AT2020mrf

The Most X-ray Luminous Cow-like Supernova

Yuhan Yao (Graduate Student, Caltech)
with Anna Ho (UC-Berkeley), Dan Perley (LJMU),
and the *SRG* team

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AT2018cow: the "Cow" supernova

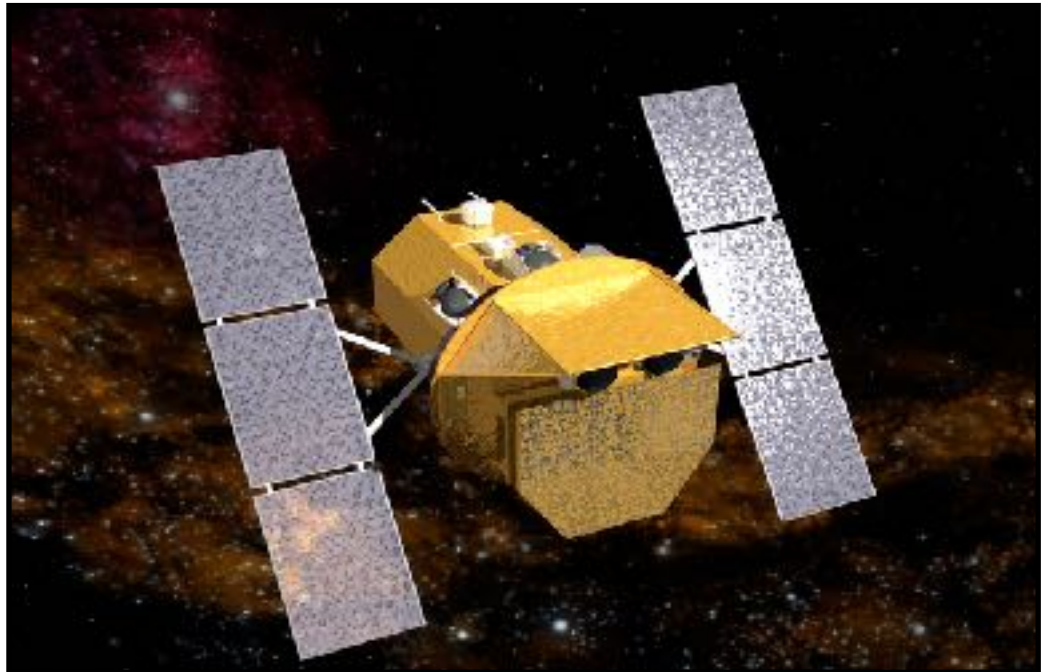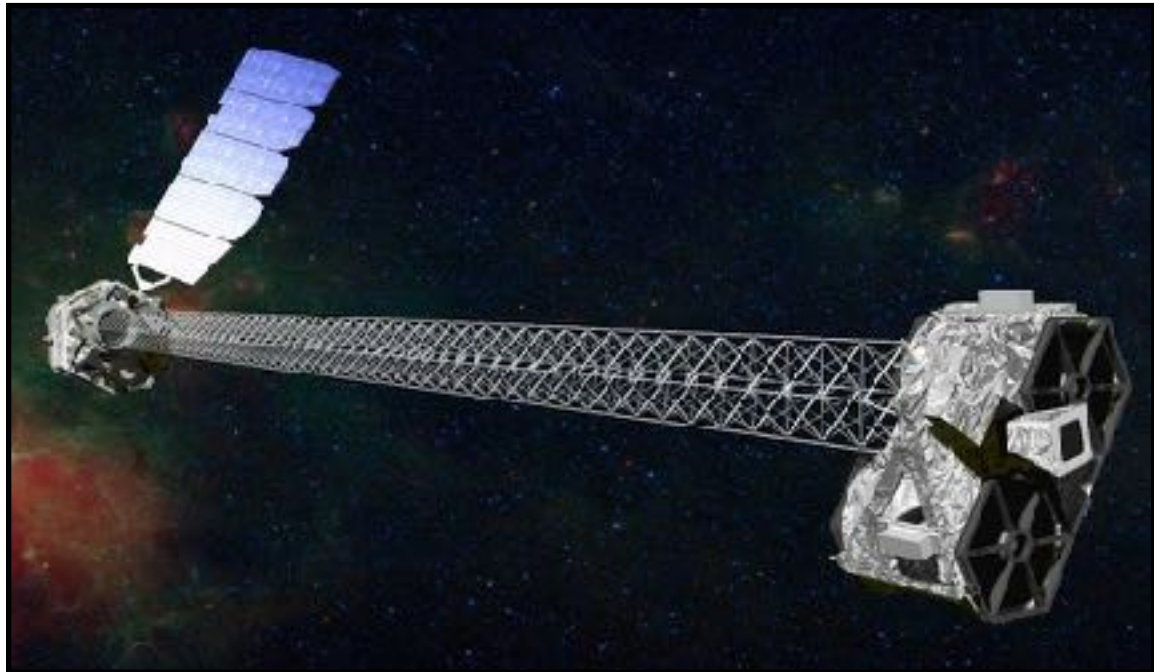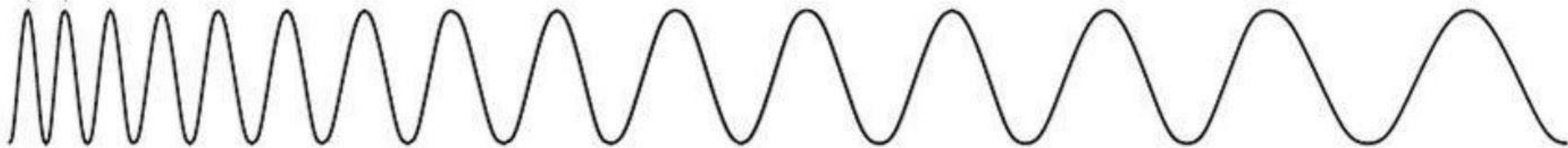The death of a star shining across the electromagnetic spectrum!

