Dust And Transients

- Physics of dust in transients
- Circumstellar extinction is not interstellar extinction
- Observational update on the SN2008S class of transients

Done in collaboration with D. Szczygiel, J. Gerke, R. Khan, J.-L. Prieto, K.Z. Stanek and T.A. Thompson

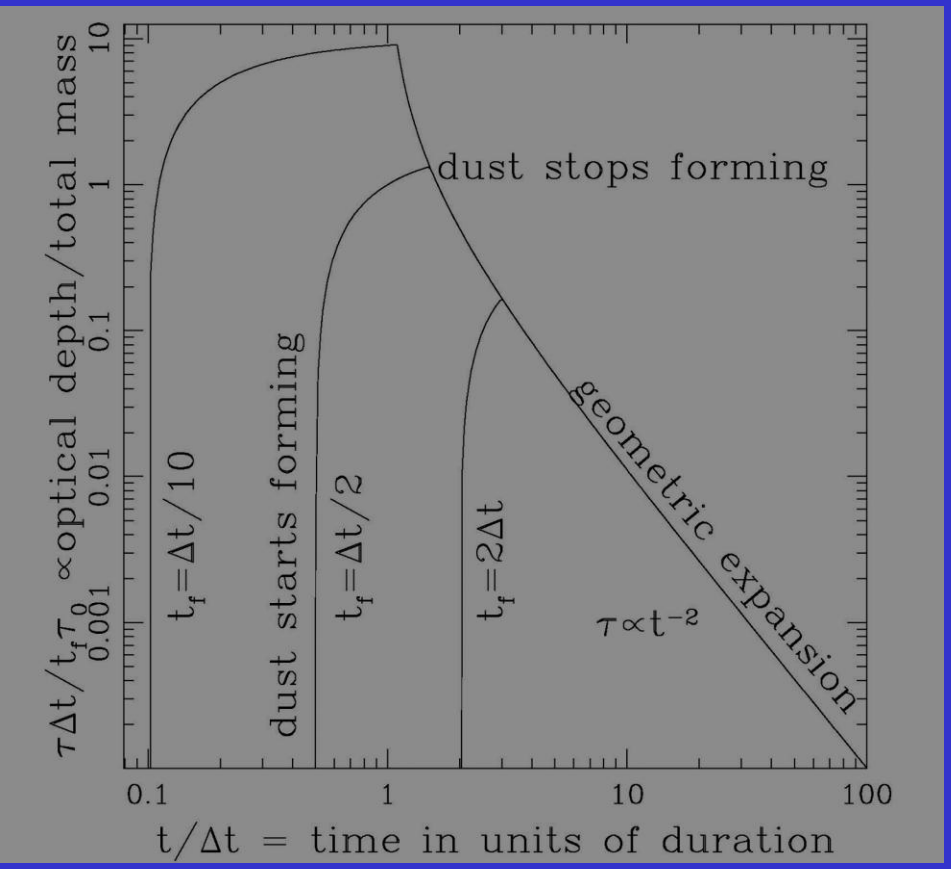
How Do You Make It?

1. Nucleate particles once cool enough ($T_{form} \approx 1000$-2000K)
2. If intrinsic radiation field is hot ($T_{rad} > 10^4$K) wind/ejecta must be dense enough to form a pseudo-photosphere (Mdot$>10^{-2.5}$ or so)
3. Density controls growth after nucleation – time scale to have significant opacity – but there is no critical density to have nucleation
4. Key number is opacity, not dust mass – reasonable dust physics if visual opacity of order 100cm^2/g or smaller (gas to dust ratios ~100 or larger)

Where Do You Make It?

