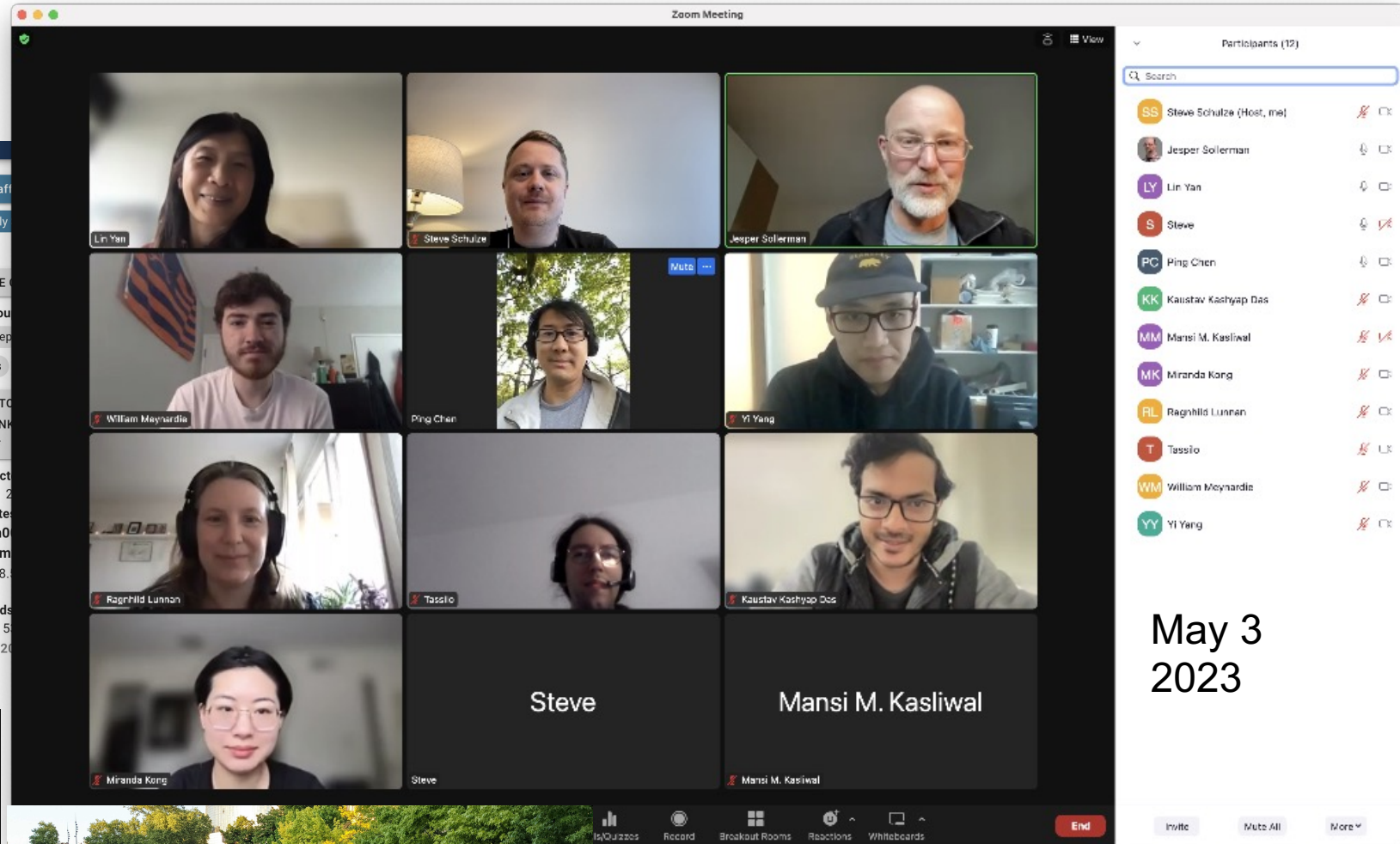
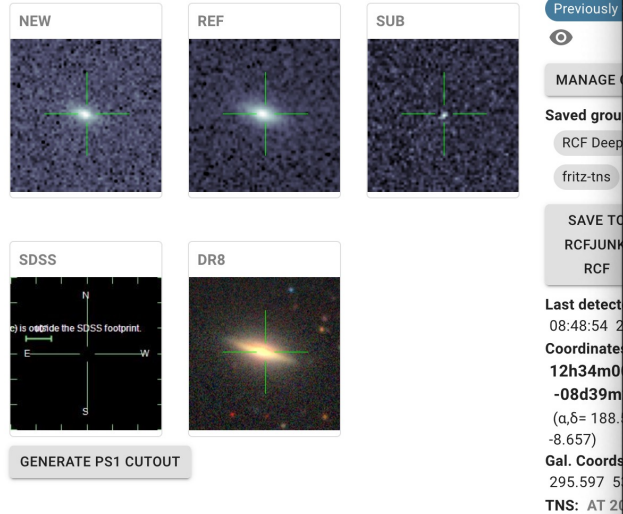
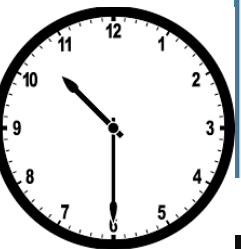


# WG: Physics of supernovae and relativistic transients: Berlin 2023



May 3  
2023



# WG overview: Physics of supernovae and relativistic transients

BTS #7564 SNe

SN Ia Physics



SLSNe



Jesper, **Steve**, Ping, **Christoffer**  
Wednesdays 19:00 (Stockholm Time)

\* Agenda, Minutes, ZTF Transients Slack  
(#119), Twiki-pages, ztftransients-email

MMA / CLU

GRB,  
neutrinos  
kilonovae



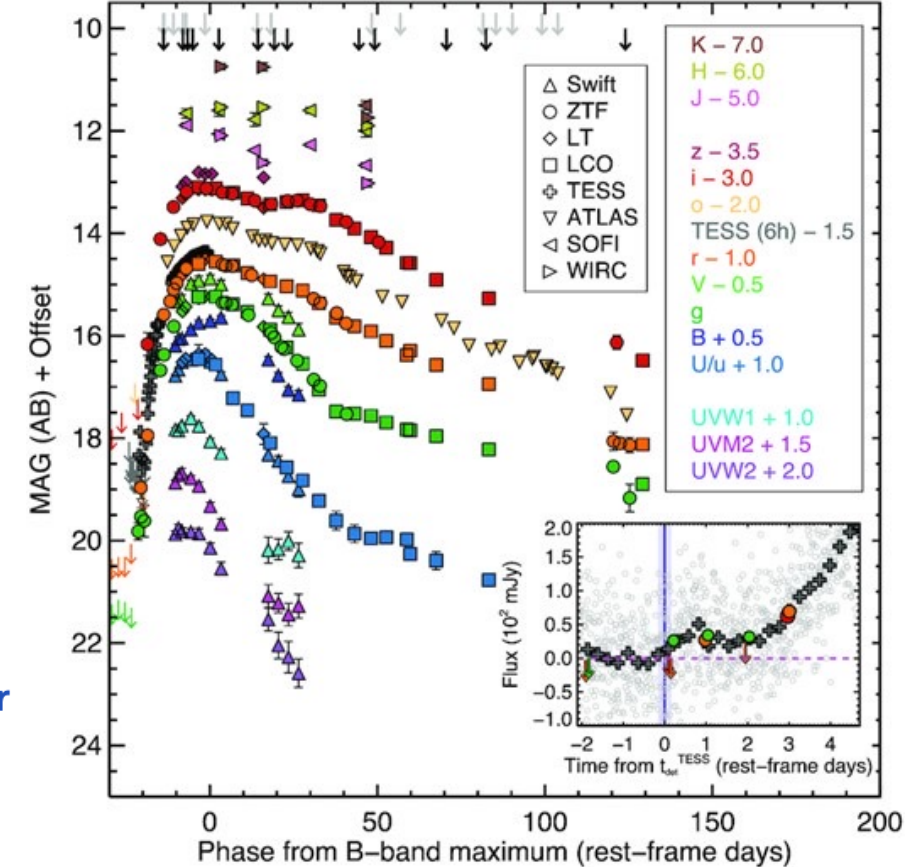


- Infant
- Precursors
- Flash spectroscopy

SN II

# SN Ia Physics

- 1 ☐ 2023MNRAS.521.1162D 2023/05 cited: 4     
**SN 2021zny: an early flux excess combined with late-time oxygen emission suggests a double white dwarf merger event**  
Dimitriadis, Georgios; Maguire, Kate; Karambelkar, Viraj R. [and 28 more](#)
- 2 ☐ 2023arXiv230412361M 2023/04     
**SN 2020udy: a SN Iax with strict limits on interaction consistent with a helium-star companion**  
Maguire, Kate; Magee, Mark R.; Leloudas, Giorgos [and 24 more](#)
- 3 ☐ 2023arXiv230410129H 2023/04     
**Early-time spectroscopic modelling of the transitional Type Ia Supernova 2021rhu with TARDIS**  
Harvey, Luke; Maguire, Kate; Magee, Mark R. [and 15 more](#)
- 4 ☐ 2023ApJ...946...83L 2023/04 cited: 3     
**SN 2020jgb: A Peculiar Type Ia Supernova Triggered by a Helium-shell Detonation in a Star-forming Galaxy**  
Liu, Chang; Miller, Adam A.; Polin, Abigail [and 25 more](#)



