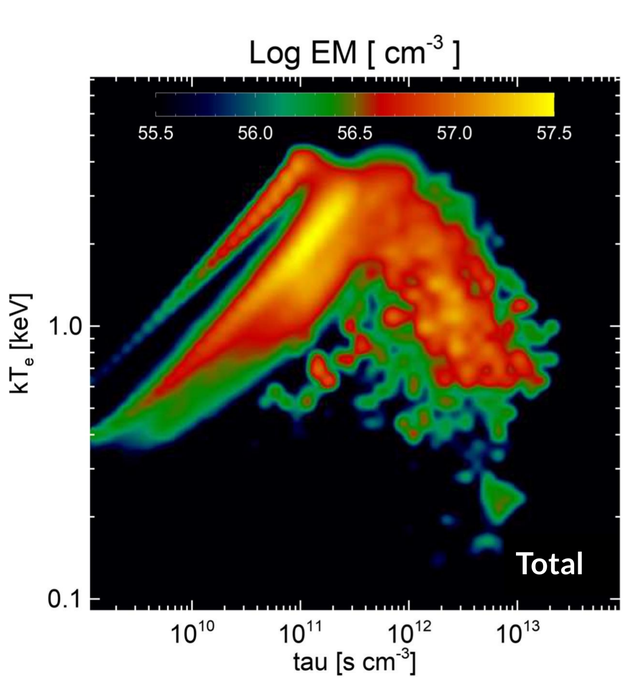
Probing Shocked Ejecta in SN 1987A: A novel diagnostic approach using XRISM−Resolve

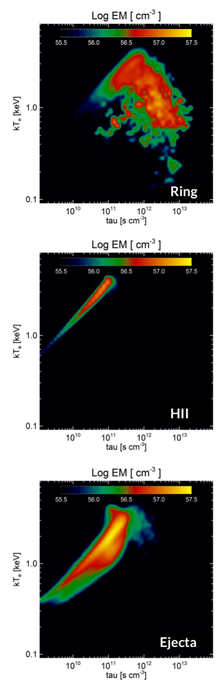
Vincenzo Sapienza (vincenzo.sapienza@inaf.it)* Marco Miceli, Aya Bamba, Salvatore Orlando, Shiu-Hang Lee, Shigehiro Nagataki, Masaomi Ono, Satoru Katsuda, Koji Mori, Makoto Sawada, Yukikatsu Terada, Roberta Giuffrida and Fabrizio Bocchino

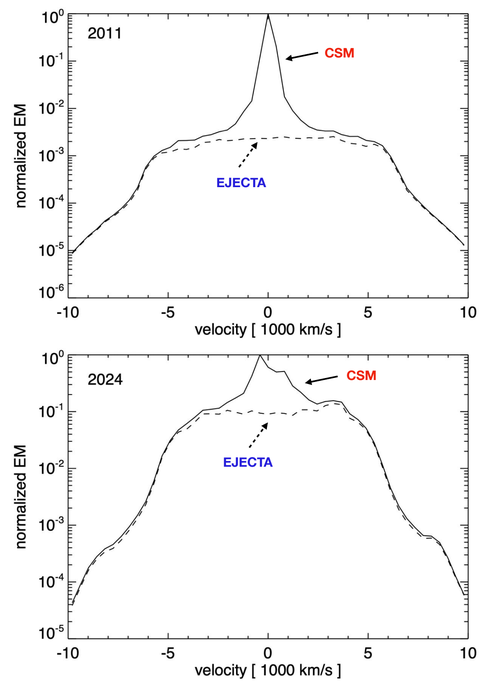
***INAF-Osservatorio Astronomico di Palermo and University of Palermo, Italy**

1. Introduction

- SN 1987A offers the opportunity to study the evolution of a SN into a SNR with the new XRISM-Resolve spectrometer
- Recent studies suggest that in the next years the **X-ray emission will increasingly stem from the ejecta**
- Our aim is to assess the proficiency of XRISM-Resolve in pinpointing signatures of the shocked ejecta in SN 1987A
- **We synthesized the XRISM-Resolve spectrum of SN 1987A for the 2024** taking advantage of a 3D MHD simulation from (Orlando et al. 2020)
- Part of the results presented here (with the gate valve open) are published in Sapienza et al. (2024)

