

# Direct Identifications of Recent Core-Collapse SN Progenitors

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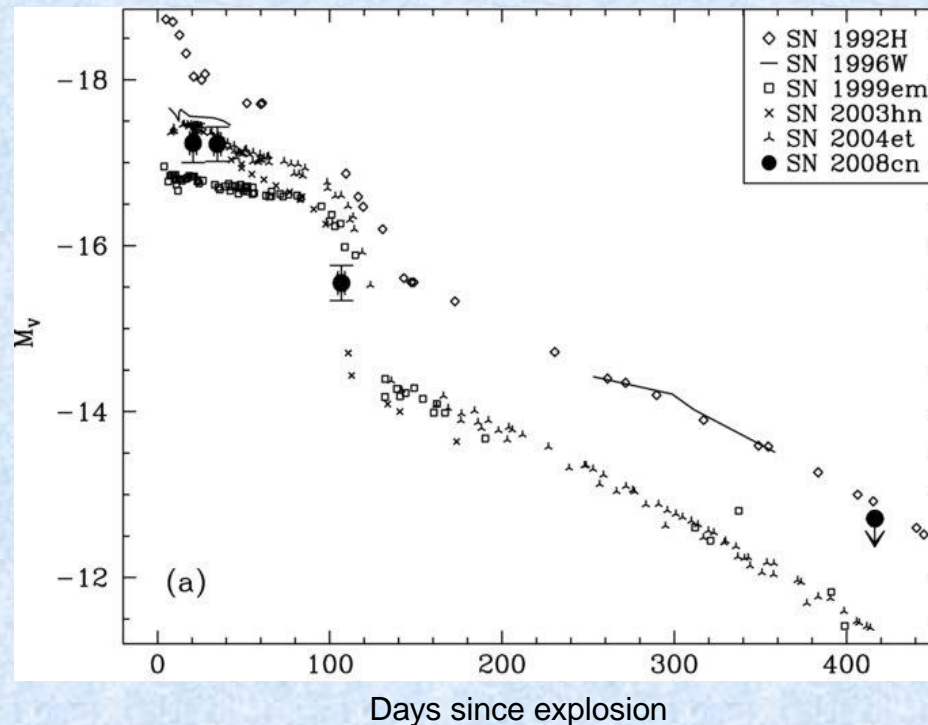
Alex Filippenko (UC Berkeley)

# Outline of talk

- SN 2008cn in NGC 4603
- SN 2009kr in NGC 1832
- SN 2009hd in M66 (NGC 3627)
- SN 2008bk in NGC 7793

# The high-luminosity SN II-P 2008cn in NGC 4603

- $M_V = -17.2$  (more luminous than 99em, less luminous than 92H)

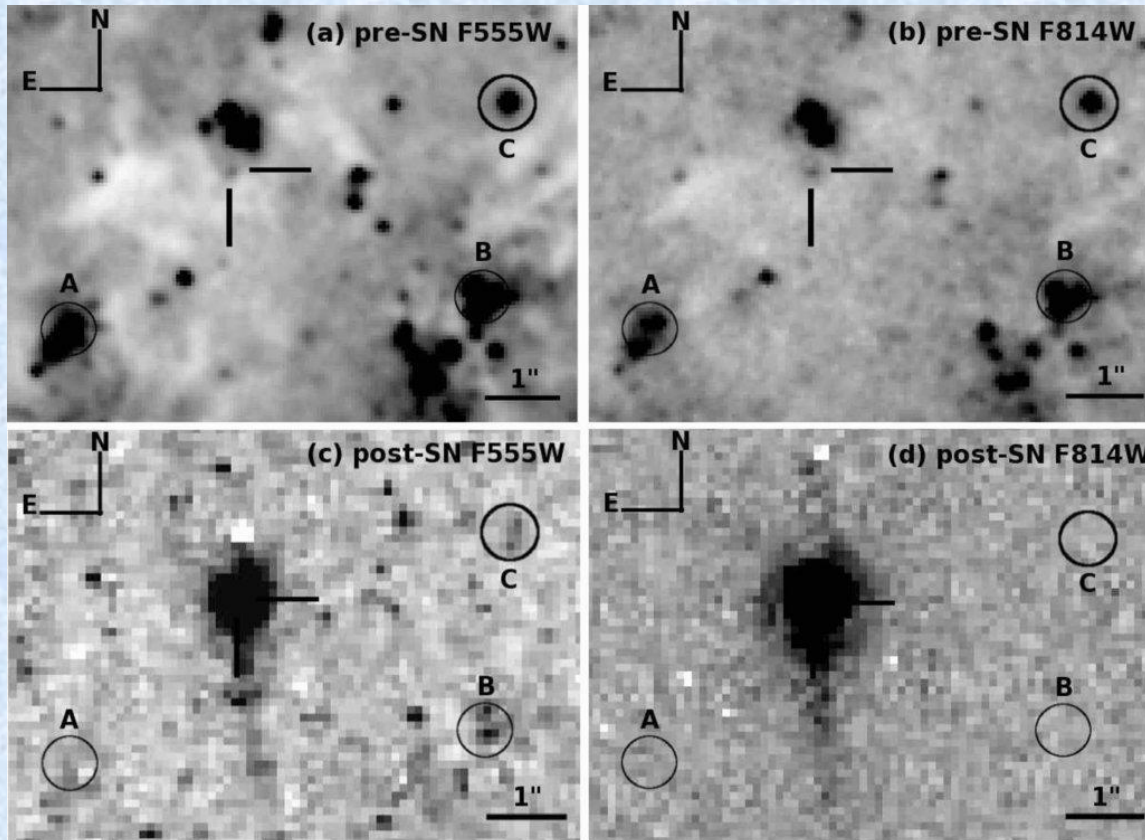


- Spectrum (CSP) most resembles the high-luminosity 96W  
(Elias-Rosa et al. 2009 --- with N. Morrell, S. Gonzales, M. Hamuy,  
J.-C. Cuillandre, R.J. Foley, N. Smith)



