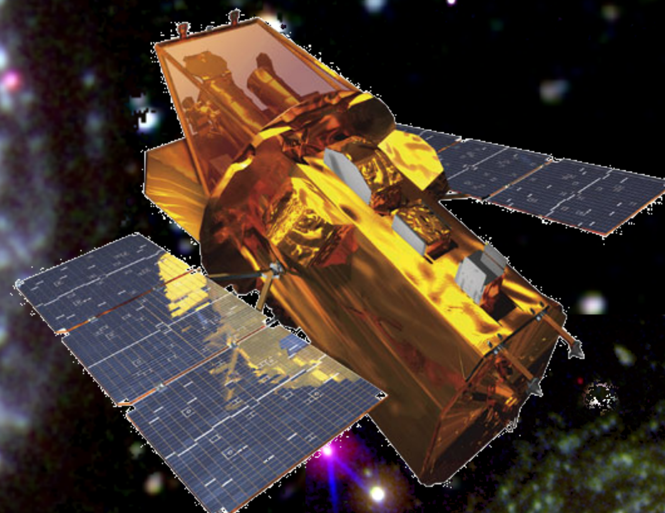
Ultraviolet Observations of Supernovae : The Peril and The Promise



Peter J. Brown

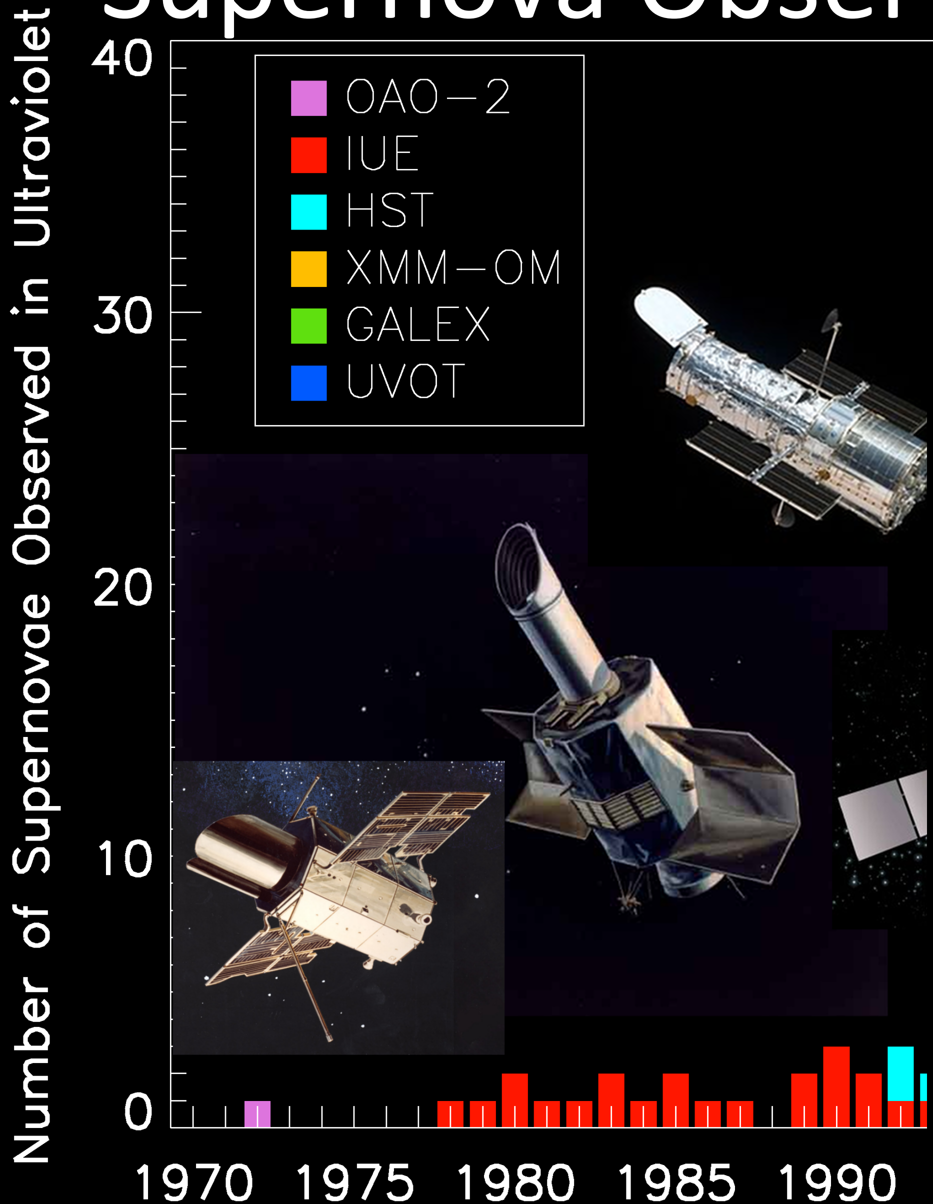
Mitchell Institute -- Texas A&M

Challenges in UV Astronomy, ESO Garching 7 Oktober 2013

Swift and CSP Observations of Type Ia Supernovae in the nearby Hubble Flow

Peter J. Brown
Mitchell Institute -- Texas A&M
Cooks Branch Workshop with CSP

Supernova Observed in the UV

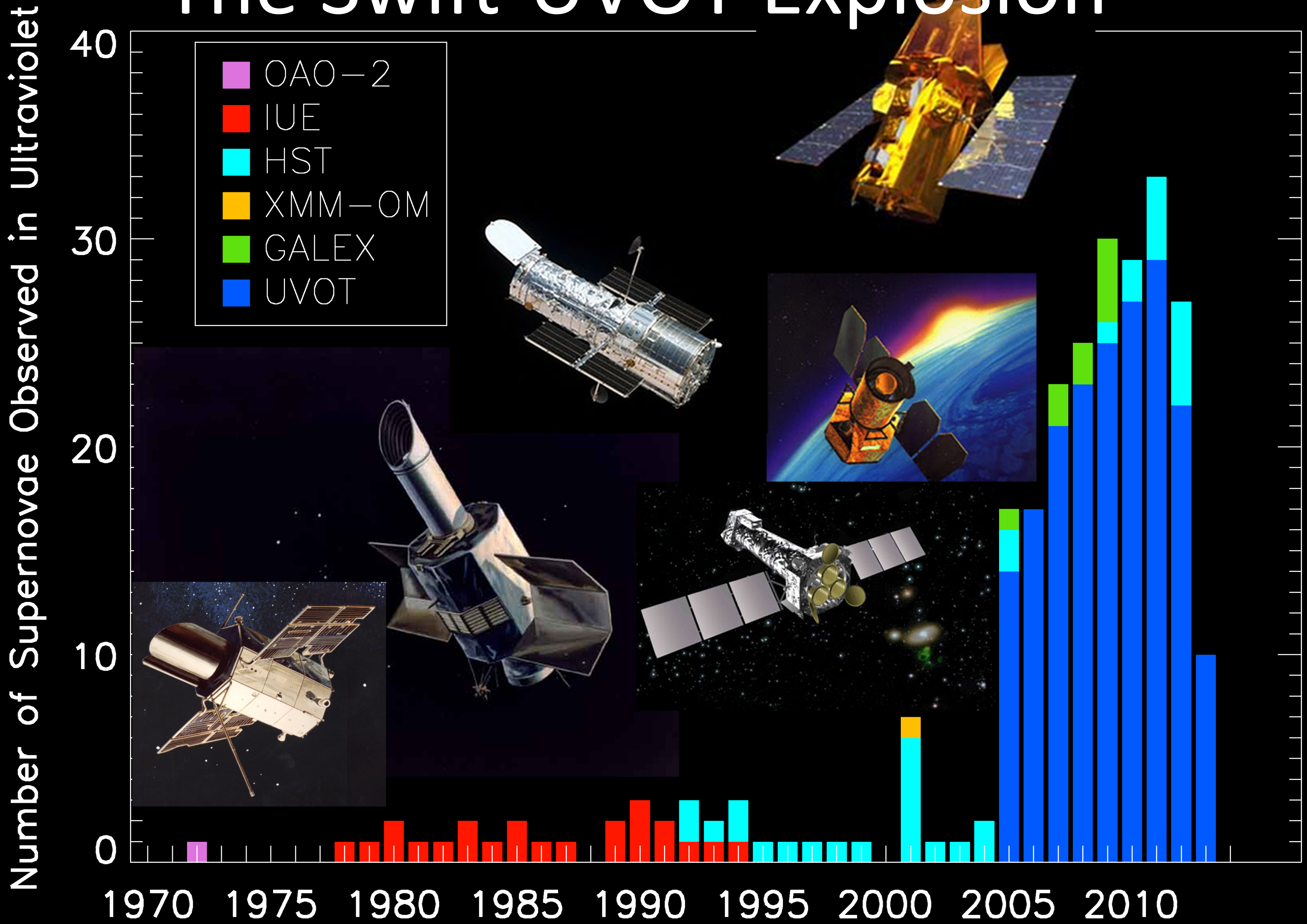


Sample size is historically small but with key contributions

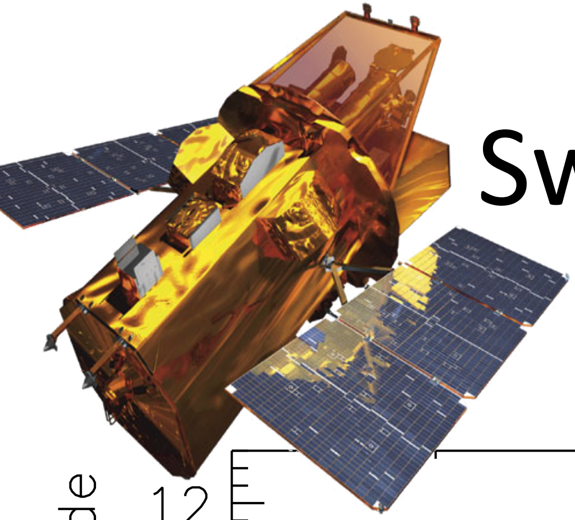
IUE – Time-series spectra revealing UV faint SNe Ia/b/c v. UV bright IIL

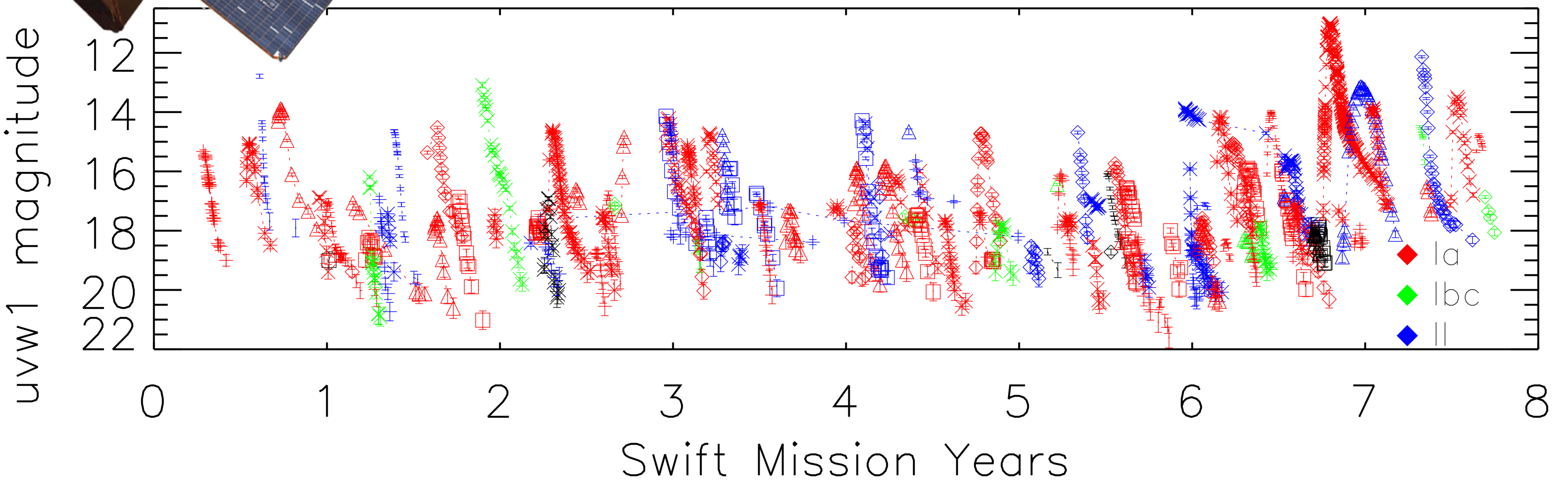
HST – high quality single epoch UV spectra of each type

The Swift-UVOT Explosion

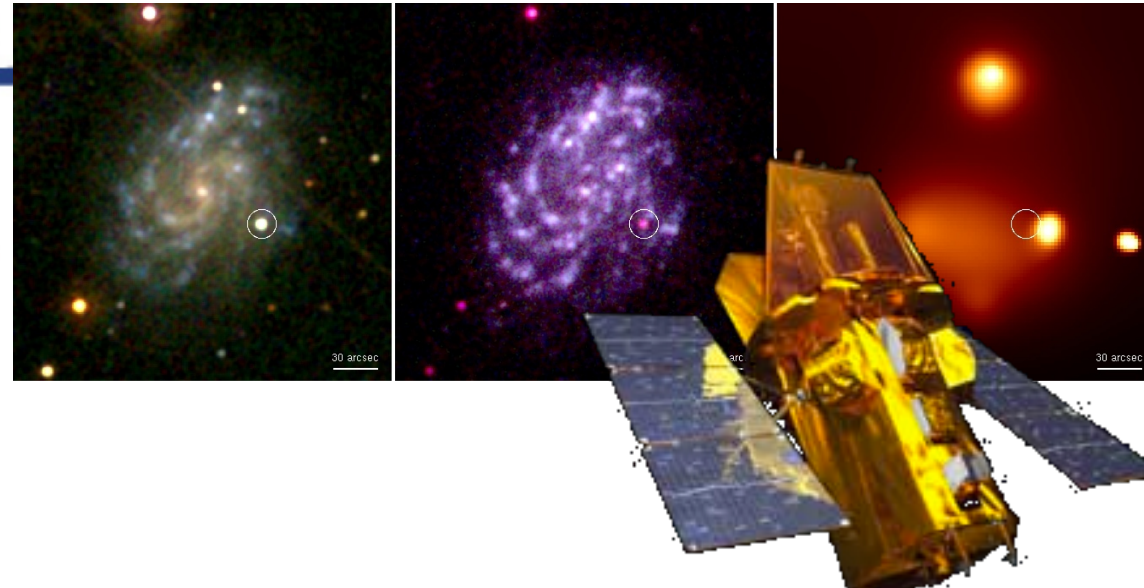


Swift UVOT Light Curves





Swift UV observations include many well sampled light curves of SNe of all major types and most subtypes



- Launched November 20, 2004
- Low earth orbit with ~90 min orbit
- Three co-aligned instruments
  - BAT – Burst Alert Tel. (15-150 keV)
  - XRT – X-Ray Telescope (0.2-10 keV)
  - UVOT - UltraViolet/Optical Telescope

