

The All-Sky Automated Survey for SuperNovae (~~ASAS~~ SN or “Assassin”)

Benjamin J. Shappee^{1,2}
on behalf of the entire ASAS-SN team

¹Hubble-Fellow, ²Carnegie-Princeton Fellow



The Sky is Big!

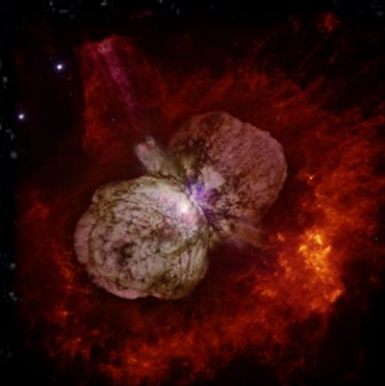
How big?

$$\begin{aligned} A &= 4\pi \times \text{steradian} = 41,250 \text{ deg}^2 \\ &= 5 \times 10^{11} \text{ arcsec}^2 \end{aligned}$$

500 Gigapixels \rightarrow 1 Terabyte/epoch
(assuming 1 arcsec pixels)

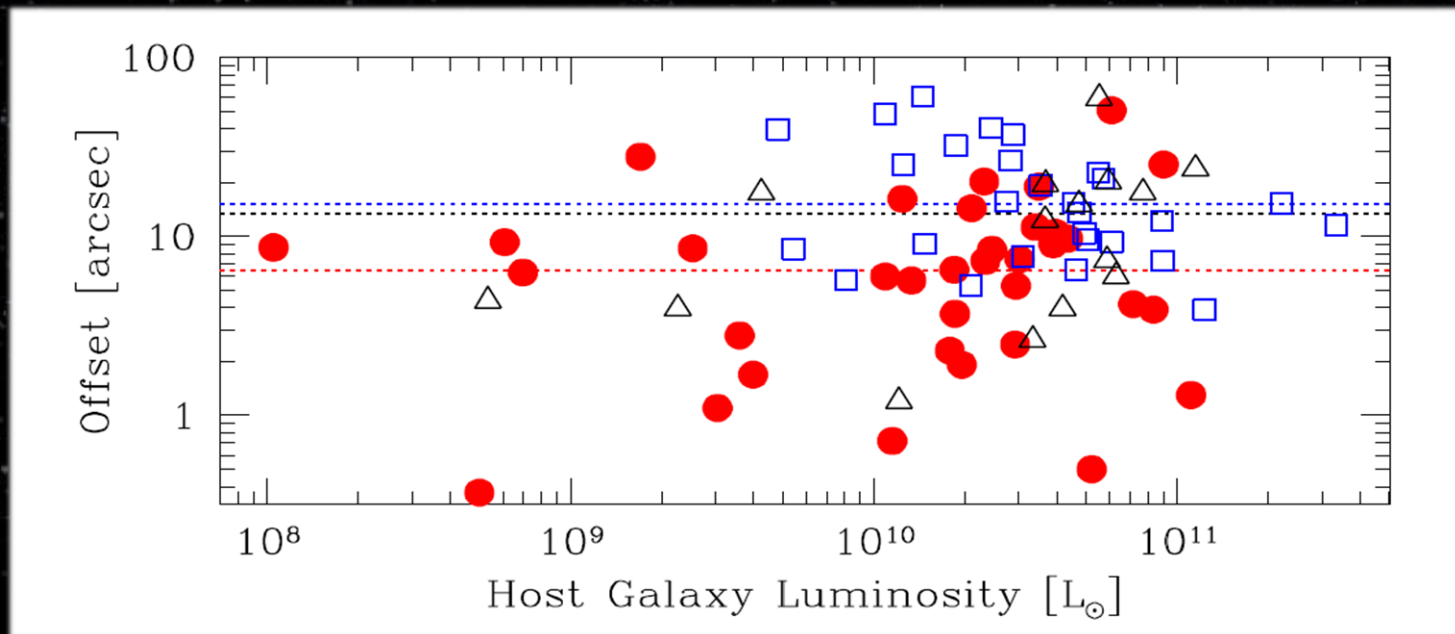
The Sky is Variable!

- Supernovae
- Stellar Flares
- Active Galactic Nuclei
- Asteroids
- Stellar Eruptions



ASAS SN Goals:

- Monitor of the entire sky every few nights in real-time
- V-band limiting magnitude $V \approx 17$
- Use commercially available Telephoto lenses and CCDs
- Find supernovae in a minimally biased search



Outline

- Introduction to ASAS-SN
- Discuss a few interesting discoveries
- ASAS-SN Patrols (our data release strategy)
- Future directions of ASAS-SN

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ASAS SN Is a Global Partnership



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(Hubble Fellow; Carnegie-Princeton Fellow)

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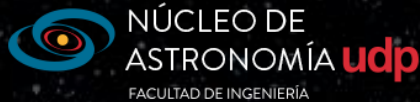
P. R. Wozniak (LANL)

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ASAS SN Is a Global Partnership



- Home base
- Scheduling and Analysis
- Aid in pipeline
- Funding
- Site support and Mounts
- Follow up resources



Haleakala
Sedgwick

McDonald

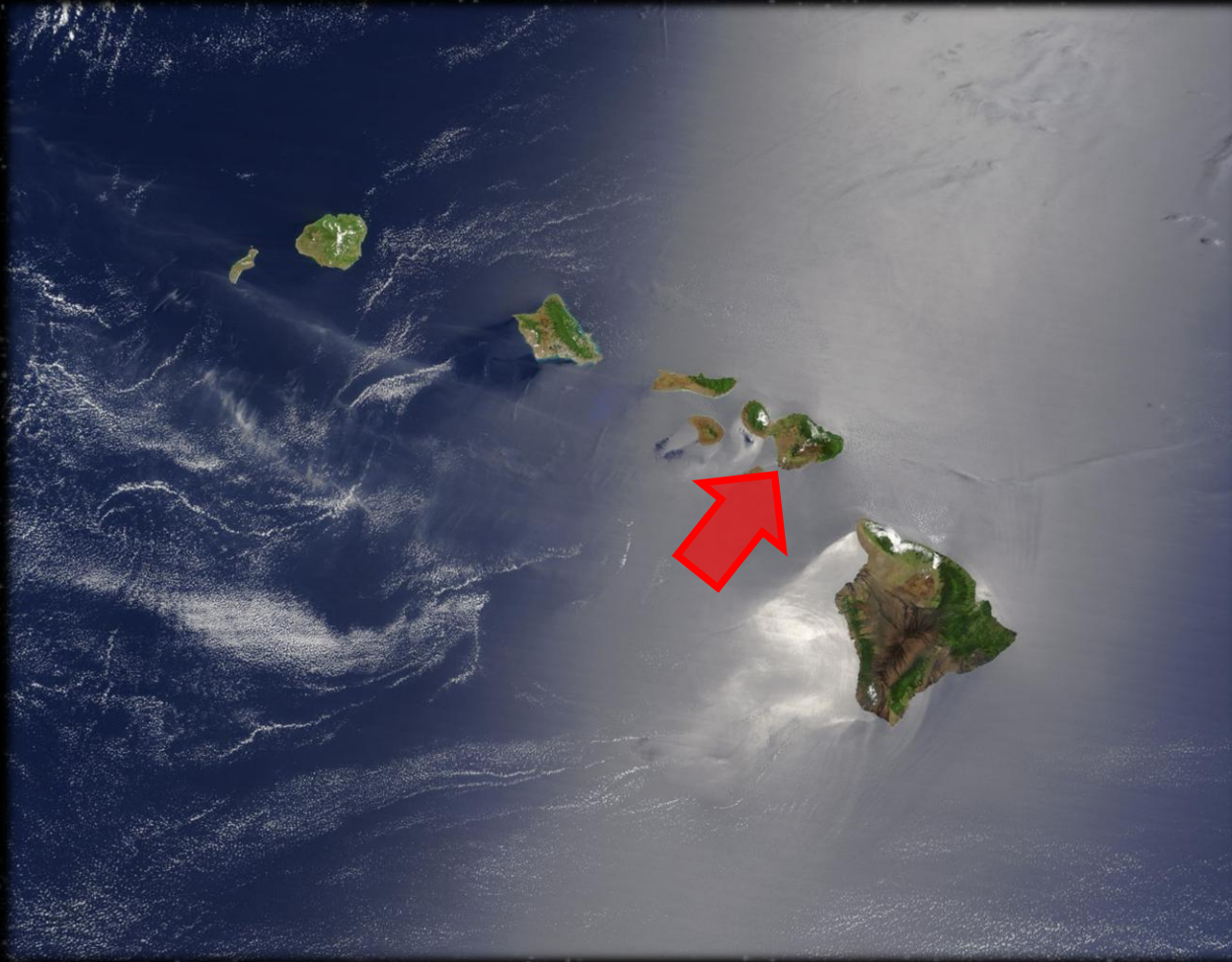
Cerro Tololo

Teide

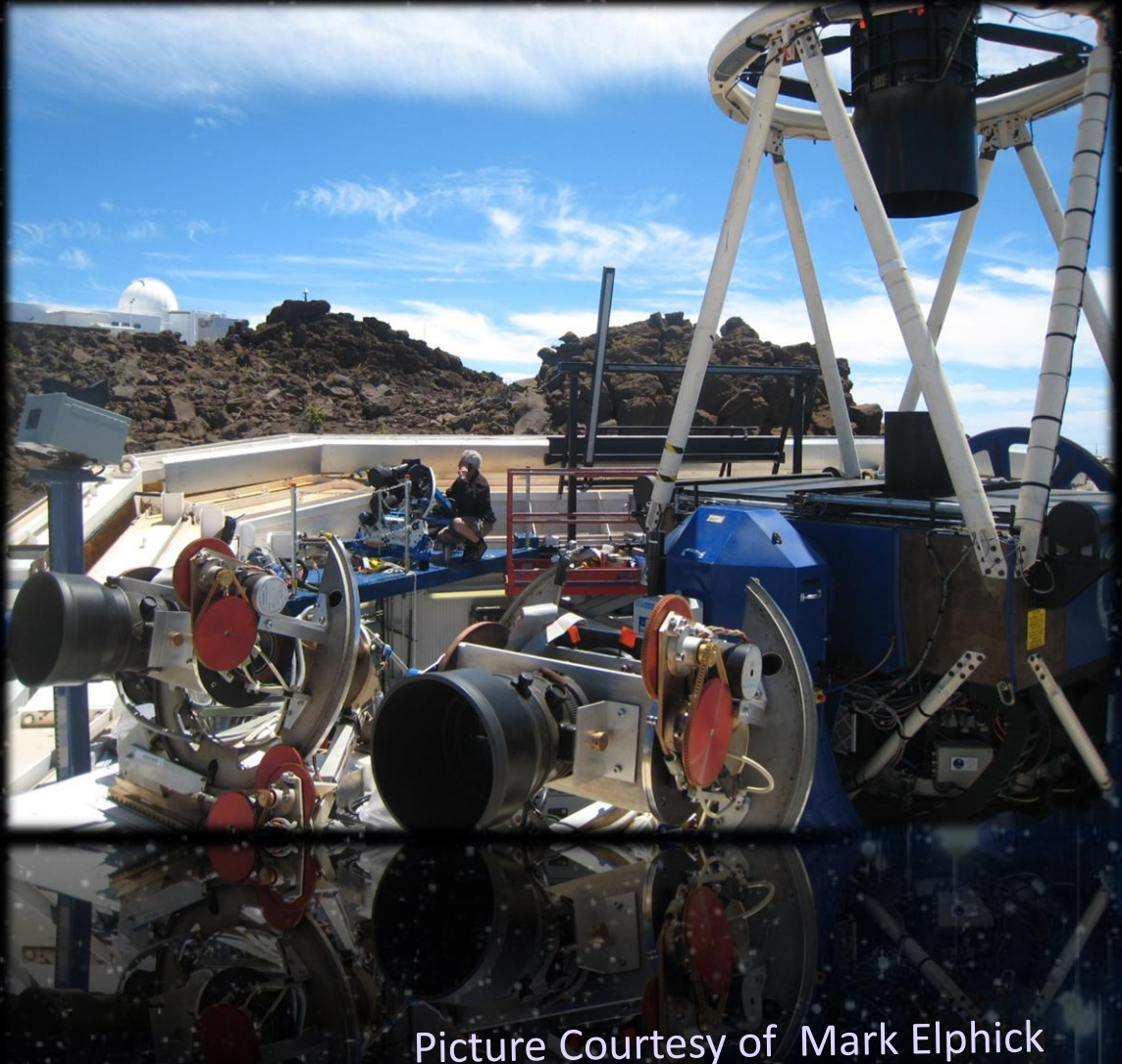
Sutherland

Siding Spring

Mount Haleakala, Maui, Hawaii



Faulkes Telescope North



Picture Courtesy of Mark Elphick

ASAS-SN North “Brutus”

- 4 telescopes on a common mount
- 4 x 14cm lens
- 4 x FLI ProLine CCD cameras
- 4 x Fairchild Imaging 2k x 2k thinned CCD
- 4 x 4.47 x 4.47 degree field-of-view
- 7.8" pixel scale
- V-band filters
- limiting magnitude $V \approx 17$
- 10,000 square degrees per night



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Picture Courtesy of Mark Elphick

Brutus Data



LCOGT Aqawan Enclosure at Cerro Tololo



Picture Courtesy of Wayne Rosing

ASAS-SN South “Cassius”

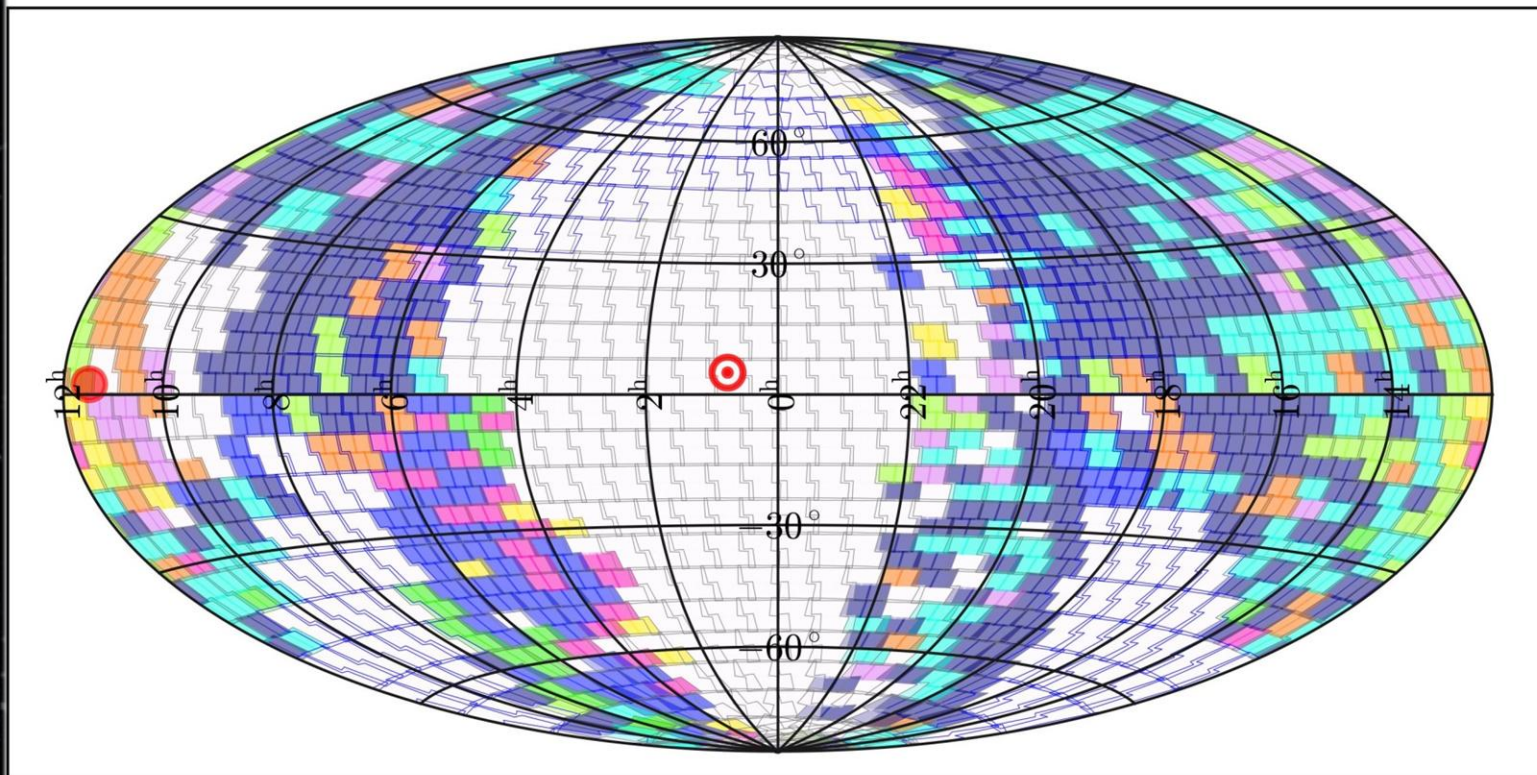
- First light on April 25, 2014
- 2 telescopes on a common mount
- 2 x 14cm lens
- 2 x FLI ProLine CCD cameras
- 2 x Fairchild Imaging 2k x 2k thinned CCD
- 2 x 4.47 x 4.47 degree field-of-view
- 7.8" pixel scale
- V-band filters
- limiting magnitude $V \approx 17$
- 5,000 square degrees per night
- May 2015 we are doubling cameras
 - **10,000** square degrees per night



Picture Courtesy of Wayne Rosing

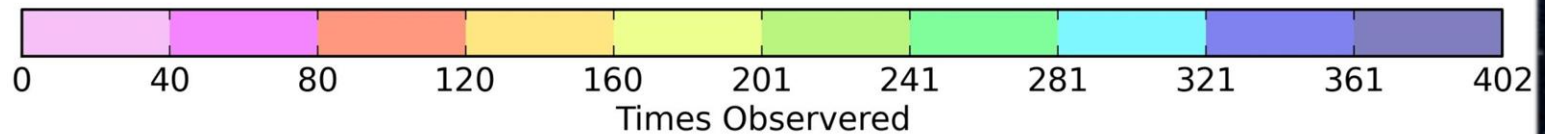
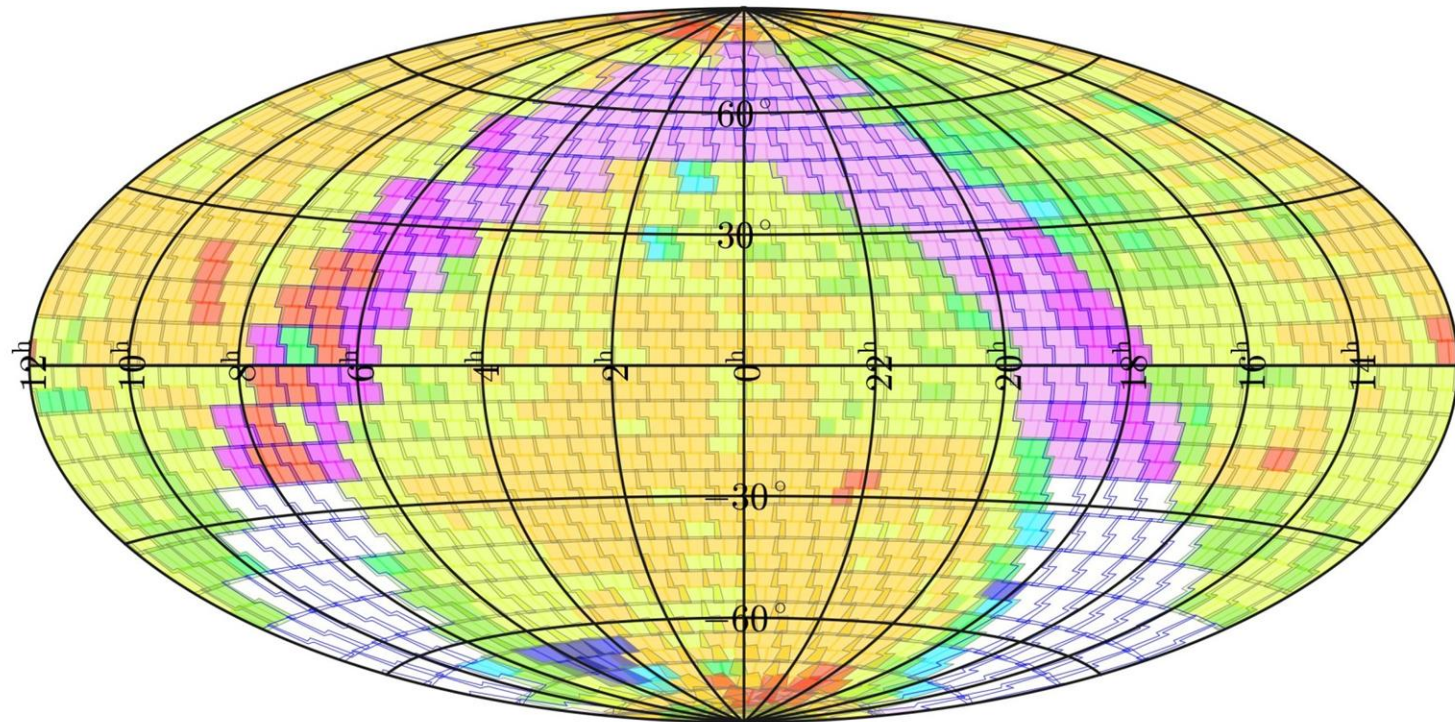
ASAS SN Cadence and Coverage