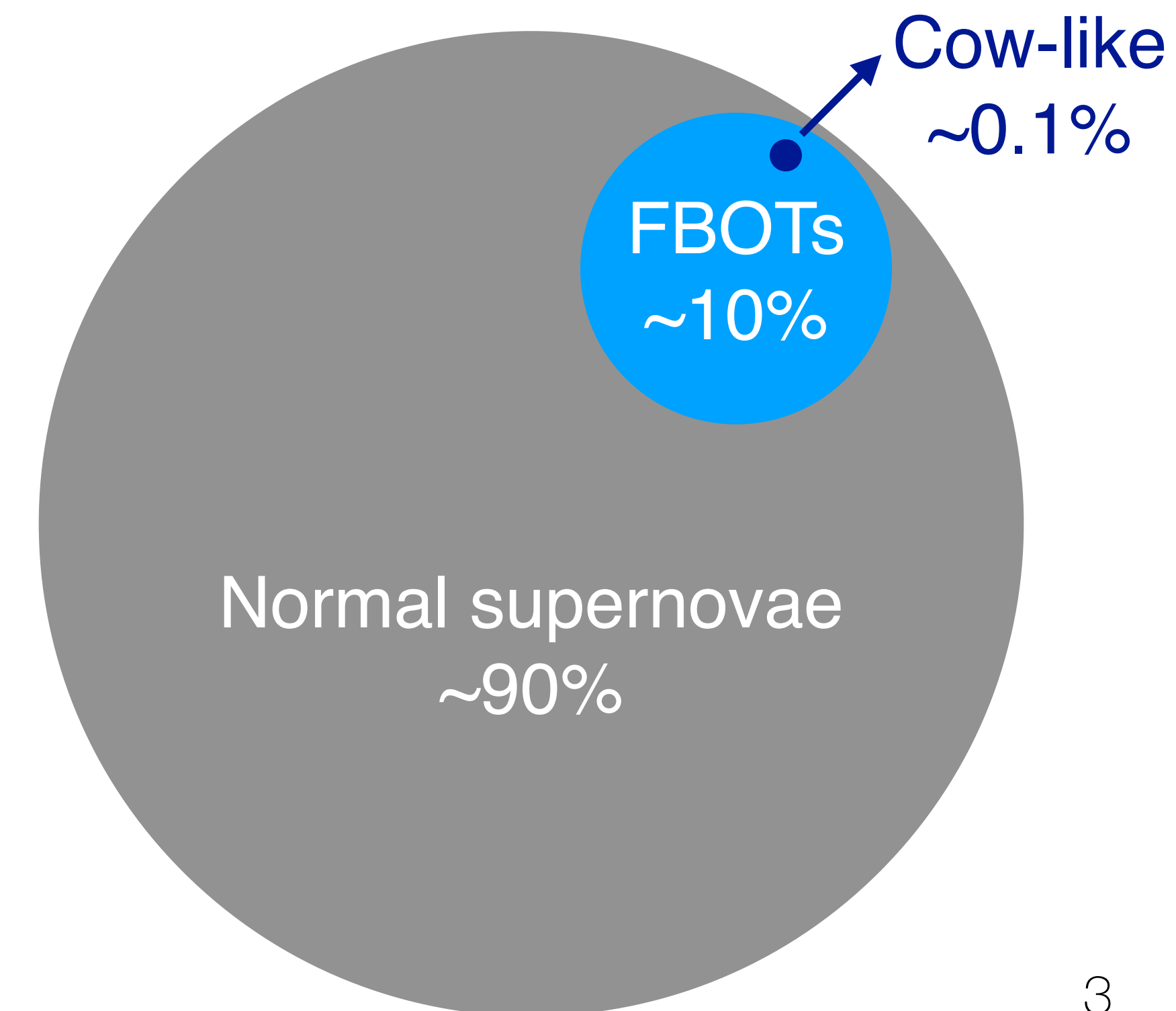| X-ray	Ultraviolet	Optical	Infrared	Millimeter	Radio

Cow-like Supernovae

- A subclass of Fast Blue Optical Transients (FBOTs)

- Very dense material surrounding the star
  Excites a shock wave that travels at a velocity = 0.1 x speed of light

