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# Thermal bremsstrahlung emission from accretion disc in non-Kerr spacetime

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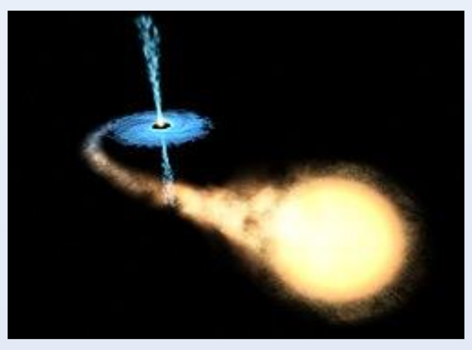
## Motivation

- Accretion flows is a prolific physical process to generate energy spectrum in AGN and BHXRBs.
- Alternative gravity theory is useful to explain LIGO and Virgo distinctive observational results.
- Johannsen-Psaltis (JP) metric is described by a deformation parameter ($\epsilon$) in addition to the mass ($M_{BH}$) and spin ($a_k$).
- JP metric provides both the black hole (BH) and naked singularity (NS) solutions.



## Objectives

- Explore accretion dynamics in the JP non-Kerr spacetime.
- Study the effect of deformation parameter ($\mathcal{E}$) on the accretion solutions and associated spectral energy distributions (SEDs).

## Model Equations

- JP metric: $$ds^2 = -\left(1 - \frac{2M_{BH}}{r}\right)(1+h)dt^2 - \frac{4M_{BH}a_k}{r}(1+h)dtd\phi + \frac{r^2(1+h)}{\Delta + a_k^2 h}dr^2 + (r^2 + a_k^2(1+h)(1+\frac{2M_{BH}}{r}))d\phi^2, \Delta = r^2 - 2r + a_k^2, h = \epsilon/r^3$$
- Radial momentum equation: $$\gamma_v^2 v\frac{dv}{dr} + \frac{1}{e+p}\frac{dp}{dr} + \frac{d\Phi^{eff}}{dr} = 0$$
- Thermal Bremsstrahlung Emissivity: $$\varepsilon_\nu^{ff} = \frac{32\pi e^6}{3m_e m_p^2 c^3}\sqrt{\frac{2\pi}{3m_e k_B}}\,\rho^2 T_e^{-\frac{1}{2}}(1+4.4\times10^{-10}T_e) \times e^{-h\nu/k_B T_e}\bar{g}_B$$
- Monochromatic disc luminosity: $$L_\nu = 2\int_{r_0}^{r_{edge}}\int_0^{2\pi}\varepsilon_\nu^{ff} Hr\,dr\,d\phi$$