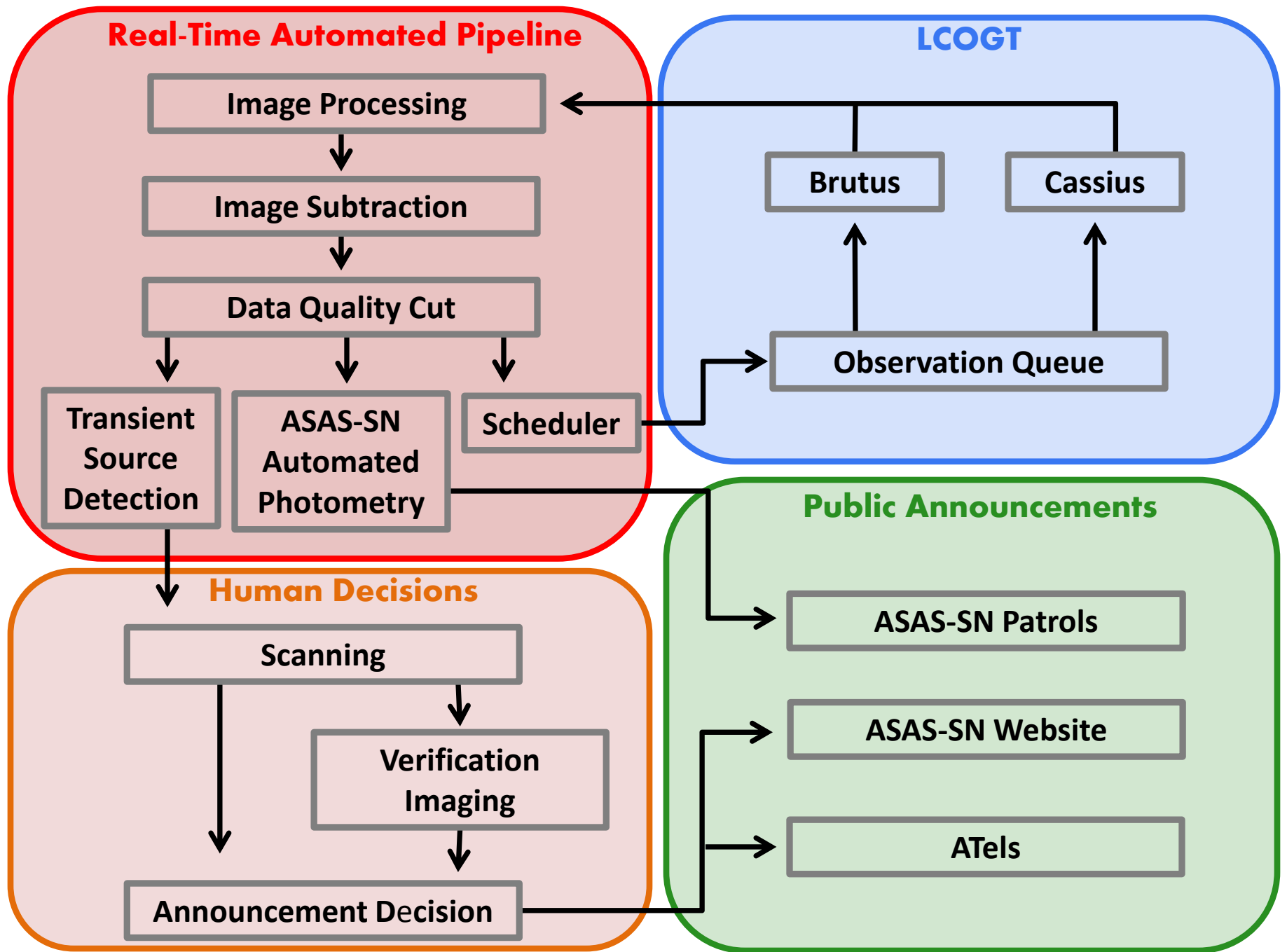
Thu Apr 2 11:14:43 2015



One Year of ASAS SN

Wed Apr 1 21:13:16 2015





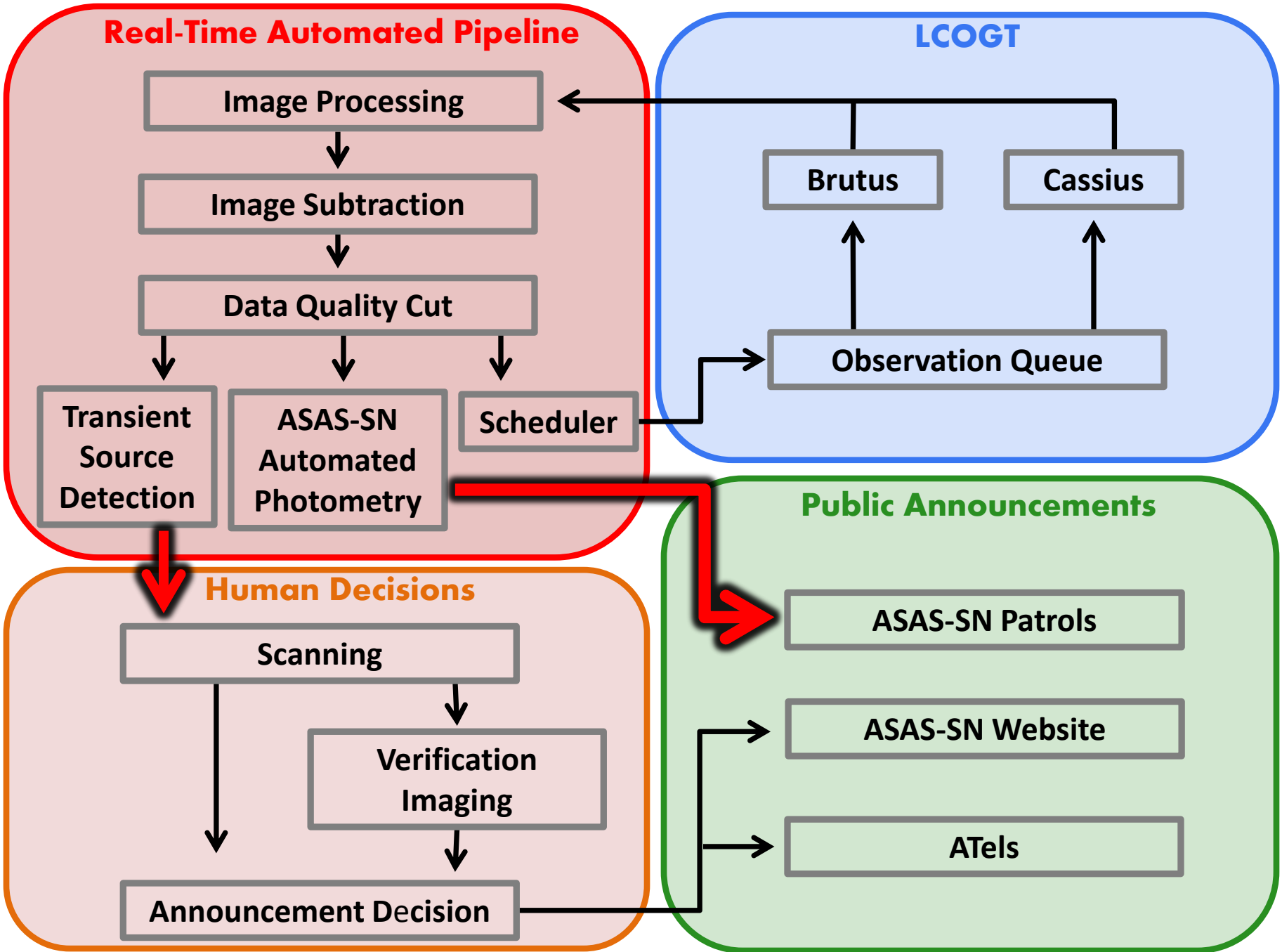
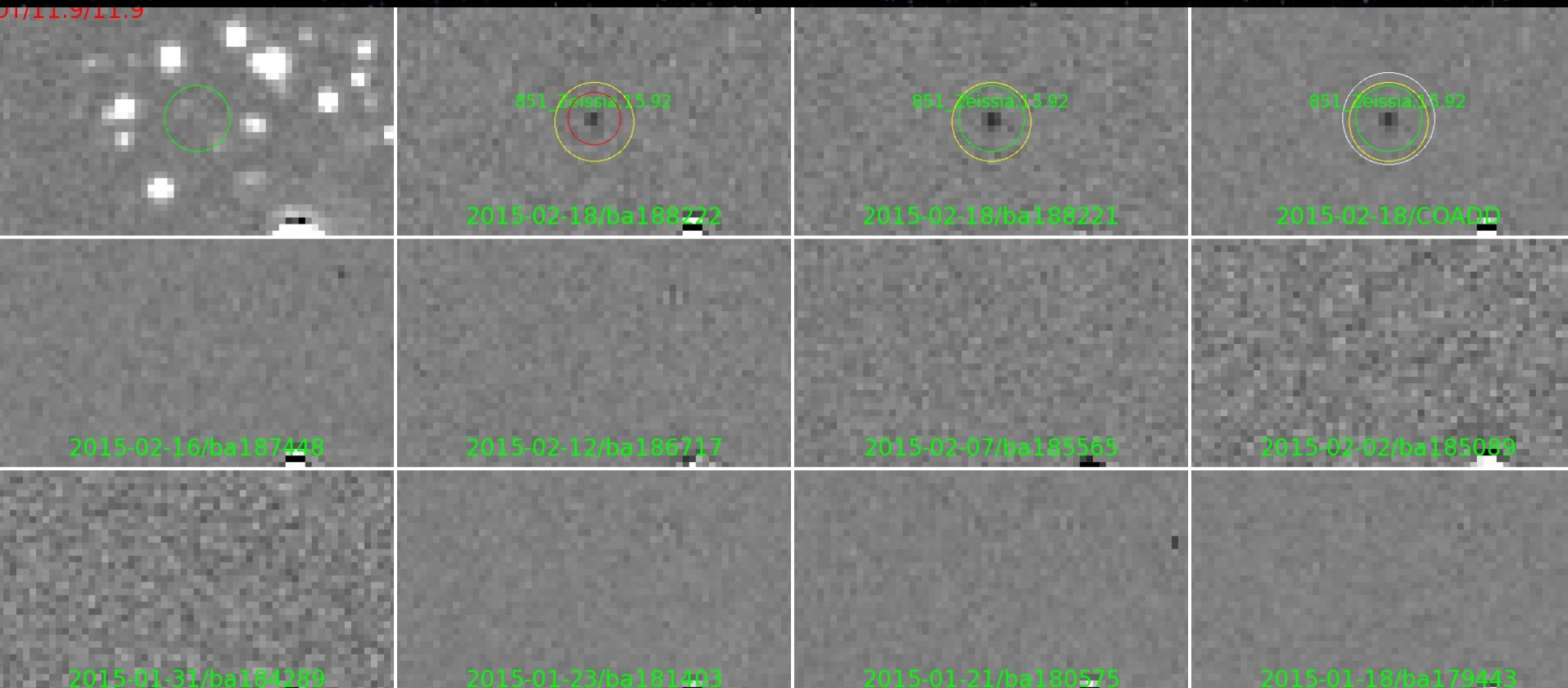


Image Subtraction



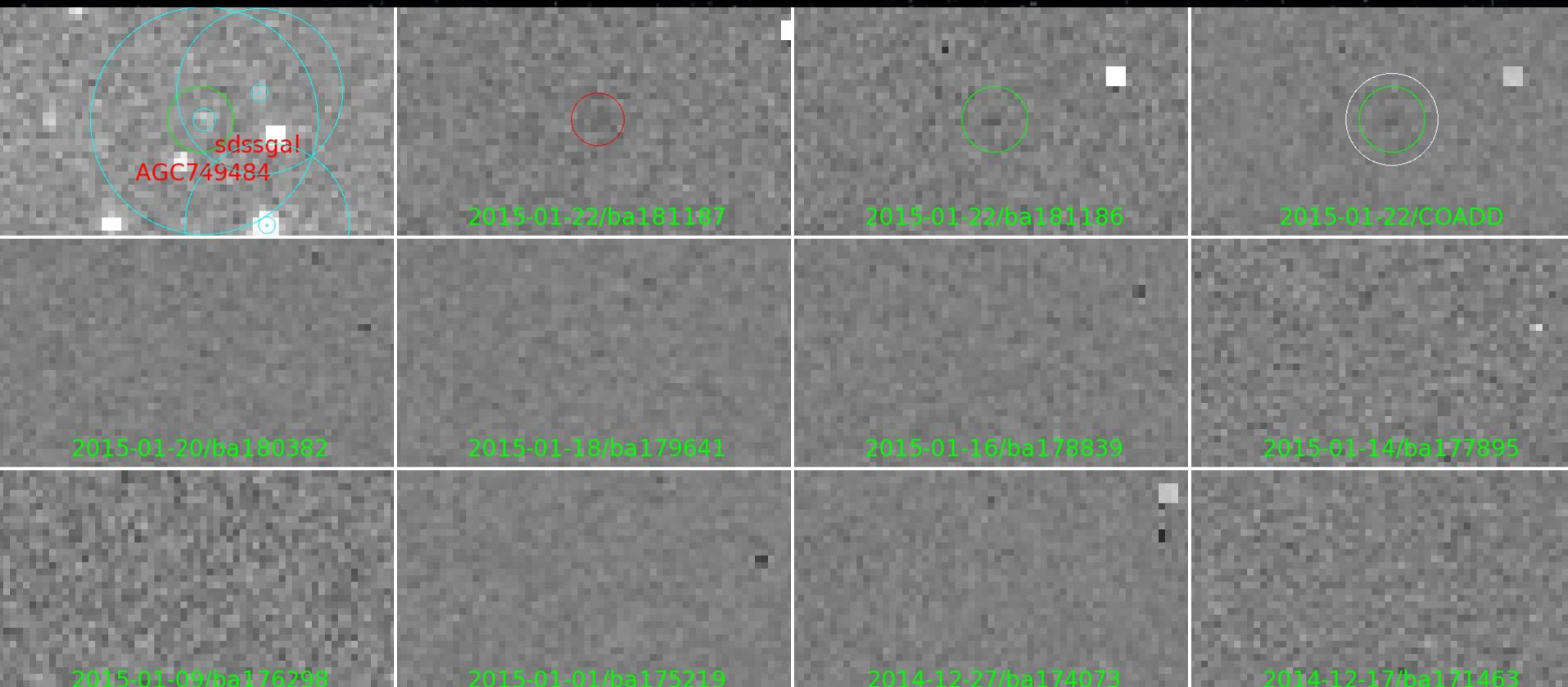
Transient Detection Pipeline

- New sources are identified on the subtracted images by SExtractor
- Detections are dominated by false positives
- Many cuts are made (flux, S/N, point-like, dithered correlations, random forest classifier)
- Candidates are then scanned by eye where further cuts can be adjusted
- Transients discovered and announced typically in **hours**
- We will soon implement stacking over multiple night's images



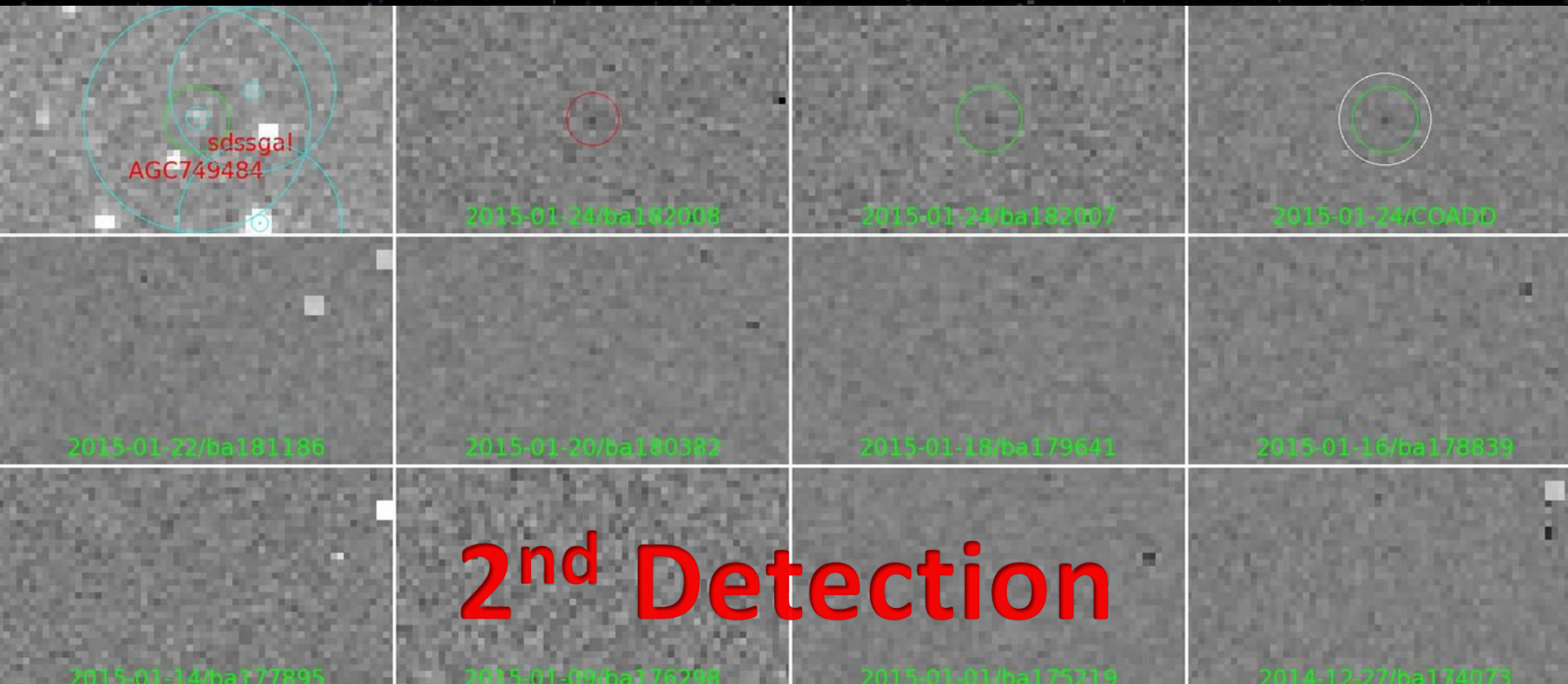
ASASSN-15bo

- ATEL #6989
 - Fernandez et al. (inc. Shappee) 2015
- $V \sim 17.1$ at 1st detection
- $V \sim 16.6$ at 2nd detection
- No redshift to the host galaxy in NED
- $z = 0.032$ from SN spectrum



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ASASSN-15bo

ASAS-SN Discovery of A Probable Supernova in SDSS J144455.21+243443.9

ATel #6989; *J. M. Fernandez (Observatory Inmaculada del Molino), J. Brimacombe (Coral Towers Observatory), R. A. Koff (Antelope Hills Observatory), S. Kiyota (Variable Star Observers League in Japan), T. W.-S. Holoien, K. Z. Stanek, C. S. Kochanek, A. B. Danilet, G. Simonian, U. Basu, N. Goss, J. F. Beacom (Ohio State), B. J. Shappee (Hubble Fellow, Carnegie Observatories), J. L. Prieto (Diego Portales; MAS), D. Bersier (LJMU), Subo Dong (KIAA-PKU), P. R. Wozniak (LANL), D. Szczygiel, G. Pojmanski (Warsaw University Observatory), E. Conseil (Association Francaise des Observateurs d'Etoiles Variables), B. Nicholls (Mt. Vernon Obs., New Zealand)*

on 25 Jan 2015; 18:29 UT

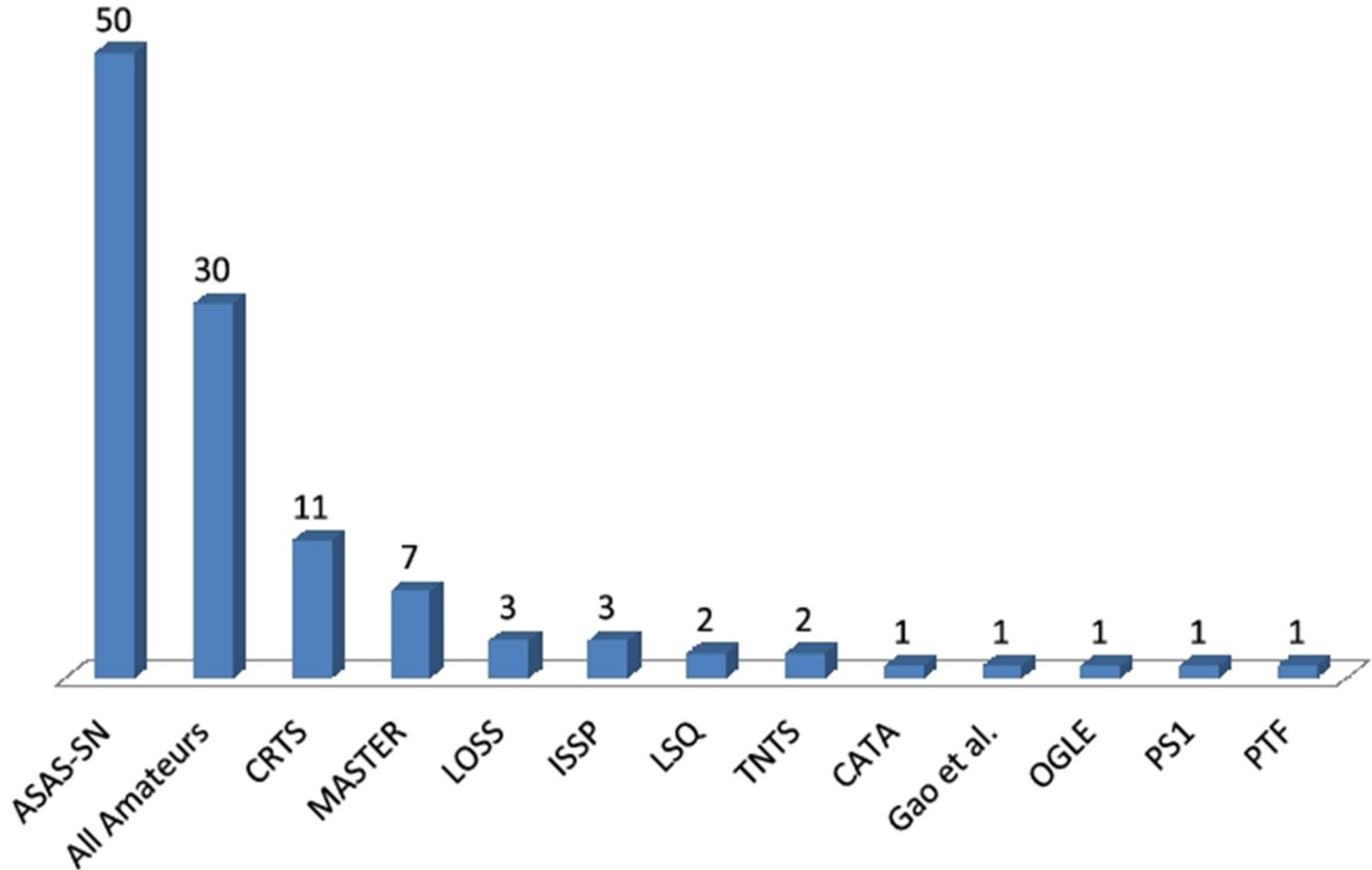
Distributed as an Instant Email Notice Supernovae

Credential Certification: Thomas Holoien (tholoien@astronomy.ohio-state.edu)



