Search for GRB prompt optical emission with „π of the Sky" apparatus

- **The concept of all time, all sky monitoring**
- **Prototype apparatus**
- **Burst recognition algorithms**
- **Project status and prospects**

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GRB's today and tomorrow

Today:

- gamma emission well understood
- central engine(s) still uncertain

Tomorrow:

- coincidence with TeV photons, neutrinos, etc
- optical observations before and during GRB
- using GRB as standard candles for cosmology

Observing prompt optical emission crucial for understanding the central engine

No one knows were the next GRB will happen

Standard approach:

- **wait for GRB alert and move there quickly**
  - **robotic telescopes listening to GCN:**
  - **BOOTES, (SUPER)LOTIS, MASTER, RAPTOR, REM, ROTSE, TAROT, ...**

New approach proposed:

- **look everywhere, all the time**
  - **wide field of view (π steradians ?)**
  - **self-triggering**

$\Rightarrow$ experiment „π of the Sky”

„π of the Sky”

Concept:

- continuous ~all sky survey (32×3000 images / night)
- large data stream (1 Terabyte / night)
- real time analysis (multilevel trigger)

Project:

- 2×16 CCD cameras, each 2000×2000 pixels
- Canon lenses f=85mm, f/d=1.2
- field of view = 2 steradians = GLAST LAT > Swift BAT

Status:

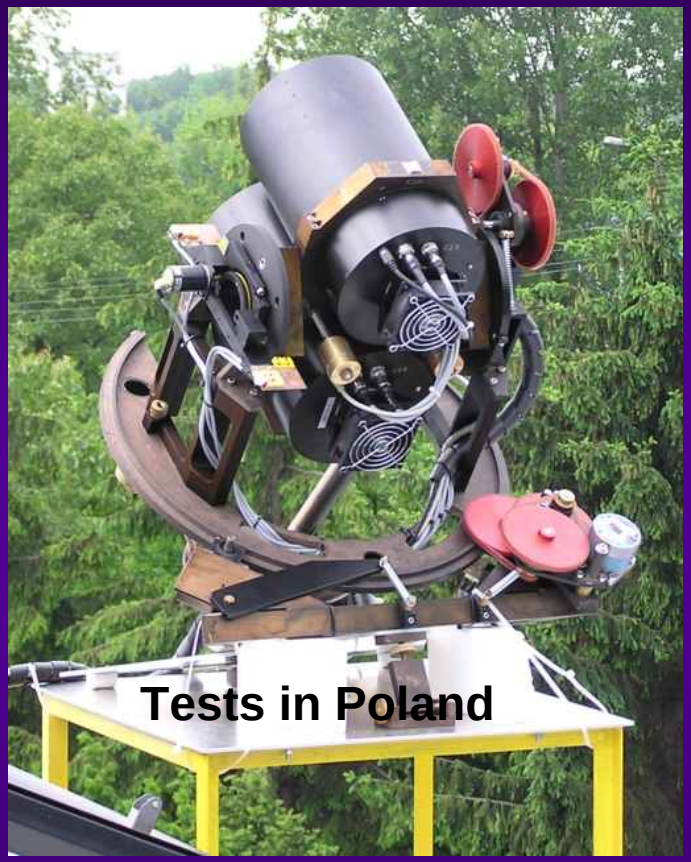
- Prototype with 2 cameras works from July 2004 in Chile
- Full system under construction (ready by fall 2006)

Collaboration:

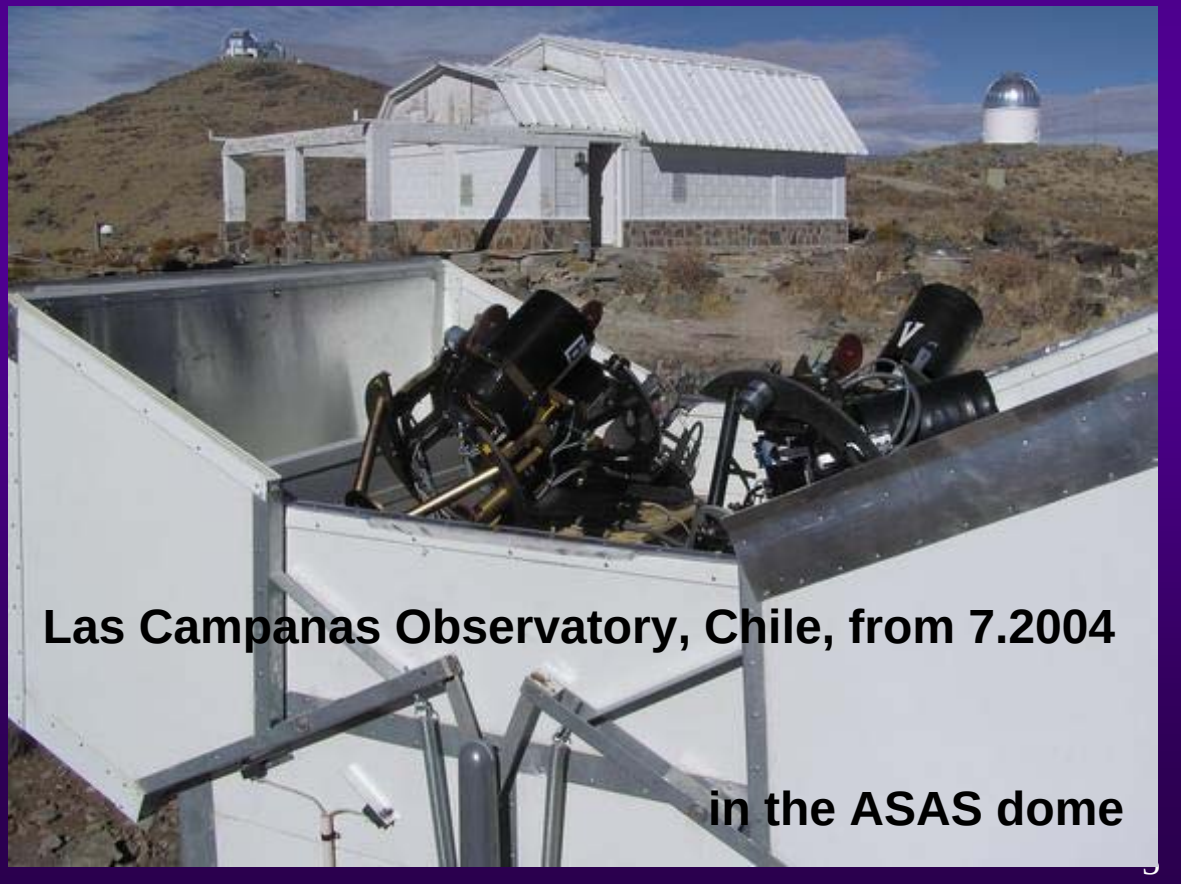
- Soltan Institute for Nuclear Studies, Warsaw (G.Wrochna)
- Center for Theoretical Physics PAS, Warsaw (L.Mankiewicz)
- Warsaw University
- Warsaw University of Technology
- Space Research Center PAS, Warsaw

