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The History of SN1885A in M31

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Contents

1. Introduction - SAndromedae

- **SAndromedae/ SN1885A:** historical supernova (SN) in the central region of M31
- first and brightest extragalactic SN ever observed
- referred to as “most fascinating event of modern astronomy”

Why is the detection of (X-ray) emission from the remnant of SN1885A of interest?

- information about the properties of SNRs at this early stage
- information about type I SNe in general

2. Type-Ia/Thermonuclear Supernovae

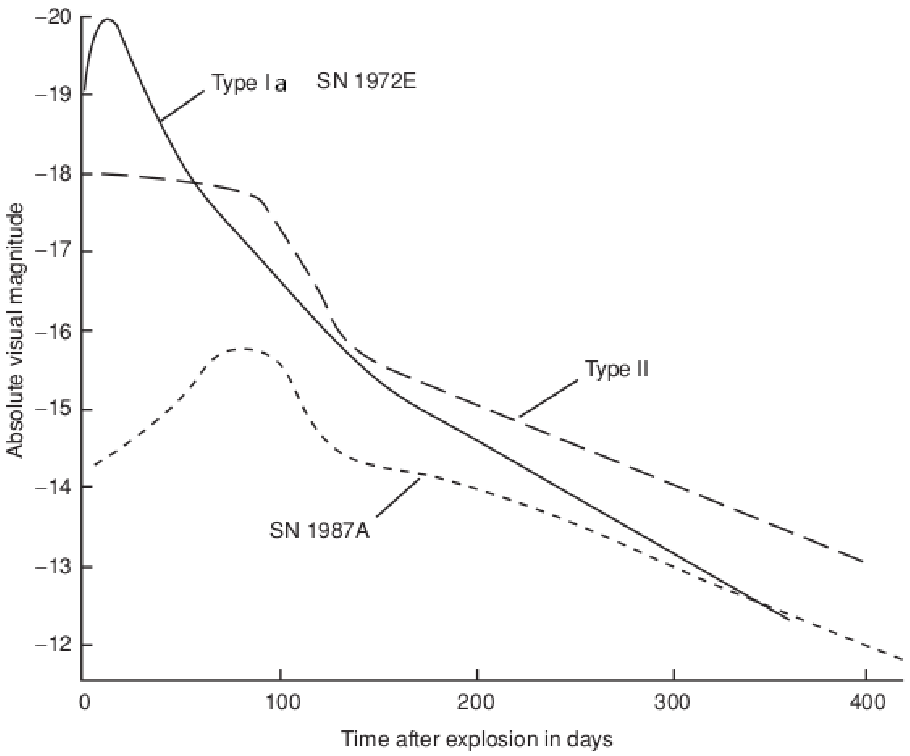
- accreting White Dwarf (WD) in binary system
- WD reaches Chandrasekhar limit ($1.44\ M_{\odot}$)

→ gravitational force > electron degeneracy pressure

- temperature rises

→ triggers nuclear fusion reactions
→ eventually: disruption of the star

- no Hydrogen lines in spectra



Seward and Charles (2010)

3. Evolution of Supernova Remnants

1. Ejecta-Dominated Phase

- shell of ejecta from explosion sweeps up surrounding ISM
- two shockwaves are created:
  → **blast-wave/forward shock**
  → **reverse shock**
- ejecta expand freely until hit by reverse shock
- $M_{ej} > M_{ISM}$
  → **evolution dominated by ejecta**
- X-ray emission expected to decrease