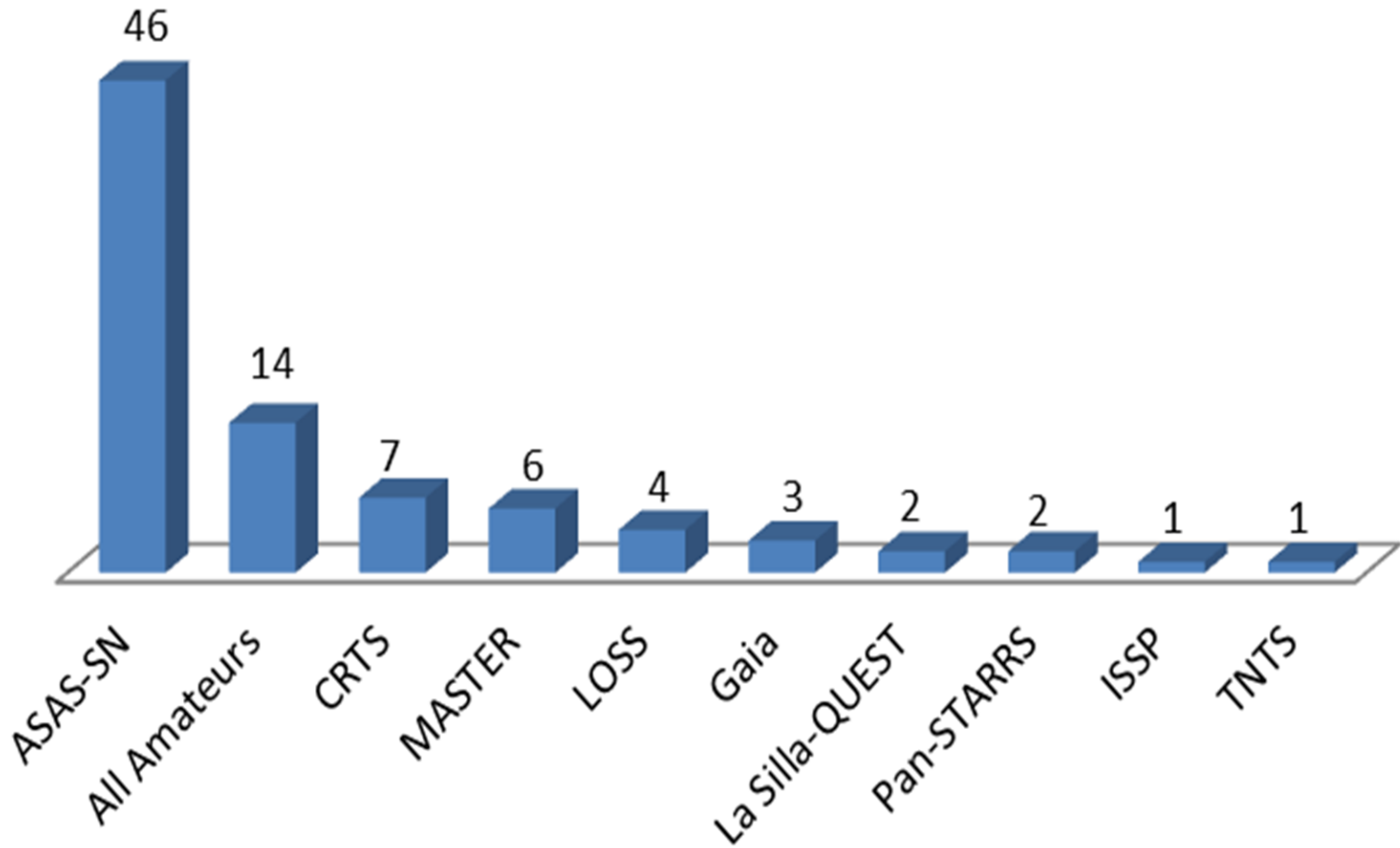
Nearby SNe

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



Nearby SNe

Bright (<17 Mag) SNe Discoveries Dec. 1, 2014 - Apr. 1, 2015

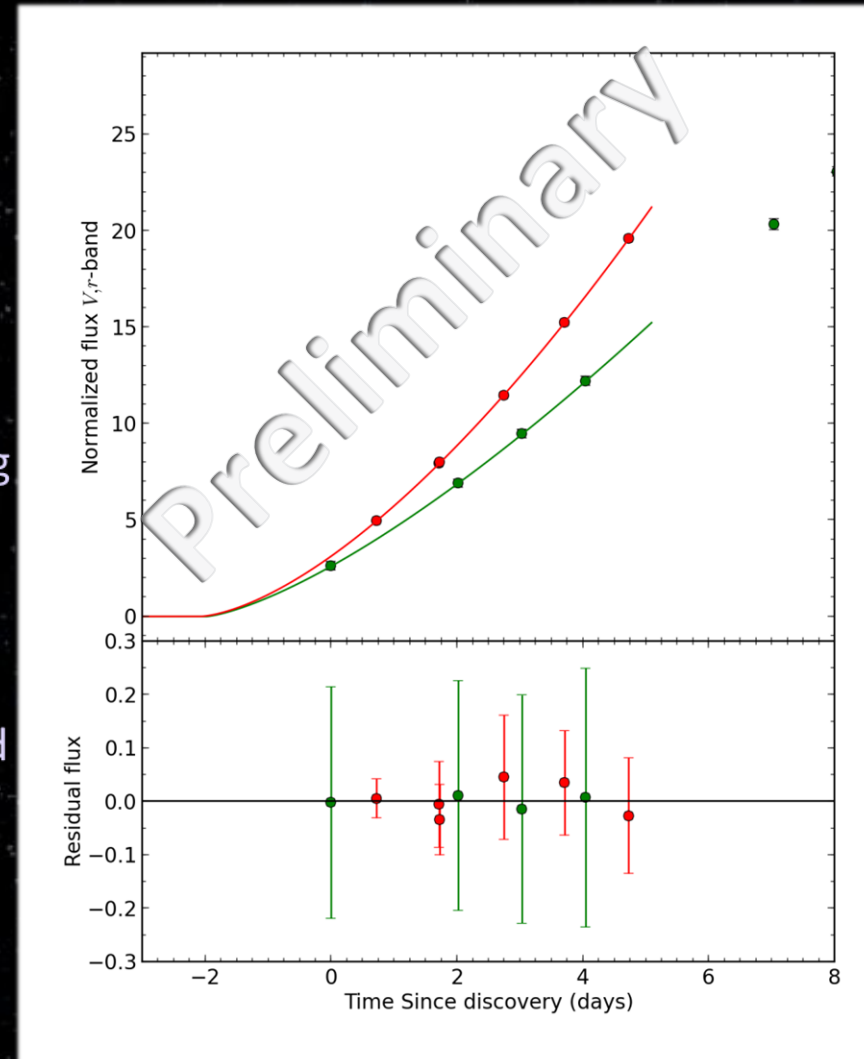


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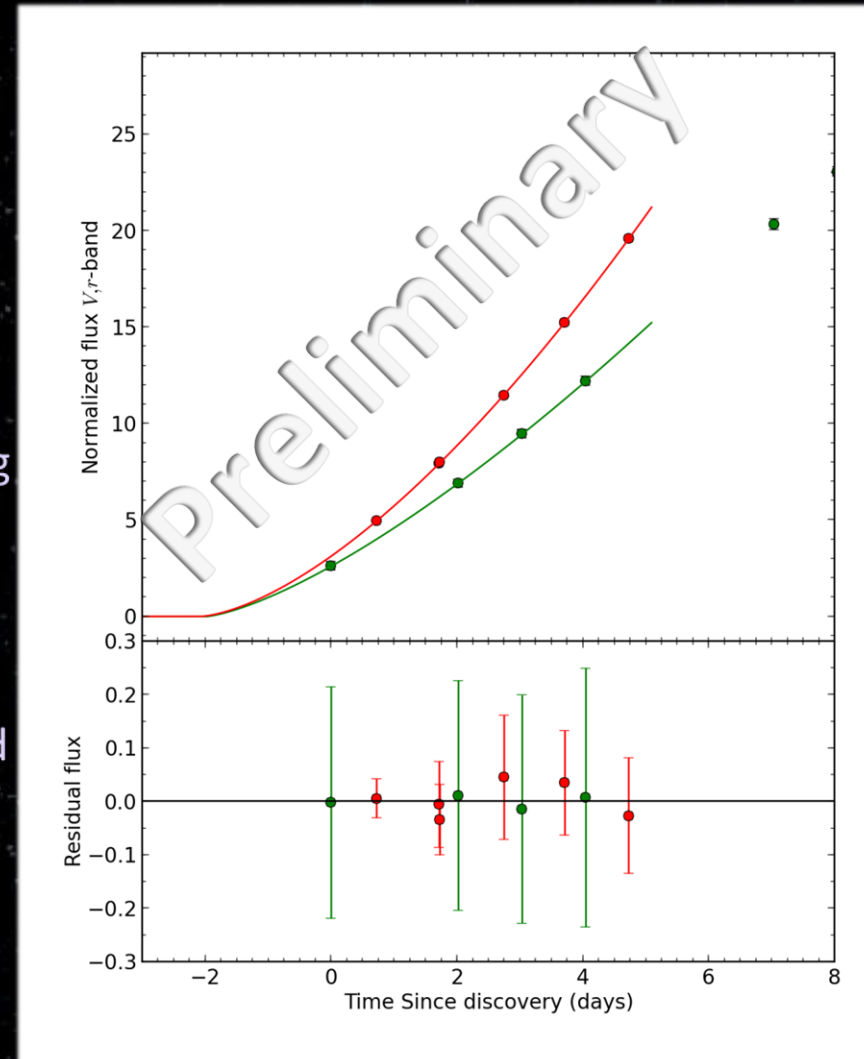
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- 150+ ATELS over first 2 years of the real-time survey
- 6 publications with 5 more in preparation
- 300+ new CVs
- ASASSN-14lp discovered <2 days after explosion (Shappee et al. 2015 in prep)
- Low-mass Young Stellar Object (YSO) in a strong ($\Delta V > 4$ mag) outburst (Holoien et al. 2014a)
- Many M dwarf flares
 - including two of the largest ever detected (Schmidt et al. 2014, Simonian et al. 2014)
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Shappee et al. 2015 in prep.

ASAS SN Discoveries

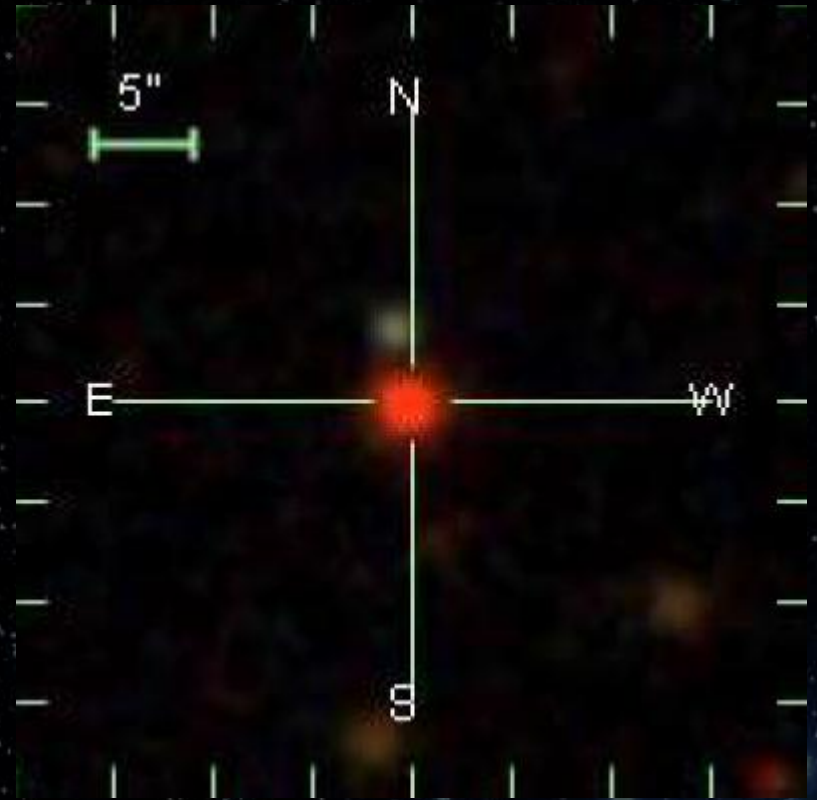
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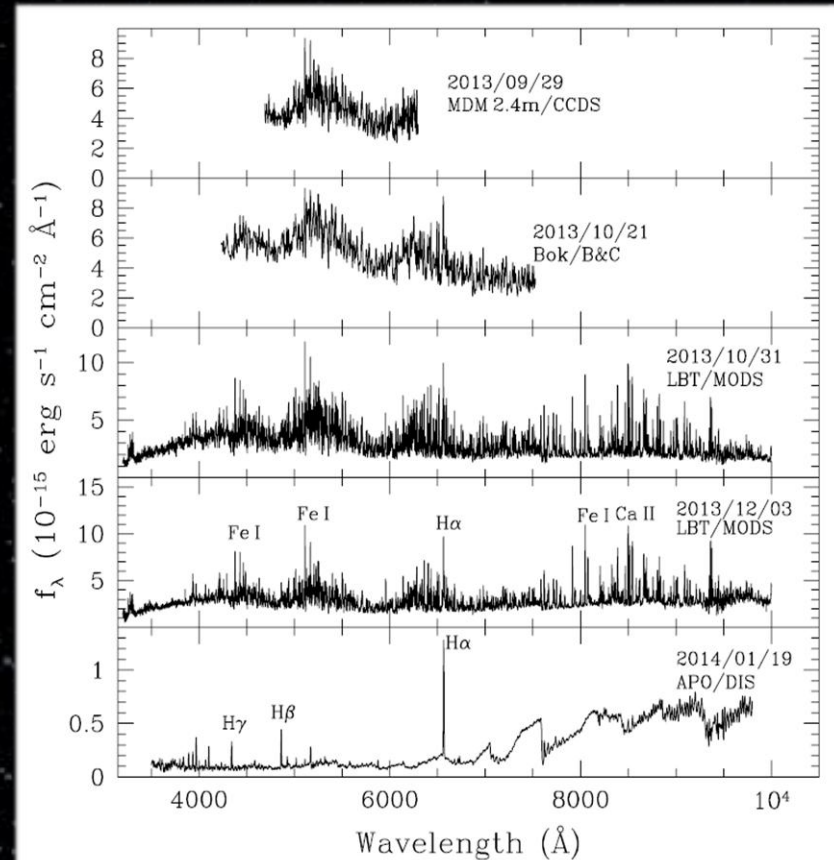
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ASASSN-13db
Holoien et al. (inc. Shappee) 2014

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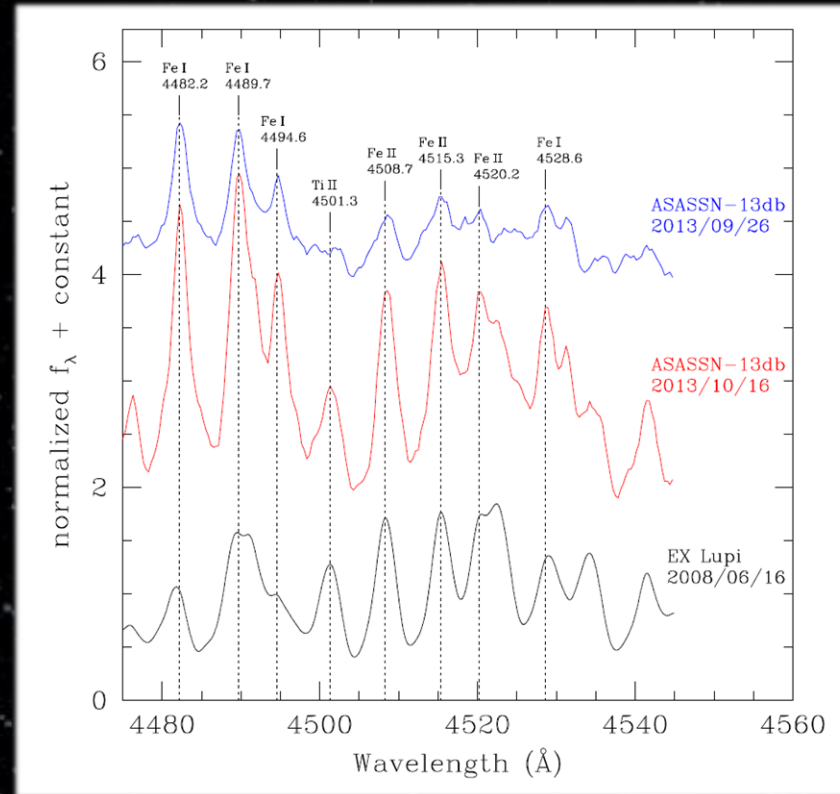


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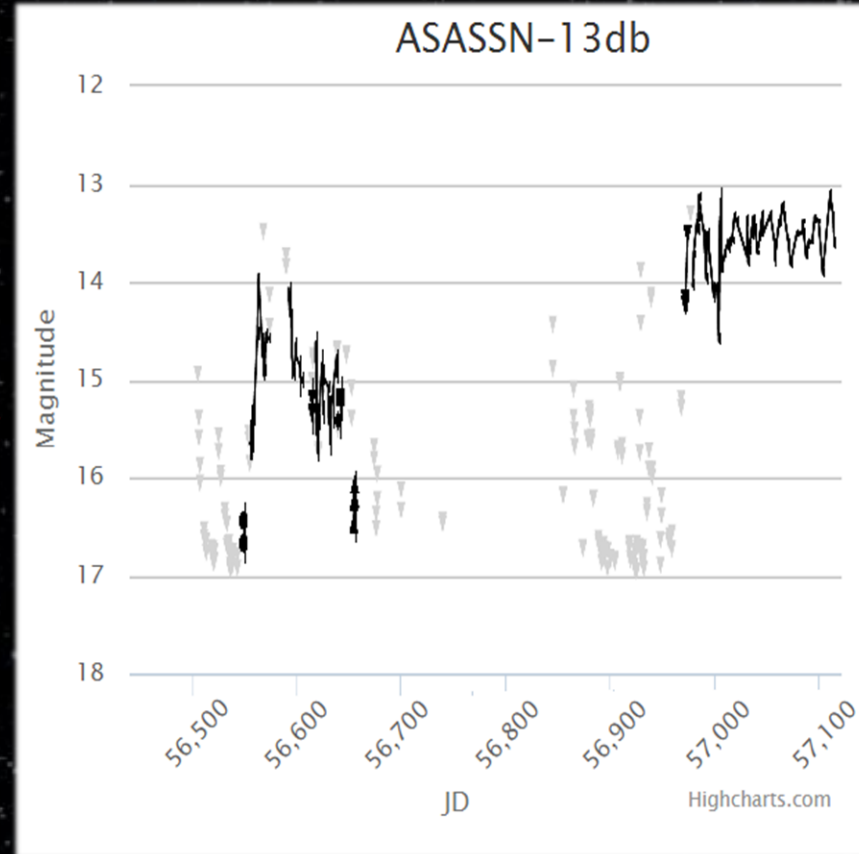
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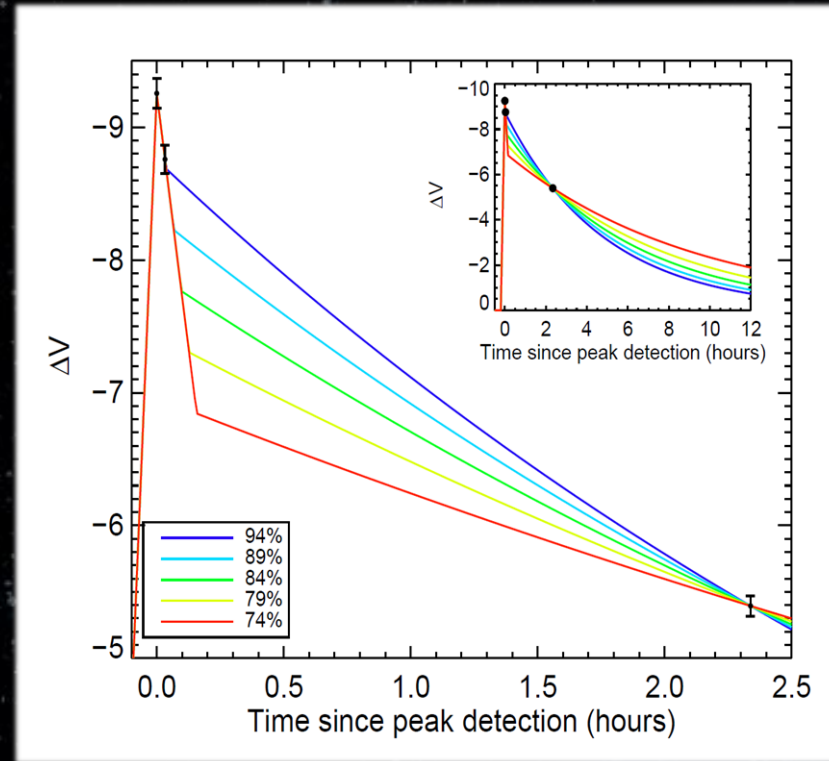
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ASAS-SN CV Patrol Website

ASAS SN Discoveries

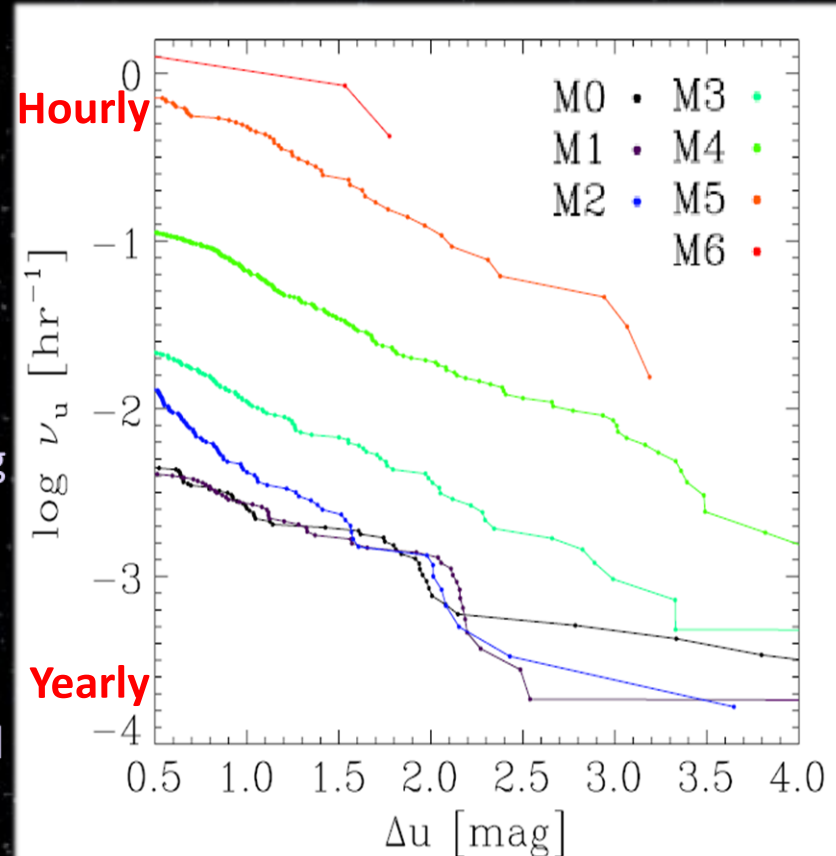
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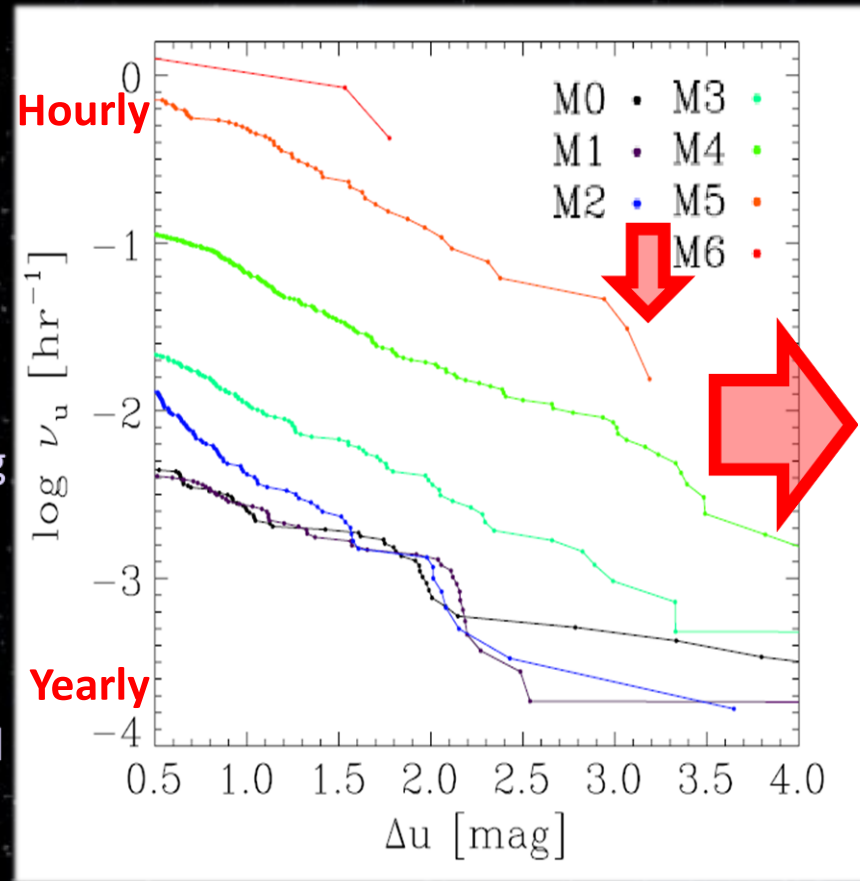


Davenport et al. 2012

02 10 12 20 32 30 32 40

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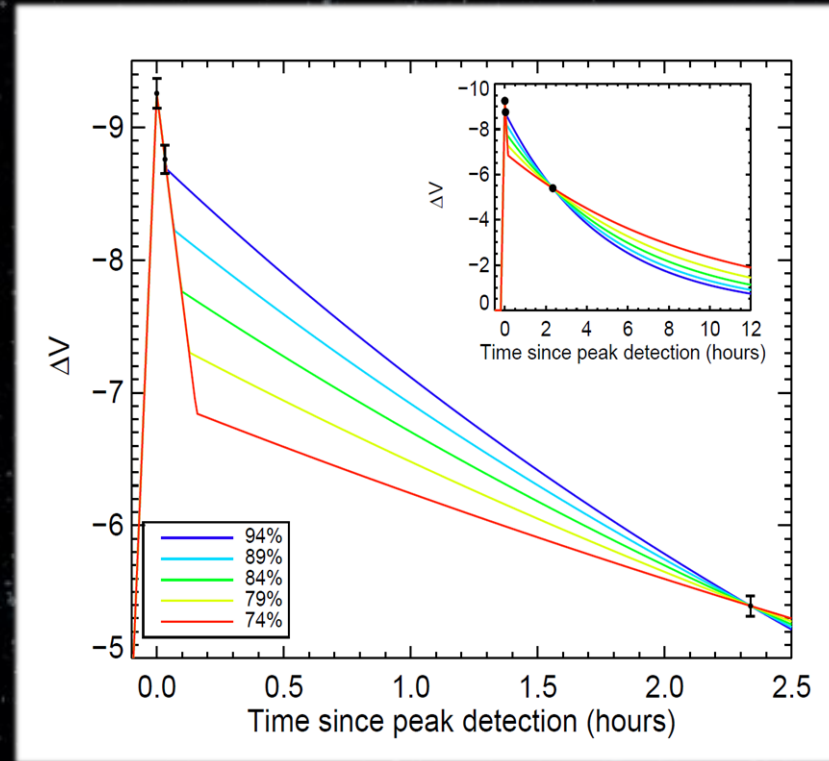


