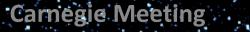
The All-Sky Automated Survey for SuperNovae (ASAS SN or "Assassin")

Benjamin J. Shappee

University of Hawai'i









ASAS SA Approach:

- Monitors the entire sky every 20 hours in real-time
- g-band limiting magnitude ≈ 18.5
- Use commercially available Telephoto lenses and CCDs
- Find supernovae in a minimally biased search
- Announce discoveries **publicly**

ASAS SN Is a Global Partnership

CASSACA

FCAPF

AARHUS UNIVERSITY

NÚCLEO DE

ULTAD DE INGENIERÍA

os Alamos

LIVERPOOL

ORES

PEKING

(University of Hawaii) C. S. Kochanek, K. Z. Stanek, T. A. Thompson, J. F. Beacom, J. Brown, T. Jayasinghe, G. Simonian P. Vallely, Josh Shields (Ohio State) T. W.-S. Holoien (Carnegie Observatories) J. L. Prieto (Diego Portales), D. Bersier (LJMU) Subo Dong, Ping Chen, S. Bose (KIAA-PKU) M. Stritzinger, Simon Holmbo (Aarhus University) L. Chomiuk, J. Strader (Michigan State) Anna Franckowiak (DESY); Katie Auchettl (DARK) Ondřej Pejcha, Michał Pawlak (Charles University) Xinu Dai (University of Oklahoma); David Martinez-Delgado (Heidelberg); P. R. Wozniak (LANL), E. Falco (CfA) N. Morrell (Carnegie Observatories) J. Brimacombe (Coral Towers Observatory) G. Pojmanski (Warsaw University)

B. J. Shappee, M. Tucker, A. Payne, A, Do, K. Hart

MOORE ASAS SN



CASSACA

Late-2019



PEKING UNIVERSITY





CAPP



ASAS SA units

- 4 telescopes per mount
- 14cm lens, 2k × 2k thinned CCDs
 - 4.47 × 4.47 degree field-of-view
 - 7.8" pixel scale
 - g-band filters
 - limiting magnitude ≈ 18.5
 - ≈6500 images per night
 - 40,000 square degrees per night



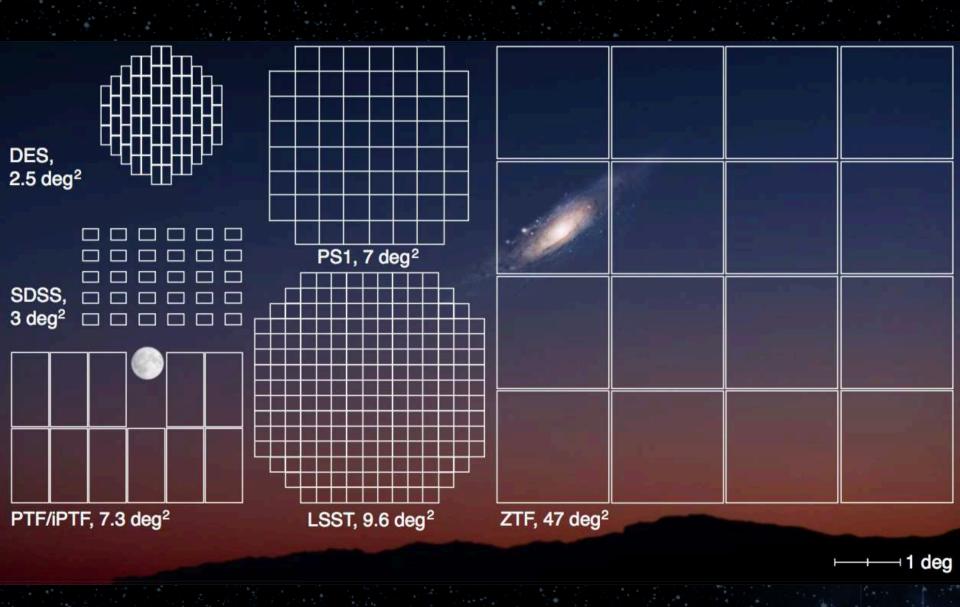
Picture Courtesy of Jon De Vera

ASAS SN "Tian Shan"

- 6th unit by the end of 2019
- 4 more telescopes
- Nanshan Station of Xinjiang Astronomical Observatory
 - Funds from Peking University using the government funding "Double First Class University Plan"



Pictures Courtesy of Xinjiang Astronomical Observatory and wikicommons





ASAS SN DES, 2.5 deg² PS1, 7 deg² 2 SDSS, PTF/iPTF, 7.3 deg² LSST, 9.6 deg²

4 cameras per unit = 80 deg^2

Currently 5 units = 400 deg^2 DES, 2.5 deg² PS1, 7 deg² SDSS, _____ 3 dea² ی و و و و و و و و ZTF, 47 deg² PTF/iPTF, 7.3 deg² LSST, 9.6 deg² i deg

Follow-up Facilities

- UH88
- Keck

 \bullet

- LCOGT 1 meters
- Magellan 2 x 6.5 meter
- LBT 2 x 8.4 meter
- Du Pont 2.5 meter
- MDM 2.4 meter
- Liverpool Telescope 2 meter
- Swift satellite
- many others (SALT, FLWO 1.5m, NOT 2.5m, Faulkes, HST, Chandra, VLA ...)