2. Sedov-Taylor Phase

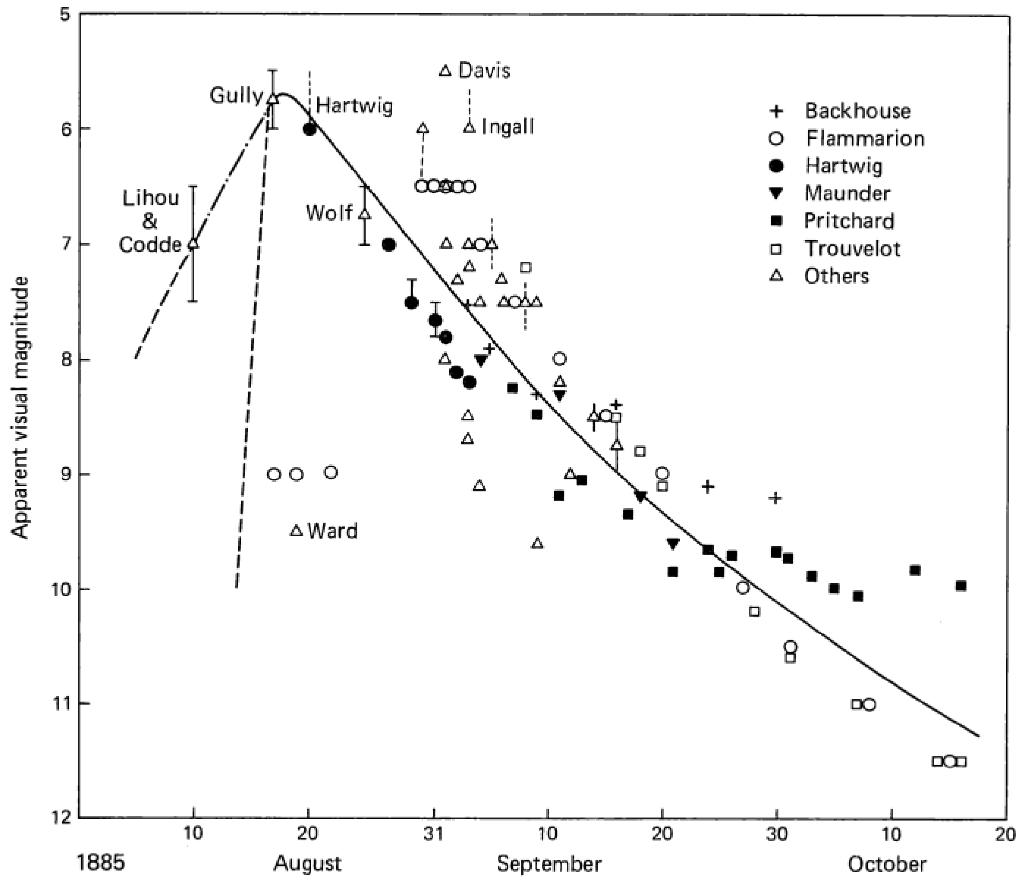
- forward shock moves further into ISM
- reverse shock moves inward
  → reaches center
- $M_{ISM} > M_{ej}$
- energy transferred from ejecta to ambient gas
- shell of ejecta expands adiabatically
  → **evolution no longer dominated by ejecta**
- X-ray emission expected to increase

4. Observations and Classification of SN1885A

- **Discovery:** 20 August 1885 by Ernst Hartwig at Dorpat Observatory in Estonia

> **maximum visual magnitude:**
> 5.7 mag around 18/19 August 1885
>
> **absolute magnitude at maximum:** -18.5 mag

- last sighting: 7 February 1886
- **Classification:** type Ia
- Unusually fast light curve, sub-luminous, unusually red at maximum



Jones (1976)

5. The Remnant of SN1885A

Discovery of SNR1885:

- Fesen et al. in 1988 in Fe I absorption images with refractor at Kitt Peak National Observatory, AZ

