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SN2011ht --- Supernova or Impostor?

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This object showed V ~ 500 — 800 km / s, with no evident higher velocities. After an initial stage, for about 3 months the photospheric outflow rate was 0.01— 0.2 M_{sun} / y. The total measurable energy was less than 10^{50} ergs. Interpretations as a true SN are essentially conjectural and a non-SN giant eruption fits the data at least as well.

I. Background

Observations of SN 2011ht (Roming et al. 2012) revealed an unusual eruption sharing characteristics with Type IIn supernovae and also with SN impostors. The spectrum soon after discovery (Pastorello et al. 2011) resembled some LBV eruptions, Intermediate-Luminosity Red Transients, and the warm hypergiant IRC+10420. Having $M_V \sim -14$ at discovery, it was designated an impostor (PSN J10081059+5150570, CBET 2851). Later, though, it reached $M_V \sim -17$ at its distance of 19.2 Mpc in UGC 5460 (Roming et al 2011). Based on luminosity and narrow hydrogen emission lines, Prieto et al. (2011a,b) suggested that it was a true SN of Type IIn. Concurrent with its visual brightening, SN 2011ht also showed a 7-magnitude UV increase in 40 days. Only a few Type IIn SNae have been observed in the near-UV and this object has the most complete early data.

Here we describe SN 2011ht's spectral evolution and its circumstellar ejecta or outflow. The data resemble an eruption driven by radiation pressure. Characterizing it as a SN is an assumption, not a deduction. There is no clear evidence for a blast wave or other SN attributes, while the light curve would fit a giant eruption as well.

