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NOVAS: A NUMERICAL OBSERVATORY OF VIOLENT ACCRETING SYSTEMS

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Abstract. Here we are presenting NOVAs, a Numerical Observatory of Violent Accreting systems, which couples a GR AMR MPI (GRAMRVAC) code able to follow accretion around a Kerr Black-hole with the ray-tracing code GYOTO. Together, they allow us to test different models by running the simulation and obtaining spectral energy distributions and power-density spectrums from which we can extract the same observables as for 'real' observations, hence making it a Numerical Observatory.

1 Introduction: why a numerical observatory?

While there are a lot of observational data and theoretical models trying to explain them, it is hard to bridge the gap between observables, such as the energy spectrum for example, and an analytical or numerical model. This is especially true when looking at highly relativistic systems such as the inner region of an accreting black-hole. The idea behind NOVAs is to create consistently, from numerical GR-(M)HD simulations the same outputs as we have from observations, *i.e.* lightcurve, energy spectrum and Power-Density Spectrum, in a compatible format to be analyzed by software like `xspec`. It makes use of several existing or in development codes:

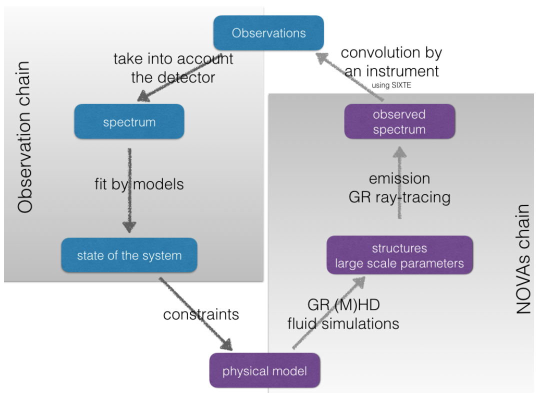

Fig. 1. How the numerical observatory of `NOVAs` works when compared with 'standard' observations. This emphasized how a numerical observatory is complementary to 'standard' observation.

• `GRAMRVAC:` All the general relativistic (GR) fluid dynamics are done with the general relativistic version of MPI-AMRVAC*.
• `GYOTO:` For all the GR ray-tracing computations, we use the open-source† GYOTO code. For details see Vincent et al. (2011).
• `SIXTE:` In order to add instrumental effects we use the SIXTE‡ package for X-Ray telescope observation

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†Freely available at `http://gyoto.obspm.fr`
‡Freely available at `https://www.sternwarte.uni-erlangen.de/research/sixte/index.php`

simulations. It allows to undertake instrument performance analyses and to produce simulated event files for mission and analysis studies.

On top of developping the GR formalism for `GRAMRVAC` we have added to the codes, when needed, new outputs and formats so that one can smoothly go from the fluid simulation to the spectrum observed by an instrument.

2 First Applications

There are numerous applications to that numerical observatory; among them we can make predictions from models, test how certain observed features can be explained, test the impact of parameters that are hard to pinpoint such as the inclination, and also test the detectability of certain features with new instruments using `SIXTE`. Here we are presenting one example of such application where we try to understand the reason behind the fact that it is harder to obtain good χ^2 for the spectral fit of high-spin systems, and that for every state.

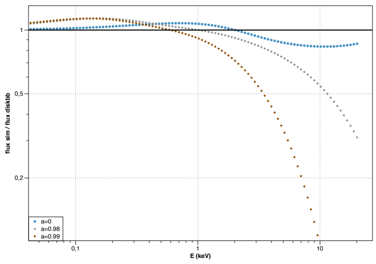

Fig. 2. Evolution as function of energy of the simulated flux over the `diskbb` flux for the same system.

In order to explore the difference between high and low spins we look at the shape of the spectrum, or more precisely at how the shape of the spectrum compares with the `diskbb` spectrum which is often used to fit spectral data. Fig.2 shows that for low spin (blue points) the full GR simulated flux is relatively close to the `diskbb` flux that it is fitted against but as soon as we go to high spin the overall shape of the spectrum starts to diverge. This would then lead to a worse χ^2 for higher spins than can be achieved for lower spins.

3 Conclusion

By combining smoothly two GR codes, one providing a full hydrodynamical solution and one providing the ray-tracing of the emission, we now have a fully functional numerical observatory which allows us to obtain spectrums and lightcurves of theoretical models with limited hypotheses. Further linking the output of NOVAs with SIXTE allows us to also test the capacity of new instruments to distinguish between models and explore new possibilities.

Among the numerous possible applications of NOVAs, we explore potential causes for the difficulty encountered when fitting high-spin systems, and in particular the inability to obtain good χ^2. We found that the shape of the spectrum diverges from the model used to fit them as the spin increases, causing the fit to be of lesser quality.

Acknowledgements

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References

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