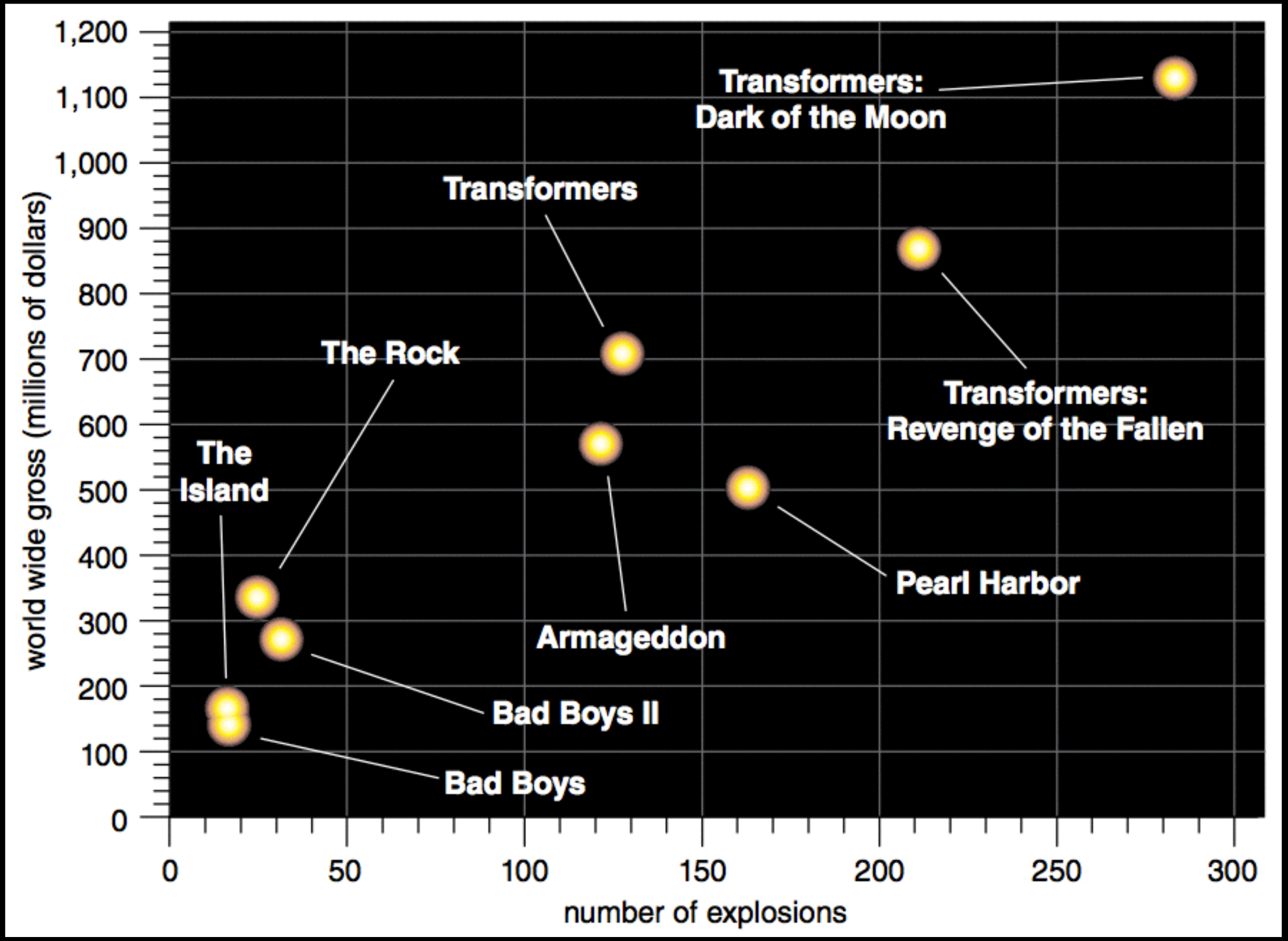
Science with

Andy Howell

Las Cumbres
Observatory Global
Telescope Network

University of California
Santa Barbara

Michael Bay movie explosions vs. box office gross



Imagine this

The closest supernova of your lifetime goes off right at this instant. Observations taken within hours will reveal the progenitor. What do you do?

Hope you already have friends at telescopes. Are there any in the dark right now?

Start making phone calls.

Start Director's Discretionary applications.

You're already too late.

Nugent et al. 2011
Li et al. 2011

SN 2011fe

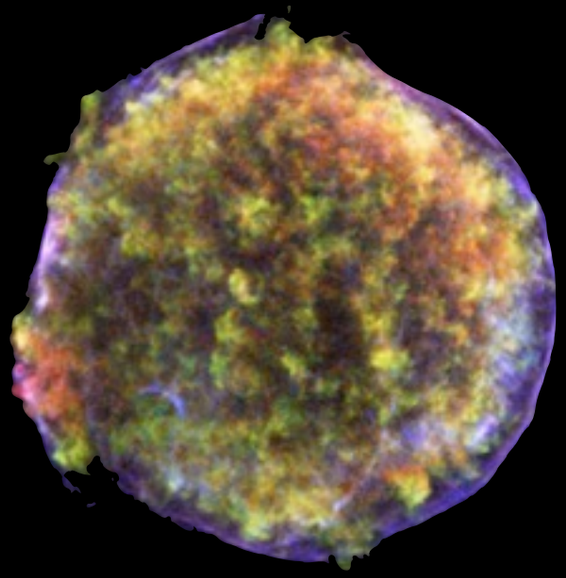
Image credit: BJ Fulton (LCOGT) / PTF.

MESSENGER Earth flyby

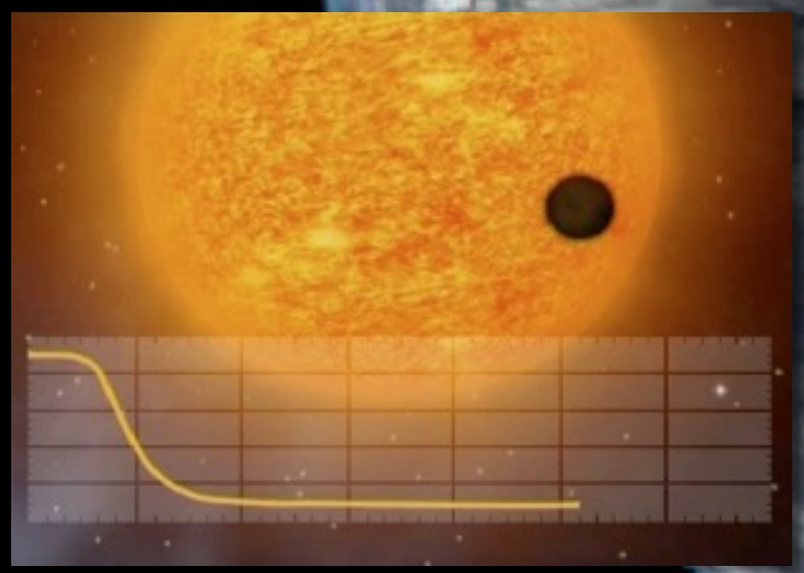
Solution: a global robotic network of telescopes. Spaced around the globe in longitude, hemisphere so that it is always dark or clear somewhere.

We keep you in the dark.

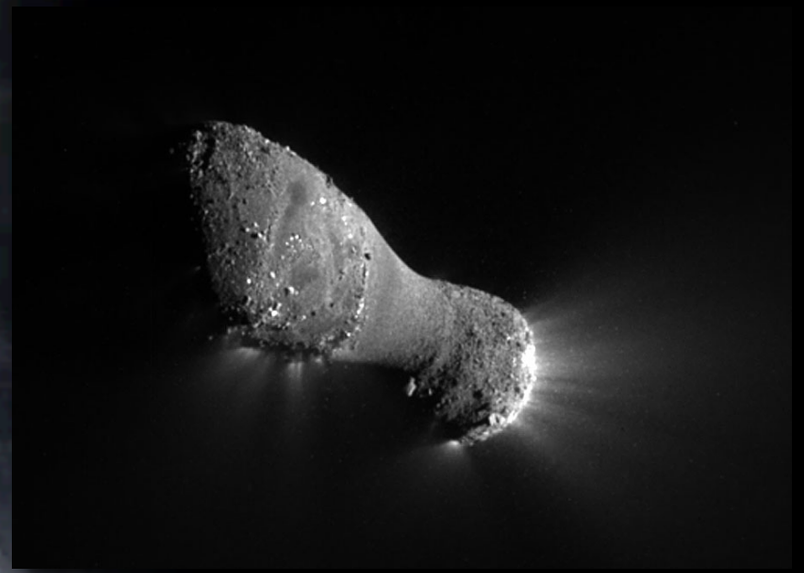
Focus on variability, especially:



Supernovae /
Dark Energy



Extrasolar planets



Solar system objects

From July/ Aug 2013 **American Scientist**

McDonald Observatory
Texas

Haleakala
Hawaii

supernova

Cerro Tololo Inter-American Observatory
Chile

Tenerife
Canary Islands
(possible future site)

China
(possible future site)

South African Astronomical Observatory
Sutherland

Sliding Spring Observatory
Australia

LCOGT.net

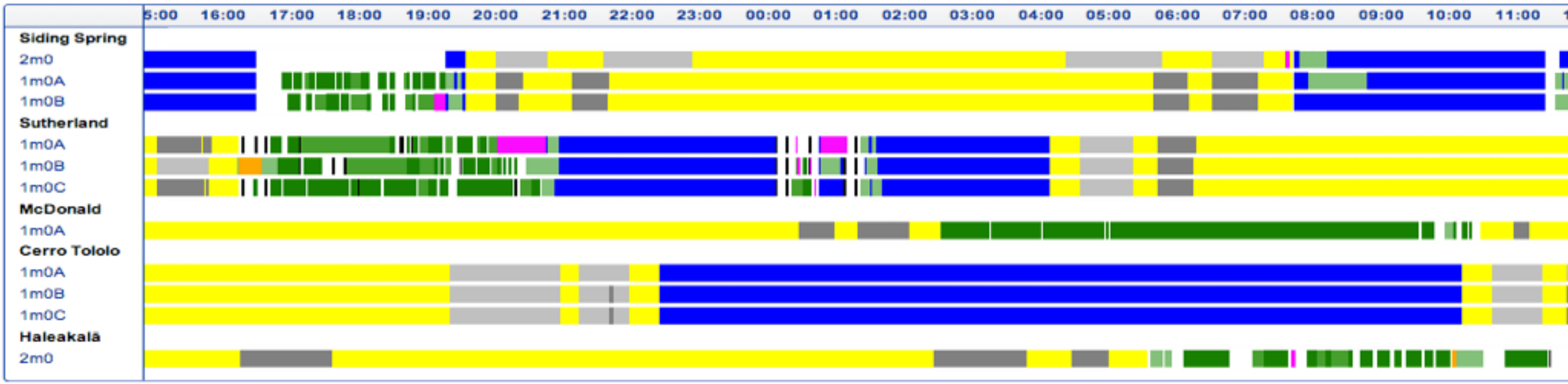
2 meter Faulkes | 1 meter | proposed

Network Scheduler

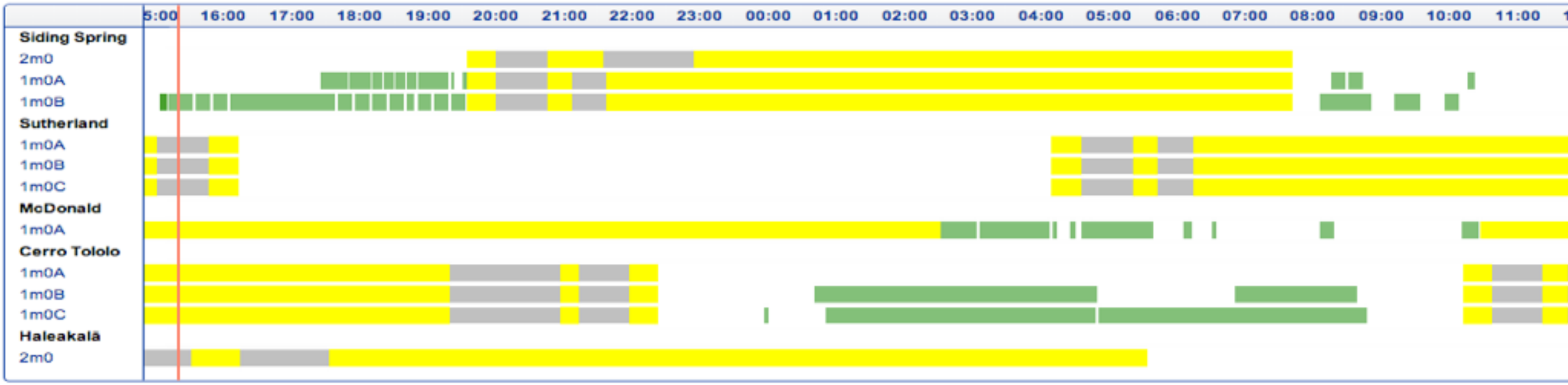
All 11 telescopes scheduled by automated scheduler that solves an optimized whole-network schedule in seconds.

Las Cumbres Observatory Global Telescope Network

Past 24 hours



Next 24 hours



Molecule id:	50807369	**Type:**	EXPOSE	**Priority:**	3	**Block id:**	19984361	**Tag id:**	SCICOLLAB
User id:	andy.howell	**Proposal:**	KEY2014A-003	**Group:**	PSN103448	**Instrument:**	kb75	**Filters:**	ip
Exposure time:	300	**Exposure count:**	2	**Status:**	completed	**Tracking #:**	0000045952	**Request #:**	000011839
Block start:	2014-06-03T17:05:00	**Block end:**	2014-06-03T17:38:48	**Site:**	cpt	**Observatory:**	domc	**Telescope:**	1m0a
Airmass:	2	**Molecule start:**	2014-06-03T17:26:52	**Molecule end:**	2014-06-03T17:37:33				

Telescopes are built at LCOGT Santa Barbara Headquarters near UCSB

30+ staff, mostly in SB. Others in Liverpool, Cardiff, Siding Spring Australia, Hawaii, Cape Town

1m Instrumentation

Imaging

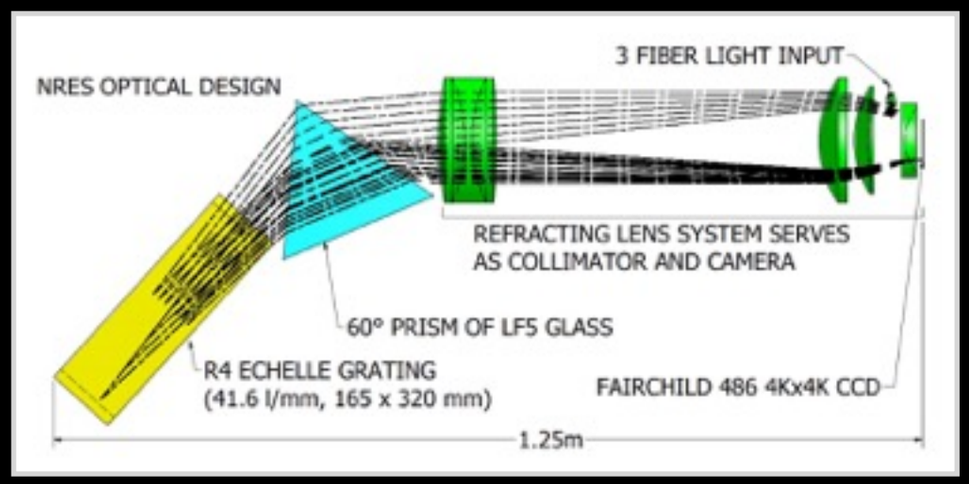
At CTIO:
SINISTRO

Elsewhere:
SBIG
imagers

Sinistro: 26.4’ x 26.4’, 0.389”/pixel.
Fairchild CCD486, backside illuminated.
21 position filter wheel, photometric shutter.
16 Mpix; 4 Mpix/s readout at ~10 e-/pix

Spectra

Coming 2015:
Network Robotic Echelle Spectrographs (NRES)
High-resolution (R~53,000), precise (≤ 3 m/s), optical (380-860 nm) echelle spectrographs



One at each 1m site (6 total), can be fiber-fed (2.58" per fiber width) by two 1m telescopes and ThAr calibration source

Will double the radial velocity planet-vetting capacity in the US and achieve accuracy better than 3 m/s to V = 12

