

# The fate of the most massive stars

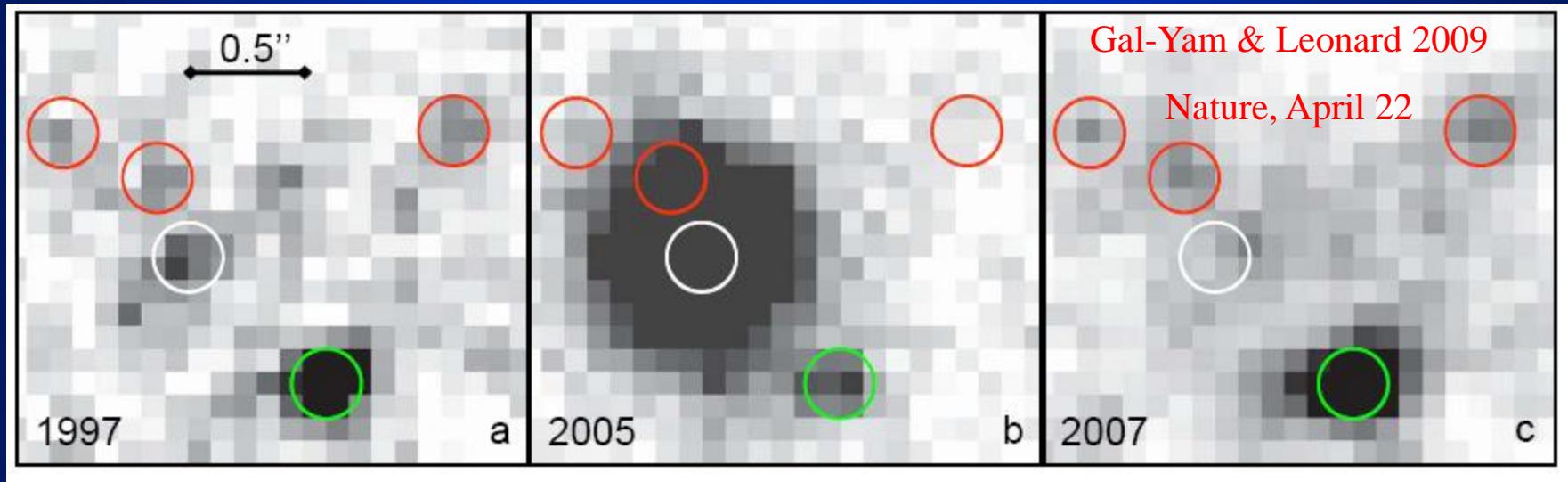
## Introducing the Palomar Transient Factory



Avishay Gal-Yam,  
Weizmann Institute of Science  
Paris 2010

# SNe IIIn from very massive stars (LBVs)

\* Direct detection of the progenitor of SN 2005gl:  $L \sim 10^6$  solar

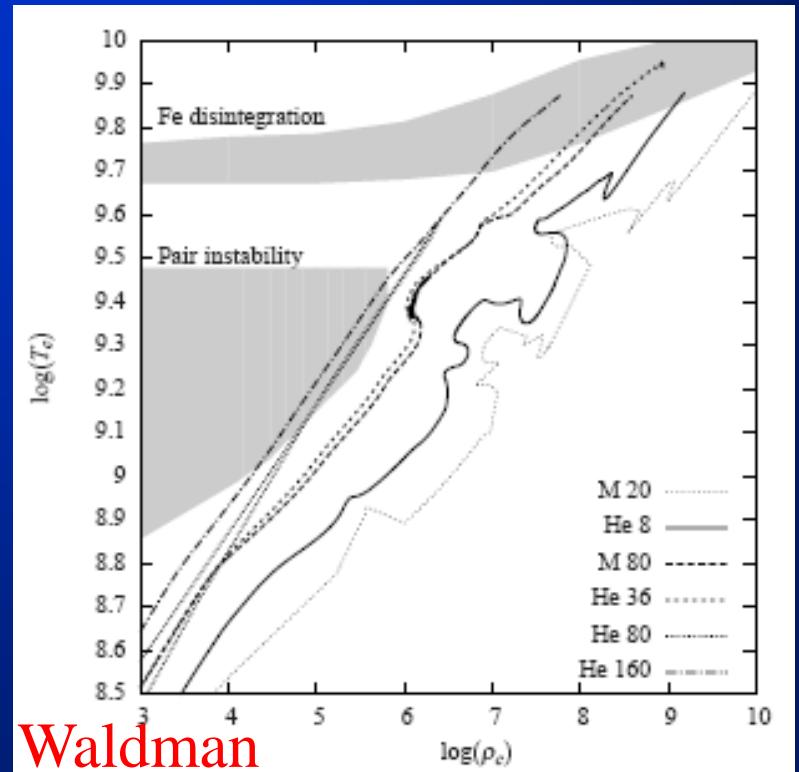


- \* In accord with works by Kotak, Smith, Trundle, ...
- \* May involve the pulsational pair instability (PPSN; Woosley et al. 2007; Smith et al. 2009; Miller et al. 2009)

# Pair Instability Supernovae (PISNE)

(Barkat, Rakavi & Sack 1967 ; Heger & Woosley 2002; Waldman 2008 ...)

- \* Helium cores above  $\sim 50$  solar masses become pair unstable
- \* In these low-density high-T cores,  $\gamma\gamma \rightarrow e^+e^-$  wins over oxygen ignition, heat is converted to mass and implosion follows
- \* Inertial oxygen ignition leads to explosion and full disruption
- \* “This is a uniquely calculable process” (Heger & Woosley 2002); “this is a trivial calculation” (Barkat 2009); “Pretty neat homework problem” (Gal-Yam 1996)



