Personal and Biased

NIR Frontiers of Supernova Study

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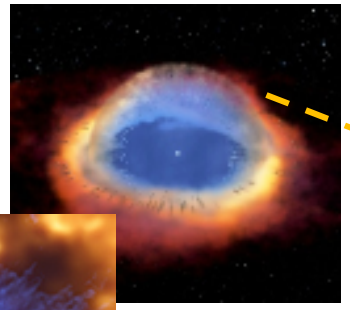
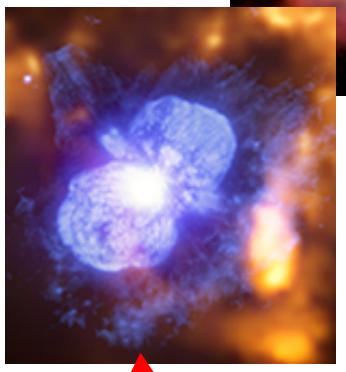
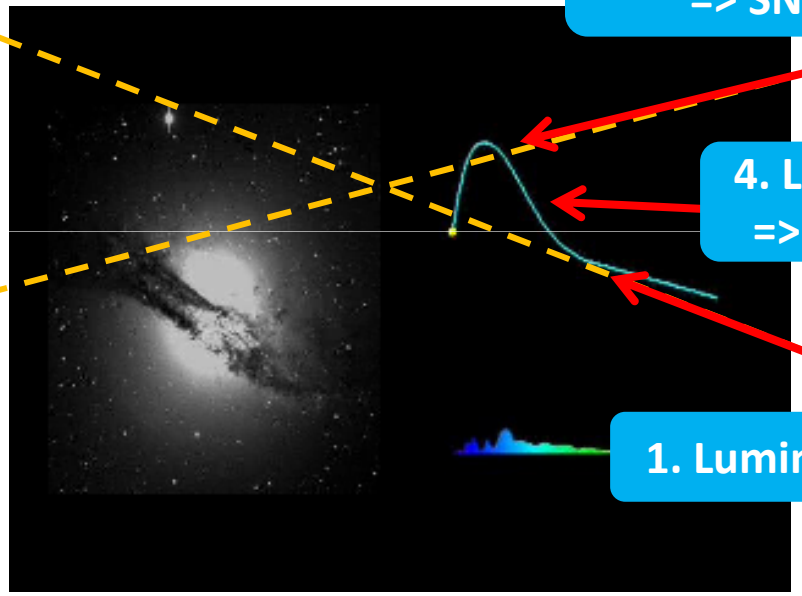
Supernovae

Chandrasekhar WD (binary)
→ SN Ia







2. SN Search in dusty gals.
=> SN rate, SFR, etc.

4. Light Curve, Spectra
=> Explosion Physics

1. Luminous => Cosmology

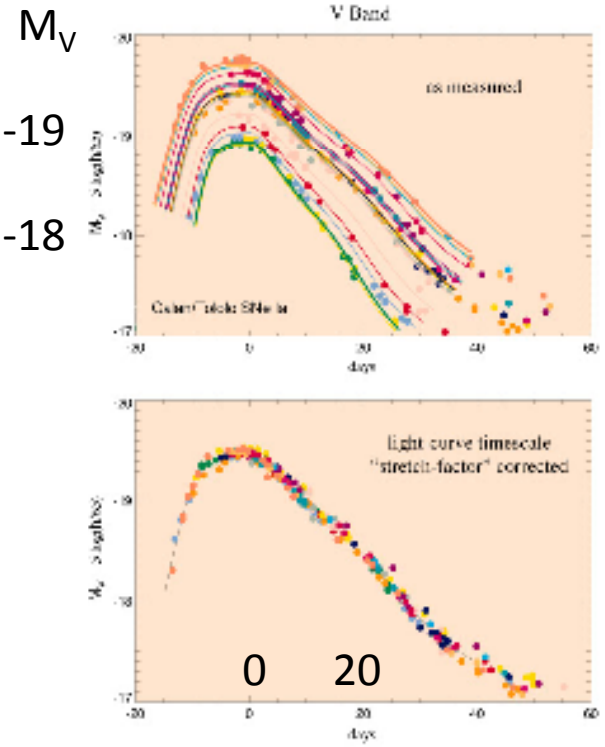
Massive star (> 8Msun)
→ SN II/Ib/Ic

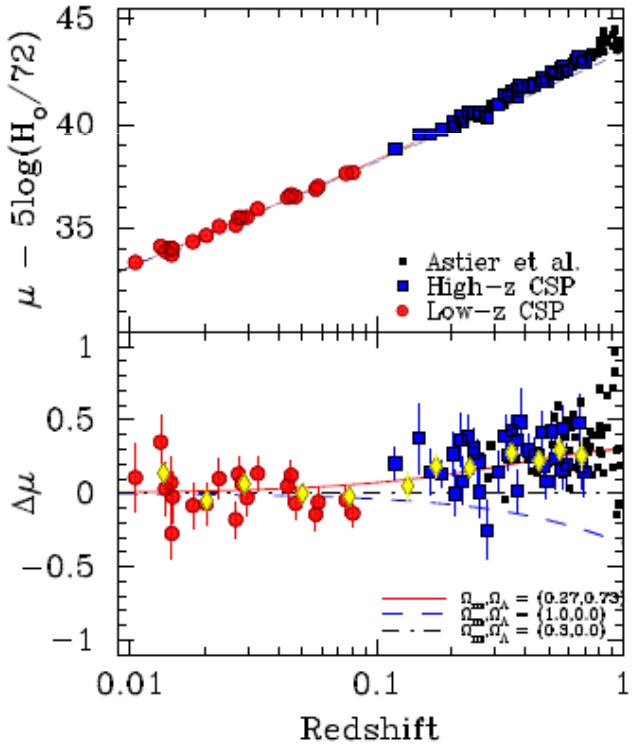
3. Progenitor Search
=> Stellar evolution, etc.

