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Search for fast and violent processes with "Pi of the Sky" experiment

grb.fuw.edu.pl

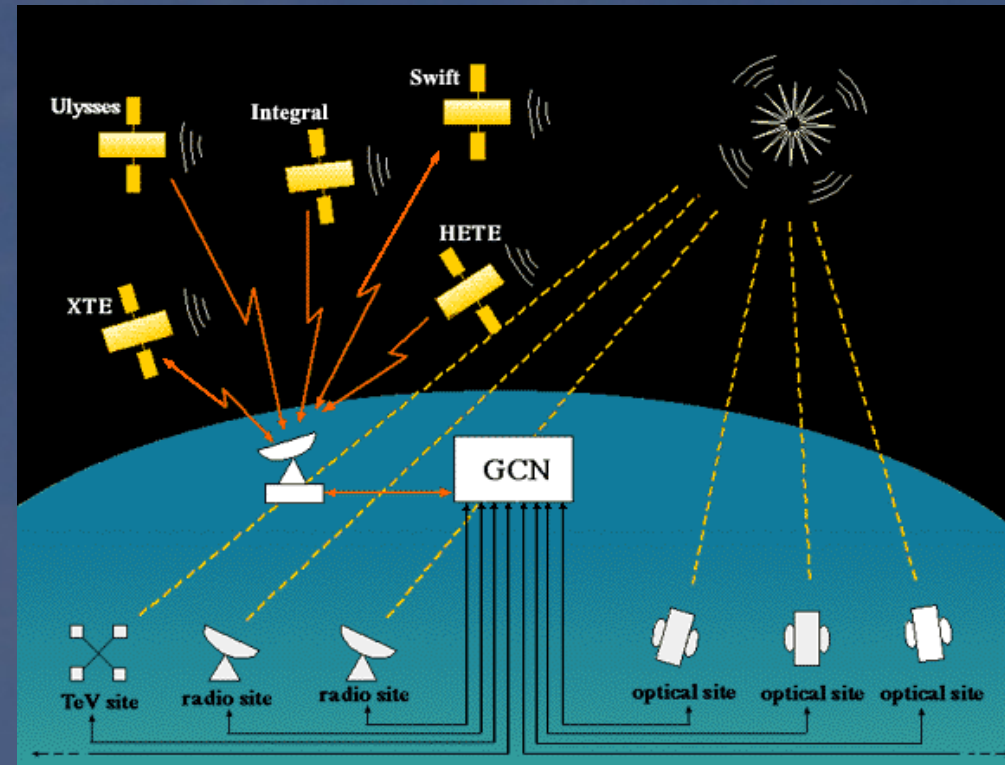
The Violent Universe, Les Houches 12th -23th march 2007

Scientific Motivation

- Investigation of short time scale (1 sec – 1 year) phenomena in optical band
- Optical counterparts of GRBs
- Automatic detections of flash like events like :
supernovae, novae
- Continuous monitoring blazars and AGNs
- Also flare stars, variable stars

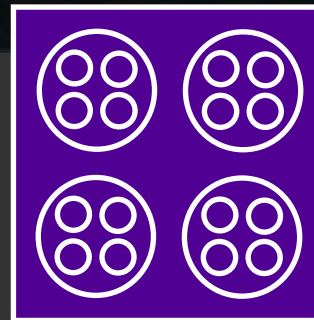
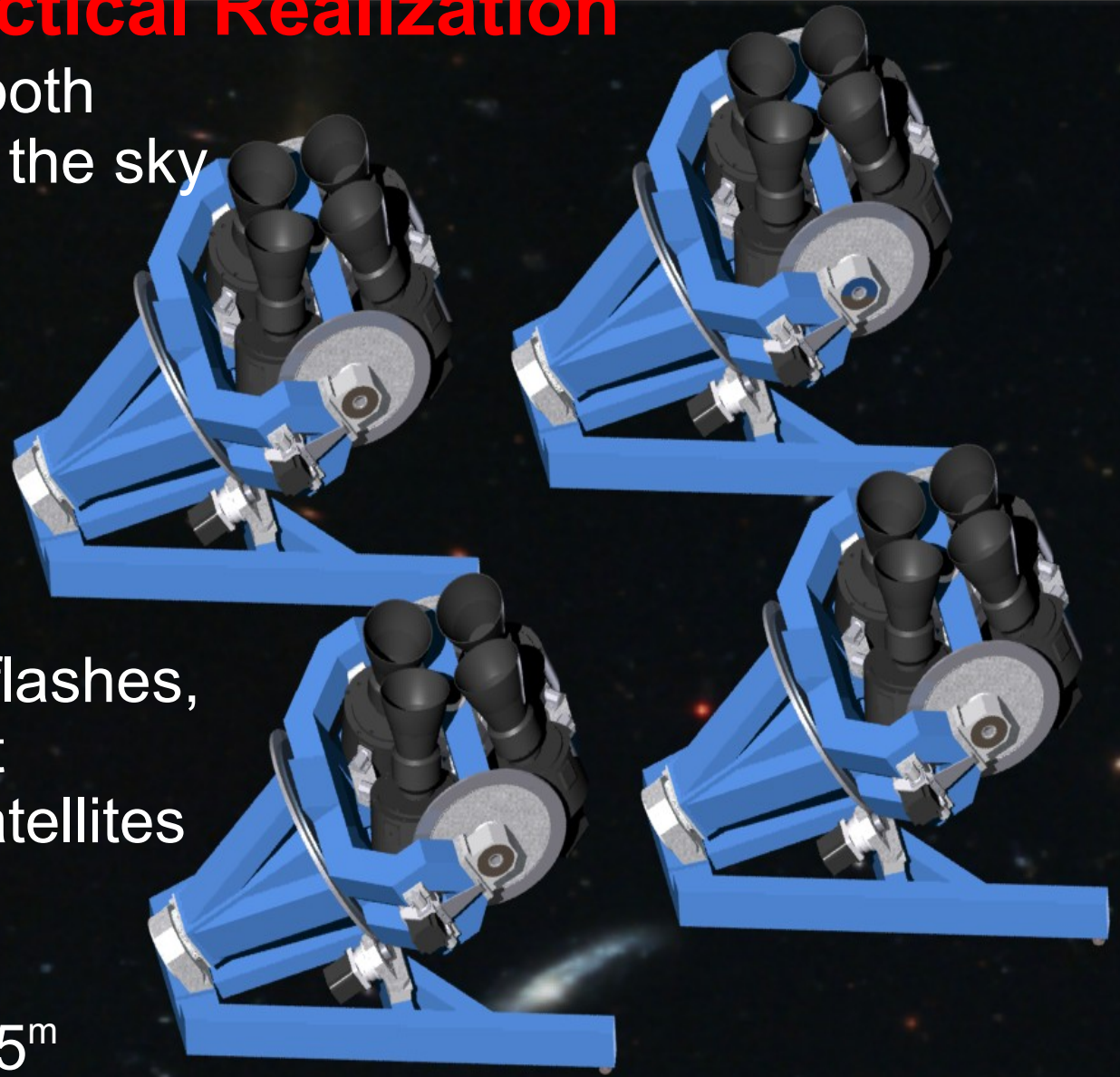
What is special in “Pi of the Sky”