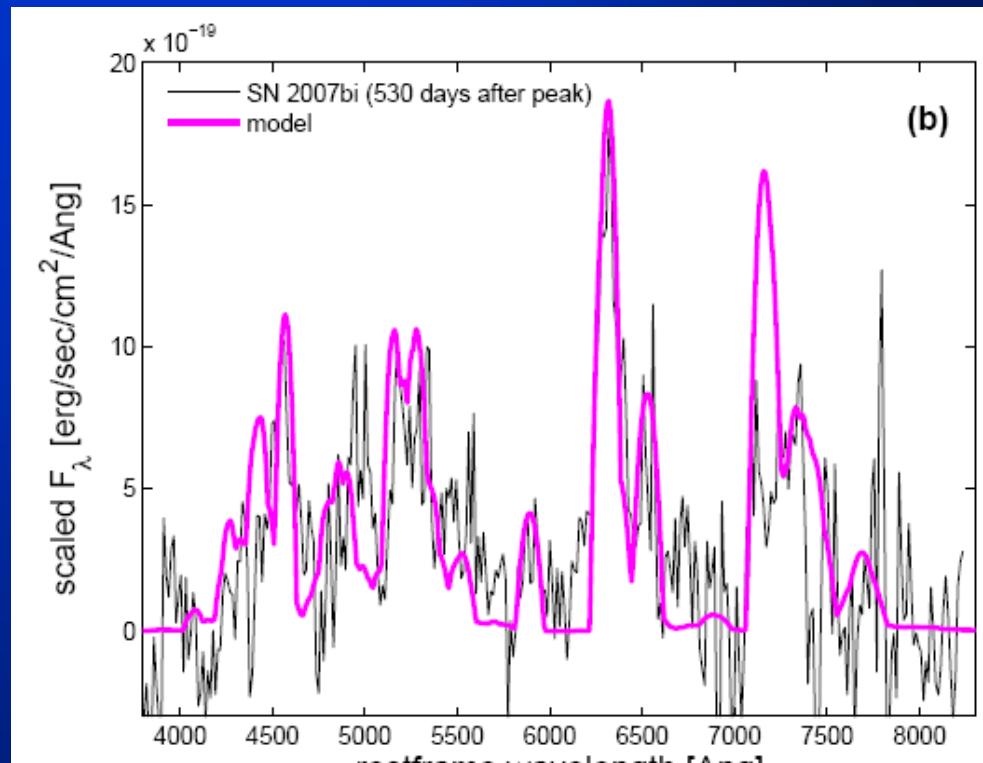
Waldman

“Smoking gun”:  
Core mass  $> 50$  solar

# SN 2007bi=SNF20070406-008

(PTF “dry run”)

- \* Type Ic SN. No interaction, no dust,  $v=12000$  km/s
- \* Luminous peak (-21.3), slow rise ( $\sim 77$  days),  $^{56}\text{Co}$  decay
- \* Ejected mass  $\sim 100$  solar,  $E_k \sim 1\text{e}53$  (scaling), 4-11 solar masses of  $^{56}\text{Ni}$
- \* Well-fit by models (Kasen)
- \* Nebular spectra: 4-6 solar mass of  $^{56}\text{Ni}$ ;  $>50$  solar total (Mazzali), consistent with 98bw

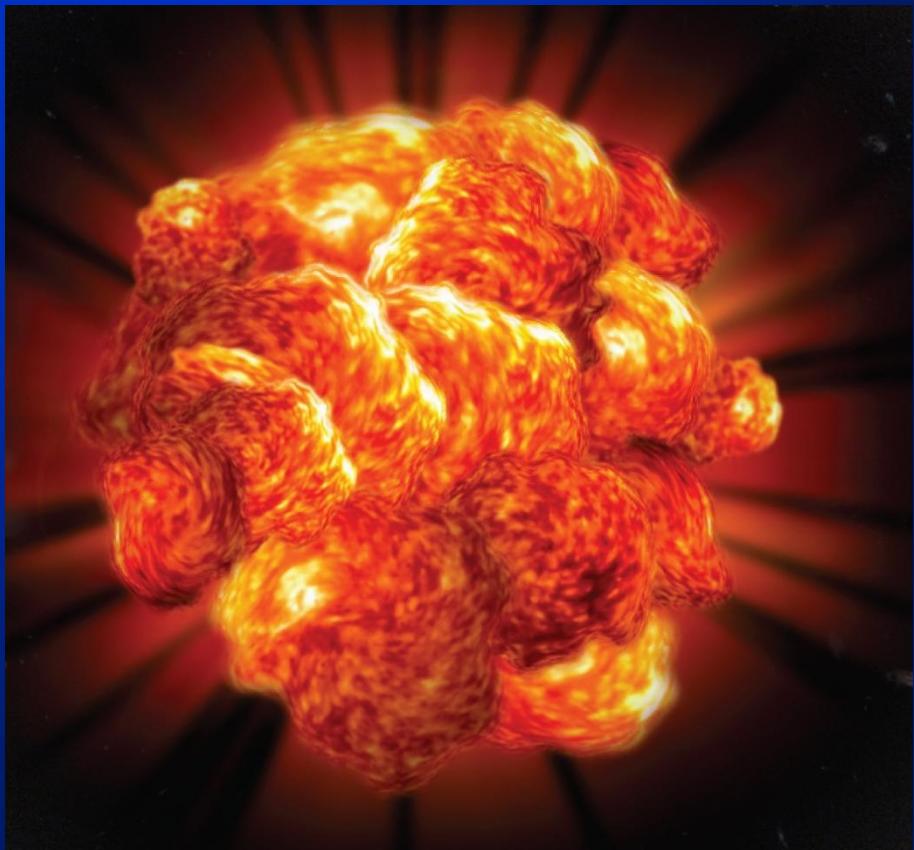


Core mass  $> 50$  robustly established;  
Gal-Yam et al. 2009, also Young et al. 2009

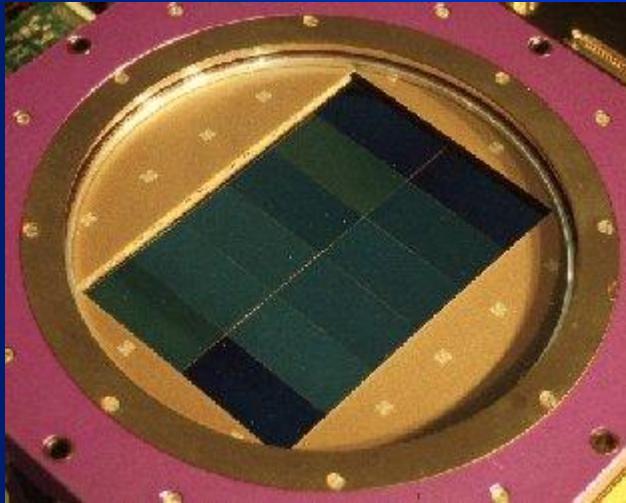
# Implications

(Gal-Yam et al. 2009)

- \* A helium core  $\sim$ 100 solar detected at  $Z \sim$  SMC
- \* Mass loss models are key
- \* PISNe happen locally, Universally, models are  $\sim$ ok
- \* Dwarfs have stars above Galactic limit ( $>200$  solar, probably)
- \* Hydrogen efficiently removed (pulsations?)

