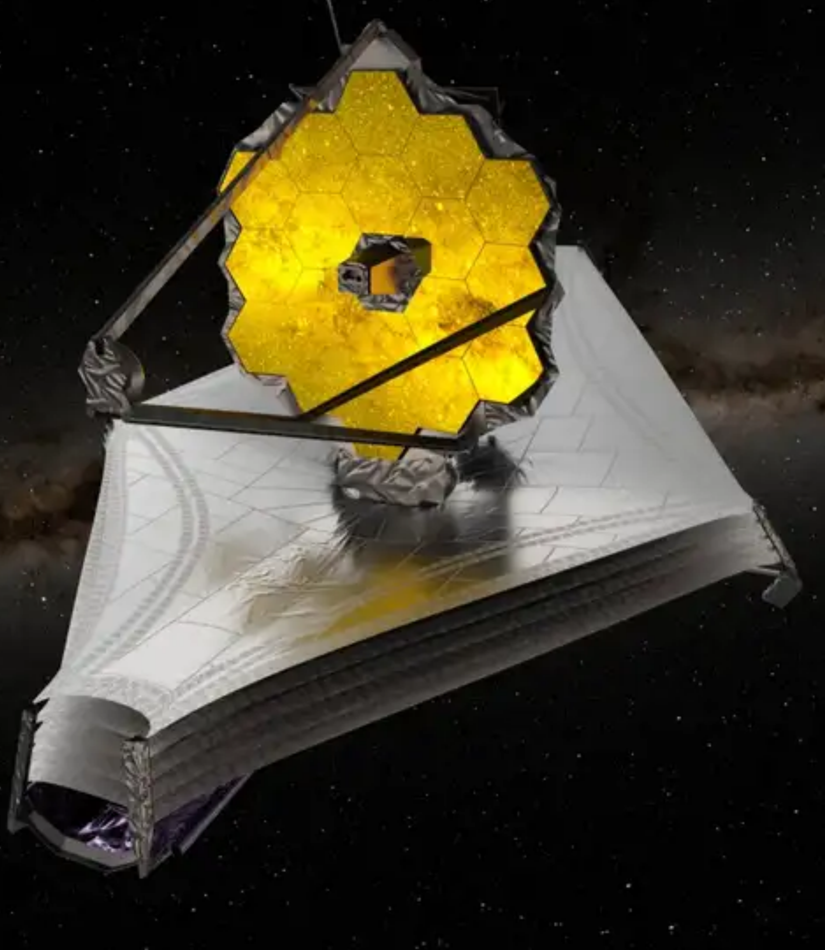
JWST NIRCam observations of Supernova 1987A – shocks, synchrotron and dust

Mikako Matsuura (Cardiff University)

M. Boyer, Richard G. Arendt, J. Larsson, C. Fransson, A. Rest, A. P. Ravi, S. Park, P. Cigan, T. Temim, E. Dwek, M.J. Barlow, P. Bouchet, G. Clayton, R. Chevalier, J. Danziger, J. De Buizer, I. De Looze, G. De Marchi, O. Fox, C. Gall, R. D. Gehrz, H. L. Gomez, R. Indebetouw, T. Kangas, F. Kirchschlager, R. Kirshner, P. Lundqvist, J.M. Marcaide, I. Marti-Vidal, M. Meixner, D. Milisavljevic, S. Orlando, M. Otsuka, F. Priestley, A.M.S. Richards, F. Schmidt, L. Staveley-Smith, Nathan Smith, J. Spyromilio, J. Vink, Lifan Wang, D. Watson, R. Wesson, J. C. Wheeler, C.E. Woodward, G. Zanardo, D. Alp, D. Burrows

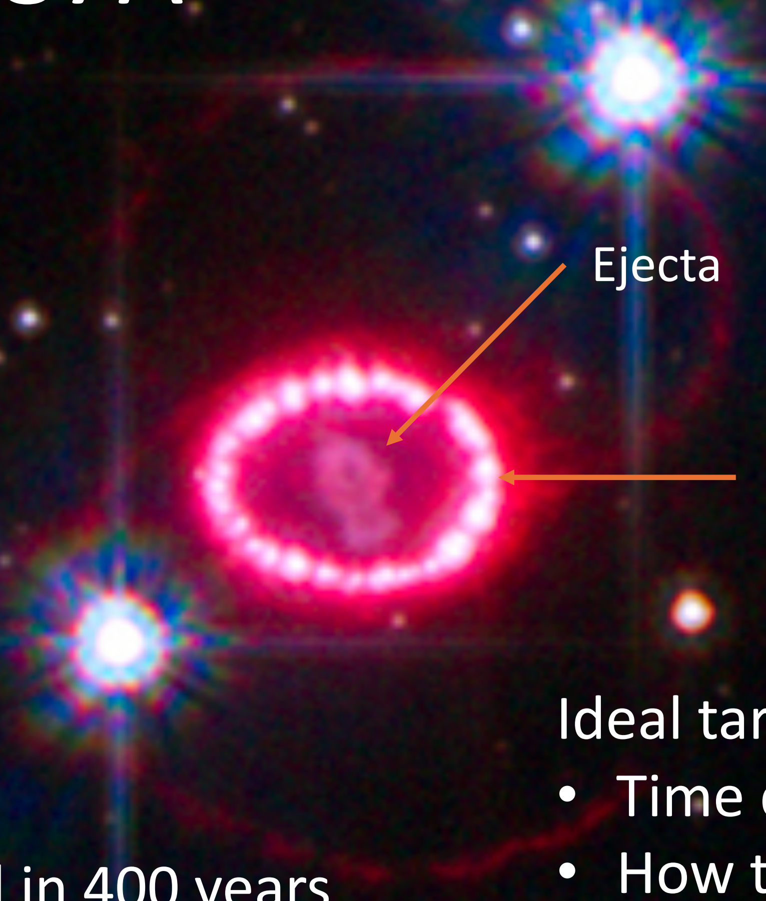
Science & Technology Facilities Council

Cardiff University / Prifysgol Caerdydd



ESA/STScI

Supernova 1987A



Type IIP
50 kpc (LMC)
Nearest SN explosion detected in 400 years
Ejecta expands at ~2,000–10,000 km s^{-1}, i.e. to 0.008–0.04” per year

Ideal target to investigate

- Time development of (inner) ejecta
- How the interaction of (outer) ejecta with circumstellar material impact surrounding material

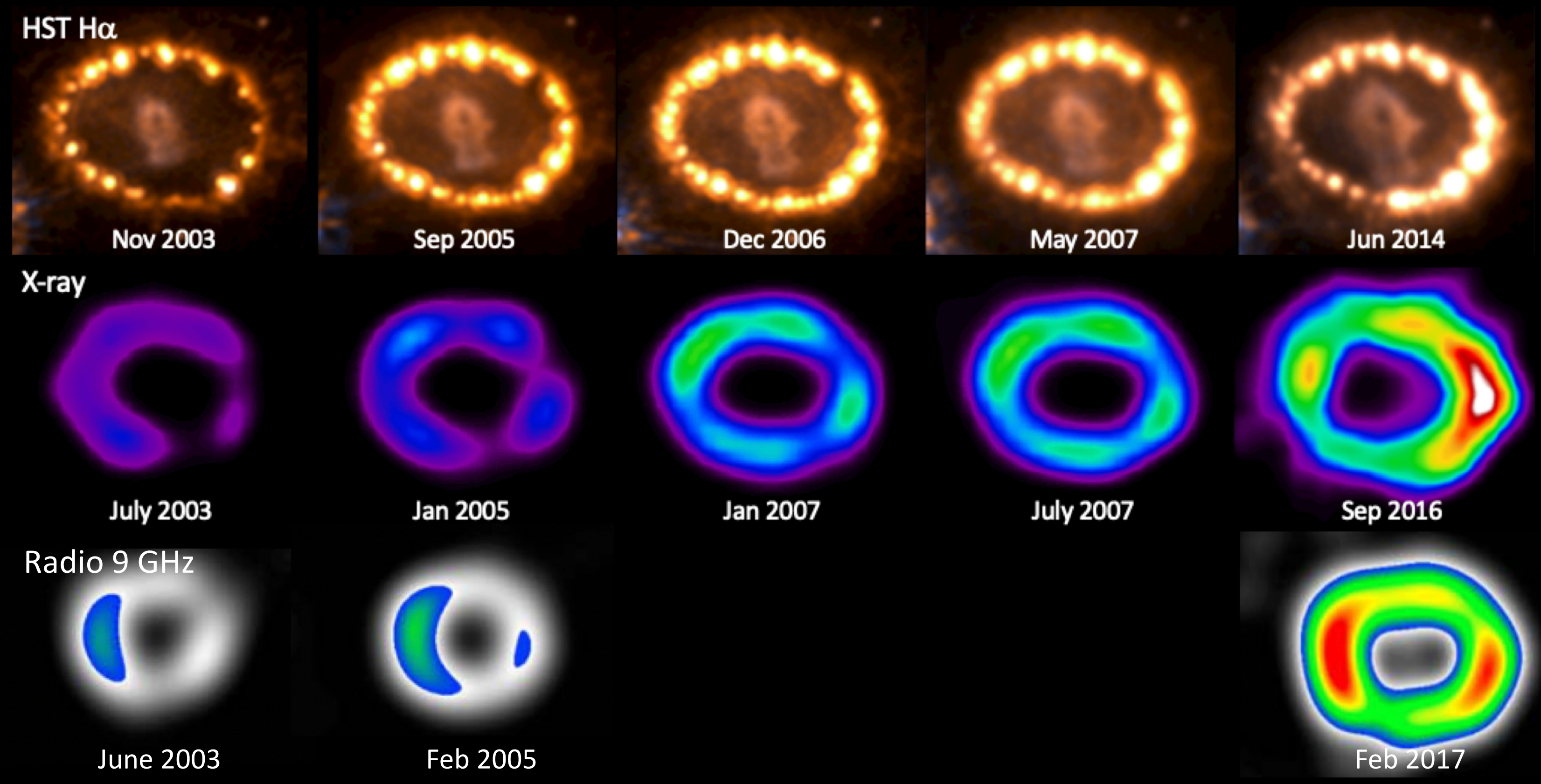
Supernova 1987A: Real - time astronomy

Hubble Space Telescope Hα monitoring

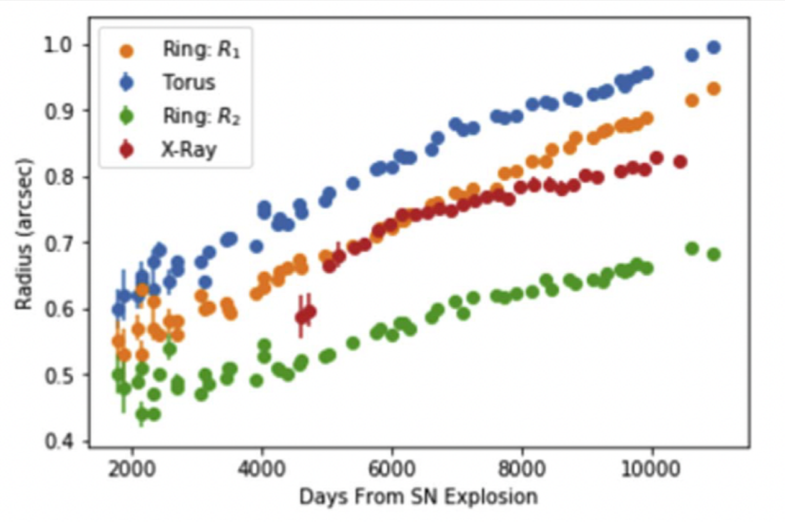
Fransson et al. (2015)

Before JWST

Kairi et al. (2016)
Cendes et al. (2018)

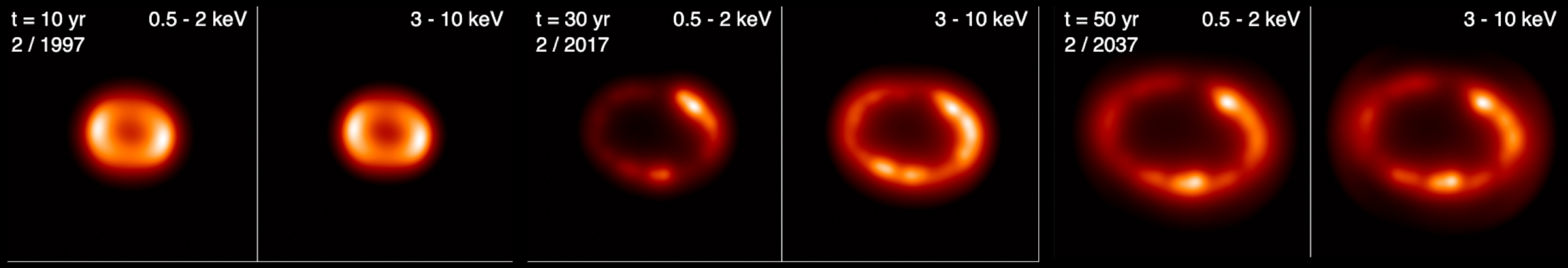


X-ray & millimeter
Diameter is getting larger
Individual clumps/hotspots are not well resolved