# The high-luminosity SN II-P 2008cn in NGC 4603

- Progenitor identified using pre-/post-SN HST WFPC2 imaging



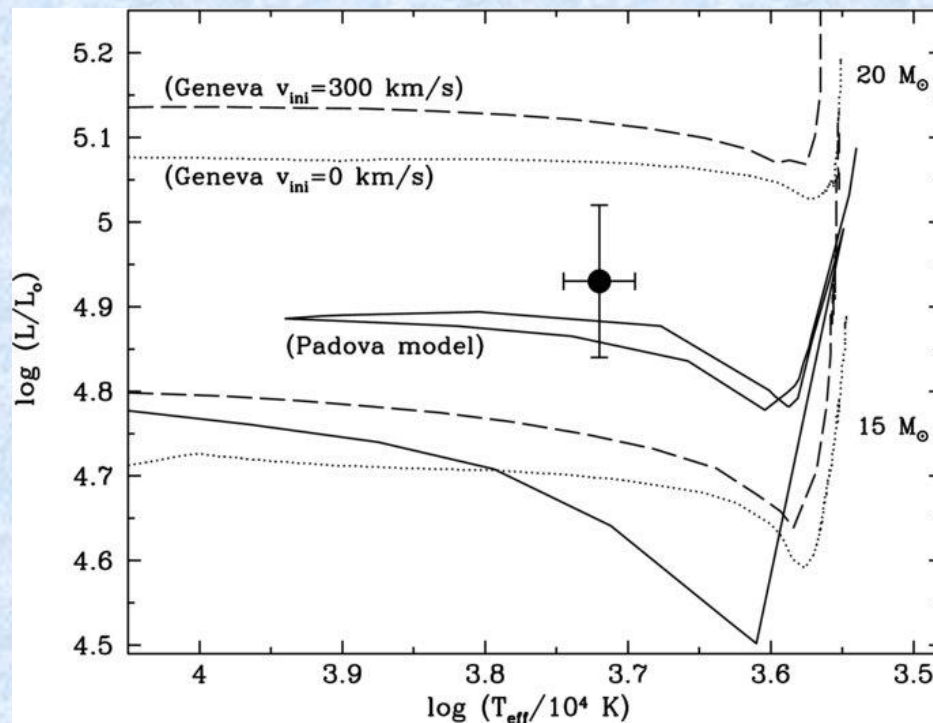
$A_V=1.08$  mag  
(from Na I D)

Distance=33.3 Mpc  
(from Cepheids)

(Elias-Rosa et al. 2009)

# The high-luminosity SN II-P 2008cn in NGC 4603

- Progenitor initial mass:  $M_{\text{ini}} \approx 17 \pm 2 M_{\odot}$



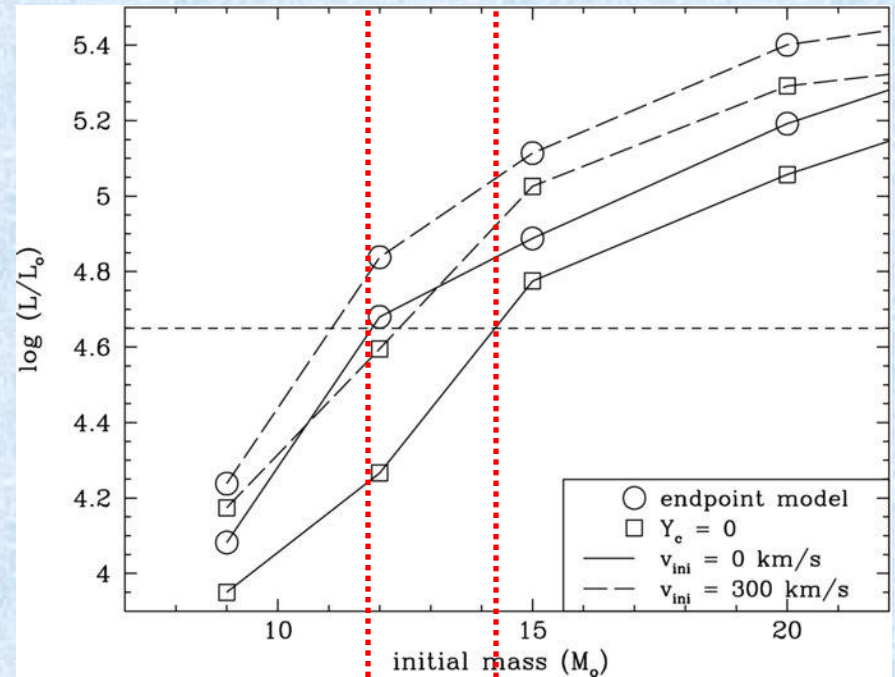
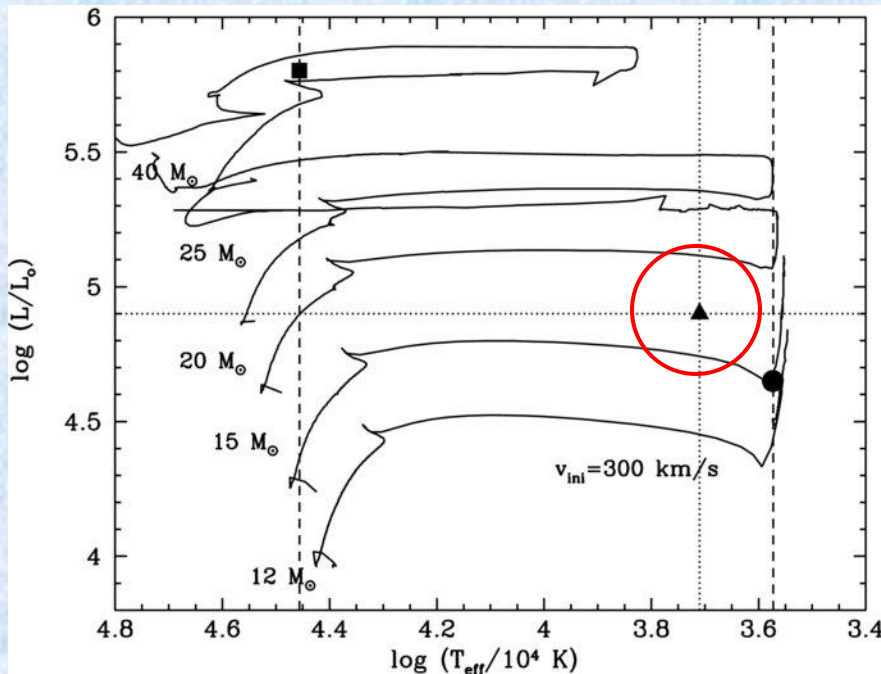
Single yellow supergiant?

