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**„Pi of the Sky”  
robotic search for cosmic flashes**

**<http://grb.fuw.edu.pl/>**

# Plan

- **“Pi of the Sky” collaboration**
- **scientific motivation**
- **detector**
- **results**
- **future plans**
- **summary**

# “Pi of the Sky” Collaboration

- **The Andrzej Sołtan Institute for Nuclear Studies**

G.Wrochna, K.Nawrocki, M. Sokołowski, J.Mrowca-Ciułacz , M.Górski

- **Center for Theoretical Physics, Polish Academy of Science**

L.Mankiewicz

- **Warsaw University**

- **Institute of Experimental Physics**

M.Ćwiok, H.Czyrkowski, R.Dąbrowski, W.Dominik, L.W.Piotrowski

- **Astronomical Observatory**

B.Pilecki, D.Szczygieł

- **Warsaw University of Technology**

- **Faculty of Electronics**

A.Burd, M.Grajda, K.Poźniak, R.Romaniuk, G.Kasprowicz, S.Stankiewicz

- **Faculty of Physics**

J.Użycki, M.Molak

- **Cardinal Wyszyński University**

K.Kwiecińska, K.Krupska

- **In cooperation with :**

professor B.Paczyński PRINCETON and G.Pojmański Warsaw University (ASAS)

# Scientific motivation

- optical counterparts of Gamma Ray Bursts - *afterglows*
- all kind of short timescale phenomena 1sec – 1 year
- supernovae explosions
- novae explosions
- variable stars
- flare stars

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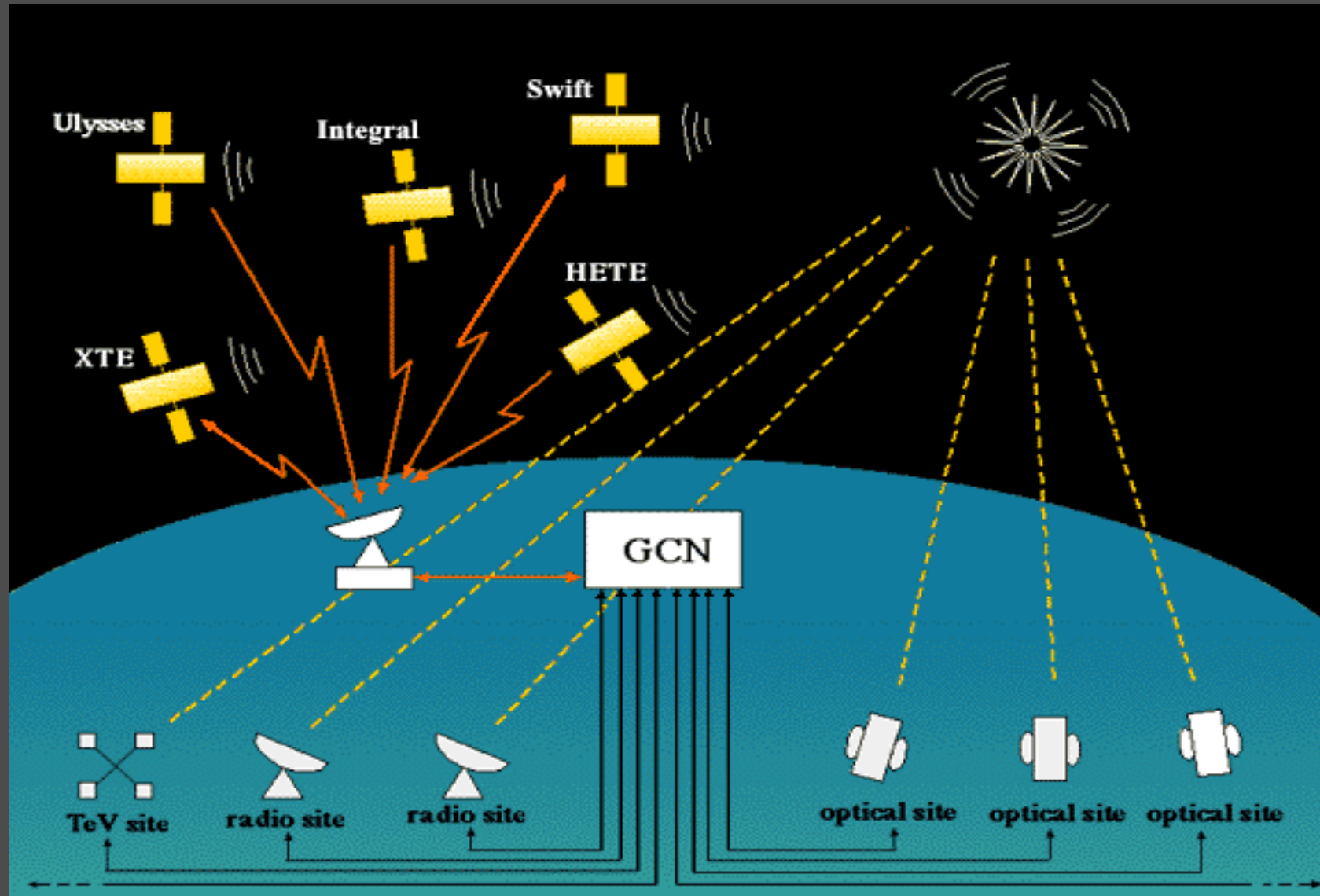
# Gamma Ray Bursts (GRB)