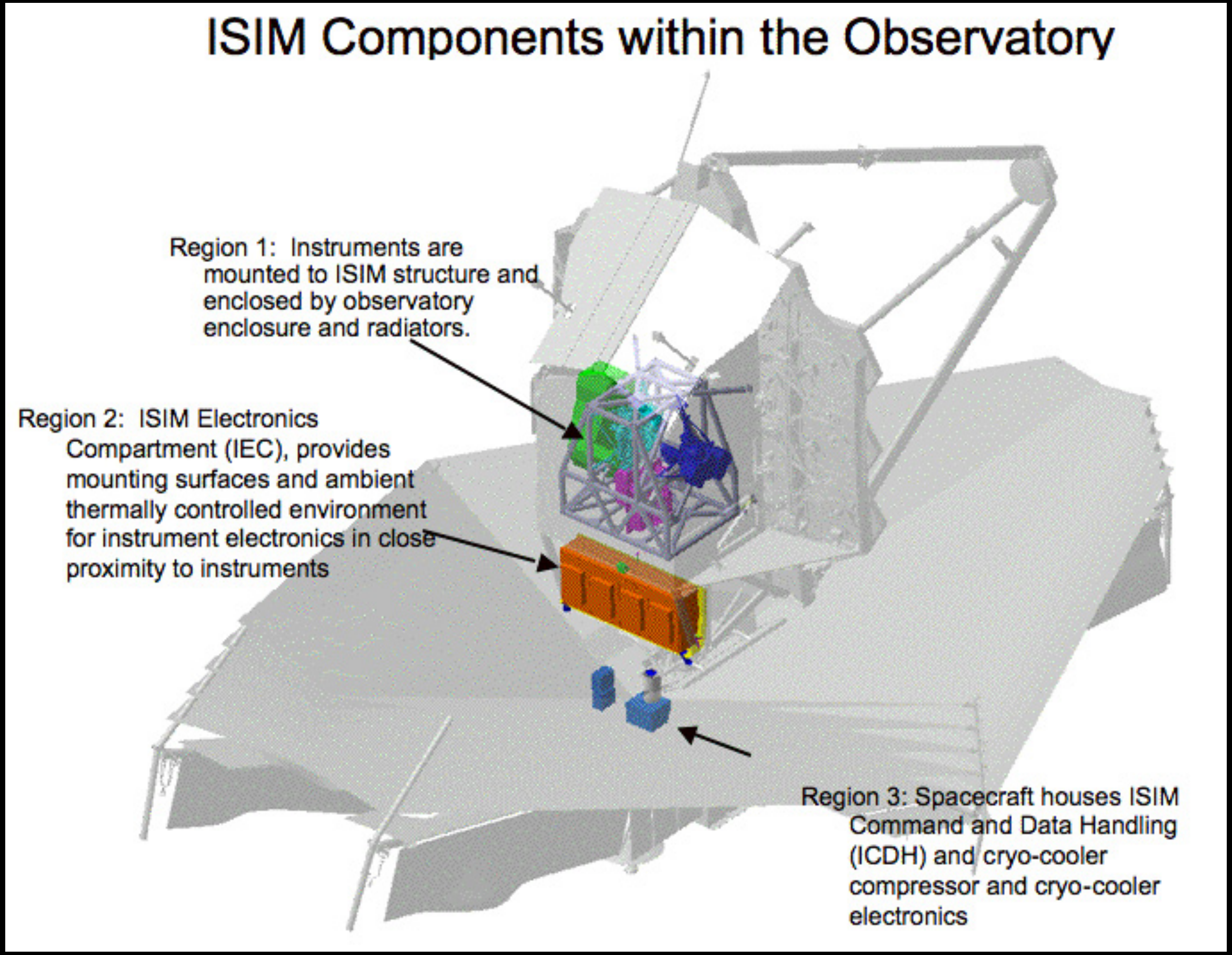
Hydrodynamic model for X-ray synchrotron (Orland et al. 2020)

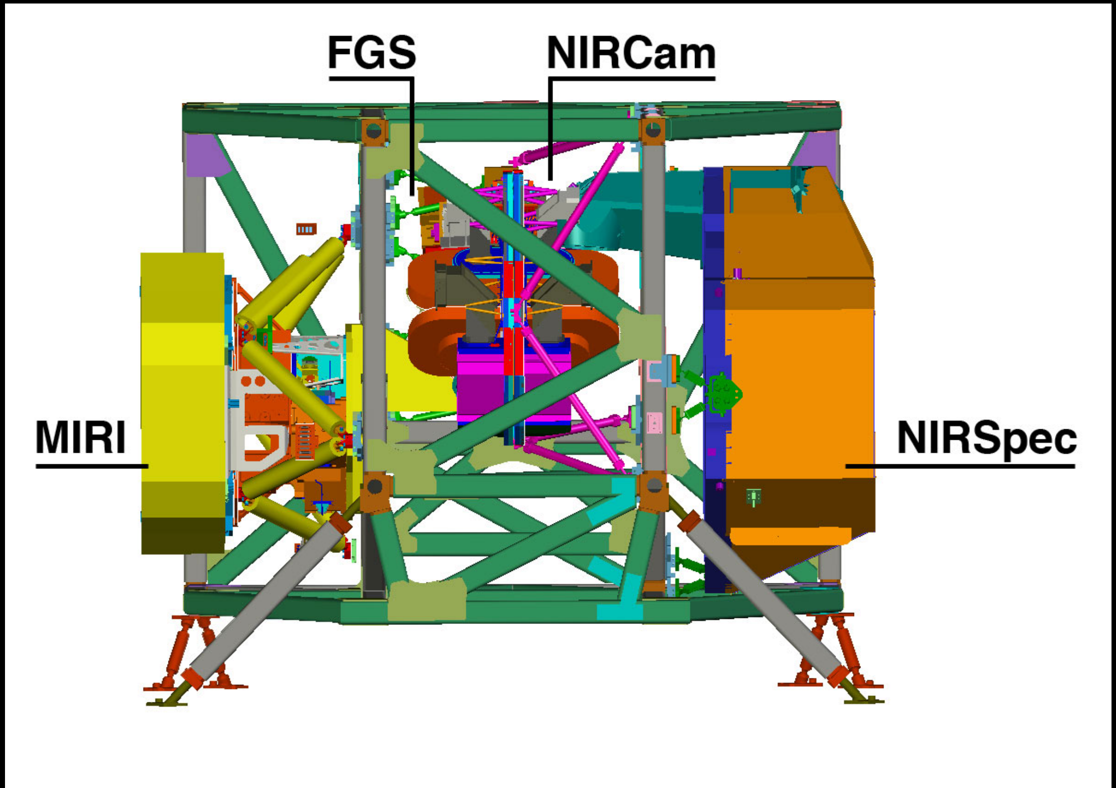
10 years
30 years
50 years



"The equatorial ring is the brightest in X-ray"

JWST

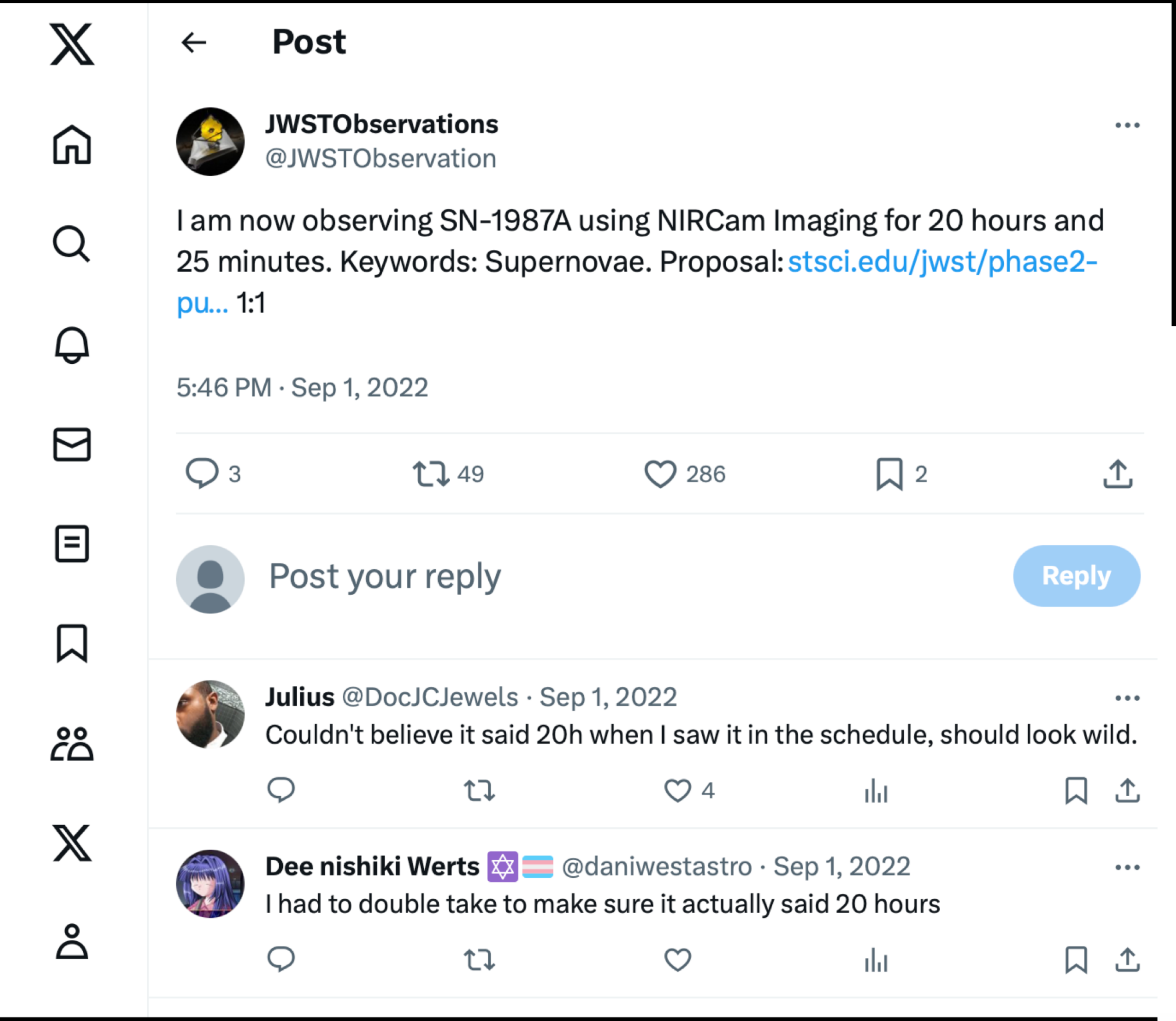




Three instruments were used for SN 1987A

- MIRI & NIRSpec – Guaranteed time Observations (Larsson)
- NIRCam – General Observers

When JWST was observing Supernova 1987A – X (Twitter) account


Post

JWSTObservations
@JWSTObservation

I am now observing SN-1987A using NIRCam Imaging for 20 hours and 25 minutes. Keywords: Supernovae. Proposal: stsci.edu/jwst/phase2-pu... 1:1

5:46 PM · Sep 1, 2022

3 49 286 2

Post your reply

Reply

Julius @DocJCJewels · Sep 1, 2022
Couldn't believe it said 20h when I saw it in the schedule, should look wild.

