HUNTING FOR HIDDEN SUPERNOVAE

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The Progenitor-Supernova-Remnant Connection
Ringberg Castle
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Optical searches are blind to supernovae heavily obscured by dust.

IR searches can provide a way forward, but have been hindered by detector cost and the bright IR night sky background.

Transient surveys now coming online will systematically explore the dynamic infrared sky.

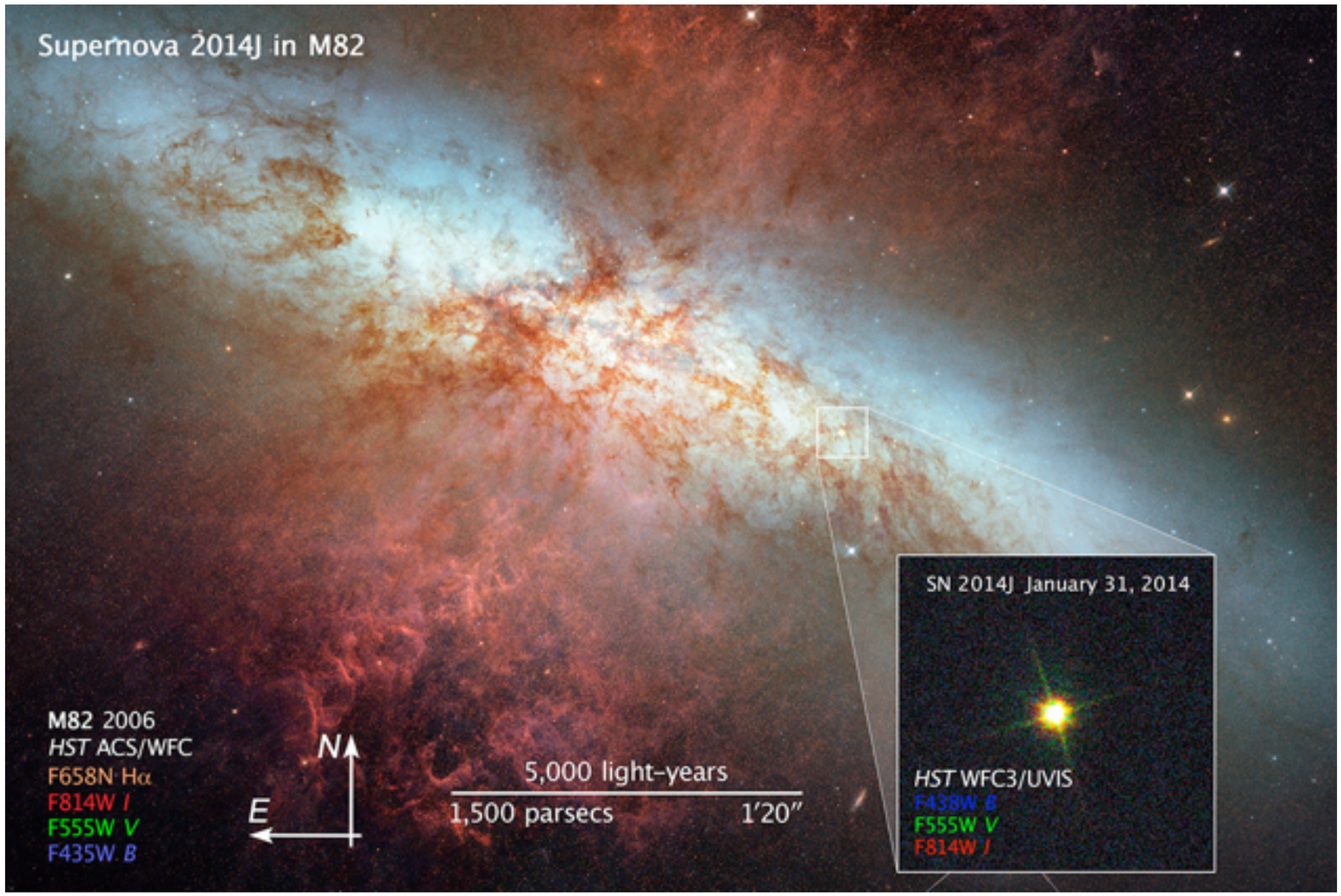


Image Credit: NASA, ESA, A. Goobar (Stockholm University), and the Hubble Heritage Team (STScI/AURA)

Open Questions:

1. What is the missing SN fraction in the local universe?
   - Can obscured SNe explain the "supernova rate problem?"

2. What are the progenitors of obscured SNe?
   - Can obscured SNe explain the "red supergiant problem?"

3. What are the environmental conditions of obscured SNe?
   - Do obscured SNe represent a separate SN population originating from extreme environmental conditions?

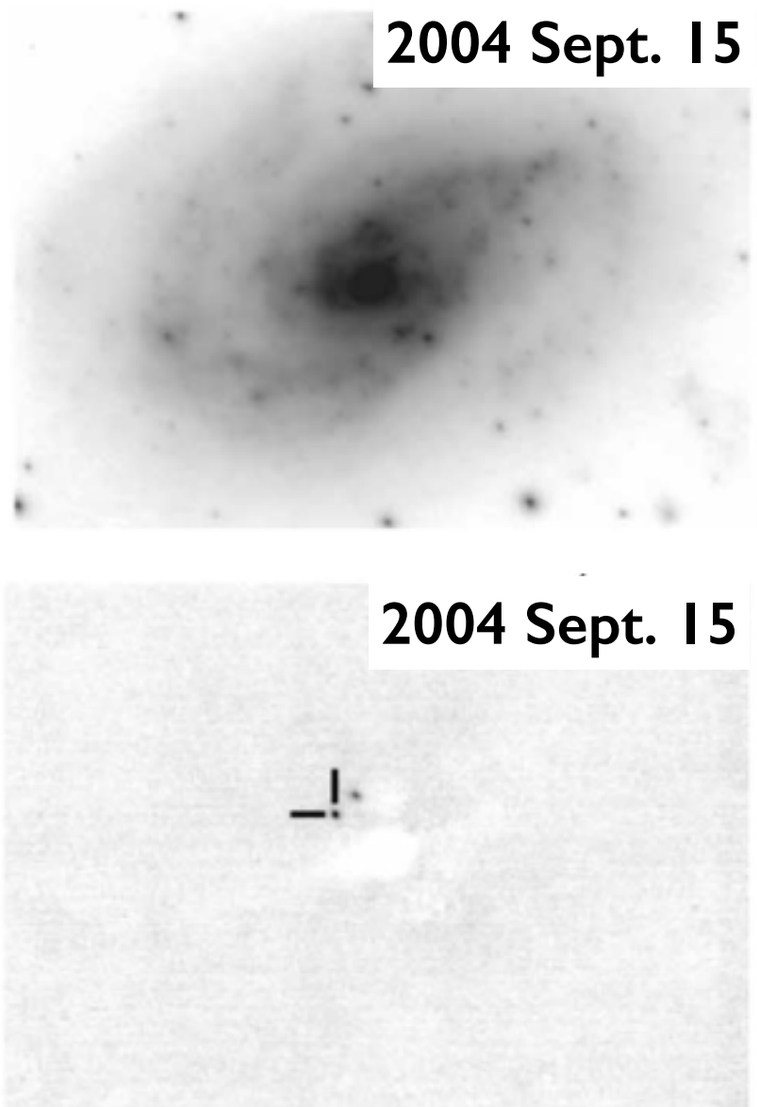
Previous searches have focused on extreme environments of (U)LIRGs and starbursts.

4 confirmed obscured SNe from near-IR, high-resolution searches (Cresci+ 2007, Mattila+ 2007, Kankare+ 2008, 2012).

Radio VLBI studies reveal scores of missed SNe (e.g., Perez-Torres+ 2009, Romero-Cañizales+ 2012).

No candidates from *Spitzer* search of nearby starbursts (PI O. Fox).

SN 2004ip in IRAS 18293-3413



NACO K_s-band
16.5" x 11.5"

Image subtraction with May 4 reference.

Mattila+ 2007

SPIRITS: A targeted search of nearby galaxies for transients in the mid-IR.