NSF funded. Prototype is Sedgwick 0.8m

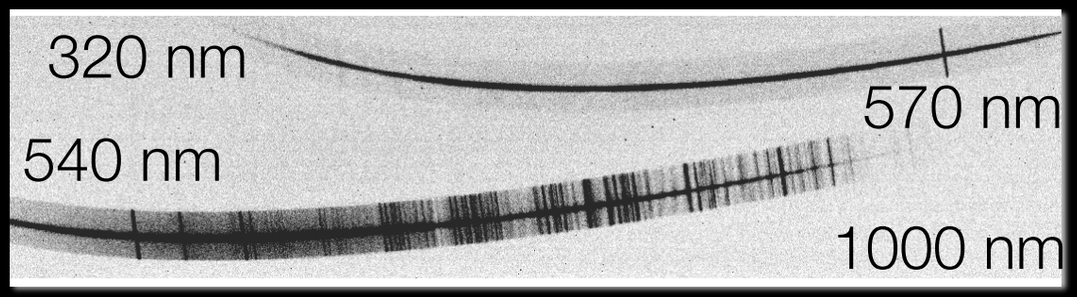
2m: FLOYDS robotic low resolution spectrographs

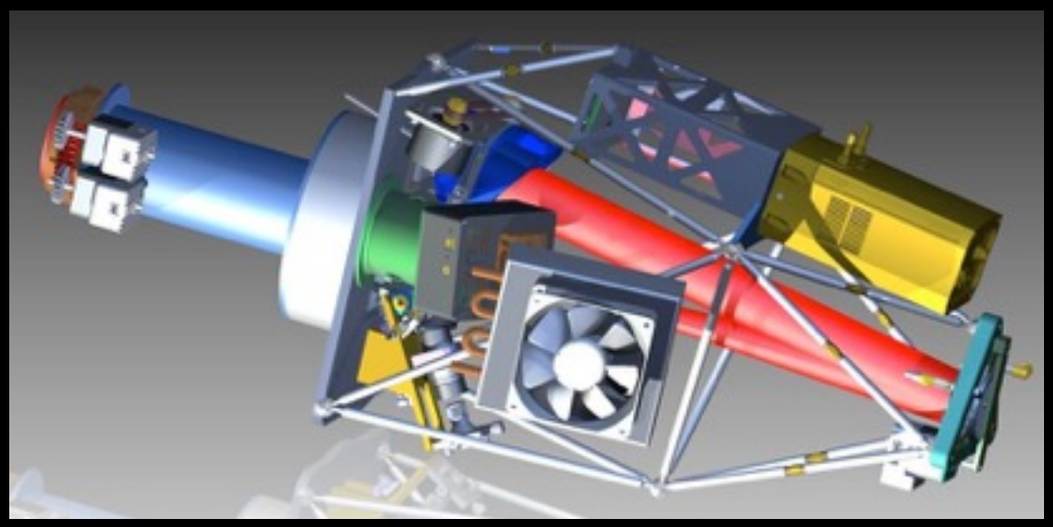
Designed for supernovae

R~400 covering 325nm -- 1000nm in one pointing (cross dispersed).

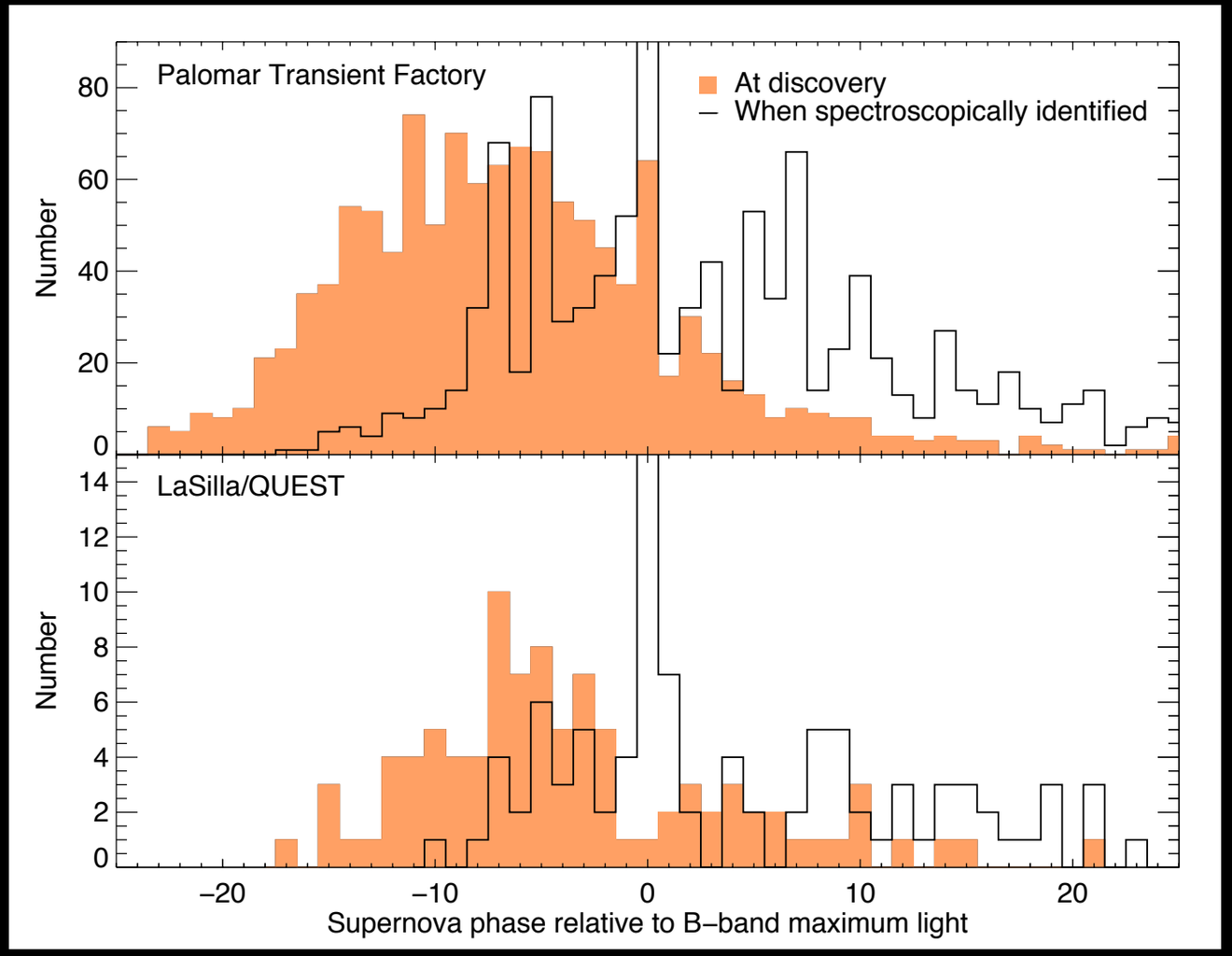
Can go down to V~19 mag with S/N=10 in 1 hour

Spectrographs are in regular nightly operation.
Pipeline reduces data, types SN 40s after readout.





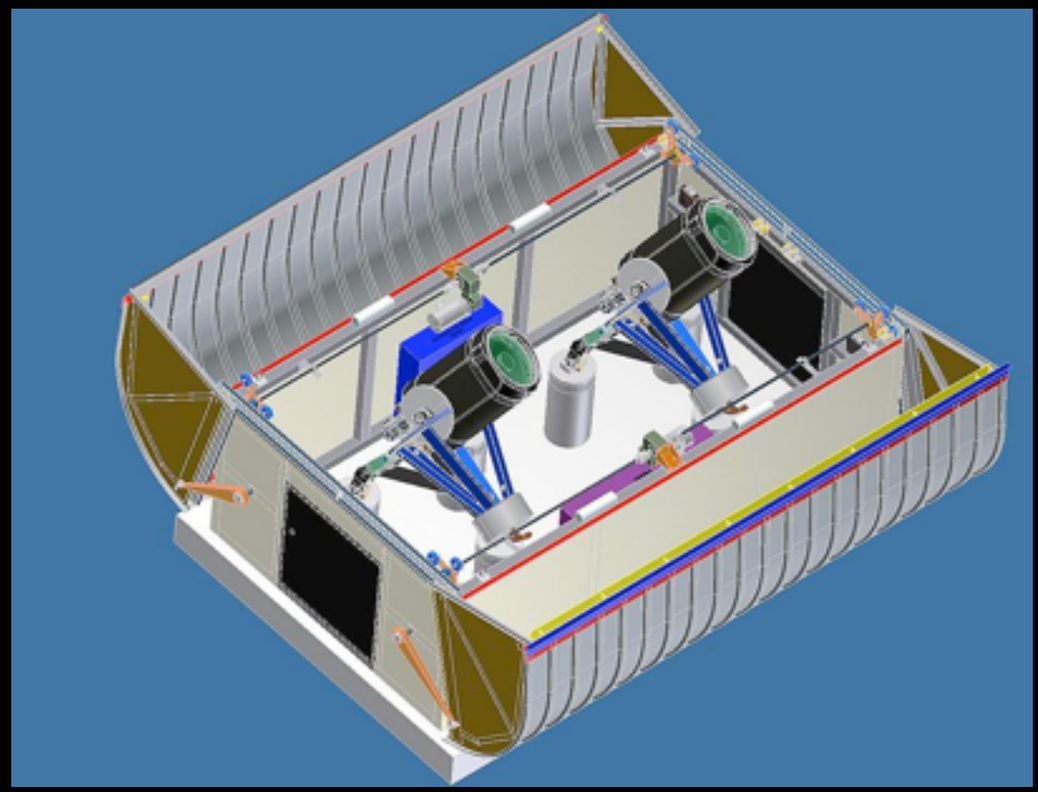
Built by Dave Sand and engineers at LCOGT



0.4m telescopes

For commercial, science, and educational use.

Up to 24 total, deployed in clusters of 2-4 at each site, contingent on funding



Phase 1: testing of a single 0.4m

Phase 2: deployment of 4 more 0.4m

Phase 3: deployment of 10 more 0.4m

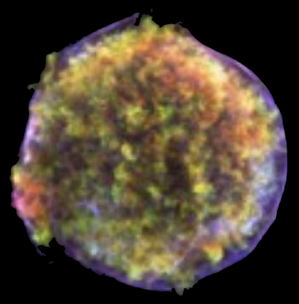
Scientists

Director: Todd Boroson
Operations: Nikolas Volgenau
Instrumentation: Joe Tufts
Founder: Wayne Rosing

Current

Past

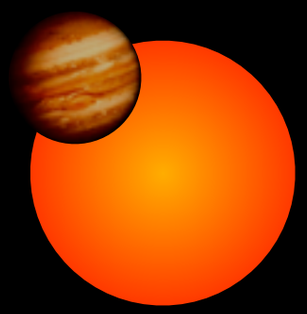
SNe



Andy Howell
Stefano Valenti
Iair Arcavi
Curtis McCully
Griffin Hosseinzadeh

Dave Sand
Federica Bianco
Ben Dilday
Melissa Graham
Jerod Parrent

Planets



Tim Brown
Rachel Street
Diana Dragomir
Rob Siverd
Amanda Fournier

Avi Shporer
Jason Eastman
Marton Hidas
Nairn Baliber

NEOs

Tim Lister

LCOGT.net

Solar System Science

Tim Lister

Near-earth objects:
Observing and reporting ~2500 objects per year from all surveys

Contracted follow-up for Catalina Sky Survey until April 2015

300 1m hours per year.

Successful NASA ROSES 2013 NEOO grant application: now hiring postdoc.