1. Reform dust in a pre-existing dense wind – seems to be the case for the 2008S class of transients
2. Form dust during period of high mass loss associated with transient – canonical picture of impostors
3. Form dust in the contact discontinuity between shocked CSM and ejecta – canonical picture for SN
4. Form dust in a new wind rebuilding itself after the transient – usually too slow

Where you make it determines the subsequent optical depth evolution



1. Rises on time scale for ejecta to reach dust formation radius
2. Approaches that for a fully formed wind if high mass loss rate continues for a period long compared to the formation time scale
3. Initially falls rapidly on the short time scale it took material to reach the dust formation radius
4. Asymptotes to the $\tau \propto t^{-2}$ scaling of a thin shell

Very similar scalings for dust formed in a shock contact discontinuity

Tyranny of Geometry

These scalings are generic to dust in an expanding medium unless there are true holes in the dust

A true “hole” is one that is (1) NEVER optically thick, and (2) requires a fixed number of scatterings to escape through

Making the geometry more complex or allowing for the growth of structure due to instabilities in the shell accelerates the evolution

Tyranny of Geometry

Once you have invoked dust, you must live with these scalings when you explain the subsequent evolution of the system

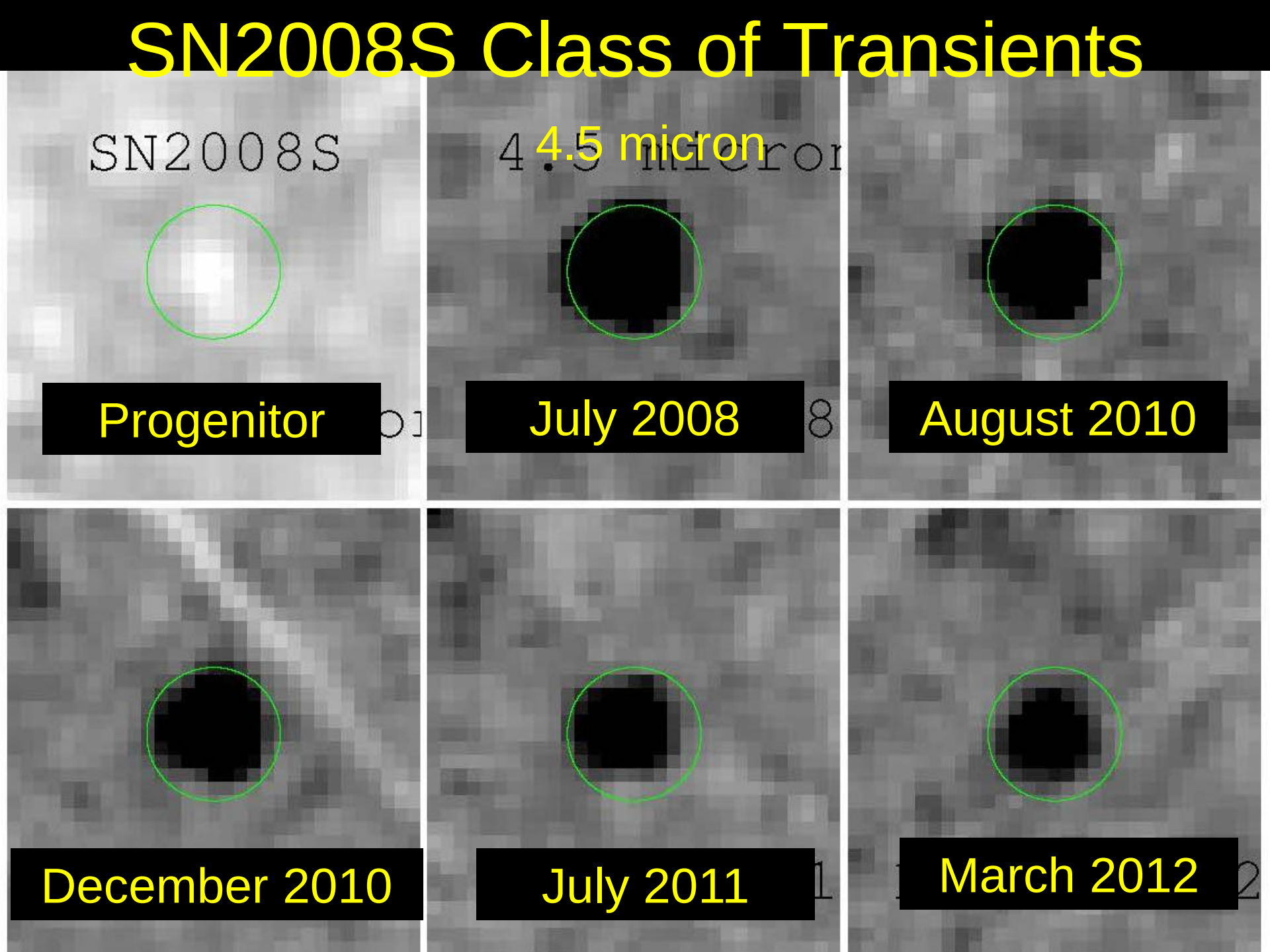
1. Optical depth drops with time, dust becomes cooler, visible light begins to escape → specific predictions for scaling with time
2. It is essentially impossible to fight optical depth changes by playing with the luminosity and temperature of the star – the optical depth is in an exponential, and the luminosity is not!

