Progenitors of supernovae:

SN 2009kr + SN 2009md?

Progenitors of supernovae

(Very short review based on Stephen Smartt et al)

Basic question: Which type of stars become which type of supernovae? Smartt and his collaborators tries to answer this question by identifying the supernovae progenitor stars in pre-explosion images.The answer will put (strong) observational constraints on stellar evolution and core collapse theory.

The systematic search started in the late 90s when the number of galaxies the HST archive had grown large enough. Over the last ten years 26% of the SNe with D<28Mpc had pre-explosion HST images.

Since then 9 progenitors and 3 progenitor star clusters have been identified. There is also 22 non-detections providing useful upper limits.

Results (1987A and 1993J not included in the sample!):

- Lower mass limit for type IIP supernovae around 8 solar masses.
- Upper mass limit for type IIP supernovae around 17 solar masses.
- Red supergiants are the typical progenitors of type IIP supernovae.
- Massive WR stars are not the (only) progenitors of type Ib/Ic supernovae.

Comment: These results are significant but obiously suffers from low number statistics! However, this will improve and in the long run the biggest problem (as usual) will be the systematic errors.

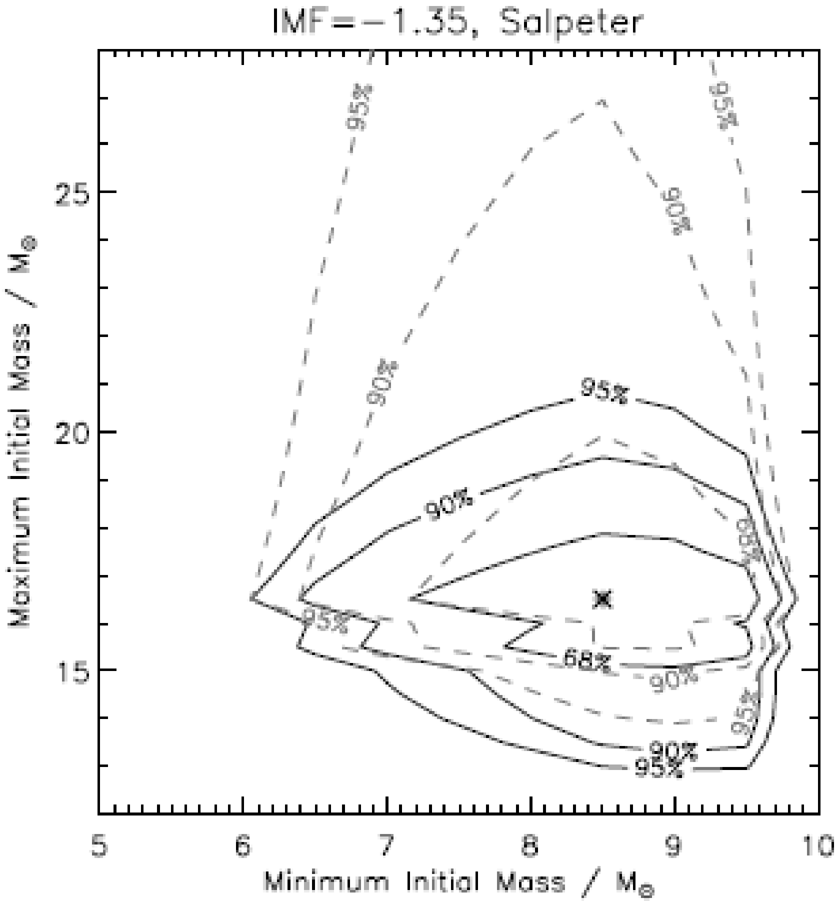


Figure 6. Plot of the likelihood function for the mass ranges of Type II-P progenitors. The star indicates the parameters with the highest likelihood and the contours the confidence regions. The dotted grey lines show the results using the seven detections only, which results in a lower mass limit of 8.5 $M_{\odot}$. The solid black lines show the contours using the fixed lower limit and allowing the maximum mass to vary.

