# VHE SUPERNOVAE: STATE OF THE ART AND LATEST OBSERVATIONS WITH THE CTAO LST-1 AND MAGIC TELESCOPES


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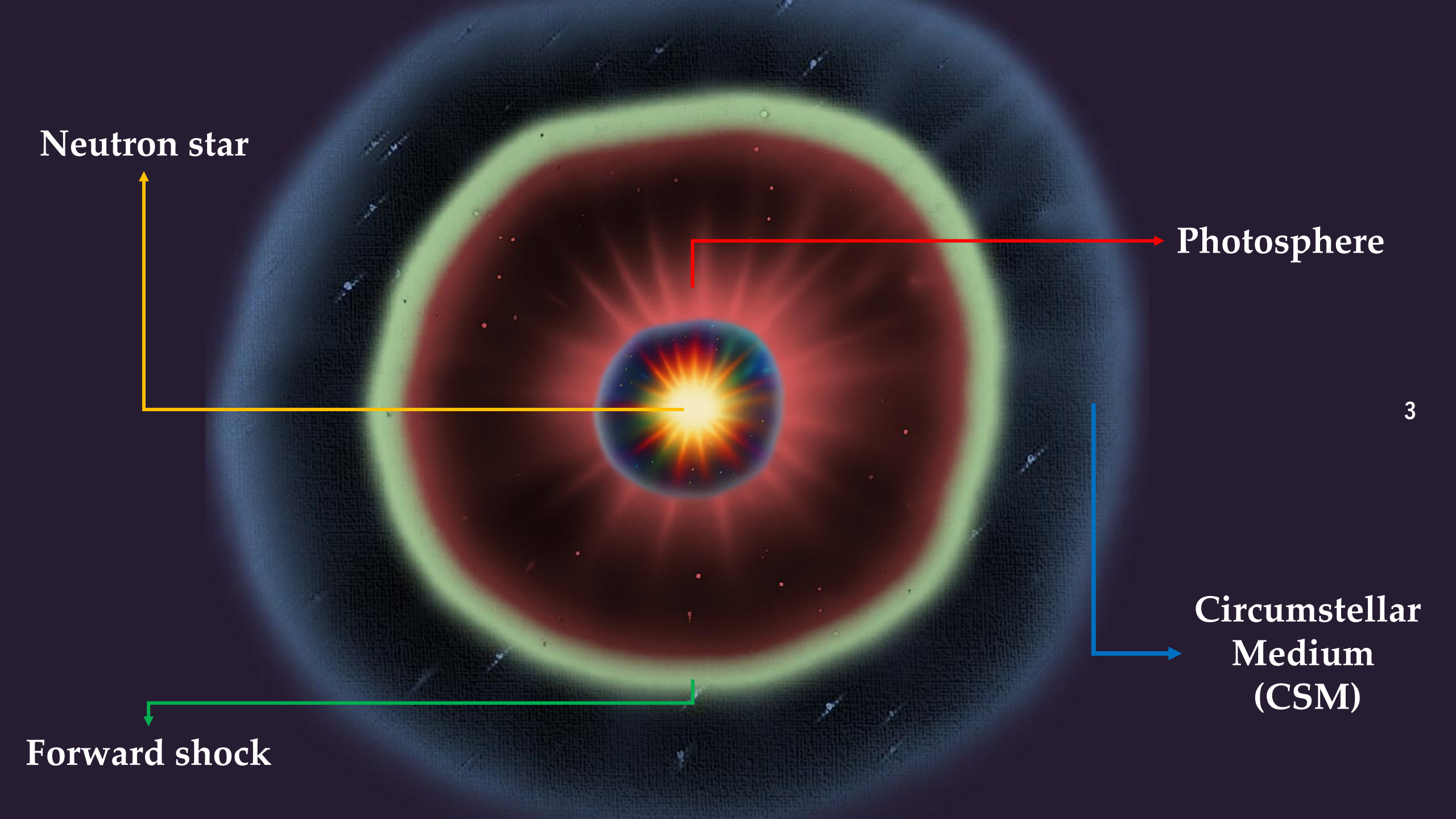
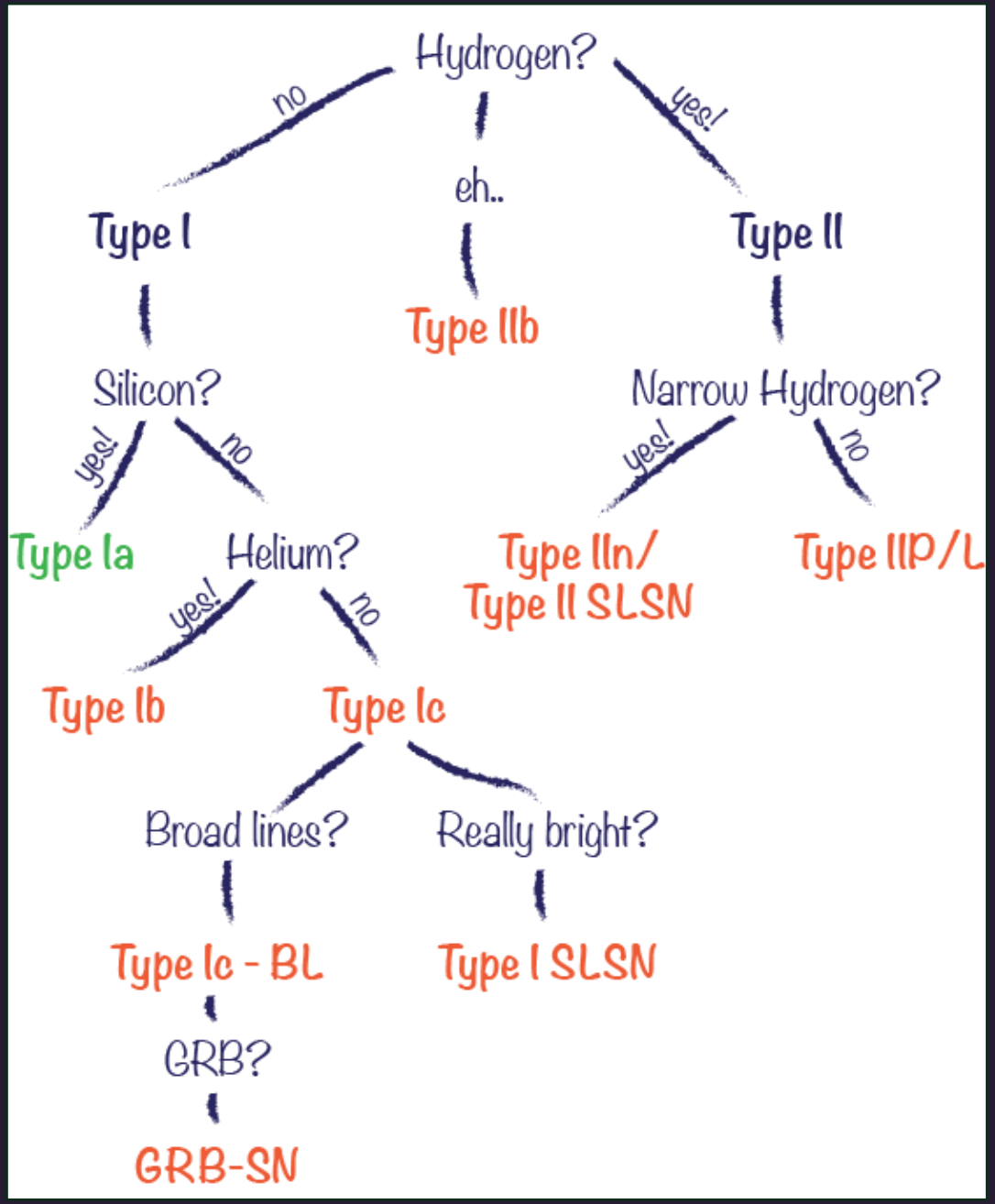
ON BEHALF OF THE CTAO-LST PROJECT AND THE MAGIC COLLABORATION