Expanding (~ 10,000 km/s) metal-rich material
Heating = Thermal energy + ^{56}Ni/Co/Fe
Cooling = Optical ~ NIR
Time scale ~ days to yrs

SN Ia Cosmology @ NIR

- Optical.
  - phenomenological estimate of M_{abs}, then σ ~ 0.2 mag.

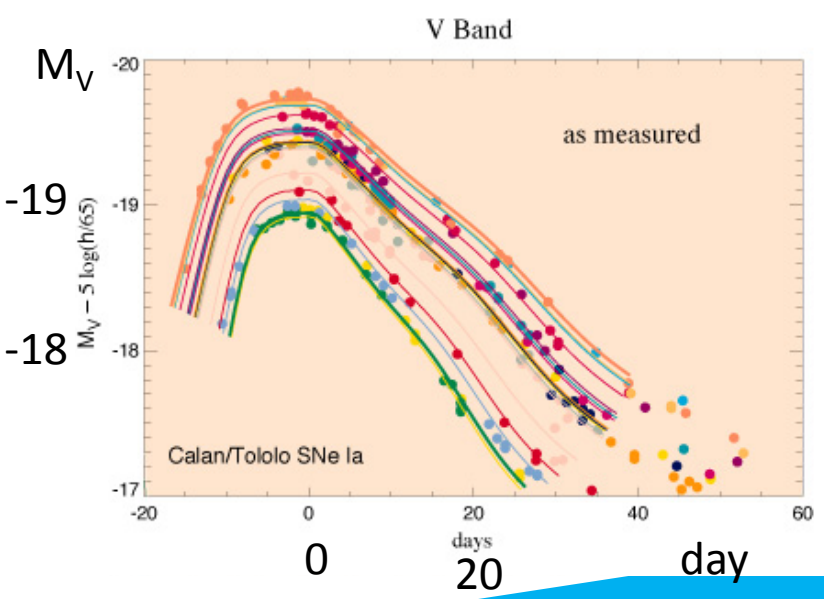




SCP (Supernova Cosmology Project)

SN Ia Cosmology @ NIR

- Optical.
  - phenomenological estimate of M_{abs}, then σ ~ 0.2 mag.
- NIR.
  - ***Better standard candles***, σ ~ 0.2 mag w/o any correction.
  - Dust free.



M_V

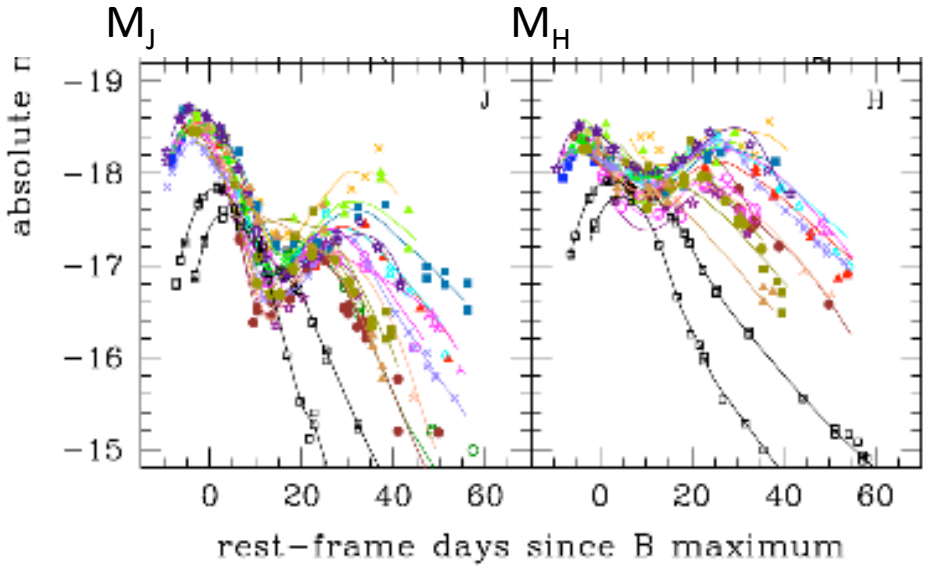
-19

-18

0

20

day



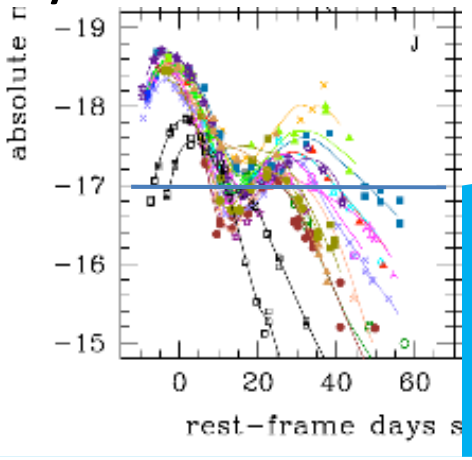
CSP (Carnegie Supernova Project)

SN Ia Cosmology @ NIR

- $M_J < -17$ → up to z = 0.15 (H_{lim} ~ 22) – 0.2 (J_{lim} ~ 23).