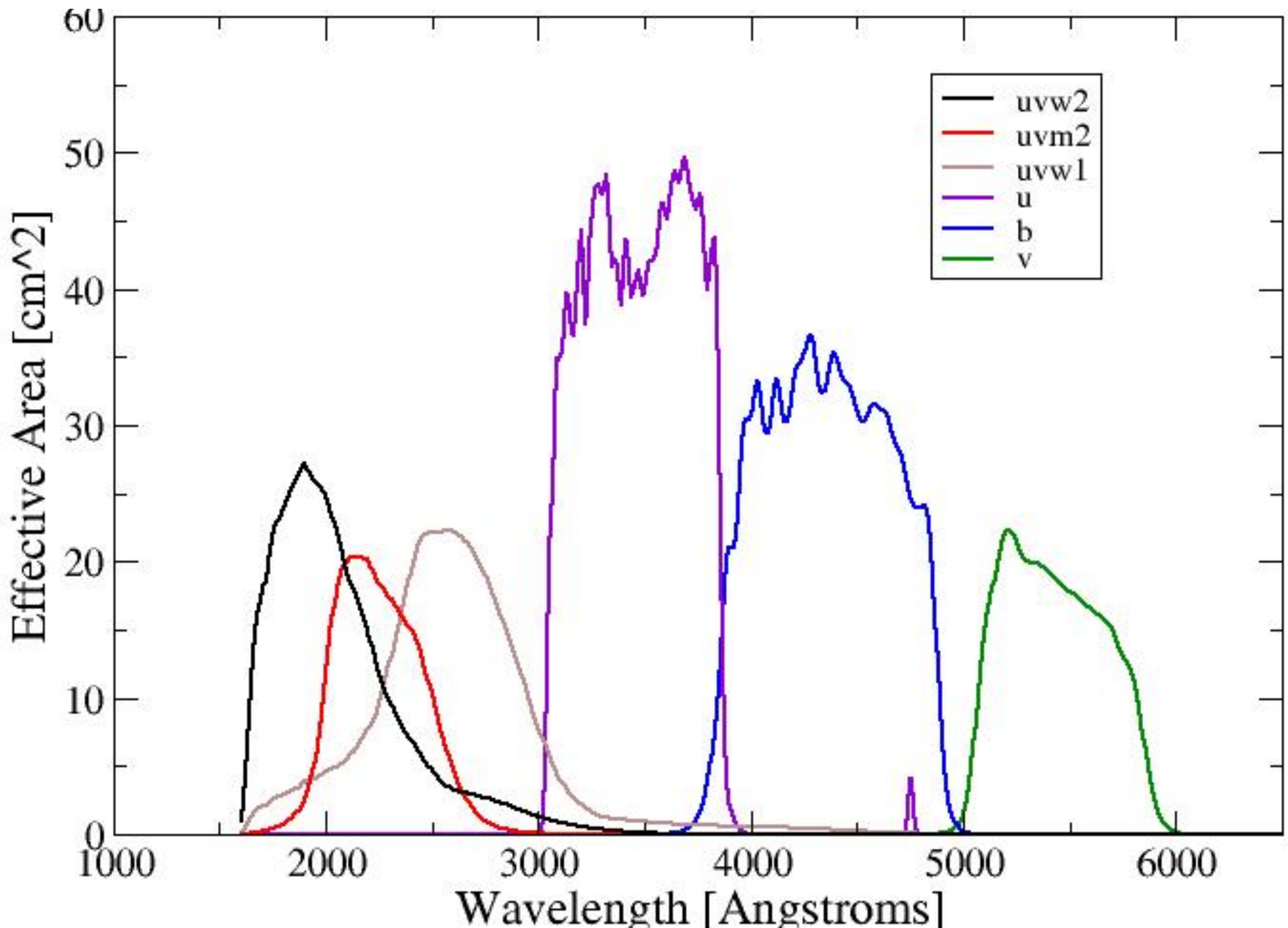
Gamma Ray Burst and Supernova Hunter

- Rapid response capability – Targets of Opportunity can be uploaded to the spacecraft for immediate observation
- Short term scheduling, required by the different behavior of burst afterglows, requires observations to be planned the day before rather than weeks in advance
- SN observations can be analyzed in near real time (hours delay from observation to analysis) to assist in planning the future observations
- Unique UV and X-ray observations unobtainable from the ground

Swift UVOT

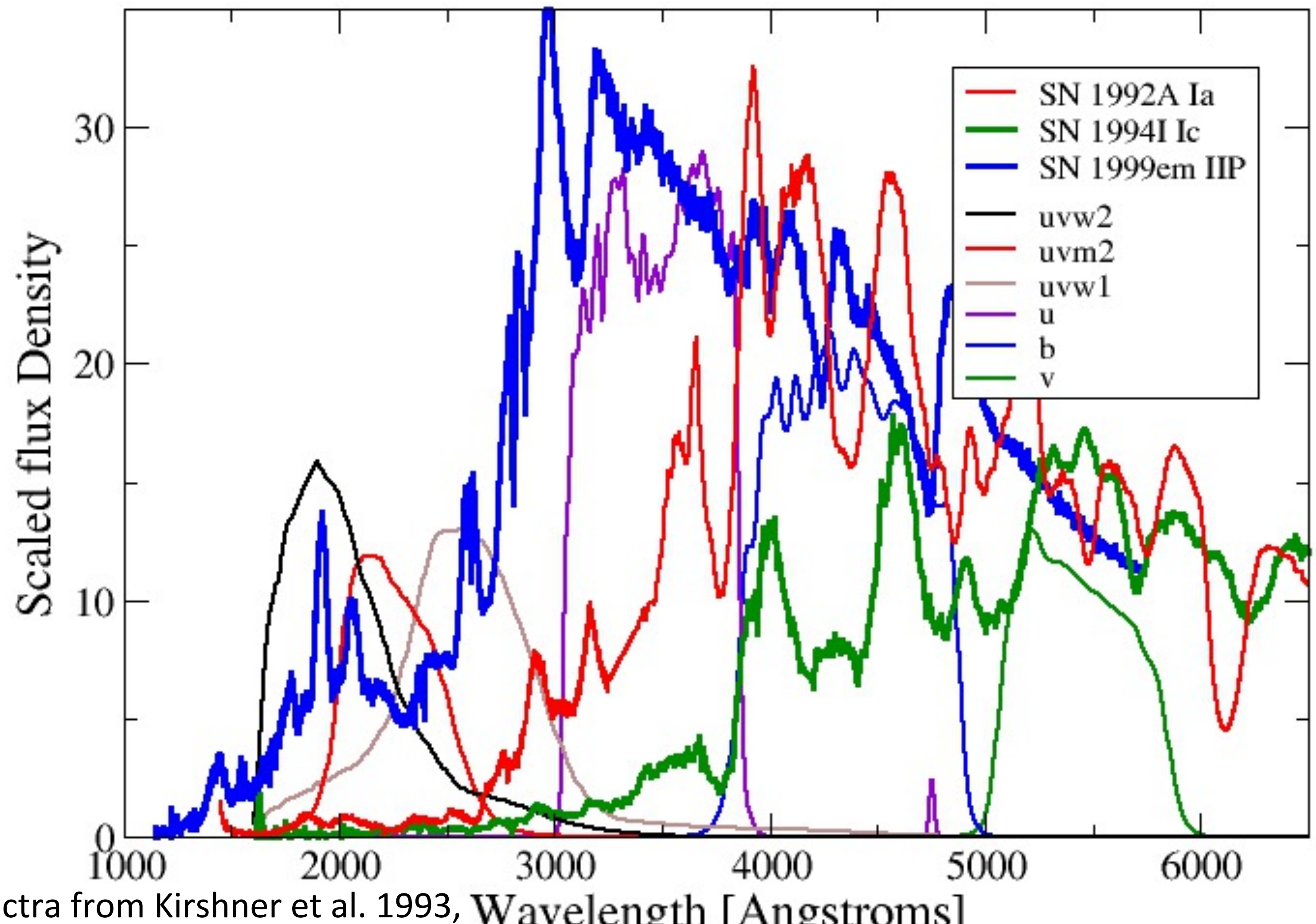
- 30 cm modified Ritchey-Chretien Telescope
- Wavelength Range 1600-6000 Angstroms
- Photon Counting detector centroiding into 0.5 arcsec virtual pixels
- 2 arcsec point spread function
- 17x17 arcminute field of view

Swift UVOT Filter Curves



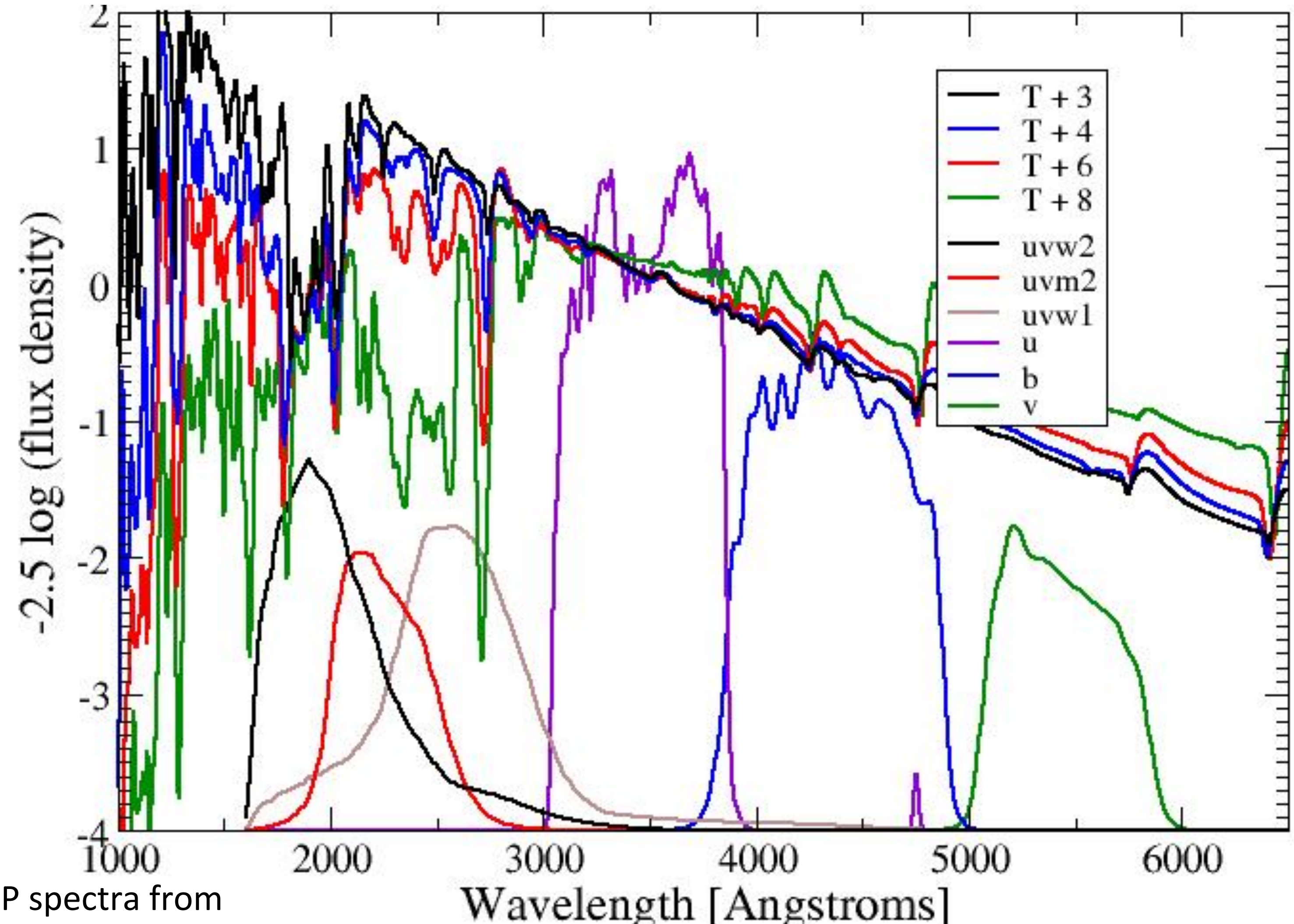
Filter Curves from Poole et al. 2008

SN types are different in the UV



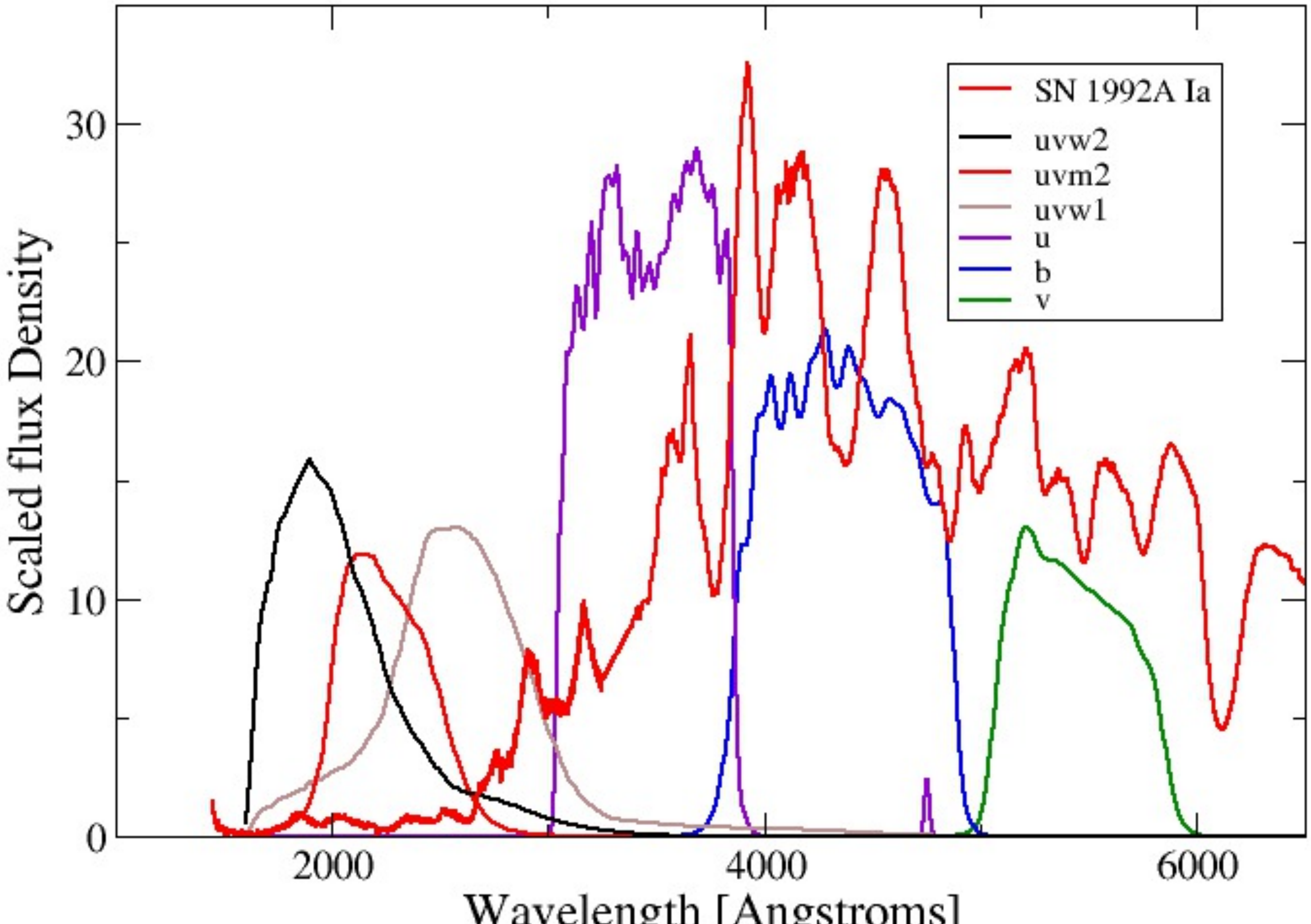
HST Spectra from Kirshner et al. 1993, Millard et al. 1999, Baron et al. 2000

