

# Followup observations of Gaia alerts with SKYNET robotic telescopes

Staszek Zola

Astronomical Observatory, Jagiellonian University  
and  
Mt. Suhora Observatory, Pedagogical University

Collaborators: D. Reichart, V. Kouprianov (UNC), D. Caton (DSO)



JAGIELLONIAN  
UNIVERSITY  
IN KRAKOW

10<sup>th</sup> Gaia Science Alerts Workshop 2019  
Catania, Dec 18<sup>th</sup> – 20<sup>th</sup>

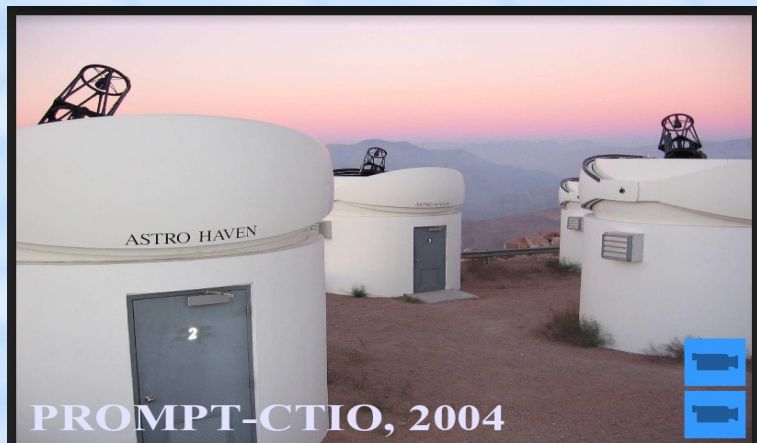


# Talk layout

- SKYNET telescopes: an observer's perspective
- Scientific results based on SKYNET data:  
long term monitoring of OJ287, Gaia19bld
- Using Cambridge Photometric Calibration Server

# SKYNET Telescopes

- Started in 2004 by D. Reichart (UNC) with a goal to observe GRBs
- PROMPT telescopes in Chile, Australia & Canada
- Currently ~20 optical telescopes (40cm -1m)
- 20m radio telescope (GB20)
- Funded mostly by NSF, but also by NASA and Mt. Cuba Astronomical Foundation
- Software (TERMINATOR) controls the network and scheduling of observations
- Works with most commercially available hardware (telescopes, domes, CCDs, filter wheels, focusers etc.)



credit: Dan Reichart





# SKYNET Telescopes

credit: Dan Reichart

Now  
16"



Now  
3 16" + 3 24" +  
32" + 40"  
In Dev  
Polarimeter,  
Spectrograph  
Proposed  
60"



Now  
4 17"  
Proposed  
17" + 28"  
or 40"

Now  
16"

## Skynet: PROMPT

# SKYNET Partners

## Requirements:

Telescope 40cm or bigger

Hardware capable of controlling by MaximDL + compatible weather station

Internet connection allowing reliable control in real time

credit: Dan Reichart



# SKYNET Science

## Skynet's Mission

- **50% Research**
  - **Publish Every ~20 Days**
  - **5 Times in Nature/Science**
  - **Leading NEO Tracker in S. Hem.**
- **50% Education / Public Engagement**
  - **Have Served ~50,000**
  - **3 Large NSF Programs**

## Skynet Science

- Gamma-Ray Bursts
- Gravitational-Wave Sources
- Fast Radio Bursts (radio)
- Blazars (optical and radio)
- Supernovae
- Supernova Remnants (radio)
- Novae
- Pulsating White Dwarfs and Hot Subdwarfs
- Wide Variety of Variable Stars
- Wide Variety of Eclipsing Binaries
- Exoplanetary Systems
- Trans-Neptunian Objects and Centaurs
- Asteroids
- Near-Earth Objects

# SKYNET Operation

## Dynamic Scheduler

- Time Sharing / Load Balancer
- Target of Opportunity (TOO)
- Priority Access Manager (PAM)

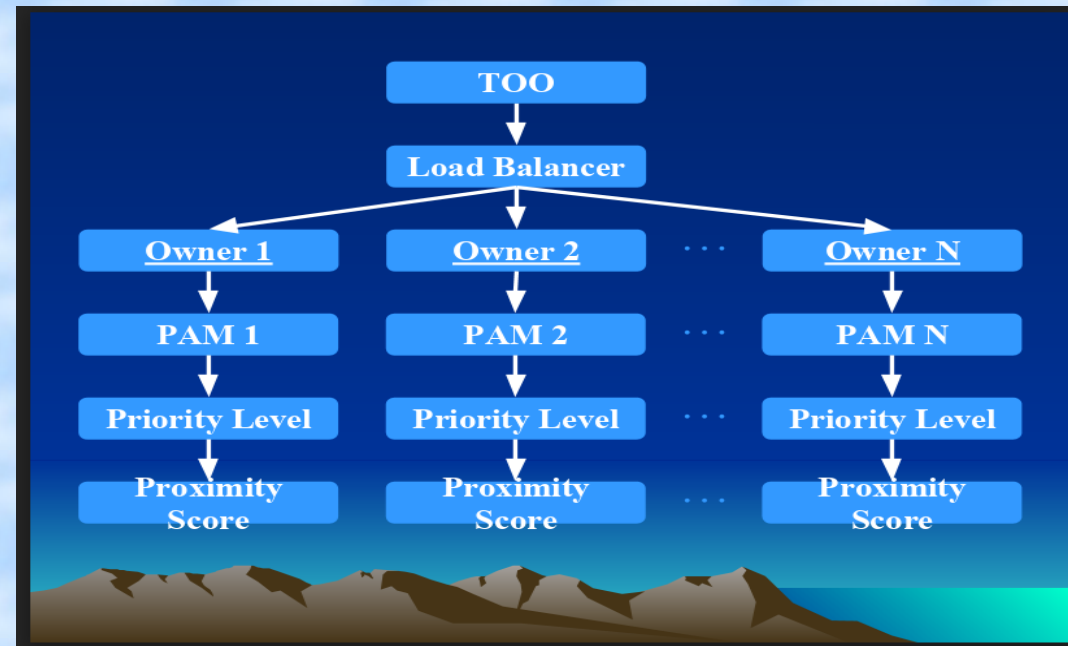
The screenshot displays two parts of the SKYNET web interface. On the left, the 'Target-of-Opportunity Schedule' table lists recipients, start dates, stop dates, and priorities. On the right, the 'Ownership - Prompt1' form allows users to manage ownership and share settings for a specific TOO.

Recipient	Start Date	Stop Date	Tel
evryscope - Evry Scope	2018-06-15 17:44	N/A	Pre
averveer - Arie Verveer	2018-06-14 02:02	N/A	Pre

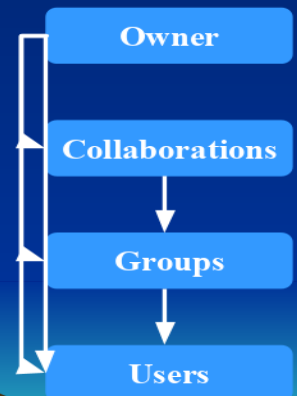
TOO   Owner	Share
<input checked="" type="radio"/> ARO	0.8
<input type="radio"/> Skynet	0.1
<input type="radio"/> CNTAC	0.1

Buttons: Reset Usage, Save Changes



## Account Management & Time Allocation

- Collaborations, Groups, and User Accounts
- Collaboration and Group Admins
- Observing Credit





