SEARCH FOR HIGH REDSHIFT SUPERNOVAE: PRELIMINARY RESULTS FROM SPRING 2001 SCP CAMPAIGN

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I report on recent (spring 2001) Supernova Cosmology Project campaign aiming at detecting and following high redshift type Ia supernovae. 14 type Ia supernovae were discovered including 2 beyond redshift 1. I present in this talk a very preliminary analysis of the lightcurve of the most distant identified candidate.

1 Introduction

This paper presents the results of the spring 2001 search for supernovae within the Supernova Cosmology Project (SCP). The aim of this campaign was to discover, to identify and to follow up supernovae at high and very high redshift respectively $z \simeq 0.5$ and $z \simeq 1$.

First, we describe the search for supernovae candidates done on wide field 4-meter class telescopes: the Canada France Hawaii Telescope (CFHT) and the CTIO-4m (Calan Tololo Inter american Observatory). Then, we present the results of spectroscopic observations done at VLT (Very Large Telescope 8m, Chile) and at Keck (10m, Hawaii). The faintest identified type Ia were followed up over two months using Hubble Space Telescope (HST). Finally, we present the analysis of the faintest one, SN2001gn at $z = 1.12$.

2 Detection, identification and follow-up of supernovae

Two types of searches were conducted on march and april 2001: shallow and deep searches. The shallow search in R band aimed at finding objects at redshifts around 0.5. This search was performed at CTIO. The deep search aimed at finding supernovae with redshift around 1, this was done within different fields at both CFHT and CTIO.

2.1 Example of candidate detection at CFHT

Observations at CFHT were done in queue mode. We searched for supernovae in 2 Cfh12k pointings totalizing approximatively 2/3 square degree, observed in the I-filter for about 3 hours at both reference and search epochs. The average image quality was about 0.8" FWHM.

Optimality of the data processing is required as we target instrumental limits of the telescope and camera. For that purpose, ToADS (Tools for Analysis and Detection of Supernovae) has been developped, it aims at detecting and analysing supernovae using image subtraction. During this search, ToADS was used to perform the basics: flatfielding, resampling and optimal addition to produce reference and search images. It then performed the subtraction between the worst quality image and the best convolved with an ad-hoc kernel fitted to minimize residuals on the subtraction. Finally, the detection was done using a matched detection and optimal PSF photometry.

ToADS led to increase by a factor of about 2 the candidate signal to noise ratio on the subtraction with respect to classical search software. A signal to noise greater than 10 was obtained for $I_{vega} = 24.6$ point-like objects.

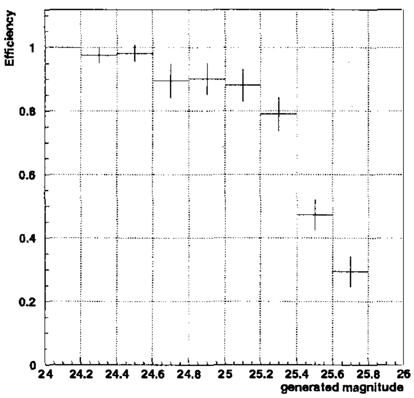

Figure 1: Efficiency of detection using ToADS as a function of I magnitude using 5σ cut for the detection.

Figure 1 shows the efficiency curve of ToADS detection built using fake supernovae. They were randomely added on images using real stars picked up in the science images, photometrically scaled and pasted. We then recomputed every step of the analysis from the resampling to the detection. One can see that efficiency is greater than 95% for $I < 24.5$ which corresponds to a $z = 1.2$ type Ia supernova at its maximum of luminosity.

2.2 Spectroscopy and follow-up

Spectroscopic observations aimed at identifying and measuring redshifts of candidates. They were carried out at VLT on FORS-1 and Keck on ESI around april 2001 new moon. 14 supernovae were identified as type Ia, 1 as type II[1]. We were able to identify SN2001gn at a redshift of 1.12.

Over 2 months, the follow-up of the faintest supernovae (beyond $z = 0.5$) was done using WFPC2 (Wide Field Planetary Camera) on HST. We were able to follow up 5 different supernovae. During the same period, GEMINI and VLT observed the two faintest ones in J band as well.

3 Preliminary analysis of SN2001gn

3.1 Photometric measurements

We performed this preliminary analysis of SN2001gn using I-Band images taken at CFHT and HST.

The supernova beeing on a bright host galaxy, it was necessary to evaluate how much galaxy light was to be subtracted to measure the flux of the supernova. Since images of the host galaxy alone were not available at the time of this analysis, we had to estimate the host galaxy contribution from images containing both the supernova and the galaxy.

