Infrared Follow-up Observations of Supernovae in the TMT Era

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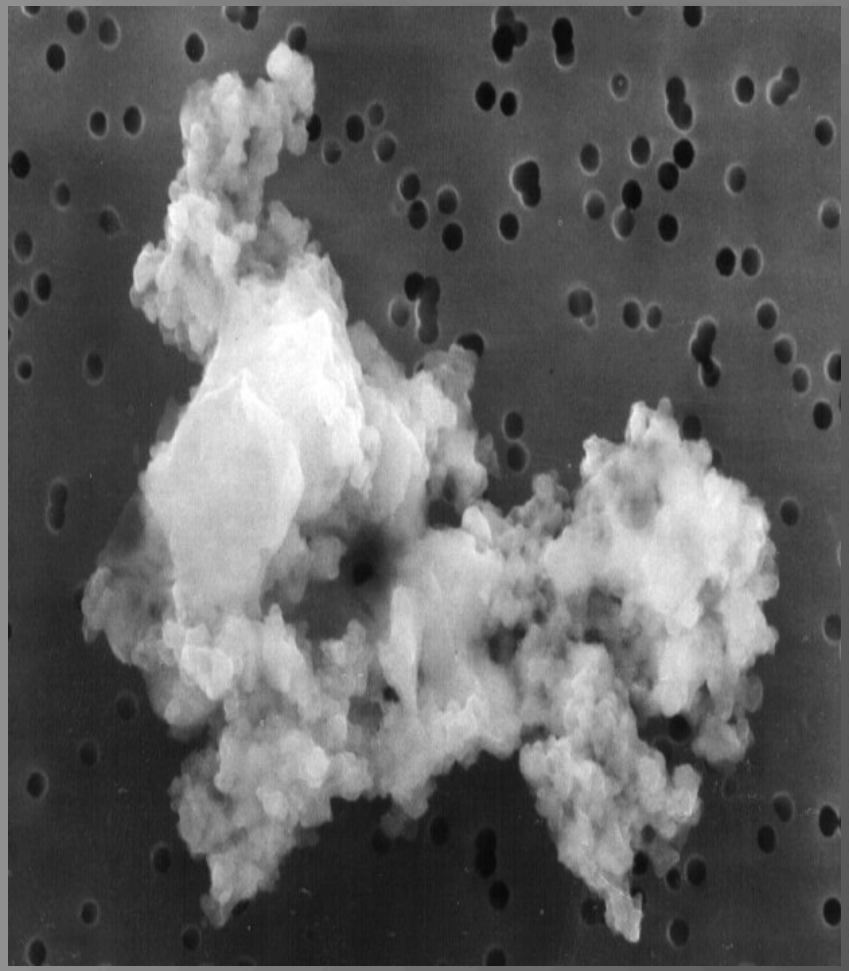
TMT DC
06/24/15

Why the Infrared

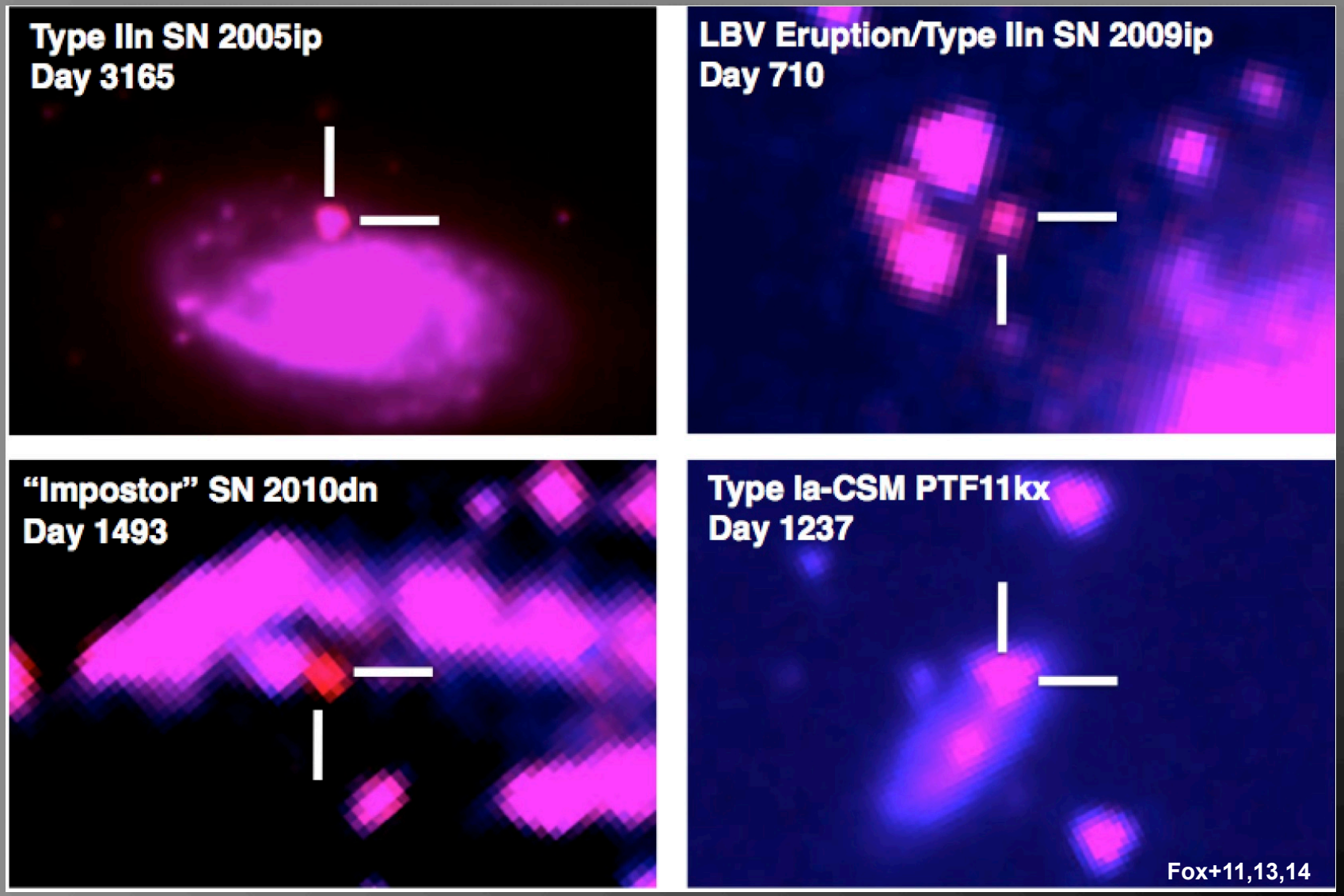
Sample Cosmic Dust Grain



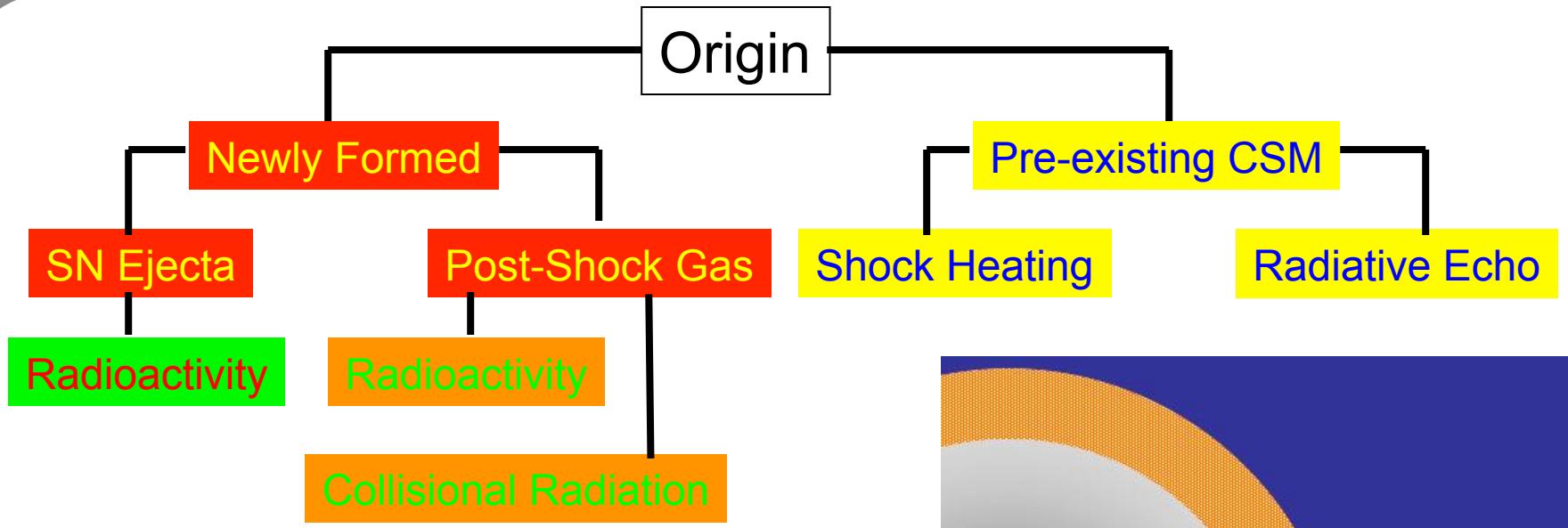
~0.1-1 micron

- Dust (warm):
  - Where does dust come from? Is it enough to satisfy the cosmic dust budget?
  - What does pre-existing dust tell us about the pre-SN mass loss? The peak SN luminosity at shock breakout?
- Dust (cold):
  - Where are the missing SNe? Are they hidden by cold, galactic dust?
- IR Hubble Diagram:
  - We can constrain dark energy parameters better with an IR Hubble Diagram.
- High-Redshift Targets:

Warm Dust


Type IIn SN 2005ip
Day 3165
LBV Eruption/Type IIn SN 2009ip
Day 710
"Impostor" SN 2010dn
Day 1493
Type Ia-CSM PTF11kx
Day 1237
Fox+11,13,14

Origin and Heating of Warm Dust



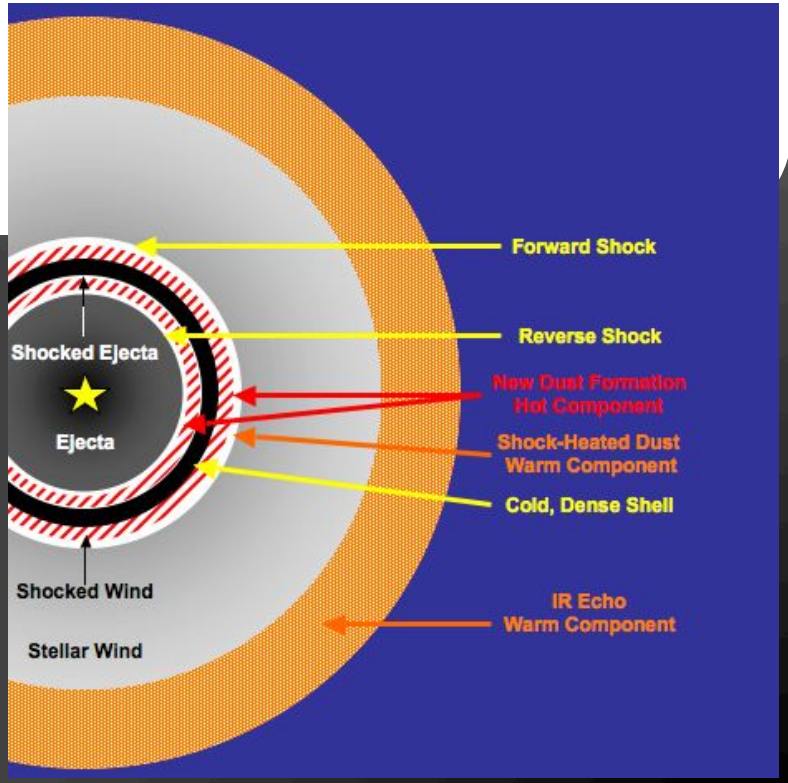
Must Consider:
1) Energetic Constraints
2) Dust Temperature Constraints

Quick Definition:
1) Blackbody Radius
2) Shock Radius
3) Evaporation Radius
4) Echo Radius

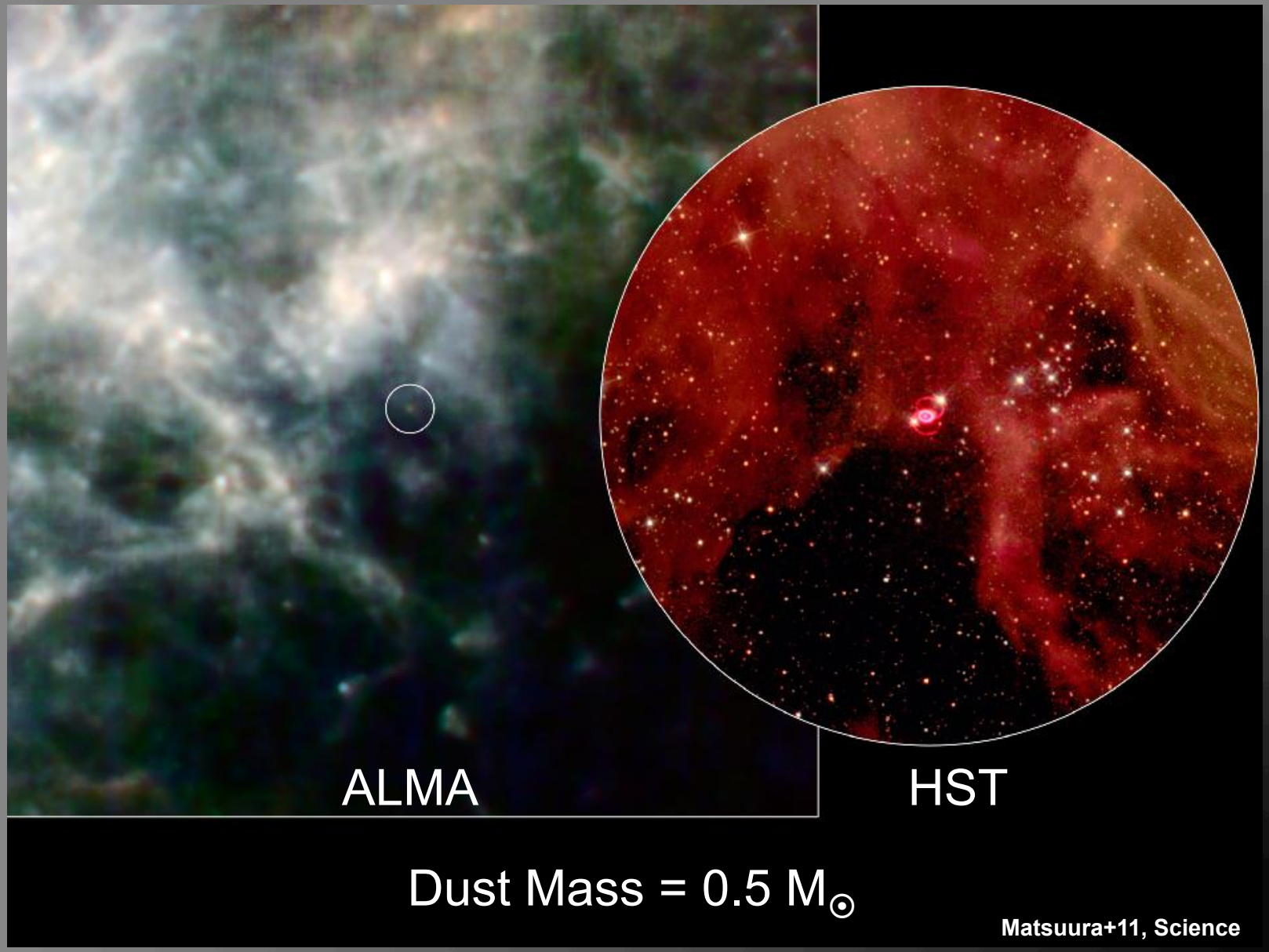
$$r_{\rm bb} = \left(\frac{L_{\rm bb}}{4\pi\sigma T_{\rm bb}^4}\right)^{\frac{1}{2}}$$

