A Search for Failed Supernovae:

Looking for Vanishing Supergiants

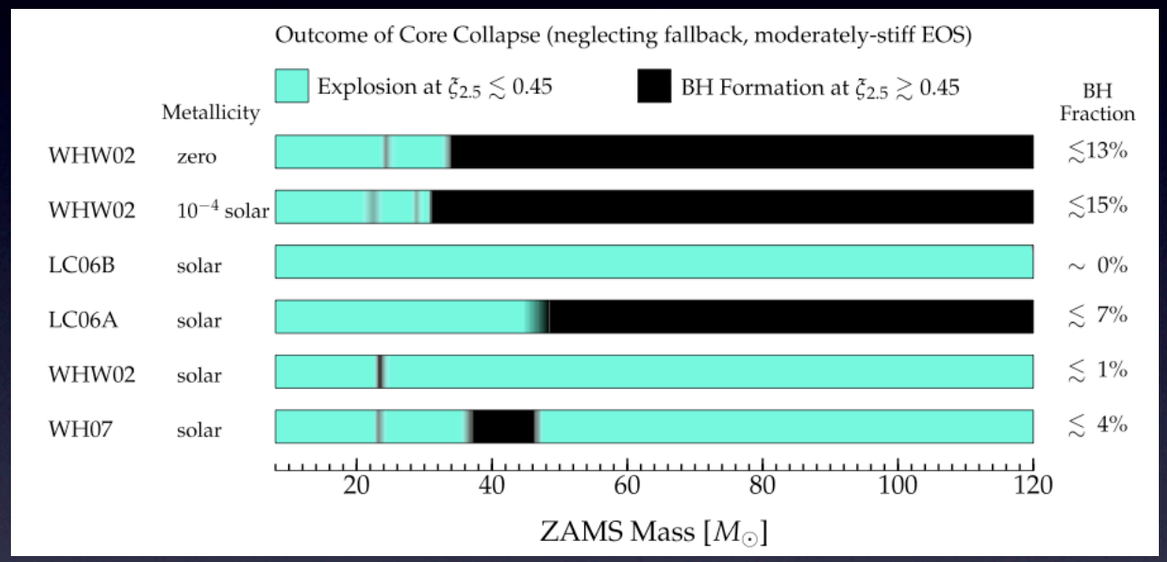
Jill Gerke

The Ohio State University
Advisor: Chris Kochanek

Collaborators: Kris Stanek, Dorota Szczygiel, Jose Luis Prieto

When Does A SN Fail?

- A Failed SN occurs when a massive star experiences a stalled shock that is not revived, or directly collapses into a black hole



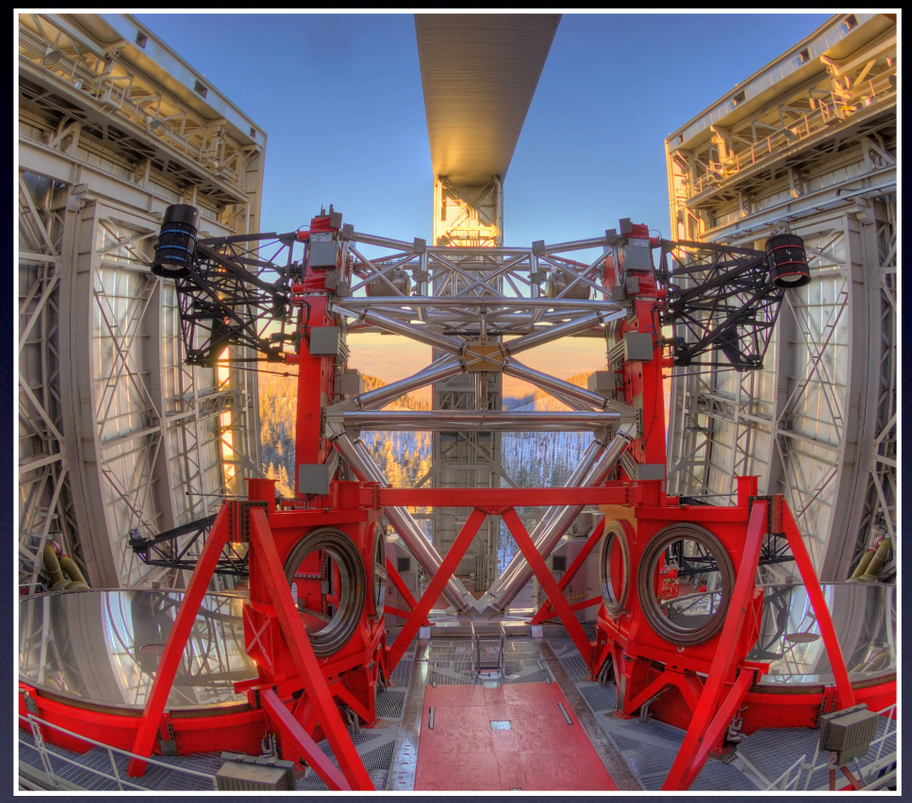
O'Connor & Ott (2011)