4

Dee nishiki Werts @daniwestastro · Sep 1, 2022
I had to double take to make sure it actually said 20 hours


JWSTObservations @JWSTObservation · 15h
I am now observing NGC-6302-CENTER using MIRI Medium Resolution Spectroscopy for 14 hours and 32 minutes. Keywords: Planetary nebulae. Proposal: stsci.edu/jwst/phase2-pu... 2:1

3 24

JWSTObservations @JWSTObservation · 16h
I am now observing NGC-6302-BACKGROUND2 using MIRI Medium Resolution Spectroscopy for 28 minutes. Keywords: Blank field. Proposal: stsci.edu/jwst/phase2-pu... 1:1

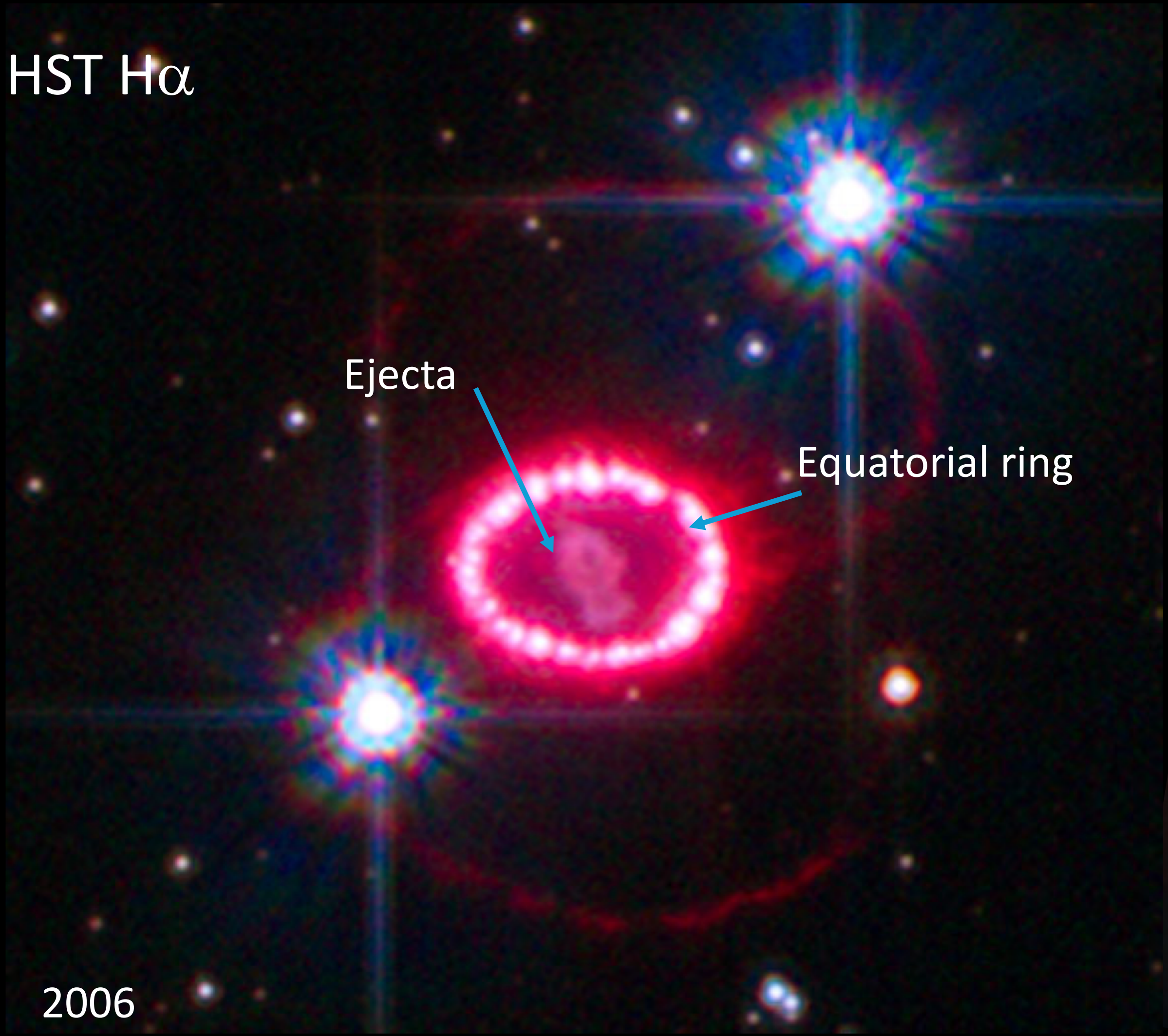
1 8

JWSTObservations @JWSTObservation · 17h
I am now observing SN-1987A using NIRCam Imaging for 20 hours and 25 minutes. Keywords: Supernovae. Proposal: stsci.edu/jwst/phase2-pu... 1:1