- short pulses ( 0.1 – 100 s ) of gamma radiation coming from point sources on the sky
- extragalactic origin and huge energies :

$$10^{53} \text{ erg / s} \sim 0.001 \text{ M}_{\odot} / \text{s}$$

- genesis still remains unknown, many hypothesis – death of massive star or collision of two neutron stars in binary system
- they may be accompanied by optical flash - afterglow
- about 3 daily, observed by satellites few in month, information is passed through GCN to all interested follow-up experiments
- more exciting details in evening talk by Grzegorz Wrochna

# GCN Network





## PROTOTYPE OF DETECTOR

- Paralactic mount, step engines  
5 steps / arc sec
- Two cameras of special design:
  - low noise (16 e)
  - fast readout 2MHz / pixel
  - mechanical shutter  $10^7$  cycles
  - objective of focal length :  
 $f = 50 \text{ mm}$  ,  $f/d = 1.4$
  - 2000x2000 CCD chip of pixel size  
 $15 \mu\text{m}$
  - field of view (FOV)  
 $33^\circ \times 33^\circ$
  - limiting magnitude  $11^m$  (on 10s),  
and  $12-13^m$  for 20 summed  
frames
- Currently installed at  
Las Campanas Observatory  
(Chile), very good conditions  
90% of observing nights

# Las Campanas Observatory ( Chile )





Pi apparatus in ASAS dome



# Observation strategy

- follow the field of view of satellite INTEGRAL or HETE in order to have “images of GRB” before, during and after the gamma detection
- 10 s exposures are taken, with 2 sec break
- on-line flash identification algorithm looks for optical transients coinciding on two cameras
- in case of GCN alert from other satellite arrives move to that position and remain there for  $\frac{1}{2}$  h
- 2 times a night scan of whole celestial sphere is performed
- collected images are used in standard photometrical analysis concerned on variable stars

# Automation of the system

- system controlled by 2 PCs is fully automatic and does not require human attention during normal work
- remotely controlled, only sporadic local support was needed ( remote power control , Boot On LAN, Wake On LAN )
- every night special script is generated according to satellite pointing information from WWW and is realized by system
- common problems are handled by system itself
- in case of major problem information is sent by e-mail or sms
- identified flashes are automatically placed on WWW page to be easily accessible for further validation

# GRB afterglow observations

## 65 GRB observed by satellites since 2004.07.01

apparatus off	North hemisphere	daytime	below horizon	clouds	outside FOV	inside FOV
1	13	30	4	3	<b>12</b>	<b>2</b>

# GRB afterglows observations

GRB	before GRB	during GRB	after GRB	GCN
<b>X 050509C</b>	-	<b>outside FOV</b>	<b>&gt;+28min &gt;13<sup>m</sup></b>	
<b>G 050412</b>	<b>&gt;11.5<sup>m</sup></b>	<b>&gt;11.0<sup>m</sup></b>	<b>&gt;11.5<sup>m</sup></b>	<b>3240</b>
G 050326	<-33min: >11 <sup>m</sup>	outside FOV		3146
G 050219B	<-20.5h: >12 <sup>m</sup>	daytime	>+3.7h: >10 <sup>m</sup>	
G 050219	<-3.7h: >11.5 <sup>m</sup>	daytime		
G 050128	<-19.7h: >11 <sup>m</sup>	outside FOV	>+4.3h: >12 <sup>m</sup>	
G 050123	<-1.8h: >12 <sup>m</sup>	daytime		2970
<b>G 041217</b>	-	<b>outside FOV</b>	<b>&gt;+30min:&gt;11.5<sup>m</sup></b>	<b>2862</b>
G 041211	<-4.7h: >11 <sup>m</sup>	daytime		
G 040924	<-3h: >11 <sup>m</sup>	daytime		
<b>X 040916</b>	<b>&lt;-13h: &gt;12<sup>m</sup></b>	<b>outside FOV</b>	<b>&gt;+17min: &gt;13<sup>m</sup></b>	<b>2725</b>
X 040912	<-4.7h: >12 <sup>m</sup>	daytime	>+19h: >10 <sup>m</sup>	
X 040903	<-18h: >10 <sup>m</sup>	daytime		
G 040827		daytime	>+12h: >10 <sup>m</sup>	
X 040825B	<-6.7h: >10 <sup>m</sup>	daytime	>+17h: >10 <sup>m</sup>	
<b>G 040825A</b>	<b>&lt;-11s: &gt; 10<sup>m</sup></b>	<b>&gt; 10<sup>m</sup></b>	<b>&gt;+7s: &gt; 9.5<sup>m</sup></b>	<b>2677</b>
<b>G 040812</b>	-	<b>outside FOV</b>	<b>&gt;+20min: &gt;12<sup>m</sup></b>	

# Perspectives for future

- work on full version of 2 x 16 cameras has been started
- FOV – at least as big as the one of SWIFT satellite  $\sim 2$  srad
- increase the limiting magnitude by 1.5
- Coincidence of 2 cameras placed in  $\sim 130$ km distance will allow rejection of planes and satellites thanks to parallax

# Summary

- “Pi of the Sky” detector is working since June-2004, ~  $10^6$  images has been collected, gives a very good lesson before construction of full system
- we determined several limits for brightness of GRB optical afterglow
- in two cases it was observation before, during and after the GRB, which was first observation of this type
- we identified about 80 optical flashes of unknown origin
- works on full system has started ...
- **<http://grb.fuw.edu.pl/>**