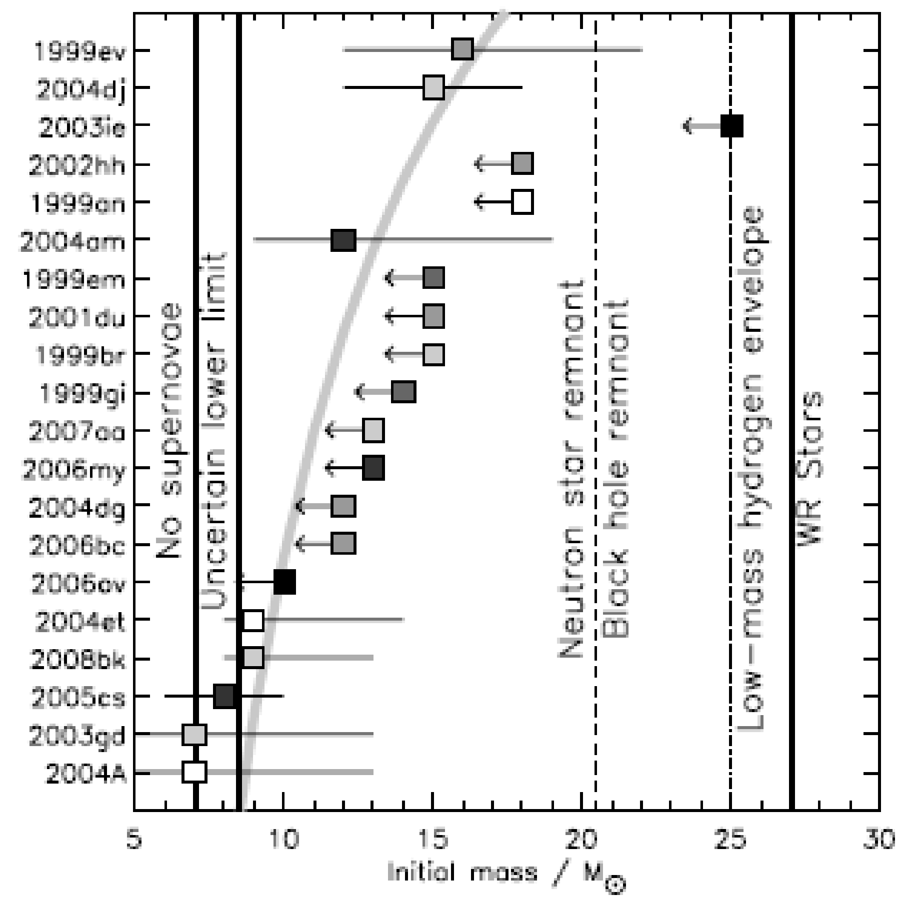
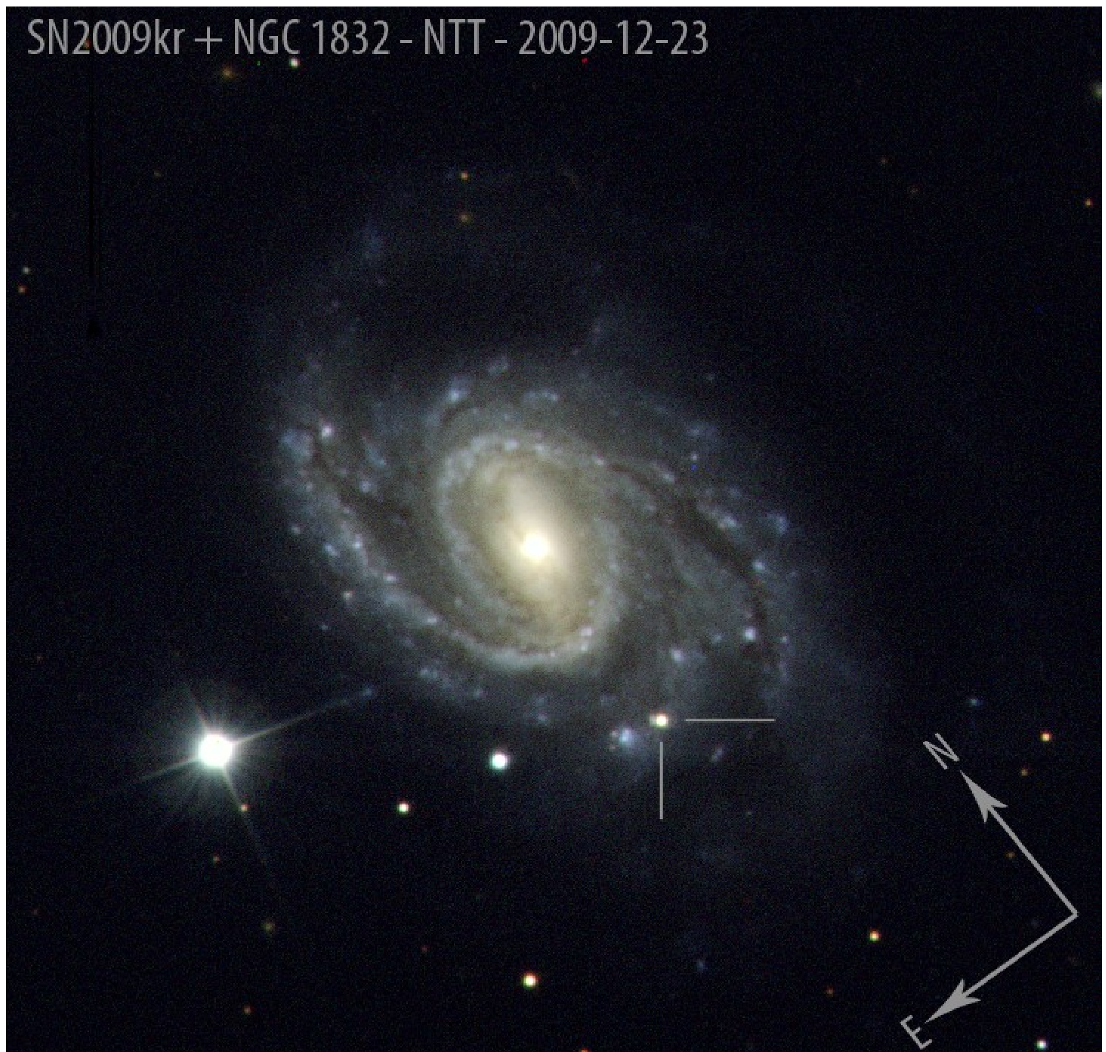