# 1. CORE COLLAPSE SUPERNOVAE


Neutron star
Photosphere
Circumstellar Medium (CSM)
Forward shock

# SN TYPES

- **IIn:**
  - Strong CSM interaction
  - High luminosity
- **II-P/L:**
  - Medium/low CSM interaction
  - Normal luminosity
- **SLSNe:**
  - Magnetar/ csm dense shell
  - Very high luminosity
- **Ia:**
  - Usually not interacting
  - High luminosity



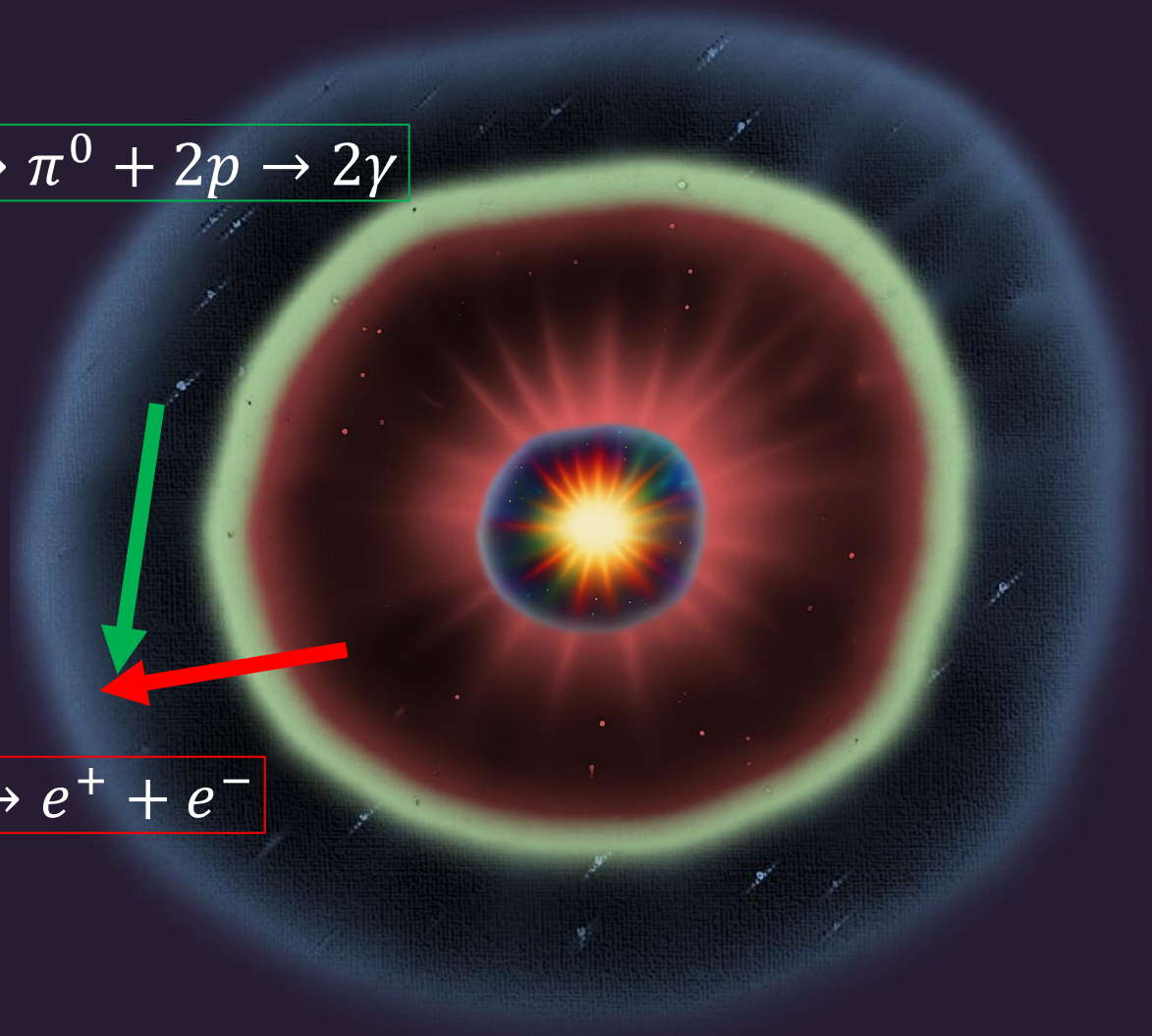

Credits: A. Villar

# WHY GAMMA RAYS?

$$p + p \rightarrow \pi^0 + 2p \rightarrow 2\gamma$$

**PP interaction:**

**Forward shock-wave + CSM = Target**

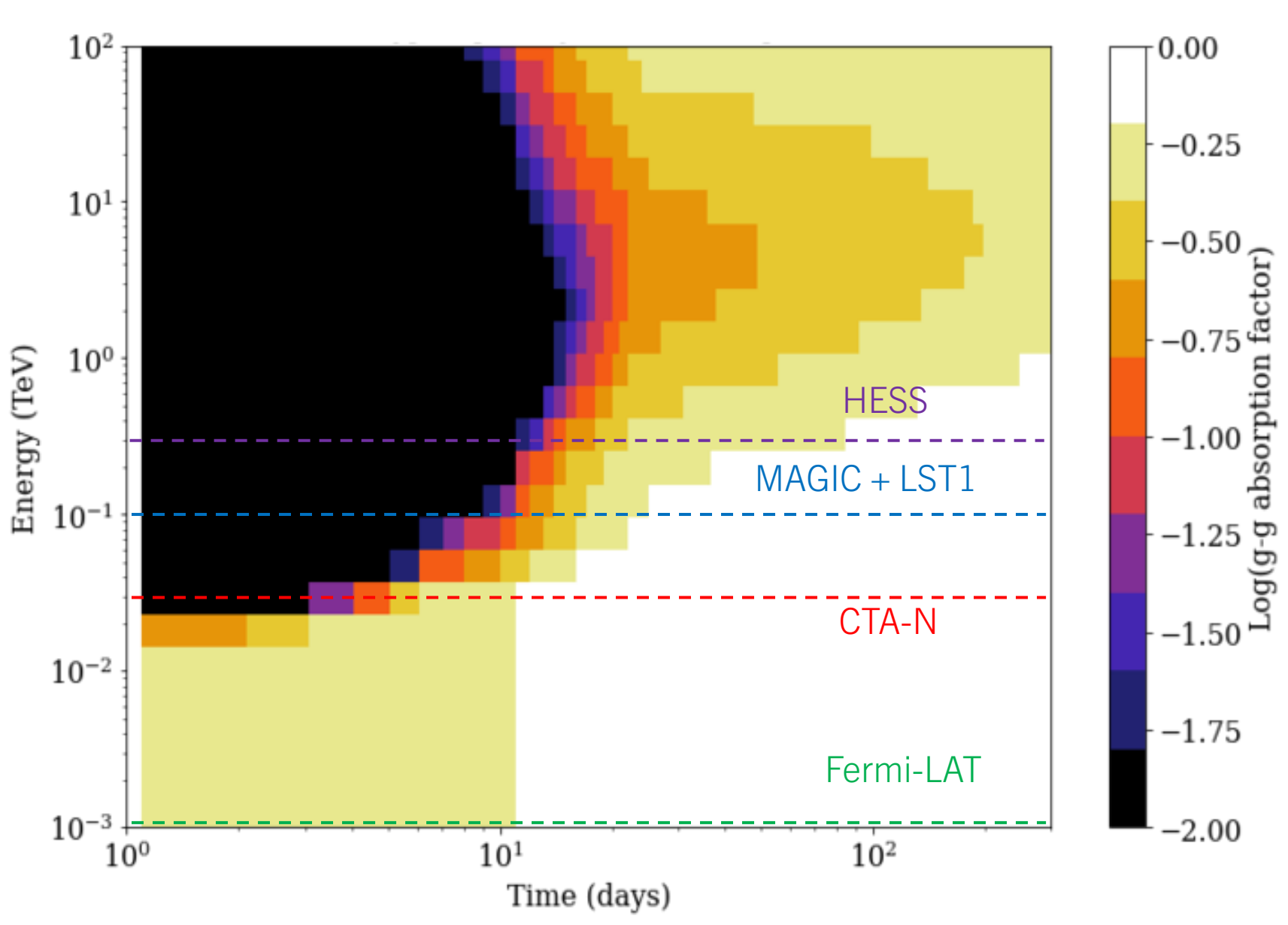


**$\gamma\gamma$ absorption:**

**Target + photosphere = ☹**

$$\gamma + \gamma \rightarrow e^+ + e^-$$

# GAMMA-GAMMA ABSORPTION




II-P model by Cristofari+2022 (credits F. Acero)

# 2. STATE OF THE ART

# STATE OF THE ART @ VHE

Very-high-energy gamma-ray observations of the Type Ia Supernova SN 2014J with the MAGIC telescopes

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

VERITAS and Fermi-LAT Constraints on the Gamma-Ray Emission from Superluminous Supernovae SN2015bn and SN2017egm

H.E.S.S. observations of SN 2024ggi

Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor

Multiwavelength observations and analysis of the progenitor

Check this out!

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NO DETECTION!

