The Nearby Supernova Factory

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January 17, 2003
The Nearby Supernova Factory Collaboration

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The Nearby Supernova Factory
Science Goals

- Anchor low-z portion of Hubble diagram
- Definitive SNe Ia template lightcurves
- Refine K-corrections
- New parameters to standardize SNe Ia
- Supernova rates
- Test for host-galaxy extinction effects
- Local velocity map
- New understanding of SNe Ia
The Nearby Supernova Factory Baseline Program

- Discover and study 300 Type Ia supernovae over 3 years
- Discovery via blind, wide-field CCD search
- Concentrate on nearby smooth Hubble-flow
- Early discovery, 10 to 15 days before maximum
- Flux-calibrated optical spectroscopy every 3-7 days
- Follow-up from -15 to +50 days; more for nearer SNe
- Lightcurve follow-up for $0.03 < z$ for peculiar velocities
- UV spectroscopy for small subset using HST
- Near-infrared lightcurves and/or spectra for small subset
Improve Measurements of Cosmological Parameters

Low-z SNe Ia greatly improve SNAP & SNLS results

Perlmutter et al. 1999

SNAP/SNLS figures courtesy Eric Linder
Choice of Redshift Range

Supernovae Discovered / year / 0.02

Magnitude Error

Redshift

SNfactory

UGC SNe

Velocity+Cosmology Error

| Redshift | Supernovae Discovered |
|----------|-----------------------|
| 0        | 20                    |
| 0.05     | 30                    |
| 0.1      | 20                    |
| 0.15     | 10                    |
| 0.2      | 0                     |

Magnitude Error:

- SNfactory
- UGC SNe
- Velocity+Cosmology Error
IFU Essential for Spectrophotometry

Telescope focal

Spectrograph input

Spectrograph output

Lenslets

Pupil imagery

Spectrum

Detector

Datacube

Light Curves (in any "filter")

Spectral Time Series

Days

Wavelength in SN Rest Frame

MB 5 log(h/65)
days

Spectrograph

input

Spectrograph

output

Lenslets

Pupil imagery

Spectrum

Detector

Datacube

Wavelength in SN Rest Frame

Days

Light Curves (in any "filter")

Spectral Time Series
SNIFS will be side-mounted on UH 2.2-m
## SuperNova Integral Field Spectrograph Specifications

| Channel      | Blue                      | Red                      |
|--------------|---------------------------|--------------------------|
| Collimator   | 70 mm focal length        | 70 mm focal length       |
| Camera       | 140 mm focal length       | 140 mm focal length      |
| Output f/#   | f/7                       | f/7                      |
| Coverage     | 3200-5400 Å               | 5200-10,000 Å            |
| Dispersion   | 2.4 Å/pixel               | 3.0 Å/pixel              |
| Grism        | 300 l/mm @ $\lambda_B = 3800$ Å | 200 l/mm @ $\lambda_B = 7250$ Å |
| Detector     | Marconi 2k × 2k           | E2V-DD 2k × 4k           |
| Calibration  | He/Hg/Cd + flat           | Ne/Ar/Xe + flat          |
## SuperNova Integral Field Spectrograph Specifications

### Integral Field Unit

| Lens specifications | 1 mm diam, f/3.5, fused silica |
|---------------------|---------------------------------|
| Size                | 15×15 1 mm diameter lenslets    |
| Angular Scale       | 0.4″/lens                       |
| Field of View       | 6″ × 6″                          |

### Auxiliary Camera & Guider Camera

| Scale               | 0.14″/pixel                   |
|---------------------|-------------------------------|
| Field of View       | two 4.7′ × 9.4′ regions       |
| Detectors           | E2V 2k × 4k                   |
| Filters             | BVugriz + extinction monitor  |
But first you’ve got to find them . . .
What’s so hard about finding low-z SNe?

- 20 SNe in 20 Deep High-z Fields
- 1 SN in 200 Shallow Low-z Fields
- detector readout rate-limiting
- Scheduled Follow-Up Photometry
- Scheduled Follow-Up Spectroscopy gives Redshift

Photometry gives SNe Ia Peak Brightness and Lightcurve Width

Many Galaxies per Field
## Search Facilities

|                  | NEAT Haleakala | Palomar 3-CCD | Palomar 112-CCD |
|------------------|----------------|---------------|-----------------|
| **Aperture**     | 1.2-m          | 1.2-m         | 1.2-m           |
| **Imager Format**| 4k × 4k        | 3 × 4k × 4k   | 112 × 2.4k × 0.6k |
| **Imager Scale** | 1.33″/pixel    | 1.0″/pixel    | 0.87″/pixel     |
| **Field of View**| 1.5° × 1.5°    | 1.1° × 3.4°   | 2.3° × 4.1°     |
| **Filters**      | open           | open          | RG 610, UBRI    |
| **Exposures**    | 3 × 20 sec     | 3 × 60 sec    | 3 × 60 sec, 140 sec |
| **Readout**      | 20 sec         | 20 sec        | 40 sec, N/A     |
| **Nightly Coverage** | 300 sq. deg. | 500 sq. deg. | 500-800 sq. deg. |
| **Start**        | March 2000     | April 2001    | August 2003     |
| **Data (compressed)** | 12 GB / night | 40 GB / night | 60 GB / night  |
Palomar NEAT Overlap: New = 08/08/2002; Gap = 0–1000 Days
Automated Supernova Discovery

