A (W.I.P) Monte Carlo Polarized Comptonization module for Black Hole Coronae

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Astrophysical Context

- Accretion disks in X-ray binaries show non-thermal emission.
- Hard X-ray emission is commonly interpreted as Comptonization of soft photon by energetic electrons.
- The emission properties are strongly connected to both the microphysics of the energization and radiation mechanism, as well as the global geometry of the system
- IXPE images provide measurements of polarization which can help constraining the geometries of coronae.

Numerical Context and Motivations

- Current radiative transfer codes mainly focus on semi-analytical or phenomenological models for the hot plasma.
- There is currently no way to extract complex Compton signatures from global general relativistic PIC simulations.
- We aim to fill that gap by developing a Comptonization code that can handle arbitrary electron distributions in Kerr spacetime.
  - We develop a code that can handle distributions from PIC simulations
  - With compatibility on CPU and GPU

I. Compton Diffusion — Energy spectrums

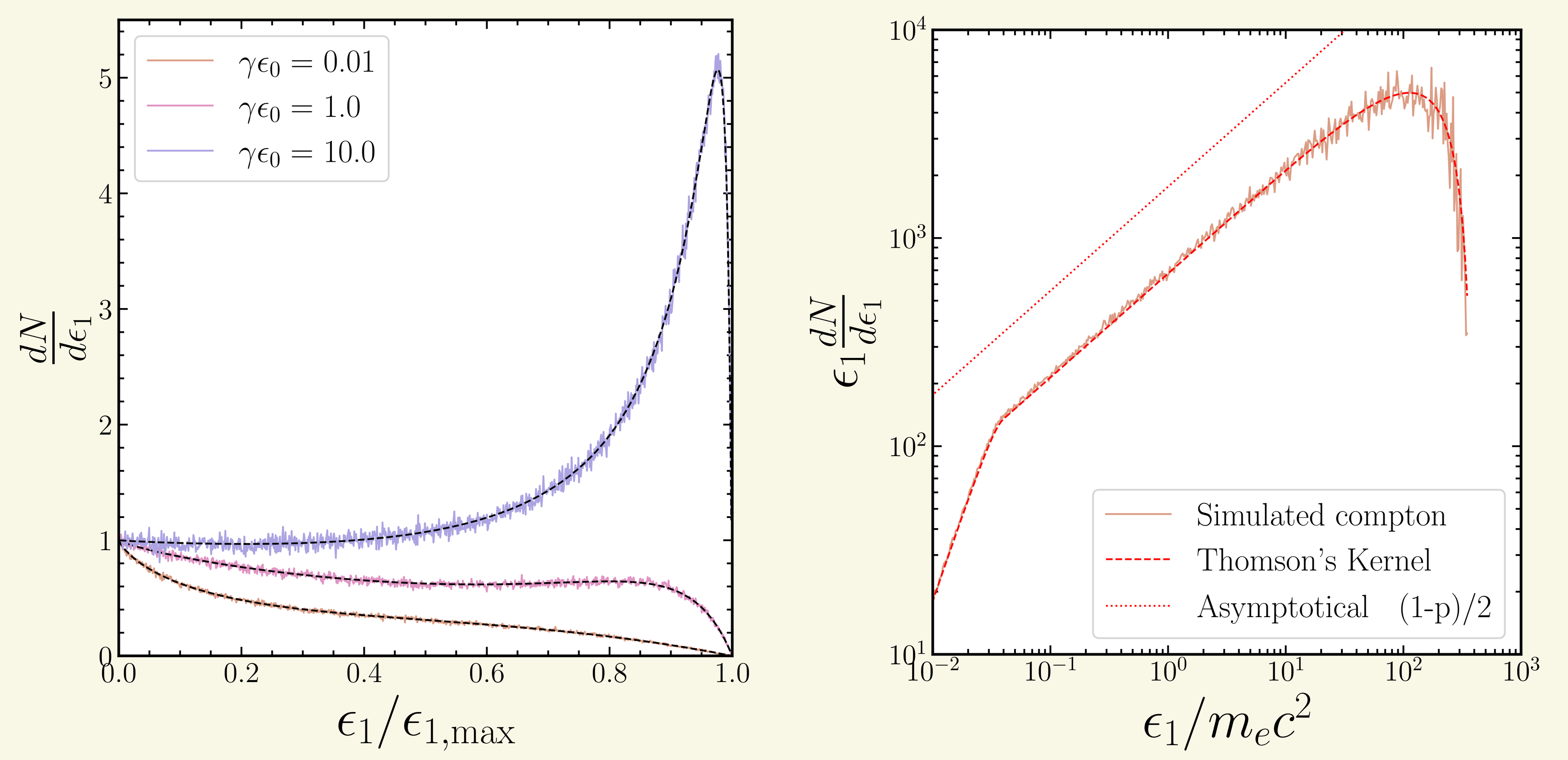


Figure: Left: Energy spectrum of a monoenergetic photon beam on a monoenergetic electron cloud, comparison with Jones predictions. Right: Diffusion of a monoenergetic photon beam on a powerlaw electron cloud, comparison with Thomson's kernel. Dotted lines show the analytical solution.

