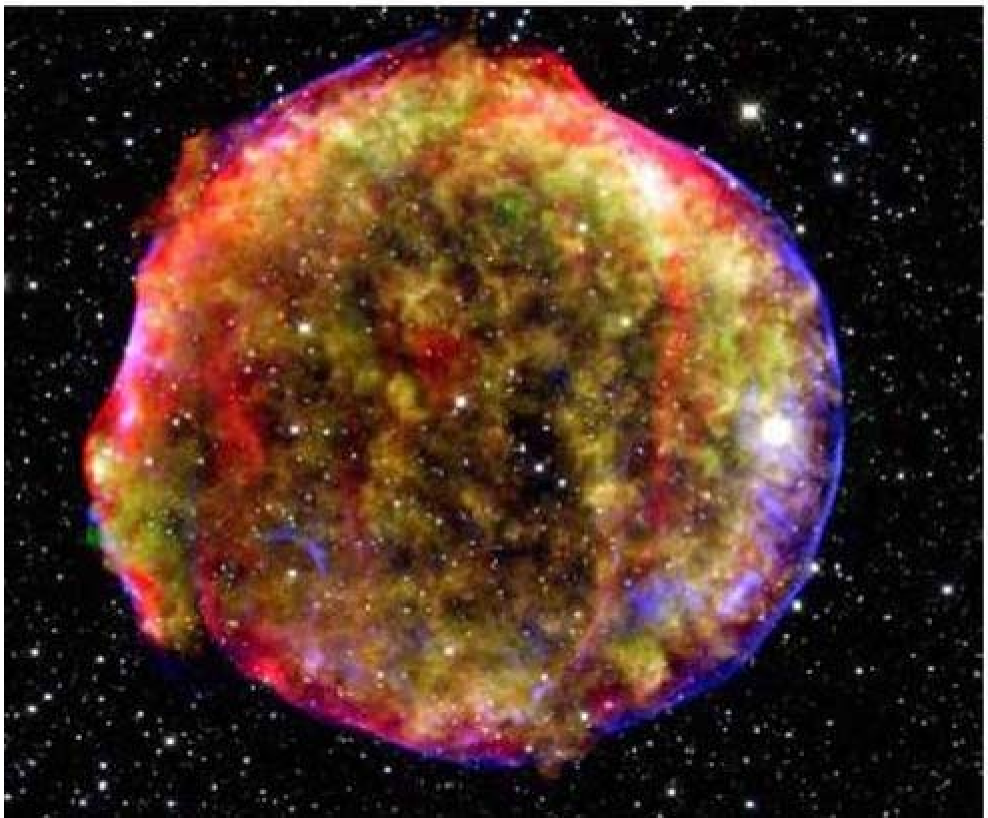
Non-standard reddening law from extinction by *circumstellar* dust

Ariel Goobar
The Oskar Klein Center
Stockholm University



Green Yellow Blue
X-ray (Hot gas with millions of degree)

Red
Infrared (Circumstellar/ Synthesized dust)

White
Optical (Foreground/ background stars)

SN1572
(Tycho's)

The case for CSM around active SNIa

- Theoretical predictions: in SD-models, mass transfer from companion + expelled material from WD surface in excess of critical accretion rate (Hachisu et al, 96,99a,b,08), prior to SN explosion.
- Spectroscopic evidence for shell of CSM (~10^{16}-10^{17}cm) for 3 near-by SNIa. <u>Claim:</u> changing sodium absorption due to changing ionization of CSM , modulated by SN radiation; but Ca-atoms locked up in dust grains.

2006X (Patat et al.);

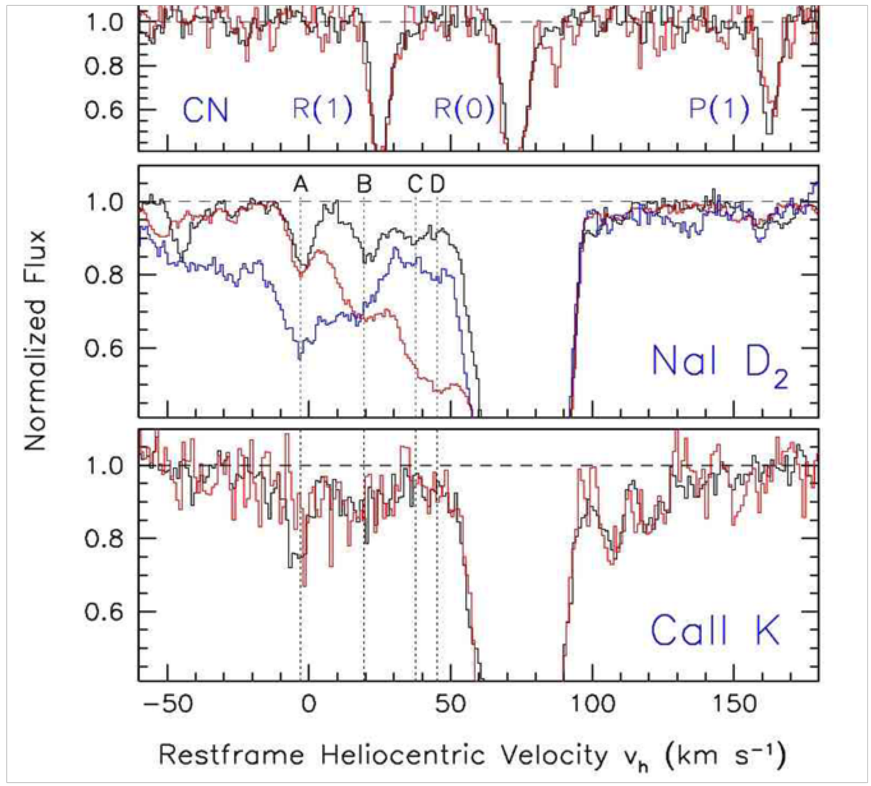
E(B-V)=1.42 0.04, **R_v=1.48 0.06** (Wang et al)

1999cl (Blondin et al.),

E(B-V)~1.1, **R_v~1.8**

2007le (Simon et al.),

E(B-V)=0.27, **R_v=2.56 0.22**

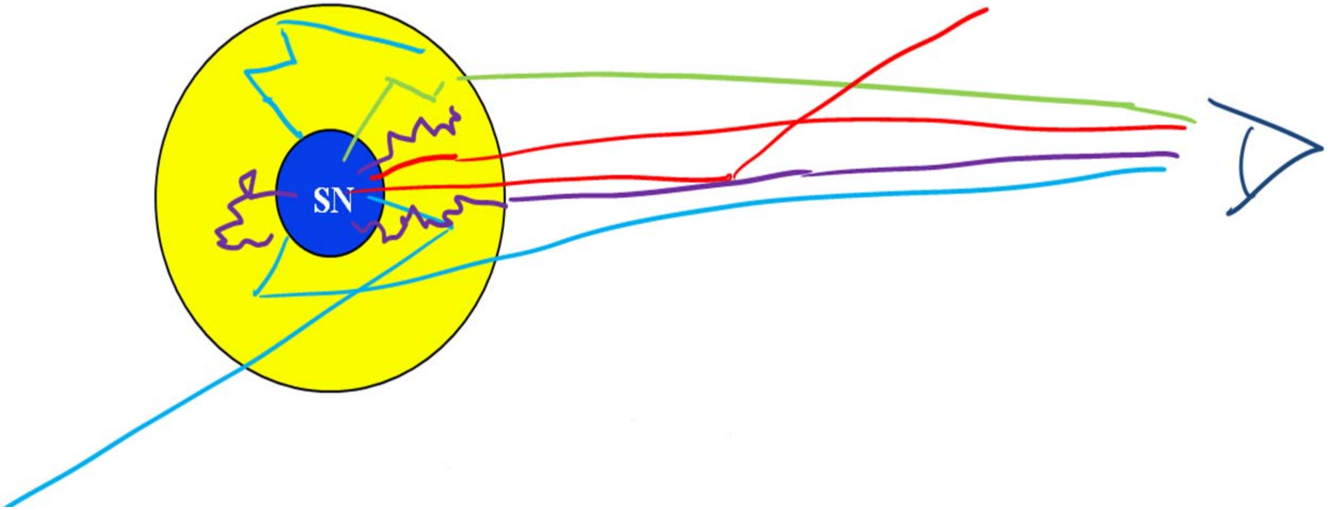


Multiple scattering in CS *dusty* medium

Observed colors after the semi-diffusive shell will depend on:

•Wavelength dependent cross-sections, albedo and scattering angles

•Dust density and shell volume



Run a Monte Carlo!

