Assignment 8

1 Final Project (Improved Proposal)

- (*50 Points*) Based on the comments you received, improve your project summary by:
  - giving a descriptive title,
  - a summary in your own words of the scientific problem to be addressed in your paper,
  - a description of the simulation code and problem setup you plan to use,
  - a description of the analyses you plan to perform on the simulation output.
  - At least one page of scientific introduction explaining the problem you are studying and why it is interesting, and reviewing relevant theoretical, computational, and observational literature.
- Remember:
  - always describe (as best you can at each point) the approach you intend to take.
  - provide some references
  - as an example, in the next page you will find a one-page proposal that I once submitted for a final project. Note that in less than one page I was able to provide the summary of the scientific project, describe the simulation, provide some hints on the analysis of the data and gave proper references. When I wrote that, I did not know how to approach the problem properly, but I read enough to have an idea.

The effect of a rotating lamppost on the iron line of reflected X-ray binary spectra

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Some observations of low-mass X-ray binaries have shown a 'Type-C' low-frequency quasi-periodic oscillations (QPOs) in their X-ray flux, with a frequency that evolves from $\sim$ 0.1 to 30 Hz [2]. These oscillations are observed when the X-ray spectrum transitions from the power-law-dominated hard state to the thermal disc-dominated soft state. In Ref. [1], a putative modulation of the iron line energy at 0.2 Hz was reported, providing evidence that the Type-C QPO observed is driven by systematic changes in the accretion geometry over the course of a QPO cycle. Their interpretation was that the QPO is produced by Lense–Thirring precession of the hot inner flow, constituting the first detection of this effect in the strong gravitation regime, as the only mechanism by which the line energy can vary without a geometric change is through shifts in the rest-frame line energy driven by changes in the disc ionization state. I want to develop a model that can lead to the modulation in the iron line energy at some frequency, in the same spirit of the authors in Ref. [1], but without assuming a change in the disk. I want to consider a rotating corona under the lamppost geometry that illuminates the disk at some r above it.

I want to calculate the illuminating flux for a lamp in Keplerian rotation just above the disk. The lamp will be defined by its cylindrical radius r_{lamp} (in the equatorial plane), its height above the disk z_{lamp}, and its azimuth ϕ_{lamp}, and modeled by a small sphere emitting radiation isotropically with a specific intensity at lamp-frame frequency. Photons will be ray traced to the Keplerian observer comoving with the disk at (r_{obs}, ϕ_{obs}) and then the illuminating specific intensity in the disk frame is computed assuming an angle i. With this illuminating profile, I will use Xillver [4] for computing the reflected spectrum. Xillver gives the reflected specific intensity as a function, mainly, of the ionization parameter ξ . I am planning to compute the illuminating flux with the GYOTO ray-tracing code [3], which launches null geodesics from an observer's screen, that are integrated backward in time to reach an astrophysical object.

The simulation will produce spectra that I can compare a) between the rotating-lamp and the power-law contribution, b) to different rotating-lamp spectra ray-traced at different times. I need to carefully analyze the variation with time of the lines, in particular around the most prominent one the Fe $K\alpha$ to investigate a) how the location of the lamp impacts the relative maxima of the direct component vs. the reflected component (in particular in the iron-line region) and b) the motion of the iron-line centroid as the lamp rotates and compare to data, by fitting the line region and modeling the energy shift with phase.

References

[1] Ingram, A., van der Klis, M., Middleton, M., Done, C., Altamirano, D., Heil, L., Uttley, P. and Axelsson, M., 2016. A quasi-periodic modulation of the iron line centroid energy in the black hole binary H1743– 322. Monthly Notices of the Royal Astronomical Society, 461(2), pp.1967-1980.

[2] Van Der Klis, M., 2006. Overview of QPOs in neutron-star low-mass X-ray binaries. Advances in Space Research, 38(12), pp.2675-2679.

[3] Vincent, F.H., Paumard, T., Gourgoulhon, E. and Perrin, G., 2011. GYOTO: a new general relativistic ray-tracing code. Classical and Quantum Gravity, 28(22), p.225011.

[4] Garcia, J., Dauser, T., Reynolds, C.S., Kallman, T.R., McClintock, J.E., Wilms, J. and Eikmann, W., 2013. X-ray reflected spectra from accretion disk models. III. A complete grid of ionized reflection calculations. The Astrophysical Journal, 768(2), p.146.