Statuts of the analysis of spring 01 supernovae

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1 Introduction

In the following, I present the analysis of the lightcurves of supernovae discovered on spring 2001. In a first part, I described the method I used to analyse the supernovae, I begin with a description of the photometry, then I present how I simulated template lightcurves in the effective instrument used for observation, finally, I explain how the lightcurve fit was done to extract the parameters (date of the maximum, magnitude at the maximum and the stretch factor).

In a second part, I show the results I obtained with the set of 6 supernovae followed with HST.

Data used for this analysis are discovery images taken at CFHT and CTIO for search during spring 2001, confirmation taken at NTT and VLT and follow-up taken using HST/WFPC2.

Deep references used for ground based observation were taken on spring 2000 and 2002 at CFHT and CTIO.

Deep references for HST observations were taken using HST/ACS on summer 2002.

2 Photometry

Three kind of photometry were done : differential photometry for ground based images using Sebastien's software, aperture photometry for HST images and finally an atempt of differential photometry for HST images.

2.1 Ground based photometry

Images from the CTIO, NTT and VLT were taken directly in the LBL data base. Headers of these images were modified to fit ToADS. Then, I installed these images in our "data base" and finally constructed sextractor catalog as mandatory for Sebastien's software.

Images from CFHT were flatfielded using deep master frame flat build with more than 50 images for each months. These images were then corrected for fringes using twilight images. Finally, I constructed catalogs and removed background using sextractor.

2.1.1 Differential photometry

Sebastien software given images flatfielded, gain multiplied and corresponding catalog done using SExtractor return photometry of the supernova (flux and error), date of observation and the band of observation and lightcurves for fiducials objects. Photometry is expressed in count in unit of the best seeing image, filter are assumed to be similar, no color correction is applied during the subtraction.

Basic principle is to construct a model of galaxy plus flux * PSF to fit the data. In this way, the PSF is constructed at each epoch using DAO software. Galaxy model is fitted on the best seeing image and convolved with a kernel to reproduce the current night condition.

The same thing is done for fiducial to check if the processing was ok.

2.2 HST photometry

Images from HST were already flatfielded. I used crrej in IRAF/stsci packages to co-add and remove cosmics. I installed images multiplied by the gain and did the sextractor catalog (without subtraction of the backgroung which was already done).

Then, using my new package in C++ called Huphot (for Hubble photometry), I constructed the photometry of supernovae.

In this package, all images are assumed to be in the ToADS fashion, *i.e*, flatfielded, gain multiplied, having a catalog and background subtracted.

2.2.1 Aperture photometry

The aperture photometry is done using an aperture of 5 pixels, the result is corrected for aperture lost using TINYTIM [2] software which computes PSF for wfpc2, finally flux is corrected for charge transfer inefficiency using Dolphin (2000).

The error is estimated as follow :

$$Err_{flux} = \sqrt{N_{pixels}\ \sigma_{back}^2 + flux}$$

Where
N_{pixels} is the number of pixel used for the flux estimation.
$flux$ is the result of the aperture photometry.
σ_{back} is the empiric dispersion of the background of the image.

2.2.2 PSF photometry

PSF photometry and astrometry was done using TinyTim[2] synthetic PSF. PSF were generated ovsersampled 10 times every 100 pixels in each direction for the Planetary Camera. The closer PSF is used to compute the flux and the postion using these PSF resampled and convolved with a kernel to reproduce the charge diffusion.

Flux and positions are calculated as follow :

$$flux = \frac{\sum_{i,j} \frac{PSF(i,j)I(i,j)}{\sigma^2_{i,j}}}{\sum_{i,j} \frac{PSF^2(i,j)}{\sigma^2_{i,j}}}$$

$$Var_{flux} = \sum_{i,j} \frac{PSF(i,j)^2}{\sigma^2_{i,j}}$$

$$X_{center\ of\ gravity} = \frac{\sum_{i,j} X(i,j)I(i,j)\ PSF(i,j)}{\sum_{i,j} PSF(i,j)}$$

where $I(i,j)$ is the value of the pixels at the position (i,j) minus the residual backgroung computed using annulus estimation.