$$r_s = v_s t$$

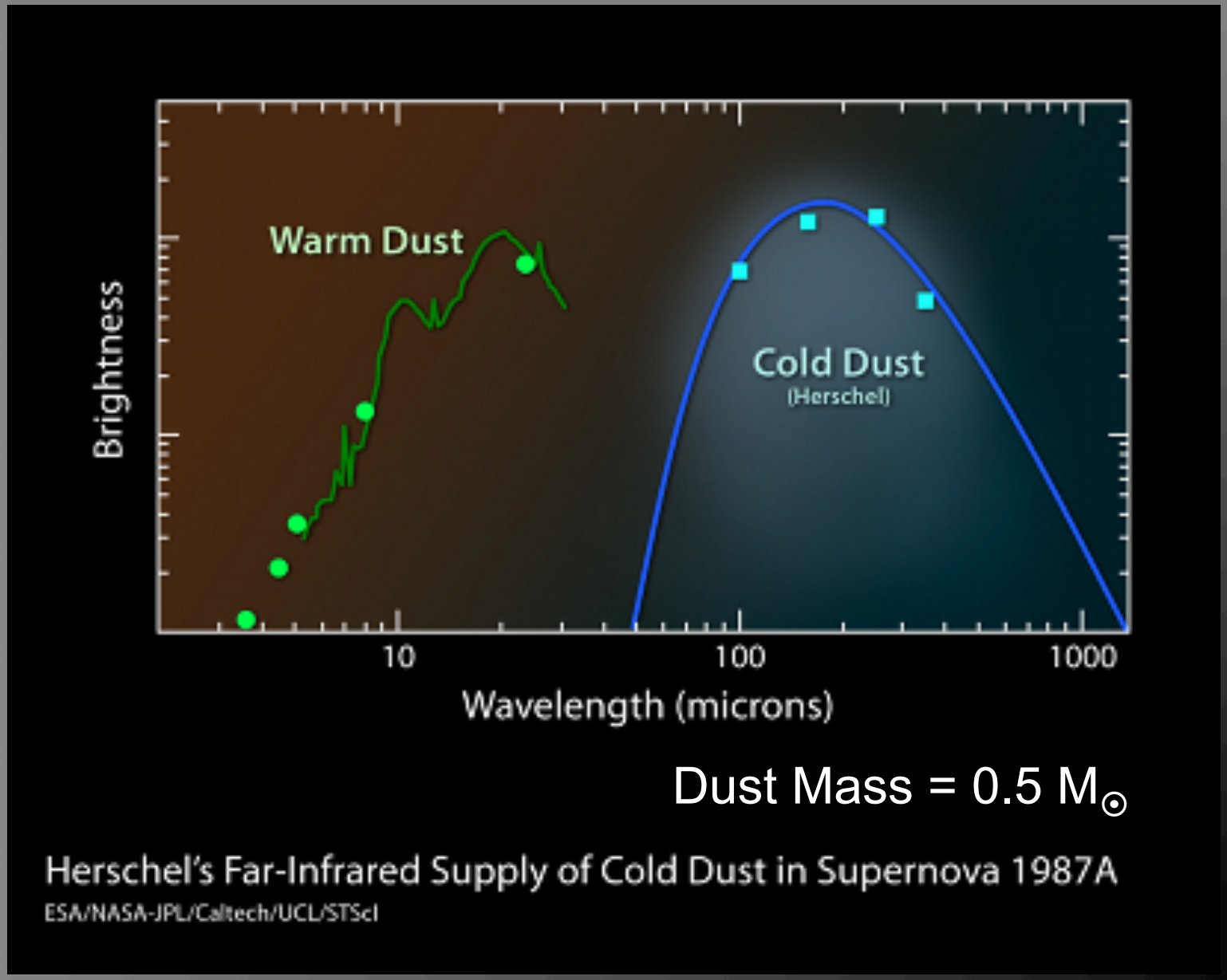
$$r_{\rm ech} = \frac{r_{\rm evap} - ct_{\rm ech}}{2}$$