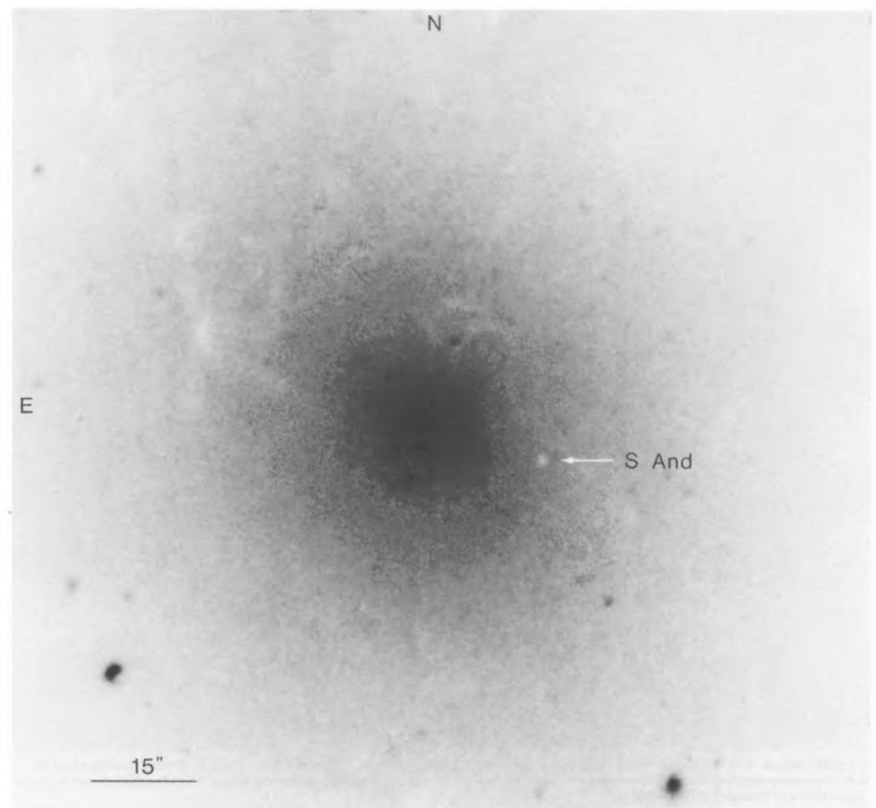
Observations with HST:

- absorption largely due to Ca II, also Ca I and Fe I
- unshocked, freely expanding ejecta
- diameter of absorption spot:

$$0.70 \pm 0.05 \text{ arcsec}$$

- expansion velocity:

$$11{,}000 \pm 2{,}000 \text{ km s}^{-1}$$



Fesen et al. (1989)

SNR1885- Radio and X-Ray Emission

Radio Emission

- observations with Very Large Array (Dickel and Dodorico, 1984)
  → upper limit on radio luminosity:

  $1 \times 10^{23}\ \mathrm{erg\ s^{-1}\ Hz^{-1}}$ at wavelength of $6.1\ \mathrm{cm}$

  → 0.4 times the luminosity of Tycho, 1.3 times that of Kepler

X-Ray Emission

- no X-ray emission detected so far
- X-ray source within $1.3\ \mathrm{arcsec}$ detected by Kareet (2002)
  → believed to be X-ray counterpart to optical nova