- Ongoing energy production from a central energy source ("engine")
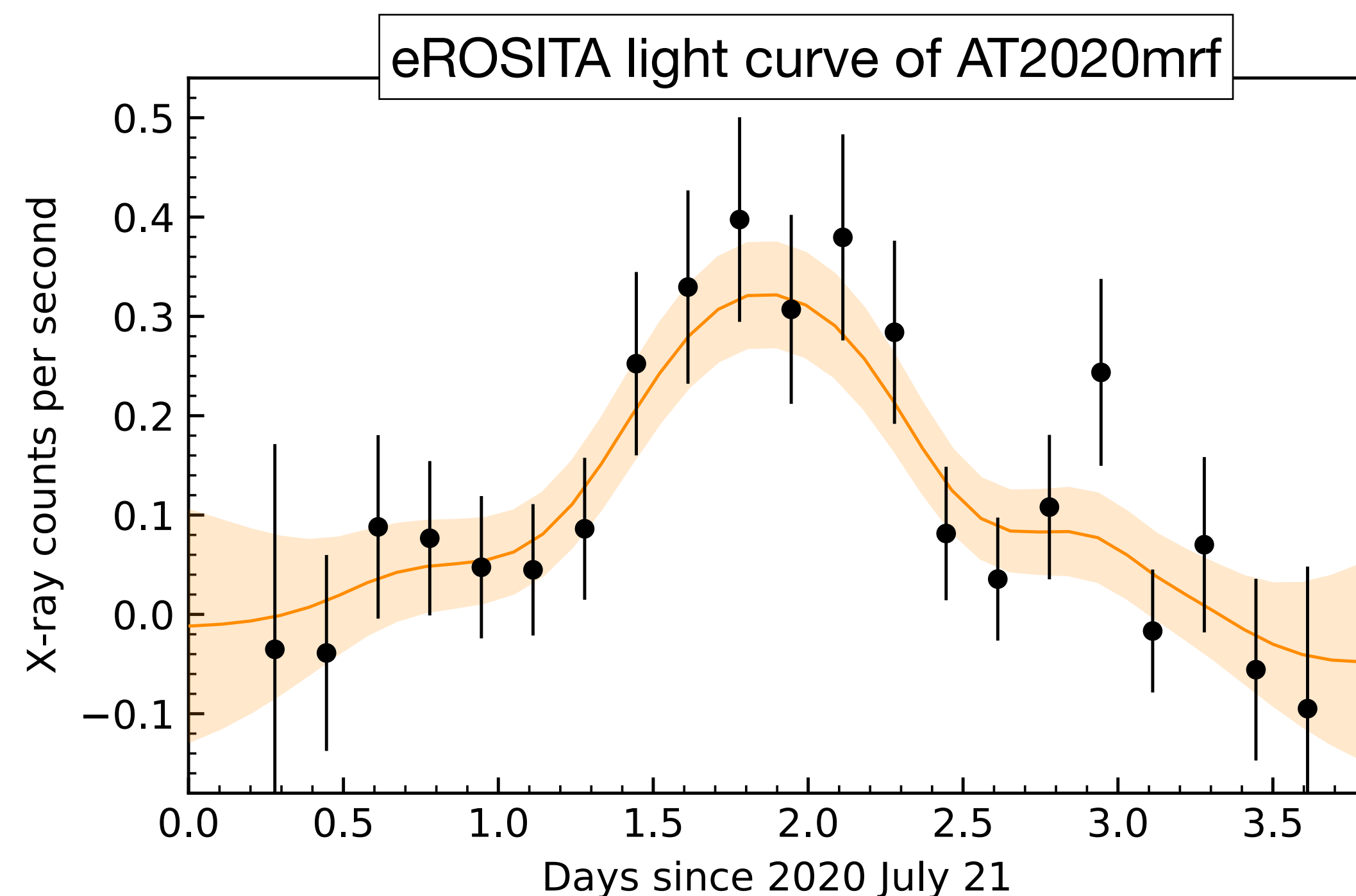
- Four objects known before