Figure 8. The initial masses of all our Type II-P progenitor stars, compared with our theoretical limits for production of SNe of different types and type of compact remnant. The box symbols are shaded on a metallicity scale, the lighter the shade the lower the metallicity, with the values taken from Table 2.

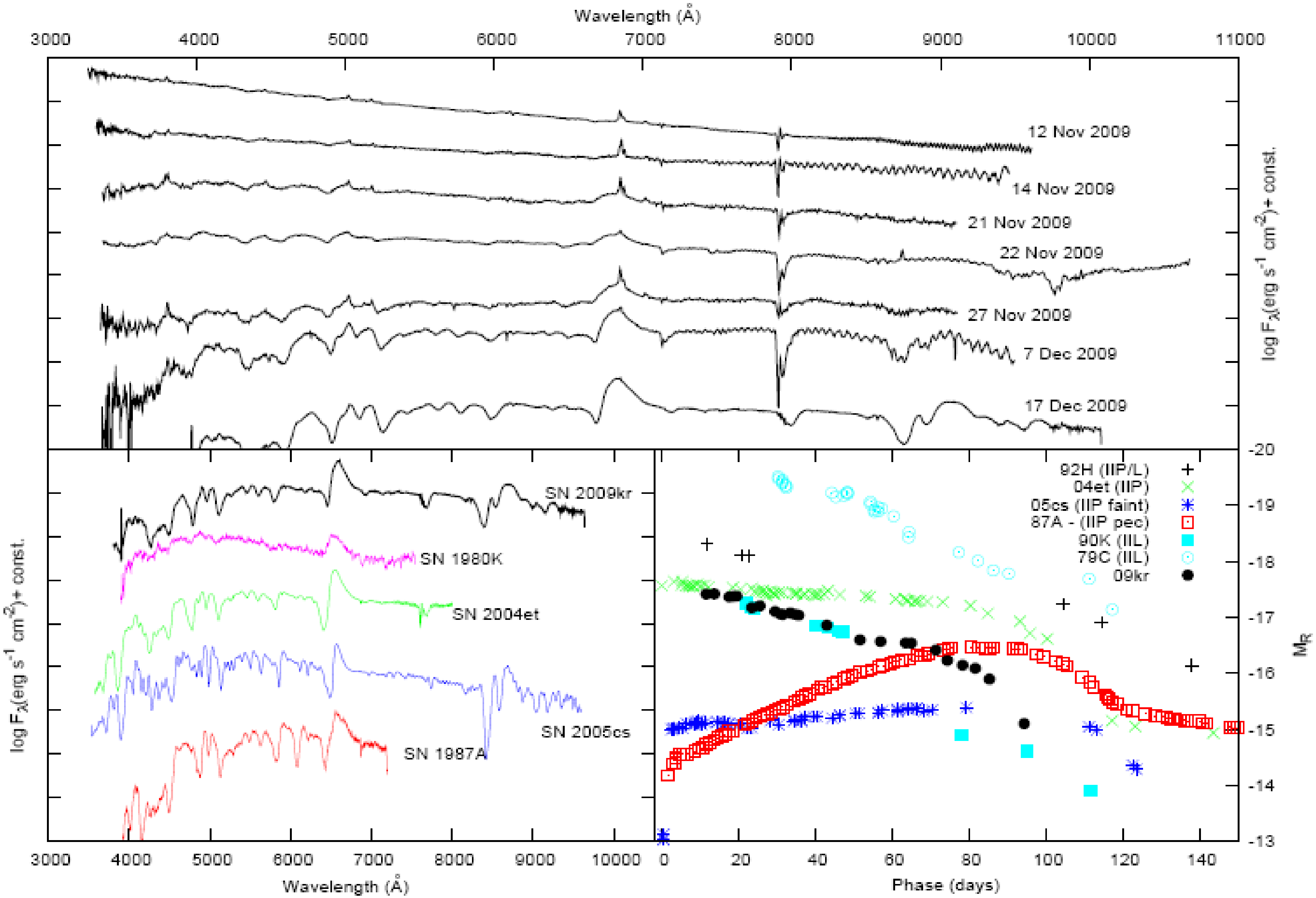
SN 2009kr

(Short review based on Morgan Fraser et al)

Discovered Nov 6 2009 in NGC 1832 at a distance of about 26 Mpc.



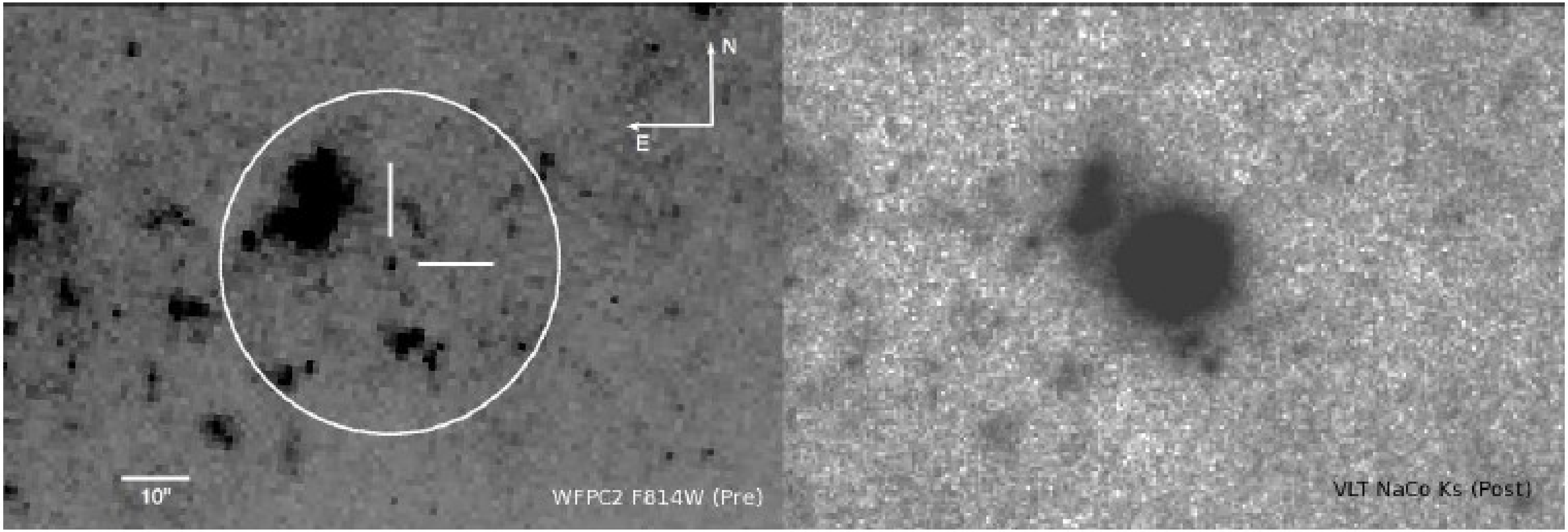
It is currently classified as a type IIL supernovae but this is still an open question.



There are pre-explosion images in the HST archive in the F555W (V-band) and F814W (I-band) filters.

Comparing these to a high resoltion AO image of the SN obtained with VLT a star (~10 sigma detection) coincident with the SN is found.

The difference in position is 6 milli-arcseconds well within the error bars of 52 milli-arcseconds.



Photometry of the progenitor gives:

$$M_V = -7.62 \pm 0.55$$
$$M_I = -8.75 \pm 0.51$$
$$V - I = 1.13 \pm 0.25$$

(There's no evidence for significant reddening in spectra so host extinction is neglected. The distance however is quite uncertain and is the main source of the error.)