1410 hours over 5 years with *Spitzer*

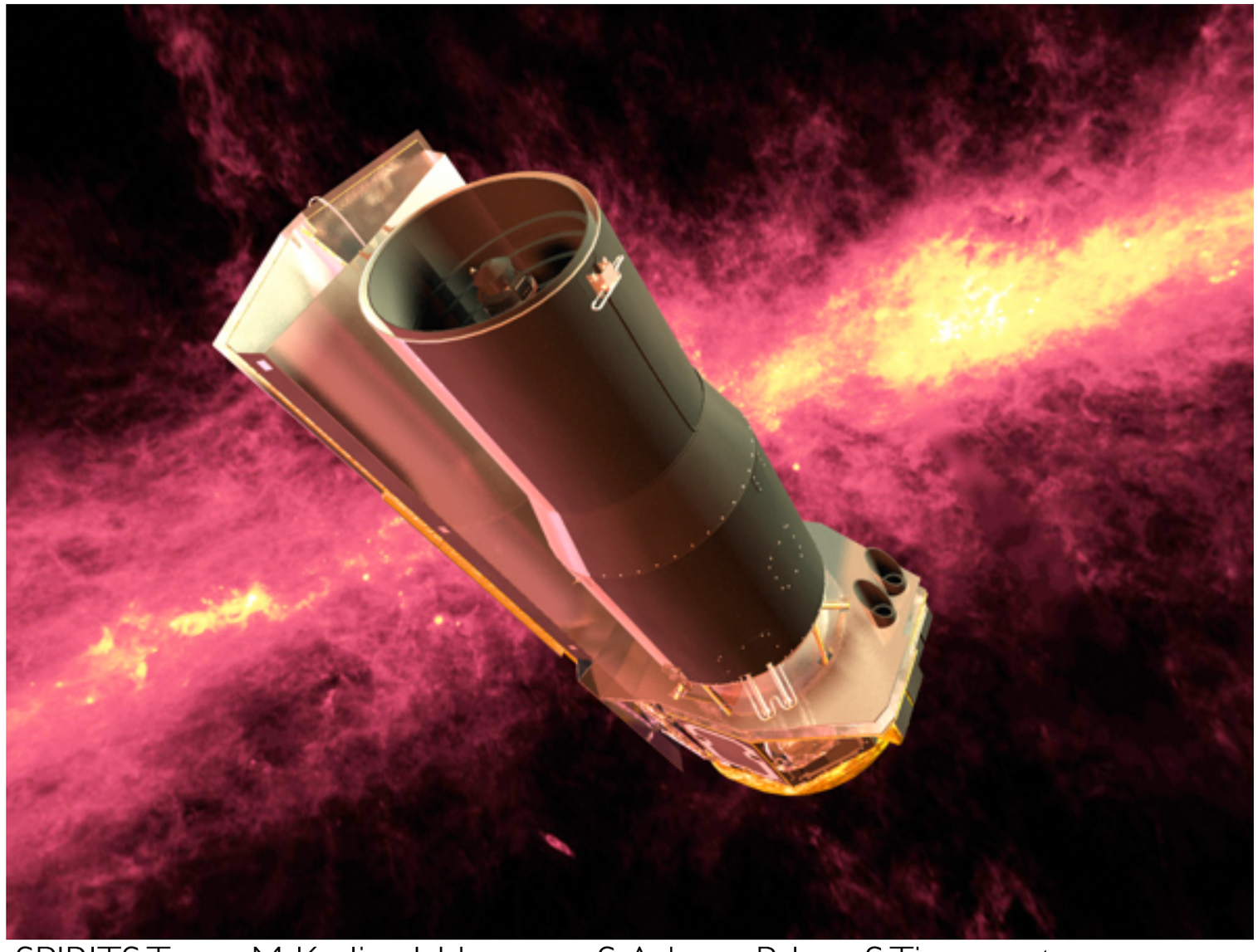
Cycles 10-12 (2014-2016)
194 galaxies x 10 epochs

Cycle 13 (2017-2018)
105 galaxies x 4 epochs

Sample < 20 Mpc

Depth of 20 mag (Vega) at [3.6] and 19 mag at [4.5]

Cadence baselines spanning one week to several years



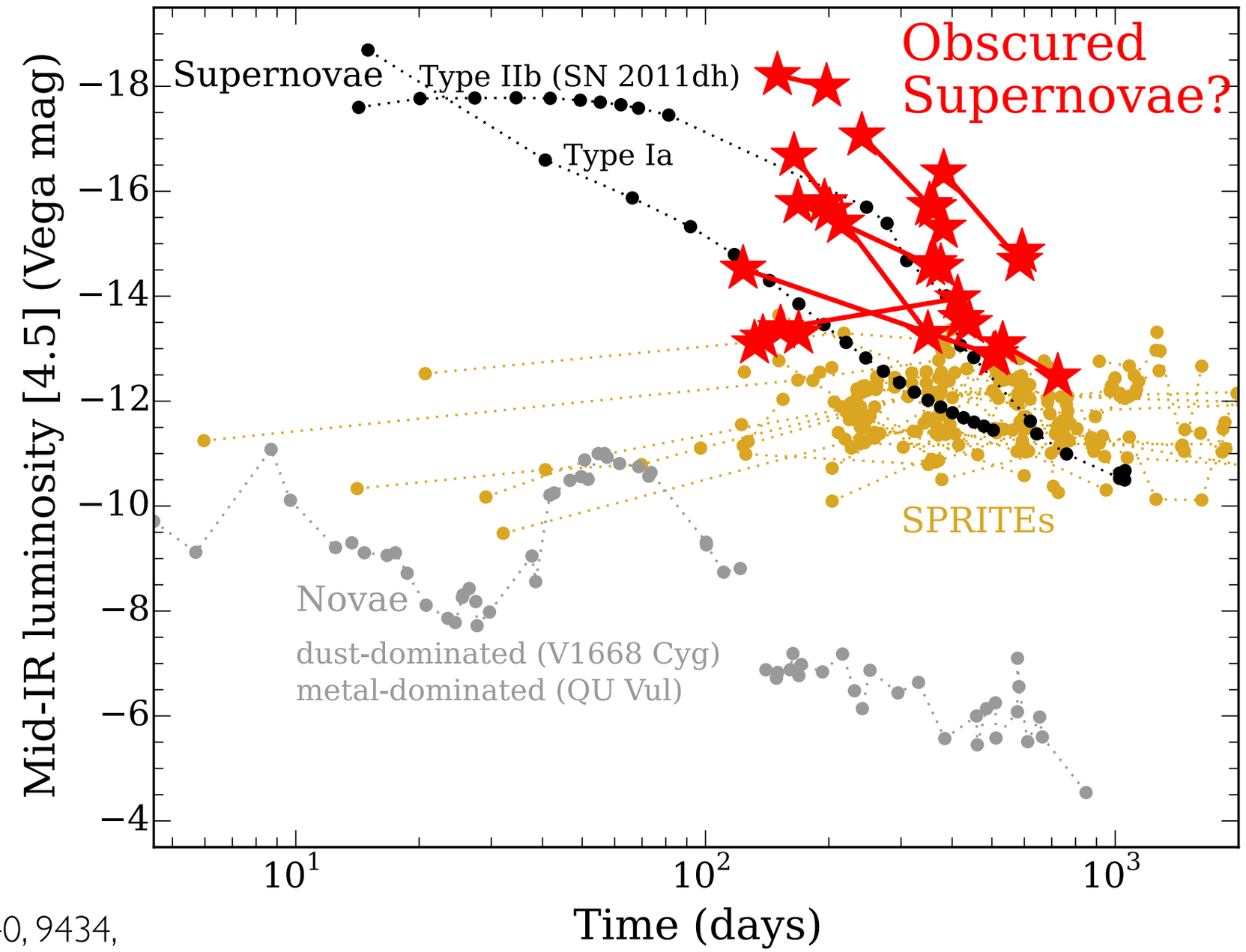
SPIRITS Team: M Kasliwal, J Jencson, S Adams, R Lau, S Tinyanont, D Perley, F Masci, G Helou, L Armus, S Van Dyk, A Cody, M Boyer, H Bond, A Monson, J Bally, O Fox, R Williams, P Whitelock, R Gehrz, N Smith, J Johansson, E Hsiao, M Phillips, N Morell, C Contreras+

SPIRITS is discovering a wide range of IR transient sources.

Identified 147+ transients:

- 37 known supernovae
- 17 likely novae
- 57 eSPecially Red Intermediate-Luminosity Transient Events (SPRITEs; Kasliwal+ 2017)

10 luminous transients are likely to be newly discovered obscured SNe.