Use dust parameters for MW and LMC by:

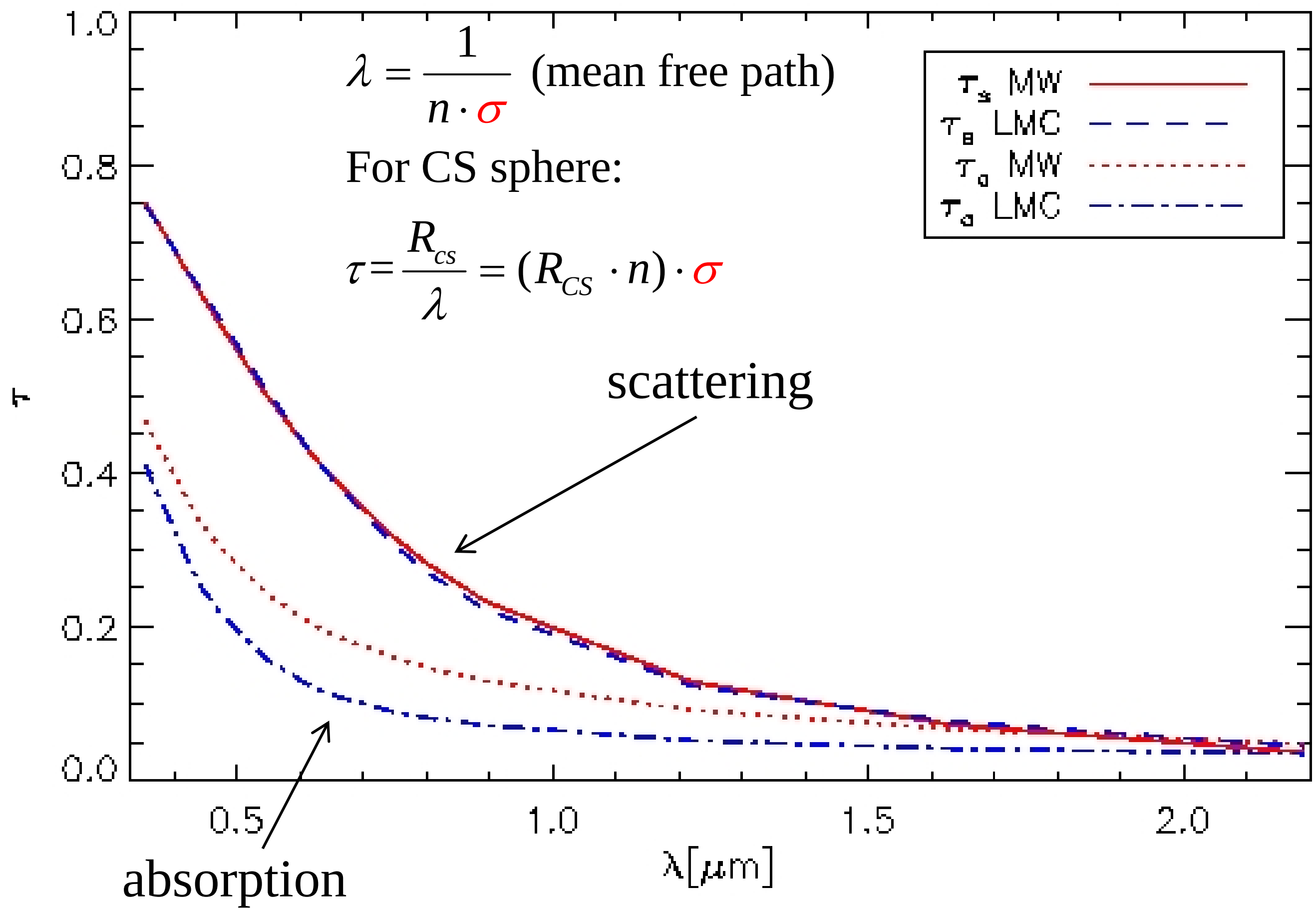
Draine ApJ 2003, Weingartner & Draine ApJ 2001

(also SMC dust , but mostly absorption (not scattering) at optical wavelengths)