Circumstellar Dust Cannot be Quantitatively Modeled by Galactic Extinction laws

1. Galactic extinction laws assume scattered photons are lost to the observer, which is not true for circumstellar dust
2. Galactic extincition laws assume ~50:50 mix of silicate and graphitic dusts – most massive stars have silicate dusts unless have undergone right dredge up phase (Carbon stars, SN2008S class)
3. When a star is creating dust, there is a dust emission contribution to the near-IR, particularly K-band

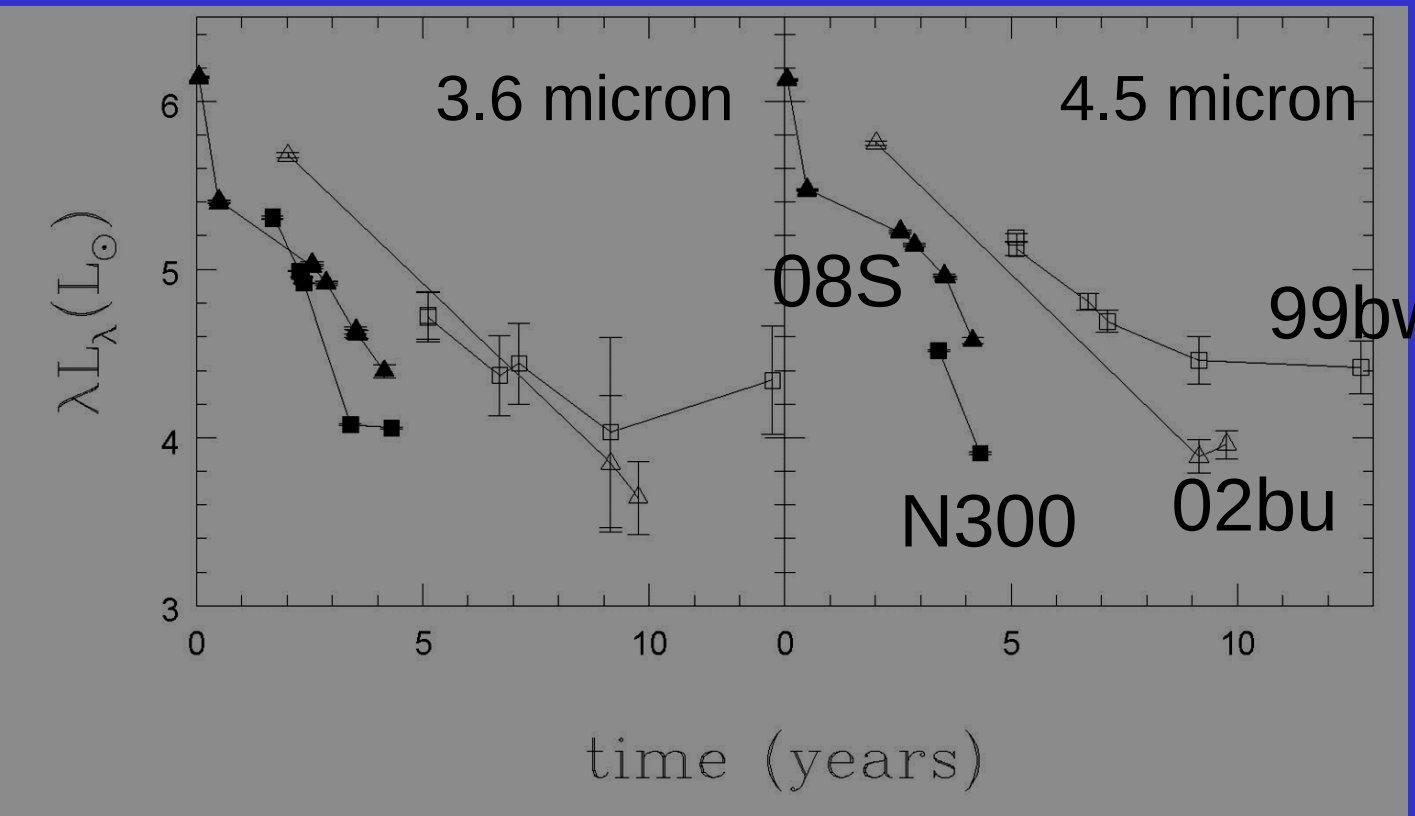
In Kochanek et al. (2012) we supply equally easy to use interpolation formulas for several circumstellar dust cases – you can just pull them out of the electronic paper with a mouse and use them