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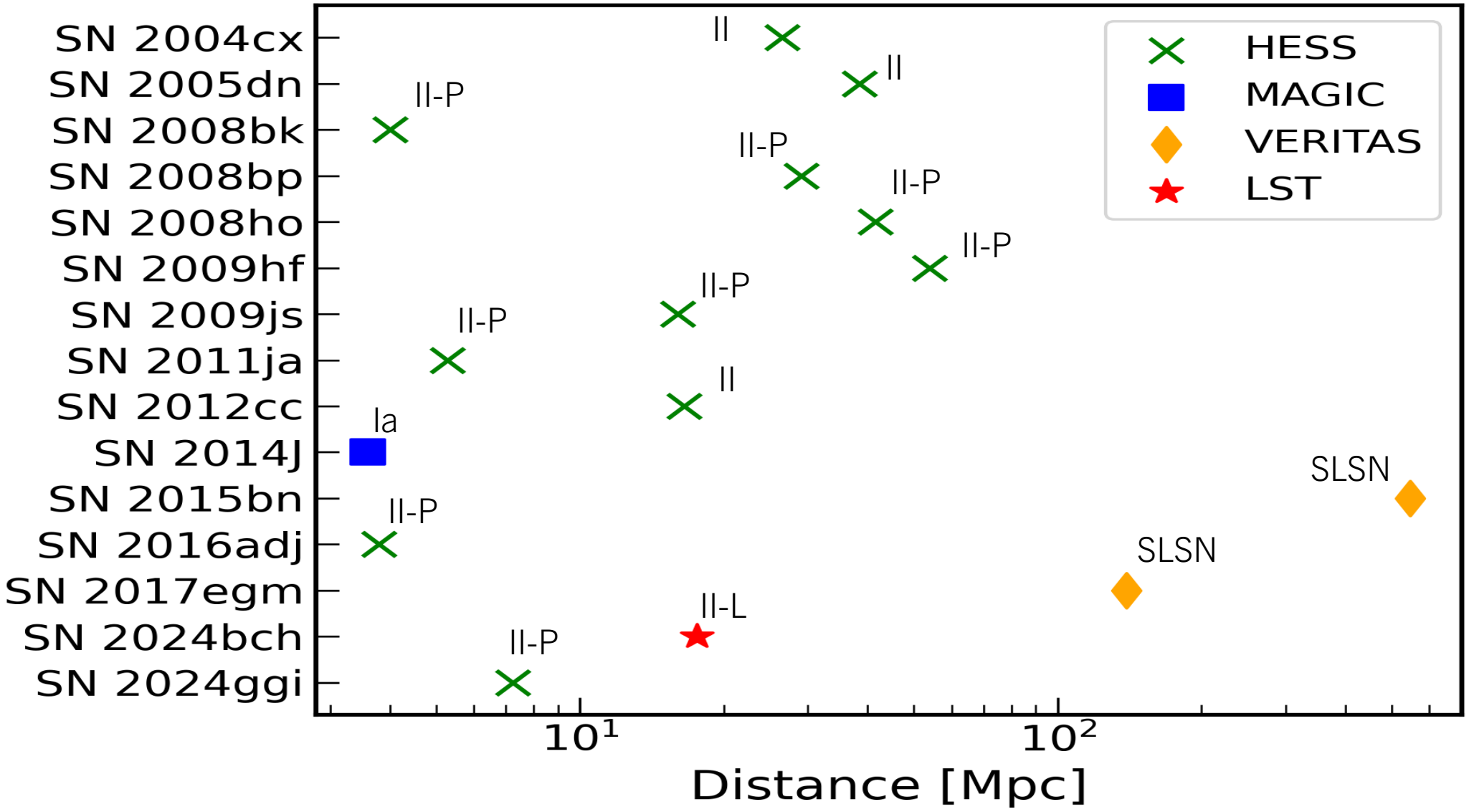
# CURRENT STATISTICS

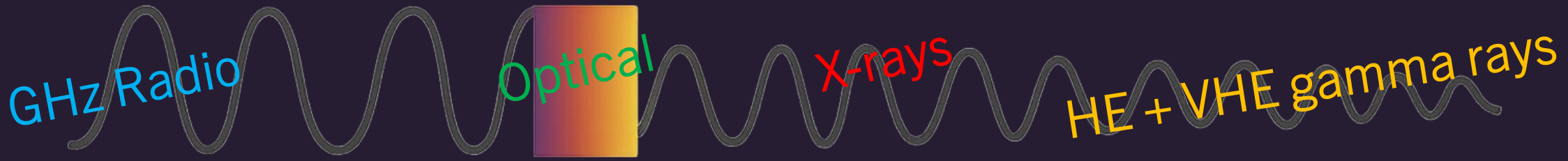


# 3. THE MAGIC + LST CAMPAIGN

# THE MAGIC+LST CAMPAIGN

- Since early 2025 we are conducting a multi-wavelength campaign led by **MAGIC+LST-1** focused on hunting gamma-rays (P.I. A. Simongini, F. Acero).
- Our campaign includes granted time with: **Las Cumbres Observatory** (P.I. A. Lopez Oramas), **Japanese VLBI Network and VLBI Exploration of Radio Astrometry** (P.I. Y. Iwata), Fermi-LAT telescope (P.I. F. Acero) + foresees ToO observations with XRT + other.



