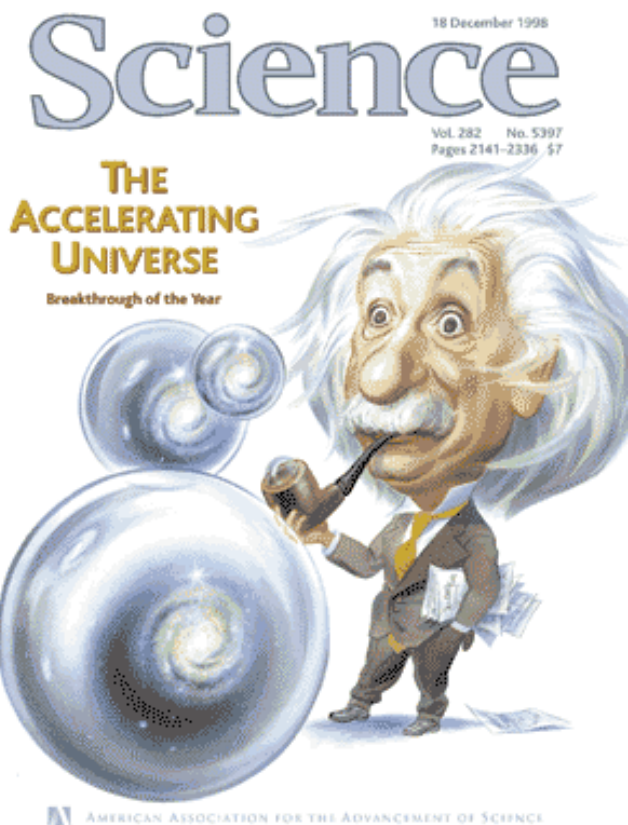


Why Do We Want to Do the SN Factory in the First Place? Fame, Glory, all the usual reasons...



EINSTEIN'S REPULSIVE IDEA

He invented antigravity in desperation and abandoned it first chance he got—but it may be the most powerful force in the universe

By MICHAEL D. LEWONICK

GRAVITY

- WHAT IT IS:** An attractive force that pulls matter together like a rubber band
- HOW IT OPERATES:** Gravity weakens over distance when the distance between two galaxies doubles, the force between them is one-fourth as strong
- WHAT THAT MEANS:** As the universe expands, gravity is less and less effective at slowing the expansion

ANTIGRAVITY (Dark Energy)

- WHAT IT IS:** A property of empty space that exerts an outward force like a compressed spring at every point in space
- HOW IT OPERATES:** A given volume of space always has the same amount of dark energy, so when the distance between two galaxies doubles, the force pushing them away from each other is twice as strong
- WHAT THAT MEANS:** As the universe expands the volume of space increases, which means more dark energy. By now, 14 billion years after the Big Bang, antigravity has overwhelmed gravity, so the expansion will get faster and faster

EXPANSION SLOWING DOWN → **EXPANSION SPEEDING UP**

Galaxies

Size of visible universe today

Size of universe 6 billion years ago

Size of universe 2 billion years after the Big Bang

Size of universe 1 billion years after the Big Bang

Size of universe 100 million years after the Big Bang

Size of universe 10 million years after the Big Bang

Size of universe 1 million years after the Big Bang

Size of universe 100,000 years after the Big Bang

Size of universe 10,000 years after the Big Bang

Size of universe 1,000 years after the Big Bang

Size of universe 100 years after the Big Bang

Size of universe 10 years after the Big Bang

Size of universe 1 year after the Big Bang

Size of universe 10 minutes after the Big Bang

Size of universe 1 second after the Big Bang

Size of universe 10 milliseconds after the Big Bang

Size of universe 1 microsecond after the Big Bang

Size of universe 1 nanosecond after the Big Bang

Size of universe 1 picosecond after the Big Bang

Size of universe 1 femtosecond after the Big Bang

Size of universe 1 attosecond after the Big Bang

Size of universe 1 zeptosecond after the Big Bang

Size of universe 1 yoctosecond after the Big Bang

Size of universe 100 years after the Big Bang

Size of universe 1 billion years after the Big Bang

Size of universe 6 billion years after the Big Bang

Size of universe 14 billion years after the Big Bang

Size of universe 20 billion years after the Big Bang

Size of universe 30 billion years after the Big Bang

Size of universe 40 billion years after the Big Bang

Size of universe 50 billion years after the Big Bang

Size of universe 60 billion years after the Big Bang

Size of universe 70 billion years after the Big Bang

Size of universe 80 billion years after the Big Bang

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Size of universe 110 billion years after the Big Bang

Size of universe 120 billion years after the Big Bang

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Size of universe 980 billion years after the Big Bang

Size of universe 990 billion years after the Big Bang

Size of universe 1000 billion years after the Big Bang

NOT SO DUMB What he called a blunder may have been a Nobel-caliber discovery

and study a distant supernova—an exploding star—astronomers from two rival research teams have jointly gathered the strongest evidence yet that the expansion of the universe is actually speeding up, like a rocket with its throttle wide open. And that means something is pushing it.

“What that something might be is, at this point, anybody’s guess. “Shake a tree full of theorists,” says Adam Riess of the Space Telescope Science Institute in Baltimore, Md., leader of the collaboration, “and 20 ideas will fall out.” For now, the unknown force is simply being called “dark energy” to emphasize its mysterious nature.

But its existence is becoming hard to dispute. The first hint came a couple of years ago, when two independent teams of astronomers tried to calibrate the cosmic expansion using Type Ia supernovas, a kind of exploding star whose intrinsic brightness is highly consistent.

Comparing the known brightness of such a supernova with how bright it appears in the sky gives a good measure of how far away it is—and thus how long ago

in cosmic history its light was emitted. Then, by measuring how fast each supernova is moving away from Earth in the overall ballooning of the universe, it can be determined what the expansion rate was at different times in the past.

To everyone’s astonishment, both groups found that instead of the gradual, gravity-driven slowdown they expected, the rate was getting faster. Says Saul Perlmutter of Lawrence Berkeley National Laboratory in California, who heads one of the groups, “We spent at least a year struggling to understand what we were seeing.” In the end, both groups decided that dark energy, functioning as a kind of antigravity, was their best guess.

Critics argued that there might be a

more conventional explanation, such as intergalactic dust, which could contaminate the brightness measurements. But the new observations seem to have closed that loophole. The newly identified supernova went off about 11 billion years ago—about 50% further back in time than the previous record holder. “If the dust were there,” says Lawrence Berkeley astrophysicist Peter Nugent, a member of Perlmutter’s team and Riess’s collaborator on the new research, “the supernova would have been much dimmer than it was.”

The new supernova’s remoteness was even more important for another reason. “If dark energy is really the explanation for what we see,” says Riess, a member of the rival team, “then its effect should have been weaker in the early universe.” That’s because while the force of gravity between galaxies falls as they move further apart, dark energy is a property of space and gets stronger as the universe expands. Shortly after the Big Bang, when the universe took up relatively little space, there wasn’t much dark energy. Now much bigger, the modern universe has more space and thus more energy to shove galaxies apart. Sure enough, this distant supernova shows that the expansion was slower long ago.

While the new observations go a long way toward confirming that dark energy is real, astronomers would love to see a few more distant supernovas, just to be sure. Unfortunately, that won’t be happening soon. The Hubble pictures that Riess and Nugent analyzed were all taken purely by chance while the telescope was looking for other things. Aiming at distant galaxies in hopes a supernova will go off is an inefficient use of the telescope’s valuable time. The best bet would be a satellite devoted to such a project—and indeed, Perlmutter and others are working on that idea, although it will take years to get off the ground.

If space really does seethe with dark energy, the fate of the universe, a matter of long-standing debate, will be clear. With more dark energy today than yesterday, and more of the stuff tomorrow than today, the cosmos should fly apart faster and faster as time goes by. There will be no Big Crunch, as some have predicted, with billions of galaxies falling in on one another in a fiery apocalypse. Tens of billions of years from now, our Milky Way galaxy will find itself alone in empty space, with its nearest neighbors too far away to see. In the end, the stars will simply wink out—and the universe will end not with a bang but with the meekest of whimpers.

TIME, APRIL 16, 2001



**Why Do We Want to Do the SN Factory in the First Place?
Fame, Glory, all the usual reasons...**

**Actually we want do do something much more mundane yet
crucial for the whole field of SN cosmology measurements:**

**We need to develop SNe into the best possible distance indicators
they can be, with a full understanding of their statistical and
systematic limitations.**

**Which means we have to increase our understanding of the
progenitors and physics of these mechanisms.**



The ultimate success of the following programs hinges on our ability to deliver the goods:

SNAP

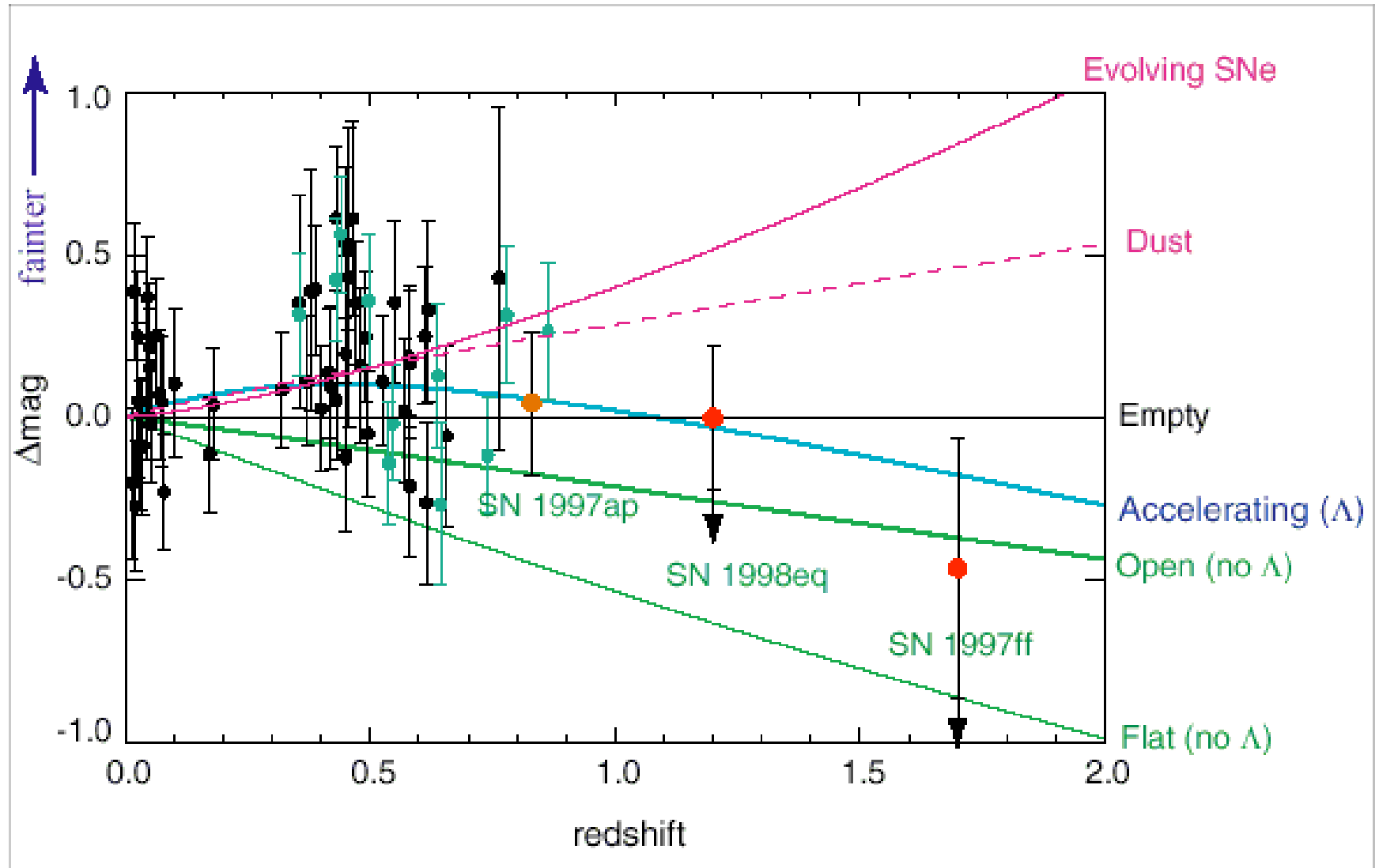
CFHTLS

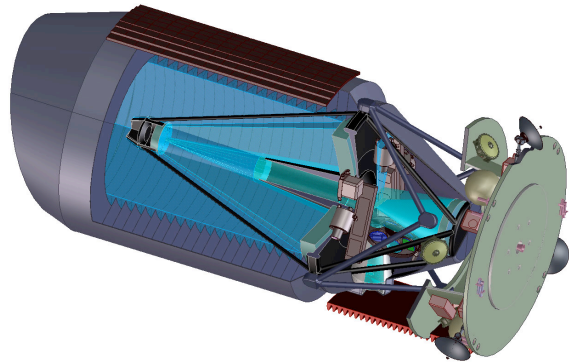
Essence/*w*-Project

Carnegie SN Search

All of these projects have cited us, in one form or another, as grounding our knowledge and understanding of nearby SNe so that the cosmological measurements made at higher- z can be improved to measure the equation of state and beyond...

