A supernova search at $z \sim 0.2 - 0.4$

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The European Supernova Cosmology Consortium supernova search aims at bridging the gap that exists in the type Ia supernova Hubble diagram at $z \sim 0.2 - 0.4$ (intermediate redshift range), in order to better constrain the measurement of the cosmological parameters Ω_M and Ω_Λ and some of its systematics. We present here our first results, the discovery and follow-up of 11 type Ia supernovae in the intermediate redshift range during 1999.

1 Introduction

Type Ia supernovae are bright stellar explosions which have been recently used as *calibrated* standard candles to determine the dynamical evolution of the universe. They are thought to arise from the thermonuclear explosion of a white dwarf, brought, e.g., by the accretion of matter from a companion. Their peak luminosity in the rest-frame B band is remarkably constant from one event to another, with a scatter of $\sim$ 10 % when a correction depending on the luminosity decline rate is applied — the calibration. By comparing in the Hubble diagram (apparent luminosity vs. redshift) nearby supernovae ($z \sim 0.05 - 0.15$) to distant ones ($z \sim 0.4 - 0.8$), Riess et al.[9](High-Z SN search) and Perlmutter et al.[7] (Supernova Cosmology Project) have determined a linear combination of the cosmological parameters Ω_M (reduced matter density) and Ω_Λ (reduced cosmological constant). With 42 distant type Ia supernovae (figure 1), Perlmutter et al.[7] measure $0.8\Omega_M - 0.6\Omega_\Lambda = -0.2 \pm 0.1$, and for a flat ($\Omega_M + \Omega_\Lambda = 1$) cosmology, they find $\Omega_M = 0.28^{+0.09}_{-0.08}$ (1 sigma statistical) $^{+0.05}_{-0.04}$ (identified systematics). Among the potential systematics is the evolution of supernovae characteristics with z. Its study requires to add more statistics at low redshift (this issue was adressed by the recent SCP nearby search) and to fill the gap that exists at $z \sim 0.2 - 0.4$ in the present Hubble diagram, between the low redshift sample and the distant one.

[a]The European Supernova Cosmology Consortium[1].

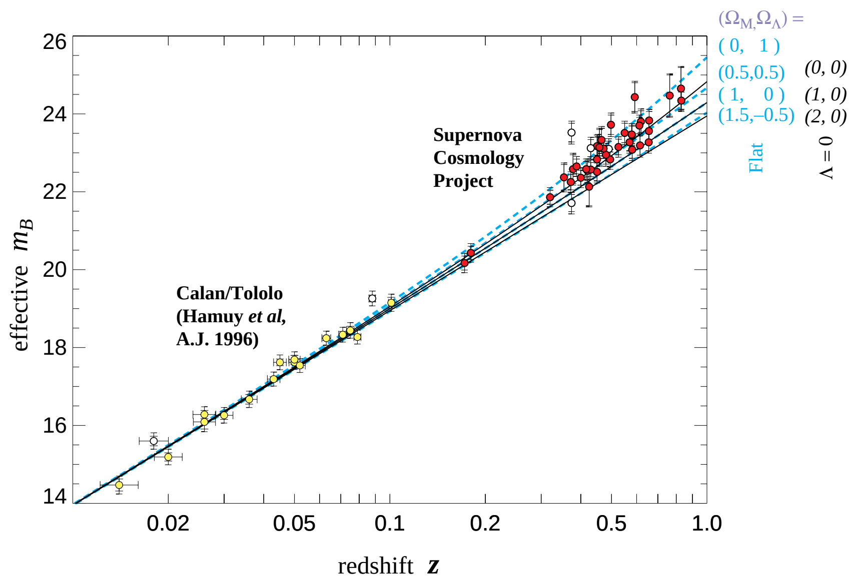

Figure 1: The Hubble diagram (magnitude vs. redshift) for 18 nearby supernovae Ia ($z \sim 0.05 - 0.15$) and 42 distant supernovae Ia from the Supernova Cosmology Project (Perlmutter et al., 1999). The solid curves are the theoretical expectation for a range of cosmological models with zero cosmological constant, and the dotted curves for a range of flat cosmological models. There is a gap in the data in the intermediate redshift range $z \sim 0.2 - 0.4$.

The European Supernova Cosmology Consortium (ESCC) present program is to bridge this gap at intermediate redshift $z \sim 0.2 - 0.4$, so that that there is a continuous, and consistent, redshift coverage in the Hubble diagram. The type Ia explosion rate in this range will also be measured and compared to measurement at other redshifts to test the theoretical predictions expected for different explosion scenarii and cosmological models.