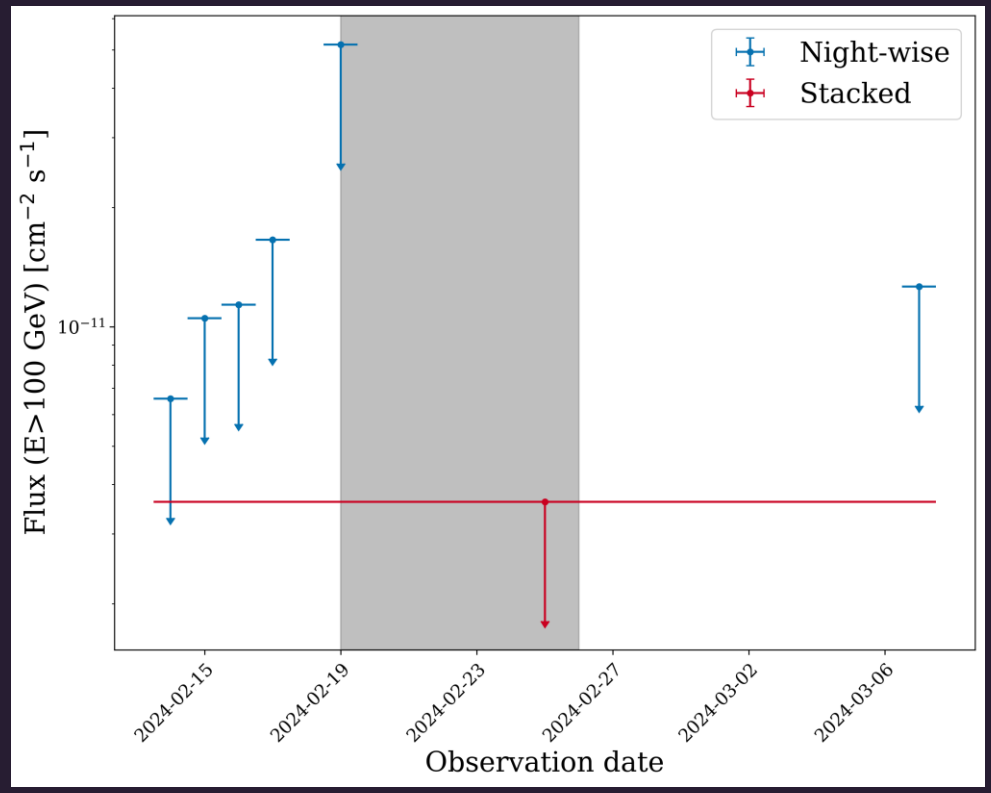


# THE MAGIC+LST CAMPAIGN

- Targets:
  - CCSNe of any kind below 10 Mpc (1-2 per year).
  - **Type IIn** below 30 Mpc (high priority) and below 100 Mpc (low priority).
  - SLSNe below 200 Mpc (1 per two years).
- Triggers:
  - We developed a pipeline to get real time alerts whenever a supernova of interest is observable (credits M. de Bony).
- Follow-up:
  - For any target supernova we trigger our MWL campaign (X-rays -> Optical -> Gamma -> Radio).

# THE CASE OF SN 2024BCH

- In this work we showed how gamma rays (even though only upper-limits) can help constraining the mass-loss history of the progenitor.
- Use of a general model (Dwarkadas+2013) that links gamma-ray flux and density of the CSM.
- Most constraining upper-limits at 100 GeV reported for a CCSN.