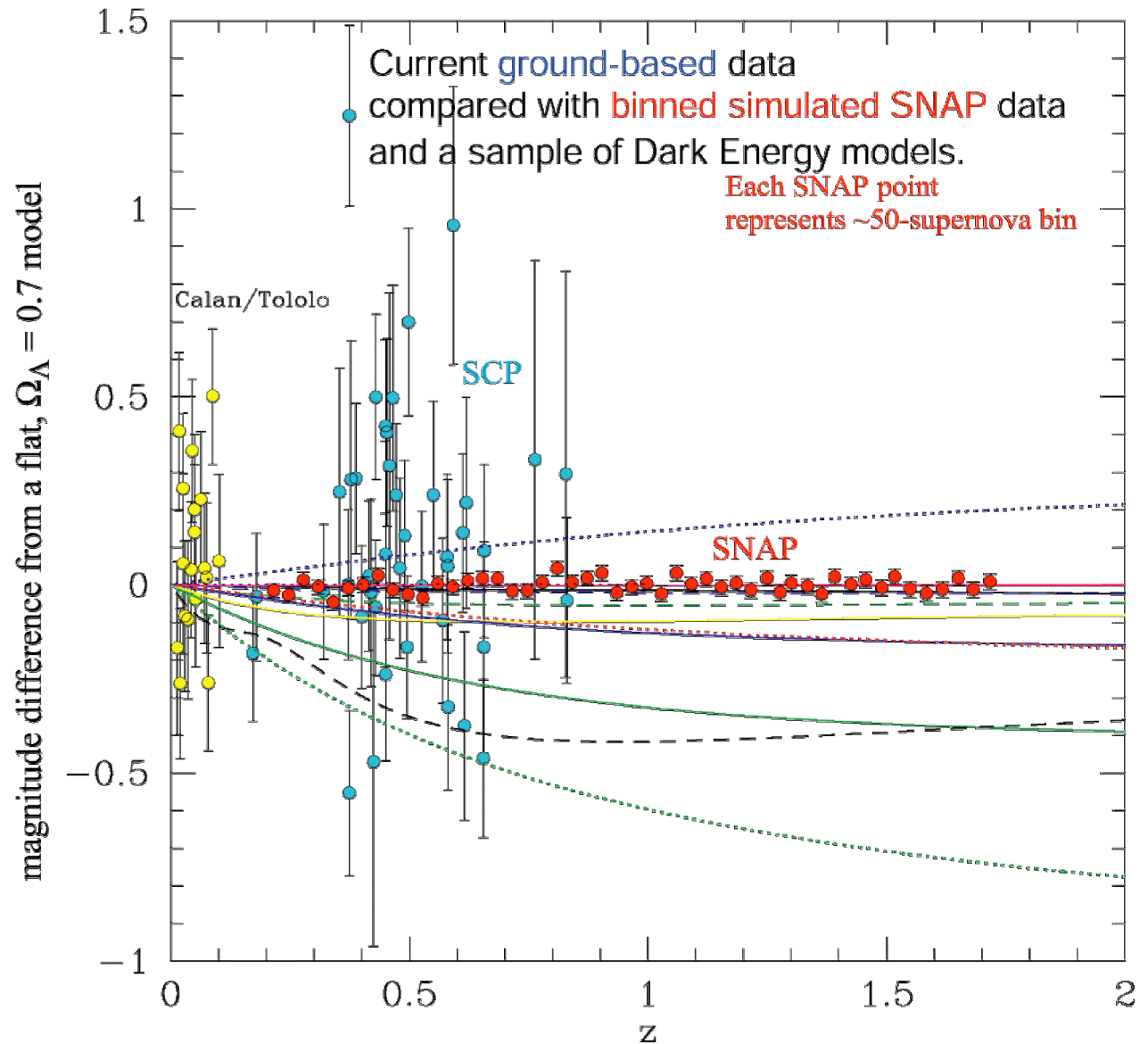
So while we won't get the glory, we will get the most important citations in the papers for each of the above projects.





SuperNova
Acceleration
Probe

2000 SNe Ia
(CFHTLS,
Essence, etc.)



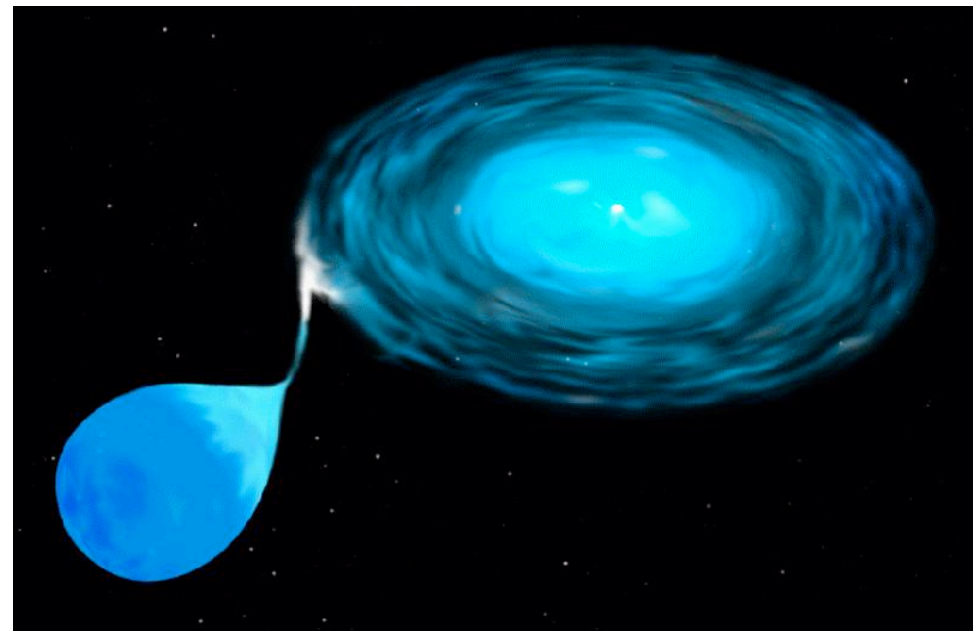
based on
Weller & Albrecht (2001)



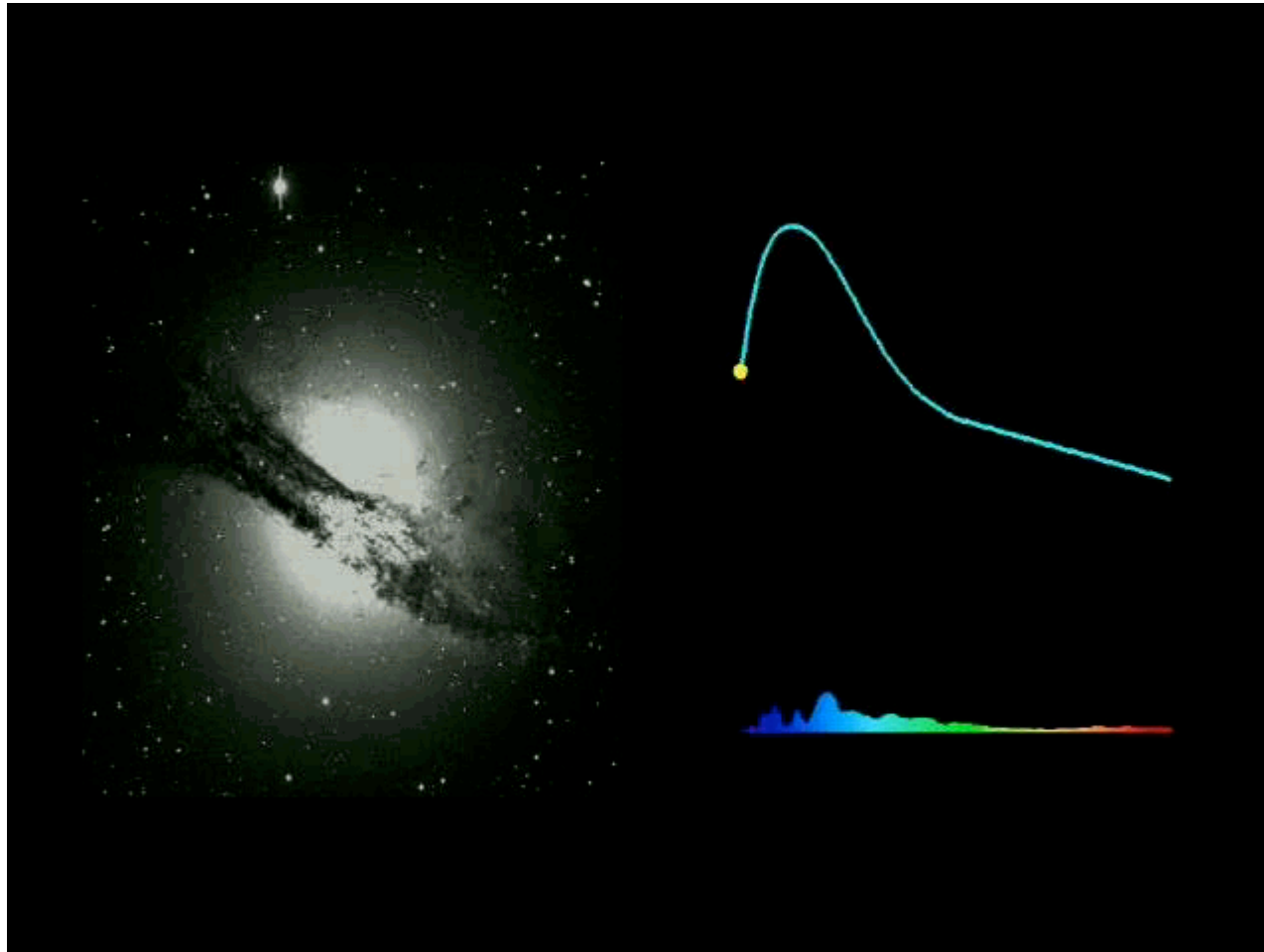
Type Ia Supernovae are bright:
For a few weeks they are as
bright as the entire galaxy they
originated in.

"Before" and "After" for SN 1999be.

Type Ia Supernovae are very similar:
They give reliable distances to better
than 10%



Artist's rendition of an accreting White Dwarf.



Type Ia Supernovae are rare: 1 every 400 years in a galaxy like our MW.



Type Ia Supernovae: Fundamentals



What we absolutely know about SNe Ia:

- Occur in all types of galaxies
- Show the presence of strong SiII and SII in their spectra
- With some small calibration (based on light-curve shape and colors) they can be turned into an excellent standardized candle $< 10\%$ in distance.

What we surmise from these observations:

- Thermonuclear explosion of a C/O white dwarf
- Powered by the decay of ^{56}Ni
- Probably close to the Chandrasekhar mass

After 30 years we only have a weak understanding of the progenitor-mechanism

Parameters which control the SN Ia SED

- Total mass of Ni^{56} synthesized
- Total mass of star.
- Kinetic energy of explosion.
- Composition and density of the star.

