Superluminous Supernovae from ZTF phase-I

Lin Yan, Z. Chen, R. Lunnan, S. Schulze, D. Perley, A. Gal-yam, J. Chen, A. Singh, Uli Feindt, L. Rauch, and other members of ZTF team

What is SLSN and why is it interesting ?

- (10 100)x more luminous than typical SNe
- Most SLSN are slow, t(rise) ~ 30 100 days, much longer than normal SNe (however, a small number can have t(rise) ~ 15d, see Lunnan et al. 2020)



ZTF SLSN discovery rate is ~ 7x higher:

- Photometric candidates and spectral follow-up are made with
 - [1] rise time > 25d; [2] prefer faint hosts
- 151 SLSN with z ~ 0.06 0.6 and peak mag < 20
- 91 SLSN-I and 60 SLSN-II



(1) SLSN-II: events with H-alpha emission

-- Majority are ejecta—CSM interaction, SN IIn (narrow H-alpha)



~100km/s, H-rich CSM, narrow H-alpha

> Ejecta – CSM interaction efficiently converts kinetic energy into optical emission

- Discovery of a small fraction (10-20%) of SLSN-II which are not SN IIn
 -- No strong narrow H-alpha
- what power these events??
- Magnetar + a bit H in the ejecta? Or interaction with disk CSM?
- T. Kanga + SLSN group in prep



(2) Large sample of SLSN-I => New discoveries

• Found 6 He-rich SLSN-Ib (only 1 was known before ZTF)





What do He lines (5876, 6678, 7065 7281) tell us?

- Need ~ 20eV(!) to excite He from ground state
- Traditional model: 56Ni decay -> Gamma ray photos
- SLSN-I may have central engines to naturally do this work



(3) Rare events: extremely slow SLSN-I: t(rise)>100d (Schulze et al. in prep)



(3) Rare events: SLSN-I \rightarrow SLSN-II, presence of large H-rich shells?



(3) Large SLSN-I sample: LC properties (Chen, Z., Yan, et al. in prep.)

• LC undulations are more common than what we knew before



- LCs with multiple peaks --19%, could be up to 34% including weak bumps
- Δ L can be high, 5 28% of the primary peak
- What are the physical causes? -- Interaction?



Phase relative to g band peak (rest frame days)



(4) Large sample SLSN-I:luminosity functionsand rates

Yan + SLSN group et al. in prep

Luminosity Functions

Only consider the complete sample: peak mag < 19.5 and z = [0.06, 0.4]

 LFs at z=[0.06,0.2] and z=[0.2,0.4] peaks at different Luminosity



Full simulation for the rates:

Simsurvey, + newly written magnetar model LC, + LC selection cuts for both simulated and real LCs