Using the known spectral distributions of supergiants (Drilling & Landolt) this corresponds to a yellow (G6) supergiant with luminosity:

$$\log L/L_{\odot} = 5.10 \pm 0.24$$

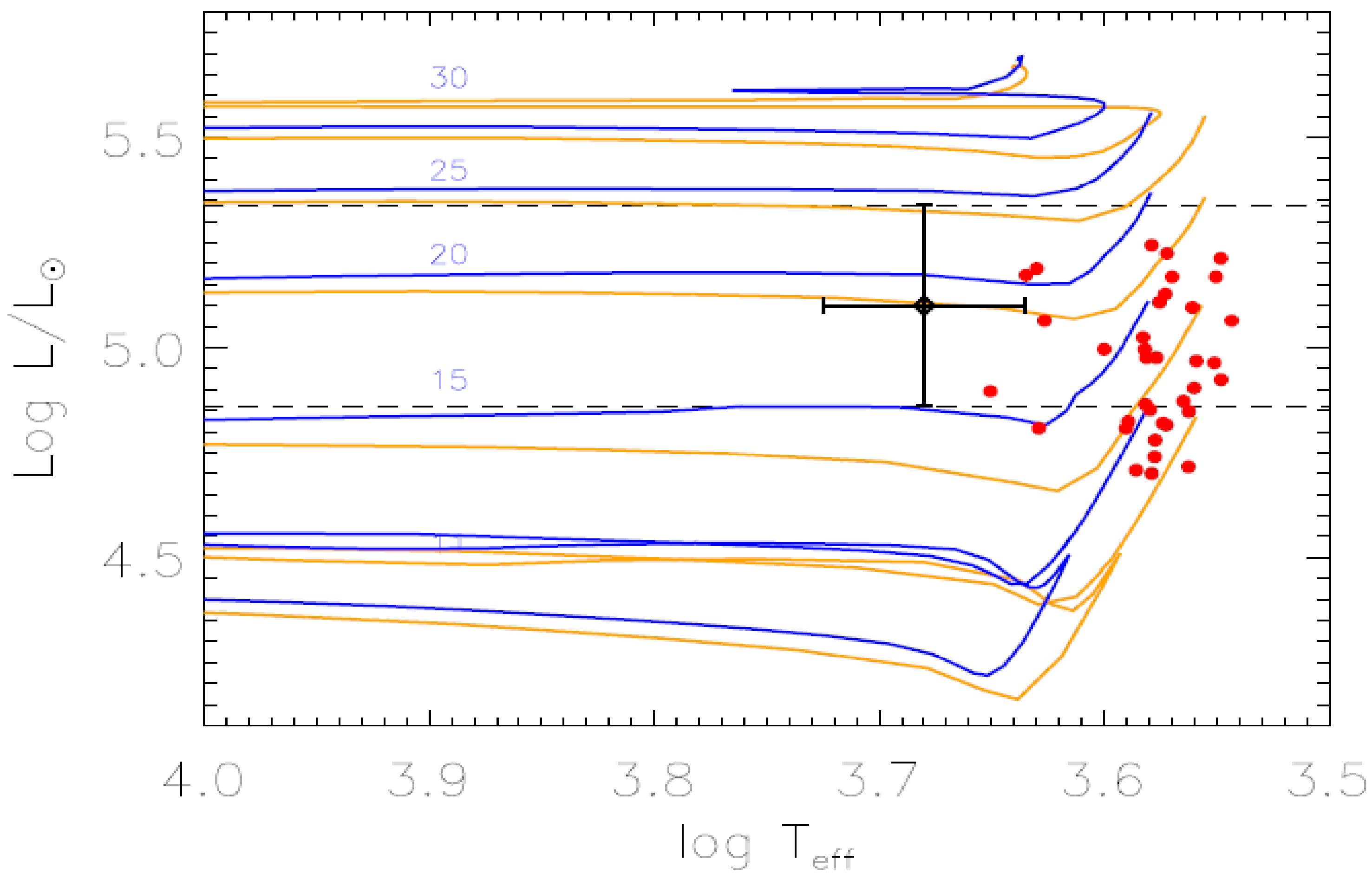
The mass is determined with a simple method previously used by Smartt. The method uses stellar model tracks calculated with the STARS code to determine a final mass-luminousity relation. The endpoints of the tracks (which corresponds to neon-burning or second drege-up for AGB stars) are assumed to give the final luminousity for stars of that mass even if the temperature/colour doesn't match the model track.

(The systematic error is estimated as the luminousity range between end of helium burning and the endpoint.)

