Pi of the Sky detector

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Plan

- „Pi of the Sky” collaboration
- Scientific motivation
- Concept
- Detector
  - Final version
  - Prototype
- Results

„Pi of the Sky” collaboration

1. Center for Theoretical Physics, Polish Academy of Science
2. The Andrzej Soltan Institute for Nuclear Studies
3. University of Warsaw
   - Institute of Experimental Physics,
   - Faculty of Mathematics, Informatics and Mechanics, University of Warsaw
4. Pedagogical University of Cracow
5. Warsaw University of Technology:
   - Faculty of Physics
   - Institute of Electronic Systems
6. Space Research Center
7. Cardinal Wyszynski University
8. Creotech

Inspired by prof. B. Paczynski

Cooperation with dr. G. Pojmanski (University of Warsaw)

Scientific motivations

General goal:

study objects varying on scales from seconds to months

- Optical counterparts of Gamma Ray Burst (optical observation before and during GRB)
- Monitoring of short timescale astrophysical phenomena (≥10s) in optical band
- Automatic detections of flash like events (supernovae, novae, flare stars explosions)
- Continuously monitoring of blasars and AGNs and variable stars (catalog of variable stars)

Afterglows of GRBs

There is a lot of question about GRB. To observe prompt optical emission is crucial for understanding its most mysterious part: **central engine**

problem:

no one knows where the next GRB will happen, so we do not know where we out to look at the sky

- Standard approach:
  wait for GRB alert listening to GCN - good option, but there is a problem with first seconds of GRBs, we missed them, so we are not sure what was happen with afterglow during the gamma emission
- New approach:
  look everywhere, all the time with self-triggering - to be sure not to overlook the afterglow, and observe them before and during gamma emission → ”Pi of the Sky” experiment

Concept

- Continuous observations of large part of the sky during the night – look everywhere, all the time
- Large data stream
- Real time analysis and reactions (online multilevel trigger base on experience from particle physics experiments)

Detector – final system (under construction)

Dome

SITE A

Parallax ~ 100 km
to reject close optical
flashes

Dome

SITE B

16 CCD per side (32 CCD)

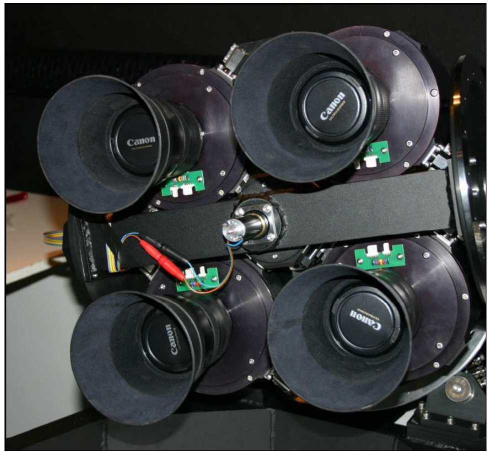
FoV for one camera: 20°x 20°, max common FoV ~1/6 sky (corresponding to FoV of SWIFT – very important!! – following SWIFT FoV every GRB detected by SWIFT will be automatically in „Pi of the Sky" FoV)

Detector – final system (under construction)

- custom designed cameras, 2k×2k pixels each,
- Canon objectives (f=85 mm, f/d=1.2)
- ethernet and USB2.0 interface
- readout noise ~30e$^-$
- 2 stage thermoelectric cooling
- angular size: 36 arcsec/pixel
- time resolutions: 10s (exposure time)
- shutter designed for ≥ 10^7 cycles
- range: 12m (1 frame), 14m (20 frames)

Detector – final system (under construction)

- one mount carrying 4 cameras
- two observation modes: side-by-side (WIDE) or common-target (DEEP)
- controlled via Controller AreaNetwork (CAN)
- run autonomous, controlled via Inthernet



Large data stream:

- 3000 frames = 25 GB / night / camera
  - → 100GB/night/mount
  - → 1.6TB/night/detector