## Results

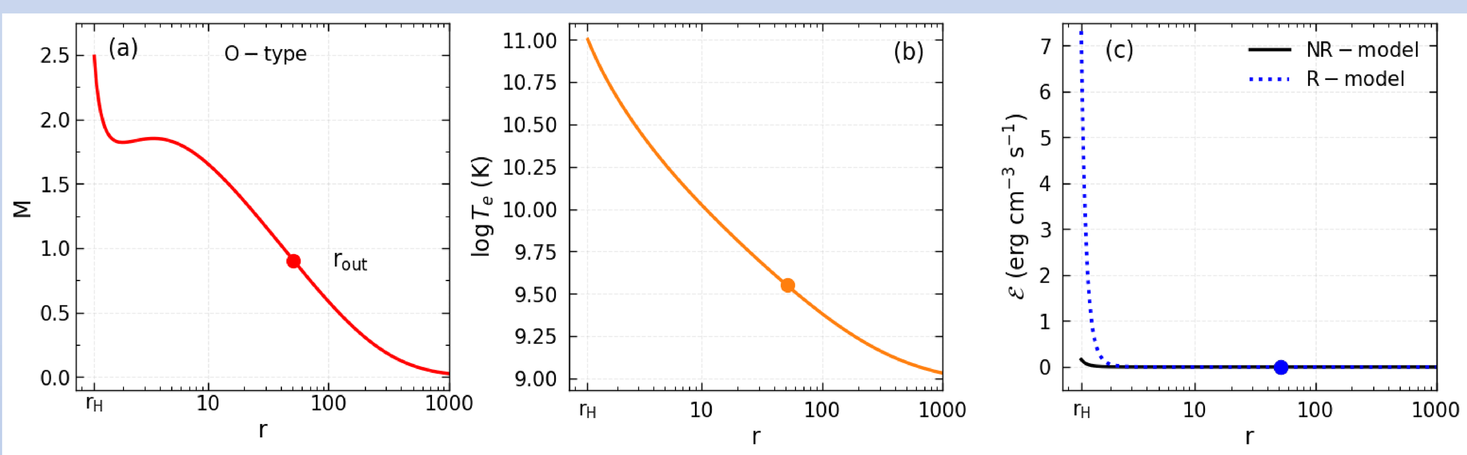



Fig. 1: Variation of (a) Mach number ($M = v/C_s$) (b) electron temperature ($T_e$) and (c) emissivity ($\mathcal{E}$) with radial coordinate (r).

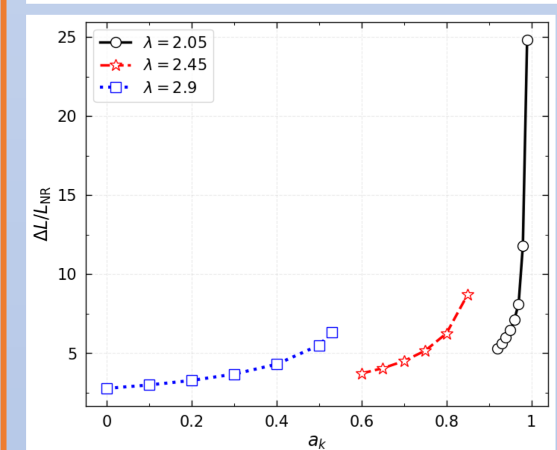



Fig. 2: Relative change in bolometric disc luminosity ($L$) as a function of $a_k$.

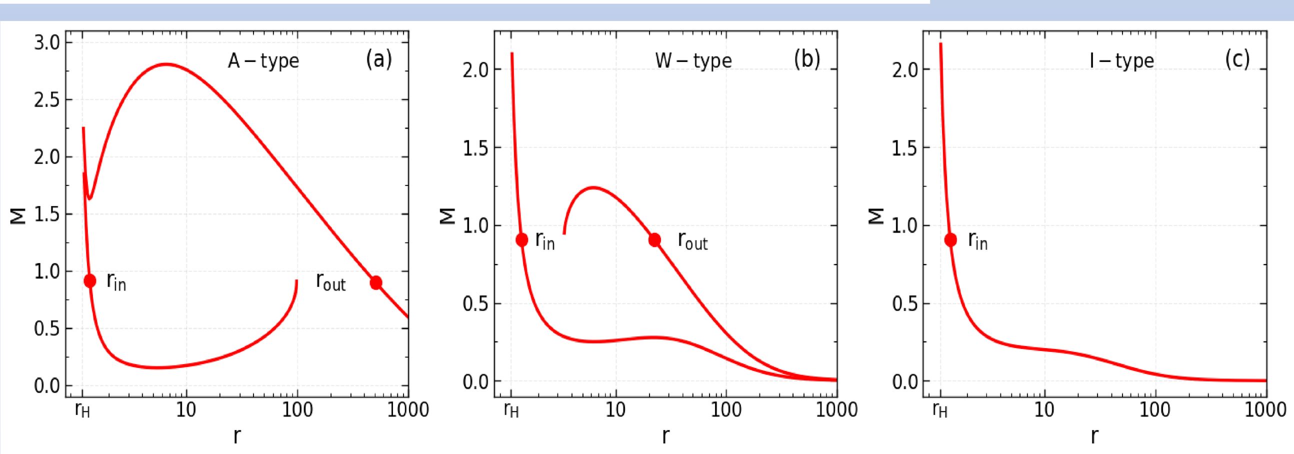



Fig. 3: Behaviour of accretion solutions for A, W and I-type flow topologies in the BH model.