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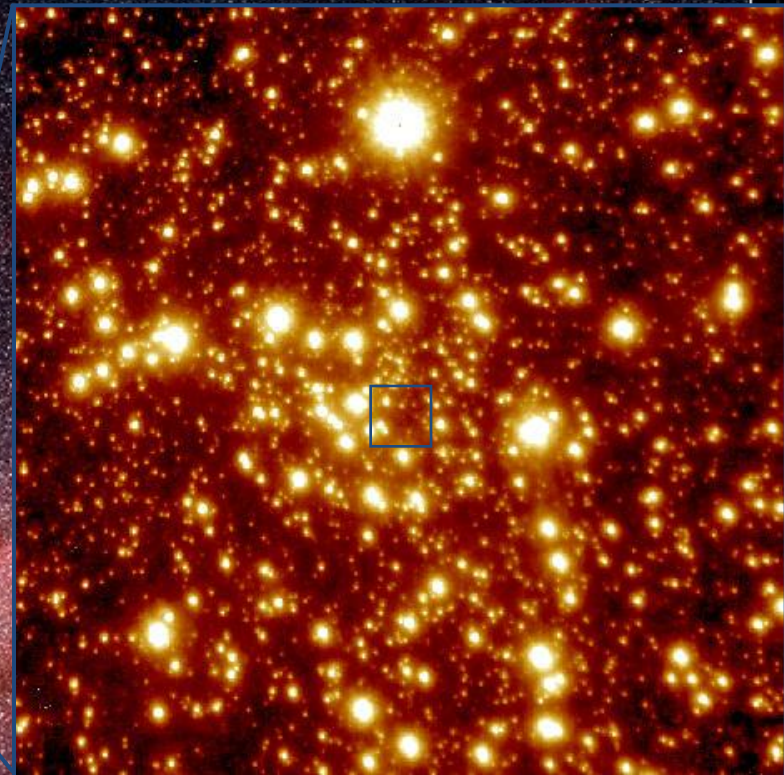
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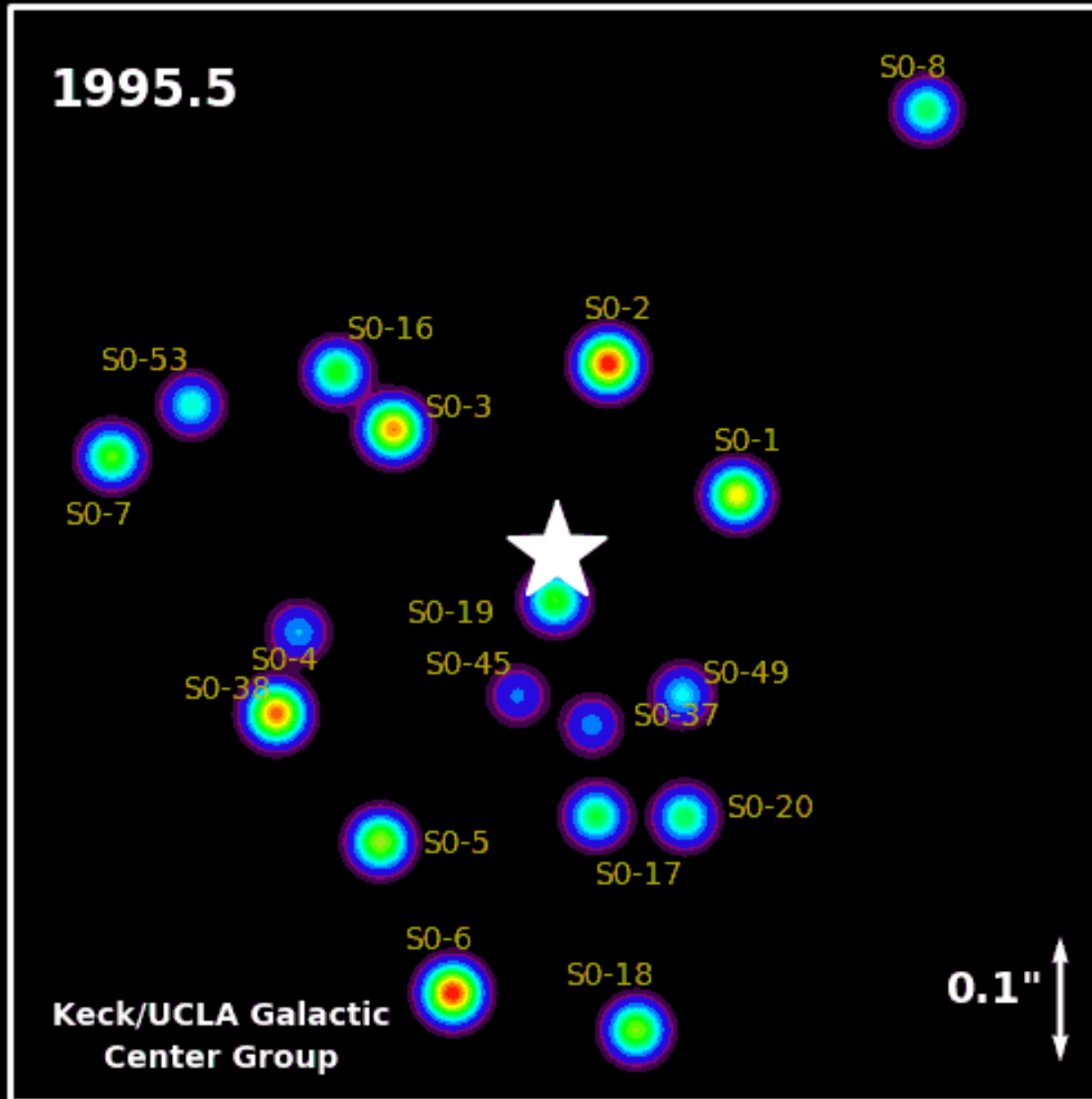
Schmidt et al. (inc. Shappee) 2014

Tidal Disruption Events

Black holes eat
whole stars.



Our own Galaxy



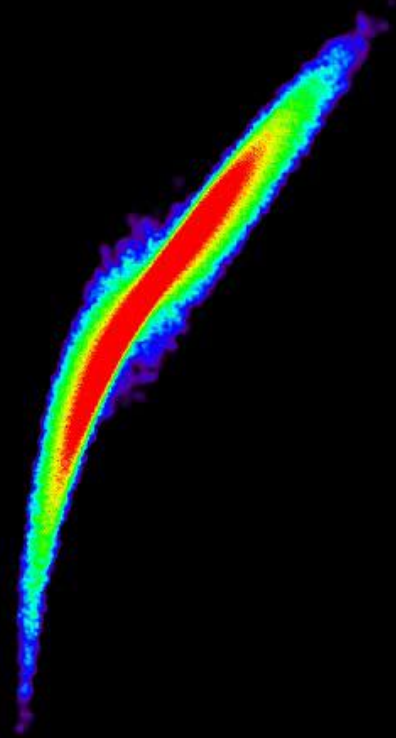
Black holes eat stars.

James Guillochon (Harvard)

**Formation of a debris disk after the
tidal disruption of a star by a
supermassive black hole**

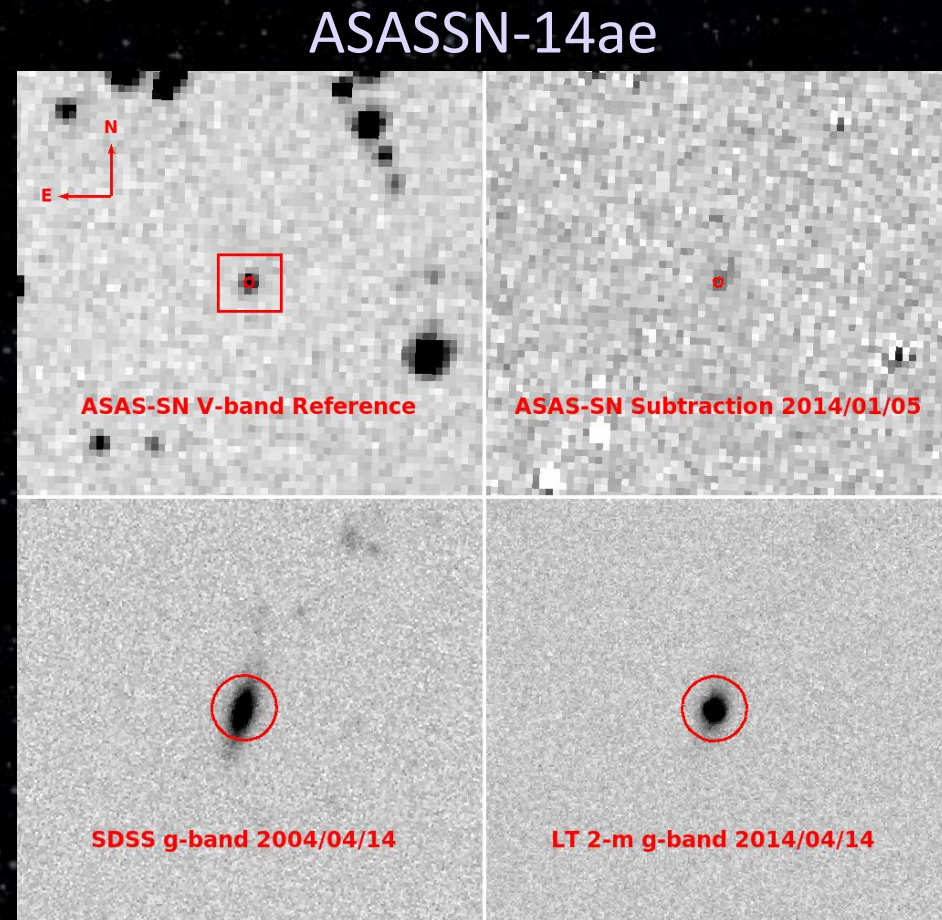


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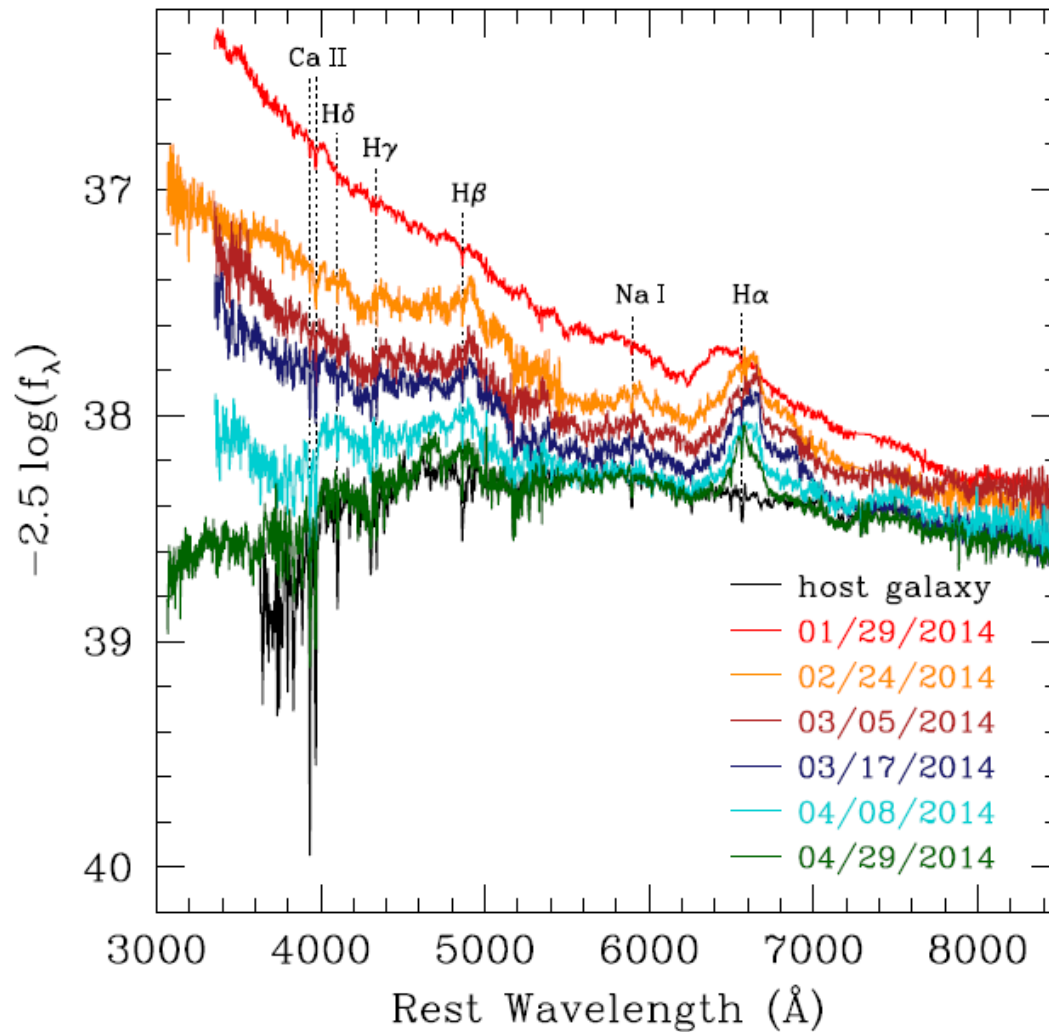
Tidal Disruption Events in ASAS-SN

- 2 events in just the past year!
- Only ~ 10 previously optical TDEs
- Brightest and best (or will be best) studied
- Appears that ASAS-SN **might** be finding more TDEs than previous rate estimates
 - Needs to be better quantified(!)
 - Holoien et al. 2015 in prep.
- Closer to theoretical rates
- Is ASAS-SN less bias than previous surveys (?)
 - Still small number statistics