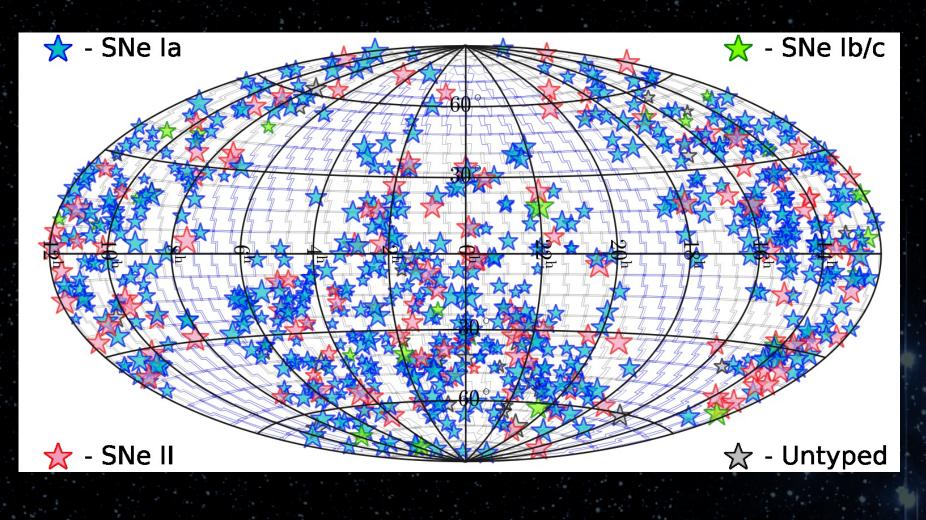




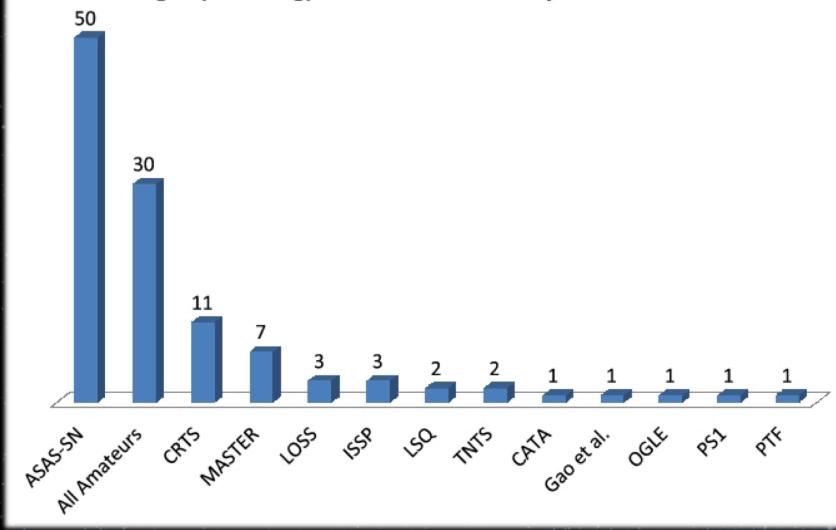


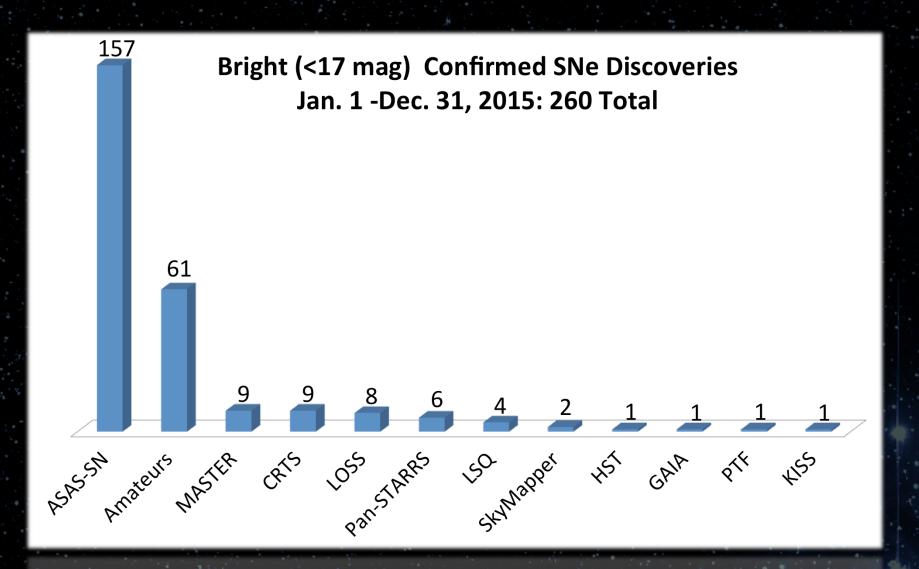
ASAS SN Supernovae Discoveries

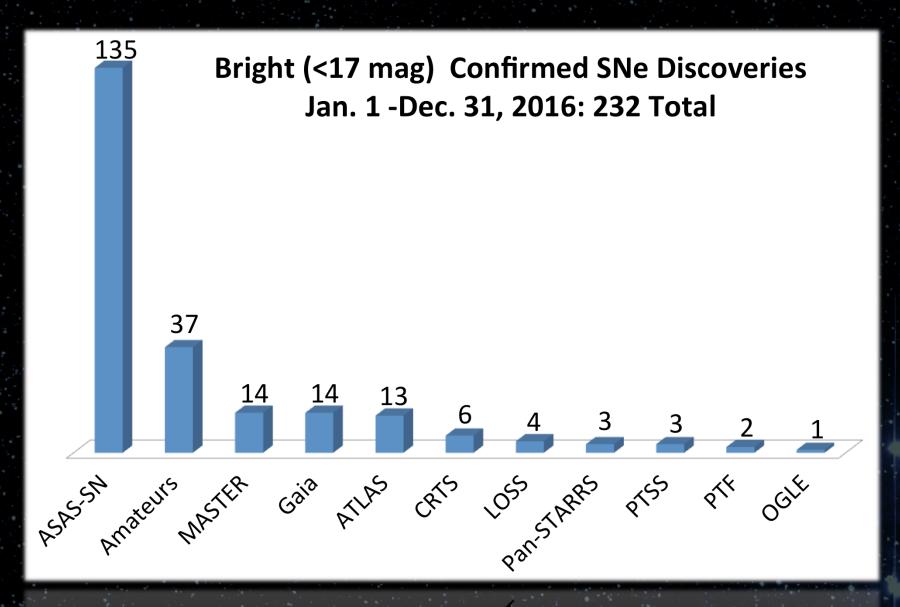
800+ Supernovae

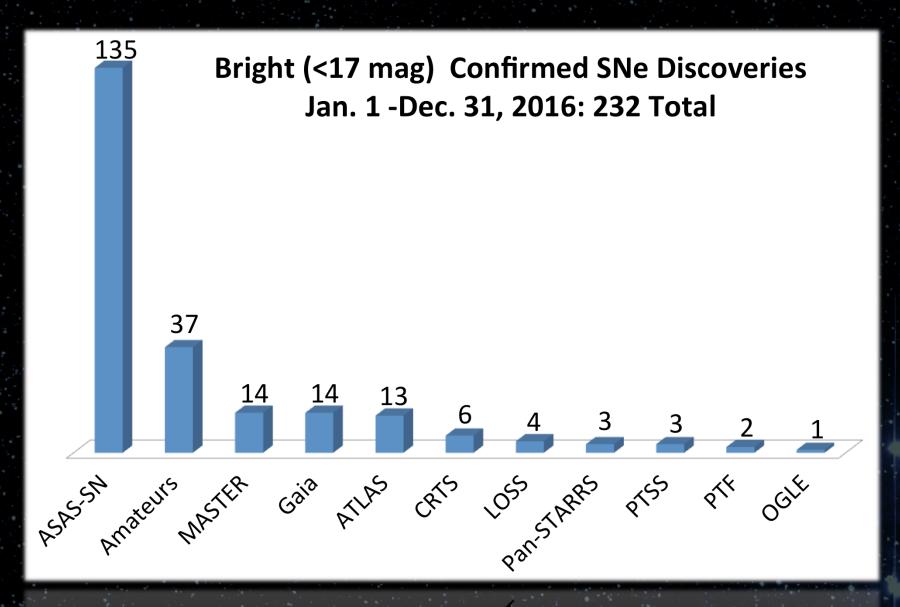


Bright (<17 Mag) SNe Discoveries May 1 - Nov. 1, 2014