### Entropy Criterion

- Region A: $\dot{\mathcal{M}}(\text{in}) > \dot{\mathcal{M}}(\text{out})$
- Region W: $\dot{\mathcal{M}}(\text{in}) < \dot{\mathcal{M}}(\text{out})$

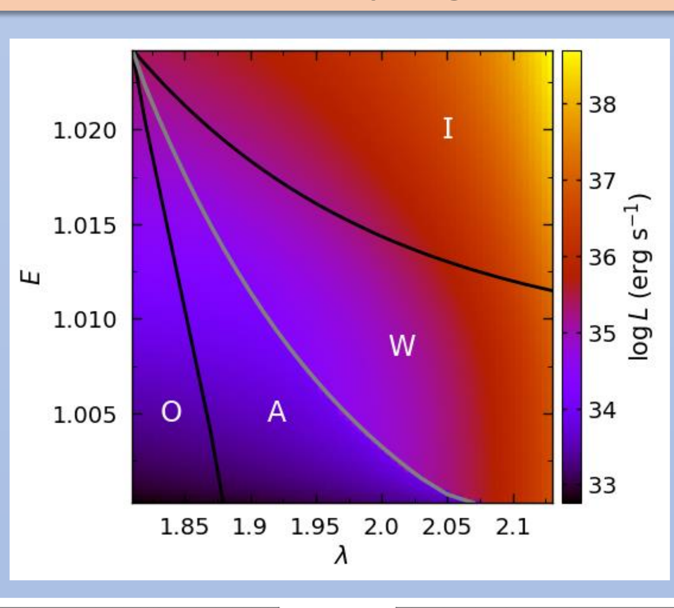



Fig. 4: Division of parameter space in energy and angular momentum ($\lambda - E$) plane according to the nature of flow topologies (e.g., O, A, W and I-types) in the BH model. Colour bar indicates disc luminosity ($L$) in erg/sec.

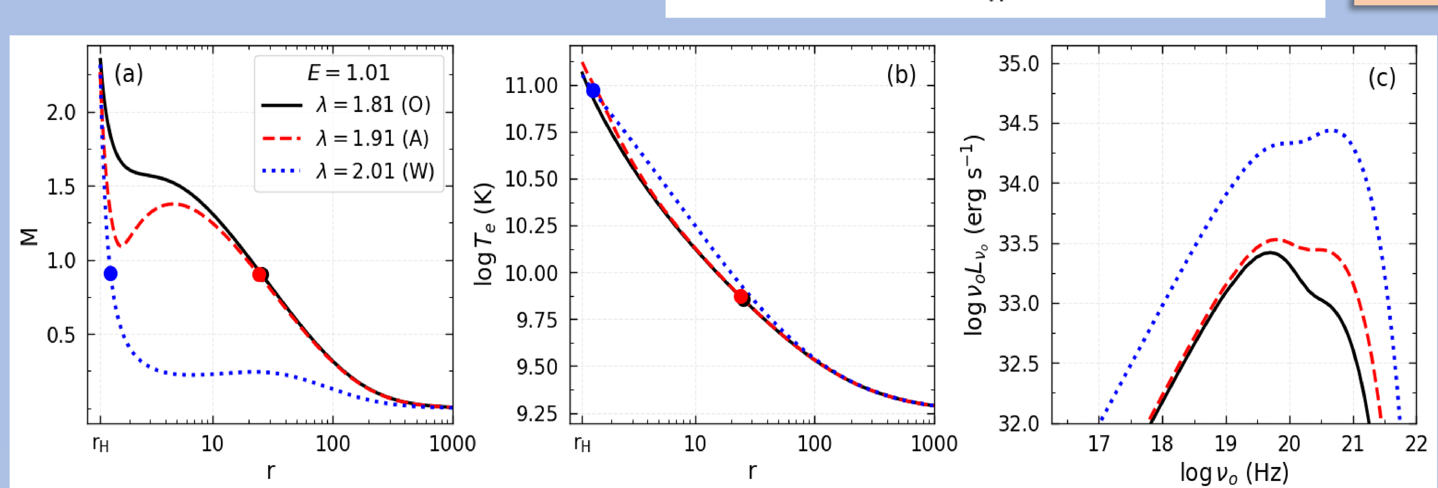



Fig. 5: (a) Global accretion solutions (b) electron temperature profiles (c) spectral energy distributions (SEDs) for O, A and W-type flow solutions.