Special thanks to B.Paczynski, G.Pojmanski / ASAS, LCO staff

„π of the Sky" prototype



- 2 CCD cameras 2000×2000 pixels
- Zeiss lenses f=50mm, d=f /1.4
- common field of view 33°×33°



- robotic mount
  by G.Pojmanski / ASAS
- autonomic operation
- controlled via internet

„π of the Sky”: robotic detector

Autonomic operation according to programme:

- follows SWIFT, HETE or INTEGRAL field of view
- detects itself optical flashes
- all sky survey twice a night (2×20min)
- follows targets of GCN alerts

High reliability:

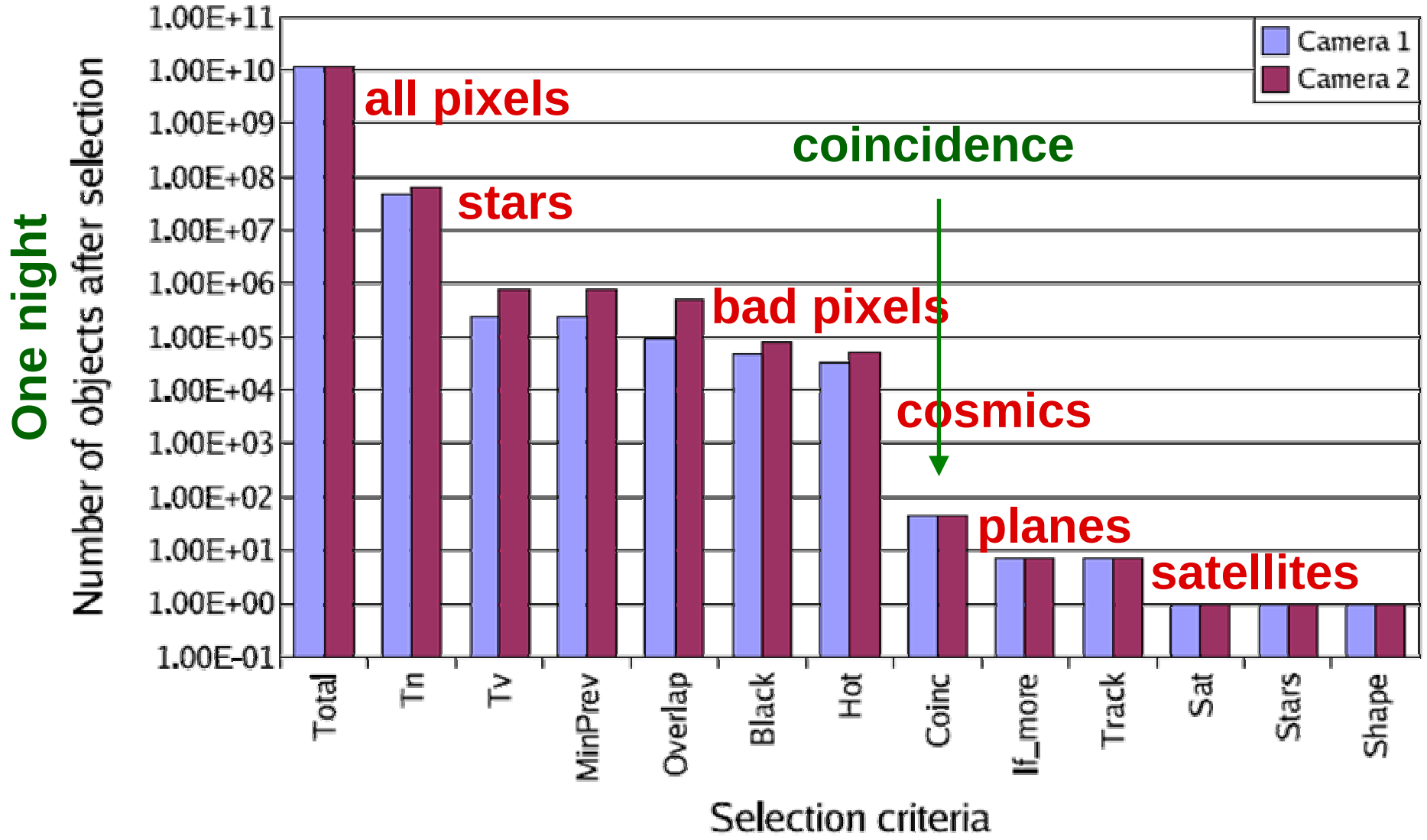
- remote-reset, Wake-on-LAN, Boot-from-LAN
- selfdiagnostics (e-mail and SMS to Poland)

