



# The Center for Astrophysical Thermonuclear Flashes

---



## Confronting Supernova Explosion Models w. Observations: Developing Type Ia SNe as Precision Tools to Probe Dark Energy

Don Q. Lamb  
Argonne-Chicago-Fermilab  
6th Collaboration Meeting  
University of Chicago

University of Chicago  
12 October 2009

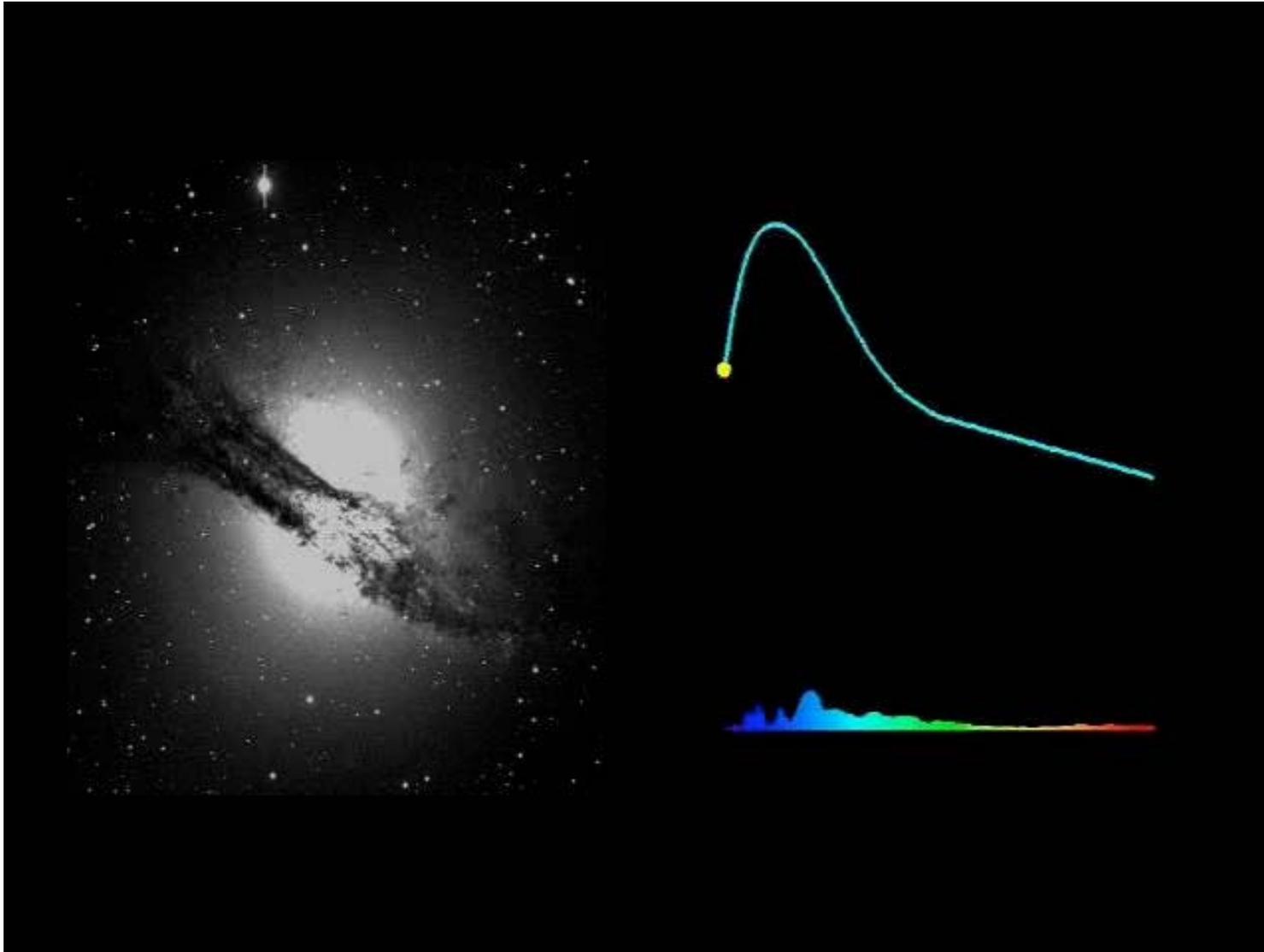


An Advanced Simulation and Computation (ASC)  
Academic Strategic Alliances Program (ASAP) Center  
at The University of Chicago





