Light-Cone Approach to Cosmological Observables beyond Linear Order

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[based on PB, G. Fanizza, G. Marozzi and M. R. Medeiros Silva, arXiv:2510.25690]

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The Era of Precision Cosmology

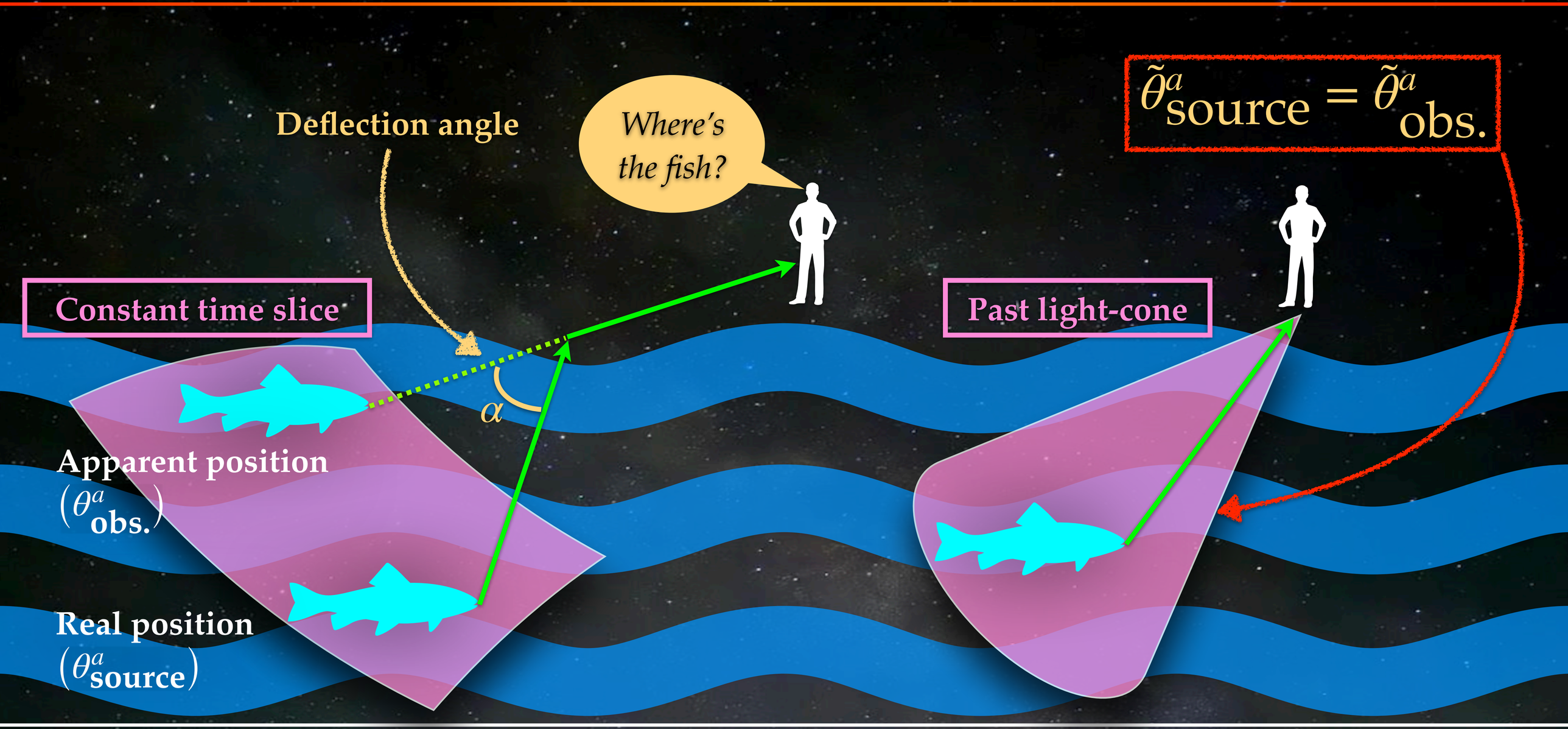
- An unprecedented amount of high-precision data from large-scale cosmological surveys (*Vera Rubin, Euclid, Roman,…*) is about to be released.