This method can only be used for a flat backgroung, for structured background, as the model is wrong it will give wrong results.

It is used only for supernova with clearly detached host ($\simeq$ 5 pixels).

2.2.3 Preliminary differential HST photometry

Preprocessing

Using reference images coadded, cosmic rays rejected but not corrected for the distorsion,I did the subtraction between WFPC2 and reference.

I used the images not drizzled because the resampling is awfull and we don't want to resample images 2 times (one for this correction and one to align on the follow up images).

When the observations were not splitted, I used a Laplacian filter to remove cosmics (replaced by the median of the 3*3 box surrounding the pixel). I checked that no cosmic had fallen on the host galaxy.

The difficult part of the job is to align images because of the lack of stars in the Planetary Camera (PC). If you are lucky, you have 3 stars in the field including the supernova. I decided to use galaxies to align.

Another problem came from the remaining cosmic rays on images, you can not use automatic source extractor to build object catalog. Finally, I constructed all catalogs by hand (something like 10 objects in common, generally faint galaxies) for all images. Then I matched catalogs of follow up and reference to produce lists of pairs. These lists were used to compute the second order transformation. Finally, I aligned the reference on the follow-up images.[1]

When images where align, and as I considered the PSF for ACS and WFPC2 to be almost the same(same optic same filters). I only had to estimate the global photometric factor between ACS and WFPC2[2]. Again, I used my hand constructed pair catalog to estimate a photometric ratio between the same object on the 2 different cameras.

Finally, I used this factor to multiply the aligned reference and did the subtraction.

The optimal photometry

The basic idea is to apply Sebastien's method to HST images. The problem is actually simpler because the PSF is not varying with time and it is well simulated by TinyTim[2]. Thus, there is no need for kernel convolution.

One improvement to this method is that we align the host galaxy on the data, images with the supernova are <u>n</u>ever resampled in the processing.

The model fitted is constructed as follow :

$$Model_o(i,j) = f_o \; PSF(i - x_{sn}, j - y_{sn}) + Gal_o(i,j)$$

where f_o is the flux of the supernova for the orbit o.
$PSF(i,j)$ is the PSF given by TinyTim[2] at the position (i,j)
$Gal_o(i,j)$ is the aligned image of the host galaxy.

We just have to minimize the following :

$$\chi^2 = \sum_{orbit=o} \sum_{pixels\ i,j} \left[\frac{I_o(i,j) - Model_o(i,j)}{\sigma^2_{i,j}} \right]^2$$

where $\sigma^2_{i,j} = Gal_o(i,j) + \sigma^2_{backref} + f_o PSF(i,j) + \sigma^2_{back}$

This minimization is initialized using flux and position estimated on the subtraction. As we want to fit simultaneoustly the position of the supernova, we express it in the refential of the not resampled host galaxy image using the transformation computed during the preprocessing. Fluxes are estimated for each orbits and eah filters.

[1] Note that only the reference image is resampled and aligned. Follow up images are not aligned.

[2] Actually the CTE has to be taken into account

Fluxes will be corrected for charge transfer inefficiencies and expressed in unit of the current orbit.[3]

The same thing will be done for the other objects to check for systematics, if the work is well done, fluxes would be zero.

State of art All the preprocessing part is working, I am currently working on the fit. The alignment work fairly well and give good subtractions. It would be interesting to have the ratio of Qe between ACS and WFPC2 as a function of the wavelength to estimate the photometric ratio between the pLanetary Camera and ACS for the subraction.

3 Fit of the lightcurve

In this section, I describe the estimation of the lightcurve parameters using effective filter of observation and the template of Peter.

3.1 Construction of effective filters

All the filter used to construct the lightcurve were simultated to reproduce zero point (the easy part) and color terms (tricky part).

3.1.1 synthetic zero point

To produce synthetic zero points, I used all information available for each telescope : filter transmissions, Quantum efficiencies of ccds, transmission of optical system and transmission of atmosphere.

All this was multiplied to obtain raw filters. These raw filters were then normalized to reproduce the zero points. If the work is well done and if all the component are correctly estimated this normalisation factor should be the same for each filter and near 1, note that generally the effective surface is generally not accurately known, so we don't expect to have 1 sharp even for HST.