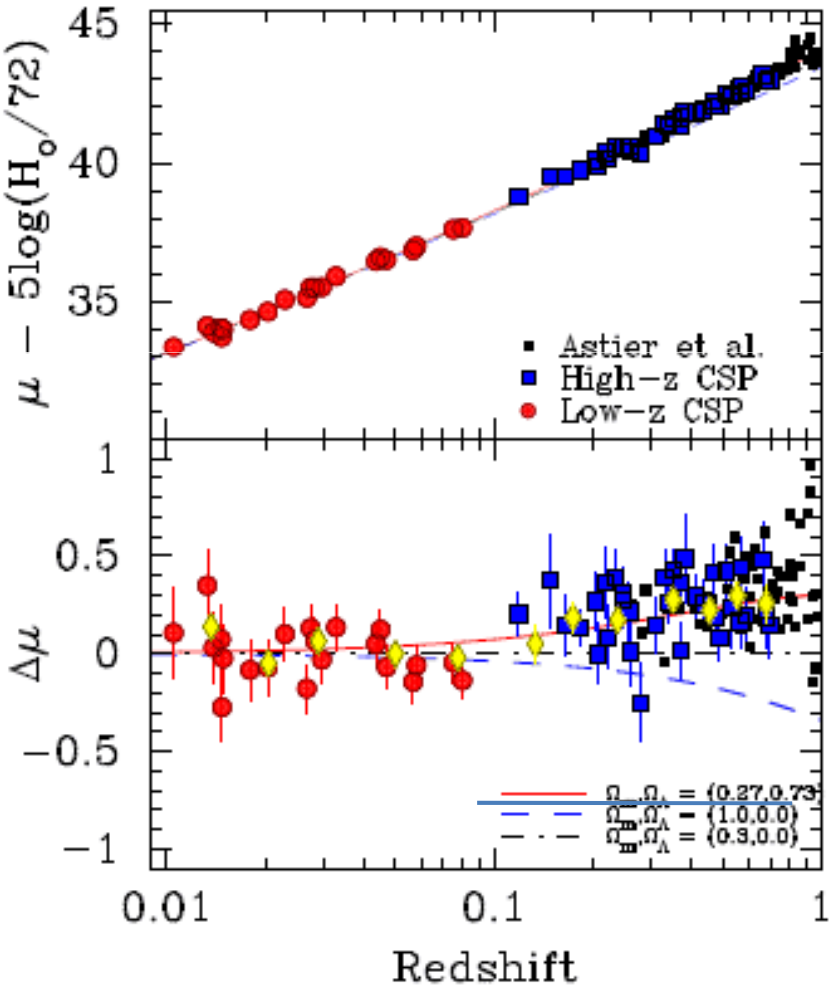
- ***Proposal:***
  - ***Cluster Patrol in J and/or H*** by TAO.
    - 8' FOV => 1.5Mpc @ z = 0.2, ~ R_{Abell}.
    - 100 galaxies /cluster => 1 SNe Ia /year/cluster (underestimate?).
    - ***3 cluster x 1 hr x 2 time/week => ~ 10 SNe Ia/3 year survey.***
  - Better strategy will increase the discovery rate.

- ***Why TAO?***
  - Need intensive coverage, < ~ 5 days.
  - J + H simultaneous imaging for K-cor.



SN Ia Cosmology @ NIR

- Does it make sense?
  - @z ~ 0.2, Ω_Λ is already visible.
  - "***a small sample, better precision***" is better than "a large sample, worse precision"?



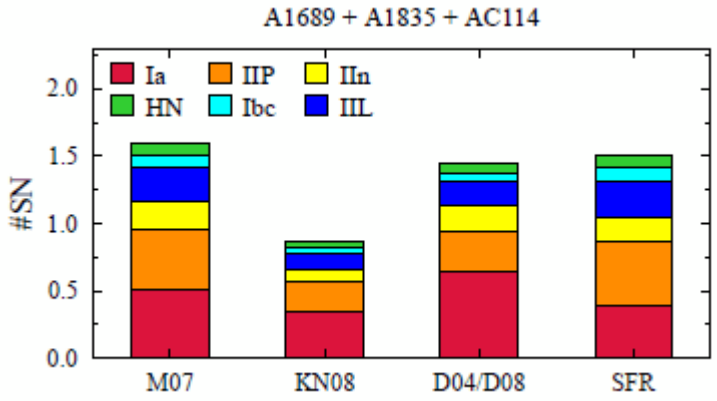
SN Ia Cosmology @ NIR

- ***Complementary Scenarios.***
  - ***Mini-TAO and/or MAGNUM.***
    - SN survey (replacing the “patrol” strategy).
    - NIR light curves of nearby SNe Ia (still need test).
  - ***Subaru/FOCAS (ToO).***
    - SN identification.
  - ***JWST***.
    - NIR Spectroscopy of nearby SNe Ia (K-cor.).