II. Compton Diffusion — Polarization

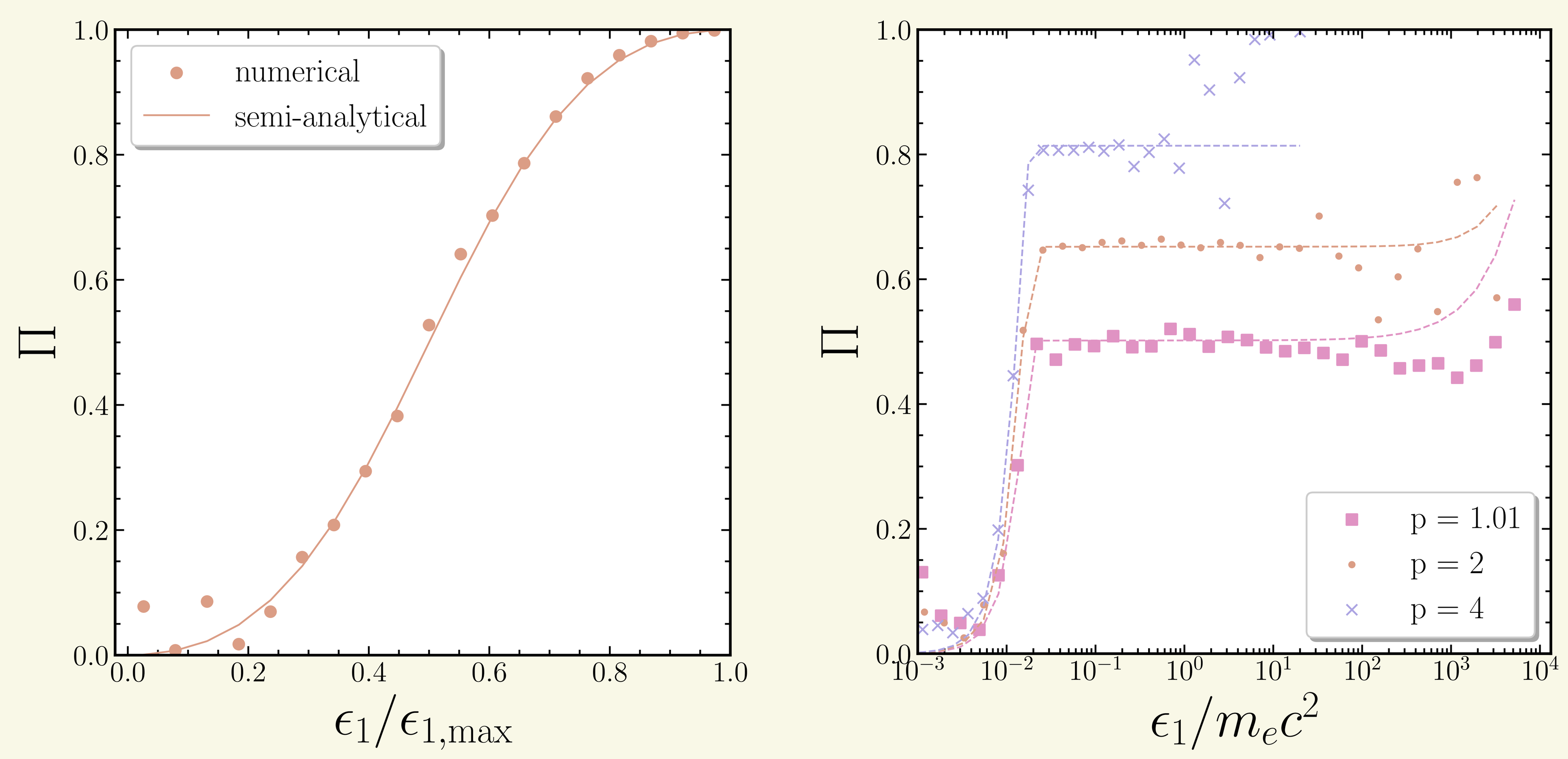
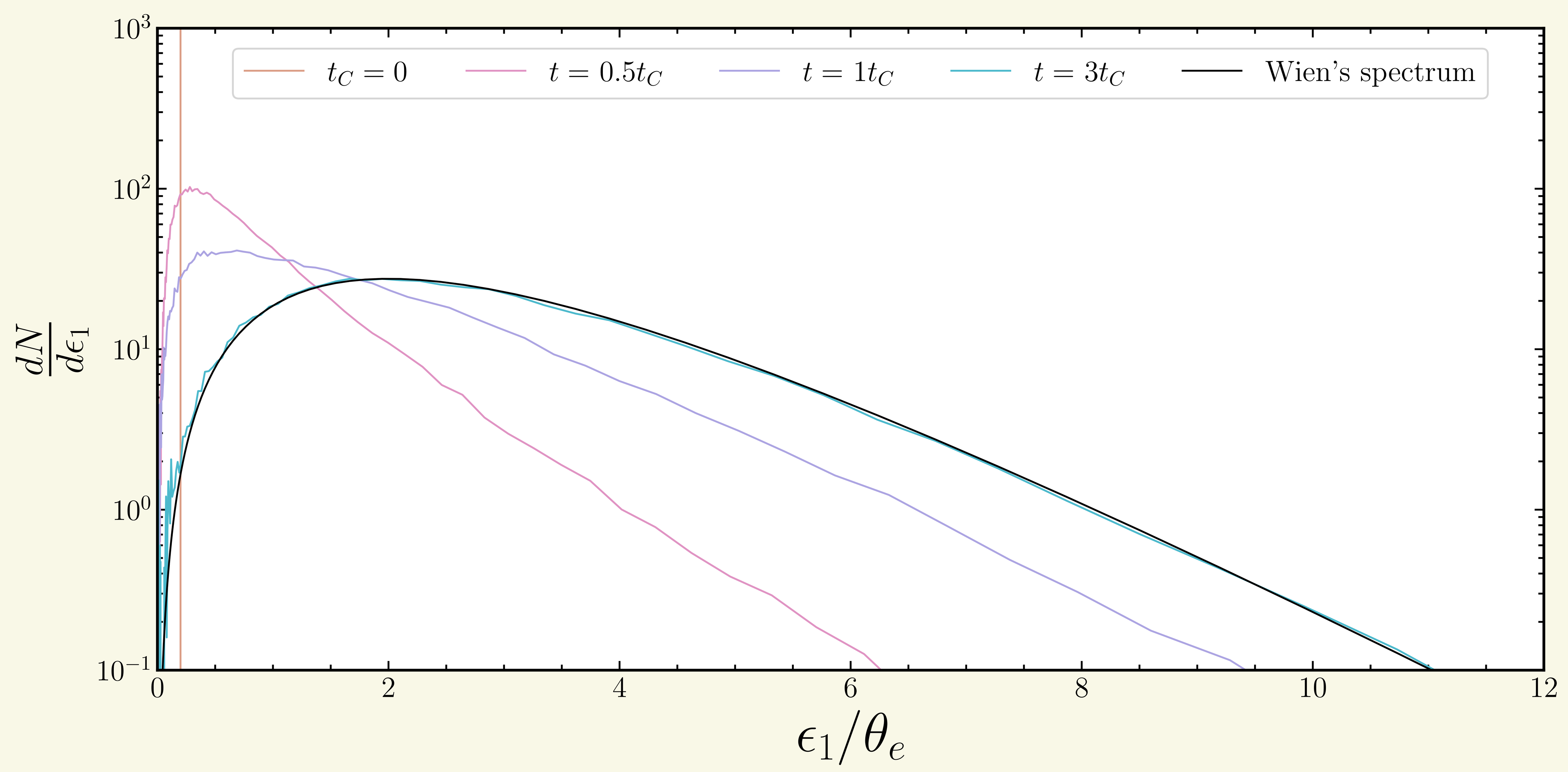