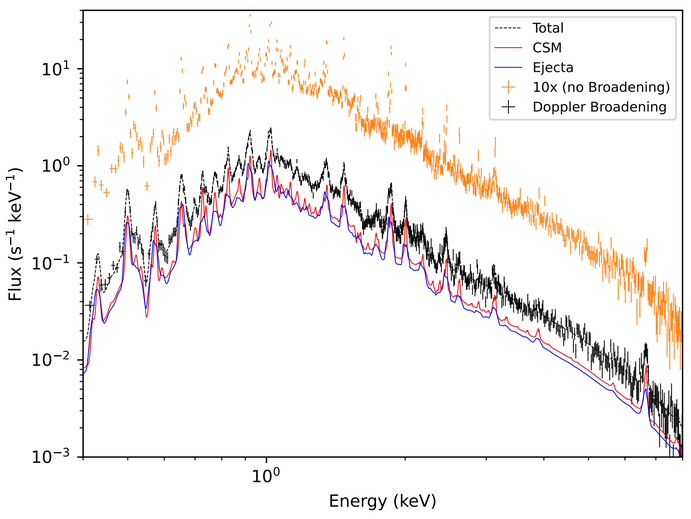






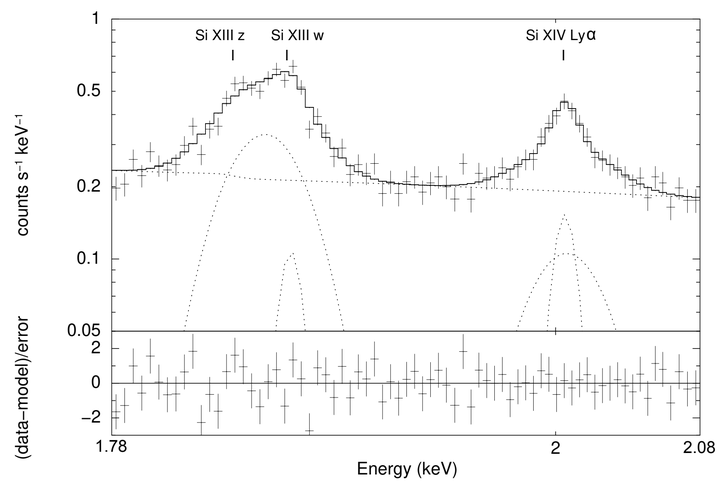
Contribution to the EM from the ejecta in 2024 increase with respect to previous epochs

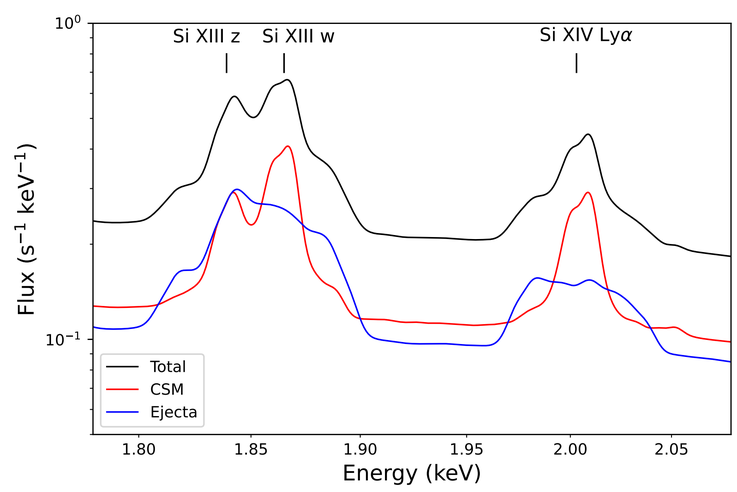
2. Synthetic Spectrum



Synthetic XRISM-Resolve spectra of SN 1987A for the 2024 with an exposure time of 100 ks. The Doppler effect broadens the emission lines (orange spectrum vs. black spectrum). The contribution to the emission of the ejecta is comparable to that of the CSM.