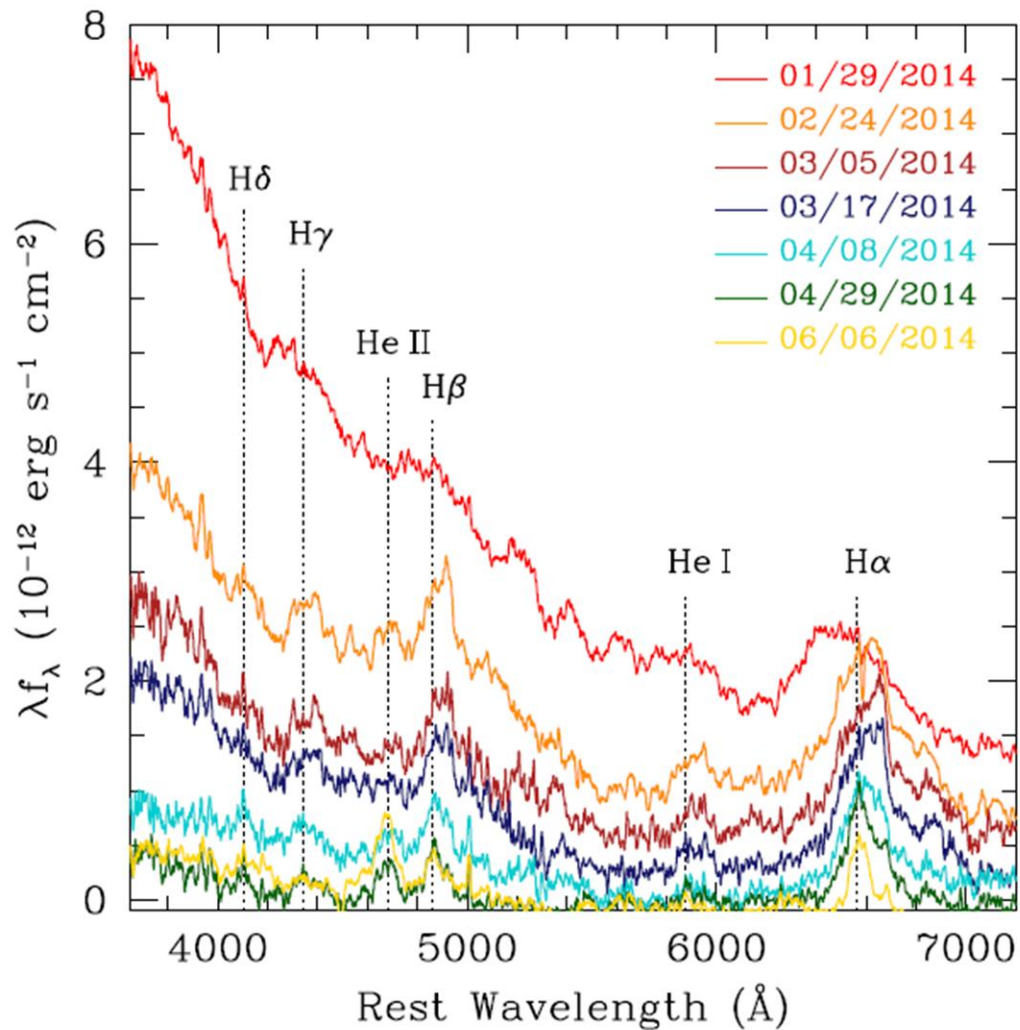


Holoien et al. (inc. Shappee) 2014b

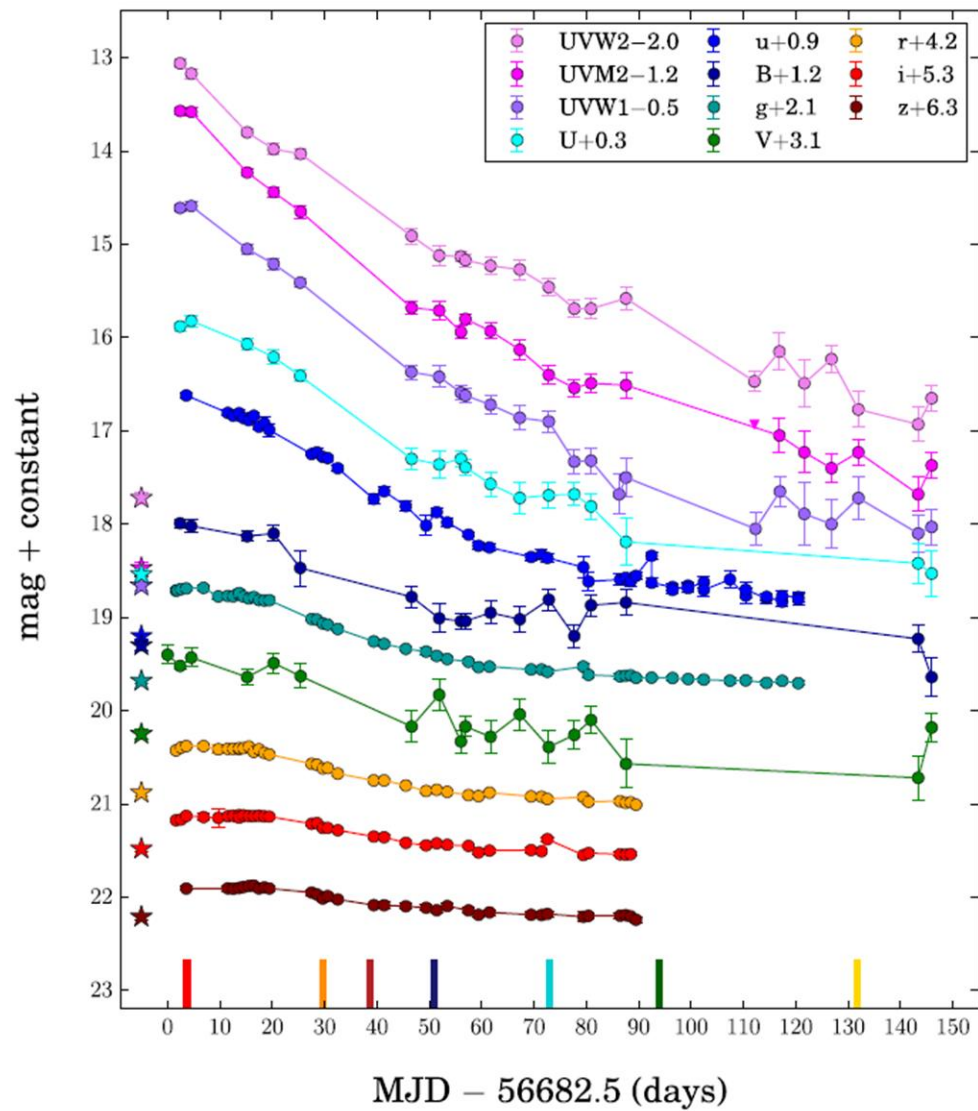
ASASSN-14ae



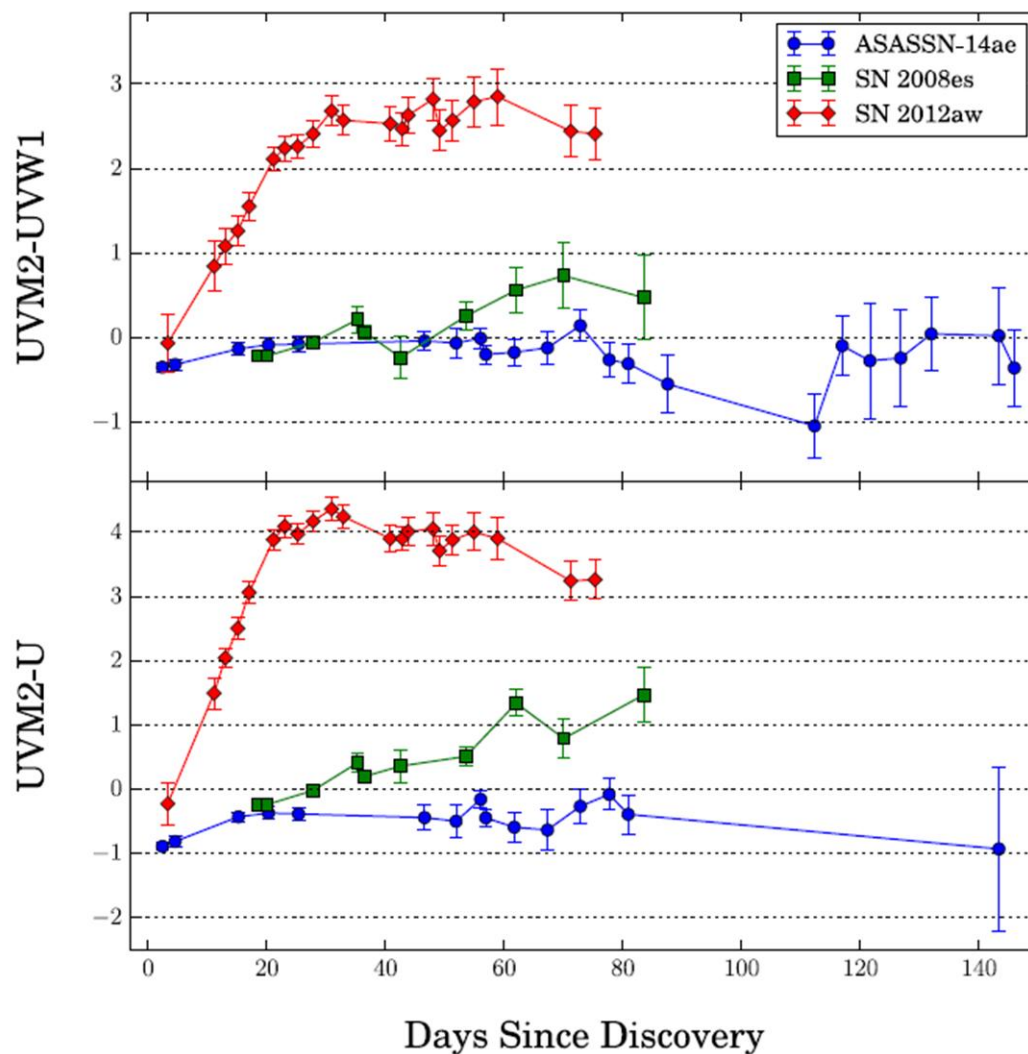
ASASSN-14ae



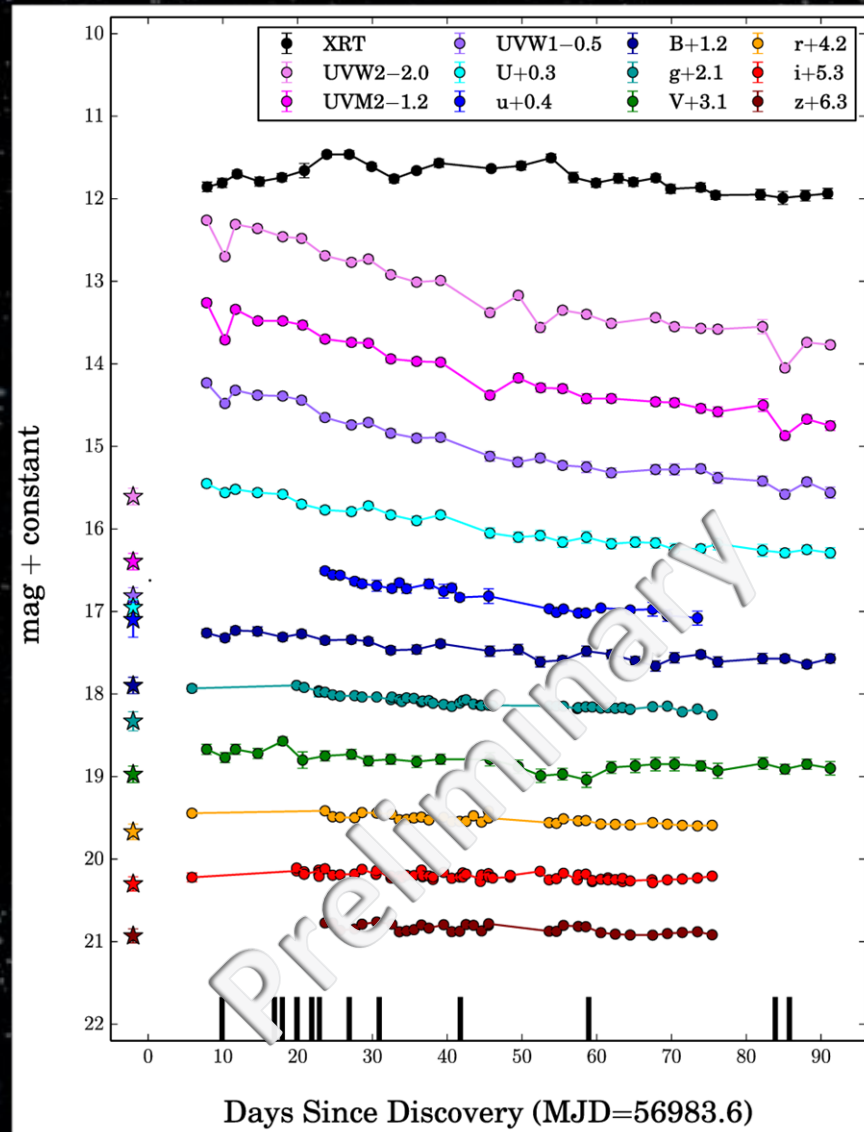
ASASSN-14ae



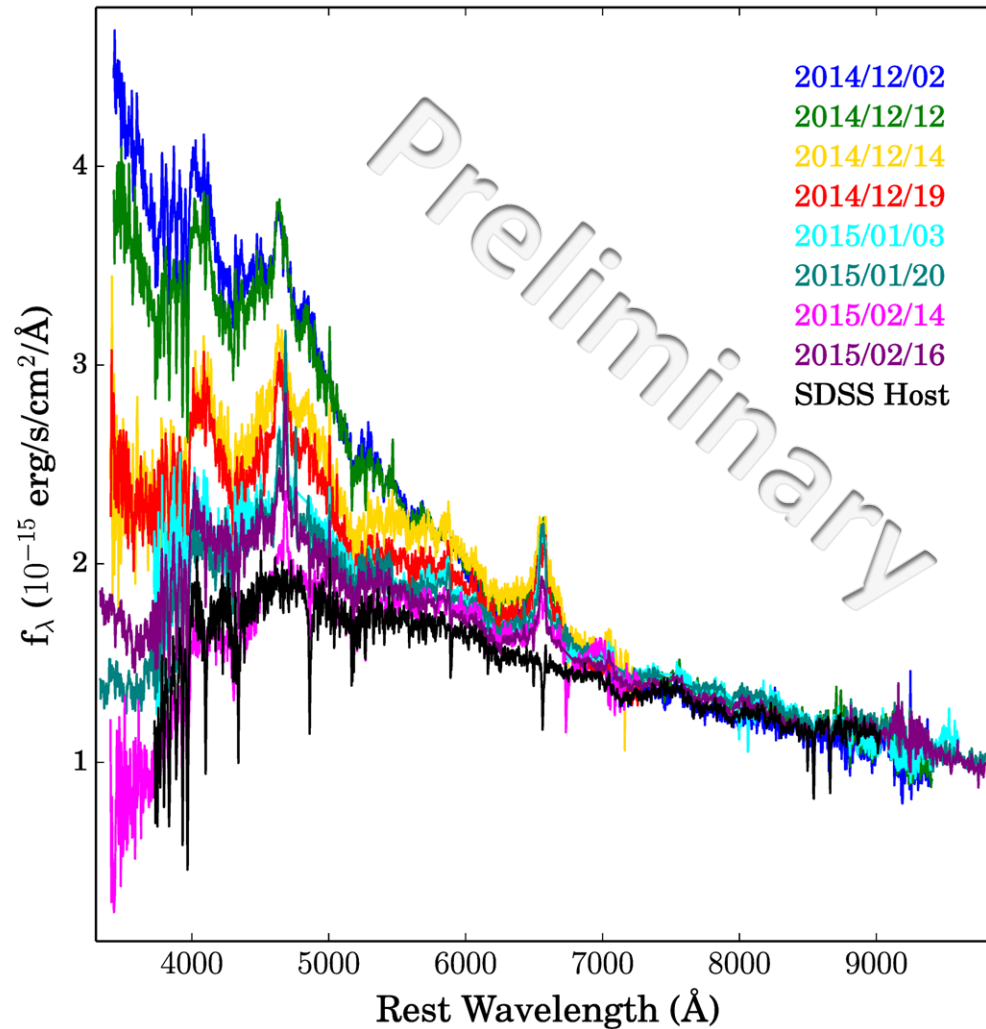
ASASSN-14ae



ASASSN-14i

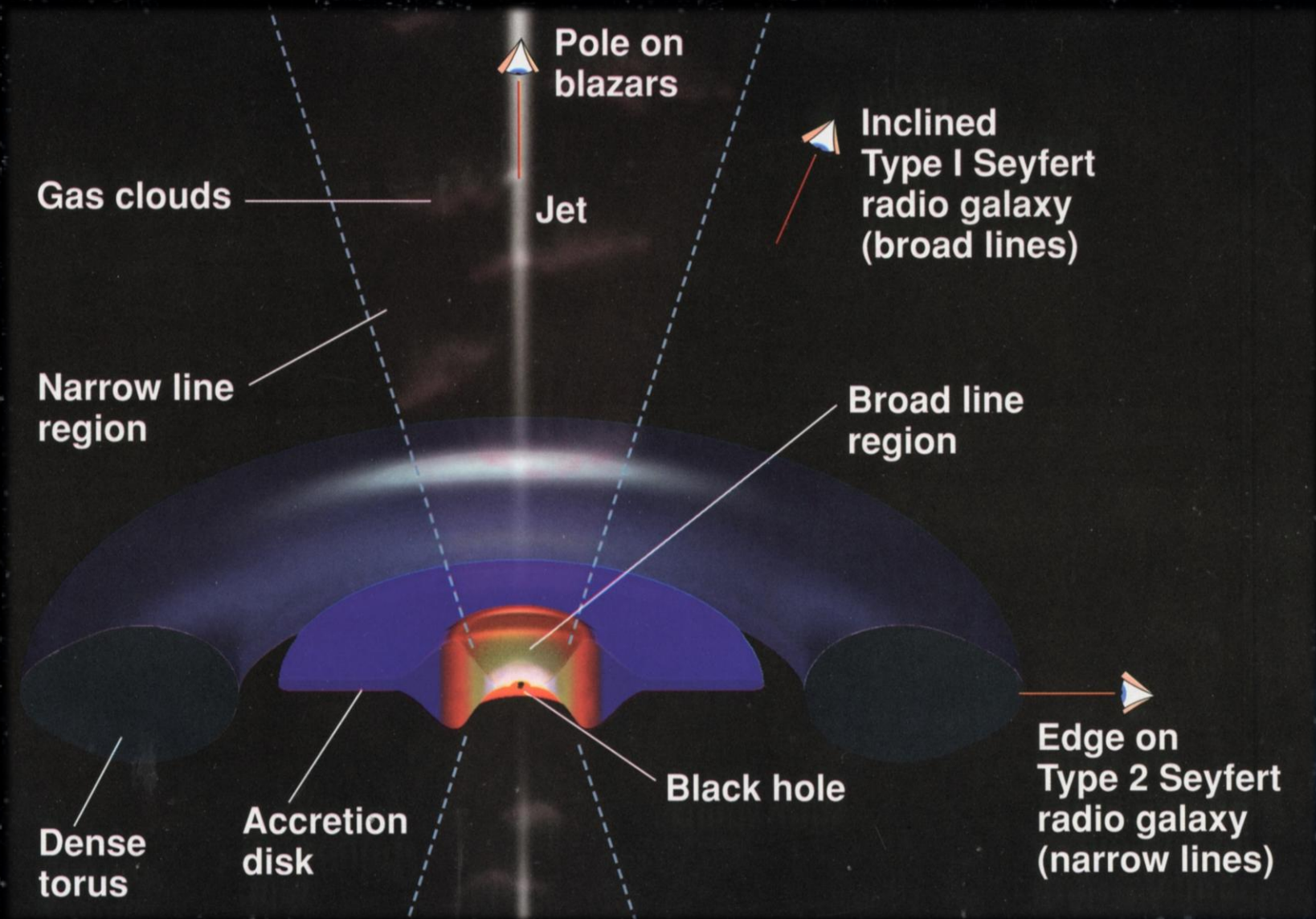


ASASSN-14li

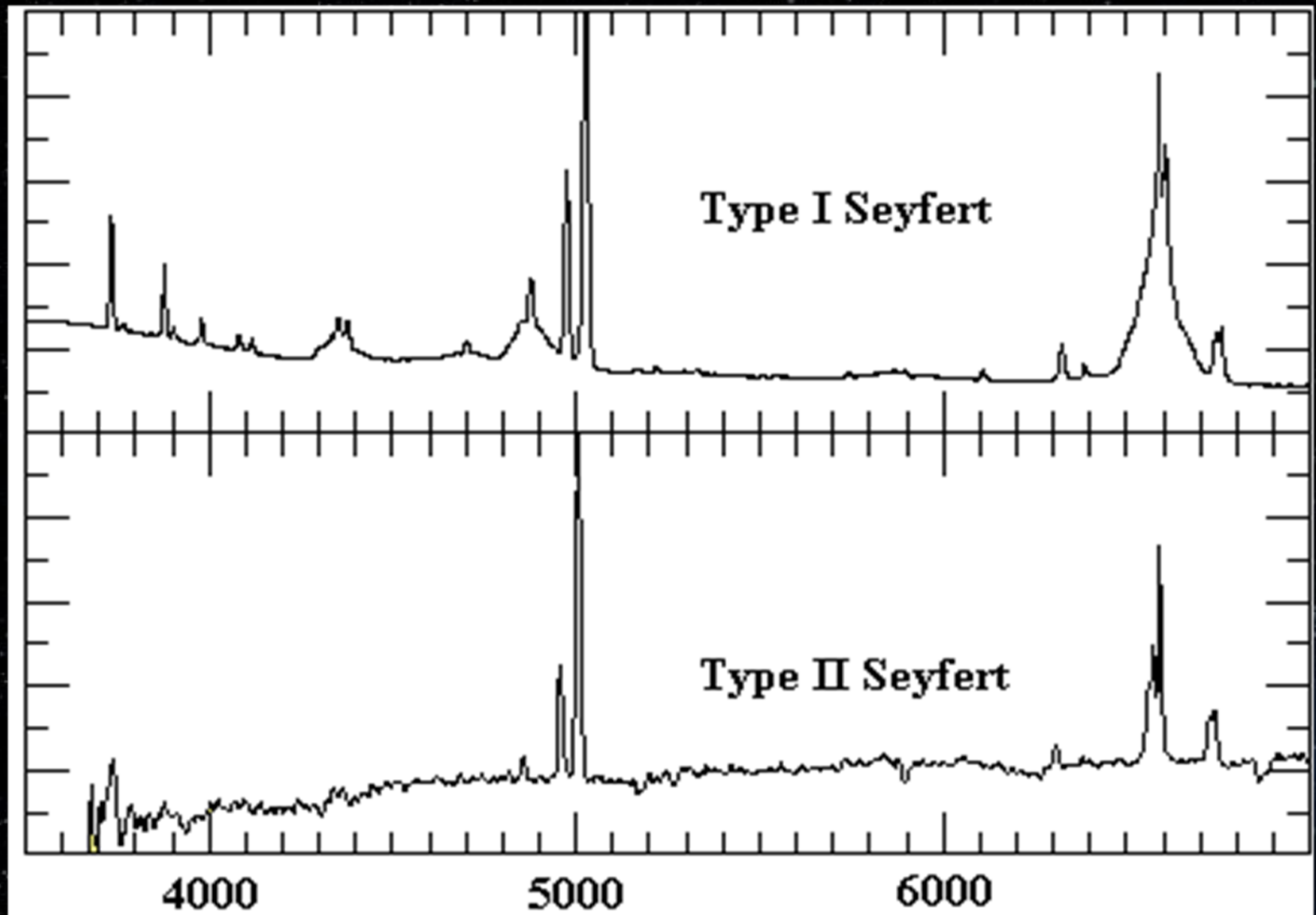


Active Galactic Nuclei

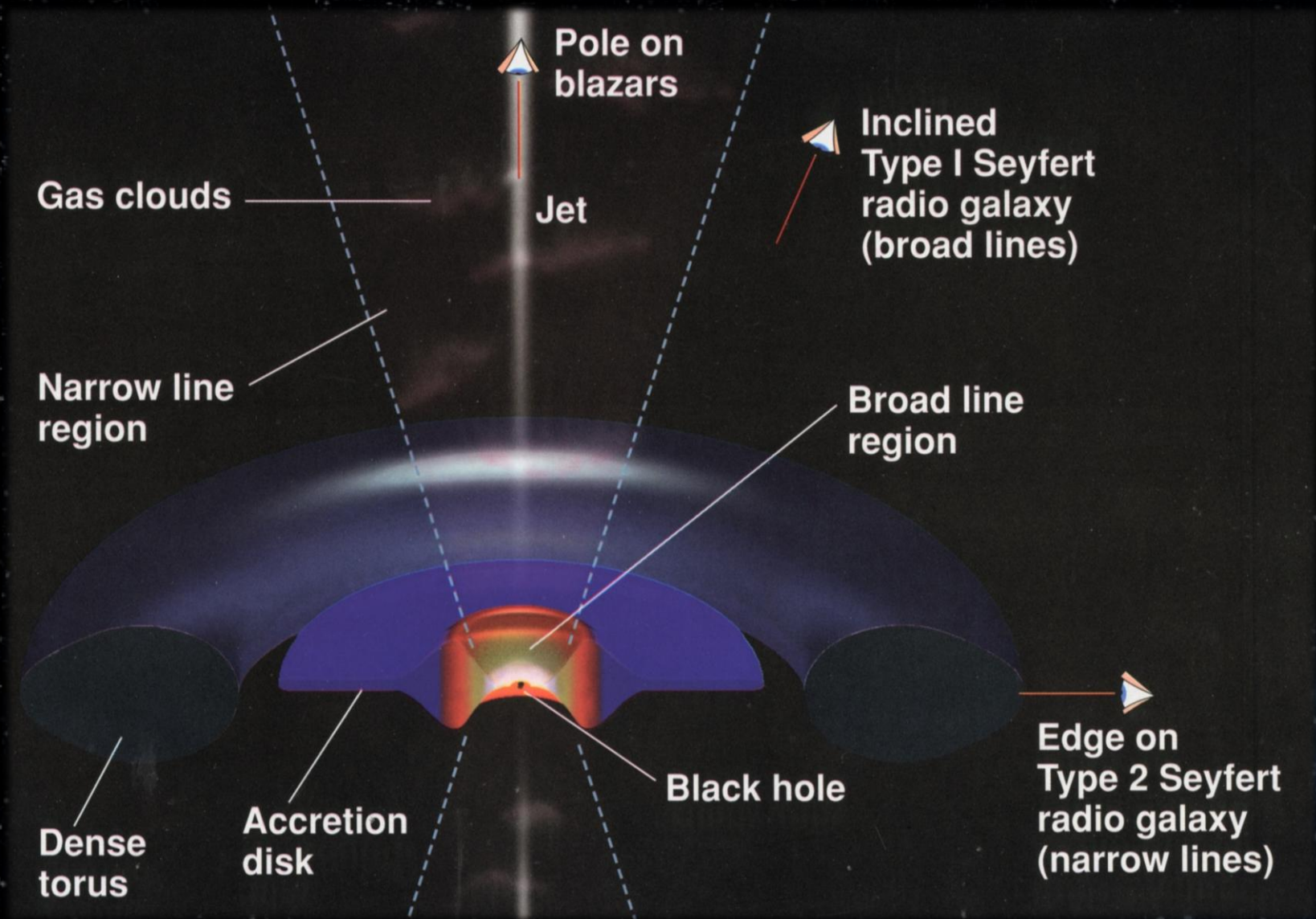
Unified Model of AGN



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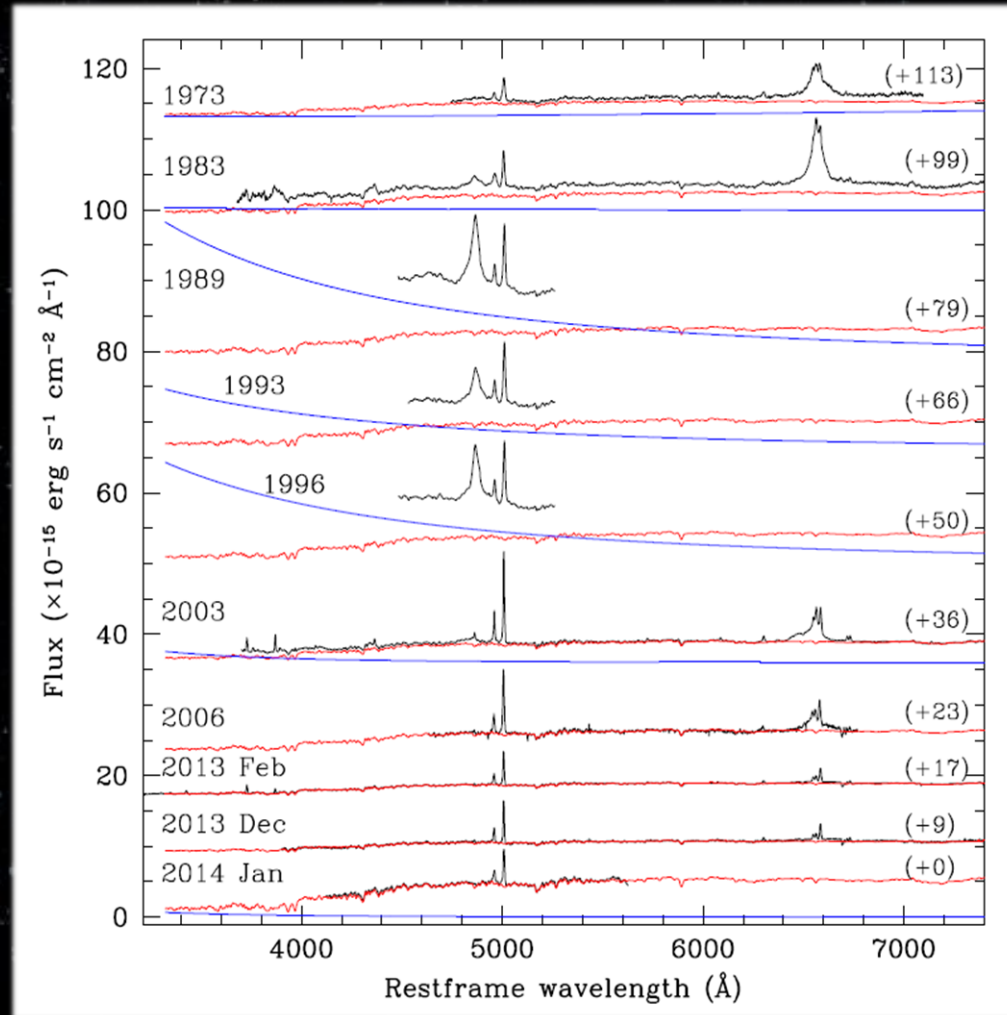


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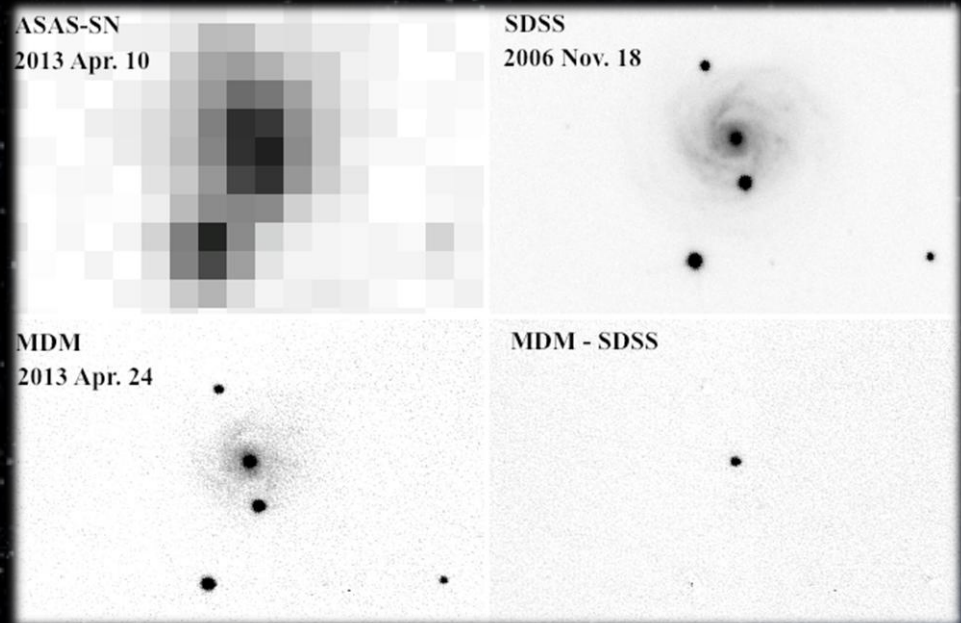
“Changing look” AGN

- 4 AGN with Vanishing broad-line components have been reported
- 5 AGN with appearing broad-line components have been reported
- Mrk 590 has done both



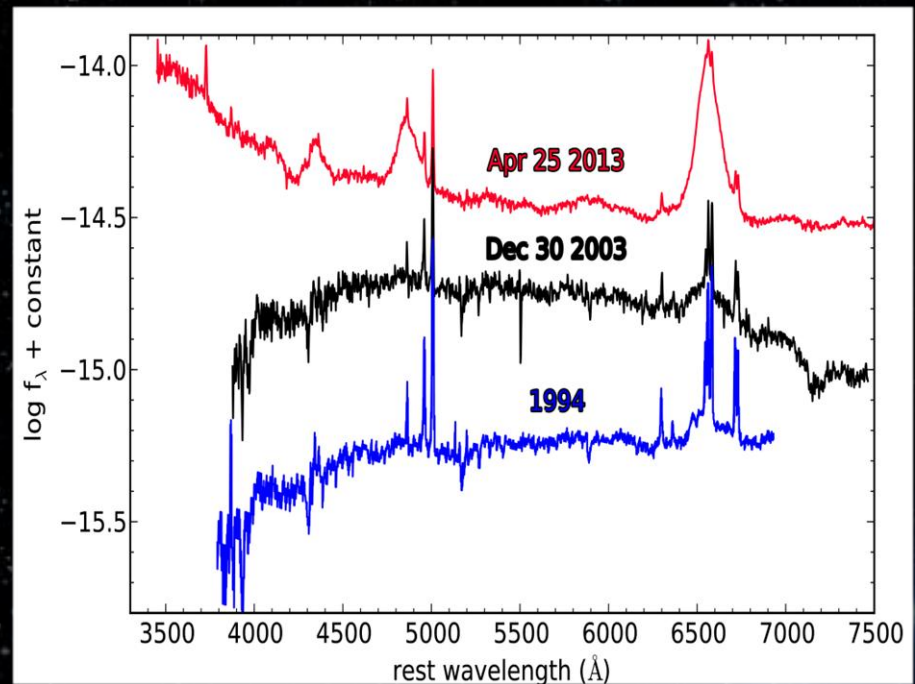
“Changing look” AGN: NGC 2617

- ASAS-SN triggered on a 10% increase in flux from AGN + host
- Follow-up imaging showed AGN continued to brighten by 1.3 mag