Normal Supernova

Credit: Bill Paxton, NRAO/AUI/NSF

Cow-like Event
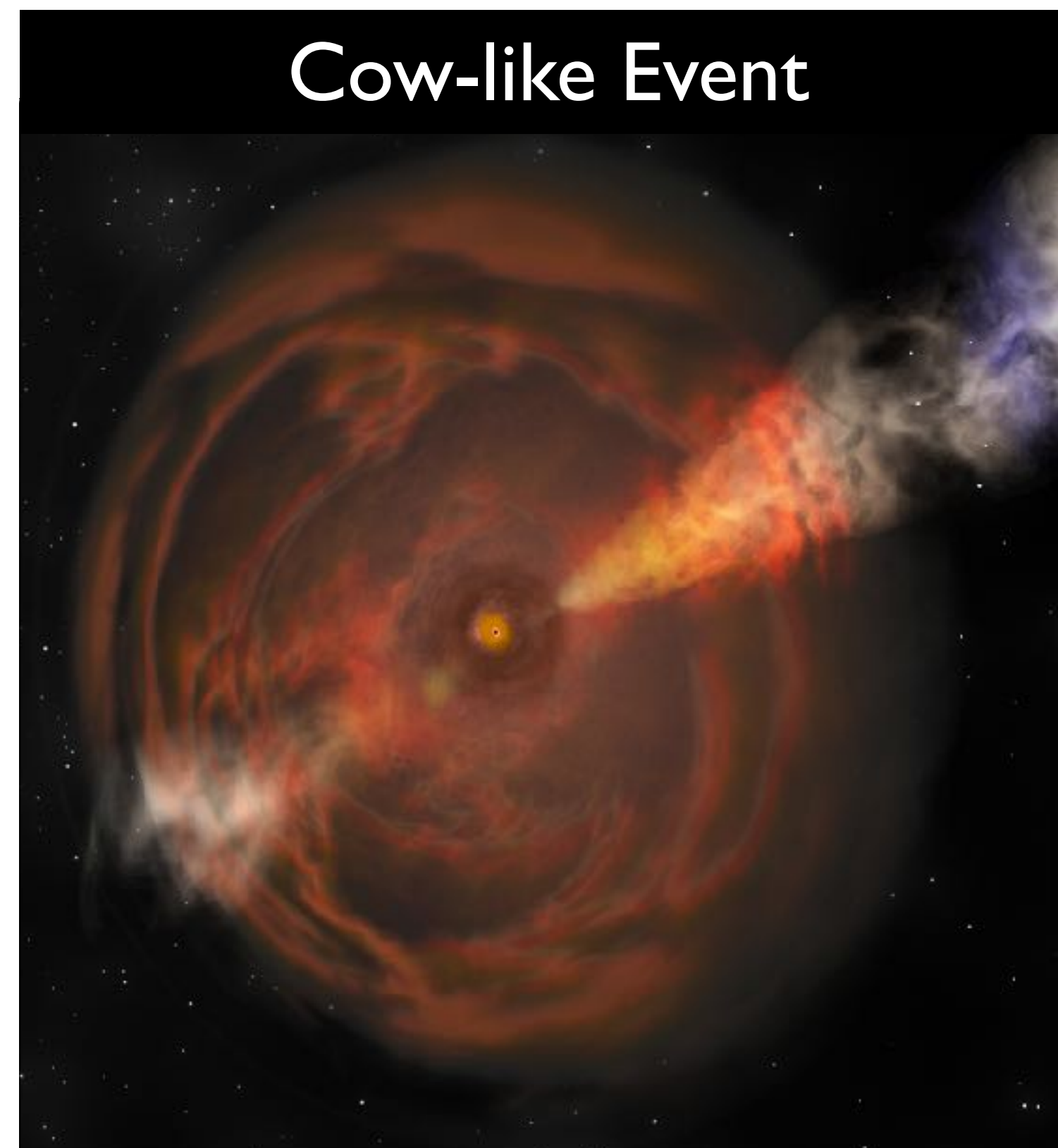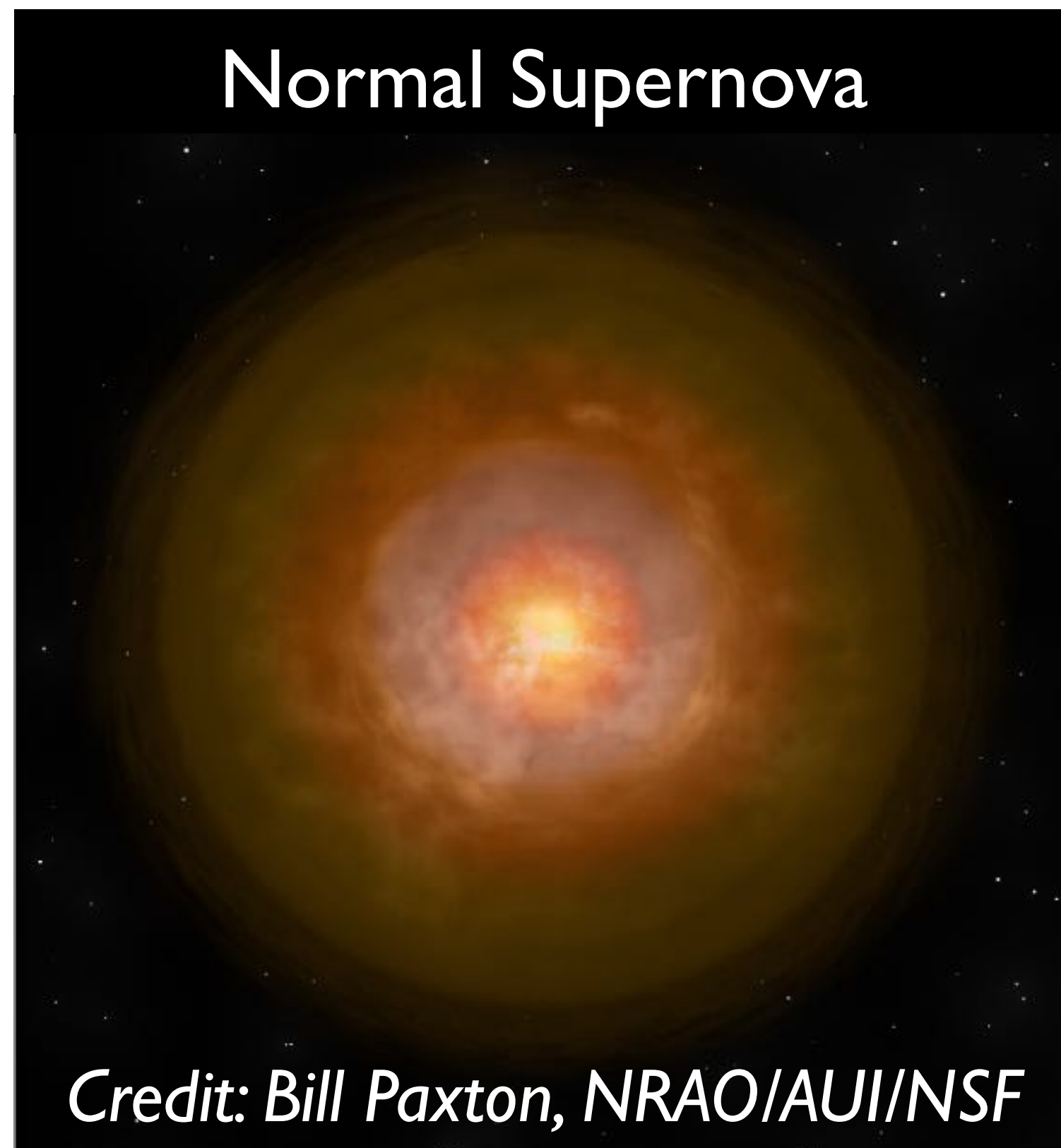
Rate of Massive Star Explosions

