SN2023ixf: the most detailed flash spectroscopy event observed from the Canary observatories

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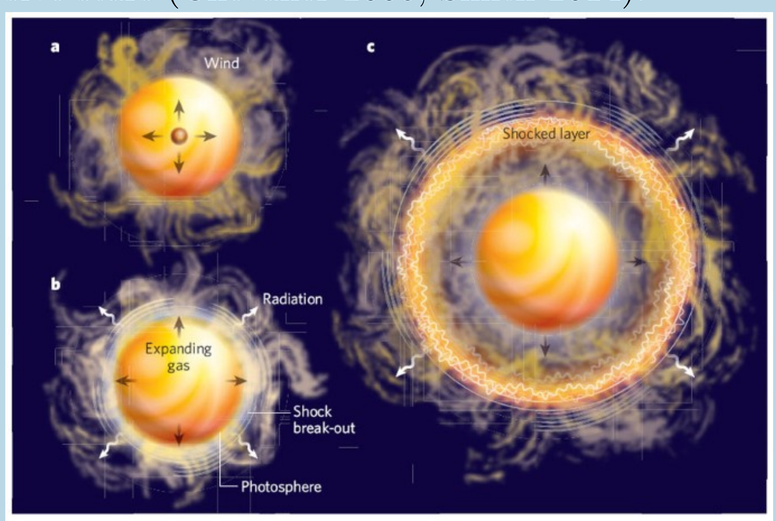
Context

Observational studies of Type II supernovae and their circumstellar material (CSM) are crucial for understanding stellar evolution, explosion mechanisms, and the mass loss history of massive stars (Chevalier 2006; Smith 2014).



Introduction

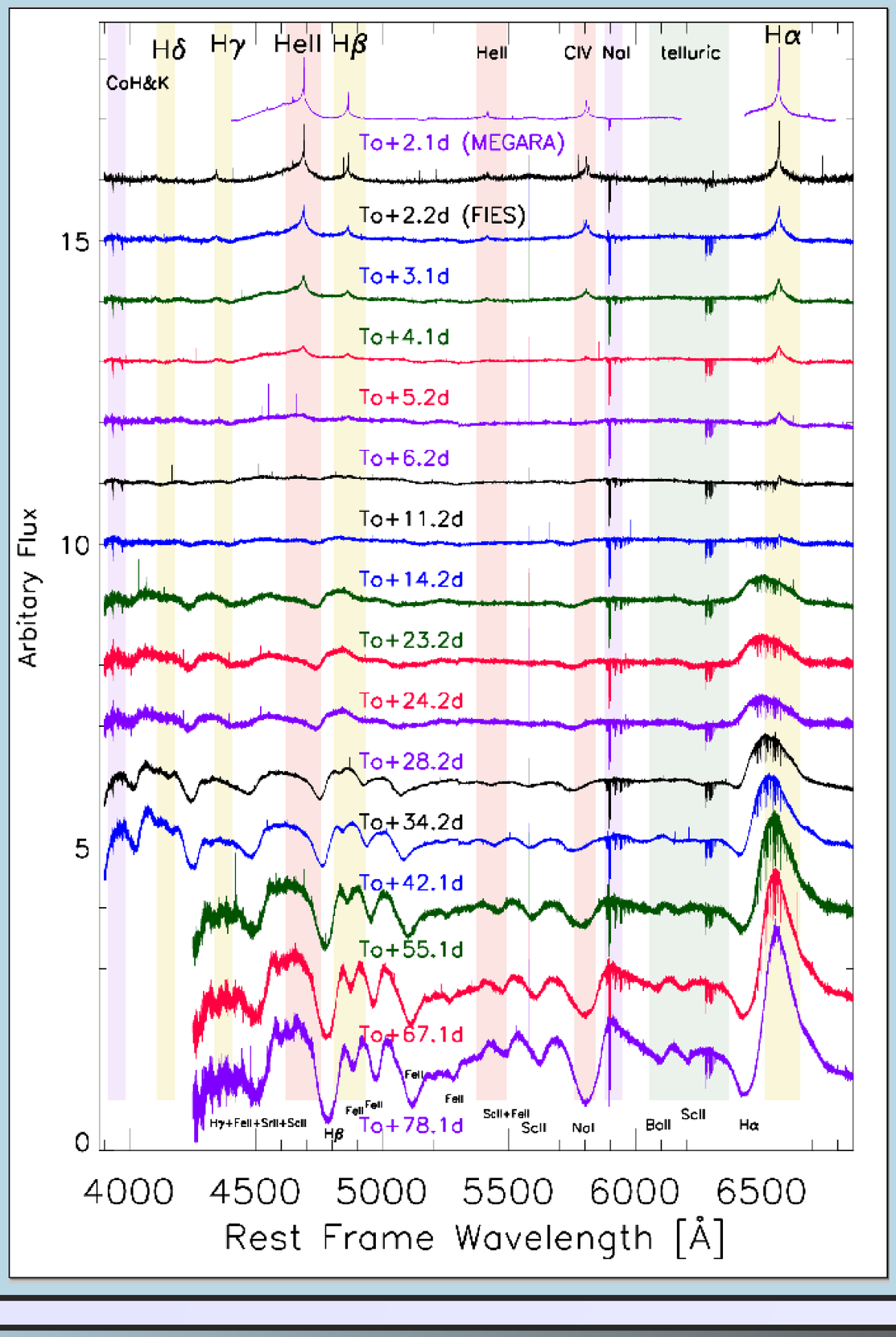
In such a fruitful context, the advent of SN 2023ixf in the nearby M101 galaxy provides a unique opportunity to test state-of-the-art high-resolution spectroscopy techniques available at the Canarian observatories. Observations obtained shortly after the explosion and during the plateau phase offer invaluable data to model explosion mechanisms, study the ejecta's expansion in the CSM, and analyze the interstellar medium. In this work, we utilize high-quality observations from HARPS-N at the 3.6m TNG, complemented by early high-resolution spectra from MEGARA at the 10.4m GTC and FIES at the 2.5m NOT. We present the spectroscopic analysis we performed and the commencement of operations of a new multidisciplinary group based in the Canary Islands. This group aims to continuously follow up Type II SNe with both photometry and spectroscopy at the Roque de los Muchachos Observatory (La Palma) and Izaña Observatory (Tenerife).