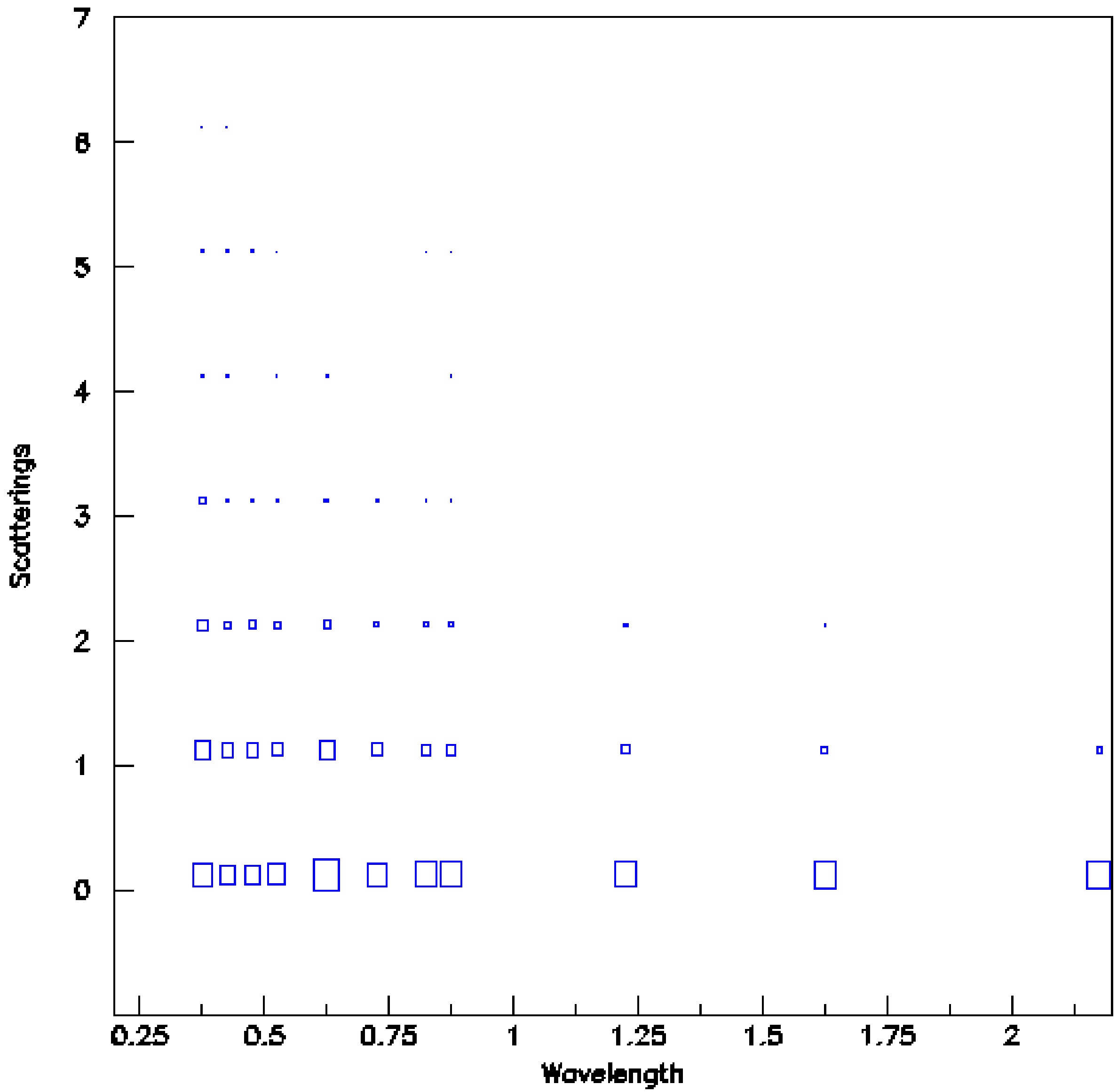
AG, ApJ 2008

see also Wang 05

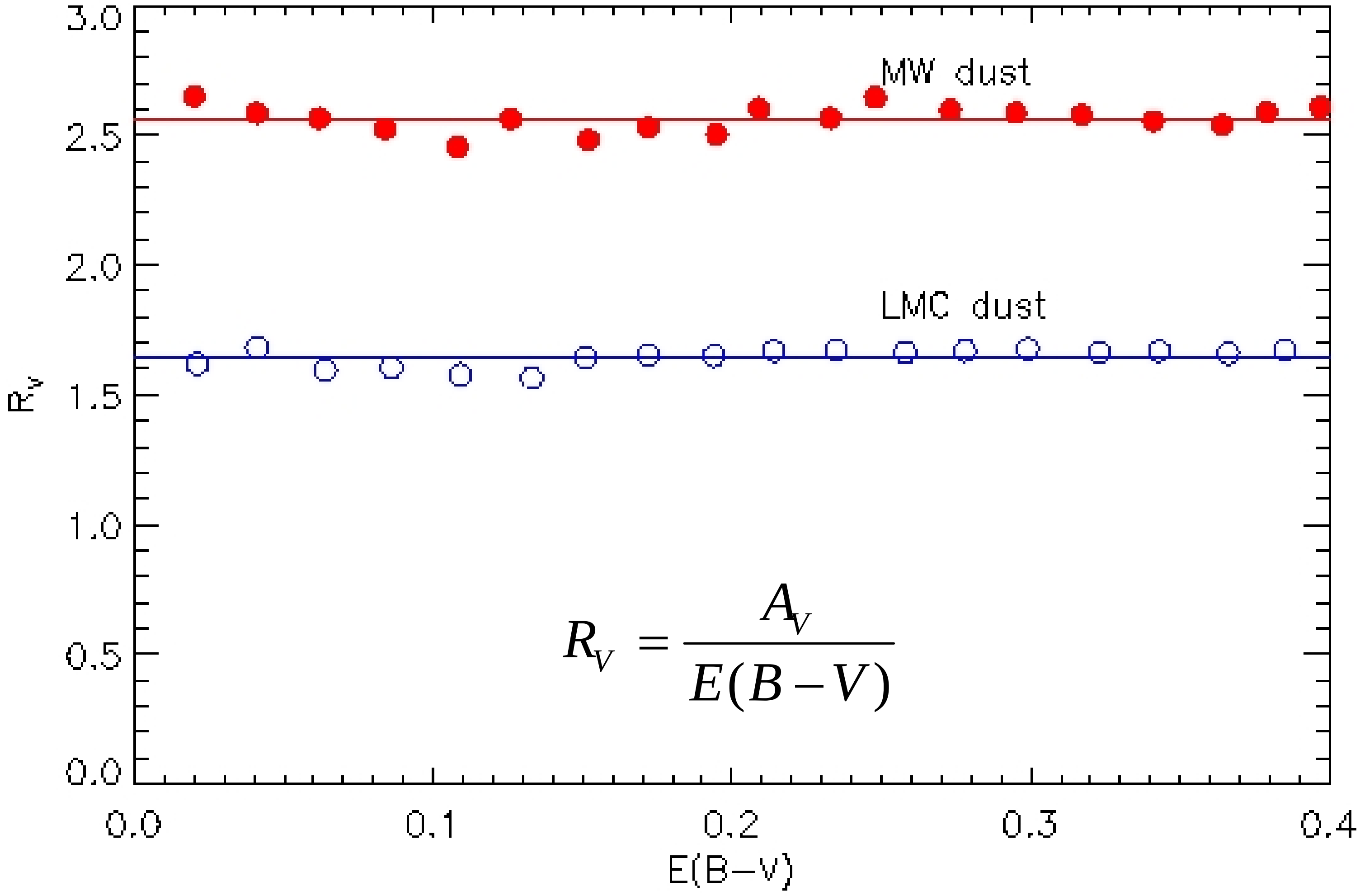
Optical depth: one realization



Scattering vs wavelength (LMC)