All of the above are a function of position in 3D
and of time.

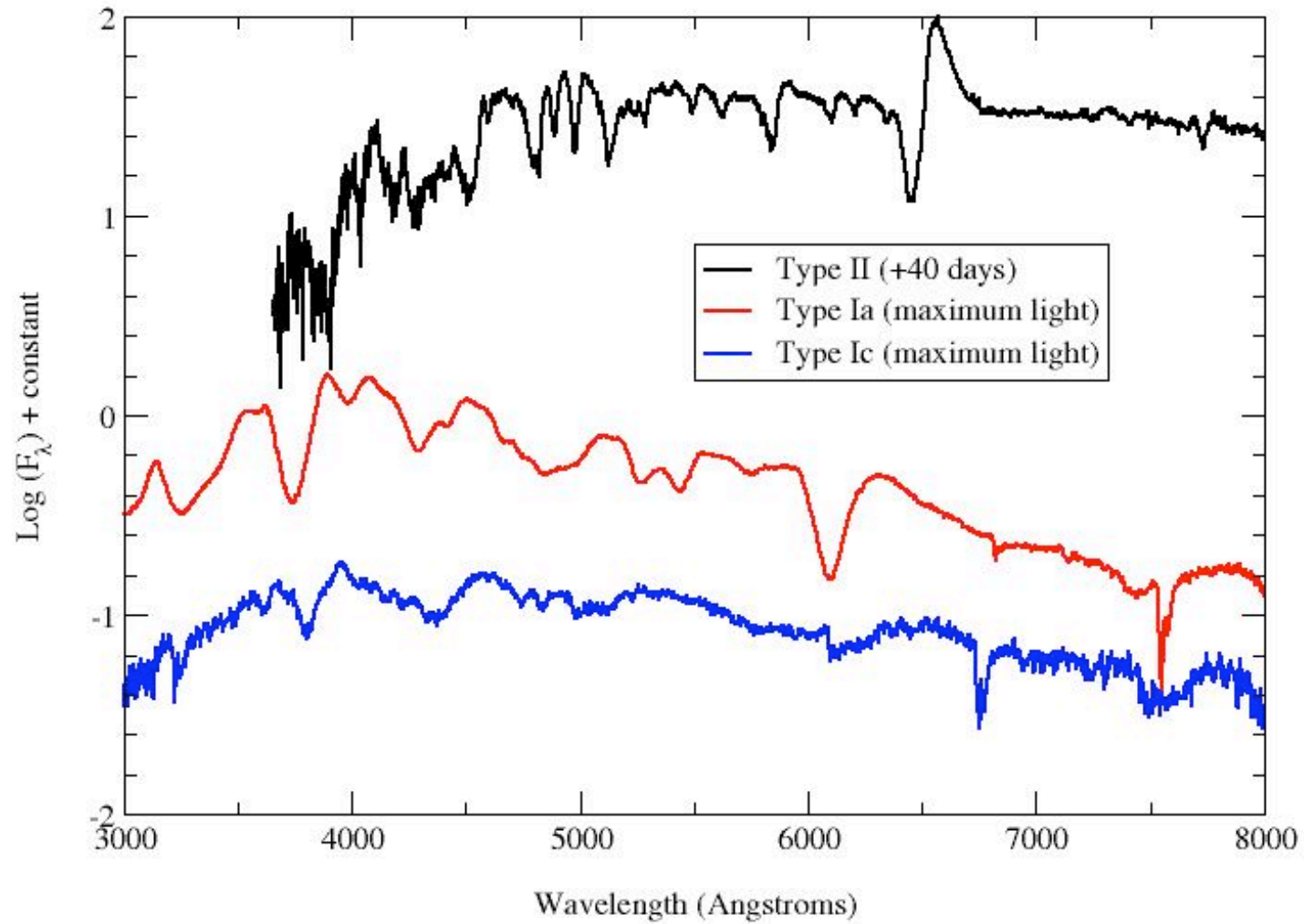


SNIFS: Fundamentals

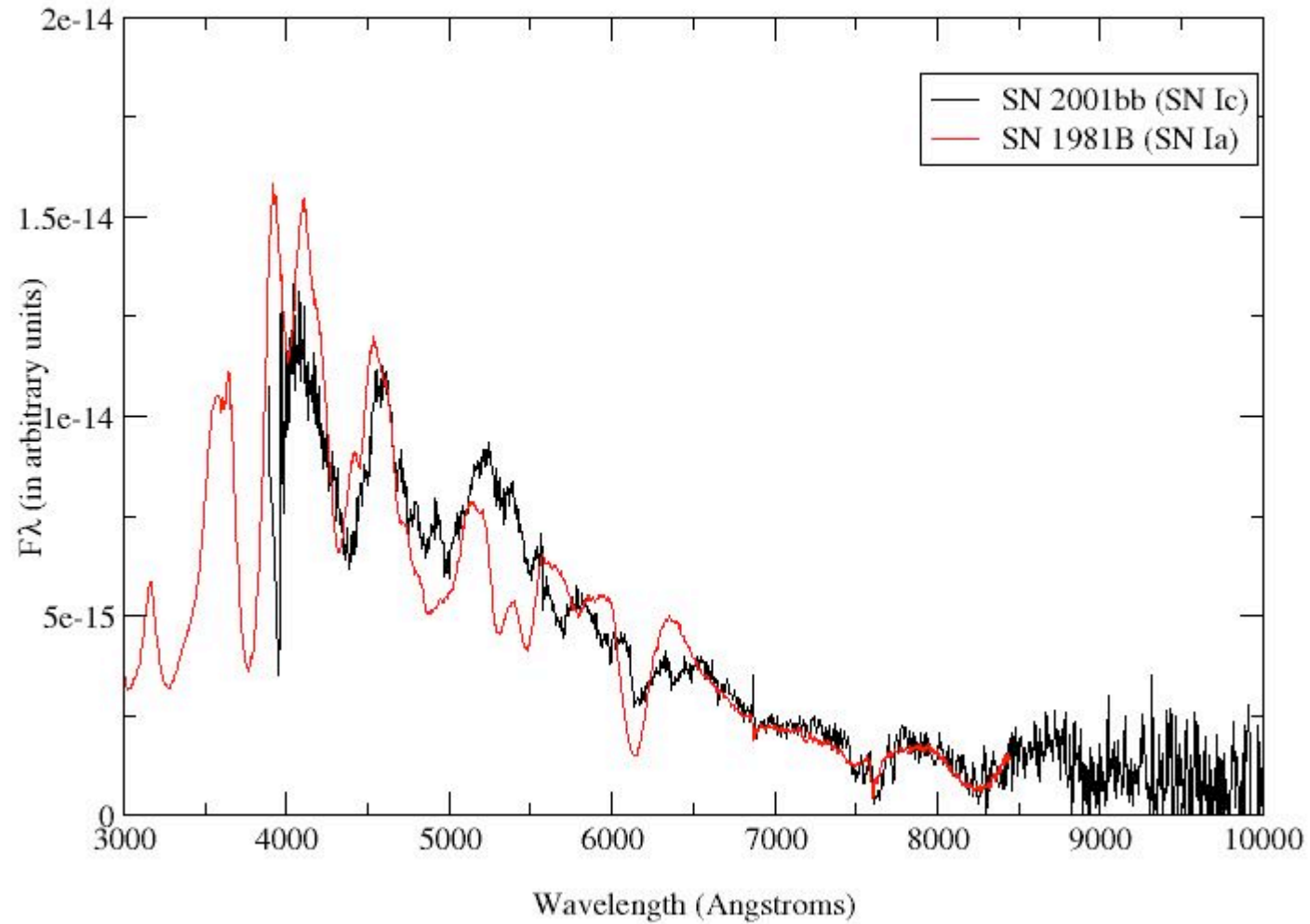


For the purposes of this talk I propose we consider SNIFS in 3 modes:

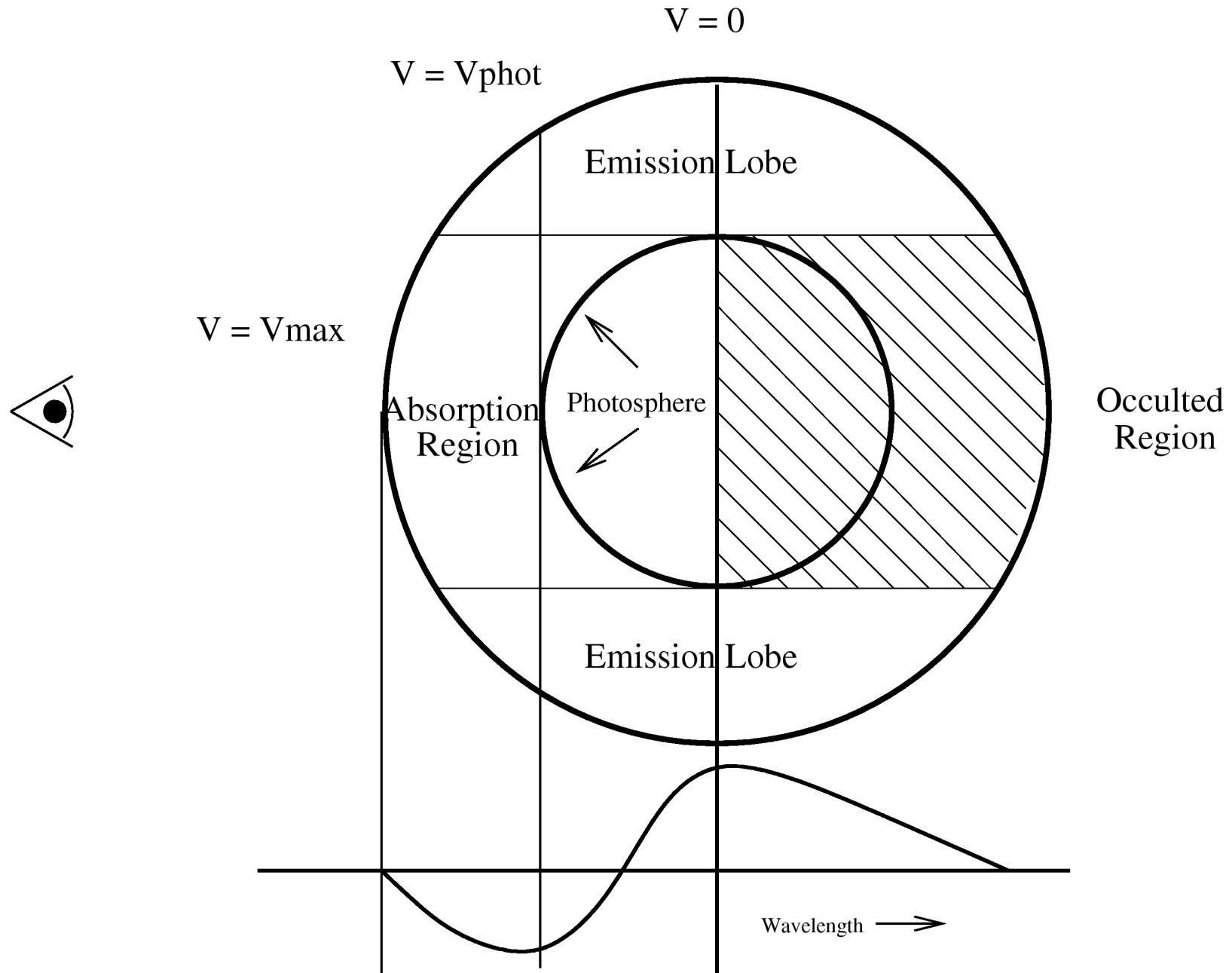
- **Science-grade spectrum**: Measure velocity and strength of all spectral features to desired accuracy
- **Id-level spectrum**: Enough to separate subtypes, junk...
- **Photometry**: S/N high enough to measure extinction properties, color evolution, etc.