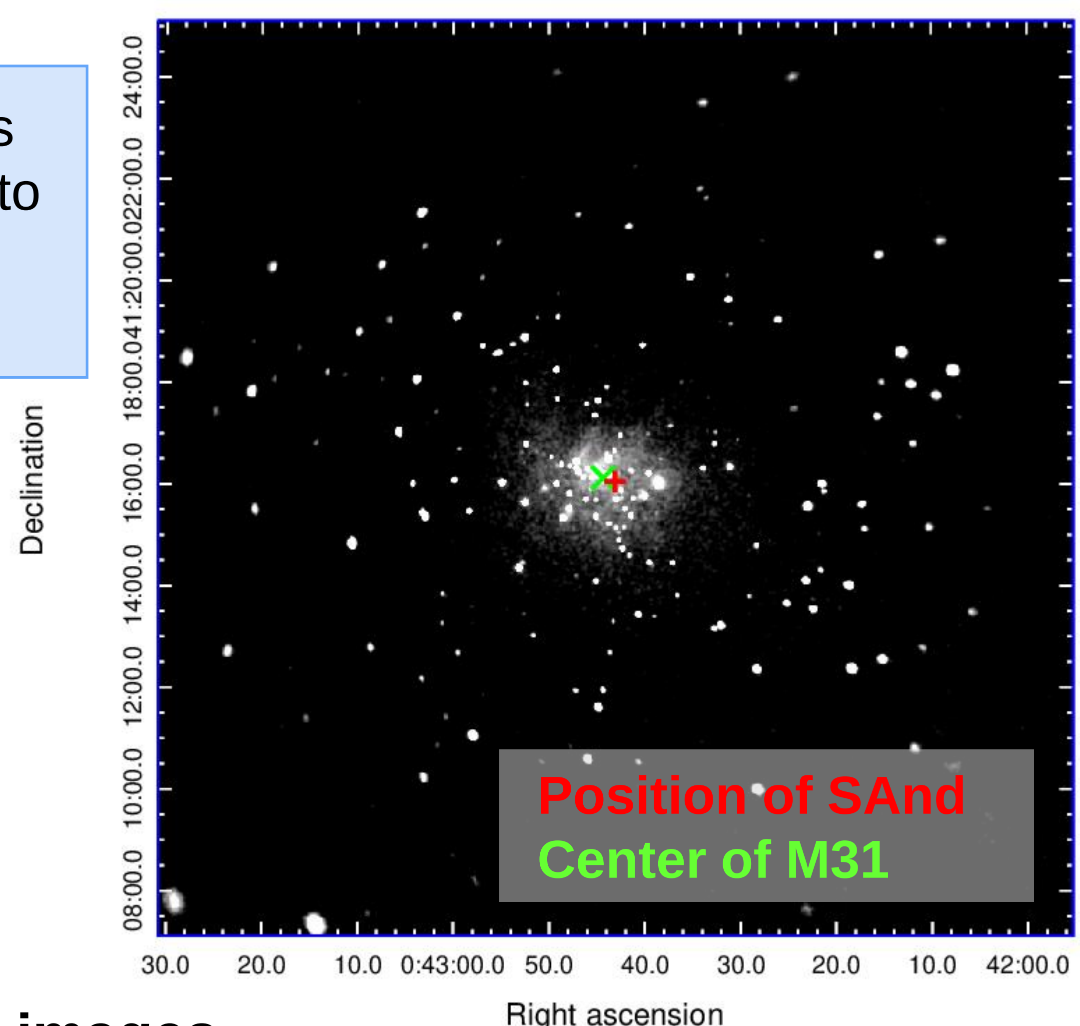
6. Search for X-Ray Emission from SNR1885

Goal: create merged images of the central region of M31 to investigate potential X-ray emission from SNR1885

- Chandra HRC-I data from 45 different observations of M31 between 2001 and 2012
- Position of SAnd:

$\mathrm{R.A.}\ 00^{\mathrm{h}}42^{\mathrm{m}}43^{\mathrm{s}}.12368$

$\mathrm{decl.}\ +41°16'03''.2124$



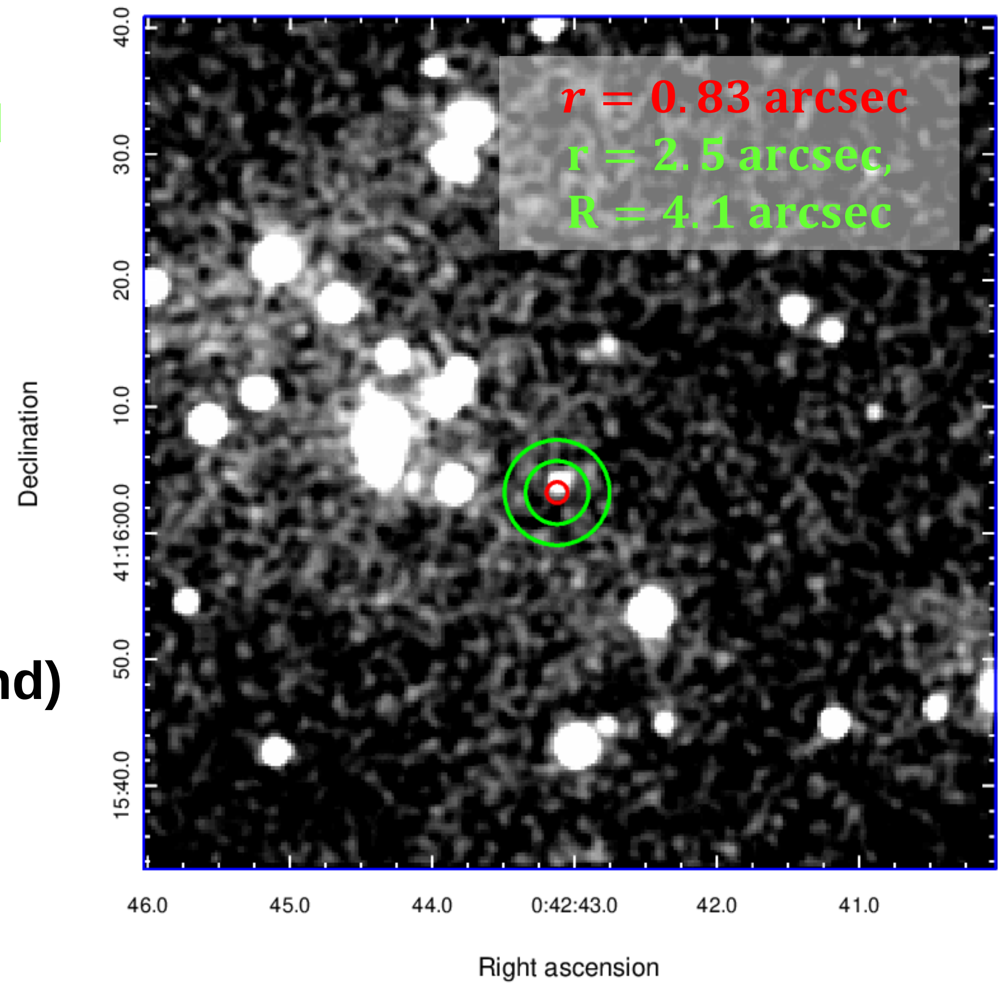
→ **SNR1885 not visible in images**

Upper Limit on X-Ray Luminosity of SNR1885

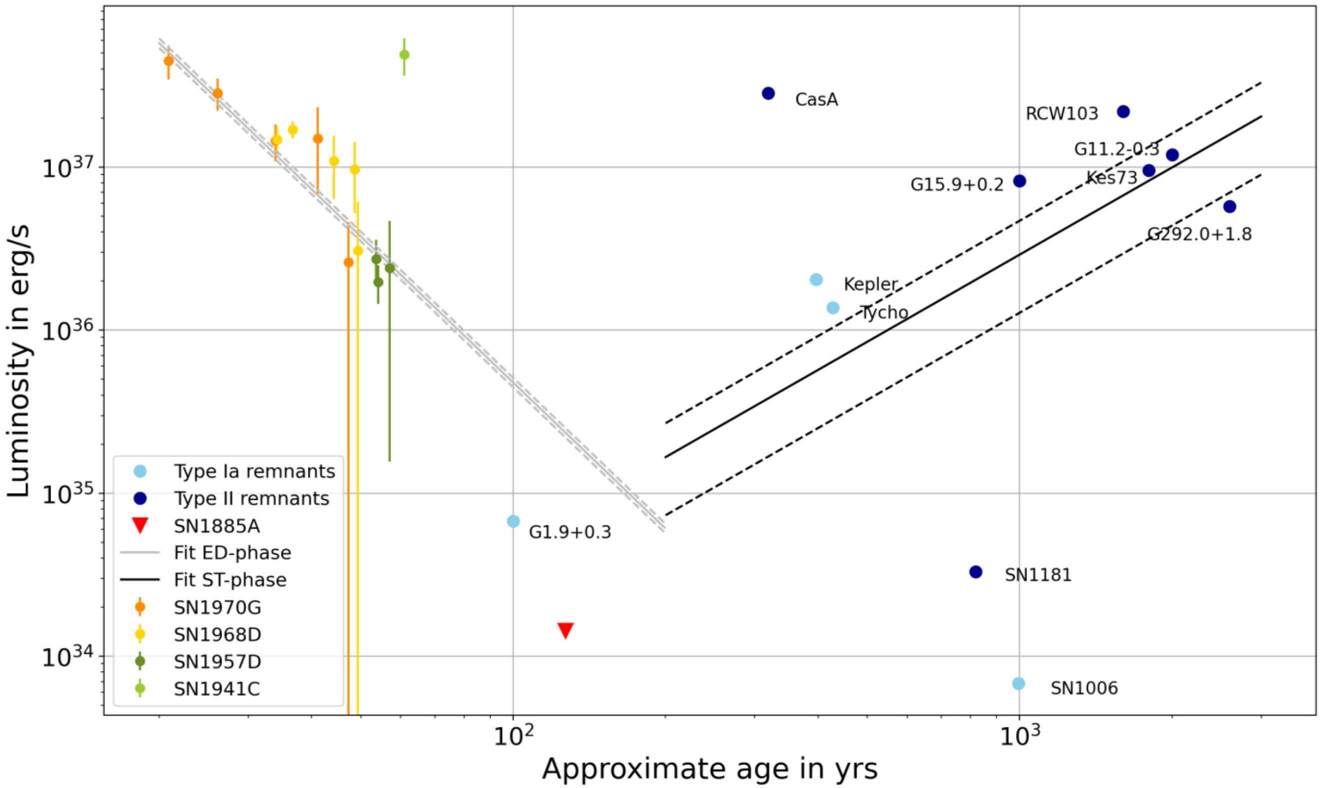
- define source and background regions
- APEC model for $kT = 1\ \mathrm{keV}$
- Galactic $n_H = 7 \times 10^{20}\ \mathrm{cm}^{-2}$
  Intrinsic $n_H = 1 \times 10^{21}\ \mathrm{cm}^{-2}$
- Distance to M31: $780\ \mathrm{kpc}$

→ **upper limit on the X-ray luminosity ($\mathbf{0.1 - 10\ keV}$ band)**

$$1.36 \times 10^{34} \mathrm{erg\ s^{-1}}$$



Comparison to other SNRs



Ramakrishnan and Dwarkadas (2020)

→ Upper limit low compared to Galactic SNRs/ X-ray SNe

→ **Possible reasons:**

freely expanding ejecta, absorption, low density ISM

7. Summary

- **SAndromedae/SN1885A:** historical SN in central region of M31
- **Discovery:** 20 August 1885 by Ernst Hartwig
- SN1885A generally classified as type Ia
- **SNR1885** discovered in 1988 in the optical
- so far, no X-ray emission from SNR1885
- obtained upper limit on X-Ray luminosity of SAnd at least two orders of magnitude lower compared to younger Galactic remnants
- X-ray emission expected to rise with further evolution of the remnant

  → **observations in the distant future necessary**

Thank you for your attention!

X-Ray Emission from Supernovae

- Thermal X-ray emission from a SNR: $L_X = \Lambda n_e^2 V$
- Chevalier (1982): Self similar solution for uniform expansion of gas into stationary surrounding medium
- Assumption: power-law density profiles for ISM and ejecta

$$\rho_{ej} \propto \left(\frac{r}{t}\right)^{-n} t^{-3} \qquad \rho_{ISM} \propto r^{-s}$$

→ solution holds for $n > 5, s < 3$

→ typically $9 < n < 11$