During the first year of operation:

- ~10 nights lost due to apparatus problems
  + ~30 nights lost due to weather
- > 300 „good” nights, 1 000 000 sky images,
  10^{10} photometric measurements

Flash recognition in real time

multilevel trigger concept *(a'la particle physics exp.)*



„π of the Sky”: GRB observations

89+40 GRB’s seen by satellites 7.2004-7.2005 & 6-9.2006:

5+4 – clouds (4+1) or apparatus off (1+3)

18+4 – Northen hemisphere

48+29 – daytime or below horizon

16+3 – outside field of view, 4+2 limits published:

GRB 040916B,	$>13.0^m$	(GCN 2725)
GRB 041217,	$>11.5^m$	(GCN 2862)
GRB 050123,	$>12.0^m$	(GCN 2970)
GRB 050326,	$>11.0^m$	(GCN 3146)
GRB 060607,	$>13.4^m$	(GCN 5241)
GRB 060719,	$>12.8^m$	(GCN 5346)

2+0 – within FOV: limits before / during / after t_0

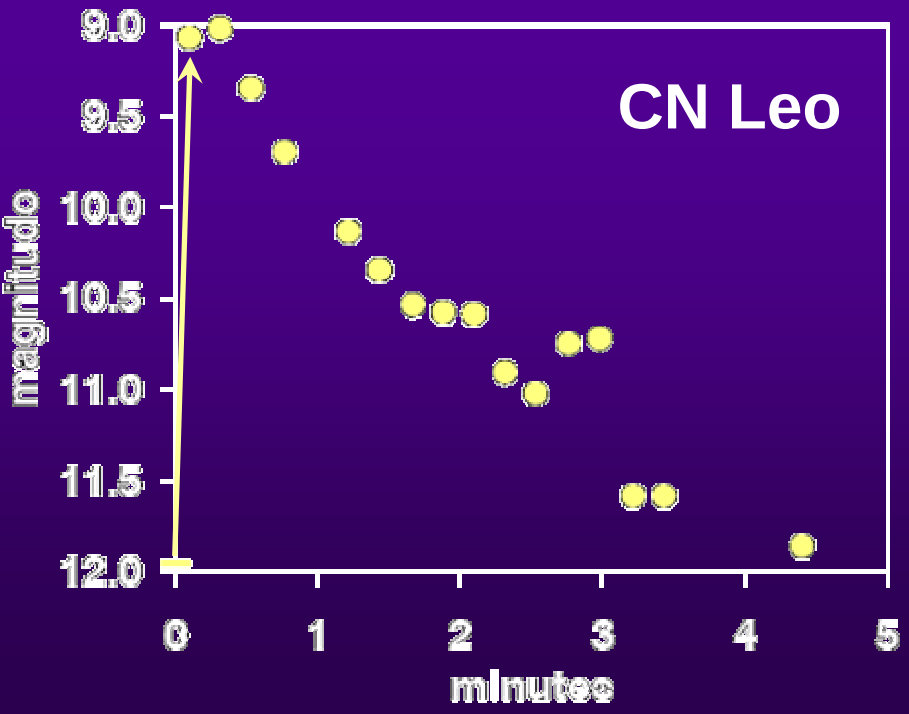
GRB 040825A (GCN 2677) **$>10.0^m$ / $>12.0^m$ / $>9.5^m$**

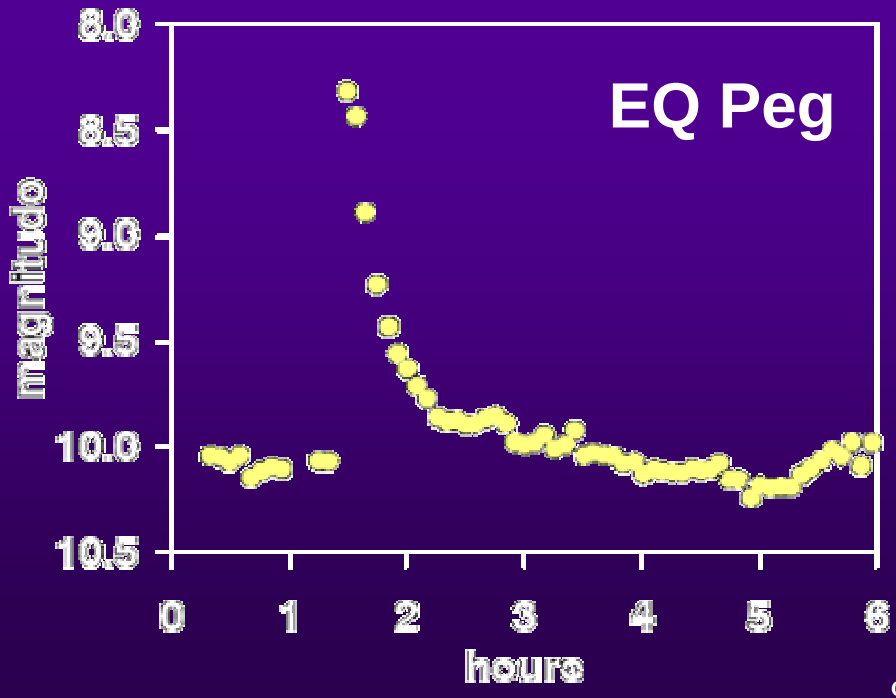
GRB 050412 (GCN 3240) **$>11.5^m$ / $>11.0^m$ / $>11.5^m$**

