

# Pi of the Sky

Robotic telescope

## Arkadiusz Ćwiek

arkadiusz.cwiek@fuw.edu.pl

National Centre for Nuclear Research

University of Warsaw



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# Pi of the Sky

## Team

- National Centre for Nuclear Research  
(formerly The Andrzej Soltan Institute for Nuclear Studies)
- Center for Theoretical Physics of the Polish Academy of Sciences
- Faculty of Physics at the University of Warsaw
- Space Research Centre PAS  
(Polish: Centrum Badań Kosmicznych PAN)
- Institut of Electronic Systems  
at the Warsaw University of Technology

Cooperation: Creotech Instruments S.A.

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# Pi of the Sky

## Scientific motivation / Research program

**Studies variable objects on time scale from seconds to months:**

- **Searching for optical counterparts of Gamma Ray Bursts**  
(Optical observations before and during GRB – large field of view, autonomous detection of flashes)
- Observations of other variables phenomena in the sky:
  - Search for novae and supernova explosions, flare stars explosions
  - Identification, measurement parameters and cataloging variable stars with short periods of volatility
  - Monitoring interesting objects
  - Monitoring of the all visible sky
  - Finding and cataloging spaces debris.



# GRB – Gamma Ray Burst

## Błyski Gamma

- Gamma Ray Bursts (GRB)  
short ( $<1000$  s), strong, non-repetitive bursts of  $\gamma$  rays from point sources in the sky
- Observed in a very wide range of spectrum, from radio waves to  $\sim$ GeV photon
- Discovered in 1967 by American spy satellite Vela  
(first publication in 1973 year)

# GRB – two class ?

- Short flashes:  $< 2s$ , hard spectrum - collision of two neutron stars ?
- Long flashes:  $> 2s$ , soft spectrum - hypernova collapse into a black hole ?