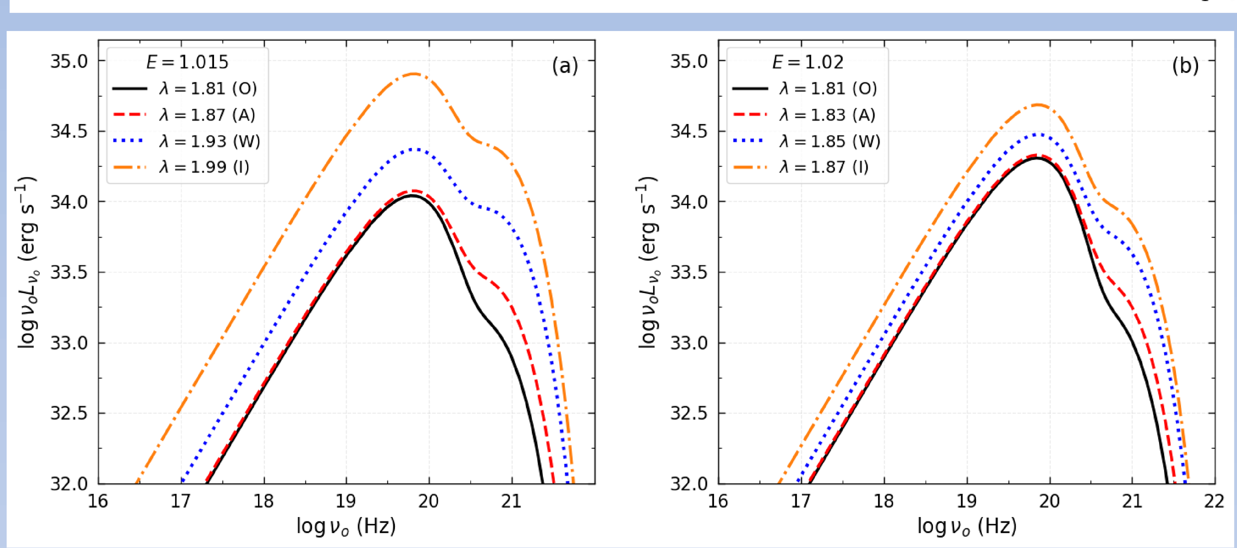



Fig. 6: SEDs for O, A, W and I-type accretion solutions for different flow energies in the BH model.

| $E$ | $\lambda$ | $r_{in}$ | $r_{out}$ | Type |
|---|---|---|---|---|
| 1.01 | 1.81 | --- | 25.3308 | O |
| | 1.91 | 1.7184 | 23.9365 | A |
| | 2.01 | 1.3981 | 22.2109 | W |
| 1.015 | 1.81 | --- | 15.7051 | O |
| | 1.87 | 1.9952 | 14.633 | A |
| | 1.93 | 1.6078 | 13.1974 | W |
| | 1.99 | 1.4136 | --- | I |
| 1.02 | 1.81 | --- | 10.3324 | O |
| | 1.83 | 2.5479 | 9.7945 | A |
| | 1.85 | 2.1608 | 9.0972 | W |
| | 1.87 | 1.9008 | --- | I |

Table I: Flow parameters, critical points and type of solutions associated with Figs. 5 and 6.