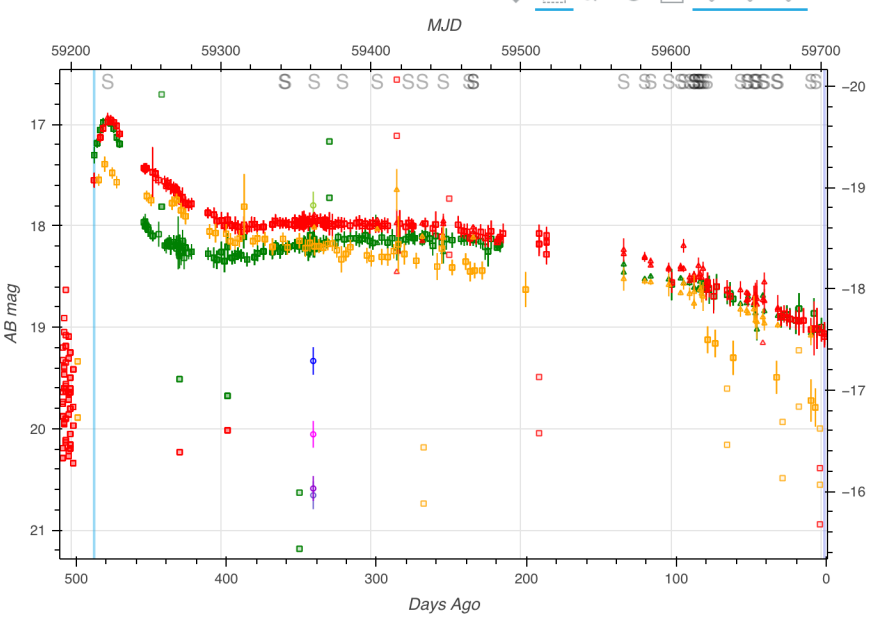


# Samples of supernovae

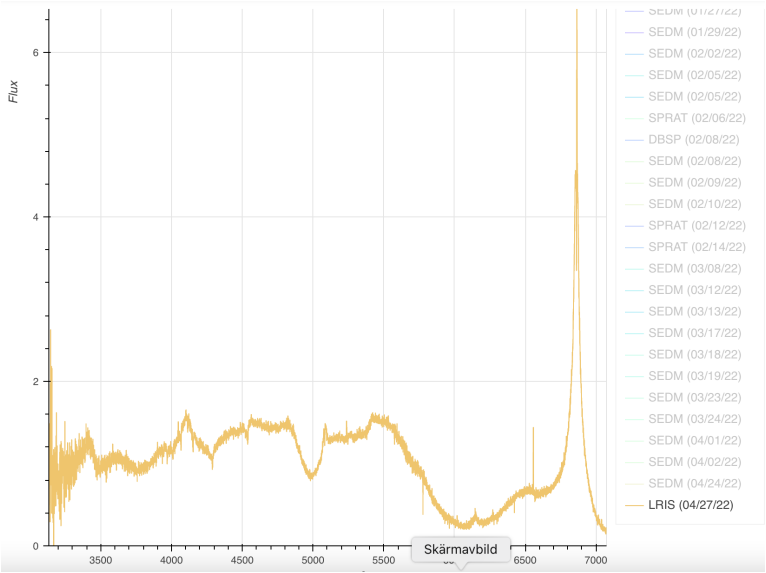
Ia-csm  
Flashers  
SLSNe-I

Ibn  
Ibc

- 
- 

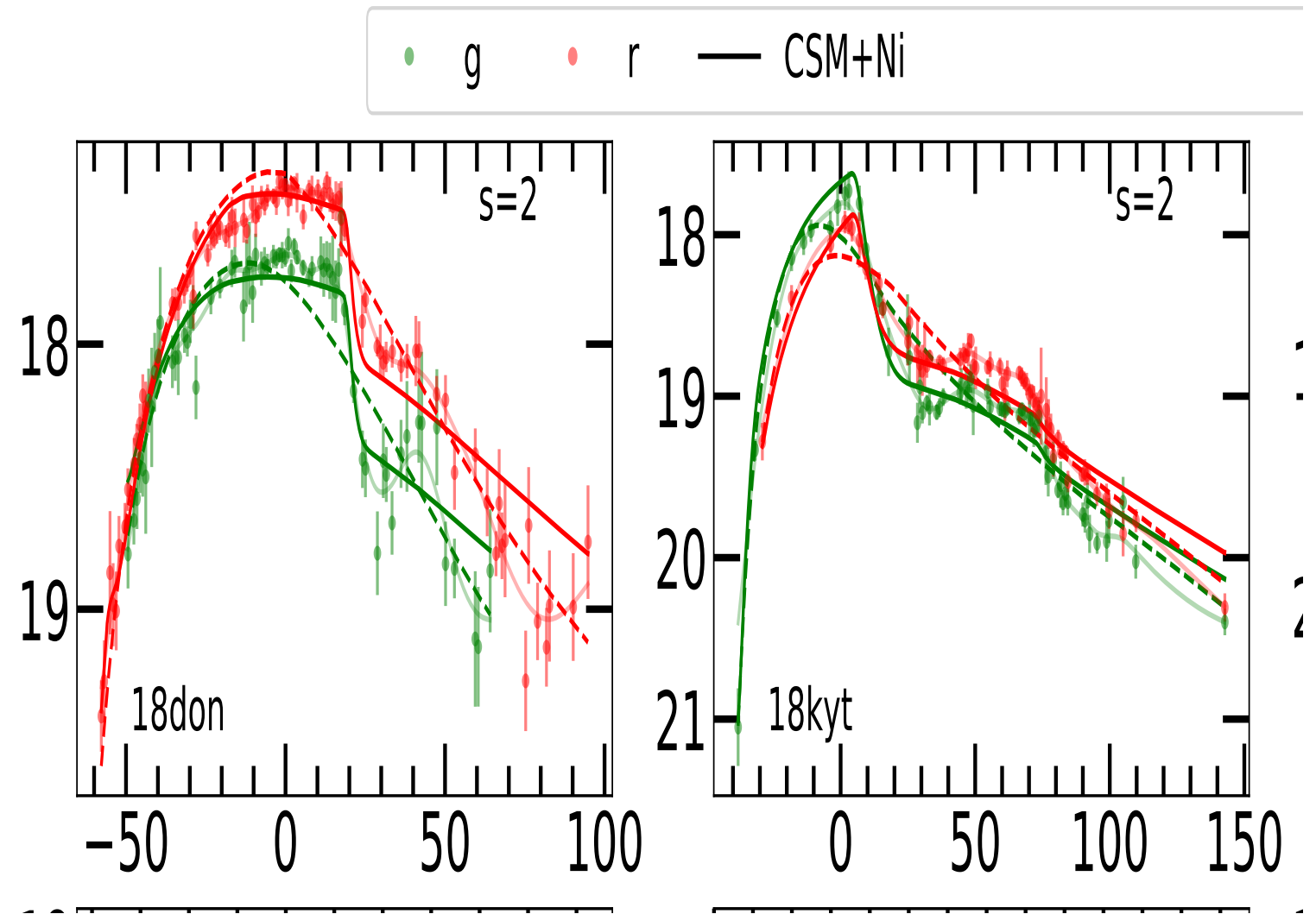


Sample --> Object



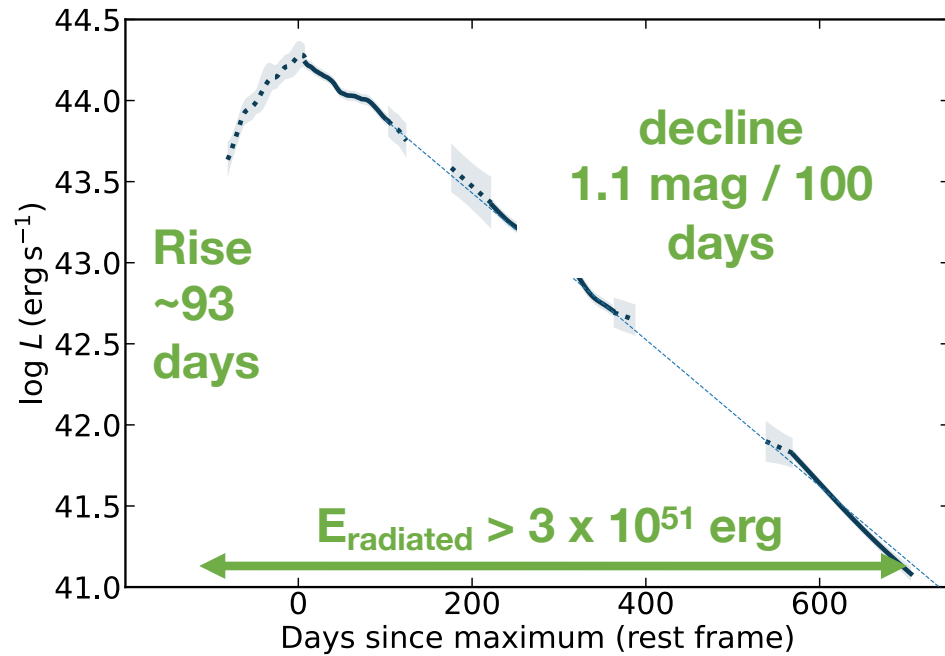
# ZTF legacy: a large (78 ZTF-I) uniformly selected SLSN-I sample