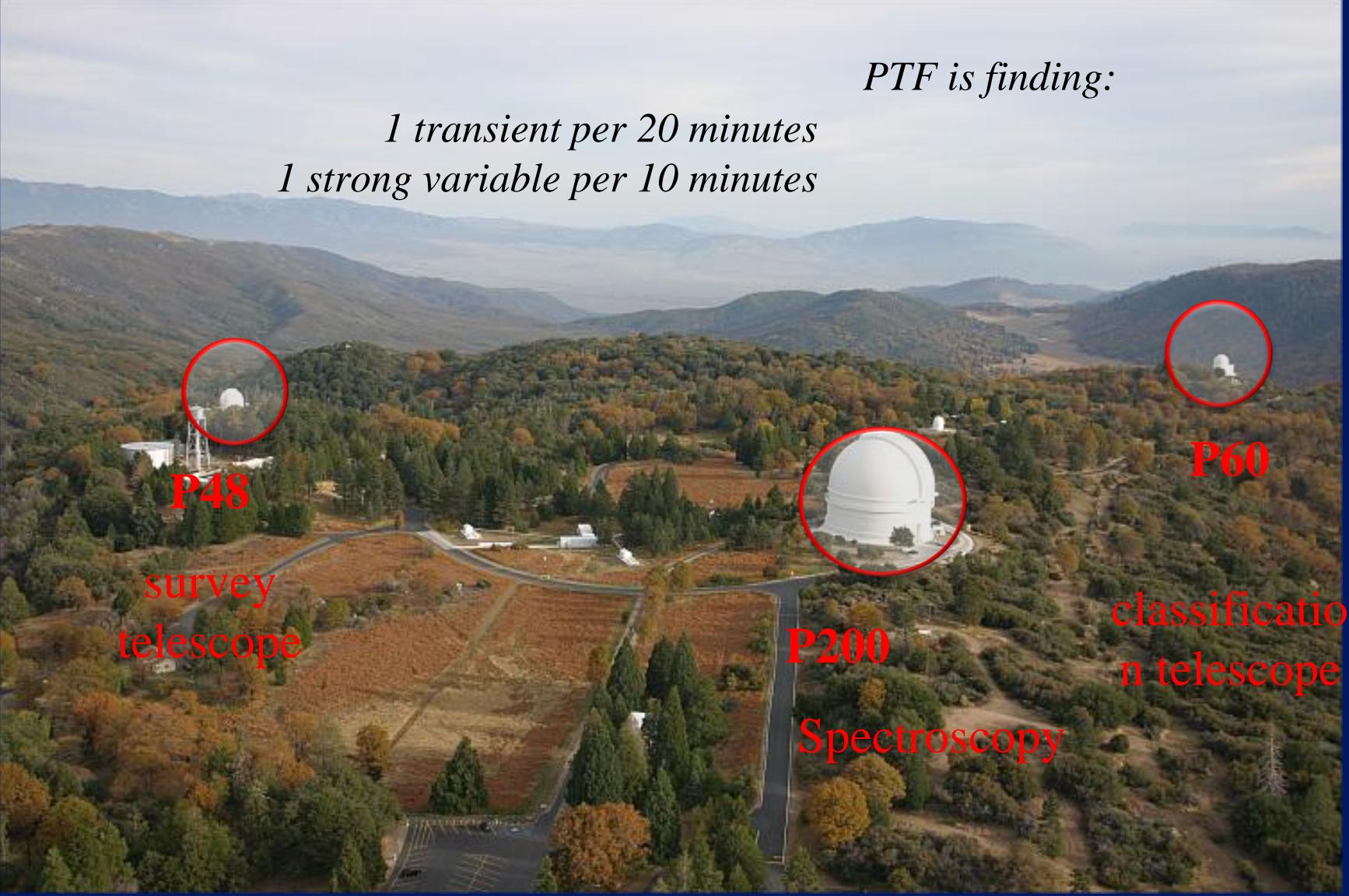


# And now: news from The Palomar Transient Factory



There is nothing like searching, if you want to find something.  
You usually find something, if you search,  
but it is not always quite the something you were after.

