

# PRECURSOR ACTIVITY PRECEDING INTERACTING SUPERNOVAE

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*An Extraordinary Journey Into The Transient Sky*

Padua | Italy

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Stockholm  
University

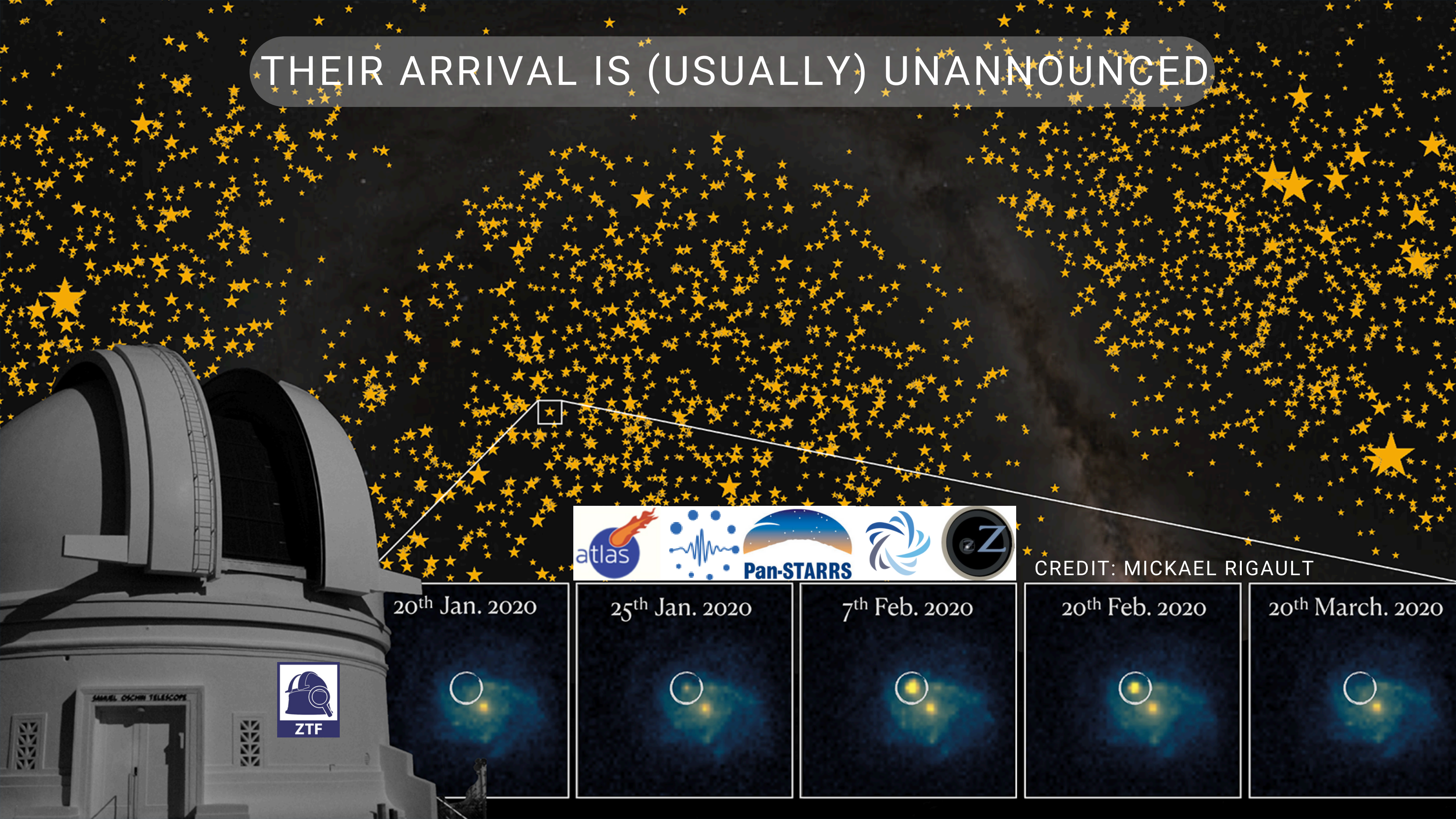


The background image depicts a dramatic cosmic event, likely a supernova or the collision of celestial bodies. At the center, a bright, glowing white and yellow core is surrounded by two large, textured, reddish-brown lobes that appear to be expanding or shattering. The entire scene is set against a deep black space, punctuated by wispy clouds of red and blue gas or dust. Several thin, straight lines of light in blue and yellow crisscross the frame, possibly representing light paths or gravitational fields. A few small, distant stars are visible in the upper left quadrant.

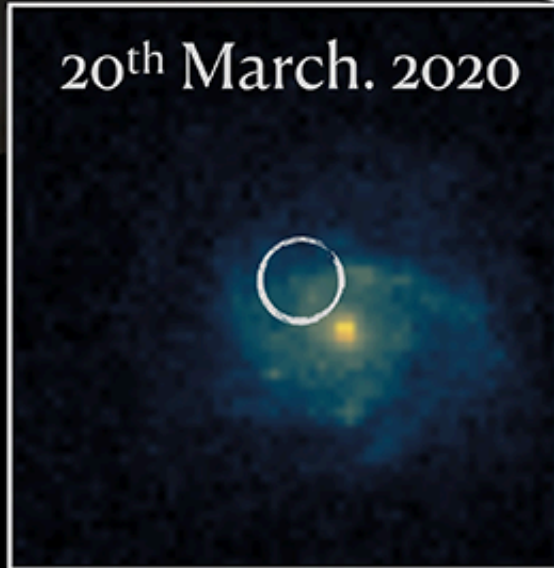
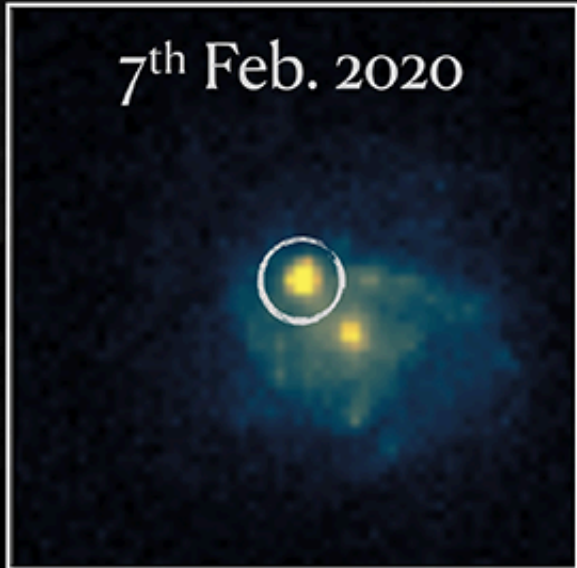
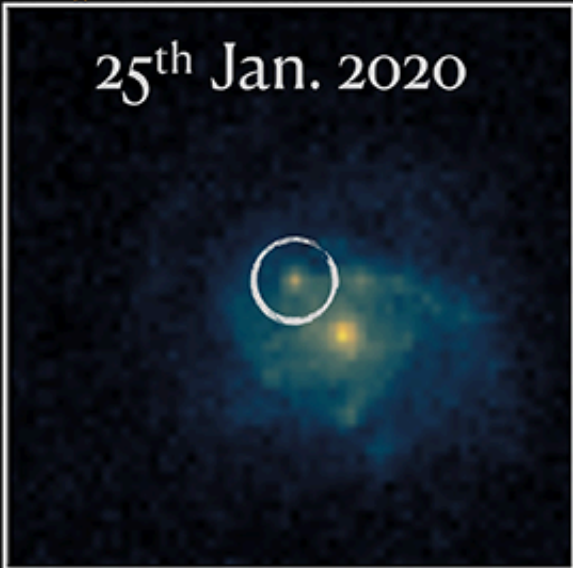
A **transient** is a short lived event that changes dramatically in brightness before fading