# Observing with SKYNET Telescopes

Observers submit observations using a web API

SKYNET ROBOTIC TELESCOPE NETWORK							
HOME MY OBSERVATORY SKYNET LIVE TELESCOPE SITES HELP							
Telescope Status							
Telescope	Control	Sun	Weather	Dome	State	Observation	RA   Dec
AURT	SKYNET	-25.09	BAD	CLOSED	IDLE	None	06:25:43.427 13:01:04.73
DSO-14	SKYNET	-12.27	GOOD	OPEN	IDLE	None	09:13:28.956 20:03:03.49
GreenBank-20	SKYNET	-10.68	GOOD	N/A	IDLE	None	05:04:30.296 38:29:07.91
MDRS-14	SKYNET	-33.43	GOOD	OPEN	IDLE	None	00:07:58.116 75:15:50.04
NSO-17-CDK	LOCKED	-4.32	BAD	ERROR	IDLE	None	03:37:48.900 26:25:30.00
PROMPT-MO-1	SKYNET	-2.67	GOOD	OPEN	CAMERA ABORTED	None	20:13:54.489 00:24:56.51
Prompt1	SKYNET	-3.98	BAD	CLOSED	CAMERA ABORTED	None	00:53:10.356 -32:28:49.03
Prompt2	MANUAL	-3.98	BAD	ERROR	CAMERA ERROR	None	11:47:49.956 -89:38:23.96
Prompt3	SKYNET	-3.98	BAD	CLOSED	IDLE	None	01:43:20.140 -09:44:18.14
Prompt5	SKYNET	-3.98	BAD	CLOSED	CAMERA ABORTED	None	06:17:50.329 -11:28:54.24
Prompt8	SKYNET	-3.98	BAD	CLOSED	CAMERA ABORTED	None	01:05:54.532 10:59:03.65
RAO-BN	SKYNET	-28.07	BAD	CLOSED	CAMERA ERROR	None	23:28:51.499 50:52:16.99
RRRT	SKYNET	-9.88	GOOD	OPEN	MOUNT ERROR	None	02:31:10.047 -08:54:32.73

Telescope Status							
Telescope	Control	Sun	Weather	Dome	State	Observation	RA   Dec
AURT	SKYNET	-20.56	BAD	CLOSED	IDLE	None	07:05:02.751 13:01:04.97
DSO-14	SKYNET	-4.41	GOOD	OPEN	IDLE	skynetadmin FLAT_DSO-14_bin1_2019_09_23	06:23:15.007 35:37:31.60
GreenBank-20	SKYNET	-3.05	GOOD	N/A	IDLE	None	05:43:50.168 38:30:14.88
MDRS-14	SKYNET	-26.61	GOOD	OPEN	IDLE	None	00:47:17.087 75:15:50.04
NSO-17-CDK	LOCKED	2.69	BAD	ERROR	IDLE	skynetadmin DARK_NSO-17- CDK_bin1_2019_09_22	04:17:08.600 26:25:30.00
PROMPT-MO-1	SKYNET	-10.99	GOOD	OPEN	IDLE	None	20:24:38.083 -28:31:57.77
Prompt1	SKYNET	4.50	BAD	CLOSED	IDLE	None	00:25:39.262 -85:40:37.00
Prompt2	MANUAL	4.50	BAD	ERROR	CAMERA ERROR	None	12:18:25.098 -87:24:22.97
Prompt3	SKYNET	4.50	BAD	CLOSED	CAMERA EXPOSING	skynetadmin DARK_Prompt3_bin2_2019_09_23	00:25:13.432 -85:40:40.40
Prompt5	SKYNET	4.50	BAD	CLOSED	CAMERA EXPOSING	skynetadmin DARK_Prompt5_bin2_2019_09_23	12:12:46.994 -83:56:56.67
Prompt8	SKYNET	4.50	BAD	CLOSED	IDLE	None	01:51:31.321 -60:13:48.40
RAO-BN	SKYNET	-23.08	BAD	CLOSED	CAMERA ERROR	None	23:28:51.499 50:52:16.99
RRRT	SKYNET	-2.18	GOOD	OPEN	MOUNT ERROR	None	02:31:10.047 -08:54:32.73



# Observing with SKYNET Telescopes

List of telescopes and detailed info available. Several sites have allsky cameras for inspecting weather conditions

TELESCOPE SITES HELP


- Athabasca University Geophysical Observatory
- Athabasca University Geophysical Observatory II
- Banner Creek Observatory
- Perth Observatory
- Cerro Tololo Inter-American Observatory
- DEMO
- DEMO-EAST
- DEMO-WEST
- Dark Sky Observatory
- Dolomiti Astronomical Observatory (DAO)
- Fan Mountain Observatory
- Hampden-Sydney College Observatory
- GORT
- Mars Desert Research Station
- Meckering Observatory
- Morehead
- Green Bank Observatory
- Northern Skies Observatory
- Rothney Astrophysical Observatory
- Shed of Science Observatory
- Siding Springs Observatory
- Yerkes

Meckering Observatory


Telescope Status

Telescope	Weather	Dome	State	Observation	RA   Dec
PROMPT-MO-1	GOOD	OPEN	CAMERA EXPOSING	4357 Guest Request	12:38:43.023 -66:13:10.71

Live Site View



Map Satellite



Recent Images

Observation: 4354108  
Exposure: 27203257  
Telescope: PROMPT-MO-1  
Filter: Lum  
Length: 40.00s  
taken 1.3m ago

Observation: 4348733  
Exposure: 27180099  
Telescope: PROMPT-MO-1  
Filter: Lum  
Length: 4.00s  
taken 2.5m ago

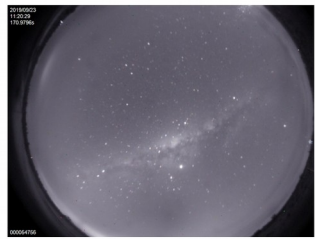
East = TOP South = Left All Times in UTC

PROMPT-MO-1

Telescope Status

Telescope	Weather	Dome	State	Observation	RA   Dec
PROMPT-MO-1	GOOD	OPEN	CAMERA EXPOSING	Observation: 4358174	22:58:25.120 -40:57:53.61

Live Site View Live Pointing



Filters

UPRIME GRIME RPRIME IPRIME ZPRIME U B  
V R I RED GREEN BLUE LUM  
HALPHA OHII CLEAR

Info

APERTURE: 0.4 m  
FOCAL LENGTH: 4477.0 mm  
F-RATIO: 11.0  
FILTERS: uprime, grime, rprime, iprime, zprime, U, B, V, R, I, Red, Green, Blue, Lum, Halpha, Ohii, Clear  
CCD SIZE: 1024 x 1024 (13 um pixels)  
FOV: 10.2 x 10.2 arcmins  
SITE: Meckering Observatory

Recent Images

Observation: 4357899  
Exposure: 27225911  
Filter: Clear  
Length: 45.00s  
taken 2.1m ago

Observation: 4354108  
Exposure: 27203257  
Filter: Lum  
Length: 40.00s  
taken 3.5m ago

Observation: 4354108  
Exposure: 27203257  
Filter: Lum  
Length: 40.00s  
taken 4.2m ago

# Observing with SKYNET Telescopes

Images are calibrated soon after gathering and available for viewing (jpg) or download (fits/jpg)

Optical Observing | Observation 4356198 My Observations / 4356198 / View

### Exposures

5 of 10 Image(s) taken

ID	Length	Telescope	Filter	Time Taken	Delay	Binning	Status
0 27208169	90.0s	DSO-14	R	Sep 22, 2019 09:55:40	N/A	1	
1 27208170	90.0s	DSO-14	R	Sep 22, 2019 09:57:16	N/A	1	
2 27208171	90.0s	DSO-14	R	Sep 22, 2019 09:58:52	N/A	1	
3 27208172	90.0s	DSO-14	R	Sep 22, 2019 10:00:27	N/A	1	
4 27208173	90.0s	DSO-14	R	Sep 22, 2019 10:02:03	N/A	1	
5 27208174	90.0s	DSO-14	R	N/A	83160 s	1	Download JPG
6 27208175	90.0s	N/A	R	N/A	N/A	1	ready
7 27208176	90.0s	N/A	R	N/A	N/A	1	ready
8 27208177	90.0s	N/A	R	N/A	N/A	1	ready
9 27208178	90.0s	N/A	R	N/A	N/A	1	ready

### Observation List

> View

> Manage Notes

> Cancel

> Resubmit

+ Add New Observation

### Campaign List

+ Add New Campaign

☐ Open Afterglow

### Observation Info

Name: oJ287dso

RA | Dec: 08:54:48.8 | 20:06:30.57

Target: oJ287

Priority: 1

Efficiency: 0.22

Telescopes: DSO-14

Pointing Offset: -0.5, 1.0 arcmins

Target Tracking: Track Target

State: active

### Master Calibration Images

ID	Type	Time Taken	Exposure Length	Filter	Binning
515173	bias	September 22, 2019 - 01:13:18			1
515129	dark	September 22, 2019 - 01:02:07	80		1
515229	flat	September 22, 2019 - 07:02:46		R	1