# What Are Type Ia Supernovae?

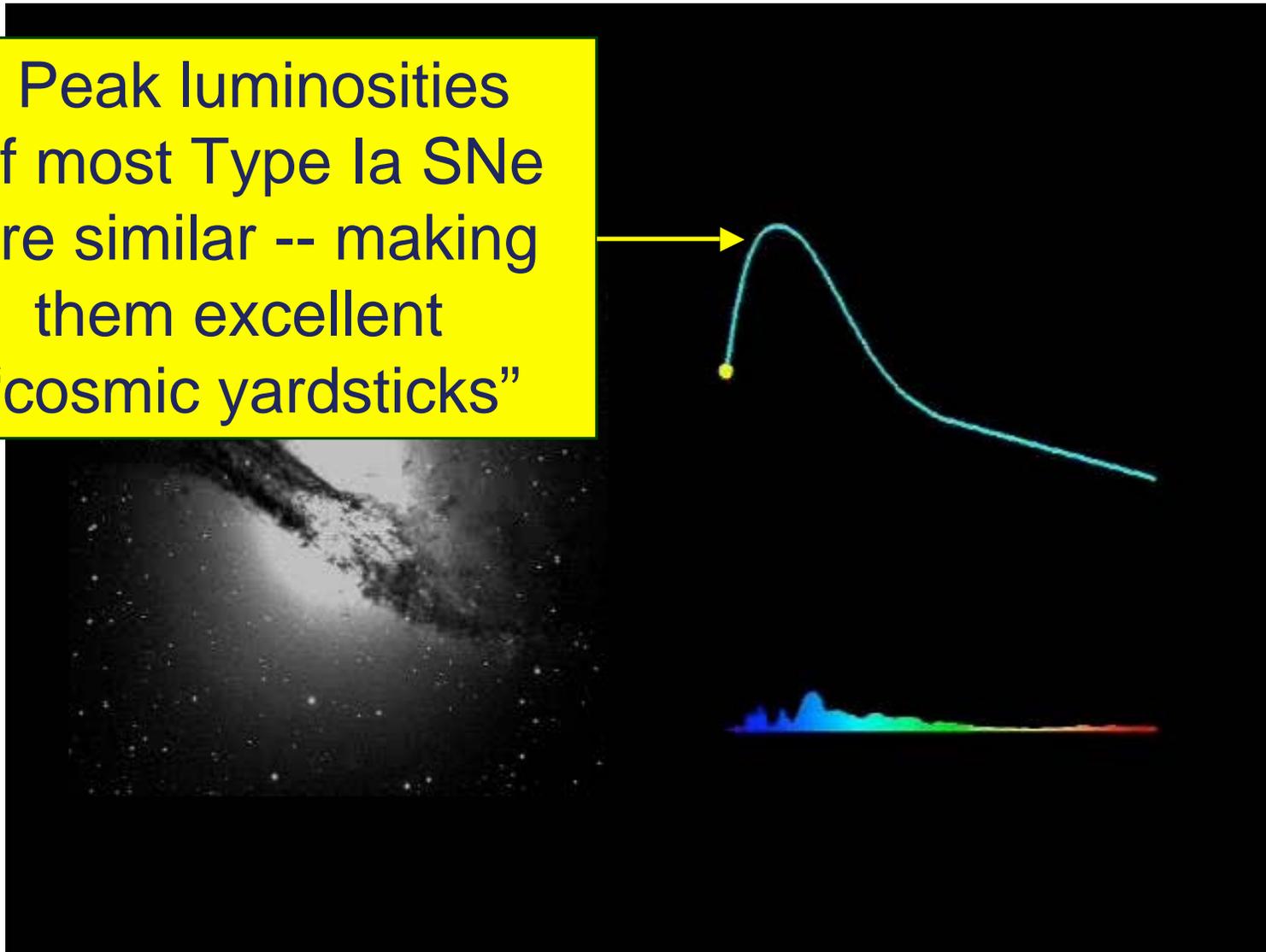




# What Are Type Ia Supernovae?

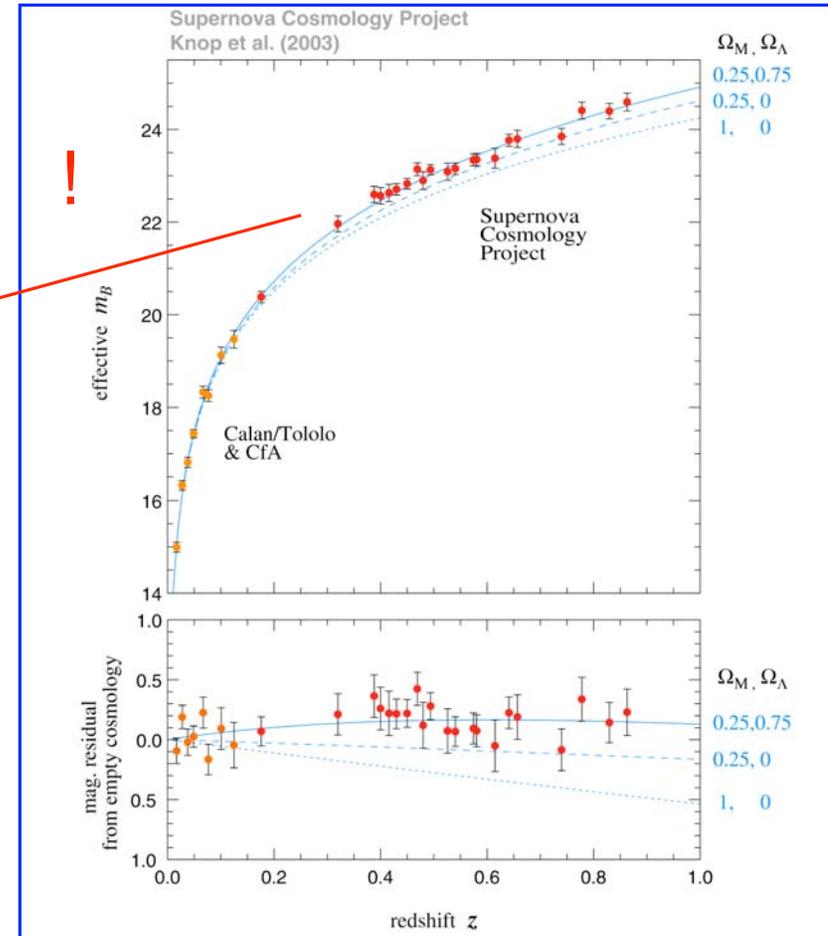