# THEIR ARRIVAL IS (USUALLY) UNANNOUNCED



CREDIT: MICKAEL RIGAULT





# A STAR ABOUT TO EXPLODE?

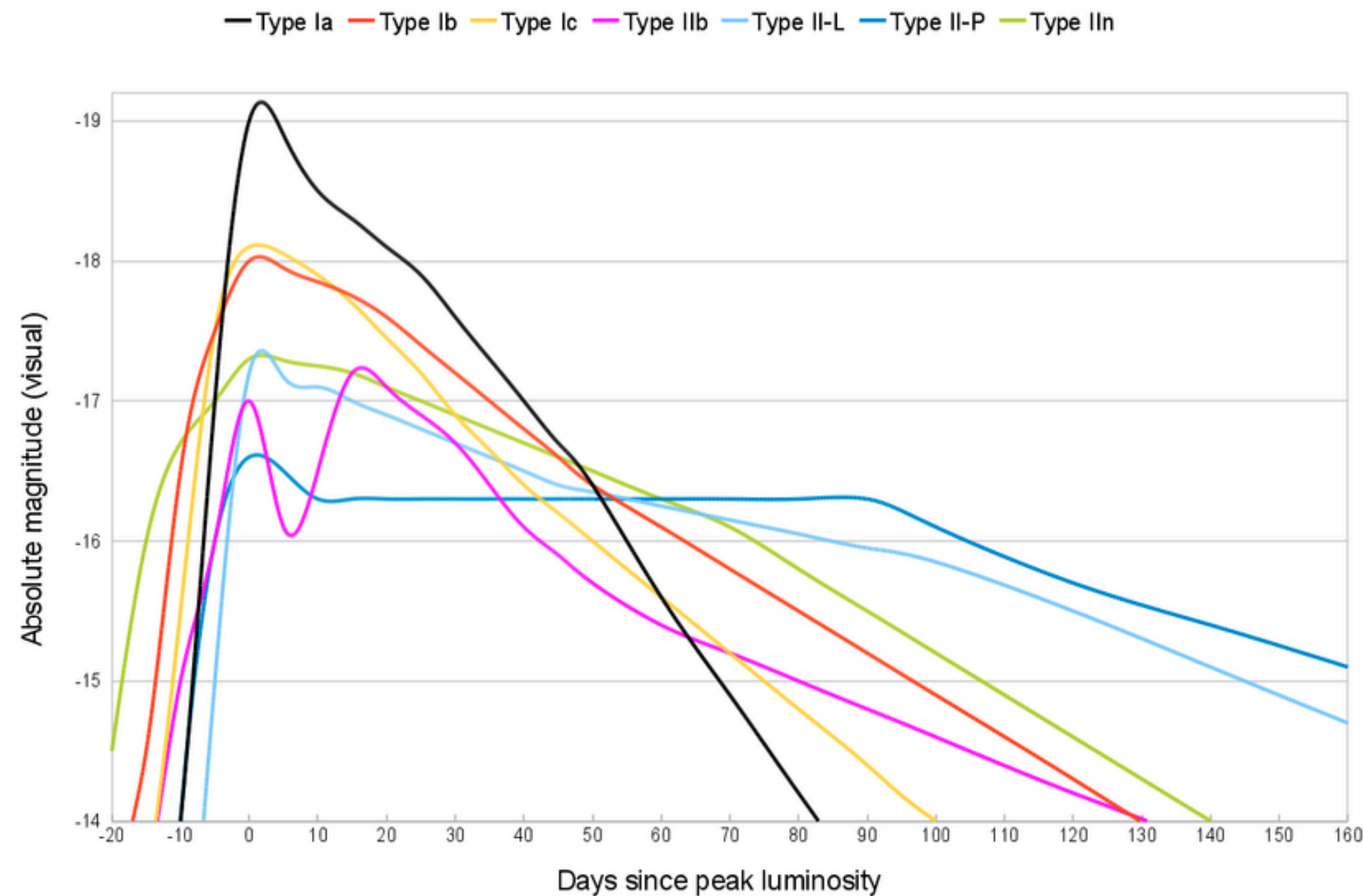




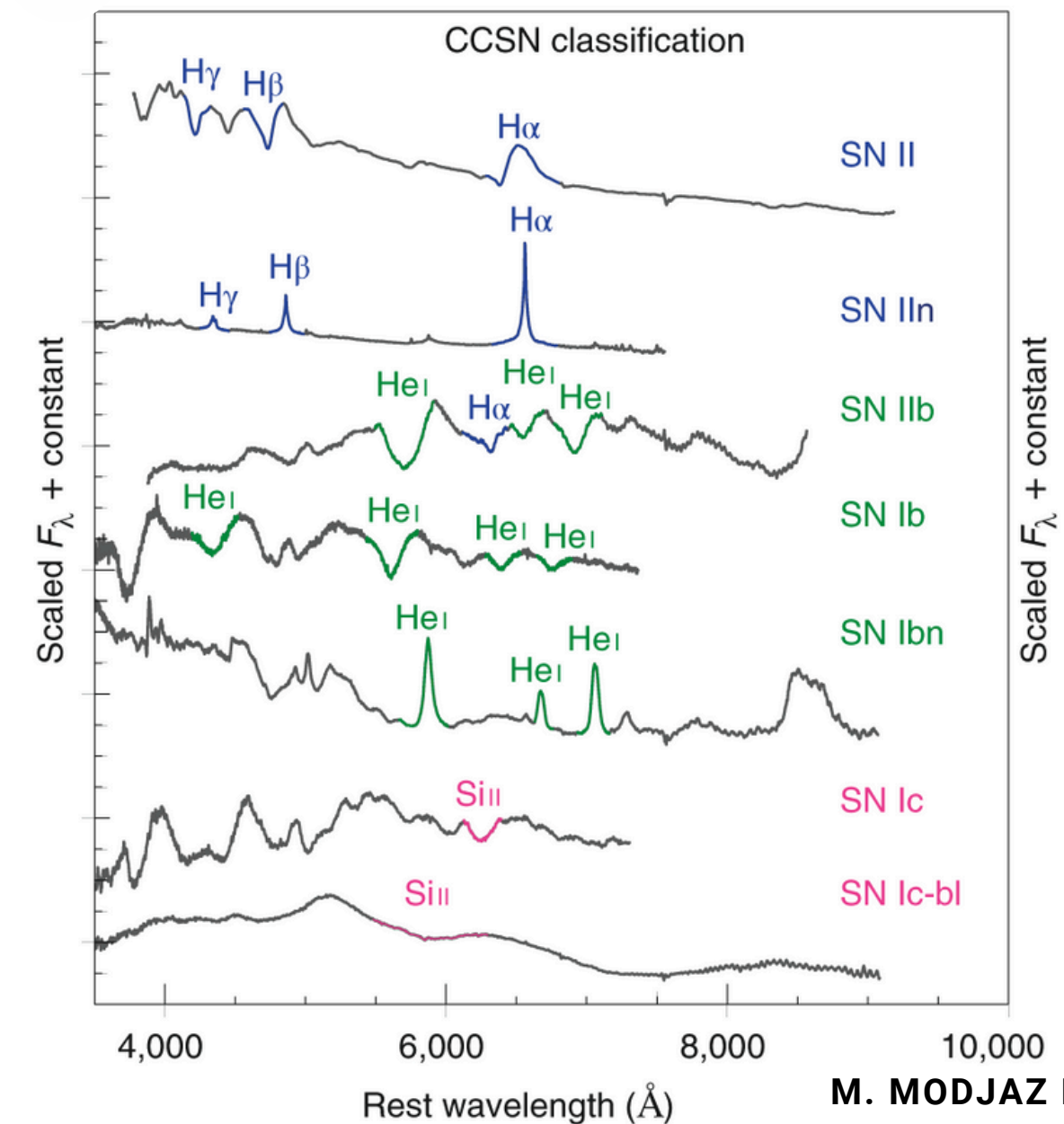
# PROGENITORS OF CORE-COLLAPSE SUPERNOVAE

## GAINING INSIGHT A POSTERIORI

How the explosion's *brightness* changes over time



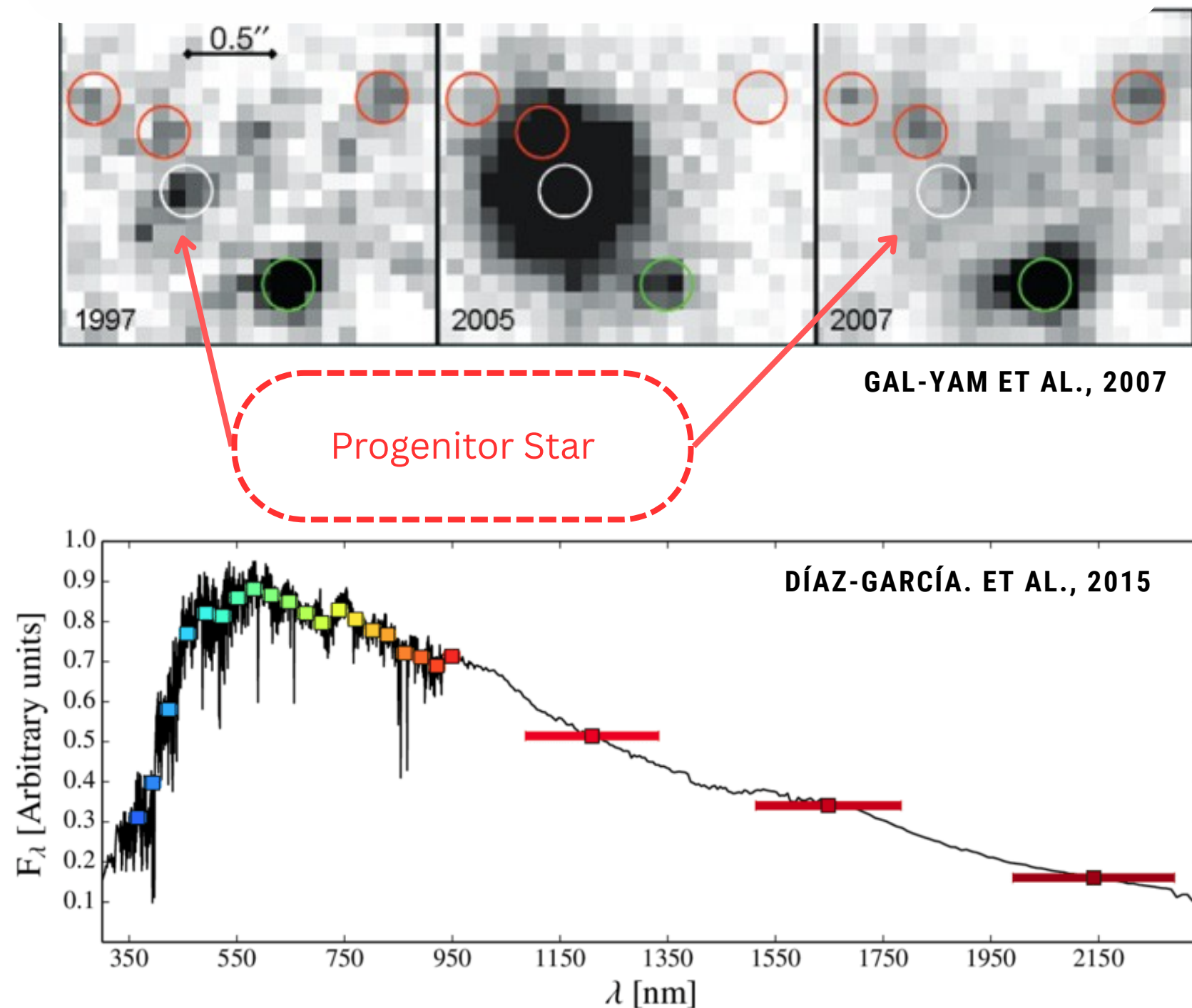
At what wavelengths the *energy* comes out