- Statistically H-poor CSM is important for SLSN-I
  - 24% LCs are much better fit by CSM interaction
- LC undulations are common! (23-49)%





# SN2018ibb – the best PISN candidate, to date



- SN 2018ibb. Led by Steve Schulze (OKC)
- Also SLSN papers by Stuart West (single object),
- Tuomas Kangas (sample SLSNII)
- Kaew Samaporn (collaboration on single object)

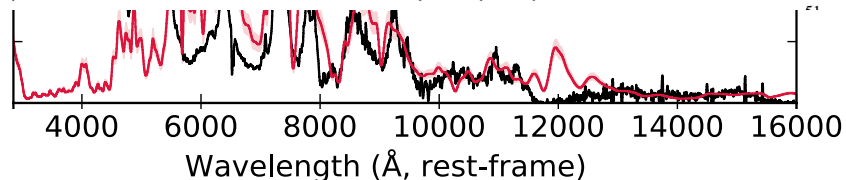
Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 9 May 2023]

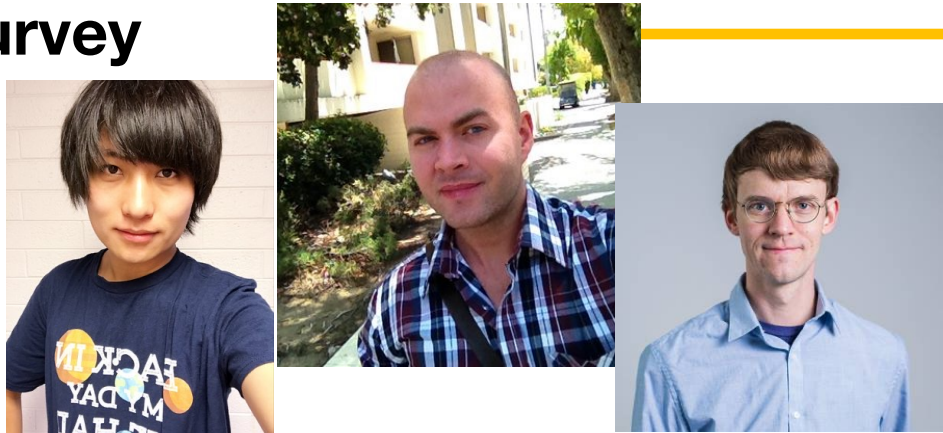
## 1100 Days in the Life of the Supernova 2018ibb -- the Best Pair-Instability Supernova Candidate, to date

Steve Schulze, Claes Fransson, Alexandra Kozyreva, Ting-Wan Chen, Ofer Yaron, Anders Jerkstrand, Avishay Gal-Yam, Jesper Sollerman, Lin Yan, Tuomas Kangas, Giorgos Leloudas, Conor M. B. Omand, Stephen J. Smartt, Yi Yang, Matt Nicholl, Nikhil Sarin, Yuhan Yao, Thomas G. Brink, Amir Sharon, Andrea Rossi, Ping Chen, Zhihao Chen, Aleksandar Cikota, Kishalay De, Andrew J. Drake, Alexei V. Filippenko, Christoffer Fremling, Laurane Freour, Johan P. U. Fynbo, Anna Y. Q. Ho, Cosimo Inserra, Ido Irani, Hanindy Kuncarayakti, Ragnhild Lunnan, Paolo Mazzali, Eran O. Ofek, Eliana Palazzi, Daniel A. Perley, Miika Pursiainen, Barry Rothberg, Luke J. Shingles, Ken Smith, Kirsty Taggart, Leonardo Tartaglia, WeiKang Zheng, Joseph P. Anderson, Letizia Cassara, Eric Christensen, S. George Djorgovski, Lluís Galbany, Anamaria Gkini, Matthew J. Graham, Mariusz Gromadzki, Steven L. Groom, Daichi Hiramatsu, D. Andrew Howell, Mansi M. Kasliwal, Curtis McCully, Tomas E. Müller-Bravo, Simona Paiano, Emmanouela Paraskeva, Priscila J. Pessi, David Polishook, Arne Rau, Mickael Rigault, Ben Rusholme

Abridged – Stars with ZAMS masses between 140 and 260  $M_{\odot}$  are thought to explode as pair-instability supernovae (PISNe). During their thermonuclear runaway, PISNe can produce up to several tens of solar masses of radioactive nickel, resulting in luminous transients similar to some superluminous supernovae (SLSNe). Yet, no unambiguous PISN has been discovered so far. SN2018ibb is a H-poor SLSN at  $z = 0.166$  that evolves extremely slowly compared to the hundreds of known SLSNe. Between mid 2018 and early 2022, we monitored its photometric and



# Bright Transient Survey

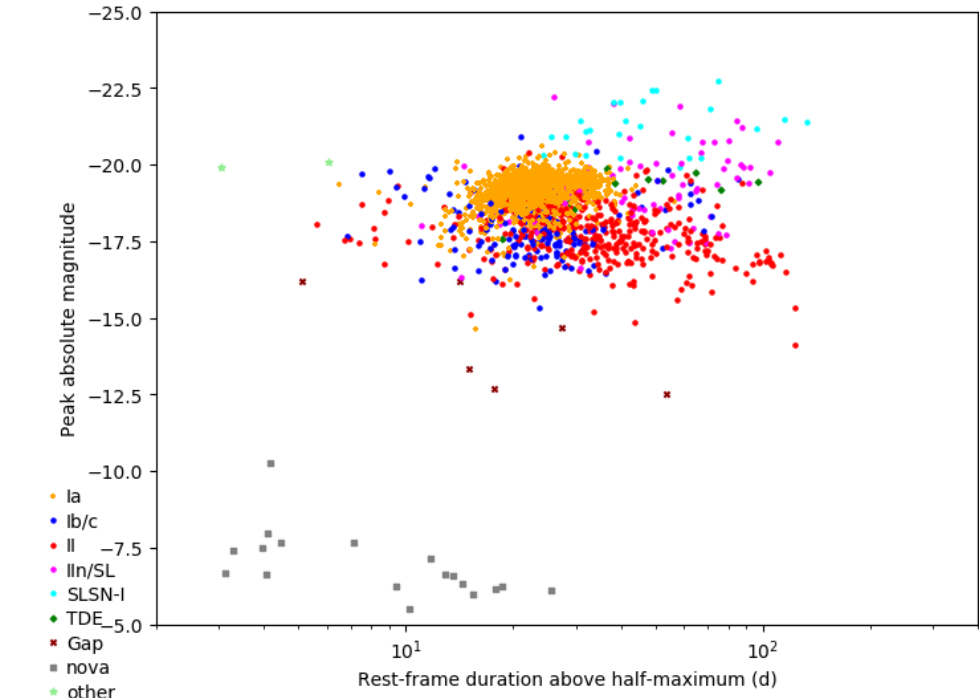
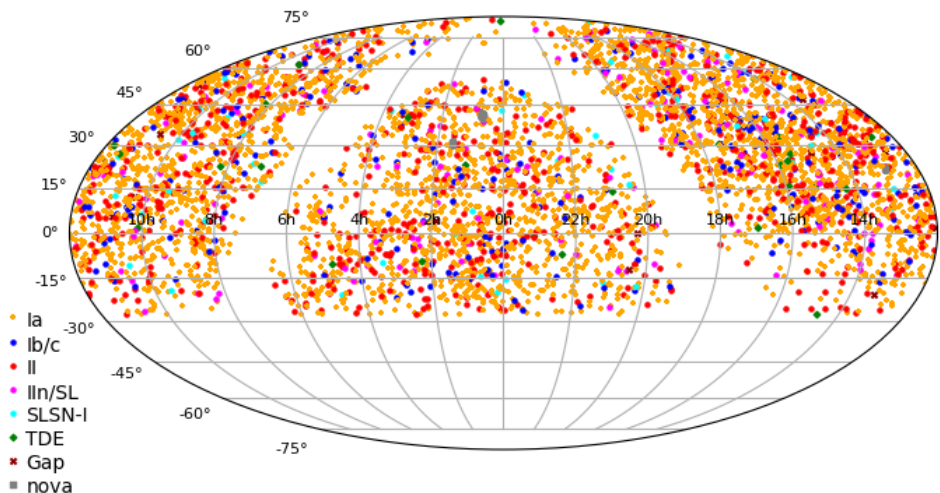


- Spectroscopic classifications for  $> \underline{95\%}$  of  $m < 18.5$  "well-observed SN-like" transients
- **7500+** classified extragalactic supernovae to date to  $m < 19.0$

Sample statistics/plots publicly online in real time:

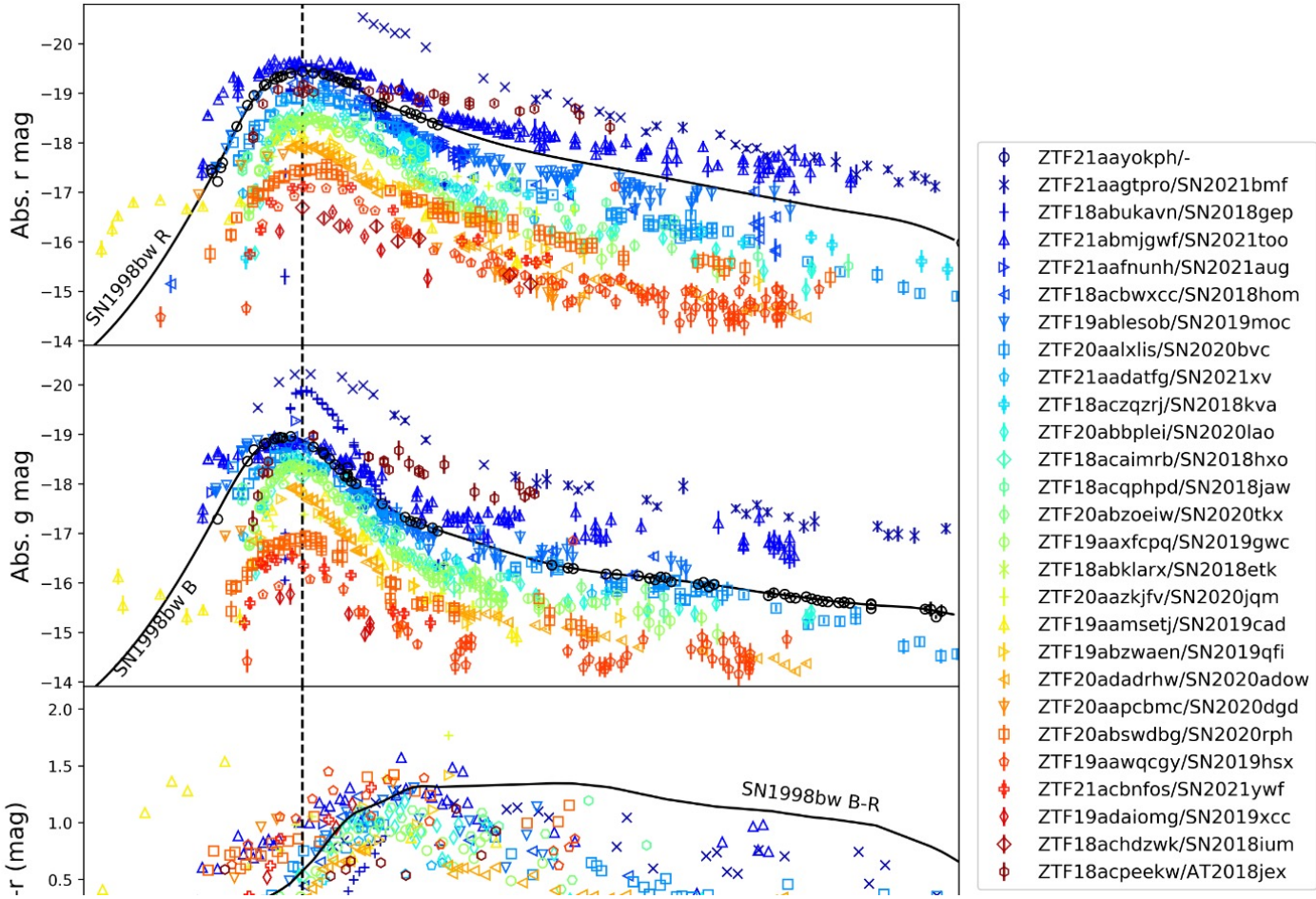
BTS sample explorer.

- **First results in**  
**Fremling et al. 2020, ApJ, 895, 32**  
**Perley et al. 2020, ApJ, 904, 35**
- **Next results in: .....**





# Broad-lined Type Ic SNe



Gokul. - sample

Shreya. - r-process



Alessandra - Radio

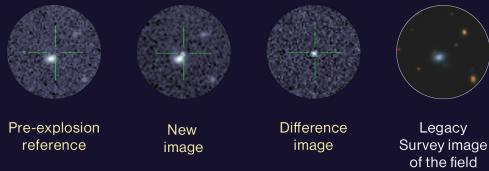


# SN 2019hgp

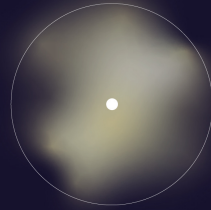
## A first example of a new type of Supernova - **Type Icn.**

Gal-Yam et al. 2022, *Nature*

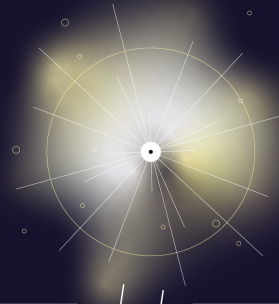
On June 8th 2019, the Supernova was discovered by the **Zwicky Transient Facility survey (ZTF)**, one day after explosion, at the outskirts of a galaxy almost 1 billion light years away.



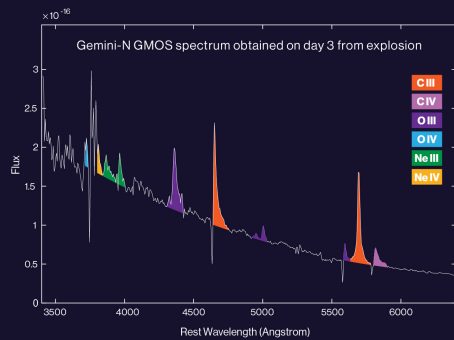
A massive, compact progenitor star surrounded by a thick carbon/oxygen/neon-rich wind.



The wind is energized by the Supernova explosion.



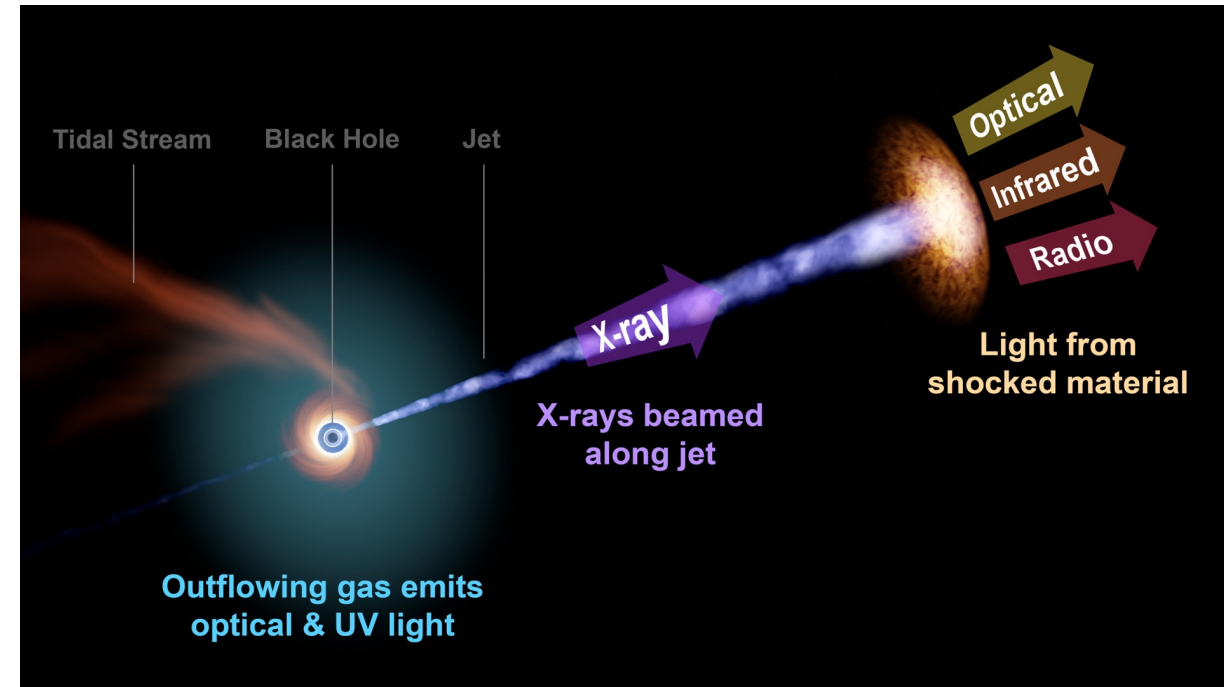
Early spectra are dominated by emission lines of highly ionized carbon, oxygen and neon, with no obvious trace of hydrogen or helium, and indicate that the Supernova exploded within a circum-stellar nebula similar to those of Wolf-Rayet stars of the WC family.



Spectra of the event were obtained by:

Gemini-North (Gemini-N/GMOS) | Liverpool Telescope (LT/SPRAT) | Nordic Optical Telescope (NOT/ALFOSC) | Palomar 60-Inch telescope (P60/SEDM) | Hobby-Eberly Telescope (HET/LRS) | William Herschel Telescope (WHT/ACAM) | the Lowell Discovery Telescope (LDT/Deveny/LMI) | the Palomar 200-Inch Hale Telescope (P200/DBSP) | the Keck telescope (Keck1/LRIS) and the Gran Telescopio Canarias (GTC/OSIRIS).