SNe IIP evolve rapidly in the UV



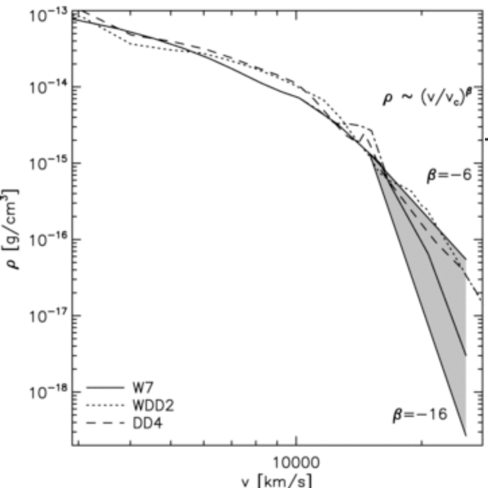
Model IIP spectra from
Dessart et al. 2008

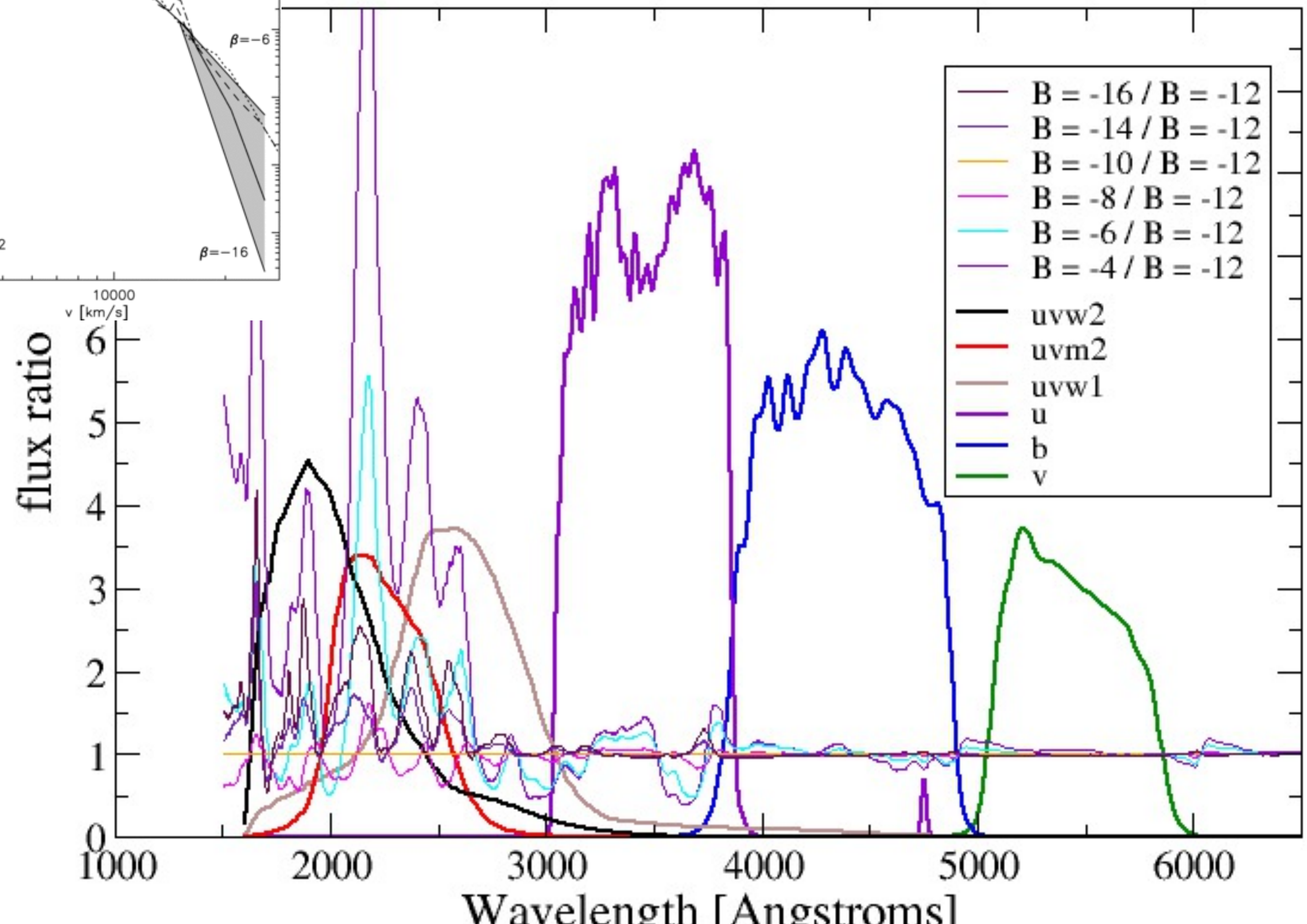
SNe Ia are faint in the UV due to metal line blanketing



HST spectrum from Kirshner et al. 1993

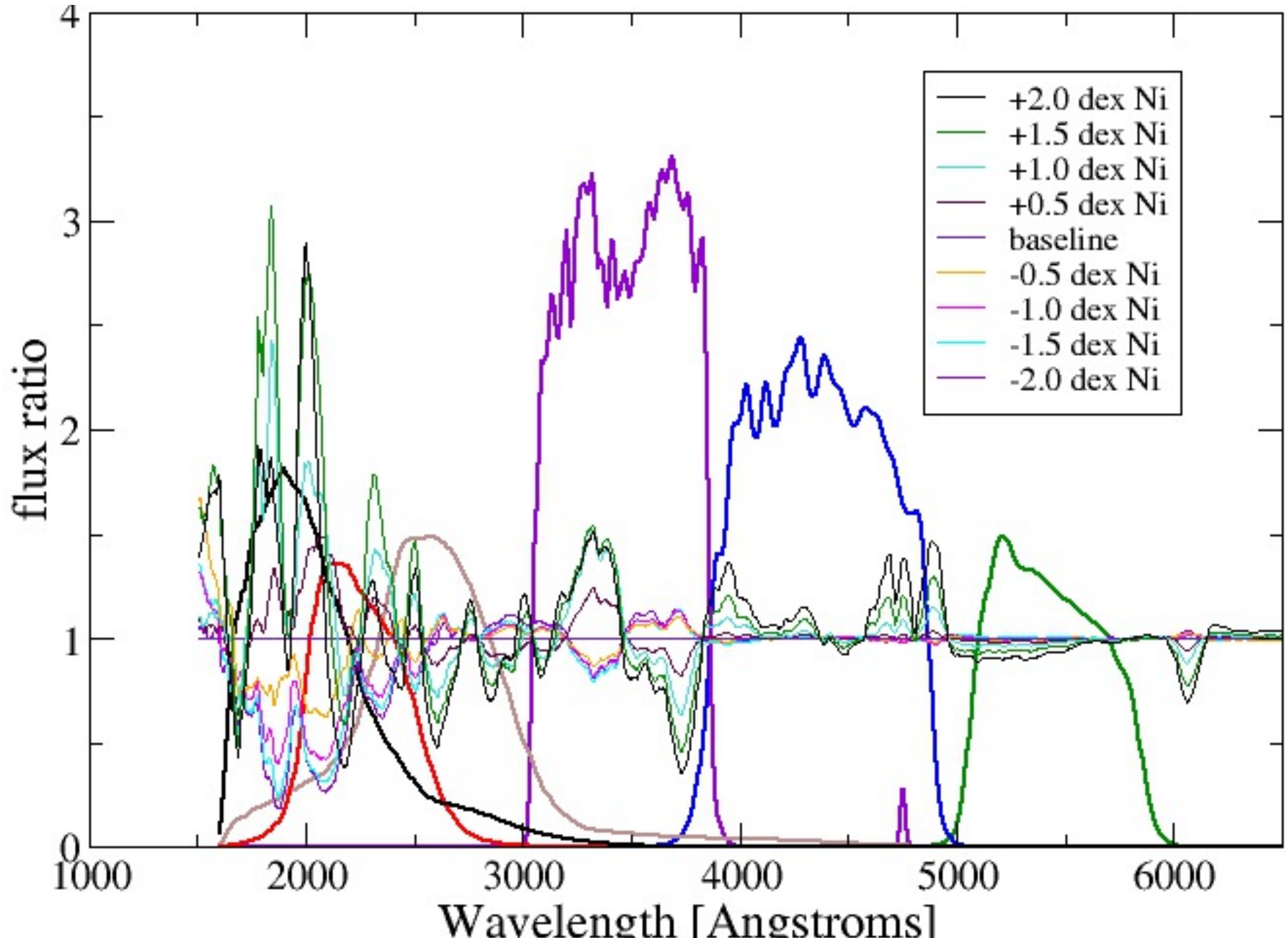
UV is sensitive to the outer density gradient