As the PSF of the WFPC2 (Wide Field Planetary Camera) is undersampled and the galaxy is poorly resolved, it was impossible to build a realistic analytic model of the galaxy.

Finally, we resorted to build an image of the galaxy using the last image where the galaxy represents more than 90% of the flux. The procedure was the following: we subtracted a $PSF * flux$ to the last image at the position of the supernova and adjusted the flux to obtain a smooth galaxy. Figure 2 shows the last image before and after the subtraction of the PSF.The PSF model was constructed using the Tiny Tim PSF generator[2].

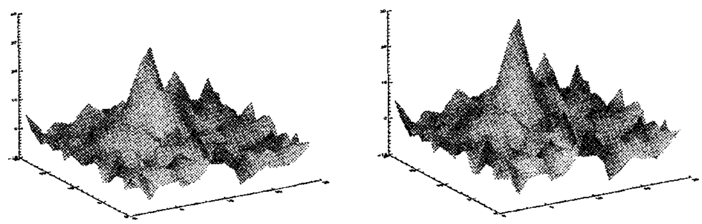

Figure 2: Last image of SN2001gn before and after the subtraction of the supernova

From here on, we estimated the flux of the system supernova+galaxy, the flux of the galaxy within the same aperture and subtracted these fluxes to obtain an estimate of the supernova flux at each period. Fluxes were finally corrected for aperture losses (8%) and charge transfer inefficiency (4%).

The first two photometric points of the lightcurve from CFHT search images were constructed considering a negligeable contribution of the supernova on the reference image (from march 30th) using differential photometry analysis.

3.2 Lightcurve model

We wanted to construct lightcurve models to fit instrumental fluxes obtained during the photometric analysis. With this aim in view, we build a model by convolving instrumental transmission of the instrument (accounting for telescope transmission, camera efficiency and filter) for every telescope (CFHT and HST in SN2001gn case) with template spectra of type Ia supernovae[3] shifted to the redshift of the supernova.

This simulation has been tested using Vega spectrum: we checked that we were able to reproduce Vega zero points presented by Holtzman[4] for every filter used.

3.3 Results and discussion

We fit lightcurve models to intrumental photometric points to estimate lightcurve parameters: the date of the maximum of luminosity, the flux at this maximum and the stretch factor. In this way, we build a model of lightcurve for every telescope and every filter used and fitted simultaneoustly the parameters. The result is presented on Figure 3. For convenience, the figure shows HST F814W filter Vega magnitude.

Finally, we correct this result for Galactic extinction[5] (0.06 mag) and calibration uncertainty (~ 0.02 mag). We measured the magnitude at max of SN2001gn to be $I_{F814W} = 24.33 \pm 0.05$ and stretch factor $s = 1.09 \pm 0.06$.

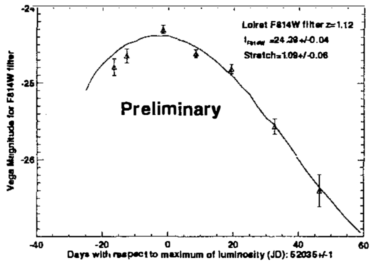

Figure 3: Lightcurve of SN2001gn using Vega magnitude for F814W HST filter. The two first points have been taken with the cfh12k, the 5 last ones with the WFPC2 at HST.

Considering an intrinsic dispersion of type Ia supernova of 0.17 mag, the magnitude of SN2001gn is 1σ fainter than expected in a $\Omega_M = 0.28$, $\Omega_\Lambda = 0.72$ cosmology.

The analysis presented here is obviously preliminary: no stretch correction has been applied to this result, F814W filter corresponds for this supernova to restframe U-Band which is poorly known for type Ia supernovae and no measure of extinction has been carried out. Furthermore, we still miss all the final references of the host galaxy. These images have been taken at spring 2002 at CFHT (for ground based I photometry) and at VLT on ISAAC for ground based infrared photometry. This will be completed with observations using the new HST camera ACS (Adavanced Camera for Survey). These references will enable us to perform simultaneous pixel to pixel subtraction of the host galaxy and allow us to perform an optimal PSF fitting photometry, to measure restframe-B and the extinction.

4 Conclusion

The 2001A SCP campaign was successfull and allowed to detect, identify and follow up 14 type Ia supernovae under excellent conditions. Among those, two had a redshift beyond 1. The preliminary analysis of SN2001gn is in good agreement with previous results from type Ia supernovae observations [6] [7]. This analysis combined with those of the 13 other supernovae discovered will provide an excellent data set to constrain cosmological parameters.

References

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