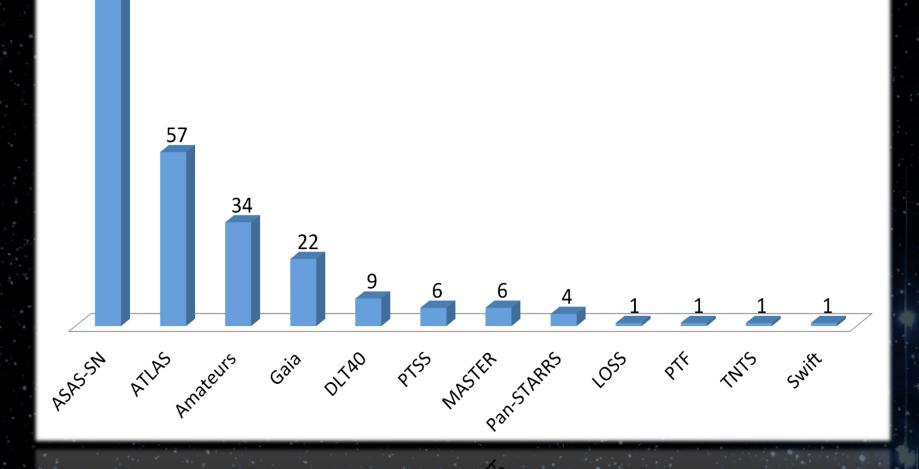


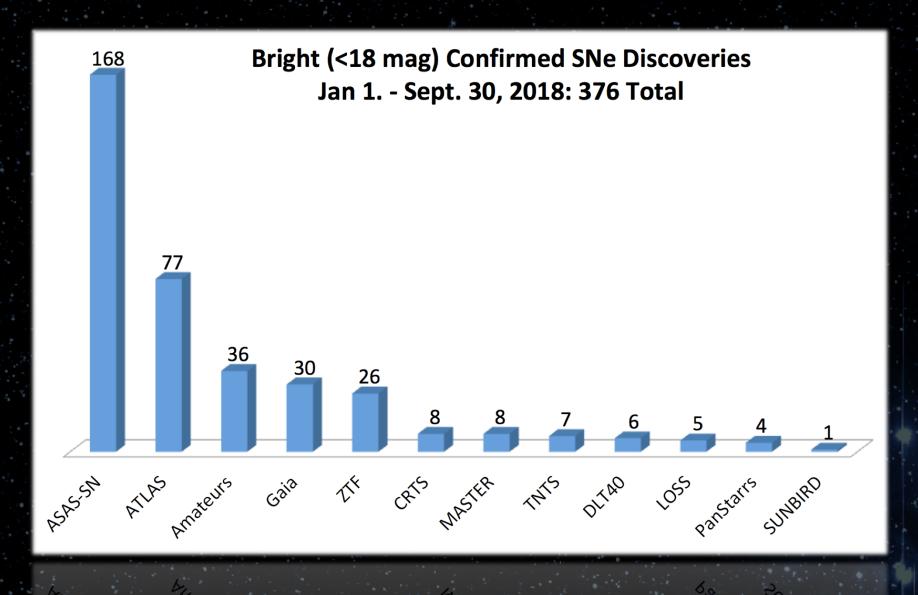




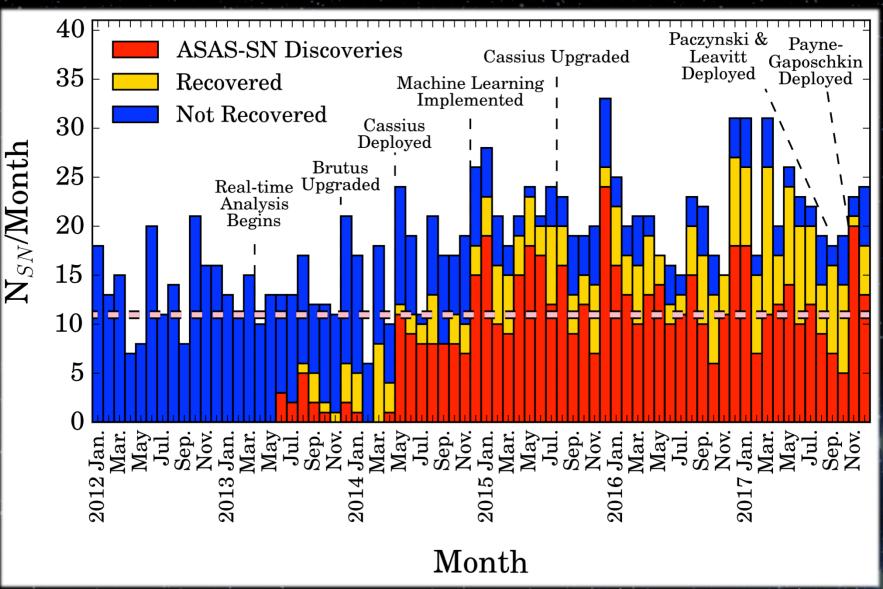
134

Bright (<17 mag) Confirmed SNe Discoveries Jan 1. - Dec 31, 2017: 276 Total



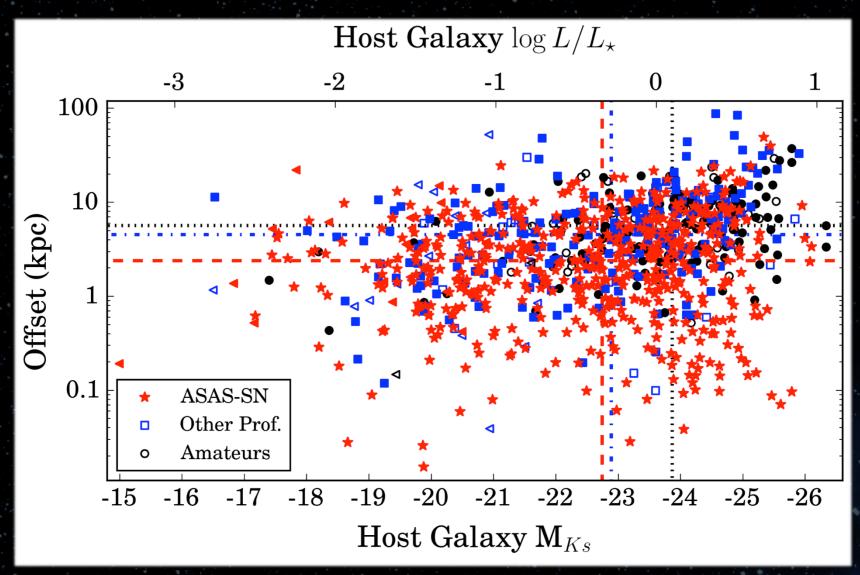


We are more complete, unbiased.