Target visibility over next 24-hours when sun is below -11 degrees

DSO 14

### Settings

Reduction: REDUCED

B/W Inversion: NOT INVERTED

Scale Preset: MEDIUM

Save

Optical Observing | Observation 4356198 My Observations / 4356198 / View

### Exposures

5 of 10 Image(s) taken

ID	Length	Telescope	Filter	Time Taken	Delay	Binning	Status
0 27208169	90.0s	DSO-14	R	Sep 22, 2019 09:55:40	N/A	1	
1 27208170	90.0s	DSO-14	R	Sep 22, 2019 09:57:16	N/A	1	
2 27208171	90.0s	DSO-14	R	Sep 22, 2019 09:58:52	N/A	1	
3 27208172	90.0s	DSO-14	R	Sep 22, 2019 10:00:27	N/A	1	
4 27208173	90.0s	DSO-14	R	Sep 22, 2019 10:02:03	N/A	1	
5 27208174	90.0s	DSO-14	R	N/A	83160 s	1	ready
6 27208175	90.0s	N/A	R	N/A	N/A	1	ready
7 27208176	90.0s	N/A	R	N/A	N/A	1	ready
8 27208177	90.0s	N/A	R	N/A	N/A	1	ready
9 27208178	90.0s	N/A	R	N/A	N/A	1	ready

### Observation List

> View

> Manage Notes

> Cancel

> Resubmit

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515229	flat	September 22, 2019 - 07:02:46		R	1

Target visibility over next 24-hours when sun is below -11 degrees

DSO 14

### Settings

Reduction: REDUCED

B/W Inversion: NOT INVERTED

Scale Preset: MEDIUM


Save

# Observing with SKYNET Telescopes

An account in the SKYNET system required for observations

Observing credit: buy time, time assigned as DDT, by a partner

Credit deducted only when data have been taken

SKYNET ROBOTIC  
TELESCOPE NETWORK

Currently signed in as **aj287**

LOGOUT

HOME

MY OBSERVATORY

SKYNET LIVE

TELESCOPE SITES

HELP

My Account | Time Accounts

Time Accounts

ID	Group	Collab	Owner	Telescopes	Balance
12694	N/A	N/A	Appalachian State	DSO-14, DSO-17	487,959
23974	N/A	N/A	Skynet	AURT, CTIO-1.0m, Doherty, DSO-14, DSO-17, MDRS-14, Morehead, NSO-17, CDK, PROMPT AUG01-1, ...	302,200

Recent Transactions

Time	Amount	Comment	Obs
2019-09-15 04:25:17	-270	debit for observation request	4338394
2019-09-15 04:26:02	-180	debit for observation request	4338395
2019-09-15 04:48:33	-180	debit for observation request	4338403
2019-09-15 07:34:01	-1,200	debit for observation request	4339461
2019-09-16 12:07:43	-240	debit for observation request	4341871
2019-09-17 01:22:30	-122	debit for observation request	4344393
2019-09-17 01:25:27	-246	debit for observation request	4344395
2019-09-17 10:40:08	-120	debit for observation request	4344379
2019-09-17 10:49:03	-280	debit for observation request	4344381
2019-09-17 11:28:31	-80	debit for observation request	4344382
2019-09-18 07:27:21	-180	debit for observation request	4345968
2019-09-18 07:40:18	-120	debit for observation request	4345969
2019-09-18 07:51:23	100	Credit for cancelling observation before completion	4293264
2019-09-18 07:55:09	-270	debit for observation request	4345970
2019-09-18 12:45:33	-240	debit for observation request	4347302
2019-09-19 04:35:59	-180	debit for observation request	4348623
2019-09-19 04:36:29	-180	debit for observation request	4348624

Time Accounts

Skynet Messages

Profile

Update Email Address

Change Password

Settings

Join a Group

Request Additional Credits

Time Account:  
23974 Skynet

Amount (credits):

Message

Submit

# Observing with SKYNET Telescopes: advantages

Telescopes located on 4 continents → almost uninterrupted observations possible

Redundancy of telescopes at similar longitudes, request for observations can be submitted to a subset of scopes

Easy to use, mostly flexible WEB interface

Possibility to check results almost in real-time: images are calibrated for bias, dark and flatfield and displayed as jpg file

No need to stay awake the entire nights



# Observing with SKYNET Telescopes: pitfalls

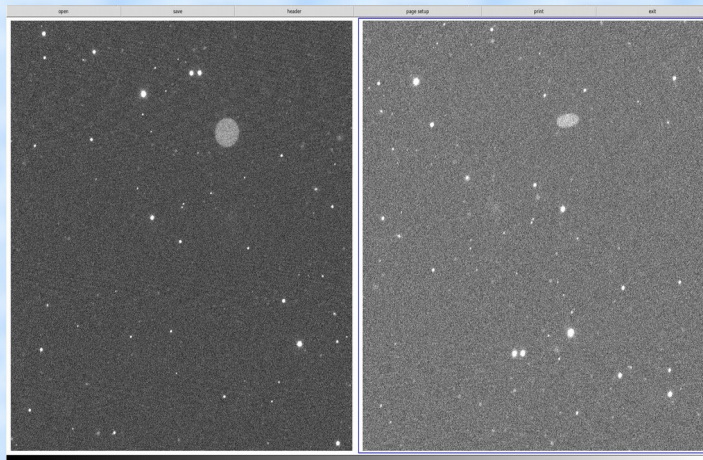
Many users: longer runs can be interrupted (even several times) on oversubscribed telescopes (e.g. PRMOPT5)

“Normal” hardware issues: images out of focus, bad pointing, filter wheel failures

Algorithm for flat taking not efficient enough, especially when CCD supports several binnings and several filters – flats can be infrequent, deteriorating quality of the data

Sometimes, data are taken in poor conditions

CCDs “memory” issues





# Observing with SKYNET Telescopes: pitfalls

CCDs “memory” issues can be severe, visual examination of images recommended if a pipeline is used for data reduction





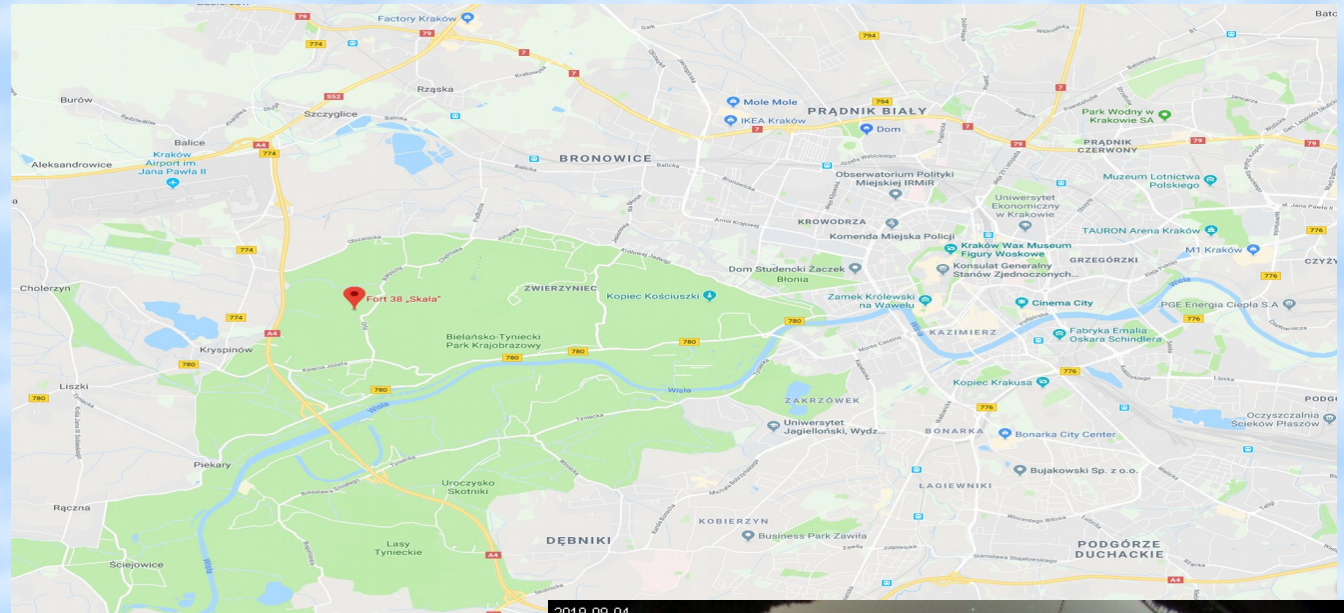
# CDK500 telescope at Astronomical Observatory of the Jagiellonian University, soon a new member of SKYNET