Comment: The method makes sense if the star is pretty close to the endpoints. However, in this case the star is pretty far off. Actually the position of the star does not match any of the tracks particulary well and raise the question if these models can be used to estimate the mass.

The Smartt method gives a mass for the progenitor of $15^{+5}_{-4} M_{\odot}$, which is close to but within the upper limit for type IIPs. This MAY be an indication that this limit also holds for type IILs. At least it does not contradict it. Only binary stars stripped of hydrogen are expected to produce type IILs in this mass range.

There is a competing paper led by Nancy Elias-Rosa which claims a mass of about $20\ M_{\odot}$. However, the method used by Nancy is to choose the track closest to the position of the star which doesn't make sense since this point on the track corresponds to hydrogen shell-burning.



Summary:

- This is the first time a progenitor is found for a type IIL supernova (if the classification holds).

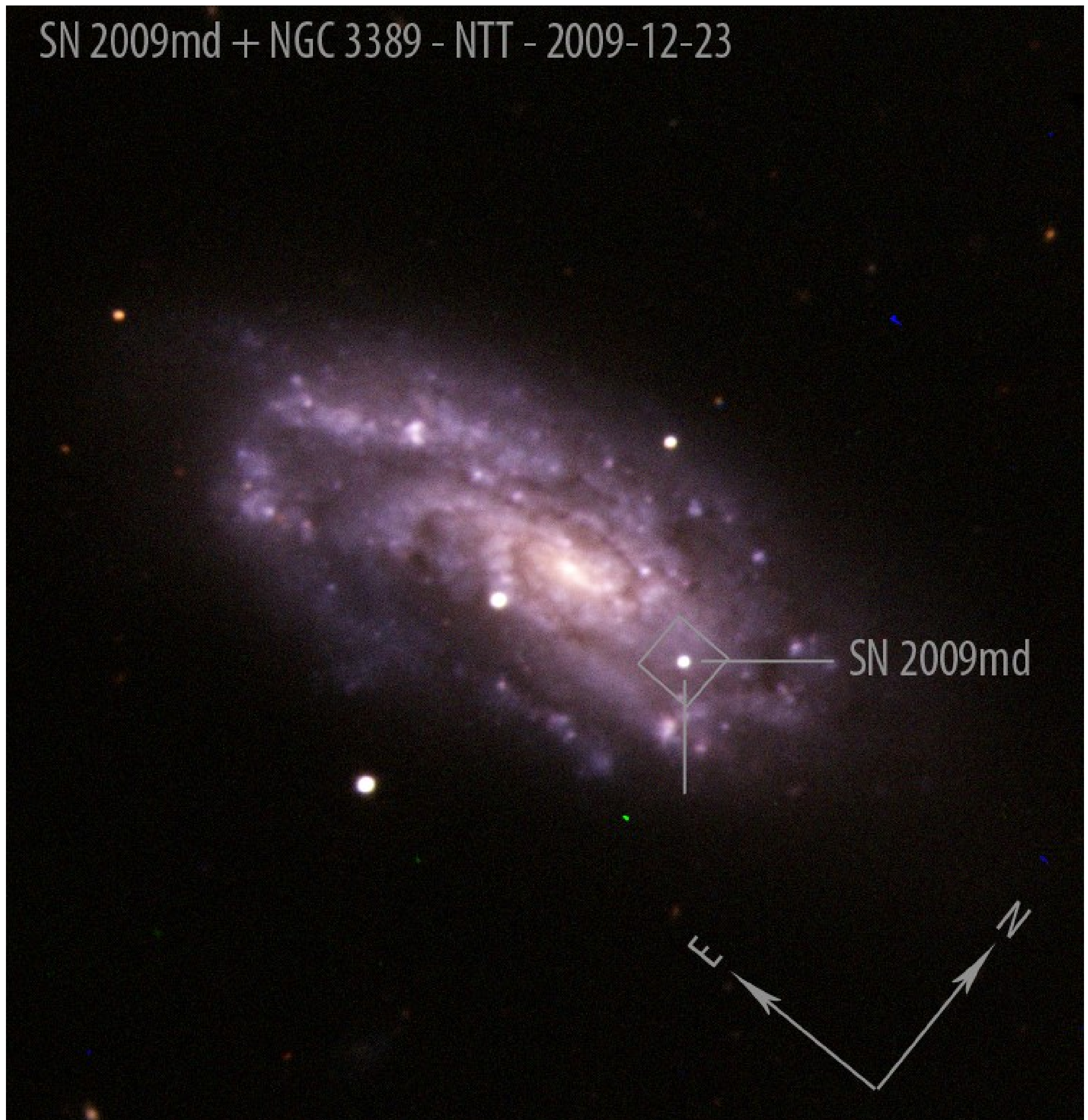
- This is the first time a yellow supergiant progenitor is found.