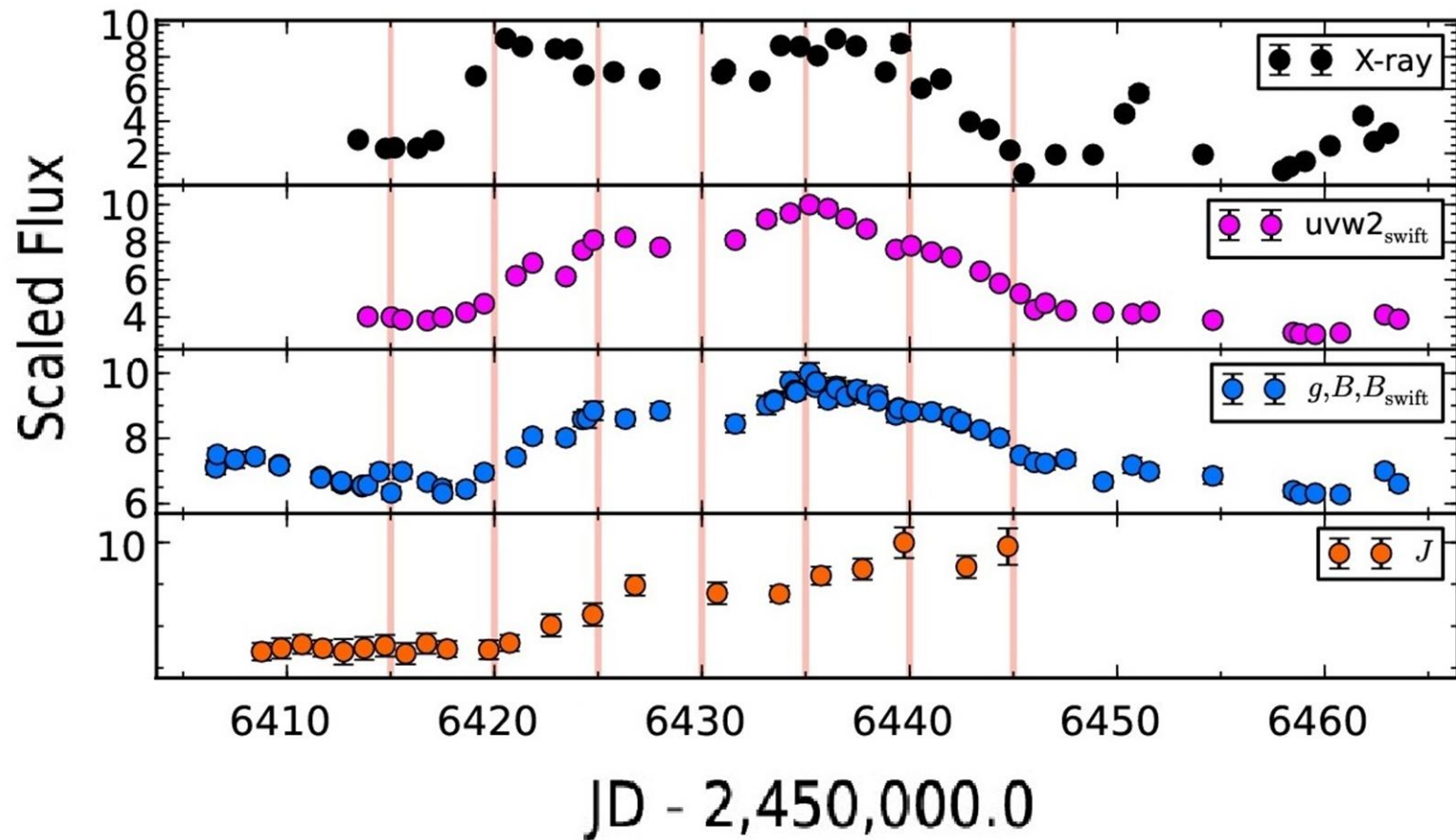


“Changing look” AGN : NGC 2617

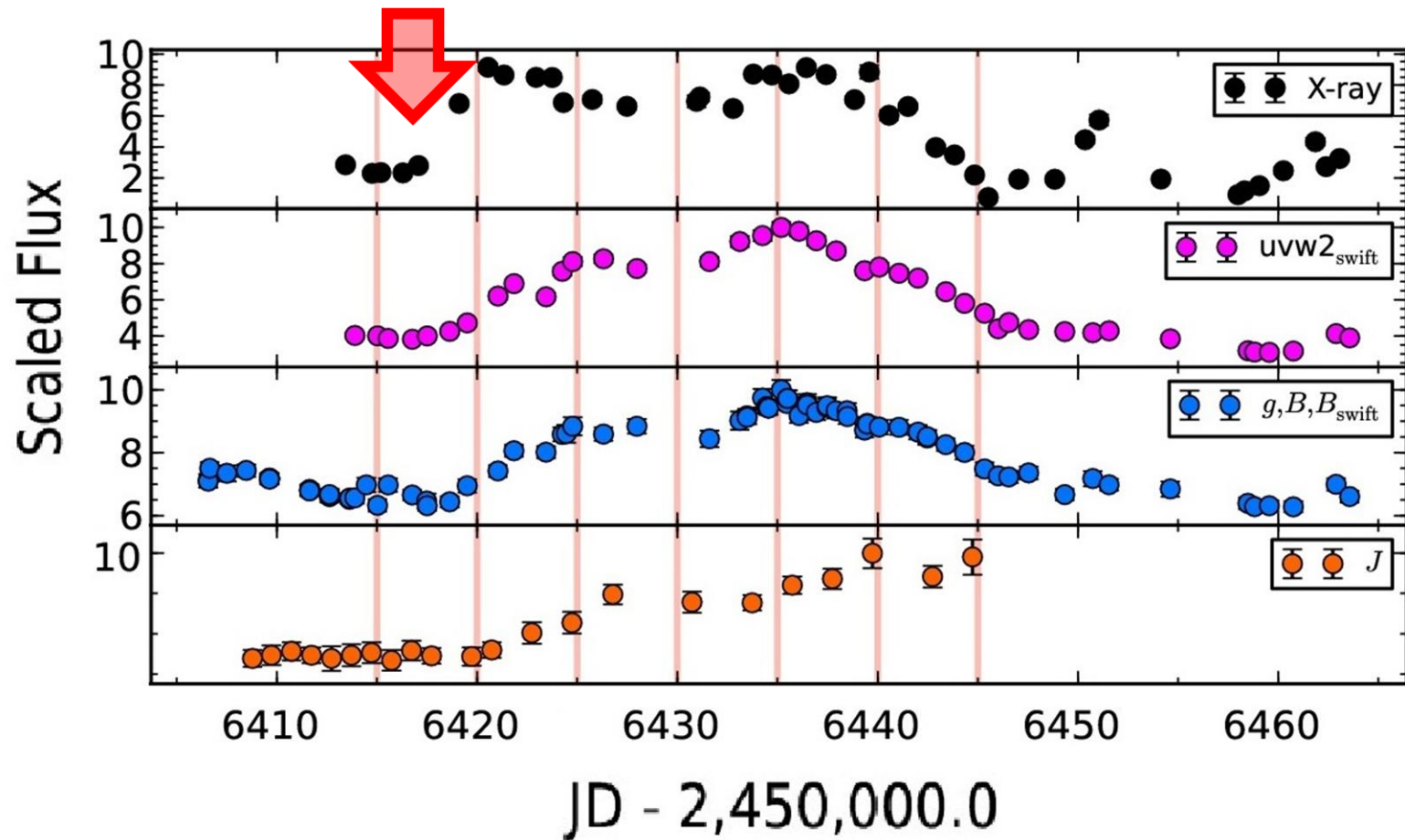
- Follow-up spectroscopy showed that the AGN changed from a Seyfert type 1.8 to 1.0
- Applied for Swift TOO observations
- Announced in ATEL #5010



