# Forcast study of Hubble constant anisotropies with large scale astronomical surveys


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The standard model of cosmology ($\Lambda$CDM) is based on General Relativity, assuming the Cosmologycal Principle, i.e. the homogeneity and isotropy of the Universe at large scale (typically $> 100$ Mpc). But in the last decade, some probes have highlighted anisotropy effects [1]: for instance residual anisotropies in the cosmic microwave background (after correction of the kinematical dipole due to the observer movement) or in the counting of far away radio-source. However, within the framework of General Relativity, there exist alternative models that do not assume the Cosmological Principle, and predict anisotropies in the Hubble parameter, and hence in the Hubble constant.

Currently, the most accurate direct measurement the Hubble constant – the current rate expansion of the Universe: $H_0 \approx 70\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$ – is based on using Type Ia supernovæ (SNe Ia) as standard candles (or more precisely as standardizable candles). Their high luminosity allows to map the Universe at large scale by measuring their distance modulus versus their cosmological redshift, i.e. by constructing the Hubble diagram which can be confronted to theoretical predictions.

In practice, to detect potential anisotropies in the Hubble constant, we need a large sample of SNe Ia mapping as much as possible the entire sky within a redshift range typically $0.02 < z < 0.2$. The Zwicky Transient Facility (ZTF[1]) [2] at Mont-Palomar Observatory (California, United States) has started its survey in 2018 and has already detected and followed up about 10,000 SNe Ia in the Northern sky $-30° < \delta < 90°$ (where $\delta$ is the declination in equatorial coordinate: $\delta = 90°$ corresponds to the celestial North pole direction). A first analysis of sensitivity to detect Hubble constant anisotropy of dipole form with ZTF data as been conducted with simulation of the first ZTF phase (2018-2020) [3]. The results of this analysis show that a dipole effect with an amplitude uncertainty of about $0.5\mathrm{km\,s^{-1}\,Mpc^{-1}}$ is achievable with a typical $15°$ uncertainty in the sky direction. With the starting of the 10-years Legacy Survey of Space an Time (LSST[2]), located at the new Vera C. Rubin Observatory (Cerro Pachón , Chile) [4], the Hubble constant anisotropy analysis can be extended on the full sky by joining futur LSST SNe Ia to the ZTF ones.

The goal of the intership will be to use combined realistic simulations of SNe Ia from the ZTF and LSST programs in order to extend current analysis of the Hubble

[1] `https://www.ztf.caltech.edu`

[2] `https://www.lsst.org`

constant anisotropy to the whole sky, by exploiting the observing cadence planned for LSST. All the codes are based on Python programming language and its data analysis tools. The student must show interest in astronomy/astrophysics and data science. This prospective study will very likely be followed by a PhD thesis.

# References


[1] P. K. Aluri, *Is the Observable Universe Consistent with the Cosmological Principle?*, Class. Quantum Grav. 40 (2023) 094001

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[3] C. Barjou-Delayre et al., *Study of the anisotropy of cosmic expansion on ZTF type Iasupernovae simulations*, paper submitted to A&A, arXiv:2601.11139

[4] Z. Ivezić et al., *LSST: From Science Drivers to Reference Design and Anticipated Data Products*, ApJ 873 (2019) 111