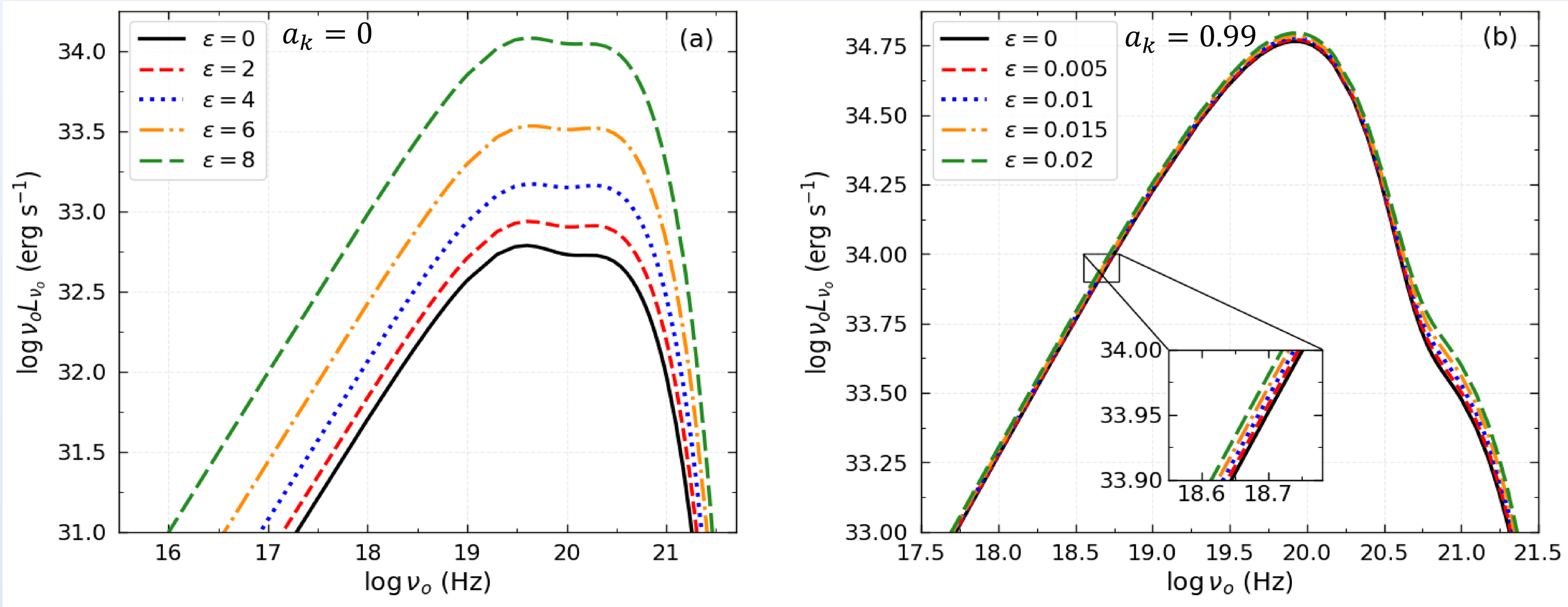



Fig. 7: Effect of deformation parameter ($\epsilon$) on the SEDs for different spin parameters $a_k$.

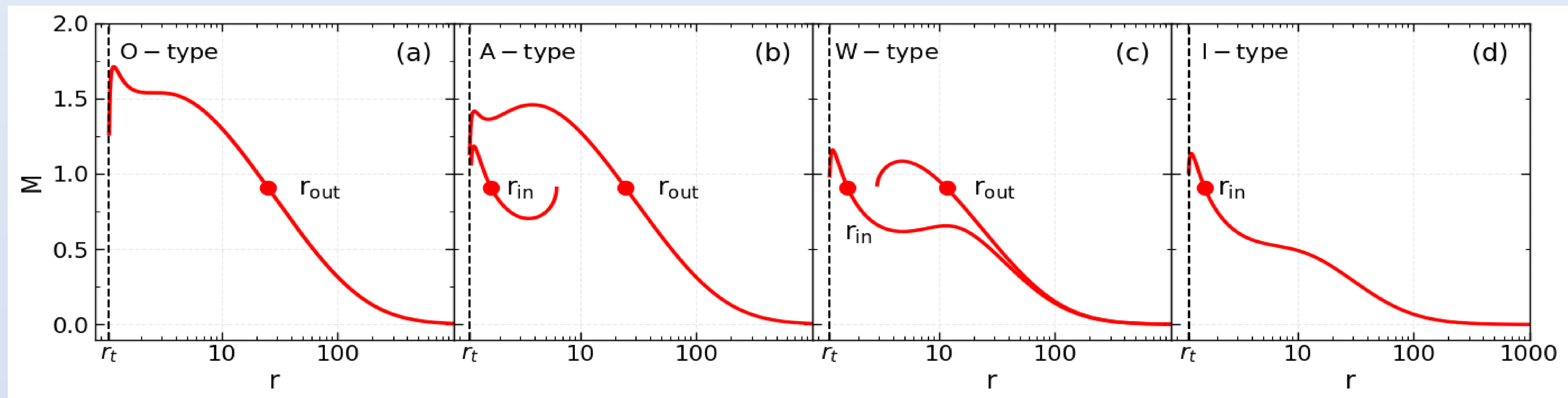



Fig. 8: Behaviour of accretion solutions in O, A, W and I type flow topologies in the NS model. Solutions are truncated at some radius $r_0 = r_t$.

