2-N_r}{M^2}\Big)\Big)a_\infty^2}{5-3\gamma+12a_\infty^2}\Big)^{\frac{1}{2}}\Big]^{\frac{-1}{2}}, \quad \gamma \neq \frac{5}{3}.$$

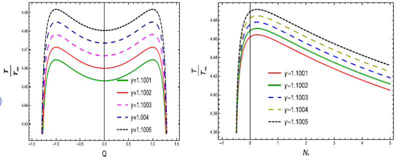
Compression Fator of Accreting Gas:

$$yu = \Big(\frac{x_s}{x}\Big)^2\Big(\frac{2}{5-3\gamma}\Big)^{\frac{1}{\gamma-1}}\sqrt{\frac{4}{5-3\gamma}}a_\infty \times \Bigg(1 + \sqrt{\frac{5-3\gamma+4\Big(3-4\big(\frac{Q^2-N_r}{M^2}\big)\Big)a_\infty^2}{5-3\gamma+12a_\infty^2}}\Bigg)^{\frac{3}{2}},$$



Temperature Ratio:

$$\frac{T_h}{T_\infty} = A^{\gamma-1}\Big[2M\Big(M + \sqrt{M^2 - (Q^2 - N_r)}\Big)^3 - (Q^2 - N_r)\Big(M + \sqrt{M^2 - (Q^2 - N_r)}\Big)^2\Big]^{\frac{1-\gamma}{2}}.$$



Conclusion

We have examined the accretion onto a charged BH surrounded by PFRF in Rastall gravity encircled by an unusual fluid source. We have provided the explicit formulas for the mass accretion, gas compression and outer horizon temperature for accreting polytropic gas. The analytical expressions for adiabatic temperature are computed. Also, by utilizing the boundary condition at infinity, we have examined the graphical behavior of temperature, by using the Ratall parameter N and charge Q.

References

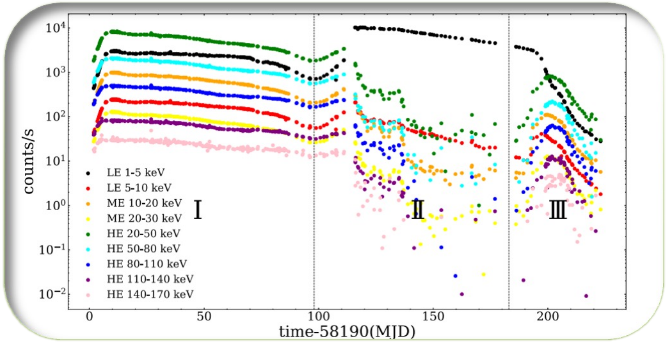
[1] H. Bondi, On Spherically Symmetrical Accretion Mon. Not. R. Astron. Soc. 112(1952)195.
[2] F.C. Michel. Accretion of Matter by Condensed Objects, Astrophys Space Sci. 15(1)(1972)153.

Paper Reference:
H. Rehman, G. Abbas, Abdul Jawad, Rong-Jia Yang, G. Mustafa
Physical analysis of Rastall PFRF black hole through accretion process
The European Physical Journal C, 83, 992 (2023)
DOI:10.1140/epjc/s10052-023-12184-5

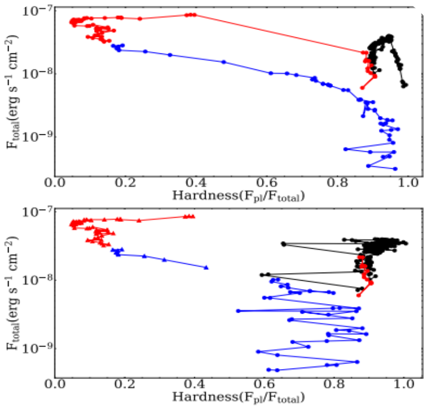
32nd Texas Symposium on Relativistic Astrophysics, Shanghai
Tsung-Dao Lee Institute, December 11-15, 2023

A possible overall scenario for the outburst evolution of MAXI J1820+070 revealed by *Insight*-HXMT

Jingqiang,Peng

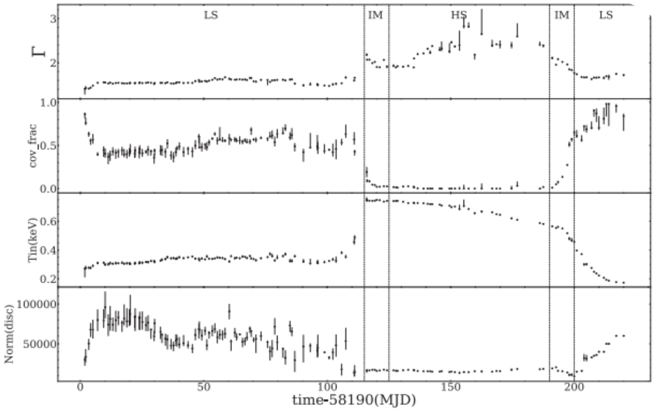


Light curves during the outburst of MAXI J1820+070 recorded by Insight-HXMT in 2018.

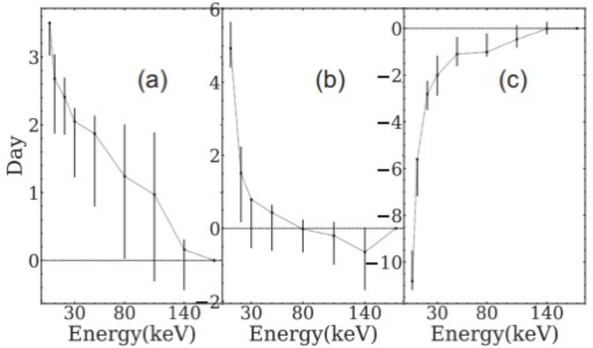


Top panel: the Insight-HXMT HID of MAXI J1820+070.

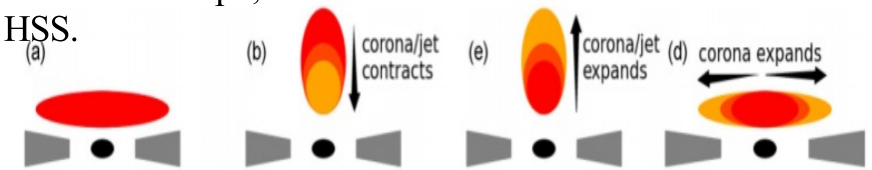
Bottom panel: by taking into account the time lags, the tracks can be reformed mostly in a linear shape, except for the data in HSS.



Spectral evolutions of the outburst



The lag–energy relationship estimated by the light curve of each energy segment for HE 140–170 keV.



Schematic figure illustrating the evolution of the corona and jet of MAXI J1820 + 070.

Shadows of Loop Quantum Black Holes: constraining LQG with EHT observation

Speaker: Hong-Xuan Jiang (TDLI, SJTU)

Method:

Semi-analytical polarized GRRT simulation of RIAF in the spacetime of LQBH.

Results:

1. Enlarged ring from LQBH.
2. Maximum LQ parameter P constrained from EHT observation:
   Sgr A* is 0.2, M 87* is 0.07

Collaborators: Cheng Liu (SPA, SJTU), Indu K. Dihingia (TDLI, SJTU), Yosuke Mizuno (TDLI, SJTU), Tao Zhu (UCGWP, ZJUT), et al.