3.1.2 synthetic color terms

The second step was the correction to reproduce colors terms.

I used Hamuy's spectrophotometric standards to construct colors in standard filters (Bessel or Landolt), then I integrated Hamuy's stars in my effective filters (normalised to reproduce zero points) and finally estimated the color terms α's.

For example, for filter R and considering $R - I$ color:

[3]Note that just the position is expressed in this referential, the host galaxy image used is the aligned one on which we add the PSF at the position estimated using the transformations

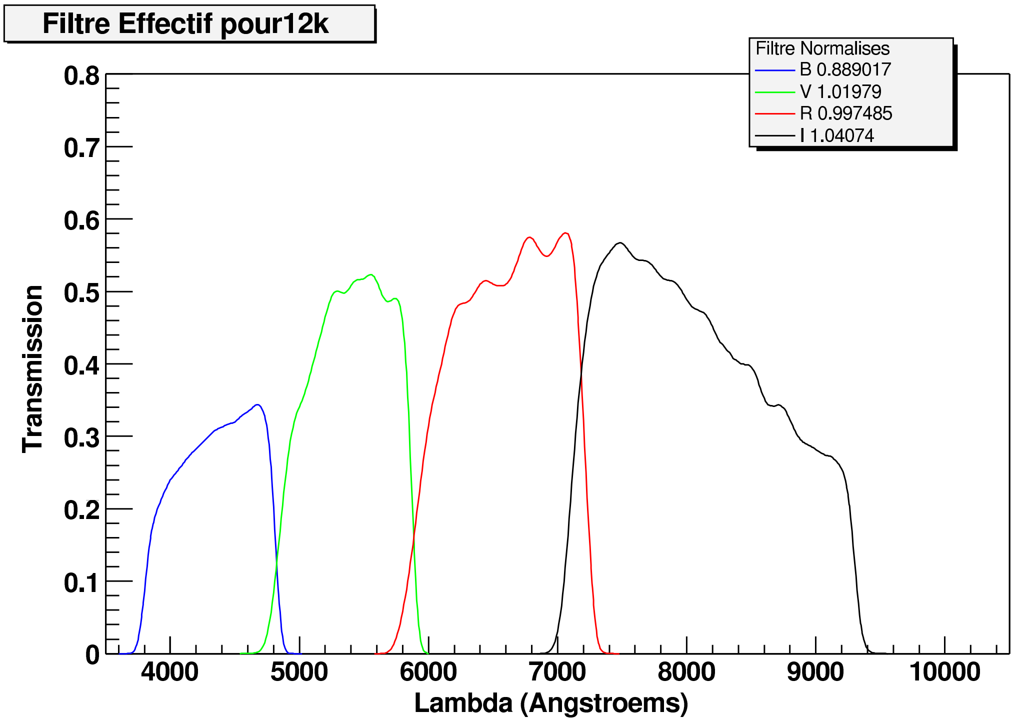

Figure 1: Simulated effective filters for the cfh12k normalized to reproduce zero points. Legend give the normalisation factor for each filter

$$\alpha = \frac{r - R}{R - I}$$

Where :

$$I = 2.5\ log_{10}\left(\frac{\int_\lambda I_{Bessel}(\lambda) * star(\lambda)d\lambda}{\int_\lambda I_{Bessel}(\lambda) * vega(\lambda)d\lambda}\right)$$

$$R = 2.5\ log_{10}\left(\frac{\int_\lambda R_{Bessel}(\lambda) * star(\lambda)d\lambda}{\int_\lambda R_{Bessel}(\lambda) * vega(\lambda)d\lambda}\right)$$

$$r = 2.5\ log_{10}\left(\frac{\int_\lambda r_{effective}(\lambda) * star(\lambda)d\lambda}{\int_\lambda r_{effective}(\lambda) * vega(\lambda)d\lambda}\right)$$

To reproduce color terms, I used a shift of the effective filter (generally less than 100 Angstroems). Actually, this is not at the moment really conclusive. [4]

[4] This problem seems to be hard, and depend really on what "standard filters" are used. Holtzman[4] did the same kind of job and had also troubles to reproduce the color terms using Landolt filters(1992) and Bessel ones. It seems to work using the KPNO filters used by Landolt at CTIO.