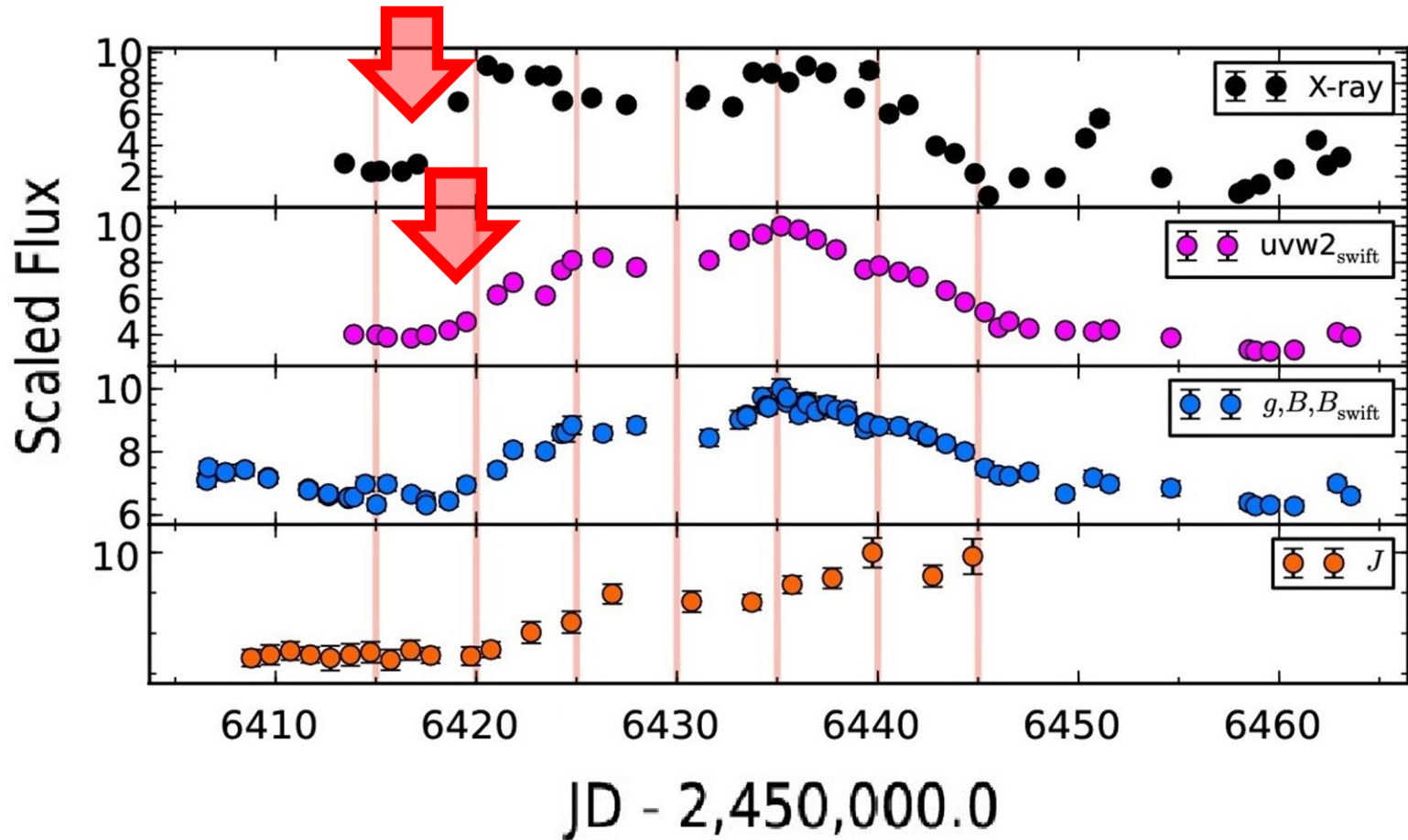
NGC 2617 X-ray–NIR light curves



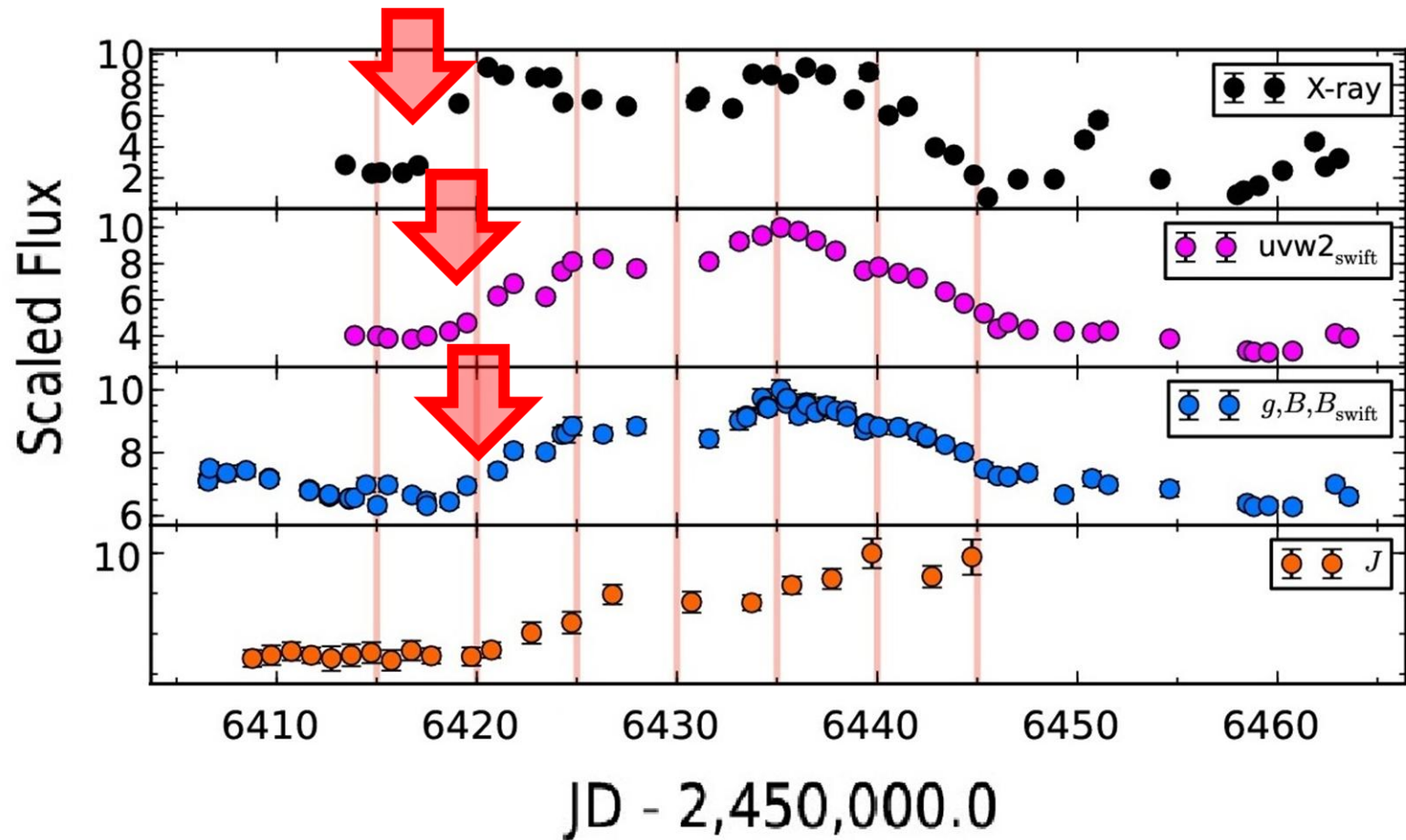
NGC 2617 X-ray–NIR light curves



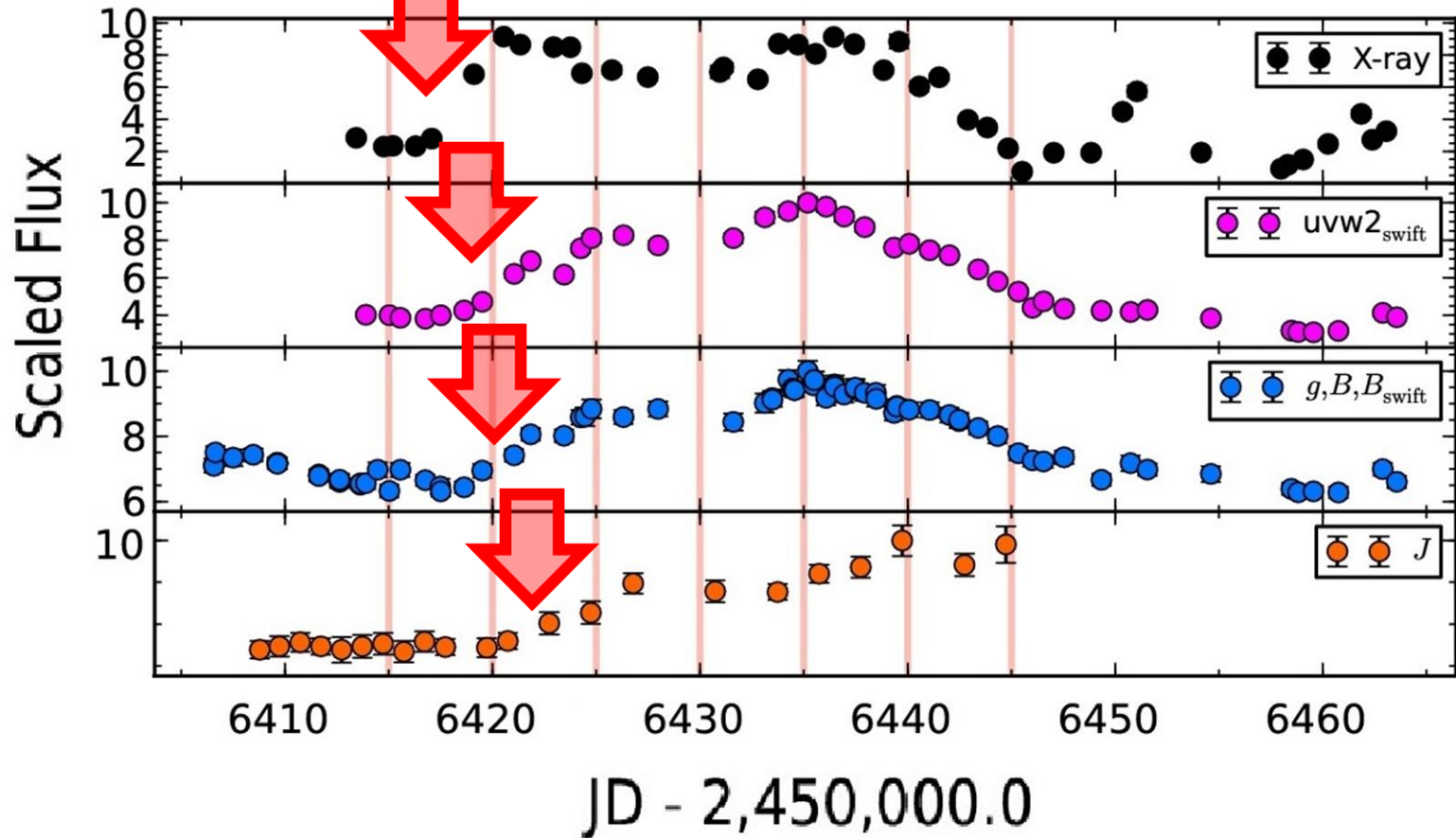
NGC 2617 X-ray–NIR light curves



NGC 2617 X-ray–NIR light curves

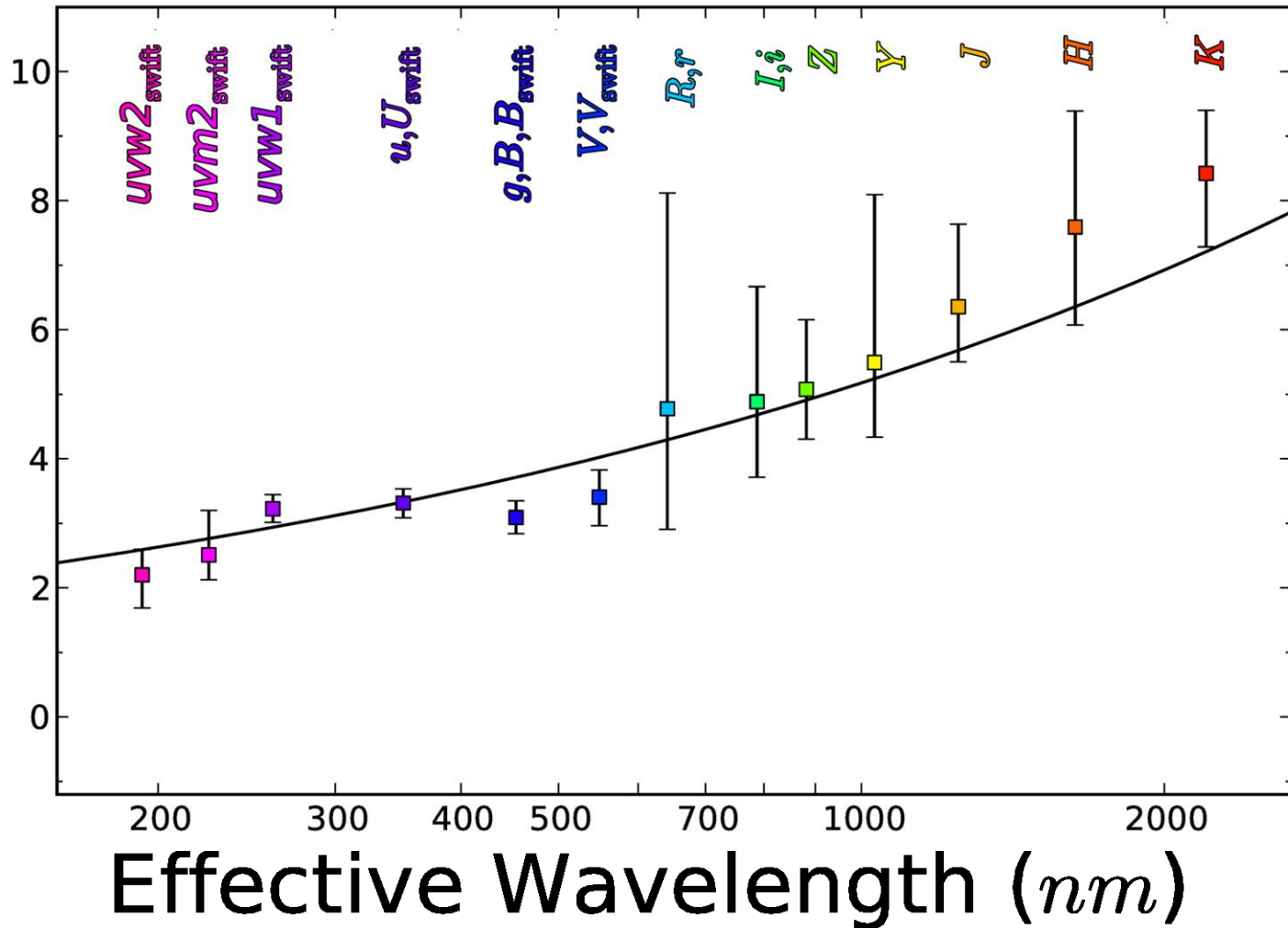


NGC 2617 X-ray–NIR light curves

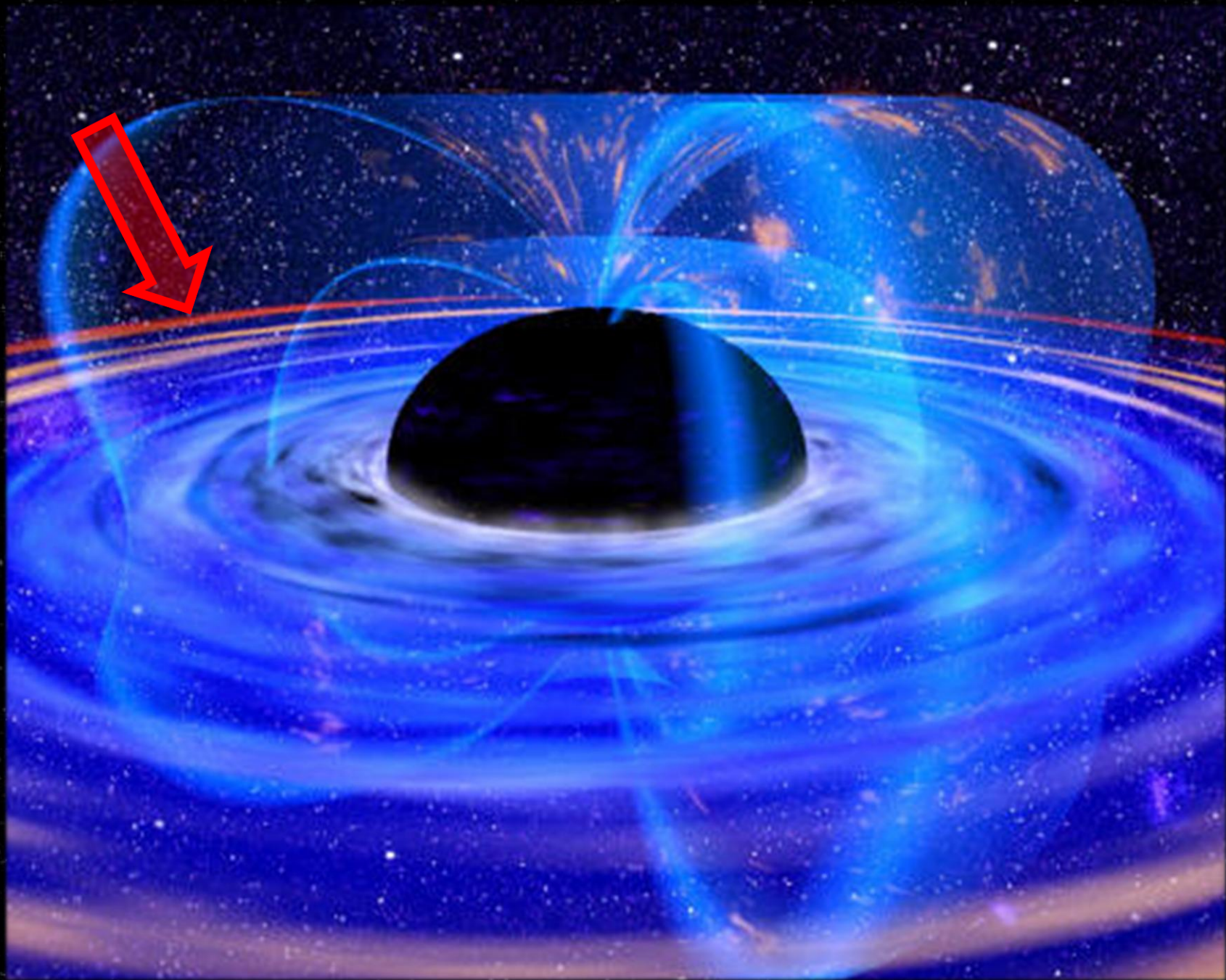


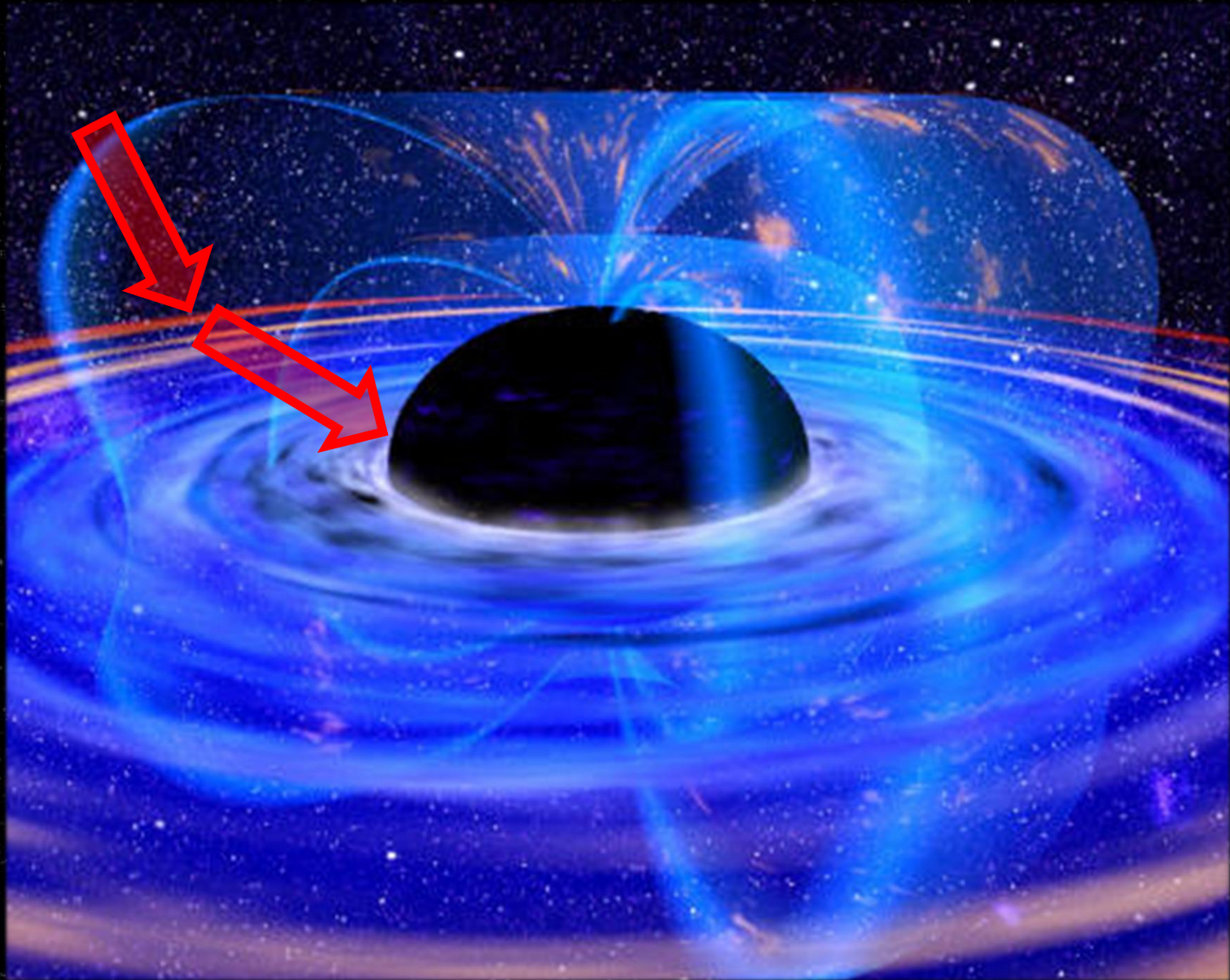
NGC 2617 Photometric Lags

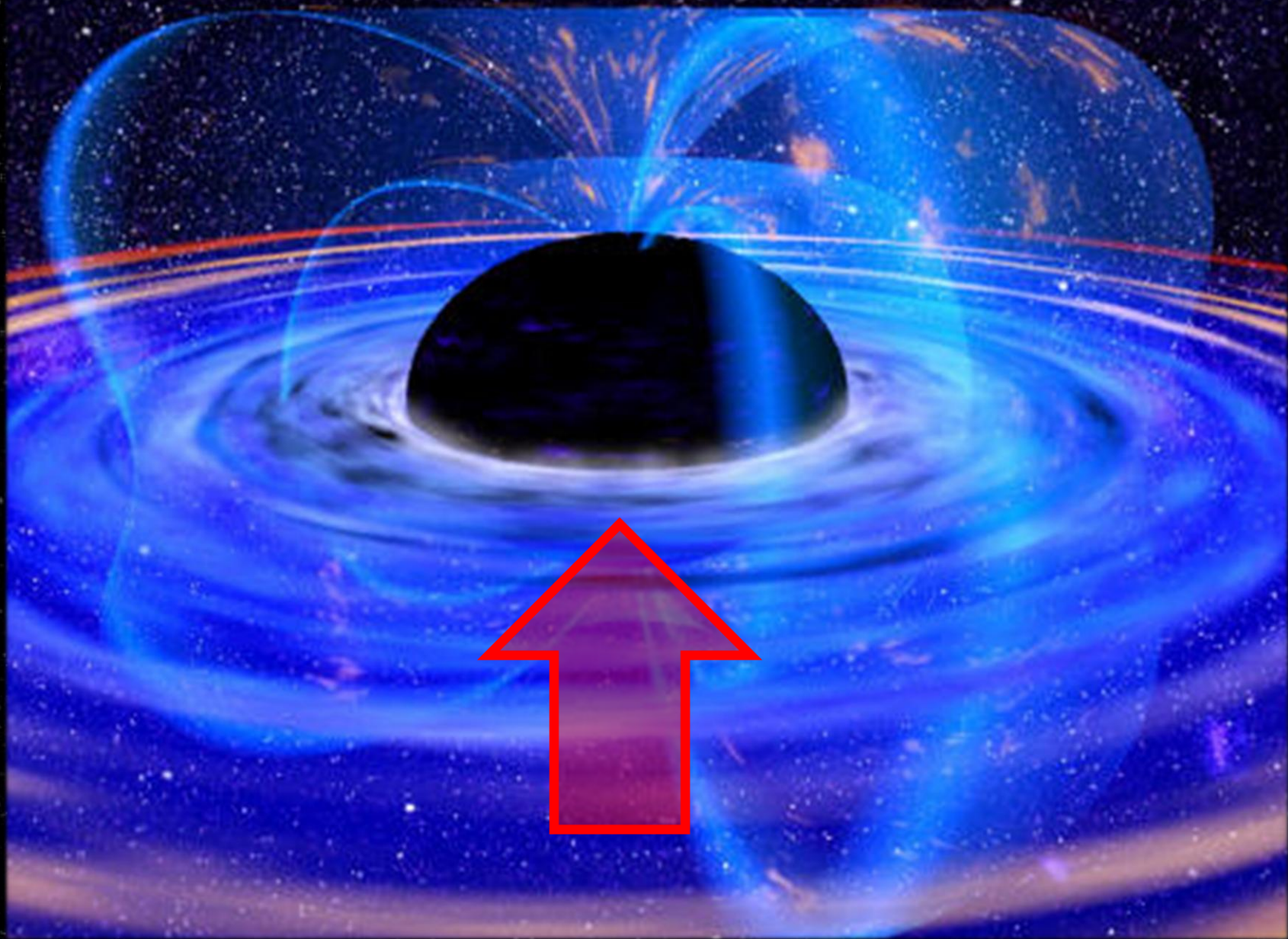
Measured Lag from X-rays (days)