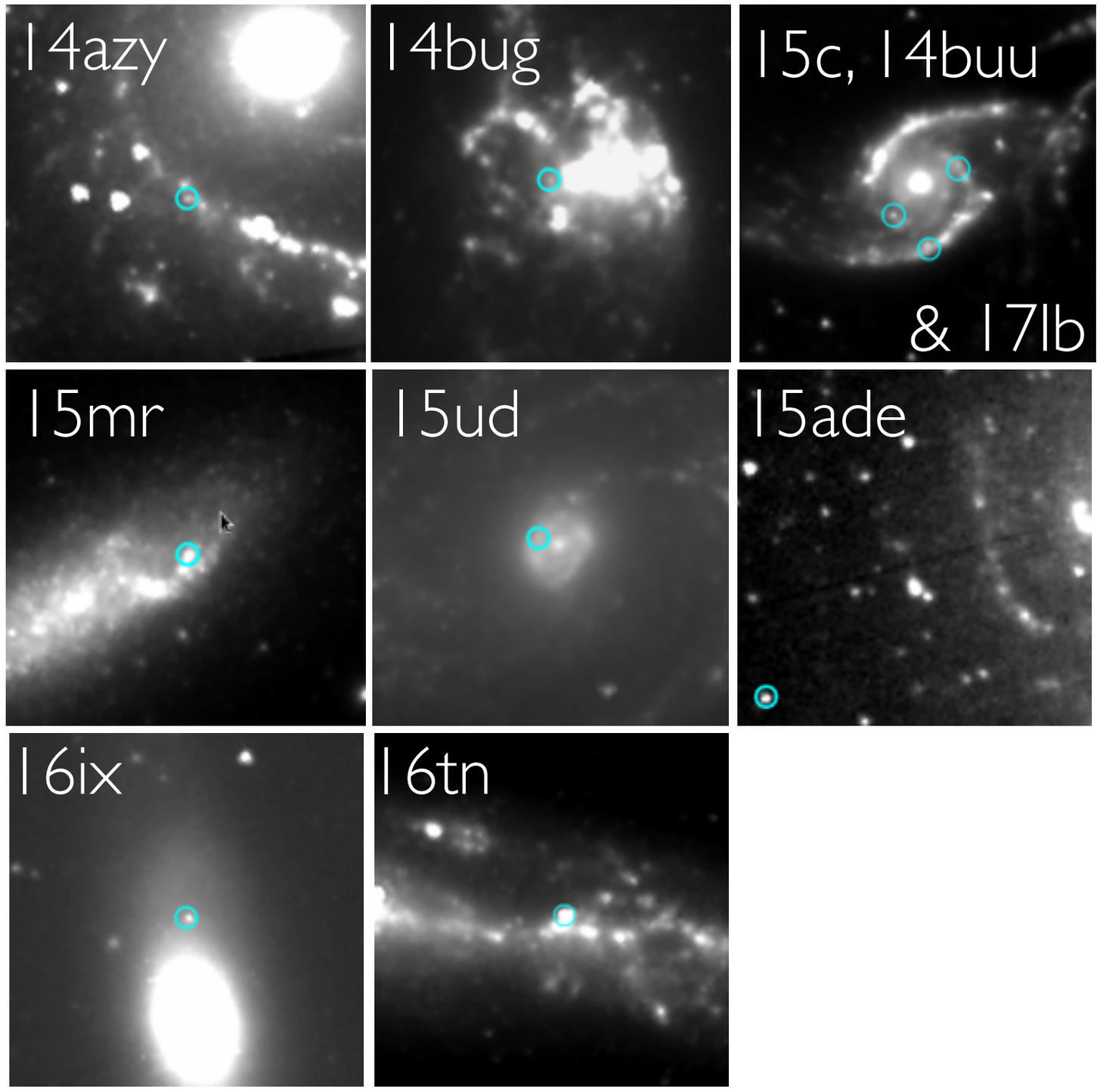
ATels: Kasliwal+ 2014: #6644
Jencson+ 2015-17: #7929, 8688, 8940, 9434, 10171, 10172, 10488

Fraction of missed obscured events may be as high as 50%.

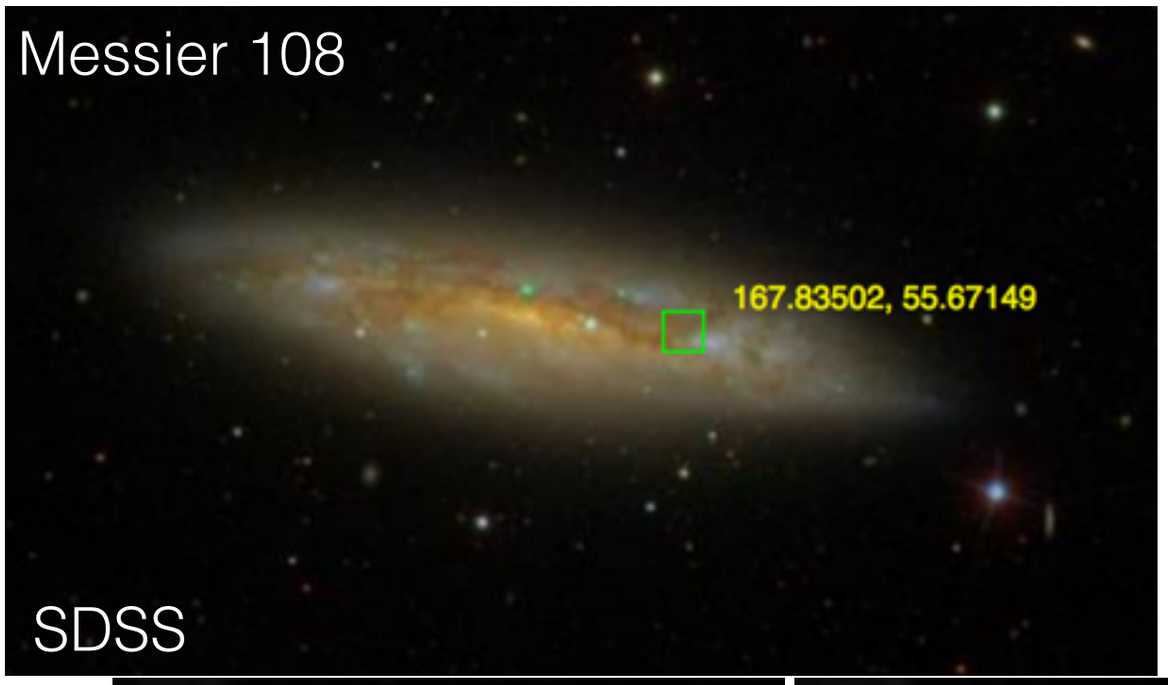
Equal number of optically discovered CCSNe in our sample since 2014

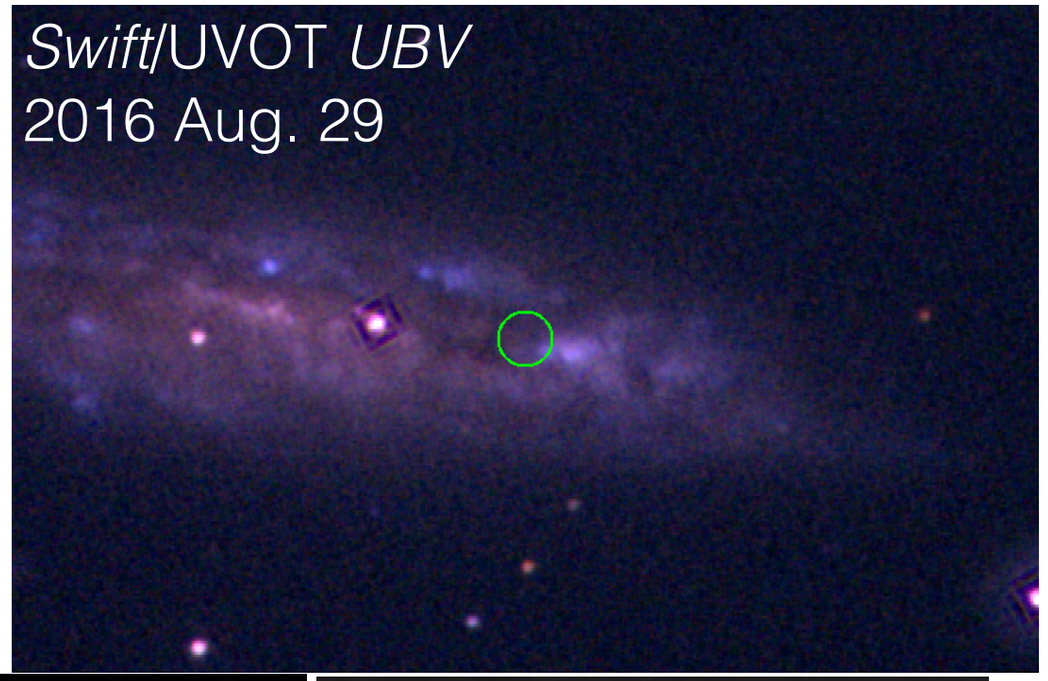
Two confirmed spectroscopically, and one additional based on optical/ near-IR light curves (Jencson+ 2017; Jencson+ in prep.)