Yellow supergiant binary?  
(Ho IX ecl. binary, SMC R47;  
Prieto et al. 2008)

(Elias-Rosa et al. 2009)

# The high-luminosity SN II-P 2008cn in NGC 4603

- Alternatives: (a) blend of  $\approx 12 M_{\odot}$  RSG +  $\approx 40 M_{\odot}$  BSG  
(b) Non-detection limit -- @ end of He burning,  $< 14 M_{\odot}$   
@ core collapse,  $< 12 M_{\odot}$

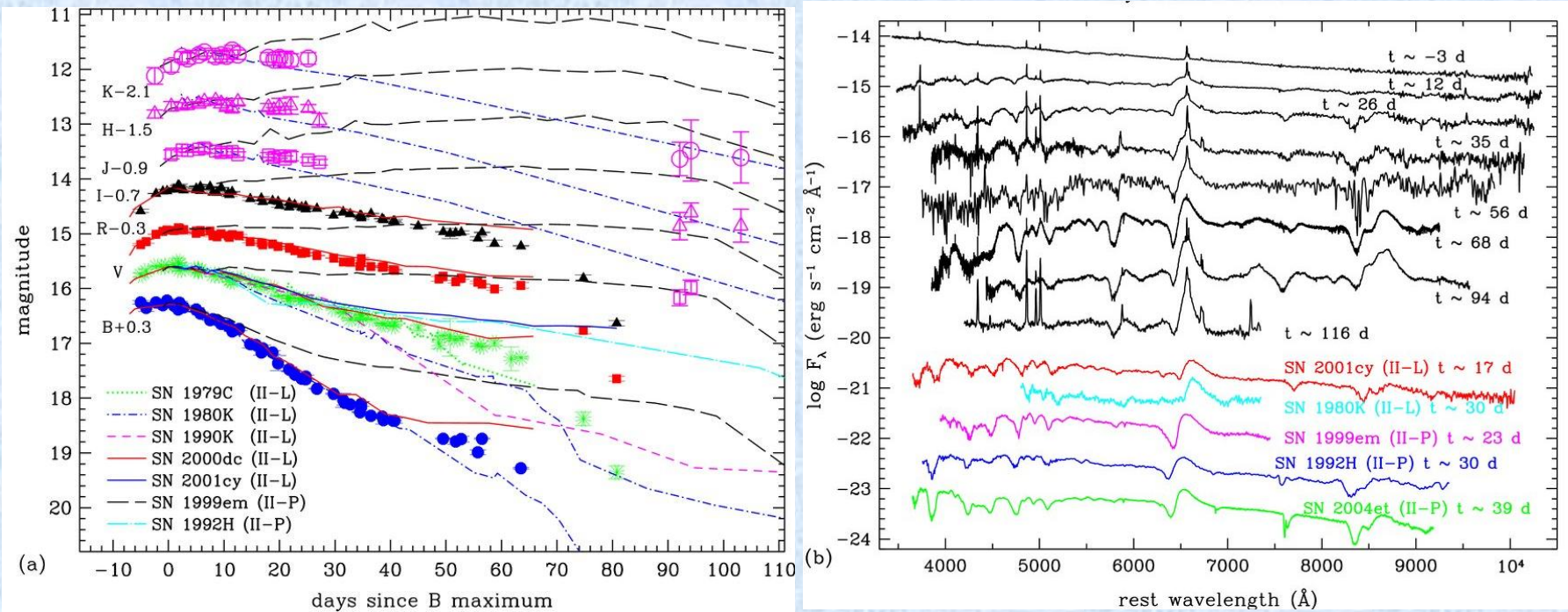


(Elias-Rosa et al. 2009)



# The SN II-L 2009kr in NGC 1832

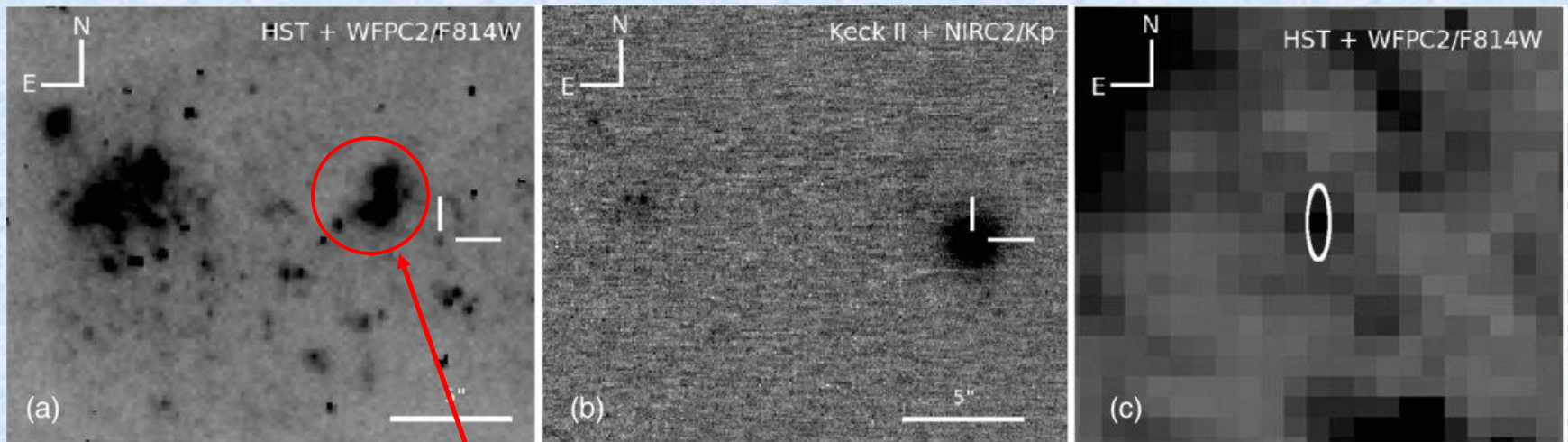
- This SN (with  $M_B = -16.5$ ) most resembles SNe II-L



(Elias-Rosa et al. 2010 --- with A.A. Miller, J.M. Silverman, M. Ganeshalingam, A.F. Boden, M.M. Kasliwal, J. Vinko, J.-C. Cuillandre, T.N. Steele, J.S. Bloom, C.V. Griffith, I.K.W. Kleiser, R.J. Foley)

# The SN II-L 2009kr in NGC 1832

- Progenitor identified using pre-SN HST WFPC2 imaging + post-SN Keck NIRC2 + AO imaging



(HII region = source of spectral narrow lines)

$A_V=0.25$  mag (from Na I D in high-res CFHT spectrum)

Distance=26.2 Mpc (from cz corrected for Virgo infall)