Nasty Spectral Comparison

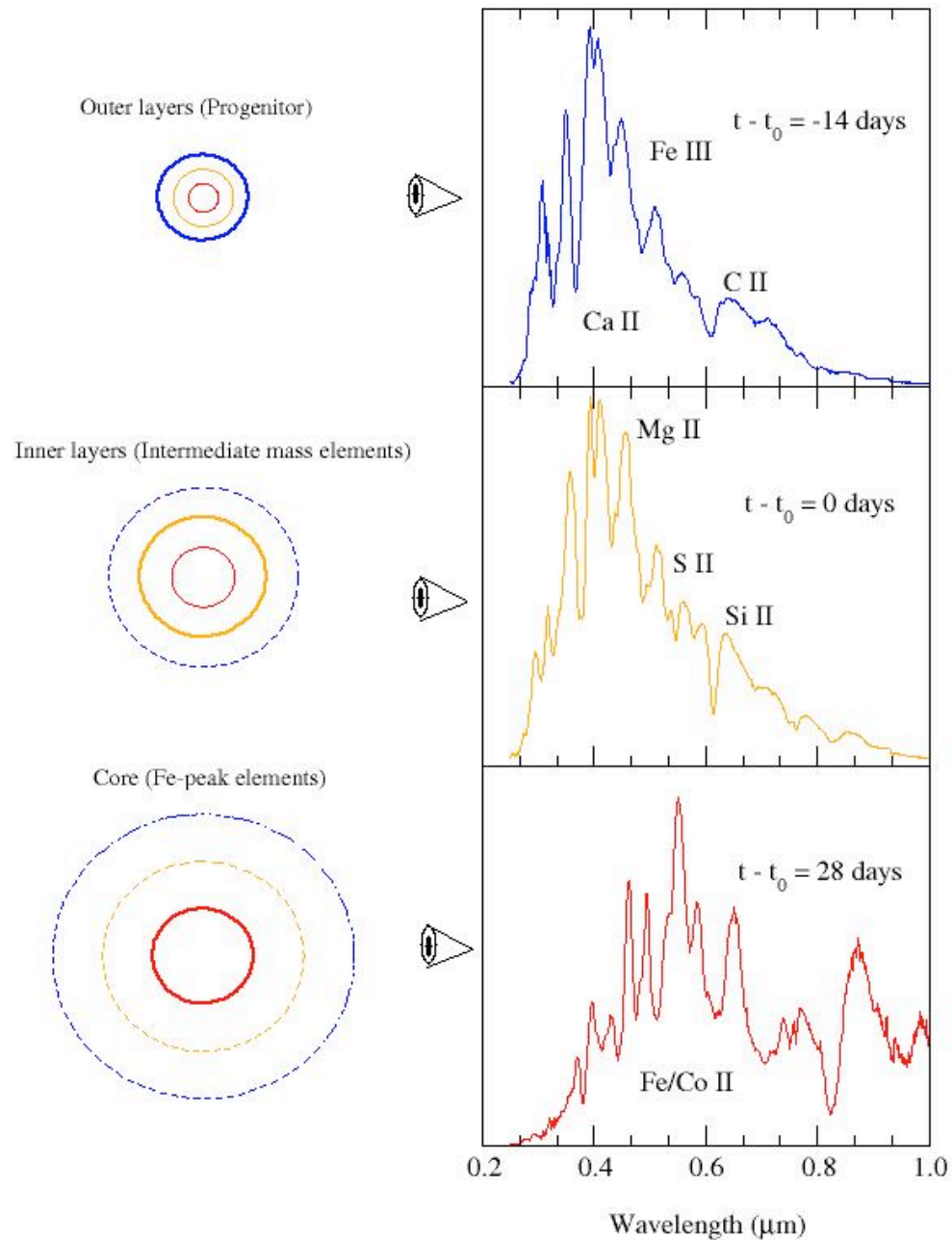


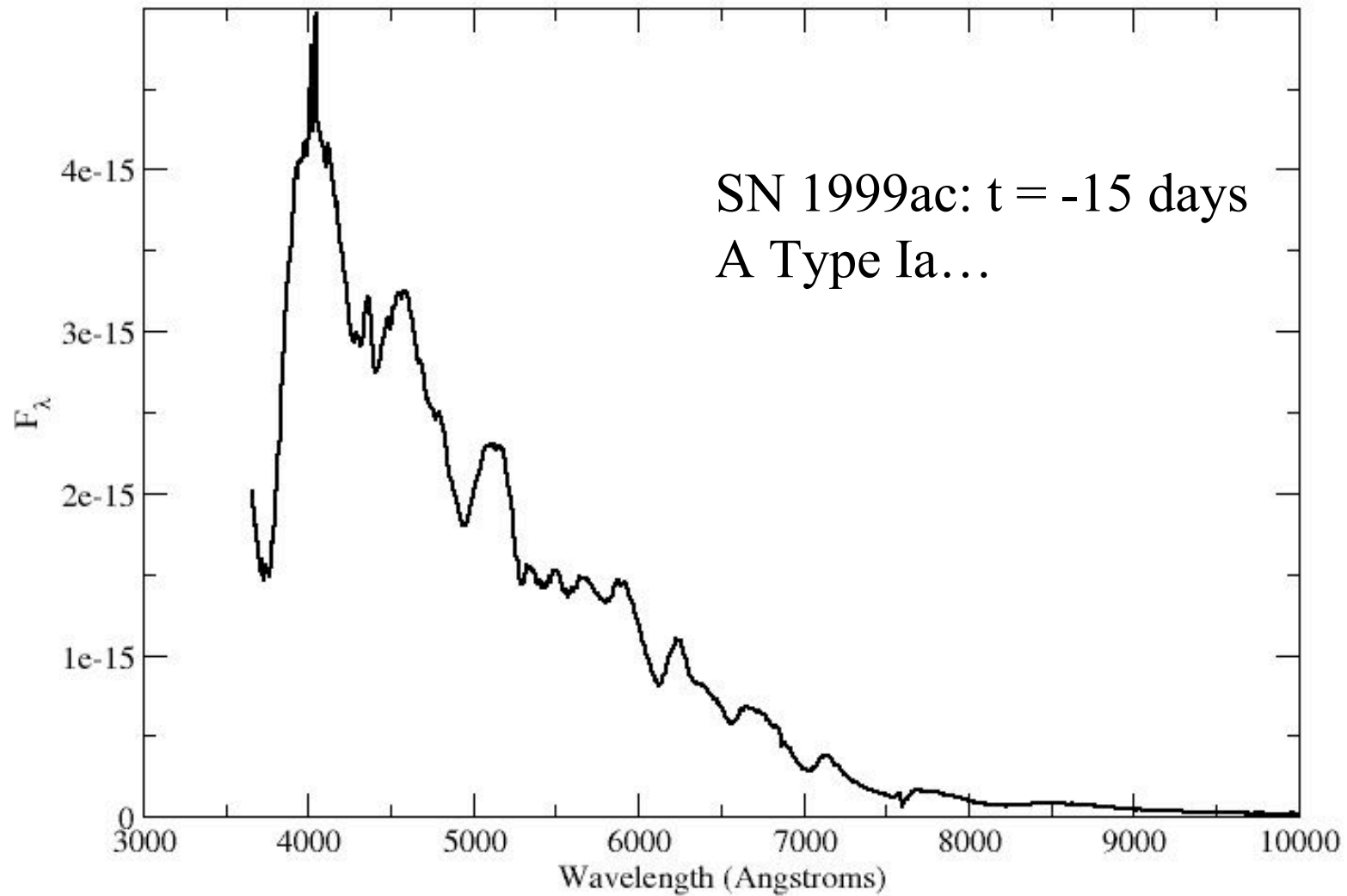
P-Cygni Spectral Line in a SN





1. The first spectrum has to be of a quality (S/N) to separate subtypes
 - In most cases ($\sim 80\%$ based on the rates of individual subtypes) the classification can be accomplished with something slightly better than photometry, since most CC SNe are blue and featureless early on.
 - For $\sim 20\%$ (Ib/c) the differences are subtle and higher S/N must be obtained
2. An early spectrum of a Ia will allow us to learn the most about the progenitor.







SN Identification & Early Spectra

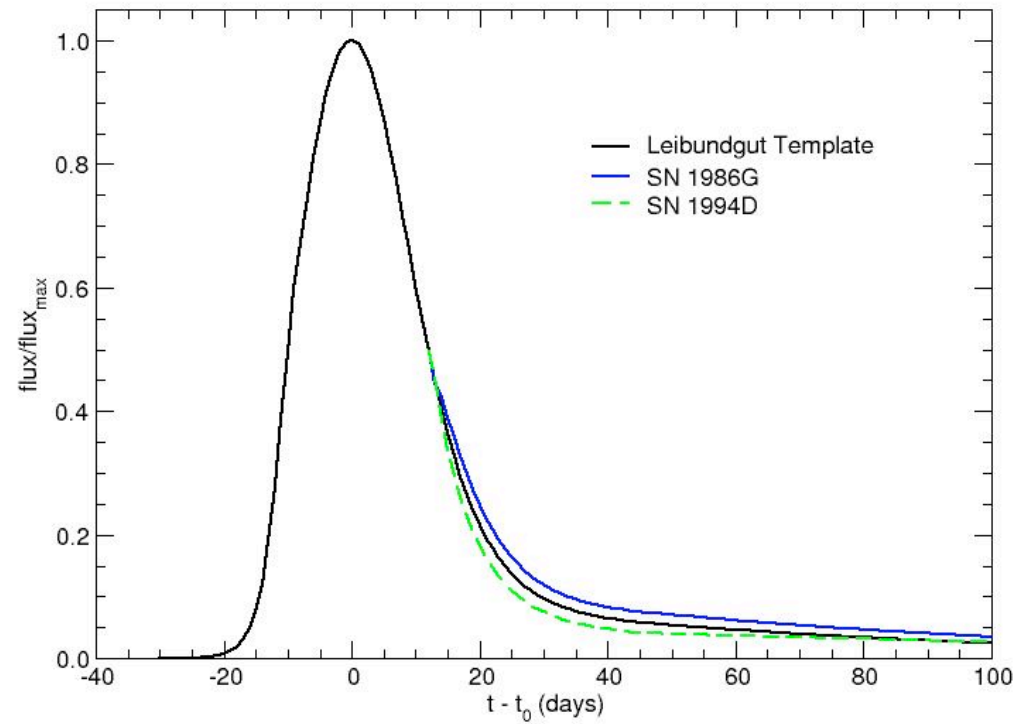
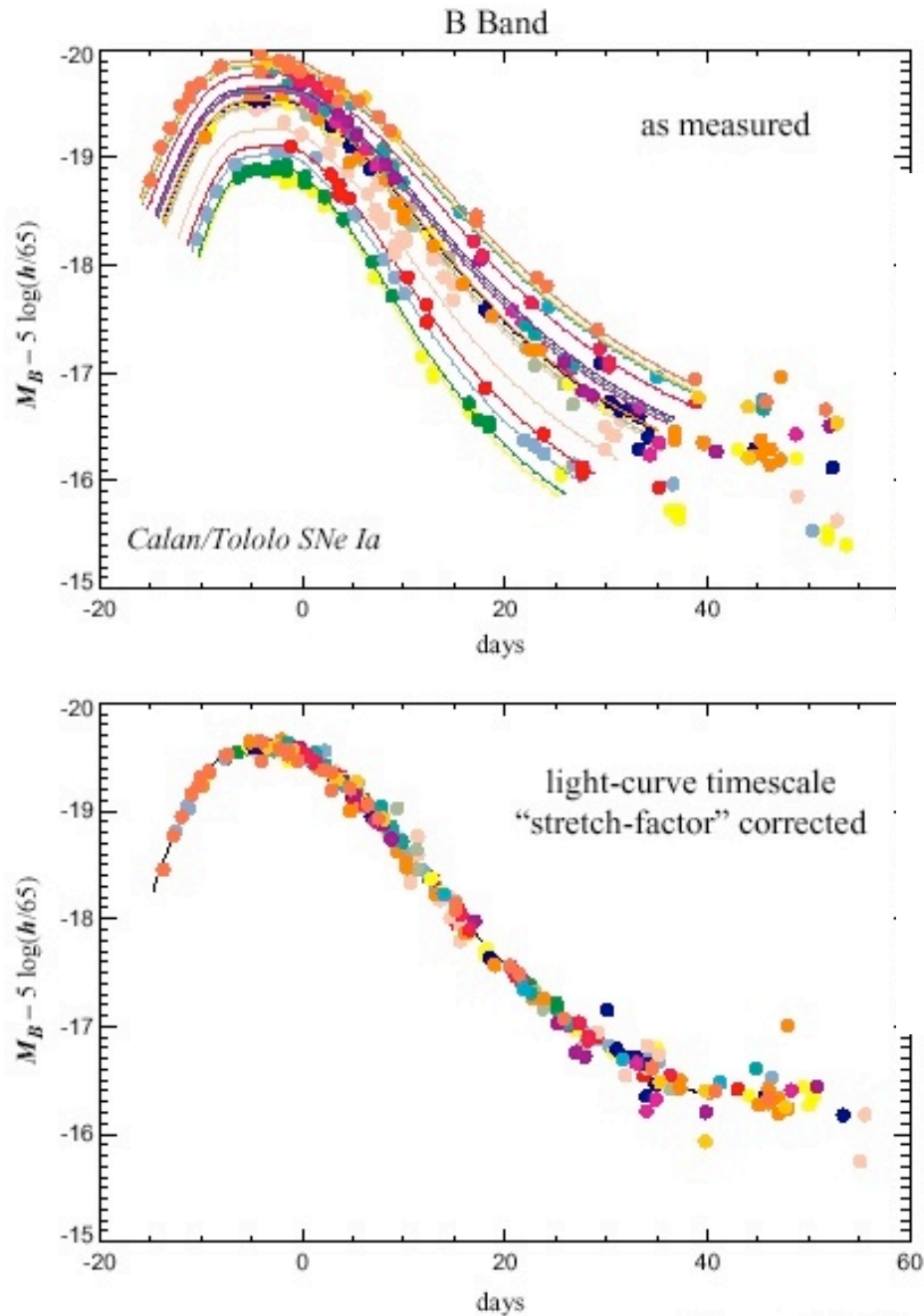