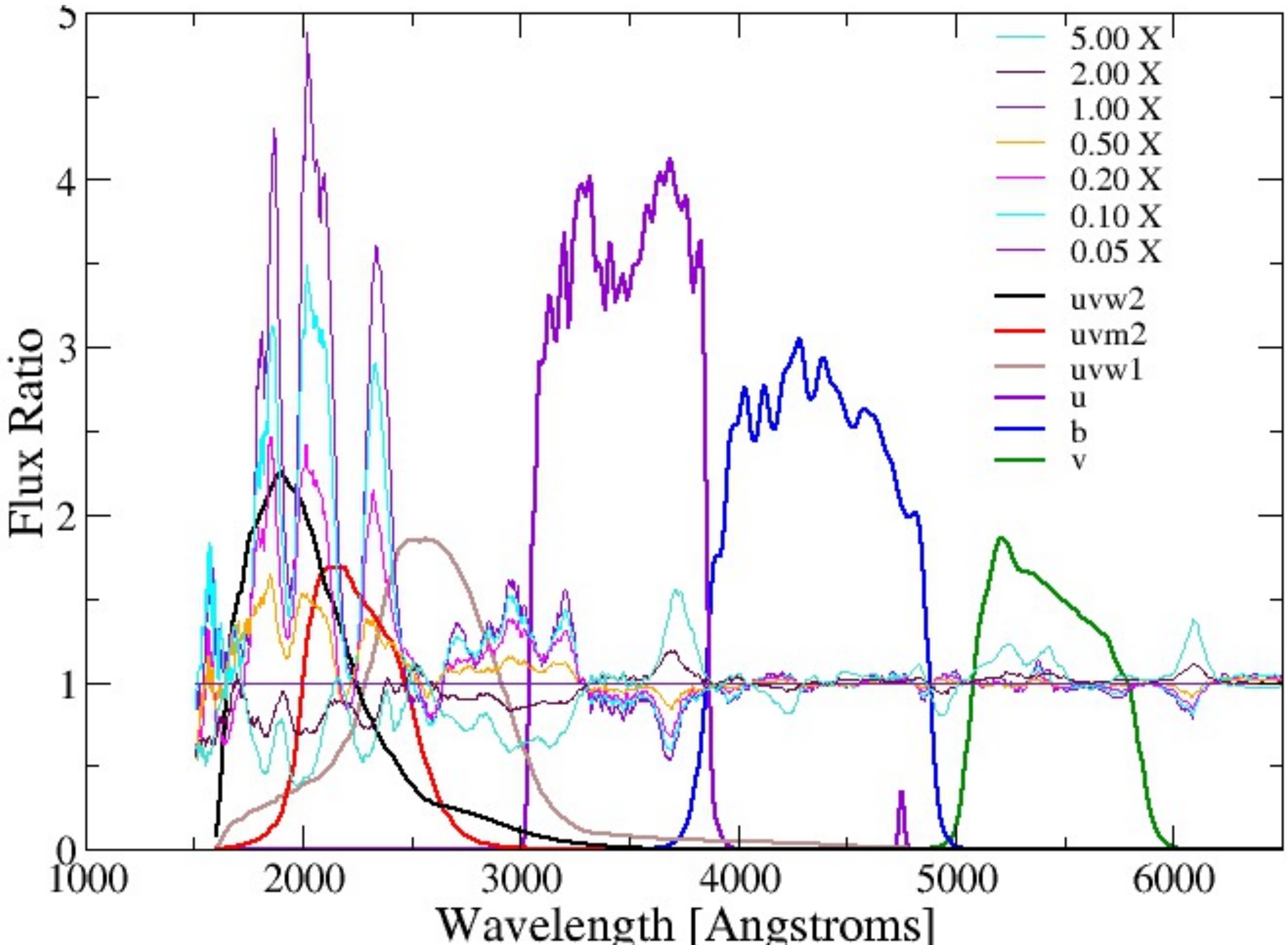
Density models from Sauer et al. 2008

UV is sensitive to Nickel abundance



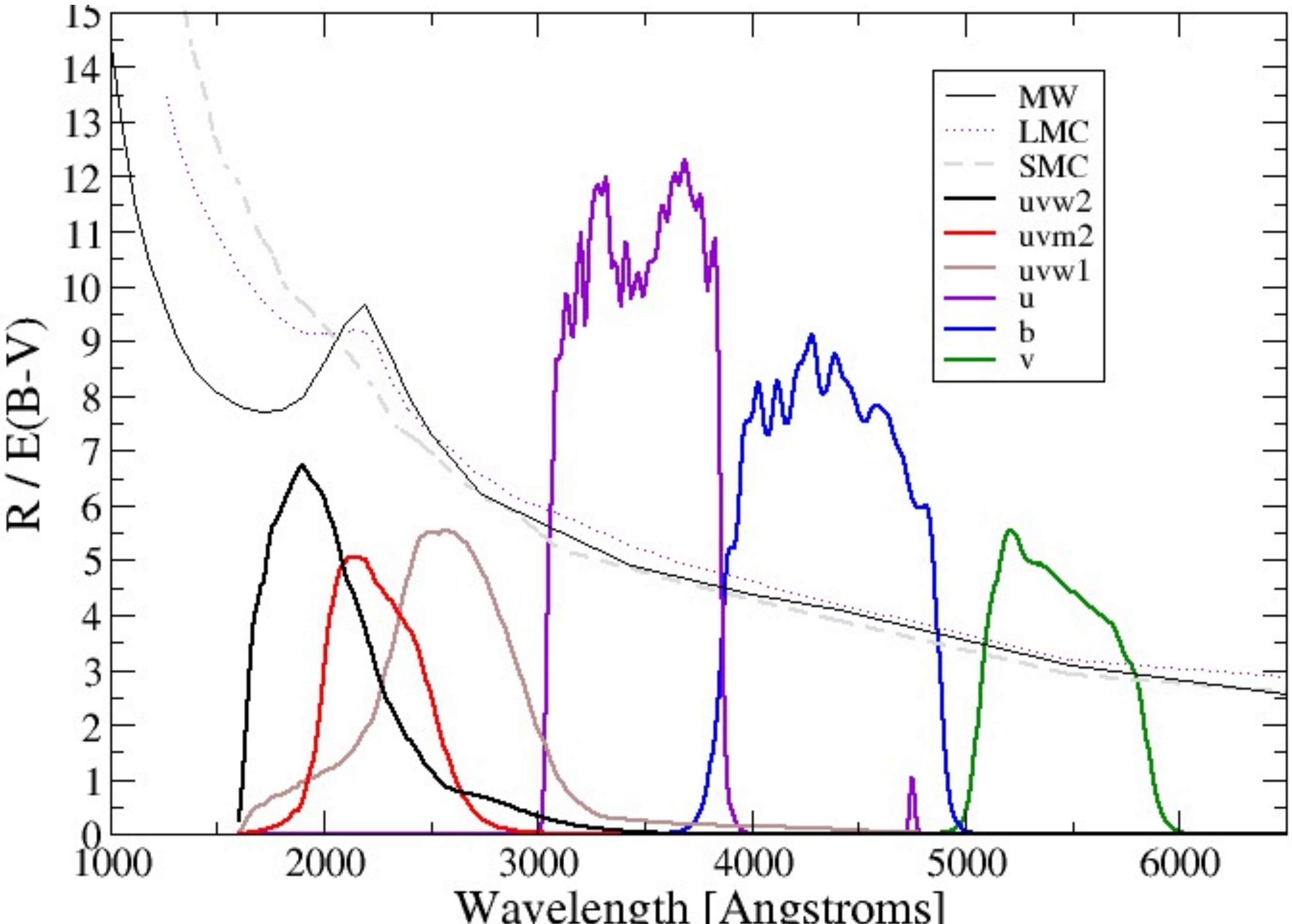
Models from Sauer et al. 2008

UV is sensitive to Metal abundance



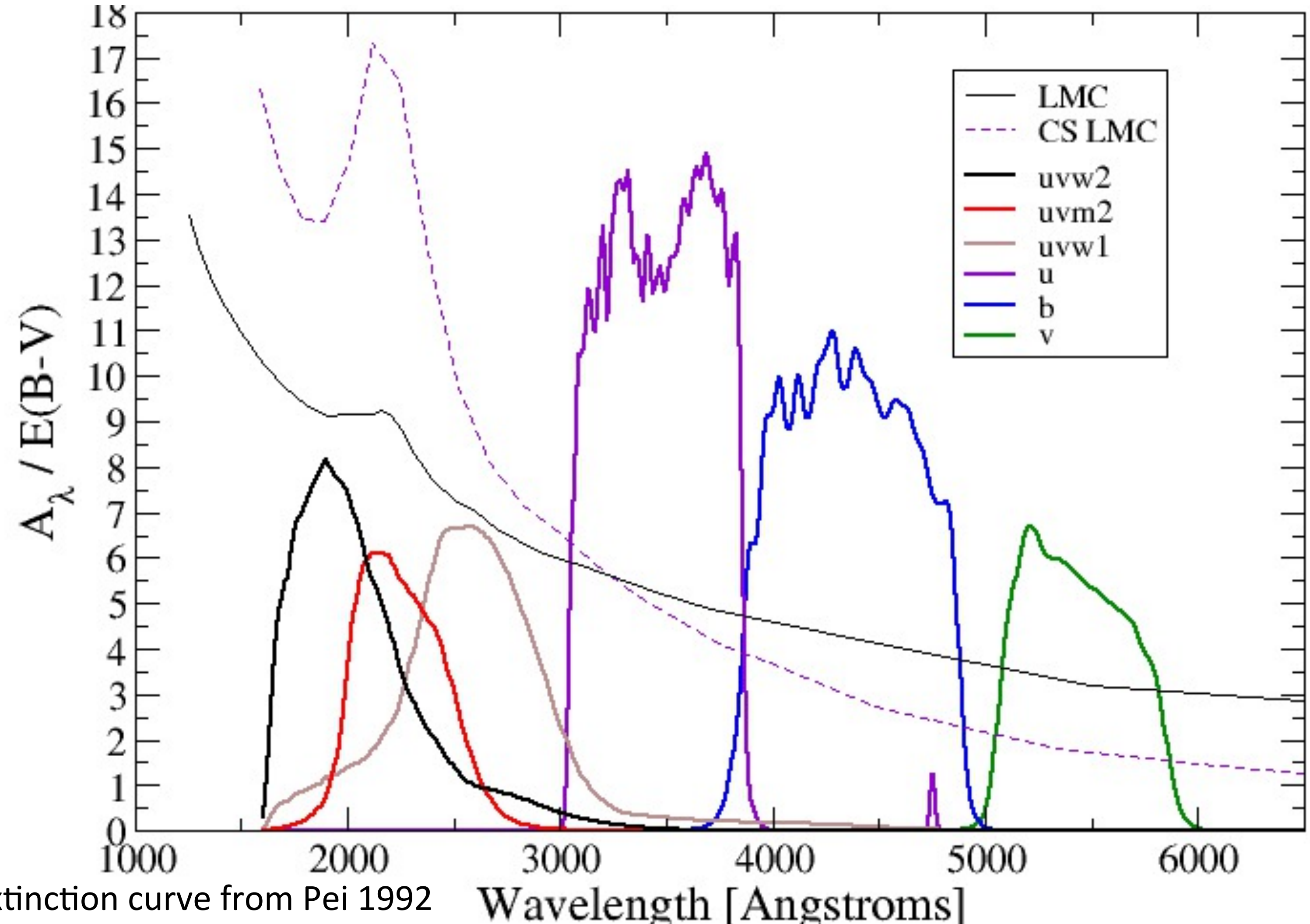
Models from Walker et al. 2012

UV is sensitive to differing extinction



Extinction curves from Pei 1992

UV is extra sensitive to circumstellar (CS) dust scattering



LMC extinction curve from Pei 1992
And CS LMC from Brown et al. 2010 based on Goobar 2008

UV Observations of SNe Ia: The Peril and the Promise

- SNe NOT promising standard candles in the UV
  - Low flux due to line blanketing from metal lines
  - Possible evolution of metallicity with redshift
  - Large, possibly uncertain, extinction
  - Uncertain extinction law
  - Velocities, asymmetry, density differences, etc, may all affect the UV much more than the optical

UV Observations of SNe Ia: The Peril and the Promise

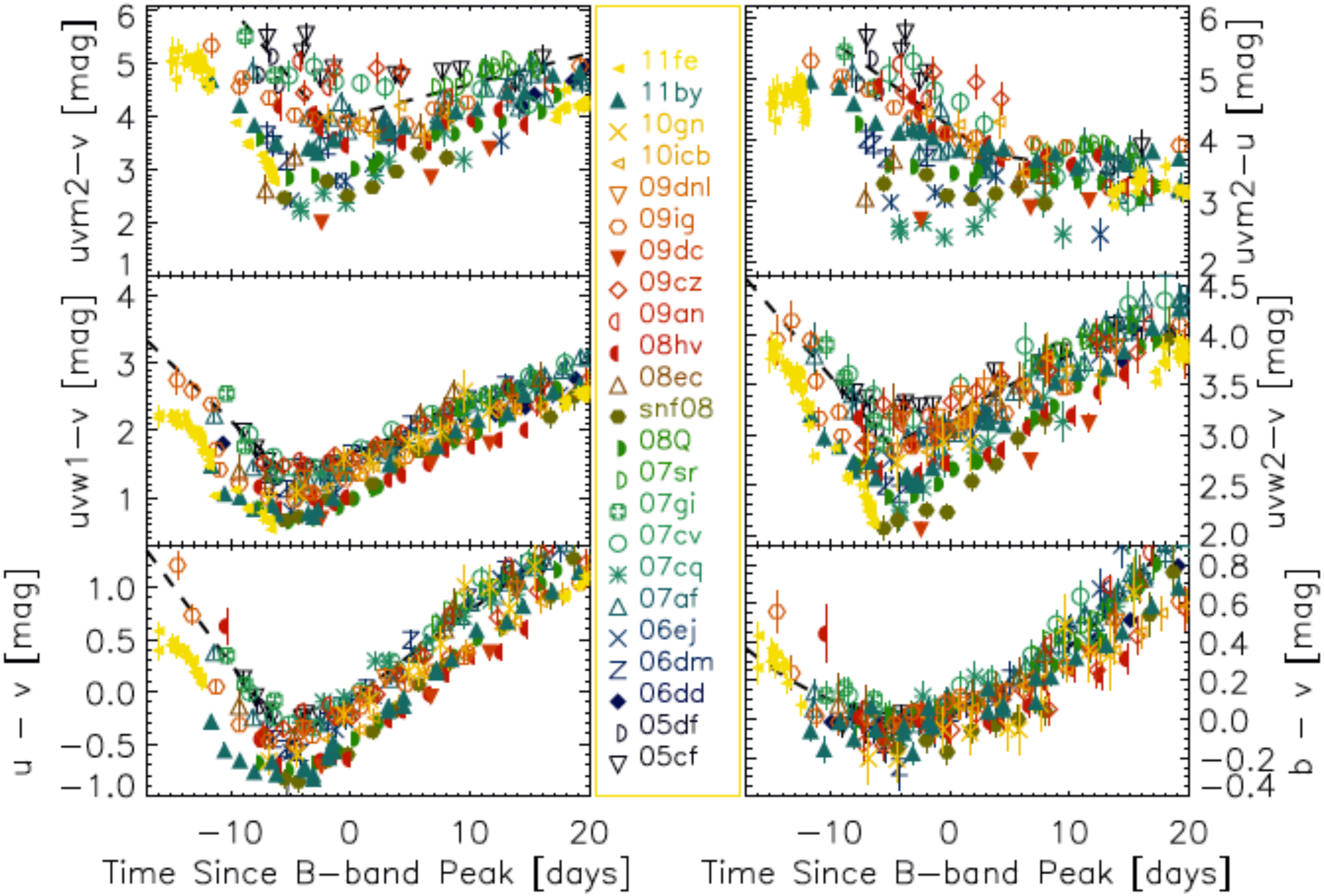
- But UV observations might have a lot to teach us about SNe Ia and how to improve their usefulness
  - Sensitive to metallicity differences which may effect the optical by a small but significant amount
  - Test for evolution of metallicity with redshift
  - Measure extinction more accurately
  - Determine shape of extinction law
  - Differences from velocities, asymmetry, density differences, etc, may be determinable from UV photometry rather than requiring spectra

UV Observations of SNe Ia: The Peril and the Promise

- Realist response – its gonna be hard
  - How do we look for differences by comparing the intrinsic colors if first we have to correct for an unknown amount of extinction with an unknown wavelength dependence which may require us to know the intrinsic colors due to metallicity, velocity, asymmetry, density, etc

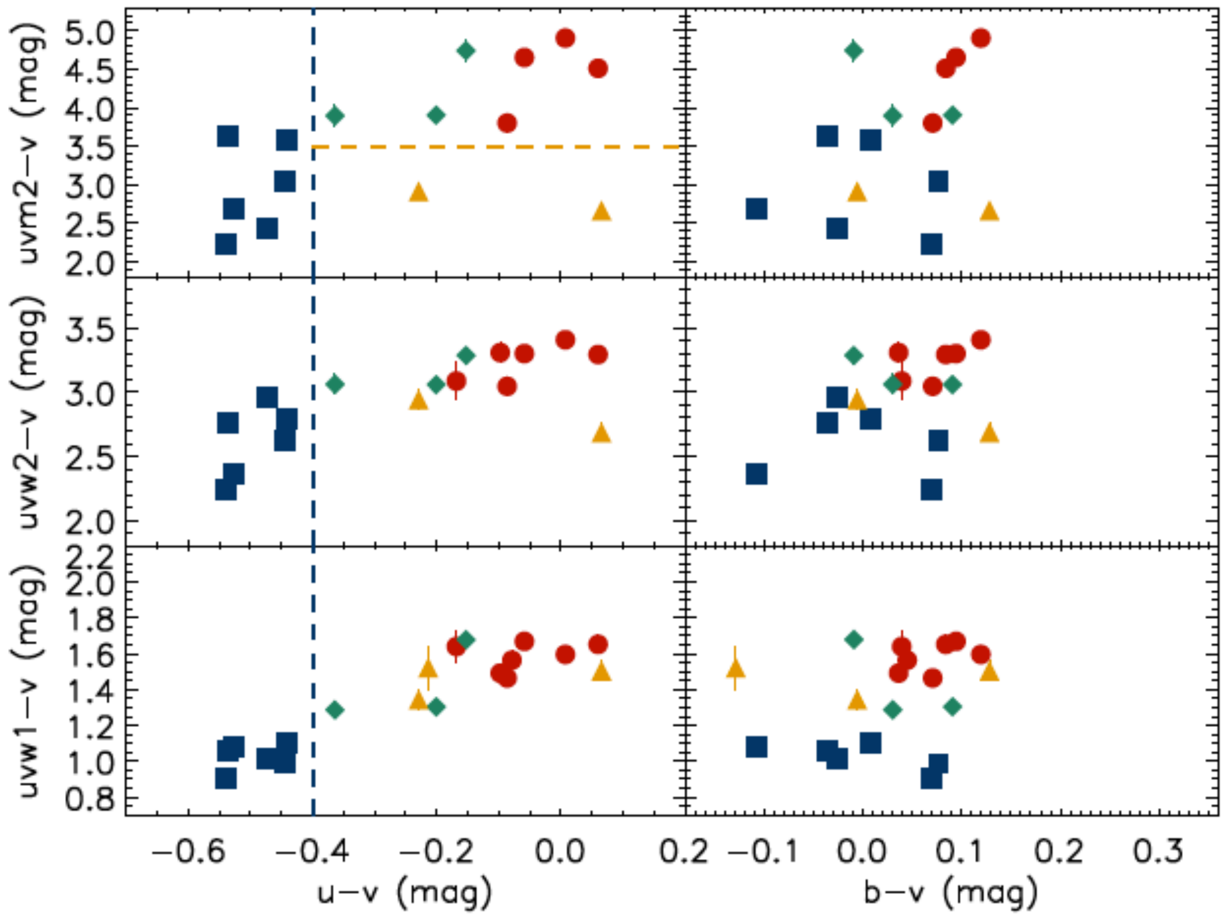
So what do we see?