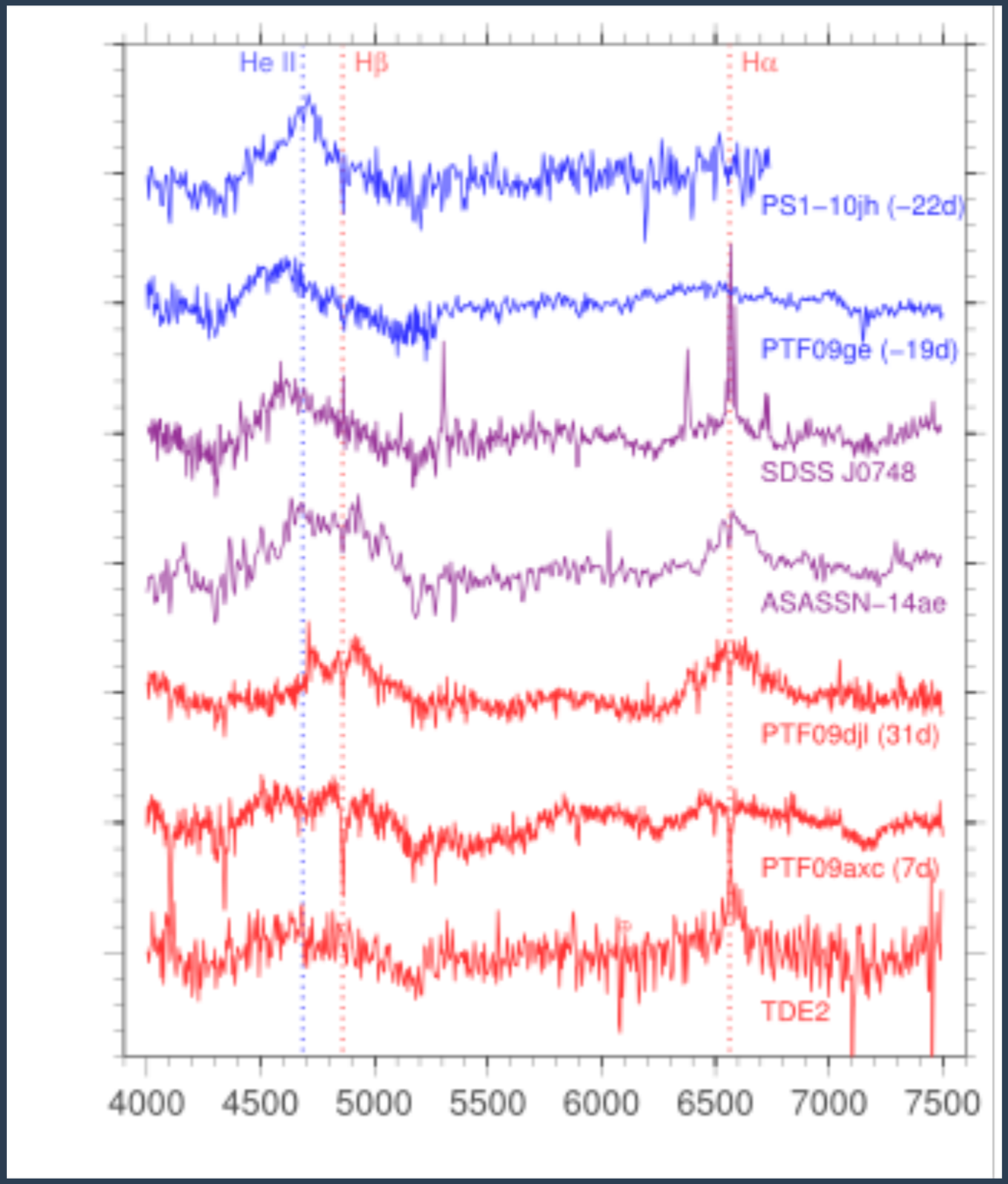
Comet Hartley imaged by EPOXI

Credit: NASA, JPL-Caltech, UMD, EPOXI

Tidal Disruption Events

Iair Arcavi

A continuum of He to H-dominated events



Gezari+ 12

Arcavi+ 14

Wang+ 11

Arcavi+ 14

Holoien+ 14

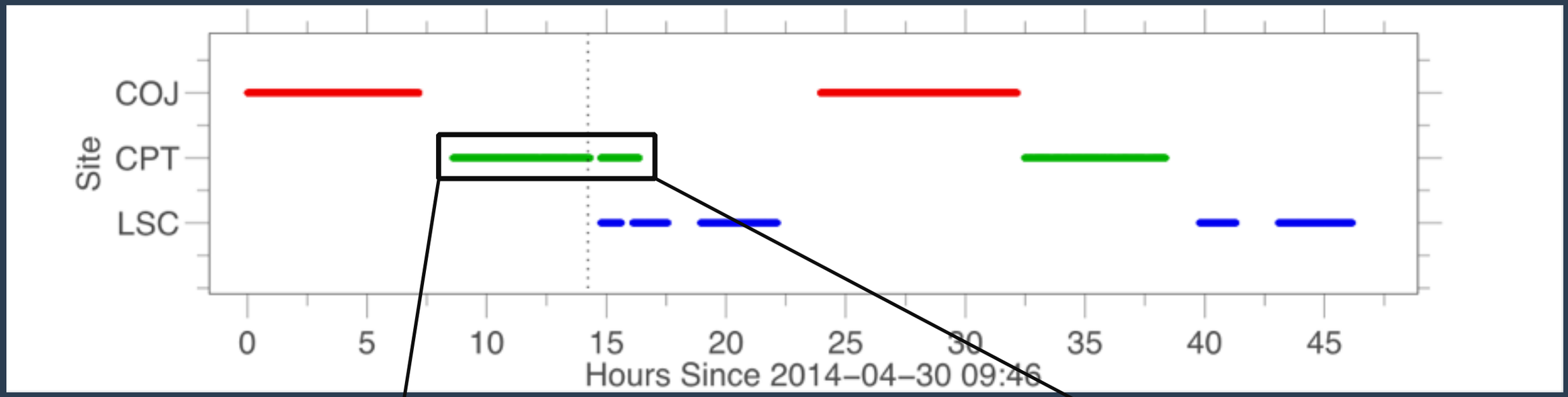
Arcavi+ 14

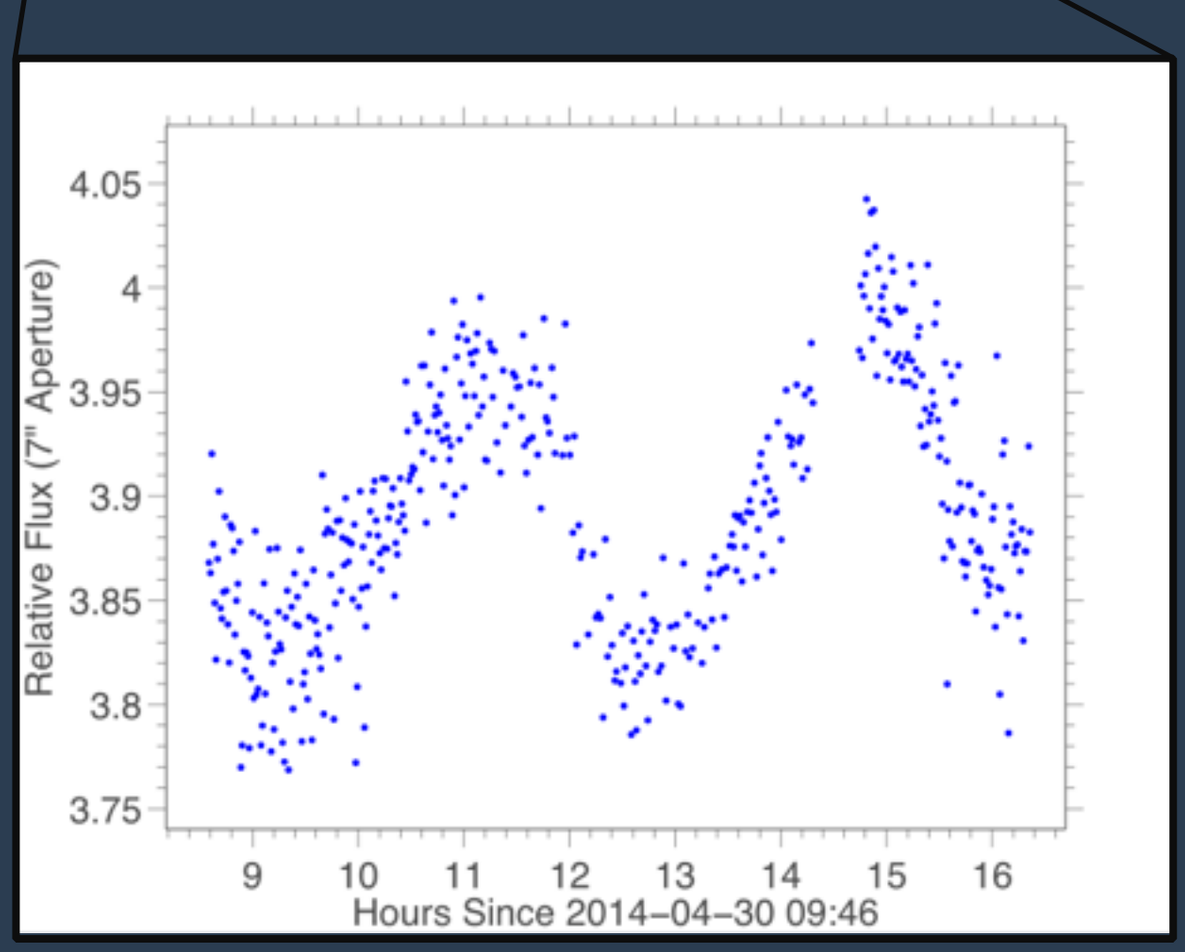
Arcavi+ 14

van Velzen+ 11

Asteroseismology of massive stars: pilot project

Iair Arcavi



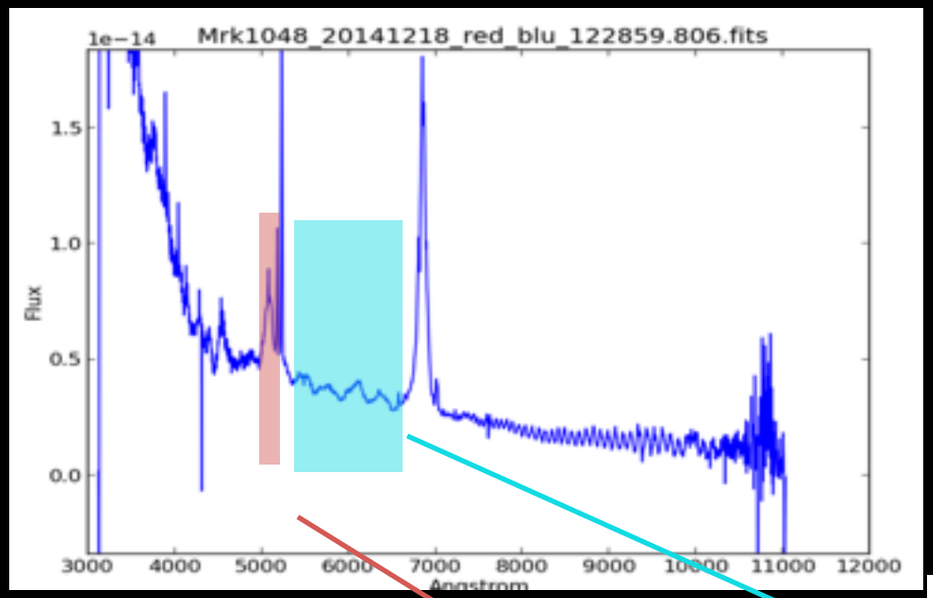


Nearly continuous observations for 48 hours!

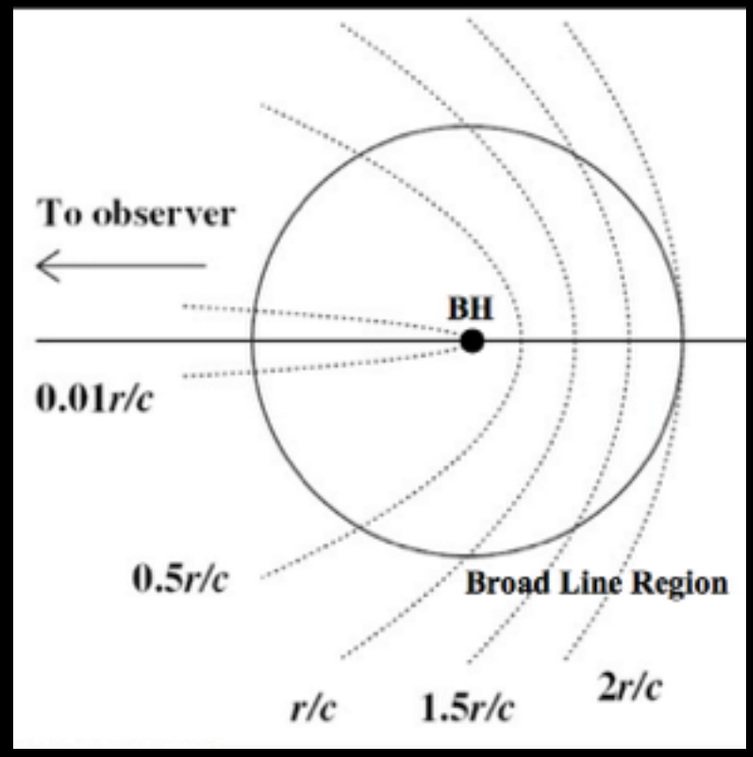
Quicklook pipeline

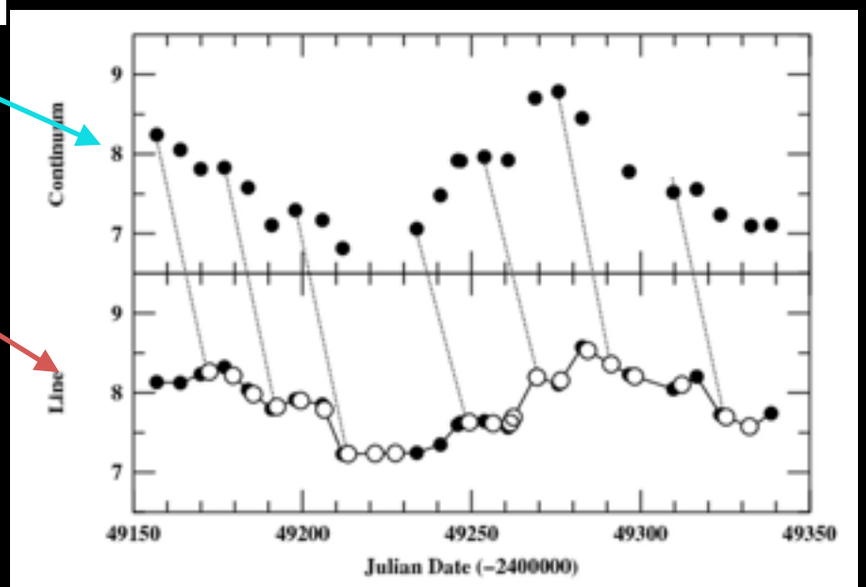
Science @ LCOGT

AGN Reverberation Mapping



Time delay between variations in the continuum and in the broad lines

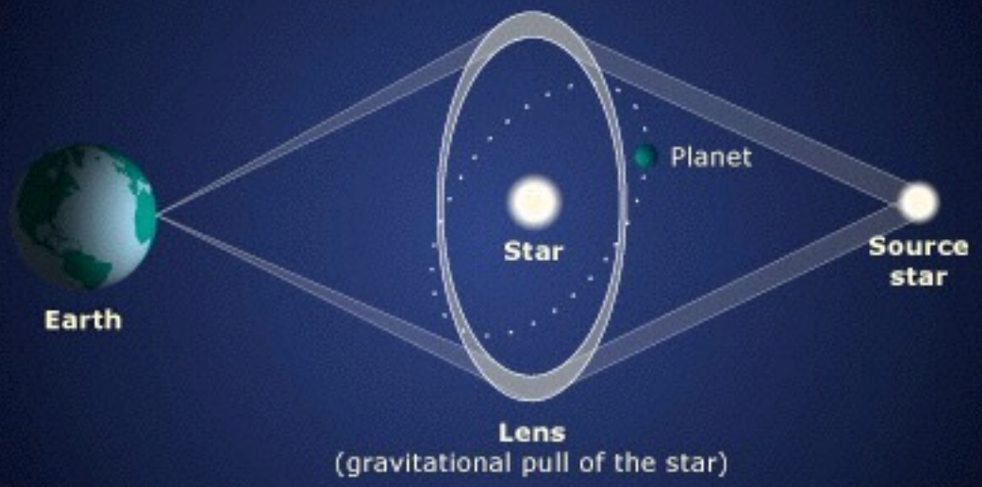




Mkn 335: Hβ line lags continuum by 15.6 d (Peterson, 2001, Fig. 24)