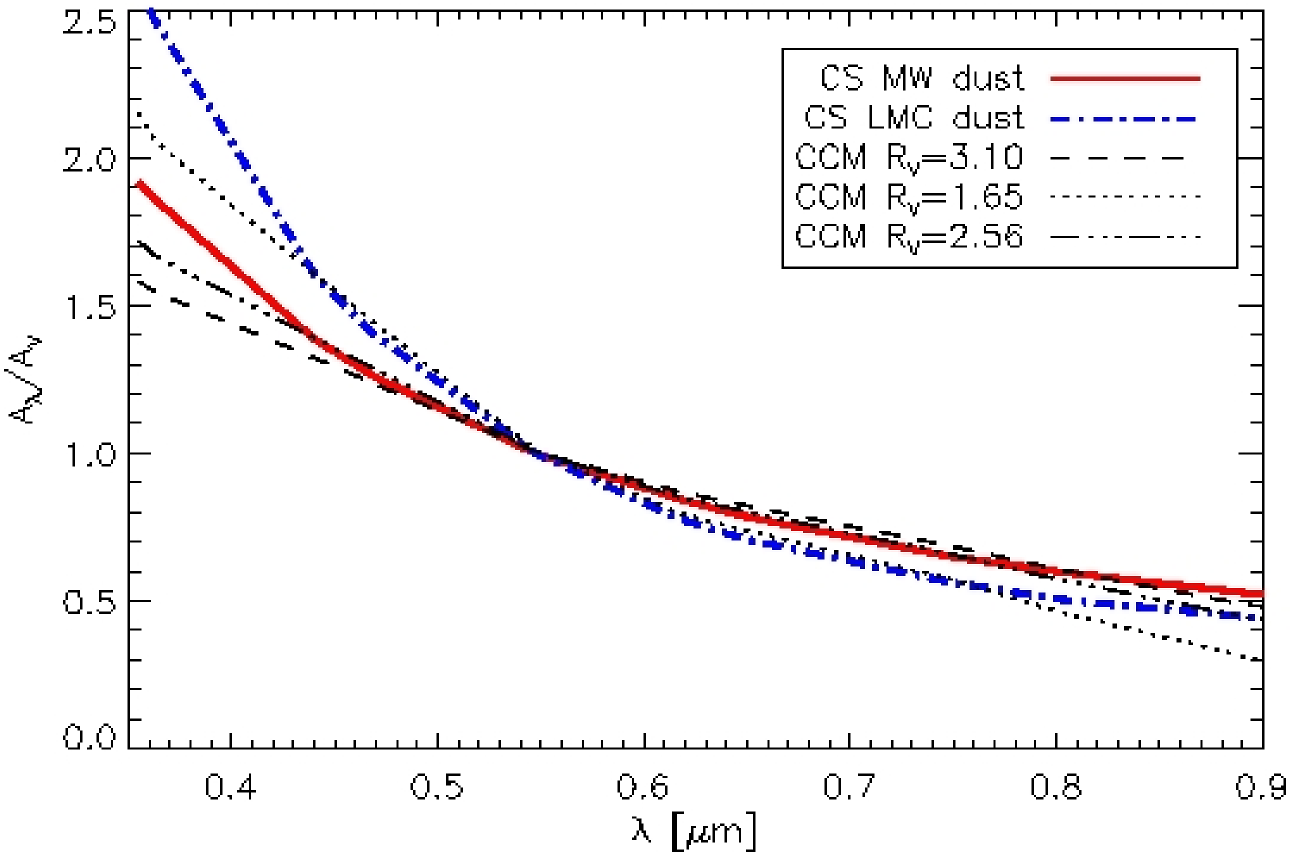
Run Monte Carlo simulation



$$R_V = \frac{A_V}{E(B-V)}$$

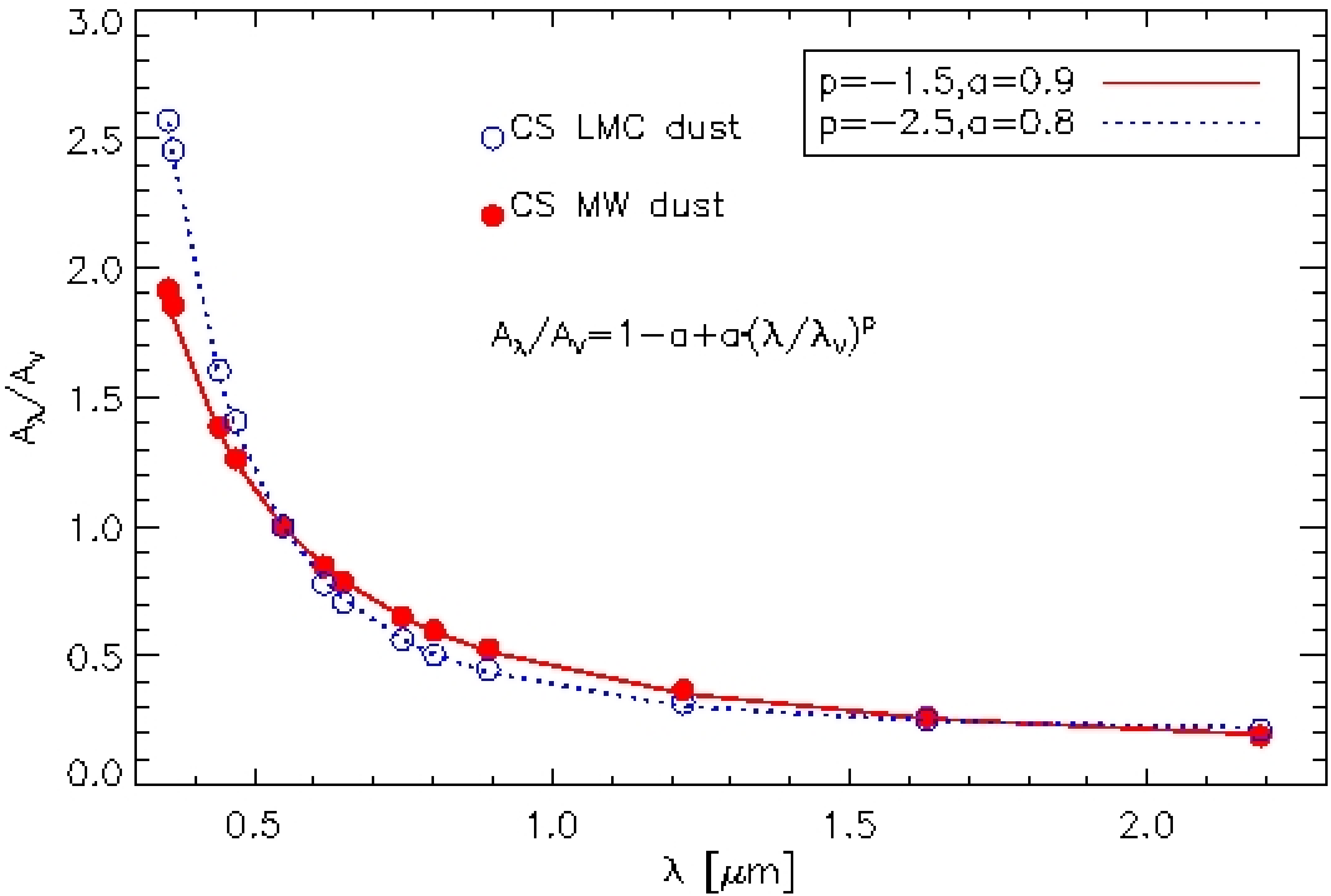
AG, 2008

Differential extinction function differs, especially towards UV



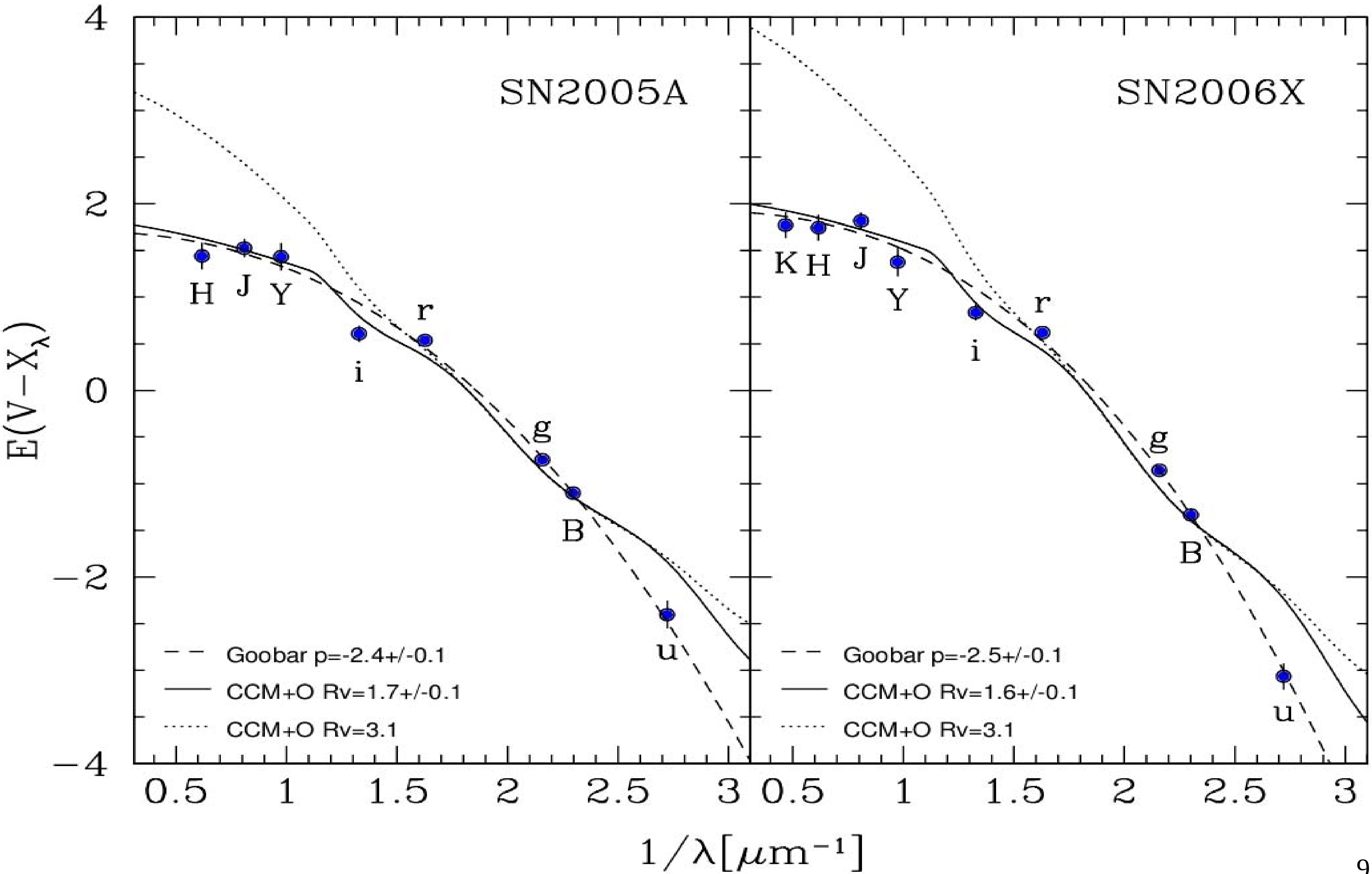