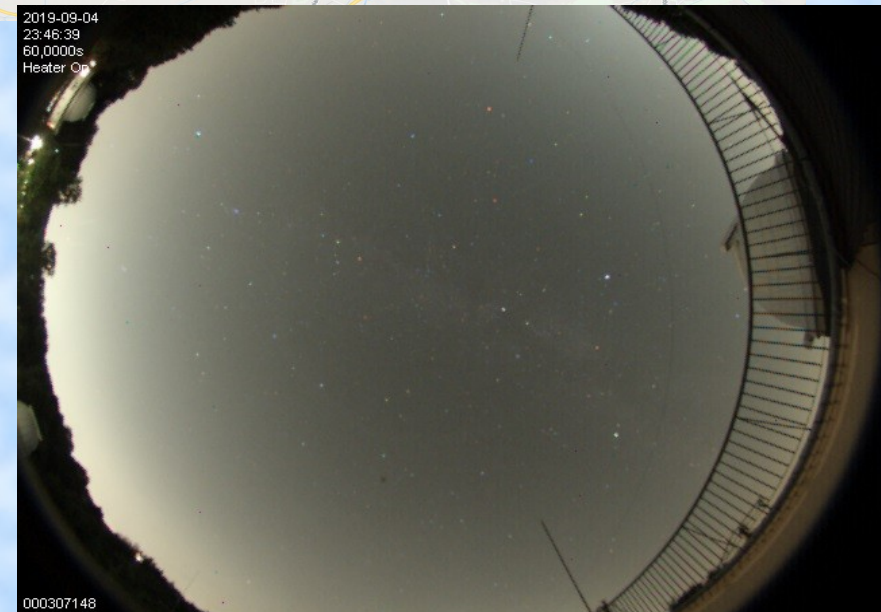


# CDK500 telescope at Fort Skala soon a new member of SKYNET

12 km from  
city center



100578048



000307148

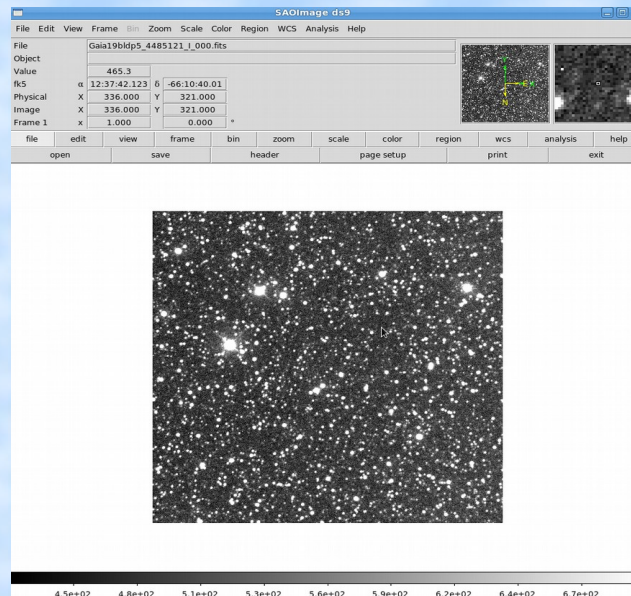


# Images taken with the SKYNET Telescopes

# Network pipeline does calibration for bias, dark and flatfield almost in real time

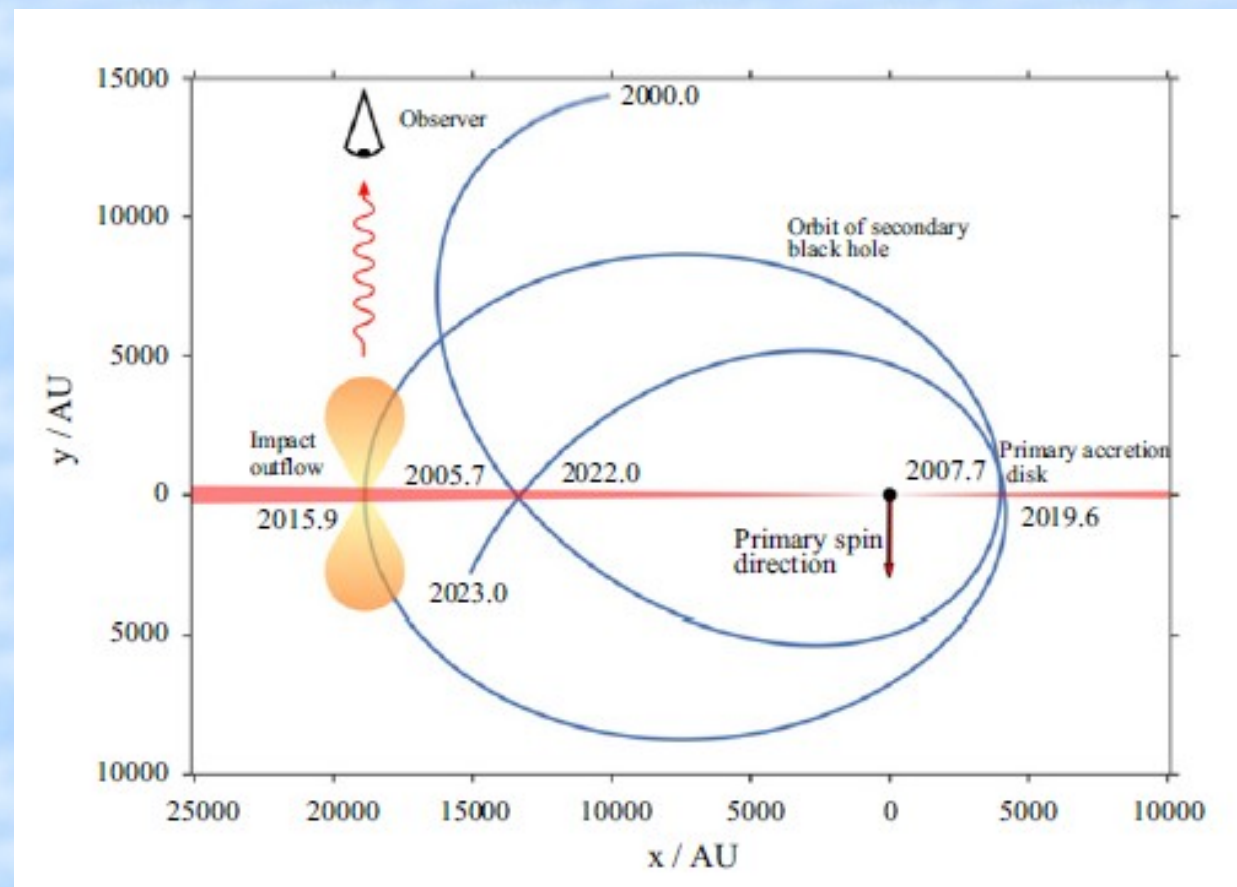
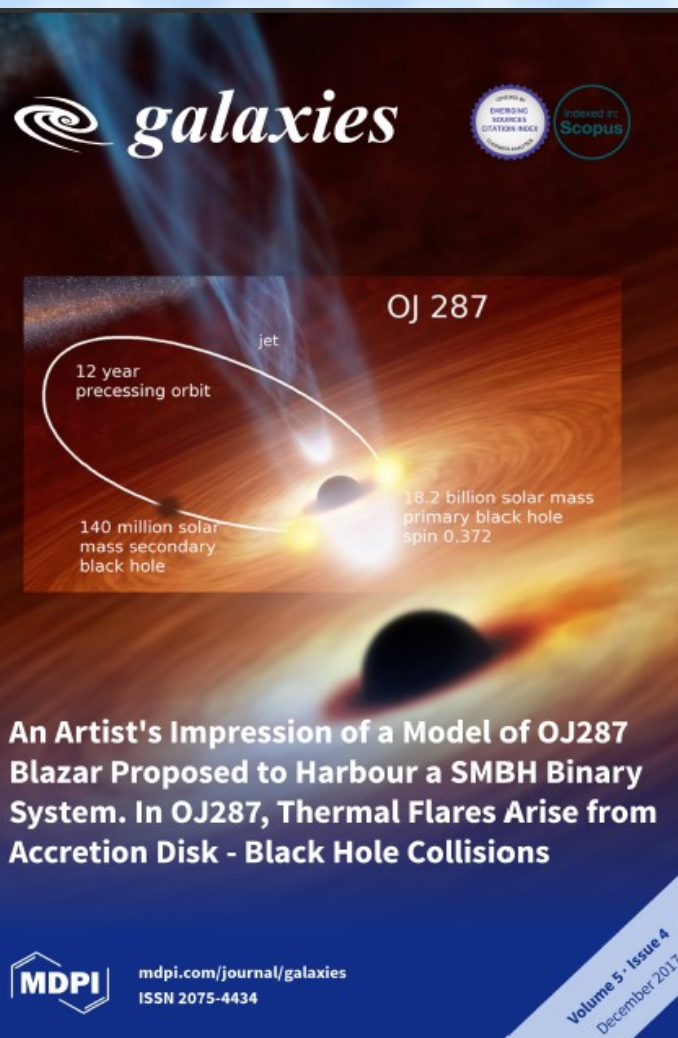
# Astrometry applied as well