- Theoretical rates for failed SN in low metallicity stars is ~15% and 0-7% for solar-metallicity stars

- Possible signals of failed SN: Gravitational waves and neutrinos

The LBT Survey for Nothing

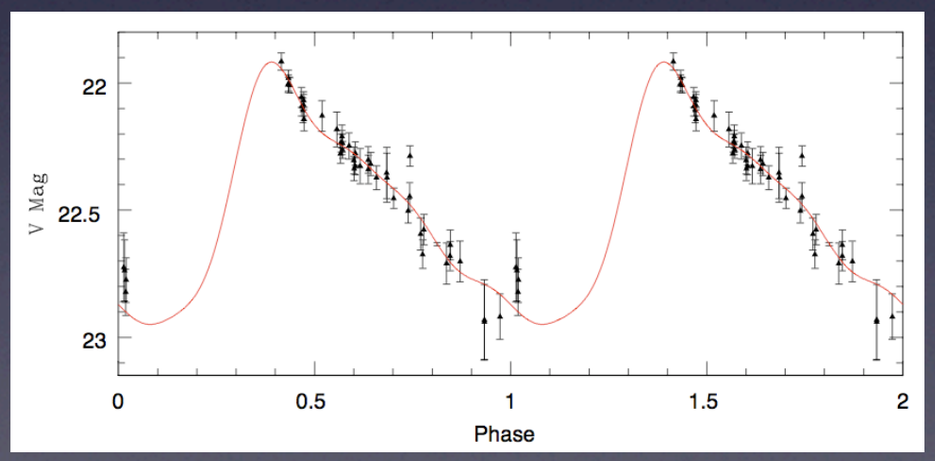
- Monitoring 25 galaxies within 10 Mpc for 4 years
  - 10^6 supergiants
  - Roughly face-on galaxies
    - Combined SN rate of ~1 per year
- Data is taken with the LBCs
  - Blue side: UVB bands
  - Red side: R band



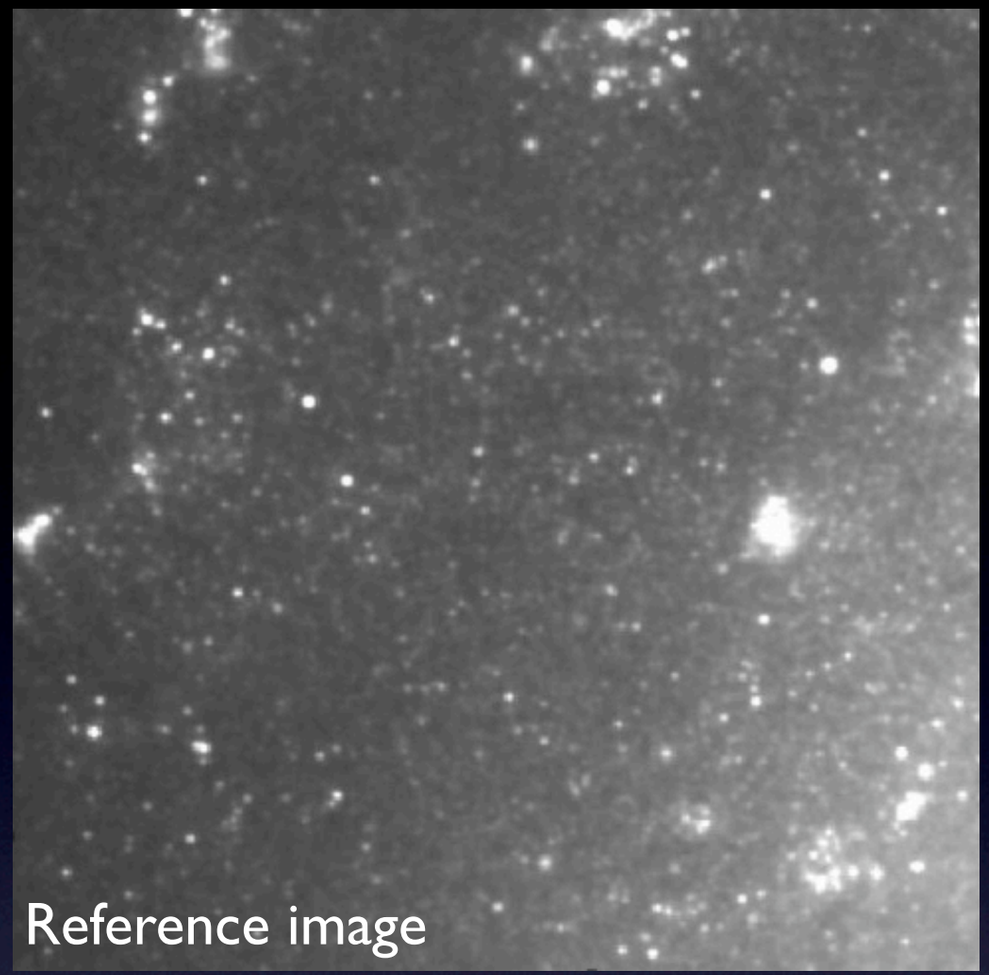
- Observation cadence
  - Typically twice per year
  - Cycling galaxies through more a period of more intensive monitoring