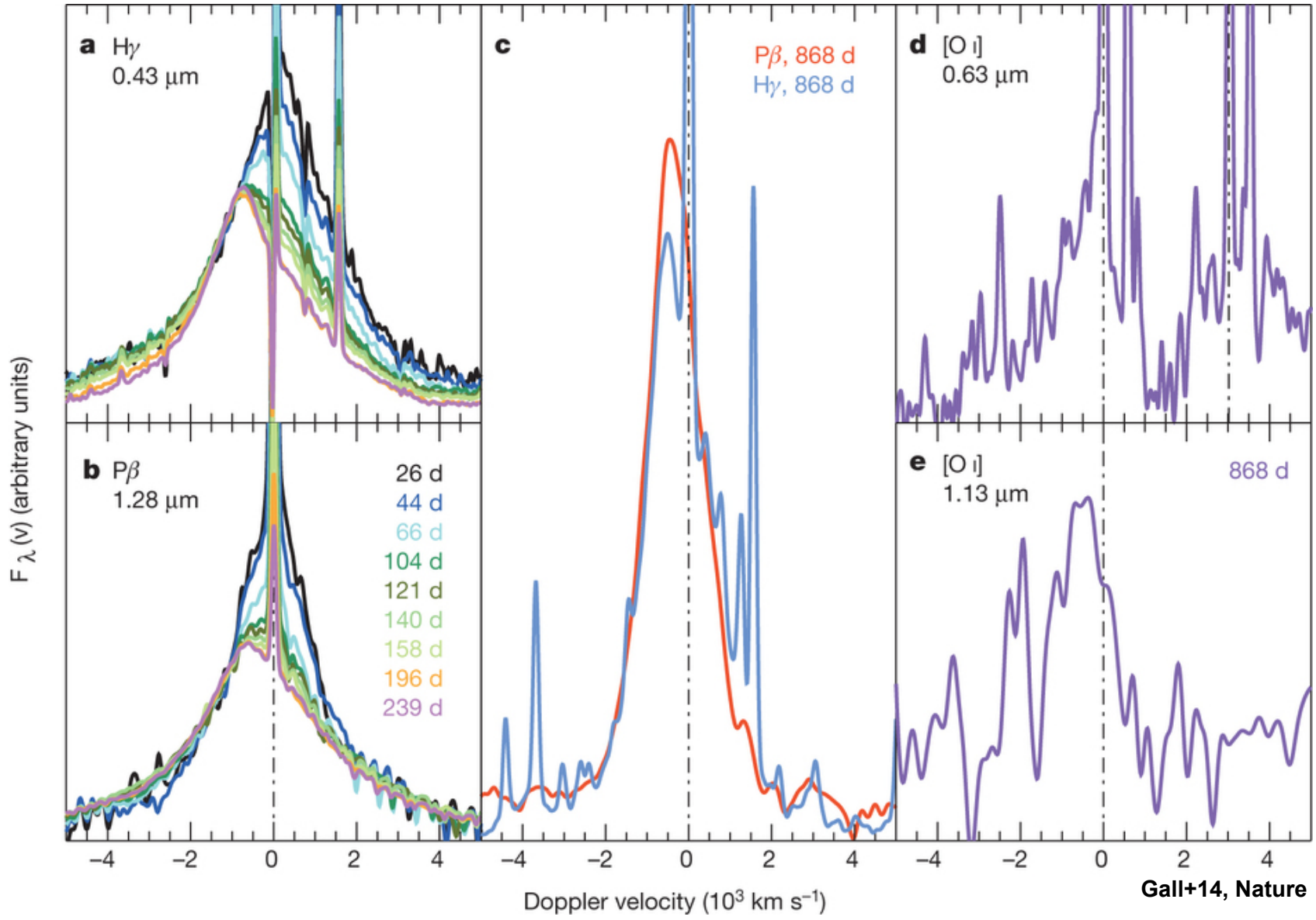
SN 1987A



SN 1987A

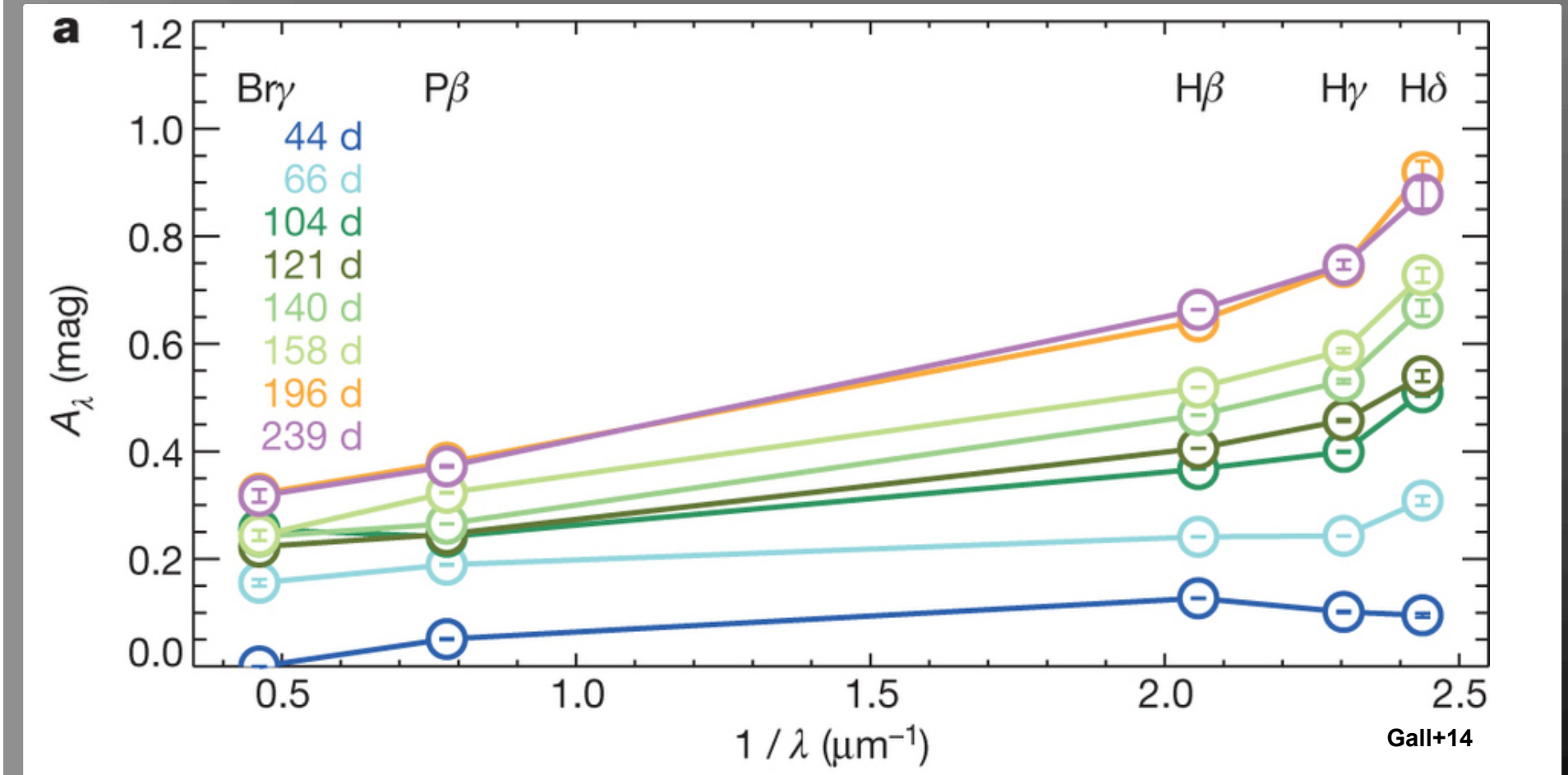

Warm Dust
Cold Dust
(Herschel)
Brightness
10
100
1000
Wavelength (microns)
Dust Mass = 0.5 $M_\odot$
Herschel's Far-Infrared Supply of Cold Dust in Supernova 1987A
ESA/NASA-JPL/Caltech/UCL/STScI

SN 2010jl



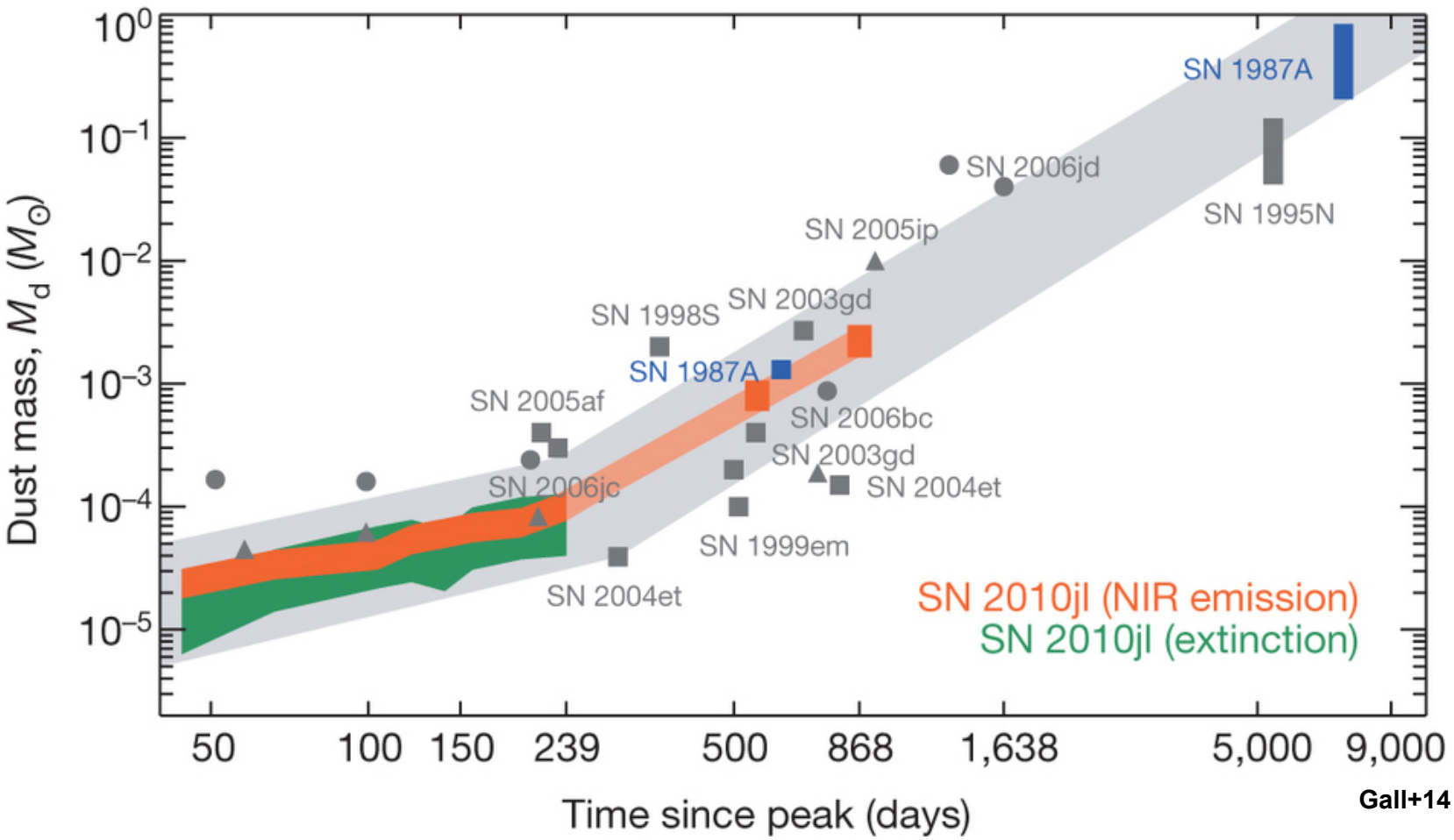
Gall+14, Nature

SN 2010jl



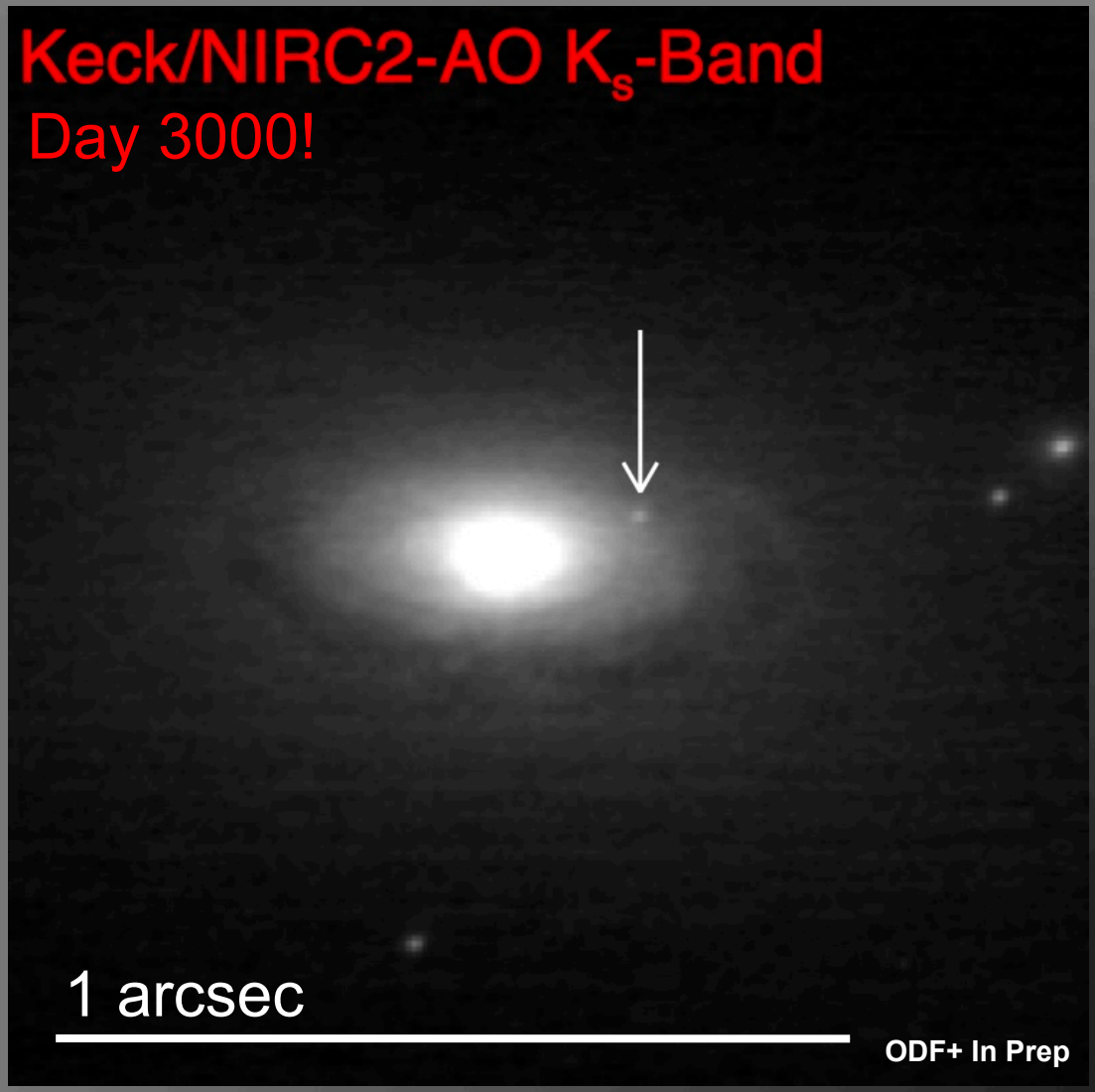
1) Dust grains are large enough to survive the reverse shock