Thorin Oakenshild



*PTF is finding:*

*1 transient per 20 minutes*

*1 strong variable per 10 minutes*

P48

survey  
telescope

P60

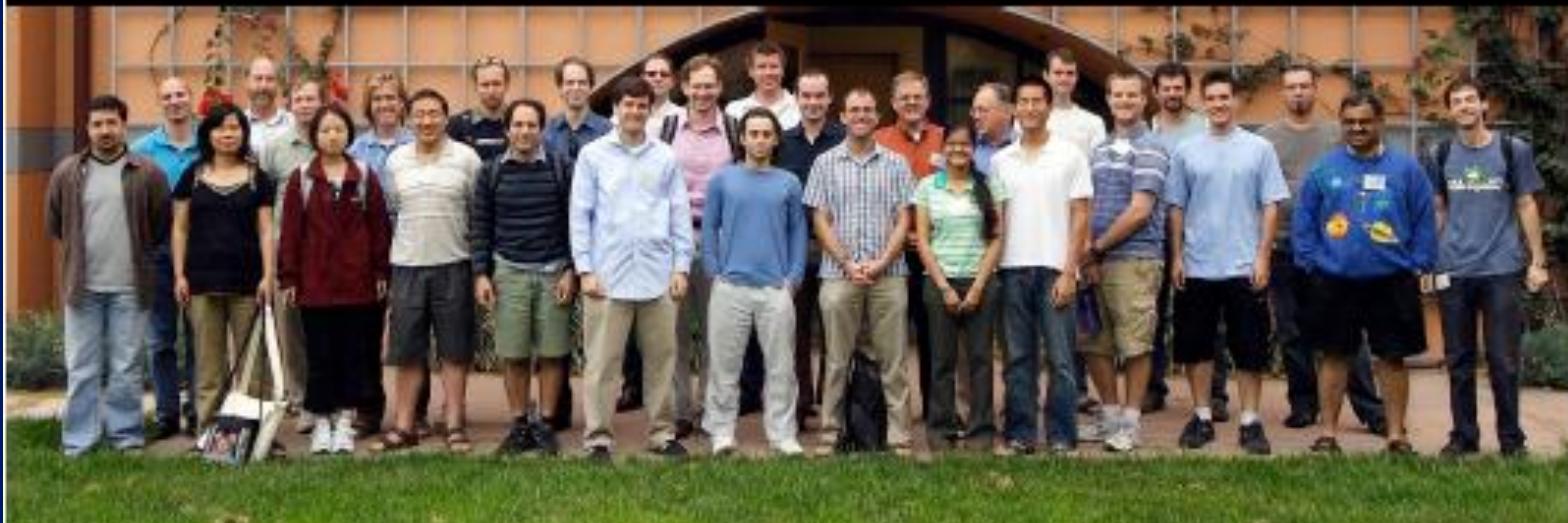
classification  
telescope

P200

Spectroscopy

# Thanks

## PTF collaboration



Caltech, LCOGT, Berkeley, LBL, IPAC, Columbia, Oxford, Weizmann



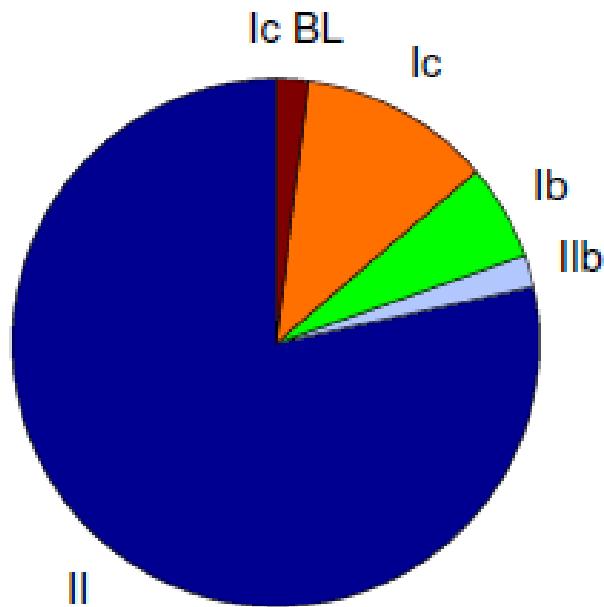


# The Core-Collapse Key Project

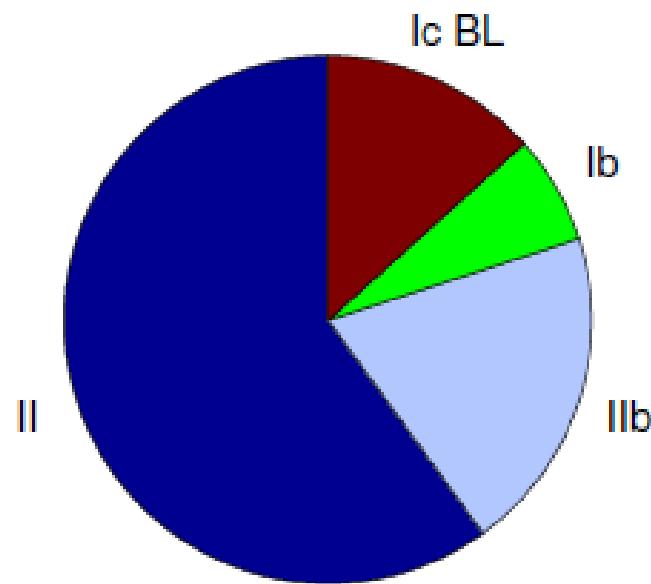
- Study the population of CC SNe
- Focus on dwarf galaxies
- New types?
- Very early events