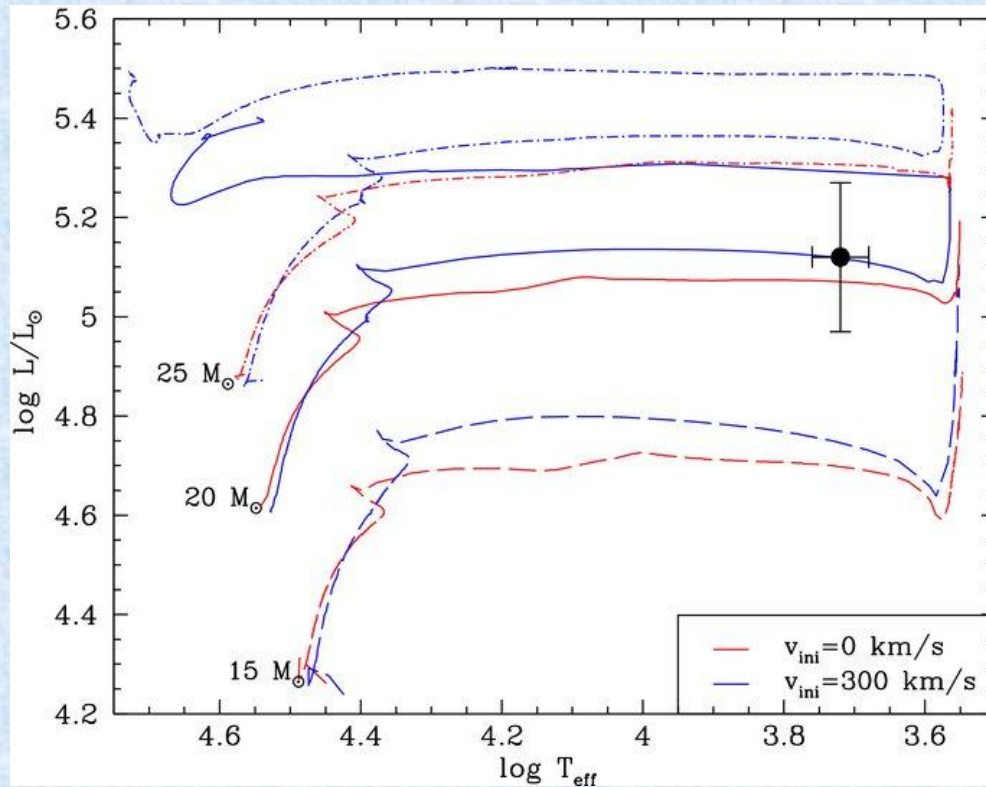
Solar metallicity from HII region emission lines

(Elias-Rosa et al. 2010)



# The SN II-L 2009kr in NGC 1832

- Progenitor initial mass:  $M_{\text{ini}} \approx 18 - 24 M_{\odot}$

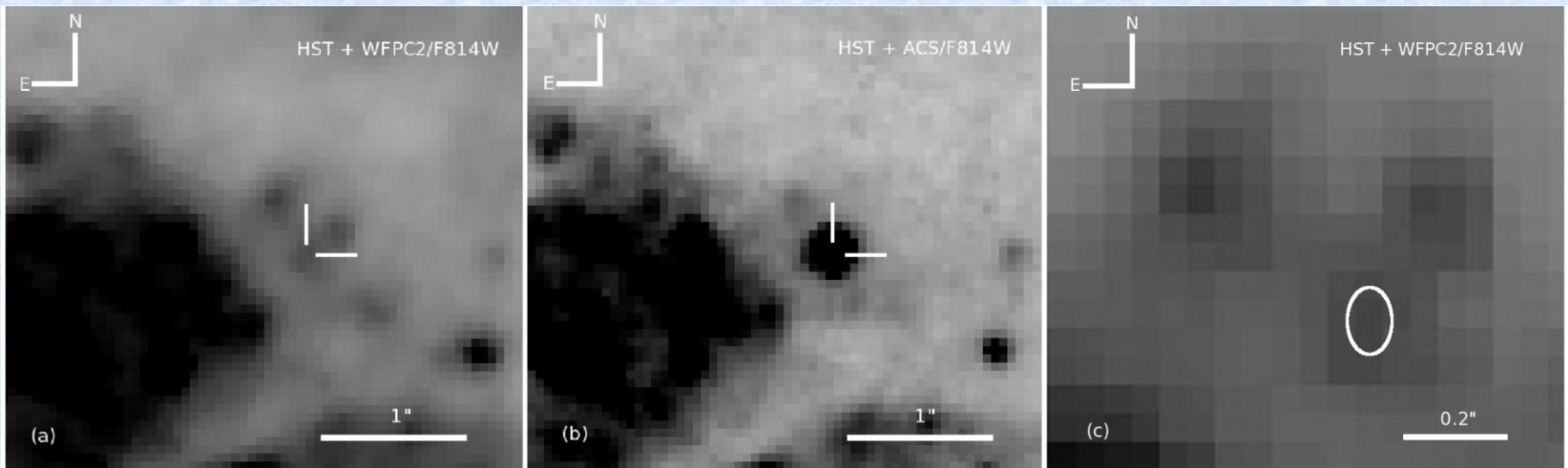


- **First-ever detection of SN II-L progenitor**
  - Yellow supergiant: consistent with predictions of Geneva rotating models
- Consistent with SN 1980K progenitor ( $M_{\text{ini}} < 20 M_{\odot}$ )
- Consistent with SN 1979C progenitor ( $M_{\text{ini}} > 17 - 18 M_{\odot}$ )

(Elias-Rosa et al. 2010)