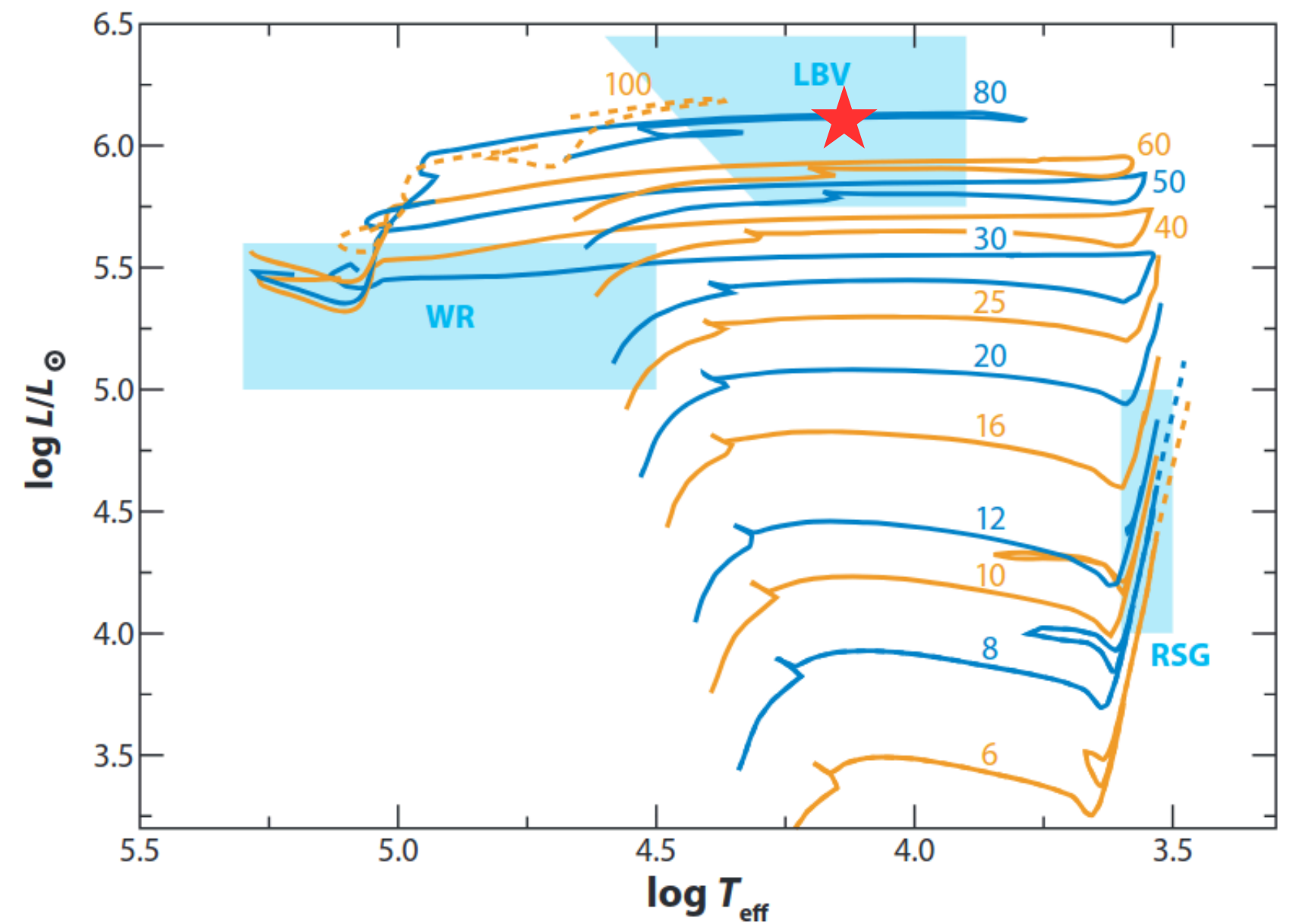


# PROGENITORS OF CORE-COLLAPSE SUPERNOVAE

## PRE- CORE-COLLAPSE DETECTIONS



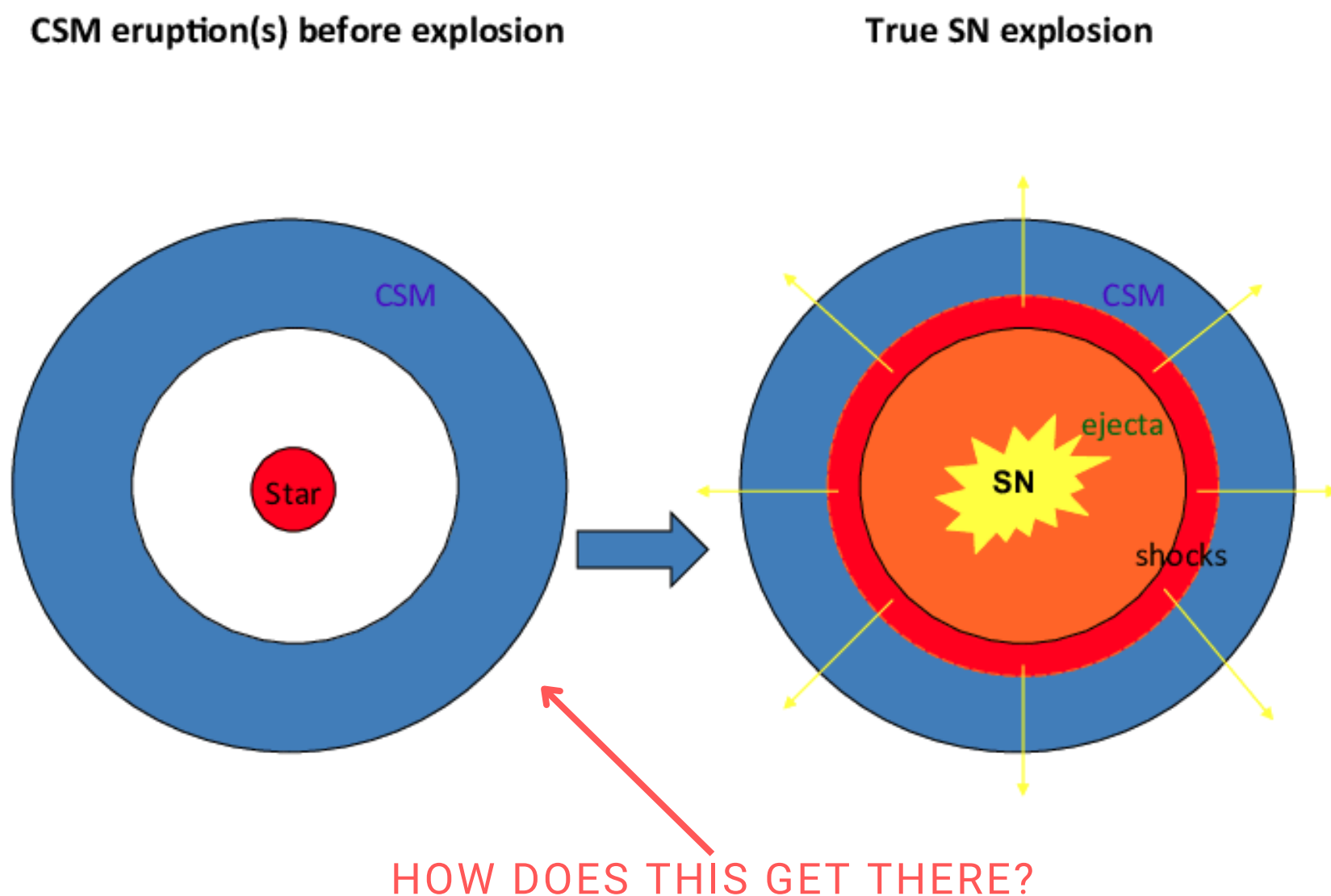
MODEL (*OBSERVATIONS*)  $\rightarrow$   $L_{\text{BOL}}, T_{\text{EFF}}$



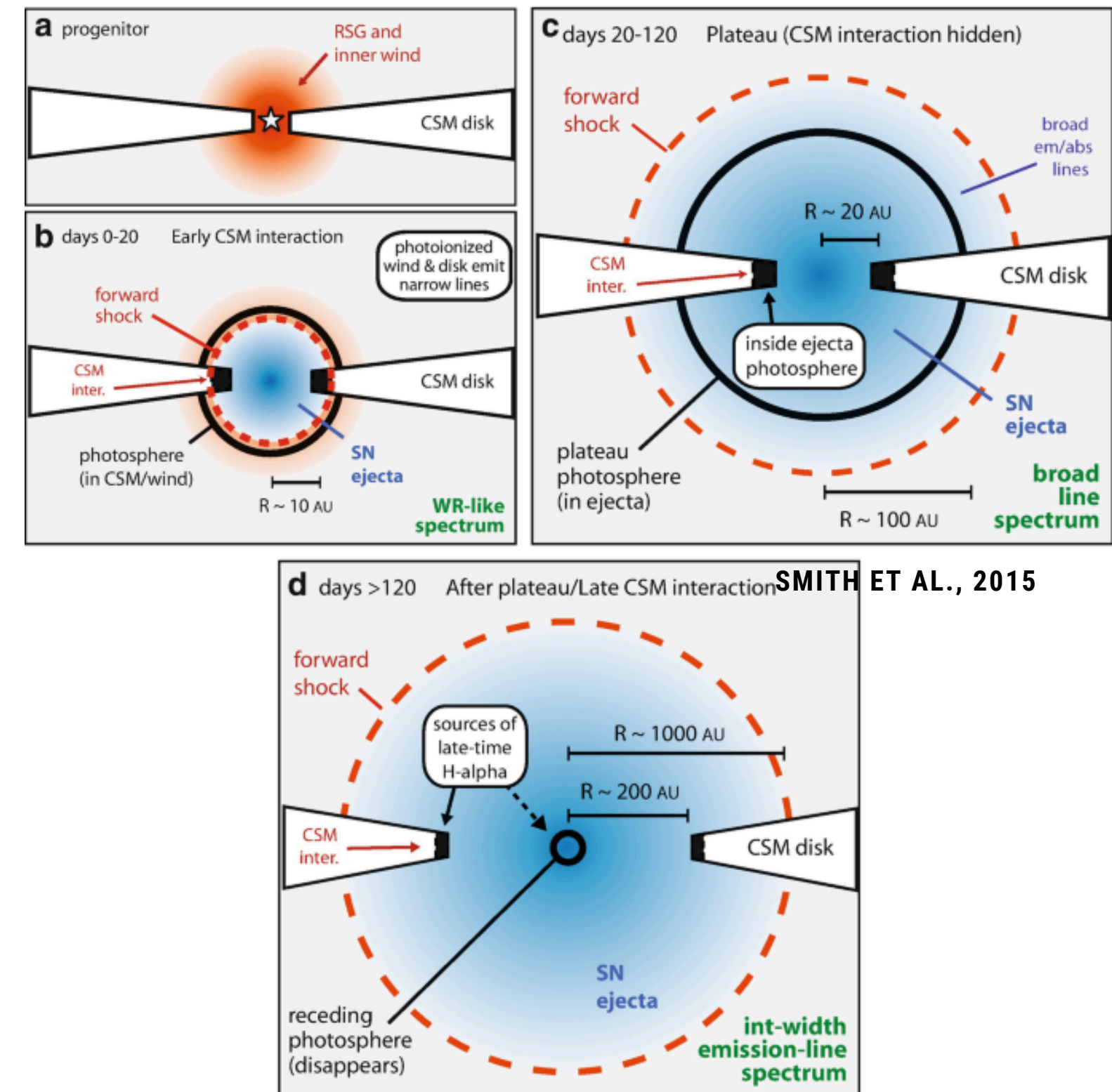


# INTERACTING SUPERNOVAE

## A) A SIMPLIFIED PICTURE



## B) MORE-REALISTIC PICTURE (ALTHOUGH NOT WELL EXPLORED)



OVER 2/3 OF TYPE II PROGENITORS NEED  $M_{\text{CSM}} \geq 10^{-2.5} M_{\text{SUN}}$  WITHIN  $R_{\text{CSM}} \sim 10^{15}$  CM