- Coverage of 2 sr provided by 2 sets of 16 cameras, compatible with SWIFT and GLAST(each camera $20^\circ \times 20^\circ$)
- < 0 reaction time
- Time resolution – 10 sec exposures (maybe 5 sec)
- Own trigger for optical flashes identification
- Large data stream to be analysed ($\sim 1\text{TB} / \text{night}$)



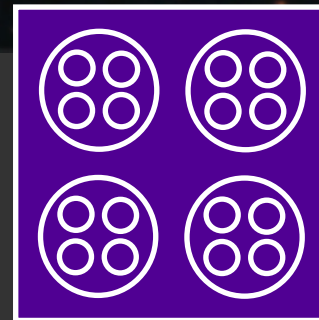
Practical Realization

- 2 set of 16 cameras – both observing same part of the sky
- Following FOV of SWIFT or GLAST every GRB will be in FOV
- Own trigger for optical flashes, parallax allows to reject flashes from artificial satellites
- Limiting magnitude of single camera $\sim 14\text{-}15^m$
- Start of the system in fall of 2007



SITE A

~ 150 km



SITE B

Building 32 cameras and 8 mounts ...

- CCD chip 2k x 2k pixels
- Readout noise $\sim 15e^-$
- Readout 2Mhz (1sec / image)
- USB2.0 and Ethernet interface
- Programmable electronics (FPGA)
- 2 stage thermoelectric cooling
- Shutter designed for $\geq 10^7$ cycles



Working since 2004-VI
upgraded in 2006-V

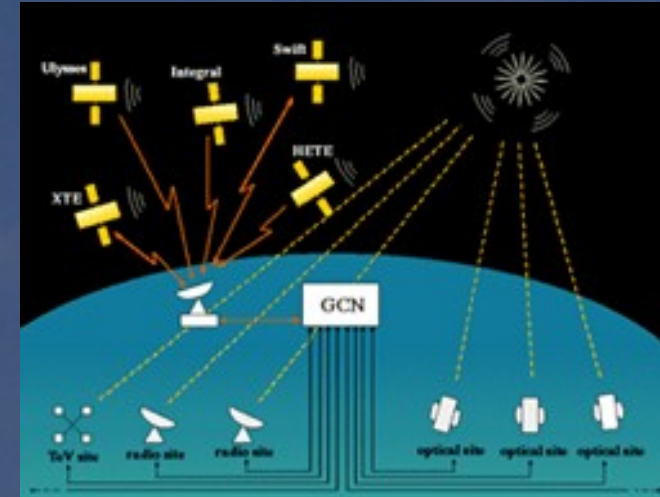


Prototype in Las Campanas
Observatory (LCO) in Chile

- 2 cameras on paralactic mount
- Following SWIFT or INTEGRAL (HETE before)
- CCD chip 2032x2032 pixels
- Canon objectives :
 $f = 85 \text{ mm}$, $f/d = 1.2$, $\text{FOV} \sim 20^\circ \times 20^\circ$
- 10s exposures, 2s dead time
- Limiting magnitude 12.5^m on 10s exposures, 13-14^m on 20 coadded images
- Fully autonomous system, controlled via the Internet
- Essential data copied to Warsaw server and available by WWW
- Alert system is claiming any problems by SMS or e-mail

