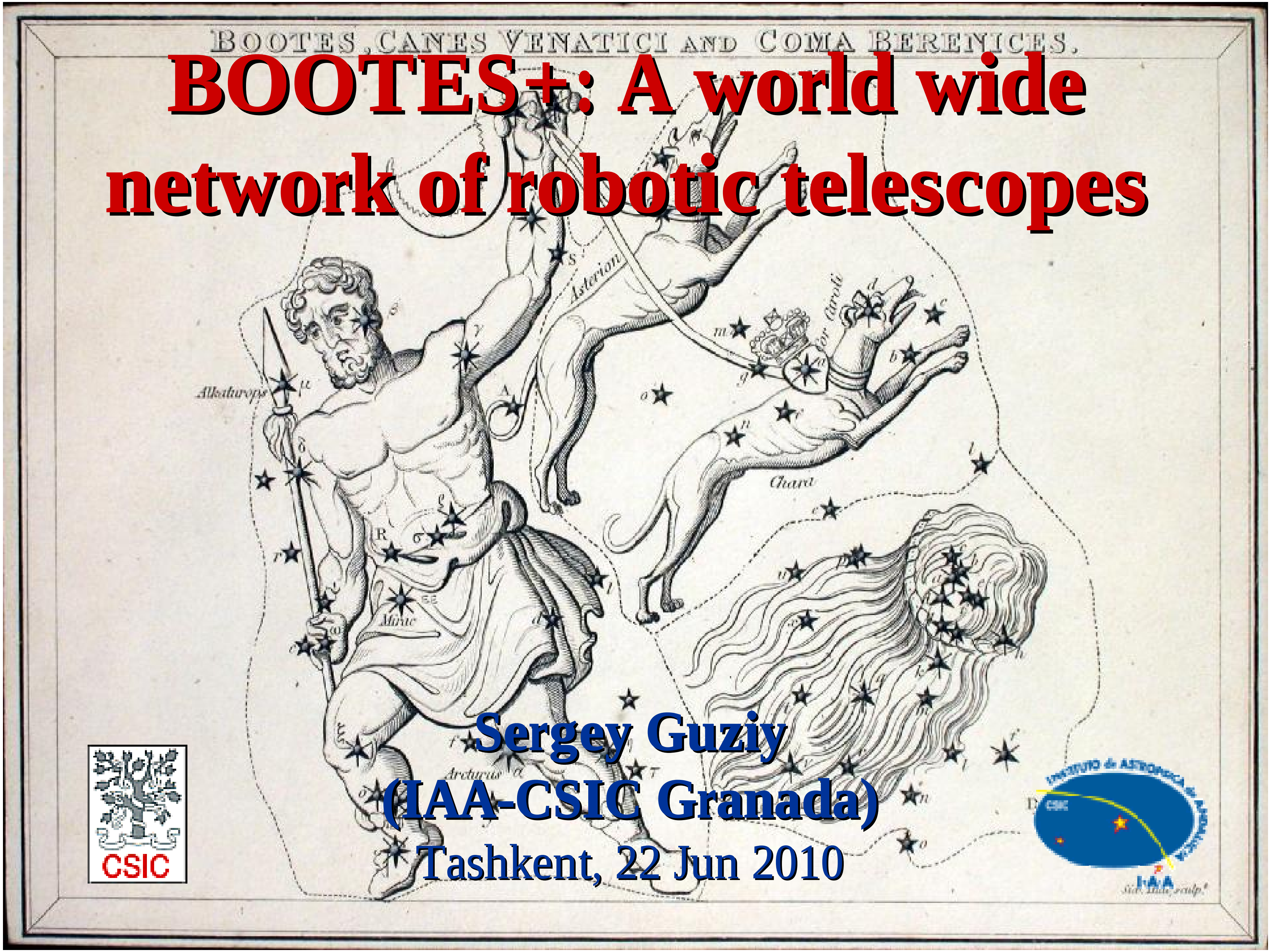


BOOTES+: A world wide network of robotic telescopes

Sergey Guziy
(IAA-CSIC Granada)

Tashkent, 22 Jun 2010

Outline

I. Robotic astronomical observatories

Some definitions
Robotic observatories worldwide
Operating Robotic Observatories
An example of robotic observatories: the BOOTES+ Network

II. Scientific applications

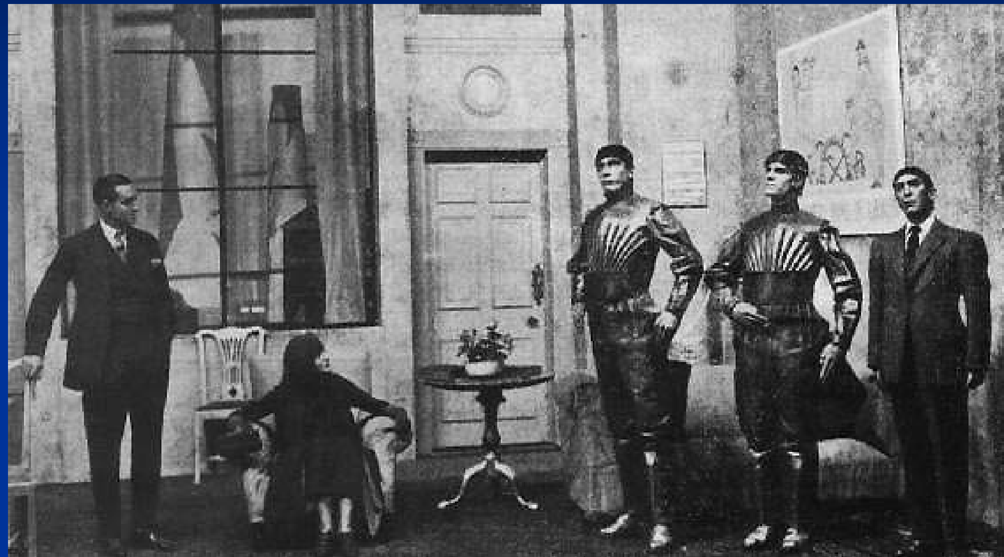
Cosmic explosions
Microlensing research

Conclusions

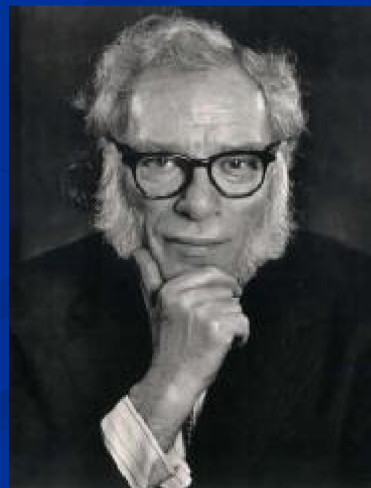
Part I: Robotic Astronomical Observatories

Who coined the word "robot" ?