Cow-like ~0.1%
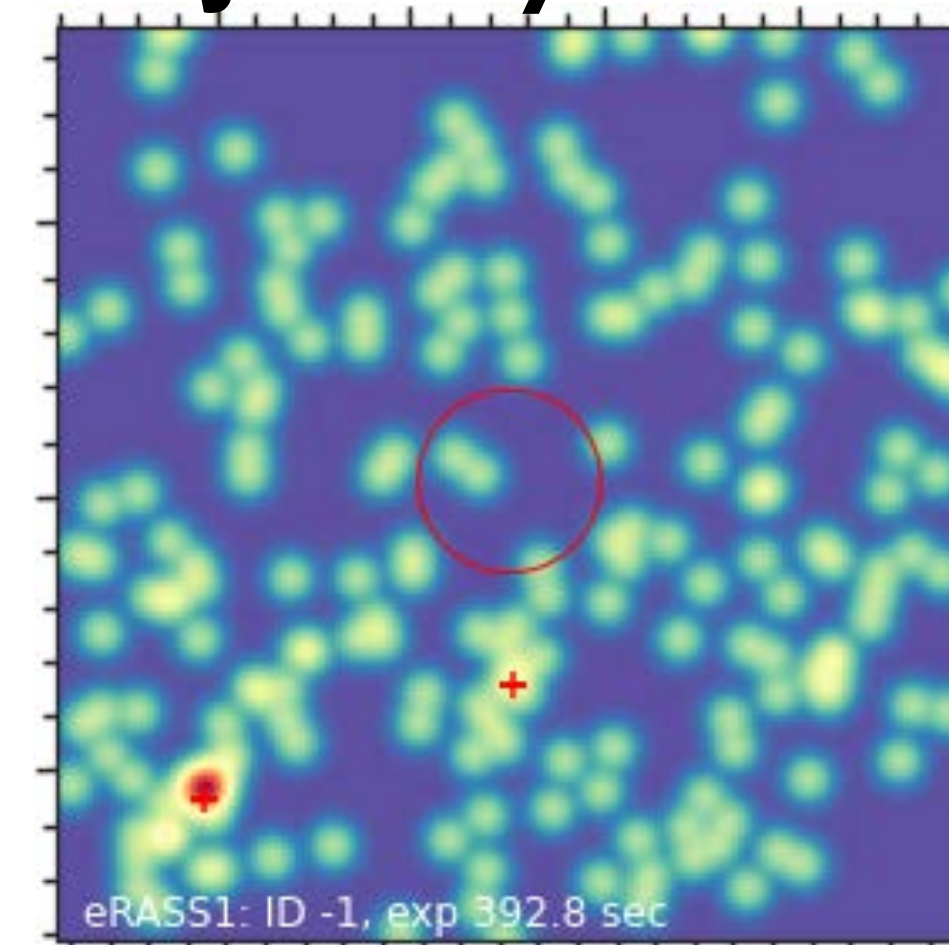
FBOTs ~10%

Normal supernovae ~90%

SRG discovers a new X-ray source

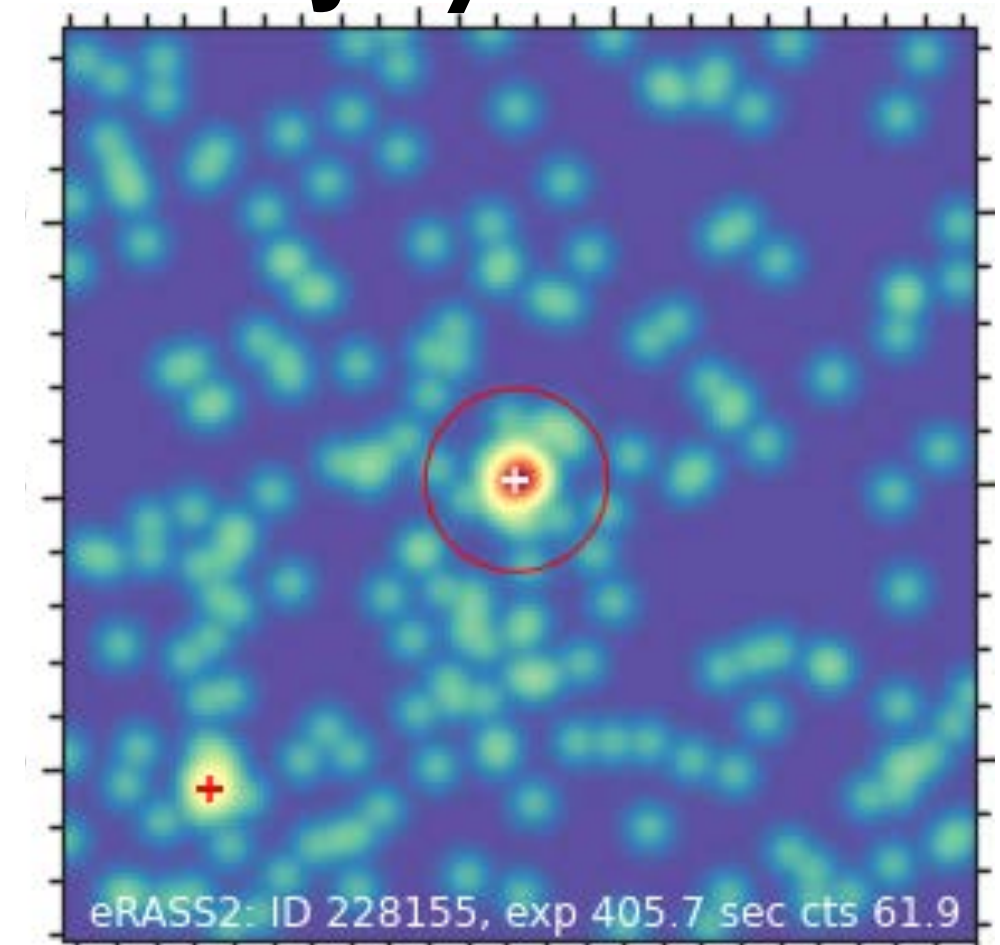- *Spektrum-Roentgen-Gamma (SRG)*
  The 1st X-ray mission at the Sun-Earth L2 point
  8 all-sky surveys in 2020—2023