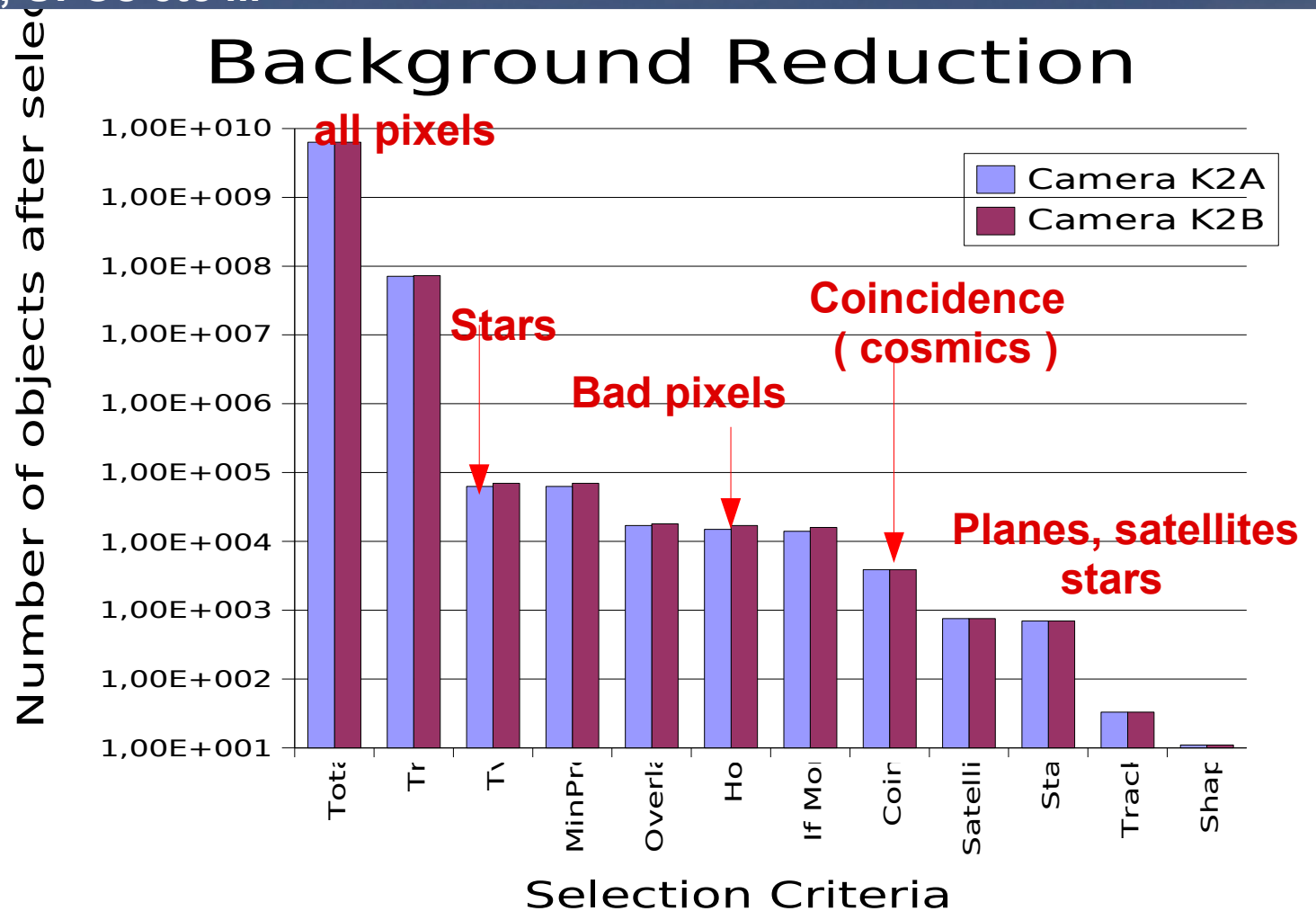
Prototype observation strategy

- 10s exposures, 2s dead time
- Follow FOV of SWIFT or INTEGRAL if not possible follow objects from GTN and WEBT list of interesting objects (blazars, AGNs etc)
- Reacts to alerts from GCN
- Evening and morning all sky scan
- On-line flash recognition algorithm looks for short timescale OT



On-line Data Analysis

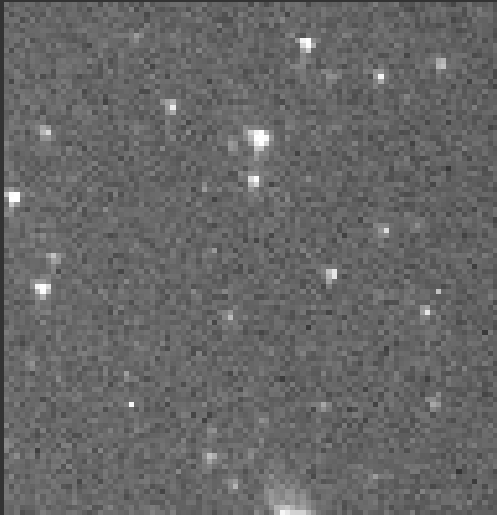
- Flash recognition algorithm, compares new image with series of previous images. Finds new objects not present on previous images (every image $\sim 2 \times 10^4$ stars)
- Rejection of background from cosmic rays, flashes from artificial satellites, constant stars, meteors, clouds, UFOs etc ...
- Flash recognition in real time multilevel trigger concept – ideas from particle physics



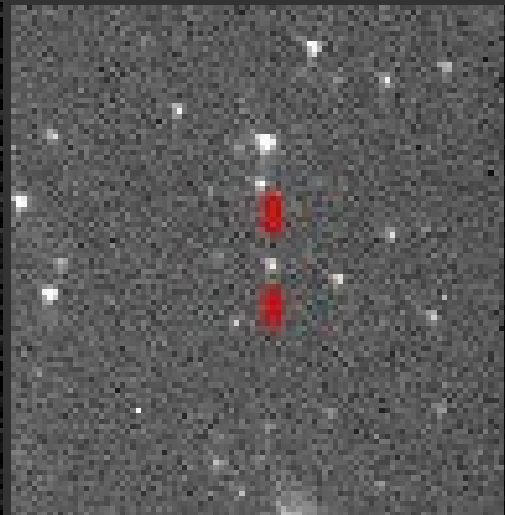
On-line Data Analysis Results

- 1 sure astrophysical event – outburst of flare star CN Leo
- 8 flashes visible on 2 consecutive images, but single camera
- 150 flashes visible on both cameras, but single 10s exposure