SN2008S Class of Transients

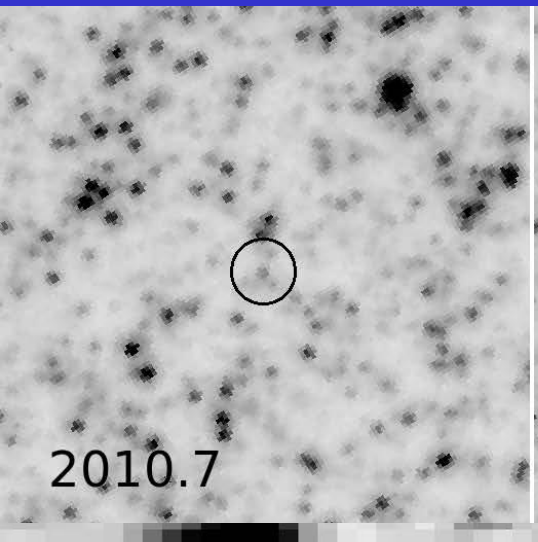


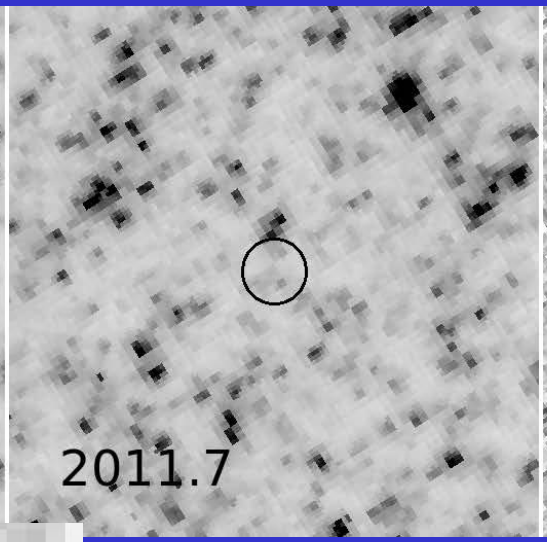
Slowly Fading
(But Still Brighter Than Their Progenitors, where known)