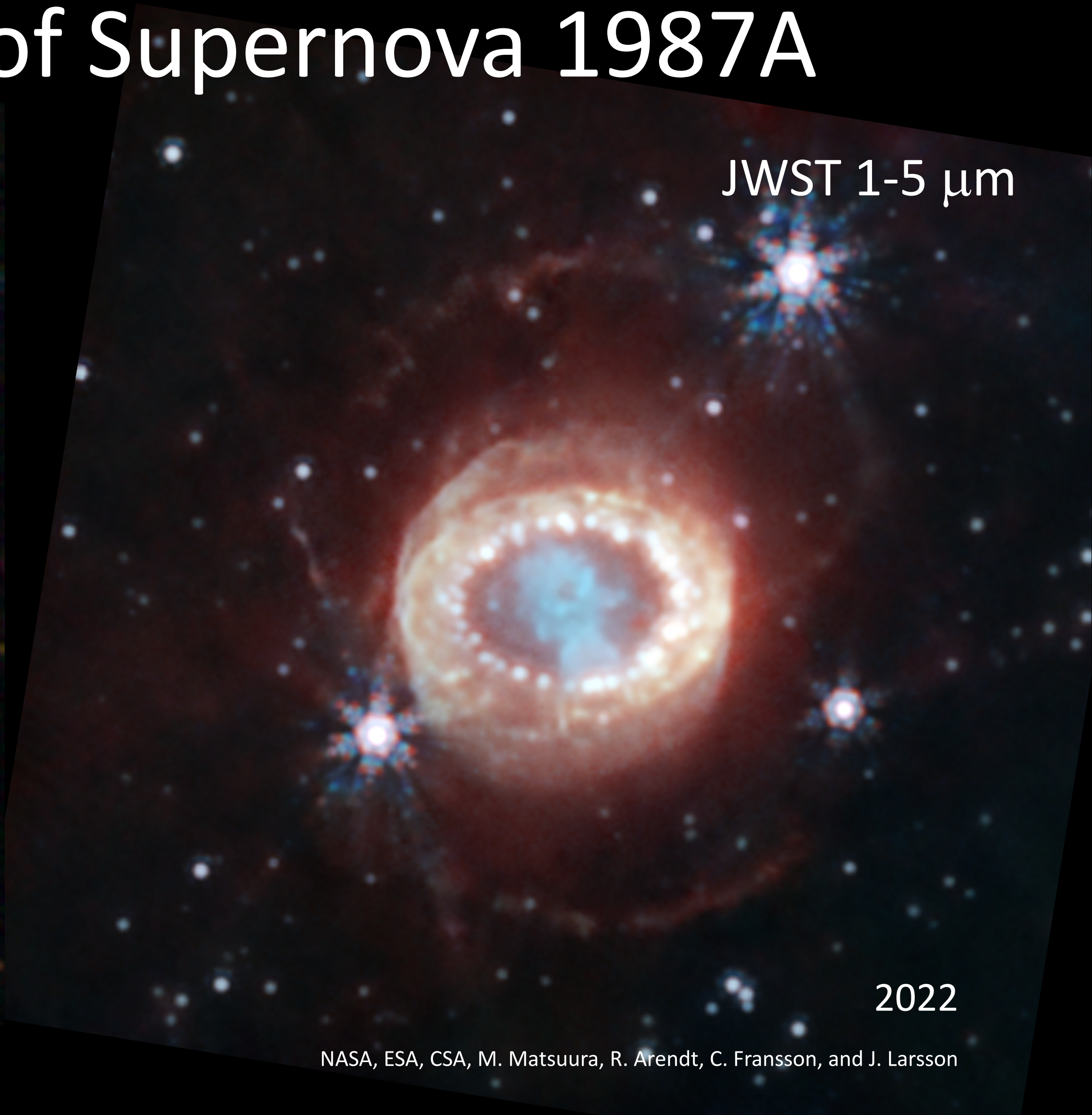
3 42 249

NASA, ESA, CSA, M. Matsuura, R. Arendt, C. Fransson, and J. Larsson

HST & NIRCam images of Supernova 1987A

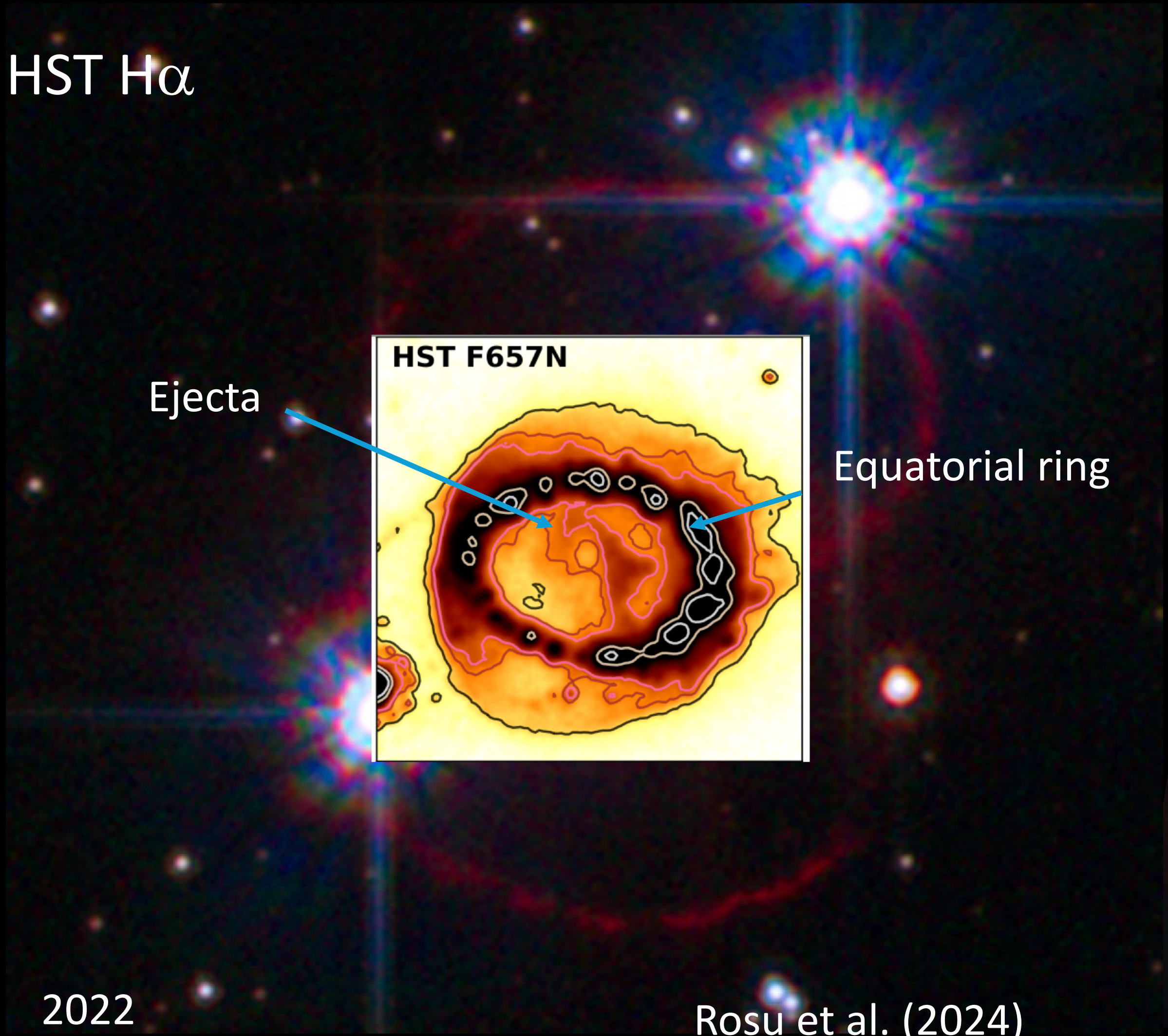


NASA/ESA/K. France/P.Challis/R.Kirshner

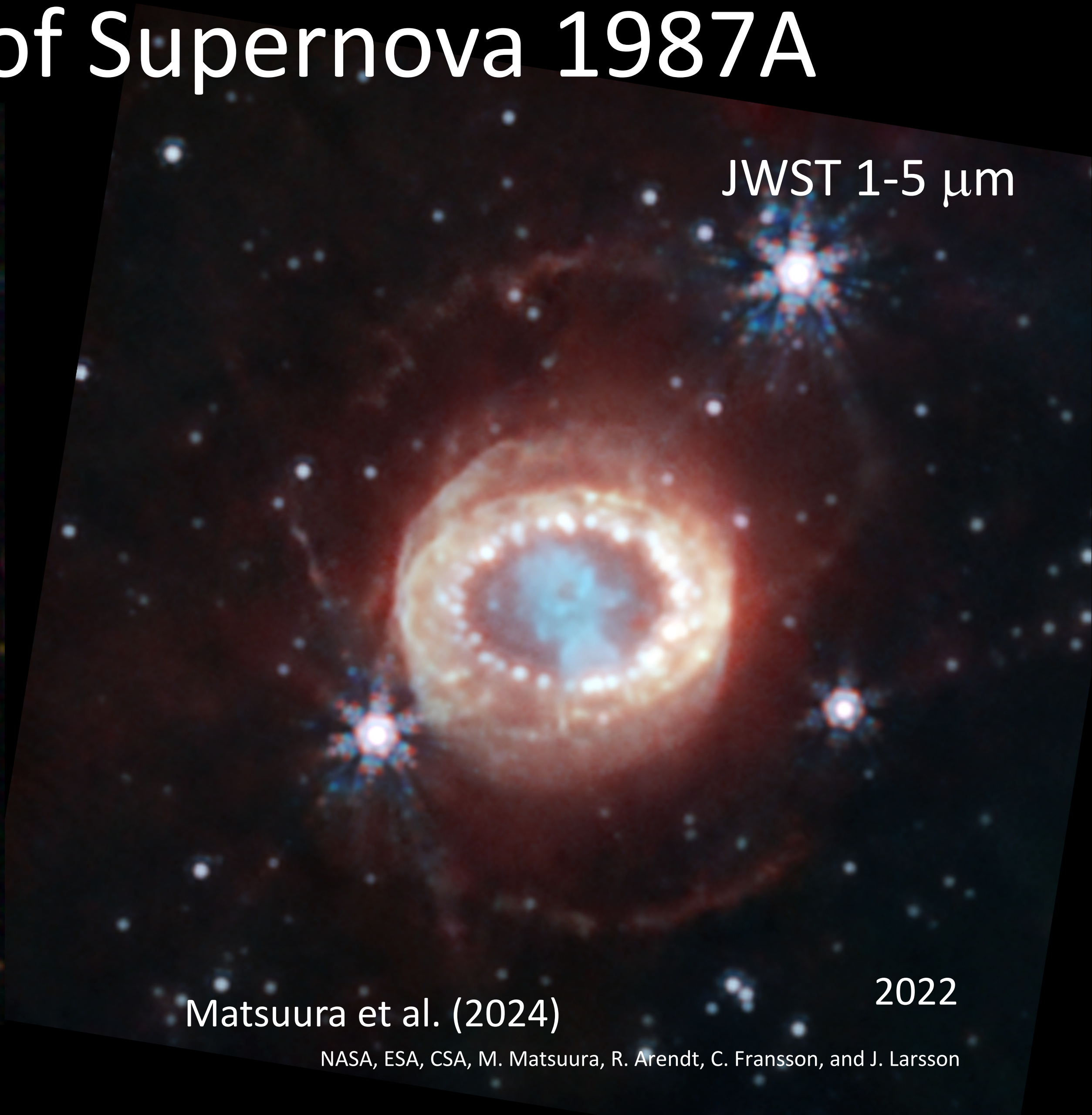


NASA, ESA, CSA, M. Matsuura, R. Arendt, C. Fransson, and J. Larsson

HST & NIRCam images of Supernova 1987A

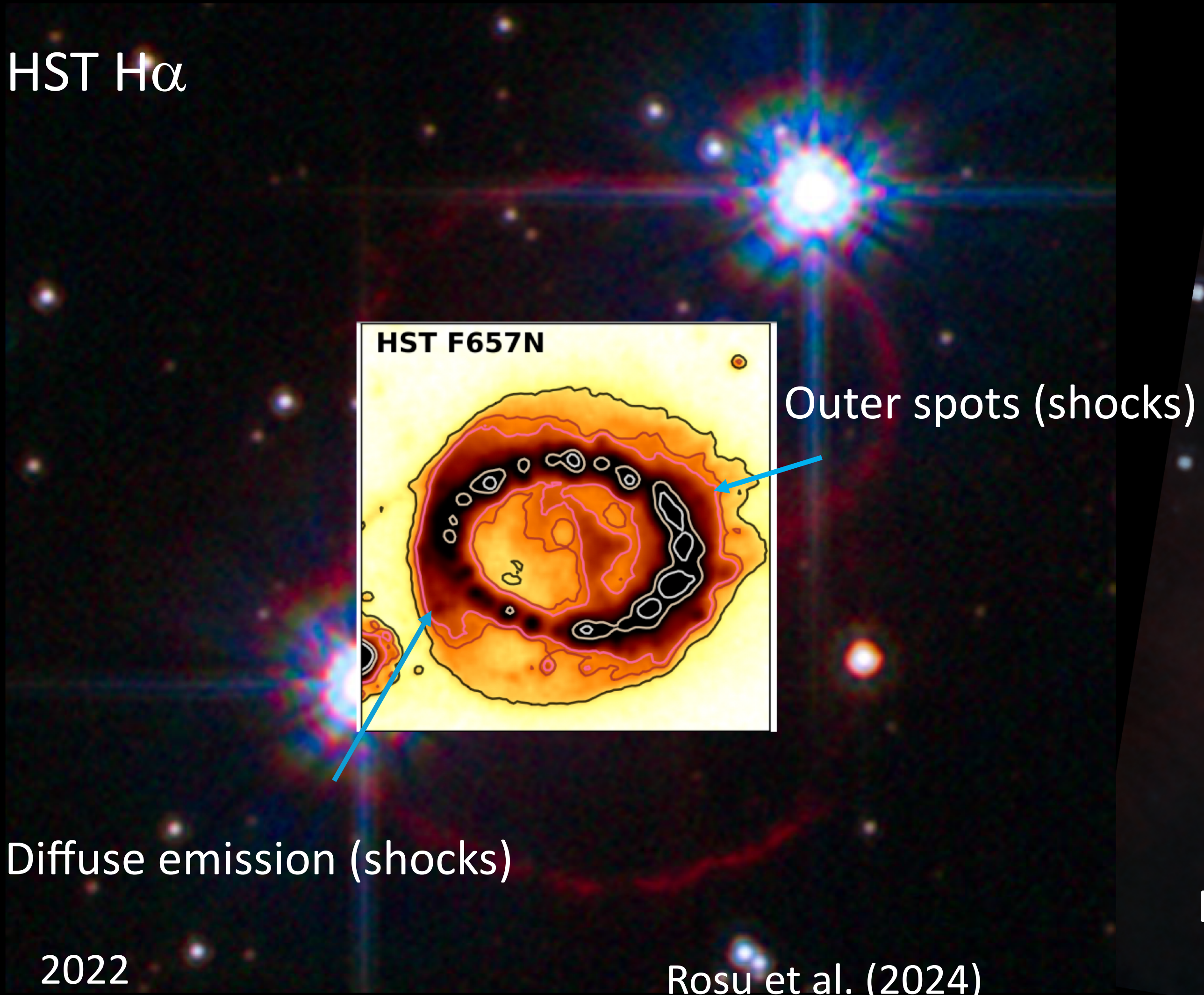


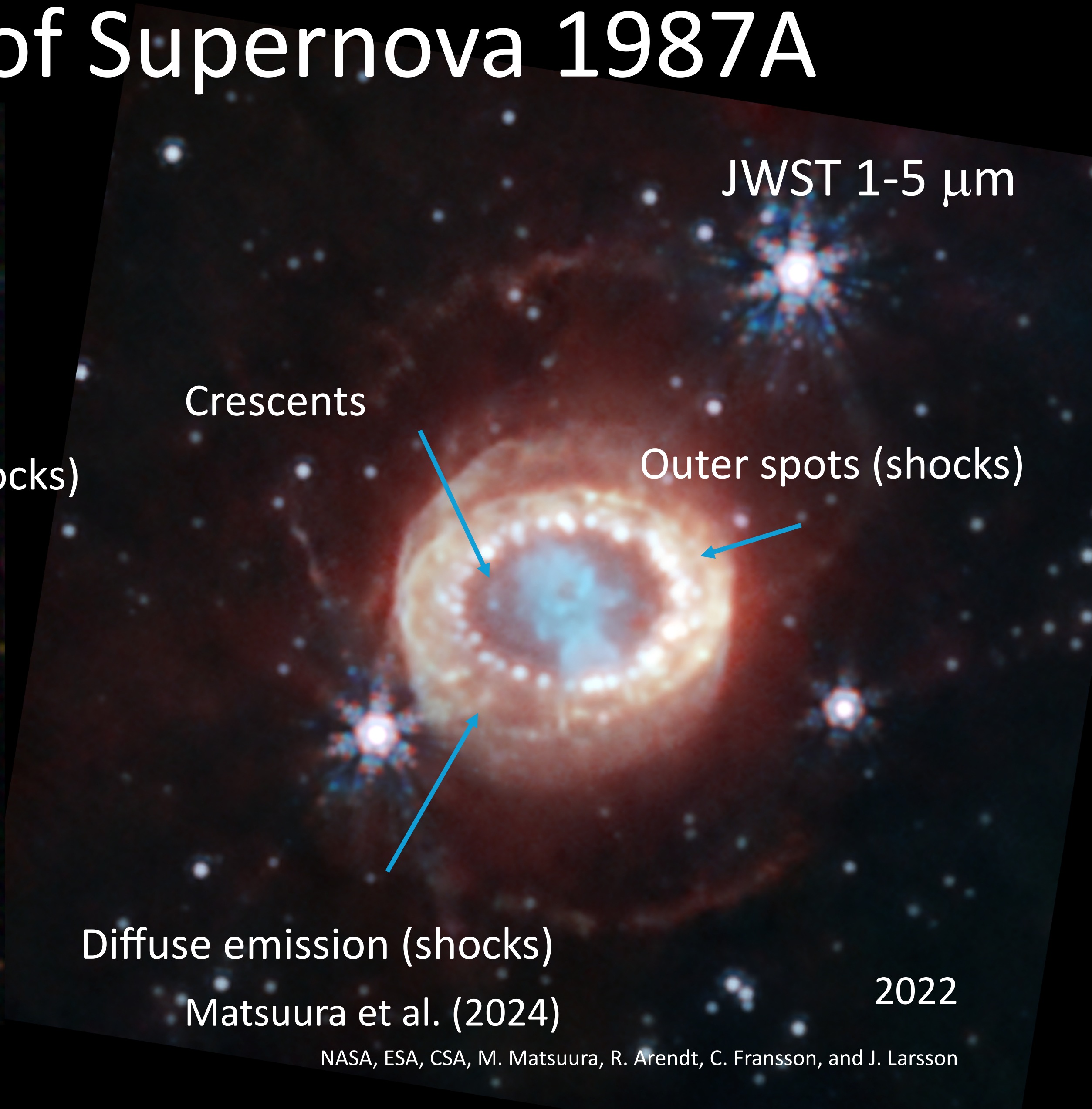
NASA/ESA/K. France/P.Challis/R.Kirshner



NASA, ESA, CSA, M. Matsuura, R. Arendt, C. Fransson, and J. Larsson