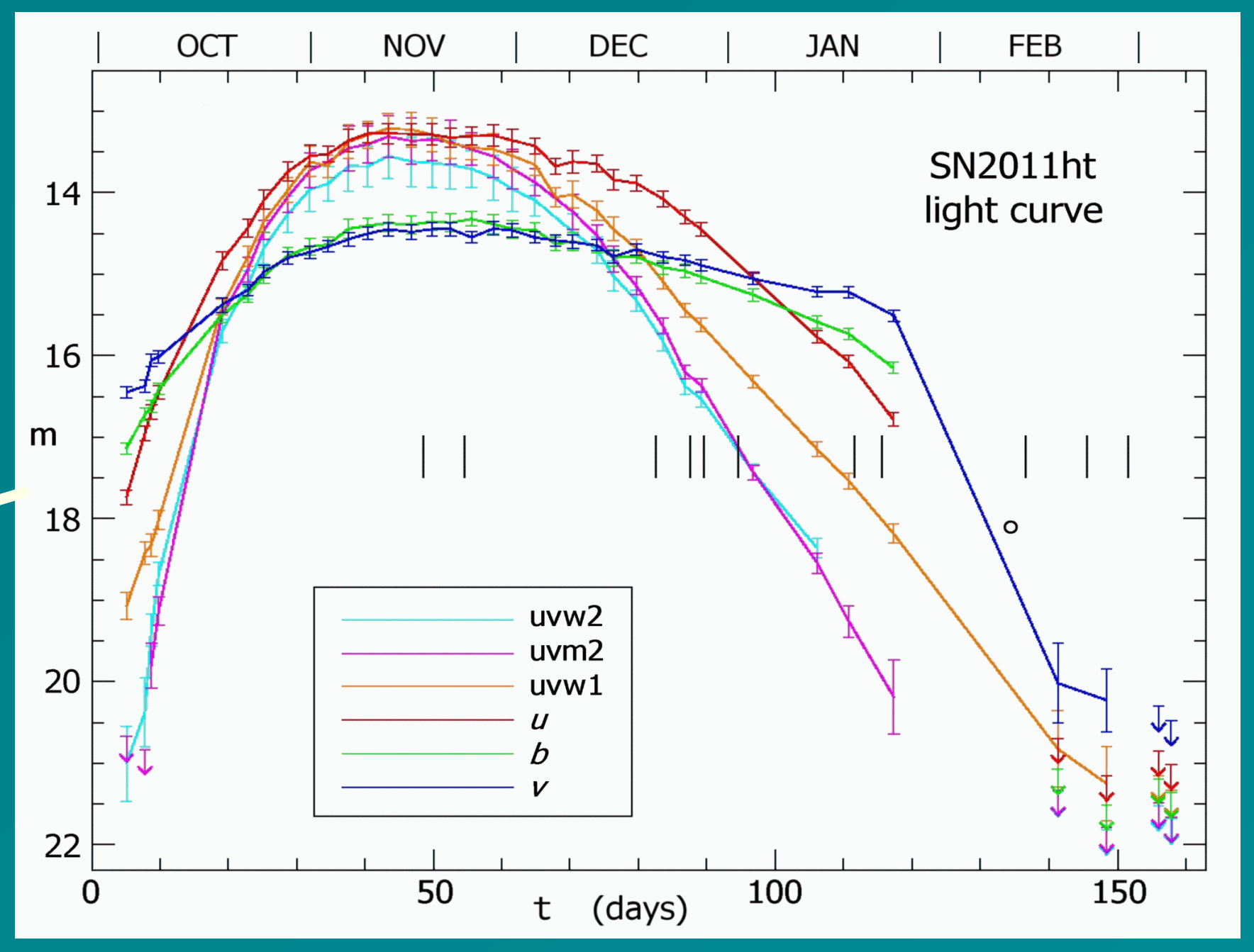

Fig. 1. Light curves at various wavelengths. Vertical tics mark times of spectroscopy; the zero-point is MJD 55833 = 2011 Sept. 29. Most of these data are from *Swift,* but the open circle is m_V from Hurst (2012).

The distance modulus is about 31.4 mag, i.e., m = 14 corresponds to M ≈ -17.4 - extinction.