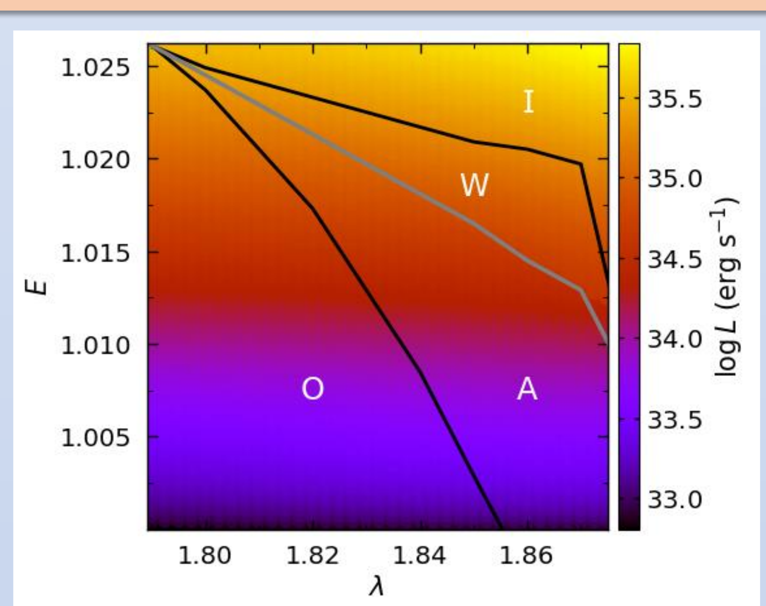



Fig. 9: Division of parameter space in $\lambda - E$ plane according to the behaviour of O, A, W and I-types flow topologies in the NS model. Colour bar at the right indicates disc luminosity ($L$) in erg/sec.

| $E$ | $\lambda$ | $r_{in}$ | $r_{out}$ | Type |
|---|---|---|---|---|
| 1.015 | 1.815 | --- | 15.6082 | O |
| | 1.835 | 2.1152 | 15.2698 | A |
| | 1.855 | 1.6405 | 14.8097 | W |
| | 1.875 | 1.4214 | --- | I |
| 1.0175 | 1.815 | --- | 12.6171 | O |
| | 1.835 | 2.0377 | 12.2021 | A |
| | 1.855 | 1.6895 | 11.7311 | W |
| | 1.875 | 1.4057 | --- | I |
| 1.02 | 1.81 | --- | 10.2935 | O |
| | 1.83 | 2.0806 | 9.744 | A |
| | 1.85 | 1.7361 | 7.4222 | W |
| | 1.87 | 1.4403 | --- | I |

Table II: Flow parameters, critical points and type of accretion solutions associated with the spectral energy distributions (SEDs) in Fig. 10.