SN 2010jl

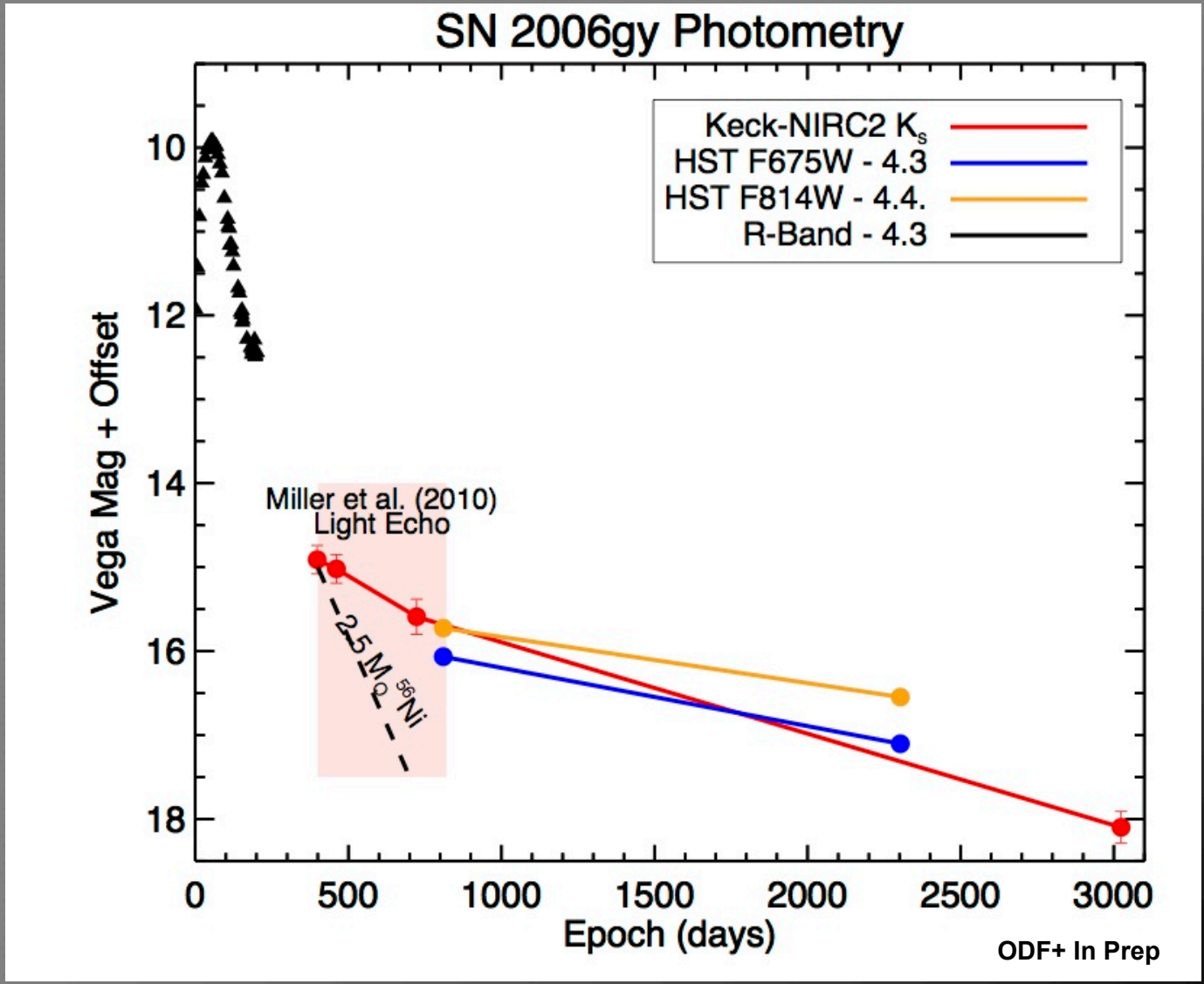


2) Dust formation accelerates after 250 days

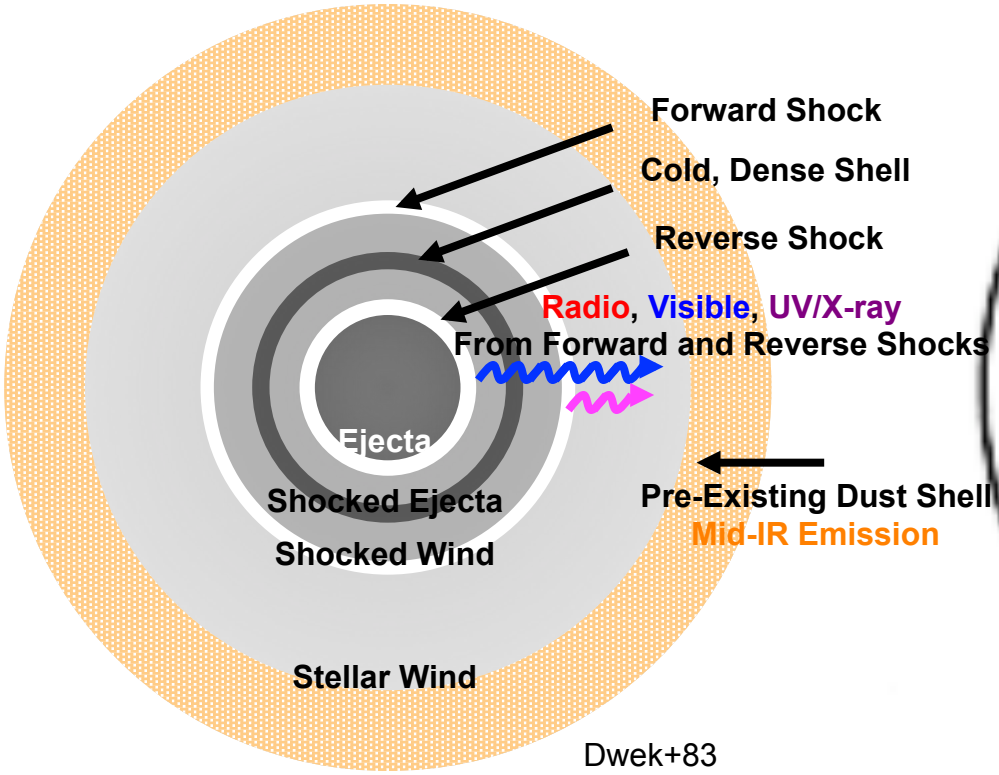
SN 2006gy



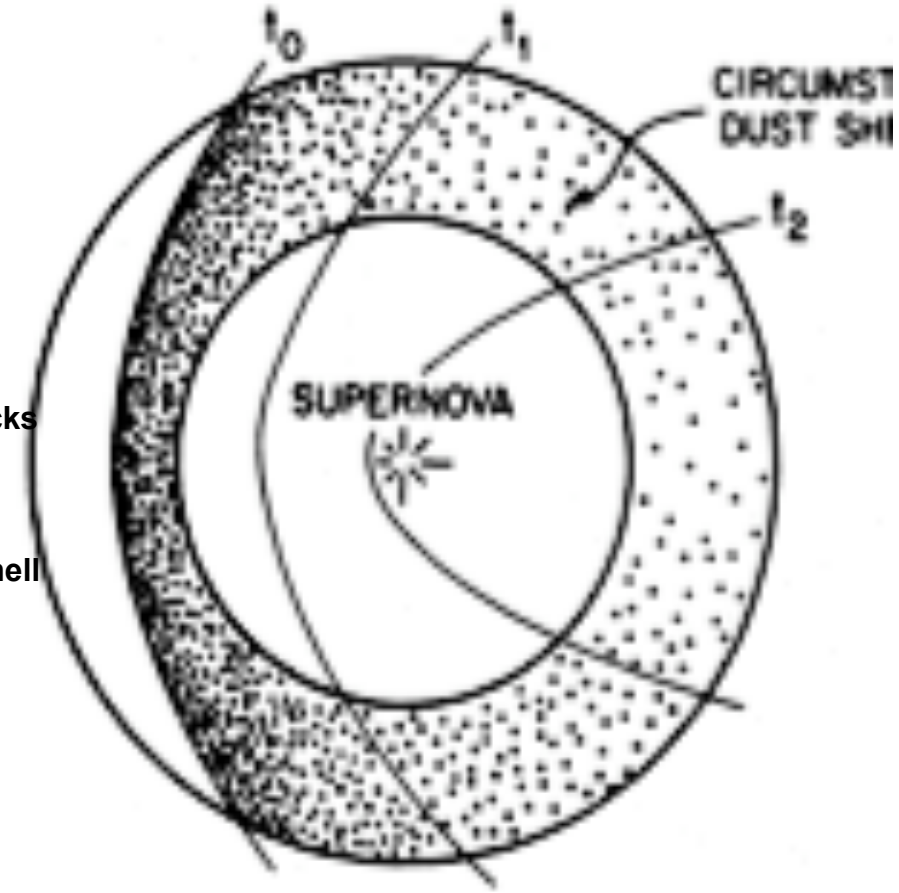
SN 2006gy


SN 2006gy Photometry
Keck-NIRC2 K_s
HST F675W - 4.3
HST F814W - 4.4.
R-Band - 4.3
Miller et al. (2010)
Light Echo
2.5 $M_\odot$ ^{56}Ni
Vega Mag + Offset
Epoch (days)
10
12
14
16
18
0
500
1000
1500
2000
2500
3000
ODF+ In Prep