Color curves of `normal' SNe Ia



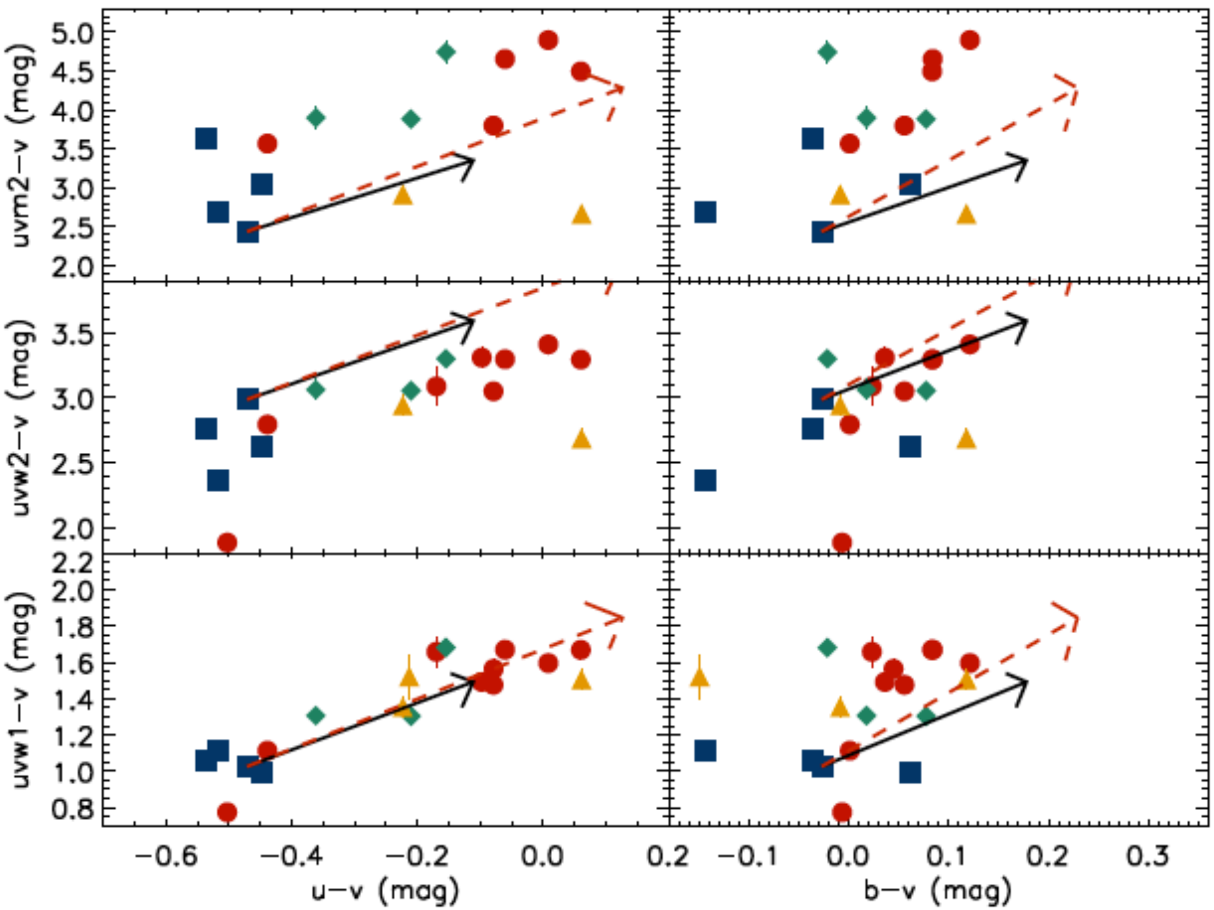
Milne et al. 2013 arXiv1308.2703M

Separation of peak colors



Milne et al. 2013 arXiv1308.2703M

Color separation not consistent with reddening vectors



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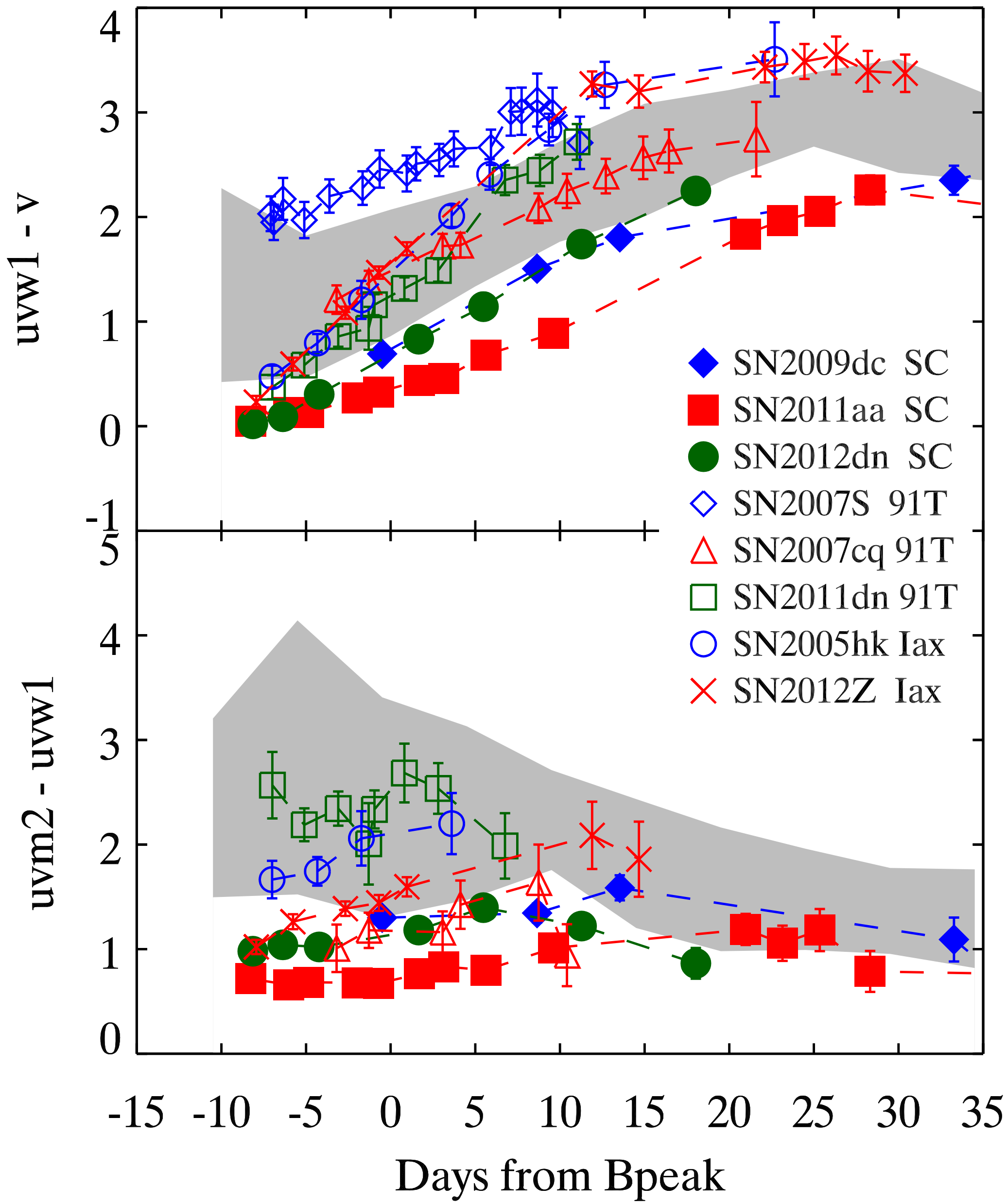
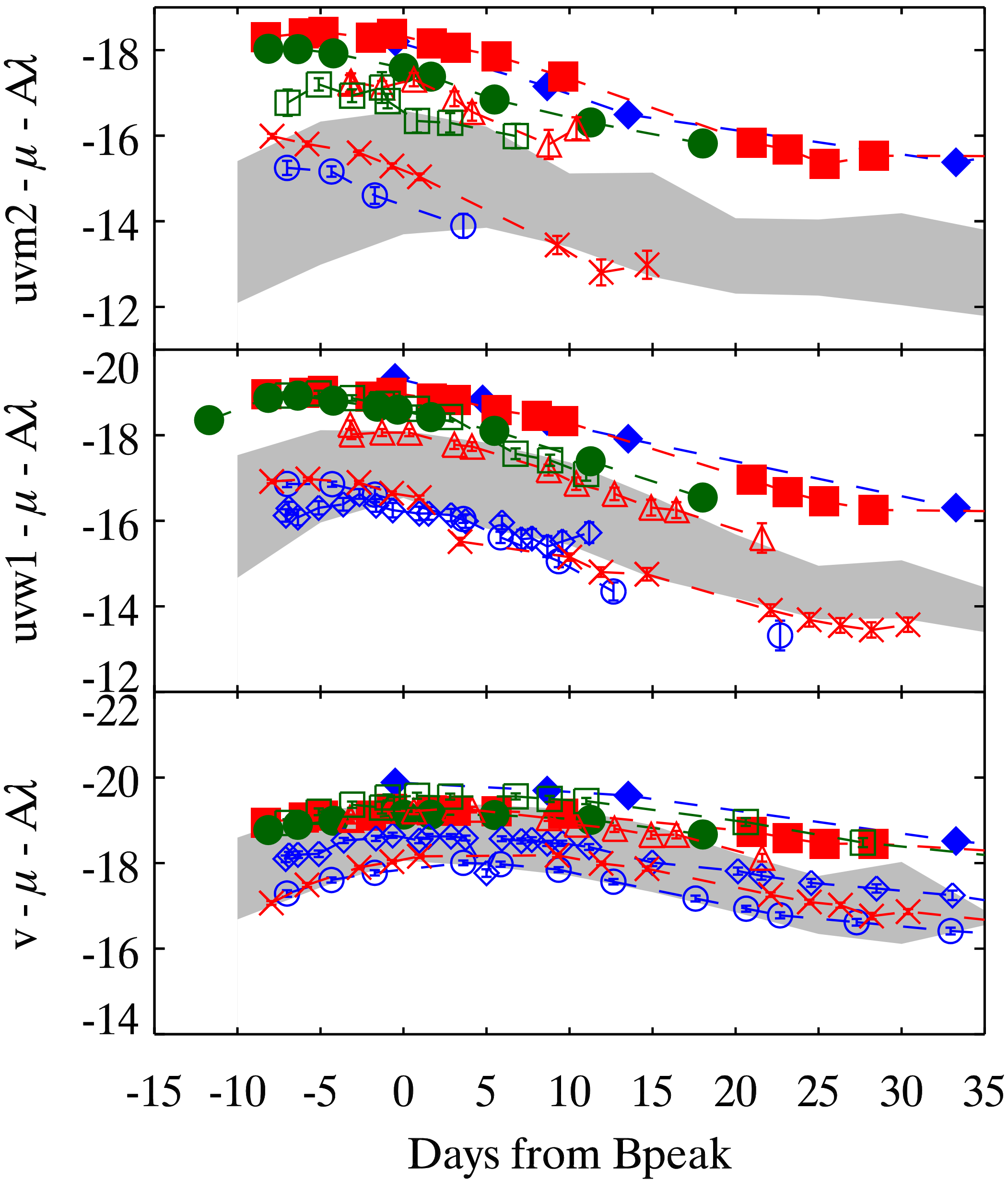


Super-Chandrasekhar Mass Candidates and SNe Iax have very blue UV colors, especially at early times