# Images ready for extraction of magnitudes



# Long term monitoring of QSOs OJ287

AGN best-known candidate to hosts a SMBH binary

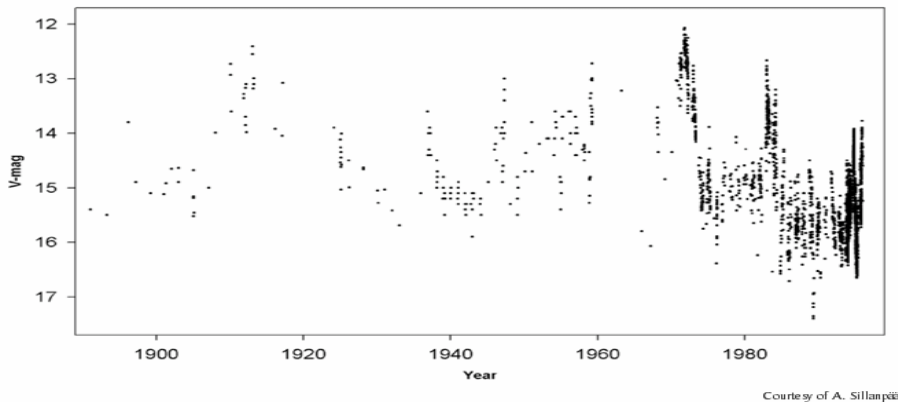


# Long term monitoring of QSOs

## OJ287

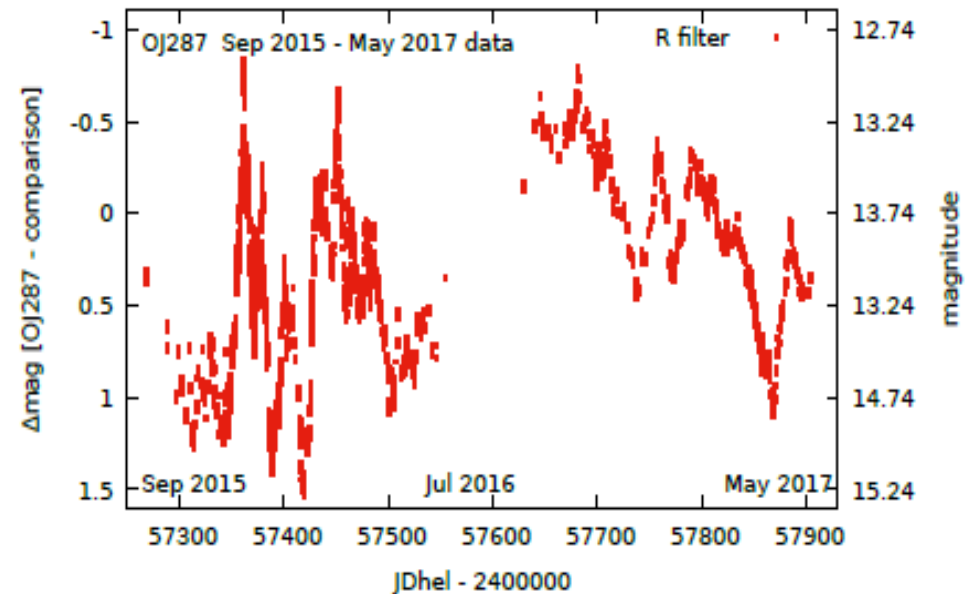
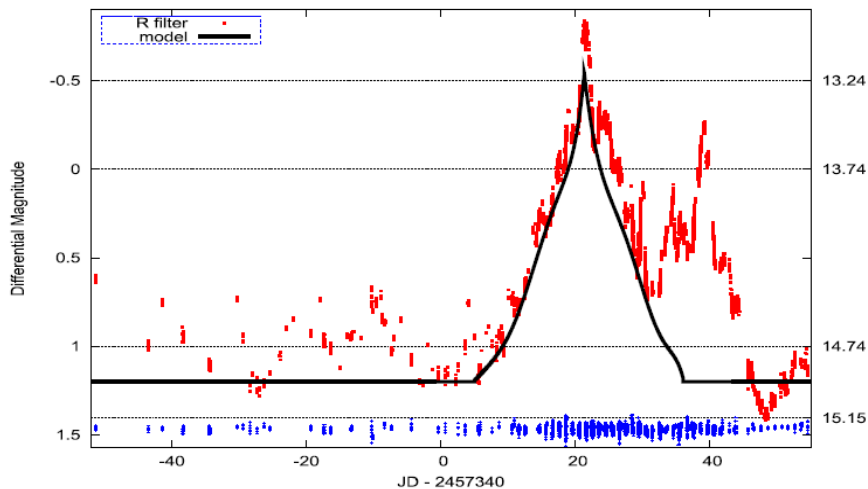
Light curve monitoring performed since 2006, extensive usage of SKYNET telescopes since 2015 led to almost daily (or more frequent) coverage

Historical V-magnitude light curve of OJ 287 (1891-1997)



Primary SMBH spin: 0.31 (0.01)

(Valtonen + 2016)





# Long term monitoring of QSOs

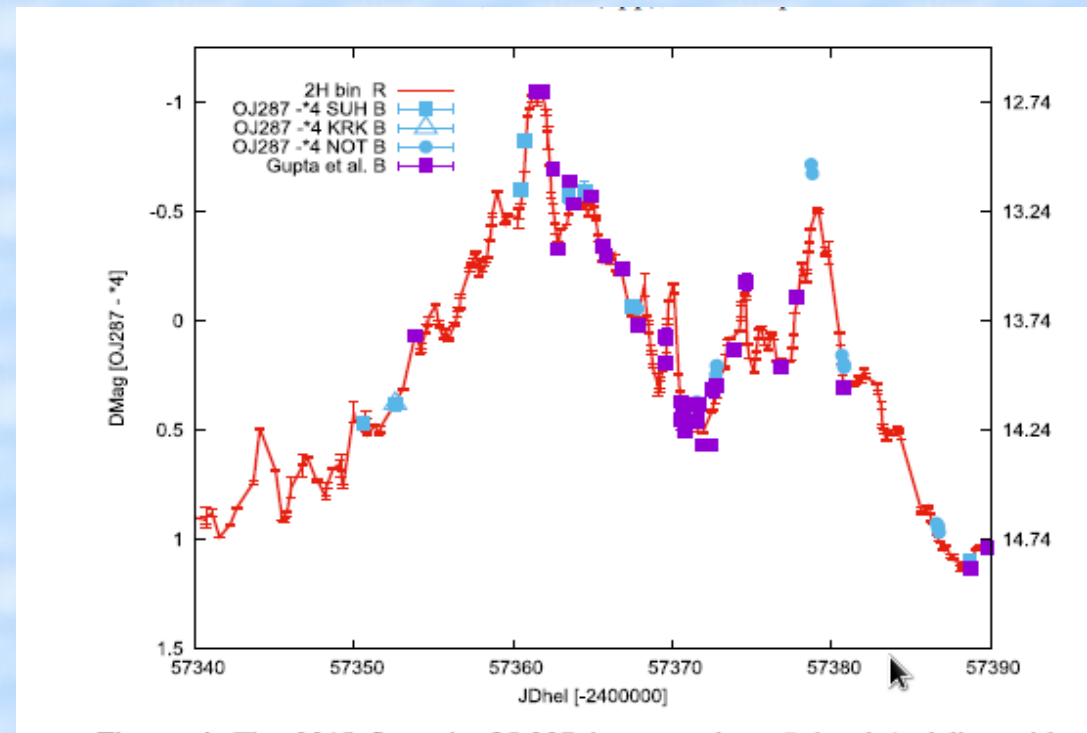
## OJ287

Analysis of disturbance propagation in the disk after the 2015 big flare led to estimation of the accretion disk parameters (Valtonen+2019):