Observations

SN 2023ixf was monitored with HARPS-N from May 21st to June 29th, 2023, for a total of 12 visits (20 hours) under the A47DDT2 program at TNG. The high-resolution optical echelle spectra (R $\sim 115,000$) had exposure times of 30-50 minutes, resulting in an average S/N of 25−40. Additionally, earlier observations were taken on May 20th, 2023, with the MEGARA spectrograph at the 10.4m GTC and the FIES at the 2.5 m NOT. MEGARA provided spectra with various resolutions, while FIES offered a spectral range of 3640-9500 Å with R $\sim 46,000$. A second FIES observation with a higher resolution (R $\sim 67,000$) was conducted three days post-explosion.

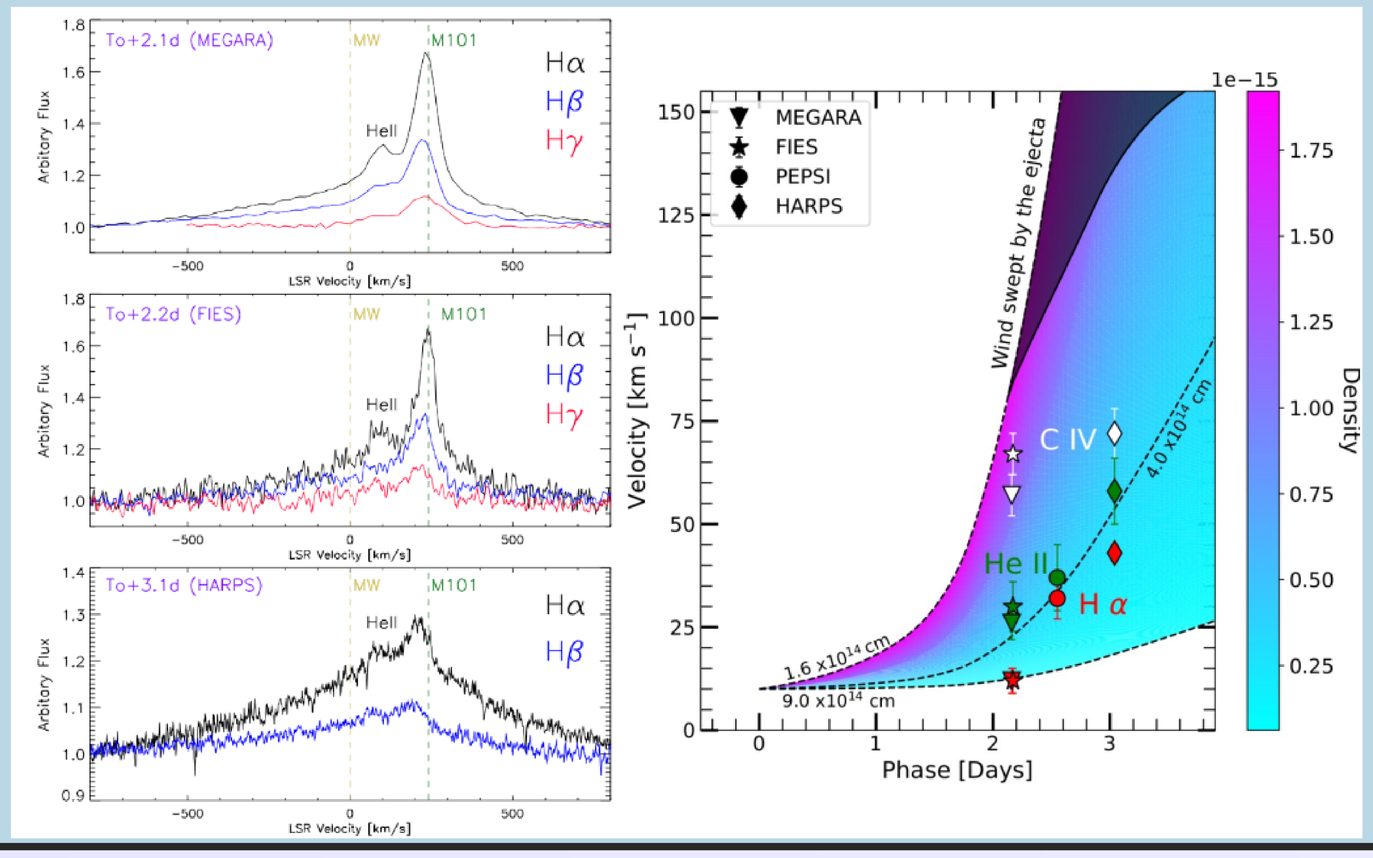
High-resolution analysis

The spectral time series of SN 2023ixf, labeled according to its phase relative to first light, reveals prominent flash features of H, He I, He II, C III, C IV, and N III. These features persist up to 14.2 days post-explosion, after which H_α emission fades, and a blue featureless continuum dominates. P-Cygni profiles emerge later. The explosion time is MJD 60082.75 (Hosseinzadeh et al. 2023).



Discussion & Conclusions

Thanks to the unprecedented high-resolution data, we were able to measure the radiative acceleration of the unshocked wind via the blueshifted Pickering lines of He, comparing them with the Balmer series. We then constructed a model in which ionized species experience this acceleration more intensely until the ejecta reaches the wind in approximately three days. Thanks to the high-resolution observations taken only 2.1 days after the explosion, we gained access to the very early evolution of this rare event. We demonstrated how Thomson scattering between free electrons and the SN radiation could accelerate the CSM.



References

[1] Chevalier, Roger A.; Fransson, Claes: *Circumstellar Emission from Type Ib and Ic Supernovae*,The Astrophysical Journal, Volume 651, Issue 1, pp. 381-391 (2006).

[2] Smith, N. *Mass Loss: Its Effect on the Evolution and Fate of High-Mass Stars*, Annual Review of Astronomy and Astrophysics, vol. 52, p.487-528 (2014)

[3] Hosseinzadeh et al.: *Shock Cooling and Possible Precursor Emission in the Early Light Curve of the Type II SN 2023ixf.*The Astrophysical Journal Letters, Volume 953, Issue 1, id.L16, 9 pp. (2023).