# The SN II-L 2009hd in M66

- Progenitor identified using pre-SN WFPC2/post-SN ACS imaging

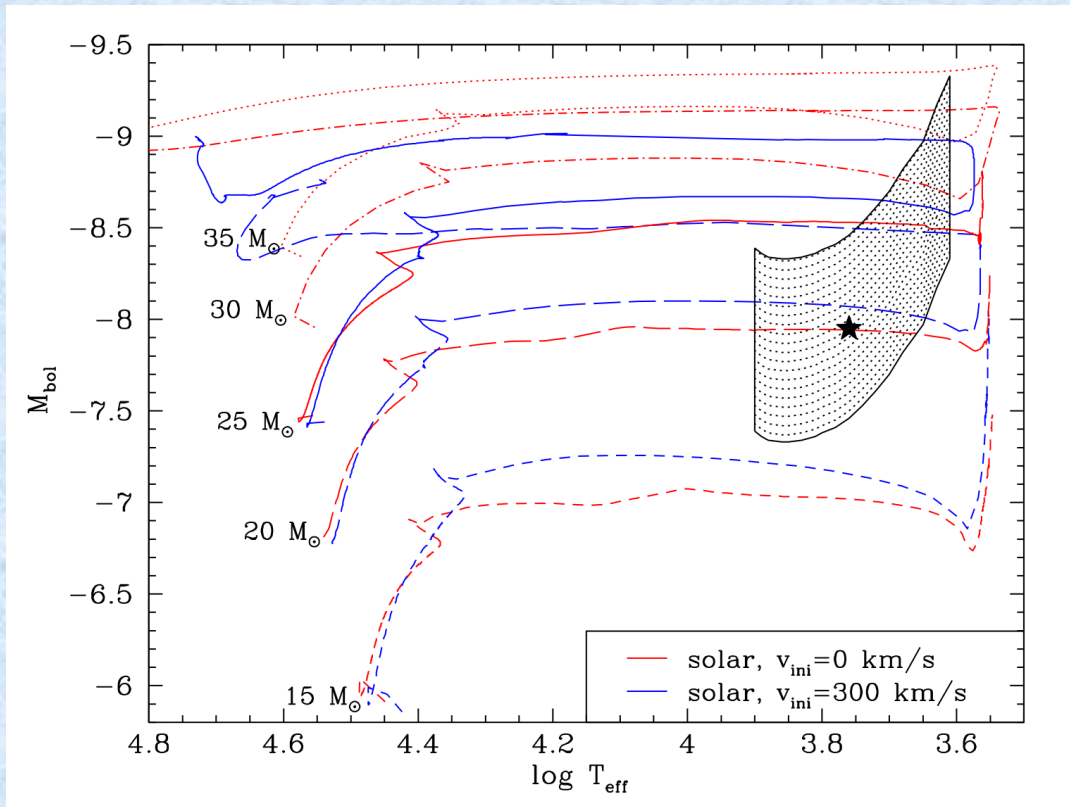


$A_V = 3.60 \pm 0.15$  mag      Distance = 9.4 Mpc (from Cepheids)

(Elias-Rosa et al. 2010b)

# The SN II-L 2009hd in M66

- Progenitor initial mass:  $M_{\text{ini}} \approx 16 - 35 M_{\odot}$



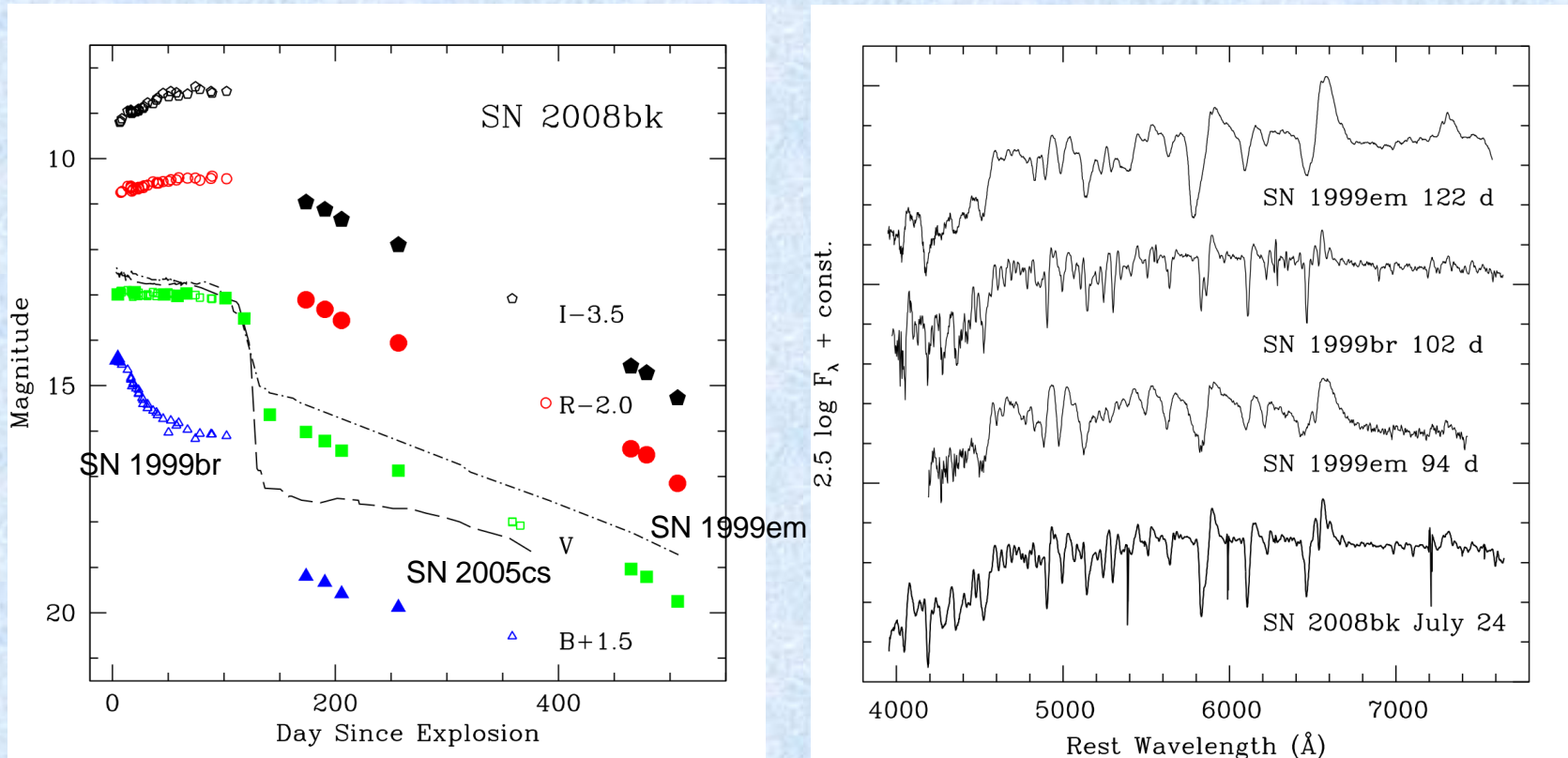
- Initial mass highly unconstrained, due to large uncertainty in F555W photometry
- However, progenitor could still be quite yellow

(Elias-Rosa et al. 2010b)



