Study of photometric classification of type Ia supernovæ of the Zwicky Transient Facility

Laboratoire : Laboratoire de Physique de Clermont (LPC), Université Clermont Auvergne & CNRS/IN2P3

Supervisors : Philippe Rosnet (philippe.rosnet@clermont.in2p3.fr), Mickael Rigault (Mickael.Rigault@clermont.in2p3.fr) and Emille Ishida (emille.ishida@clermont.in2p3.fr)

The Big Bang theory was experimentaly born in 1929 with the discovery of the expansion of the Universe by Edwin Hubble, i.e. the recession velocity of galaxies as a function of their distance to us. The Big Bang picture was confirmed and specified by further cosmological measurements like the cosmic microwave background (CMB) or the early nucleosynthesis. The next step was passed in 1998 by the discovery of the acceleration of the expansion in a way similar to the Hubble historical one, but using type Ia supernovæ (SNeIa) as standard candles to map cosmological scales. Supernovæ are stellar explosions which mark the late stage of development of a range of stellar objects. More specifically, SNIa phenomenon is an explosion of a carbon-oxygen white-dwarf with a typical emission spectrum. Thermonuclear explosion occurs when the mass of a white-dwarf exceeds the stable limit (around 1.4 $M_{\odot}$) either by the matter accretion from a companion star, or by the merging with another white-dwarf, and the brightness of a SNIa can be calculated at any distance in the framework of any cosmological model. Thus, comparing the observations with theoretical predictions one determines the cosmological parameters of the Universe. From a theoretical point of view, the acceleration of the expansion of the Universe can be explained in Einstein equations of General Relativity by the introduction of a cosmological constant or more generally by a cosmological fluid with a negative pressure, called dark energy. This result has led to the standard model of cosmology, also called ΛCDM model (Λ = cosmological constant, and CDM stands for 'Cold Dark Matter', a necessary ingredient to explain for instance the rotation velocity of stars inside galaxies).

The next generation telescope – like the Large Synoptic Survey Telescope (LSST) – has the objective to address the question of the nature of the Dark Energy. To reach this goal, accurate measurements of different cosmological probes must be done, including the Hubble diagram with numerous SNeIa at high redshift (z), in the interval $0.1 < z < 1$. One challenge of the SNeIa science within LSST will be to first identify SNeIa from other transient events without spectrometer (SNIa emission spectra are characterized by specific absorption lines), using only photometric considerations (LSST will be equipped with 'ugrizy' filter-band system)

In the mean time, the Zwicky Transient Facility (ZTF) at Mont Palomar Observatory (United States) has started its survey beginning 2018, for three years, using the Samuel Oschin 48-inch Schmidt telescope with a new camera (about 600 Mpixels) and a large field-of-view (47 square-degrees) equipped with three filters (G, R and I). Its goal is to detect about $3,000$ SNeIa to address cosmological questions of the nearby Universe, in the redshift range $0.01 < z < 0.1$, i.e. complementary to the LSST program. The telescope is accompagnied by a spectrograph and imager machine (called SED Machine) aiming to produce spectra for numerous transients. The ZTF data sample, with both photometric and spectroscopic measurements of transients, is a unique opportunity to address the question of SNeIa classification with a photometric survey. Upto now 600 SNeIa and few hundreds other supernovae (non Ia) have been recorded by the photometric survey with spectroscopic information.

This research training aims both to learn the basic astrophysics characterizing SNeIa and to analyze together the photometric and the spectrosocpic data sets of ZTF to build the best SNeIa classifier based on photometric measurements only; the spectrometric data will be used as a bench-mark. Standard analysis techniques, and if possible machine learning tools (see Ref. [1] for an up-to-date review), will be deployed. The work will be based on Python programmable language with its data analysis tools. The student must show interest in astrophysics/cosmology and data science.

PS : Candidate must send to the three supervisors

- a short CV including Master 1 (and if possible 2) grades,
- a letter of recommendation would be a plus.

References

[1] M. Lochner et al., *Photometric Supernova Classification with Machine Learning*, ApJS 225 (2016) 31, arXiv:1603.00882