Nature 2022

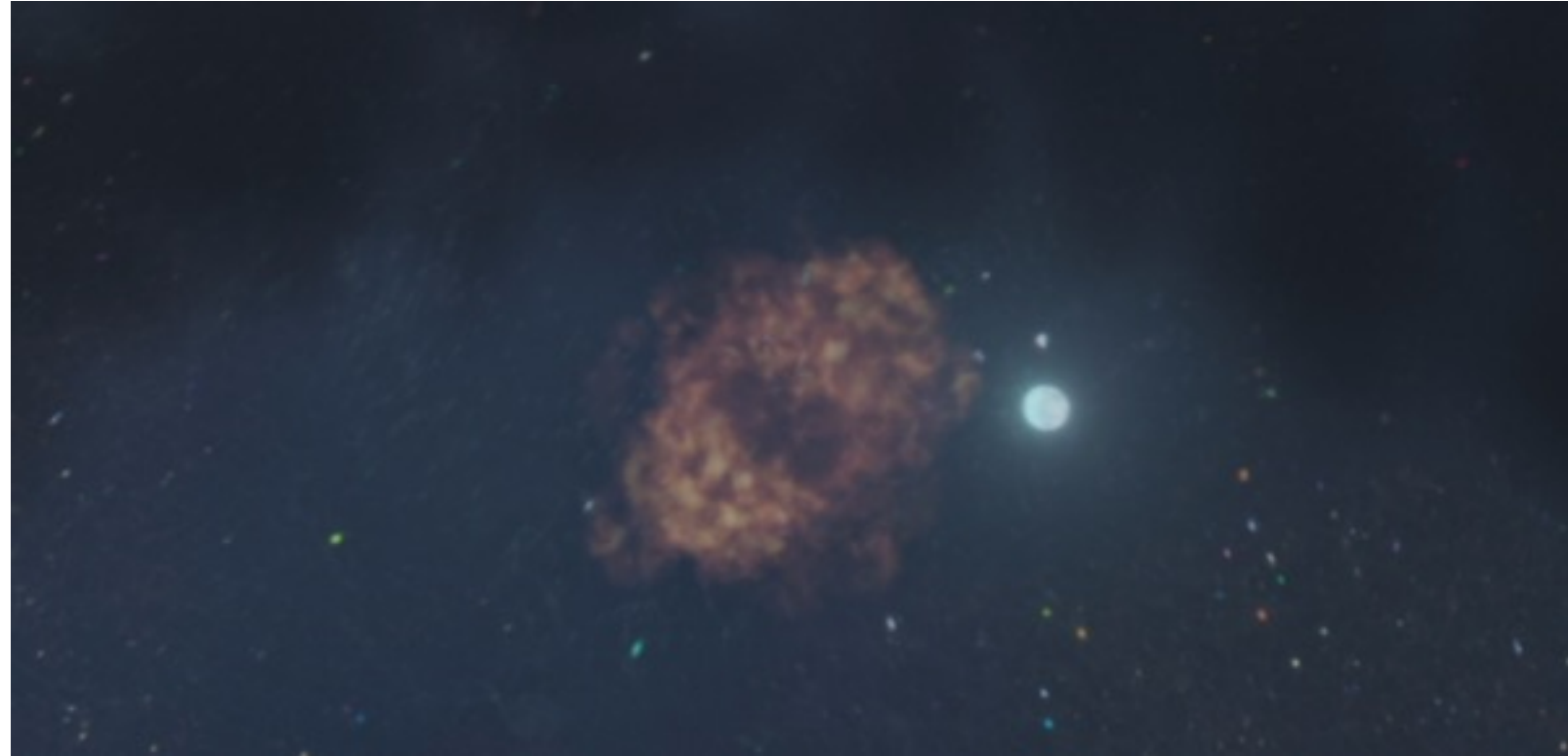
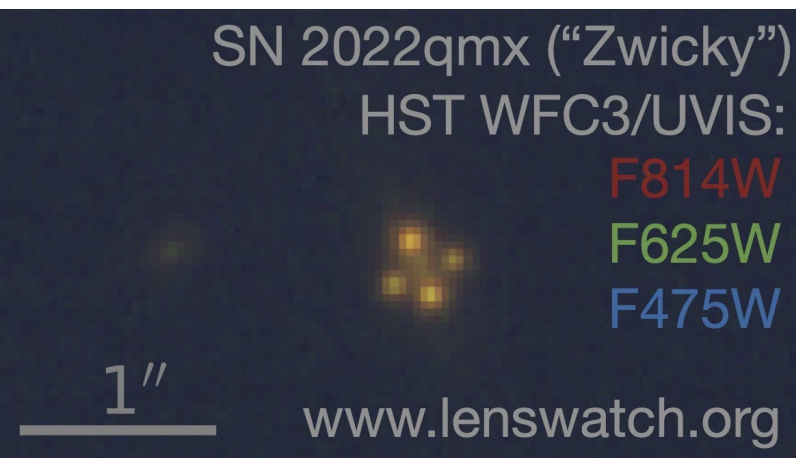


Andreoni, Coughlin et al.

Gal-Yam et al.



Nature+ 2023



Kool, Johansson, Sollerman et al.

Goobar, Johansson, Schulze, et al.

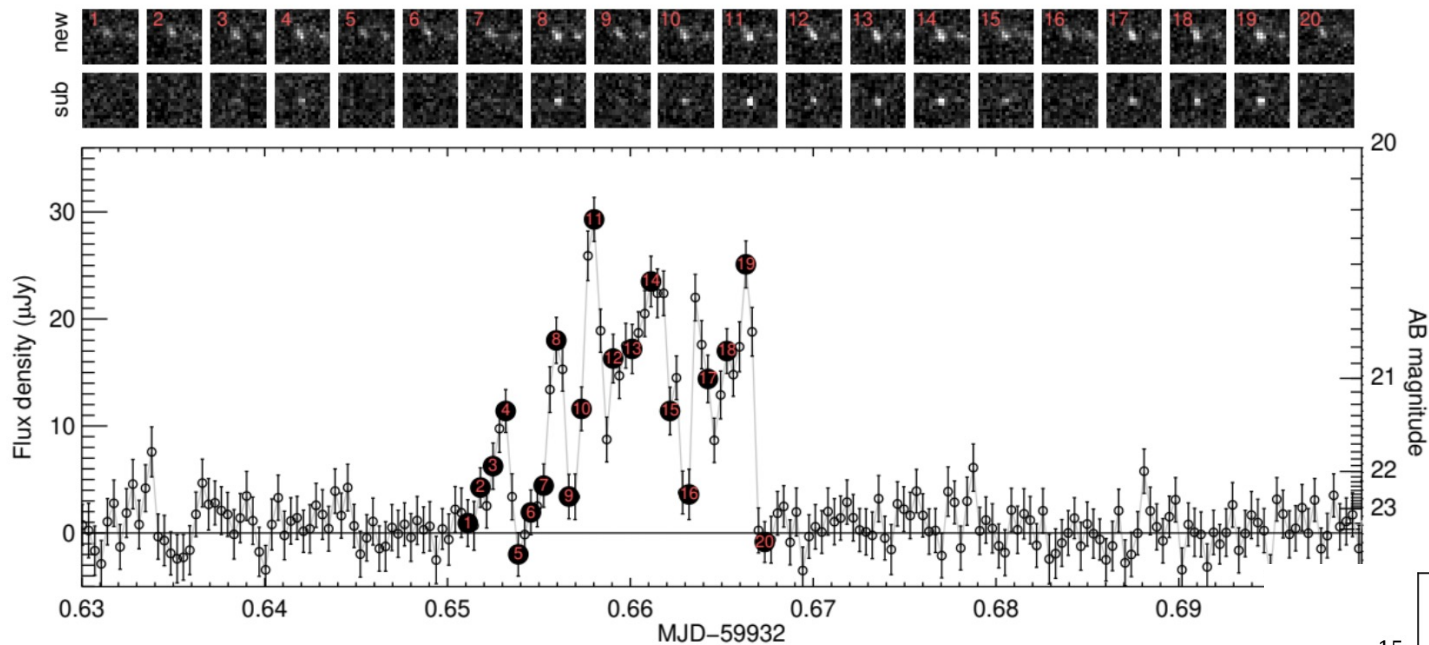
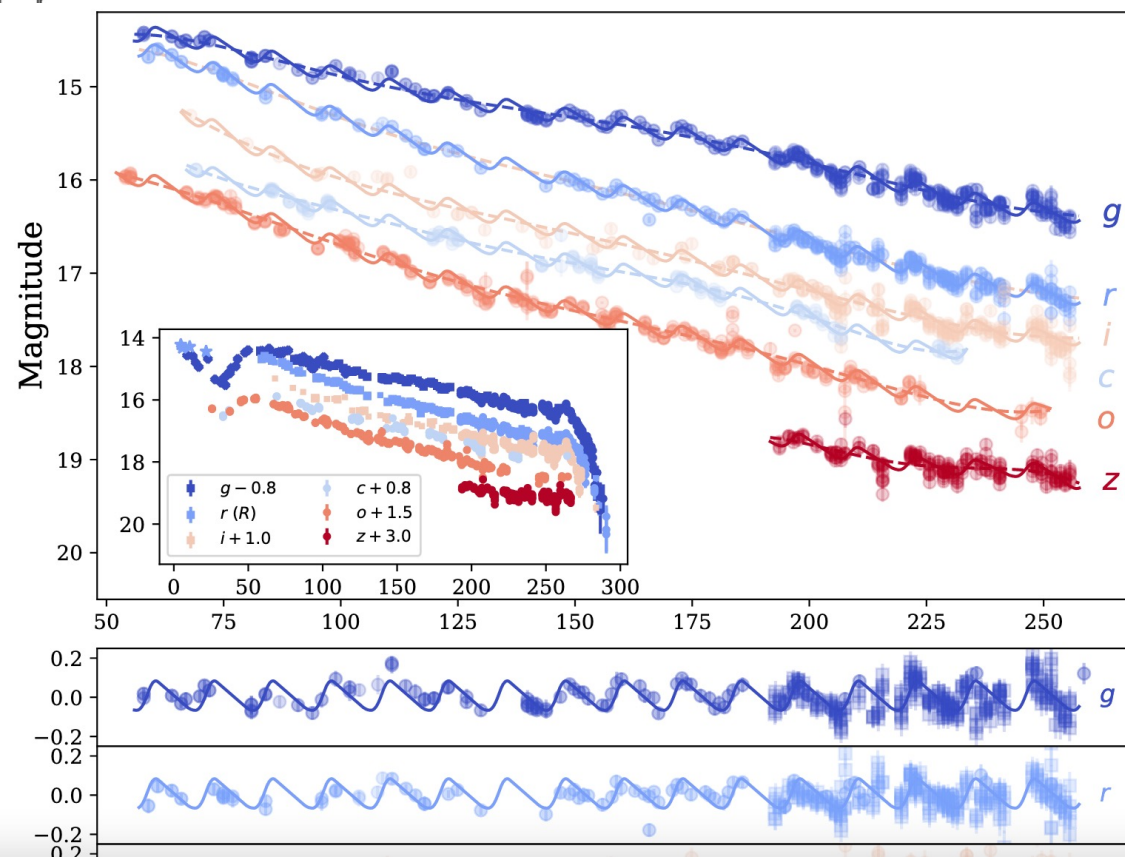