# SN 2009IP-LIKE TRANSIENTS

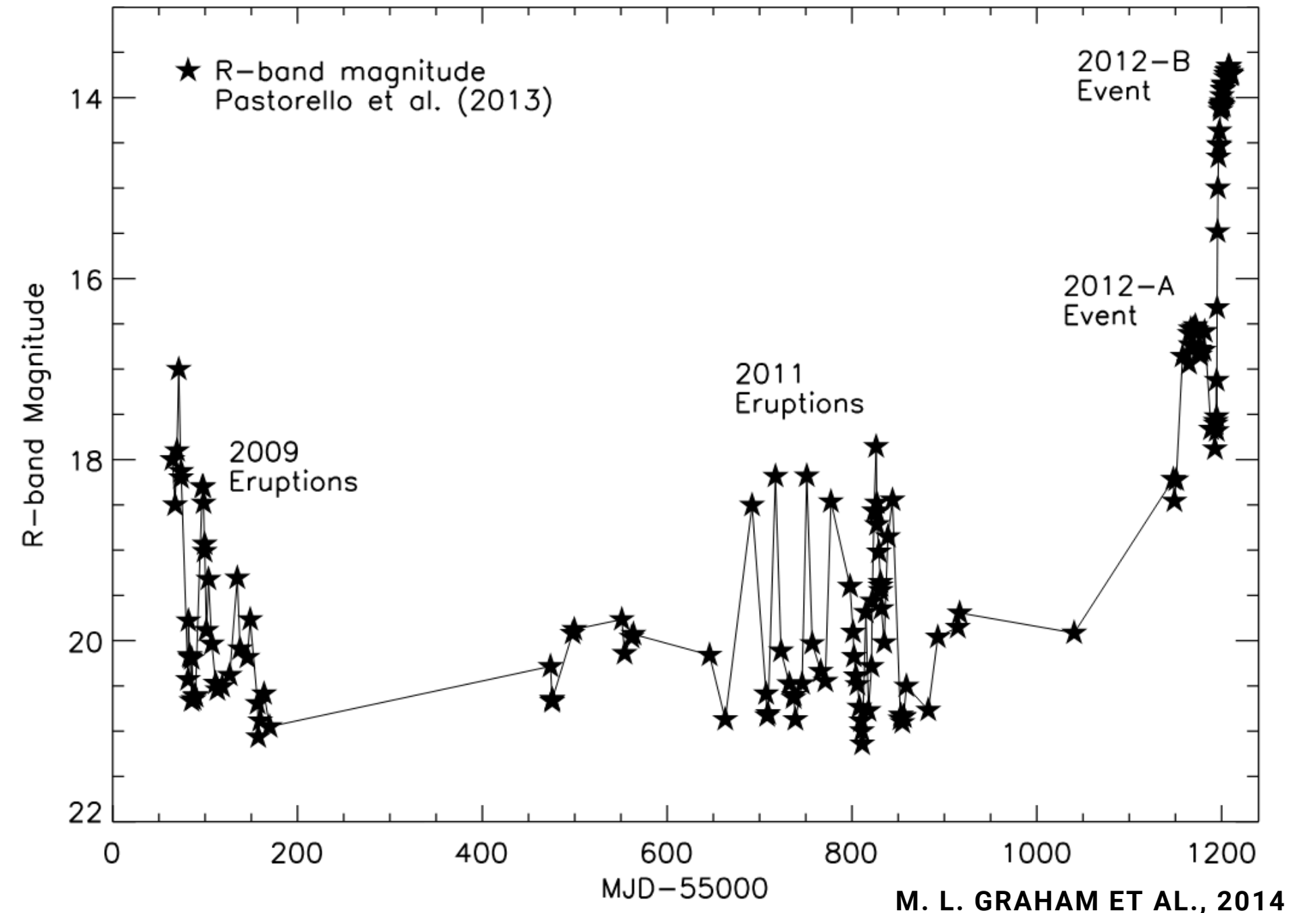
YEARS LONG ``*PRECURSOR ACTIVITY*''  
FOLLOWED BY TWO EXPLOSIONS –  
THE LATTER BEING A *GENUINE SN*\*



OPPORTUNITY TO FIND A STAR *BEFORE*  
IT EXPLODES



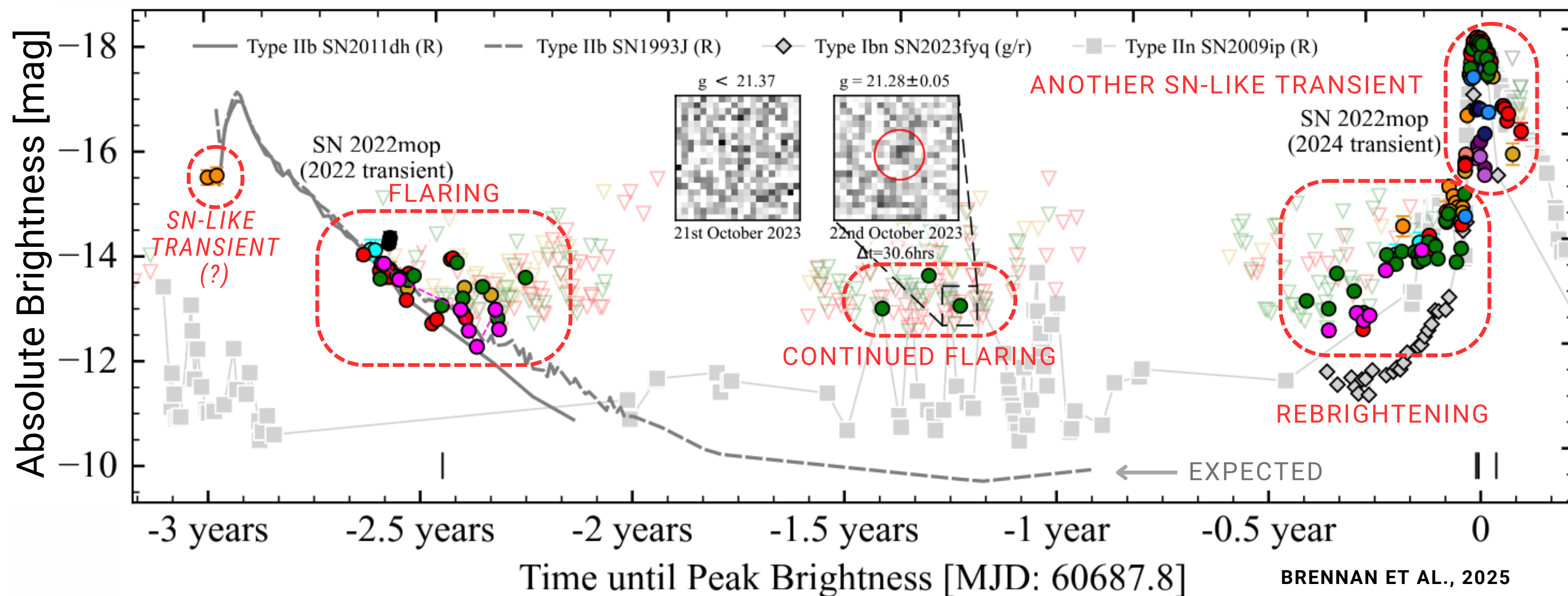
EMISSION DOMINATED BY  
INTERACTION → STAR *OBSCURED*



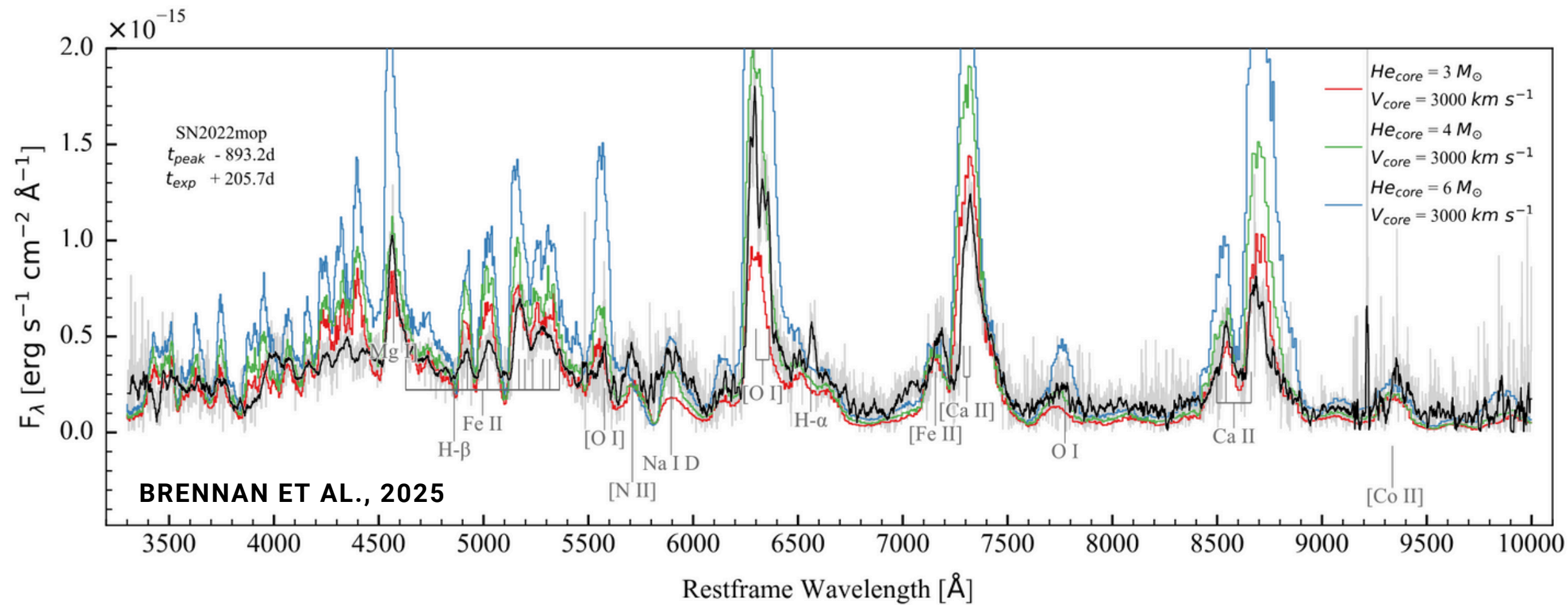
**Papers on SN 2009ip:** Smith et al., 2010; Foley et al., 2011; Fraser et al., 2013; Mauerhan et al., 2013; Ofek et al., 2013; Ouyed et al., 2013; Pastorello et al., 2013; Potashov et al., 2013; Prieto et al., 2013; Smith et al., 2013; Soker et al., 2013; Tsebrenko et al., 2013; Graham et al., 2014; Levesque et al., 2014; Margutti et al., 2014; Mauerhan et al., 2014; Smith et al., 2014; Fraser et al., 2015; Martin et al., 2015; Moriya et al., 2015; Smith et al., 2016; Graham et al., 2017; Pastorello et al., 2018; Chugai et al., 2022; Fransson et al., 2022; Pessi et al., 2022; Reguitti et al., 2022; Smith et al., 2022; Pessi et al., 2023.