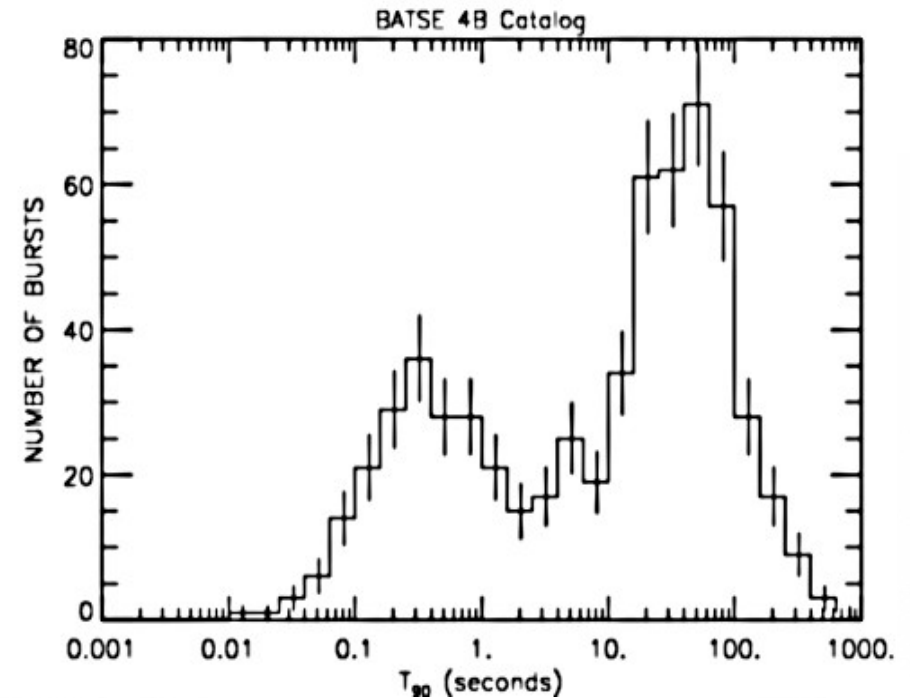
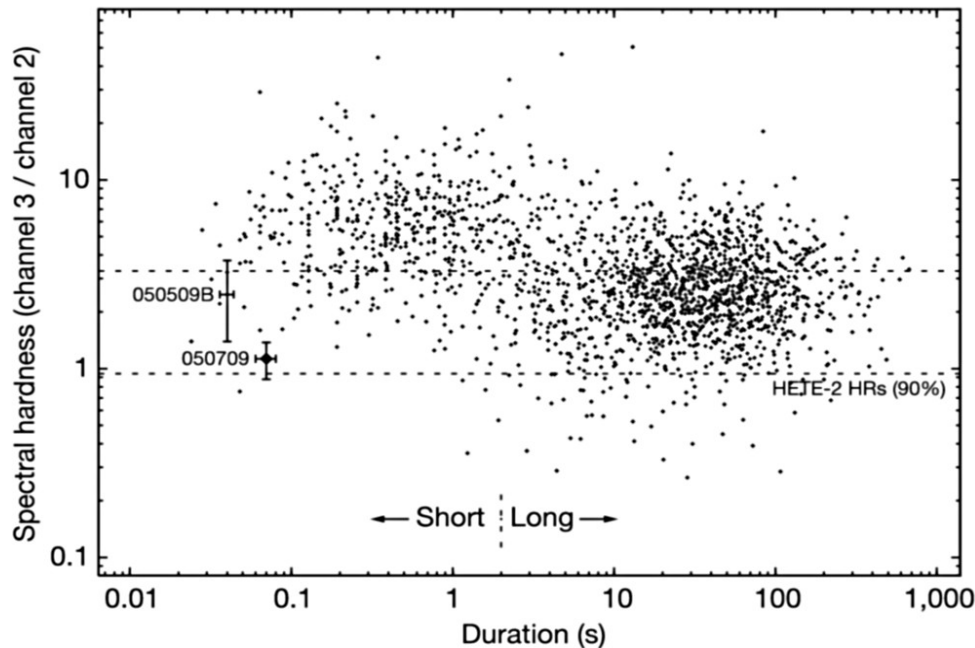


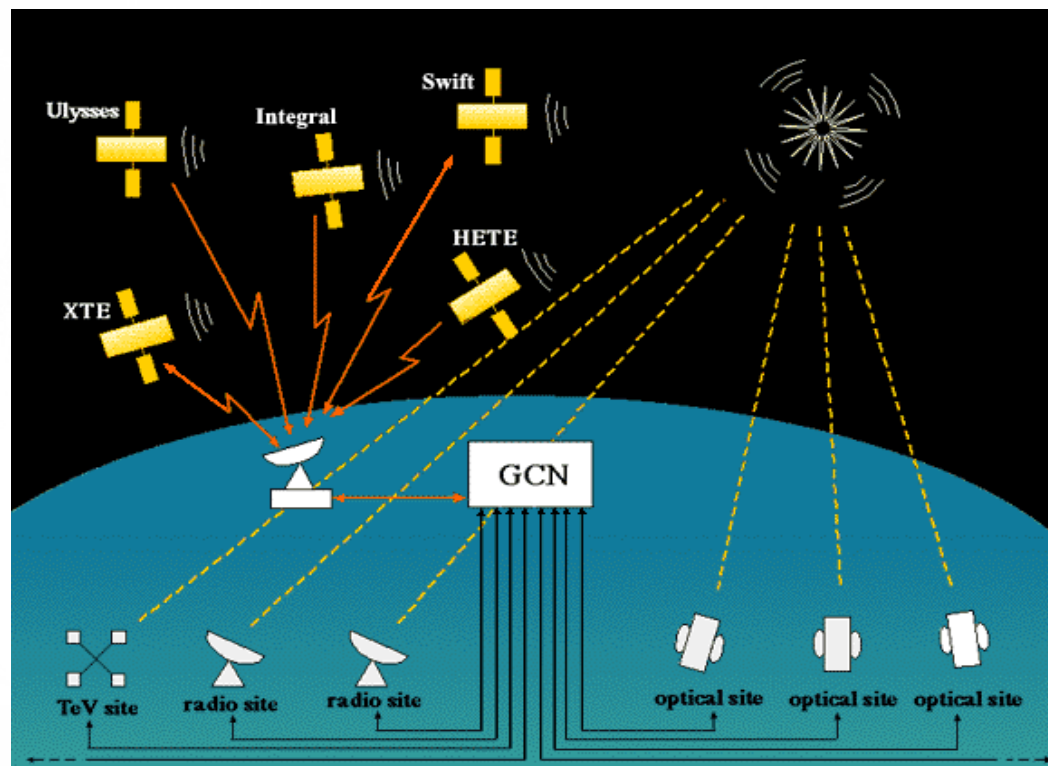
Figure 1 | The classic BATSE duration-spectral hardness diagram<sup>1</sup>.