HST & NIRCam images of Supernova 1987A



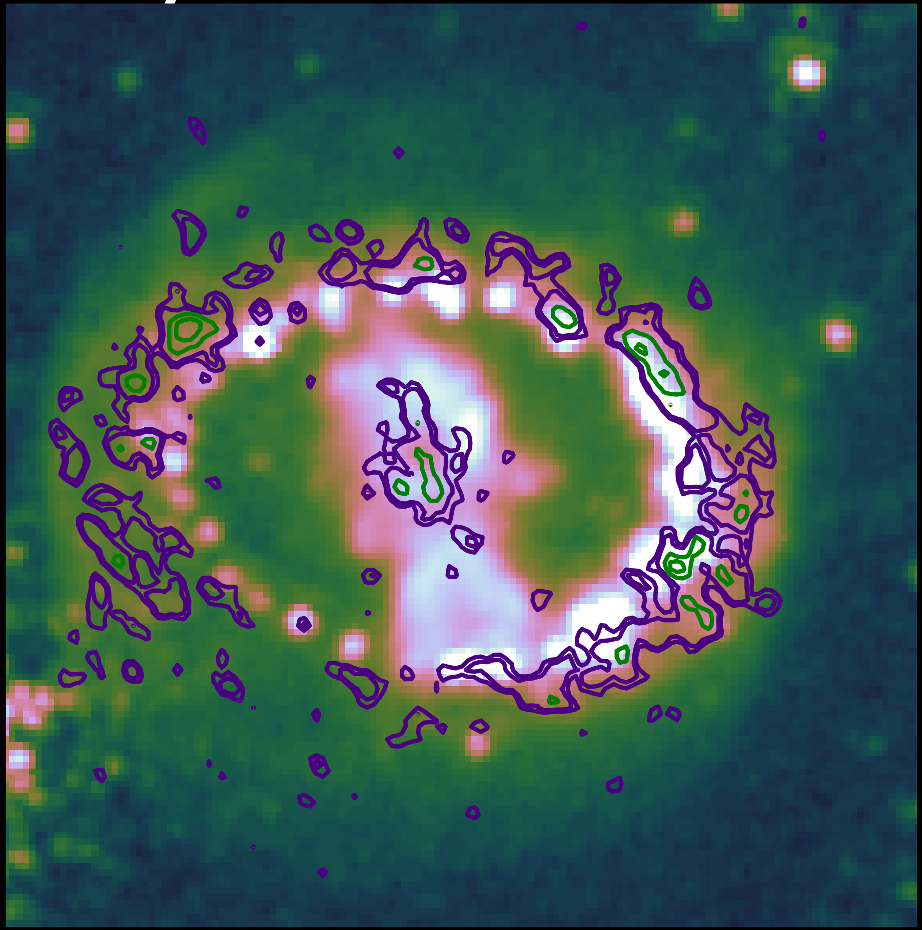


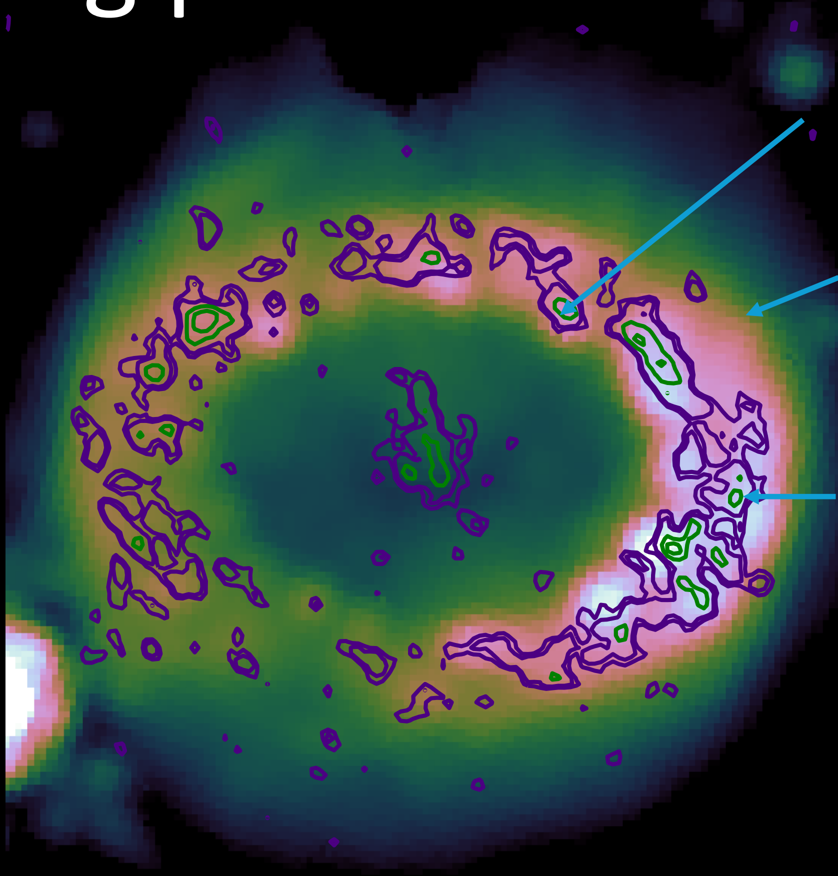
NASA/ESA/K. France/P.Challis/R.Kirshner

NASA, ESA, CSA, M. Matsuura, R. Arendt, C. Fransson, and J. Larsson

NASA/ESA/K. France/P.Challis/R.Kirshner

Synchrotron – viewing particle accelerations





F164N [Fe II]
Ionised gas tracer
Clumps in the Ring

Line contour ALMA 315GHz
Synchrotron in the ring + outer spots
Dust in the ejecta

JWST 3.56 μm
Synchrotron + dust

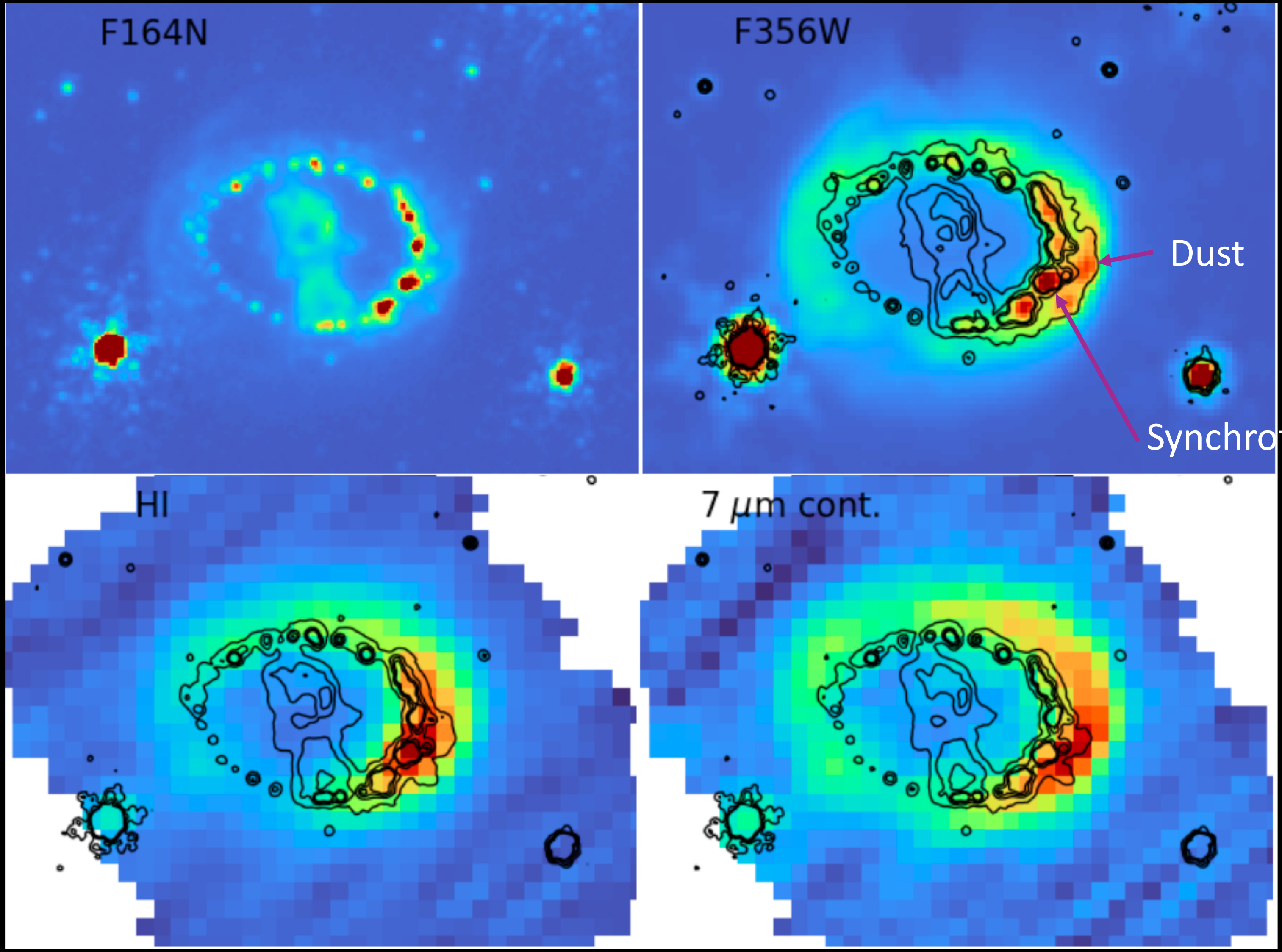
Synchrotron & Dust

NIRCam

[Fe II] recombination
(not shocks)