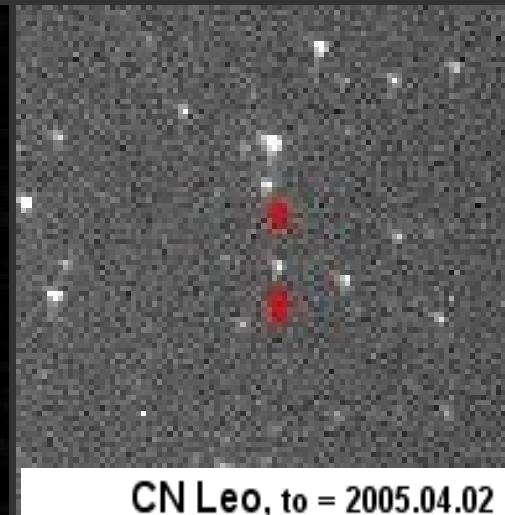
-1



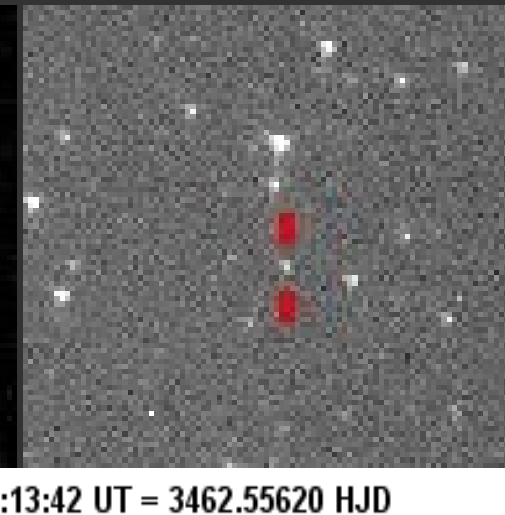
0



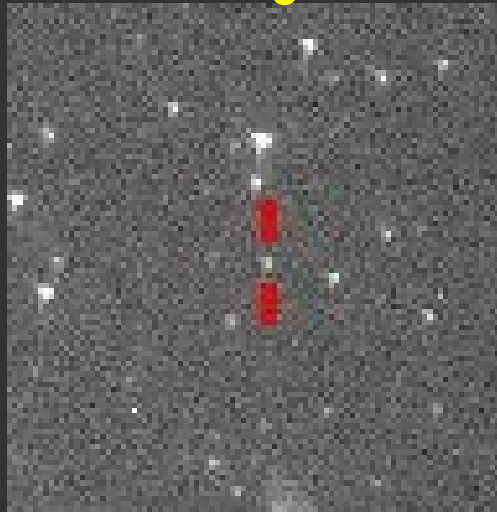
+1



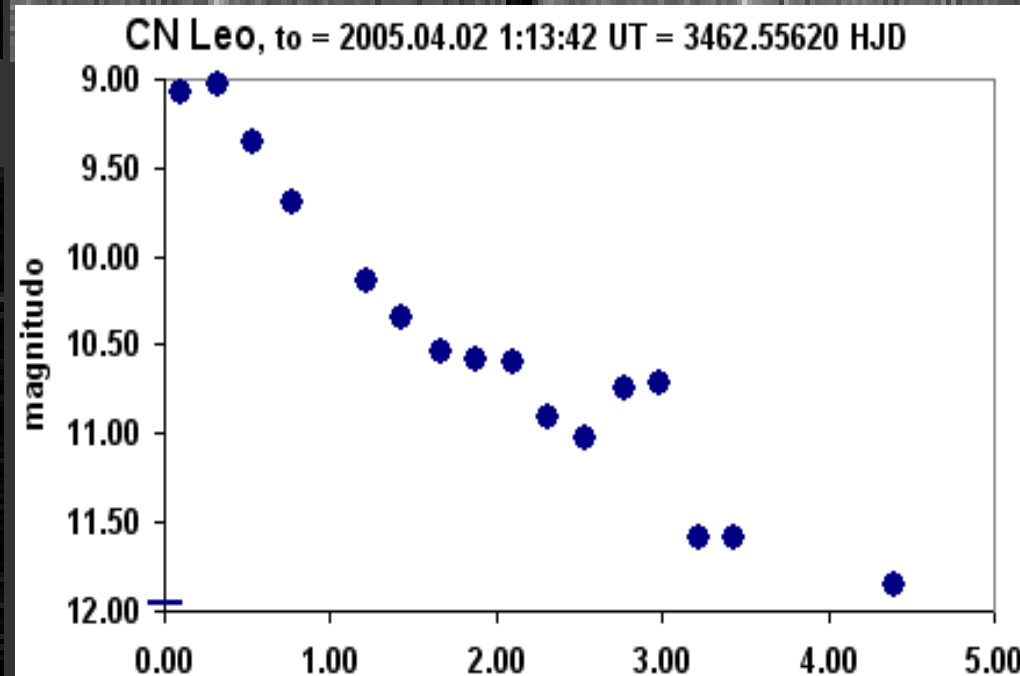
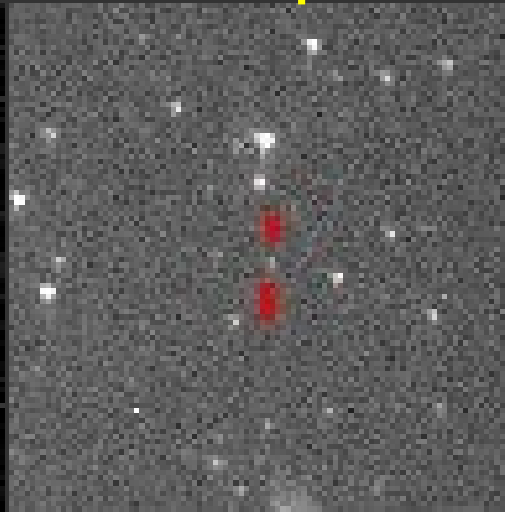
+2