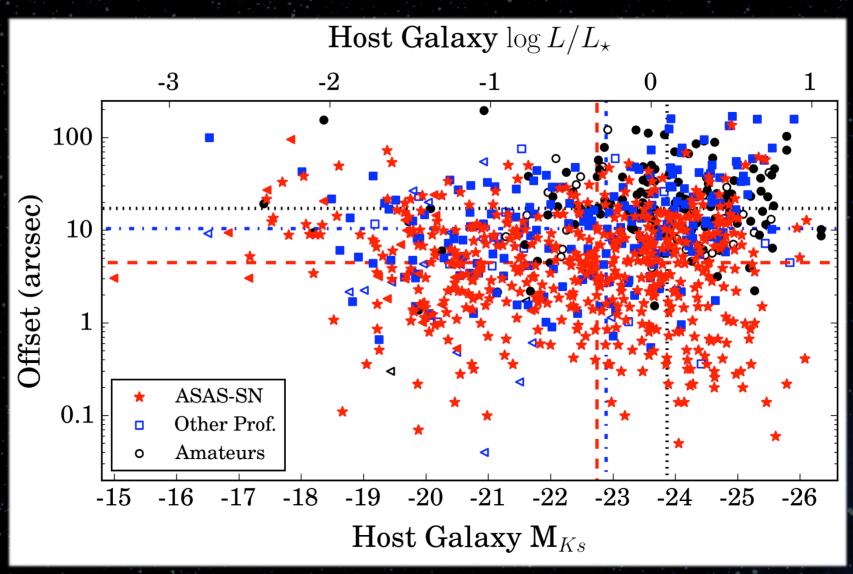
Holoien et al. (incl. Shappee) 2017b

The first unbiased supernova sample



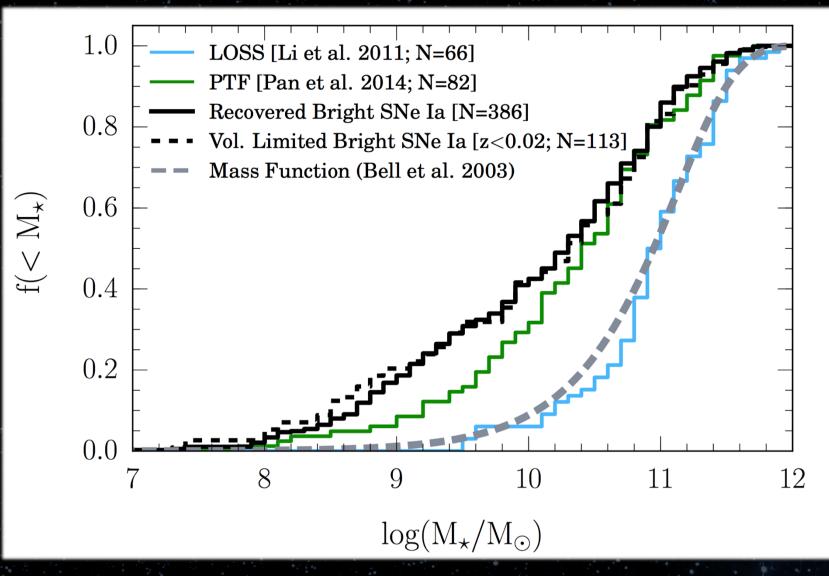
Holoien et al. (incl. Shappee) 2018c

The first unbiased supernova sample



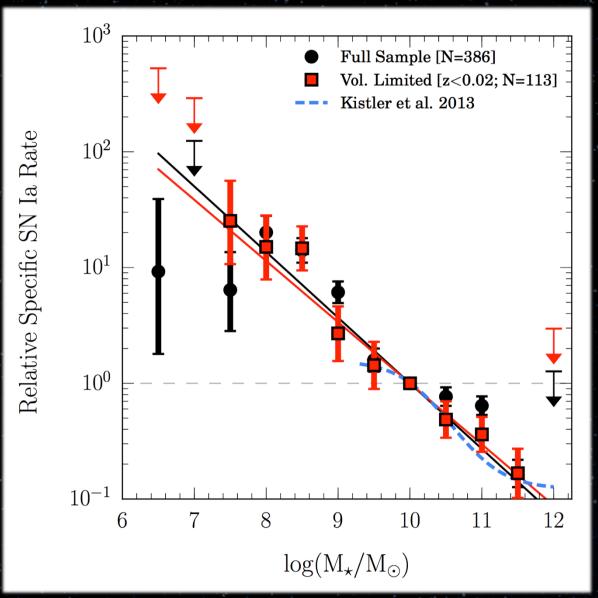
Holoien et al. (incl. Shappee) 2018c

Unbiased rate measurement



Brown et al. (incl. Shappee) 2018

Unbiased rate measurement



Brown et al. (incl. Shappee) 2018

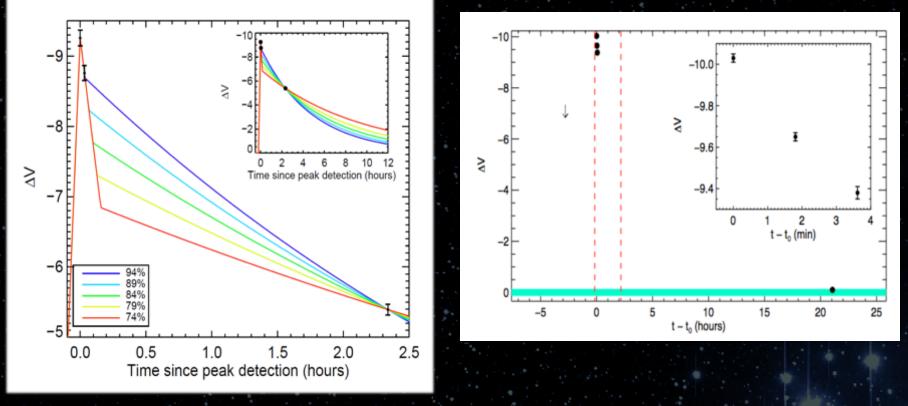
Other science highlights so far

50+ publications, 750+ ATels, 1000+ new cataclysmic variable, novae search, 2 comets, and growing.

Dramatic Stellar Flares in ASAS SN

ASASSN-13cb

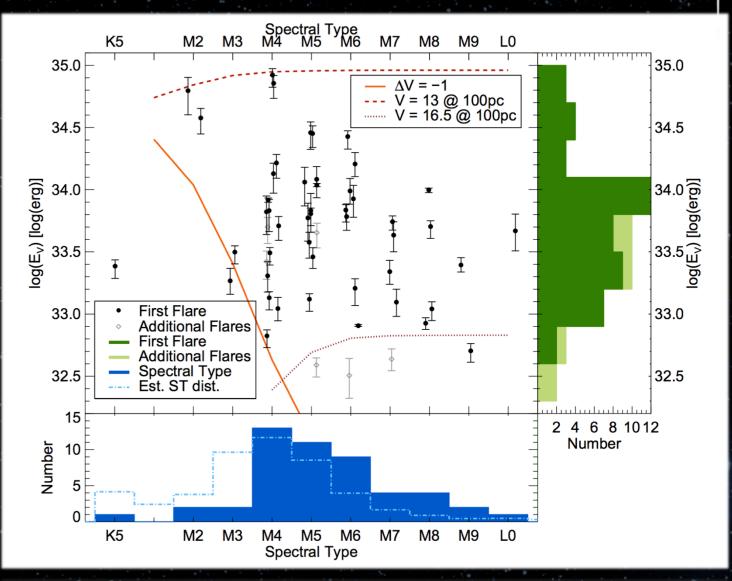
ASASSN-16ae



Schmidt et al. (incl. Shappee) 2016

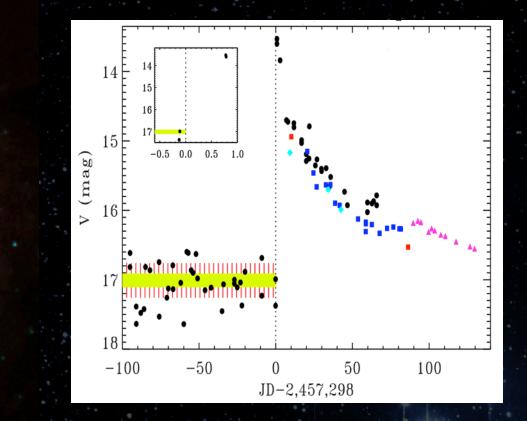
Schmidt, Shappee et al. 2016

Dramatic Stellar Flares in ASAS SN



Schmidt, Shappee et al. 2018

Outbursts from Young Stellar Objects

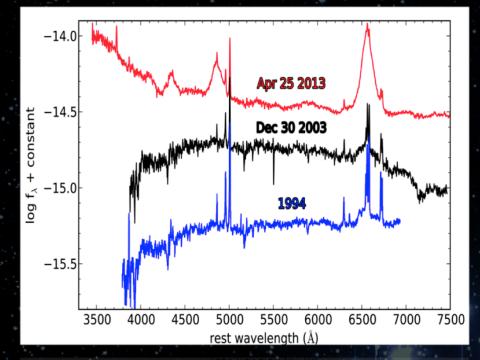


ASASSN-15qi Herczeg et al. (incl. Shappee) 2016

Ε

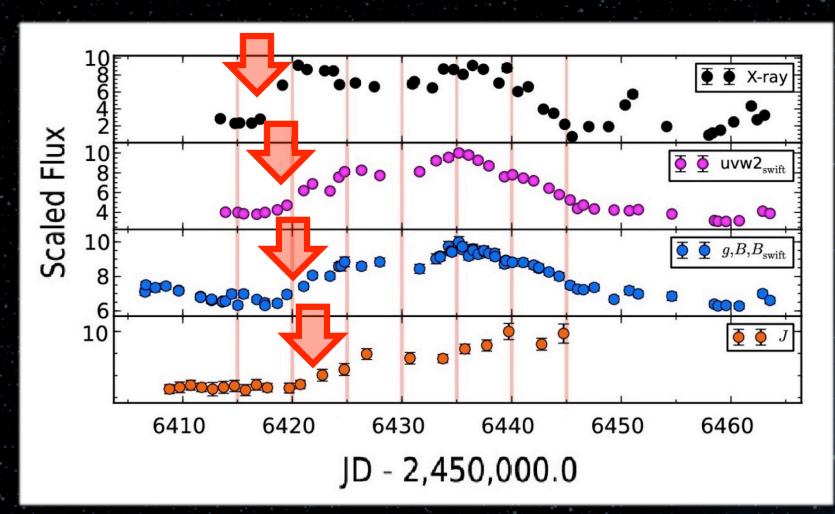
"Changing look" AGN: NGC 2617

- ASAS-SN triggered on a 10% increase in flux from AGN + host
- Follow-up imaging showed AGN continued to brighten by 1.3 mag
- Follow-up spectroscopy showed that the AGN changed from a Seyfert type 1.8 to 1.0