- It's one of the most massive progenitors found so far (only the progenitors of 1999ev, 1987A and 2005gl are estimated to be more massive).

SN 2009md

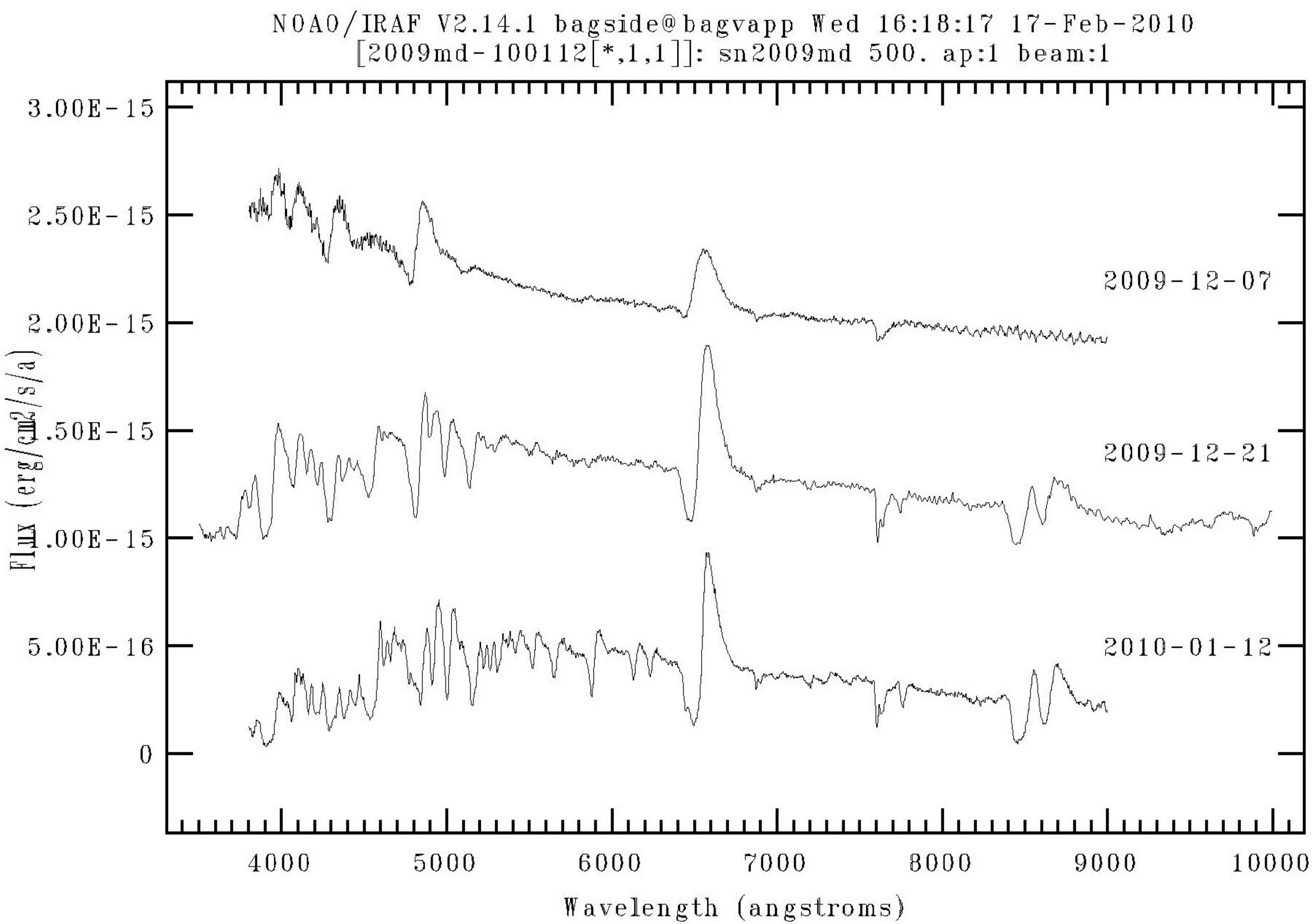
(short review based on preliminary results)