Cardelli law does not fit entire optical windows, for any R_V

Power-law

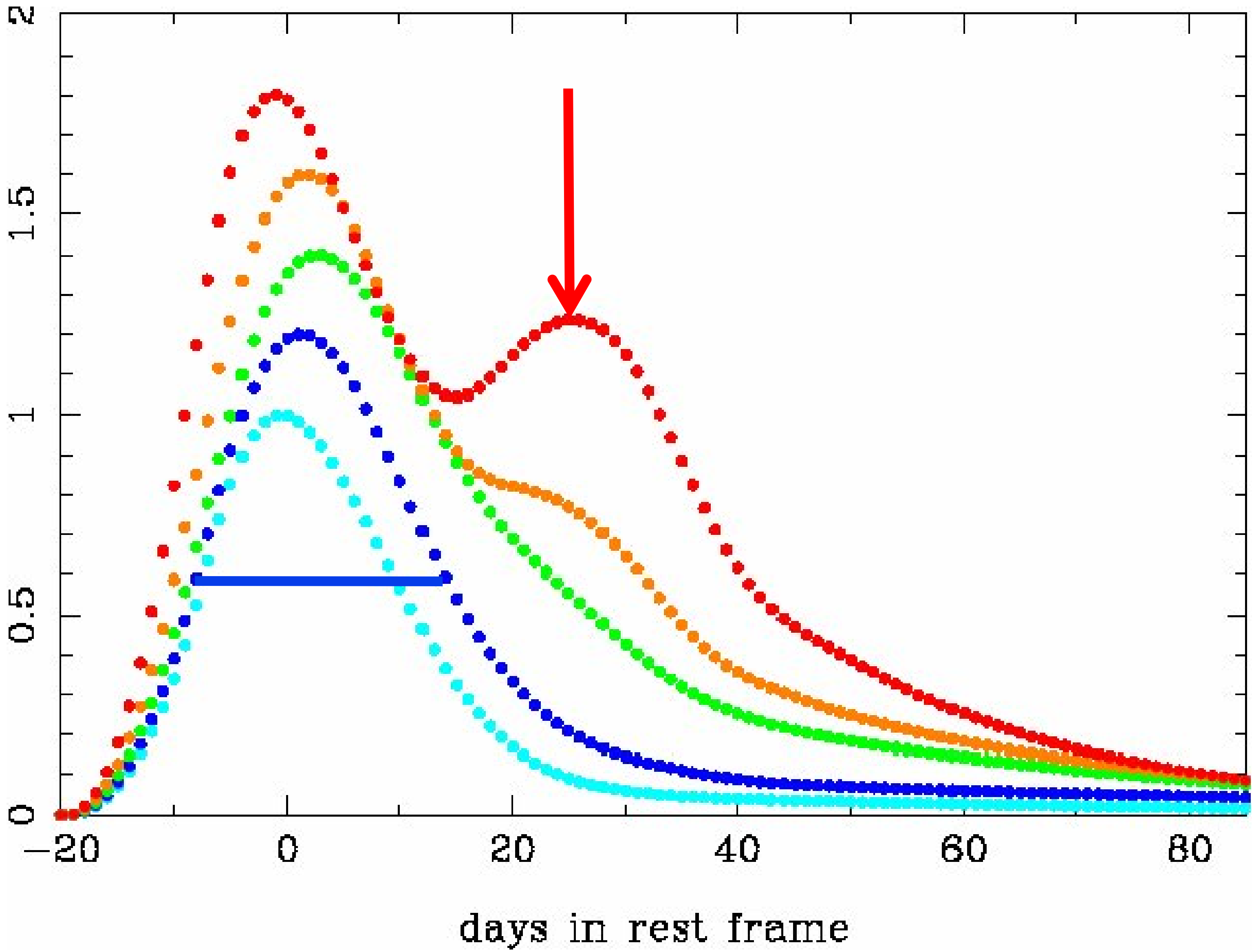


p=−1.5,a=0.9
p=−2.5,a=0.8
CS LMC dust
CS MW dust
$A_\lambda/A_V=1-a+a(\lambda/\lambda_V)^p$
A_λ/A_V
λ [μm]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.5
1.0
1.5
2.0