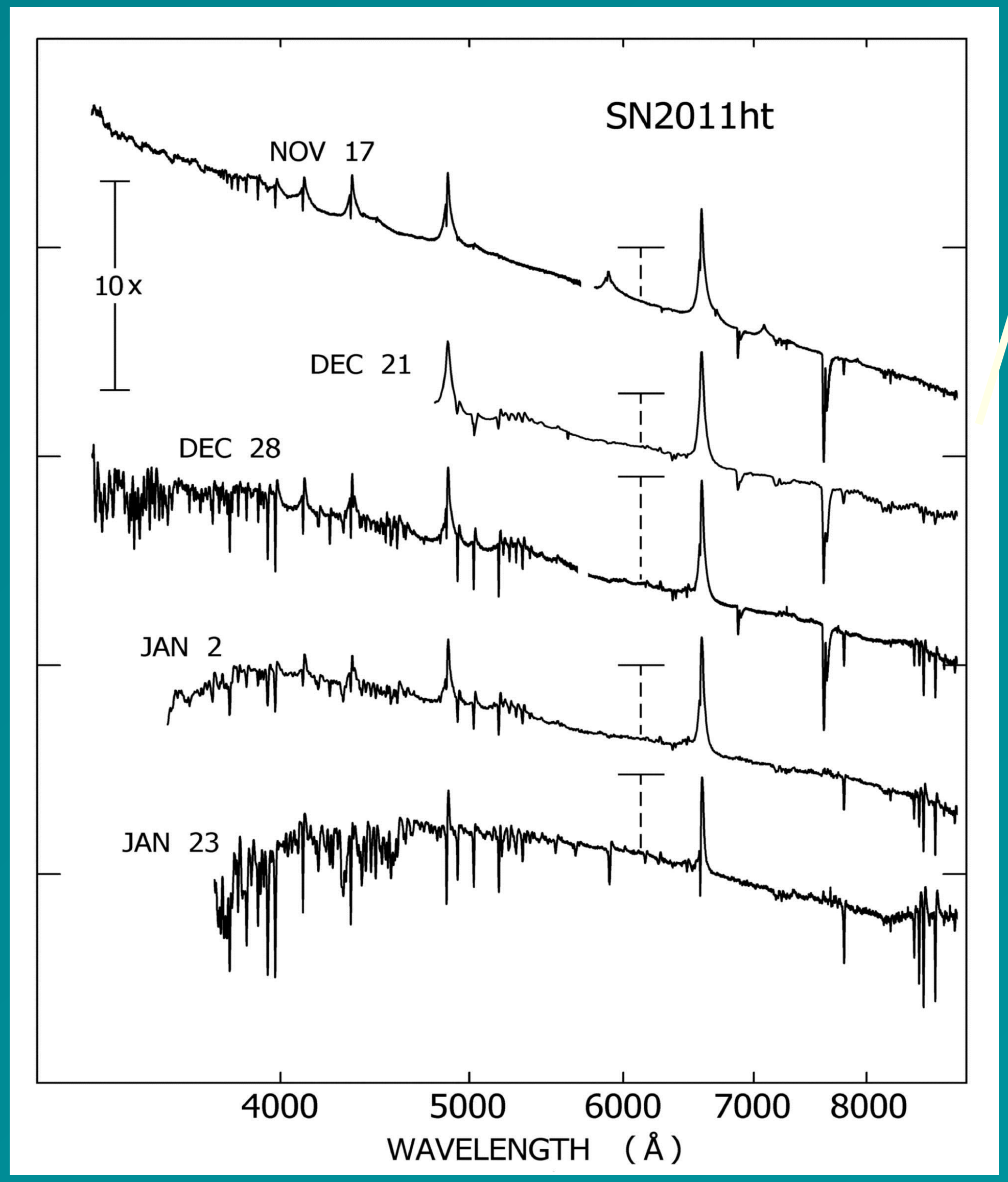

Fig.2: **Hot dense flow** in November, **cooler dense flow** in December-January. These are MMT and LBT data, and horizontal bars mark 10^{-14} erg cm^{-2} s^{-1} A^{-2}.

II. Spectral Evolution

For a few weeks after discovery the spectrum showed a "hot dense wind" state described by Roming et al (2012). Strong, asymmetric Balmer emission lines and broad He I emission dominated. In December it began to resemble a "cool dense wind" which continued through January (Fig. 2). In the same manner as a lower-luminosity giant eruption, it resembled a late F or G-type supergiant plus strong H, Fe II, and Ca II emission lines. The physical reasons have long been familiar (Davidson 1987).

The radiative energy release was of the order of $10^{49.4}$ ergs, and it was not accompanied by 10 times as much kinetic energy (see text box IV).

Then the February decline shown in Fig. 1 left the flow in a warm lower-density state (Fig. 3). The Balmer lines lost their strong Thomson-scattering wings. SN 2011ht then resembled several SN impostors and luminous stars with rapid mass loss.