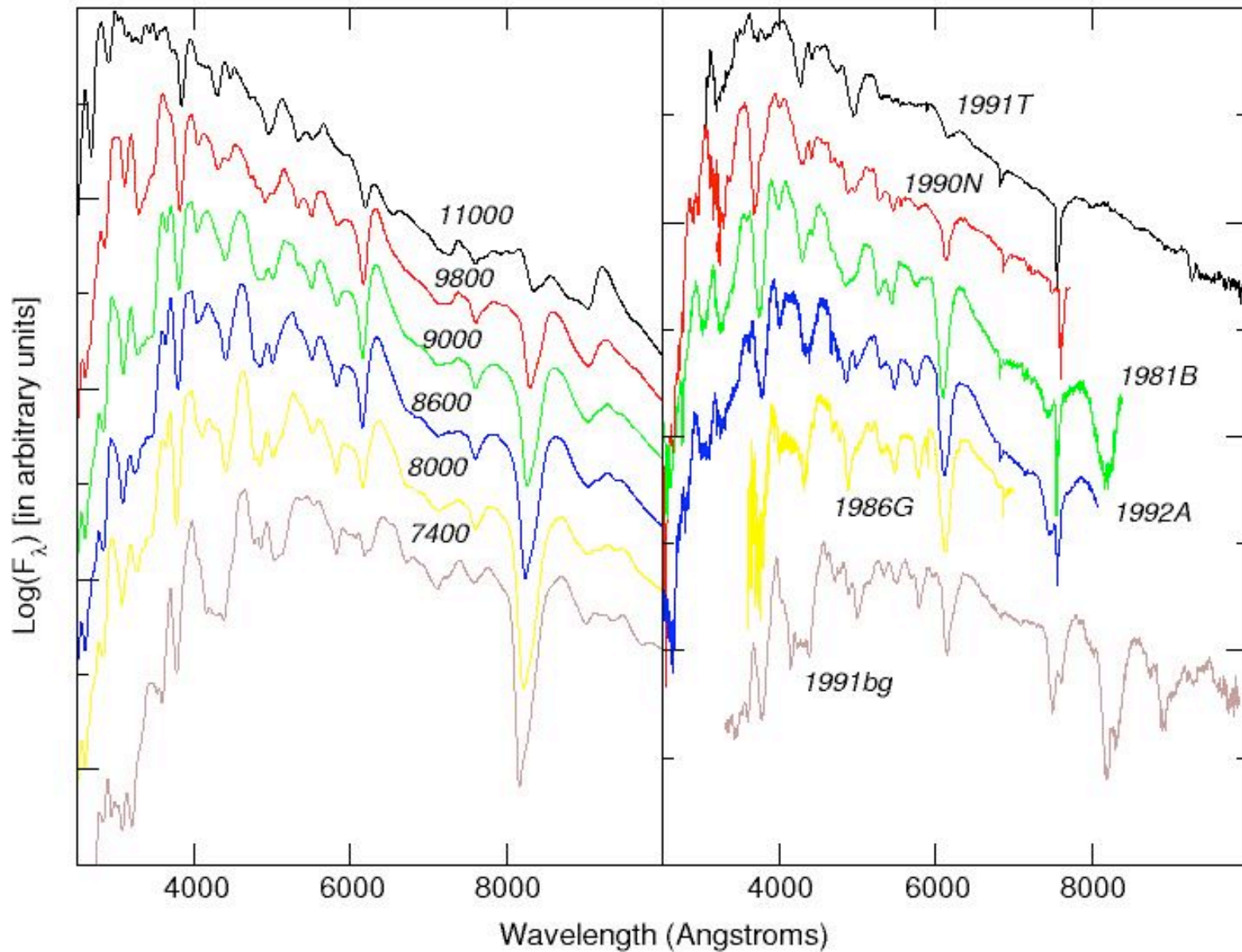
Conclusion (for now):

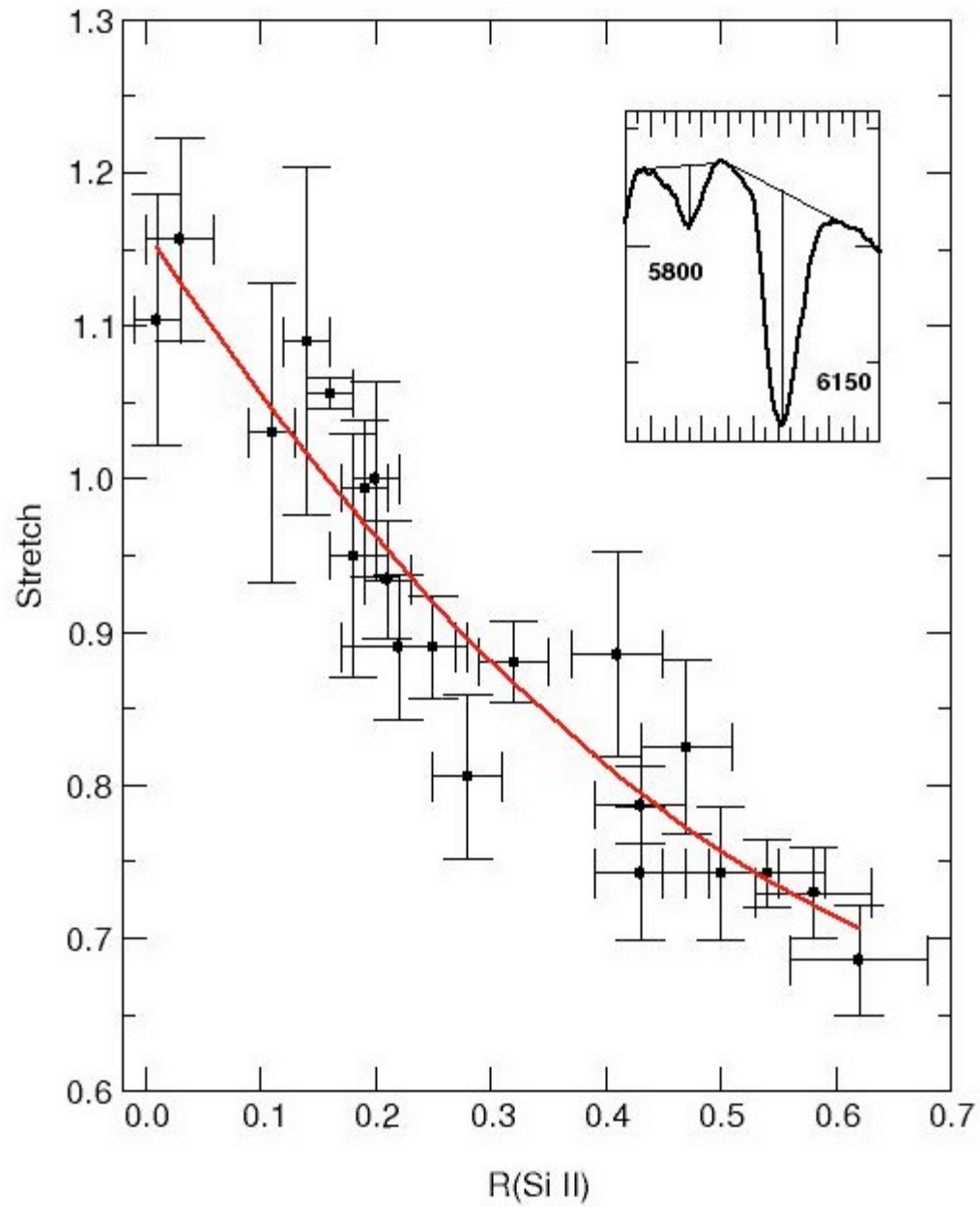
Until we can prove to ourselves that we can conclusively separate subtypes of all SN, I would be in favor of only operating in two modes: Science-grade and photometry.

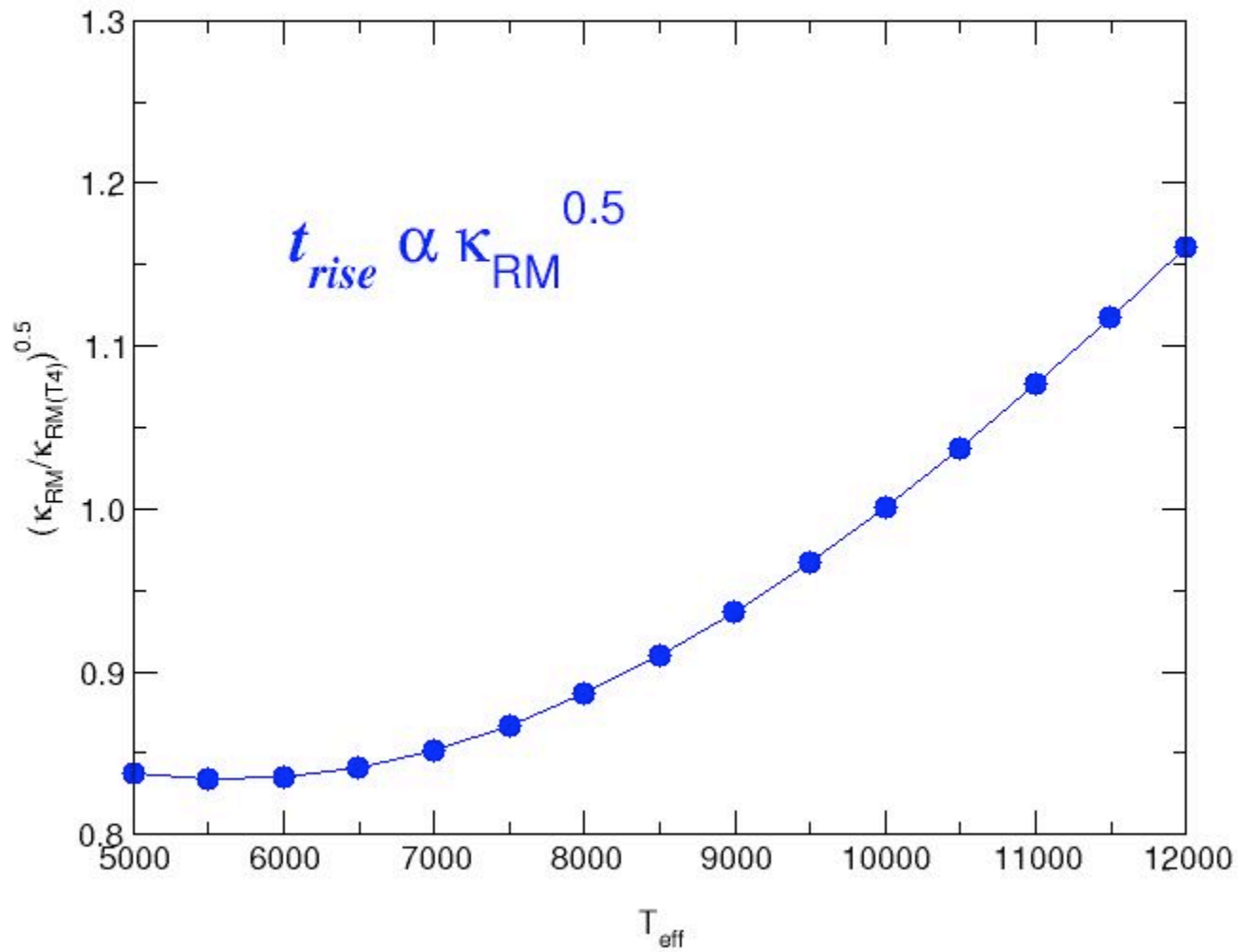
- The science gain is huge for a high S/N early spectrum
- The separations of subtypes, based on what we know/have now, will be difficult without high S/N
- The contamination factor will be acceptable. NEAT & LOTOSS have about a 50/50 split between Ia's and CC SNe while ESSENCE is about 70/30.