- In July 2020, discovered a new X-ray source

- Fast X-ray variability

eROSITA

eROSITA light curve of AT2020mrf

X-ray counts per second

Days since 2020 July 21

January 2020

eRASS1: ID -1, exp 392.8 sec
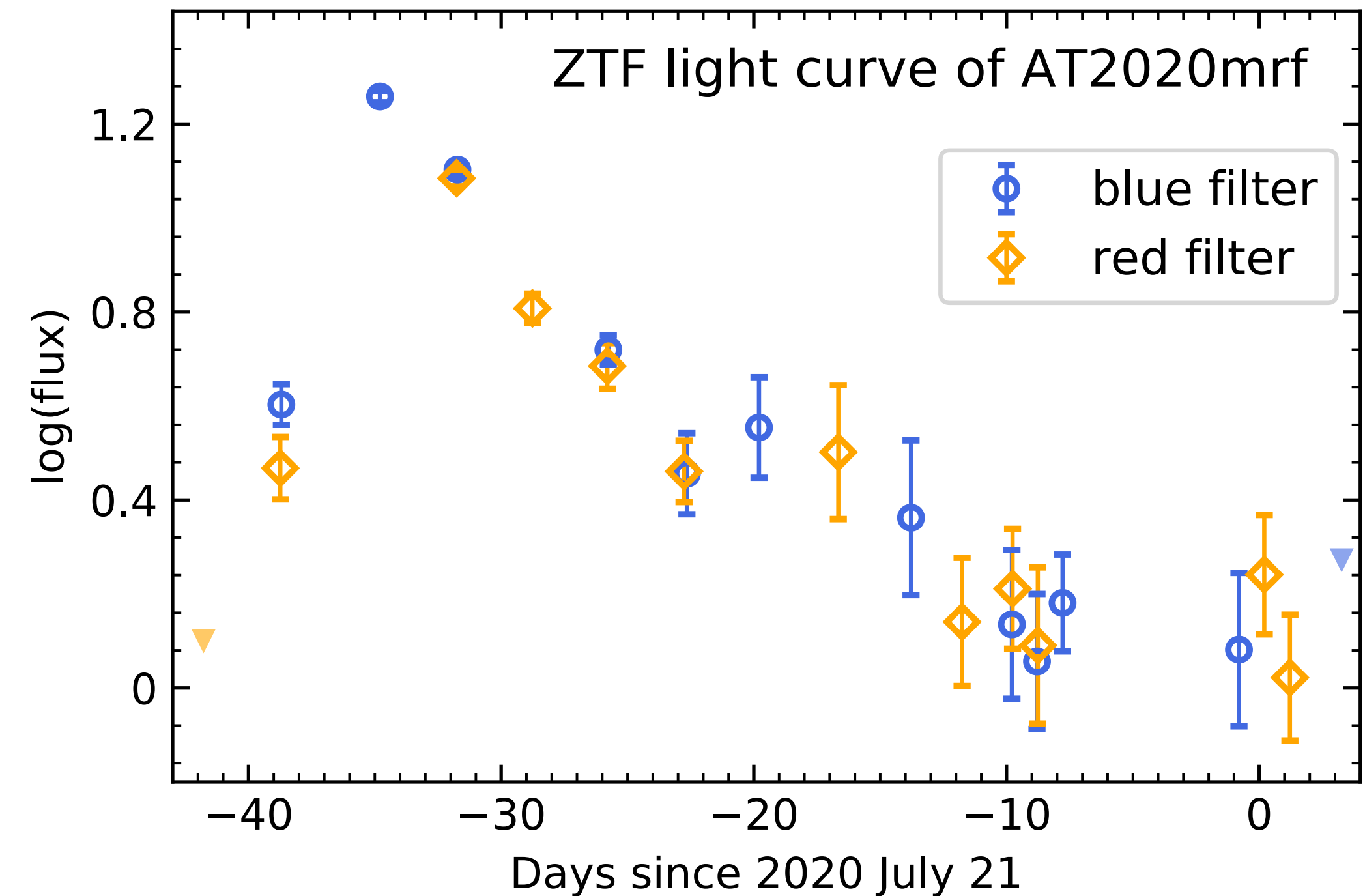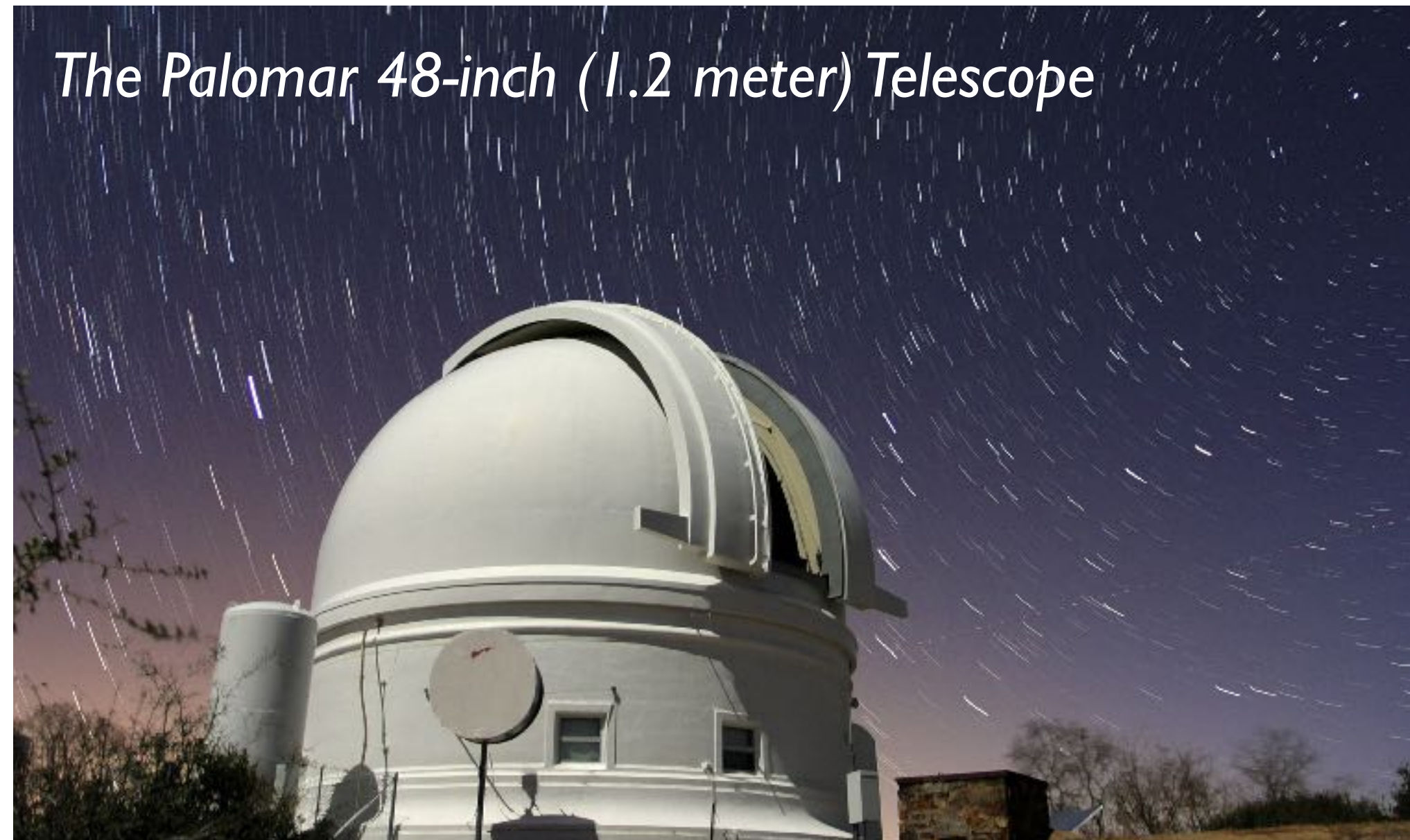
July 2020

eRASS2: ID 228155, exp 405.7 sec cts 61.9

4

Also detected in the optical as an FBOT

- In June 2020, a fast & blue **optical** transient was detected by the Zwicky Transient Facility (**ZTF**) optical survey at the Palomar Observatory

The Palomar 48-inch (1.2 meter) Telescope

ZTF light curve of AT2020mrf

blue filter
red filter

log(flux)

Days since 2020 July 21

- From a small star-forming galaxy 2×10^9 light years away

- In 2021, detected in the **radio** by the NRAO's Very Large Array (**VLA**) and uGMRT

→ **AT2020mrf is another Cow-like Event!**

One year after the stellar death…
# still detected by *Chandra*!

