Upper limits on TeV gamma-ray emission from core-collapse supernovae observed with H.E.S.S.

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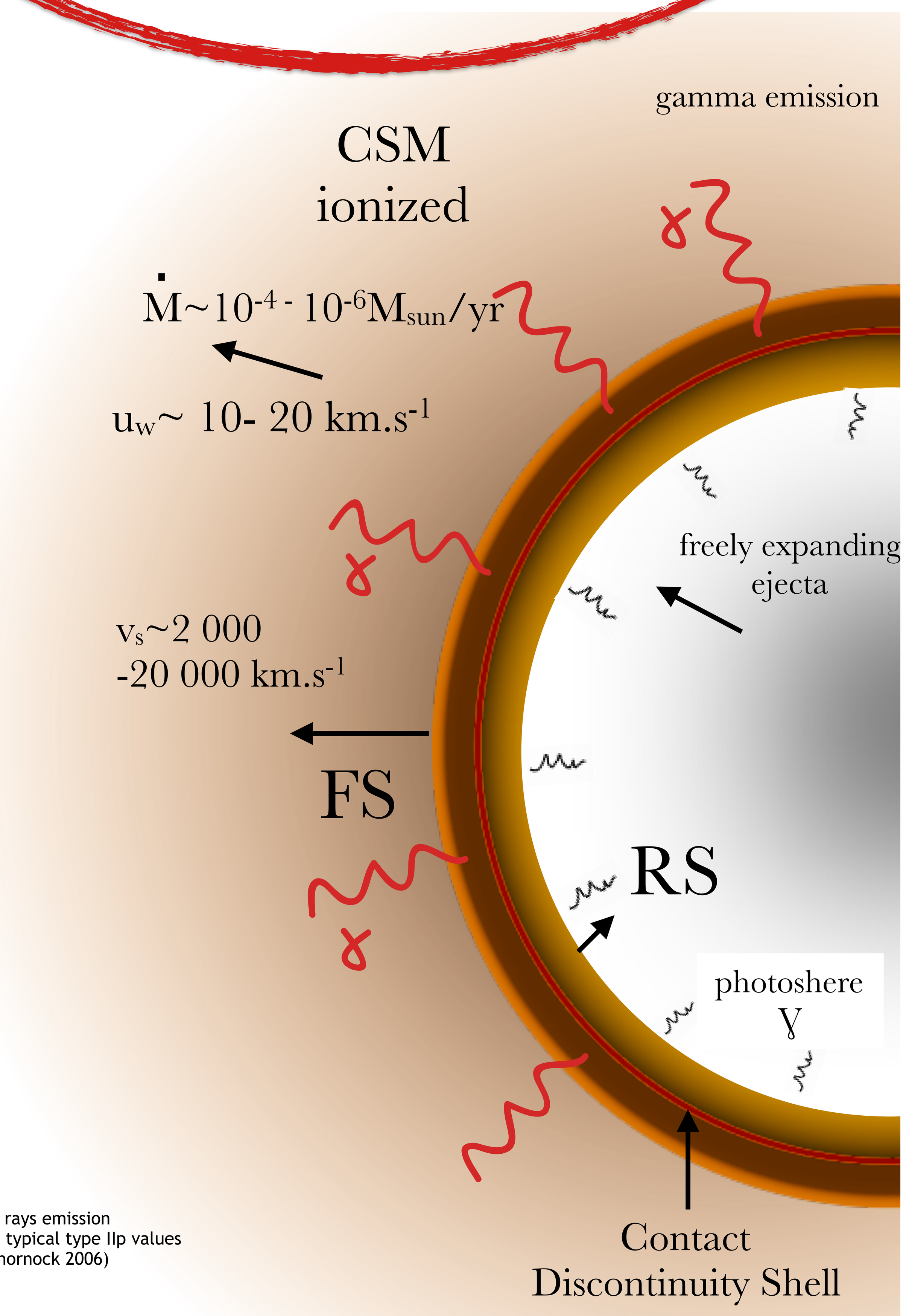
Supernovae as PeV cosmic rays sources?