+3



+4



Example of single image flash visible on both cameras

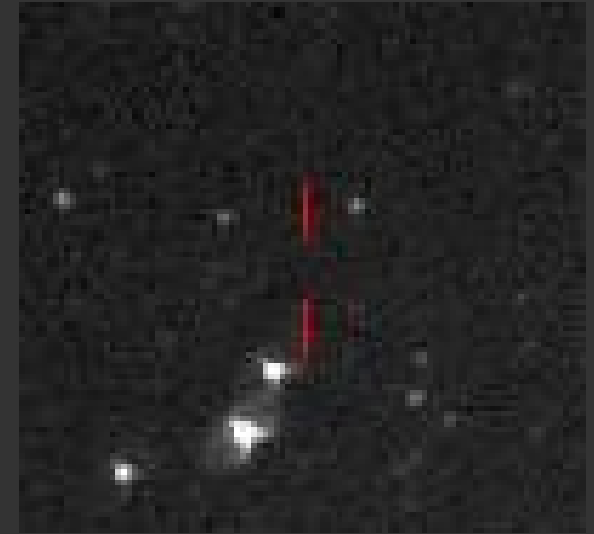
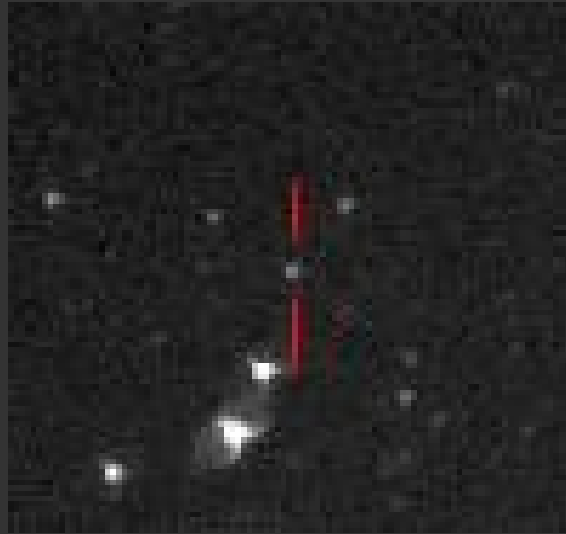
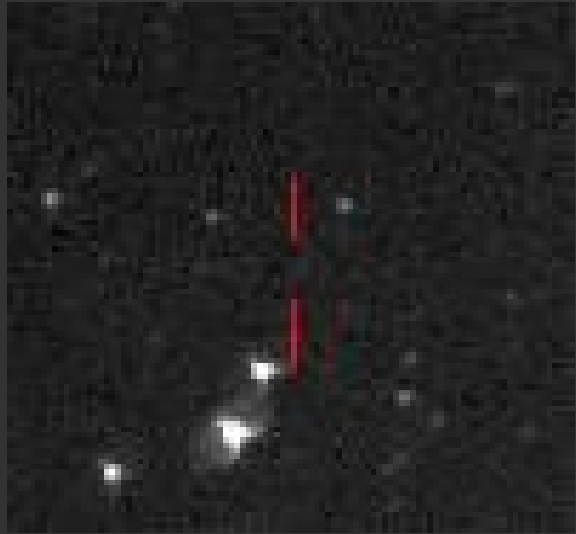
These can still be flashes from non cataloged artificial satellites reflecting sunlight only parallax in the full system will give a chance to reject them (if $d < 70000$ km)

-1

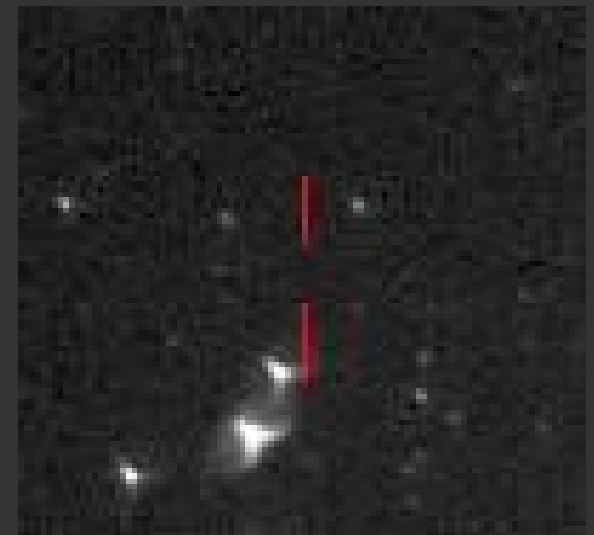
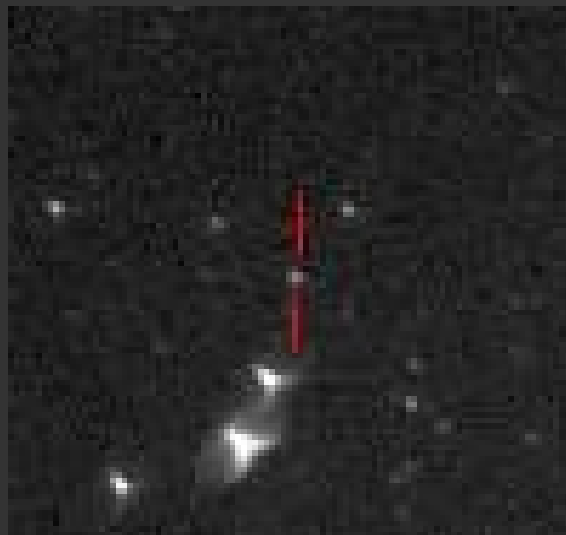
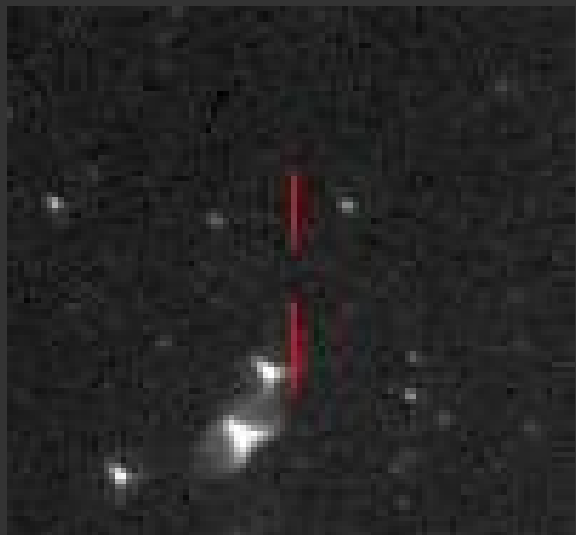
0

+1

k2a

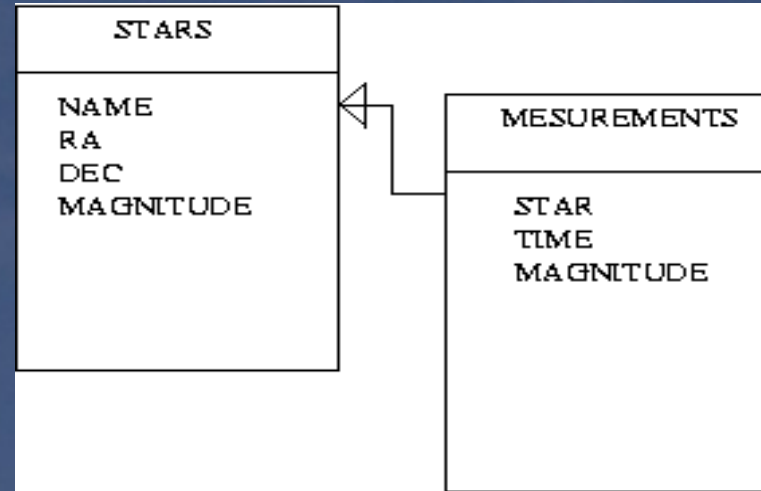


k2b



Off-line Data Analysis

- Data after reduction (photometry and astrometry). Measurements of stars brightness are loaded to PostgreSQL database
- Pi-Star catalog available by WWW
- Database is huge and must be optimized for specific queries
- Algorithms check lightcurves of stars in database and look for interesting events