The word robot was coined in 1921 by the Czech writer Karel Ĉapel (1890-1938) in his play "Rosum's Universal Robots" (R.U.R.) in which three robots were despited. The new word was suggested by his brother Josef Ĉapel (cubist painter).



Isaac Asimov (1920-1992) coined in 1941 the word Robotics in his play "Liar!": as the branch of the science and technology related to "robots": design, manu-facturing and applications.



Robotic Astronomical Observatories (2)

Following the consensus reached on the Málaga 2009 conference

Automated Scheduled Telescope *[Robot]*

A telescope that performs pre-programmed observations without immediate help of a remote observer (i.e. Avoiding an astronomer moving of the mount by hand).

Remotely Operated (remote) Telescope *[Teleoperated Robot]*

A telescope system that performs remote observations following the request of an observer.

Robotic Autonomous Observatories *[Autonomous Robot]*

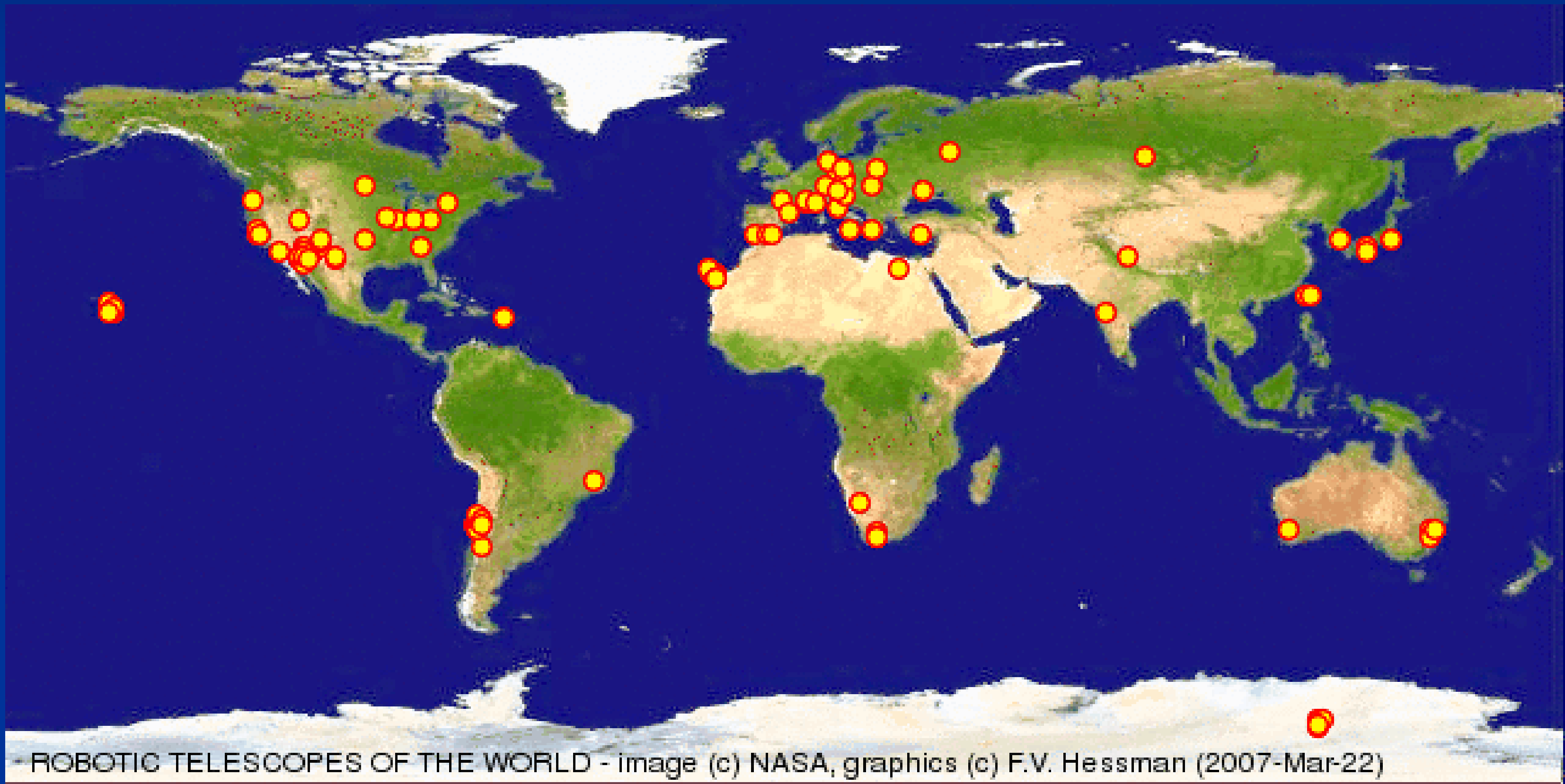
A complete observatory in which the telescope performs various remote observations and is able to adapt itself to changes during the task execution without any kind of human assistance (i.e. Weather monitoring; the system must not endager a human!).

Robotic Intelligent Observatories *[Intelligent Robot]*

A robotic observatory in which decisions will be taken by an artificial intelligent system. The next step forward !

RAOs worldwide (1)

More than 100 instruments so far



RAOs worldwide (2)

Around 40 in Europe and half (!) in SPAIN

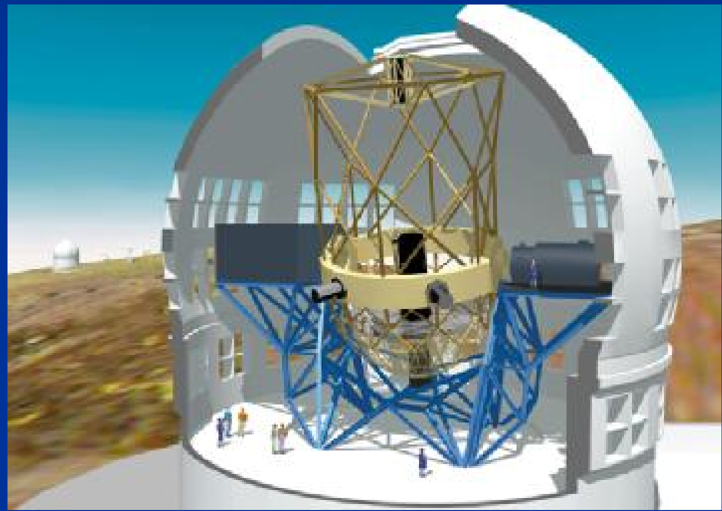
RAOs worldwide (3)