# Supernovae: dwarf vs. giant hosts

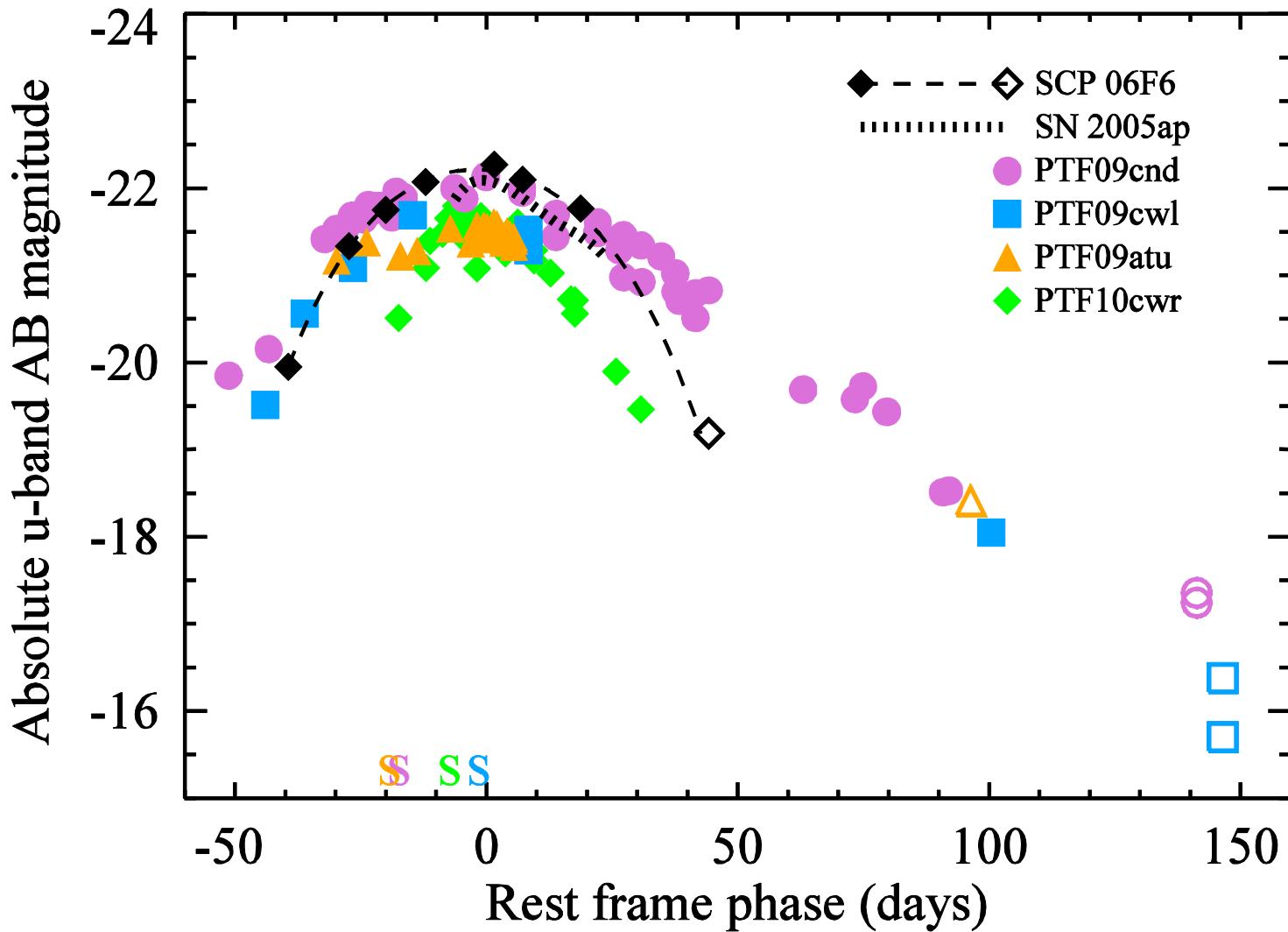
Giant Hosts (52)



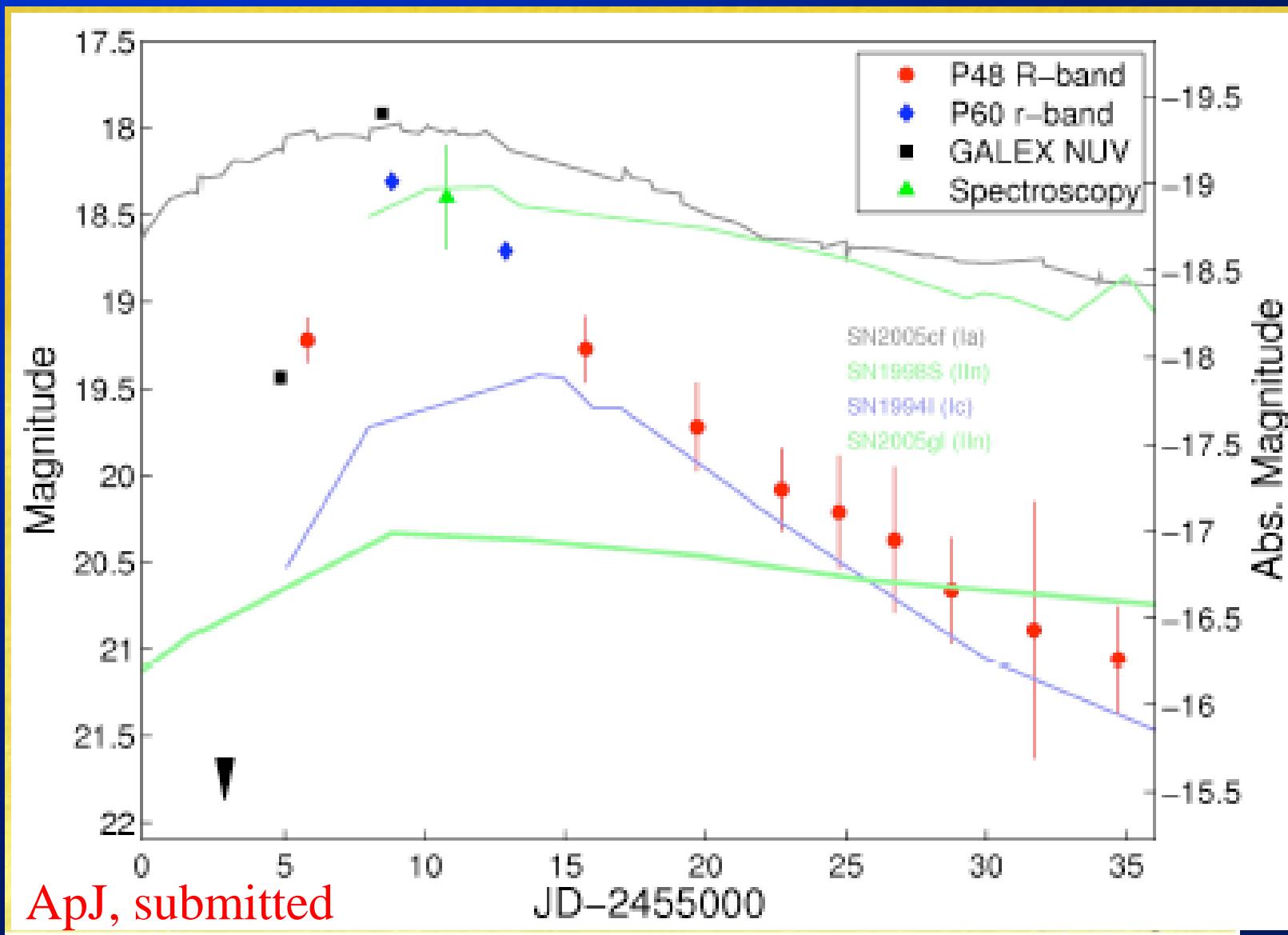
Dwarf Hosts (15)