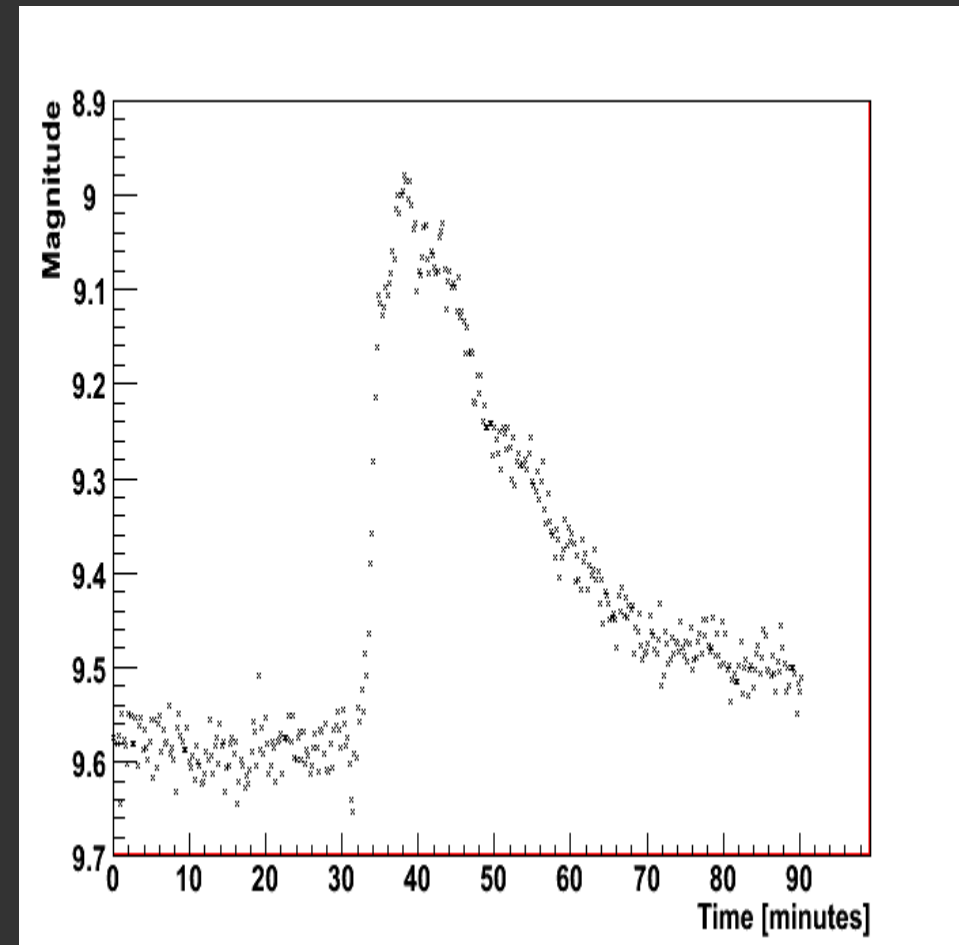
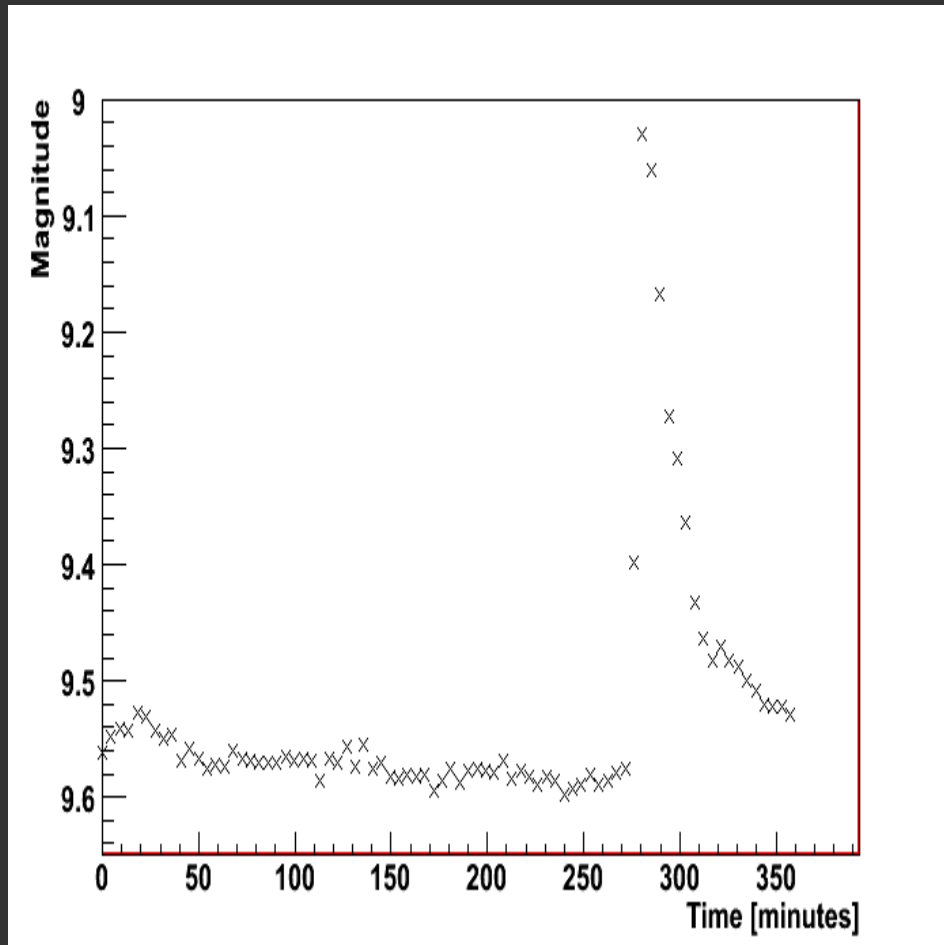
**SCAN DATABASE SINCE
20060523 :**