Search for cosmic flashes

„π of the Sky" prototype at LCO, July 2004 – July 2005

- **~100 flashes seen by both cameras, in one frame only**
  (could be satellites reflecting sunlight)
- **6 flashes seen in >1 frame** (not confirmed/excluded by others)
- **1 flash identified as CN Leo flare star outburst**
- **Several slower star-flares detected off-line**

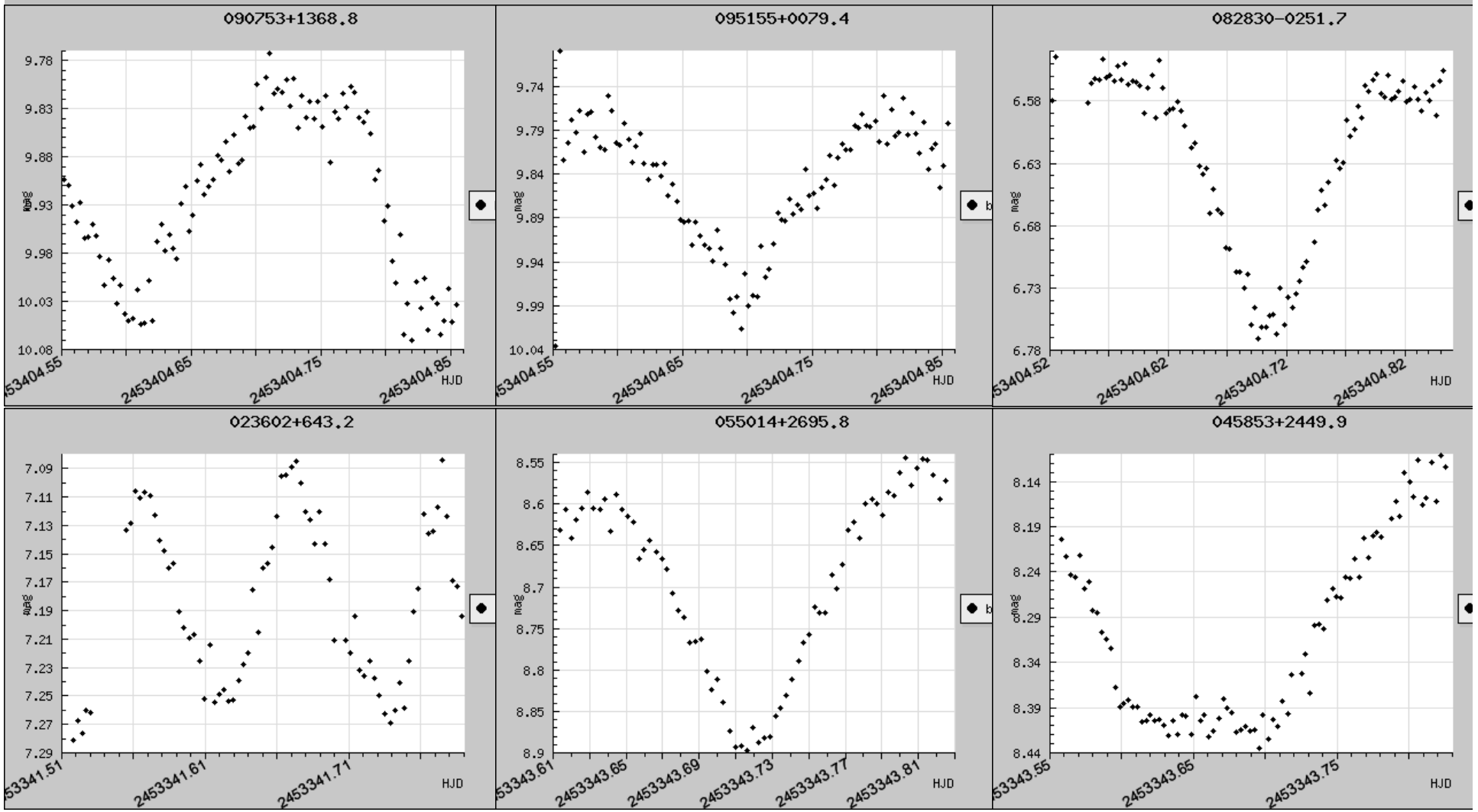




„π of the Sky” general goal:

study objects varying on scales from seconds to months

Examples of variable stars – light curves (one night)



