The GYOTO code: introduction

Frédéric Vincent[1]
and the GYOTO team

[1]CNRS, Observatoire de Paris/LESIA

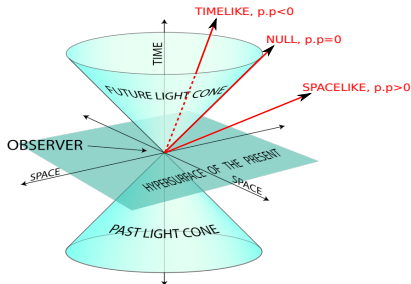Frédéric VINCENT   The GYOTO code: introduction
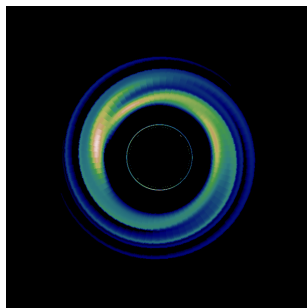
The basics

- Given some spacetime $(\mathcal{M}_{4D}, g_{\mu\nu})$
  $\mathcal{M}_{4D}$ 4D smooth manifold, g Lorentzian metric
- GYOTO integrates the **equation of geodesics**

$$\ddot{x}^{\mu} + \Gamma^{\mu}_{\alpha\beta}\dot{x}^{\alpha}\dot{x}^{\beta} = 0$$

- Geodesics: timelike or null (+ spacelike also possible)

What is it used for?

- Doing astrophysics
- Light curves, spectra, images
- of "stuff" around typically black holes / neutron stars
- Metrics implemented so far:

  rotating black hole,

  rotating stars and neutron stars,

  few compact alternatives to black holes in GR,

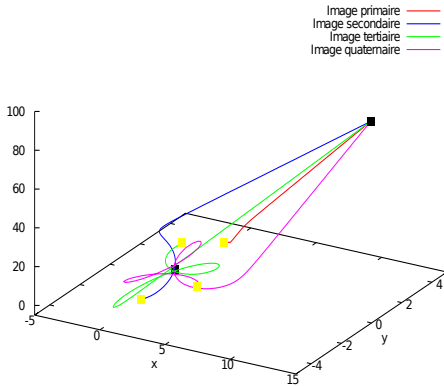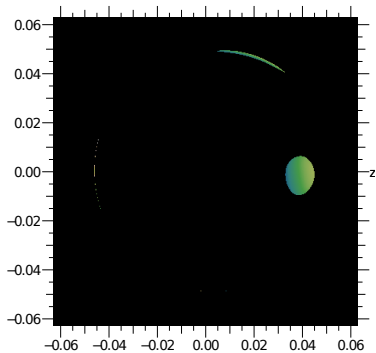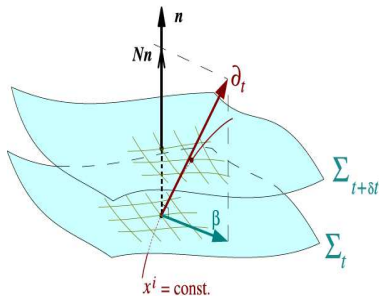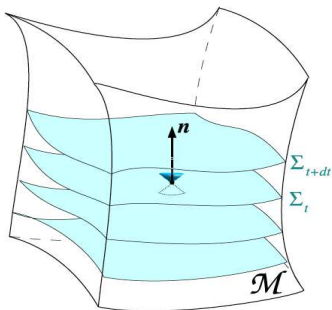 few black holes of alternative gravity theories.

What it could be used for?

- Visualization of spacetimes
- Probably the most interesting for you with Sage!

Example: timelike geodesic
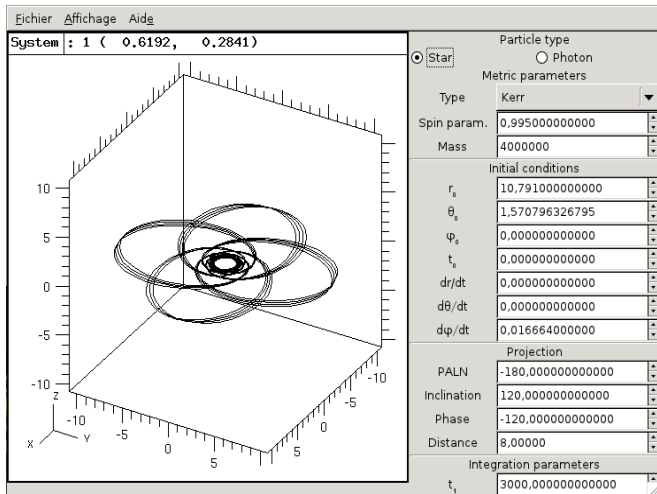
Example: timelike+null geodesics

Frédéric VINCENT   The GYOTO code: introduction

Gourgoulhon (2007), arxiv 0703035

Numerical spacetimes (3+1 formalism)

- Intrinsic geometry: 3-metric γ_{ij}
- Extrinsic geometry:
  extrinsic curvature tensor K_{ij}, lapse N, shift β^i
- **Lorene**: computes these quantities for a given spacetime
  www.lorene.obspm.fr

Equation of geodesics in 3+1

- GYOTO can also integrate the 3+1 equations of geodesics

$$
\begin{cases}
\dfrac{\mathrm{d}X^i}{\mathrm{d}t} = NV^i - \beta^i & \text{(1a)} \\[2ex]
\begin{aligned}
\dfrac{\mathrm{d}V^i}{\mathrm{d}t} = {} & NV^j \left[V^i \left(\partial_j \ln N - K_{jk} V^k \right) + 2K^i_{\ j} - {}^3\Gamma^i_{\ jk} V^k \right] \\
& - \gamma^{ij}\partial_j N - V^j\partial_j\beta^i \, .
\end{aligned}
\end{cases}
$$

Vincent, Gourgoulhon, Novak, CQG, 29, 245005 (2012)

- or equivalently the 4D usual equation

$$
\ddot{x}^\mu + \Gamma^\mu_{\alpha\beta}\dot{x}^\alpha\dot{x}^\beta = 0
$$

with Christoffels computed from 3+1 metric quantities

Conclusion of introduction

- GYOTO is a geodesic integrator (it is also an integrator of the GR radiative transfer equation, but probably not interesting for you)
- it can be easily used with any 4D analytical metric
- it also handles 3+1 numerical spacetimes.
- Now: the numerics (Thibaut)

Frédéric VINCENT   The GYOTO code: introduction