# Ray tracing, parallax, position and redshift drift in numerical relativity

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In the recent years, the unprecedented accuracy reached by the experimental apparatus has opened a new era of cosmological observations, referred to as the "real-time cosmology", concerned with measuring small temporal changes of positions, redshift and distances of objects at cosmological scales. The time variations of such quantities are known as *optical drift effects* and their estimation can provide a direct and model-independent measurements of the large scale structure and of the expansion history of the Universe.

I will present a numerical approach to the problem of evaluating the parallax, position drift (proper motion) and redshift drift (secular change of the redshift) of faraway sources in numerical relativity. The mathematical machinery is based on the covariant formulation of the geometric optics using the *bilocal geodesic operators* (BGO) and their relation to the geodesic deviation equation and curvature [1]. The analysis of the optical properties of complicated spacetimes using the BGO formalism constitutes an efficient approach to probe the dynamics of the inhomogeneities on the large scale.

## References

[1] M. Grasso, M. Korzyński, J. Serbenta, "Geometric optics in general relativity using bilocal operators", *arXiv preprint arXiv:1811.10284*, 2018, *Accepted for publication in Phys. Rev. D.*