Range of apertures (included expected instruments by 2010)

aperture ≤ 0.25m	77	45.3%
0.25 < aperture ≤ 0.50m	37	21.8%
0.50 < aperture ≤ 0.75m	14	8.2%
0.75 < aperture ≤ 1.00m	17	10.0%
1.00 < aperture ≤ 1.25m	7	4.1%
aperture > 1.25m	18	10.6%

Operating RAOs (1)

Telescope Control Operating Systems



Commercial automatization systems:
TCS by Optical Mechanics (OMI) ∅ = 0.4 – 1 m.
(Open or Closed source)

Specific control systems:
GTC ∅ =10 m.

Operating RAOs (2)

Observatory Managers

AUDELA: Developed by A. Klotz et al. (Toulouse), starting in 1995. Open source code. Linux/Windows.

ASCOM: Dessigned in 1998, by B. Denny (USA), as an interface standard for astronomical equipment, based on MS's Component Object Model, which he called the Astronomy Common Object Model. Mostly used by amateur astronomers, has been also used by professionals. Windows. Widely used in SN, MP searches.

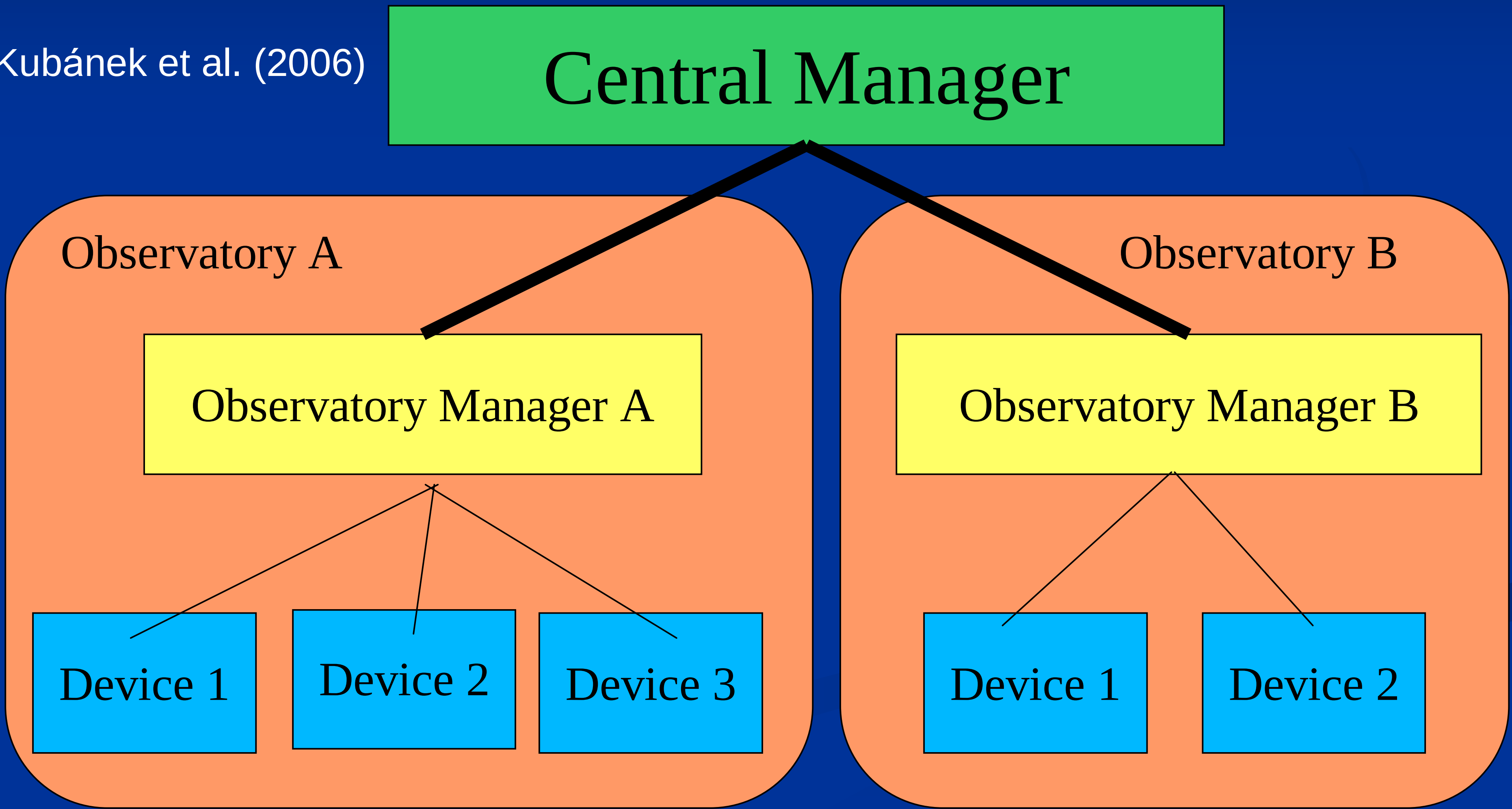
RTS2: The Robotic Telescope System version 2, is being developed by P. Kubánek, (Ondrejov/Granada) starting in 2000. Open source code. Linux/Windows (command line and graphical interface foreseen). Widely used in GRB searches.

INDI: The Instrument Neutral Distributed Interface (INDI) was started in 2003. In comparison to the Microsoft Windows centric ASCOM standard, INDI is a platform independent protocol developed by E. C. Downey (USA). Open source code. Not so widely spread as the upper layer interface was not done.