Disk viscosity:  $0.26(0.1) \rightarrow$  magnetic disk

Accretion rate:  $0.08(0.04)$

Prediction for summer 2019  
thermal outburst





# Long term monitoring of QSOs

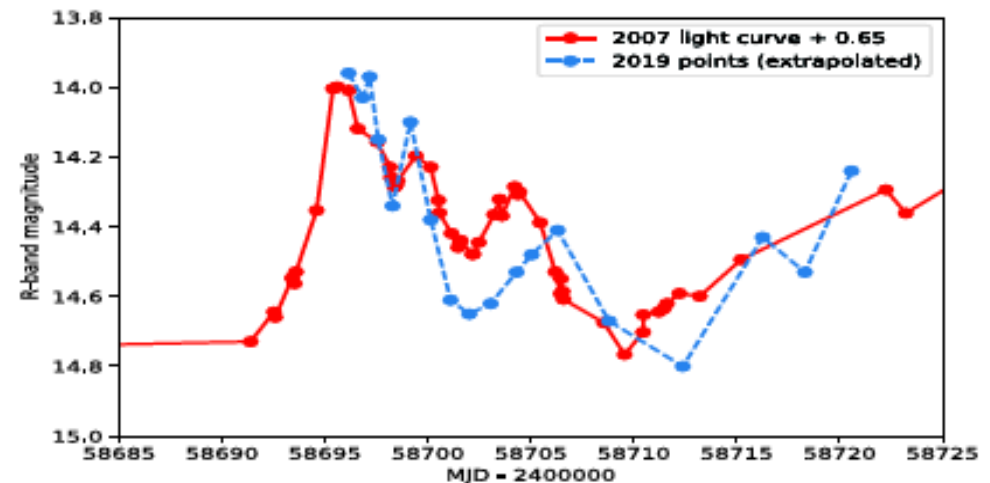
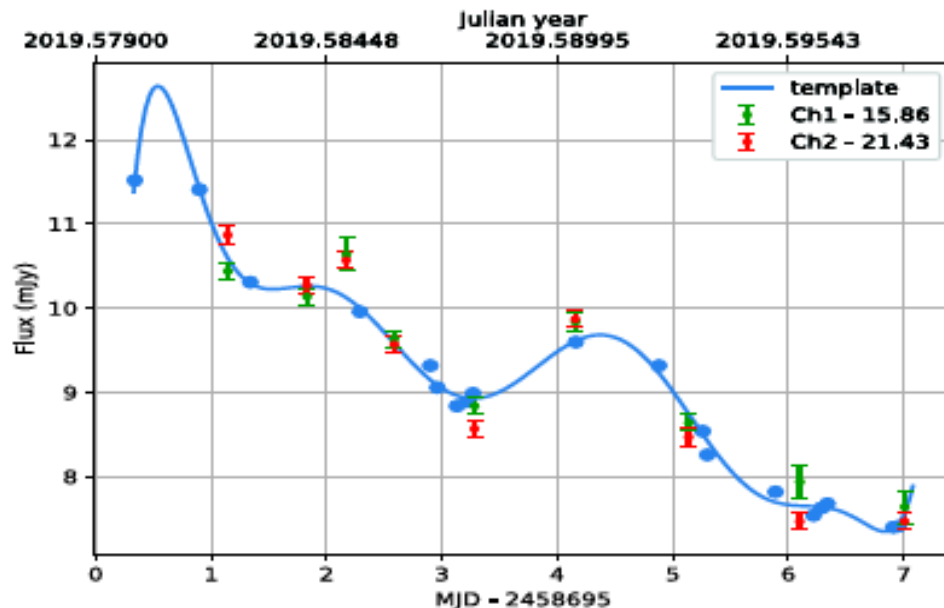
## OJ287

Spitzer IR observations in summer 2019, cross-calibrated with optical data from ground based telescopes (Feb & Sep 2019)

Lane+ 2019

Detection of OJ287 host galaxy (Nilsson+ submitted)

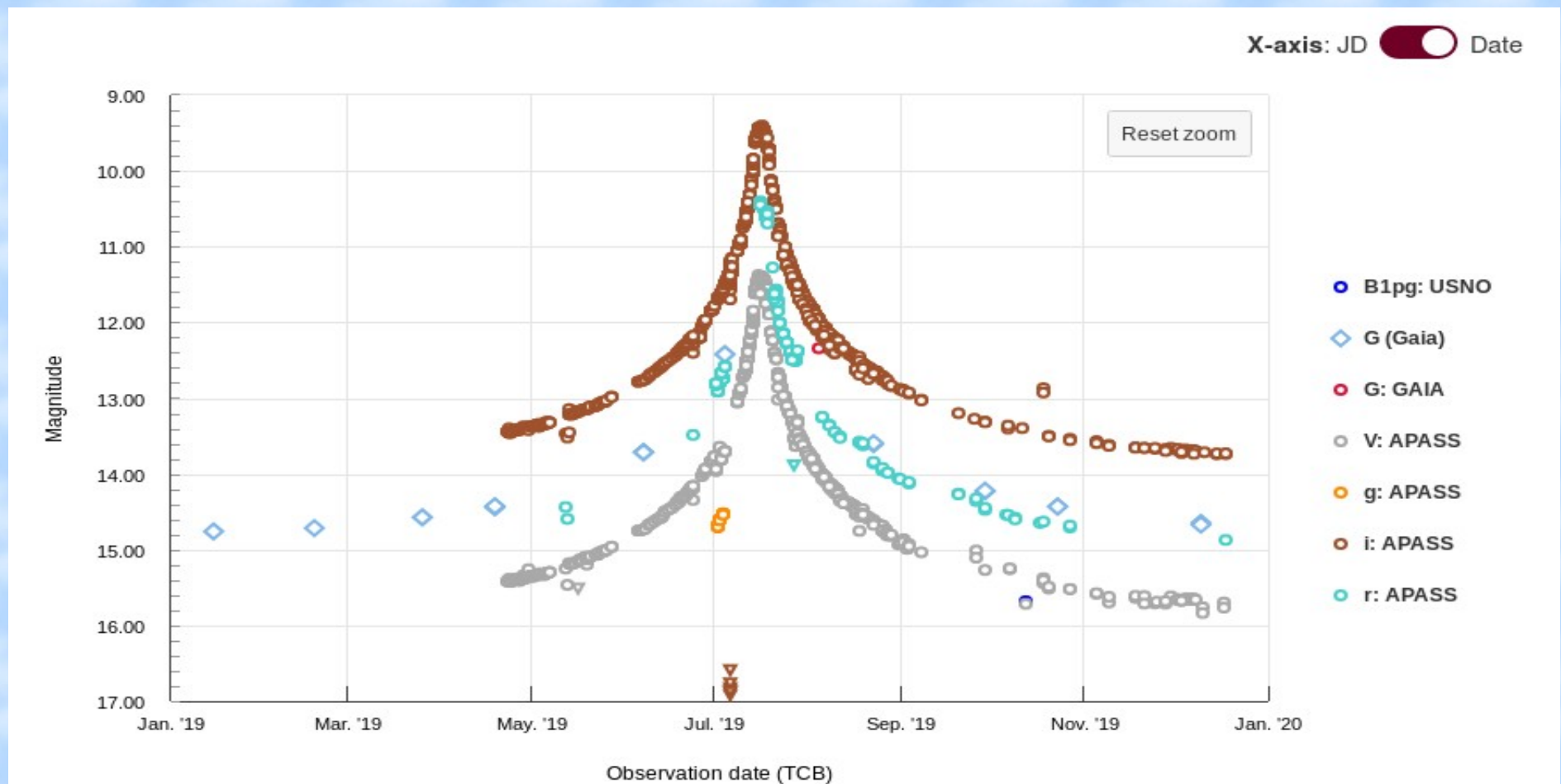
### 2019 Spitzer Light Curves And Comparison to 2007 Flare