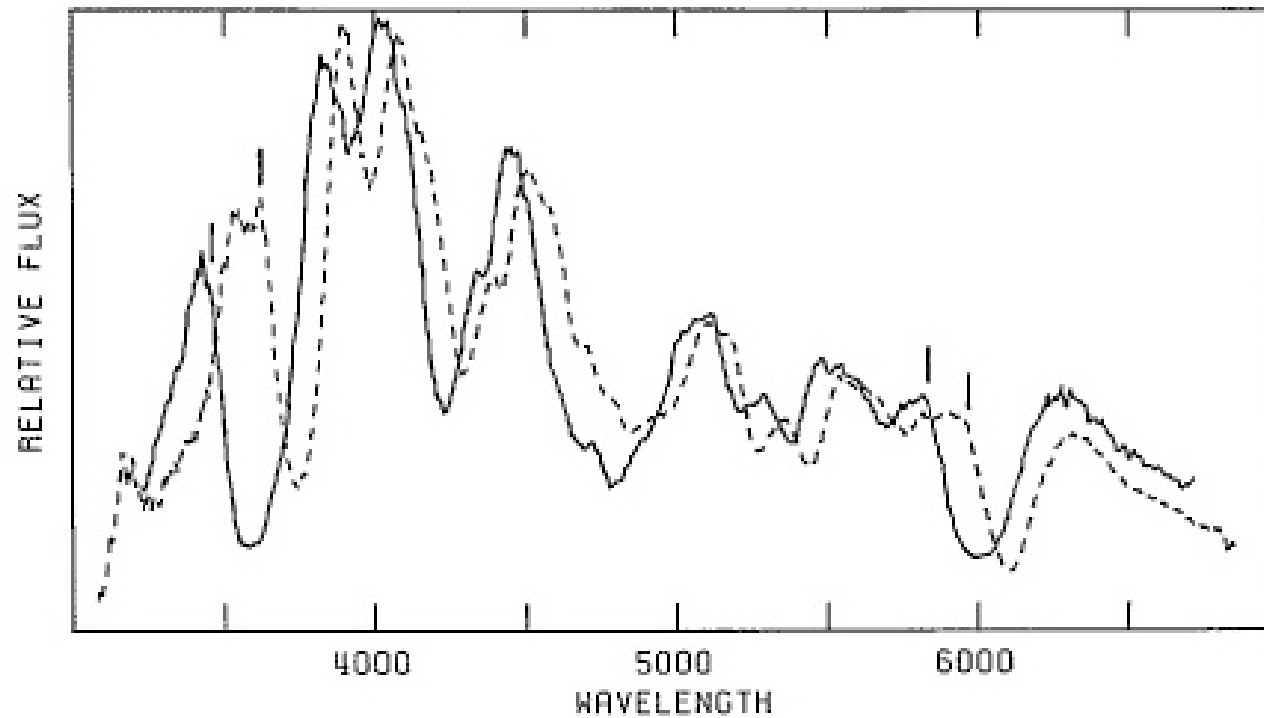
Next question: How much of each?







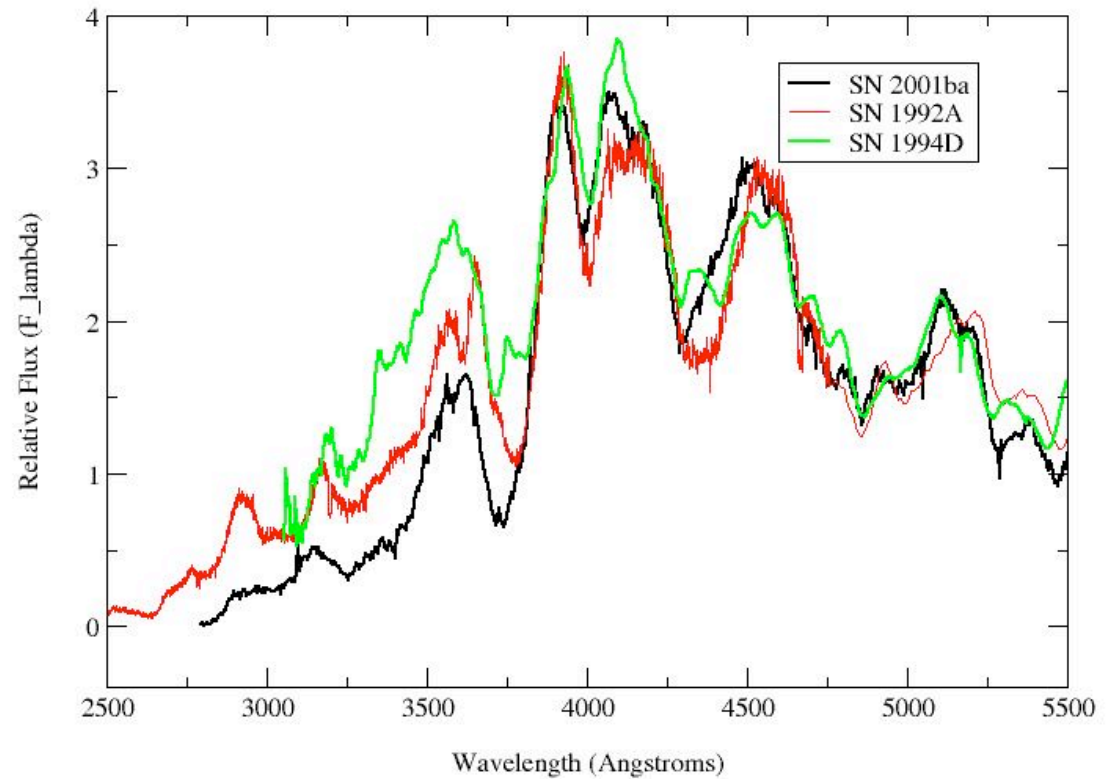
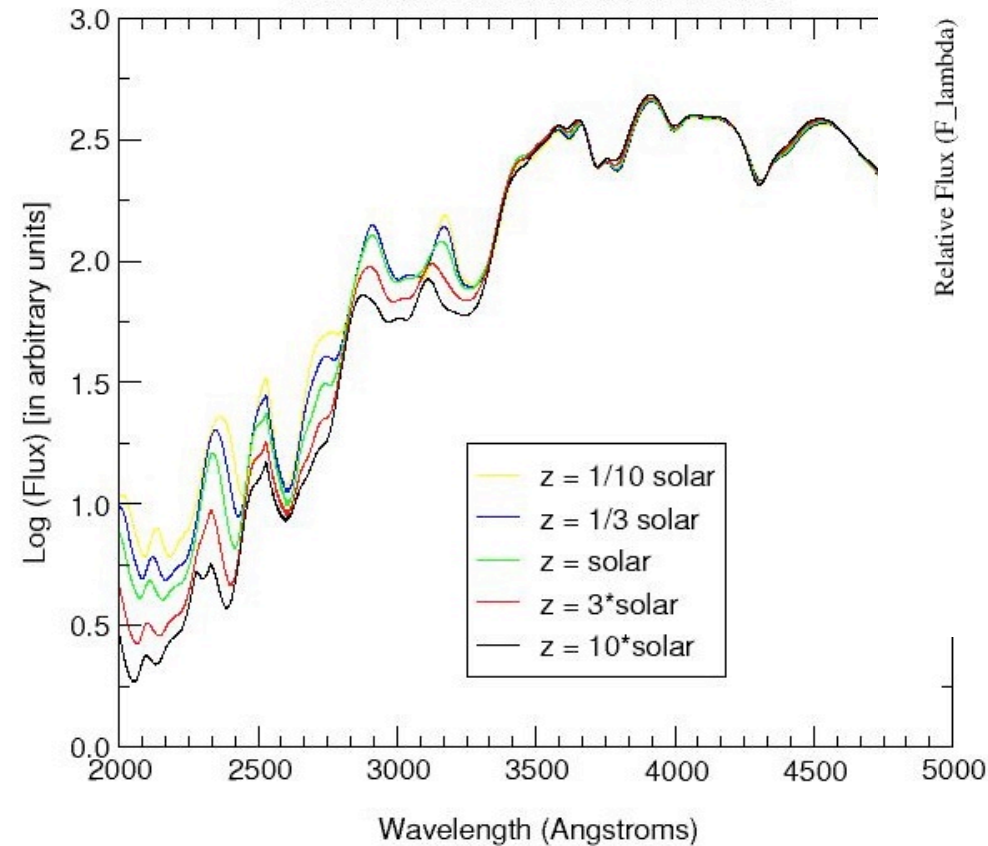