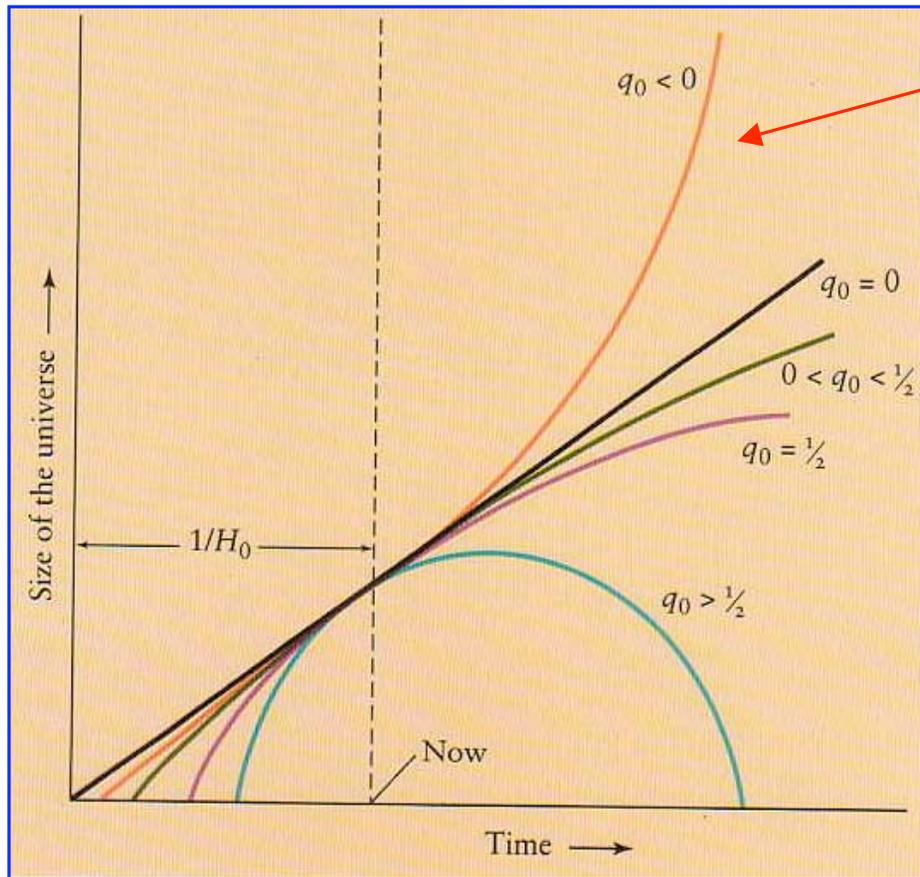


Peak luminosities of most Type Ia SNe are similar -- making them excellent "cosmic yardsticks"