# PRECURSOR ACTIVITY PRECEDING INTERACTING SUPERNOVAE I: BRIDGING THE GAP WITH SN 2022MOP





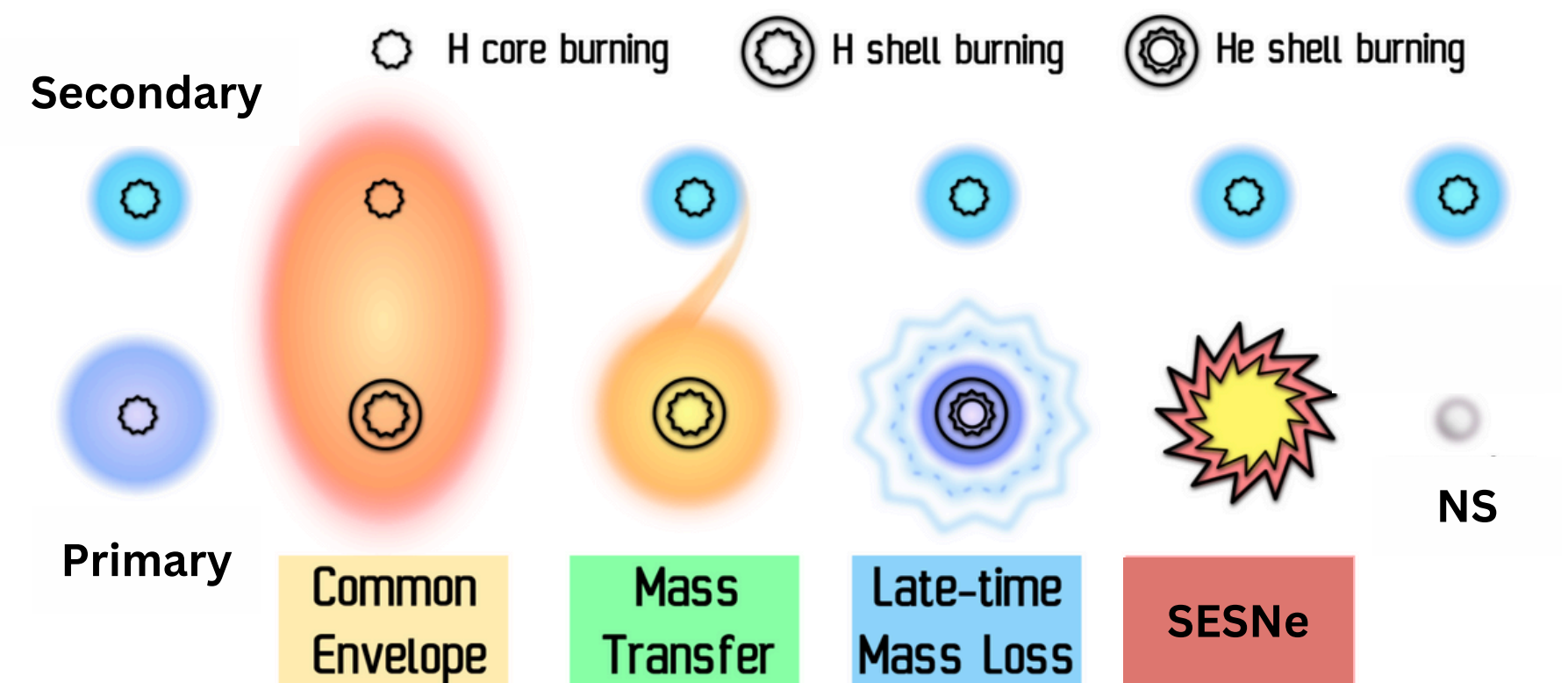


## NEBULAR SPECTRUM

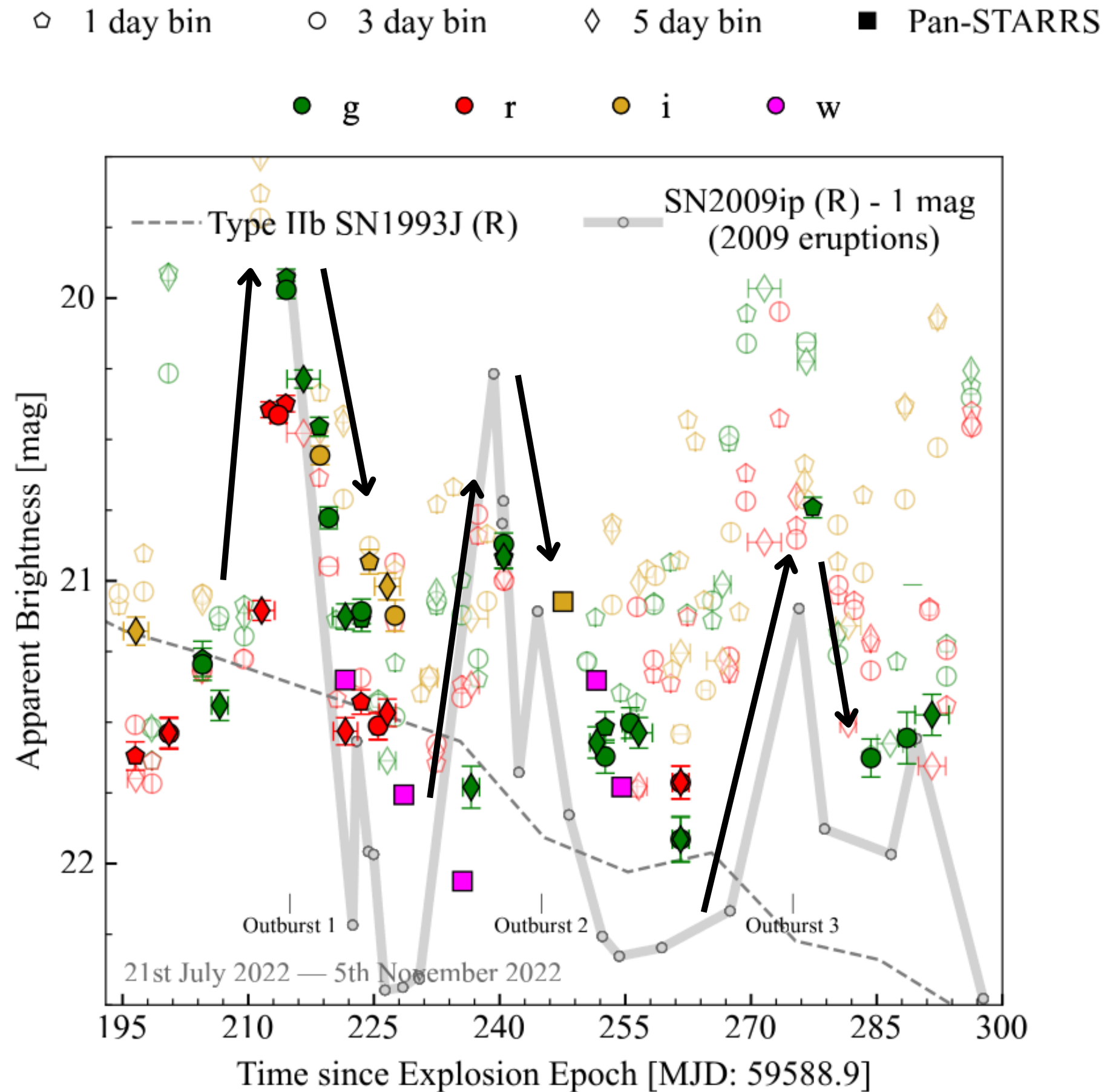
- [O I], MG I, AND [CA II]
- *LATE TIME SPECTRUM OF A SUPERNOVA*

## (POSSIBLE) FORMATION PATHWAY

- NEUTRON STAR CONTINUES TO INTERACTION WITH COMPANION (?)







BRENNAN ET AL., 2025

- ~200 DAYS POST EXPLOSION
- **FLARING** SEEN IN LATE TIME LIGHTCURVE - NOT RADIOACTIVE DECAY
- SIMILAR TO 2009 ERUPTIONS OF SN 2009IP
- ~30 DAY PERIOD