MIRI

7 μm HI recombination



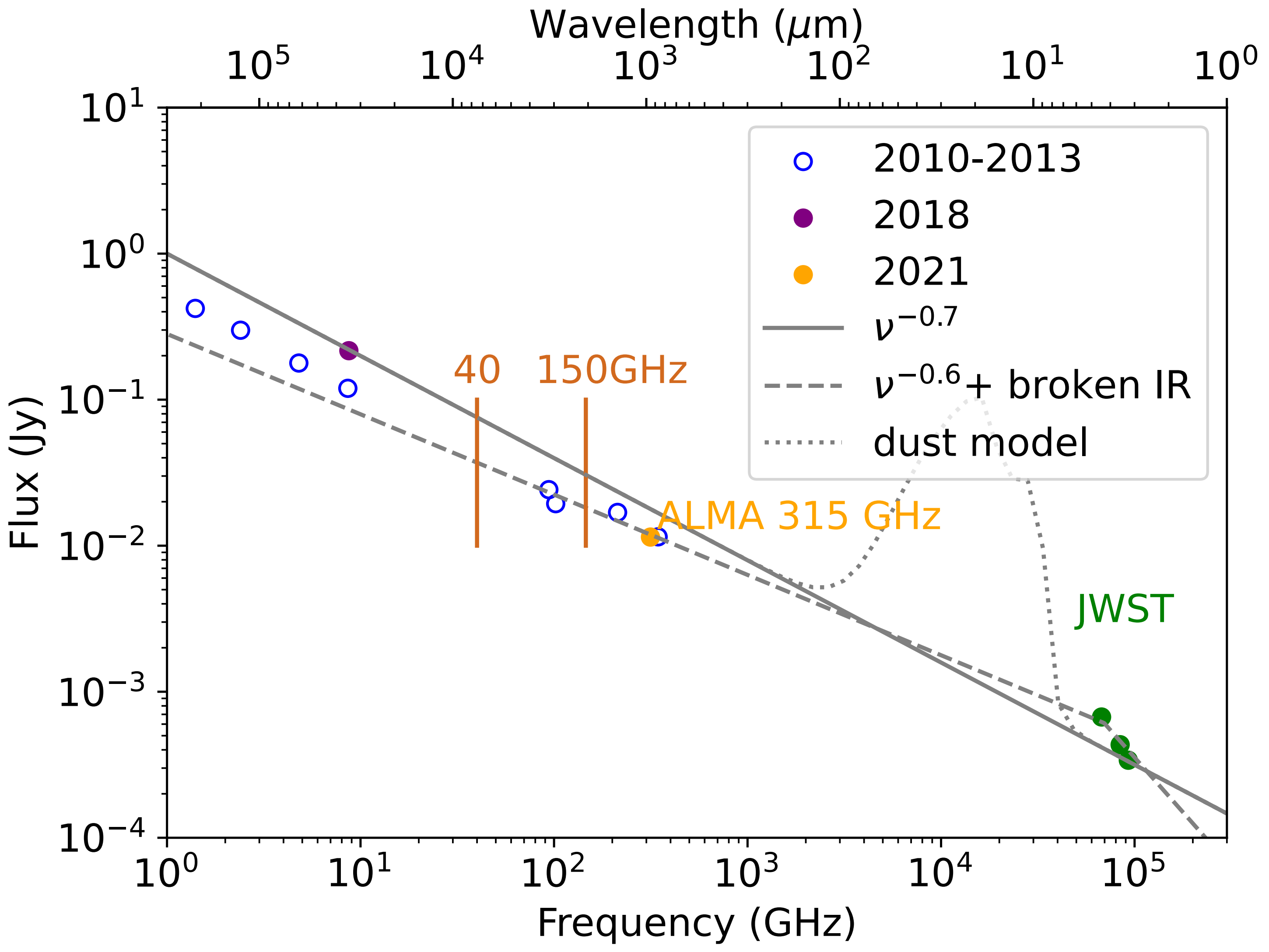
3.56 μm continuum

7 μm dust

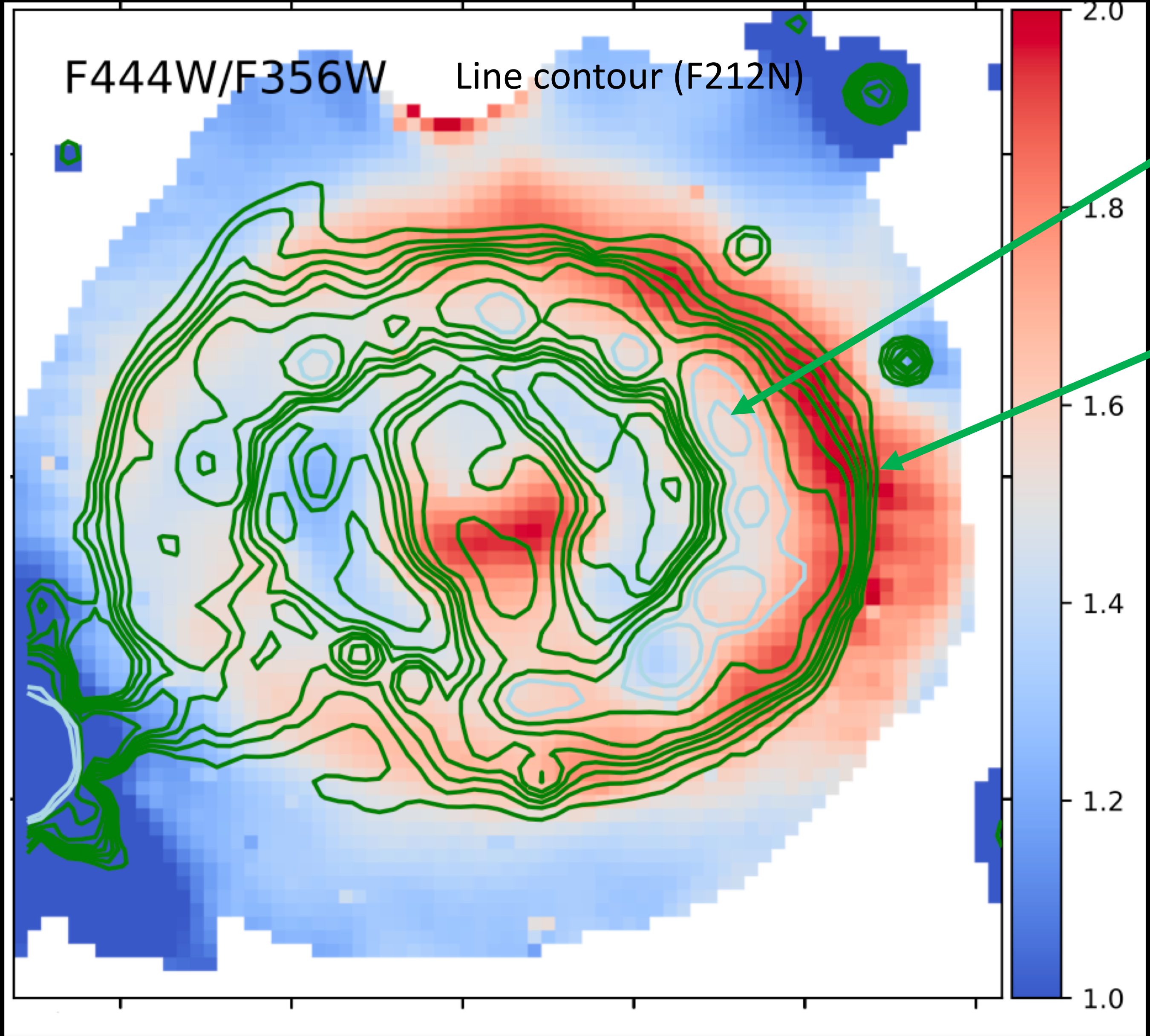
Synchrotron spectral index α: $F_\nu \propto \nu^{-\alpha}$

Total SED

Millimetre wavelength α~ 0.6-0.7



Synchrotron spectral index α: $F_\nu \propto \nu^{-\alpha}$ (So as dust)



Millimetre wavelength α~ 0.6-0.7

Clumps in the Ring

Spectral index α ~1.0–1.5

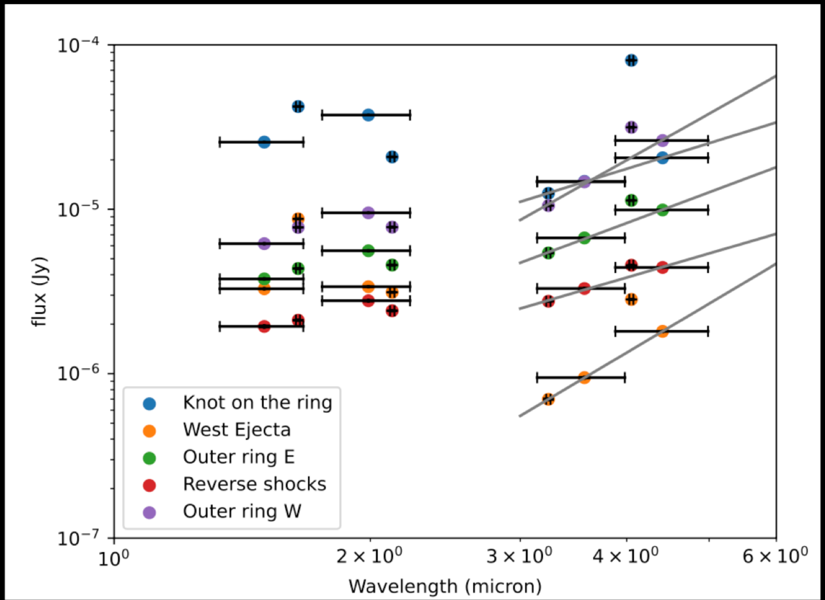
The magnetic field of ~2 mG

ALMA Polarisation (Zanardo 2018)