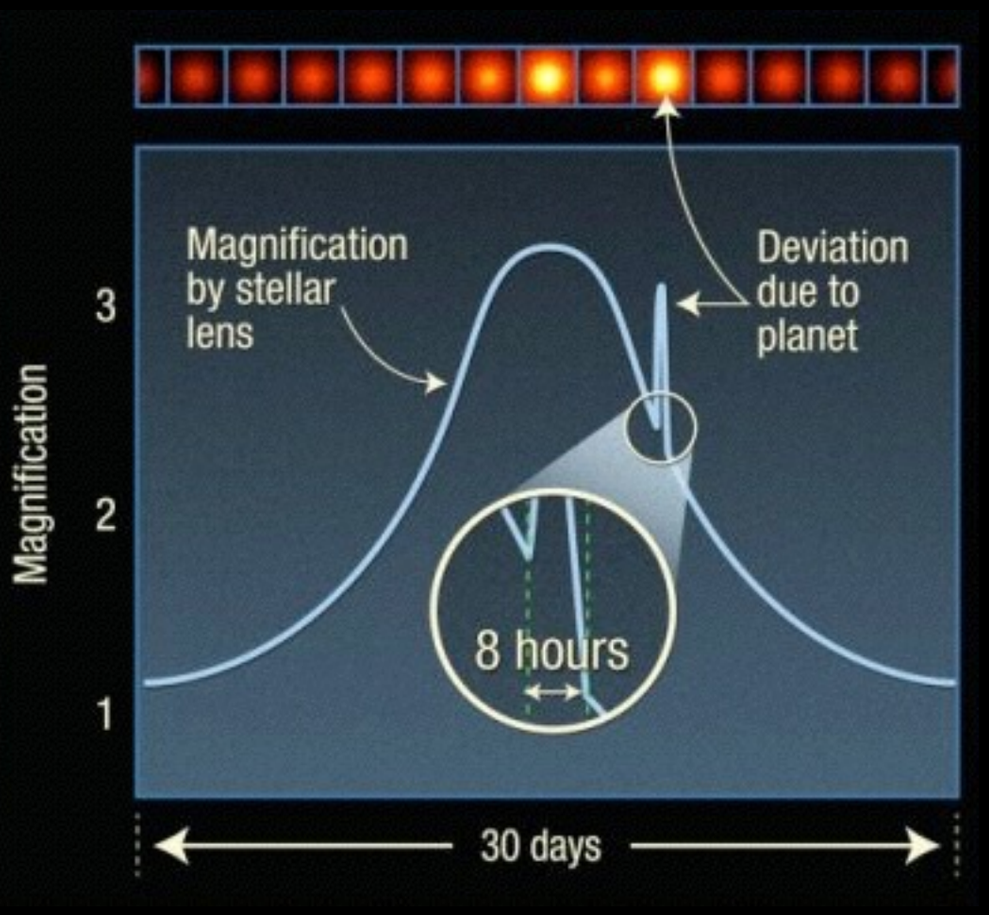
$$M_{BH} = f\,(c\Delta T\, V^2 / G)$$

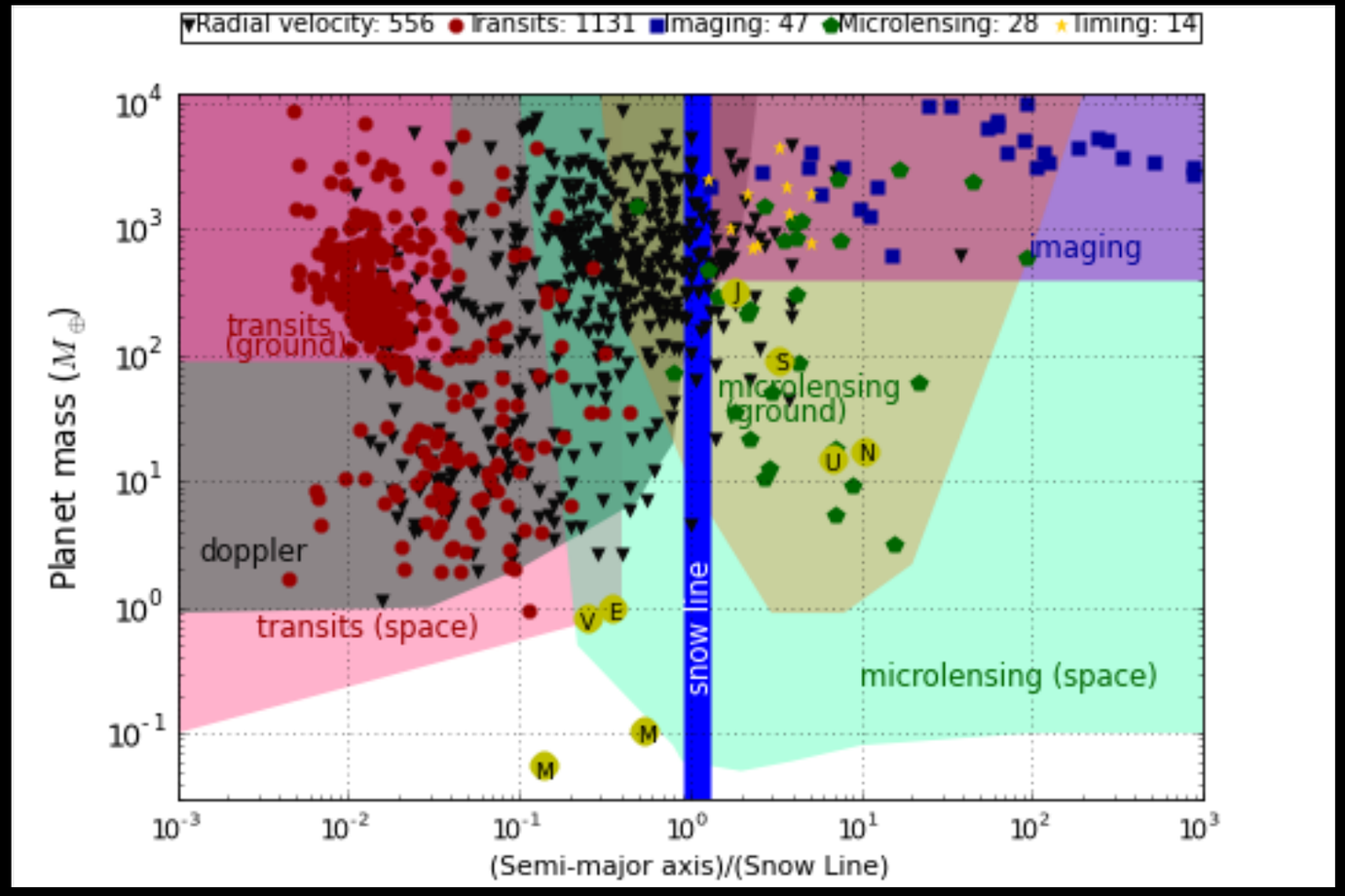
Microlensing Key Project



PI: Rachel Street

Discovers planets at ~1-10 AU separation from host stars, around the snowline region central to planet formation theory.





The Supernova Group at UCSB / LCOGT

Current

Andy Howell
Stefano Valenti
Iair Arcavi
Curtis McCully
Griffin Hosseinzadeh

Past

Federica Bianco
Ben Dilday
Melissa Graham
Jerod Parrent
Dave Sand

We’re involved in more supernova surveys than any group in the world: Palomar Transient Factory, Pan-STARRS1, LaSilla-Quest, Supernova Legacy Survey, PESSTO.

In the past year the SN group at UCSB/LCOGT has contributed to 54 papers, including 3+1 in Nature.

Supernova Key Project

LCOGT
Iair Arcavi
Andy Howell
Griffin Hosseinzadeh
Stefano Valenti

South Africa
Bruce Bassett
Steve Crawford
Eli Kasai
Roy Maartens
Matthew Smith
Abiy Tekola

University of Colorado
Alexander Conley
Emily Levesque

iPTF
Yi Cao
Avishay Gal-Yam
Ariel Goobar
Mansi Kasliwal
Peter Nugent
Eran Ofek
Robert Quimby
Jesper Sollerman

University of Texas
Howie Marion
Jeffrey Silverman
Jozsef Vinko
Craig Wheeler

LaSilla-QUEST
Charles Baltay
Nan Ellman
Ryan McKinnon
David Rabinowitz
Emma Walker

Australian National University
Michael Childress
Richard Scalzo
Brian Schmidt
Brad Tucker
Fang Yuan

Chile?
e.g. Mario Hamuy
Santiago Gonzalez Gaitan
...

KMTNet
Dae-Sik Moon

Other
Melissa Graham
Eric Hsiao
Mark Phillips
David Sand

China
Guojie Feng
Hubiao Niu
Lifan Wang
Xiaofeng Wang
...

Supernova Key Project

Allocation LCOGT time over 3 years:
1m time: 1030 hours / semester
2m time: 250 hours / semester

Goals Build a sample of 600 supernovae to:

1. Observe supernovae soon after explosion to search for signs of their progenitors

2. Measure Dark Energy

3. Do statistical population studies

4. Build the first statistical samples of exotic SNe

5. Obtain optical light curves and spectroscopy in support of UV observations, IR imaging and spectroscopy, host galaxy studies, high resolution spectroscopy, and late-time spectroscopy with large telescopes.

Other facilities used by the Key Project

Feeder Surveys

Survey	Facilities
iPTF	Palomar 48 (search)
LSQ	La Silla Schmidt
Skymapper	1.3m Skymapper telescope
KMTnet	17% of the time on three 4 sq. deg. 1.6m telescopes for SN Survey.

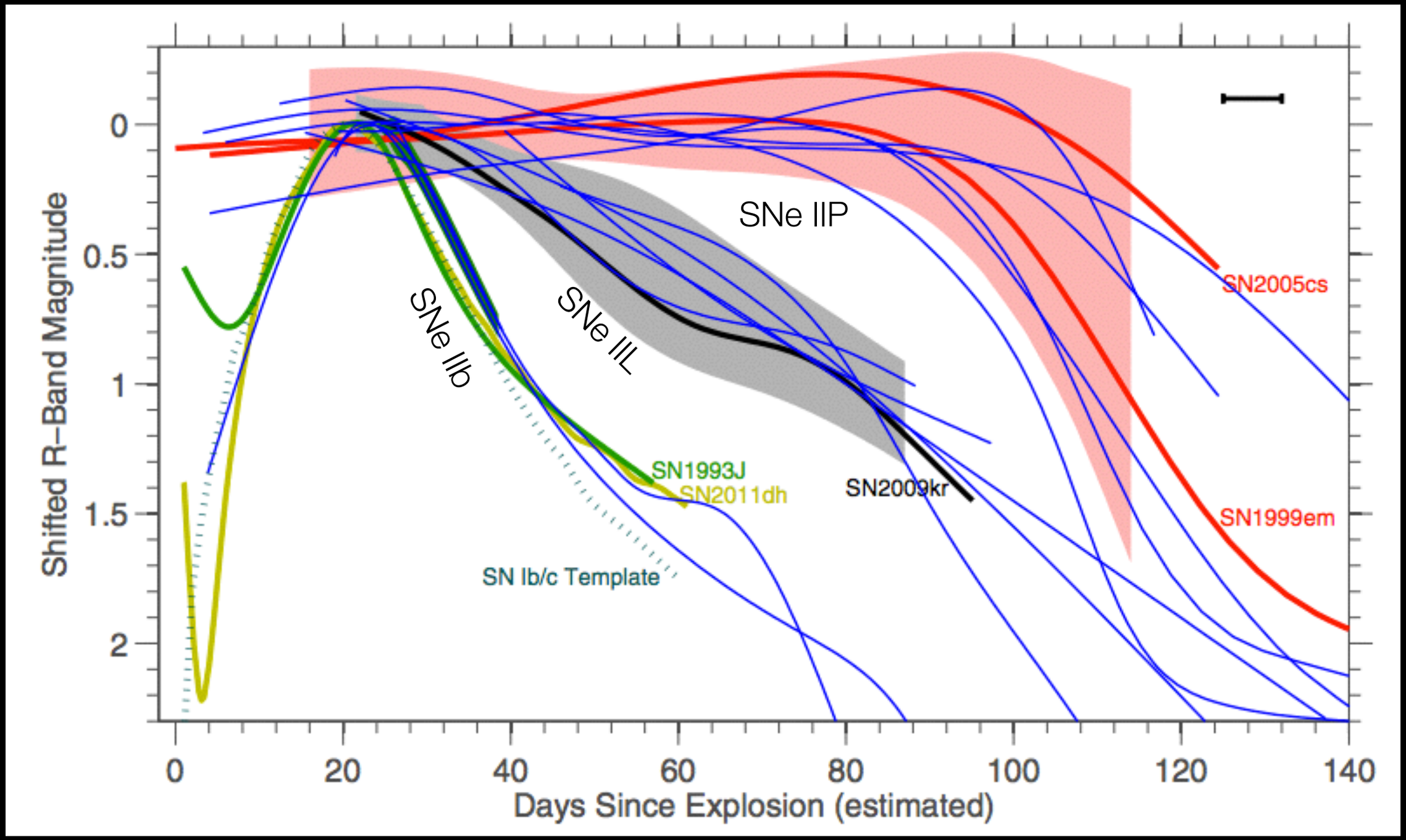
Also: KAIT, Gaia

Major Followup

Telescope	Ap. (m)	Purpose
NTT	3.6	PESSTO optical and NIR spectra
Keck	10	High and low resolution spectroscopy
Gemini	8	Low resolution optical and NIR spectroscopy
Magellan	6.5	IR spectroscopy
Salt	9.2	Low resolution spectroscopy

What are SNe IIL?

Arcavi et al. 2012



3 classes of SNe.

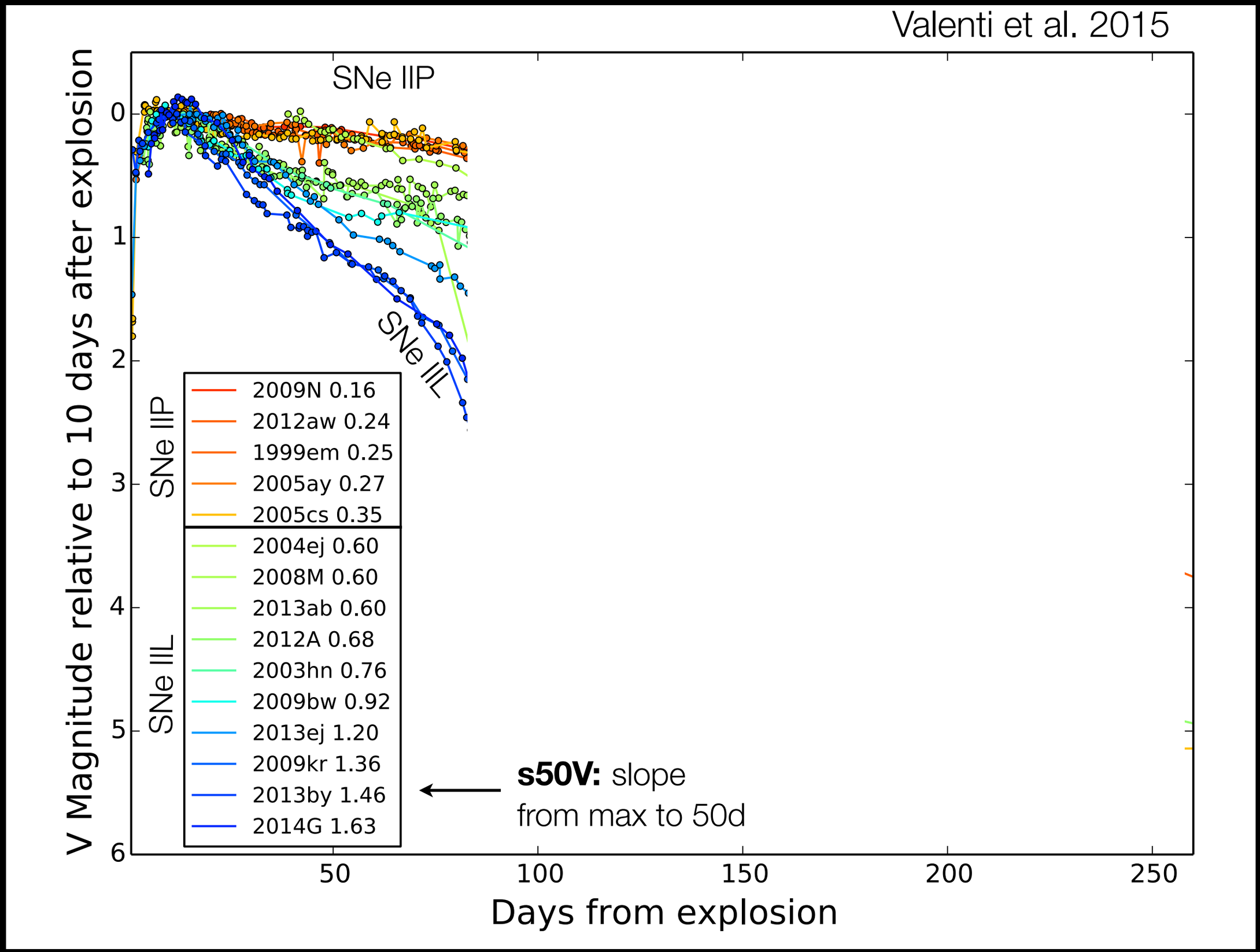
Plateau length should be proportional to stellar mass.

$$t_p = 99 \frac{\kappa_{0.34}^{1/6} M_{10}^{1/2} R_{0,500}^{1/6}}{E_{51}^{1/6} T_{\mathrm{ion},5054}^{2/3}} \text{ days}$$

Plateau length from Popov 1993

What are SNe IIL?

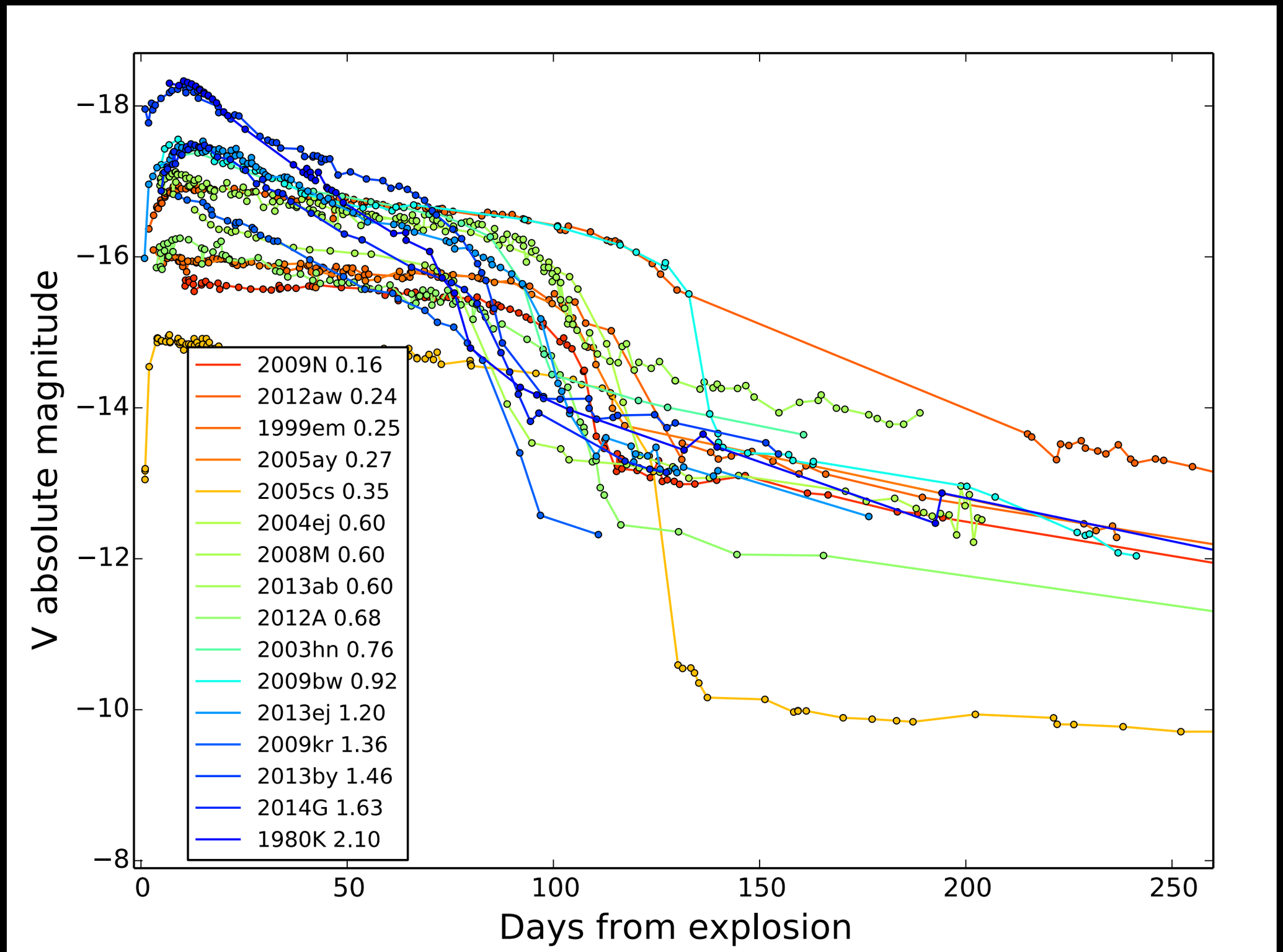
Data are from literature and LCOGT



All SNe IIL actually have plateaus if you follow them for long enough!