Operating RAOs (3)

RTS2: www.rts2.org

Kubánek et al. (2006)



Operating RAOs (4)

RTS2 (3): Additional image processing software

1. Astrometry pipeline (to check telescope pointing and improve the accuracy)

2. Pipeline for automatic data analysis:

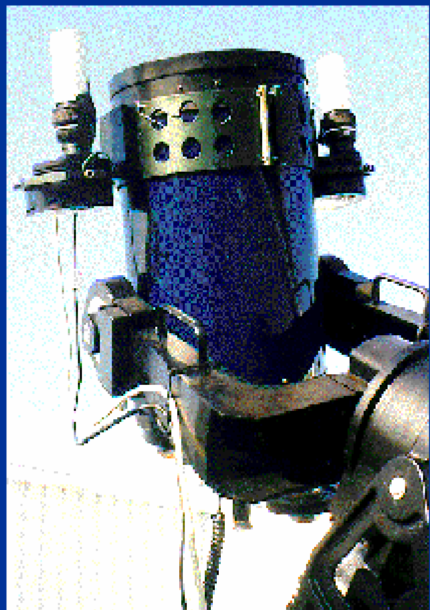
   Astrometry and photometry (Jelínek and de Ugarte Postigo 2006)

   transient object detection, in JIBARO (de Ugarte Postigo (2005))

The BOOTES Network (1)

BOOTES (Burst Observer and Optical Transient Exploring System)

BOOTES-1 (INTA/CSIC/AUS/CVUT) in El Arenosillo (Huelva). *Robotic* 0,3m Ø telescope and wide-field cameras, since june 1998, thanks to the fruitful Spanish-Czech collaboration.



1998

The BOOTES Network (2)

BOOTES (Burst Observer and Optical Transient Exploring System)

The variety of setups at the BOOTES-1 astronomical station over the years, including the new site at the ESAt building.

2000

2005

2006

2009

The BOOTES Network (3)

BOOTES-2: a 0.3m ∅ telescope installed in 2001 and replaced in 2008 by the **0.6-m** ∅ TELMA fast slewing telescope (|v| = 100 deg/s, |a| = 20 deg/s^2) and larger opening roof. Participated by U. de Málaga.

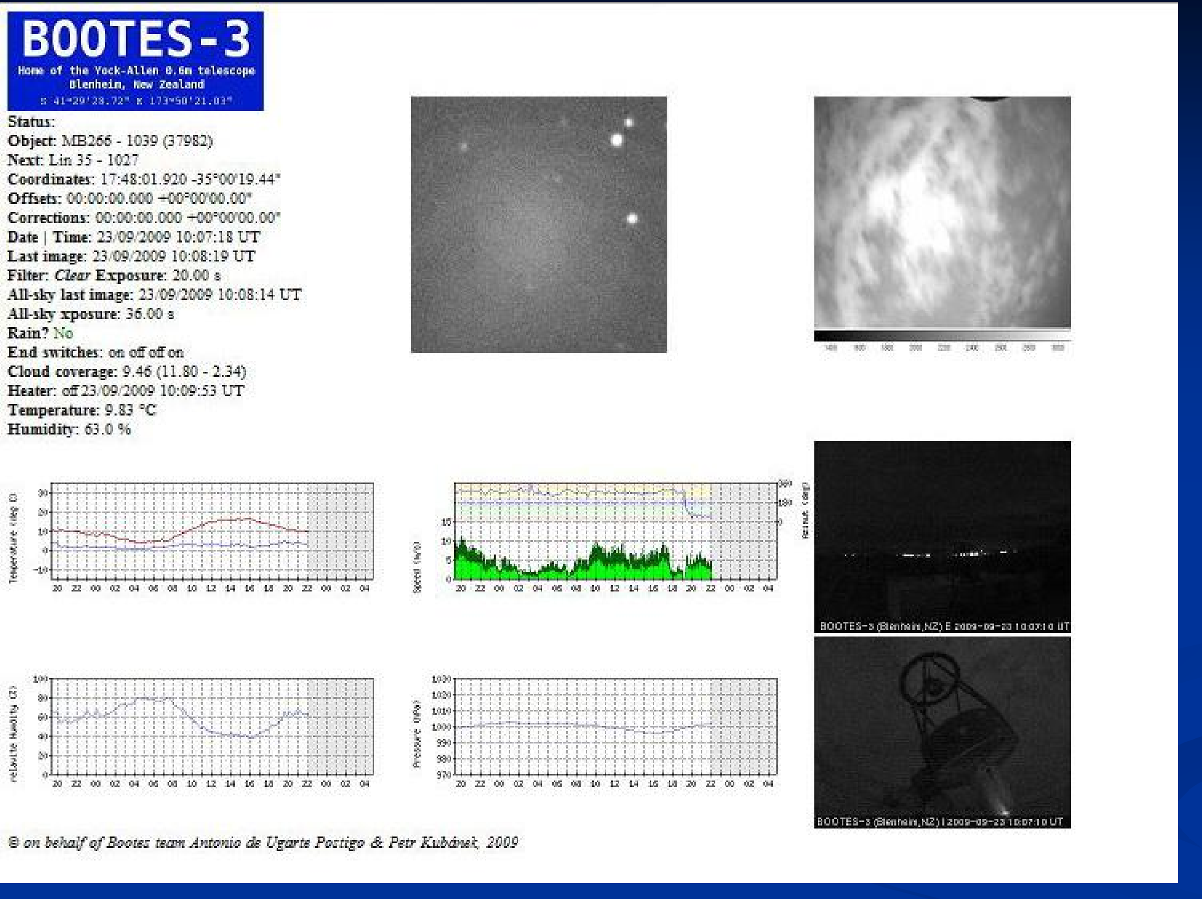
Jun 2008 : imaging (unfiltered)
Jun 2010: imaging (g'r'i'ZY filter set) down to r' = 20
Nov 2009: agreement with Univ. of Málaga for collaboration
Spring 2011 : spectroscopy (400-1100 nm) with COLORES, down to r' = 16

The BOOTES Network (4)

BOOTES-IR/T60 OSN (CSIC), *robotic* 0.6m ∅ altazimuthal telescope, Sierra Nevada, working in the optical since 2004 and in the near-IR (0.8-2.5 μm) since 2009/2010.