# The SN II-P 2008bk in NGC 7793

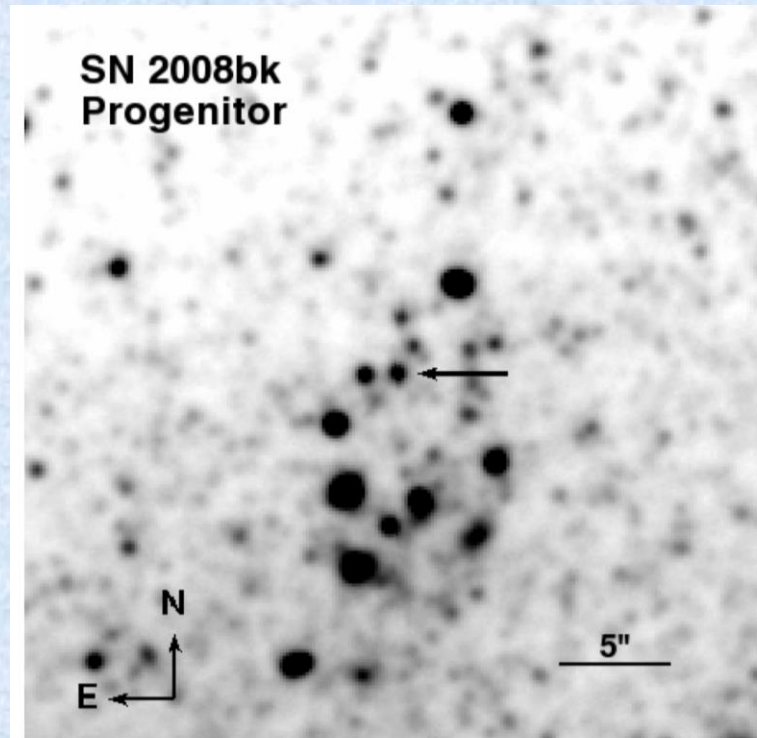
- “Kissing cousin” of subluminous SN II-P 1999br in NGC 4900



(Van Dyk et al. 2010 --- with T.J. Davidge, S. Taubenberger, S. Howerton, N. Morrell, G. Pignata, M. Hamuy)

# The SN II-P 2008bk in NGC 7793

- Progenitor characterized from Gemini-S GMOS g'r'i' images

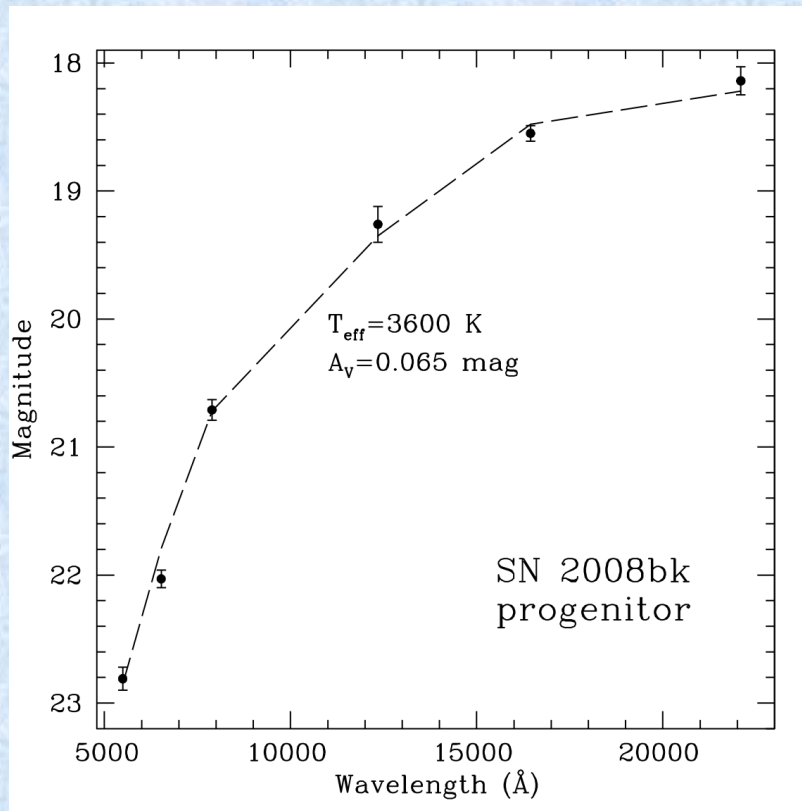


Progenitor ID'ed by Li et al. (2008), Maoz & Mannucci (2008),  
Mattila et al. (2008)

(Van Dyk et al. 2010)

# The SN II-P 2008bk in NGC 7793

- Progenitor SED beautifully matched by that of M3 supergiant



VRI mags transformed from  
g'r'i' mags

$A_v = 0.065 \text{ mag}$   
(~entirely Galactic  
Foreground)

$\mu_0 = 28.00 \pm 0.10$   
from rederived TRGB  
(distance=3.98 Mpc)

Solar metallicity from spectrum  
of HII region in environment

$$M_{\text{bol}} = -7.00 \pm 0.13 \text{ from V}$$

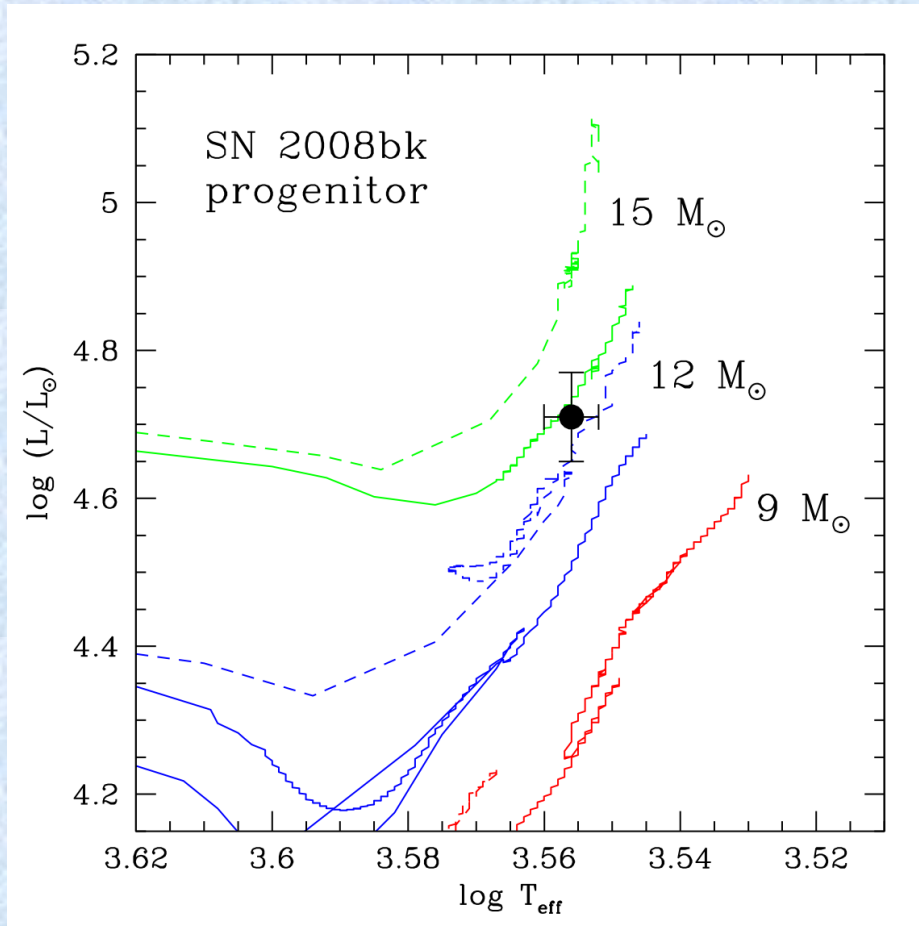
$$M_{\text{bol}} = -7.03 \pm 0.15 \text{ from K}$$