Shappee et al. 2014

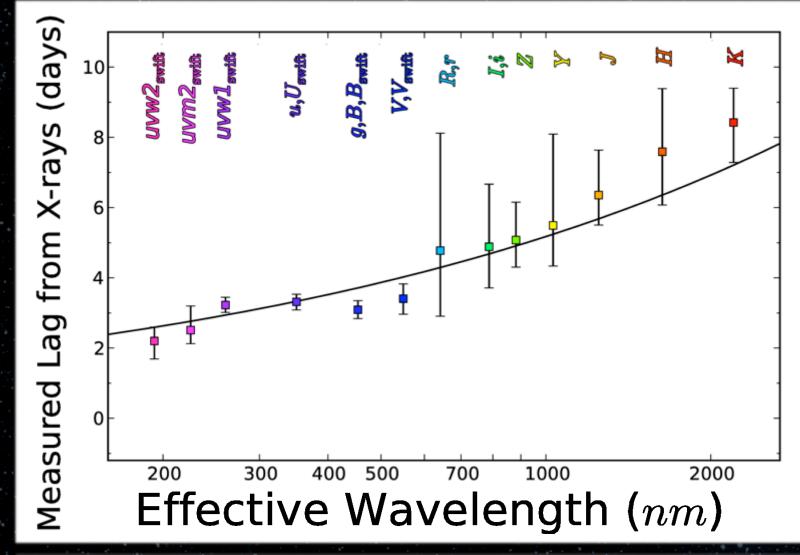
NGC 2617 X-ray–NIR light curves



450,000.0

Shappee et al. 2014

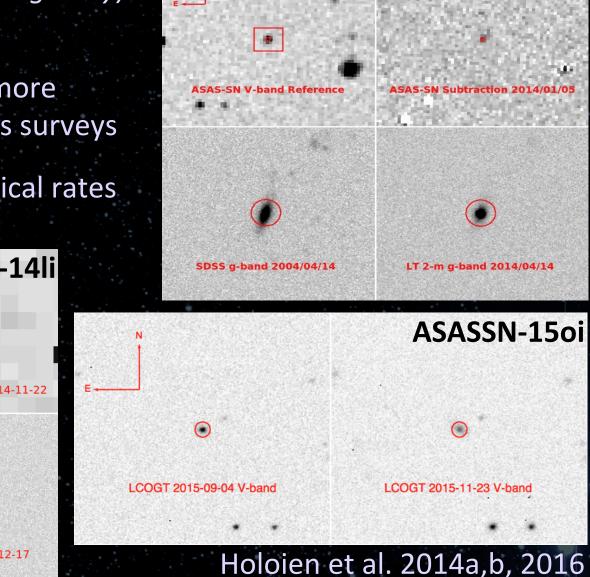
NGC 2617 Photometric Lags



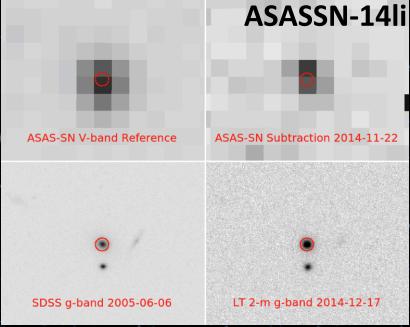
Shappee et al. 2014

Tidal Disruption Events in ASAS SN

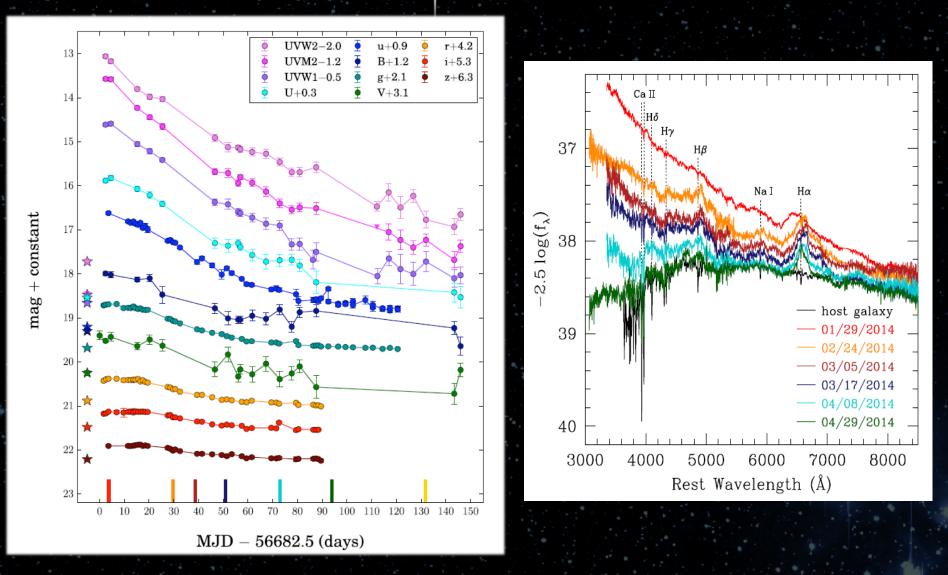
- 7 of the brightest and (arguably) best-studied
- ASAS-SN seems to be more complete than previous surveys
- Rates closer to theoretical rates