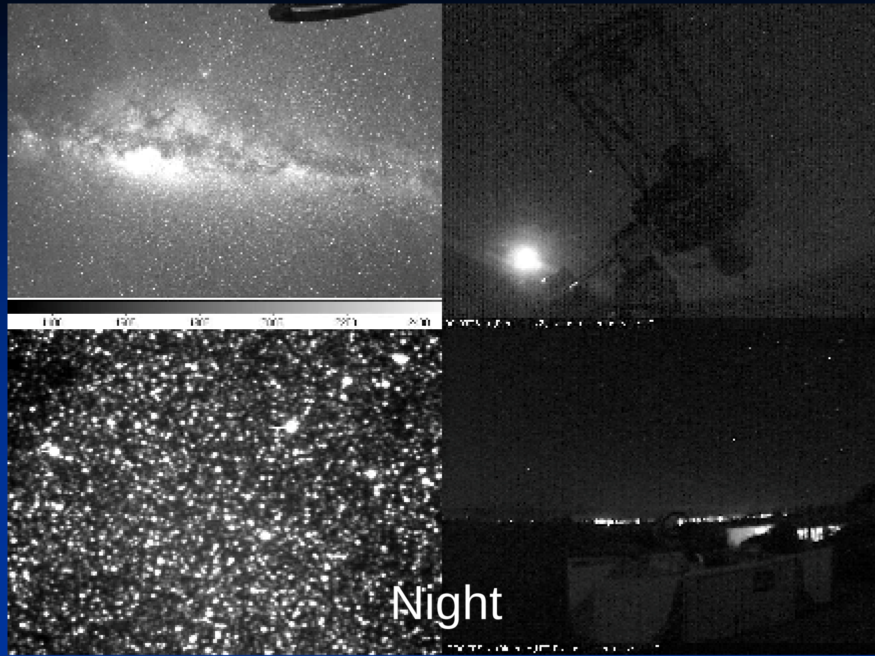
The BOOTES Network (5)

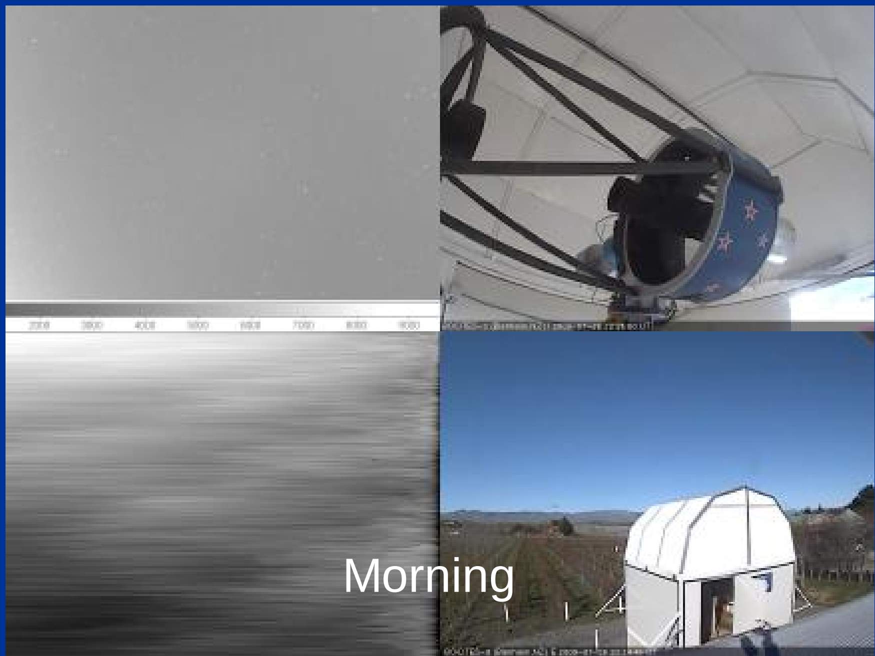
BOOTES-3 (CSIC-UoA), *robotic* 0.6m ∅ telescope and wide-field camera in Blenheim (New Zealand), in 2009.



BOOTES-3 webpage image

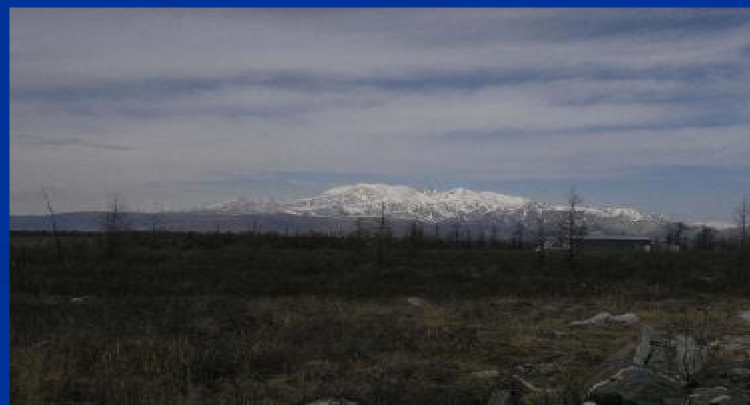

Evening


Night


Morning

The BOOTES Network (6)

BOOTES-4 (CSIC-IKI), *robotic* 0.6m ∅ telescope in Mondy Observatory (Siberia), foreseen for summer 2010 (optical)



The BOOTES Network (7)

BOOTES-5 (CSIC-UNAM): a *robotic* 0.6m ∅ telescope in San Pedro Mártir for 2012 (funding already applied for)

The BOOTES Network (8)

BOOTES Network philosophy

Identical (very fast, 0.6m diameter, 10' FOV) telescopes spaced around the Earth (4x as of 2010, goal are 7x)