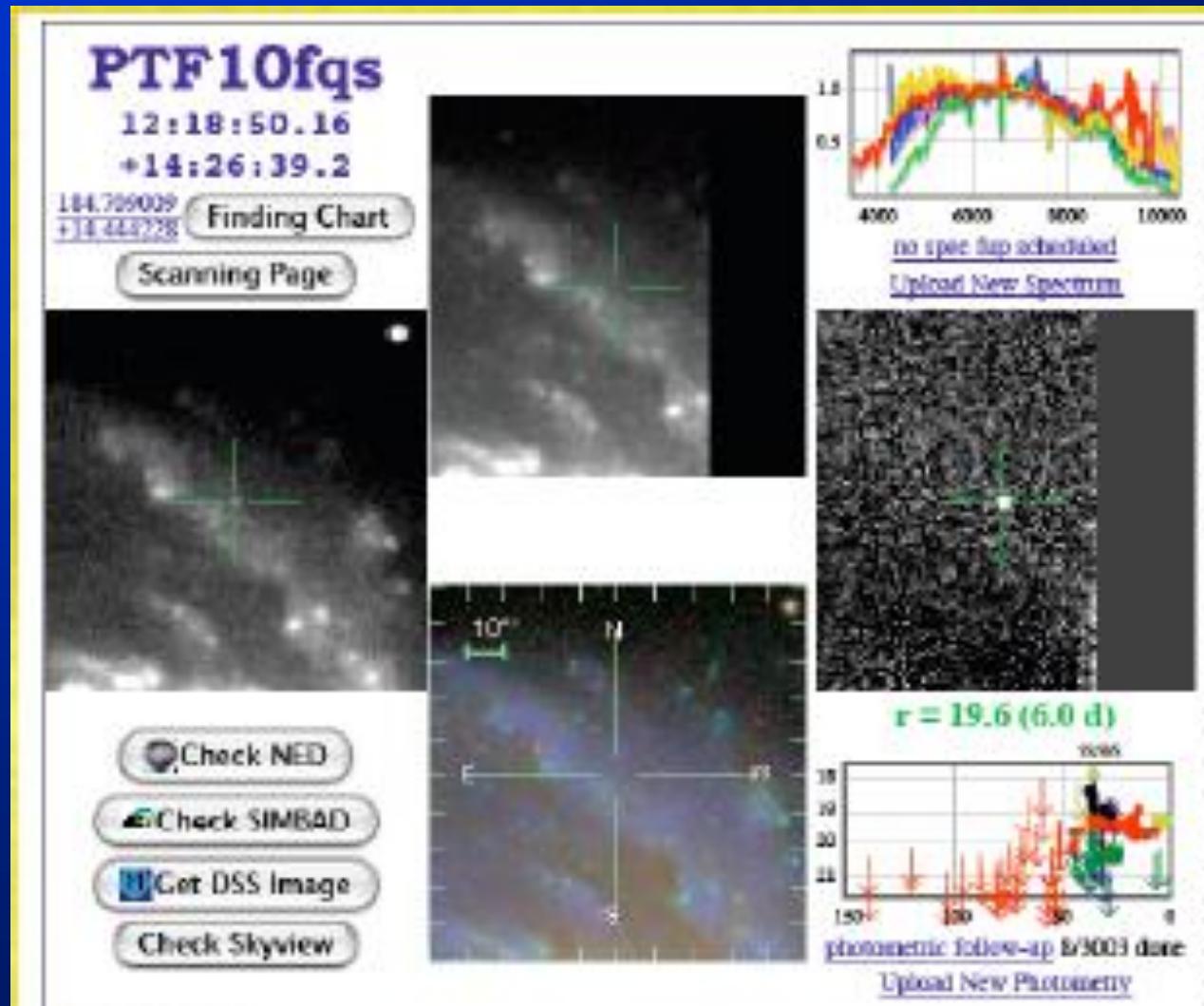
# Luminous blue SNe (Quimby)



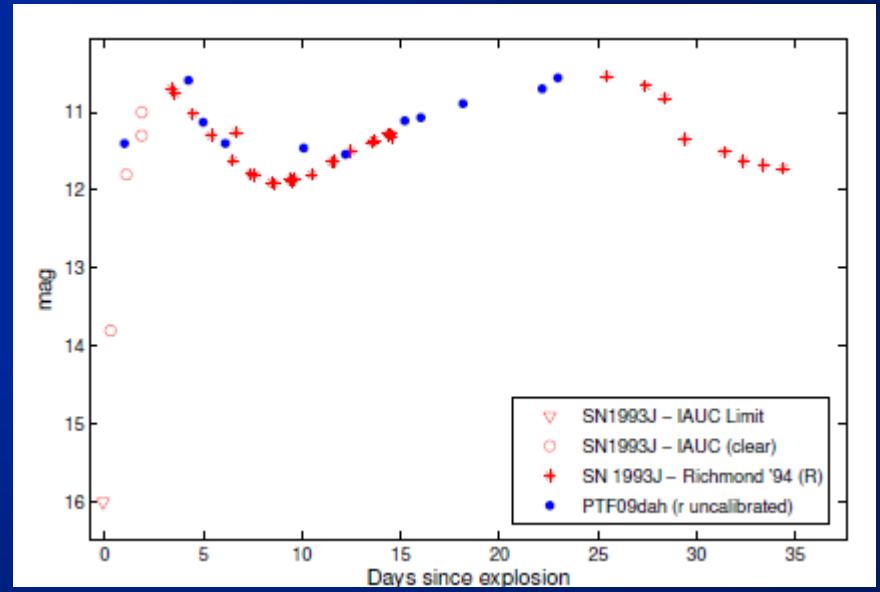
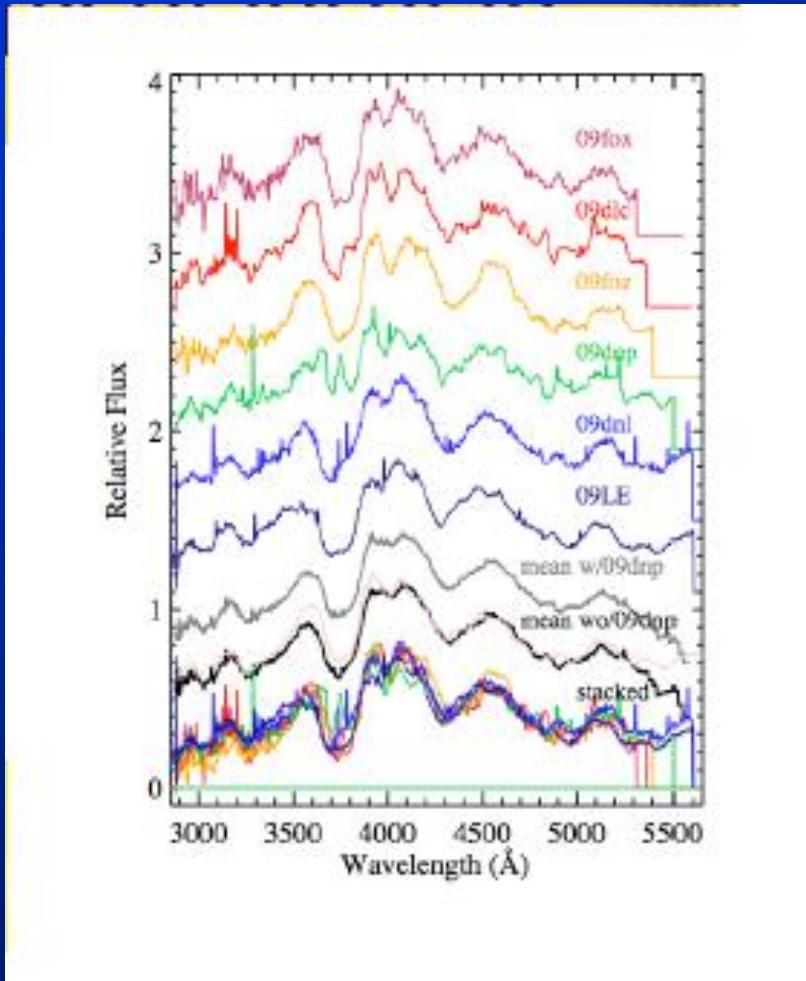
# Shocking news (Ofek)