Twardość widma (stosunek liczby zliczeń w przedziale energii 300-100keV do liczby zliczeń w przedziale energii 25-100keV) vs czas błysku

$T_{90}$  – czas w którym rejestrowane jest od 5% do 95% zliczeń

# GRB cont.

- Currently GRB search by satellites:
  - Integral (2002), field of view  $30^\circ \times 30^\circ$ , 3 keV - 10MeV
  - SWIFT (2004) Field of View 1.5 sr 0.1-150 keV
  - FERMI (2008) 2 sr field of view, 10 keV-300 GeV
- GCN (GRB Coordinate Network) – auto. broadcast inf. from satellite
  - large telescopes make further measurements
- Delay observation
  - processing and transmission of information from satellite
  - Time of moving to the GRB position



# Pi of the Sky

## Inspiration

- The project was inspired by prof. B. Paczynski
- The proposed new strategy of measurements
  - continuous visual observation of a large area of the sky
    - observation of flash before the flash high temporal resolution
  - Big time resolution
    - comparable with the duration used
  - self-recognition algorithm flashes "on-line"
    - identification independent of satellites





# Pi of the Sky

## Concept of telescopes

- Big field of view  
( commercial photographic lenses => moderate cost )
- sensitive CCD camera + low-boisterous electronics
- **2 sets of 16** cameras (each set of 4 mounts, with 4 cameras)
  - duża szansa, że błysk w polu widzenia
  - paralaksa - odrzucanie tła od satelitów
- Dedicated equatorial mount (fast moving to the flash)
- Reliable and fully autonomous operation (the system should operate without human intervention) niezawodność i w pełni autonomiczna praca (the system should operate without human intervention))