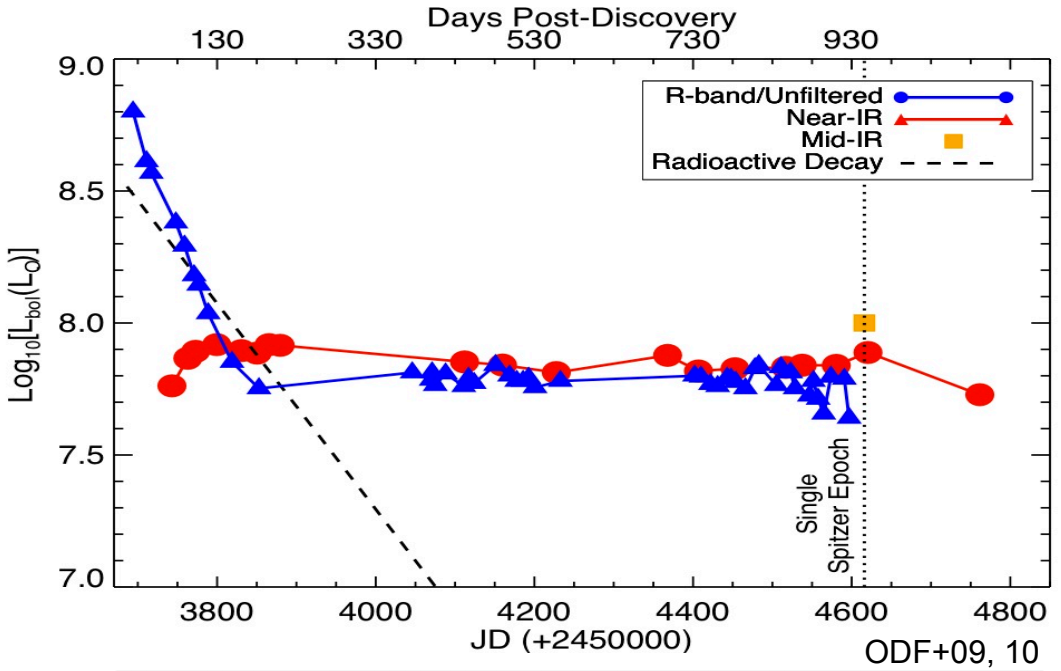
CSM Interaction or Light Echo?



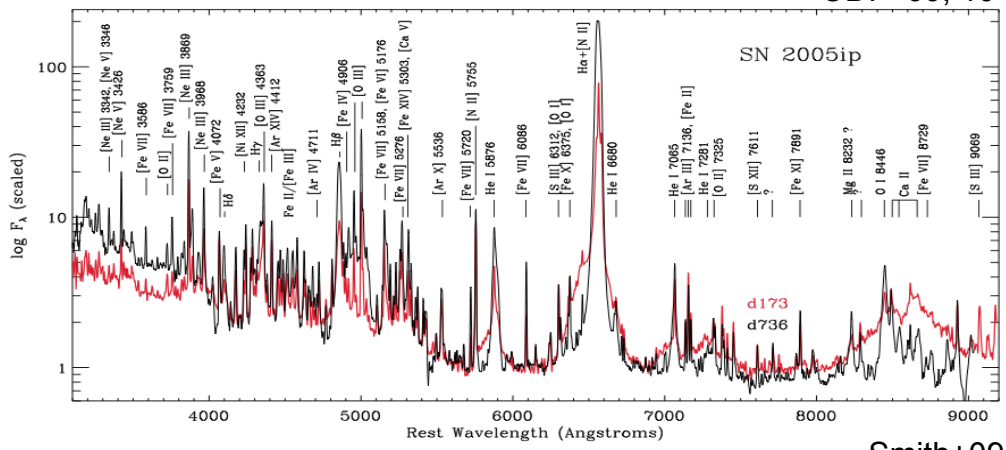
Dwek+83



CSM Interaction (SN 2005ip)