ASASSN-14ae

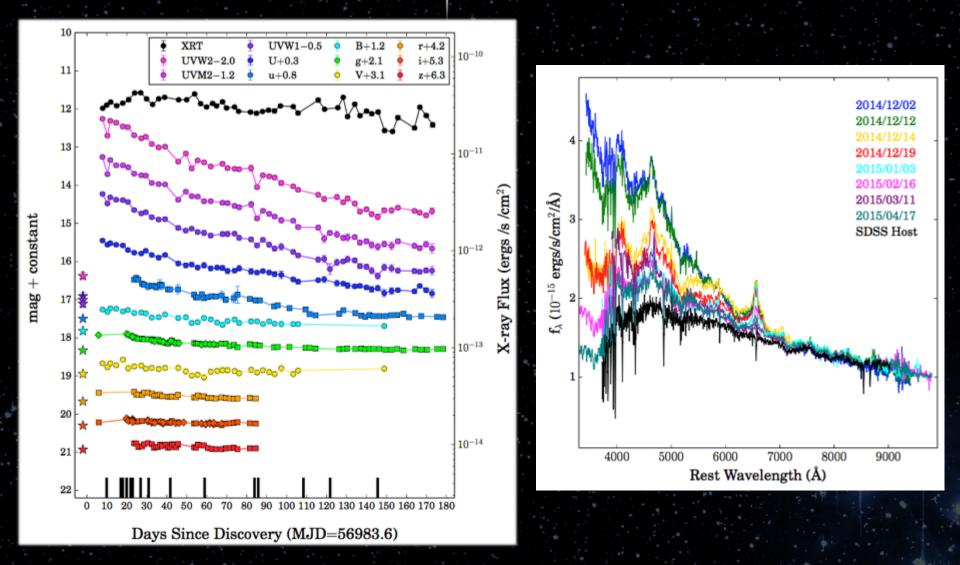






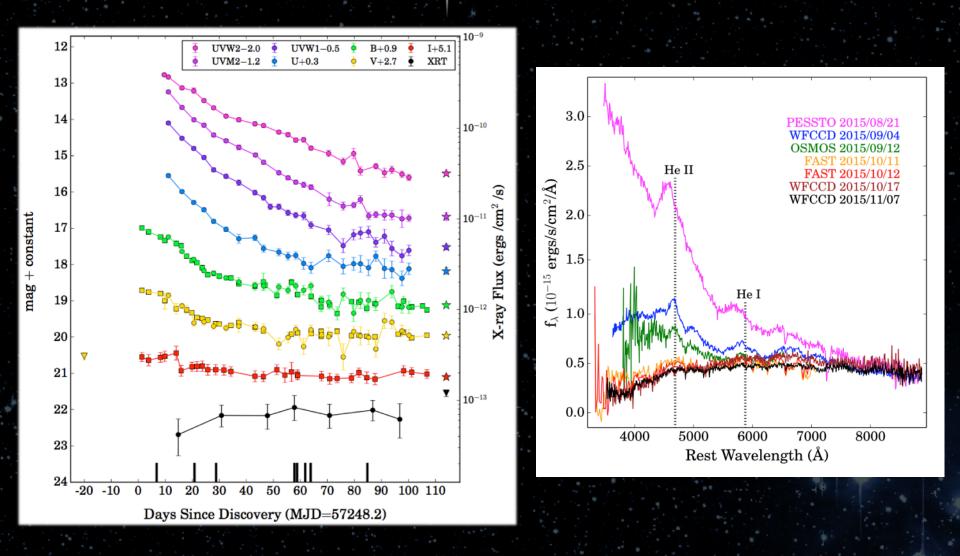
Holoien et al. (incl. Shappee) 2014b

ASAS SN -14li



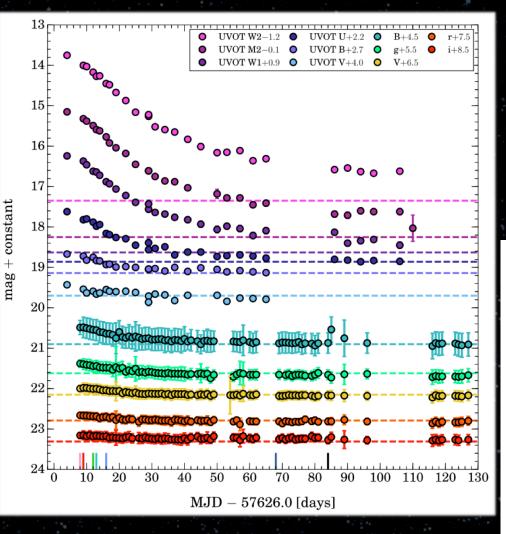
Holoien et al. (incl. Shappee) 2016

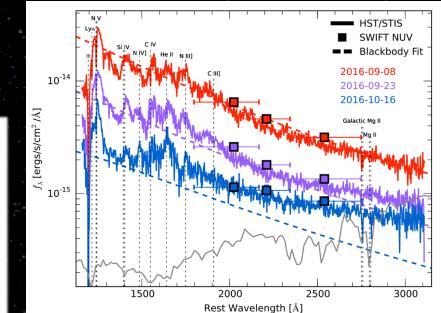
ASAS SN-150i

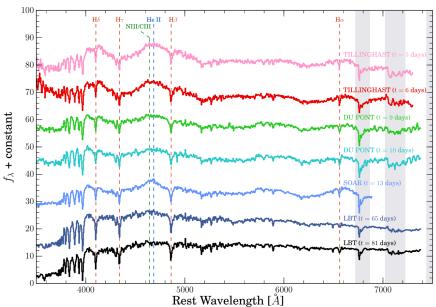


Holoien et al. (incl. Shappee) 2016b

iPTF 16fnl

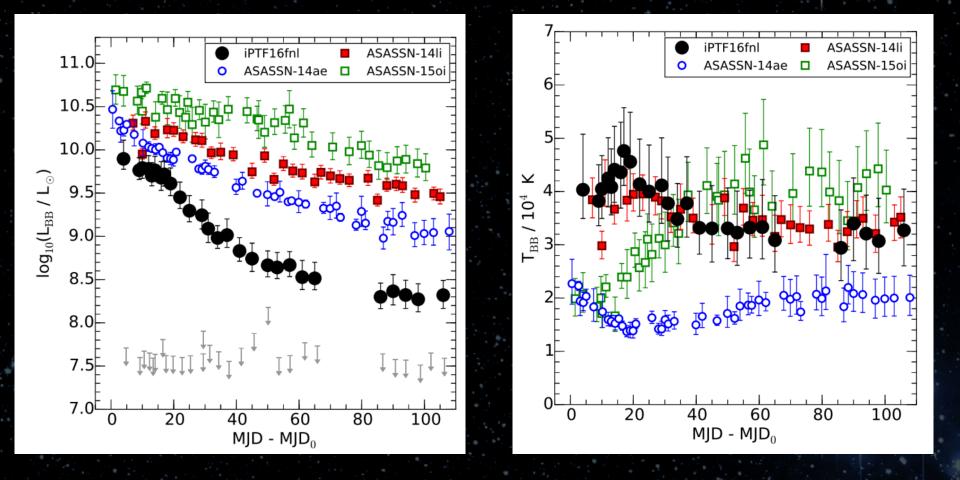






Brown et al. (incl. Shappee) 2017

Tidal Disruption Events in ASAS SN

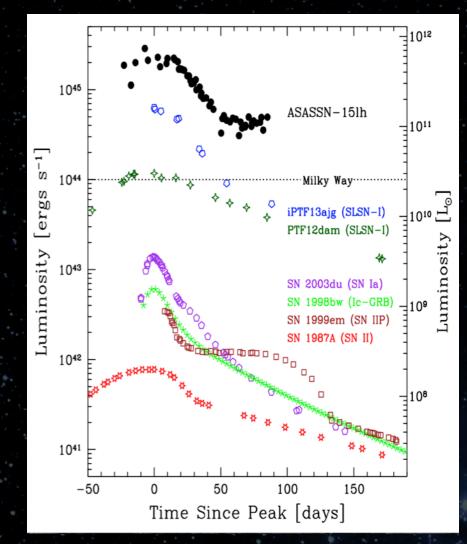


Brown et al. (incl. Shappee) 2017

The most luminous supernova(?)

• Nuclear transient, massive host

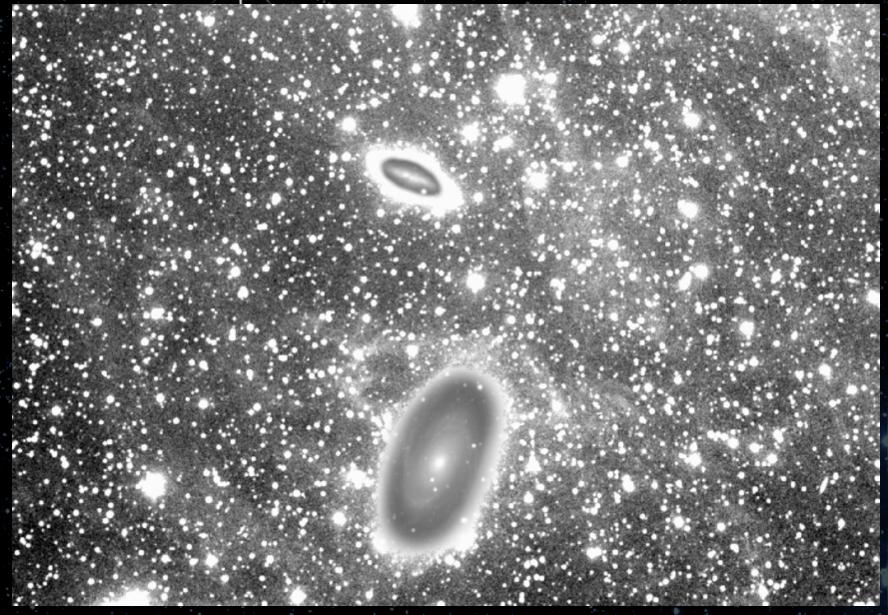
- The most luminous SN ever discovered? Dong, Shappee, Prieto et al. 2016
- Magnetar powered supernova? (most energy possible?) Metzger et al. 2015
- TDE like no other? Leloudas et al. 2016
- Extreme events challenge all models, unbiased survey



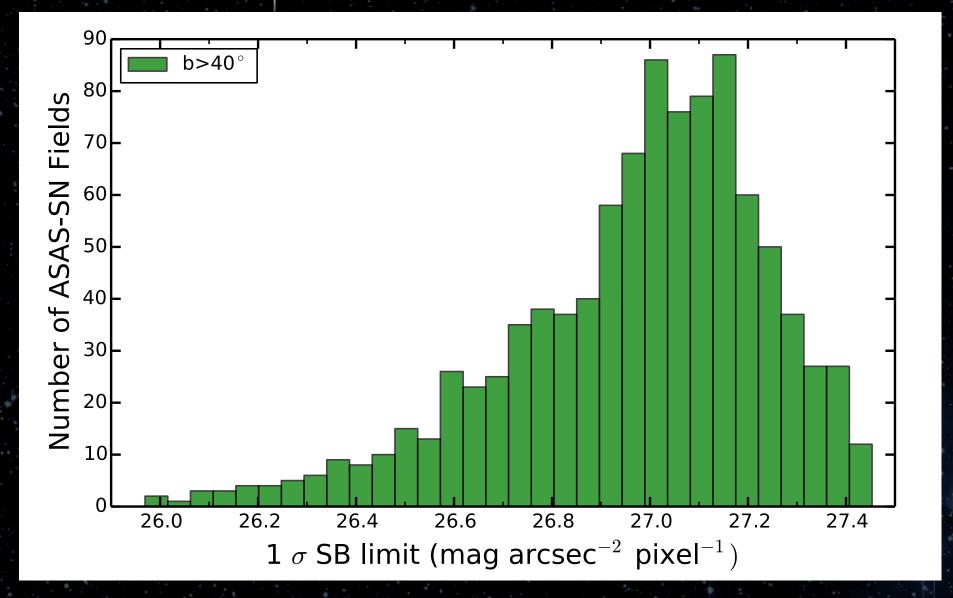
Dong, Shappee et al. 2016

New science with ASAS SN !