Figure 3: **Selected images from two flares in the AT2022tsd light curve,  $\approx 100$  original transient event. Top: A flare was detected across five Magellan/IMACS  $g$ - $b$ :**

Anna Ho

Ping Chen







12.00-16.00 Tuesday Berlin

12.00-12.15 Jesper Introduction

12.15-12.35 Ido Irani - Early-time UV light curves of Type II SNe (shock cooling) (15 + 5 min)

12.35-12.50 Kaustav Kashyap - Early-time light curves of SESNe (shock cooling + double nickel distribution) (10 + 5 min)

12.50-13:05 Sean Brennan - Bright Interacting Transients (10 + 5 min)

13.05-13.25 Yashvi Sharma - Reborn SNe and together long-time interactors (15 + 5 min)

13.25-13.35 Christoffer Fremling and William Meynardie - The Double-peaked ZTF21abmldj (5 +

5 min + time for discussion

Ping Chen - ZTF22aapubuy (10 + 5 min)

Lin Yan - SLSNe spectroscopy (10 + 5 min)

Steve Schulze - The Si+S flasher (5 + 5 min)

Dan Perley - The complete BTS sample (15 + 5 min)

K-Ryan - SNe II light curves (10 + 5 min)

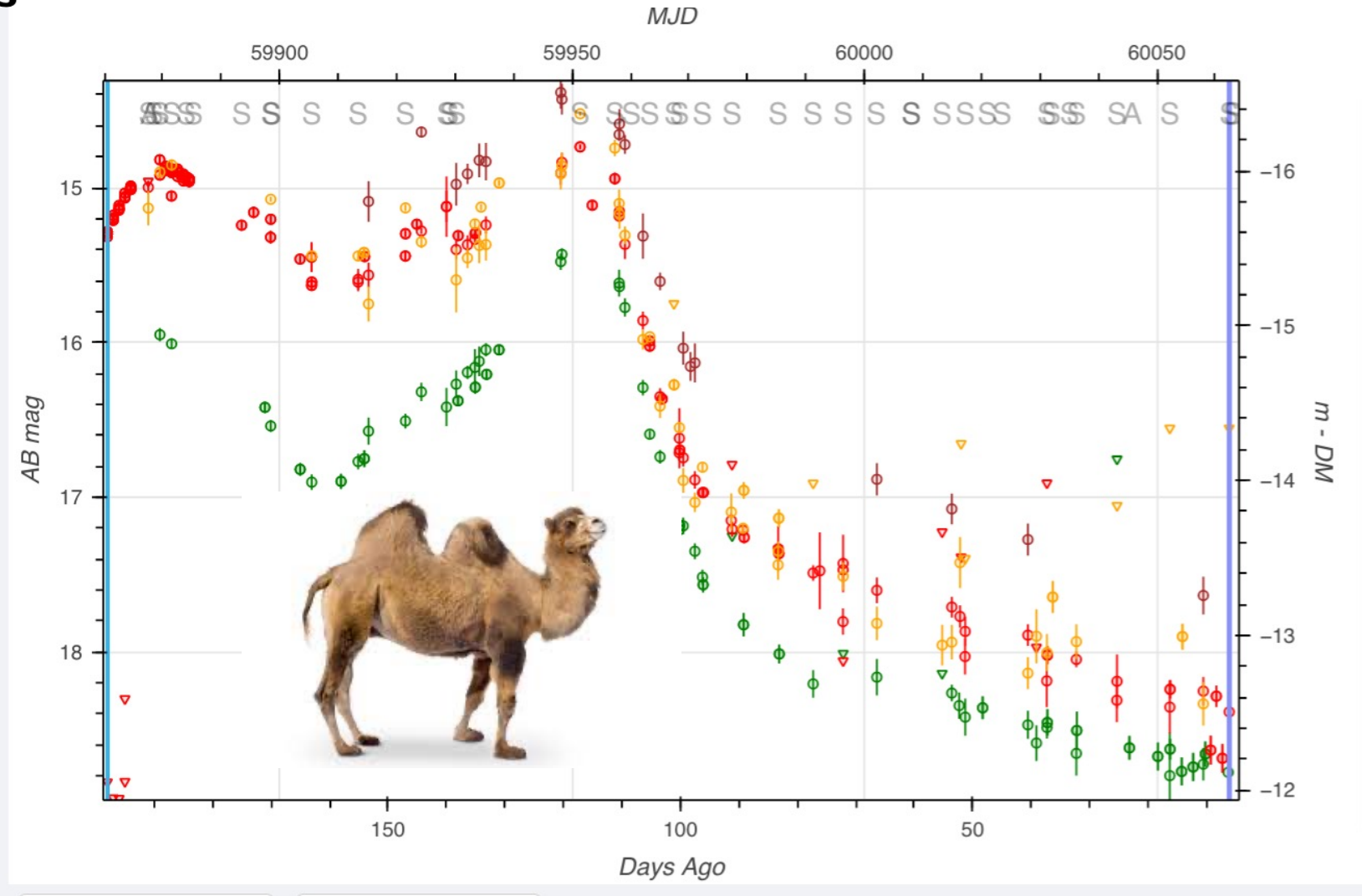
General discussion

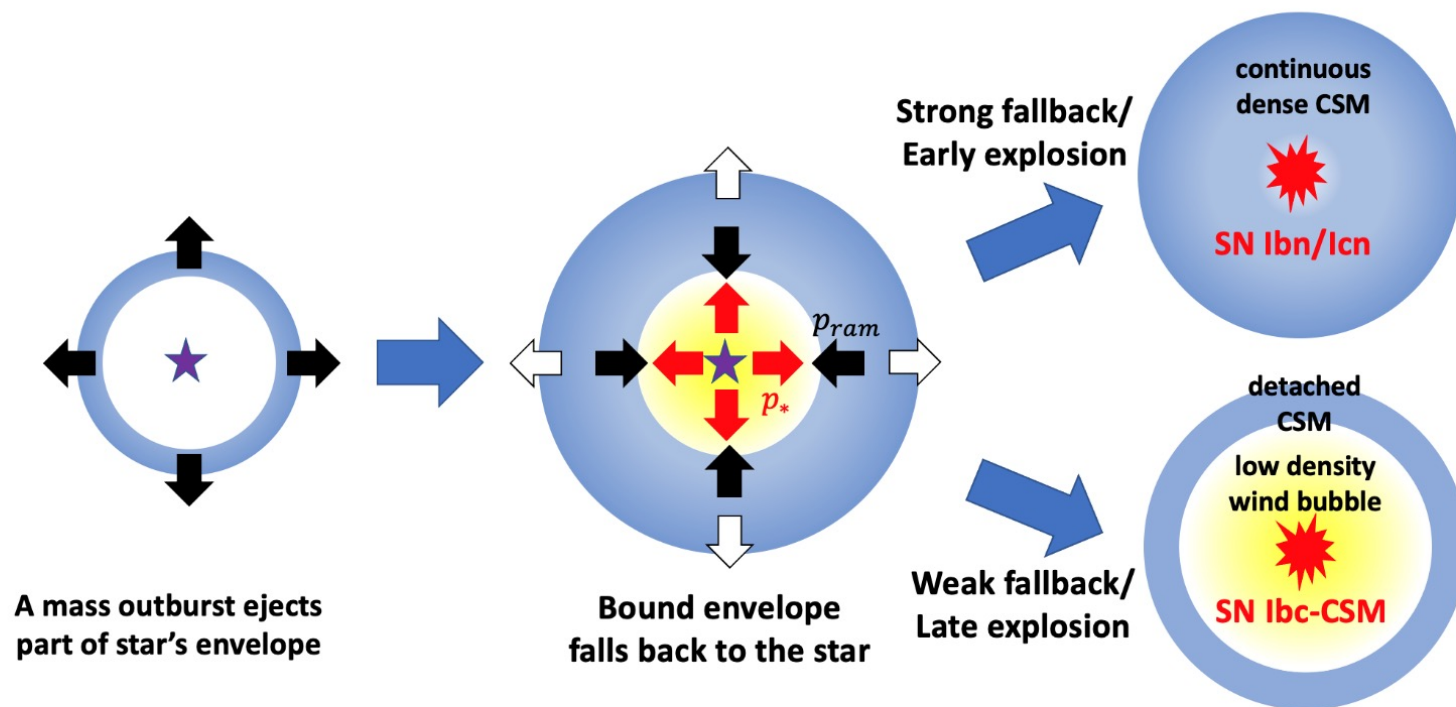


# The Bactrian? Broad-lined Type-Ic supernova SN 2022xxf with extraordinary two-humped light curves

H. Kuncarayakti,  
Kankare, M. Kaw  
M. Fraser, C. P. G  
Anderson, C. Ash  
Gromadzki, S. L.  
R. L. Riddle, Y. Sh

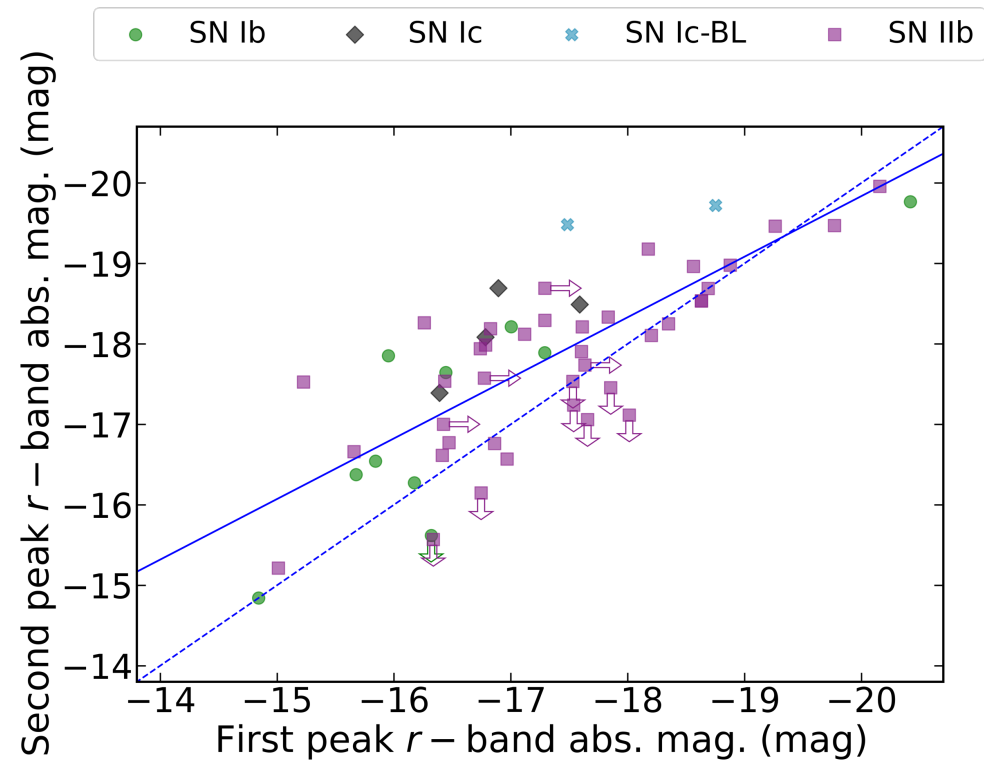
Valle, L. Dessart, K. Hinds, E.  
, P. Charalampopoulos, Q. Fang,  
. Moran, I. Murata, I. Salmaso, J. P.  
Galbany, A. Gal-Yam, M.  
Iler-Bravo, M. Nicholl, F. Ragosta,



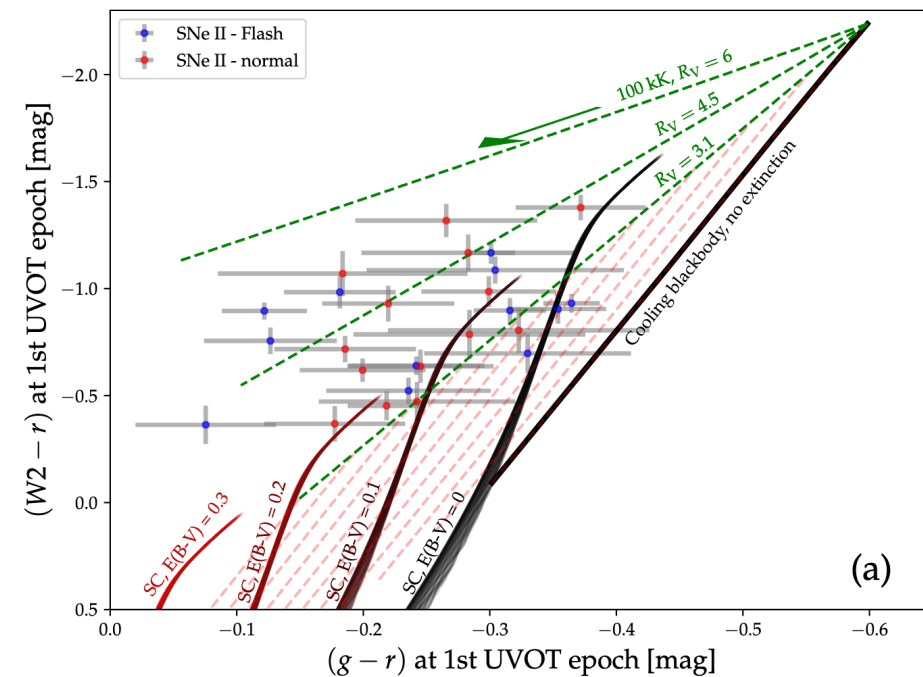


**Fig. 1.** Schematic picture of our model for the diverse structure of hydrogen-poor CSM in interacting Type Ibc SNe. Whether the CSM is detached at core-collapse is set by the competition between the ram pressure of the infalling CSM and the outward pressure from the remnant star.