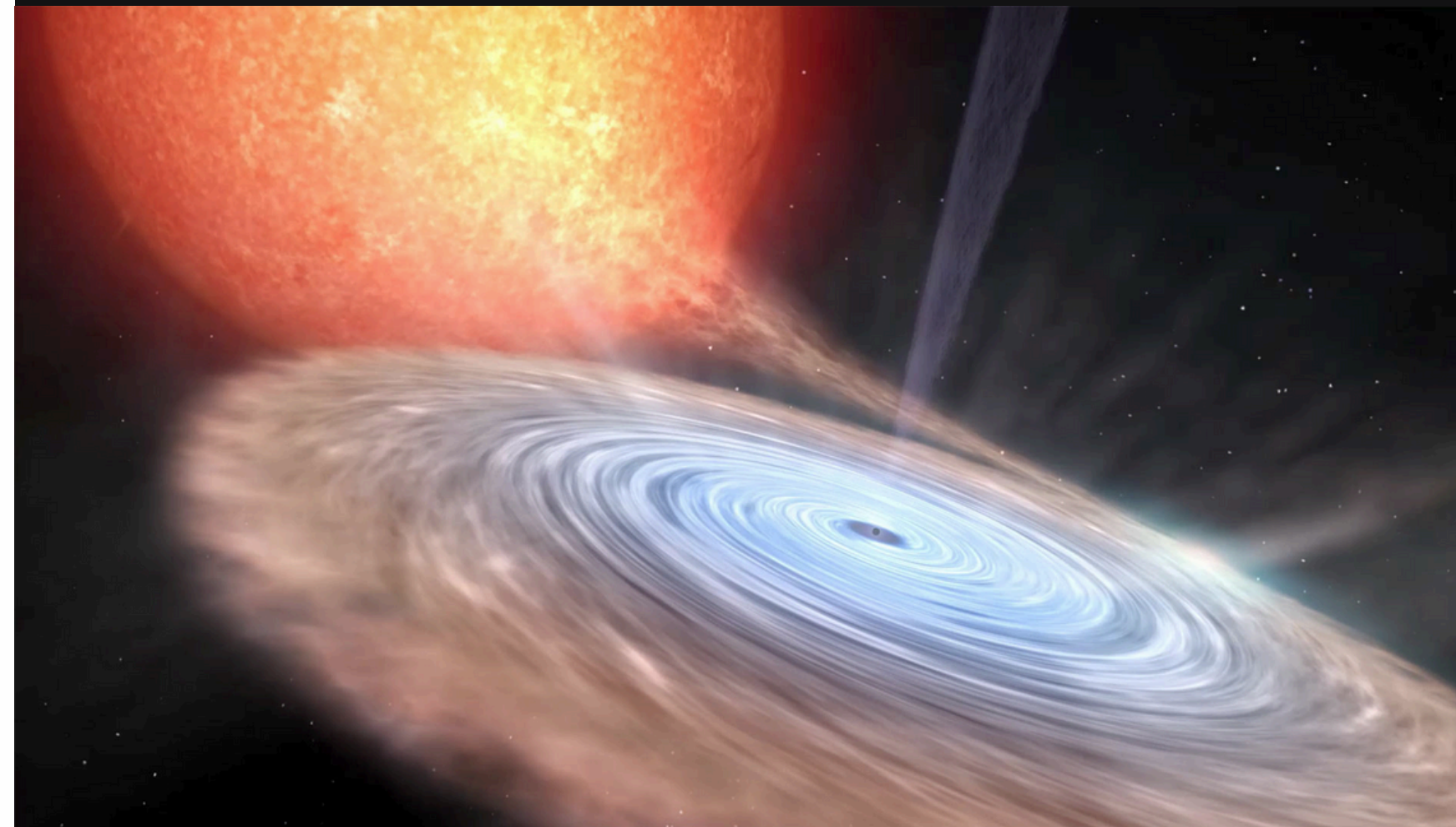
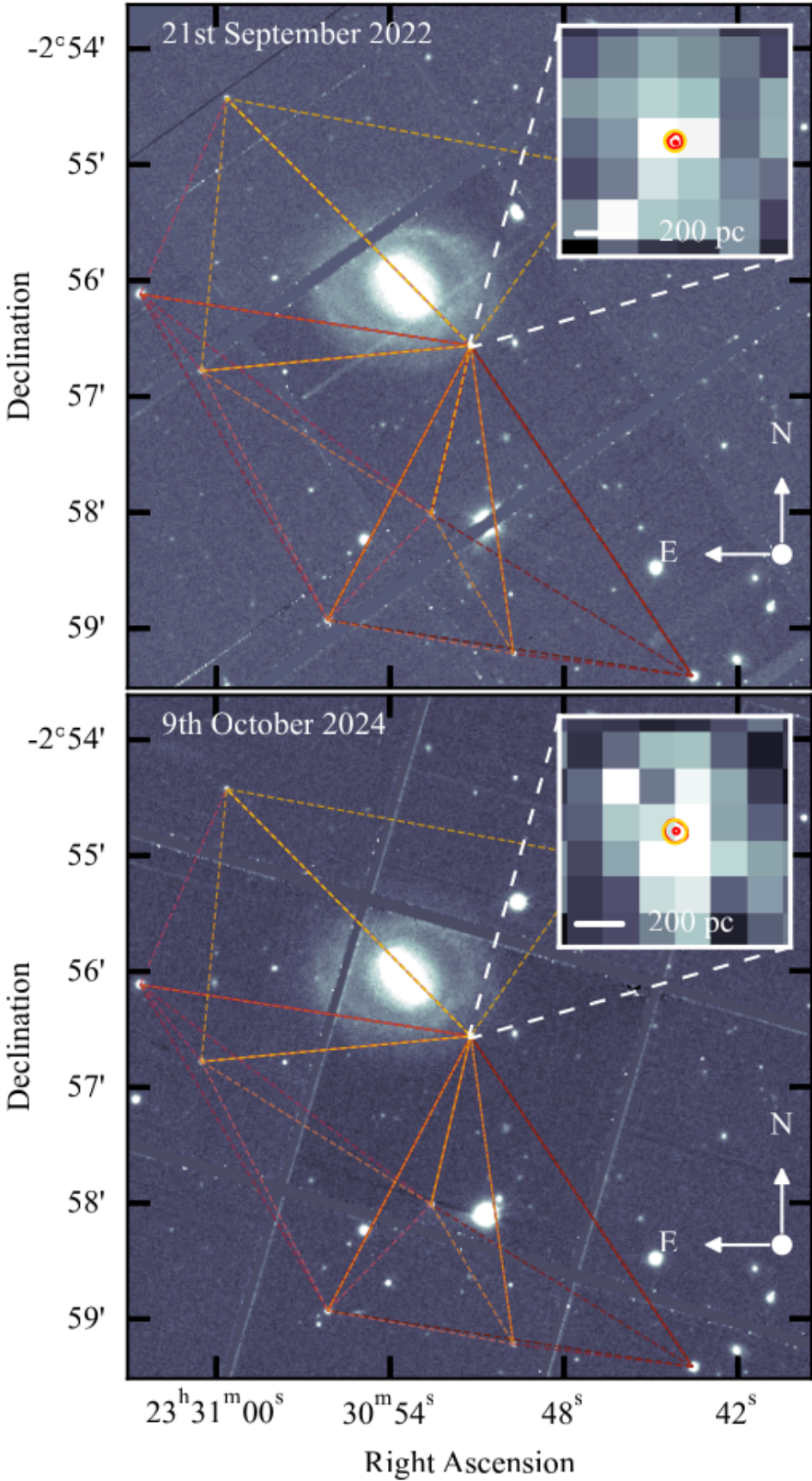
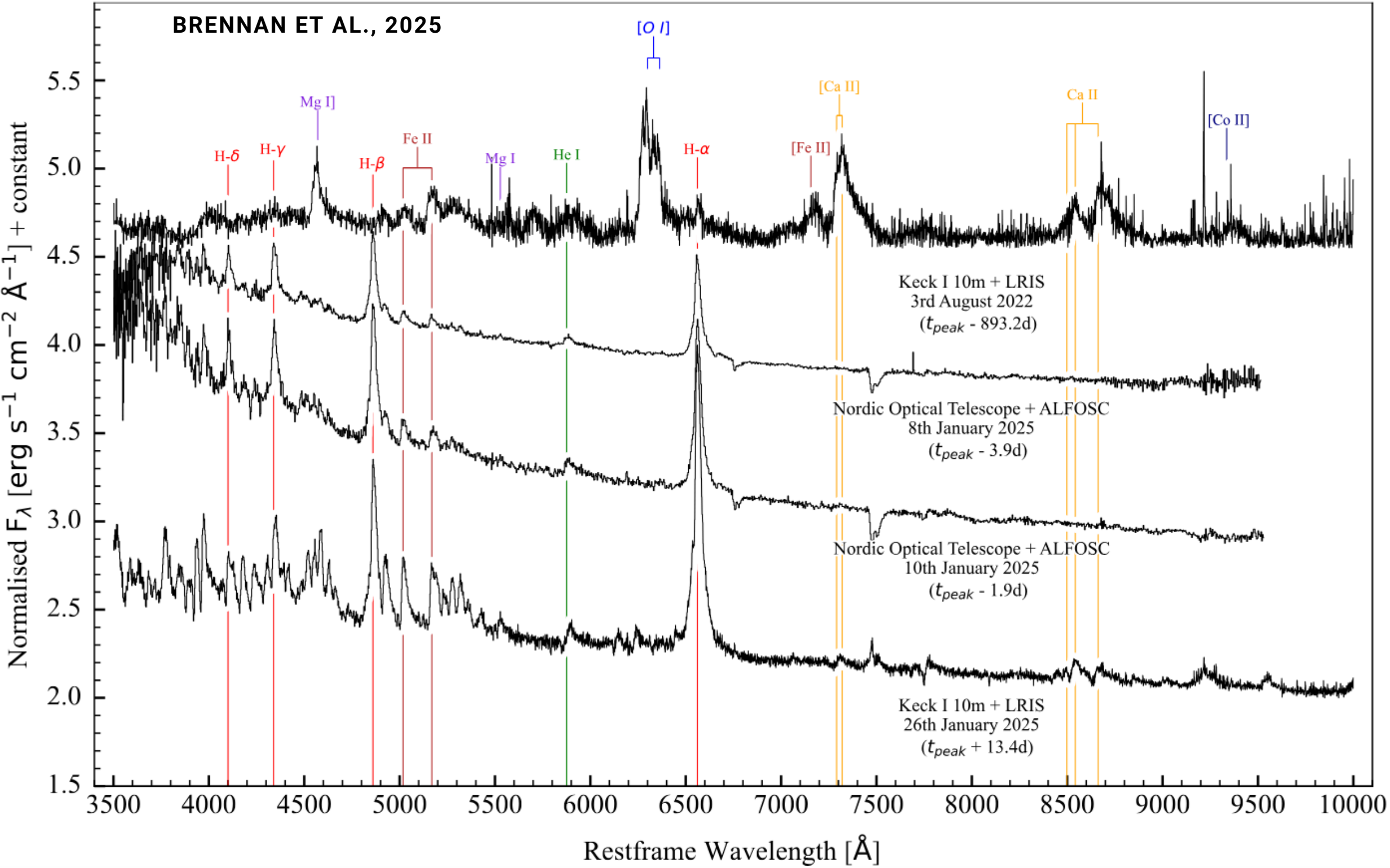


Image credit: Instituto de Astrofísica de Canarias.

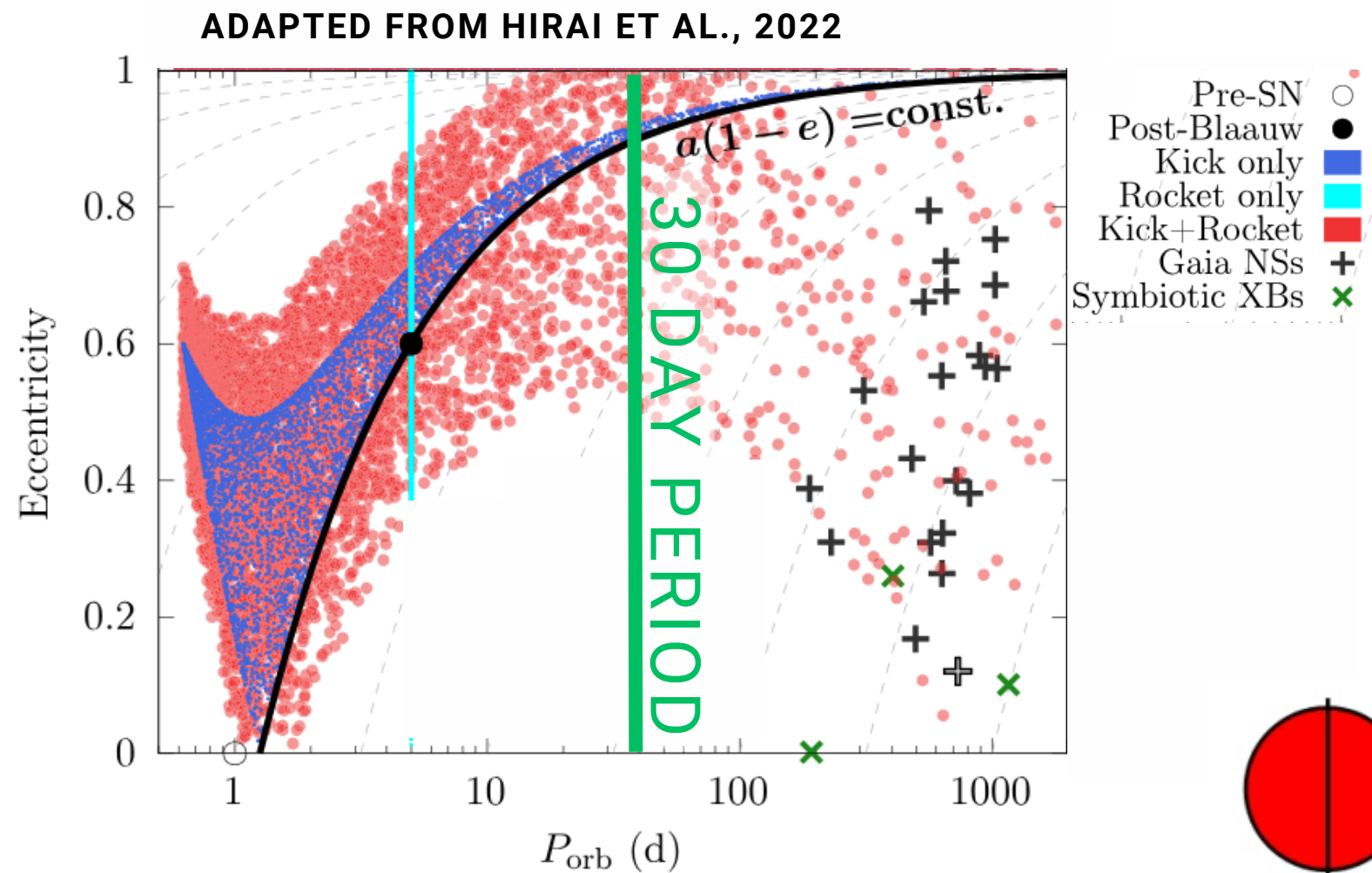
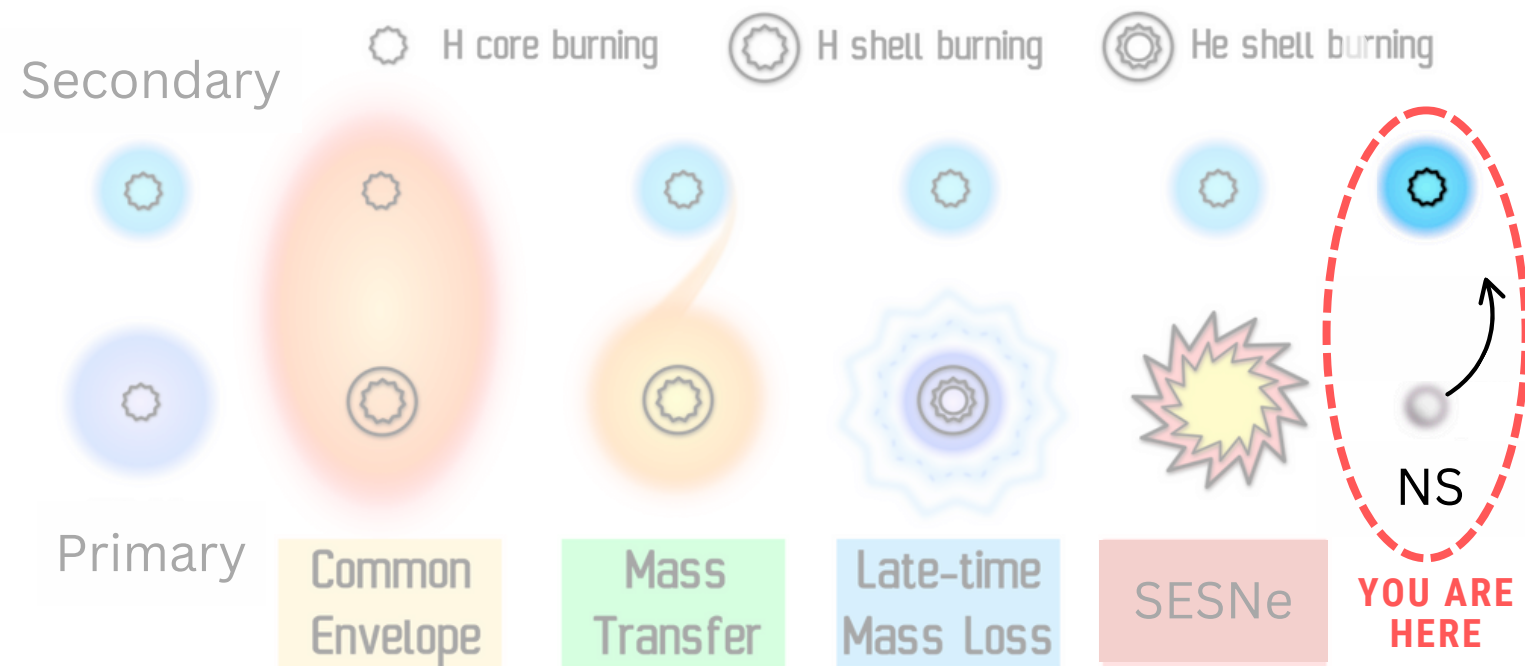