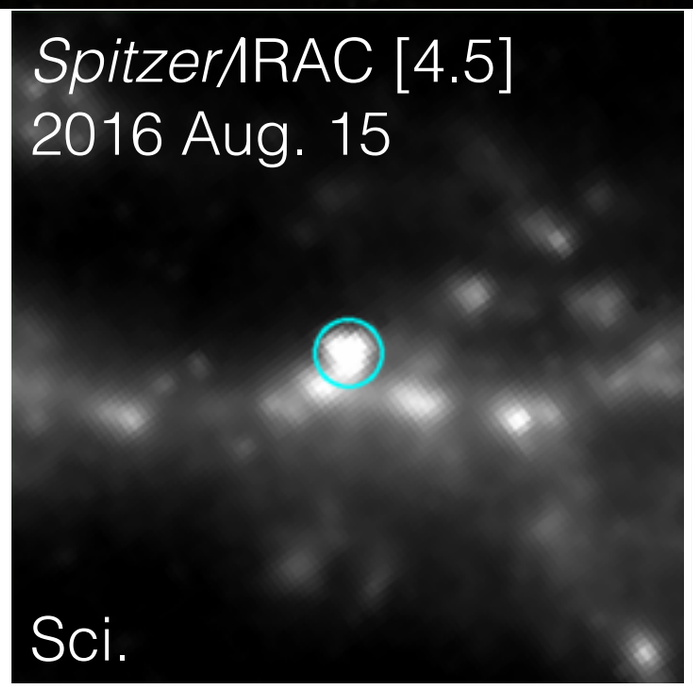
Radio follow-up with VLA and ATCA ongoing

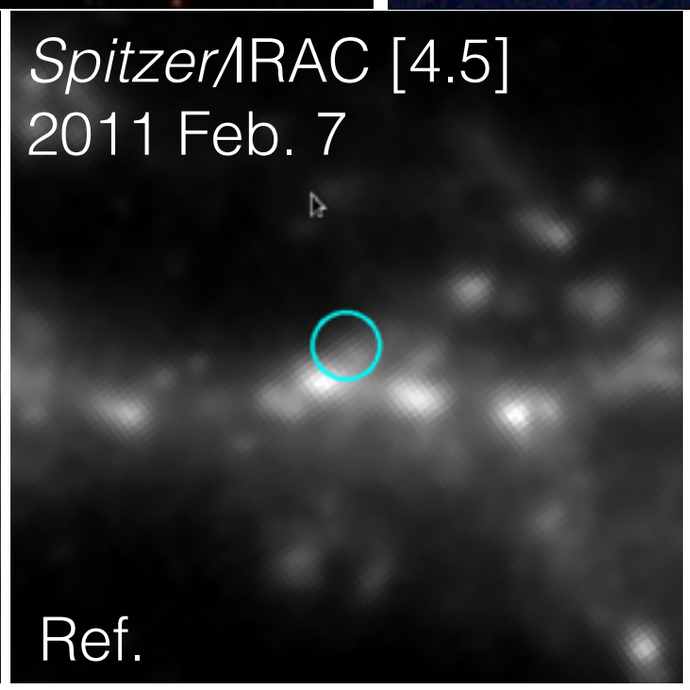


SPIRITS 16tn: a highly obscured, probable CCSN at only 9 Mpc.