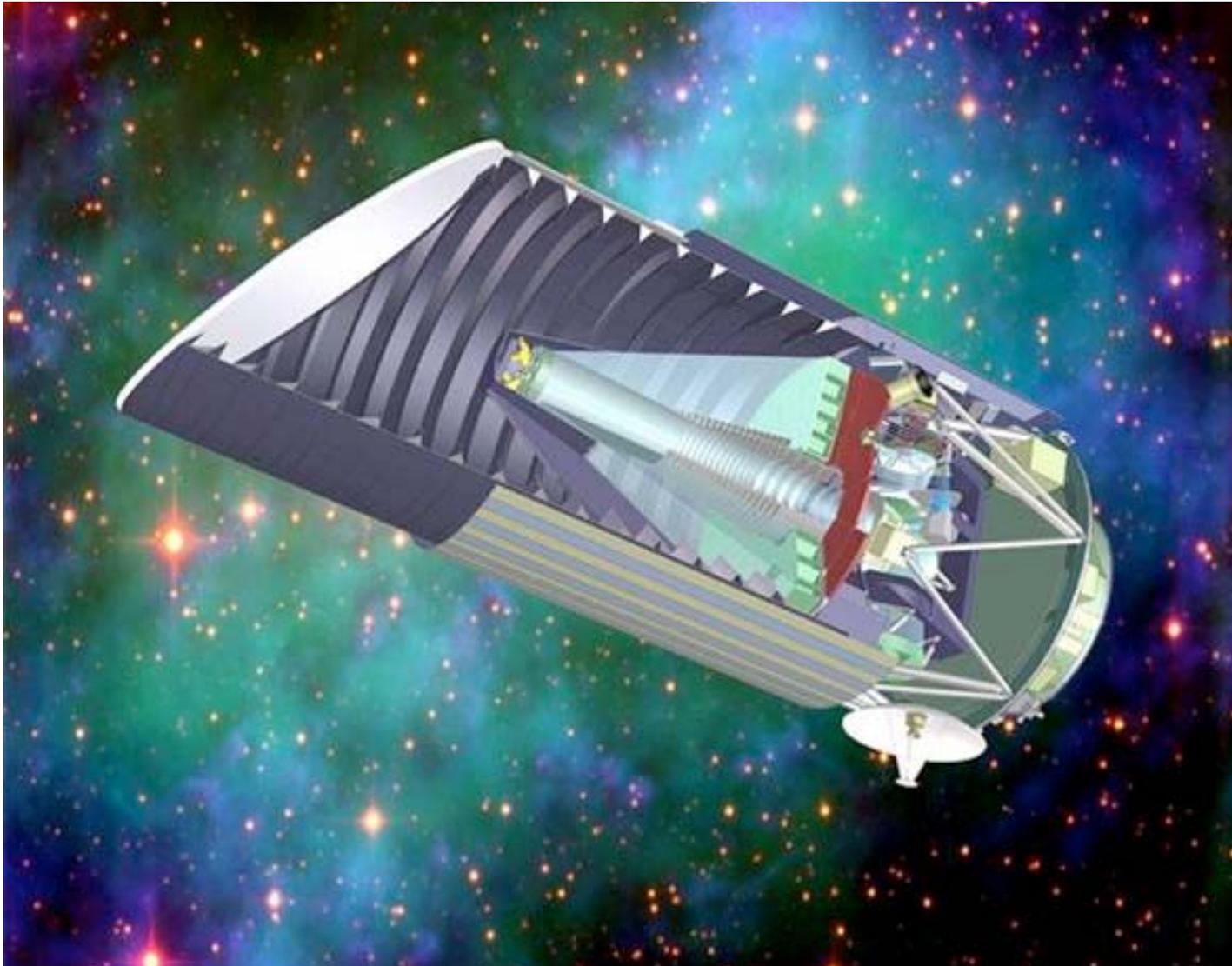
# Accelerating Expansion of Universe





# Joint Dark Energy Mission

---



[The ASC/Alliances Center for Astrophysical Thermonuclear Flashes](#)  
The University of Chicago



# Type Ia Supernovae



Image copyrighted by Mark A. Garlick



## Accretion

- Stellar binary in which main sequence star transfers mass onto white dwarf

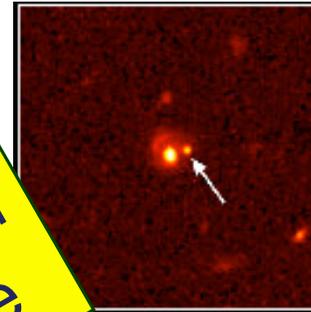


Image credit P. Garnavich/CfA

## Lightcurve

- Expansion of star ejects the ejecta
- Radioactive decay of  $^{56}\text{Ni}$  heats the ejecta to high temperature, which makes the supernova visible

Radioactive decay of  $^{56}\text{Ni}$  heats expanding gas and makes explosion visible

Nuclear energy powers the explosion

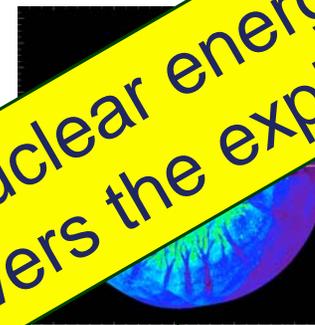


## Smoldering

- Subsonic convection in core of white dwarf
- Heat transport is by electron conduction

~1000 yr

## Ignition



## Flame

- Nuclear burning initially due to laminar flame
- Buoyancy—driven turbulence increases nuclear burning rate
- Transition from deflagration to detonation occurs, causing the star to explode

~seconds



# Argonne Leadership Computing Facility



- ❑ Current Computational Resources
  - ❑ 556 TF Blue Gene/P (*Intrepid*) supercomputer
  - ❑ 8 PB file system
  - ❑ Powerful graphics platform (*Eureka*)
- ❑ Future Computational Resources
  - ❑ 20 PF Blue Gene/Q is planned



The Center for Astrophysical Thermonuclear Flashes

## Simulation of the Deflagration Phase of a Type Ia Supernovae

**Ignition occurs 100 km from the center of the star.  
Hot ash is shown in yellow and stellar surface in blue.**

*This work was supported in part at the University of Chicago by the DOE NNSA ASC ASAP and by the NSF. This work also used computational resources at LBNL NERSC awarded under the INCITE program, which is supported by the DOE Office of Science.*