3.2 Construction of the template

To construct the observed lightcurves models I integrated Peter's template trough the effective filters.

Peter's template has been normalize to reproduce Gerson lightcurves in restframe B.

The template will be corrected to reproduce U and V lightcurves using available datas (maybe Jha thesis).

Another problem with the template is that it is not continuous in time, introducing wriggles in the lightcurves. It seems really hard to construct a continuous template as it is based on different supernovæ.

To remove the wrigles, I use the mean flux over 5 days for a given date. What may be better would be to fit analytic models to these simulated lightcurves.

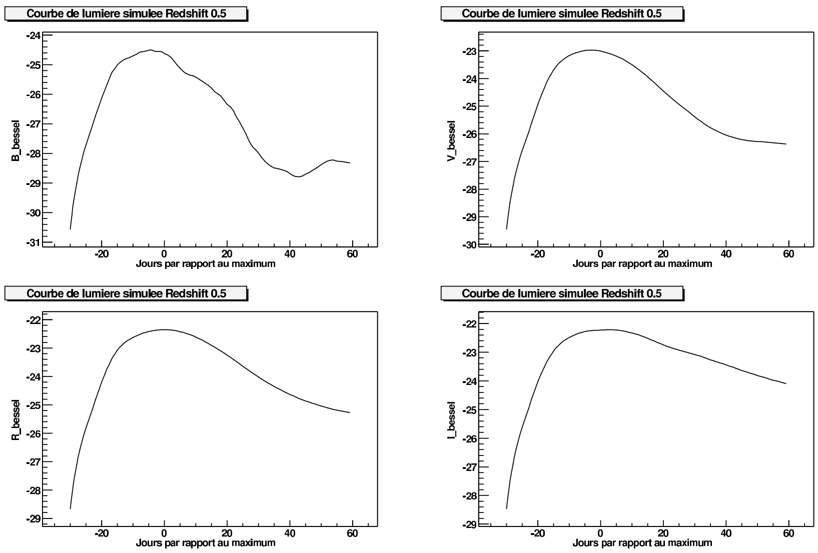

Figure 2: Simulated lightcurve for a SN Ia at a redshift of 0.5 in Bessel filters

3.3 Fit of the lightcurve

At this point, we have photometry from the ground and HST not corrected for color, the redshift, the normalized effective filters for every telescope and the lightcurce template simulator.

Using all these ingredients we are able to simulate, for a given observation filter and a given date, the flux expected from the supernova at a given redshift.

So, we minimised the following χ^2:

$$\chi^2 = \sum_{night=l} \frac{(\alpha flux_l(phase) + Back - F_l)}{\sigma^2}$$

$$Flux_l = \frac{D_{mirror}}{Abs_l} \int_\lambda sn\left(\frac{\lambda}{(1+z)}, phase\right) * Filter_{eff}(\lambda)\ d\lambda$$

$$phase = \frac{t - t_{max}}{stretch}$$

$$\sigma^2 = Var_{flux}$$

Then, we have 3 + n parameters, the date of the maximum (the day of the maximum of the template spectra), the stretch (considered to be independant of the band of observation), the background and the α's in every band.

This is done simultaneoustly for every observations points in every band.

4 Analysis

4.0.1 2000fr

Redshift : 0.543.
Follow-up : CFHT/HST.
Ra = 14:01:57.763
Dec = 04:43:43.18

HST follow-up

2001gm WFPC2			
Filter	# of exposure	Total exposure	Date
F814W	2	2200	08/05/2000
F814W	2	1200	15/05/2000
F675W	2	1200	15/05/2000
F555W	2	1300	15/05/2000
F814W	2	1200	28/05/2000
F675W	2	1200	28/05/2000
F555W	2	1300	28/05/2000
F814W	2	800	10/06/2000
F675W	2	1000	10/06/2000
F814W	2	2300	22/06/2000
F675W	2	2400	22/06/2000
F814W	2	2300	08/07/2000
F675W	2	2400	08/07/2000

4.1 2001gm

Redshift : 0.478.
Follow-up : CFHT/HST.
Ra = 14:01:51.180
Dec = 05:05:38.52

4.1.1 Observations

HST follow-up

2001gm WFPC2			
Filter	# of exposure	Total exposure	Date
F675W	1	0.50	Apr 30 2001
F814W	1	0.50	Apr 30 2001
F675W	1	1100.00	May 1 2001
F814W	1	1000.00	May 1 2001

4.1.2 Preliminary lightcurve

Just one HST point. No lightcurve.