(Van Dyk et al. 2010)



# The SN II-P 2008bk in NGC 7793

- Progenitor initial mass:  $M_{\text{ini}} = 12 \text{ -- } 15 M_{\odot}$



- **Next to SN 1987A, the least ambiguous detection so far**

- Consistent with SN 1999br progenitor ( $M_{\text{ini}} < 15 M_{\odot}$ )

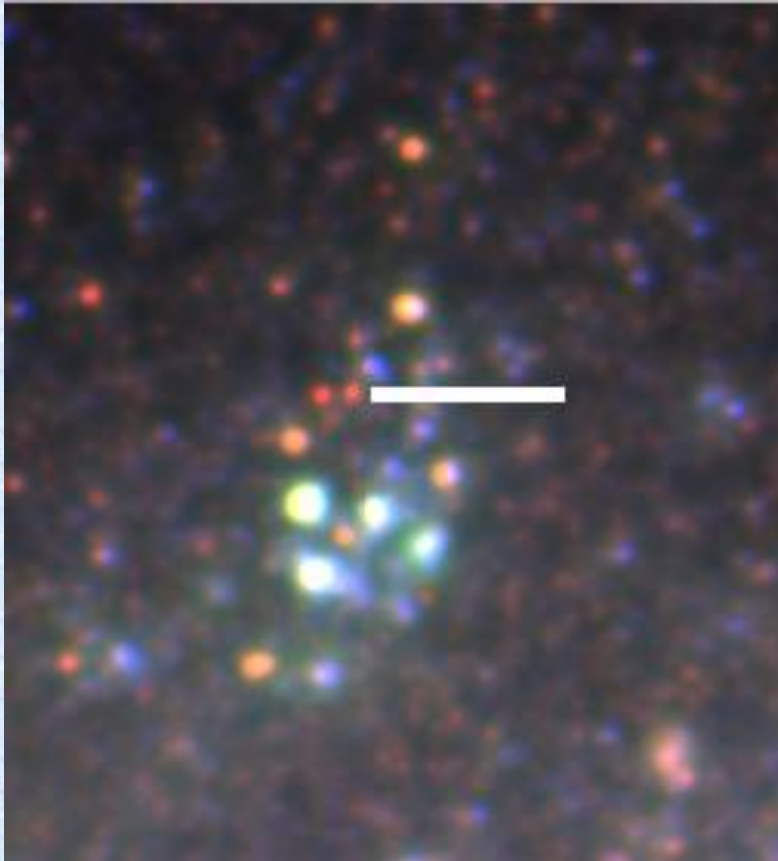
- for 08bk,  $M_V = -15.1$  mag

for 99br,  $M_V = -13.8$  mag  
(from EPM distance,  
 $M_V = -16.3$  mag)

(Van Dyk et al. 2010)

# The SN II-P 2008bk in NGC 7793

- The second least ambiguous detection so far



Gemini g'r'i' from 2007 Sep-Oct

NOT VRI from 2009 Aug

(Van Dyk et al. 2010)

# Summary

- SN 2008cn progenitor: yellow supergiant with  $\Delta M_{\text{ini}} \approx 17 \pm 2 M_{\odot}$  (? Binary? Blend? Undetected?)
- SN 2009kr, first ID of a SN II-L progenitor: yellow supergiant with  $M_{\text{ini}} \approx 18 \text{ -- } 24 M_{\odot}$
- SN 2009hd progenitor  $M_{\text{ini}}$  not well constrained

***All above are very likely to be CSM interactors***

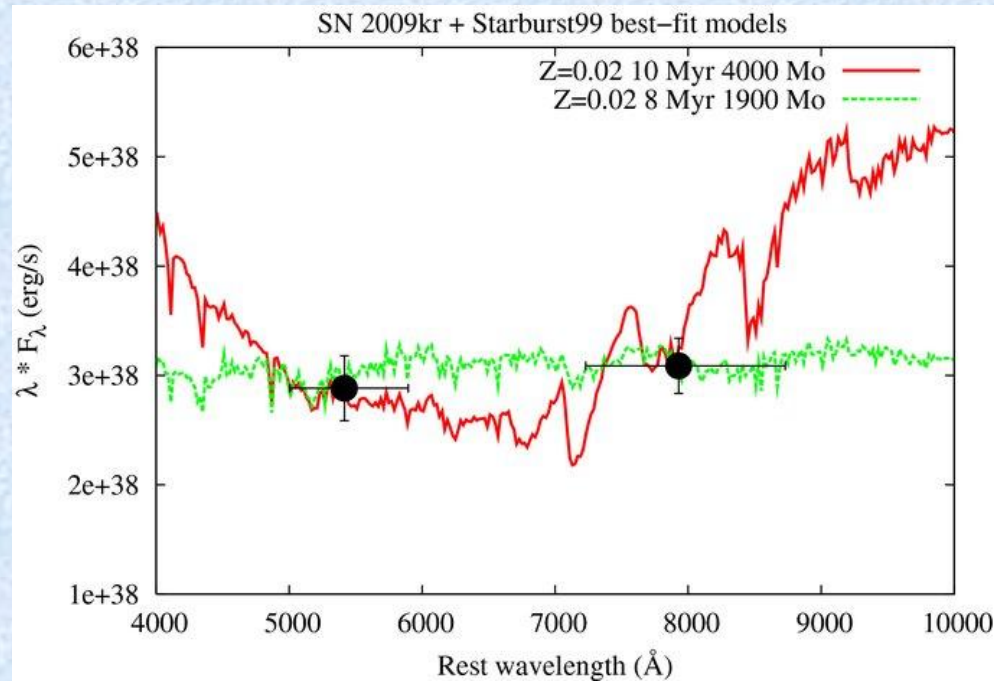
- SN 2008bk had a M3 supergiant progenitor, with  $M_{\text{bol}} = -7.0$  and  $M_{\text{ini}} = 12 \text{ -- } 15 M_{\odot}$
- SN 2008bk, best ID since SN 1987A
- SN Ib/c progenitors hard to detect: either in clusters or extinguished by dust -- *maybe, someday we'll get lucky*