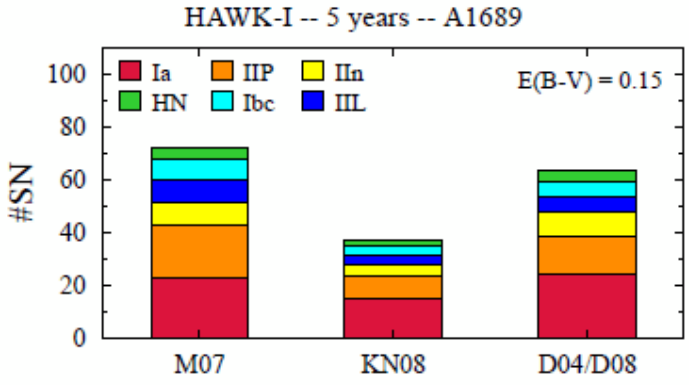
Byproduct: Higher-z SN?

- ***Monthly deep survey*** MAY catch a few SNe @ z ~ 1 – 2, by ***gravitational lensing***.
  - Complementary w/ the cluster patrol.
  - Useful for rate study?
  - Cosmology (SNe Ia + time delay) is not promising (?).

Stanishev+ 09; Goobar+ 09



VLT/ISAAC, J+Z (2 hrs each; J_{lim} ~ 24)
4 month x 3 clusters



VLT/HAWK-I, J (2 hrs each; J_{lim} ~ 24.6)
5 yrs x 1 clusters

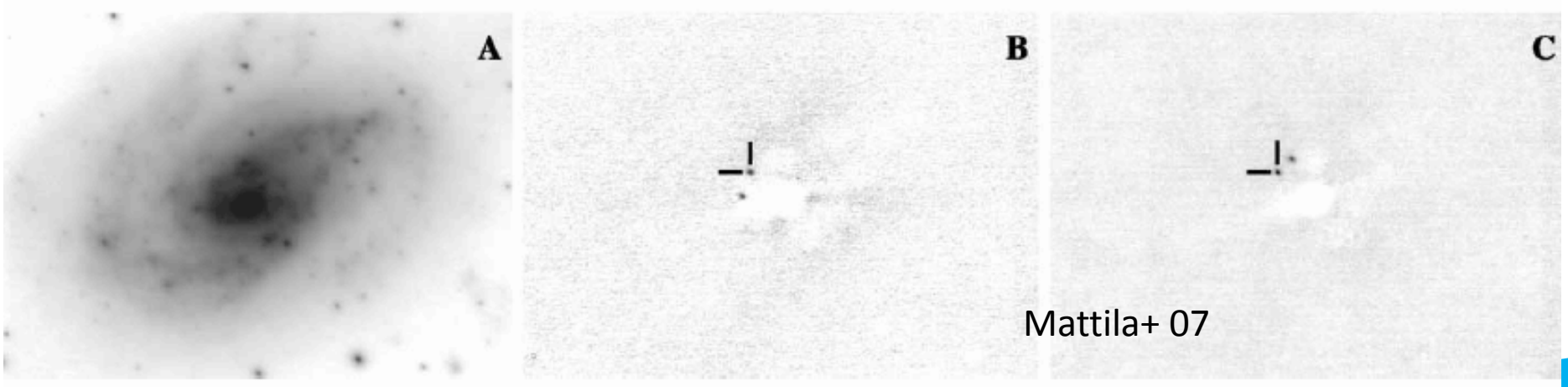
Obscured SNe Search

- ***SN search has been conducted in optical.***
  - SNuB = SNe / 100yr / 10^{10} (L_B/Lsun).
- ***A large fraction of SF = dusty starburst galaxies.***
  - SNe in LIRGs (+ULIRGs) are HIDDEN.
  - L_B in these galaxies is NOT a good measure.
- ***Cosmic SN rate is then highly model dependent.***

- Importance of ***DIRECT SN detections*** in dusty galaxies.
  - Go to NIR. SNuJ, SNuH, SNuK.
  - Core-Collapse, SNe II (Ib/c is more difficult).

Obscured SNe Search

- ***A lesson from the past study*** (Grossan+ 99).
  - Even in NIR, a large fraction of SNe are likely missed.
  - Why? Host galaxy nucleous.



Mattila+ 07

- ***AO***… VLT just started. One detection. Continue?

Obscured SNe Search

- M_J ~ -18, A_J ~ 3→ J = 20 - 21 @ z = 0.03. → 10 min?