Figure: Left: Polarization degree of a monoenergetic photon beam on a monoenergetic electron cloud. Right: Polarization degree of a monoenergetic photon beam on a powerlaw electron cloud. Both spectrums are computed from the observer point of view at the spherical coordinate ($\theta = 85, \phi = 0$)

III. Photon-electron thermal gas equilibrium

Figure: Energy spectrum of the photon population after scattering on a thermal electron gas of normalized temperature $\theta_e = 0.01$. The spectrum is shown at multiple time steps expressed in units of $t_C = 1/c\sigma_T n_e \theta_e$. In the case of saturated Comptonization ($\tau \gg 1$), the spectrum tends over time to match Wien's law: $f_{\text{Wien}} \propto \left(\frac{\epsilon_1}{\theta_e}\right)^2 e^{-\frac{\epsilon_1}{\theta_e}}$



Conclusion and perspectives

- We provide a parallel CPU/GPU Comptonization module in the Kerr metric.
  - C++, SYCL framework for best compatibility between CPU and GPU (250000 photons interaction per sCPU)
  - GR pusher with Kerr metric
  - Compton scattering with Thomson and Klein Nishina regimes
  - Polarization is also handled
- Work done during a 6 month internship, to be continued during a thesis this Fall.
- Next step:
  - Test finite optical depth.
  - Test GR + polarization.
  - Load electron distributions from PIC simulation to get non thermal and non isotrope distribution functions.