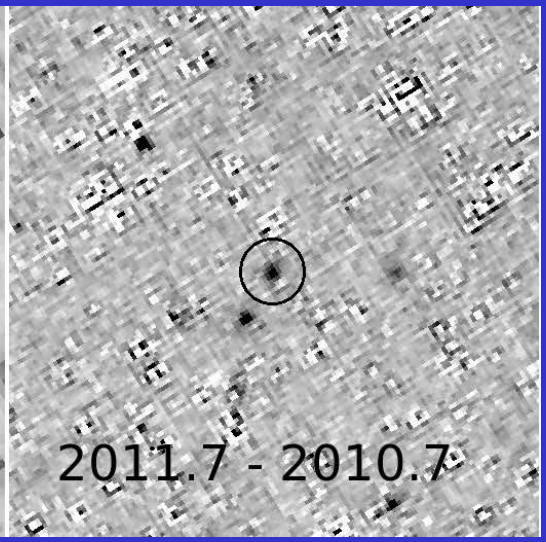
SN1999bw may have leveled out



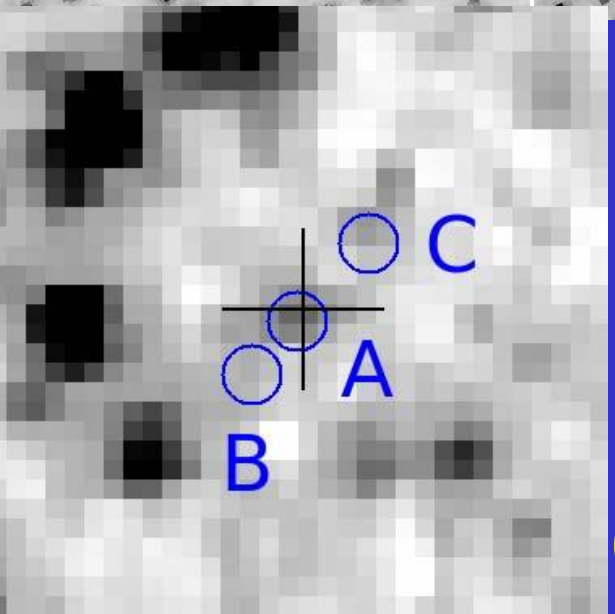
All Are Very Faint/Invisible at H-band







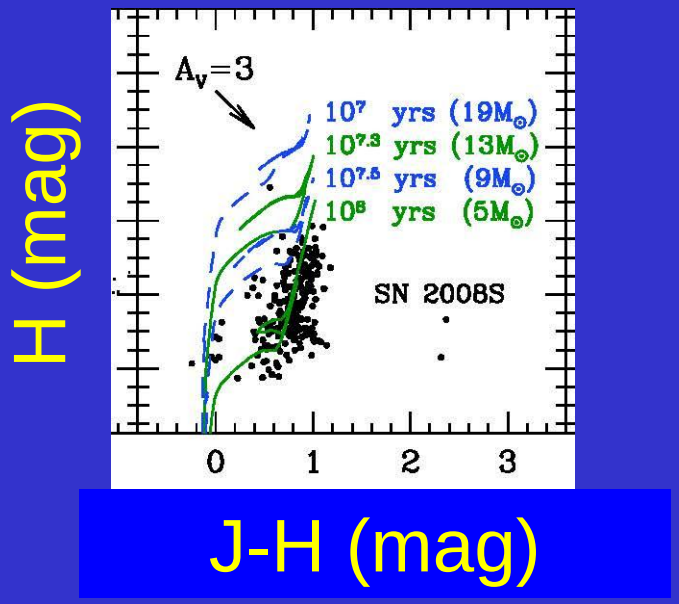
08S



02bu

Because of crowding, only absolutely certain of ID for 08S where we can see variability

Aside From NGC300, Environments Lack Massive (>10M$_\odot$) Stars



Association with AGB stars by Prieto et al. (2008) and Thompson et al. (2010) appears correct.

Evolution

- Evolution remains consistent with dust re-forming in a pre-existing wind after being destroyed by an explosive transient rather than dust in ejecta
- However, no X-rays detected from an expanding shock – limits do not as yet rule out this aspect of the Kochanek (2011) model, but …..
- Still no clear cut answer on nature of transient
- Further studies rendered difficult last week by SST decision that only large proposals were allowed access to SST+HST time, contrary to the RFP