ASAS SN: Low Surface Brightness



ASAS SN: Low Surface Brightness

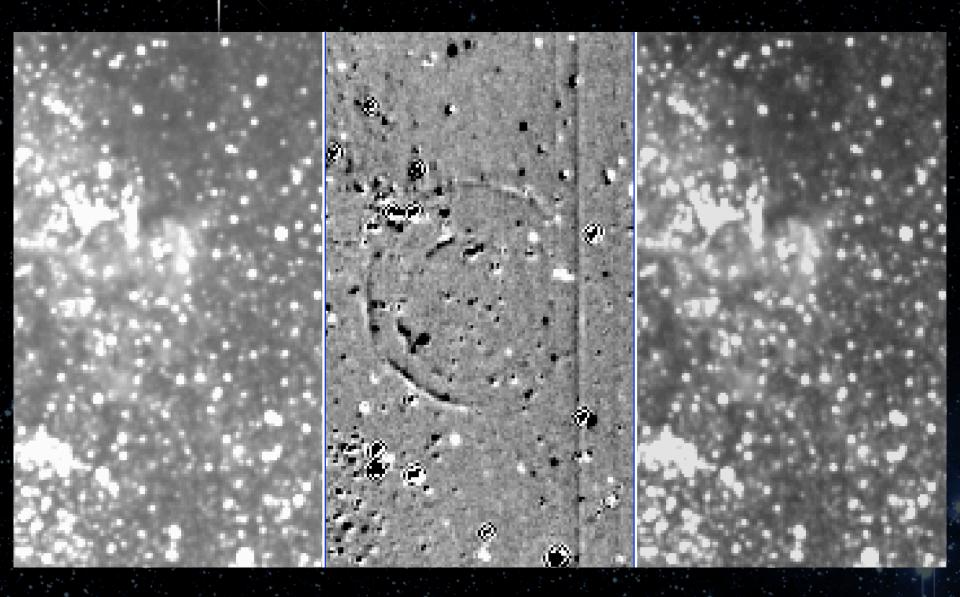


Light echoes, Time machines.

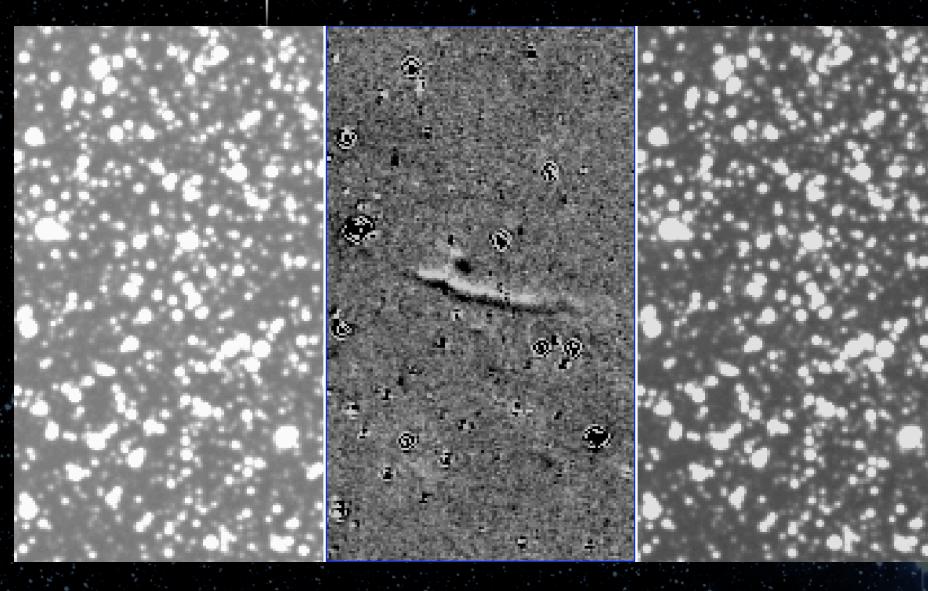
				Distance		Search Area
SN Name	RA	Dec	Date	(kpc)	Туре	(square deg)
Cas A	23:23	+48:58	1680	3.2	SN IIb	66
Tycho	00:25	+64:09	1572	2.3	Norm. SN la	287
Eta Car	10:45	-59:41	~1840	2.4	Great Eruption	36
SN 1181	02:05	+64:49	1181	2.6	?	2400
P Cygni	20:17	+38:02	1600	1.6	Great Eruption	3000
Crab Nebula	05:34	+22:01	1054	1.9	SN II?	3000
W49B	19:11	+09:06	1000	8	Core-Collapse?	113
Kepler	17:30	-21:29	1604	2.9	Pec. SN Ia?	140
SN 1006	15:02	-42:06	1006	2.2	Norm. SN Ia?	2300
RCW 86 (SN 185)	14:43	-62:28	0185	2.8	SN Ia/II ?	6000

Table adapted from Armin Rest Supernova Earth Echo P. Marenfeld and NOAO/AURA/NSF