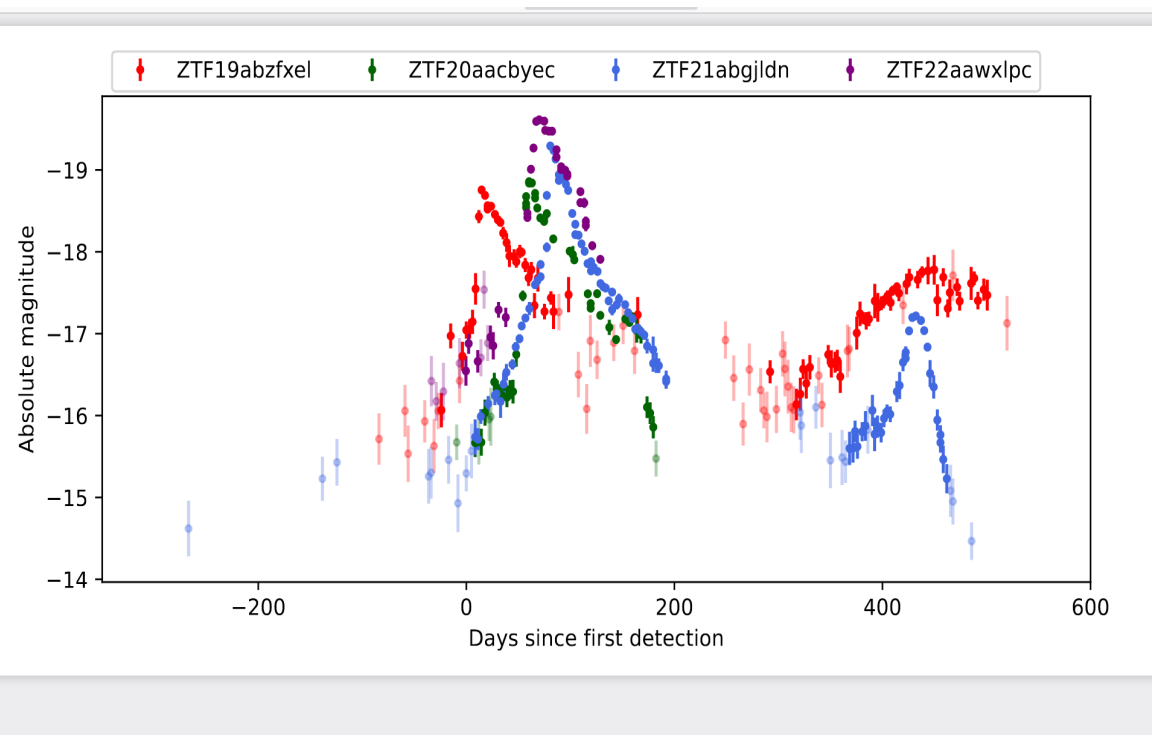




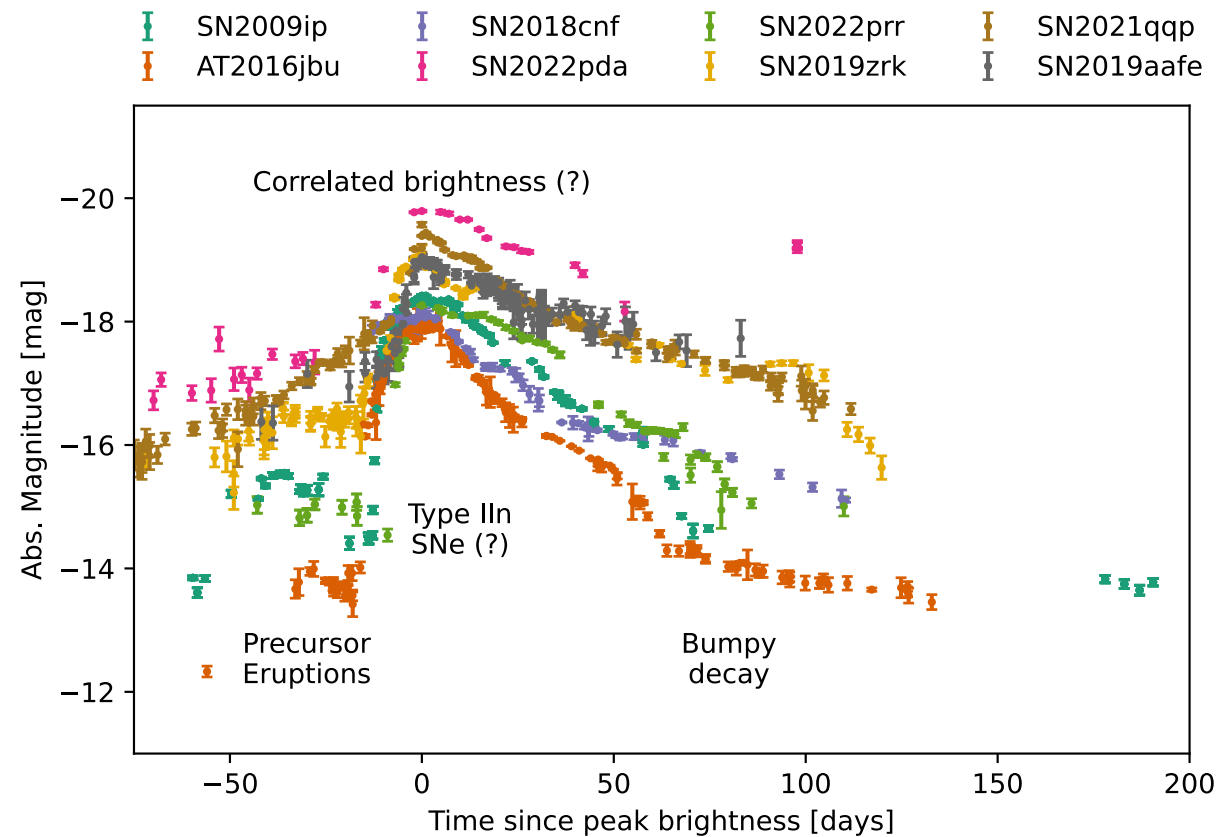
Kaustav  
 Double-peaked  
 SNe Ibc



Ido  
 SNe II UVOT



Sharma  
Zombie SNe II<sub>n</sub>

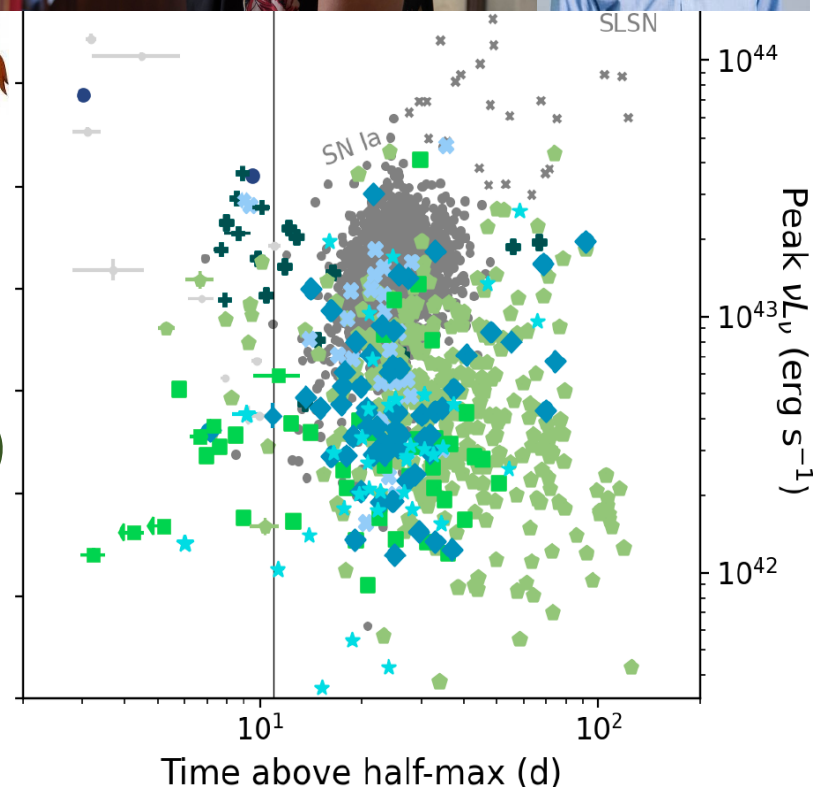
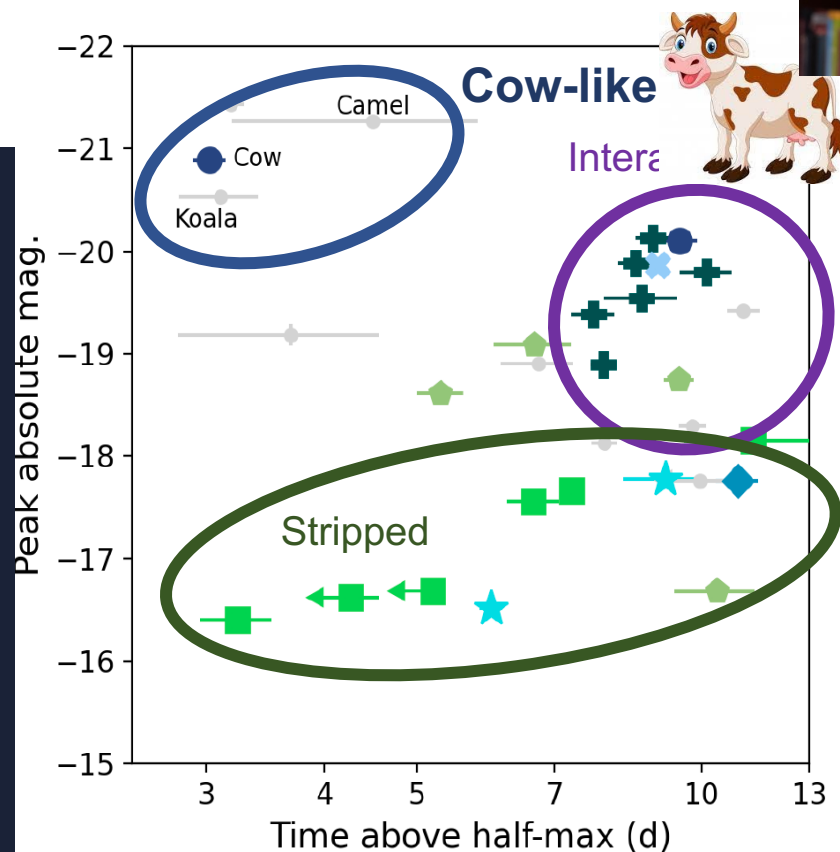


Brennan  
Pre-cursors

# Fast transients

- Events similar to 18cow : fast, blue, **luminous radio & X-ray**
- Six new events since 2018, all (co-)discovered by ZTF
- Six ZTF-discovered afterglows without a detected GRB.

Most "FBOTs" are  
Ibn's, I Ib's, stripped  
Ib, etc. (Ho et al. 2021)





2023 Berlin:

Legacy. - Final samples

Fritz, Wiserep, Ampel, Data

Sharing, overviewing data

**Will have papers to write for  
many years to come!!!**

ZTF-III & O4 & Supernovae!

2022 Paris:

Fritz, duplicates, filterwheel, zeolites

Pipelines / Classifications efforts; SSC

Sharing Data

Storing Data – Wiserep / Fitsfiles

Samples

RRM. - Ampel, ZTFRest, Infants...

Simplify collaborations