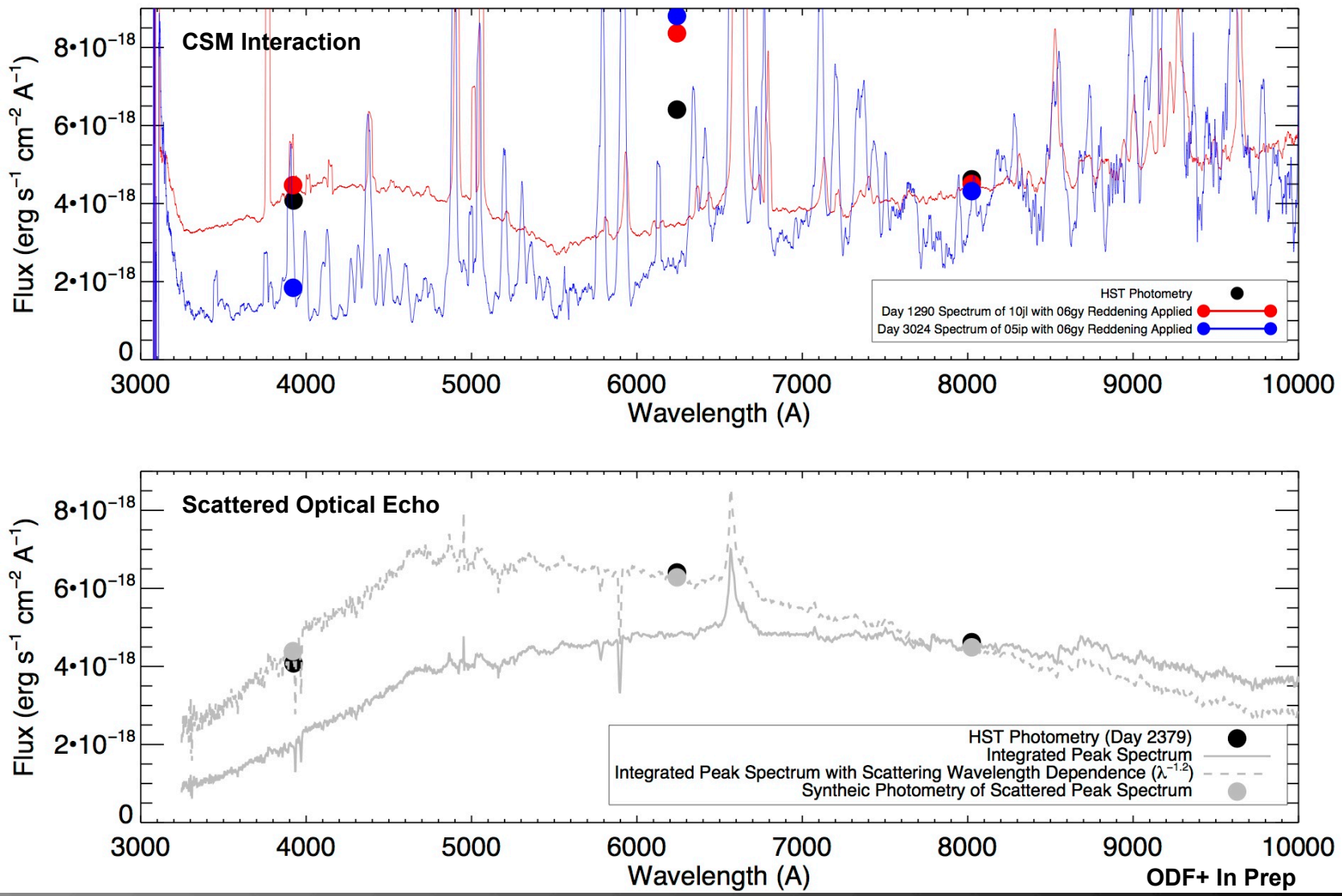


ODF+09, 10

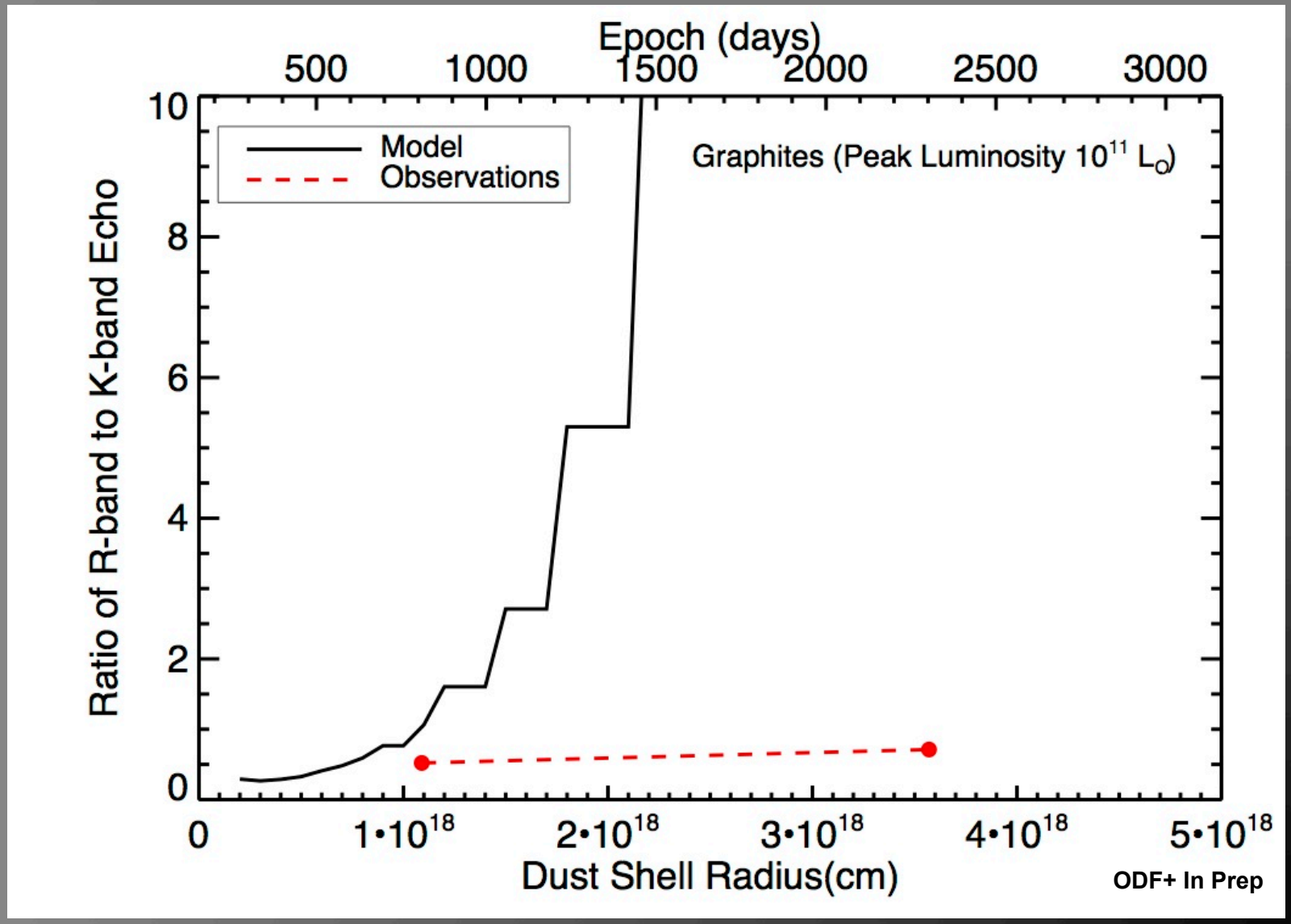


Smith+09

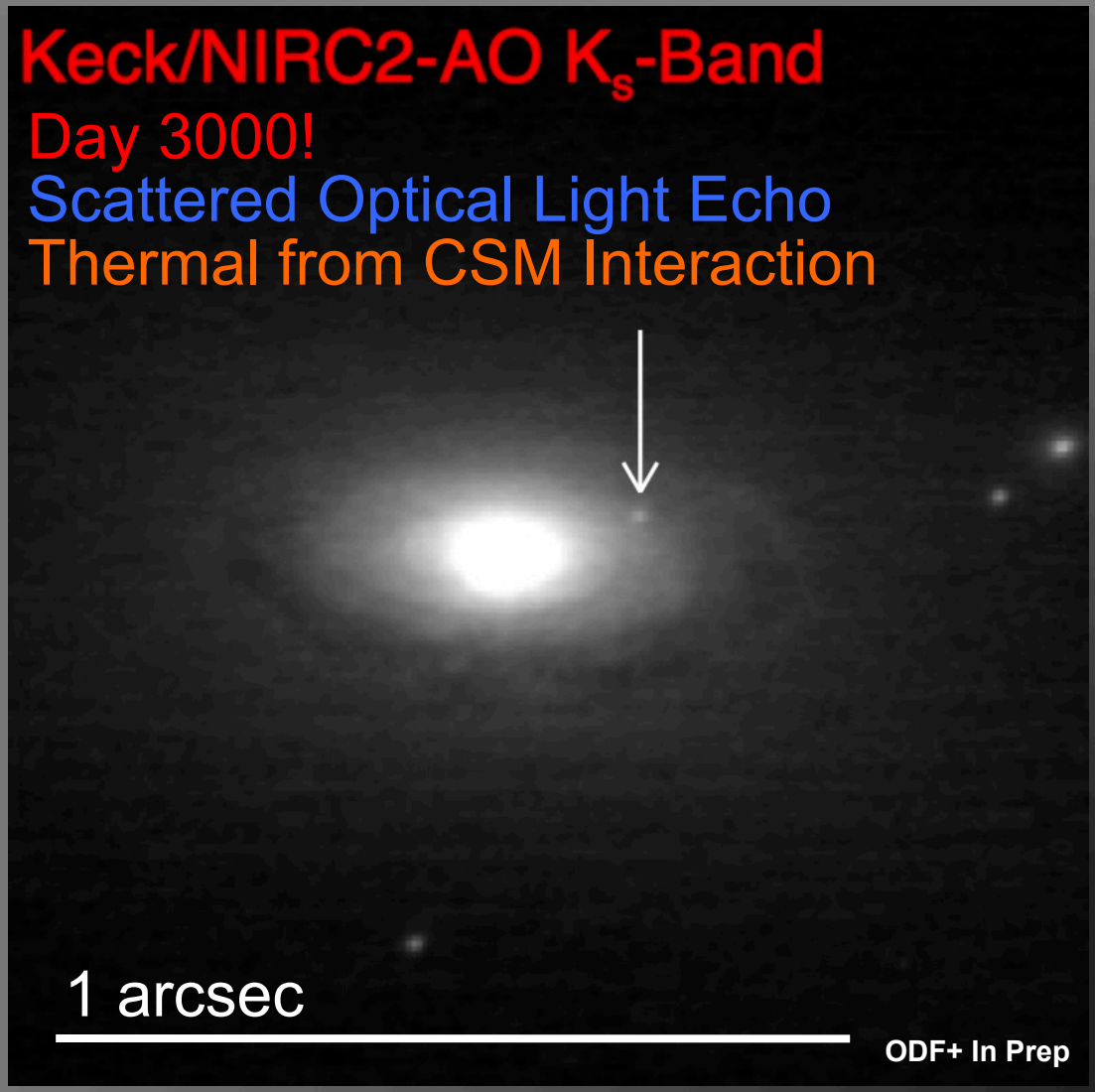
Scattered Optical Light Echo



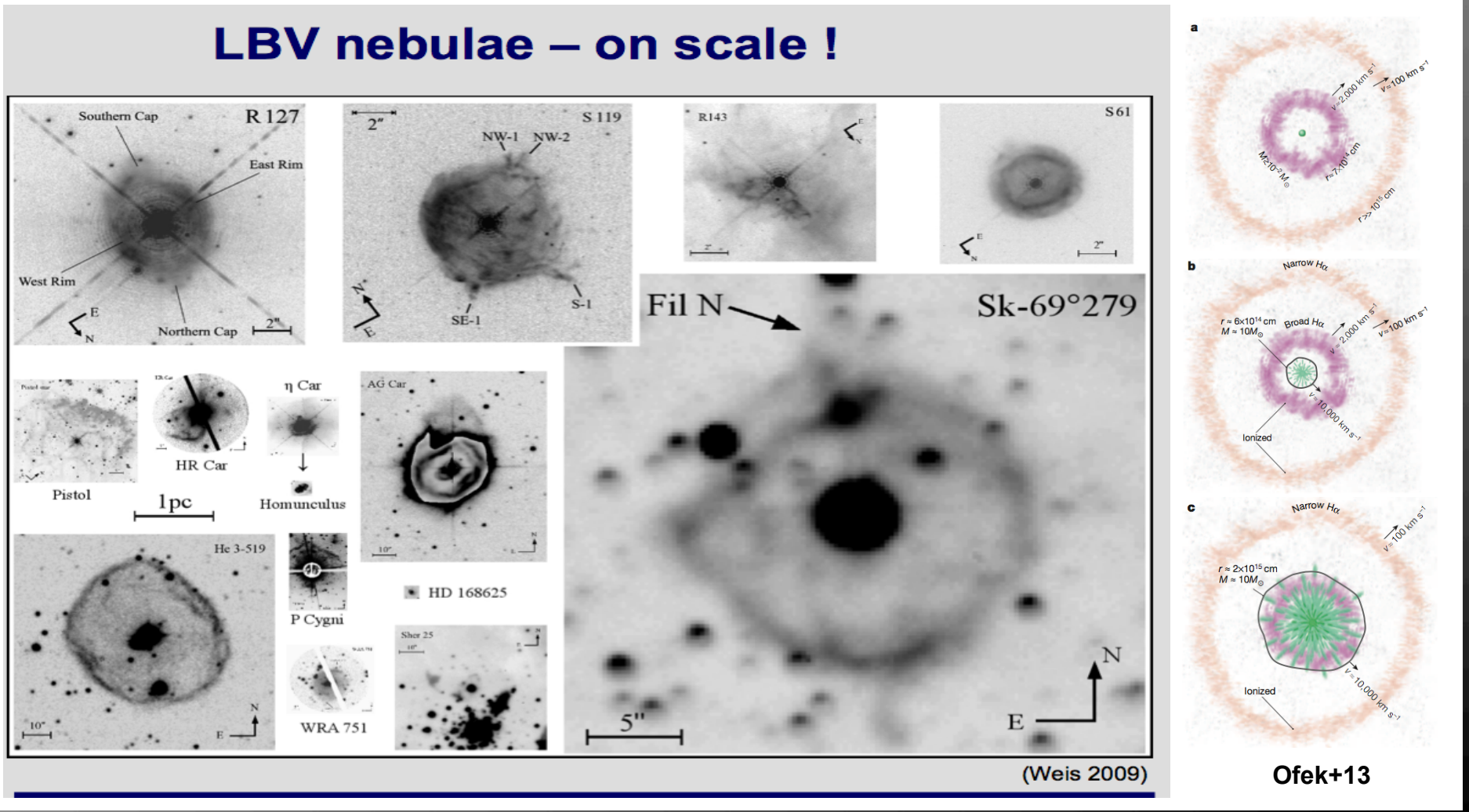
Thermal CSM Interaction



SN 2006gy


Keck/NIRC2-AO K_s-Band
Day 3000!
Scattered Optical Light Echo
Thermal from CSM Interaction
1 arcsec
ODF+ In Prep

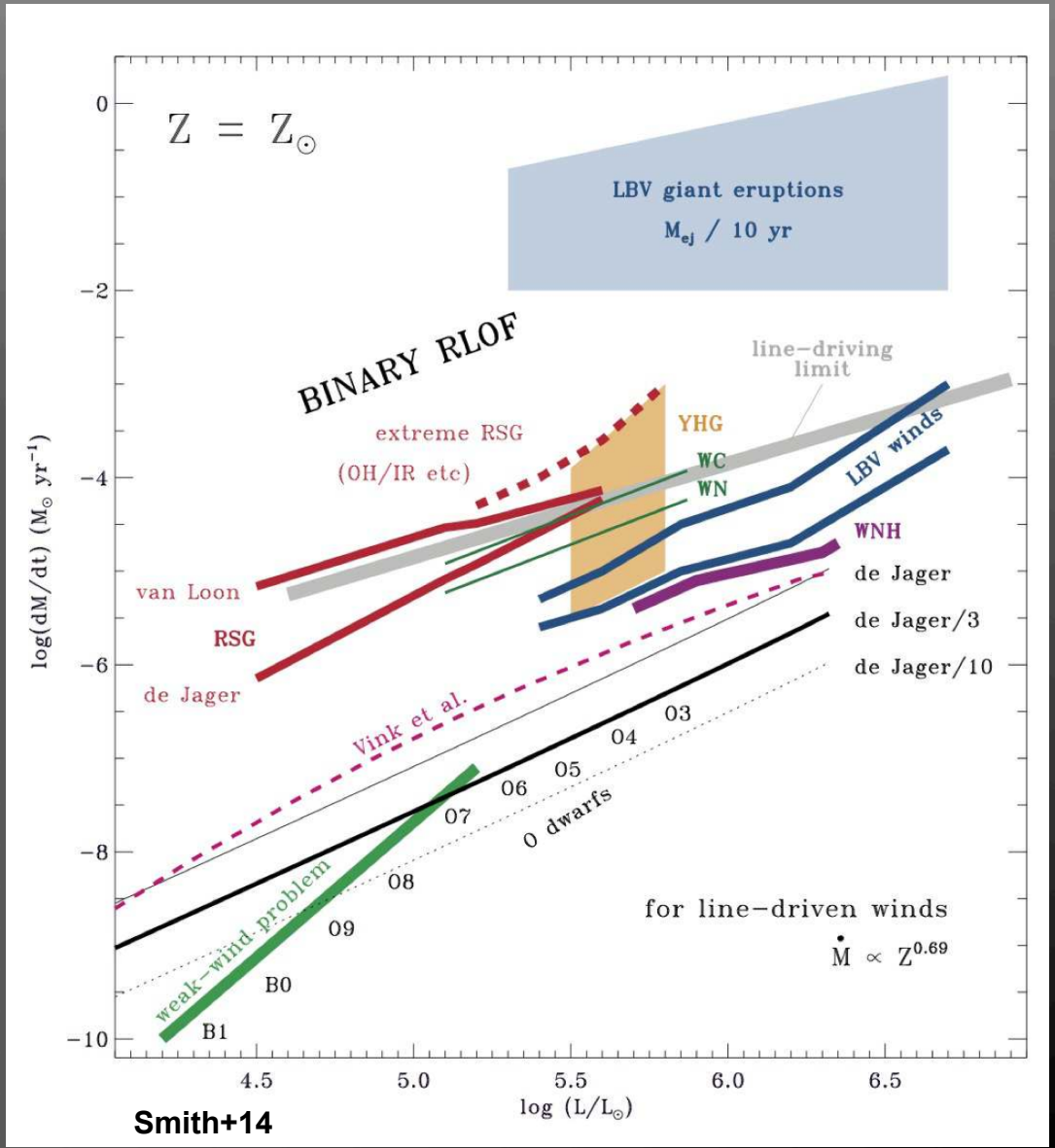
Why Does it Matter?



Ofek+13

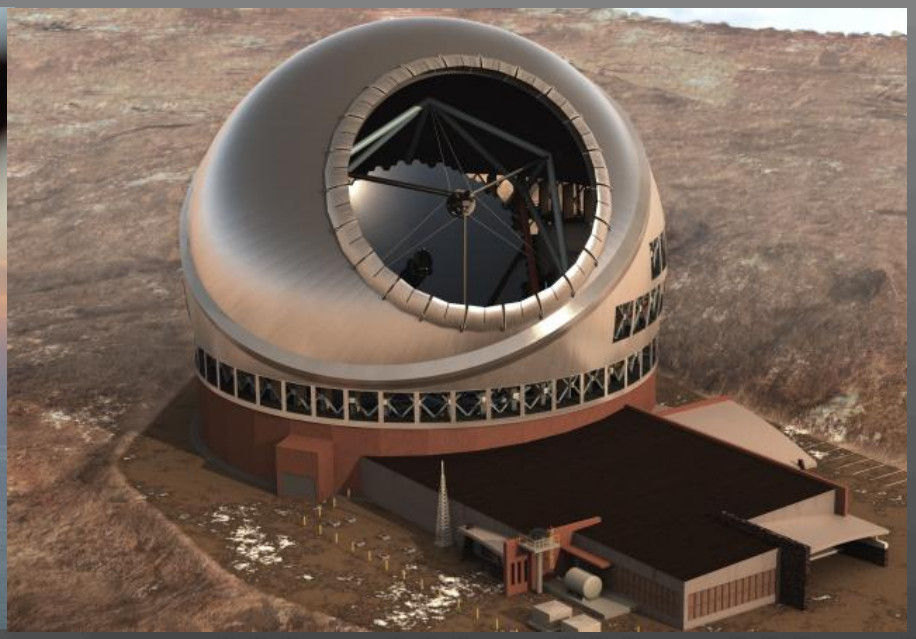
Why Does it Matter?

- Metal Line Driven Winds
- Continuum Driven Winds (e.g., Smith+06)
- Gravity-Wave Driven Winds (e.g., Quataert+12)
- Binary Accretion (e.g., Kashi+10)



Smith+14

Looking Forward to TMT



- High Redshift Targets (GRBs, SNe, Host Galaxies)
- Very late-time SNe (>10 years)
  - Post CSM interaction phase
  - Dust formation history
- Direct detections of even more progenitors (Astrometry)

- Time Resolution not a factor
- 1 night per month (for all transient teams?)
- Other instruments to consider
  - Mid-IR photometry (spectroscopy?)
  - Multi-wavelength observations
  - IFU for host galaxy studies
  - Spectropolarimetry for asymmetries

Infrared is the Future of Transient Astronomy