Carnegie Supernova Project: reddest SNIa (Folatelli et al, priv. com)

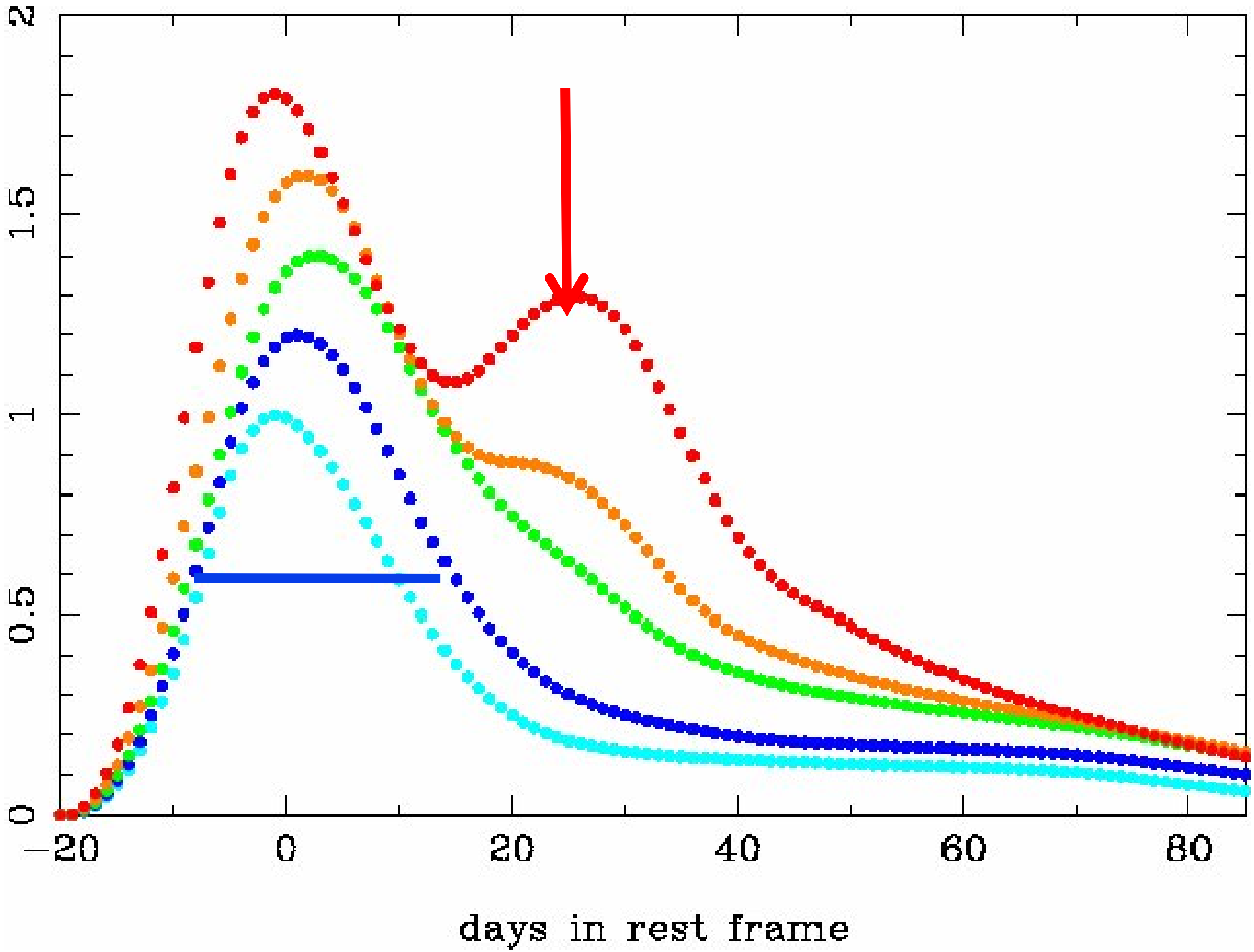


$R_{cs}=1\cdot10^{16}$ cm



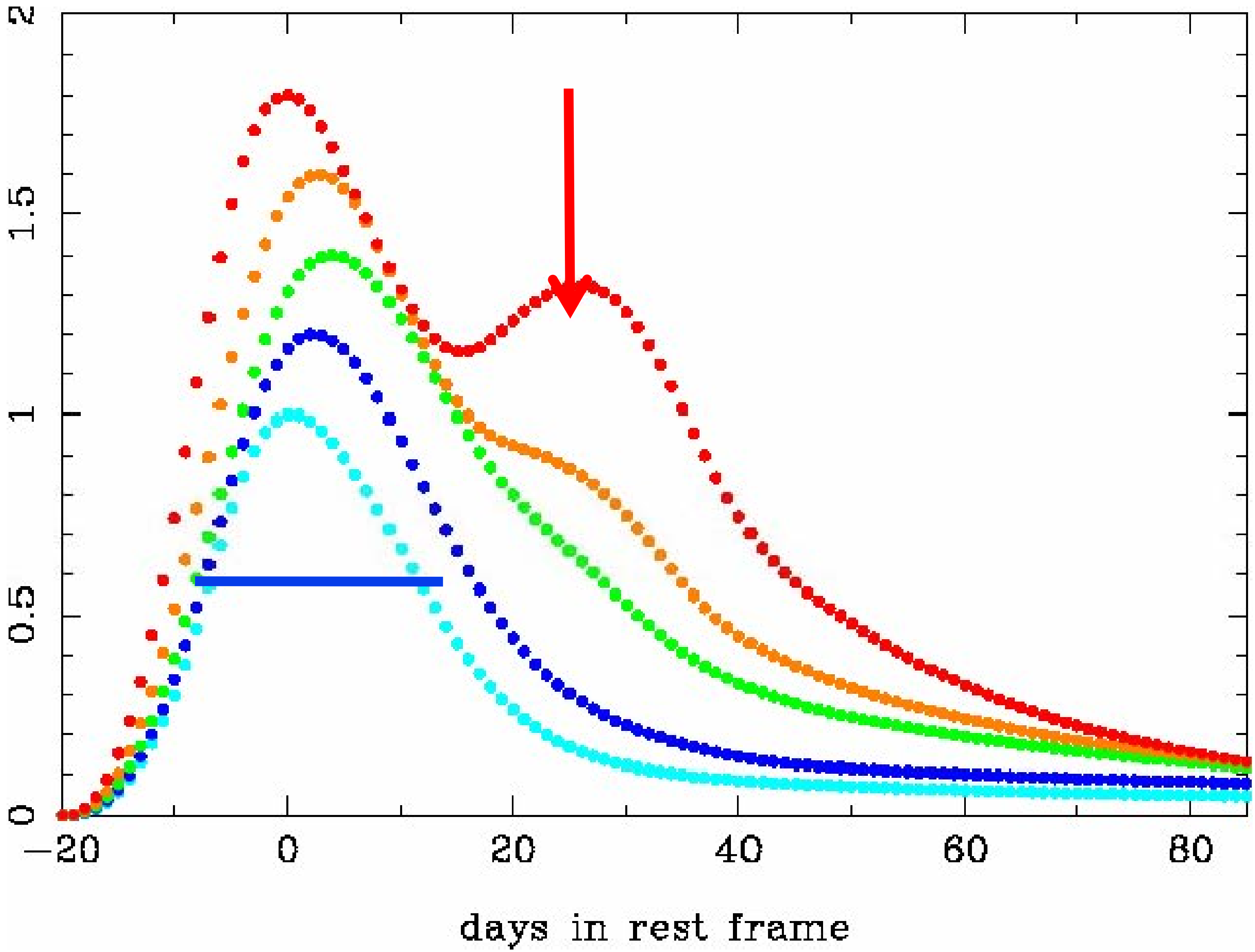
Amanullah & AG

$R_{cs}=1\cdot10^{17}$ cm



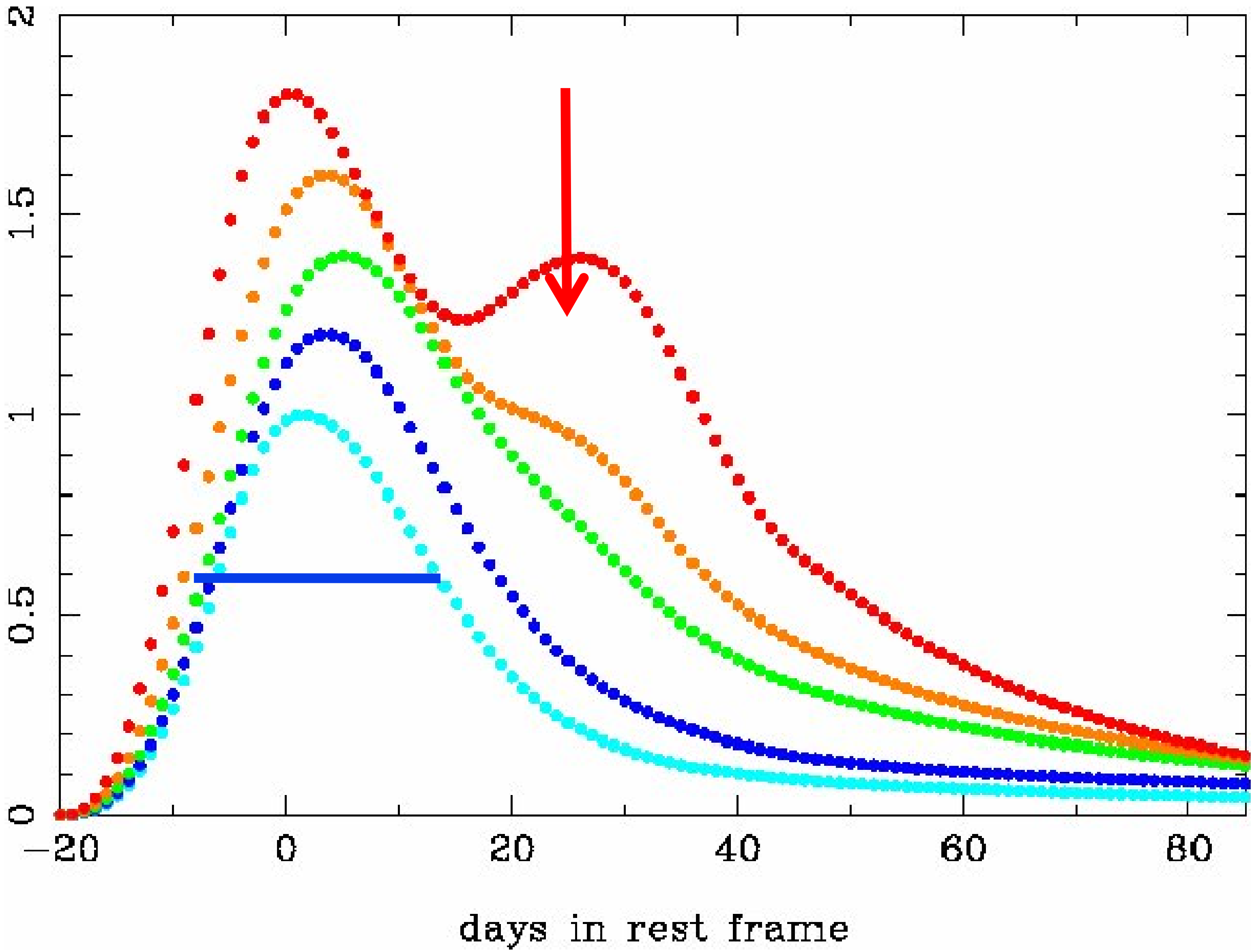
Amanullah & AG

$R_{cs}=5\cdot10^{17}$ cm



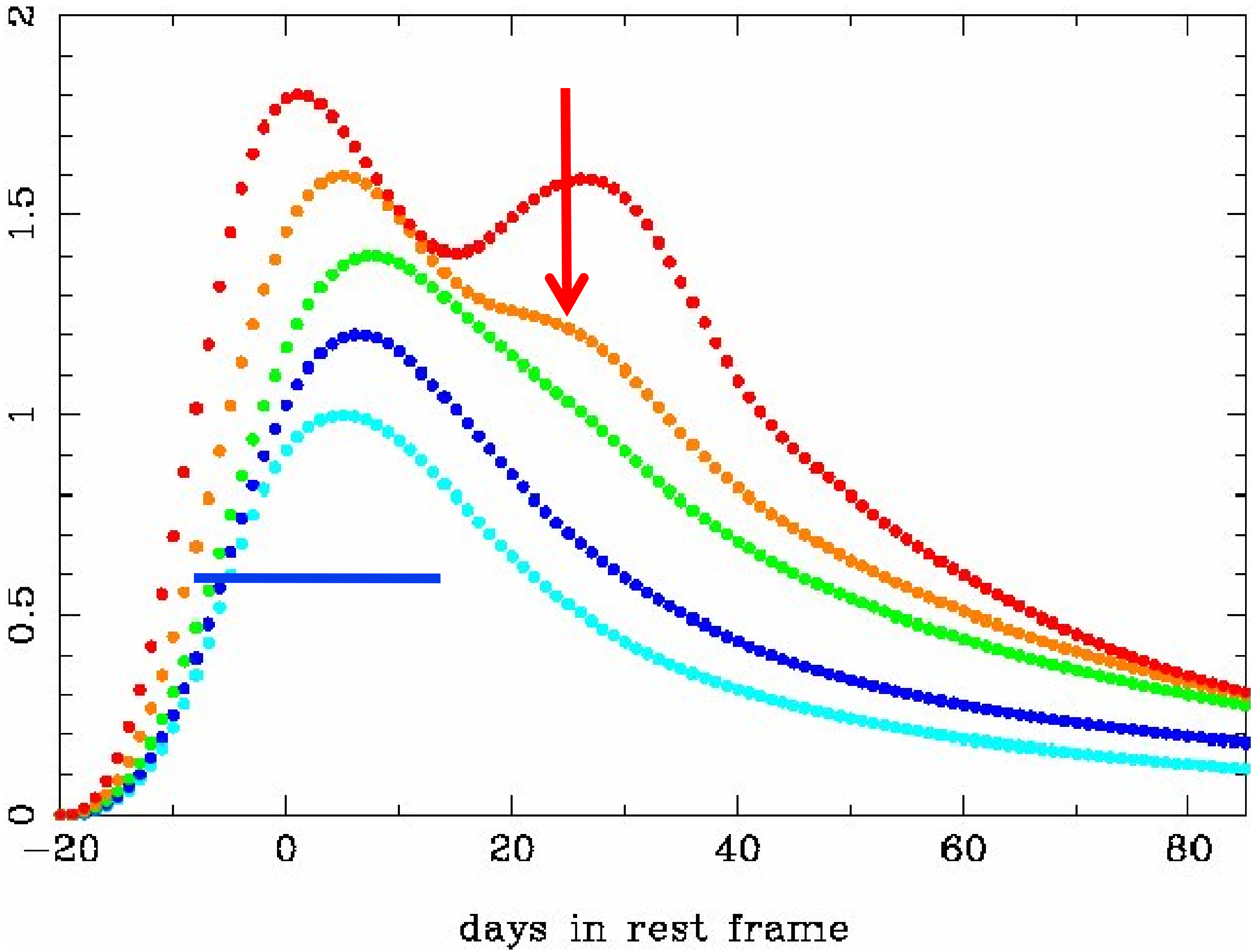
Amanullah & AG

$R_{cs}=1\cdot10^{18}$ cm



Amanullah & AG

R_{cs}=5·10^{18} cm



Amanullah & AG

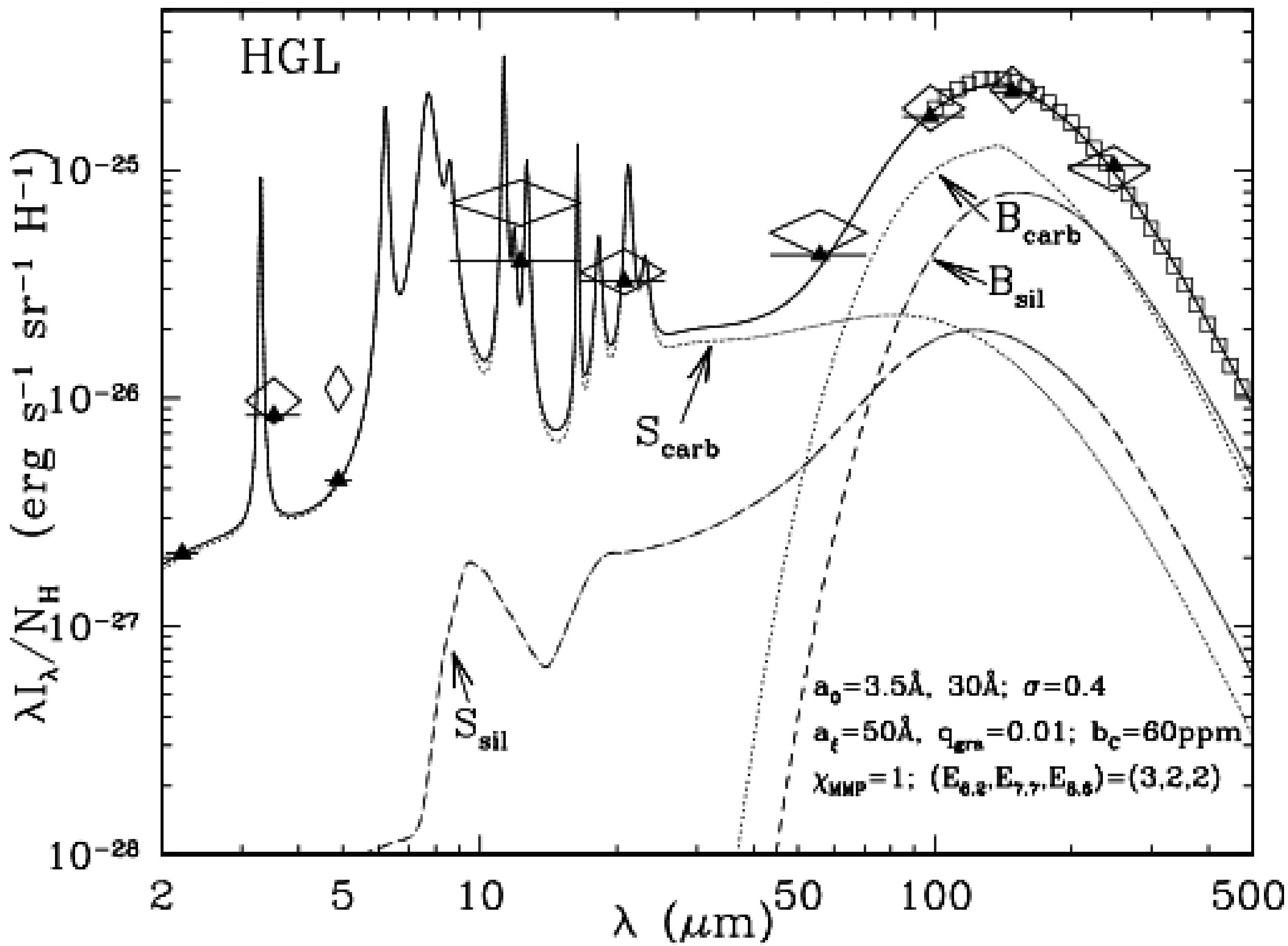
Summary & Outlook

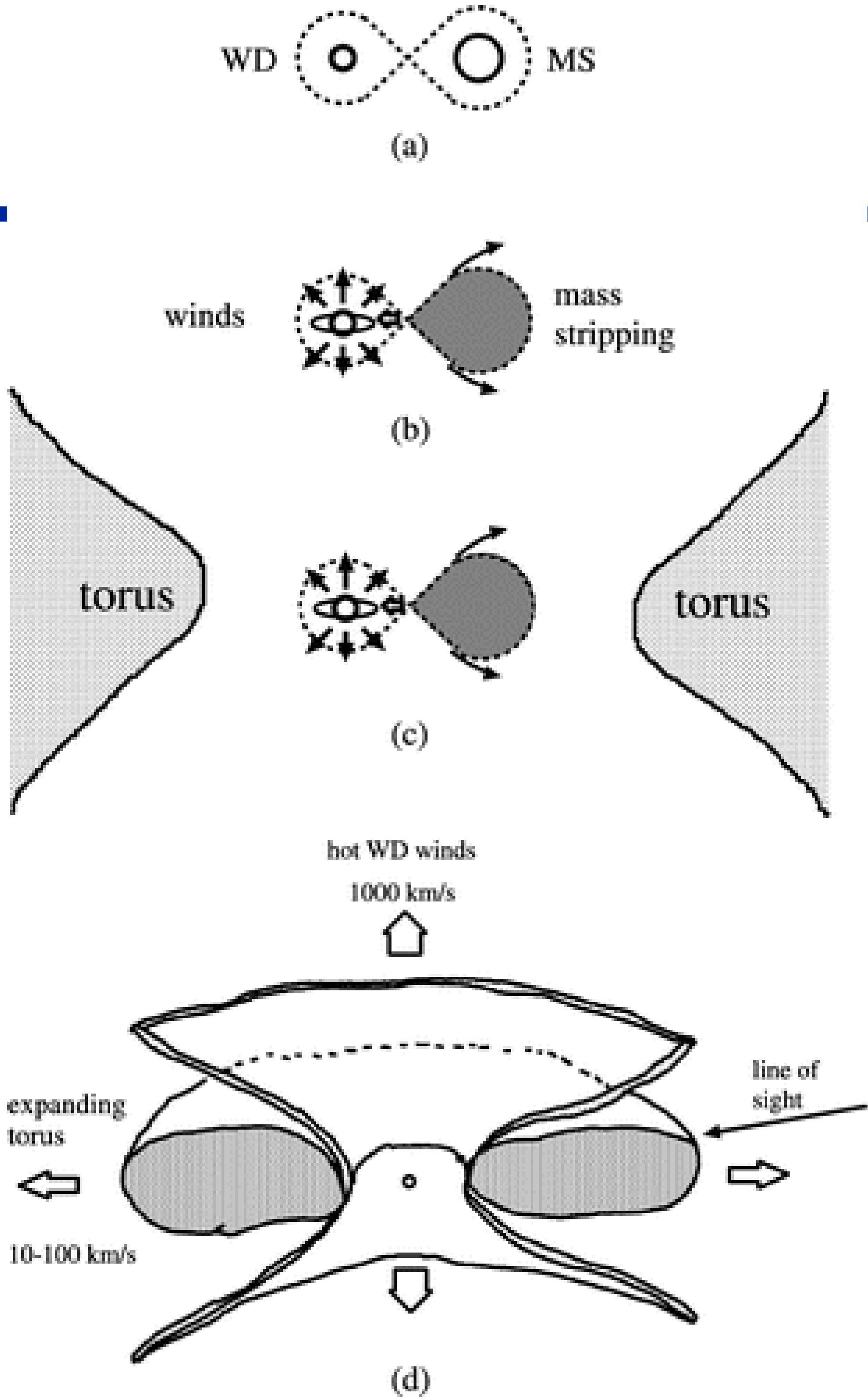
- Local effects, such as interaction with circumstellar dust, as claimed for 3 near-by SNIa, could explain low R_v /β + introduce lightcurve shape variations.
- Question: If main reason for $R_v<3.1$ is local, why is there so little interstellar extinction?
- Restframe near-IR observations least affected by dust, combined with optical data are critical.
- Predictions:

1. Measured color excess should change with SN epoch!
2. LC peaks and late time flux in various bands correlate with shape and color excess (related to shell size in the model)
3. Dust emission in far-IR (Apex program approved, but need reddened SN really close!)