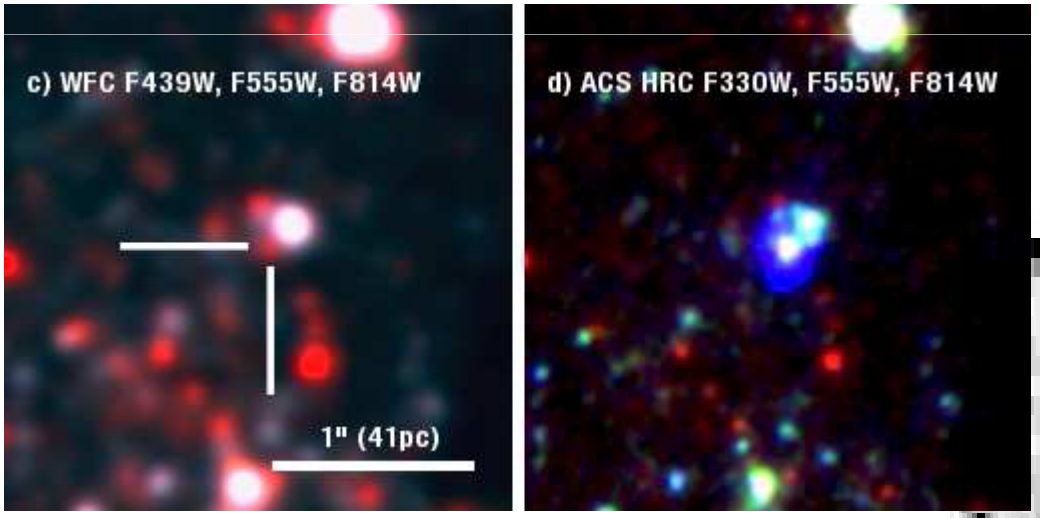
- ***Proposal.***
  - ***LIRGs AO patrol*** at z < 0.03.
    - L_{FIR} ~ $10^{10\text{-}11}$Lsun, 10 (?) SNuFIR => ~ 0.1 – 1 SN /yr/gal.
    - ***30 galaxies x 10 min/month*** => ***~ 3 - 30 SNe II/1 year survey.***
  - Exposure time should be optimized.

- ***Why TAO?***
  - NIR AO. Patrol observations (hard w/ 8m at least now).

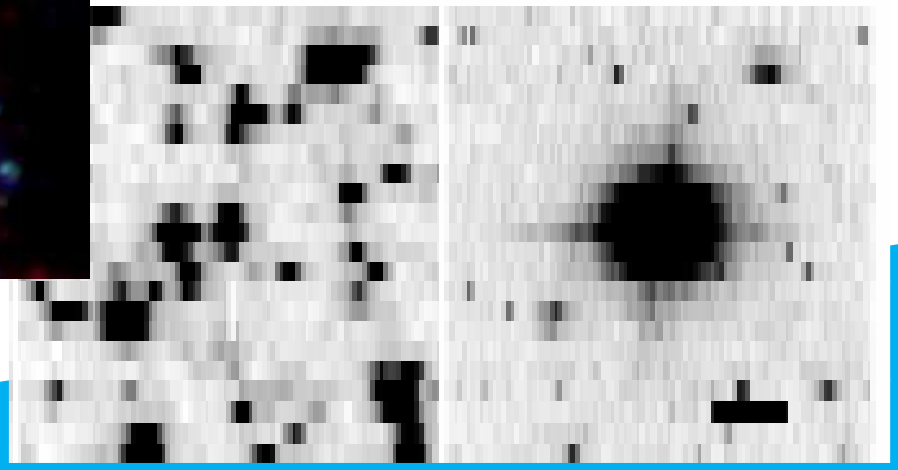
Direct Progenitor Search in NIR

- ***Pre-SN image vs. post-SN image.***
- Intensively done by HST. VLT/NIR/AO started.