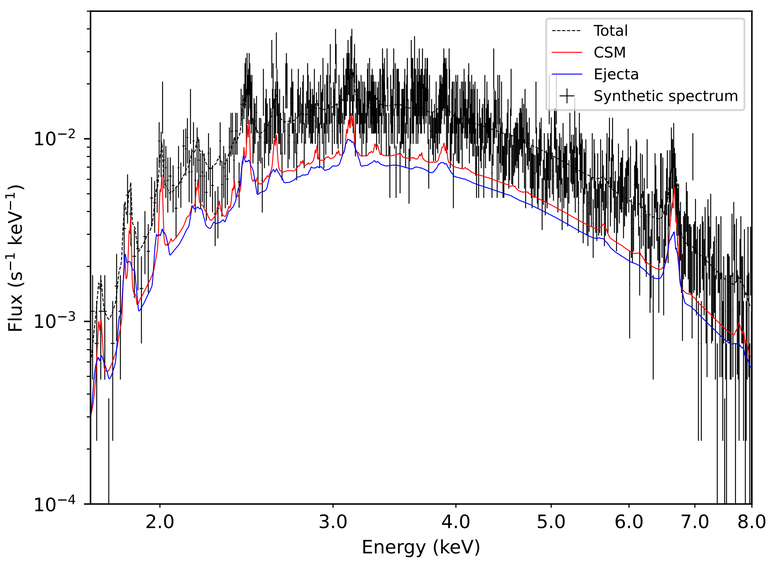
3. Emission line profile





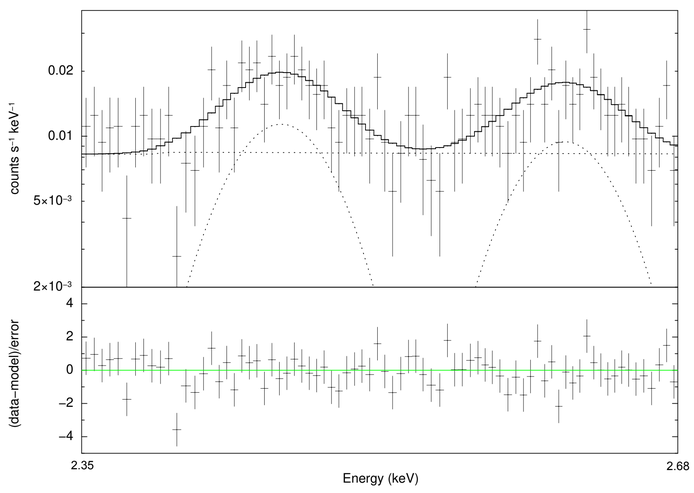
The **line profile of Si XIV shows a structure with broad wings and a narrow peak**. The broad line wings are clearly associated with the rapidly expanding ejecta (see right panel). Si XIII lines, exhibit a broader profile, with a dominating influence of the ejecta. This effect can be attributed to the ionization state of the ejecta (**freshly shocked and heavily under-ionized**). The ejecta dynamics can be revealed measuring the width of the Gaussian line (right panel). From the fit we retrieved an ejecta velocity consistent with the model (3160^{+210}_{-190} vs. 3280 km s^{-1}).

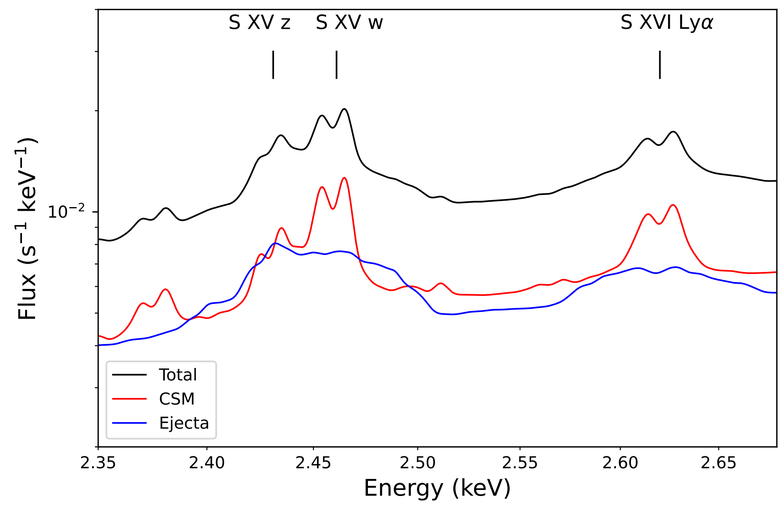
4. Synthetic spectrum (Gate Valve Closed)



XRISM safety gate valve for the Resolve has not opened so far and the effective area of XRISM-Resolve results degraded.
Following the same procedure as in Box 2, we updated the synthetic spectrum of SN 1987A for the year 2024 with 160 ks exposure.

5. Ejecta Dynamics (Gate Valve Closed)





The effective area below 2 keV is severely compromised, hampering the diagnostic for the Si lines. The quality of **the spectrum remains adequate for applying the same diagnostics to the S lines**.
The Gaussian lines, detected with $> 5\sigma$ significance, show a **velocity of 3300^{+800}_{-700} km s^{-1}**.

6. Summary

- We present the synthesis of the future XRISM-Resolve spectrum of SN 1987A
- We leveraged 3D MHD modelling to derive observables for the future epochs
- The synthetic spectrum takes into account the Doppler broadening effect and shows a **complex and largely broadened emission lines, due to the increased contribution from shocked ejecta** (characterized by higher velocities)
- The measurement of the Doppler broadening in future observations will provide direct evidence for the shocked ejecta and their expansion
- We also show that **even in the forthcoming observation with the gate valve closed, it will be possible to derive the ejecta dynamics from the S emission lines.**

References

Orlando, S., Ono, M., Nagataki, S., et al. 2020, A&A, 636, A22
Sapienza, V., Miceli, M., Bamba, A., et al. 2024, ApJ Letters, 961, L9

SCAN THE QR CODE TO HAVE ACCESS TO THE PUBLISHED LETTER