- No evidence is found that supernova remnants (SNRs) accelerate cosmic ray (CR) particles beyond the Knee (~3 x10^{15} eV). If the supernova (SN) is the driving force, perhaps higher energy acceleration is occurring in the early stage of SNR evolution.
- Theoretical studies predict that PeV particles shall be produced if the core collapse SN shock propagates in a very dense circumstellar medium (CSM) as the growth of plasma instabilities driven by the particle acceleration itself, leads to a fast magnetic field amplification. (e.g [1][2][3][4]).
- The type of SNe that exhibit these high-density stellar winds are type IIP, IIb and IIn SNe. (e.g. [5],[6]).
- Dense CSM is also a requirement for sufficient number of pion production, and hence gamma-ray/neutrino emission.
- We studied SNe observed by H.E.S.S to investigate whether there are bright gamma-ray sources among them. As we see no emission for noone of the object we present upper limits (UL) on their flux.

10 SNe selected

- Core-collapse : 9 SNe are type IIP, SN 2016adj is type Ib
- Host galaxy with z < 0.01
- Observed by H.E.S.S. within 1yr since SN discovery
- SN 2016adj triggered dedicated observations

SNe	Host Galaxy	Distance (Mpc)	Exposure (hrs)	Upper Limit (95%CL) on F(>1 TeV)(10^{-13} cm^{-2} s^{-1})	Mass Loss Rate UL (10^{-5}M$_\odot$yr^{-1}km^{-1}s)
SN2004cx	NGC 7755	26 ± 5	39.9	**1.9**	**6.7**
SN2005dn	NGC 6861	38.4 ± 2.7	53.1	**0.41**	**3.8**
SN2008bk	NGC 7793	4.0 ± 0.4	9.6	**4.8**	**1.4**
SN2008ho	NGC 922	41.5 ± 2.9	1.4	**7.7**	**9.4**
SN2008bp	NGC 3095	29 ± 6	4.7	**5.5**	**15.9**
SN2009js	NGC 918	16 ± 3	4.8	**11**	**3.1**
SN2009hf	NGC 175	53.9 ± 3.8	4.0	**5.3**	**19.9**
SN2011ja	NGC 4945	5.28 ± 0.38	3.8	**5.2**	**1.77**
SN2012cc	NGC 4419	~20	3.0	**10**	**11.6**
SN2016adj	Cen A	3.8 ± 0.1	13	**1.7**	**0.25**



Sketch for the gamma rays emission at SN shock front with typical type IIp values (inspired by Smith &Chornock 2006)

Constraints on the mass loss rate

None of the 10 SNe have been detected in TeV gamma-rays. Probably because the CSM densities were not be high enough for the 9 objects observed.

Using the model developed in [7], we can put limits on the mass loss rates, which determines the circumstellar density. We found ULs values spanning from ~ 2.5 x 10^{-5} M$_\odot$yr^{-1} up to ~ 1.6 x 10^{-3} M$_\odot$yr^{-1}, considering a wind velocity of 10 km.s^{-1}. These values can be compared to the estimate mass loss rate of SN 1993J of 3.5 10^{-5} M$_\odot$yr^{-1} [8].

We could put our ULs on the flux in perspective of the mass loss rate of the progenitor before outburst versus the distance to the source (see Fig.3).