Discovered Dec 4 2009 in NGC 3389 at a distance of about 22 Mpc



Classified as type IIP most similar to 2005cs

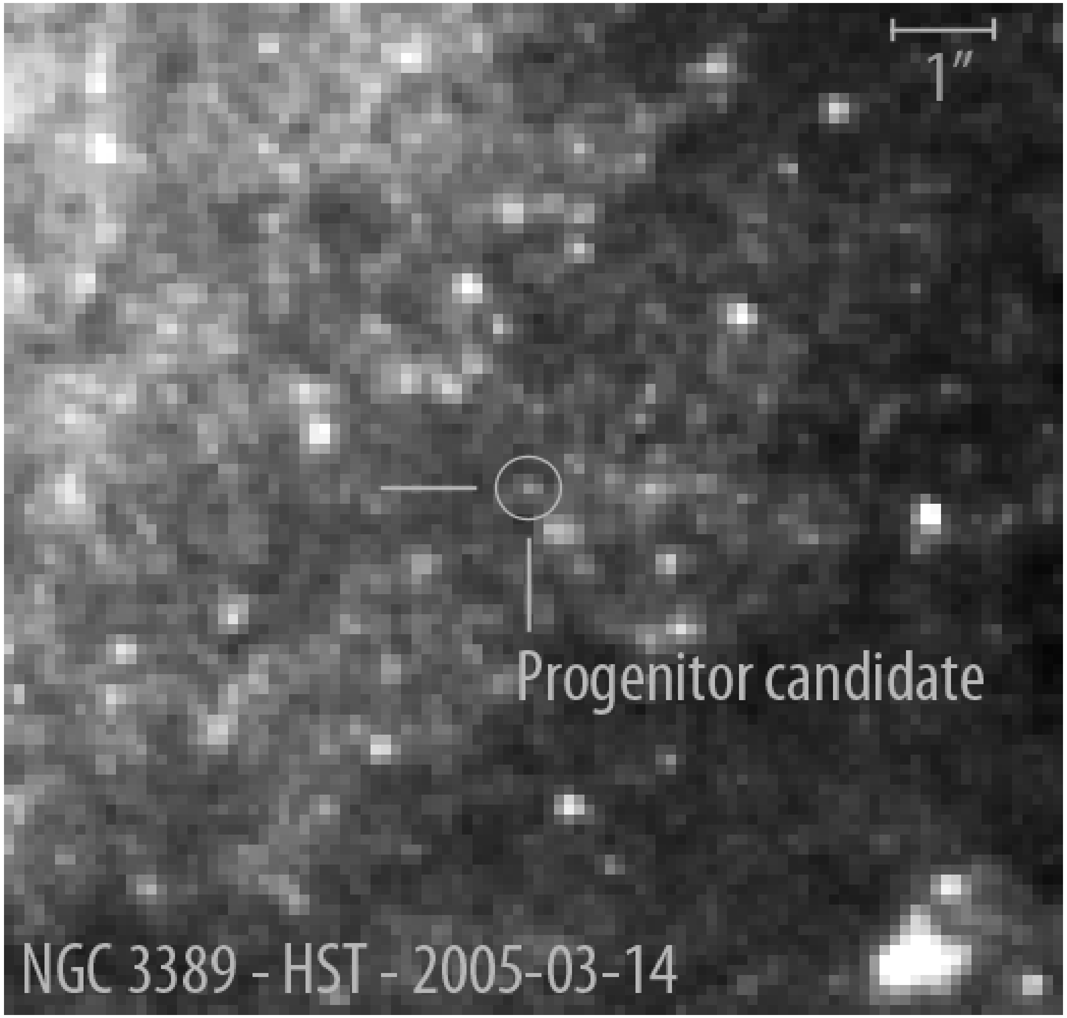
Plateau absolute V-magnitude ~-15 → underluminous



There are pre-explosion images in the HST archive in the F606W (V/R-band) and F814W (I-band) filters.

Preliminary comparision with a NOT image of the SN shows a star coincident with the SN. The difference in position is ~50ms and the error at least ~150ms.

Unfortunately we have so far failed to get a high resolution AO image of the SN.



Preliminary photometry of the progenitor candidate gives:

$$M_V = -5.44 \pm 0.7$$

$$M_I = -7.3 \pm 0.2$$

$$V - I = 1.8$$

(From spectra the host extinction is estimated to be comparable to the (small) galactic extinction. Distance is taken as the Virgo-infall corrected from NED.)

This corresponds to a red (K4) supergiant with luminosity:

$$\log L / L_{\odot} \sim 4.4$$

Using again the Smartt method the mass is estimated to be around 8 solar masses.

As mentioned before the SN was most similar to 2005cs, an underluminous supernova which had a progenitor with estimated mass around 7 solar masses.

This suggests that a substantial part of the underluminous type IIP supernovae come from low mass stars which is interesting since the high or low mass origin of underluminous type IIP has been debated.