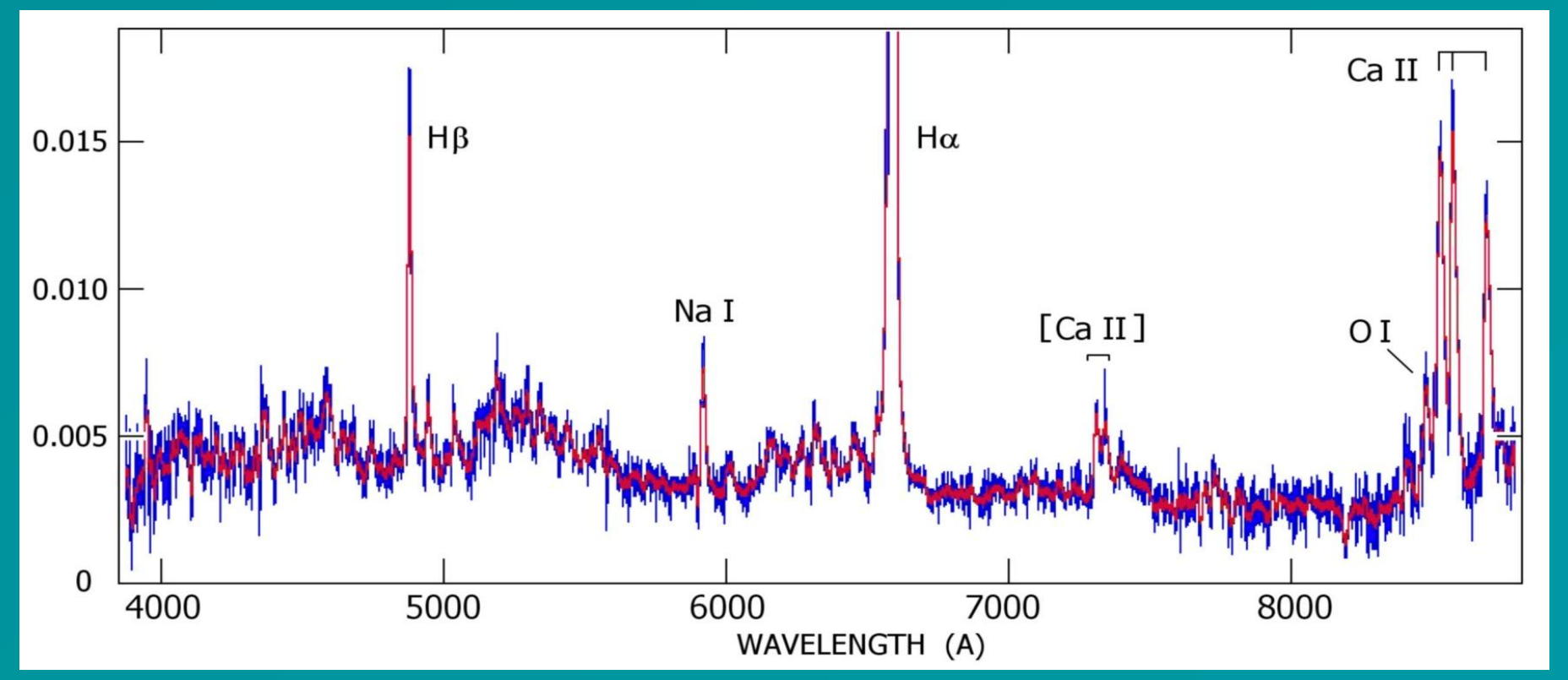

Fig. 3: **Warm lower-density** state in February. MMT (blue) and ARC (red) data, vertical scale in units of 10^{-14} erg cm^{-2} s^{-1} A^{-2}.

III. Kinematics and Ejecta

Emission line peaks agreed with the 1090 km/s redshift of UGC 5460. During the first four months, absorption line centers consistently showed a blueshift of -550 km/s relative to the emission lines and the galaxy. Evidently there were outflow speeds of 500—700 km/s.

During the decline these velocities may have increased by modest amounts. Hα had a FWHM of about 900 km/s in the late warm wind (Fig. 3). **There is no observational evidence for high velocities in SN 2011ht, and no evidence for a blast wave.** If a blast wave did occur, it's hard to see how it could have involved enough mass even for an electron-capture SN.

(Incidentally, Chandra data cast strong doubt on X-rays reported earlier.)

In the early phase with T ~ 13000 K and L > 10^8 L_{sun}, the photosphere had R ~ 30 AU. As L and T decreased, the photosphere moved outward to ~ 60 AU. At ~ 600 km/s, material would have required 5--6 months to reach that distance – i.e., pre-eruption ejecta but not old ejecta. The February visual decline probably signaled dust formation as well as the end of the eruption.