# Gaia16aye + Gaia19bld

Gaia16aye: Yerkes-41 telescope, sloan filters

Gaia19bld: Prompt5, Prompt8, Prompt-MO, R-COP



# CPCS: data upload

## Please make an observer's life easier

- JD vs MJD
- Exposure time

```
Gaia19bldp5_4554963_I_001.fits
File Edit Font
BITPIX = -32 / 8 unsigned int, 16 & 32 int, -32 & -64
NAXIS = 2 /number of axes
NAXIS1 = 512 /fastest changing axis
NAXIS2 = 512 /next to fastest changing axis
DATE-OBS = '2019-12-15T08:24:23' /YYYY-MM-DDThh:mm:ss observation start,
EXPTIME = 50.000000000000000 /Exposure time in seconds
EXPOSURE = 50.000000000000000 /Exposure time in seconds
SET-TEMP = -20.000000000000000 /CCD temperature setpoint in C
CCD-TEMP = -19.846480500000002 /CCD temperature at start of exposure in
XPIXSZ = 26.000000000000000 /Pixel Width in microns (after binning)
YPIXSZ = 26.000000000000000 /Pixel Height in microns (after binning)
XBINNING = 2 /Binning factor in width
YBINNING = 2 /Binning factor in height
XORGSUB = 0 /Subframe X position in binned pixels
YORGSUB = 0 /Subframe Y position in binned pixels
READOUTM = 'Monochrome' / Readout mode of image
FILTER = 'I' / Filter used when taking image
IMAGETYP = 'Light Frame' / Type of image
SITELAT = '-30 10 03' / Latitude of the imaging location
SITELONG = '-70 48 19' / Longitude of the imaging location
JD = 2458832.8502685 / Julian day at start of exposure
FOCALLEN = 4576.0000000000000 /Focal length of telescope in mm
APERTURE = 410.0000000000000 /Aperture diameter of telescope in mm
APTAREA = 132025.4349410539 /Aperture area of telescope in mm^2
SWCREATE = 'Maxim DL Version 5.23 140402 2HE8X' /Name of software that cr
the image
SBSTDVER = 'SBFITSEXT Version 1.0' /Version of SBFITSEXT standard in effe
OBJECT = ' '
TELESCOP = ' ' / telescope used to acquire this image
INSTRUME = 'Apogee USB/Net'
OBSERVER = ' ' / Skynet user who submitted observation
NOTES = ' '
FLIPSTAT = ' '
SWOWNER = 'Dan Reichart' / Licensed owner of software
LATITUDE = -0.526524626164 / Latitude in radians; negative = south
LONGITUD = -1.235787164266 / Longitude in radians; negative = west
RA = '12:37:32.5' / Target Right Ascension, J2000
DEC = '-66:06:40.888' / Declination of target, J2000
TELRA = '12:37:32.5' / Right Ascension reported by telescope,
TELDEC = '-66:06:40.888' / Declination reported by telescope, J2000
```

# CPCS: data upload

## Please make an observer's life easier

Data upload requires: MJD, exposure time

live run as default

Logged as PROMPT5-0.4, Staszek Zola

### Follow-up Data Uploading Form

Event ID:

MJD OBS:

Exposure time (sec):

Comment(optional):

SExtractor catalog  
(ASCII, FITS, FITS-  
LDAC):  No file selected.

Matching radius:

Force filter:

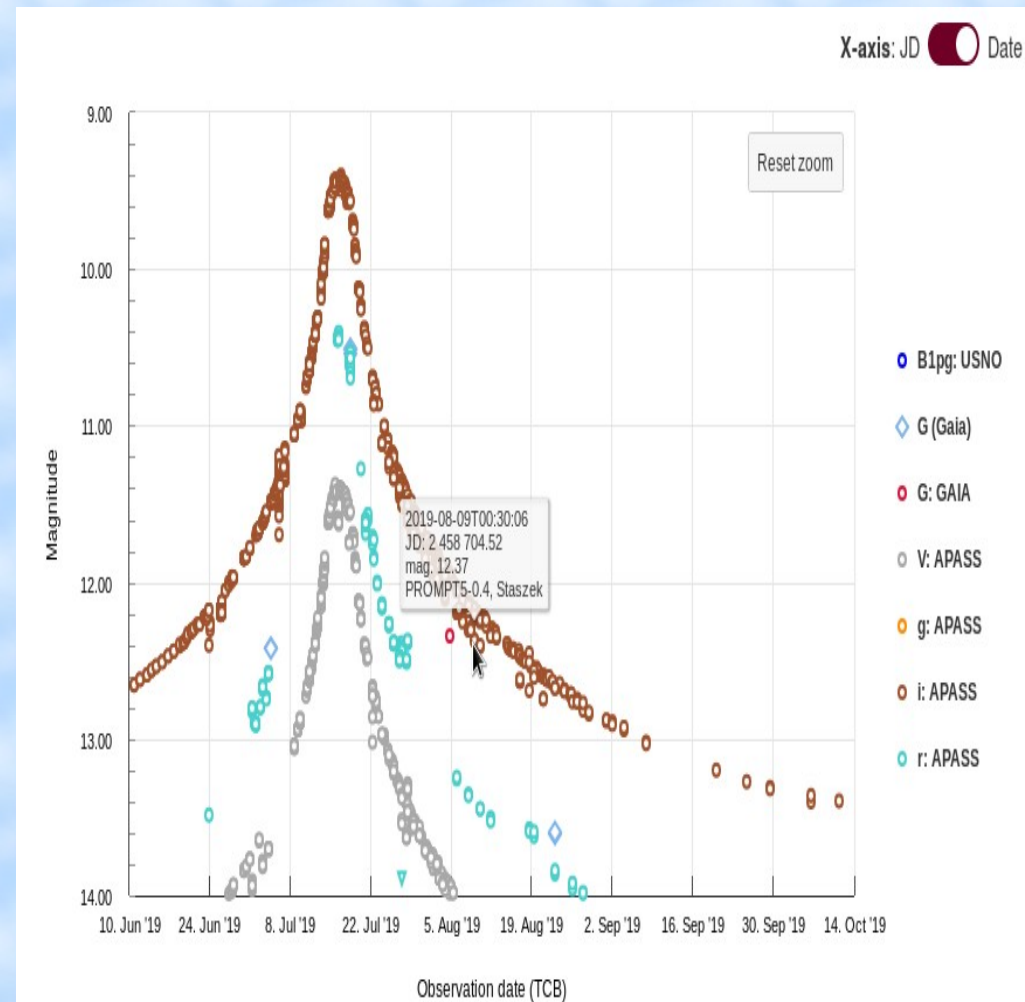
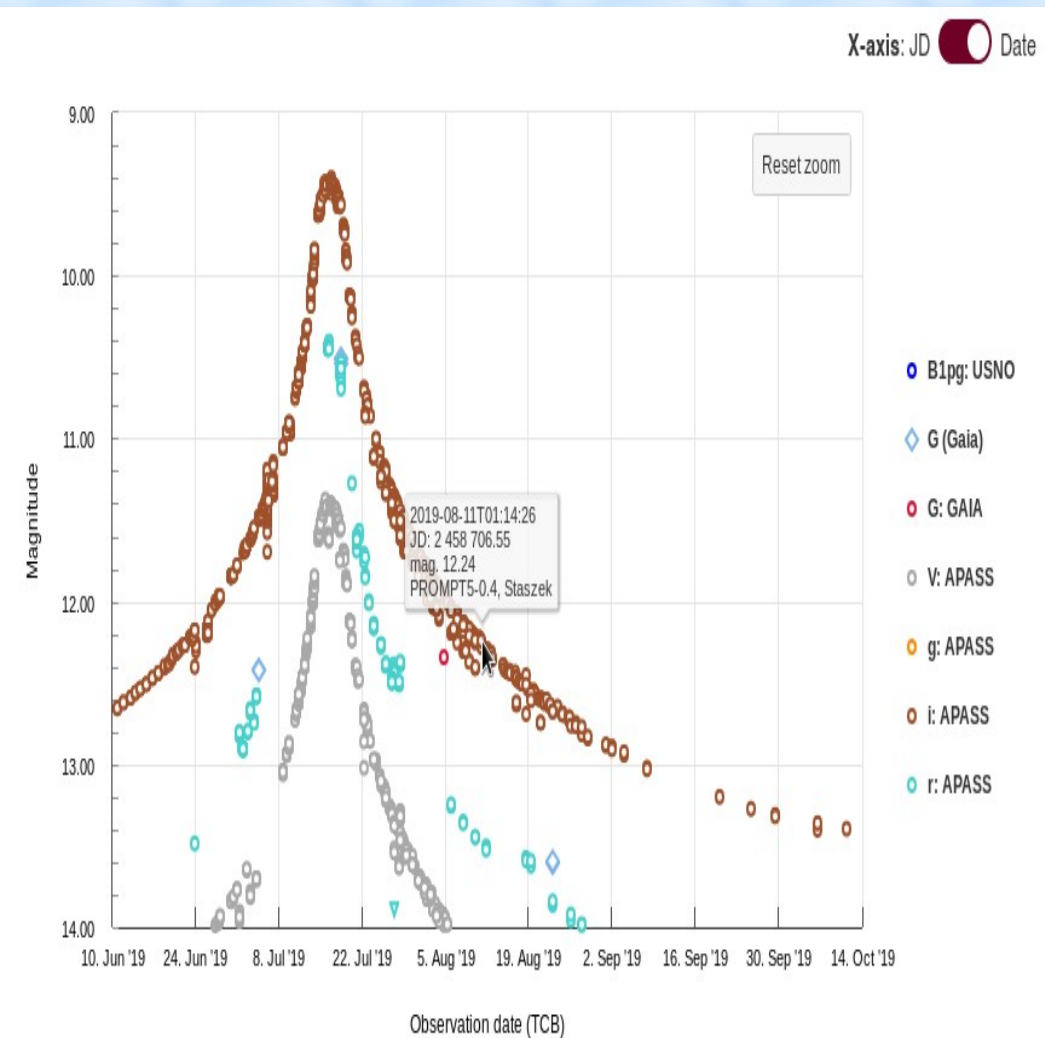
Dry Run (no data will be  
stored in the database): ☐