# Pi of the Sky

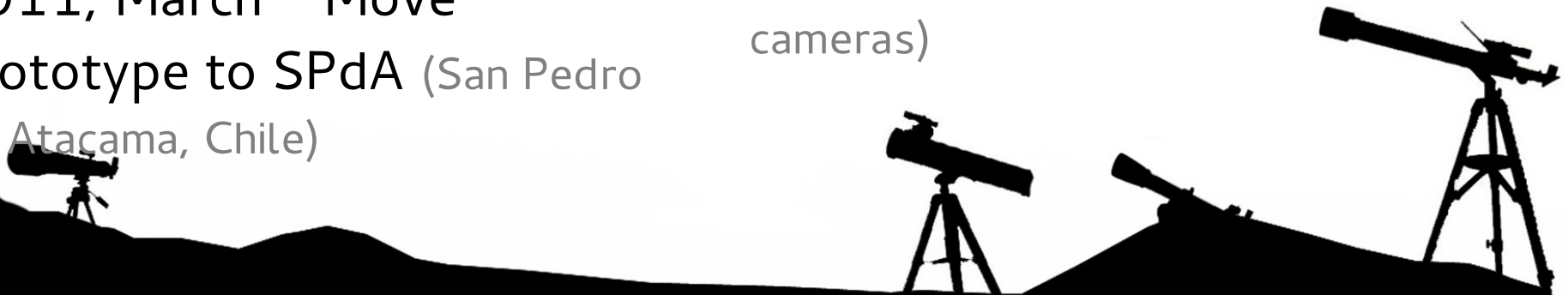
## Krótką historia

### Prototype:

- 2003 – Firsts tests in Brwinow about Warsaw
- 2004 czerwiec – Instalation in LCO (Las Campanas Observatory, Chile)
- 2006 June – Instalation new camera and leans
- 2011, March – Move prototype to SPdA (San Pedro de Atacama, Chile)

### Full System:

- 2010 September – Instalation first mount new type (4 CCD caemra on one mount FOV  $4 * 20 \times 20$ ) in INTA (Instituto Nacional Tecnica Aeroespacial), Spain
- 2013 July ? – instalation next three mount (in the sum of 16 cameras)



# Pi of the Sky

## Detectors

- The highly sensitive cameras are an original design of our team:
  - Ready element CCD chip is only  $2048 \times 2048$  px
  - particularly important: Shutter  $\sim 10$  openings
  - low-boisterous electronics
  - Full control and data transfer via the Internet
- Leans Canon  $f = 85$  mm,  $d = f/1.2$
- FoV  $20^\circ \times 20^\circ$
- 10 s exposures, range  $\sim 11^m$ ,
- to  $13^m$  in the totals after 20 fotos
- fully autonomous operation (including diagnostics, detection and correction of known problems)
- monitoring via the Internet



# Pi of the Sky

Observatory in San Pedro de Atacama, Chile

- The new location prototype installation - March 2011
- Two CCD cameras observing the same area of the sky (elimination of false flashes)



# Pi of the Sky

INTA research station, near Huelva, Spain

First detector of full system,  
instalation: october 2010

Each detector include 4 CCD camera, on a developed  
by us on an equatorial mount, which could operate in  
two modes:

- WIDE - observation of the neighboring areas of the  
sky (which gives rise widenia  $\sim 40^\circ \times 40^\circ$ )
- DEEP - Observation of the same area of the sky

In July of this year. we plan to install another three  
such detectors.

# Pi of the Sky – data

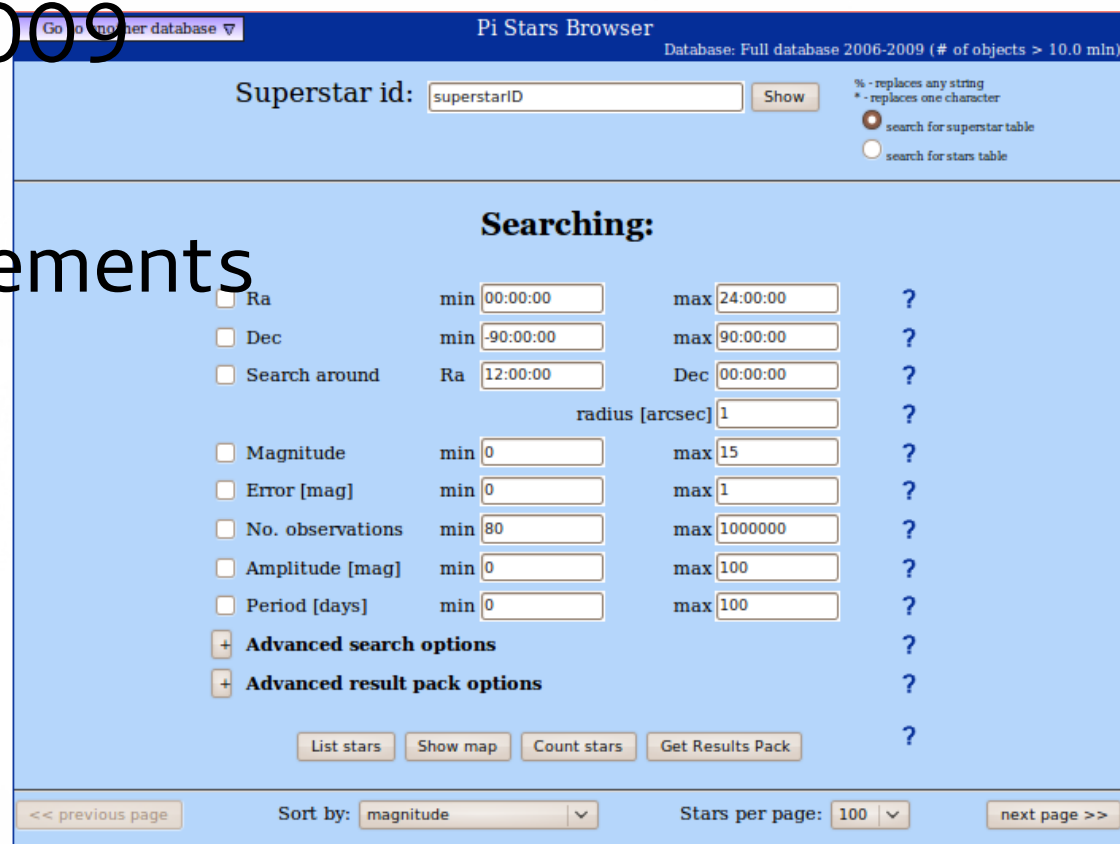
- All collected of data are publicly available