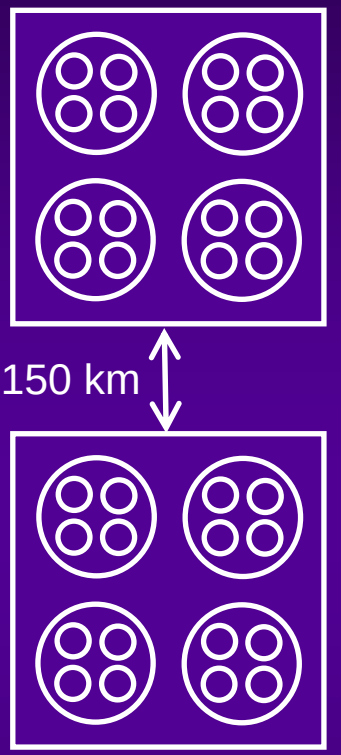
„π of the Sky" – final system design

CCD camera 2000×2000 pixels of 15μm

- custom made, with CCD STA 0820

Canon lenses *f* =85mm *f* /1.2

- 10s exposures
- $m_{max\ (1\ frame)} = 12^m$
  $m_{max\ (20\ frames)} = 14^m$



16 cams cover 2 sterad. = GLAST LAT > Swift BAT

- each camera FoV = 20° × 20°

2 axes robotic mount, 4 cams/mount

- two modes: *side-by-side* or *common-target*

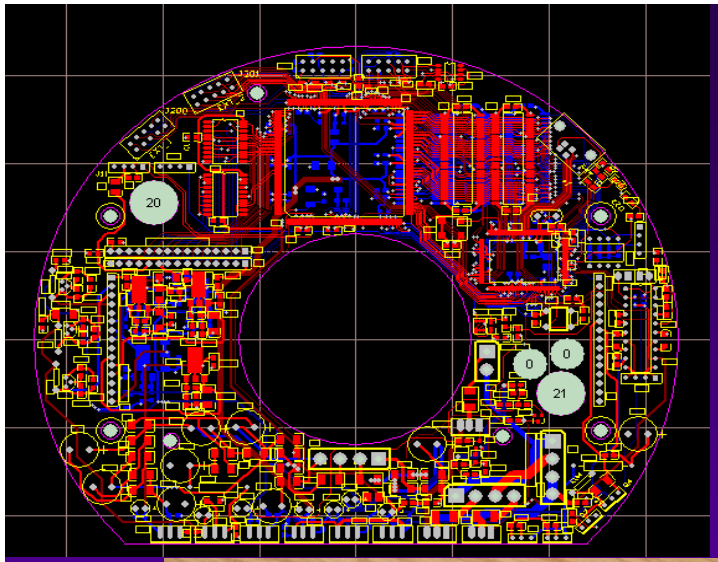
2 systems ~150km apart (e.g. La Palma + Tenerife)

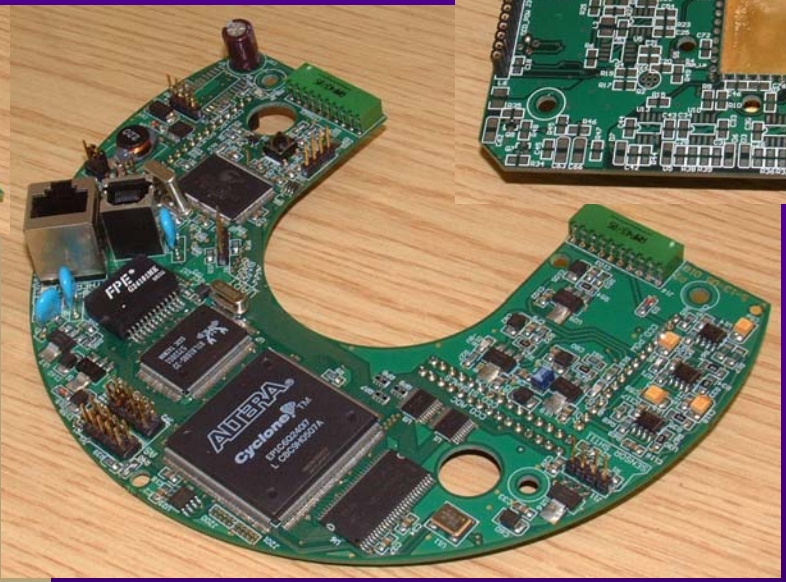
- 1 pixel parallax ⇒ 700 000 km distance to object


„π of the Sky”

„π of the Sky" cameras

- 2000×2000 pixels of 15μ×15μ
- quantum efficiency ~30%
- readout noise ~15 e^-
- ADC 16 bit × 2 MHz ⇒ 1 s / frame
- ethernet + USB



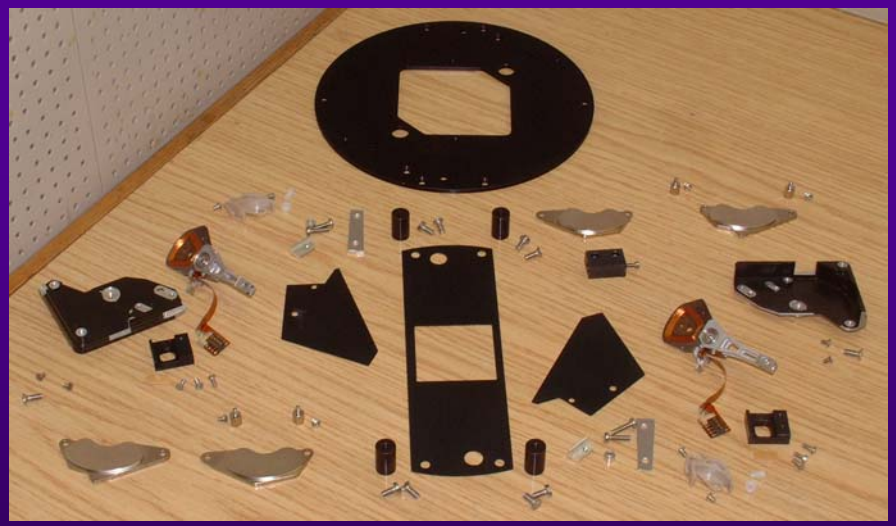


- programmable electronics (FPGA)
- on board processor + RAM
- 2 stage thermoelectric cooling
- shutter designed for 10^7 openings