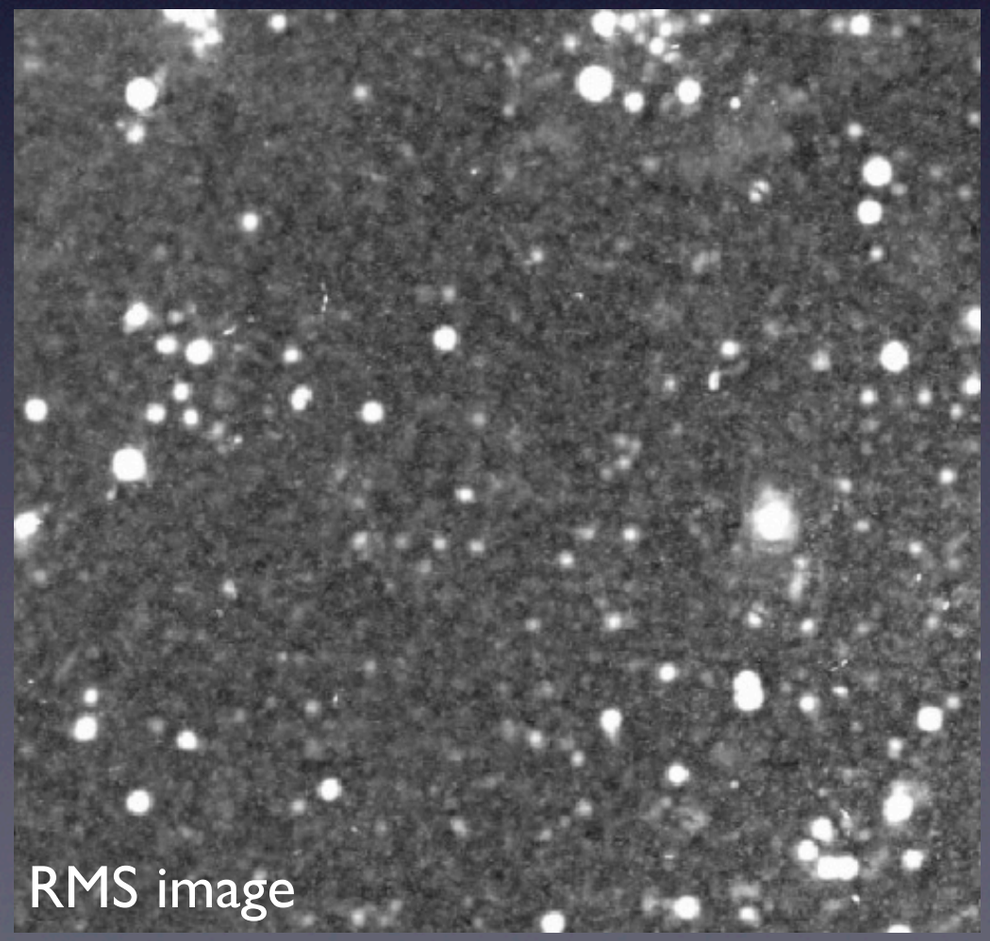
Method

- ISIS image subtraction (Alard 2000)
- Differential photometry
  - Reduced crowding
  - Study both bright and variable sources



30 day Cepheid, which corresponds to ~6$M_\odot$ evolved star (Bono et al. 2000)


Reference image


RMS image

Candidate Selection and Preliminary Results

Source List: $L \geq 10^4 L_\odot$ or $\Delta L : \nu L_\nu \geq 10^4 L_\odot$

Selection Criteria

1. at least 80% as bright in the second epoch as in the first.
2. fade in luminosity by 50% between the first and last observations.