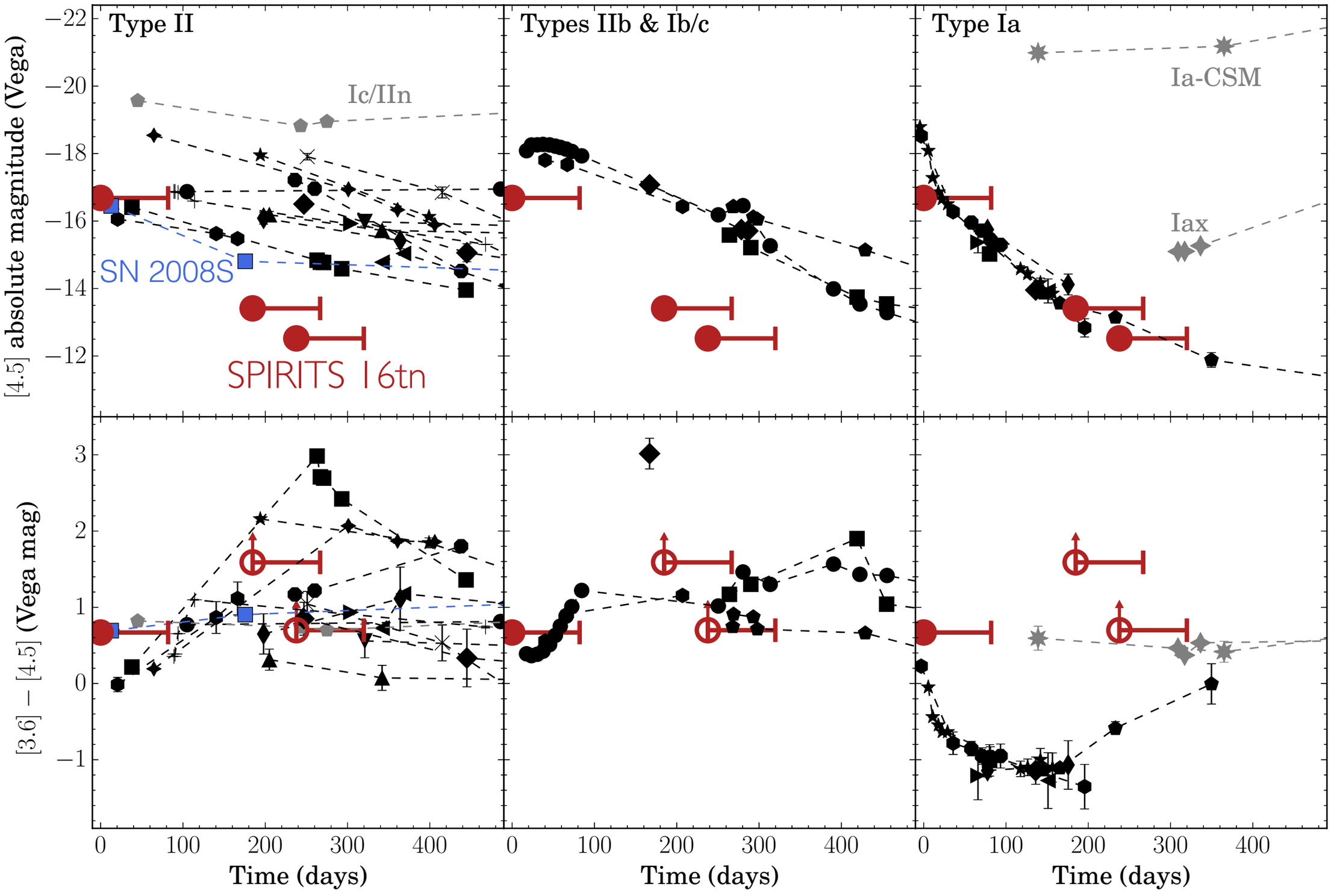






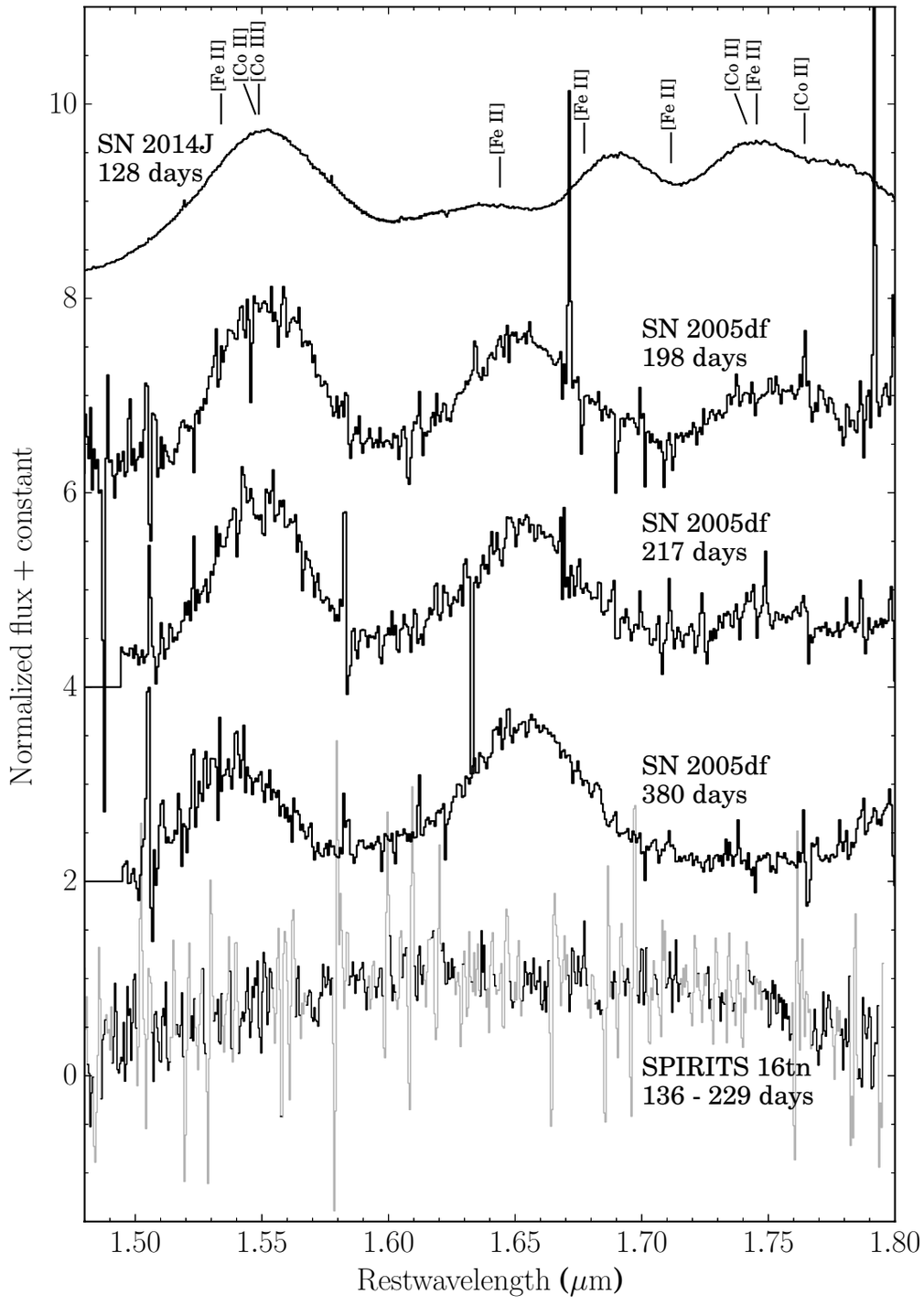
Jencson+ in prep.

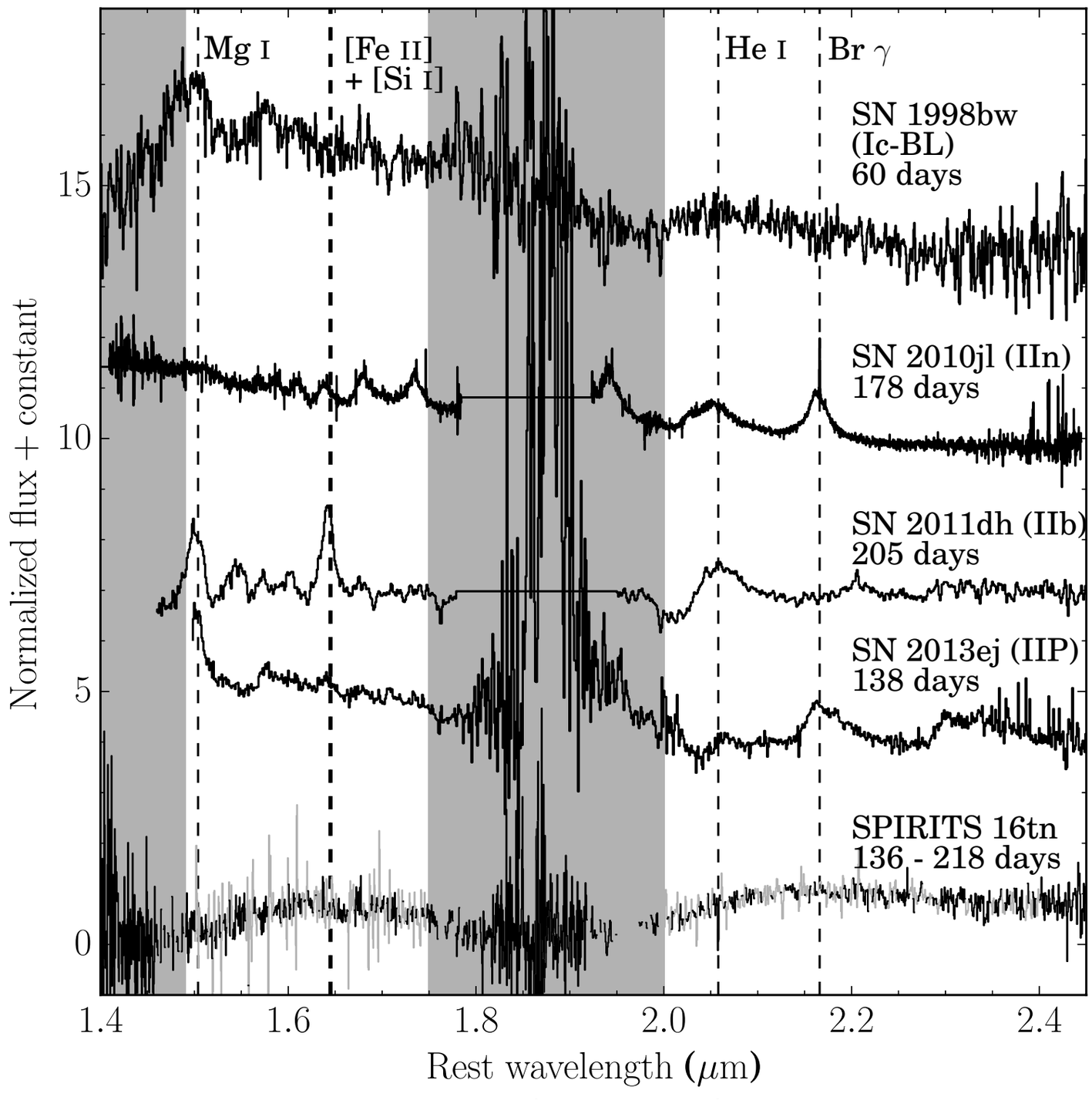
SPIRITS 16tn is unique in its mid-IR properties.



Jencson+ in prep.