What are SNe IIL?

Valenti et al. 2015



SNe IIL are more luminous than SNe IIP

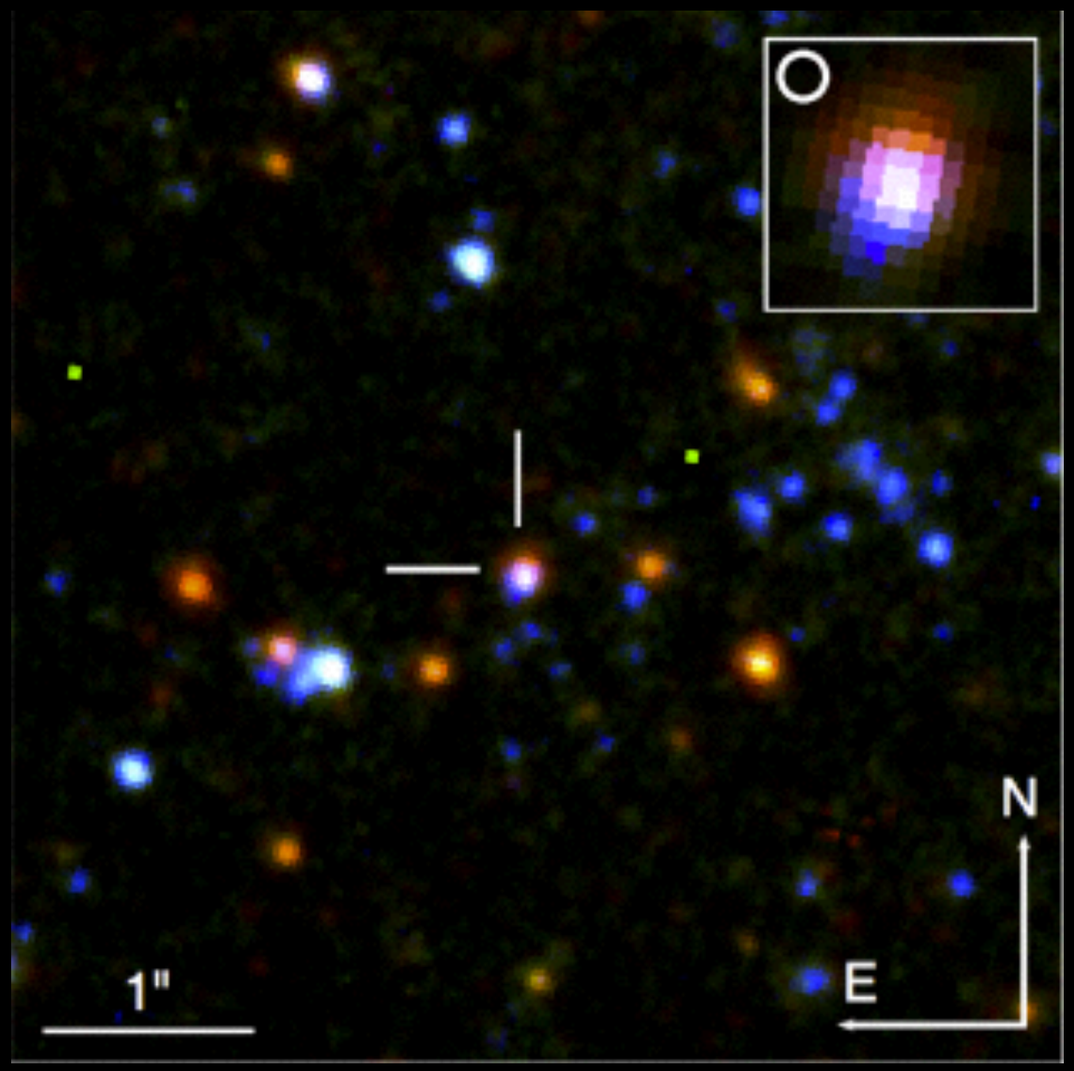
Are they from similar progenitors, but with an additional source of energy at early times?

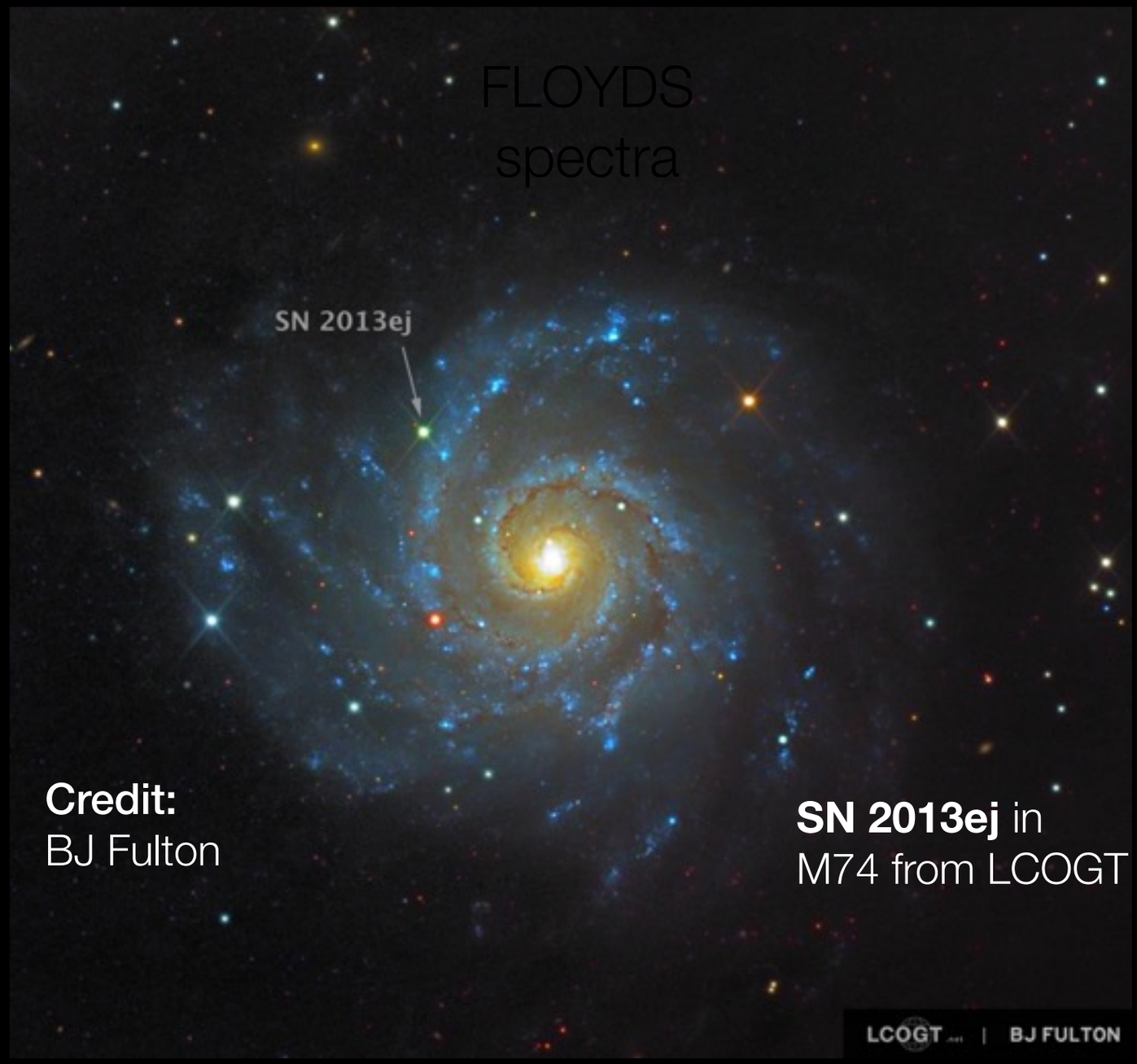
Direct imaging

Fraser et al. 2014

SN 2013ej was a Type II SN in M74.

HST color composite of F435W, F555W and F814W. Inset shows progenitor candidate, circle shows uncertainty.



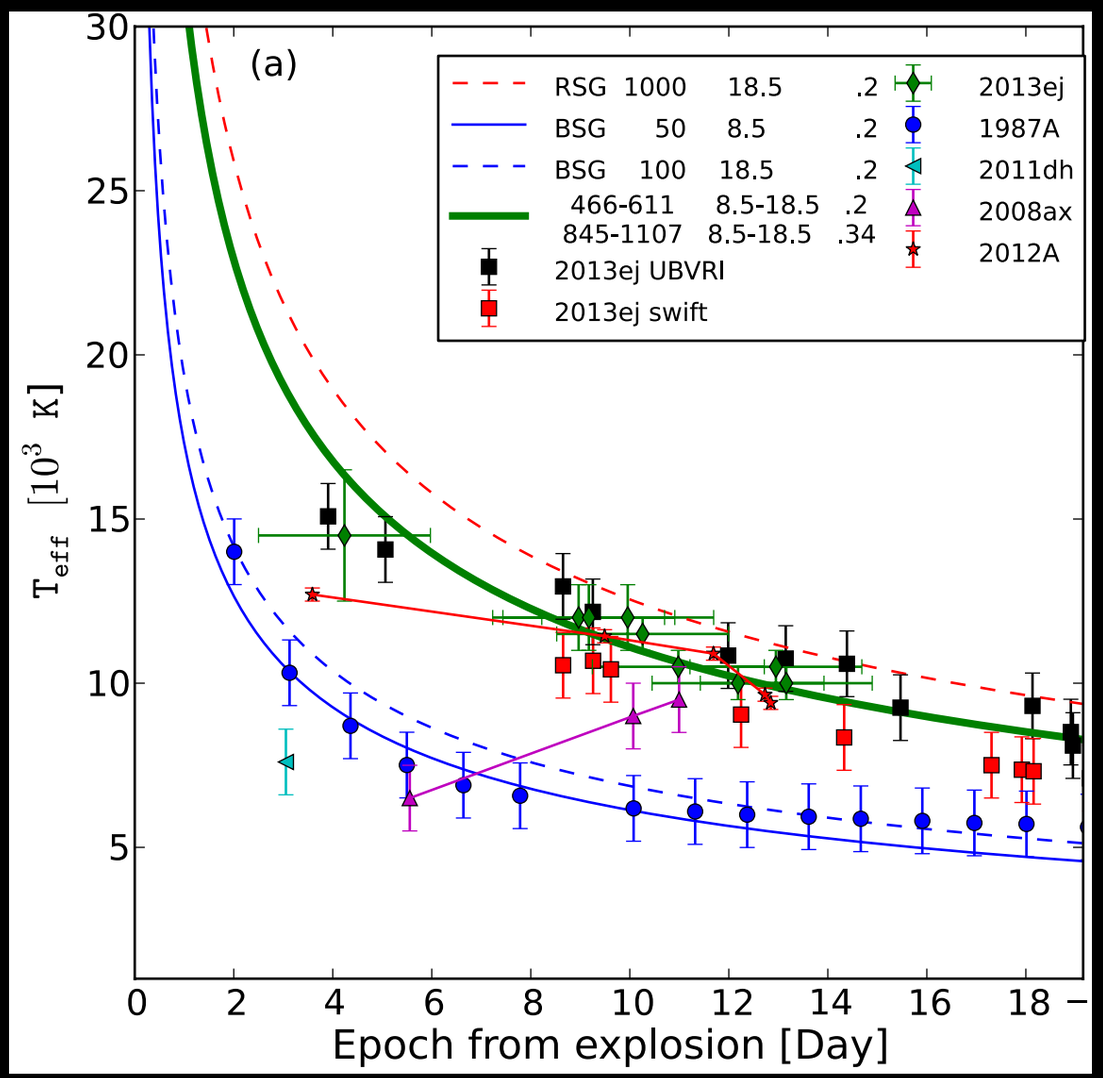


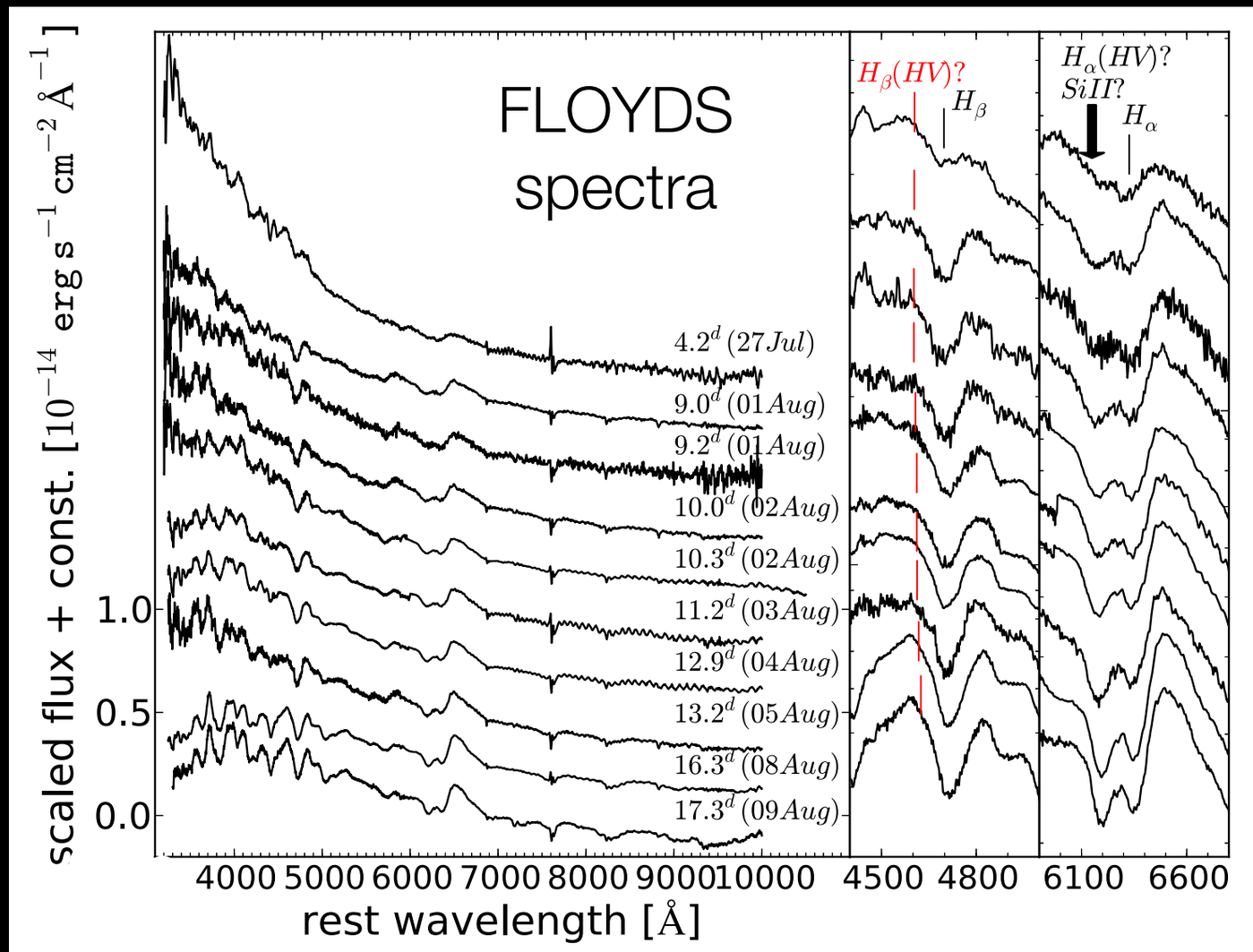
Blue source blended with red source. If red source is the progenitor, then position is consistent with 8-15.5 $M_\odot$ progenitor.

Measuring the progenitor with shock cooling!

Valenti et al. 2014

With LCOGT we get lightcurves, spectra soon after explosion.