SN IIP 2005cs (Maund+ 05), HST

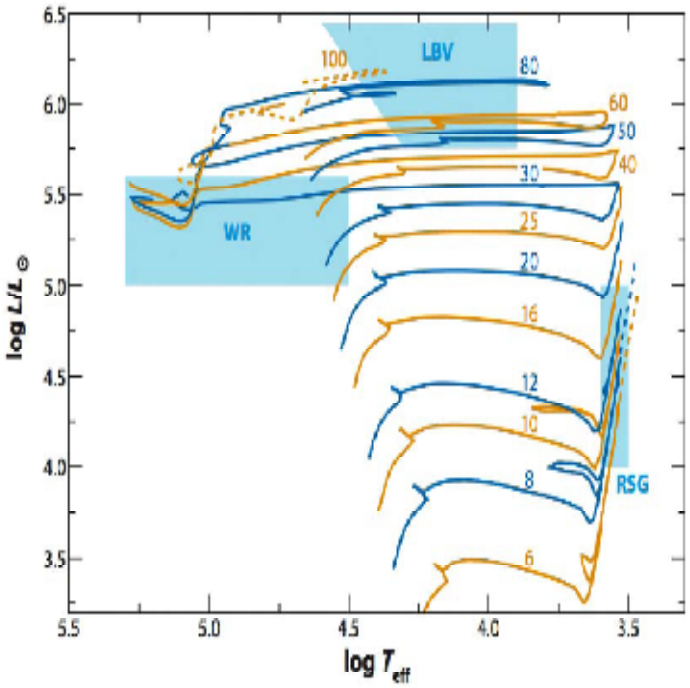


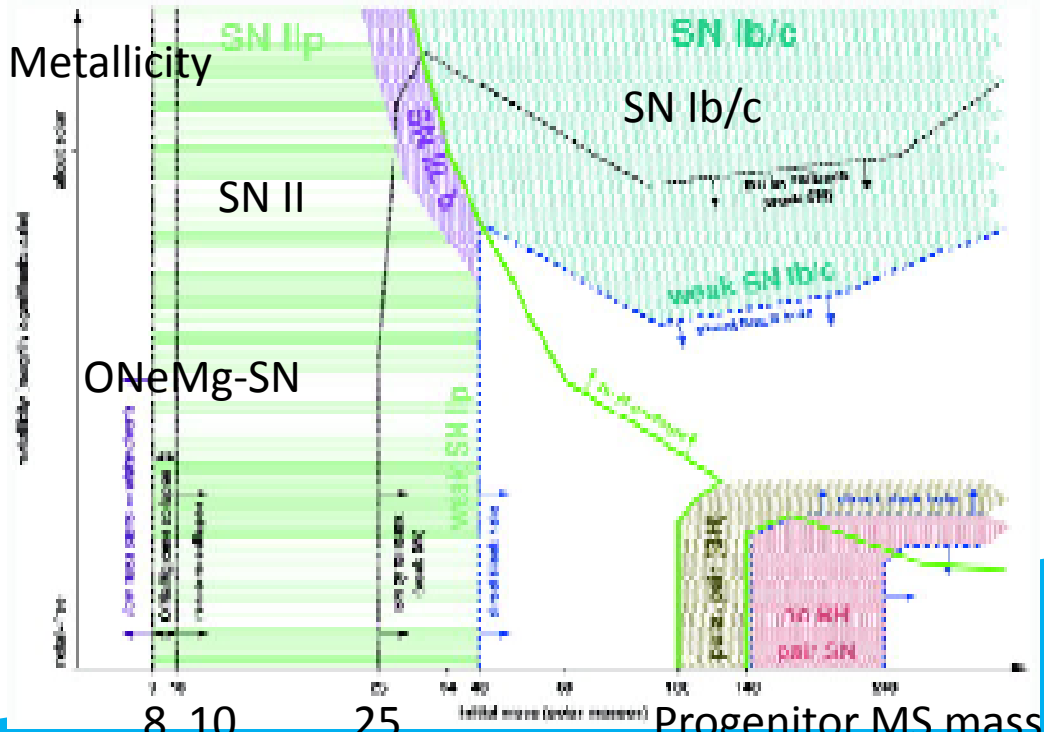
SN IIP 2008bk (Mattila+ 08)
VLT+NACO, K, AO



Direct Progenitor Search in NIR

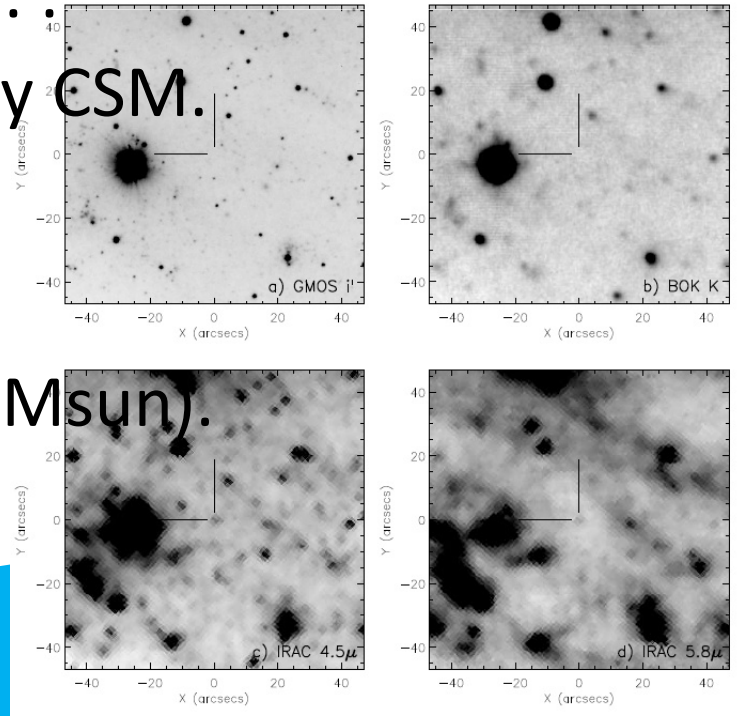
- Testing stellar evolution and explosion theories.
- Complementary w/ e.g., light curve modeling.