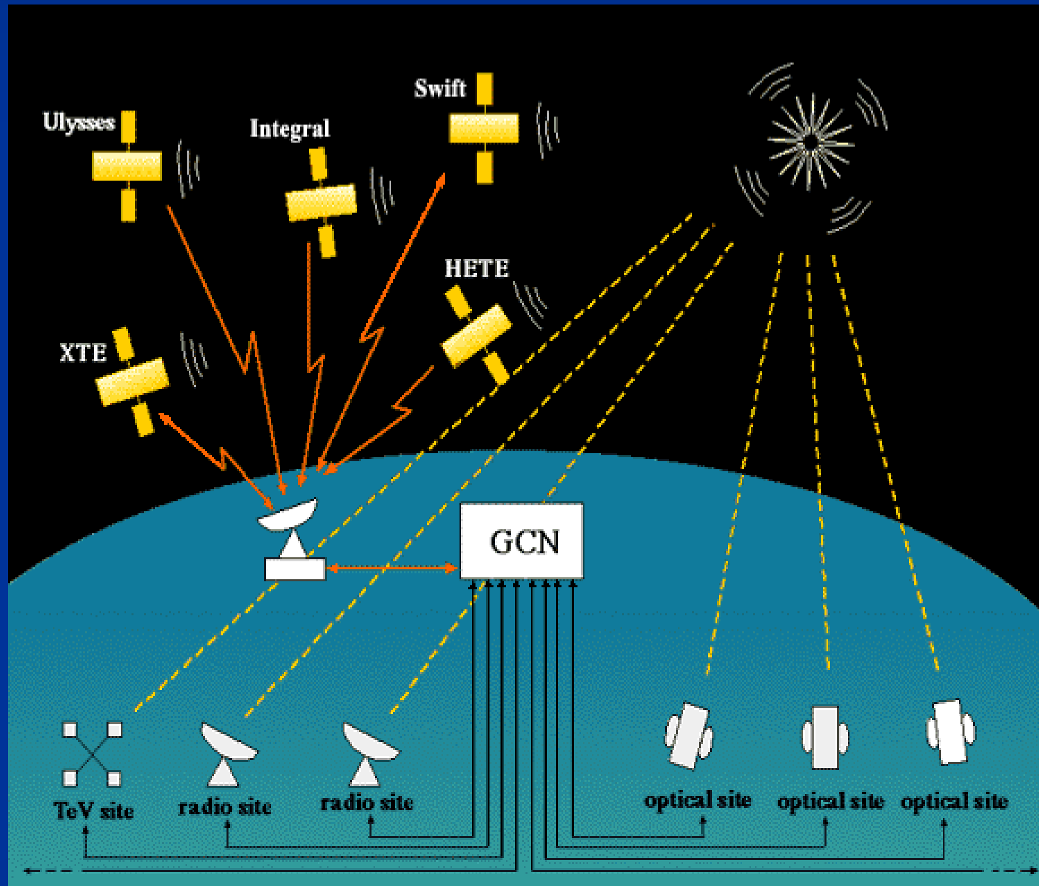
Identical sets of non-overlapping filters for the optical instrument: g'r'i'ZY covering the range 0.4-1.0 μm

Identical fast-readout (10 MHz @ 14-bit) three-stage Peltier (-90 C) EMCCD cameras

Well suited for observing the *SVOM*/ECLAIRS GRBs.

Part II: BOOTES scientific capabilities

Alerts from the Universe !



Scientic applications

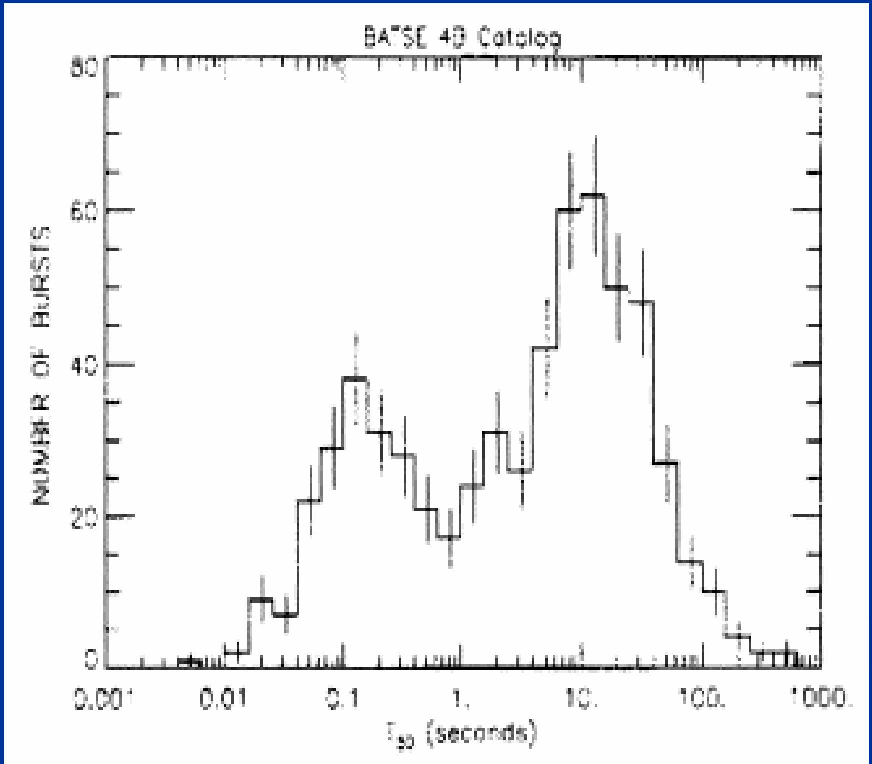
Scientific Use of RAOs (aprox. statistical based on provided info)

Description	Number of Ref.'s	Percentage
Gamma-Ray Bursts	29	22.3%
Service observations	21	16.2%
Photometric monitoring	14	10.8%
Education	15	11.5%
All-sky surveys	12	9.2%
Exoplanet searches	10	7.7%
Supernovae search	9	6.9%
Asteroids	7	5.4%
Spectroscopy	4	3.1%
Astrometry	4	3.1%
AGN, Quasars	3	2.3%
(Micro-)Lensing	1	0.8%
Other uses	8	6.2%

Cosmic Explosions (1)

Cosmic Explosions: GRBs, SNe, etc.