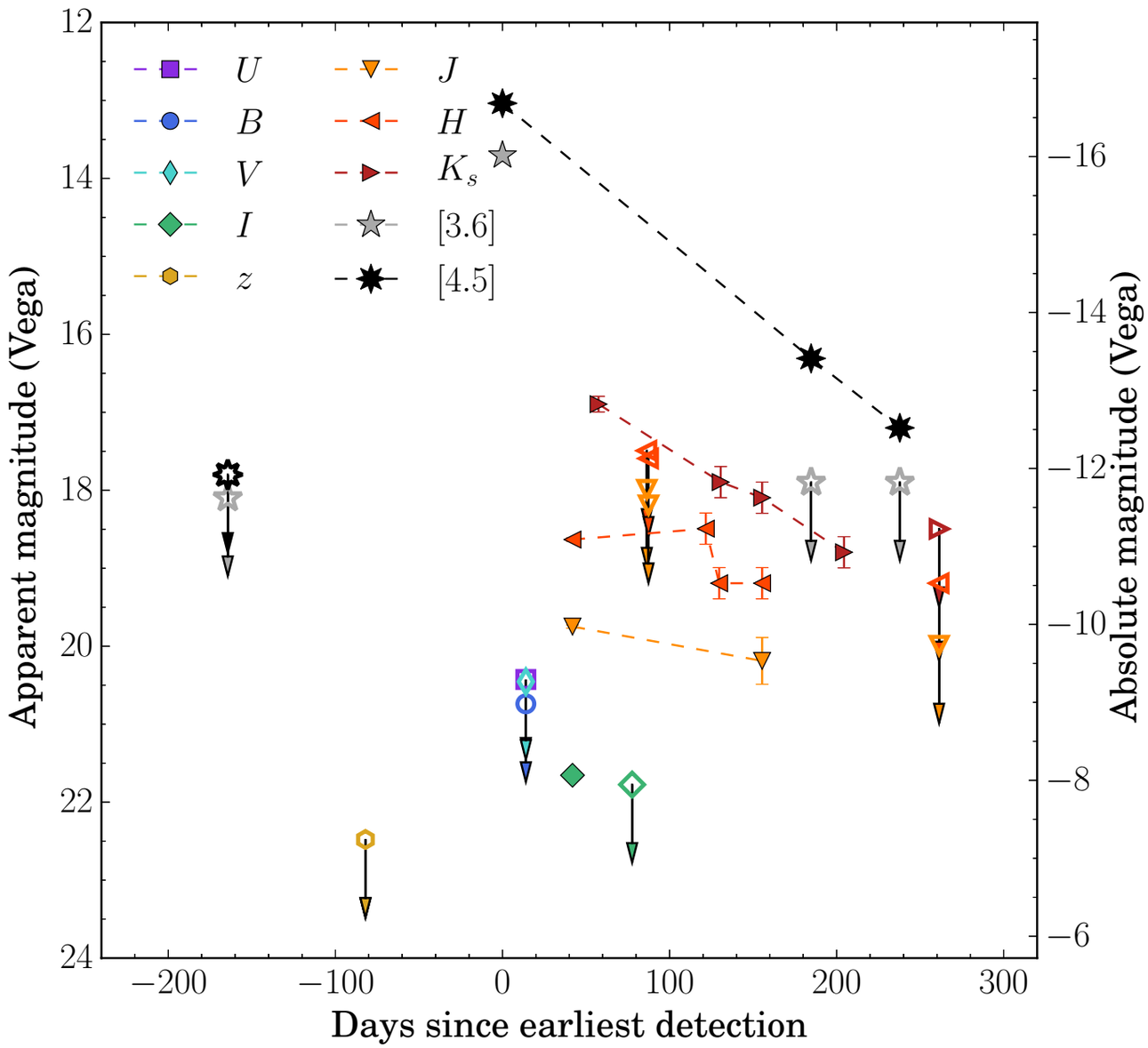
Near-IR spectrum rules out an SN Ia.

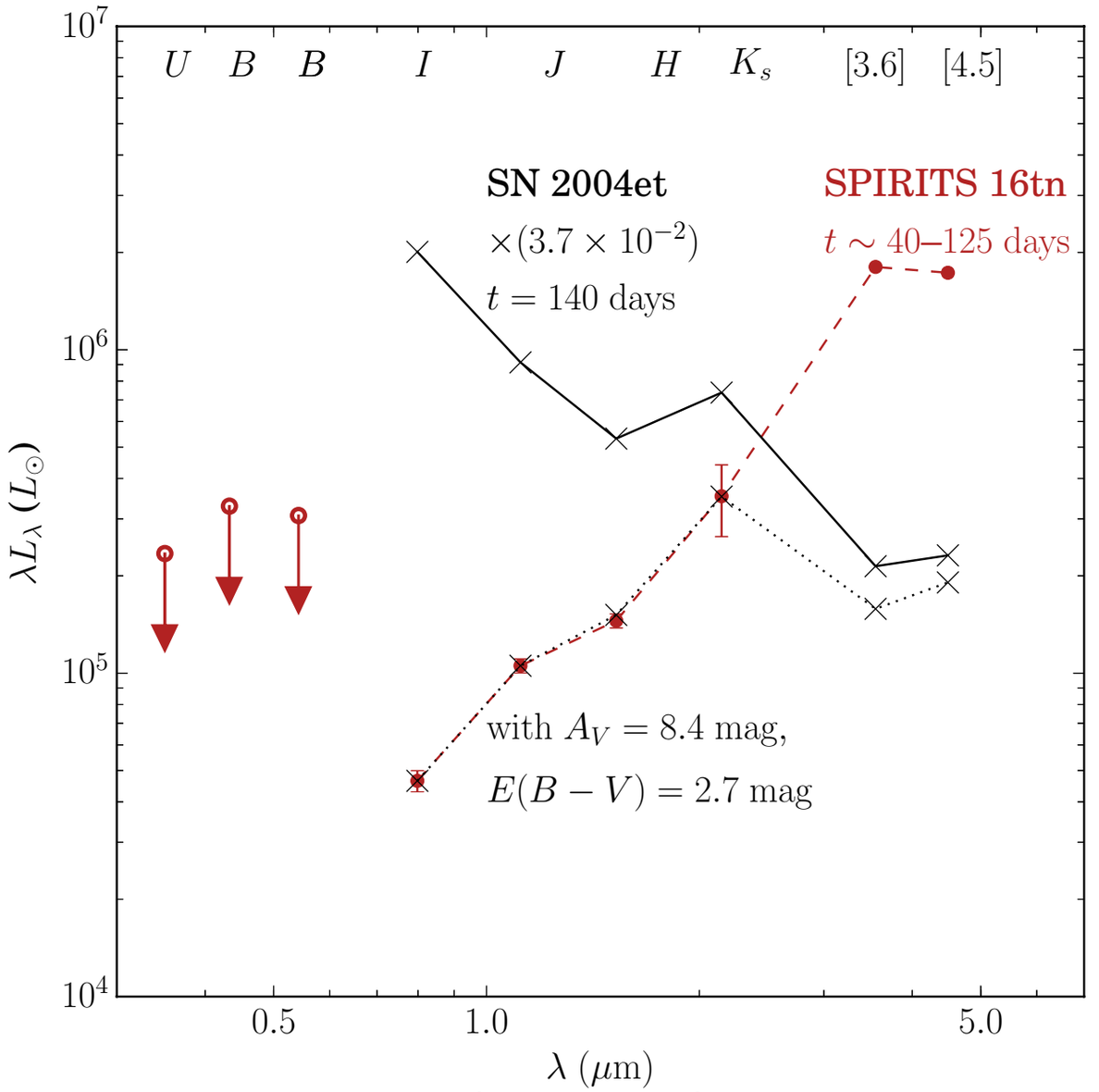




Jencson+ in prep.

Comparisons with Type II SN suggest $A_V \sim 7$ - 9 mag.





Jencson+ in prep.

VLA and AMI radio non-detections suggest a weak event or significant absorption.