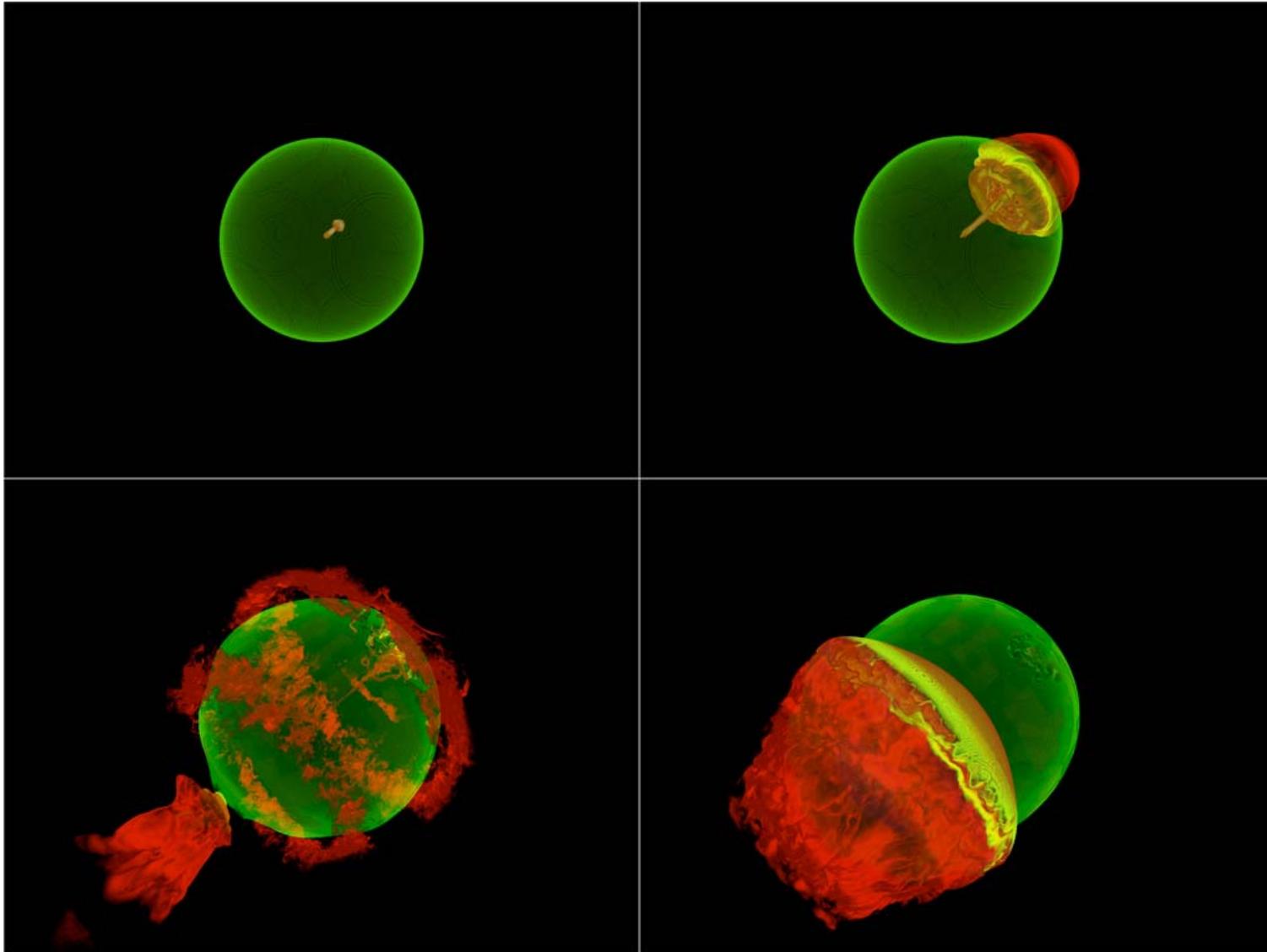


An Advanced Simulation and Computation (ASC)  
Academic Strategic Alliances Program (ASAP) Center  
at The University of Chicago





# Nuclear Flame Ignites at a Single Point Off-Center





The Center for Astrophysical Thermonuclear Flashes

## Simulation of the Deflagration and Detonation Phases of a Type Ia Supernovae

**Ignition occurs 40 km from the center of the star.  
Hot material is shown in color and stellar surface in green.**

*This work was supported in part at the University of Chicago by the DOE NNSA ASC ASAP and by the NSF. This work also used computational resources at LBNL NERSC awarded under the INCITE program, which is supported by the DOE Office of Science.*

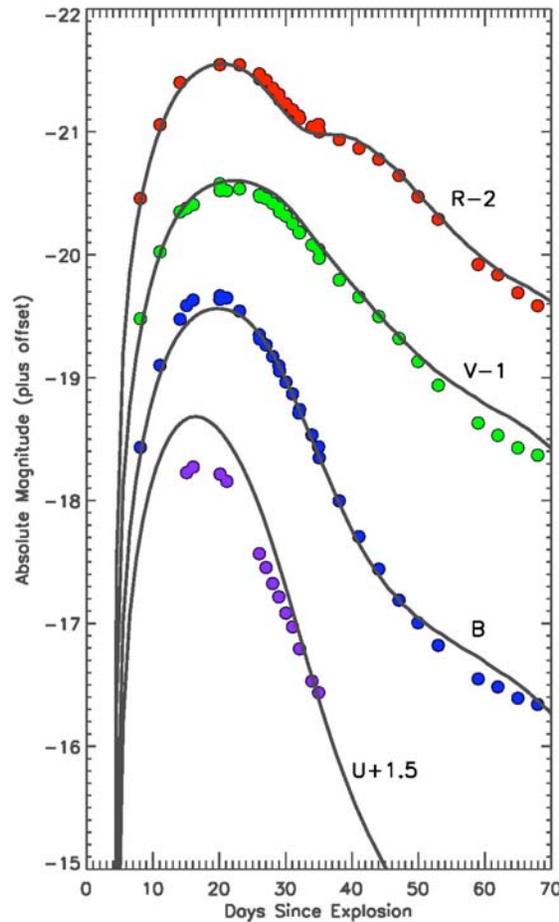


An Advanced Simulation and Computation (ASC)  
Academic Strategic Alliances Program (ASAP) Center  
at The University of Chicago