- Necessary for the SNfactory or any large-scale study of nearby supernovae
- Requires automated data processing
  - Data transfer
  - Image processing and cleaning
  - Subtraction of matching image stacks
  - Identification of objects on subtracted frame
- Hard part: supernova discrimination
  - Supernova? Asteroid? Variable Star? Artifact?
Data is sent from the Palomar 48″
along the HPWREN wireless network
and up to LBL/NERSC.

- Archived on NERSC High-Performance Storage System (HPSS)
- Massive robotic tape vault
- 100 petabyte capacity
- Transfer rates of 10 Mb/s from Palomar→HPSS
- Images processed and subtracted on the NERSC Parallel Distributed Systems Facility (PDSF)
- 400-CPU workstation cluster
- 2 TB local storage for SNfactory processing
- Automated job submission and queuing system processes and subtracts images with no human action
The Challenge is in the Numbers

- Each night transfer and process
  - 21,000 images (CCD frames)
  - 50-60 gigabytes
- Compare with previous observations
  - 20 terabytes of reference data
  - Database of millions of images
- Automate
  - Image Processing
  - Candidate Identification
  - Quality Control
Automated Image Processing

- Processing continuous throughout the night
- Download images
- Group according to dark calibration frame and CCD
- Clean and process images
  - Bias correct
  - Dark subtract
  - Flatfield (*this is the tricky one*)
- Load into image database
- Final run at 8:30 am every morning
- All processing finished by noon
Image Database

- PostgreSQL database stores information for all of the images processed from search telescopes
- Currently holds several million images
- Used for matching search and reference images
- Examples of some of the database tables:
  - Image quality information (on all 2,935,265 images)
  - Transformations between images (4,560,472 pairs)
  - Subtractions of images (260,718)
Image subtraction to find SNe

- Query database for matching images
- Verify images quality and USNO star catalog match
- Calculate transformations between images
- Move all images to the same coordinates and sum
- Generate separate reference and search image stacks
- Calculate point spread function convolution to image stack with the worst seeing - difficult to do well
- Subtract image stacks: \( \text{SUB} = \text{NEW} - \text{REF} \)
- After adjusting by proper flux ratio
SN Candidate Identification

- Scan subtracted image, SUB, for objects
- Object identification
  - star, galaxy, cosmic ray, artifact, etc.
- SN candidate must be consistent in all frames
- Quantitative score cuts select only interesting objects
- Our current automated screening leaves us with 1% of the images to scan for supernova candidates
- Takes one person < 2 hours to scan a night’s data
Discovery of 2002cx
SNfactory Prototype Search

- Fall 2002 - Spring 2003, I carried out a prototype search to verify the SN discovery pipeline.
- 78 SNe were found in ~6 months
  - 69 SNe found first by us
  - 9 SNe reported first by other groups
- 45 SNe spectroscopically classified
  - 30 Ia, 2 Ib/c, 13 II
- Discovery rate: ~12.5 SNe/month ⇒ 150 SNe/year
  - 2/3 Ia fraction ⇒ ~100 SNe Ia / year
- Conclusion: Search pipeline verified as a success!
Successful test of Search Pipeline

some of our 83 SNe discoveries reported in the IAUC
Discovery Mag of SNe in Search

Supernovae Discovered per 0.5 discmag bin

"R"-band Discovery Magnitude

All SNe

SNe w/ known z
Discovery Mag of SNe in Search

Supernovae Discovered per 0.5 discmag bin

"R"-band Discovery Magnitude

Discovery efficiency

SNe w/ known z

All SNe
Redshift of SNe from prototype search

57 SNe w/ known z
The Nearby Supernova Factory will

- be the largest nearby supernova search yet.
- be the only long-term, blind, CCD-based nearby SN search.
- implement a unique instrument optimized for automated SN studies.
- obtain the most extensive set of SN Ia spectra ever.
- provide improved statistical constraints on cosmological parameters.
- greatly improve current SN Ia standardization methods.
- offer the possibility of new and improved methods of standardizing SNe Ia.
- provide new insights into the physics of SNe Ia.
- begin in earnest in spring 2004.