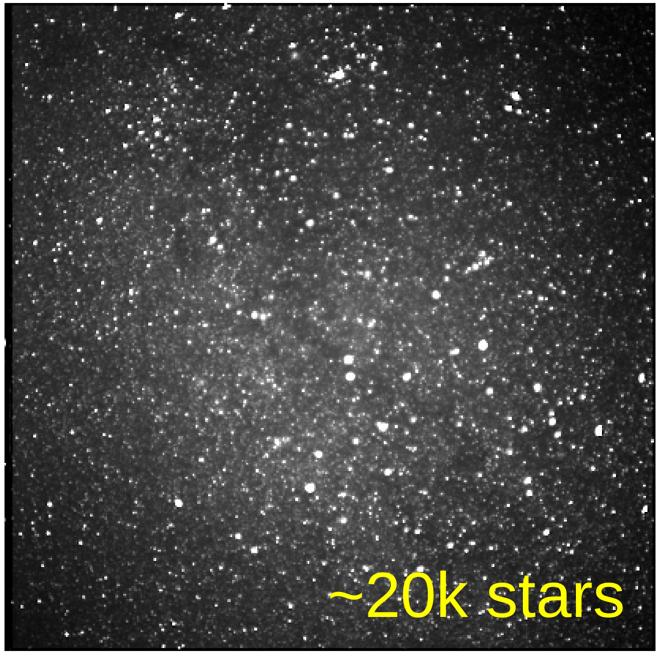
Detector - prototype

Las Campanas Observatory, Chile

(since June 2004 in ASAS dome)

Detector - prototype

- 2 CCD (2kx2k) on one paralactic mount (coincidence)
- FoV of one camera 20°x 20°
- range:
  - 12m (1 frame),
  - 13m (20 frames),
- 10s exposures, 2s dead time
- IR-cut + R Johnson-Bessel filter (since May 2009)



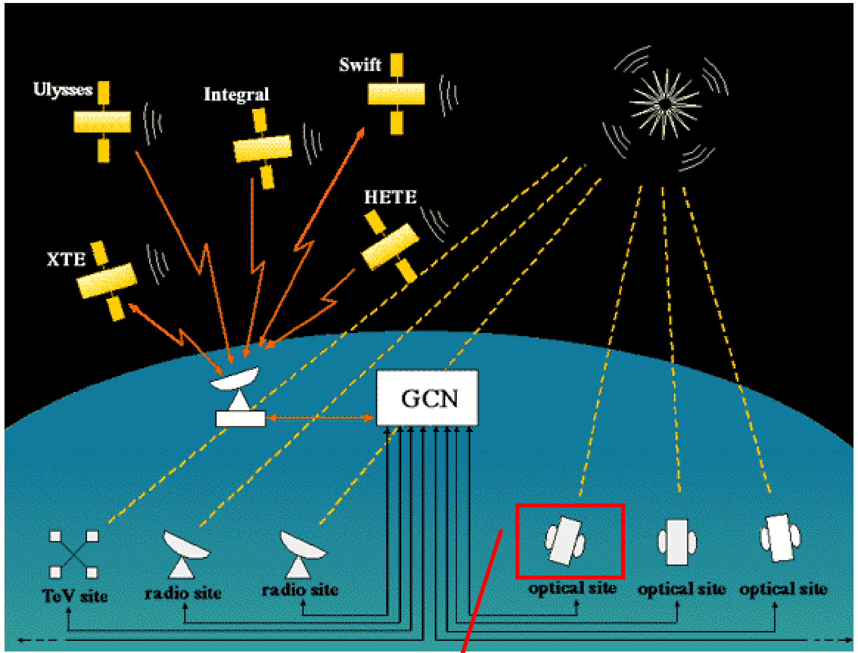
Detector - prototype

Apparatus was designed to operate at LCO without a permanent human supervisor → system very reliable. Achived by:

- self-diagnostic (should any failure occur, the system sends an SMS with the appropriate information to the mobile phone of a person in charge),
- remote monitoring,
- hardware redundancy,
- flexible configuration,

Detector - prototype (observation strategy)

- Follow FOV of SWIFT or INTEGRAL (if not possible follow objects from GTN and other interesting objects like blazars, AGNs, special variable stars)
- reacts to alerts from GCN
- evening and morning all sky scan
- on-line flash recognition algorithm looks for short timescale OT