The ESCC brings together physicists and astrophysicists from various institutes and countries (see authors list[1]), and has already discovered and study 11 type Ia supernovae in the intermediate distance range during 1999.

In the following section, I shall describe our search and follow-up set-up, and the output of the search we undertook in the spring and fall of the year 1999.

2 The ESCC search set-up and technique

We rely mostly on the facilities of the Isaac Newton Group at the Observatory del Roque de los Muchachos, La Palma, Spain.

The detection images are taken in the frame of the Wide Field Survey (McMahon et al.[6]), with the Wide Field Camera mounted at the 2.5-m Isaac Newton Telescope (INT). The INT Wide Field Camera is a mosaic consisting of four 2k×4k thinned EEV CCDs and covers a ∼0.25 square degree field. We search for supernovae by comparing two frames ("reference" and "new") of the same field exposed ~ 25 days apart. The images are semi-automatically processed at the telescope the day following their observation, using a home-made C++ package software TOADS (TOols for Analysis and Detection of Supernovae). The technique used for the spring and fall 1999 search consists in subtracting the reference image from the new image after geometrical and flux alignment, and the convolution of the image of superior seeing to match the images point spread functions (PSF). The subtraction image thus obtained is searched for point-like sources, selected according to their signal-to-noise ratio. Asteroïds and cosmic rays are rejected by splitting the new image exposure time in two, and requiring that the

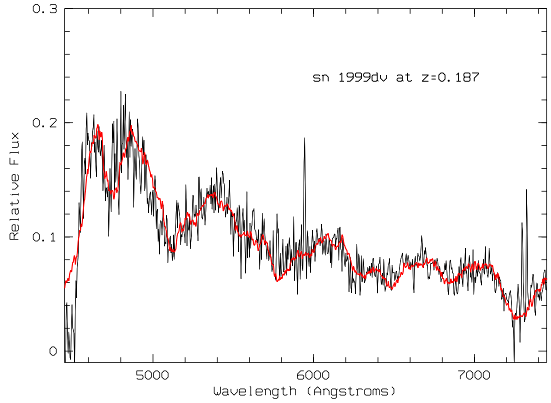

Figure 2: SN199dv spectrum obtained at the William Herschel Telescope, on September, 13, 1999. The solid line shows a type Ia supernova template spectrum (SN1992A, five days before maximum luminosity) redshifted to $z = 0.187$.

supernova candidate is present at the same location on both exposures. Since october 1999, the subtraction technique has been improved, as presented in P. Astier et al.[3] in this volume. The selected supernovae candidates are then visually checked by two independant scanners, and re-observed the following night. If confirmed (i.e. re-detected), their spectroscopic observation is scheduled.

The spectroscopic identification and follow-up is mainly performed at the 4-m William Herschel Telescope (WHT), and the photometric follow-up at the 1-m Jacobus Kapteyn Telescope (JKT) and the INT. We also use for both spectroscopic and photometric follow-up the Nordic Optical Telescope, at the same observatory, and more marginally some other telescopes (ESO-3.6-m, Danish-1.54-m) at the European Southern Observatory (La Silla, Chile) and at the Pic du Midi Observatory (France).

3 The ESCC first results

As a test run, a search in March-April 1999 over 12 square degrees in B and r', reaching a redshift limit of $z \sim 0.4$, produced 10 supernovae candidates, two of which were spectroscopically identified as type Ia supernovae at respectively $z = 0.36$ and $z = 0.43$ (IAU Circ. 7182[4] and 7207[5]).

In 1999 fall, 30 square degrees were observed in September and October in g', with a limiting magnitude $g' \sim 22$, and 15 supernovae candidates were selected. They were all observed at the WHT, using the ISIS spectrograph. Ten of them were identified as type Ia supernovae at a mean redshift of $z \sim 0.3$ (IAU Circ. 7278[2]). Among these 10 type Ia supernovae, 8 were discovered before reaching their maximum luminosity. SN199dv spectrum is presented in figure 2.

An extensive multi-color photometric follow-up was performed on the 5 nearest supernovae at $z \sim 0.2$ on the INT, JKT and NOT telescopes.

4 The Future

Our present task is the analysis of our already-acquired data (rates determination, light curve production, and subsequently cosmology). In spring 2000, we conducted a joint run with the EROS[b] team, EROS providing supernovae in the nearest part of the intermediate reshift range

[b]Expérience de Recherche d'Objet Sombres, see N. Regnault et al.[8], in this volume.

($z \sim 0.15$) and the spectroscopic and photometric follow-up beeing performed by the ESCC. We hope to increase our statistics in the intermediate redshift range in the following years.

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