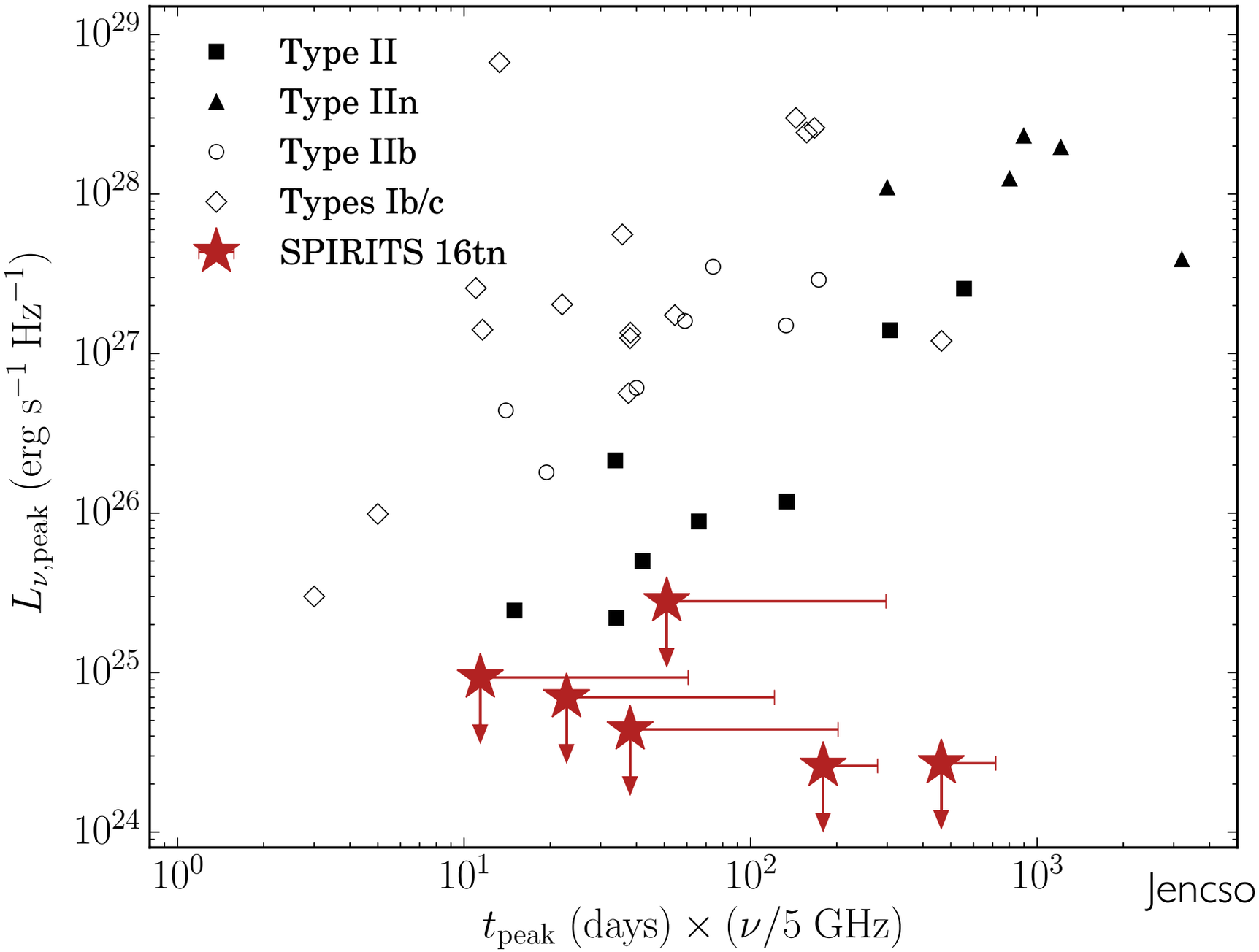
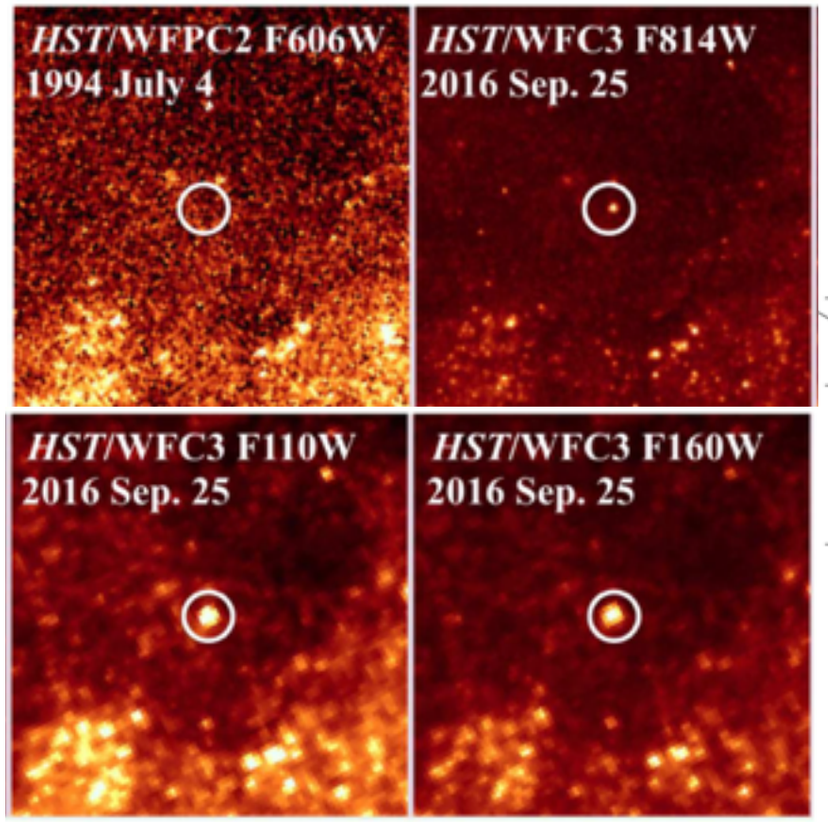


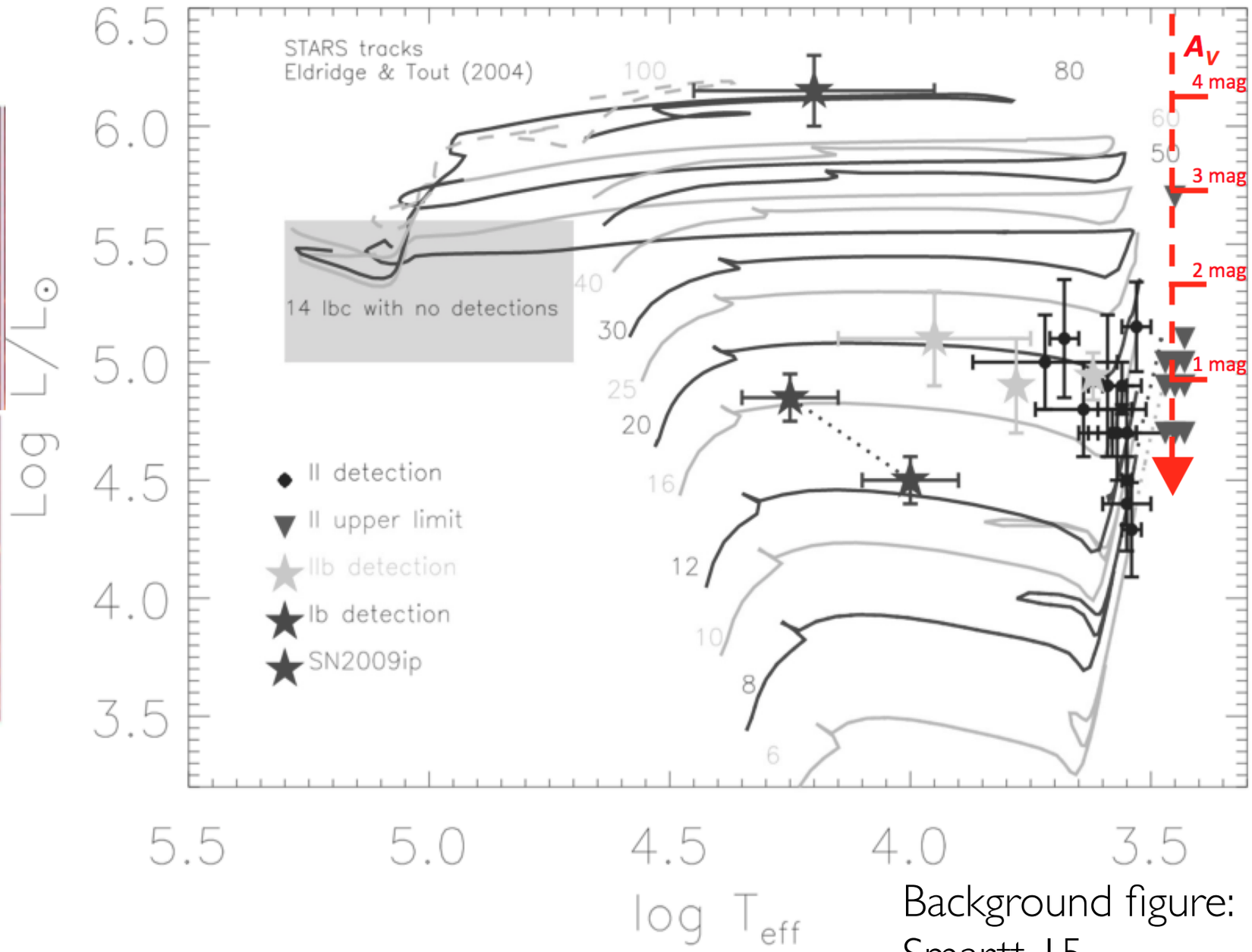
Figure adapted from Romero-Cañizales+ 14.

Jencson+ in prep.

No detection of the progenitor star in archival optical HST imaging.