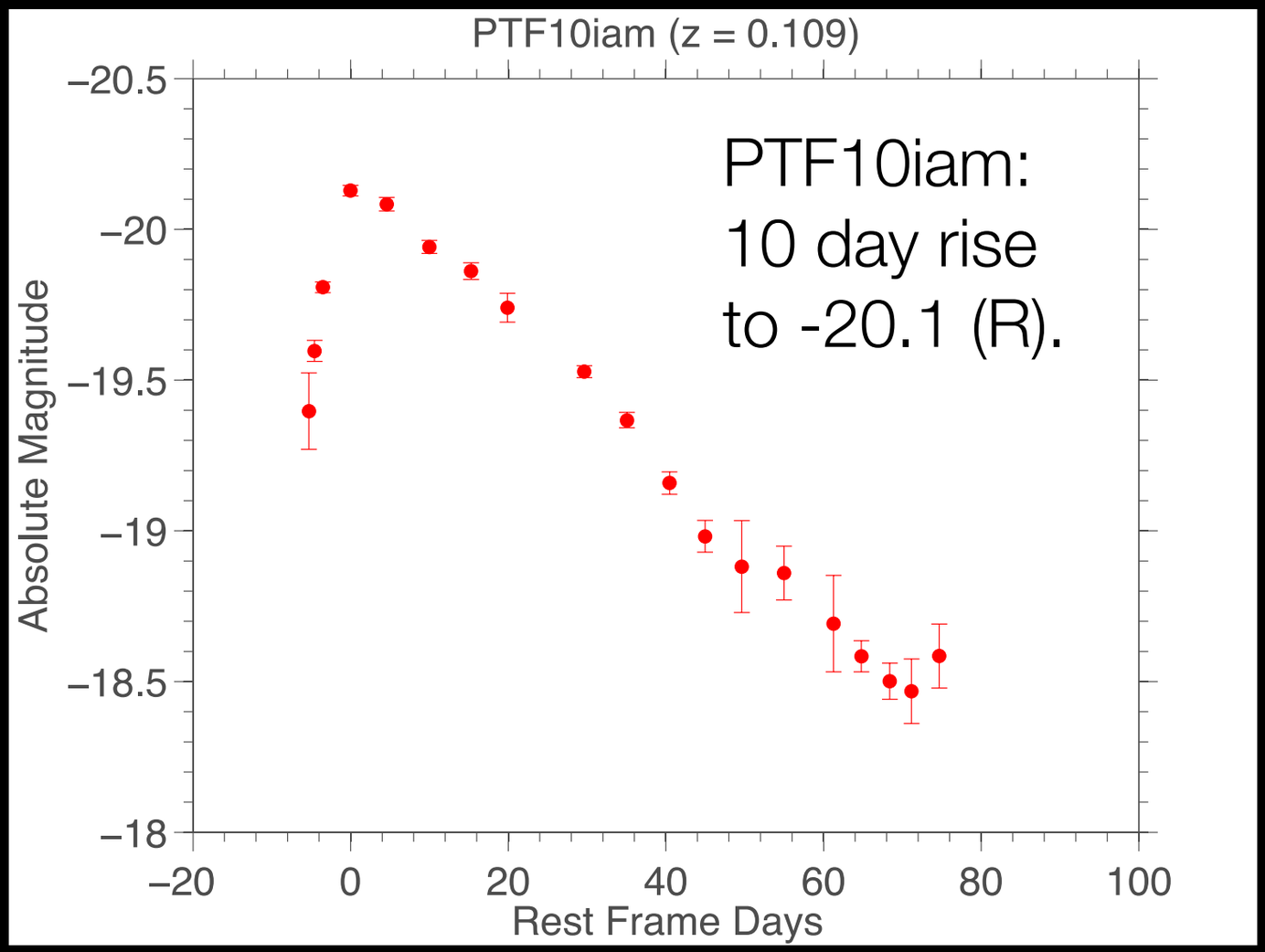
Shock cooling measured with FLOYDS (green points), reveals the progenitor of SN 2013ej was a red supergiant with R=450-600 $R_\odot$!

RAPIDLY RISING TRANSIENTS IN THE SUPERNOVA - SUPERLUMINOUS SUPERNOVA GAP

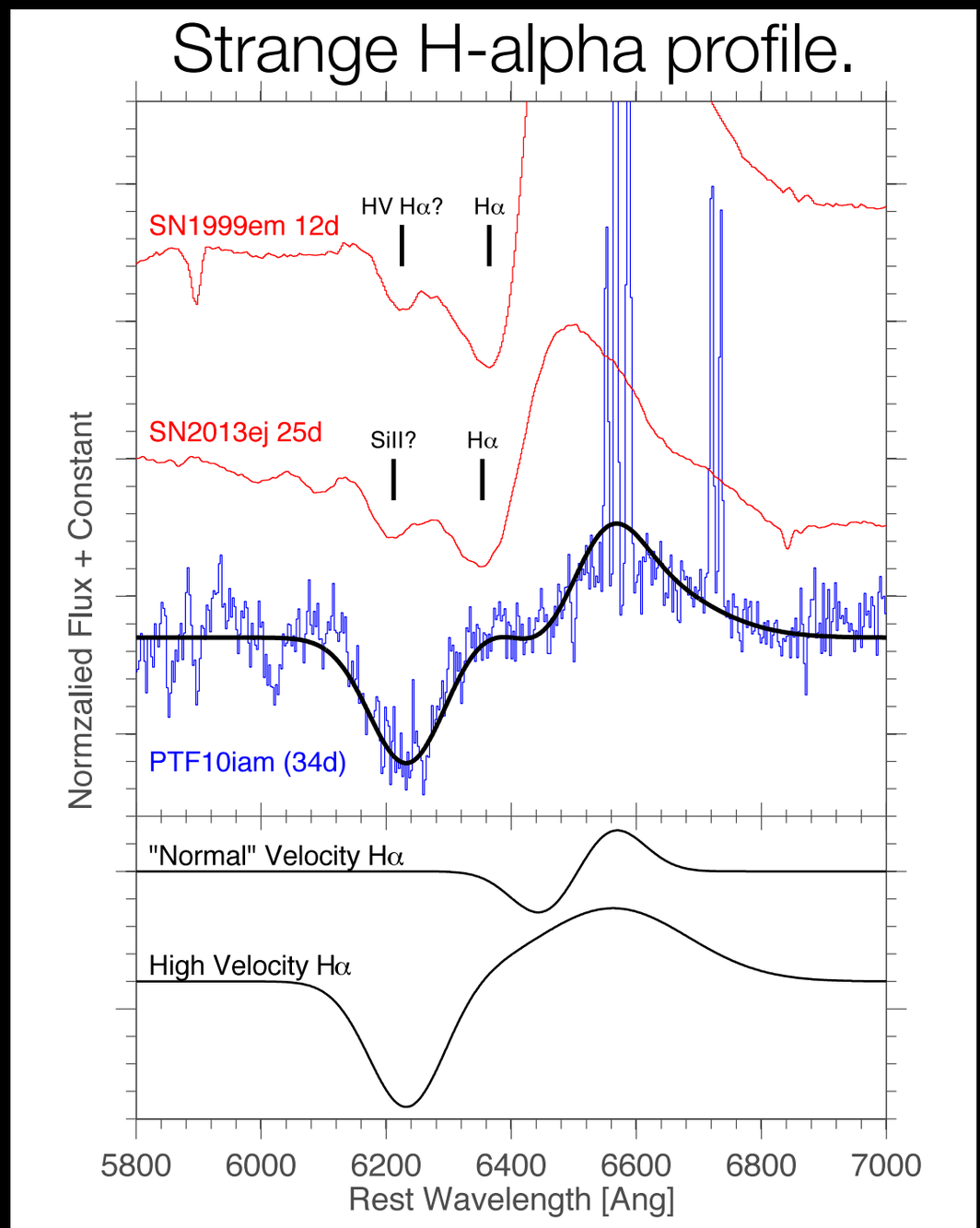
Iair Arcavi[1,2], William M. Wolf[3], D. Andrew Howell[2,3], Lars Bildsten[2], Avishay Gal-Yam[4], Boaz Katz[4], Daniel A. Perley[5,⋆], Curtis McCully[2,3], Stefano Valenti[2,3], Gilad Svirski[6], SNLS and PTF Builders?

[1]Las Cumbres Observatory Global Telescope, 6740 Cortona Dr, Suite 102, Goleta, CA 93111, USA iarcavi@lcogt.net
[2]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106, USA
[3]Department of Physics, University of California, Santa Barbara, CA 93106, USA
[4]Department of Particle Physics and Astrophysics, The Weizmann Institute of Science, Rehovot, 76100, Israel
[5]Department of Astronomy, California Institute of Technology, MC 249-17, 1200 East California Blvd, Pasadena, CA 91125, USA and
[6]Racah Institute for Physics, The Hebrew University, Jerusalem 91904, Israel

Draft version March 5, 2015



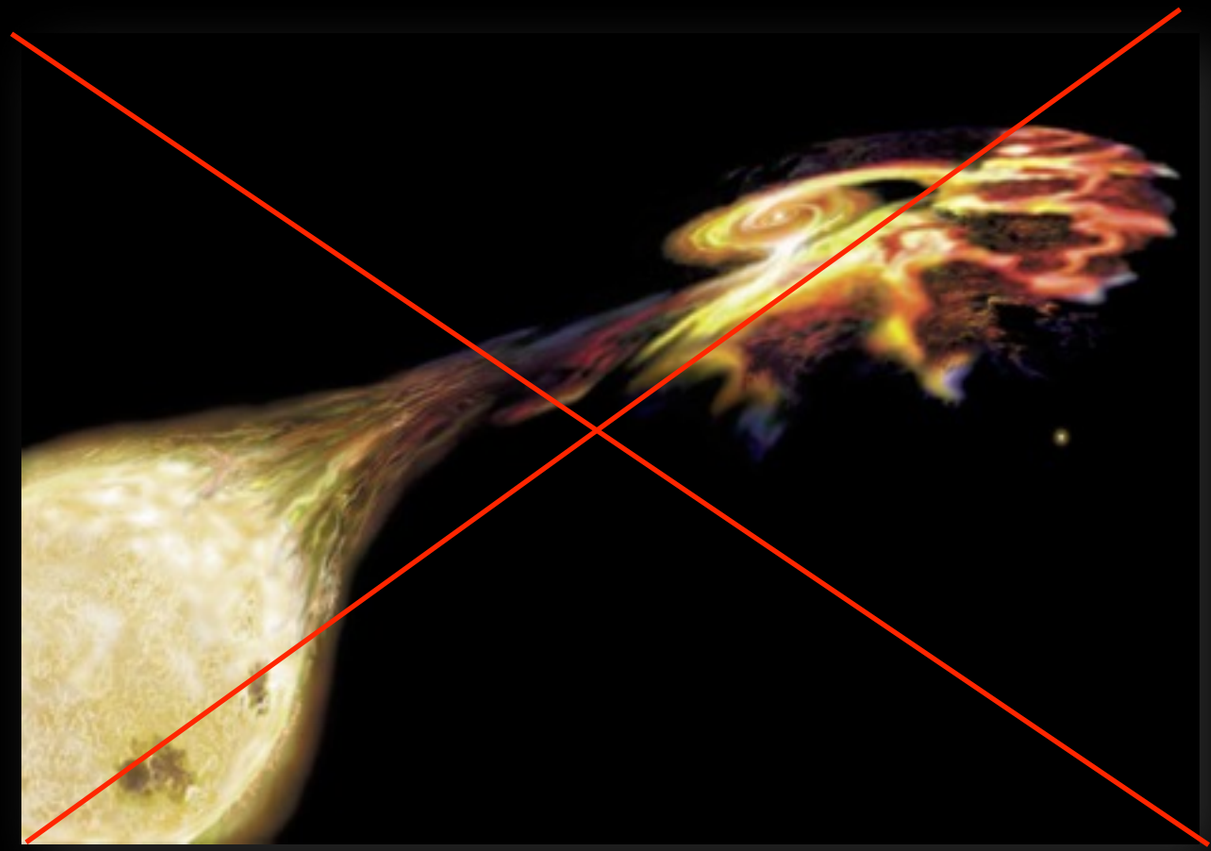
Three other fast-rising, intermediate luminosity events from SNLS without spectra.



Evidence against the single degenerate channel

No evidence for surviving companions in SN remnants (e.g. Schaefer & Pagnotta 2012)

SN Ia delay time distribution is proportional to t^{-1} (predicted from double degenerate model, inconsistent with SD model)



In most SNe, no circumstellar hydrogen is seen.

Some supernovae seem to require a progenitor of more than a Chandrasekhar mass (perhaps consistent with DD merger)

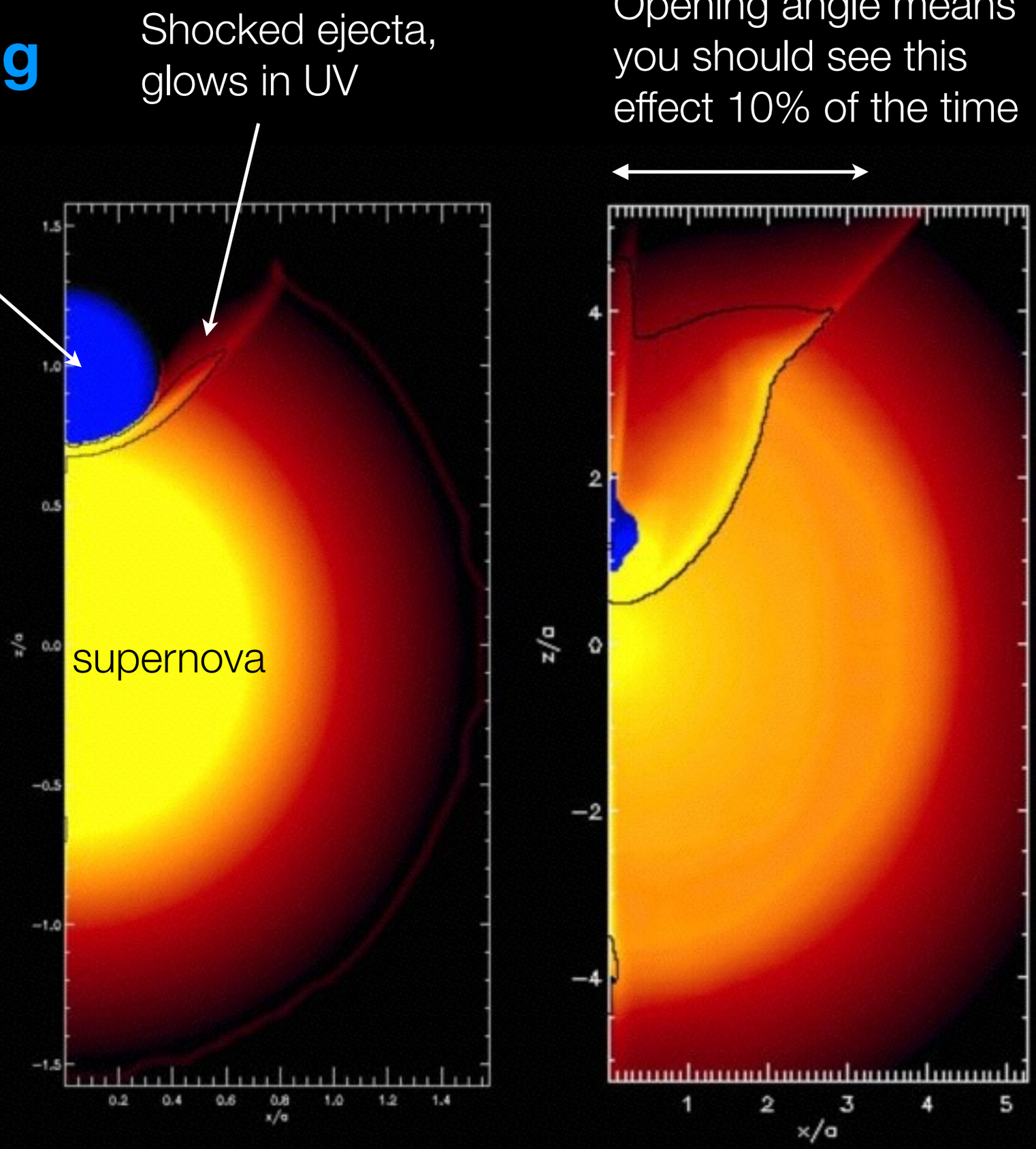
Searches for shocks from companion stars say < 20% of SNe have red giant companions.