# “Gap” objects (Kasliwal)



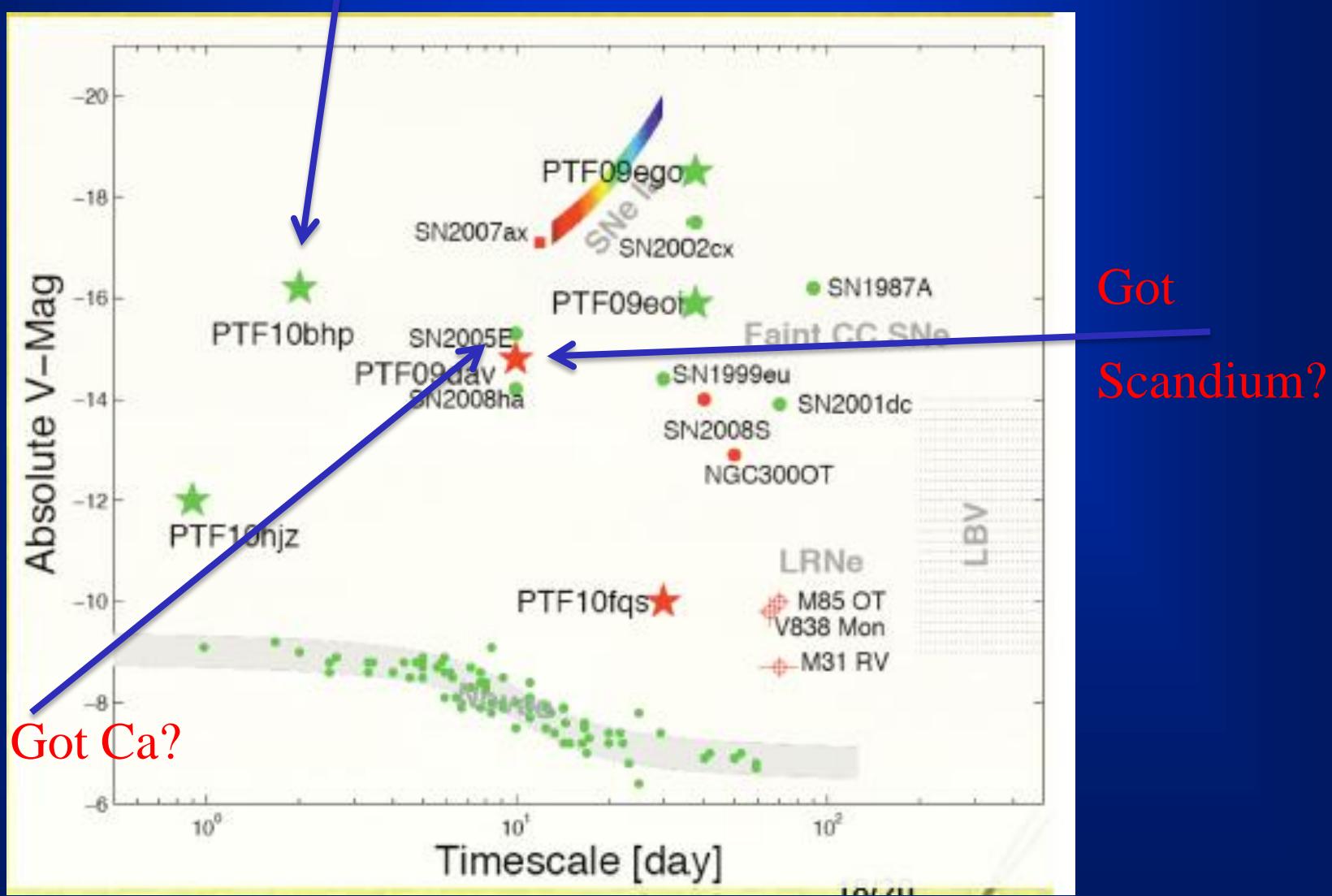
# Baby Supernovae: the first days



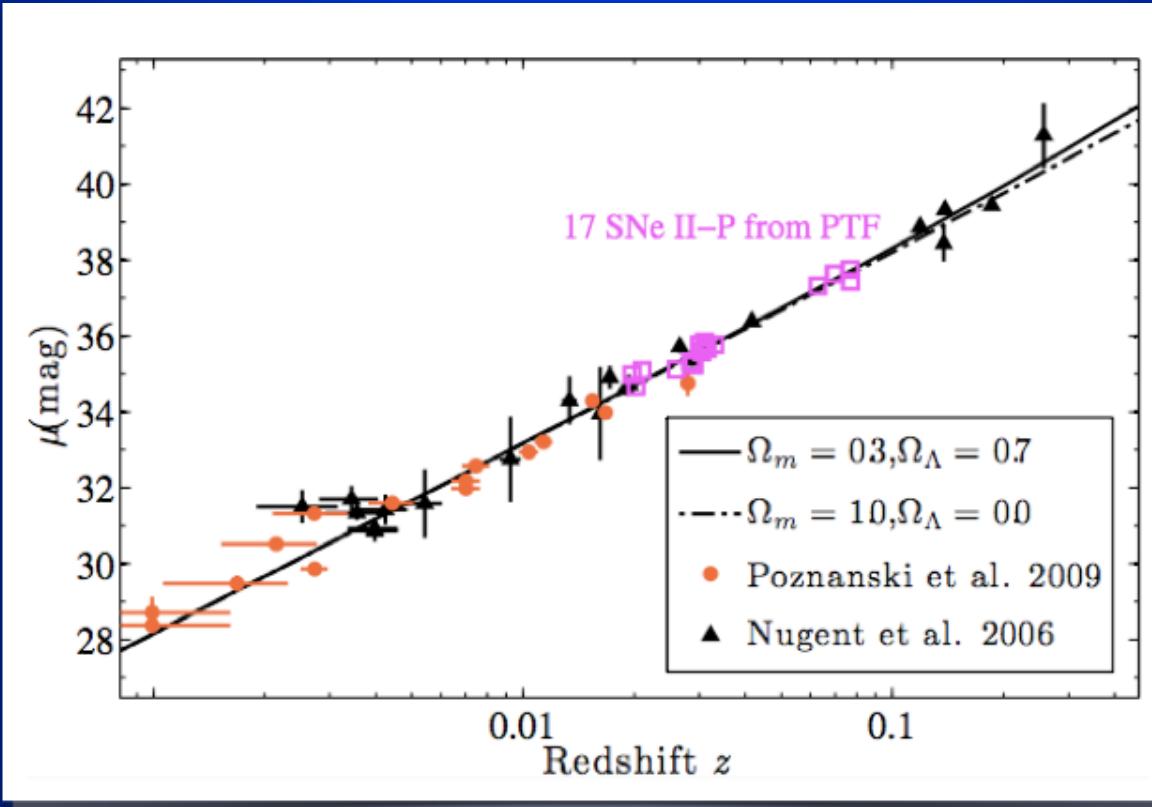
Core-collapse SNe: Arcavi

SNe Ia: Nugent, Sullivan, Howell, Ellis

# Fast transients ... ?



# II-P Cosmology



- Photometry - piggy-back on core-collapse project.
- Spectroscopy - dedicated time with Keck + random.

# Follow-up is key ...

**PTF09dfk**

23:09:13.42  