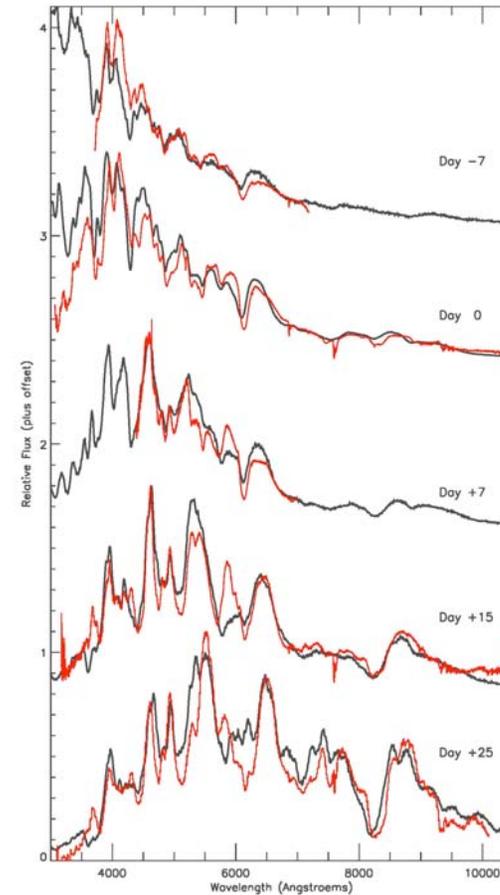




# Validation of Type Ia SN Explosion Models Using High-Quality Observations



Comparison of U, V, B, R light curves predicted by GCD model and obs. of Type Ia supernova SN 2001el