Chandra X-ray Observatory

- AT2020mrf's X-ray is **x20** brighter than
  AT2018cow at **~1 month** since explosion

- *Chandra* observations in June 2021
  AT2020mrf's X-ray is **>200 brighter** than AT2018cow at **~1 year** since explosion

- **29** photons received in the 1st 6 hours, **10** photons received in the second 6 hours
  Fast X-ray variability persists

→ **X-rays must be supplied by an active central engine**

Nature of the central engine

An actively accreting **black hole** or a rapidly spinning **neutron star**
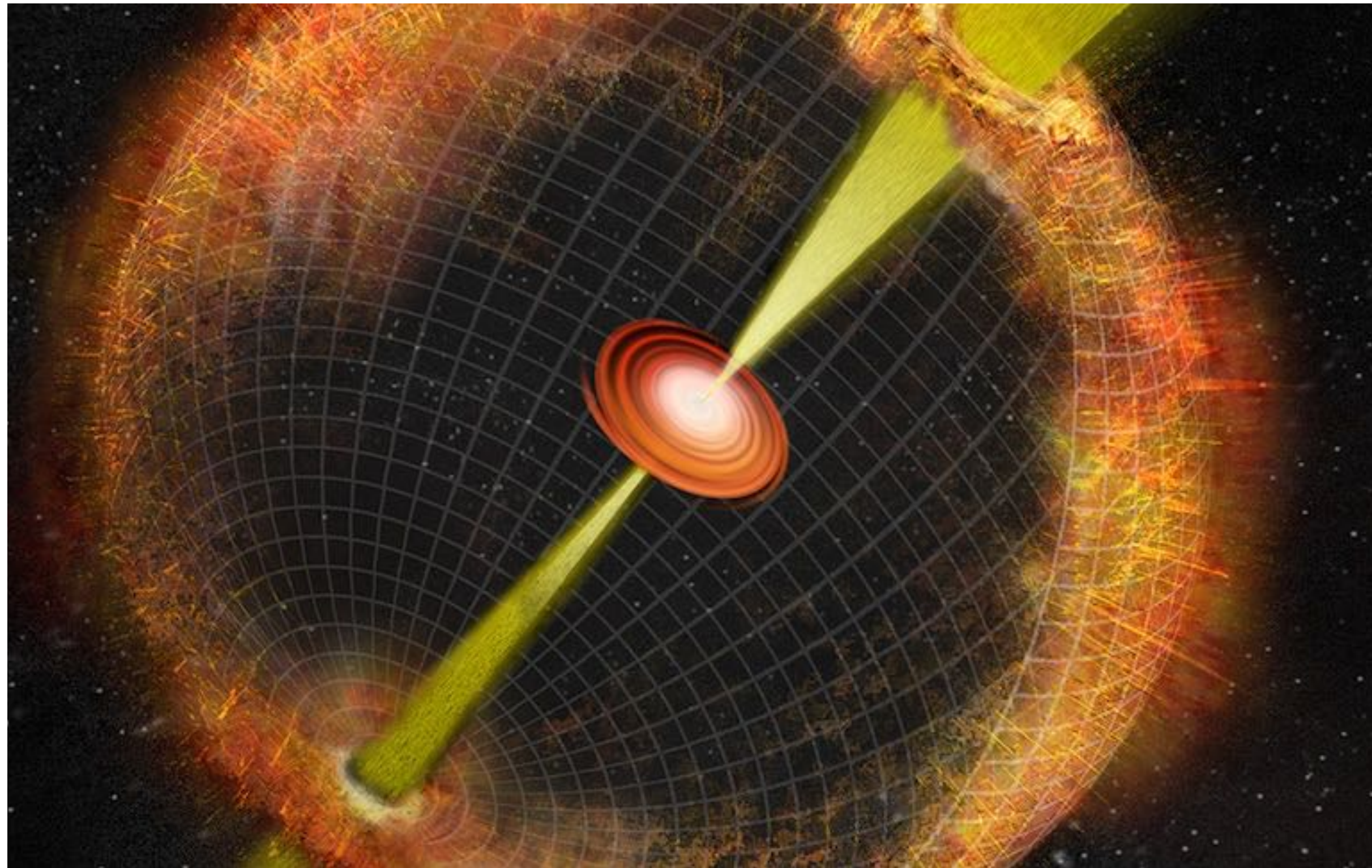
Credit: Bill Paxton, NRAO/AUI/NSF

Credit: Shanghai Astronomical Observatory, China

What we have learnt from AT2020mrf?

1. The most luminous Cow-like supernova in the X-ray

2. Demonstrates the diversity of Cow-like events

3. Further established Cow-like events as an emerging class of stellar explosions that produce an active central "engine" (i.e., a black hole or a neutron star) that is mostly exposed to the observers.

Cow-like events will continue to be prime transients for X-ray telescopes.
X-ray observatories provide an important window onto the birth of compact objects.

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