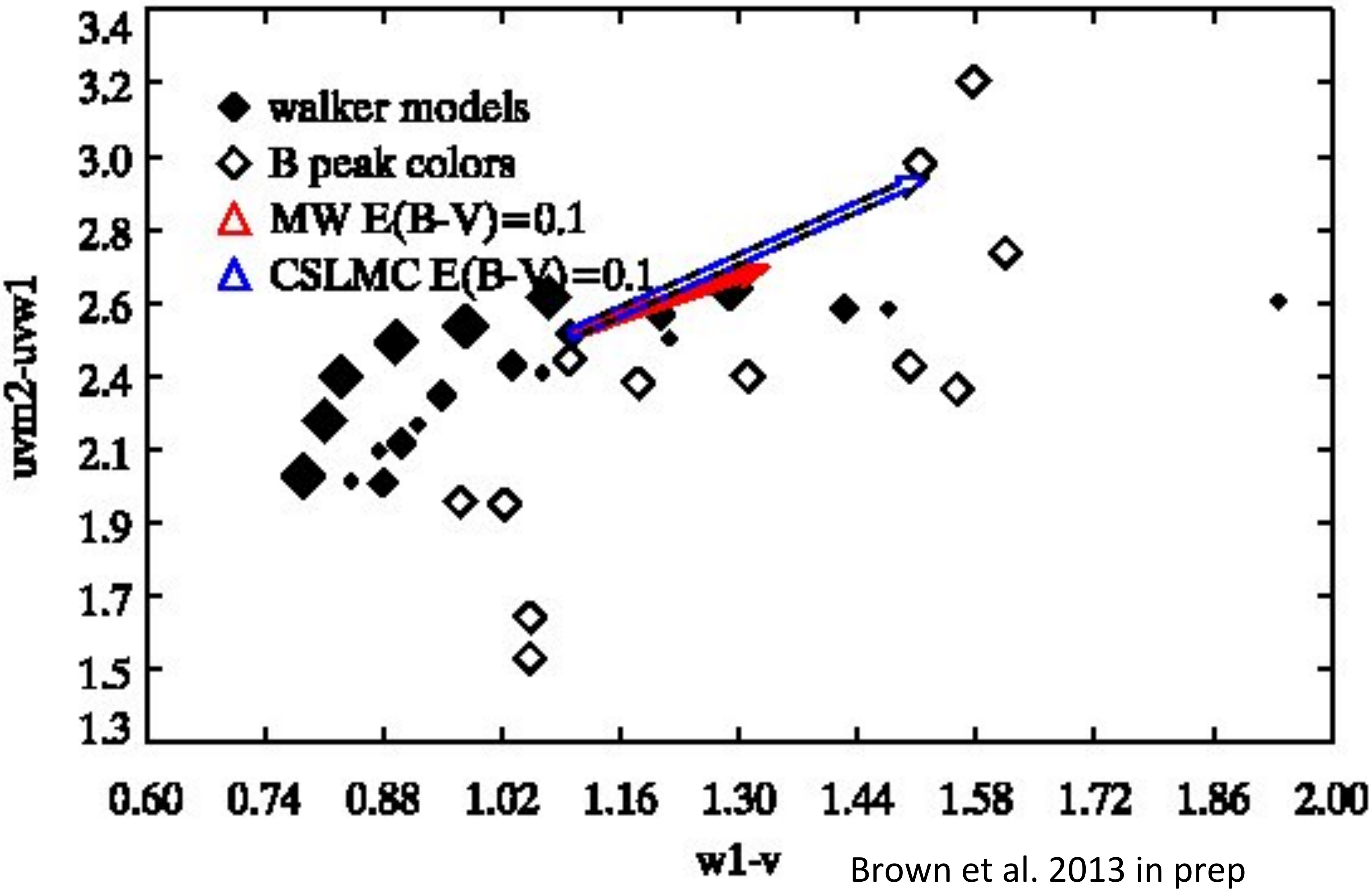
Brown et al. 2013 in prep



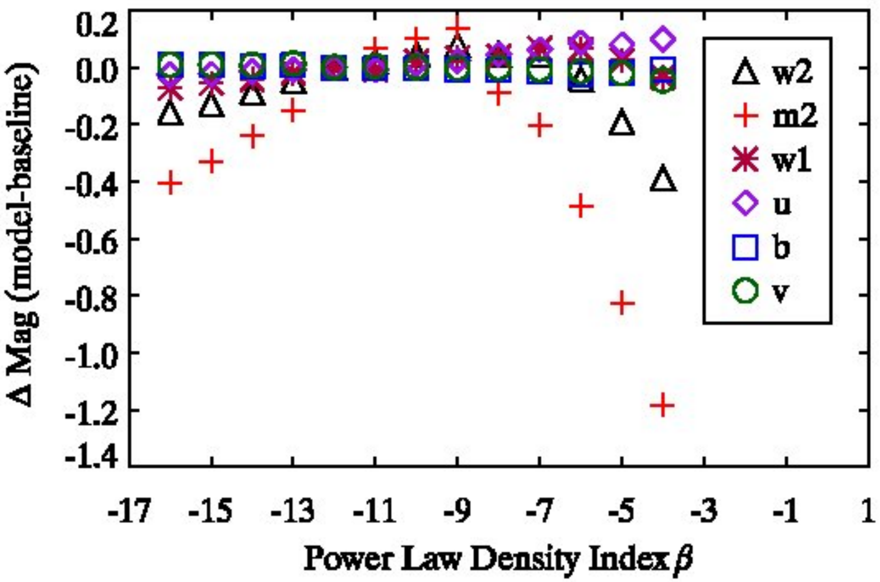
Our Super-Chandrasekhar Mass Candidates aren't exceptionally bright in the optical, but really bright in the UV

Brown et al. 2013 in prep

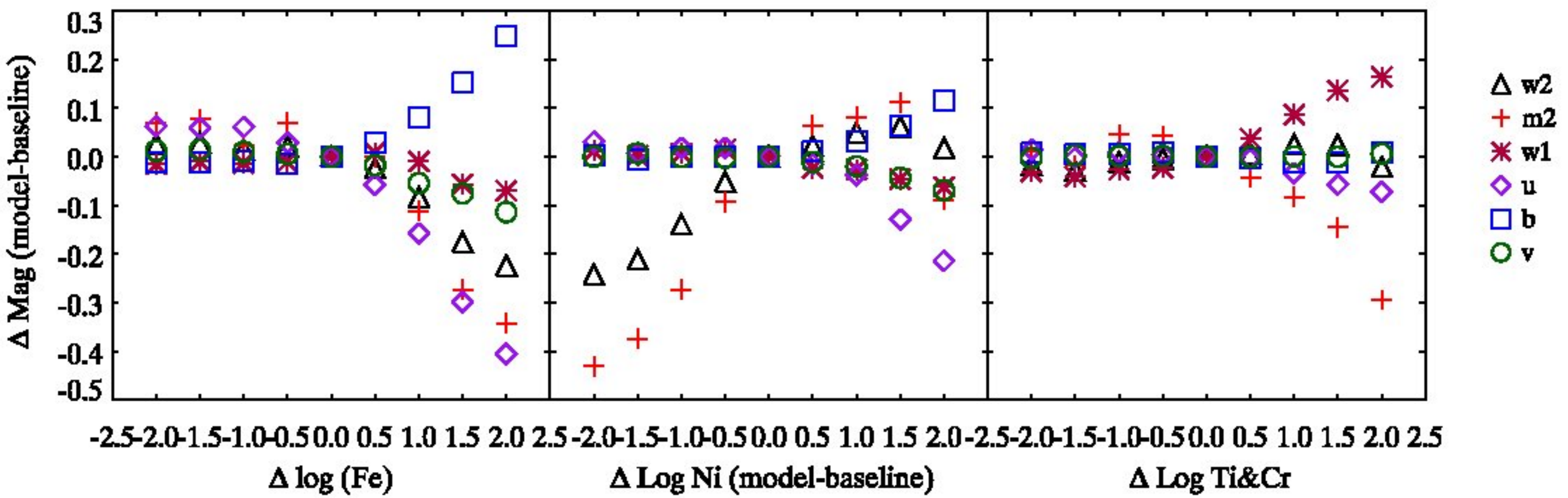
Observed colors inconsistent with metallicity as the only source of variation



Brown et al. 2013 in prep

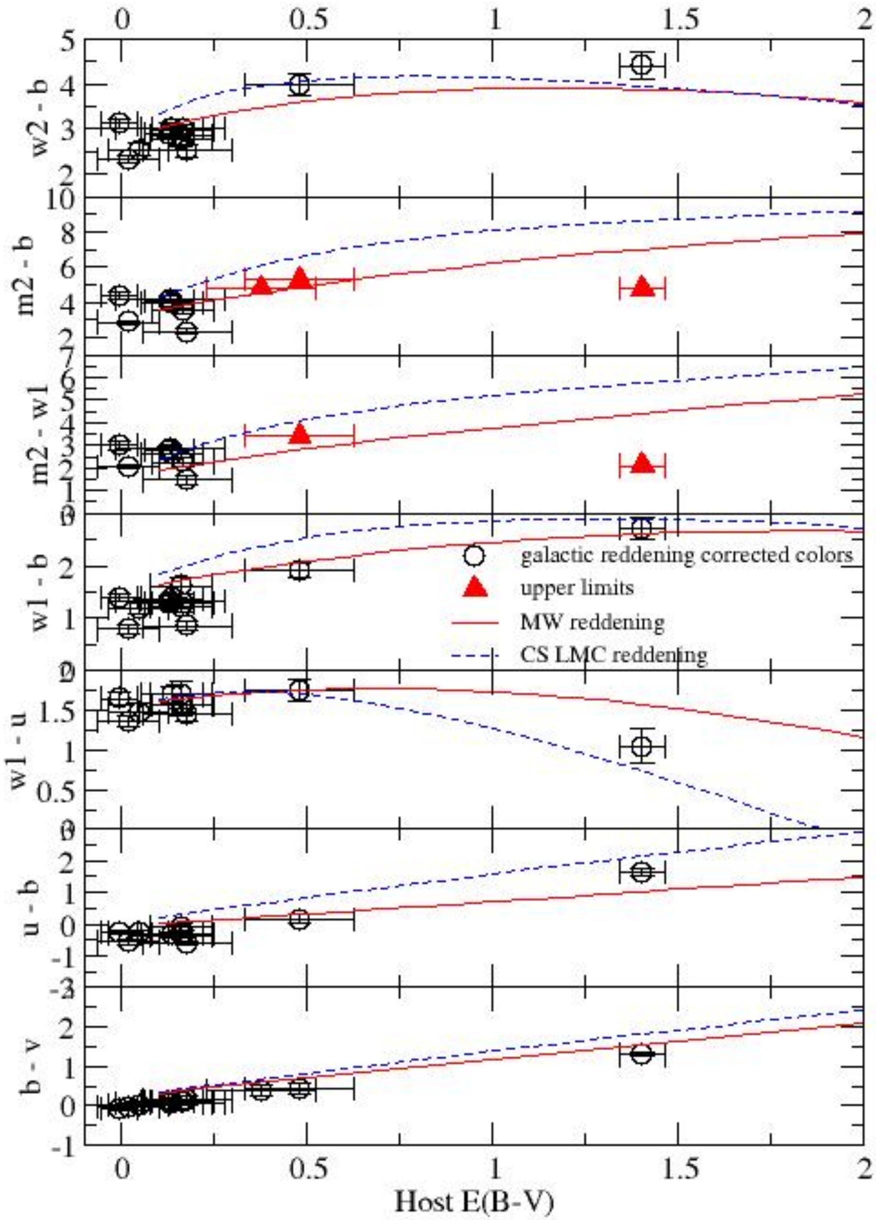


Density also has a huge effect on the mid-UV and other metals can produce unique differences (Sauer et al. 2008)



Brown et al. 2013 in prep

UV Colors sensitive to reddening



uvm2 most sensitive to differences in extinction curves due to the optical tails of uvw2 and uvw1

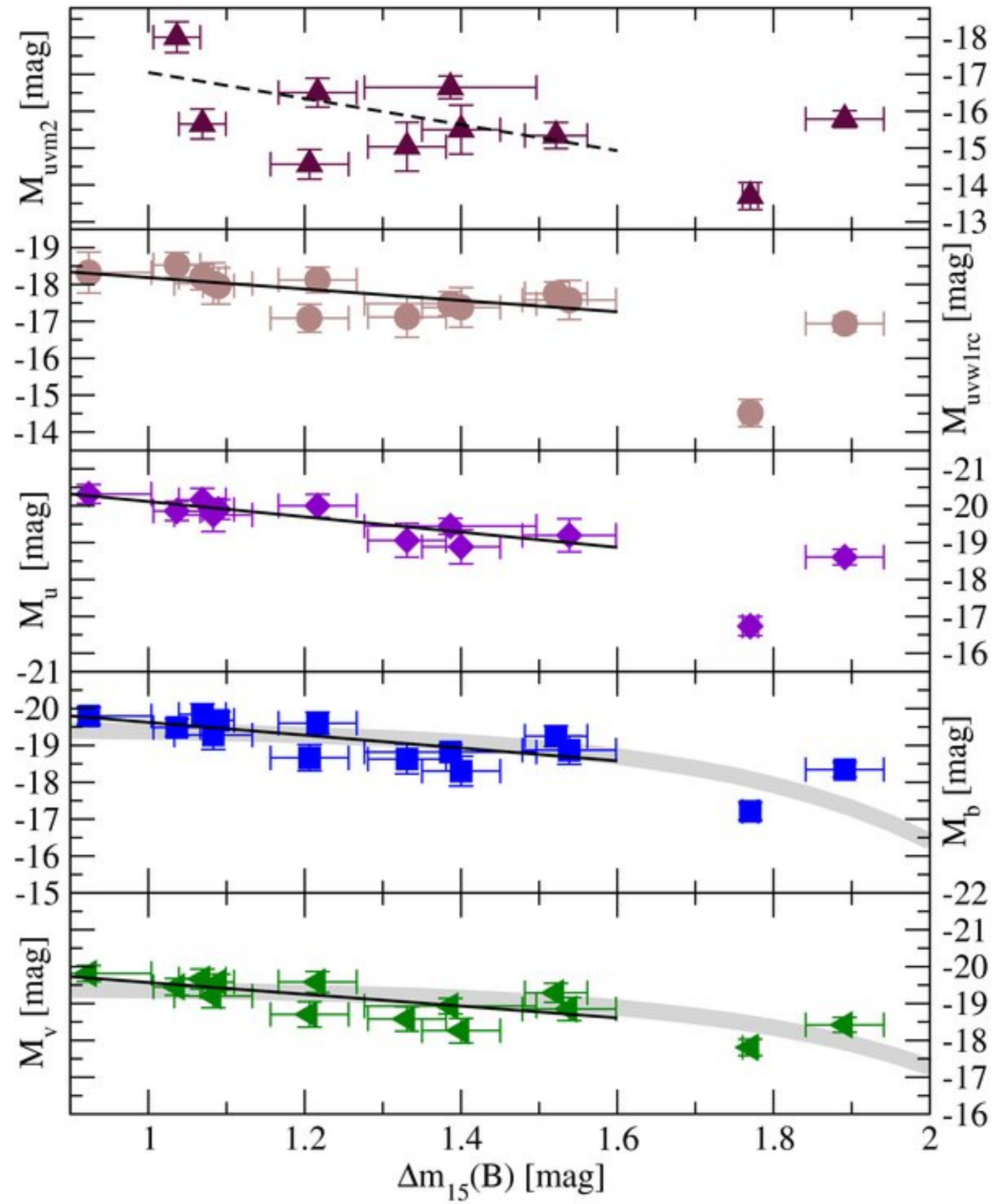
But large scatter in intrinsic, low-reddening m2-optical colors makes the zeropoint uncertain

Few uvm2 detections for reddened SNe (red triangles indicate limits on the colors)

UV Absolute Magnitudes

Optical and near-UV filters are consistent with no scatter, i.e. observational errors are larger than intrinsic scatter

Mid-UV shows much larger scatter, but tying it to optical scatter (ie Hubble residuals) difficult due to the large scatter/errors



Brown et al. 2010

Error Sources and reduction

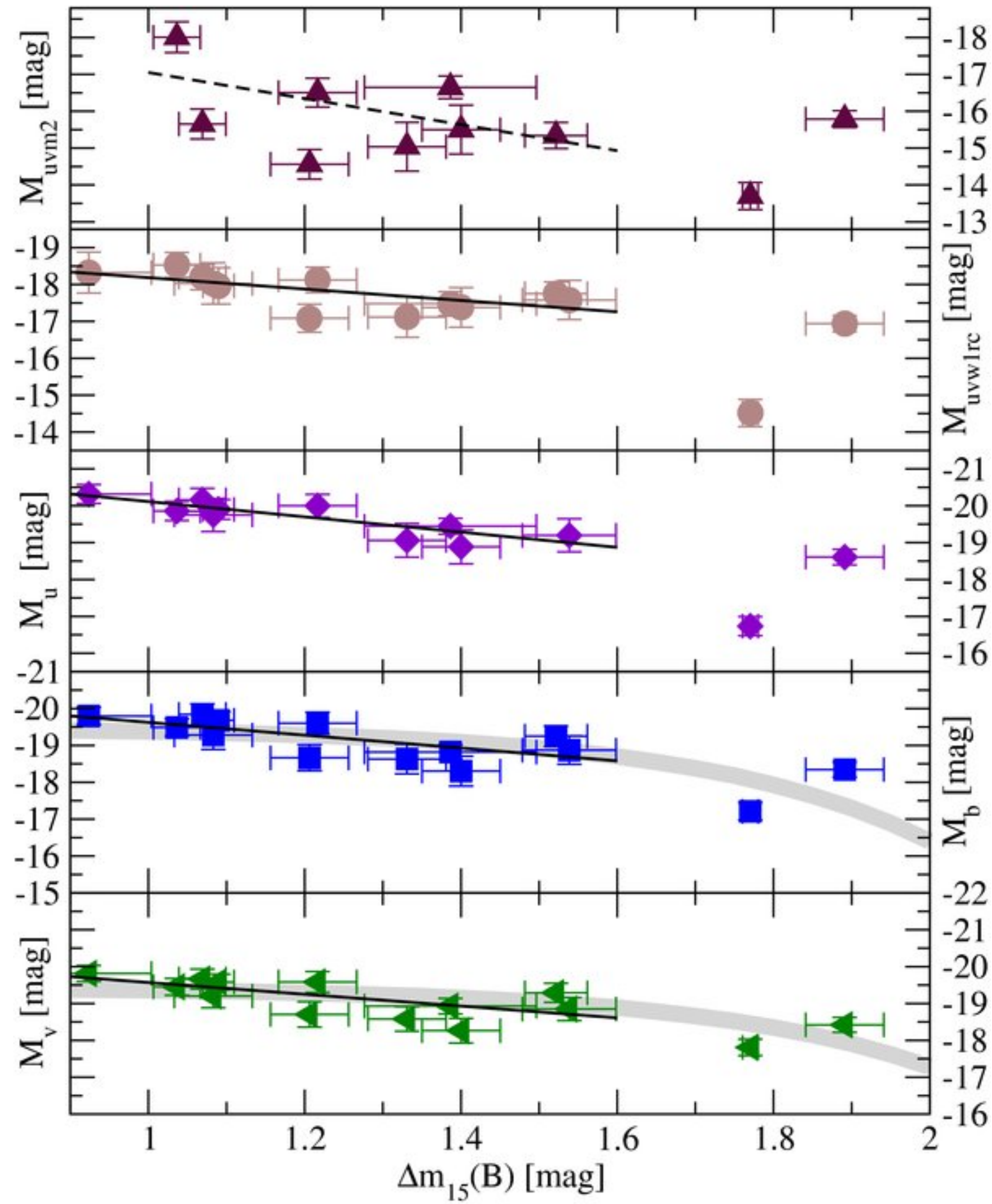
Photometry – new modes weight the time more heavily to the UV