MJD most often source of mistakes



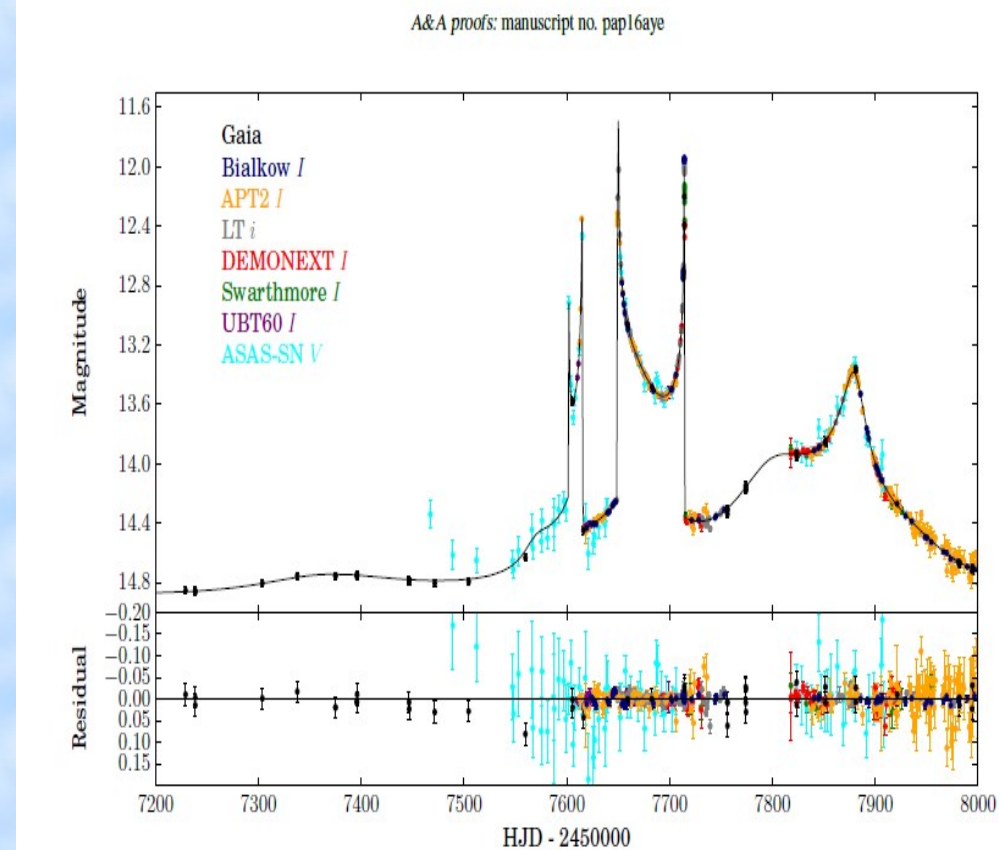
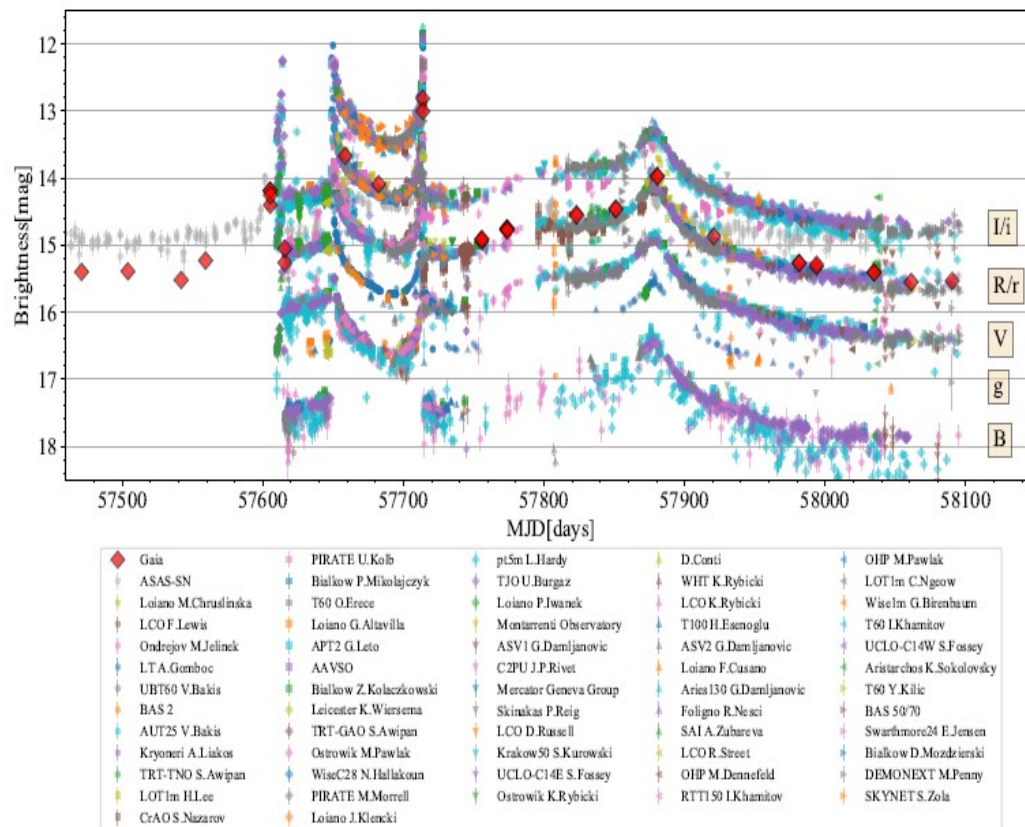
# CPCS: photometric system calibration

There is an offset between Sloan i' and wide band I filters



# Multisite long term campaigns need coordination

Wyrzykowski+ 2019



# Instead of conclusions: a wish list (CPCS v 1.0)

Use data stored in FITS header !

If not standard keywords are used → “punish” an observer by requesting manual typing of required numbers e.g. MJD

Make a dry run as a default, introduce a button to store data after a dry run is completed and results checked

Create a library of subset of events to be stored in a user account on the server

Make some coordination of long term campaigns, especially provide an info on filters to be used, cadence, S/N

as of Dec 19 morning

# Instead of conclusions: a wish list (CPCS v 1.0)

Use data stored in FITS header ☺ (ver 2.0)

If not standard keywords are used → “punish” an observer by requesting manual typing of required numbers e.g. MJD

Make a dry run as a default, introduce a button to store data after a dry run is completed and results checked

Create a library of subset of events to be stored in a user account on the server ☺ (BH TOM)

Make some coordination of long term campaigns, e.g. provide recommendations on filters to be used, cadence, S/N





Thank you !