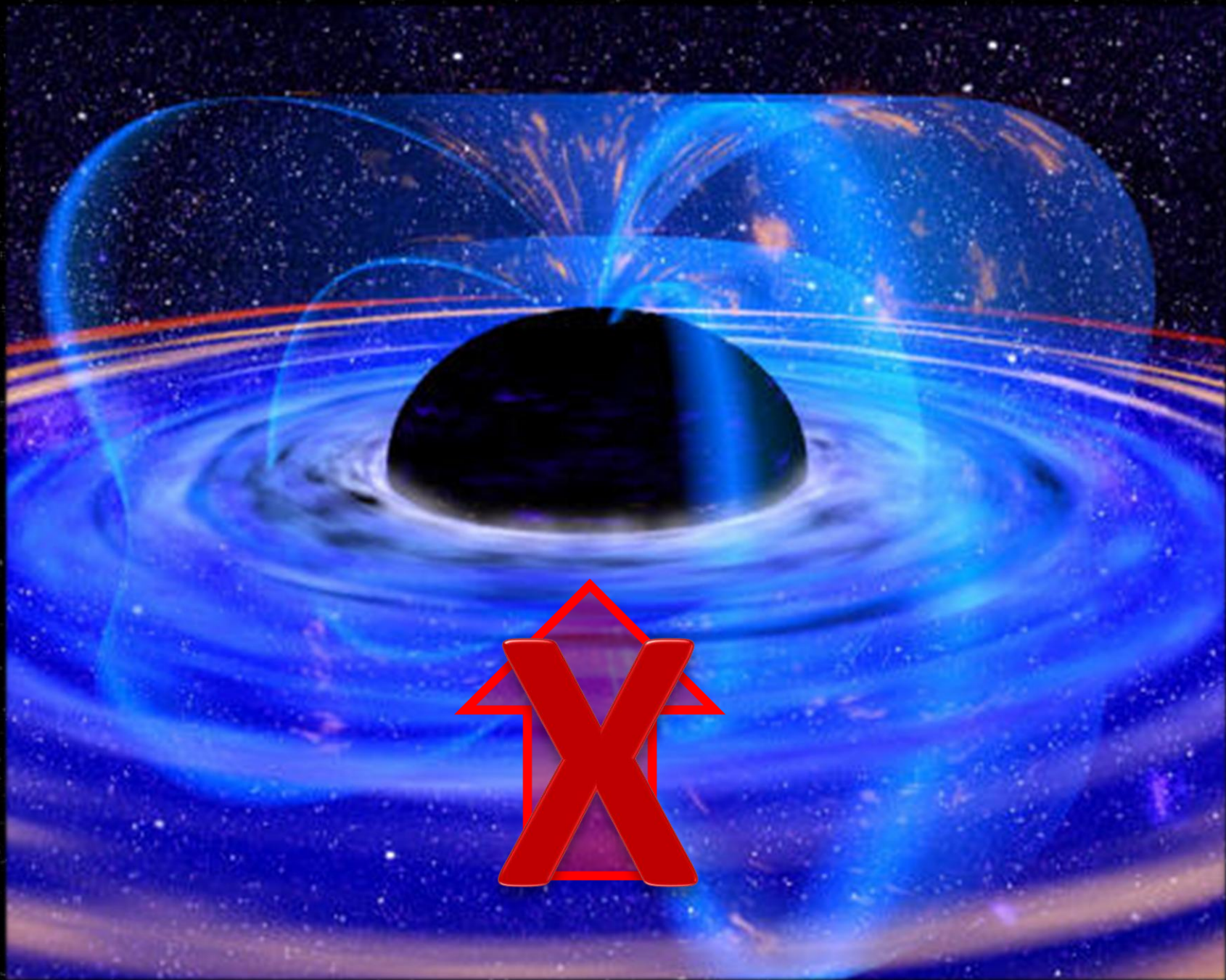








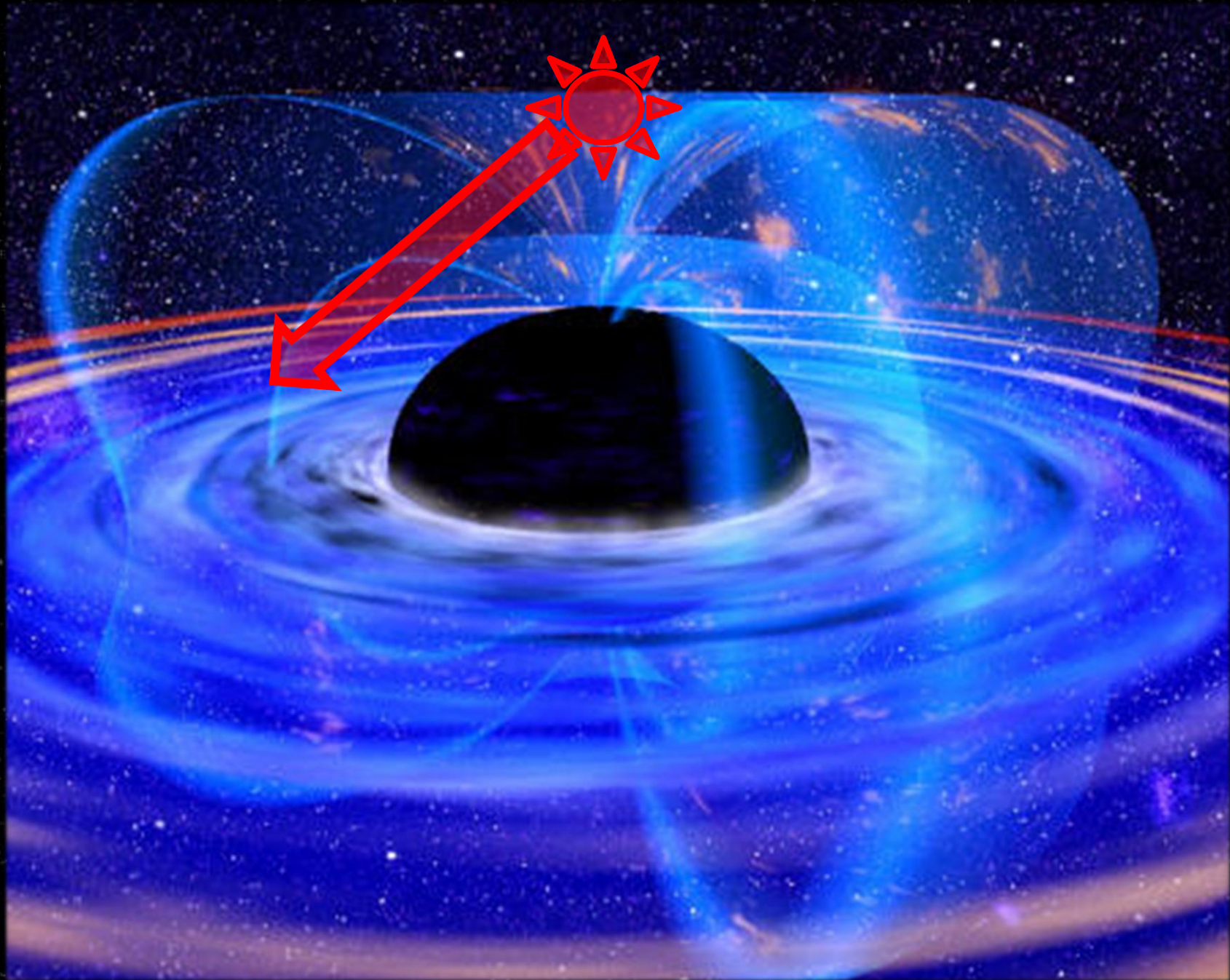


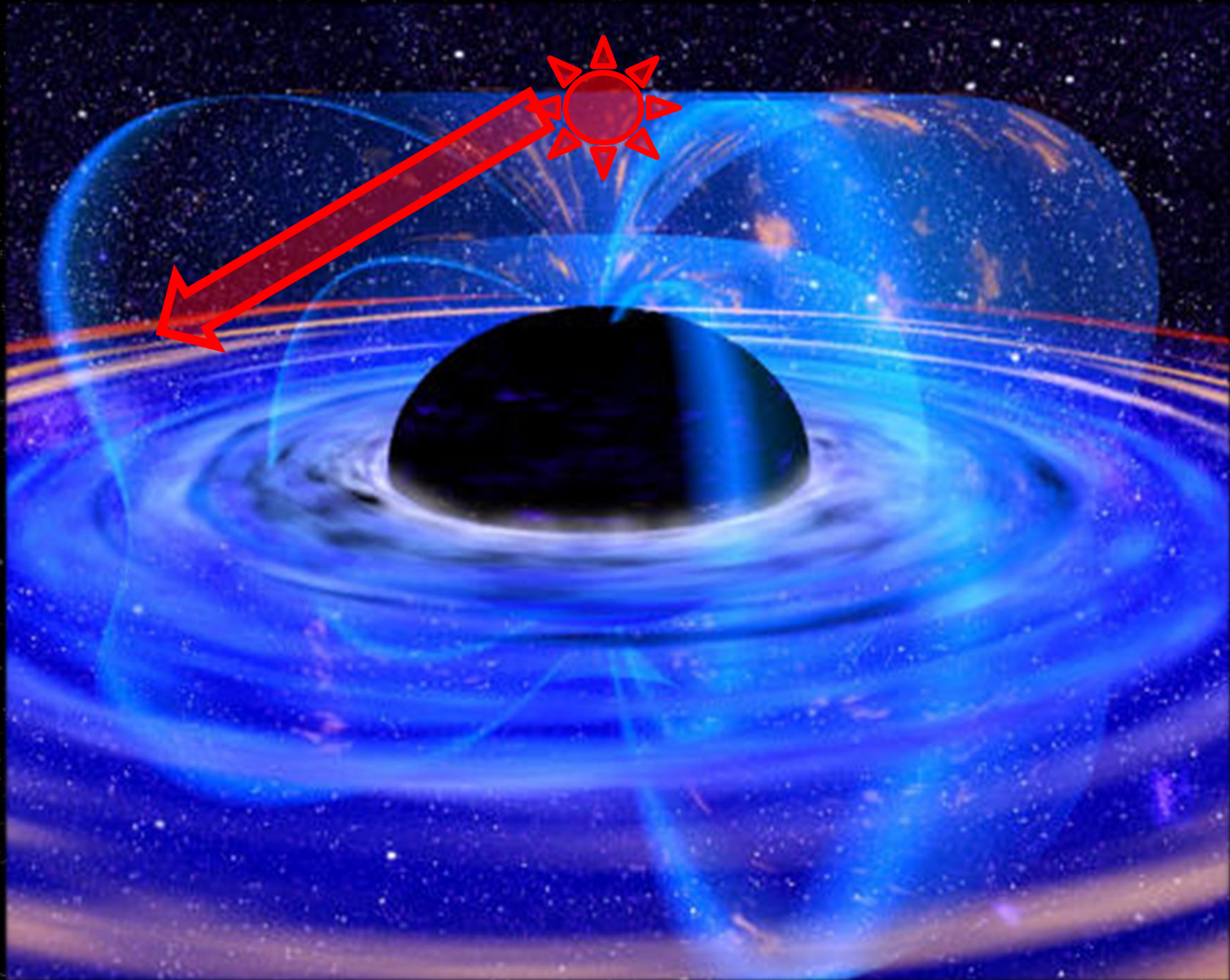


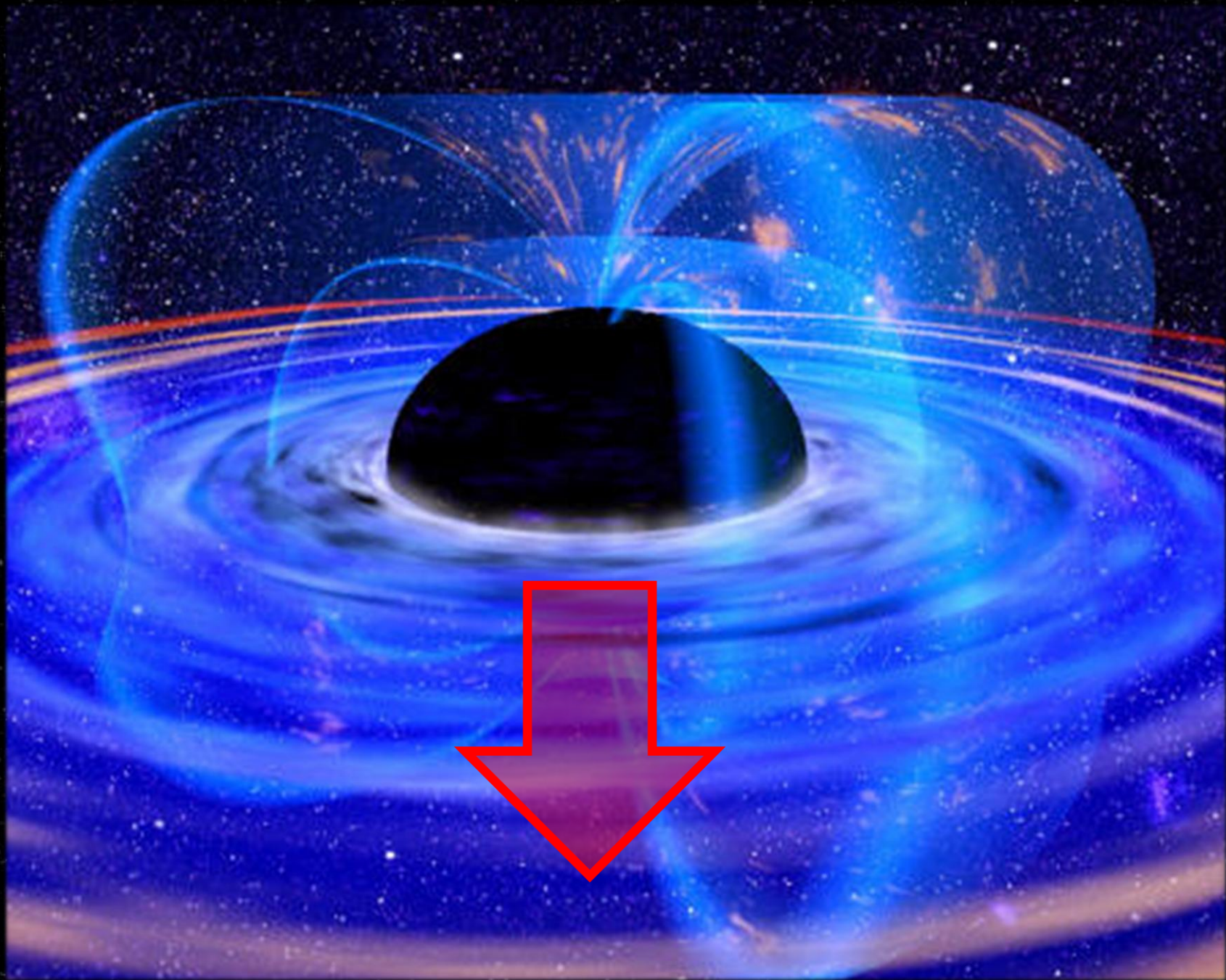




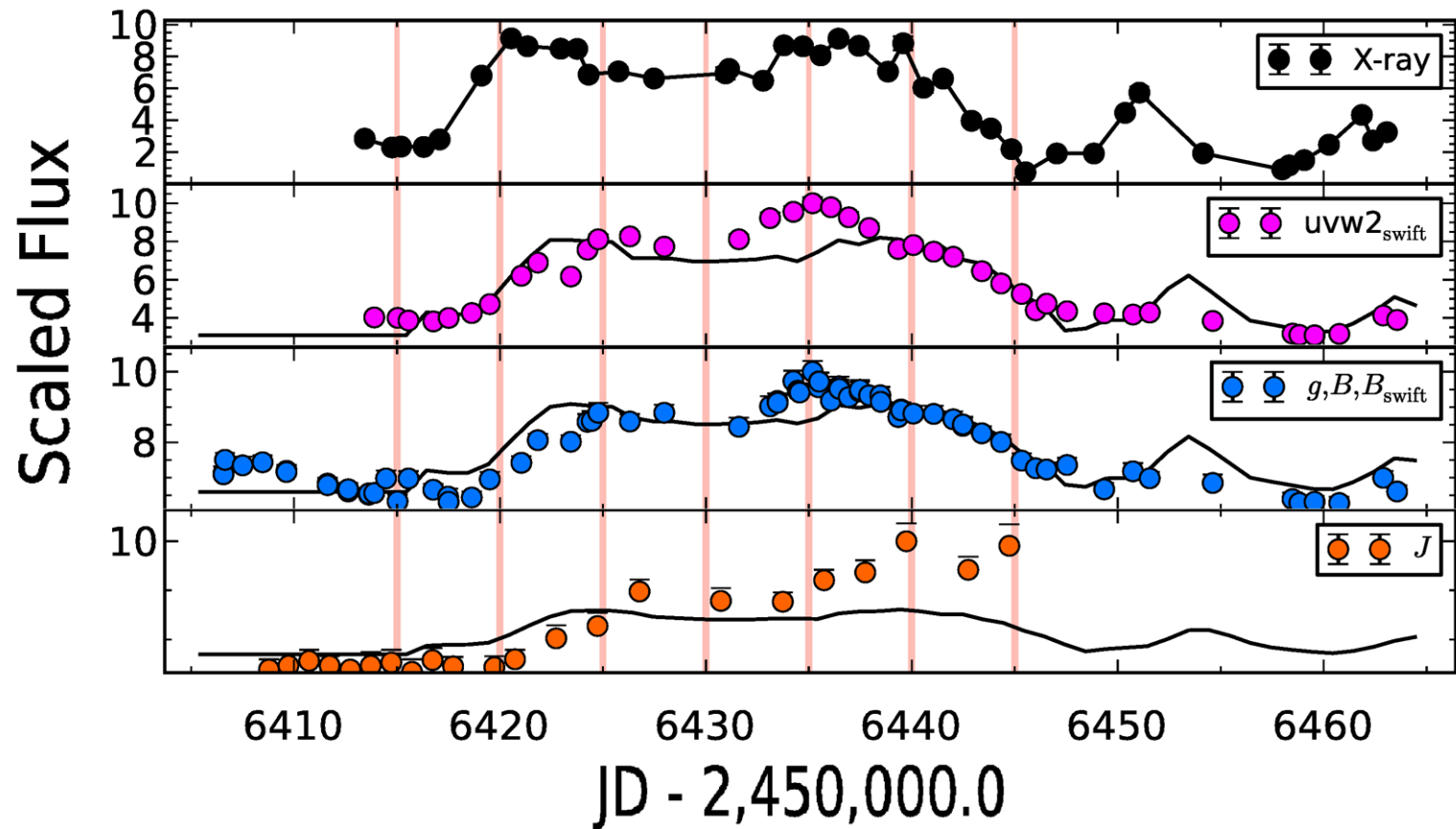






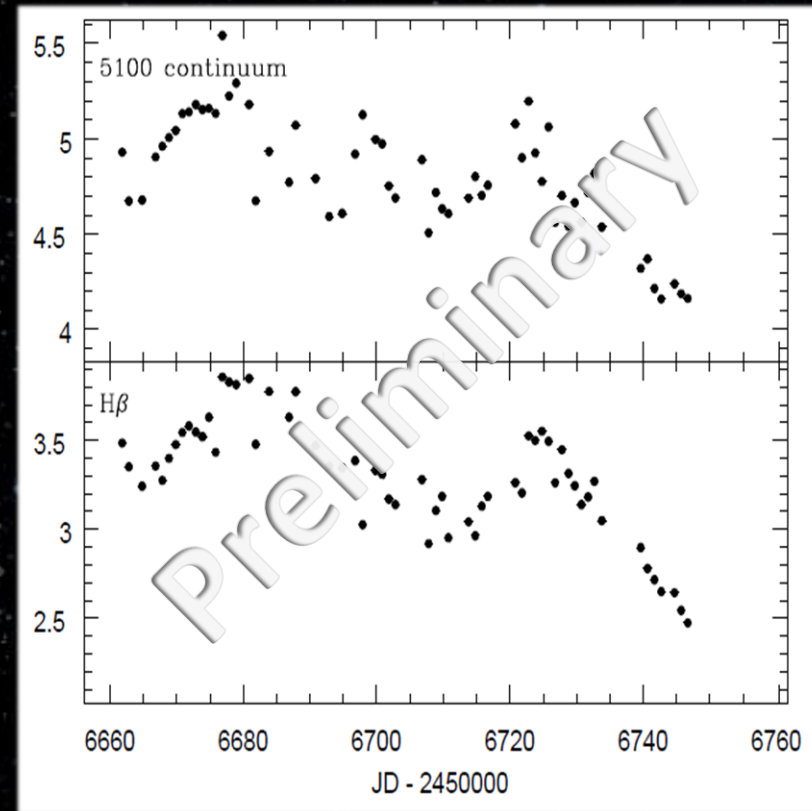


NGC 2617 X-ray–NIR light curves



What's next for NGC 2617?

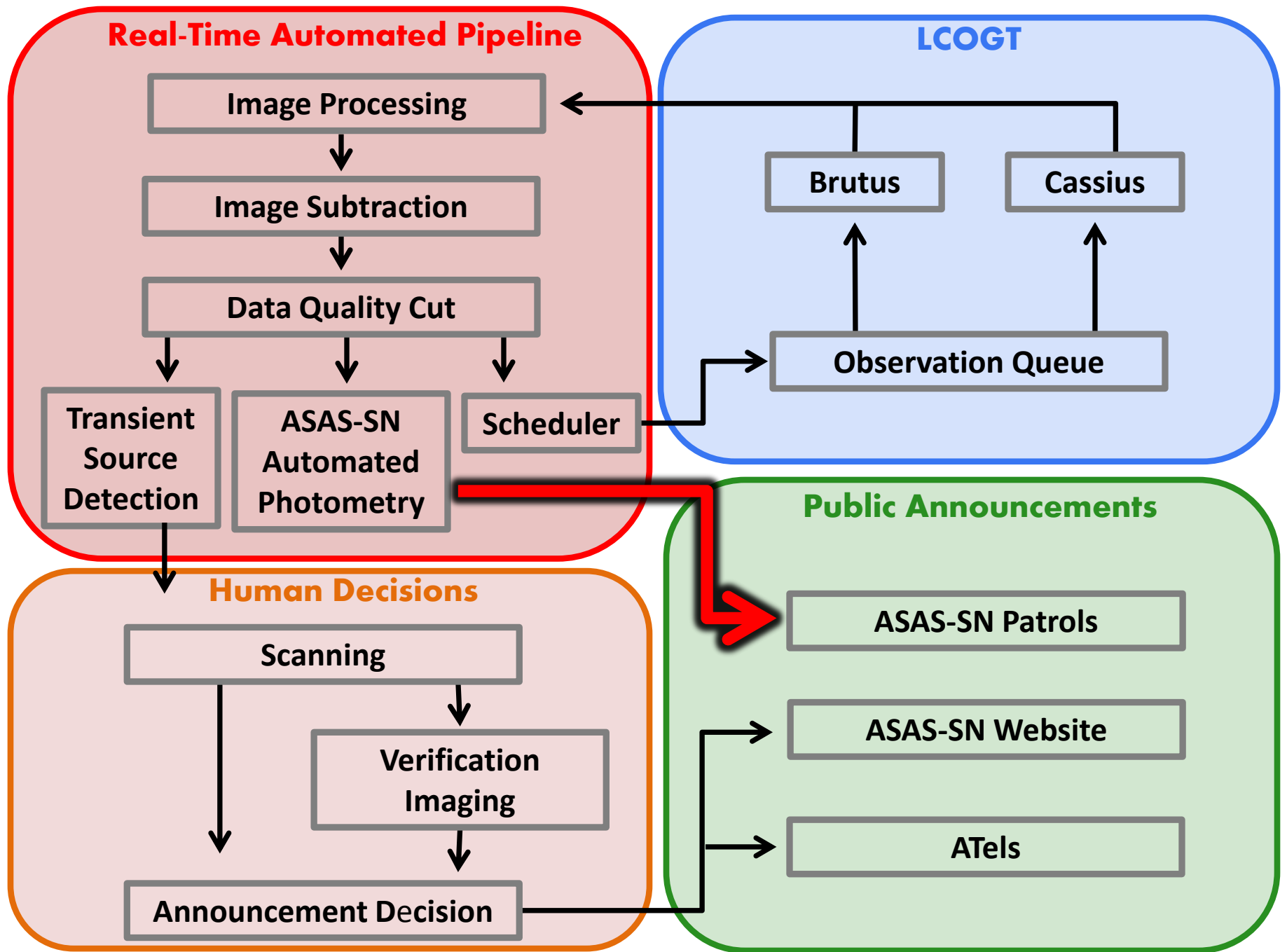
- Current observations show that NGC 2617 is still active
- We completed a 3 month reverberation mapping campaign in 2014
 - Daily spectra
 - Daily swift X-ray, UV, and optical observations
- Results coming out later in 2015
- More theoretical work is needed!



Fausnaugh et al. (inc. Shappee) 2015

Outline

- Introduction to ASAS-SN
- Discuss a few interesting discoveries
- ASAS-SN Patrols (our data release strategy)
- Future directions of ASAS-SN



ASAS-SN Patrols

ASAS-SN data releases that are:

- Organized
- Focused
- Useful
- Fast Cadence (2-3 days)
- Base-line of years
- Real-time

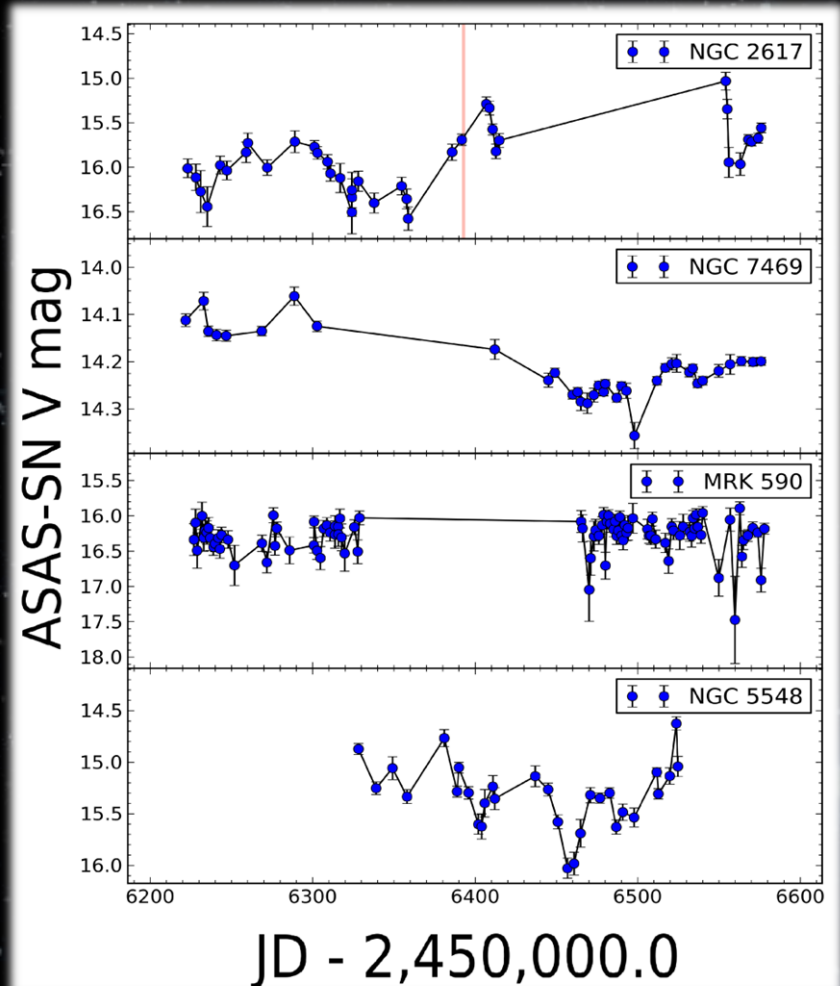
First Patrols:

- CV
- M dwarfs
- Quasar
- Blasars
- AGN
- Suggestions? (Please let us know!)

CV Patrol Demo

ASAS-SN AGN Patrol

- Inspired by NGC 2617
- Monitor ≈ 3000 AGN, Blazars and Quasars
- 2–3 day cadence
- Light curves made public real time
- Characterize AGN Variability
- Detect and announce large flares like NGC 2617
 - Determine if X-rays driving an UV–NIR flare is unique or ubiquitous



Outline

- Introduction to ASAS-SN
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ASAS-SN: Looking Forward

- Expanding ASAS-SN South, “Cassius”
 - Next few months, camera purchased
 - Improve cadence, sky coverage, and **gaps in data**
 - 20,000 square degrees a night
- Start the south Galactic Plane
- Further Expansion (with funding)
 - With 4 sites and 16 cameras
 - **entire sky every night!**
- Variable Stars
 - Led by Andres Jordan Universidad Católica
- All Public Data in a USEFUL WAY
 - Long term goal
 - What will **YOU** do with **ASAS-SN**?



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Haleakala

Sedgwick



McDonald



Cerro Tololo



Teide



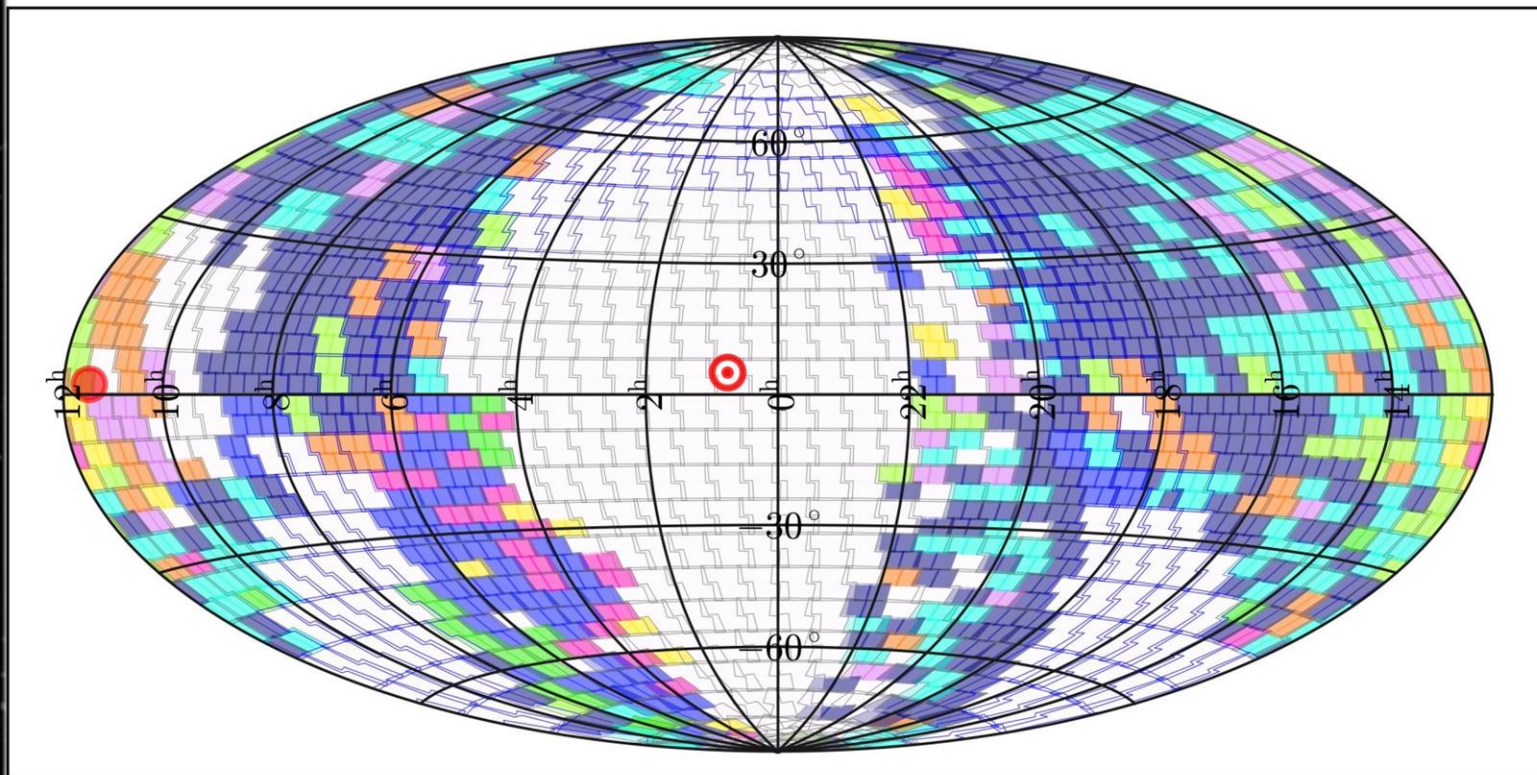
Sutherland



Siding Spring

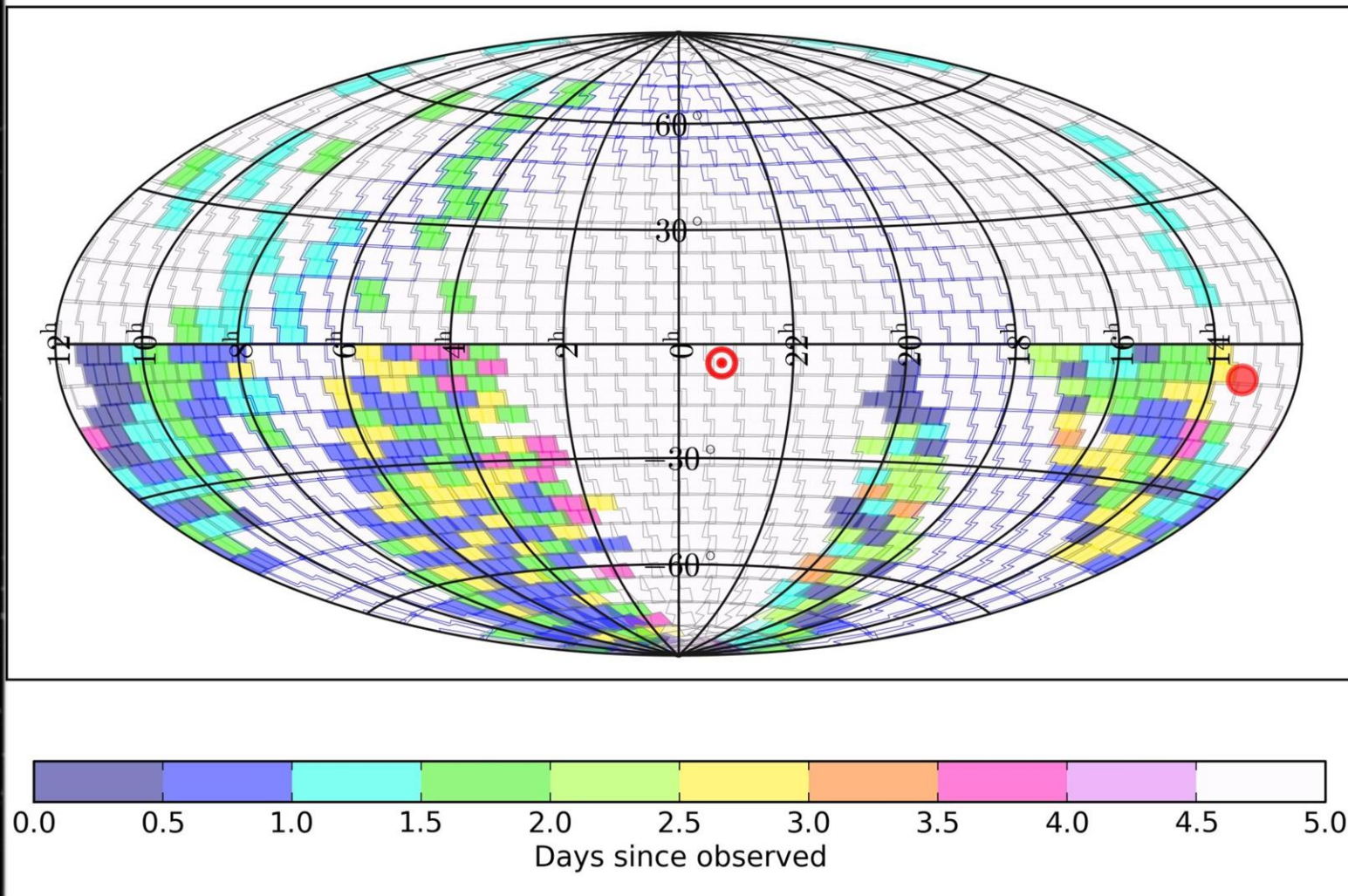
ASAS SN Cadence and Coverage

Thu Apr 2 11:14:43 2015



ASAS SN Cadence and Coverage

Sun Mar 8 15:15:02 2015



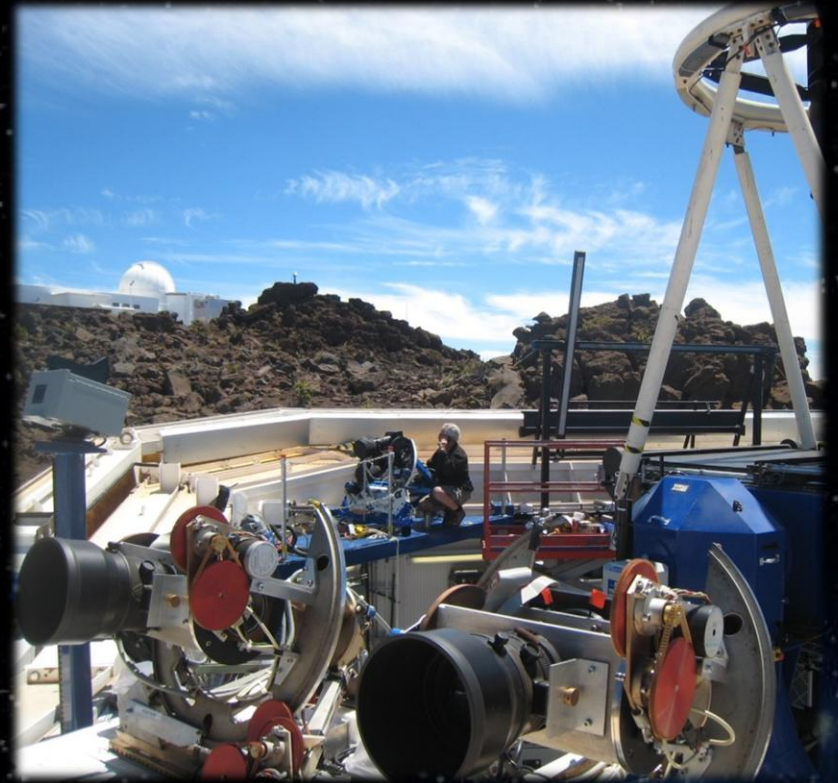
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Variable Stars: Looking back at ASAS

- The original All-Sky Automated Survey (ASAS)
- Low cost project to monitoring of the whole available sky
- $8 \leq V \leq 14$ mag
- 10^7 stars and 50,000 new variables
- 209 **refereed** publications with “ASAS” in their abstract
 - 36 in 2015
- ASAS-SN
 - Faster cadence
 - Deeper ($V \leq 17$ mag)
 - >1000 times the volume



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