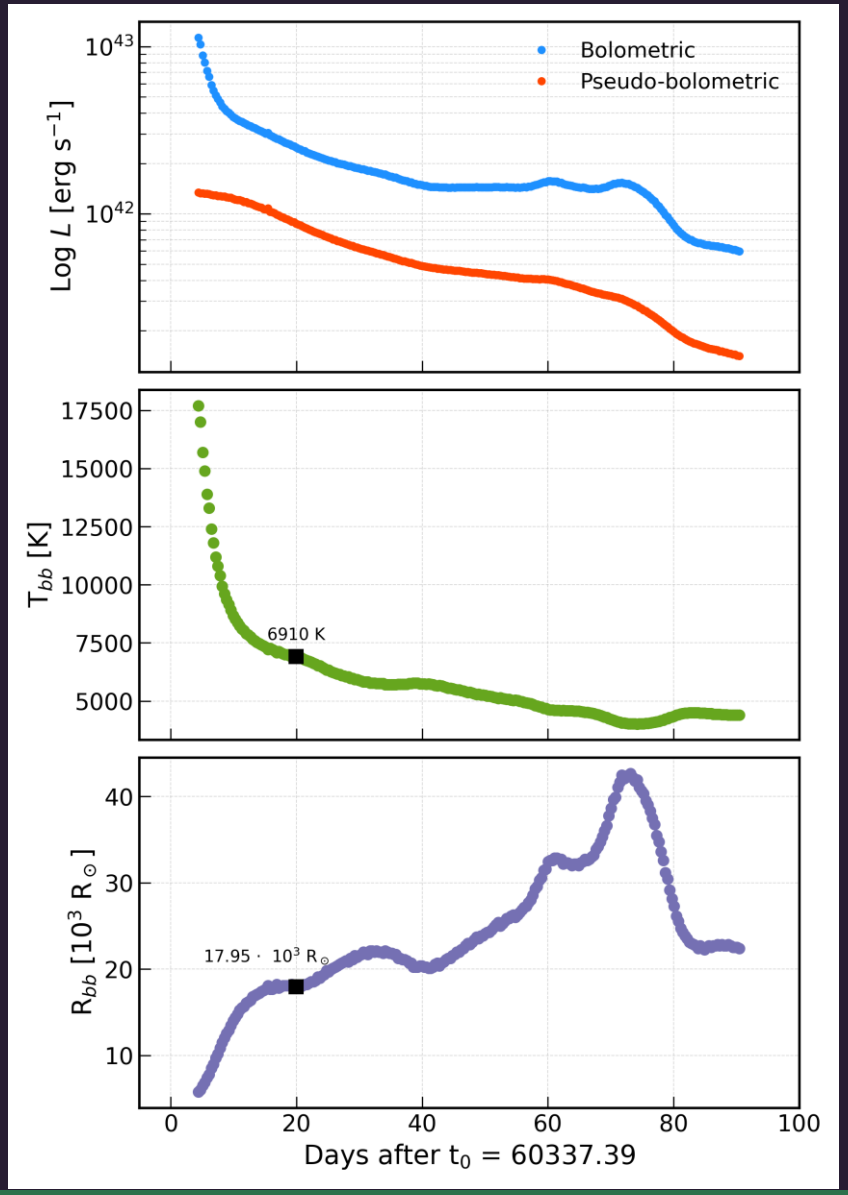

$$\rho_{CSM} \propto \sqrt{F_\gamma(E_0, t, d)}$$



LST Collaboration, A&A, 2025 "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor"

# THE CASE OF SN 2024BCH

- We presented the first multi-wavelength interpretation of a SN event that involves VHE gamma-rays.
- The study of the photosphere (from optical data) helps understanding the behaviour of gamma-gamma and thus applies more significant constraints to gamma-ray flux.






LST Collaboration, A&A, 2025 "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor"

# THE CASE OF SN 2024BCH

- We constrain $\rho_{CSM} \leq 10^{-4} \frac{M_\odot}{yr} \frac{s}{km}$ indicating a low density CSM.
- The photospheric evolution suggests that at the bulk of LST-1 observations (T0+20 days), the gamma-gamma attenuation could have had a minimum impact.