<http://grb.fuw.edu.pl/pi/databases>

- Database 2006 - 2009

- $16.7 \cdot 10^6$  objects

- $2.16 \cdot 10^9$  measurements



The screenshot shows the 'Pi Stars Browser' interface. At the top, it says 'Database: Full database 2006-2009 (# of objects > 10.0 mln)'. Below this is a search bar for 'Superstar id:' with a 'Show' button. To the right, there are radio buttons for 'search for superstar table' (selected) and 'search for stars table'. The main section is titled 'Searching:' and contains several search criteria with checkboxes and input fields:

- Ra: min [00:00:00] max [24:00:00] ?
- Dec: min [-90:00:00] max [90:00:00] ?
- Search around: Ra [12:00:00] Dec [00:00:00] ?
- radius [arcsec] [1] ?
- Magnitude: min [0] max [15] ?
- Error [mag]: min [0] max [1] ?
- No. observations: min [80] max [1000000] ?
- Amplitude [mag]: min [0] max [100] ?
- Period [days]: min [0] max [100] ?
- Advanced search options ?
- Advanced result pack options ?

At the bottom, there are buttons for 'List stars', 'Show map', 'Count stars', and 'Get Results Pack'. The footer shows navigation controls: '<< previous page', 'Sort by: magnitude', 'Stars per page: 100', and 'next page >>'.

# Plans for the future

- Integration telescopes Pi with GLORIA network
- Install the next three detectors in INTA
- Build of a new detector:
  - New optics ( $f=300\text{mm}$ ,  $d=f/1.5$ ) → increase the range
  - Speed cameras (min. 3 fps)
  - Speed mount (moved to flash in about 10 s)
  - This allows, inter alia:
    - quick response to GCN alerts and flashes detected by Pi of the Sky
    - better detection and tracking satellites and "space junk"
- Further development of CCD cameras (consortium with Creotech)





# Pi of the Sky

## Symmary

- After 40 years since the discovery of GRBs are still a mystery (do the "hunt" for early optical flashes)
- A new approach in Pi of the Sky
  - Monitoring of heaven and self-discovery
  - GRB080319B confirmed proof of concept
  - Further development of infrastructure
- We are part of a European network of GLORIA
  - Intelligent network of robotic telescopes
  - Open access to professional data and time of observation
  - More information on:

<http://gloria-project.eu/pl/>





# Thank you for your attention

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