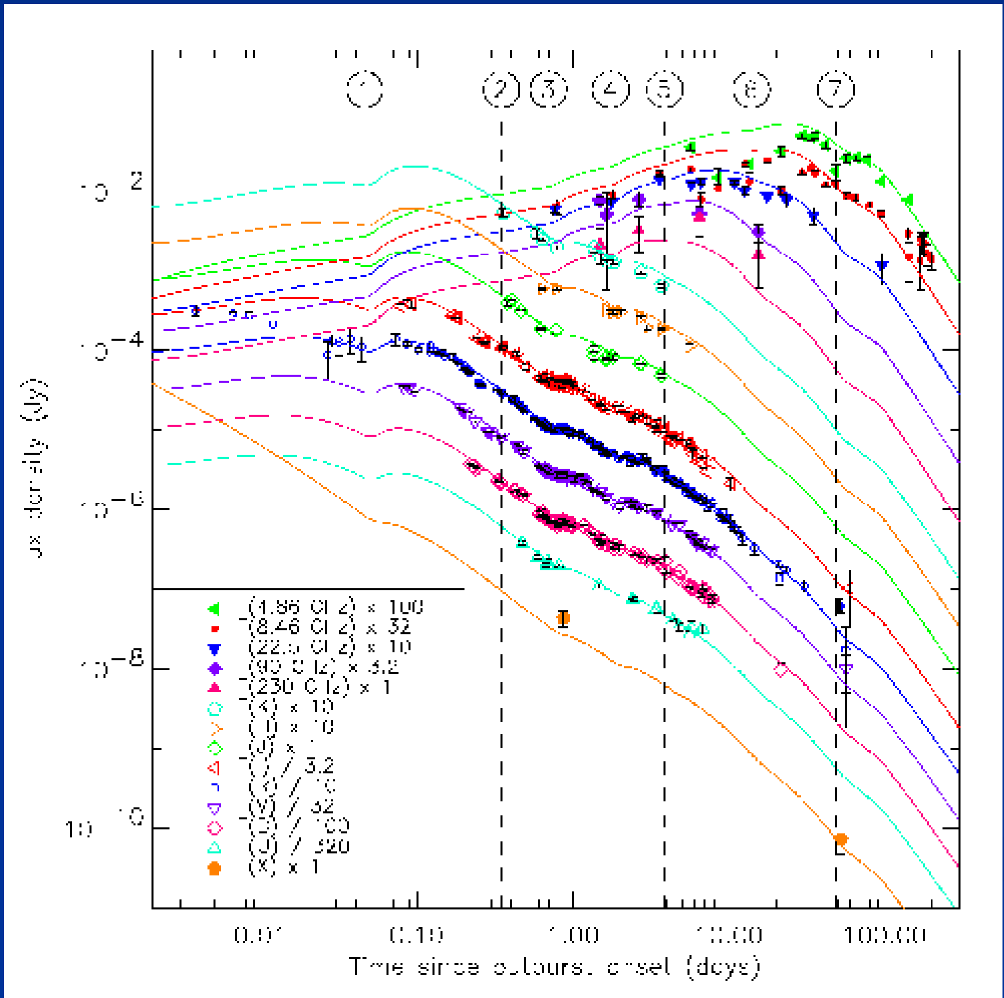
Gamma-Ray Bursts (GRBs) were discovered in 1967 by the four *VELA* spacecraft

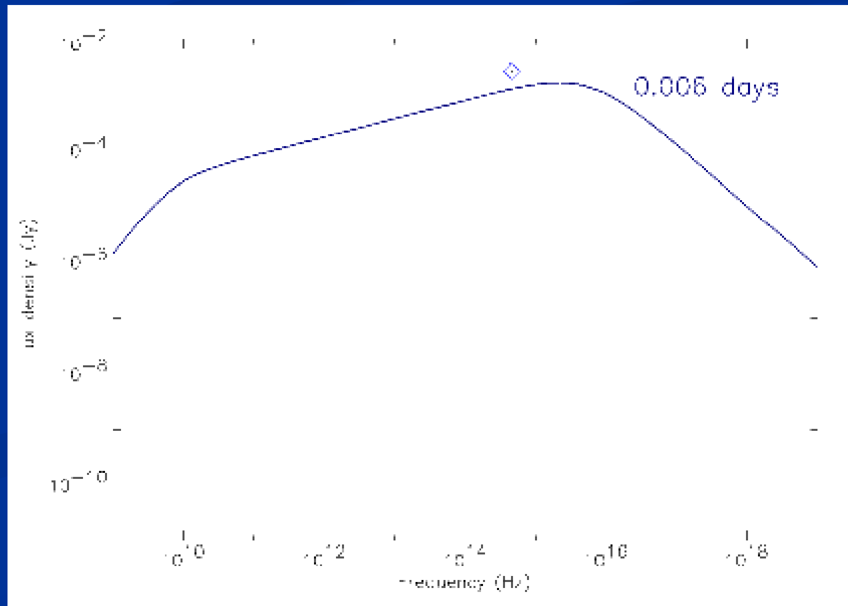


- **Short** but very **intense** high-energy events.
- **Isotropic** distribution (BATSE+KONUS) è Cosmological origin
- May be clasified into TWO groups
  - ~ 0.2s (25%)
  - ~ 30s (75%)
- The counterparts for **all bursts** can be observed in all wavelengths (X, UV, opt, IR, radio): the ***afterglow***

Gamma-ray bursts (2)

Multi-λ modelling (eg. de Ugarte Postigo et al. 2006)





Cosmic Explosions (3)

(100 GRBs followed up by BOOTES in Dec 2004-Dec 2008)

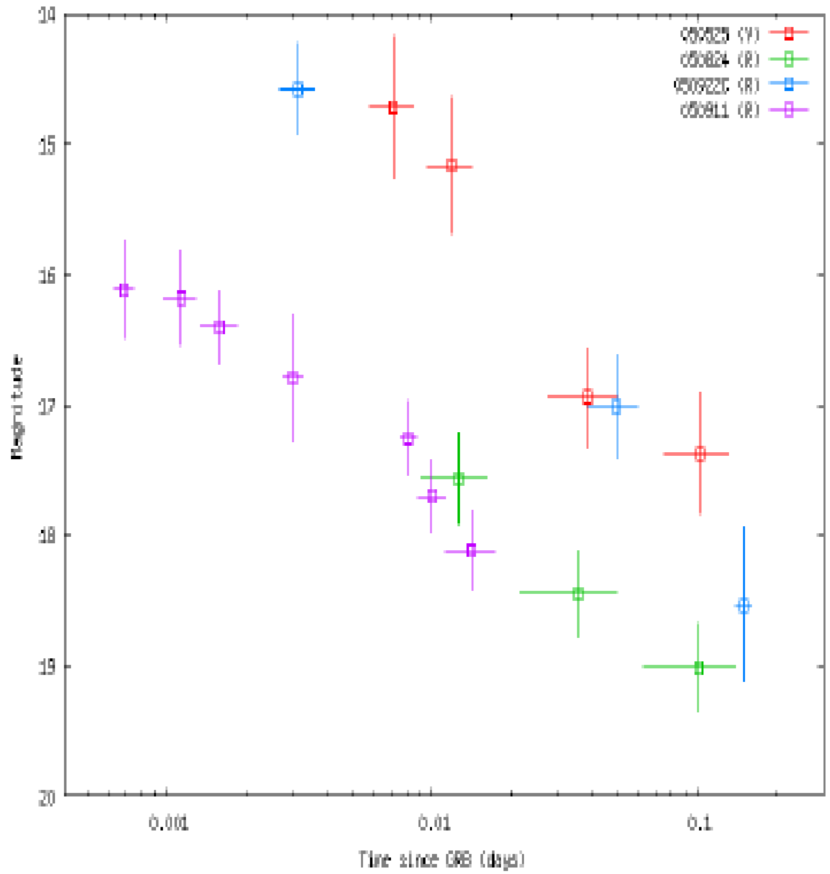
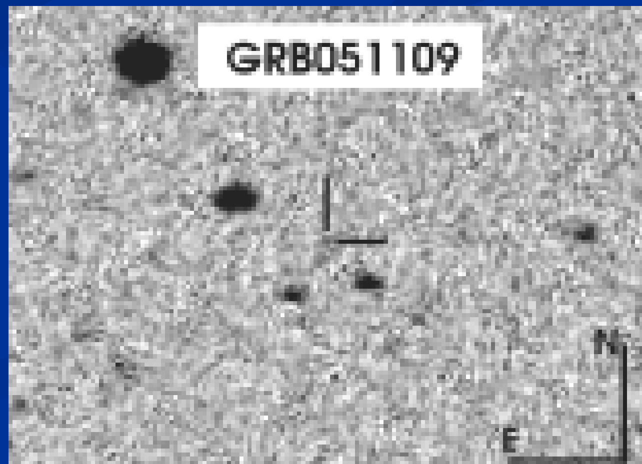