K corrections – probably need larger sample of UV spectra

Reddening – a modest reddening uncertainty of 0.05 propogates into an extinction uncertainty of 0.4-0.5 mags in the near-UV

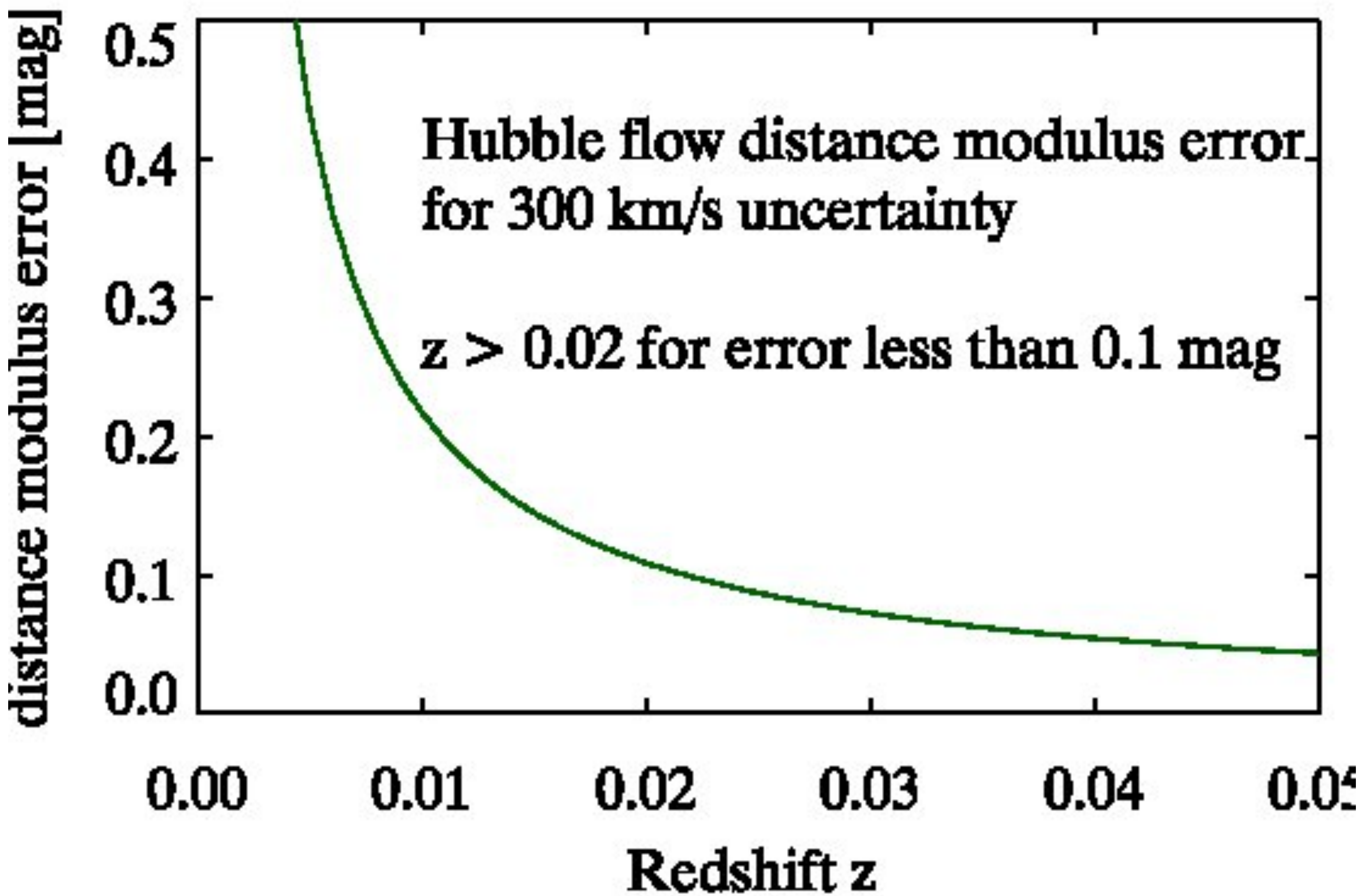
A = R x E(B-V) (R_m2~8-10)

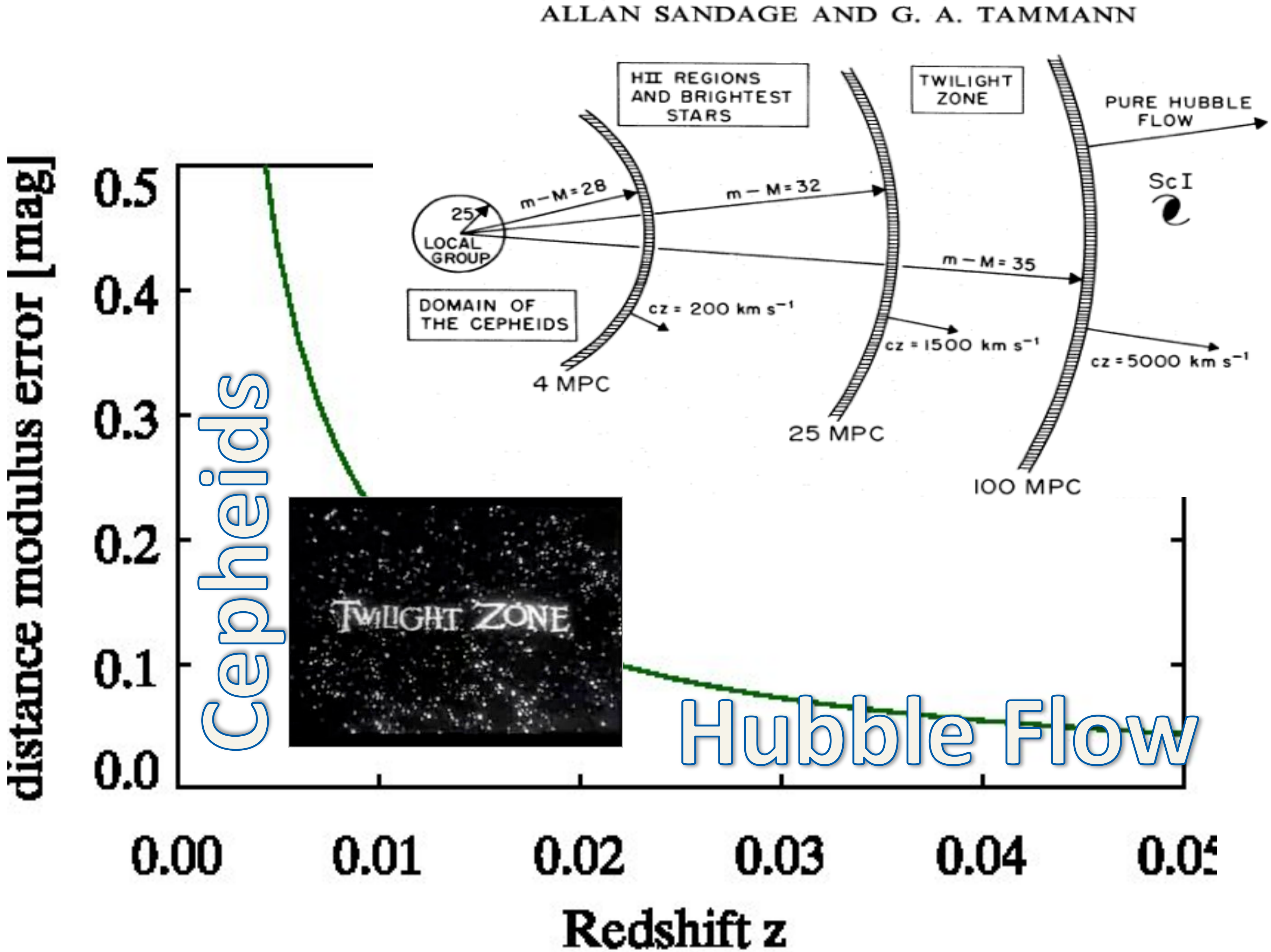
UV extinction law for SNe is not understood anyway