4.2 2001gn

SN2001gn (Loiret/Boccherini)
redshift = 1.12
Ra = 14:01:59.900

Dec = 05:04:59.61

This supernova was discovered at CFHT in the field D4 on CCD10.

4.2.1 Observations

Ground based search

2001gn CFHT					
Instrument	Date	Exposure	Band	Seeing	Airmass
Cfht12K	30/03/2001	9900	I	0.707405	1.078
Cfht12K	16/04/2001	9900	I	0.674849	1.11927
Cfht12K	20/04/2001	3300	I	0.578831	1.0994
Cfht12K	16/03/2002	6000	I	0.96361	1.0644
Cfht12K	19/03/2002	9600	I	0.772492	1.07525
Cfht12K	12/04/2002	7200	I	0.665646	1.41433
Cfht12K	13/04/2002	7200	I	0.852001	1.114
Cfht12K	17/04/2002	3600	I	0.799042	1.16433
Cfht12K	20/04/2002	3600	I	0.80896	1.09733
Cfht12K	22/04/2002	3600	I	0.790335	1.11333
Cfht12K	11/05/2002	3600	I	0.671101	1.28267
Cfht12K	17/05/2002	3600	I	0.797946	1.1
Cfht12K	20/05/2002	3600	I	0.560936	1.10567

Follow-up with WFPC2

2001gn WFPC2			
Filter	# of exposure	total Exposure	Date
F814W	2	1.00	Apr 30 2001
F814W	2	2300.00	May 1 2001
F850LP	6	7100.00	May 7 2001
F814W	4	4700.00	May 11 2001
F814W	4	4700.00	May 22 2001
F814W	6	7100.00	Jun 4 2001
F814W	5	7200.00	Jun 18 2001

Deep references with ACS

2001gn ACS			
Filter	# of exposure	total exposure	Date
F850LP	1	1100.00	May 20 2002
F814W	1	1100.00	May 20 2002

4.2.2 Preliminary lightcurve

The lightcurve is just the one I presented at this summer SCP meeting. Analysis is presented in the Annexe 1.

4.3 2001go

SN2001go (Somme/Bruch)
Ra = 14:02:00.950
Dec = 05:00:59.18
redshift = 0.552

4.3.1 Observations

Follow-up with WFPC2

2001go WFPC2			
Filter	# of exposure	Total exposure	Date
F675W	2	2200.00	Apr 30 2001
F814W	2	2000.00	Apr 30 2001
F675W	2	2300.00	May 8 2001
F814W	2	2400.00	May 8 2001
F675W	2	2300.00	May 18 2001
F814W	2	2400.00	May 18 2001
F675W	2	2300.00	May 25 2001
F814W	2	2400.00	May 25 2001
F675W	4	4700.00	Jun 5 2001
F814W	4	4800.00	Jun 5 2001

Ground based search

2001go					
Instrument	Date	Exposure	Band	Seeing	Airmass
Cfht12K	30/03/2001	9900	I	0.739289	1.078
Cfht12K	16/04/2001	9900	I	0.723259	1.11927
Cfht12K	20/04/2001	3300	I	0.641815	1.0994
Cfht12K	16/03/2002	3600	I	0.945849	1.061
Cfht12K	19/03/2002	7200	I	0.762572	1.08183
Cfht12K	12/04/2002	3600	I	0.990792	1.41433
Cfht12K	13/04/2002	3600	I	0.867425	1.114
Cfht12K	17/04/2002	1800	I	0.83433	1.16433
Cfht12K	20/04/2002	1800	I	0.888939	1.09733
Cfht12K	22/04/2002	1800	I	0.874302	1.11333
Cfht12K	11/05/2002	3600	I	0.766144	1.21083
Cfht12K	17/05/2002	1800	I	0.853967	1.1
Cfht12K	20/05/2002	1800	I	0.636183	1.10567
NttSusi	26/04/2001	9600.04	I	0.628854	1.26275

4.3.2 Preliminary lightcurve

No ACS reference. The galaxy backgroung is fitted with the lightcurve. Nothing can be done without a good estimate of the host flux.