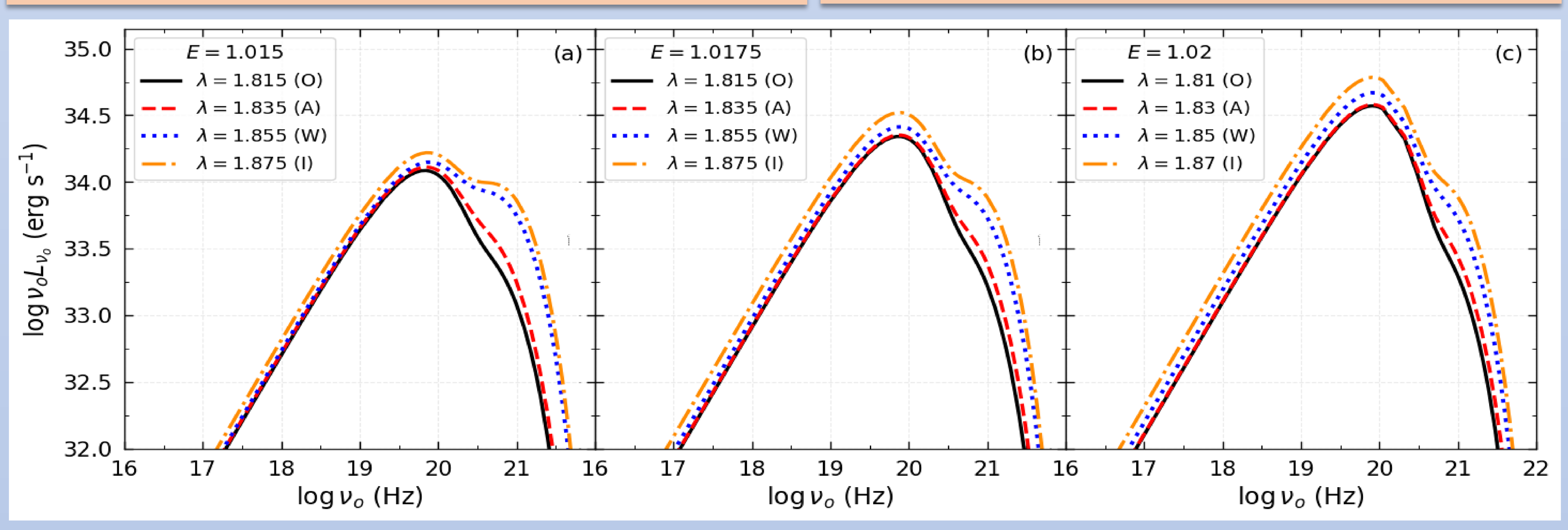



Fig. 10: SEDs corresponding to the O, A, W and I-type accretion solutions around the NS object for different flow energies.

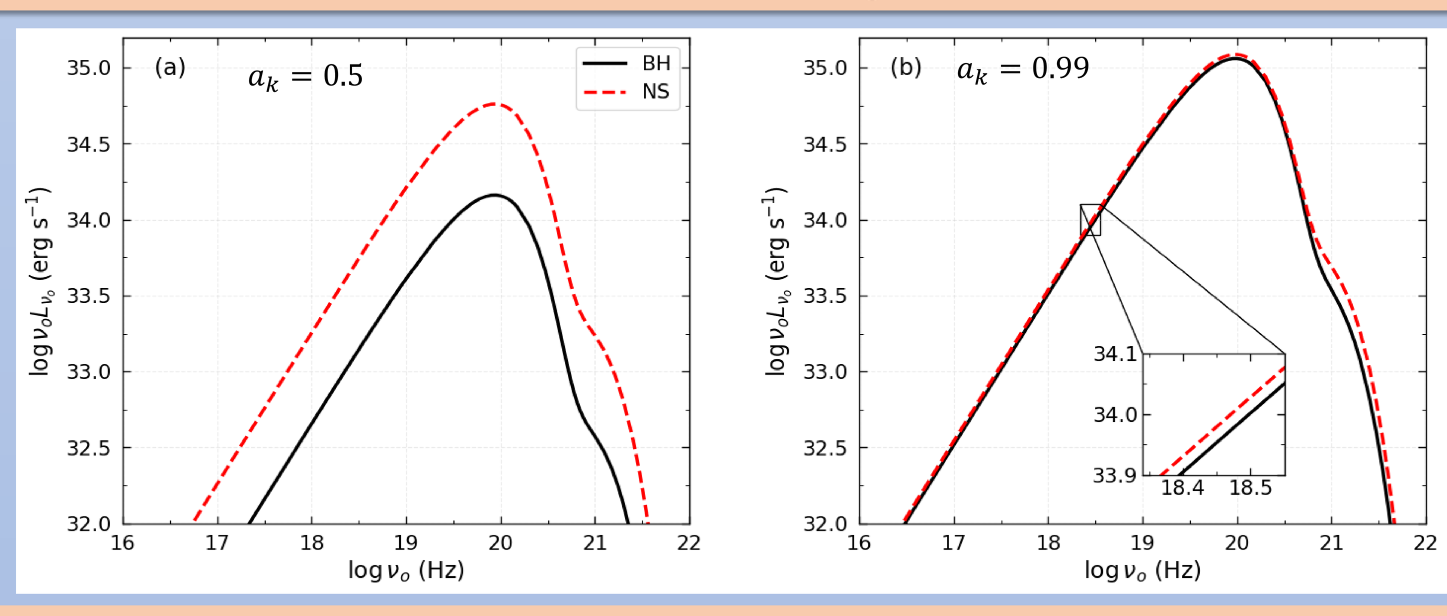



Fig. 11: Comparison of SEDs obtained from BH and NS models at the same flow parameters ($\lambda, E$).

## Conclusions

- Electron-electron emission can surpasses electron-ion emission for hot accretion flow.
- Relativistic effect dominates for high spinning BHs.
- A non-Kerr BH produces high luminous power spectrum compared to a Kerr BH.
- In BH model, SEDs for W and I-type topologies differ significantly from O and A-types topologies.
- In NS model, SEDs for different flow topologies are identical, which is inconsistent with the results in BH model.
- In both BH and NS models, I-type topologies produce maximum SEDs than other flow topologies.
- Luminosity distribution for the NS model is higher than the BH model. These results help to distinguish BH and NS objects through the quantitative analysis.

## 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).

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