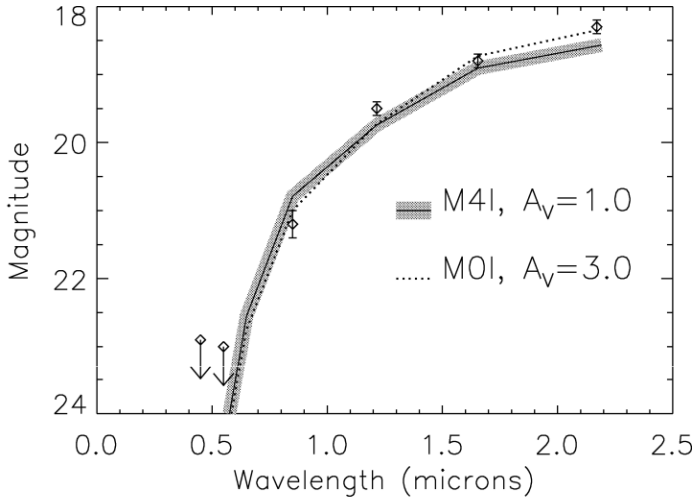
Direct Progenitor Search in NIR

- ***NIR, a possible new window for a class of SNe.***
- SN 2008S.
  - Progenitor NOT detected in optical.
  - IR detection (3-4μm), Spitzer. .
  - ~ 6 – 8Msun, hidden by dusty CSM.
- ONeMg core-collapse?
  - Theoretically expected (8-10Msun).
  - Potentially abundant (faint).



Direct Progenitor Search in NIR

- 2008bk, J ~ 19 @ 4 Mpc
  - → up to ~ 20 – 30 Mpc (J_{lim} ~ 23).
- ***AO + Wide Field necessary.***
  - 0.2" seeing → 20 pc
  - 8' FOV → 50 kpc (> ~ R_{gal})



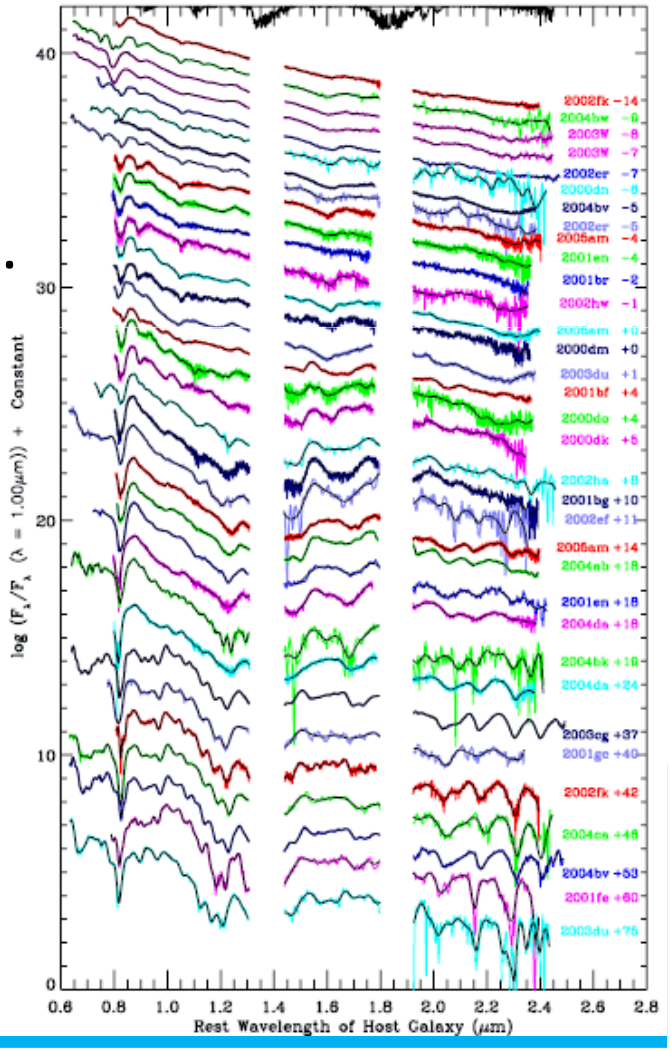
- ***Proposal:***
  - AO imaging of nearby large galaxies (anyway should be done!).
  - ***Two AO images @ a few weeks / a few yrs AFTER SN*** (disappear?).

- ***Why TAO?***
  - AO/NIR (but can be done by others….). Optical search maybe biased.
  - Potentially large sample coverage (vs. JWEB, 8-m).

NIR Nearby SN Followup

- ***SNe Ia @ early phases (< 3 months).***
- ***SN Search by MiniTaO/MAGNUM?***
- M_J = -16, ***J = 19 – 20 @ z ~ 0.03.***
  - J, H Light Curves ("standard" candle).
    - ~15 SNe Ia
    - ~ 7 w/ good temporal coverage.
  - NIR Spectra.
    - ~ 35 SNe Ia, mostly single epoch.
- Outer layers
  - Compositions → progenitors.
- Template for Cosmology.