Nearby SNe Ia SN 2011fe and SN 2014J have no evidence of SD compaion from HST preimaging, companion interaction, or circumstellar material.

Companion shocking

If a supernova hits a companion star, the ejecta will be shocked and glow in the UV and blue for a few days if seen from the right angle (Kasen 2010).

The supernova lightcurve should show a bump for a few days after explosion in the UV, B, and V bands, decreasing with wavelength.



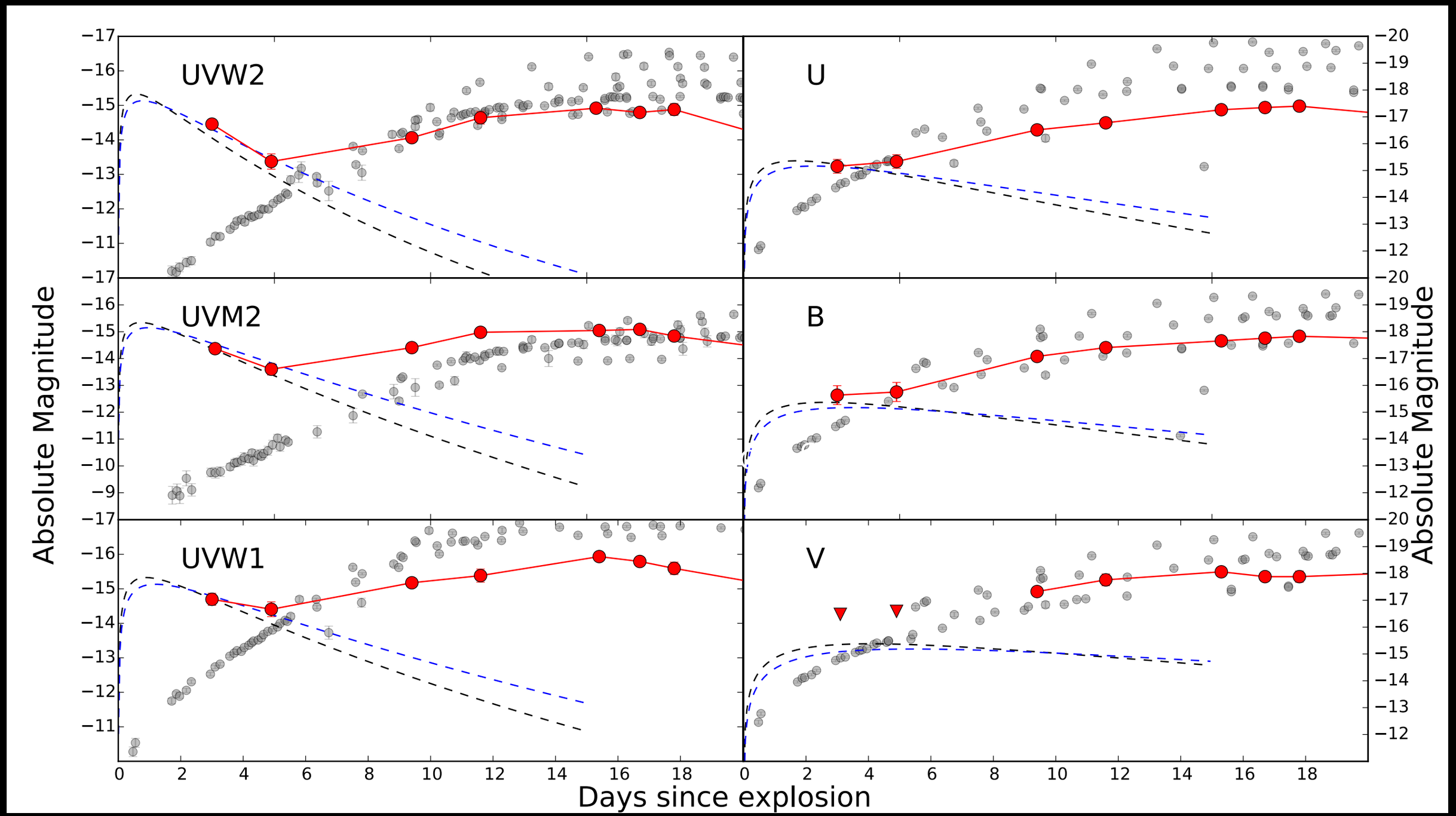
iPTF14atg

Nature, accepted

Ultraviolet Radiation from Supernova-Companion Collision in a Type Ia Supernova

Yi Cao[1], S. R. Kulkarni[1,2], D. Andrew Howell[3,4], Avishay Gal-Yam[5], Mansi M. Kasliwal[6], Stefano Valenti[3,4], J. Johansson[7], R. Amanullah[7], A. Goobar[7], J. Sollerman[8], F. Taddia[8], Assaf Horesh[5], Ilan Sagiv[5], S. Bradley Cenko[9], Peter E. Nugent[10], Iair Arcavi[3,11], Jason Surace[12], P. R. Woźniak[13], Daniela I. Moody[13], Umaa D. Rebbapragada[14], Brian D. Bue[14], Neil Gehrels[9]

Shocking in iPTF14atg: lightcurves



Cao et al. 2015

Red: data from Swift

Gray: data from other supernovae

Blue dashed: Expected effect from shocking hypothesis

welcome to

SNEx

the SupernovaExchange

insert object name or coordinates

SN2014ad SN Ic-BL z = 0.005

11:57:44.44 -10:10:15.7
179.435167 -10.171028

Known as:
PSN1157444
PSN1157
SN2014ad

Known to:
ANU
ASASSN
Boulder
CfA
Chase
China
CSP
ex-LCOGT
iPTF
LBNL
LCOGT
LSQ
OKC
Padova
PESSTO
PS1
PTF
Public
QUB
SAAO
Skymapper
UCB
UT
Grant to all sharing groups

Science Interests:
Well Sampled SNe Ic-BL

Object Comments

SV blue continuum, strange features, in close galaxy, spectrum taken from M. Childress

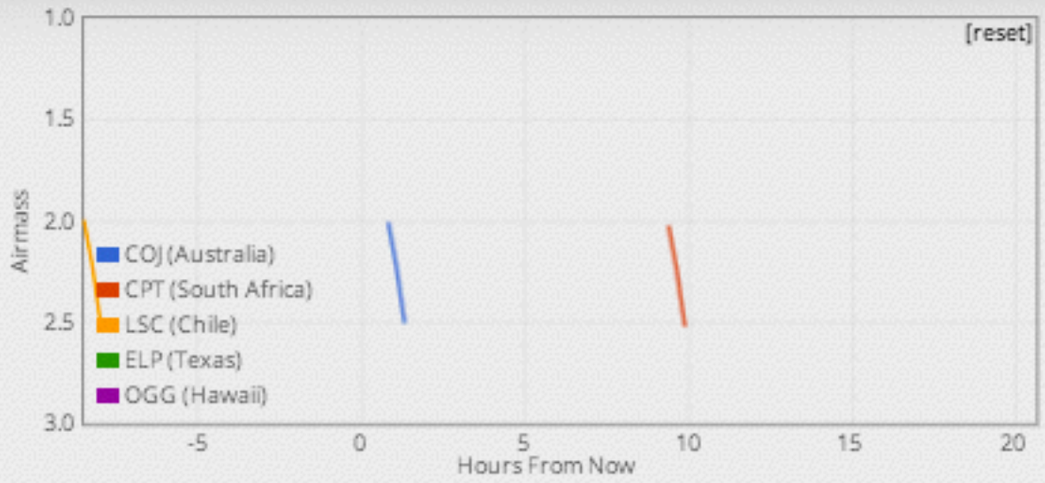
iair No recent data, trying to split observations
2014-03-25 00:00:00

dah We missed the peak. Should we still follow this?
2014-04-14 00:00:00 *Delete this comment*

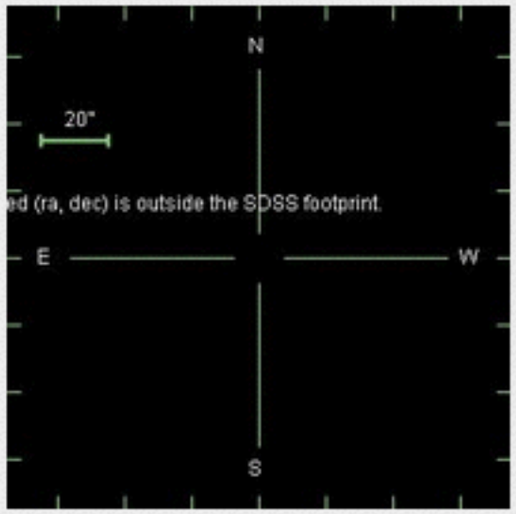
iair Yes, Ic-BL's are super rare, continuing followup. We can collaborate for peak data.
2014-04-14 00:00:00

Add a comment...

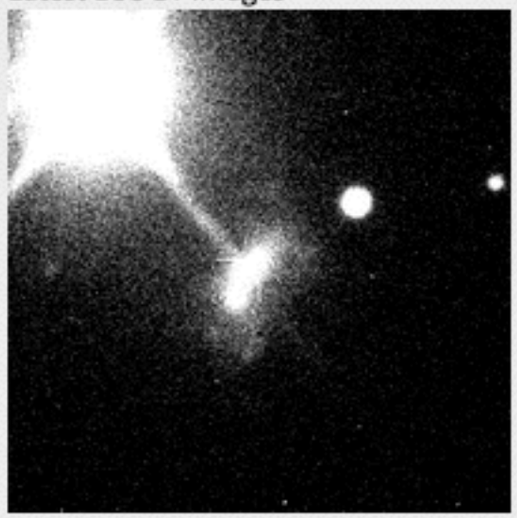
Current Visibility at LCOGT



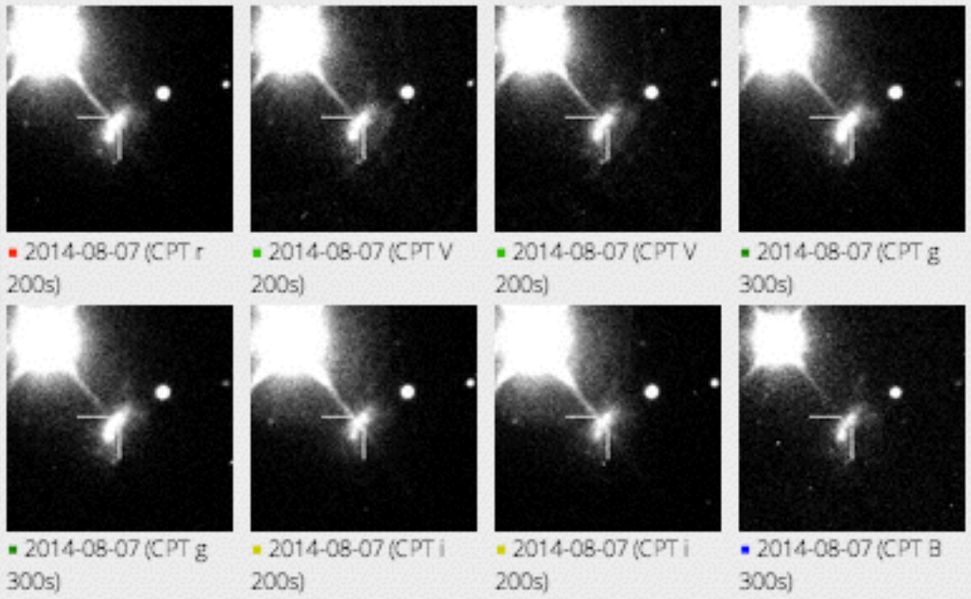
SDSS



Latest LCOGT Images

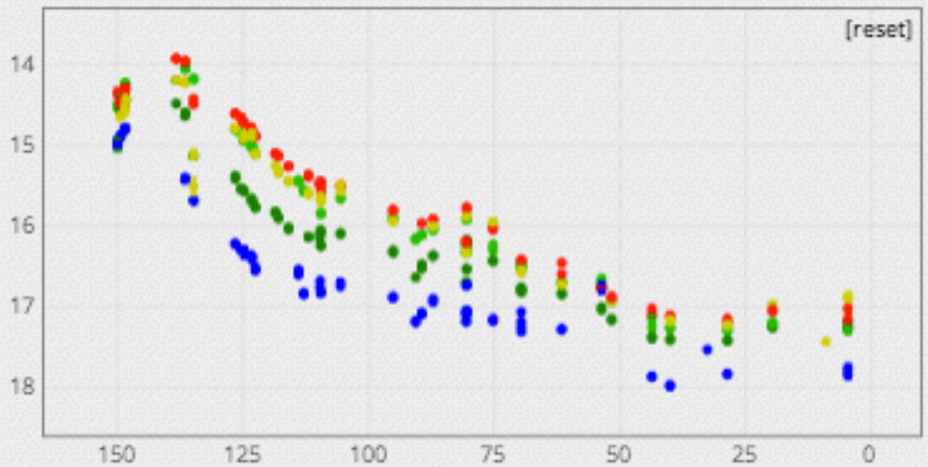


2014-08-07 (CPT r 200s)

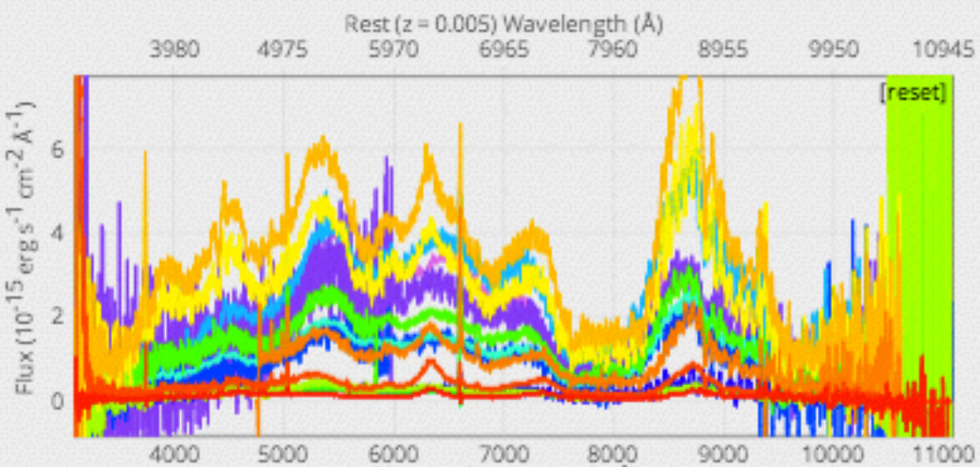


2014-08-07 (CPT r 200s)
2014-08-07 (CPT V 200s)
2014-08-07 (CPT V 200s)
2014-08-07 (CPT g 300s)
2014-08-07 (CPT g 300s)
2014-08-07 (CPT i 200s)
2014-08-07 (CPT i 200s)
2014-08-07 (CPT B 300s)

Calibrated Photometry Display instrumental photometry



Spectroscopy



SN2014ad SN Ic-BL z = 0.005

11:57:44.44 -10:10:15.7
179.435167 -10.171028

Known as:
PSN1157444
PSN1157
SN2014ad

Known to:
ANU
ASASSN
Boulder
CfA
Chase
China
CSP
ex-LCOGT
iPTF
LBNL
LCOGT
LSQ
OKC
Padova
PESSTO
PS1
PTF
Public
QUB
SAAO
Skymapper
UCB
UT
Grant to all sharing groups

Science Interests:
Well Sampled SNe Ic-BL

Submitted Sequences

Photometry: 3-day cadence of B (2x200s), V (2x120s), g (2x200s), r (2x120s), i (2x120s) starting 2014-05-08, ending 2014-06-03, using Sbig
iair: Lowering cadence