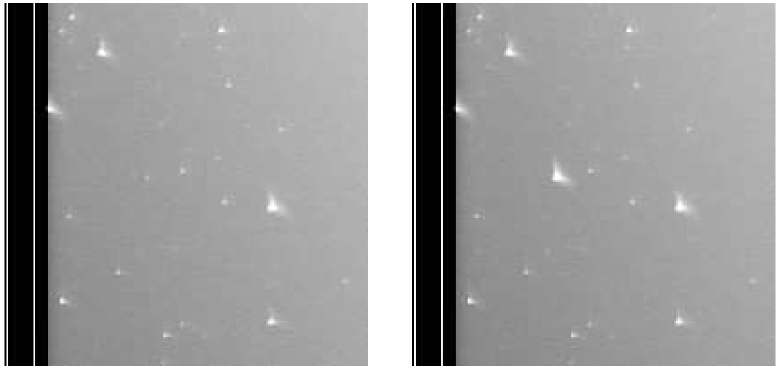


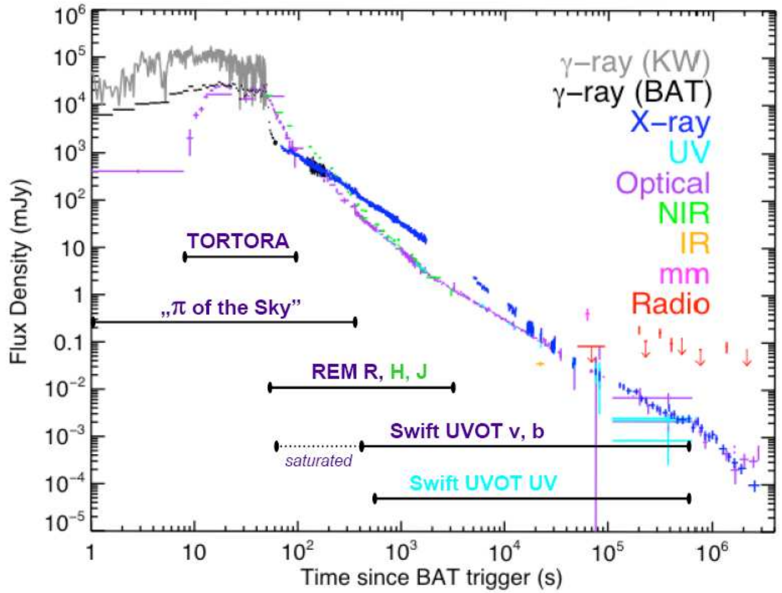
Pi of the Sky

Detector – prototype algorythms

- On-line data analysis
  - First level: compare new images with series of previous images to find new objects →reduce data stream to be analysed,
  - Higher levels: sophisticated multilevel flash recognition trigger used in particle physics, rejection of background events,
- Off-line data analysis
  - searching for novae like events (normal + scan observations)
  - runing fast photometry on individual frames (remove single frames after a few days and save all data in database)
  - runing precise photometry on images superposed by 20 (save result in DB and stored permanently)

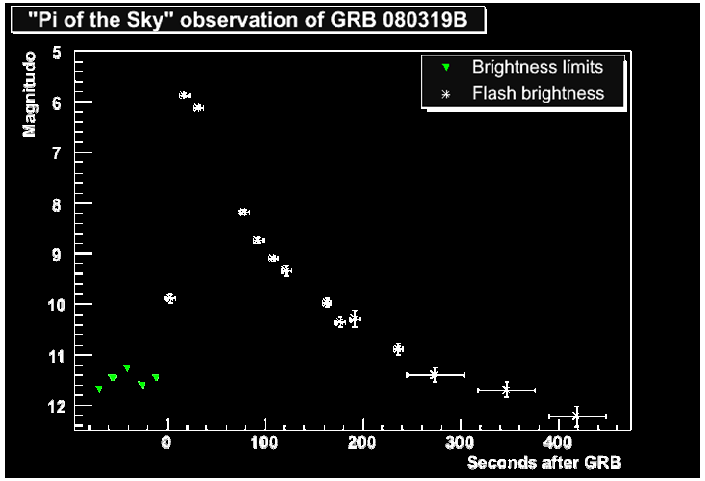
Results GRB080319B





A naked-eye burst

- automatically identified by on-line flash recognition algorithm
- optical observation during gamma emission with 10s time resolution
- peak brightness 5.3 m



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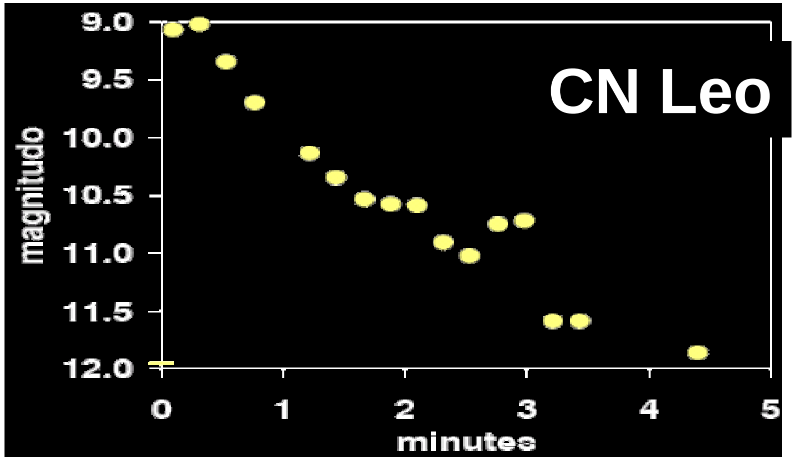
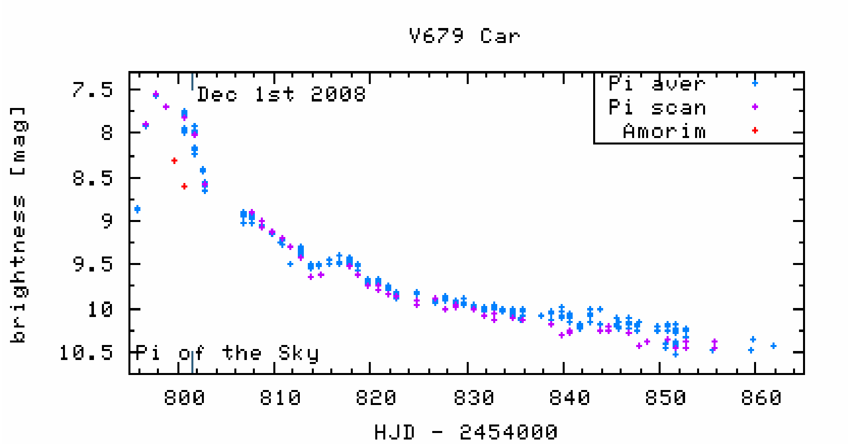
Results