„π of the Sky" construction

camera parts

assembly line

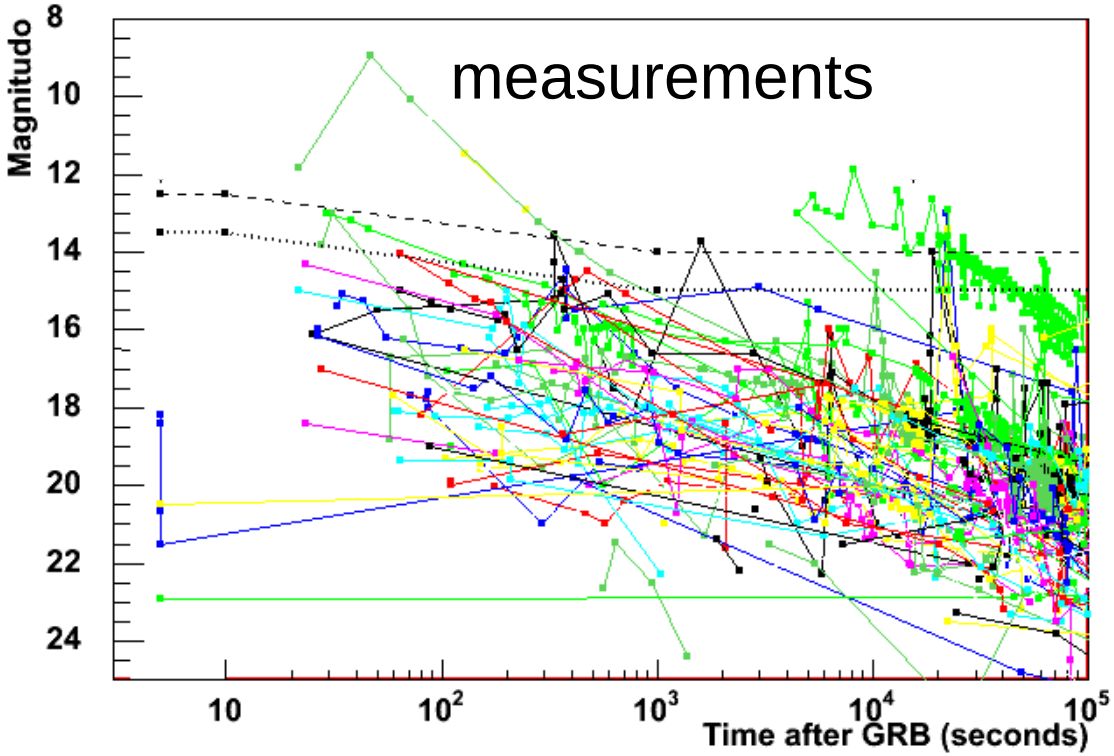


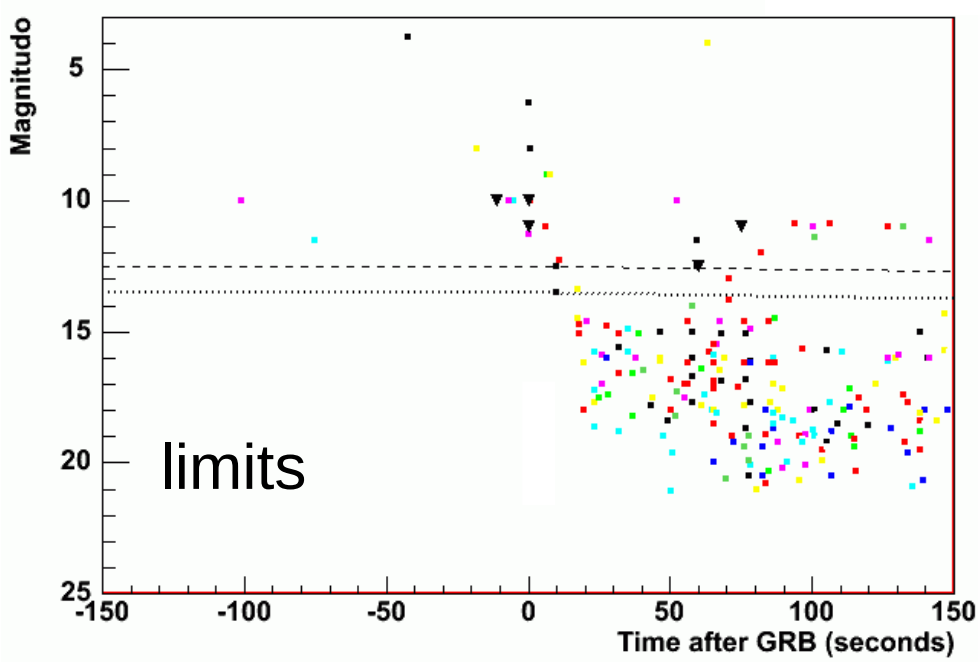
shutter parts

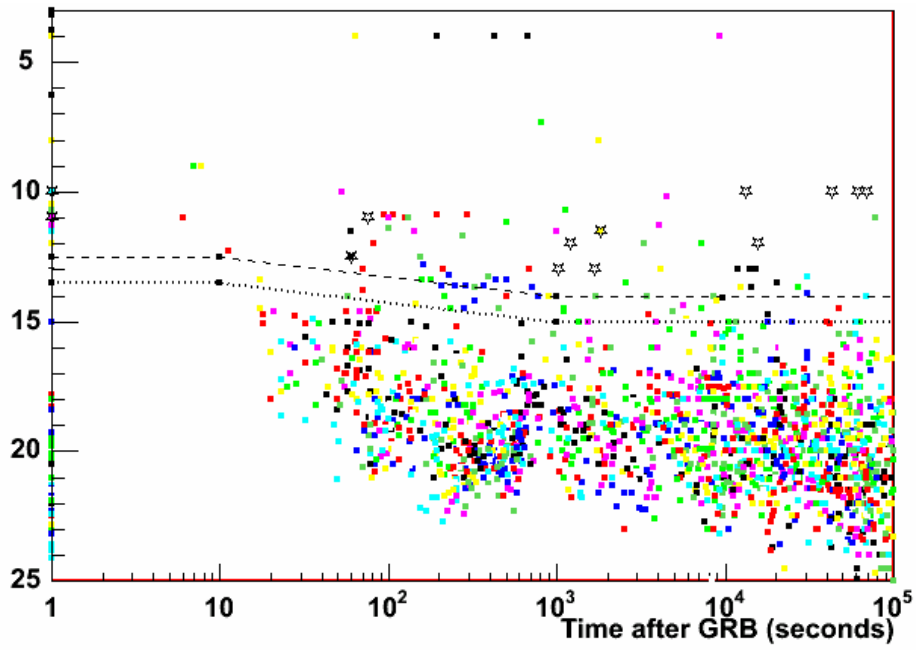
GRB optical observations

Very few points <20s after GRB t_0

dashed line – „π of the Sky” range
dotted line – filter corrected

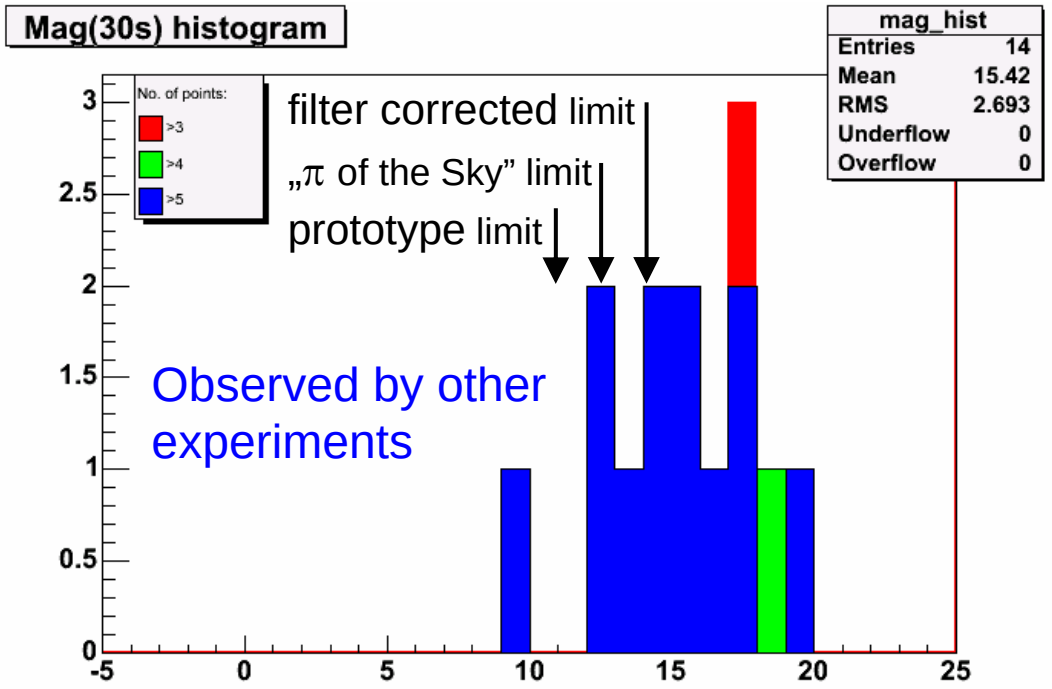


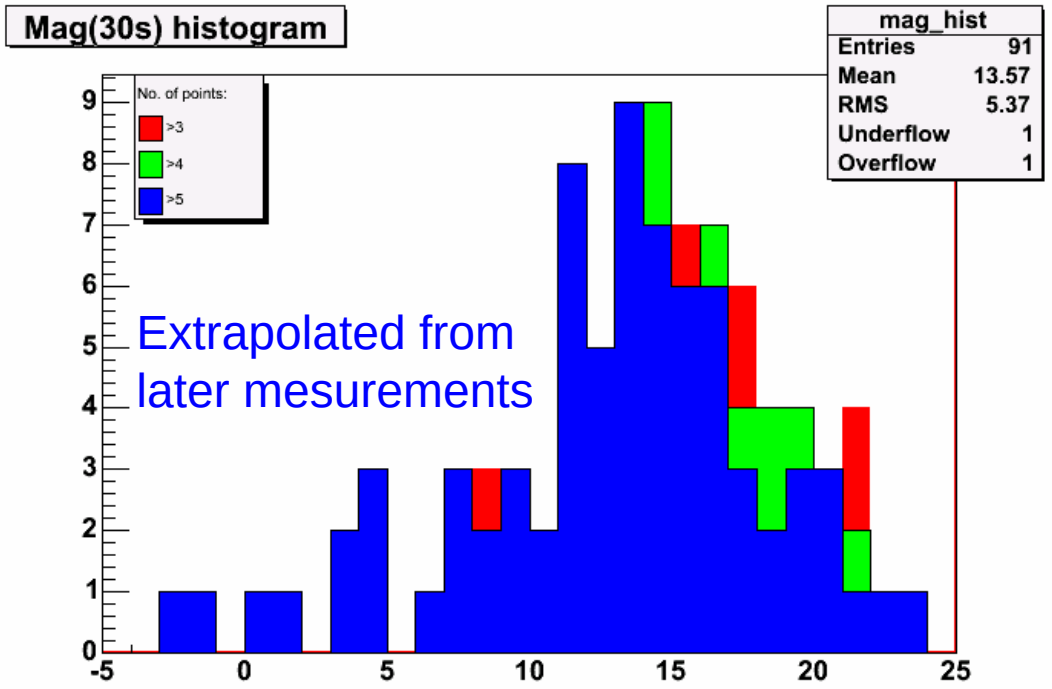




Prompt optical GRB observations

- „π of the Sky” is optimized for $t < t_0 + 60$ s