- From optical analysis we constrained progenitor's properties: combining optical + VHE results we conclude that the progenitor was a Red Super Giant.



LST Collaboration, A&A, 2025 "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor"

# THE CASE OF SN 2024BCH

- W… …ing a low density CSM.
- T… …t at the bulk of LST-1 o… …amma attenuation could h…
- F… c… was a Red Super Giant.

## Supernova [ edit ]

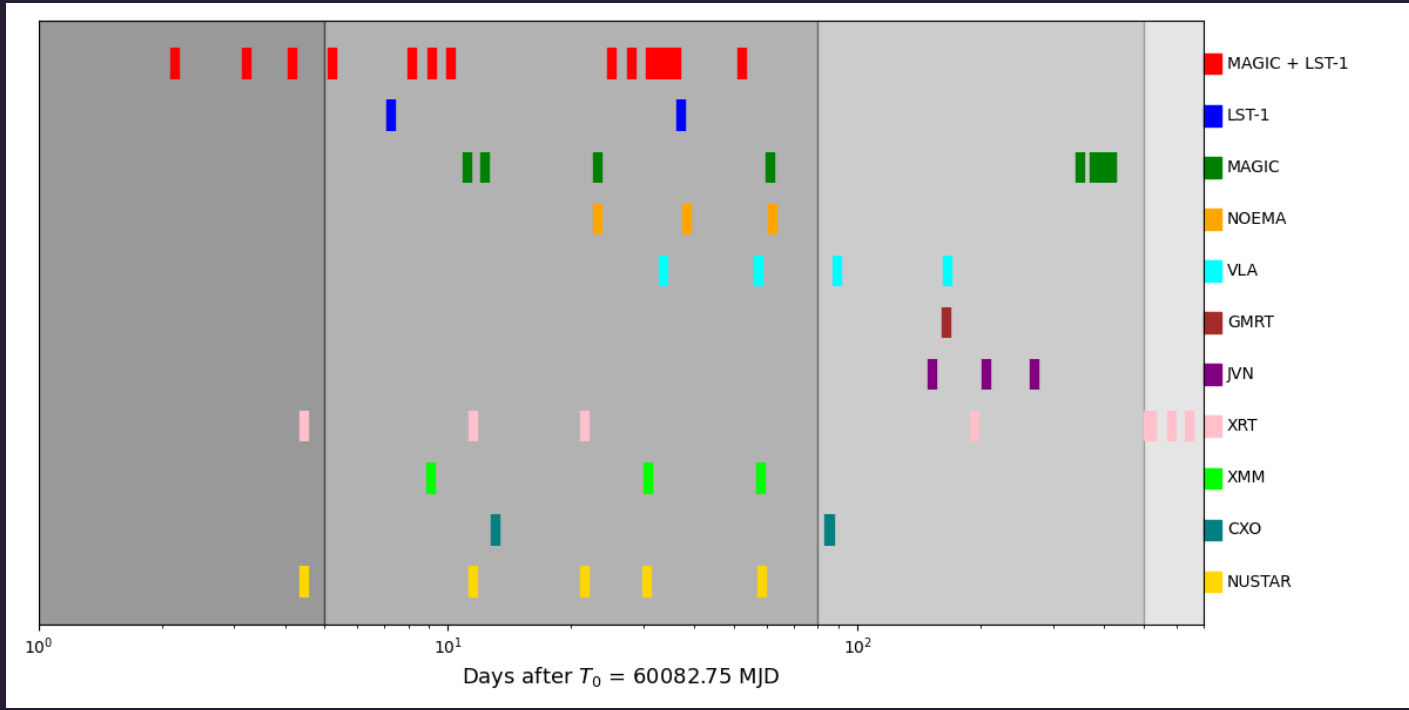
One supernova has been observed in NGC 3206: American amateur astronomer Patrick Wiggins discovered **SN 2024bch** (Type II, mag. 16.1) on 29 January 2024.[6] Later analysis suggested that the supernova was Type IIn-L with a red supergiant progenitor.[7]