**Extras**

# The SN II-L 2009kr in NGC 1832

- Possible cluster

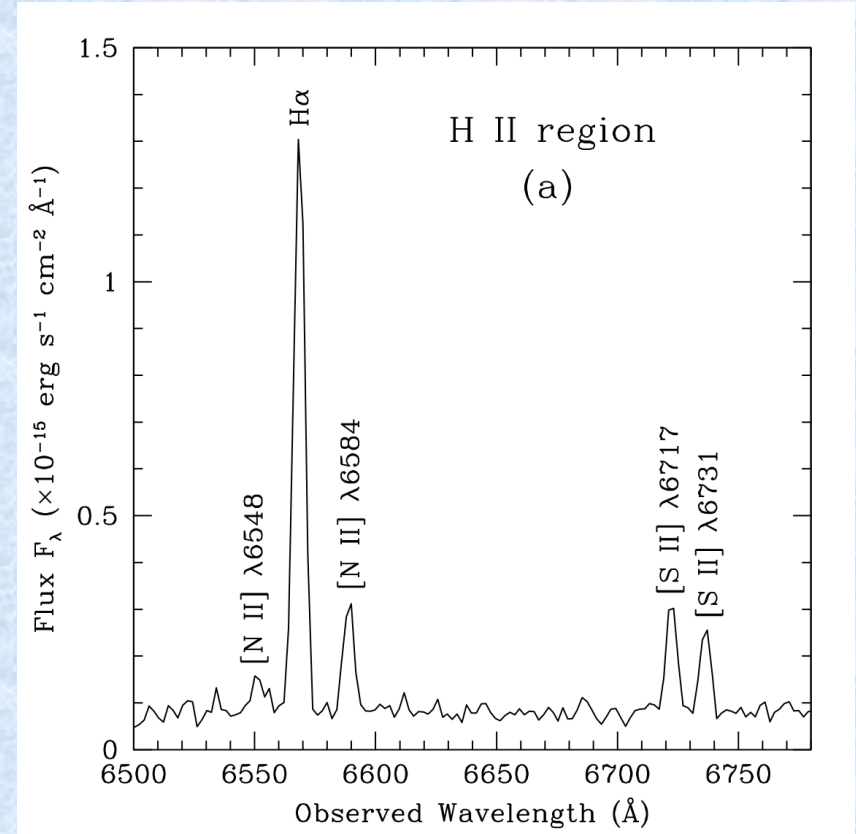
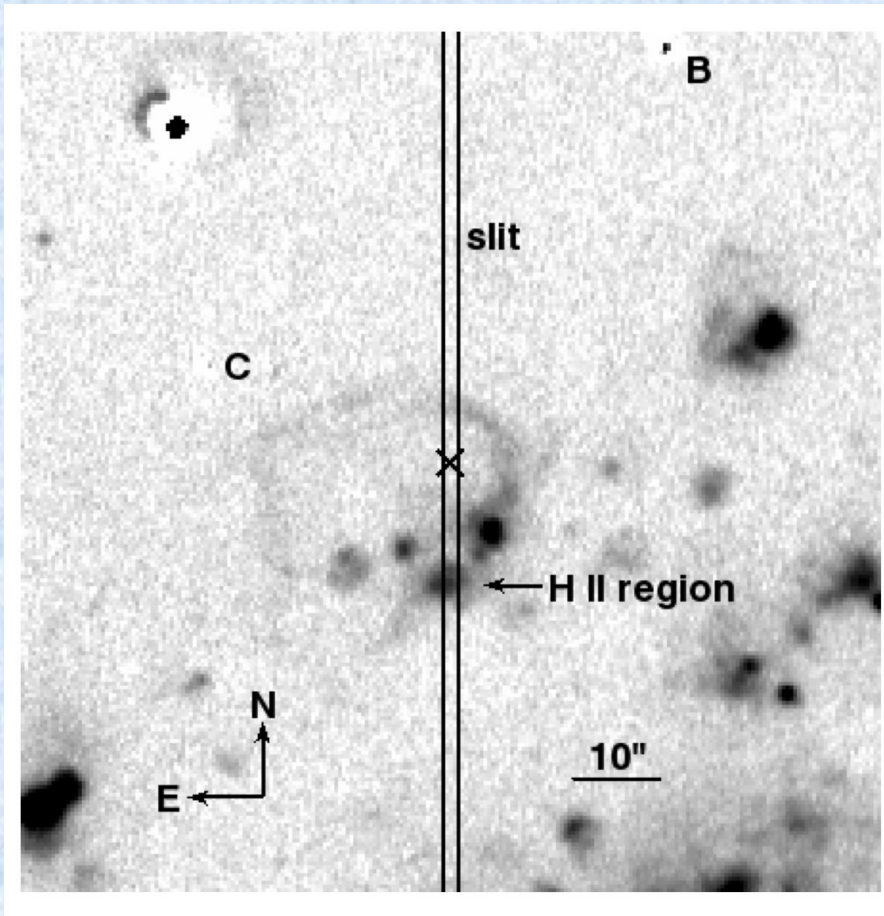


- 10 Myr cluster still consistent with progenitor of  $M_{\text{ini}} \sim 20 M_{\odot}$ , with  $M_{\text{min}}(\text{cluster}) \sim -7.6$  mag
- 8 Myr cluster also fits, with  $M_{\text{min}}(\text{cluster}) \sim -8.1$  mag
- Star:  $M_V < -7.8$  mag
- We would expect  $M_V < -8.6$  mag for clusters (Bastian et al. 2005)

(Elias-Rosa et al. 2010)

# The SN II-P 2008bk in NGC 7793

- HII region in SN environment and its spectrum



(Van Dyk et al. 2010)



# Humphreys-Davidson Limit

- Loci of progenitors of SNe 2009kr and 2009hd