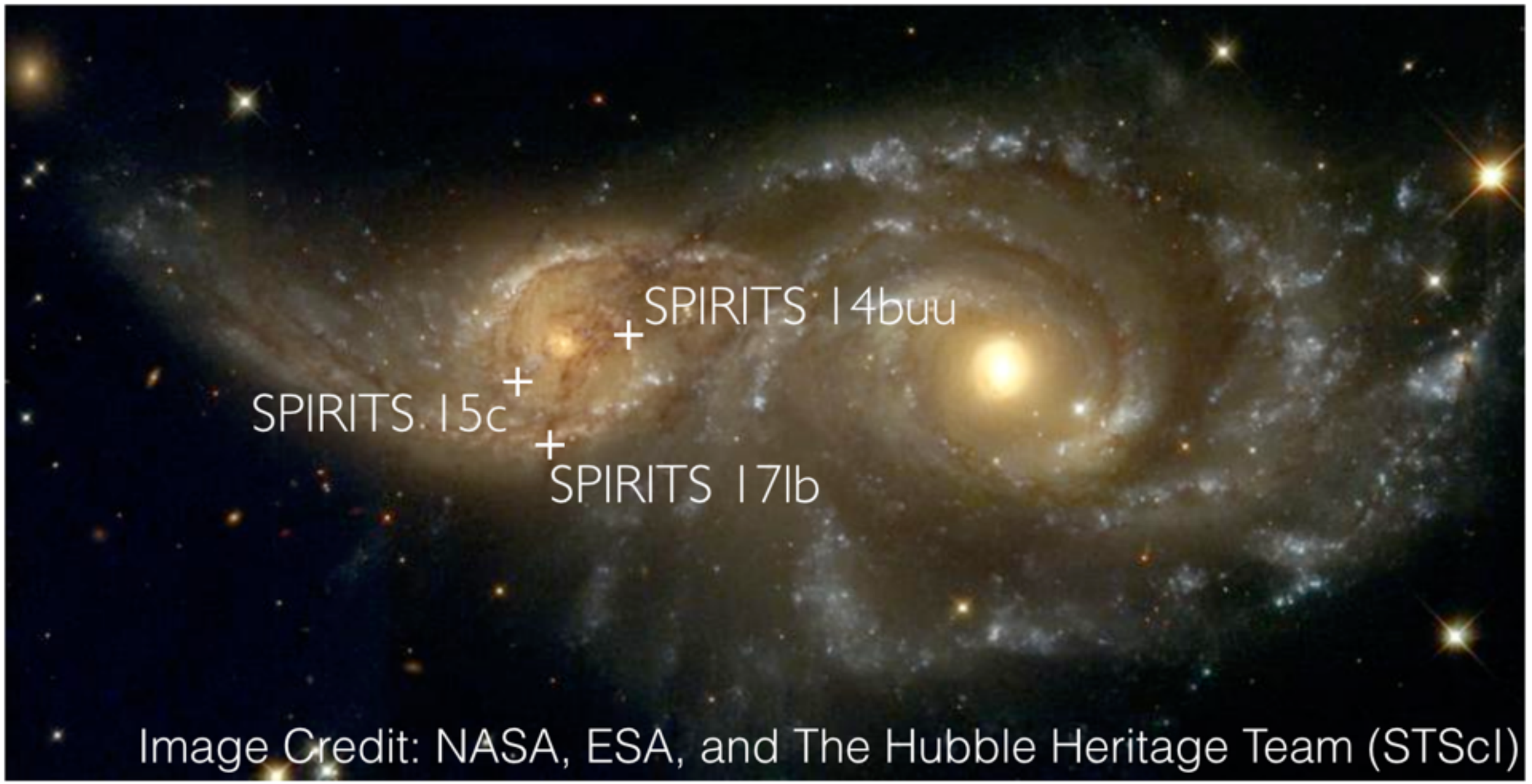


Jencson+ in prep.



Background figure: Smartt 15

SPIRITS 14buu, 15c, & 17lb: 3 SNe in 4 years in IC 2163.



Jencson+ 2017

A combination of IR searches will be sensitive to obscured SNe at a range of distances.

SPitzer InfraRed Intensive Transients Survey (SPIRITS):

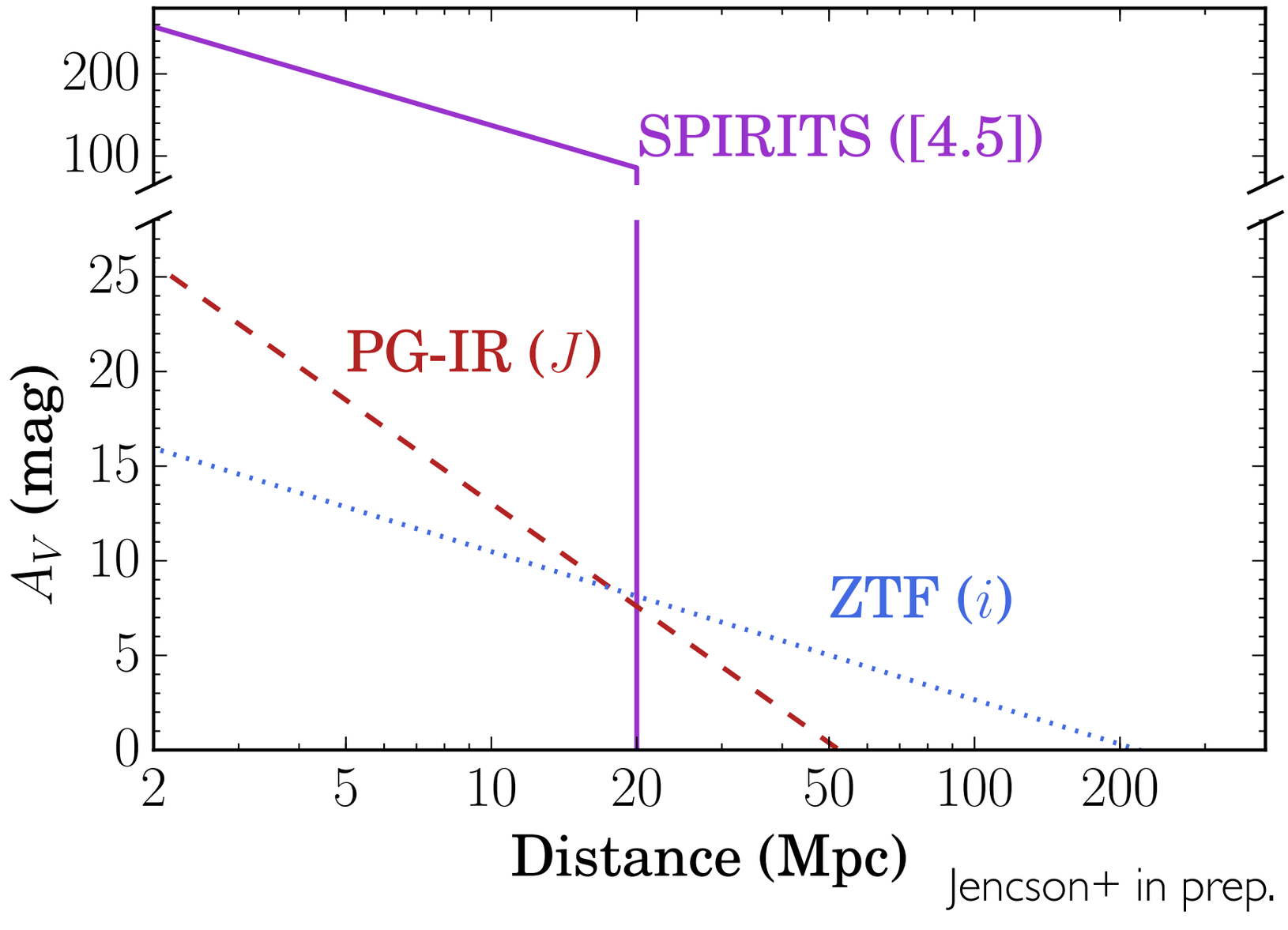
- 3.6 and 4.5 μm targeted survey of nearby galaxies.

Palomar Gattini-IR (PG-IR):

- Nightly J-band survey of 15000 deg^2.
- Expect ~ 13 SNe within 50 Mpc in 1 year.

Zwicky Transient Facility (ZTF):

- i-band survey of 6700 deg^2 at 4-day cadence.
- Expect ~ 50 CCSN within 100 Mpc in 1 year.



Jencson+ in prep.

Summary

Optical searches for SNe may miss events heavily obscured by dust.

SPIRITS is an ongoing search for transients in the mid-IR, and has found 10 dust obscured SN candidates thus far.

SPIRITS 16tn, our nearest candidate at only 9 Mpc, is a probable low-energy SN, though its mid-IR properties are unique among previously studied events.

With upcoming surveys in the optical and near-IR, we can systematically search for reddened SNe and obtain spectroscopically complete samples across varying levels of obscuration.

Searching for and characterizing obscured SNe will allow us to probe their significance for the missing SN fraction, and whether these events represent a separate population originating from extreme environmental conditions and progenitor systems.