- To take advantage of these new opportunities, theoretical predictions should be as accurate as the level of precision of cosmic surveys:

Non-linear effects → **Impact on Large Scale Structure Cosmological Observables**

- It can be convenient to use the **Geodesic Light-Cone coordinates** [Gasperini, Marozzi, Nugier, Veneziano, JCAP, 1107 (2011) 008], accounting for how light-rays propagate in a clumpy universe.

GLC Coordinates: Physical Interpretation



GLC Coordinates: Formal Definition

- The **GLC coordinates** are

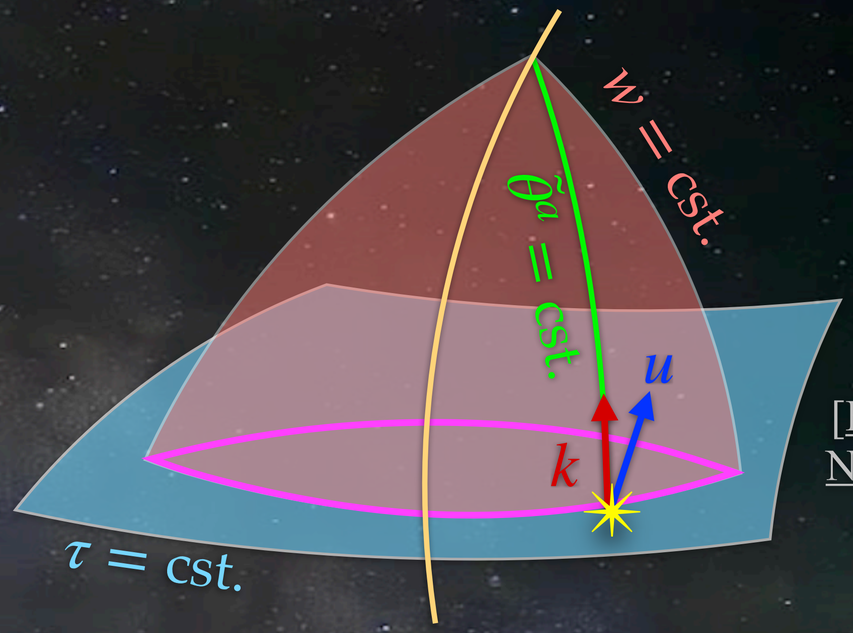
$$x^\mu = (\tau, w, \tilde{\theta}^a)\,, \quad a = 1,2$$

τ = const. $\leftrightarrow$ geodesic obs. | w = const. $\leftrightarrow$ past LC | Angular directions in the sky

- The **GLC gauge** is

$$\mathrm{d}s^2 = -2\Upsilon \mathrm{d}\tau\,\mathrm{d}w + \Upsilon^2 \mathrm{d}w^2 + \gamma_{ab}(\mathrm{d}\tilde{\theta}^a - \mathcal{U}^a \mathrm{d}w)(\mathrm{d}\tilde{\theta}^b - \mathcal{U}^b \mathrm{d}w)$$

Induced metric on $\mathbb{S}^2 \ni \tilde{\theta}^a$



[Fleury, Fanizza, Nugier, JCAP, 06 (2016) 008]

Cosmological Observables in the GLC Gauge

- In the GLC gauge, observables have fully non-linear expressions (**redshift**, **angular distance**, **redshift drift**…).
- By building a perturbation theory on the light-cone, observables are factorized as local products of perturbations at the source and observer position.

Results

- Gauge-invariant expressions for observables to higher perturbative orders;
- Angular distance-redshift relation as seen by a free-falling observer with new terms at the observer;
- Model-independent solution to the long-standing problem of divergences $\sim r^{-n}$ around the observer position.

Thanks for your attention!

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