# A *HYDROGEN POOR* SESN BECOMES A *HYDROGEN RICH* SN 3 YEARS LATER

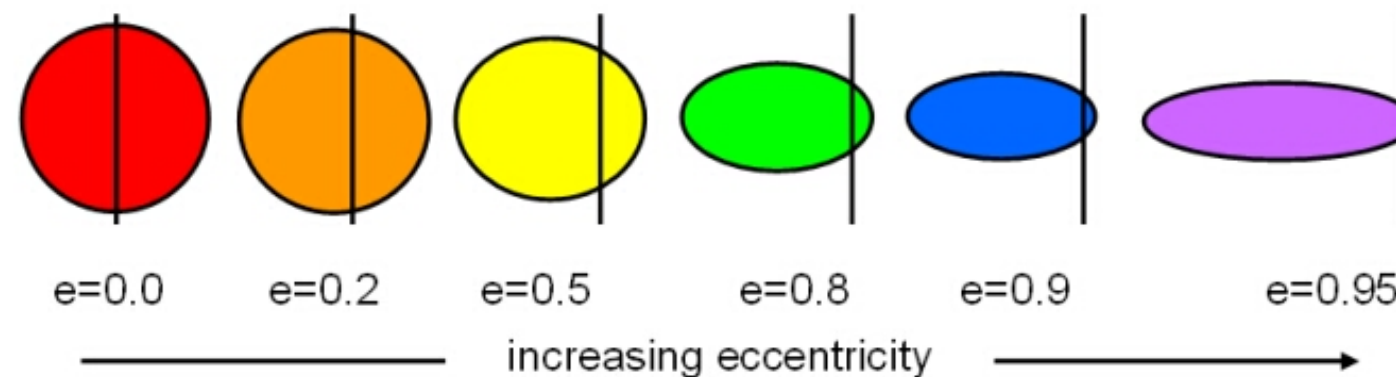
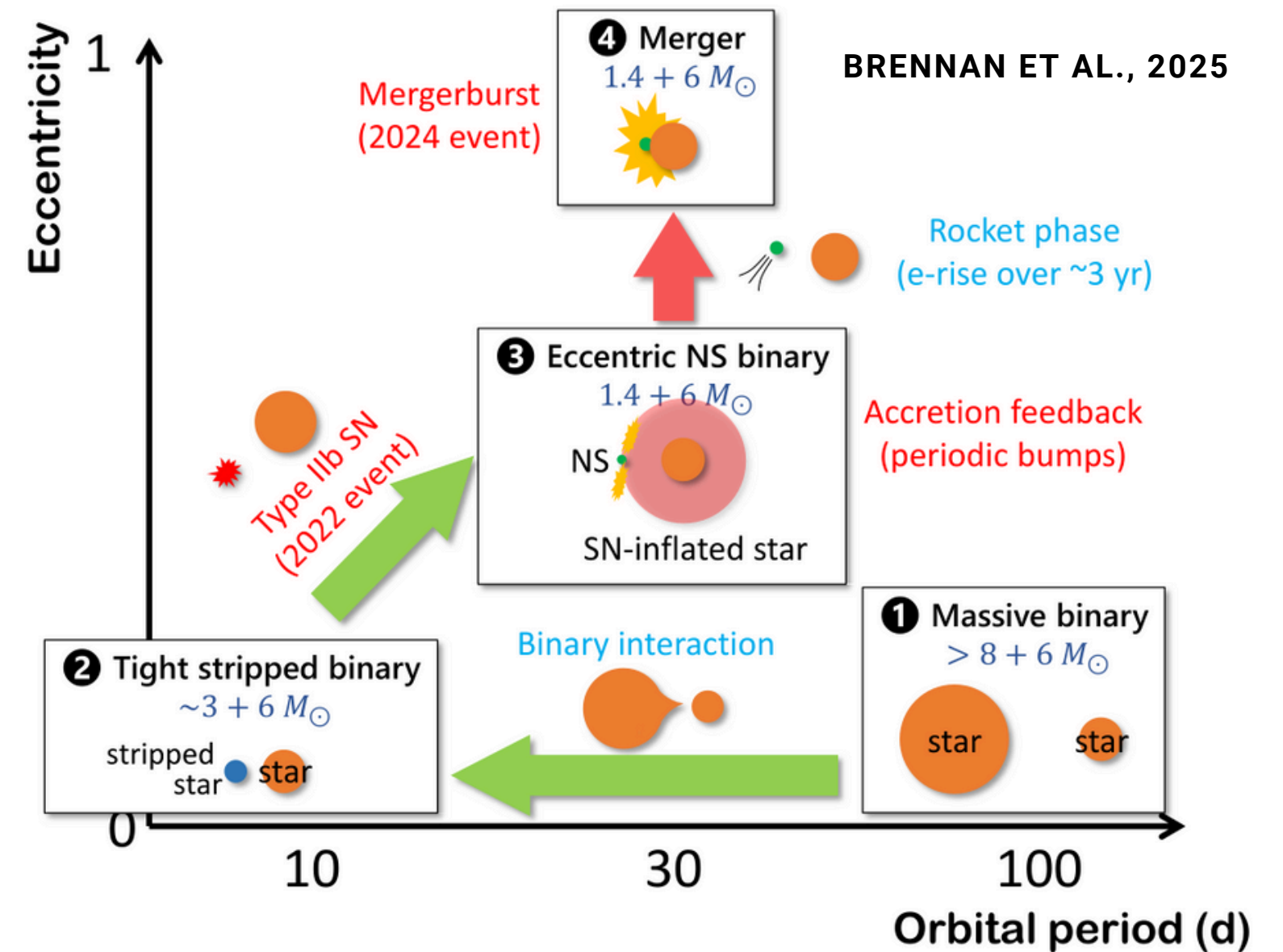