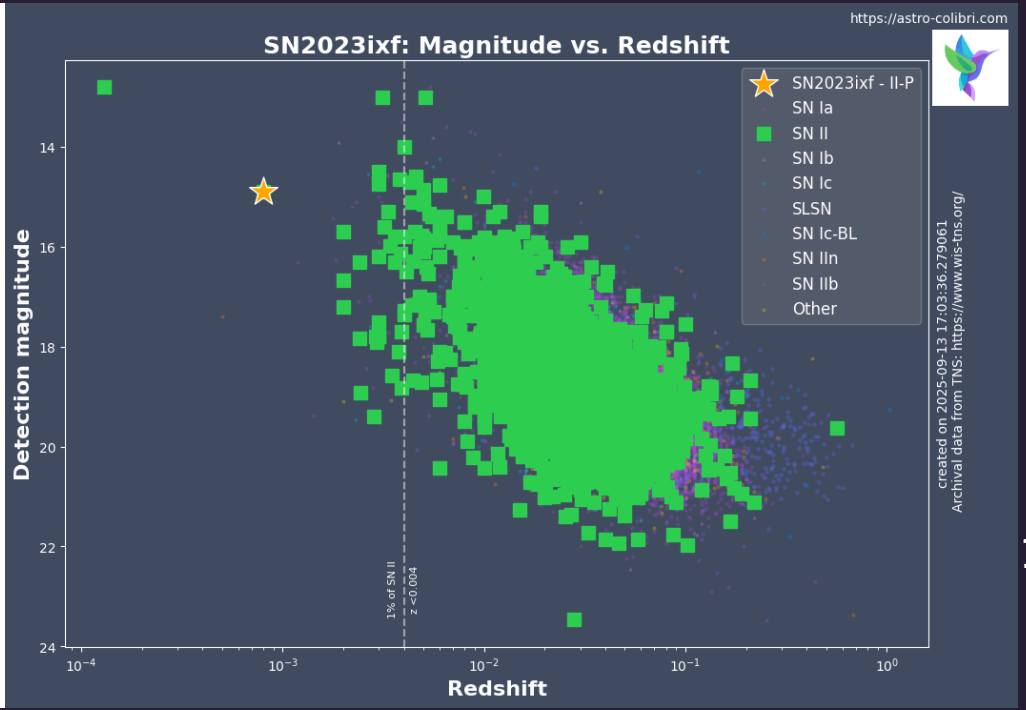
7. ^ Abe, K.; et al. (2025). "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor: Multiwavelength observations and analysis of the progenitor". *Astronomy and Astrophysics*. **702**. arXiv:2508.20048. Bibcode:2025A&A...702A.125A. doi:10.1051/0004-6361/202554721.



LST Collaboration, A&A, 2025 "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor"

# THE CASE OF SN 2023IXF






- Intense follow up of SN 2023ixf in joint MAGIC+LST-1 configuration.
- Unprecedented opportunity to study the entire evolution (also with MWL data)
- Tailored model in progress.

LST&MAGIC Collaboration, in prep, (credits A. Lopez, G. Pirola, A. Carosi, A. Aguasca, P. Cristofari)

# 3. CONCLUSIONS

- VHE Supernovae are a new exciting class of objects yet to be discovered!
- The current MAGIC+LST-1 configuration is the best to achieve a detection (with a bit of luck) before the upcoming CTAO-North.
- We need multiwavelength effort: (i) proper modelling; (ii) late triggers.
- Past observations of LST/MAGIC already proved the capabilities of our telescopes, now it's optimization time.
- The first detection of a VHE Supernova is on the corner!

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# 4. REFERENCES

- LST Collaboration 2025, A&A, 702: “Constraining the TeV gamma-ray emission of SN 2024bch, a possible type IIn-L from a red supergiant progenitor”
- MAGIC Collaboration 2017, A&A, 602, 10.1051/0004-6361/201629574
- H.E.S.S Collaboration 2019, A&A, 626, 10.1051/0004-6361/201935242
- VERITAS Collaboration 2023, ApJ, 945, 10.3847/1538-4357/acb7e6
- H.E.S.S Collaboration 2025, PoS, 501, 10.22323/1.501.0576
- Cristofari et al. 2022, MNRASS, 5011, 10.1093/mnras/stac217