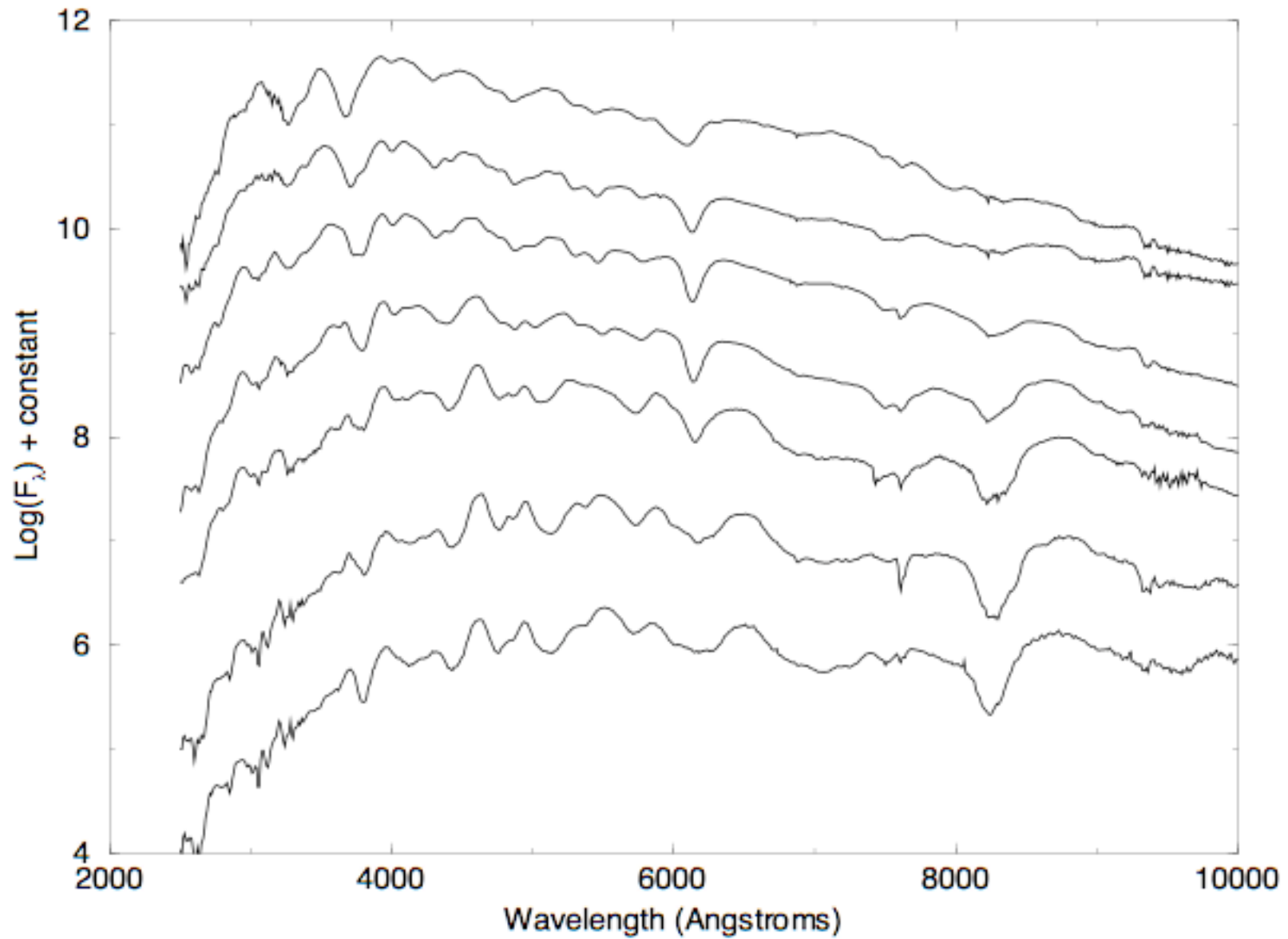
Differences in the Kinetic Energy? A comparison of SN 1984A (dashed) with SN 1981B (solid).

Model W7 at Maximum Light

Metallicities from 1/10 solar to 10*solar



Differences in the Metallicity?





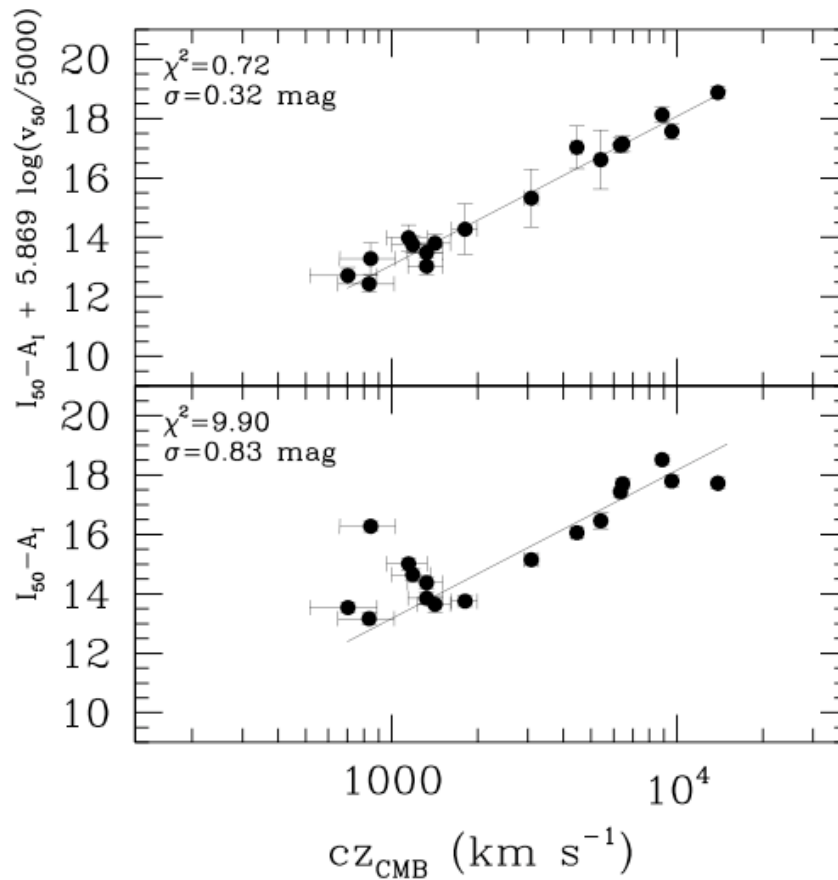
More Science...



Other Possible Science Programs in affiliation with SN Factory:

More Ia research (HST, Polarization, IR, ...)

SNe II research (another way to get distances at very little cost)

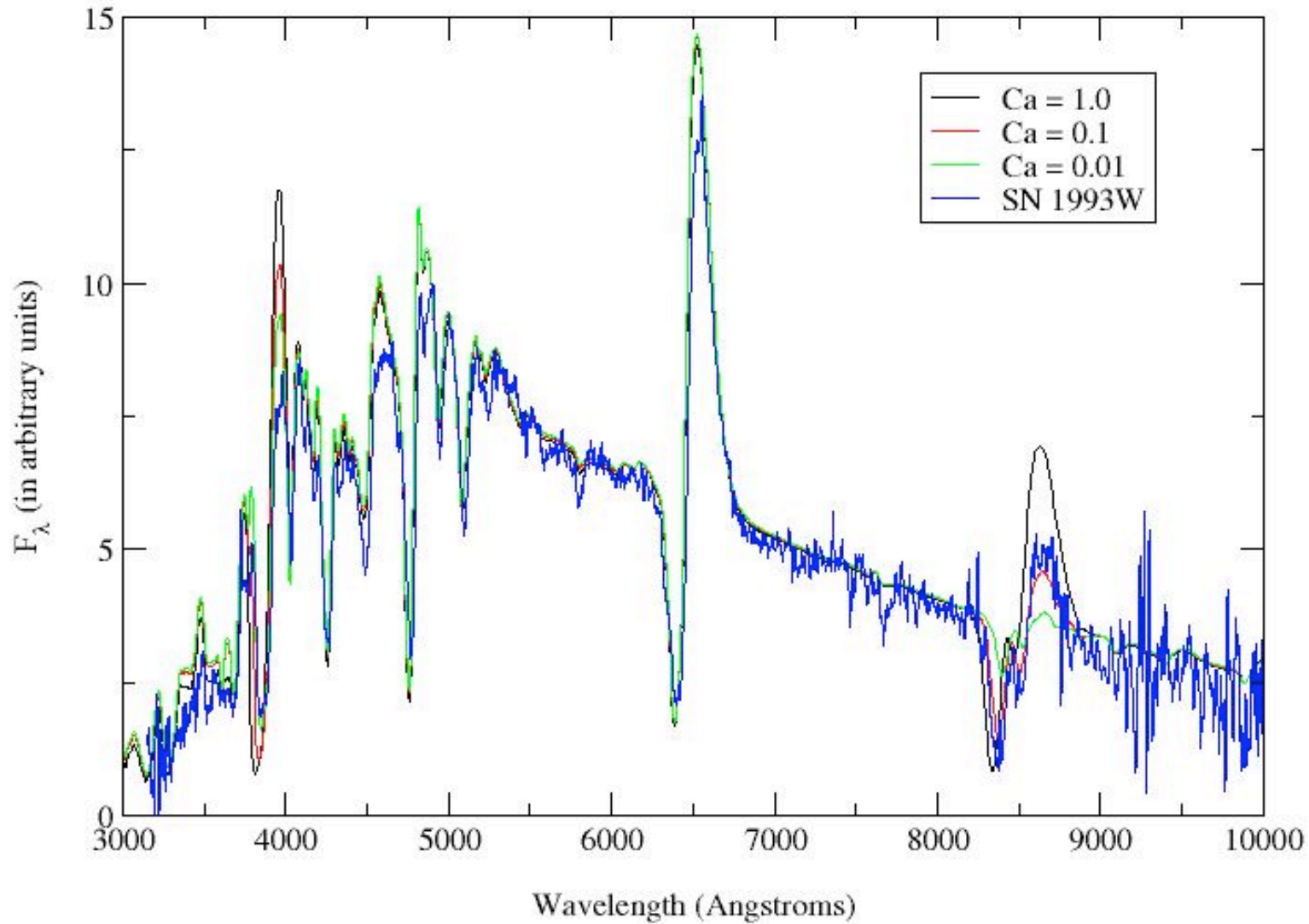


Hamuy's Method

~15% distance

SN 1993W

(Hot off the press, 3 days old...)