Marion+ 09



NIR Nearby SN Followup

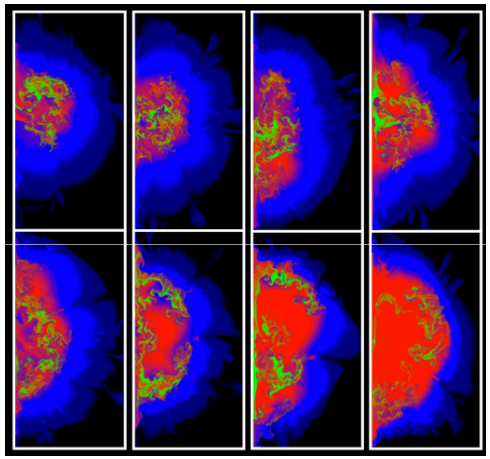
- ***SNe Ia @ late phases (> 3 months).***
- SN 2003hv@20 Mpc… J ~ 18/19/20 @ 100/200/300 days.
  - J, H Light Curves.
    - ***Only a few published, no good temporal coverage (1 in 100 days).***
  - NIR Spectra… "semester" proposal is a problem (e.g., Subaru).
    - ***Motohara, Maeda+ 06: 3 SNe Ia @ 200 – 400days (single epoch).***
    - ***J_{lim}@4hr, S/N = 10 …19 mag w/o AO, 20.5 mag w/AO.***

- A large fraction emitted in NIR (thermal structure in SNe).
- e+ contribution. Escape fraction => B-filed, e+ in the Galaxy.
- ^{57}Co.
- Dust (core-collapse SNe).
- Explosion Geometry.

NIR Nearby SN Followup

- ***Explosion Geometry (example of science cases).***

Maeda, Taubenberger+ 09, ApJ, submitted



Kasen, Roepke, Woosley 09, Nature

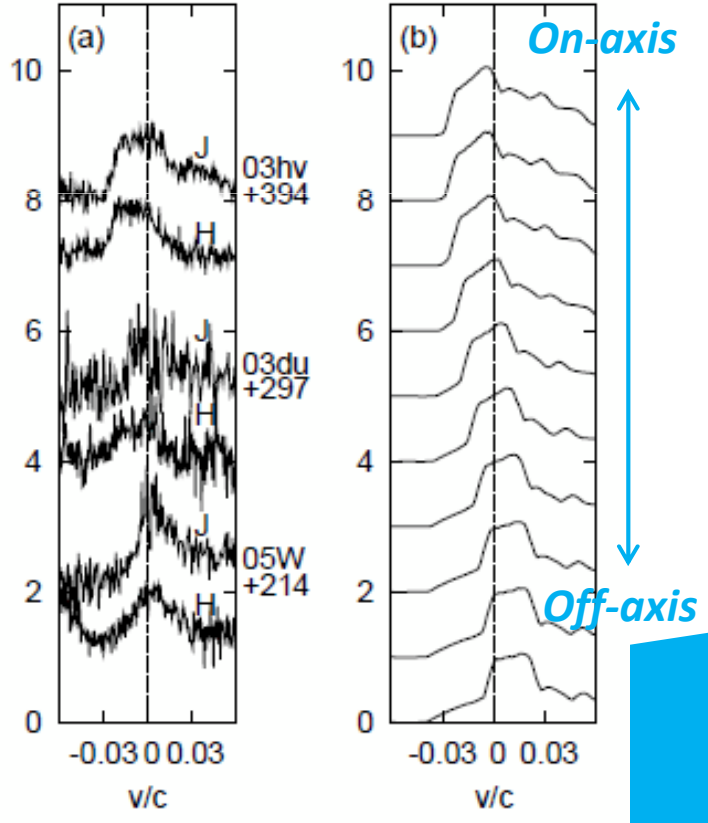
Recent models…

Asymmetric.

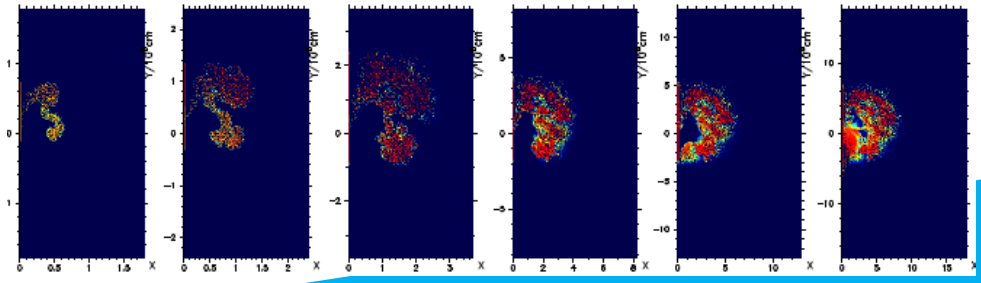
Specific Axis?

⇩

NIR can probe it!



Maeda, Roepke + 09, ApJ, submitted



Data from Motohara, Maeda+ 06

Summary

- ***Proposed scenarios.***
  - ***SN Ia cosmology → Hubble diagram @ z ~ 0.2.***
    - 6 hr / week x 3 yrs: 10 SNe Ia w/ good luminosity estimate.
  - ***SN II in dusty gals. → "True" SN rate.***
    - 5 hr / month x 1 yr: 3 – 30 SNe II.

Best for TAO?

  - ***Progenitor Search → NIR likely a new window.***
    - Post-SN images taken by, e.g., AO-NIR nearby gal. servey.
    - Another two post-SN images. "Cheap".

Best for TAO?

  - ***Nearby SNe followup → Good dataset. Cosmology.***
    - Sampling nearby SNe. ***MiniTAO, MAGNUM?***