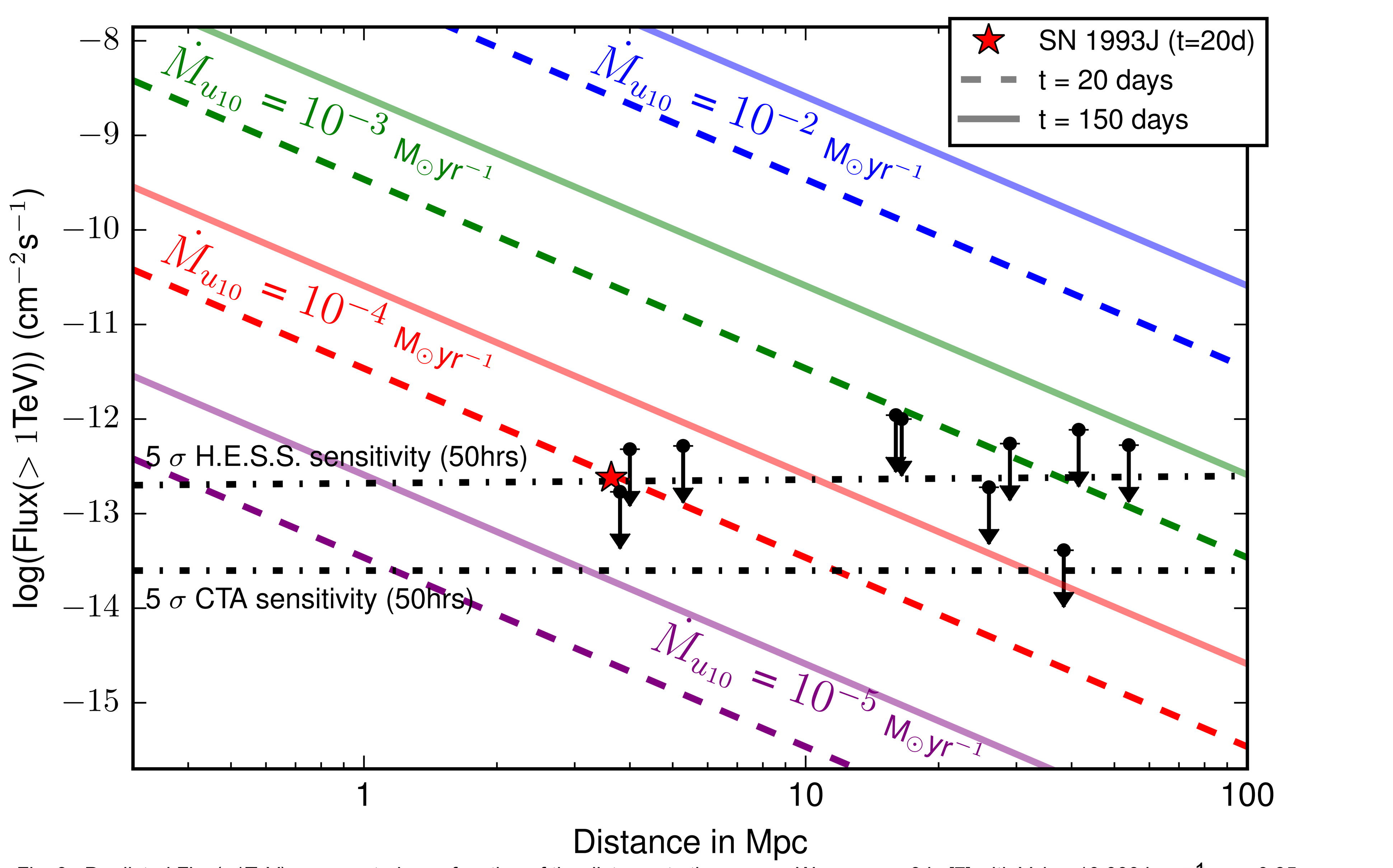


Fig. 3 : Predicted Flux(>1TeV) represented as a function of the distance to the source. We use eq. 9 in [7] with Vsh = 10 000 kms^{-1}, m = 0.85. Mass loss rates are in unit M$_\odot$yr^{-1}, with u_w = 10 kms^{-1}.Different values for the period of observation are considered : t = 20 days (full lines) and t = 150 days (dotted lines) after SNe explosion. Our 2 sigma ULs on the flux are represented as well.

Conclusion

- This non detection can be related to similar studies as SNe have not been observed in VHE gamma rays so far [9][10][11].
- This result does not disprove that SNe accelerate cosmic rays, as the CSM densities may be too low for detectable gamma-ray emission.
- Fig 3. shows that a type IIP SNe with a mass loss rate of 10^{-4} M$_\odot$yr^{-1}, occuring at a distance of 10 Mpc, shall be detectable with H.E.S.S. 20 days after outburst. CTA could detect a type IIP SNe with a mass loss rate of 10^{-4} M$_\odot$yr^{-1}, occuring at 30 Mpc.
- SNe within 10 Mpc occur regularly, and should be followed up with gamma-ray observations. However SNe with dense CSM are more rare.
- Cherenkov telescopes may observe gamma-ray emission from SNe in the future. The observations shall be made within weeks after outburst : a trigger on observation seem to be the right strategy to adopt.

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