#STARS = 8.258.607
#MEASUREMENTS = 293.094.652

Off-line Data Analysis - Algorithms

- Identification of new objects in star catalog (nova-like events)
- Identification of brightness increase of existing objects

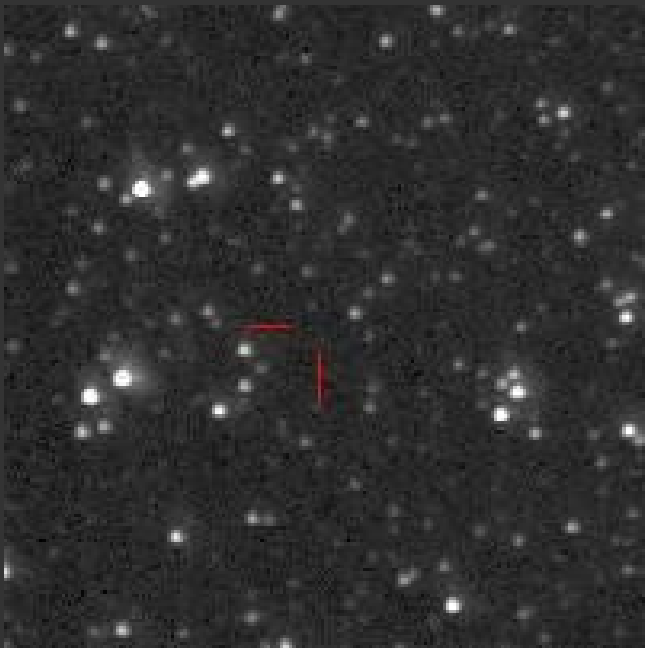
Automatic detection of outburst of flare star GJ 3331A / GJ 3332



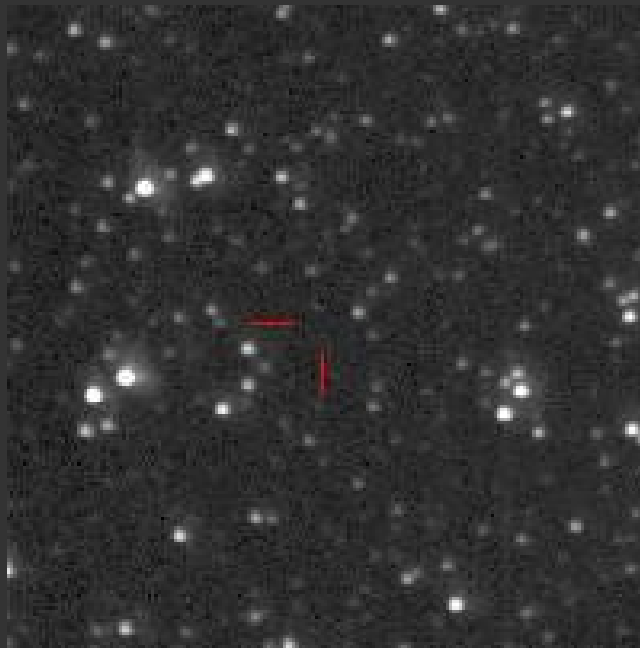
Nova-line identification algorithm

Algorithm checks all objects newly added to the star catalog and rejects background from star fluctuations, hot pixels etc

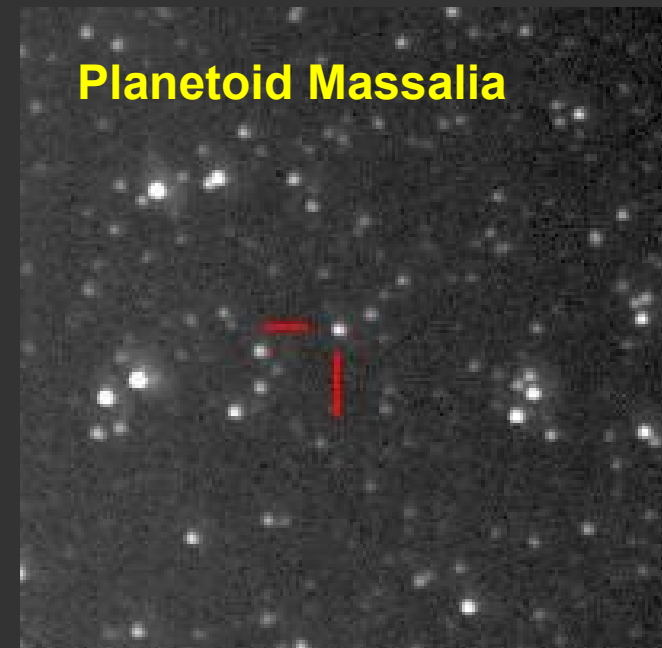
2006-12-28



2006-12-29



2007-01-09 (11 images)



Currently only background events from planetoids are found, but they are good tool for testing.
Possibility of identifying “killer asteroids”