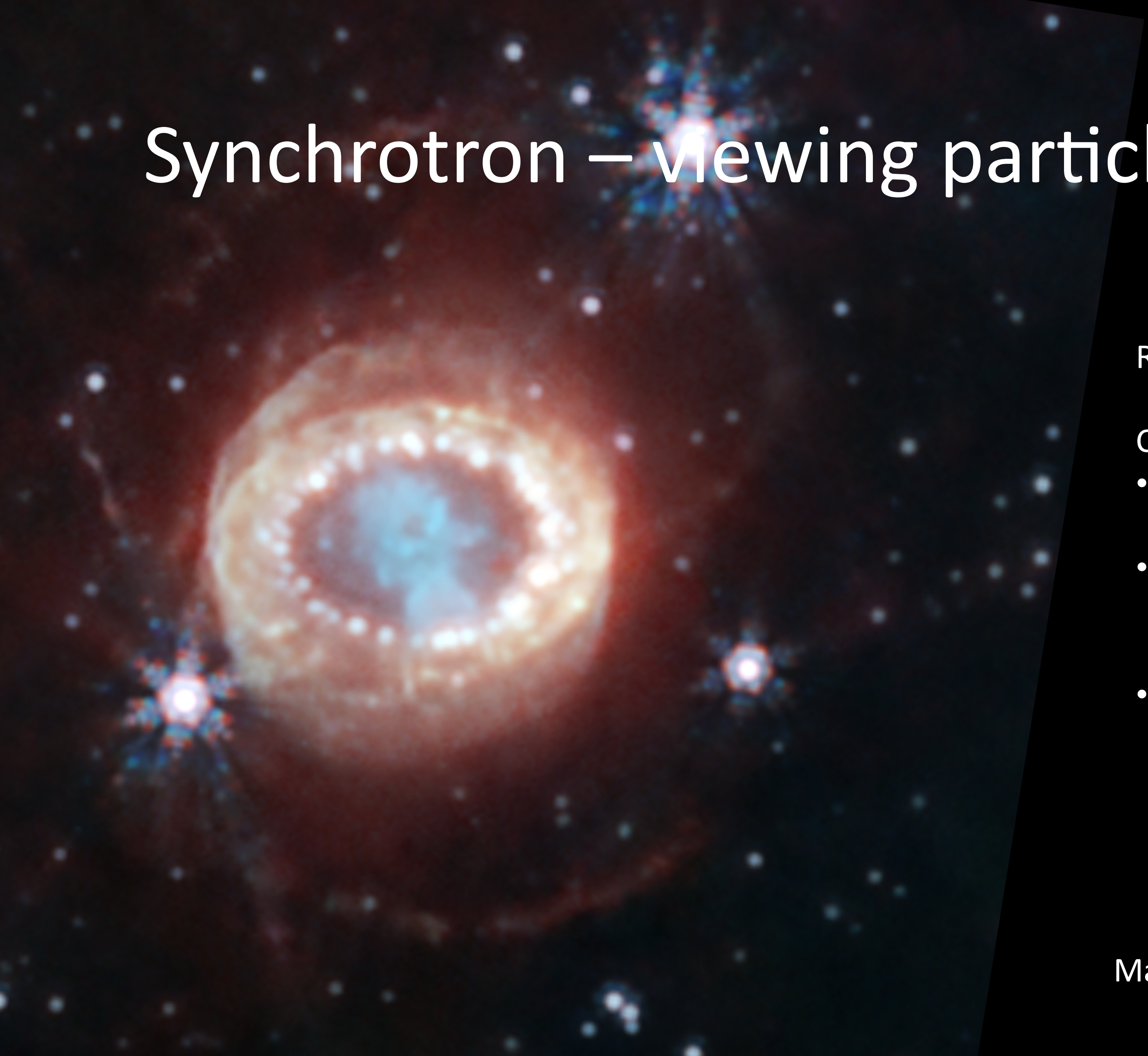
Outer spots

Spectral index α ~ 1.5–2.0

Synchrotron + Dust



Synchrotron – viewing particle accelerations

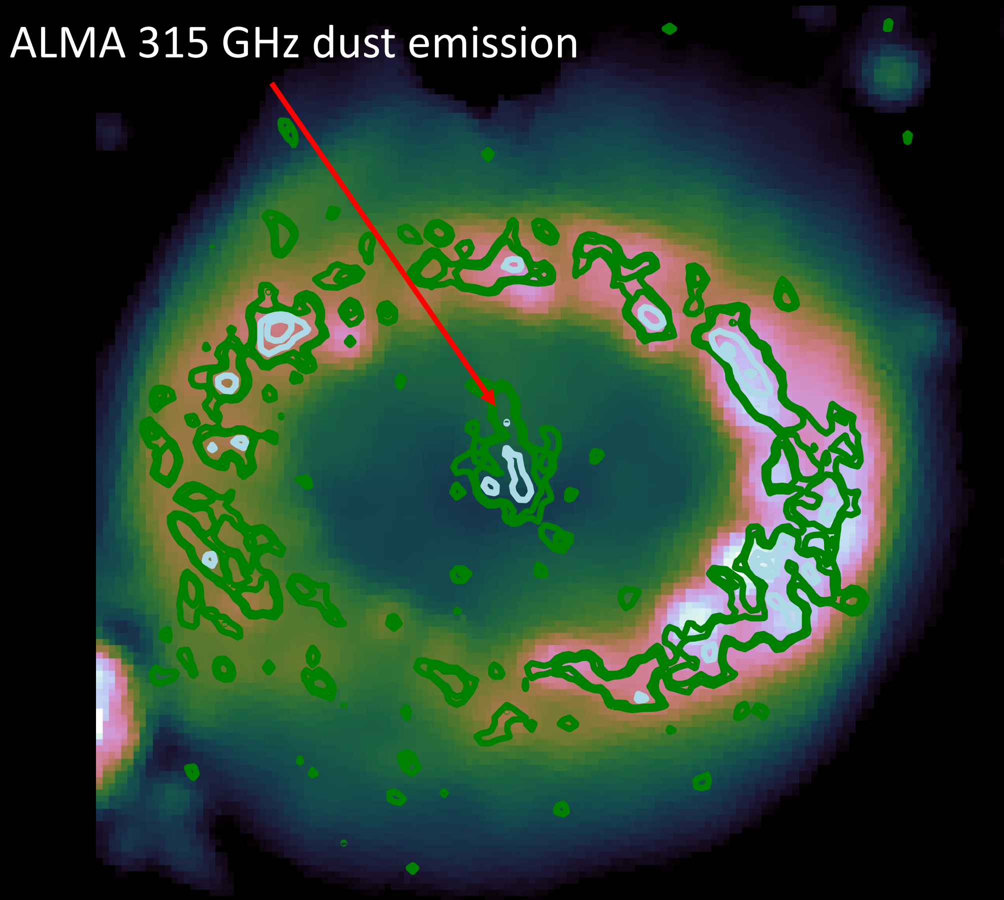


Radial distributions

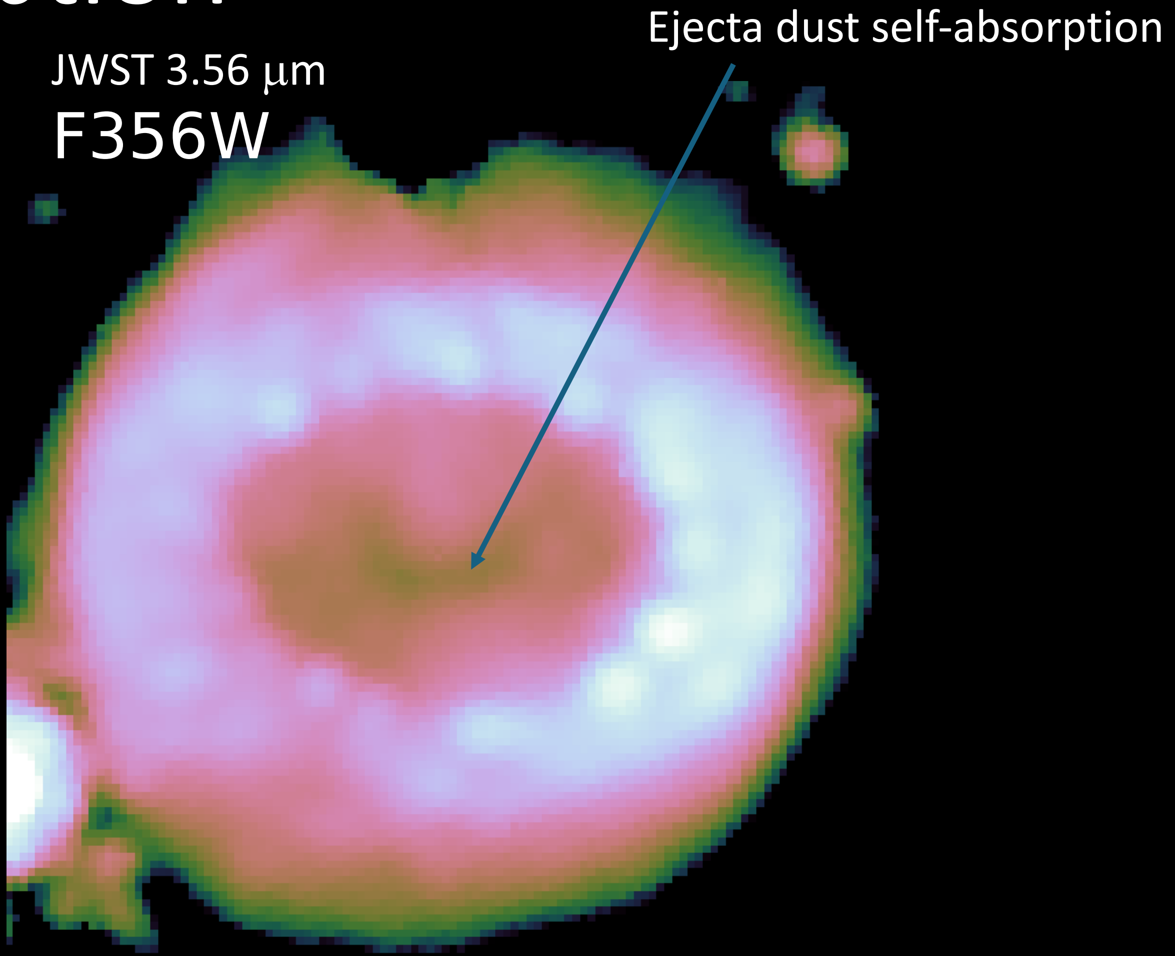
Cooling time scale
- Dust <10 years (a few years)
  - Small dust grains
- Synchrotron
  - ~10 years
  - The magnetic field of ~2 mG
- Hydrogen recombination lines
  - ~10–15 years
  - Shocked gas (10^7 K)
    - X-ray (not optical)

Matsuura et al. (2024)

Ejecta dust – self-absorption



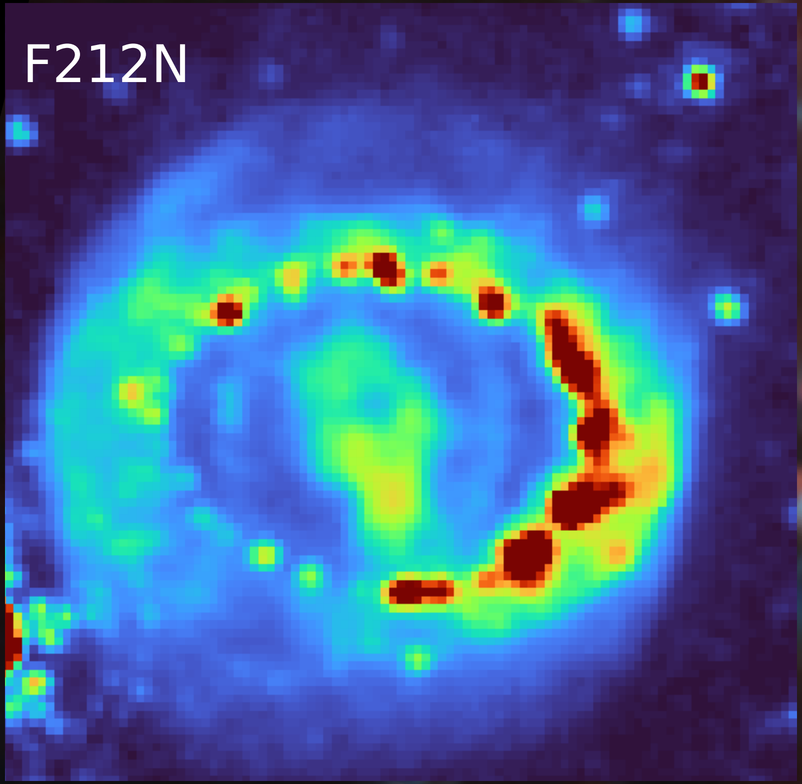
Colour: JWST 3.56 μm
Line contour: ALMA 315GHz
Dust emission from the ejecta

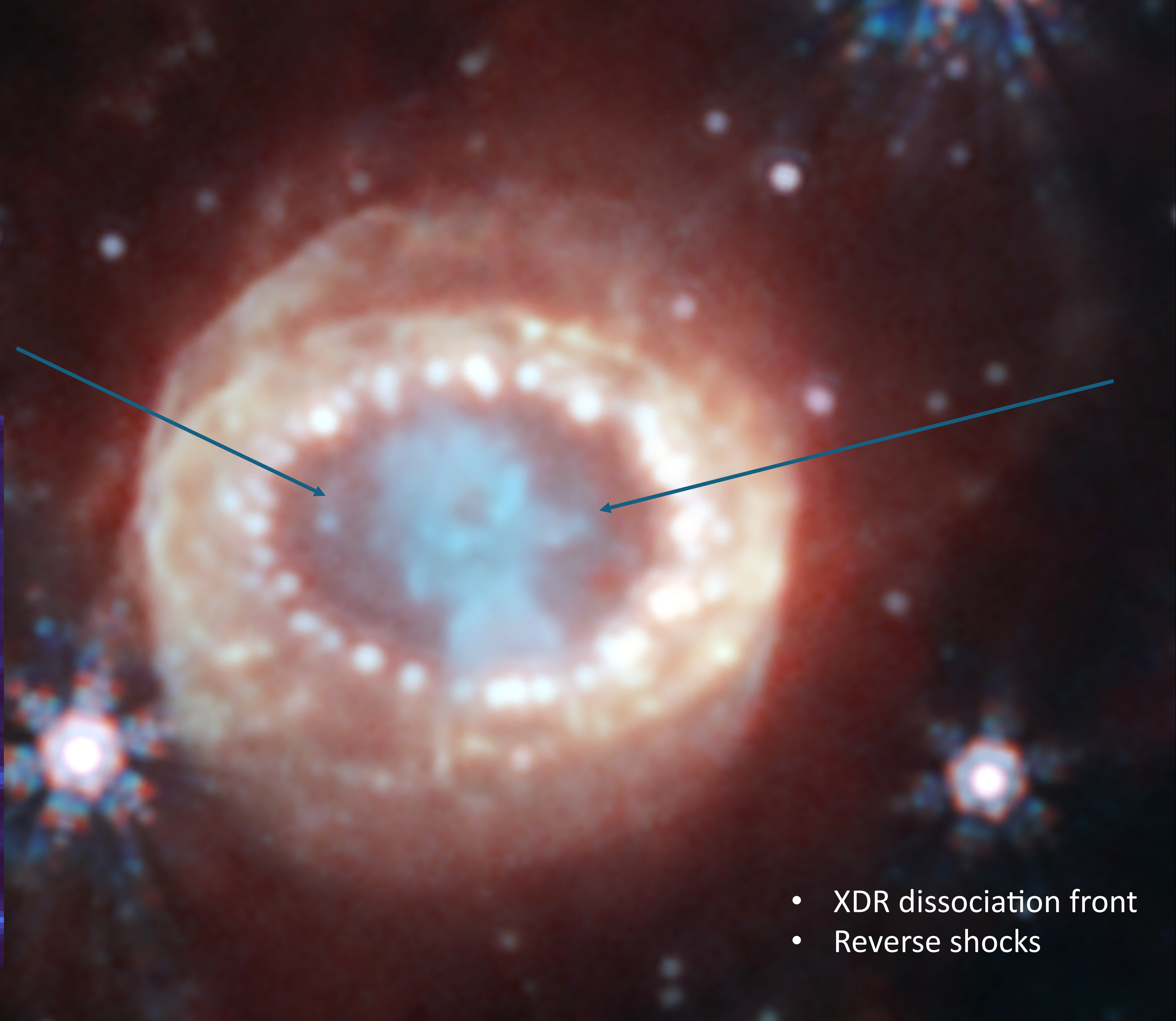


Herschel FIR estimate of ~0.5 Msun dust
(Matsuura et al. 2015)