M51 data was used as a test case, we found 10 candidates

An example candidate:

Initial luminosity: 3.4 $10^4 L_\odot$

Last observed luminosity: 1.0 $10^4 L_\odot$

Failed SN Rate Limits

Survey baseline: T = 4 years

Normal SN rate: $R_{sn} \simeq 1$ per year

Expected Number of Failed SN: $N_{fs} = f_{fs} \times R_{sn} \times T$

If we find no viable candidates at this point in the survey, this implies a 90% confidence limit of:

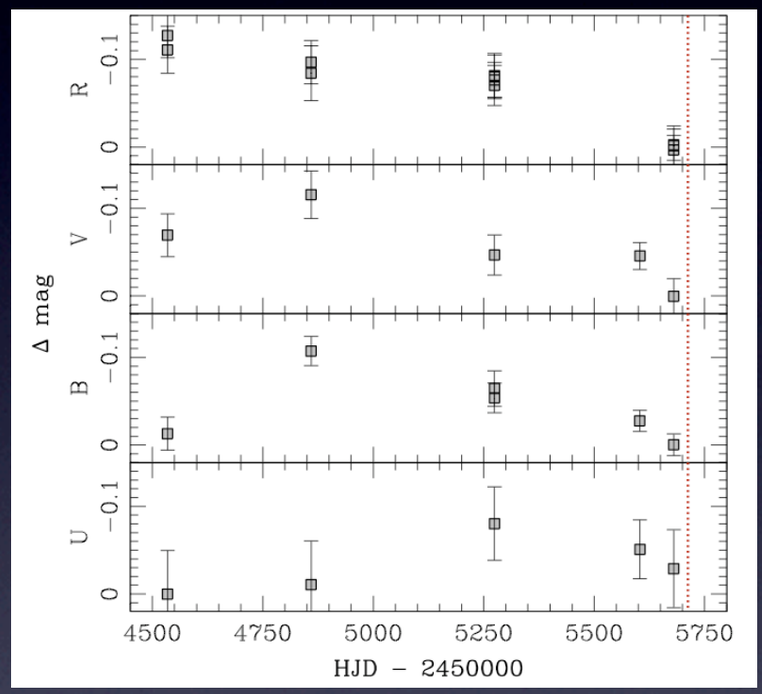
$P(0)=e^{ f_{fs} \times R_{sn} \times T} = 0.1$ giving $f_{fs} < 0.6$

Future Limits:

If the rate is $f_{fs} \simeq 0.05, 0.1$ or 0.2, a 10 year survey has a 40%, 63% and 86% probability of success.

Bonus Science

- **Supernova Progenitors**: In Szczygiel et al. (2012a) we found that the candidate progenitor star of SN 2011dh in M51 was fading.



- **SN Impostors**: Prieto et al. (2008b) and Szczygiel et al. (2012b) both use this survey to place limits at optical wavelengths for 2008S, before and after the explosion, respectively.
- **Cepheids**: We have completed a study of M81 (Gerke et al. 2011) and have begun analyzing NGC 4258.
- **Variable stars**: Many types of variable stars can be studied. For example, Prieto et al. (2008a) reported the discovery of a yellow supergiant eclipsing binary in Holmberg IX.

References

Alard, C. 2000, A&AS, 144, 363
Benvenuto, O. G., Bersten, M. C., & Nomoto, K. 2012, arXiv:1207.5807
Bono, G., Castellani, V., & Marconi, M. 2000, ApJ, 529, 293
Gerke, J. R., Kochanek, C. S., Prieto, J. L., et al. 2011, ApJ, 743,176
Kochanek, C. S., et al. 2008, ApJ, 684, 1336
Kochanek, C. S., Szczygiel, D. M., & Stanek, K. Z. 2012, arXiv:1202.0281
O'Connor, E., & Ott, C. D. 2011, ApJ, 730, 70
Prieto, J. L., Stanek, K. Z., & Kochanek, C. S., et al. 2008a, ApJL, 673, L59
Prieto, J. L., Kistler, M. D., Thompson, T. A., et al. 2008b, ApJL, 681, L9
Szczygiel, D. M., Gerke, J. R., Kochanek, C. S., & Stanek, K. Z. 2012a, ApJ, 747, 23
Szczygiel, D. M., Prieto, J. L., Kochanek, C. S., et al. 2012b, ApJ, 750, 77

LBT photo: Marc-Andre Besel and Wiphu Rujopakam