GRB observations

In period 2004-07-01 to 2005-08-07

(FOV $\sim 33^\circ \times 33^\circ$, following HETE FOV) , GRB# = 89

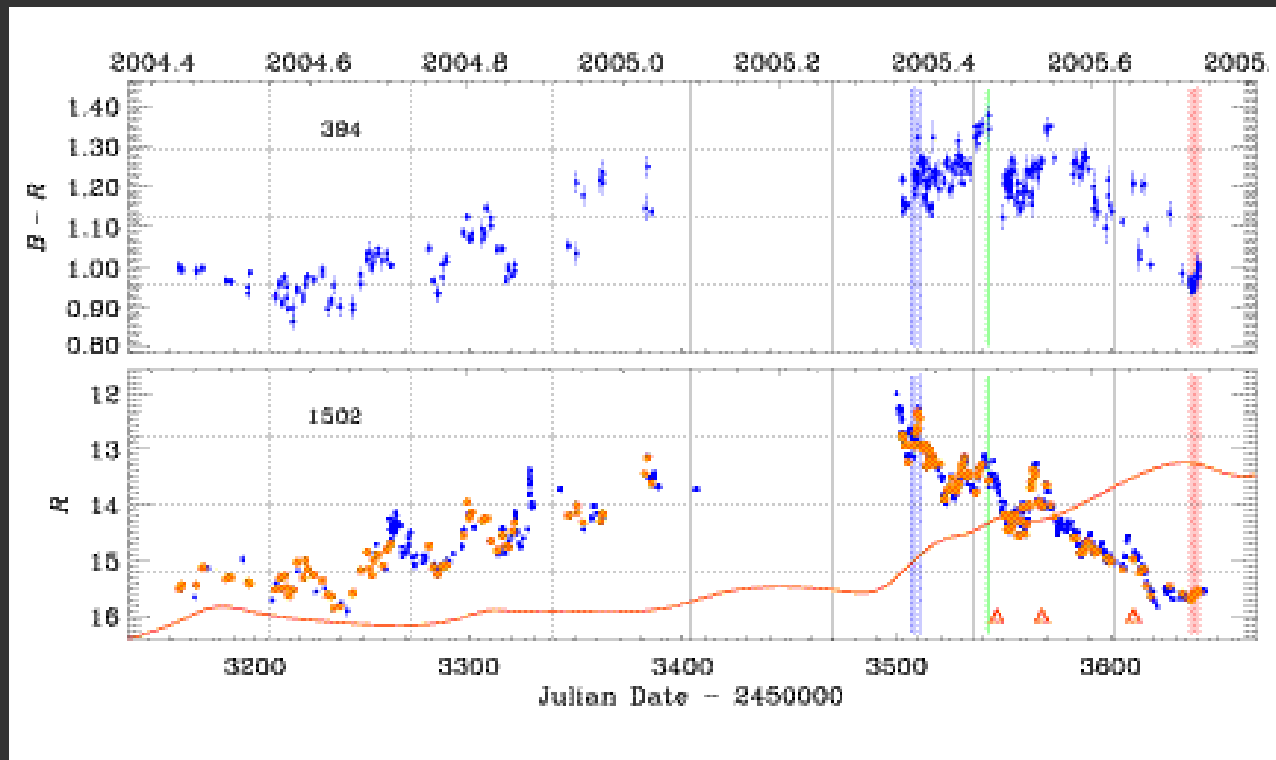
apparatus off	North hemisphere	daytime	below horizon	clouds	outside FOV	inside FOV
1	18	40	8	4	16	2

Since 2006-06-01 (FOV $\sim 20^\circ \times 20^\circ$) , GRB# = 76

apparatus off	North hemisphere	daytime	below horizon	clouds	outside FOV	inside FOV
4	4	41	17	2	8	0

Monitoring of interesting objects

We have observed blazar 3C454.3 in activity phase, when it reached $R=12^m$ and was well in the range of our detector (our most distant object $z=0.859$)
It was a falling slope of the light curve, the maximum was not observed



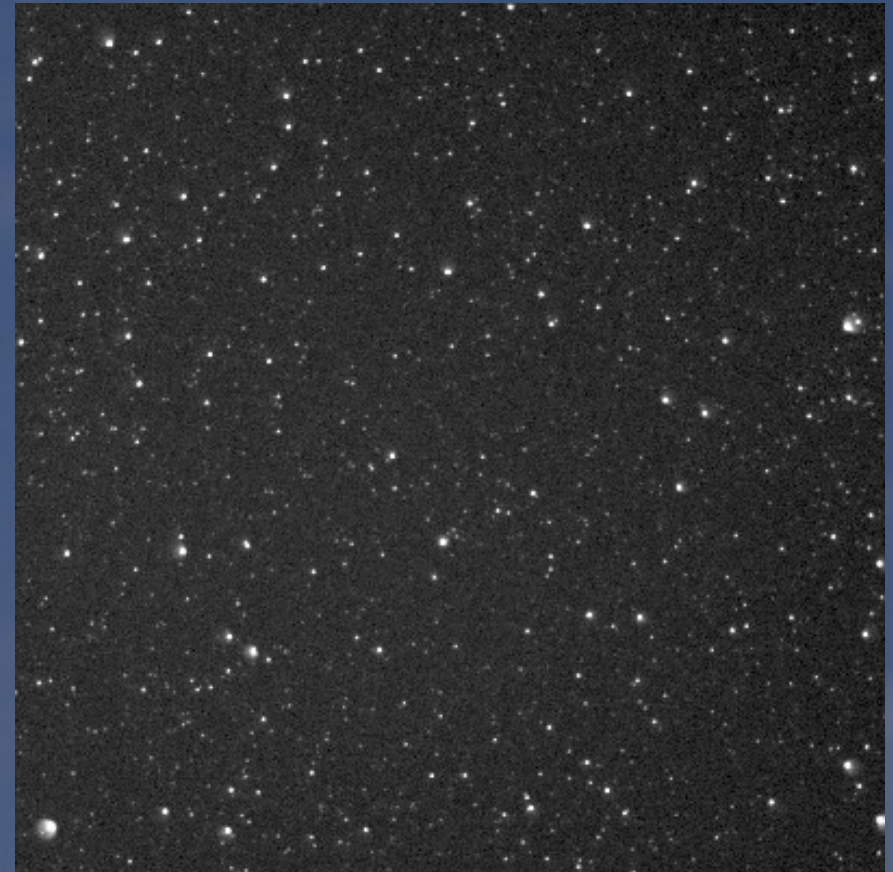
We decided to permanently monitor the list of interesting objects like blazars and AGNs. We joined GTN (Global Telescope Network), people from this group can add objects which are added to observation plan and get their light curves

If you have any interesting objects for monitoring we are opened for cooperation !

Background examples



**“Star Wars” like
background**



Meteors

Thank you for attention

More information of WWW page :

grb.fuw.edu.pl