Crescents

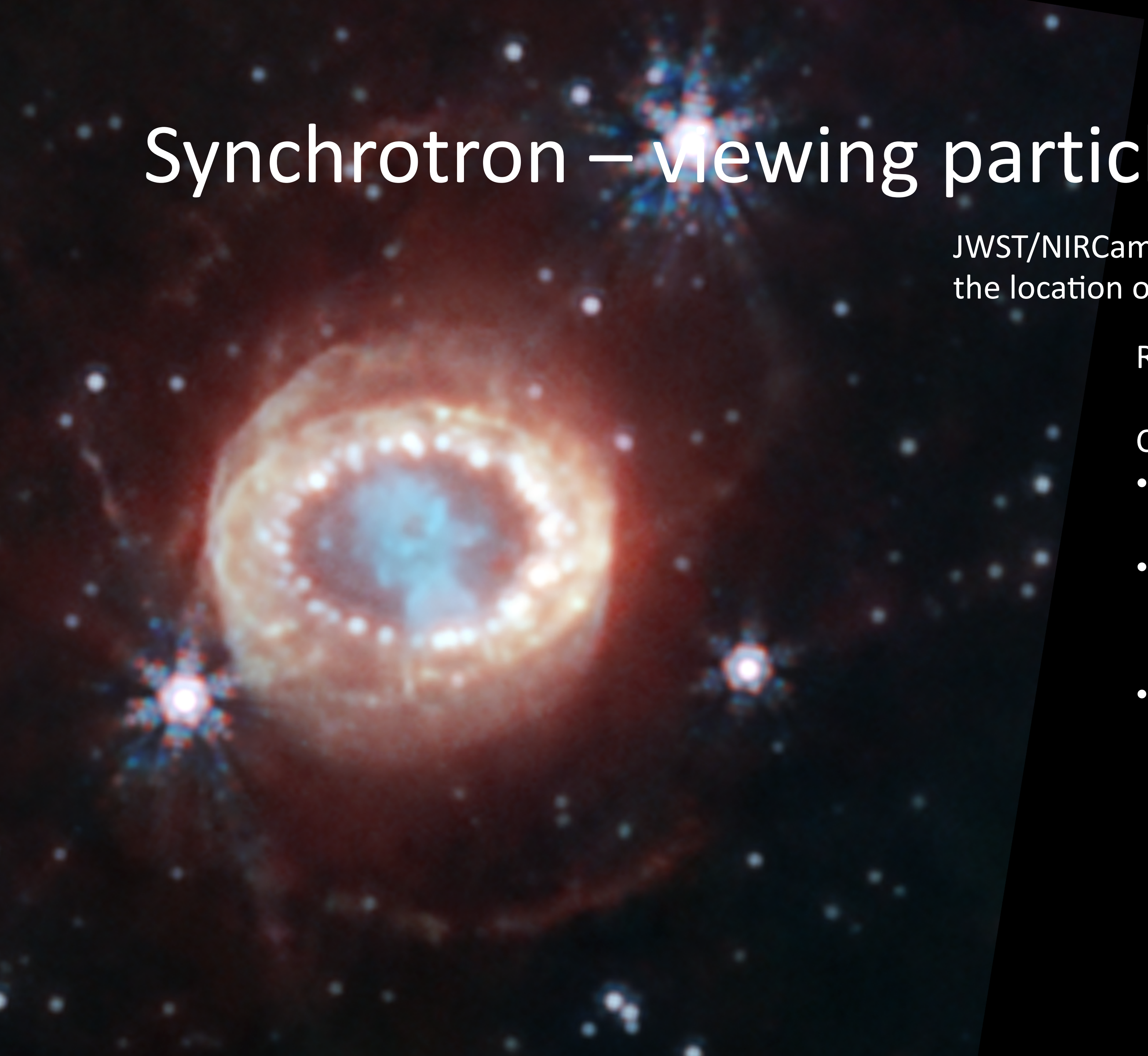
2.12 μm H_2





- XDR dissociation front
- Reverse shocks

Synchrotron – viewing particle accelerations



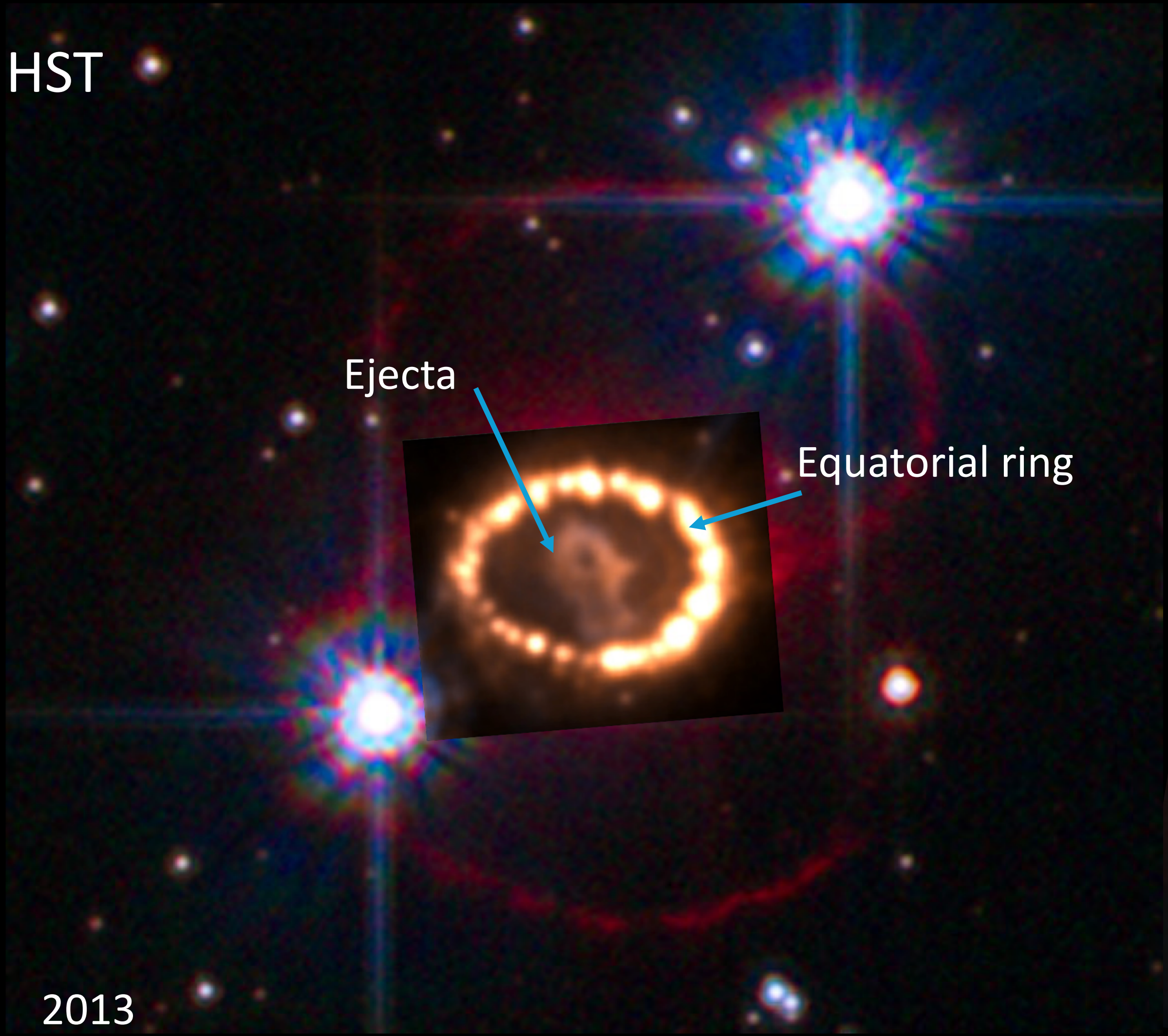
JWST/NIRCam – high spatial resolution images to detect the location of shocks

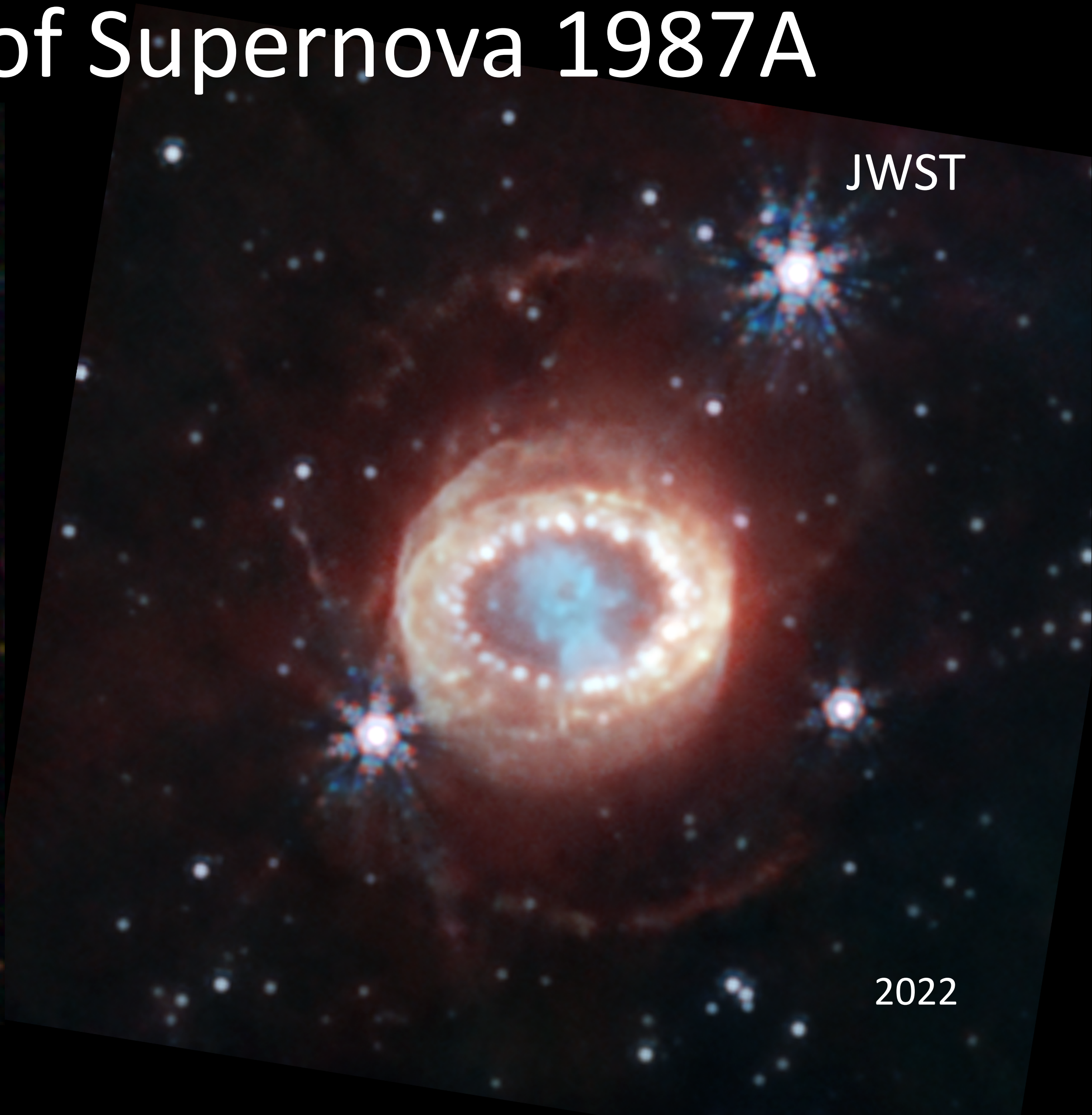
Radial distributions of different components

Cooling time scale

- Dust <10 years (a few years)
  - Small dust grains
- Synchrotron
  - ~10 years
  - The magnetic field of ~2 mG
- Hydrogen recombination lines
  - ~10–15 years
  - Shocked gas (10^7 K)
    - X-ray (not optical)

HST & NIRCam images of Supernova 1987A



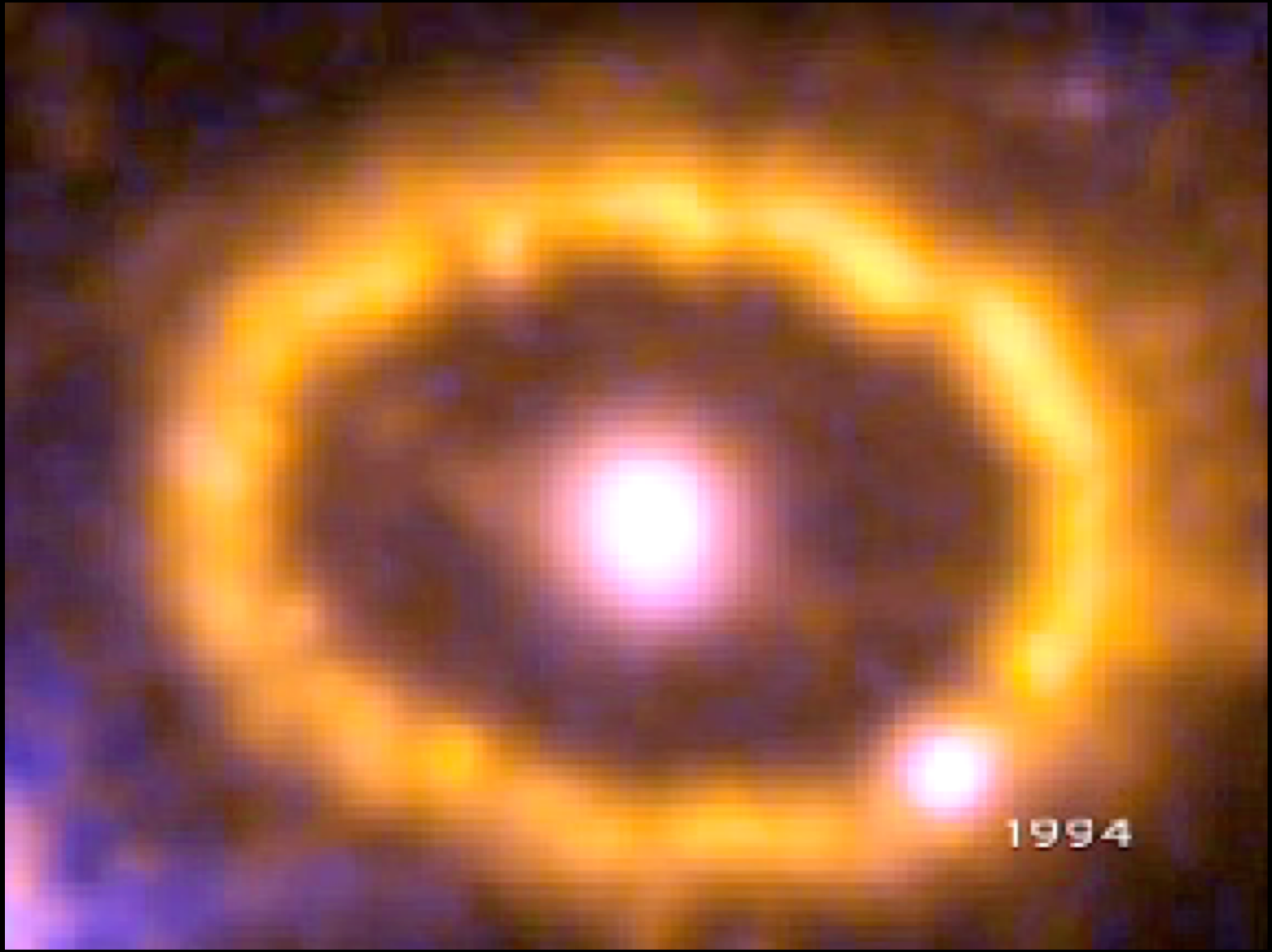


NASA/ESA/K. France/P.Challis/R.Kirshner

Larsson et al. (2019)

Supernova 1987A

Real-time astronomy



HST