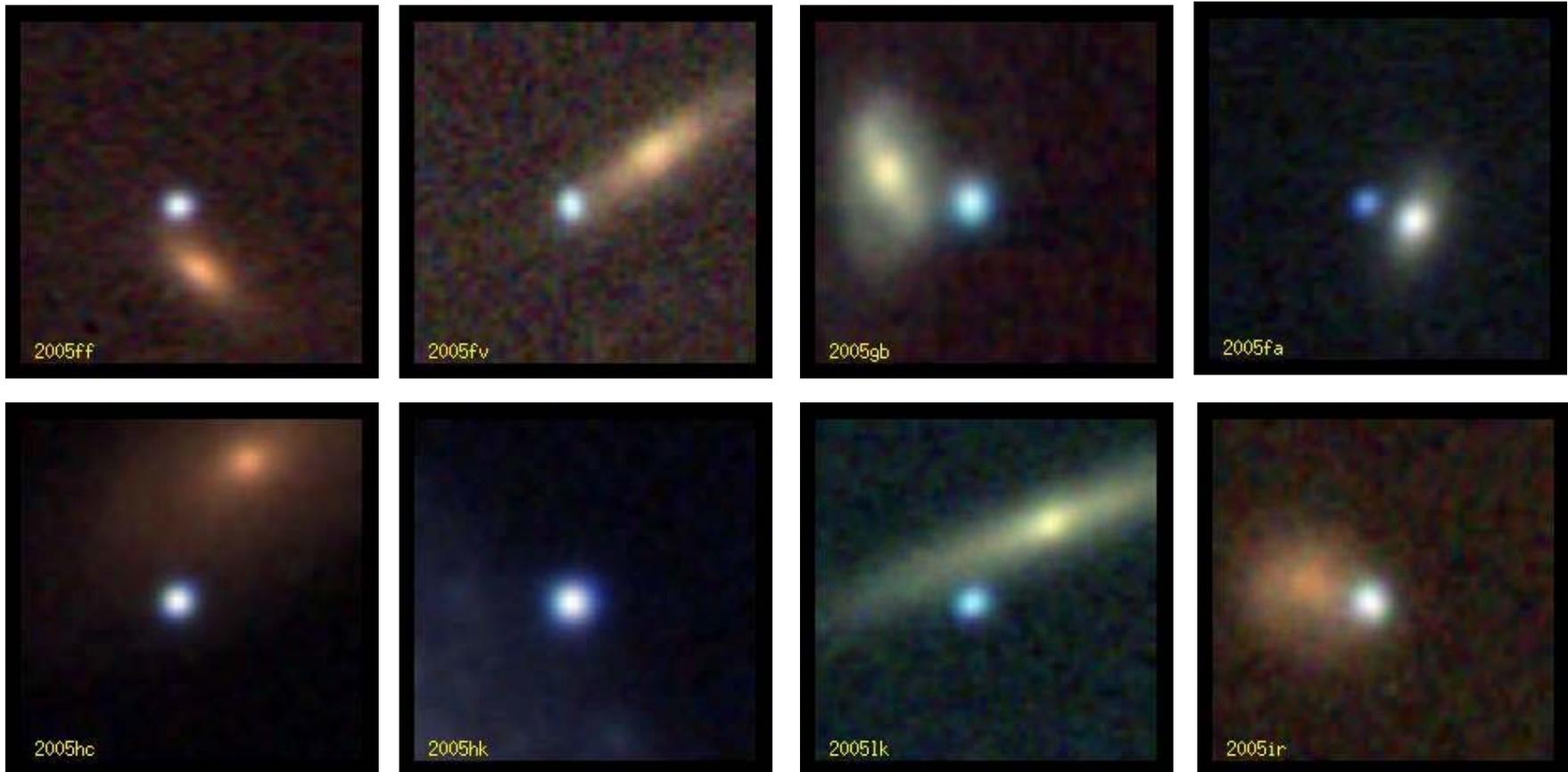


Comparison of spectra predicted by GCD model and obs. of Type Ia supernova SN 1994D

*Kasen and Plewa (2006)*



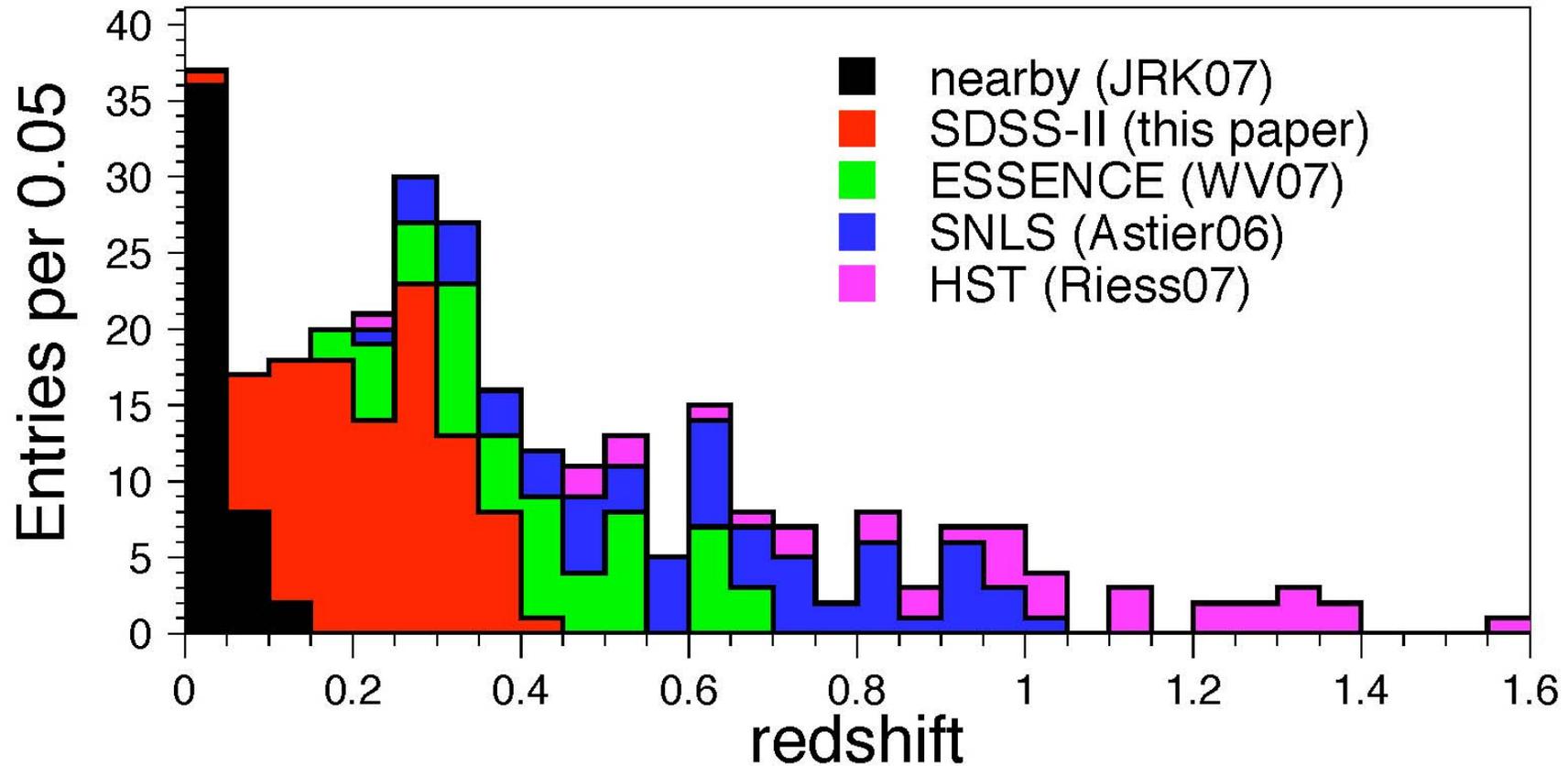
# SDSS-II Supernova Survey Project



SDSS-II Supernova Survey identified more than 500 Type Ia SNe and obtained high-quality light curves and spectra for many of them (Holtzman et al. 2009, Kessler et al. 2009)