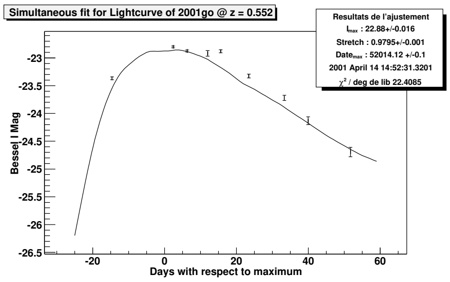

Figure 3: Preliminary lightcurve of 2001go

4.4 2001gq

SN2001gq (Gresse/Salieri)
Ra = 14:01:51.380
Dec = 04:53:12.40
redshift = 0.671

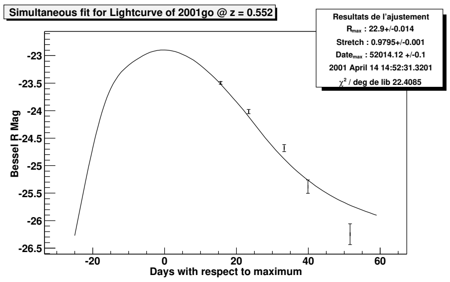

Figure 4: Preliminary R lightcurve of 2001go

4.4.1 Observations

Follow-up with WFPC2

2001gq WFPC2			
Filter	# of exposure	Total exposure	Date
F675W	2	2300.00	May 10 2001
F814W	2	2400.00	May 10 2001
F675W	2	2300.00	May 18 2001
F814W	2	2400.00	May 18 2001
F675W	2	2300.00	May 24 2001
F814W	2	2400.00	May 24 2001
F675W	4	4700.00	Jun 6 2001
F814W	4	4800.00	Jun 6 2001

4.4.2 Observations

4.4.3 Ground based search

2001gq CFHT					
Instrument	Date	Exposure	Band	Seeing	Airmass
Cfht12K	30/04/2000	8640	I	0.641347	1.278
Cfht12K	07/04/2000	7200	I	0.532623	1.214
Cfht12K	29/03/2001	10560	I	0.67156	1.07313
Cfht12K	15/04/2001	9900	I	0.696978	1.45407
Cfht12K	17/04/2001	3960	I	0.788381	1.1385
Cfht12K	18/04/2001	3300	I	0.660122	1.0972
Cfht12K	19/04/2001	3300	I	0.578718	1.0708
VltFors1	28/04/2001	1199.95	I	0.521163	1.3275

4.4.4 Preliminary lightcurve

Almost no host galaxy pollution for this one. Just aperture photometry. The lightcurve looks pretty good.

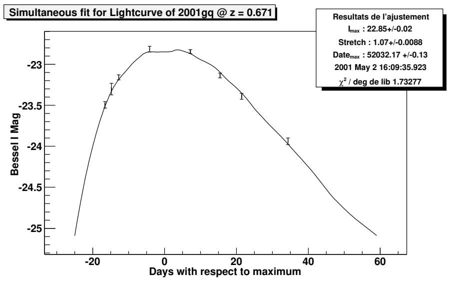

Figure 5: Preliminary I lightcurve of 2001gy

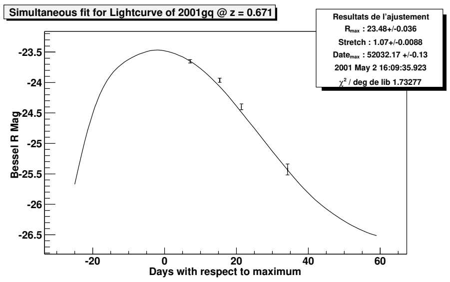

Figure 6: Preliminary R lightcurve of 2001gq

4.5 2001gy

SN2001gy (Massenet)
Ra = 13:57:04.540
Dec = 04:30:59.83
redshift = 0.511

4.5.1 Observations

Follow-up with WFPC2

2001gy WFPC2			
Filter	# of exposure	Total exposure	Date
F675W	1	1100.00	Apr 30 2001
F814W	1	1000.00	Apr 30 2001
F675W	2	2300.00	May 18 2001
F814W	2	2400.00	May 18 2001
F675W	2	2300.00	May 24 2001
F814W	2	2400.00	May 24 2001
F675W	4	4700.00	Jun 5 2001
F814W	4	4800.00	Jun 5 2001