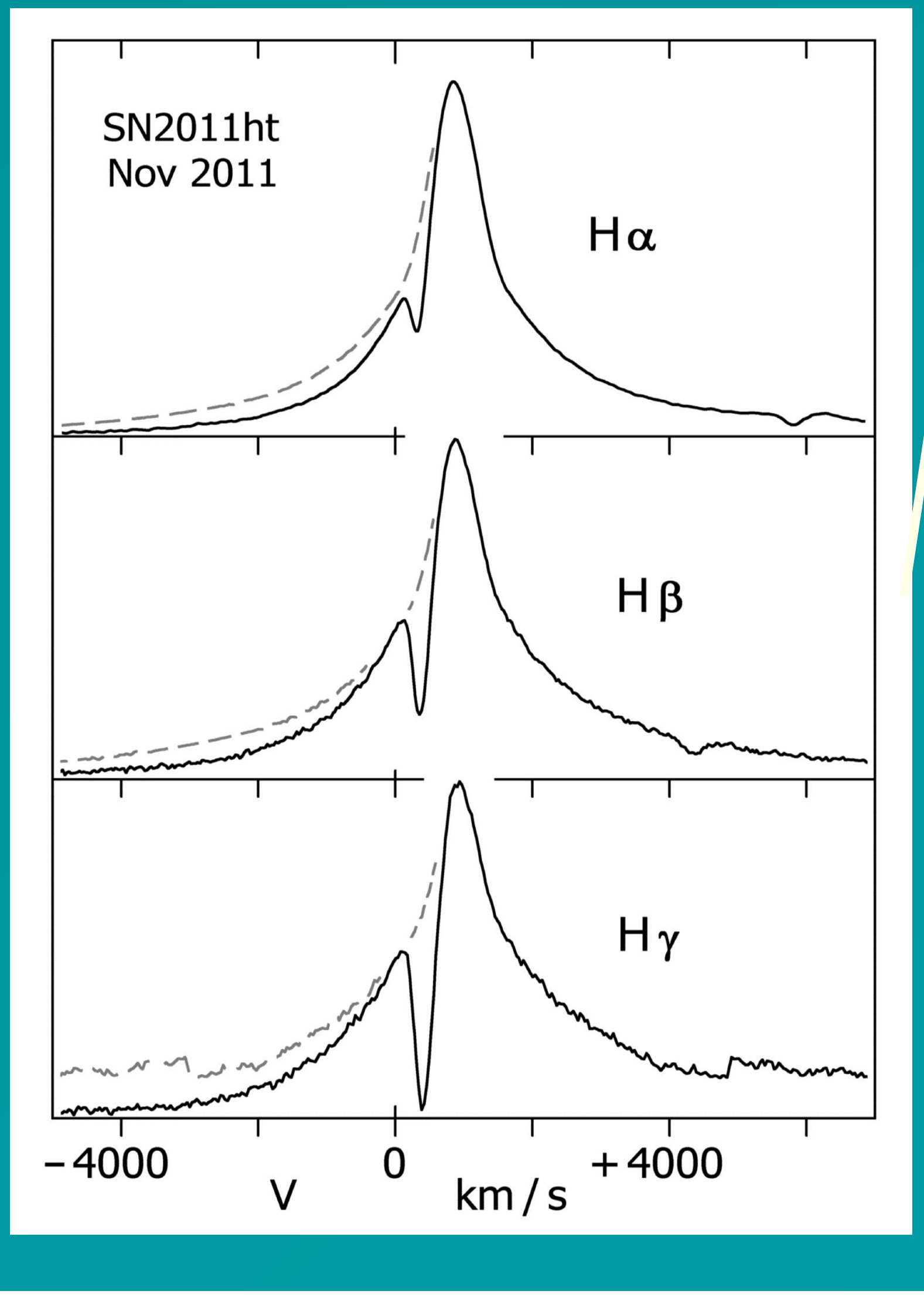

Fig. 4: Balmer profiles in November; dashed lines are reflections of the long-wavelength sides. The wings are clearly due to Thomson scattering, since they have the right shapes and deductions based on this assumption are consistent with other reasoning (see text box IV).se are clearly Thomson-scattering shapesin February. MMT (blue) and ARC (red) data, vertical scale in units of 10^{-14} erg cm^{-2} s^{-1} A^{-2}.

IV. Scattering Wings and Mass Loss Rate

The broad asymmetric wings don't imply high bulk velocities. They have classic Thomson-scattering profiles, Dessart et al 2009 demonstrated that similar wings in SN1994W were due to Thomson scattering, and this interpretation leads to consistent results for SN 2011ht.

We can use the Balmer wings to estimate outflow densities, following the precedent of Eta Car where this method worked long ago (Davidson et al 1995). In Nov. 2011, the Hβ wings indicated a relevant optical depth parameter $\tau_{sc} \sim 3$. This implies an outflow rate of roughly 0.05 M_{sun}/y outside the photosphere at that time, and an emission radius close to 30 AU – which agrees with the photosphere size based on L and T.

Moreover, according to the classic M_{dot} $L^{-0.7}$ vs. T relation (Davidson 1987), this result implies that a modest decrease in L would cause the photosphere to resemble an F or G supergiant -- which did indeed happen a few weeks later (text box II and Fig. 2). 0.05 M_{sun} /y is huge by normal stellar standards but picayune for a supernova.

This estimate refers to a zone that a blast wave would have reached 3 to 6 weeks earlier, so a SN should have dispersed the pre-existing material there. If, on the other hand, our estimate refers to material lagging behind owing a SN blast wave, then the 500—700 km/s speed should have decreased later -- a Hubble flow. (And, in that case, why did hydrogen lines dominate?)

Thus it is difficult to see how a strong SN-style blast wave could have occurred in this object. Weaker shocks may have existed, but if so they could have resulted from an instability almost anywhere in the star.

V. SUMMARY

1. No SN-like high velocities were seen.
2. An unobserved strong blast wave appears quite unlikely for reasons outlined in text box IV.
3. Total observed energy < 10^{50} ergs, luminous plus kinetic.
4. *Observed* mass loss < 0.1 M sun. A larger amount may have escaped early in the event, but not at very high speeds.
5. So far there no obvious reason why a non-SN giant eruption cannot produce a radiative output of $10^{49.4}$ ergs. (Dessart et al 2009 also made this same remark.)
6. One can liken the light curve (Fig. 1) to various types of SNae, but non-SN eruptions can behave similarly (see HD 1994, Van Dyk 2005, etc.)
7. (Not mentioned elsewhere in this poster, for lack of space) It is difficult to understand how dust formed so rapidly in SN 2011ht – but a blast wave hypothesis doesn't help.