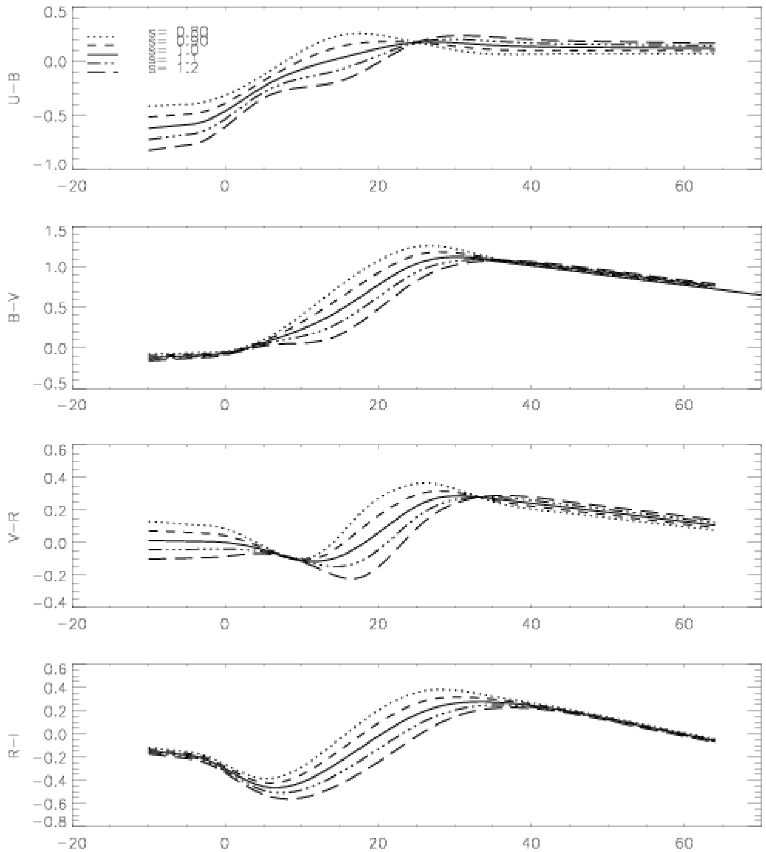
Extra material

Dust emissivity

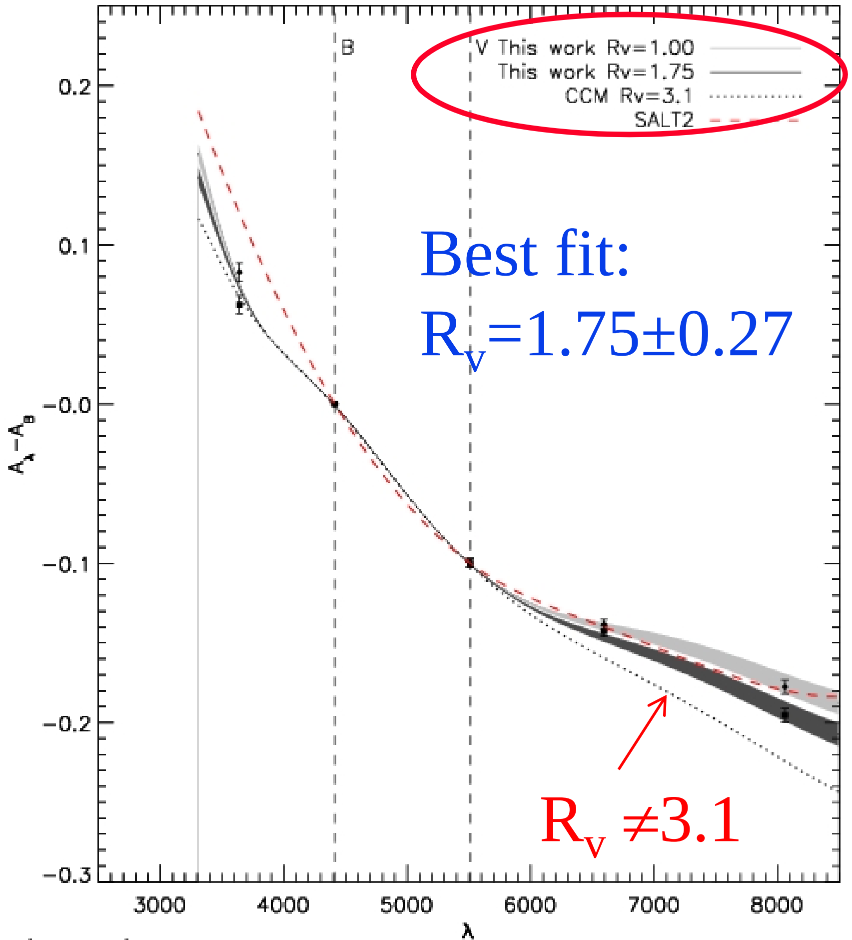



WD
MS
(a)
winds
mass stripping
(b)
torus
torus
(c)
hot WD winds
1000 km/s
expanding torus
line of sight
10-100 km/s
(d)

Global fit to minimize color dispersion in low-z SNIa data



Color-shape relation
Structure around day 20



& AG, 2008, A&A

Freedman et al.

TABLE 7
COSMOLOGICAL RESULTS

R_V	Band	Ω_m	w	rms
1.74	$W^{i'}_{BV}$	0.27 ± 0.02	-1.05 ± 0.13	0.13
	W^{B}_{BV}	0.27 ± 0.02	-1.08 ± 0.14	0.15
3.1	$W^{i'}_{BV}$	0.26 ± 0.02	-1.20 ± 0.13	0.20
	W^{B}_{BV}	0.25 ± 0.03	-1.24 ± 0.16	0.24

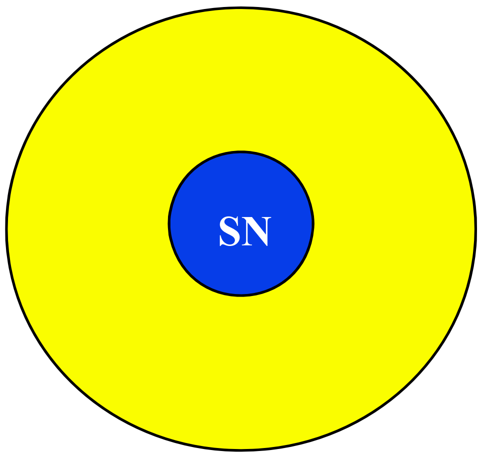
High-z: arXiv:0907.4524 (CSP)
Freedman et al, R_V=1.74±0.27

Multiple scattering in CS *dusty* medium

Observed colors after the semi-diffusive shell will depend on:

•Wavelength dependent cross-sections, albedo and scattering angles

•Dust density and shell volume



Run a Monte Carlo!

Use dust parameters for MW and LMC by:

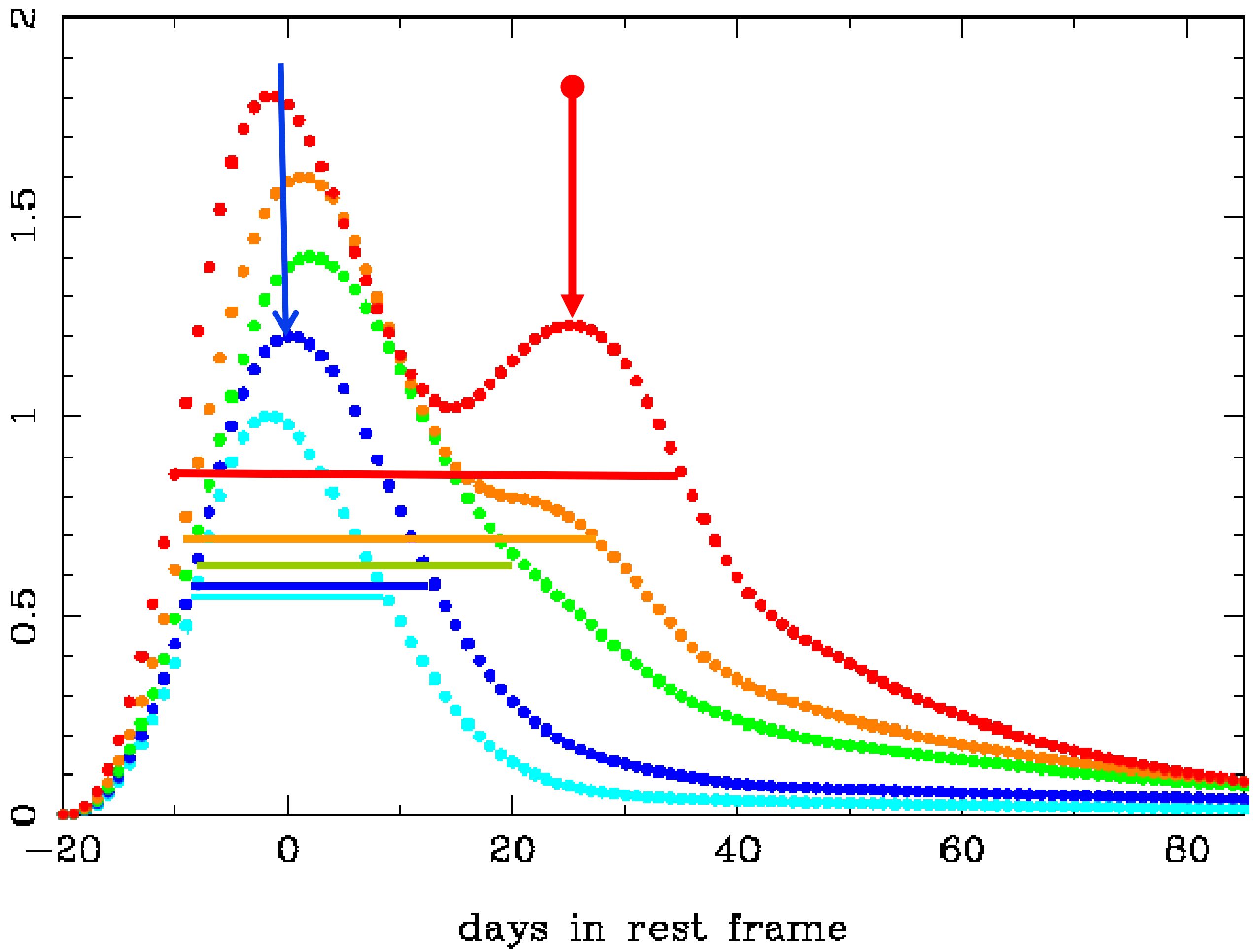
Draine ApJ 2003, Weingartner & Draine ApJ 2001

(also SMC dust , but mostly absorption (not scattering) at optical wavelengths)

AG, ApJ 2008

see also Wang 05

Lightcurve shape perturbations from CS-shell size?



$R_{cs}=10^{16}$ - $5\cdot10^{18}$ cm

- **Thin shell ($0.05\cdot R_{CS}$)**