+07:48:15.4

347.305930  
+7.804291

[Finding Chart](#)

[Scanning Page](#)

**SN Ib/c**

no spec fup scheduled

[Upload New Spectrum](#)

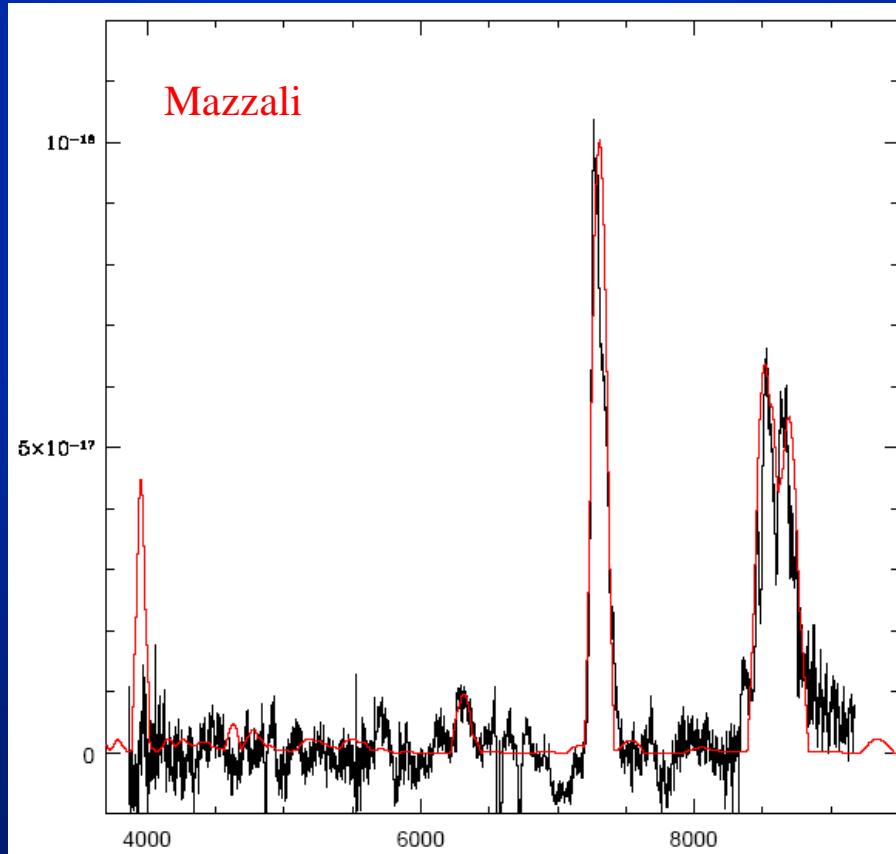
**Check NED**

**Check SIMBAD**

**Get DSS Image**

**r = 16.4 (154.8 d)**

# SN 2005E (Perets et al. Nature)



Peculiar abundances (C, O, Ca, Ni56) = (0.1 0.037 0.135 0.003) solar  
Total ejected mass is <0.3 solar !

# PTF news ... SNe Ia?