Deep references with ACS

2001gy ACS			
Filter	# of expouse	Total exposure	Date
F814W	2	2200.00	May 2002

4.5.2 Ground based search

2001gy CFHT					
Instrument	Date	Exposure	Band	Seeing	Airmass
CtioMosaic2	28/03/2001	6300	I	0.859777	1.41529
CtioMosaic2	29/03/2001	7200	I	1.09199	1.47975
CtioMosaic2	18/04/2001	18900	I	1.18201	1.37624
CtioMosaic2	20/04/2001	7200	I	1.0583	1.30075
CtioMosaic2	15/04/2002	2952.92	I	0.864019	1.377
CtioMosaic2	17/04/2002	8100	I	1.57017	1.34256
CtioMosaic2	07/05/2002	3600	I	1.34219	1.23825
CtioMosaic2	09/05/2002	4500	I	0.926369	1.3648
NttSusi	26/04/2001	2400.01	I	0.64461	1.771

4.5.3 Preliminary lightcurve

Lightcurves presented in figures 7 and 8 were produced using all available data except for the ACS reference. The galaxy backgroung was estimated during the fit of the lightcurve.

We still miss the deep reference in R band for this one.

4.6 2001gz

SN2001gz (Dvorak)
Ra = 13:56:04.090
Dec = 05:10:55.13
redshift = 0.73?

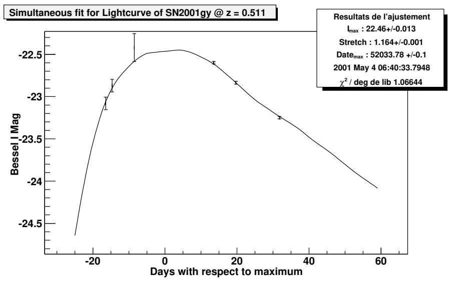

Figure 7: Preliminary lightcurve of 2001gy

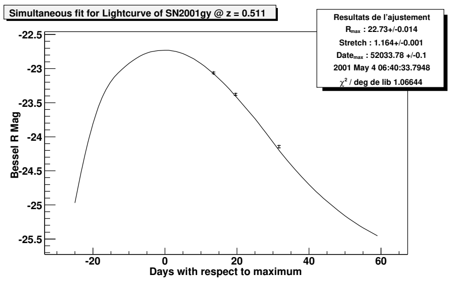

Figure 8: Preliminary lightcurve of 2001gy

4.6.1 Observations

Follow-up with WFPC2

2001gz WFPC2			
Filter	# of exposure	Total exposure	Date
F675W	1	0.50	Apr 30 2001
F814W	1	0.50	Apr 30 2001
F675W	2	2300.00	May 8 2001
F814W	2	2400.00	May 8 2001

Deep references using ACS

2001gz ACS			
Filter	# of exposuse	Total exposure	Date
F814W	1	2200.00	Jul 24 2002

4.6.2 Preliminary lightcurve

No lightcurve as we have just on single hst point. One ACS reference has been taken.

4.7 2001hb

SN2001hb (Satie)
Ra = 13:57:11.950
Dec = 04:20:27.07
redshift = 1.05

Follow-up with WFPC2

2001hb WFPC2			
Filter	# of exposuse	Total exposure	Date
F814W	2	2.00	Apr 30 2001
F850LP	6	7100.00	May 7 2001
F814W	4	4700.00	May 11 2001
F814W	4	4700.00	May 22 2001
F814W	6	7100.00	Jun 4 2001
F814W	5	7200.00	Jun 18 2001

Deep references with ACS

2001hb ACS			
Filter	# of exposure	Total exposure	Date
F814W	2	2200.00	Jul 24 2002
F850LP	2	2200.00	Jul 24 2002

Ground based search

2001hb					
Instrument	Date	Exposure	Band	Seeing	Airmass
CtioMosaic2	28/03/2001	13500	I	0.958898	1.44967
CtioMosaic2	18/04/2001	18900	I	1.2385	1.37624
CtioMosaic2	20/04/2001	7200	I	1.127	1.30075

4.7.1 Preliminary lightcurve

This supernova have deep reference but there is absolutely nothing on it. Then I deciced not to use these references. The preliminary lightcurve if just a corrected aperture flux.