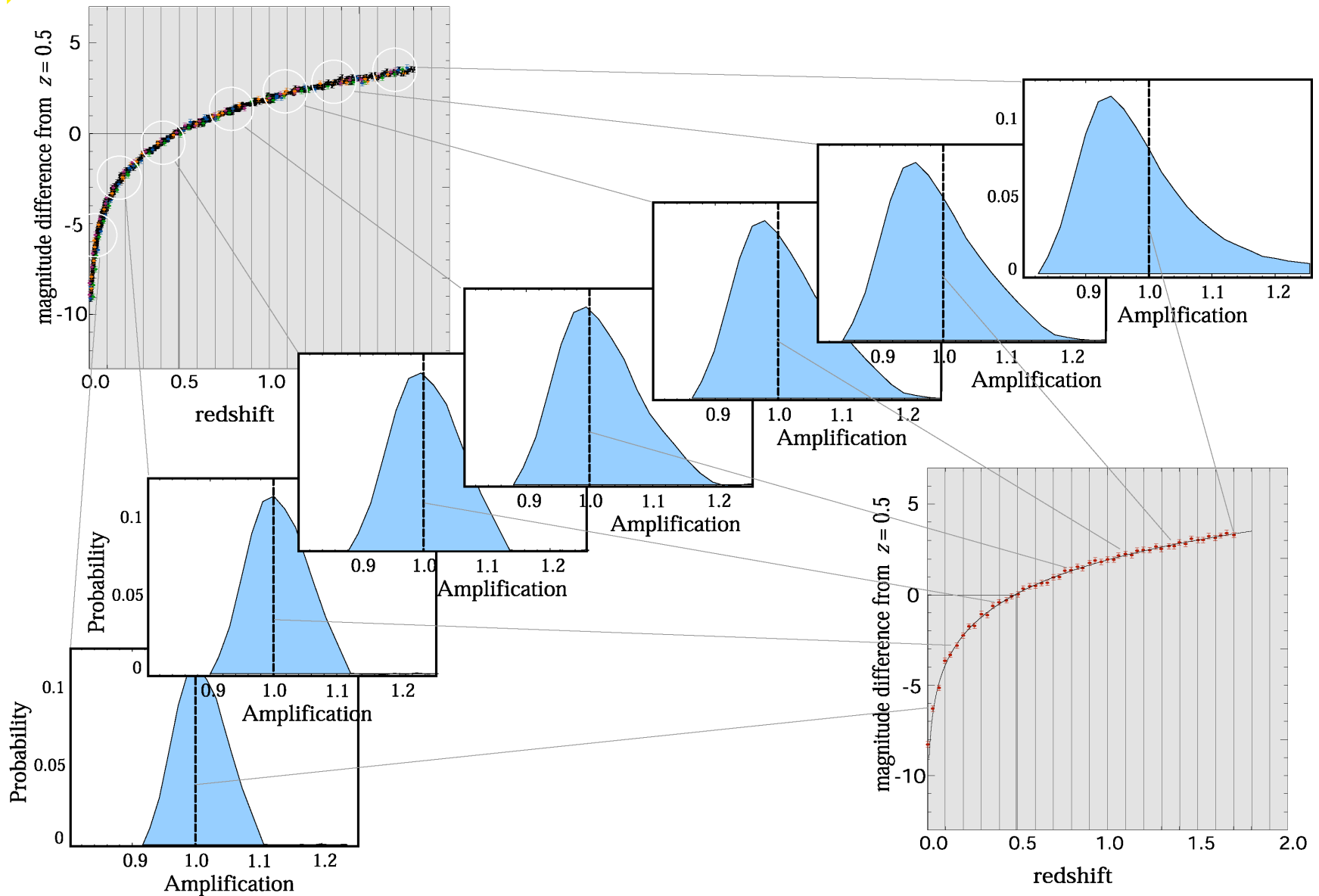


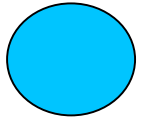
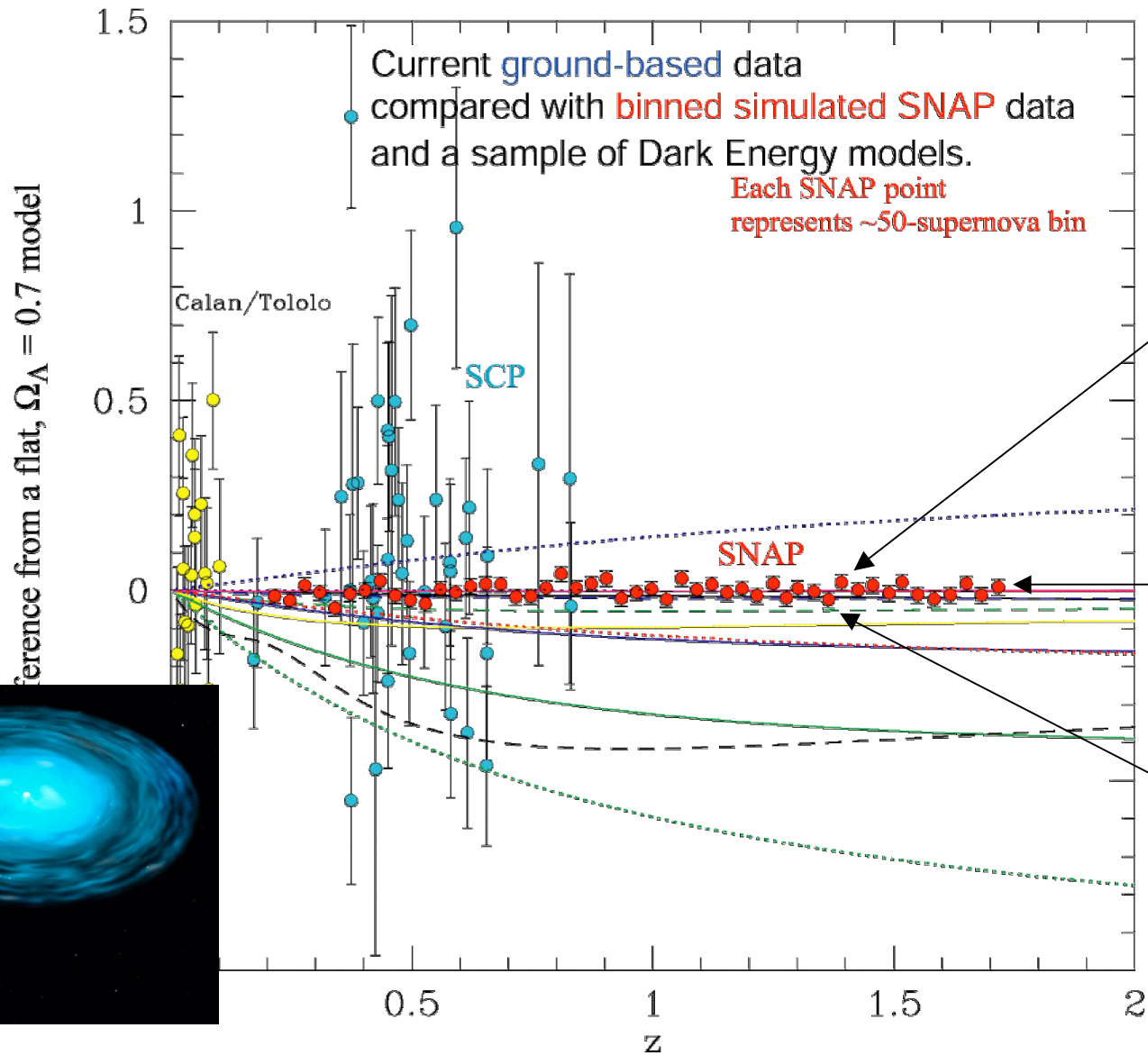
SEAM

~ 10% distance

3

Fit/average lensing distributions to construct redshift-binned Hubble diagram:

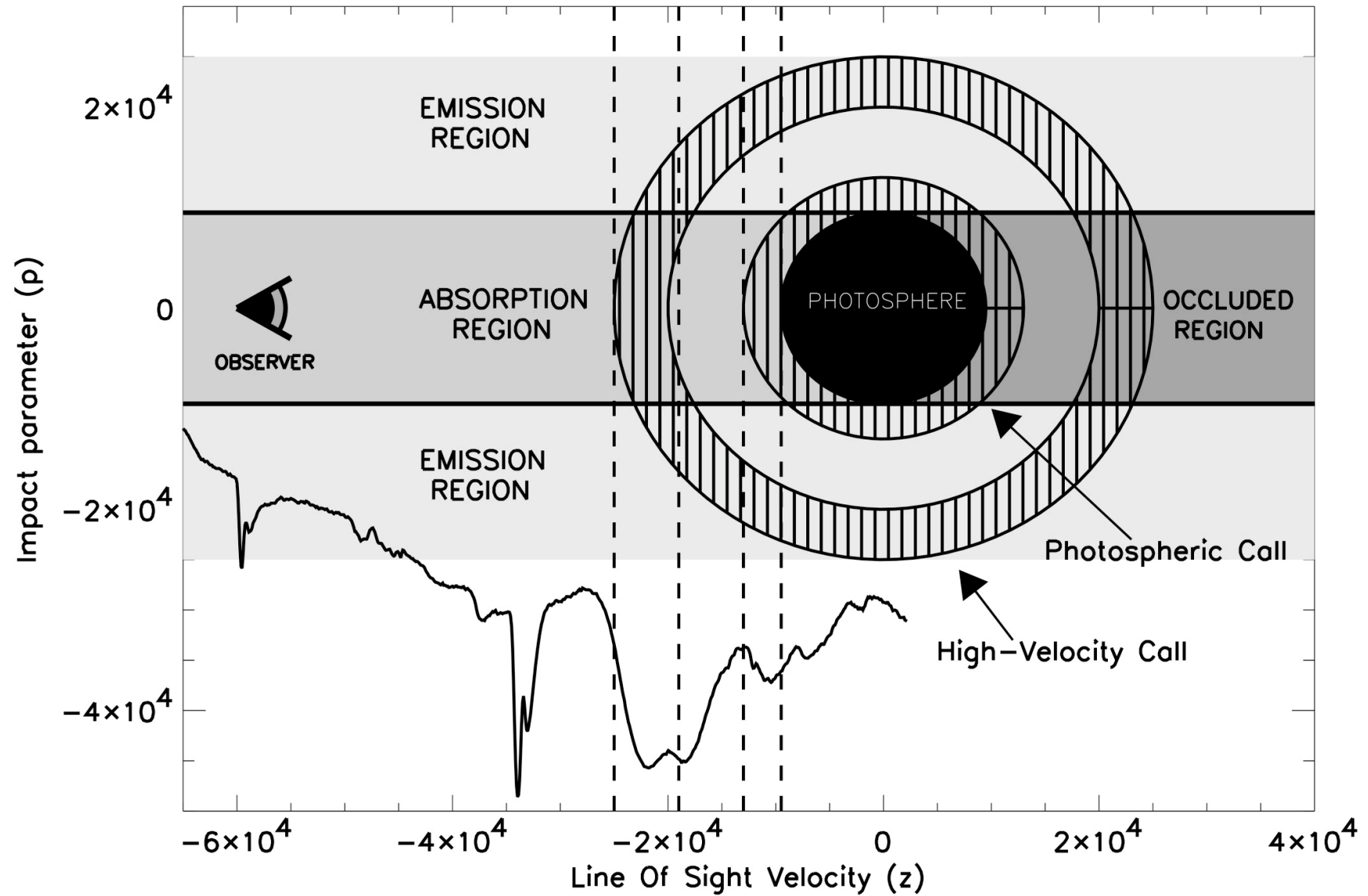




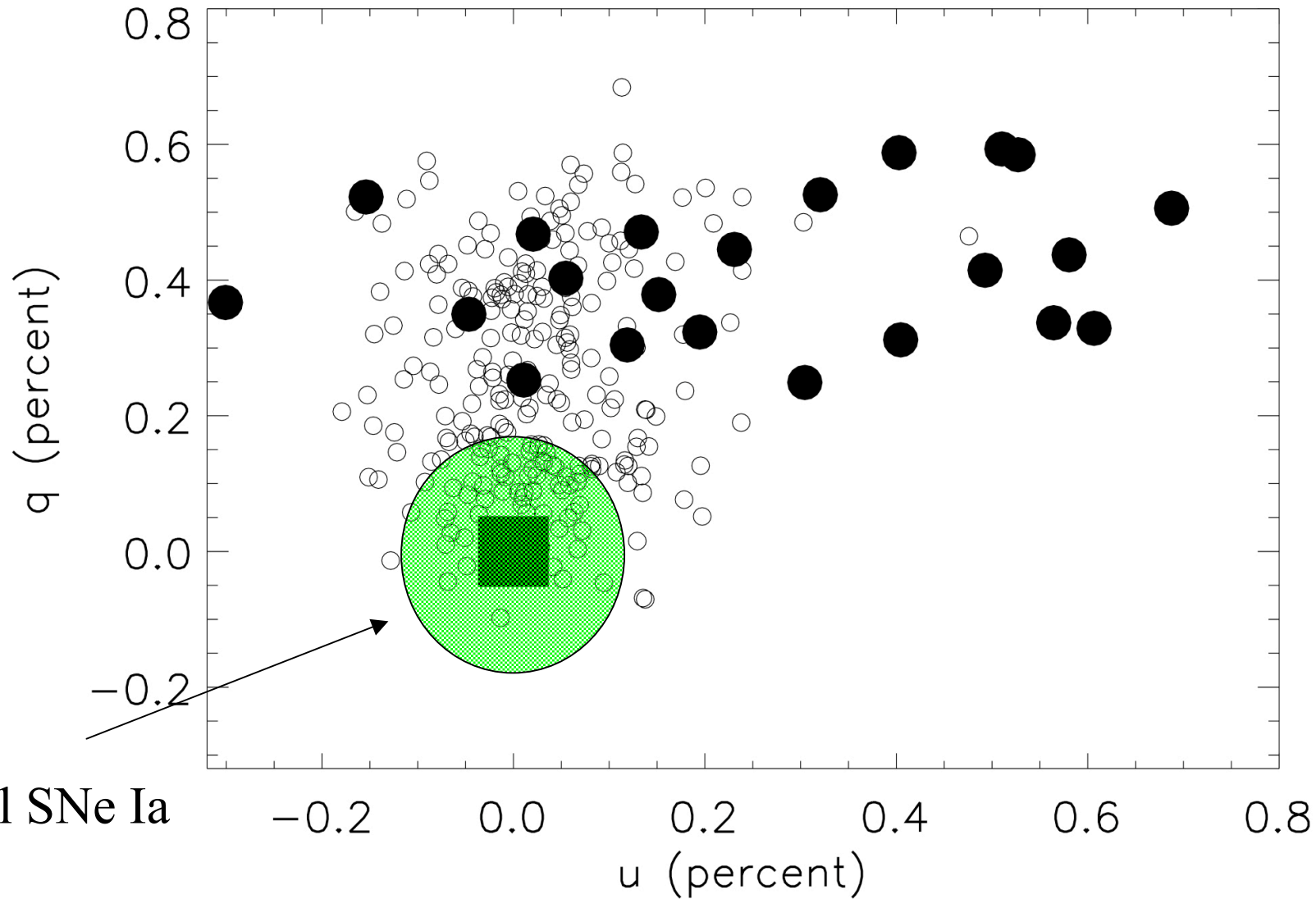
Evolves with Age of Universe?

based on
Weller & Albrecht (2001)

Formation of the Ca II IR triplet



SN2001el q-u Plot: Sept 25



Typical SNe Ia