- Only 14 measurements by other experiments exist in this range
- Extrapolation to 30s from later time suggest, that „π of the Sky” will see ~1/4 of visible GRB



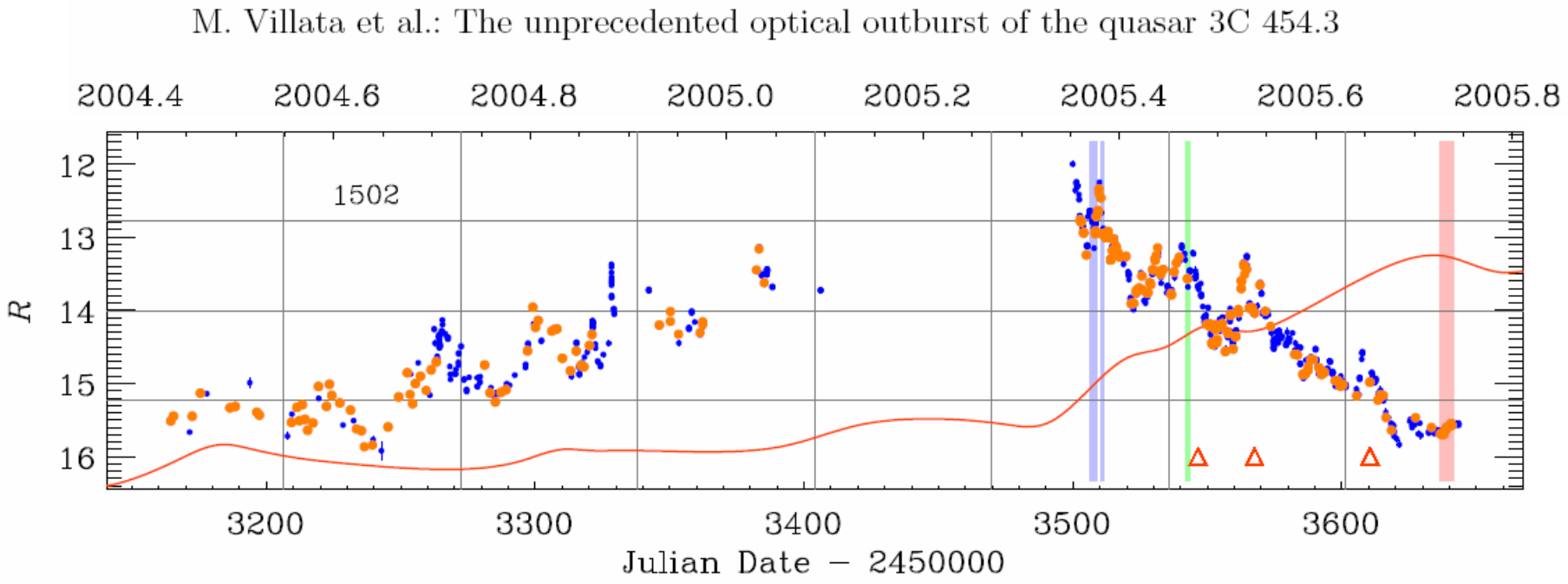


„π of the Sky” – new possibilities

- Participate in multiwavelength campaigns (missions SUZAKU, ECLAIR, AGILE, GLAST)
- Search for coincidence with cosmic rays (project MAZE)
- Join Global Telescope Network (GTN) and Whole Earth Blasar Telescope (WEBT)

Example: 3C454.3 outburst peak of R=12^m missed!

Later seen also by „π of the Sky” – record z = 2.9



Long term perspectives

Polish institutes participating in „π of the Sky" project have the expertise in:

- **high precision mechanics**
- **low noise analog electronics**
- **modern digital electronics**
- **particle detectors, PMT, APD, scintillating cristals**

Possible participation in future projects:

- **TelesFor - Robotic Telescope Forest (~200 cameras)**
- **POGO - baloon soft γ-ray polarimeter**
- **POLAR - satellite hard X-ray polarimeter**
- **…**