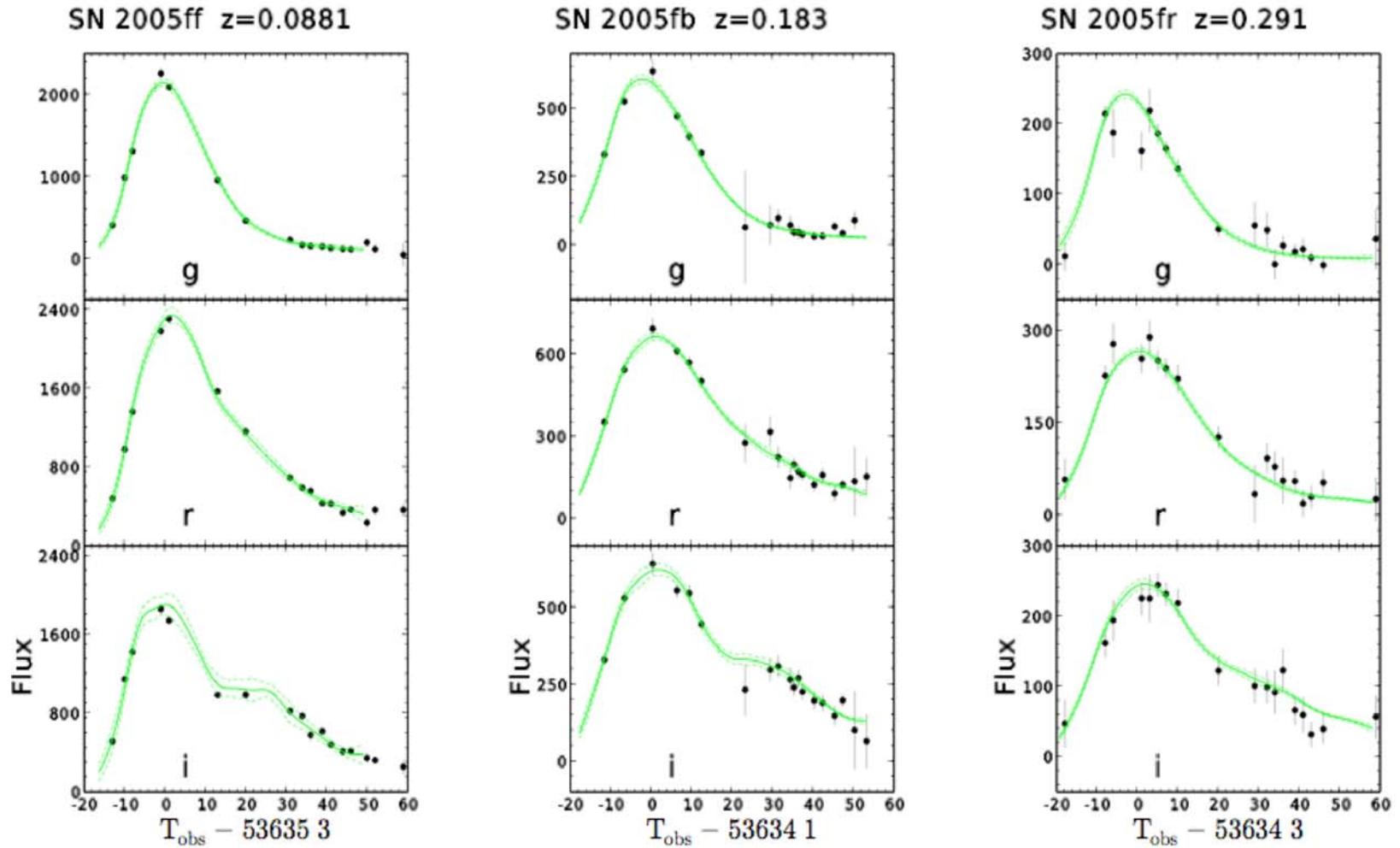
# SDSS-II Supernova Survey Type Ia SNe vs. Redshift



Kessler et al. (2009)



# Examples of SDSS-II Supernova Survey Type Ia SN Light Curves



An Advanced Simulation and Computation (ASC)  
Academic Strategic Alliances Program (ASAP) Center  
at The University of Chicago





# Conclusions

---



- ❑ Flash Center has so far carried out more than 50 large, multi-scale, multi-physics, 3D simulations of the explosion phase of thermonuclear-powered (Type Ia) SNe
- ❑ Radiation transfer calculations using the results of these simulations are being carried out by Dan Kasen (UC Santa Cruz), Chris Fryer and Aimee Hungerford (LANL), and Eddie Baron (Oklahoma) and Daan van Rossum (Chicago) to produce light curves and spectra
- ❑ SDSS-II Supernova Survey Project has identified more than 500 nearby Type Ia SNe and obtained high-quality light curves and spectra for a large fraction of them
- ❑ Collaboration between the Flash Center and the SDSS-II Supernova Survey Project will confront the calculated light curves and spectra with observations to better understand Type Ia SNe with the goal of making them precision tools for probing dark energy