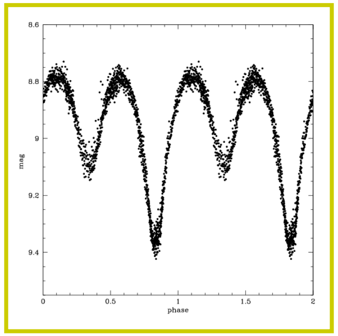
- outburst of flare star CN Leo (on-line algorithm)
- outburst of cataclysmic binary (discovered by „Pi of the Sky" off-line algorithm):
  - Nova in Carina 2009 (V679 Car)
  - 1RXS J023238.8-371812 (2007)
  - VSX J111217.4-353828 (2007)
  - and a few novae discovered by other experiments but also discovered automatically by our algorithms

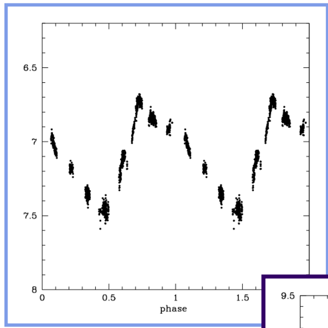


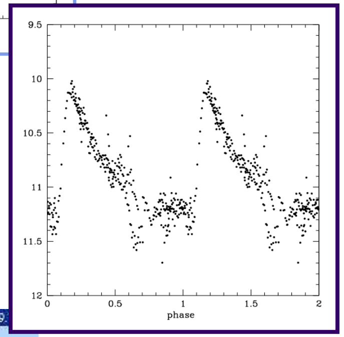


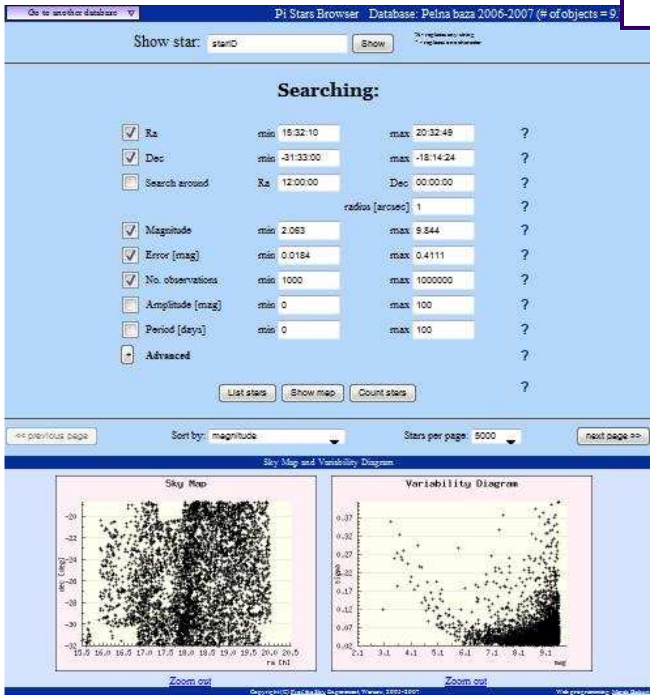
Results

- catalogue of variable stars (data 2004 – 2005) – data 2006-2007 under construction
- data bases of measurements
  - Data period VII.2004-VI.2005 (4.5 mln of objects, 790 mln measurements)
  - Data period V.2006-XI.2007 (10.8 mln of objects, 1002 mln measurements)









More about „Pi of the Sky”:

- Marcin Sokołowski

  „Detection of short optical transients of astrophysical origin in real-time”, Monday at 16:00 (session III)

- Krzysztof Nawrocki

  „PiMan: system manager of the „Pi of the Sky” experiment”, Tuesday at 10:30 (session V)

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