Note that the two first points from CTIO on the lightcurve are not calibrated they have been moved to fit the lightcurve.

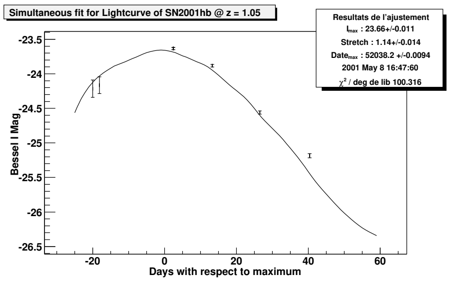

Figure 9: Preliminary I lightcurve of 2001hb

A ANNEXE

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 $z = 1.12$.

A.1 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.

A.1.1 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 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

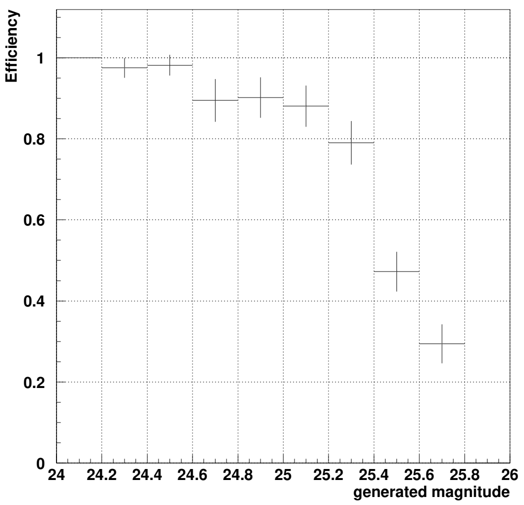

Figure 10: Efficiency of detection using ToADS as a function of I magnitude using 5σ cut for the detection.

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.

A.1.2 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.

A.2 Preliminary analysis of SN2001gn

A.2.1 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].

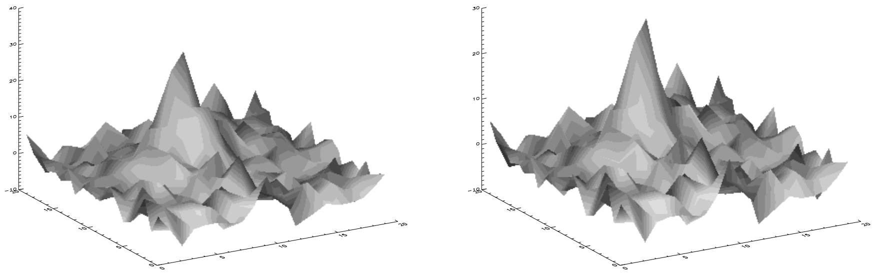

Figure 11: Last image of SN2001gn before and after the subtraction of the supernova

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.

A.2.2 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.

A.2.3 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 $s = 1.09 \pm 0.06$.

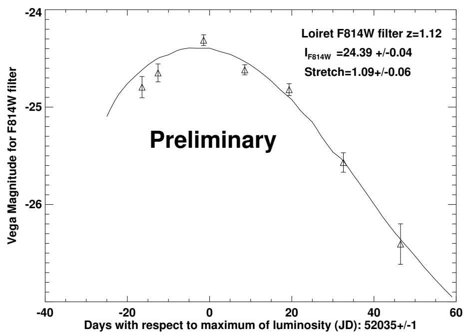

Figure 12: Lightcurve of SN2001gn using Vega magnitude for F814W HST filter. The two first points have been taken with the cfh12k, the 5 last ones with the WFPC2 at HST.

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.

A.3 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.

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