**TRANSIENT TRIANGULATOR -**  
(SOON) AVAILABLE ON GITHUB





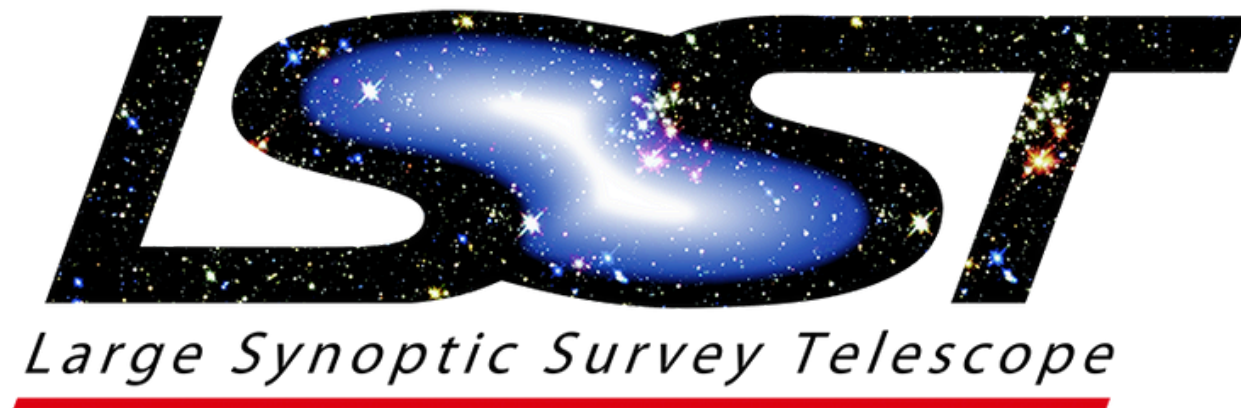
# NEWLY FORMED NEUTRON STAR INTERACTS WITH ITS COMPANION: *MERGERBURST*





# *PRESTO* - PRE SUPERNOVA TARGETED OBSERVATIONS

GOAL: IDENTIFY PRE SN ACTIVITY AND FOLLOWUP



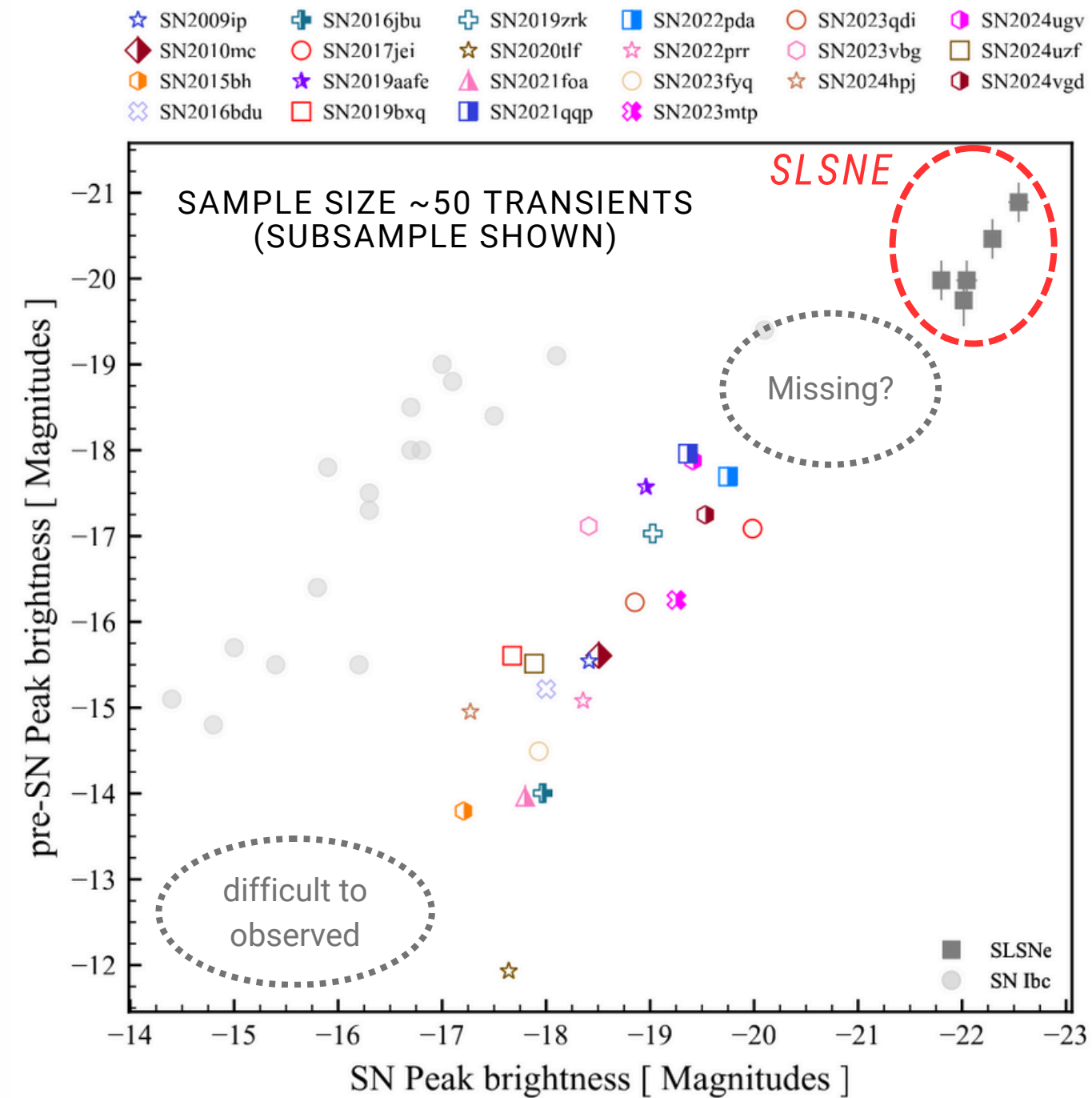
*WORK IN PROGRESS*

- IDENTIFY THIS ACTIVITY *BEFORE* CORE-COLLAPSE OCCURS
- HIGH CADENCE OBSERVATIONS
  - PERIODICITY AND IN-SPIRAL (~CHIRP SIGNAL)
- EXPLORE PANCHROMATICALLY
  - IR (DUST AND NEBULAR FEATURES)
  - UV - XRAY (INTERACTION)

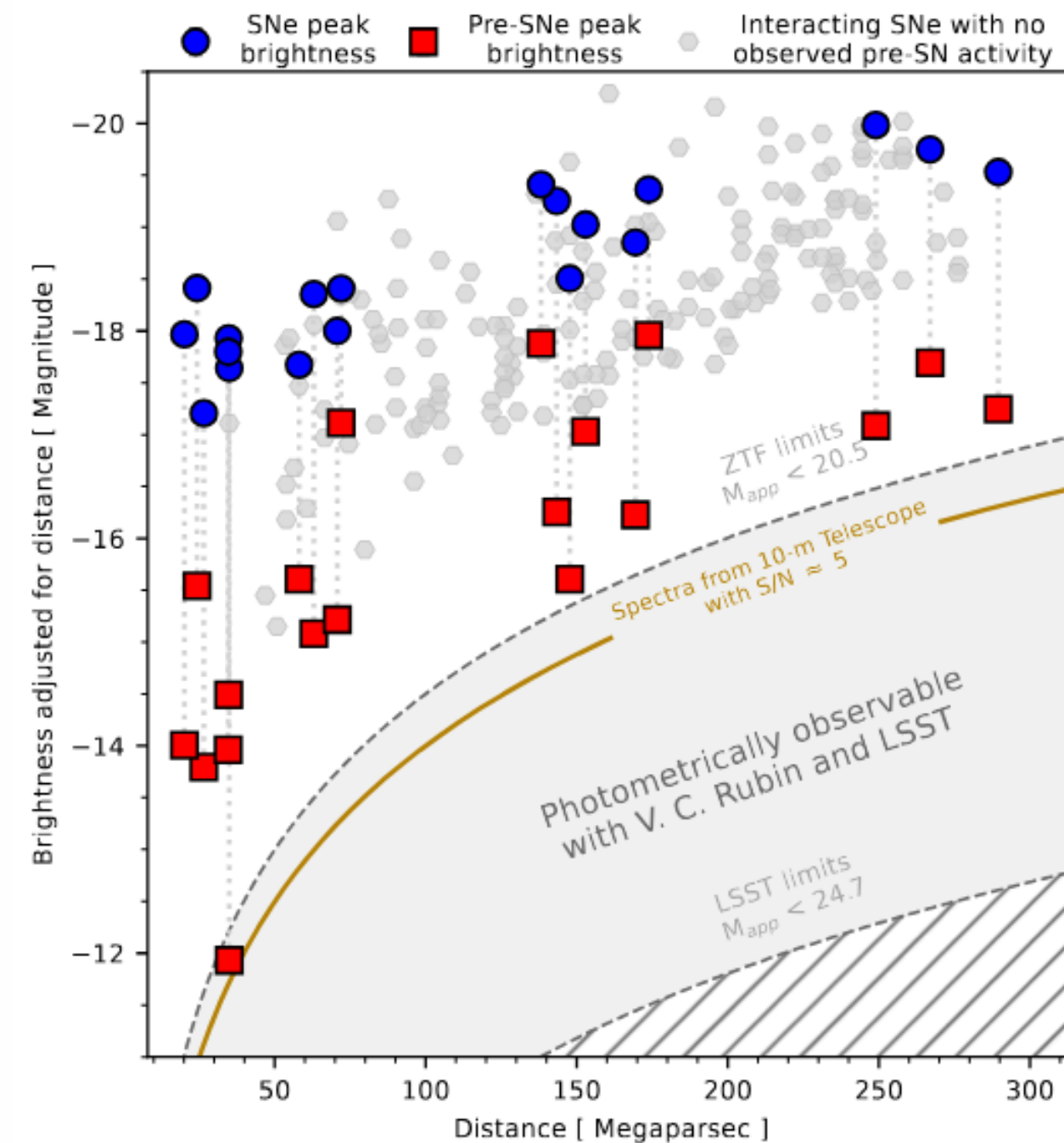


# PRESTO - PRE SUPERNOVA TARGETED OBSERVATIONS

## PRELIMINARY WORK



BRIGHTER ACTIVITY YIELDS BRIGHTER SUPERNOVAE

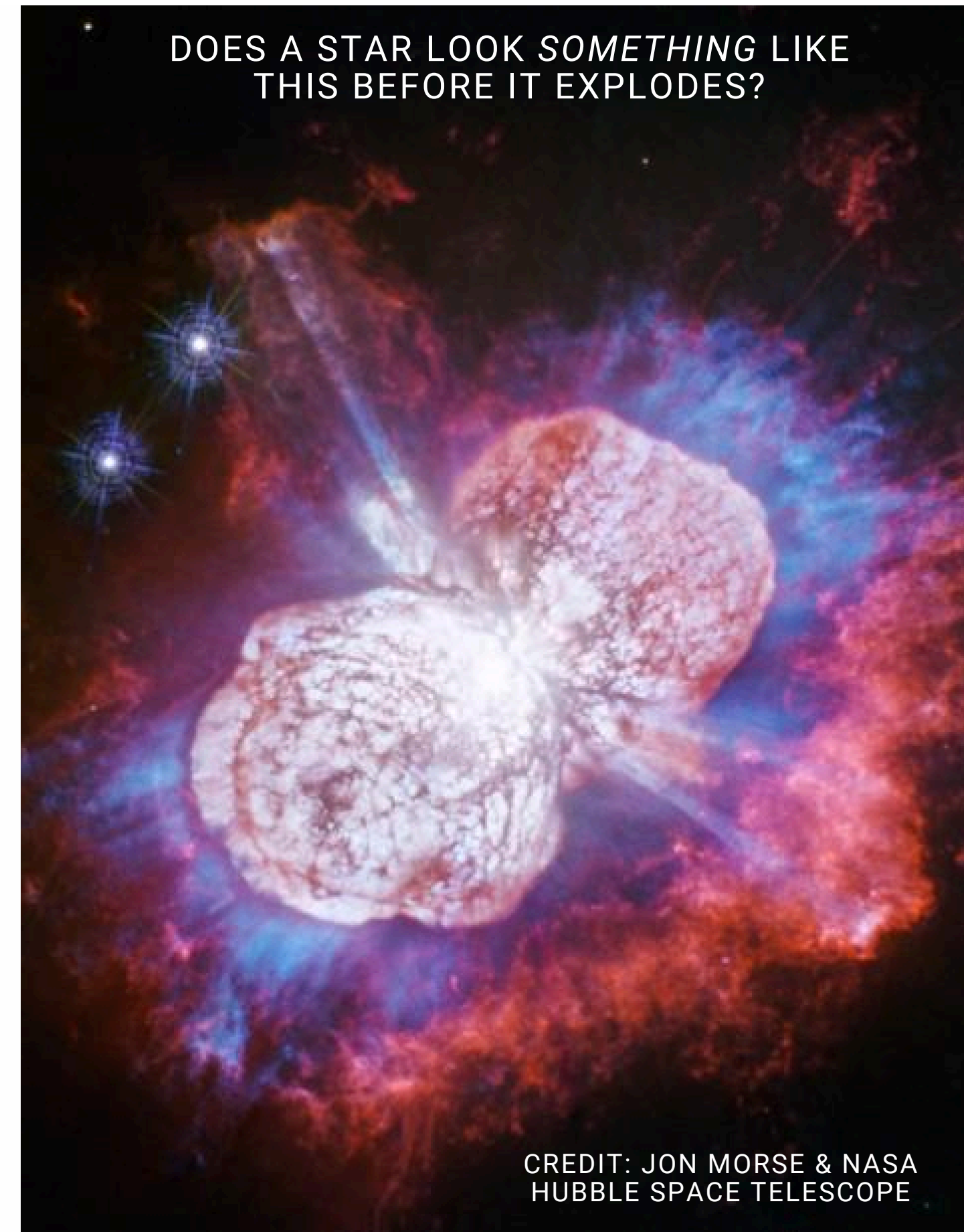


NEW MAGNITUDE SPACE TO EXPLORE WITH RUBIN



## TAKE HOME POINTS

- IT IS POSSIBLE TO IDENTIFY A STAR BEFORE IT EXPLODES
- NO HIGH CADENCE FOLLOW UP (*YET!*)
- SELECTION CRITERIA (*IN PROGRESS*) FOR RUBIN ERA





## OPEN QUESTIONS

- MERGER BURST EXPLOSION PATHWAY (?)
- CAN A MERGER TRIGGER CORE-COLLAPSE?
  - IS THIS 'CORE-COLLAPSE'
  - SN V.S. SN IMPOSTOR
- PROGENITOR-SUPERNOVA CONNECTION
  - EFFECTS OF CSM
  - ASSUMPTION OF HYDROSTATIC-EQUILIBRIUM