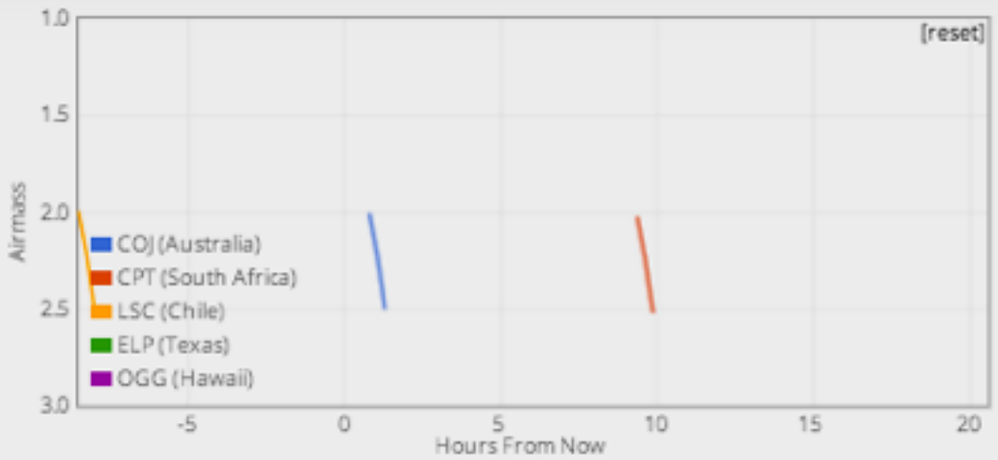
Spectroscopy: Single observation of 1800s starting 2014-05-08, ending 2014-05-09, using Floyds

Photometry: 7-day cadence of B (2x300s), V (2x200s), g (2x300s), r (2x200s), i (2x200s) starting 2014-06-03, ending 2014-08-05, using Sbig
SV: change airmass from 2 to 3

Spectroscopy: 7-day cadence of 3600s starting 2014-07-16 using Floyds (Tags: Well Sampled SNe Ic-BL)
Stop this sequence

Photometry: 7-day cadence of B (2x300s), V (2x200s), g (2x300s), r (2x200s), i (2x200s) starting 2014-08-05 using Sbig (Tags: Well Sampled SNe Ic-BL)
Stop this sequence

Current Visibility at LCOGT



Add a Photometric Sequence

	Exposure Time	No. of Exposures	Block No.
U	0	2	1
B	200	2	1
V	120	2	1
R	0	2	1
I	0	2	1
u	0	2	1
g	200	2	1
r	120	2	1
i	120	2	1
z	0	2	1

Science Tags
No tags selected +

Repeating every 3 days

Airmass Limit 2
Camera SBIG (1m)
Program SN Key Project
Priority Normal
Reminder in 7 days

Data granted to

ANU	iPTF	PTF
ASASSN	LBNL	Public
Boulder	LCOGT	QUB
CfA	LSQ	SAAO
Chase	OKC	Skymapper
China	Padova	UCB
CSP	PESSTO	UT
ex-LCOGT	PS1	
Grant to all sharing groups		

Pre-approved / urgent observations

Comments

Submit

Add a Spectroscopic Sequence

Once in the next 1 days

Exposure Time 1800
Airmass limit 2
Site Any
Program SN Key Project
Priority Normal
Reminder in 2 days

Science Tags
No tags selected +

Data granted to

ANU	iPTF	PTF
ASASSN	LBNL	Public
Boulder	LCOGT	QUB
CfA	LSQ	SAAO
Chase	OKC	Skymapper
China	Padova	UCB
CSP	PESSTO	UT
ex-LCOGT	PS1	
Grant to all sharing groups		

Pre-approved / urgent observations

Comments

Submit

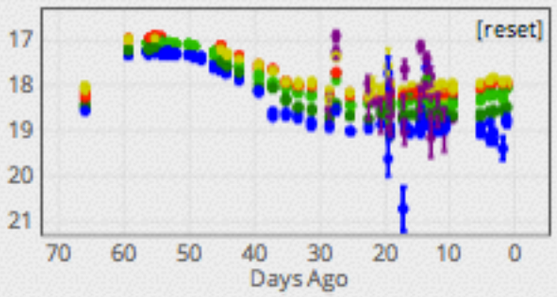
Scheduling

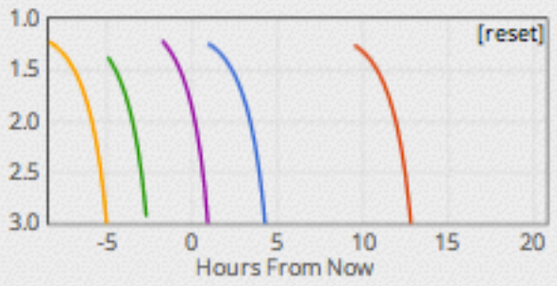
Pending Requests

Target	Type	Cadence	Priority	Instrument	Exposures	Start	End	Reminder	Tags & Comments

Expired/Current Reminders for Active Requests

Target	Type	Cadence	Priority	Instrument	Exposures	Start	End	Reminder	Tags & Comments
iPTF14aru SNHunt248	Phot	1d	None	Sinistro	B 2x200s V 2x120s g 2x200s r 2x120s i 2x120s	2014-06-28 03:37:42 by iair	Ongoing	2014-08-11 02:11:43	





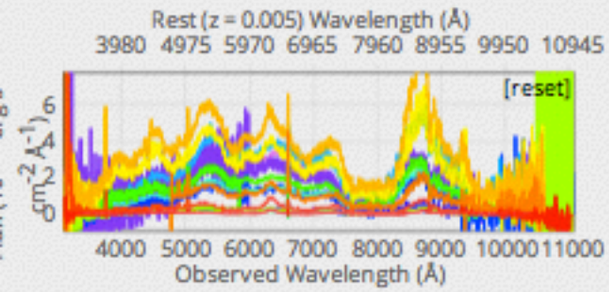
Stop Sequence

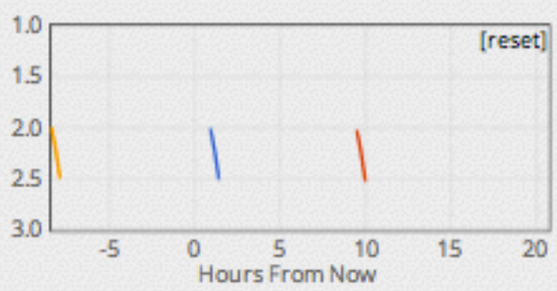
Continue Sequence As-Is

and display new reminder in 7 days

Modify Sequence

PSN1157 PSN1157444 SN2014ad	Spec	7d	None	Floyds	1x3600s	2014-07-16 00:18:34 by iair	Ongoing	2014-08-12 21:18:15	Tags: Well Sampled SNe Ic-BL





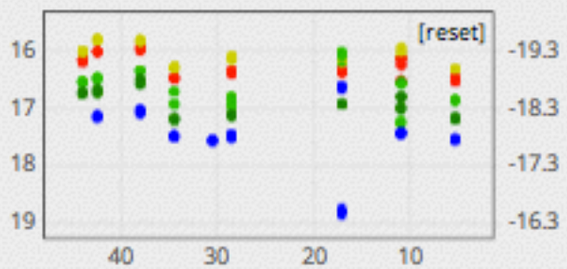
Stop Sequence

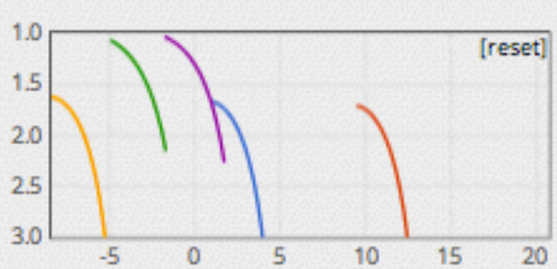
Continue Sequence As-Is

and display new reminder in 7 days

Modify Sequence

iPTF14bgw	Phot	5d	None	Sinistro	B 2x240s V 2x180s g 2x240s r 2x180s i 2x180s	2014-08-05 21:32:40 by SV	Ongoing	2014-08-12 21:32:40	Tags: SN II Plateau Lengths



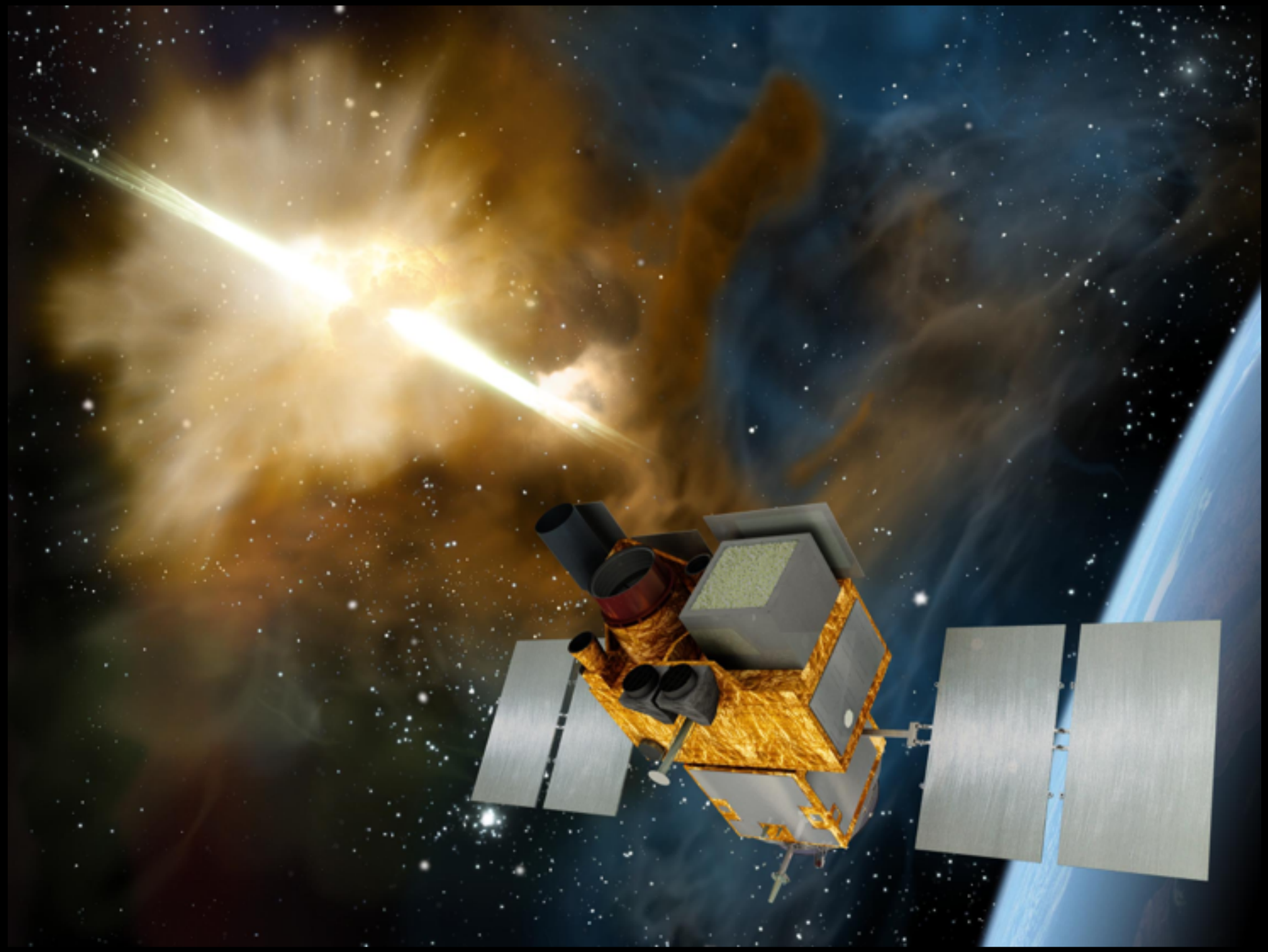


Stop Sequence

Continue Sequence As-Is

and display new reminder in 7 days

Modify Sequence



We are in talks with French colleagues to do ground-based optical follow-up for the French/Chinese SVOM GRB/X-ray satellite launching in 2021.

A (likely serendipitous) Detection of a Type IIn Supernova in Optical Follow-up Observations of IceCube Neutrino Events

IceCube Collaboration: M. G. Aartsen[1], M. Ackermann[2], J. Adams[3], J. A. Aguilar[4], M. Ahlers[5], M. Ahrens[6], D. Altmann[7], T. Anderson[8], C. Arguelles[5], T. C. Arlen[8], J. Auffenberg[9], X. Bai[10], S. W. Barwick[11], V. Baum[12], R. Bay[13], J. J. Beatty[14,15], J. Becker Tjus[16], K.-H. Becker[17], S. BenZvi[5], P. Berghaus[2], D. Berley[18], E. Bernardini[2], A. Bernhard[19], D. Z. Besson[20], G. Binder[21,13], D. Bindig[17], M. Bissok[9], E. Blaufuss[18], J. Blumenthal[9], D. J. Boersma[22], C. Bohm[6], F. Bos[16], D. Bose[23], S. Böser[24], O. Botner[22], L. Brayeur[25], H.-P. Bretz[2], A. M. Brown[3], N. Buzinsky[26], J. Casey[27], M. Casier[25], E. Cheung[18], D. Chirkin[5], A. Christov[4], B. Christy[18], K. Clark[28], L. Classen[7], F. Clevermann[29], S. Coenders[19], D. F. Cowen[8,30], A. H. Cruz Silva[2], J. Daughhetee[27], J. C. Davis[14], M. Day[5], J. P. A. M. de André[8], C. De Clercq[25], S. De Ridder[31], P. Desiati[5], K. D. de Vries[25], M. de With[32], T. DeYoung[33], J. C. Díaz-Vélez[5], M. Dunkman[8], R. Eagan[8], B. Eberhardt[12], B. Eichmann[16], J. Eisch[5], S. Euler[22], P. A. Evenson[34], O. Fadiran[5], A. R. Fazely[35], A. Fedynitch[16], J. Feintzeig[5], J. Felde[18], K. Filimonov[13], C. Finley[6], T. Fischer-Wasels[17], S. Flis[6], A. Franckowiak[24], K. Frantzen[29], T. Fuchs[29], T. K. Gaisser[34], R. Gaior[36], J. Gallagher[37], L. Gerhardt[21,13], D. Gier[9], L. Gladstone[5], T. Glüsenkamp[2], A. Goldschmidt[21], G. Golup[25], J. G. Gonzalez[34], J. A. Goodman[18], D. Góra[2], D. Grant[26], P. Gretskov[9], J. C. Groh[8], A. Groß[19], C. Ha[21,13], C. Haack[9], A. Haj Ismail[31], P. Hallen[9], A. Hallgren[22], F. Halzen[5], K. Hanson[38], D. Hebecker[24], D. Heereman[38], D. Heinen[9], K. Helbing[17], R. Hellauer[18], D. Hellwig[9], S. Hickford[17], G. C. Hill[1], K. D. Hoffman[18], R. Hoffmann[17], A. Homeier[24], K. Hoshina[5,39], F. Huang[8], W. Huelsnitz[18], P. O. Hulth[6], K. Hultqvist[6], S. Hussain[34], A. Ishihara[36], E. Jacobi[2], J. Jacobsen[5], G. S. Japaridze[40], K. Jero[5], O. Jlelati[31], M. Jurkovic[19], B. Kaminsky[2], A. Kappes[7], T. Karg[2], A. Karle[5], M. Kauer[5], A. Keivani[8], J. L. Kelley[5], A. Kheirandish[5], J. Kiryluk[41], J. Kläs[17], S. R. Klein[21,13], J.-H. Köhne[29], G. Kohnen[42], H. Kolanoski[32], A. Koob[9], L. Köpke[12], C. Kopper[26], S. Kopper[17]

The LCOGT SN group is also involved in LIGO/VIRGO and Fast Radio Burst follow-up programs

For more see **Brown et al. 2013**

Las Cumbres Observatory Global Telescope Network

Brown, T.M., Baliber, N.[1], Bianco, F.B.[2], Bowman, M., Burleson, B., Conway, P., Crellin, M., Depagne, É.[3], De Vera, J., Dilday, B., Dragomir, D., Dubberley, M.[4], Eastman, J.D., Elphick, M., Falarski, M., Foale, S., Ford, M., Fulton, B.J.[5], Garza, J., Gomez, E.L., Graham, M., Greene, R., Haldeman, B., Hawkins, E., Haworth, B., Haynes, R., Hidas, M., Hjelstrom, A.E., Howell, D.A., Hygelund, J., Lister, T.A., Lobdill, R., Martinez, J., Mullins, D.S., Norbury, M., Parrent, J., Paulson, R., Petry, D.L., Pickles, A., Posner, V., Rosing, W.E., Ross, R., Sand, D.J.[6], Saunders, E.S., Shobbrook, J., Shporer, A.[7], Street, R.A., Thomas, D., Tsapras, Y., Tufts, J.R., Valenti, S., Vander Horst, K., Walker, Z., White, G., Willis, M.

Las Cumbres Observatory Global Telescope Network, 6740 Cortona Dr. Suite 102, Goleta, CA 93117, USA