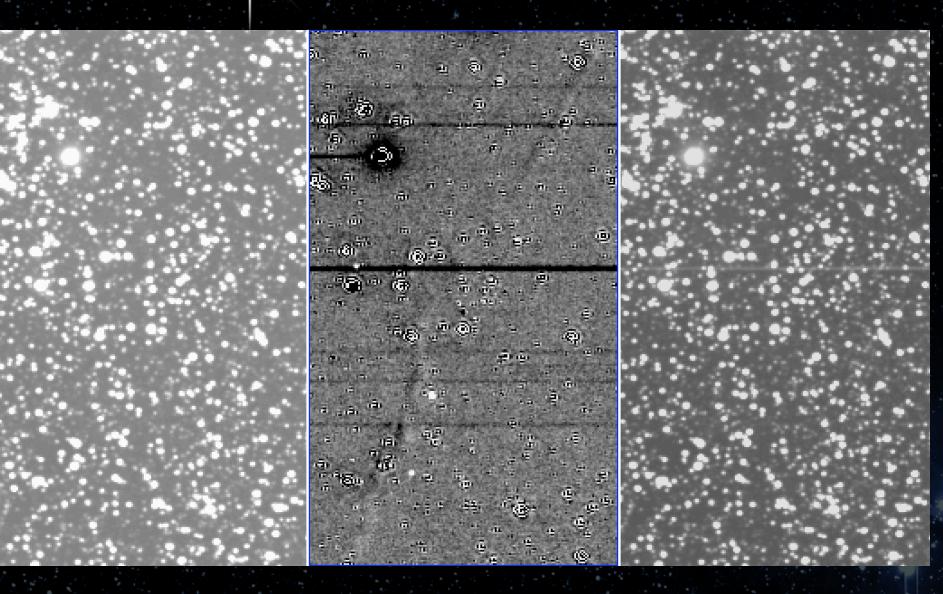
ASAS SN: SN 1987A light echoes



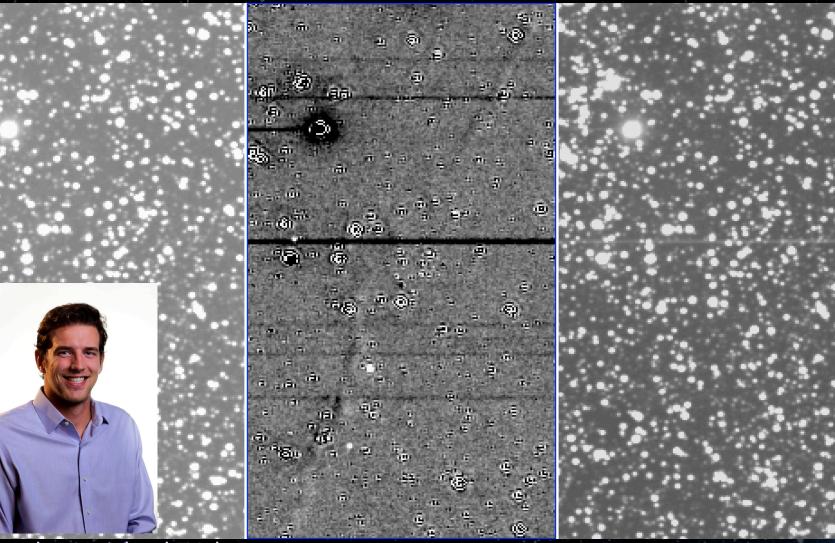
ASAS SN: Tycho light echoes



ASAS SN: Cas A light echoes

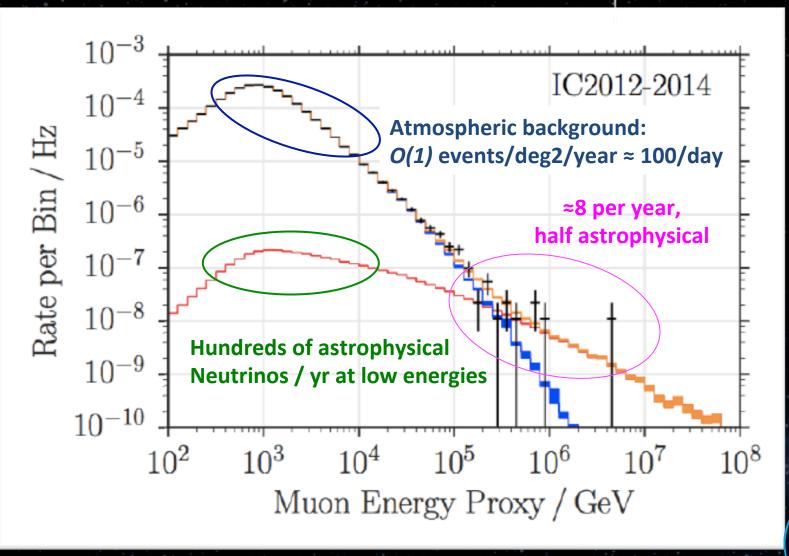


ASAS SN: Cas A light echoes



Grad student Michael Tucker

CECUBE + ASAS SN



Slides courtesy of Anna Franckowiak and Robert Stein





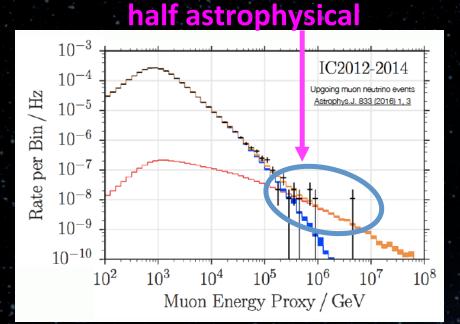
Two Approaches To ASAS **Correlate Neutrinos**



ASAS-SN observes

neutrino error

Roughly 8 per year,

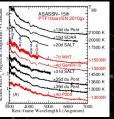




(how significant is detection?)

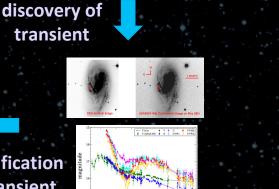
neutrino arrives





transient

identification of transient



Slide courtesy of Anna Franckowiak and Robert Stein

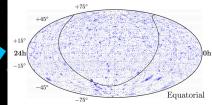
Two Approaches To ASAS SA Correlate Neutrinos



ASAS-SN scans entire sky

> ASAS-SN finds many transients

After ≈1year: Cross-correlate with neutrinos search for statistically significant excess



IceCube detects ≈100 neutrinos per day

 10^{-3} IC2012-2014 10^{-4} Upaoina muon neutrino events $/ H_{z}$ 10^{-5} Astrophys.J. 833 (2016) 1. 3 Rate per Bin 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{3} 10^{5} 10^{2} 10^{4} 10^{6} 10^{7} 10^{8} Muon Energy Proxy / GeV

Hundreds of astrophysical Neutrinos per year at low energies

Slide courtesy of Anna Franckowiak and Robert Stein



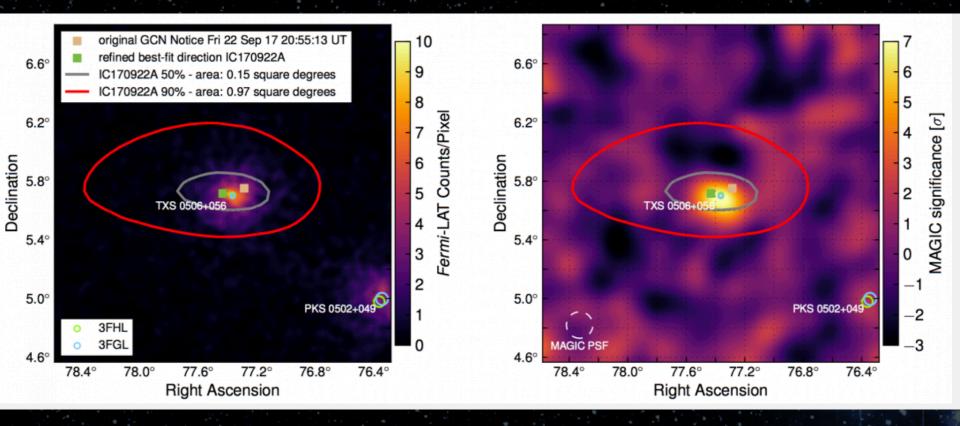
IceCube-170922A



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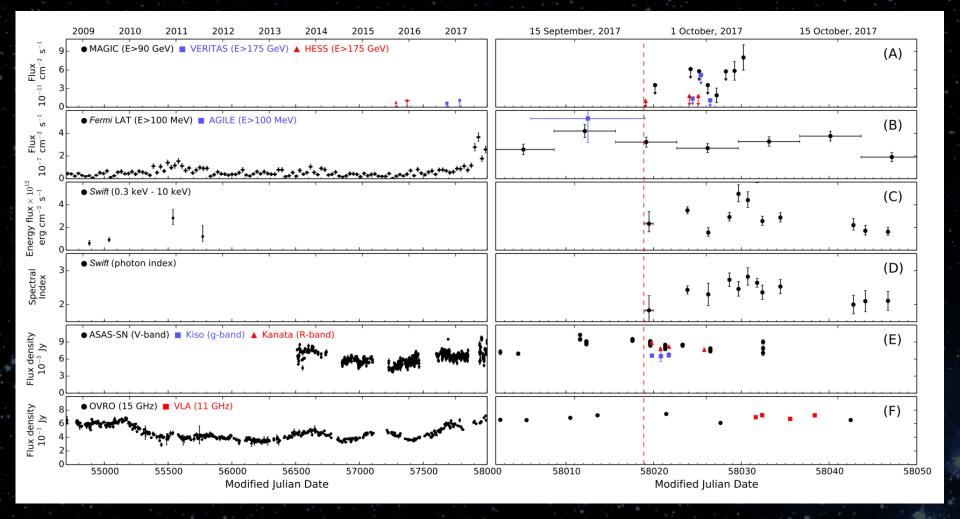
IceCube-170922A

ASAS





IceCube-170922A ASAS





IceCube-170922A

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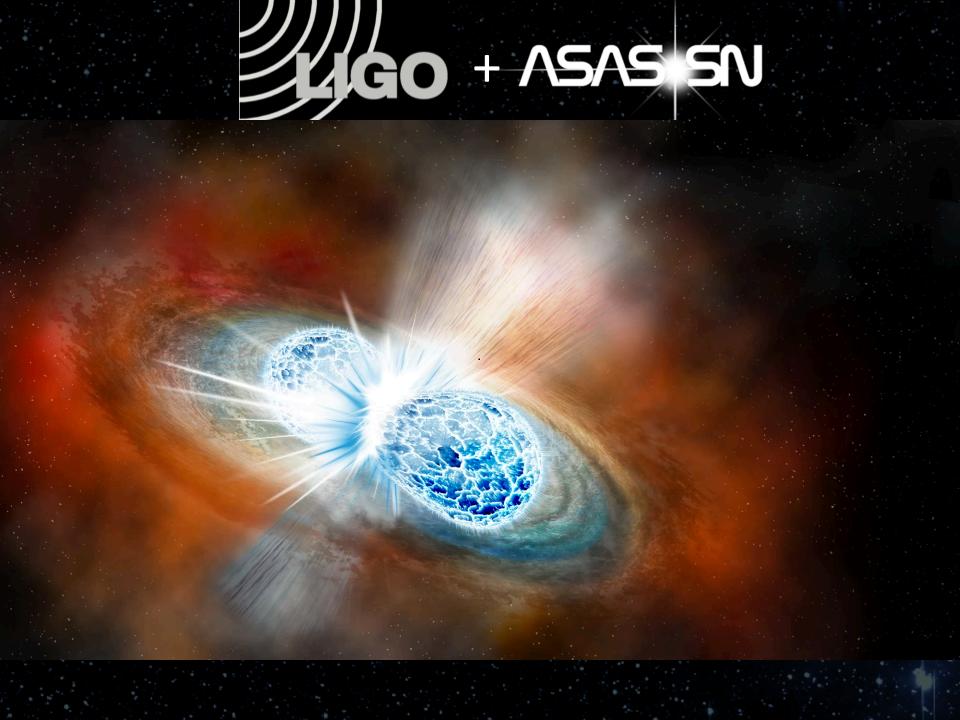
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ASAS SN

Vu





Late-2019









- ASAS-SN automatically triggers in ≈ 30 seconds
- GW170817 would have taken 2 fields from *South Africa*
 - ASAS-SN distribution around the globe is a major advantage.