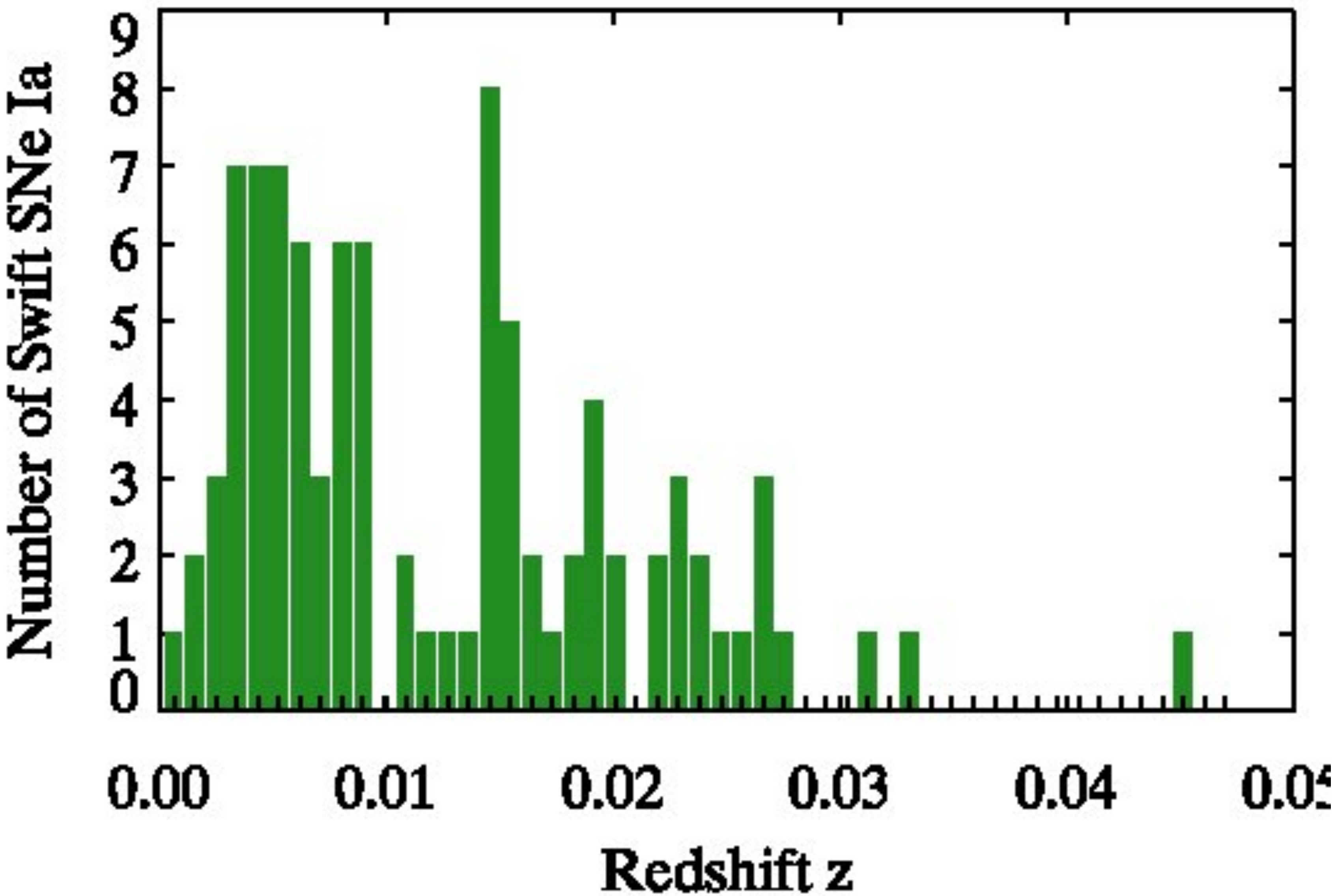
Brown et al. 2010

Dominant Error in the Optical is Distance



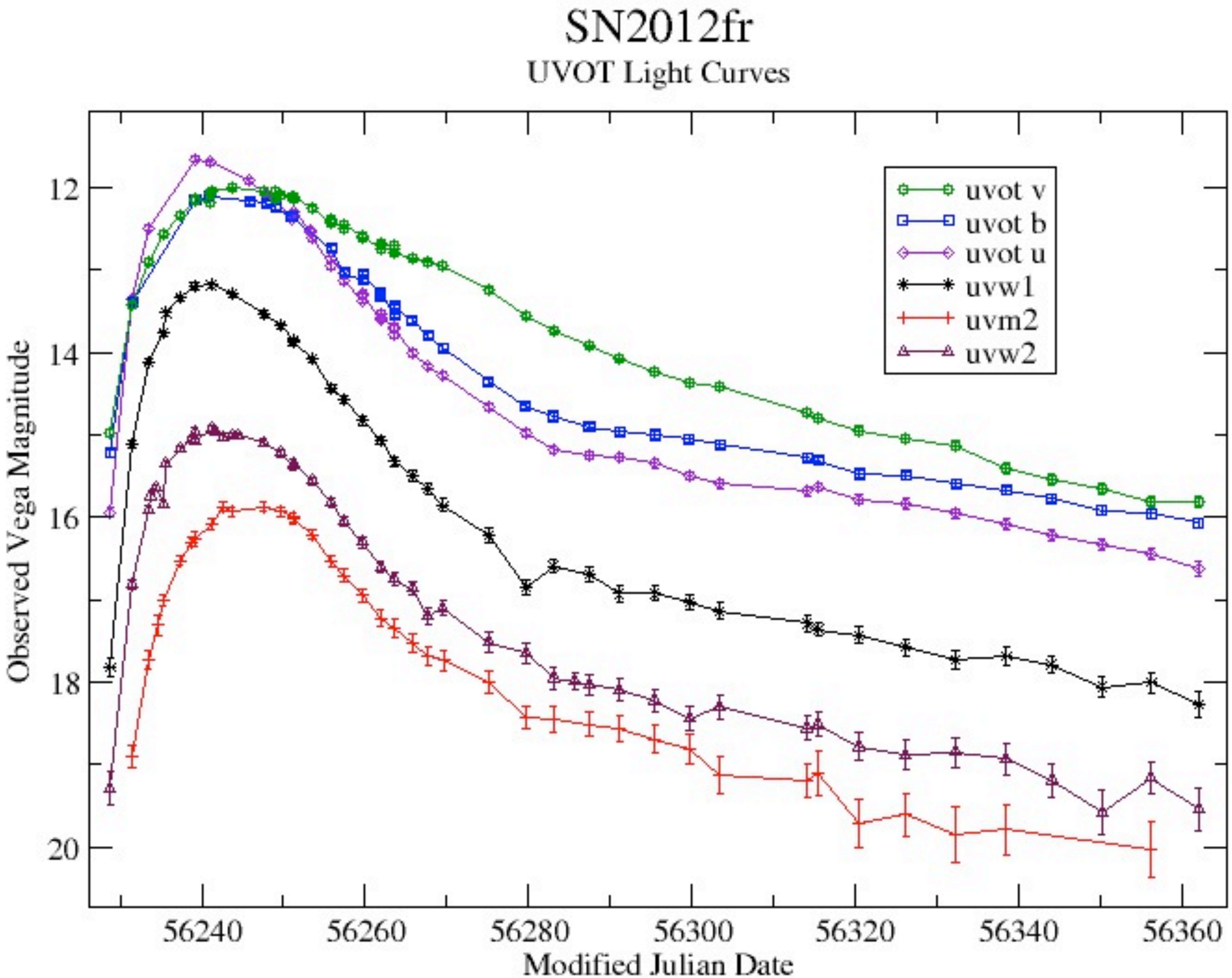

ALLAN SANDAGE AND G. A. TAMMANN
HII REGIONS AND BRIGHTEST STARS
TWILIGHT ZONE
PURE HUBBLE FLOW
m − M = 28
m − M = 32
m − M = 35
25
LOCAL GROUP
ScI
DOMAIN OF THE CEPHEIDS
cz = 200 km s⁻¹
cz = 1500 km s⁻¹
cz = 5000 km s⁻¹
4 MPC
25 MPC
100 MPC
distance modulus error [mag]
0.5
0.4
0.3
0.2
0.1
0.0
Cepheids
TWILIGHT ZONE
Hubble Flow
0.00
0.01
0.02
0.03
0.04
Redshift z

Most Swift SNe are in the Twilight Zone

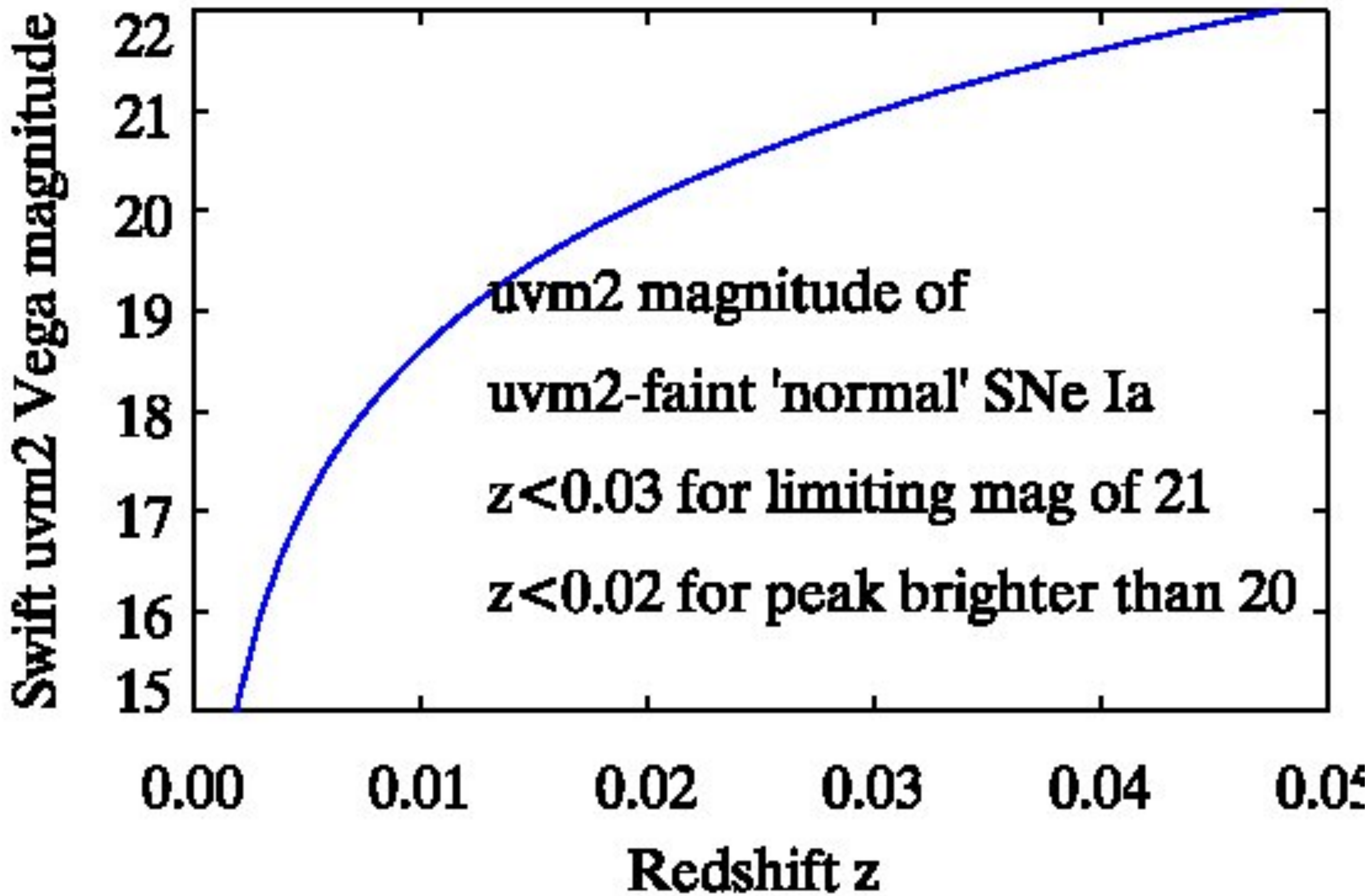


Reducing Distance Errors

- More Swift SNe with Cepheid/other distances
  - Still very small numbers, maybe half a dozen
- Cepheid/other distances to more Swift SNe
  - These are some of the best observed SNe
- Push out into the nearby Hubble flow
  - $z > 0.02$


SN2012fr
UVOT Light Curves
uvot v
uvot b
uvot u
uvw1
uvm2
uvw2
Observed Vega Magnitude
12
14
16
18
20
56240
56260
56280
56300
56320
56340
56360
Modified Julian Date

Redshift Limits



Swift-CSP Observations of Hubble Flow SNe

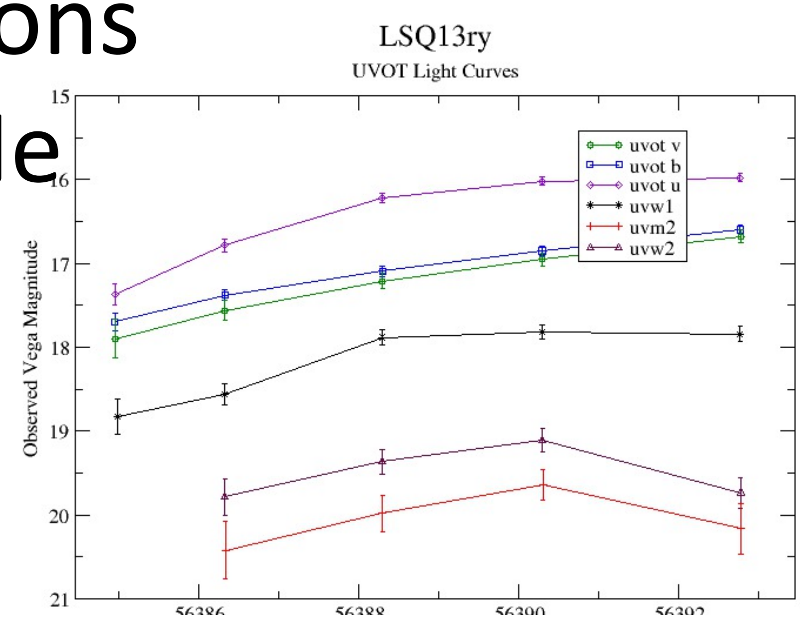
Approved Swift Guest Investigator program to observe ten SNe between 0.025 < z < 0.035

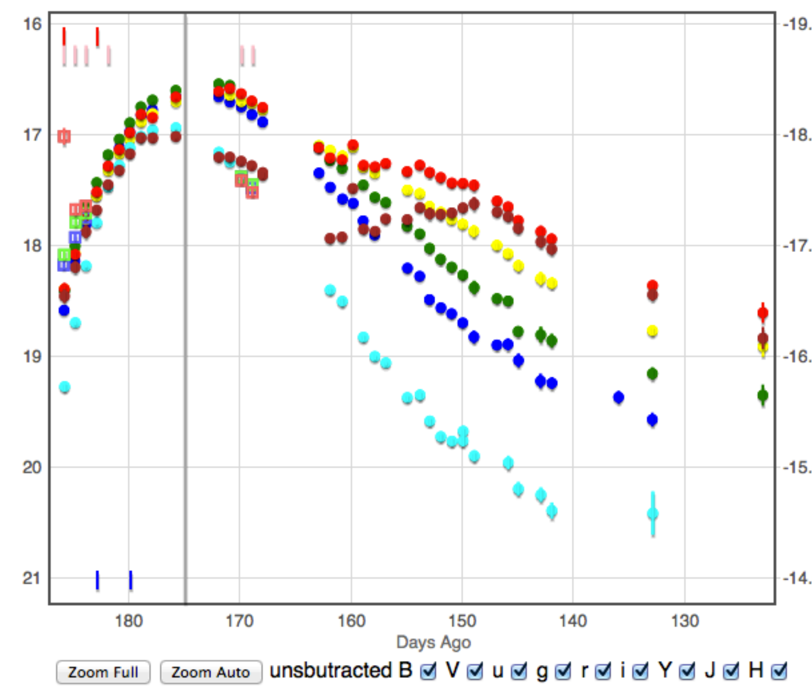
Swift observes in UV/optical for five epochs near the peak

CSP obtains fuller optical/NIR light curves for better width, color, and reddening determinations at epochs where UV is too faint

One year Cycle 10 began in April -- one target observed at end of CSP season

– LSQ13ry at z=0.029





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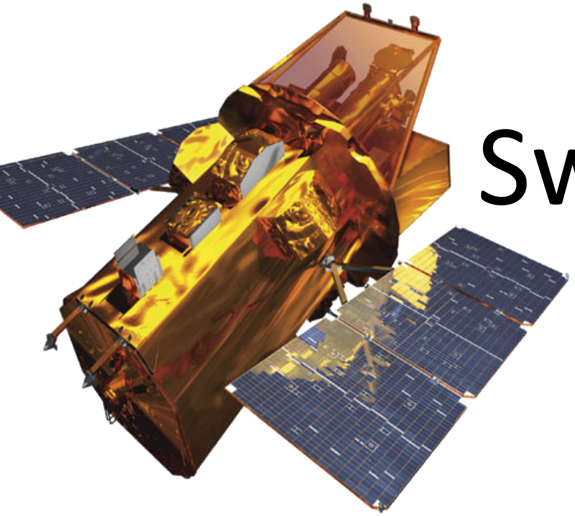

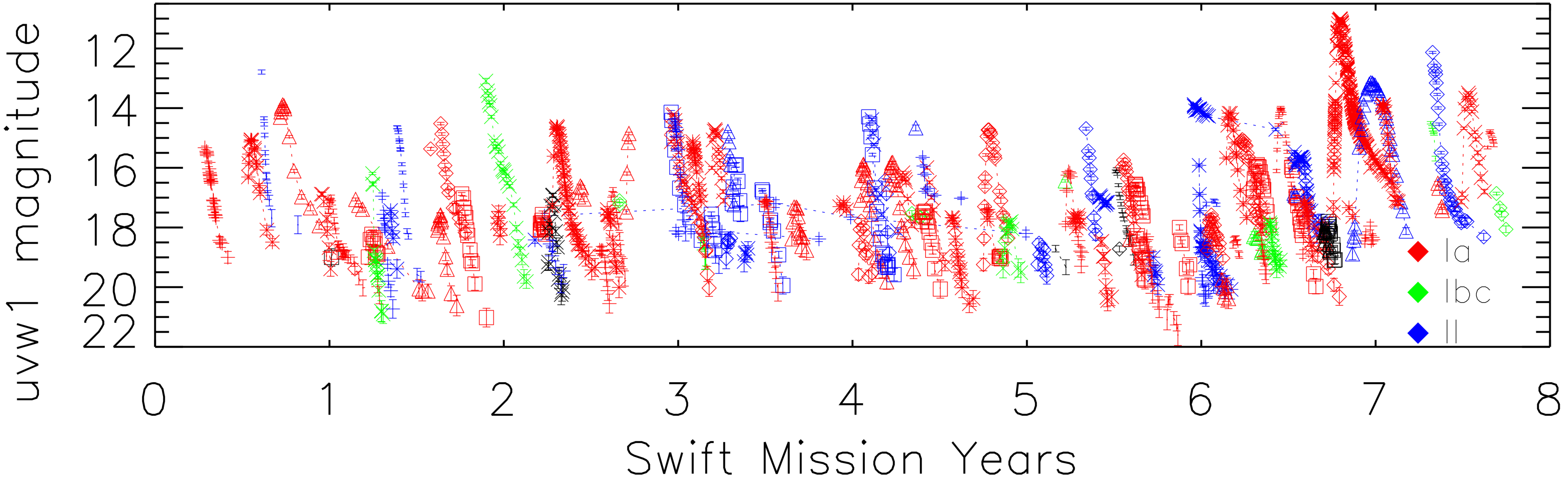

SOUSA

Swift
Optical
Ultraviolet
Supernova
Archive

SOUSA

- [Raw Images]
- Organized Images (incl. templates)
- Photometry Products (count rates, backgrounds, corrections)
- Final Photometry
- SED-dependent products

(flux values, extinction factors, etc.)

Project funded by NASA's
Astrophysics Data Analysis Program