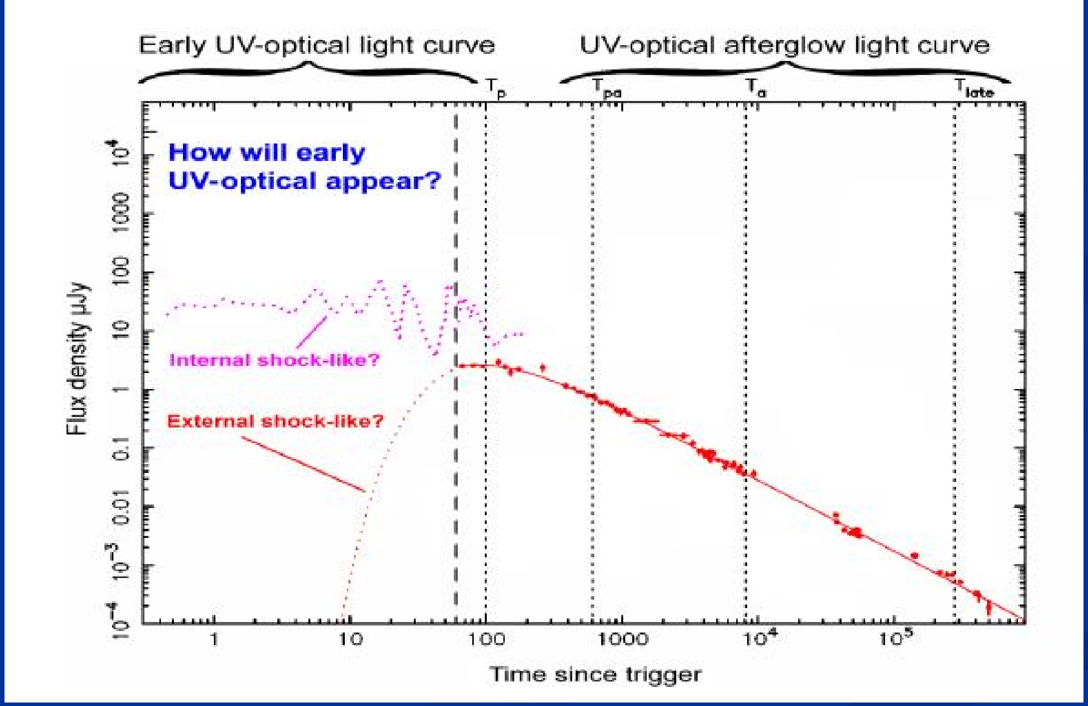
Figure 7: GRBs observed by BOOTES-1B.



Jelínek et al. 2009, PhD Thesis

Gamma-ray bursts (4)

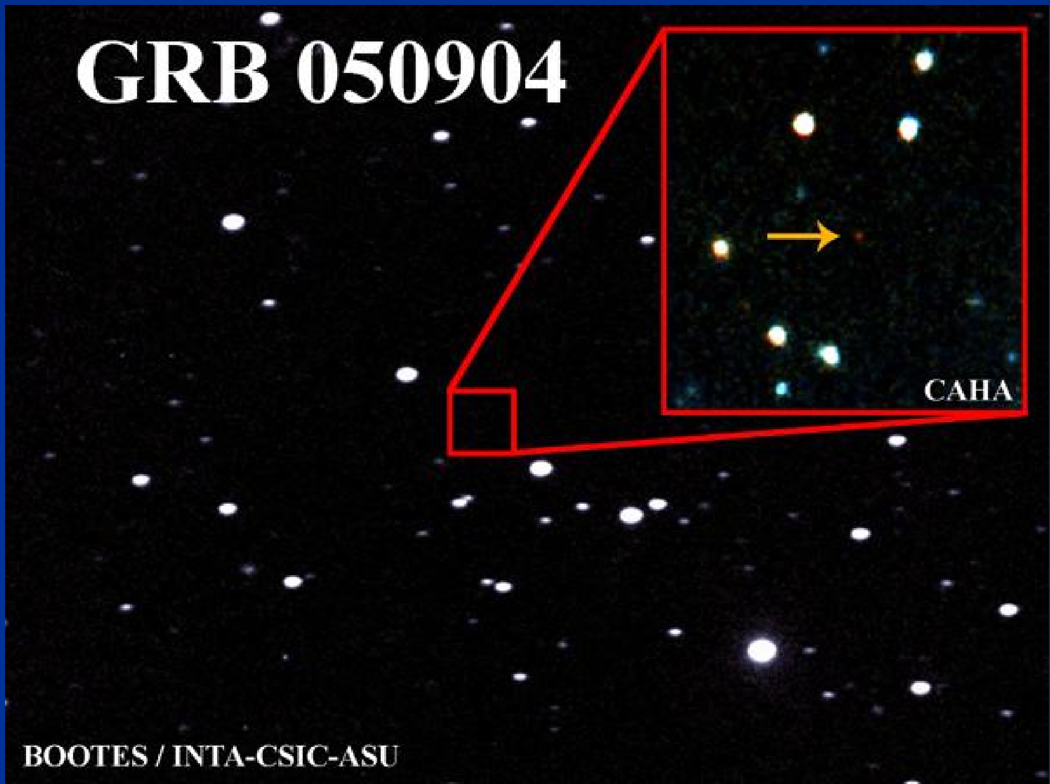
¿Why an ultrafast slewing telescope? An ultrafast, 0.6m diameter robotic telescope can shed light on the initial GRB afterglow / prompt emission phases

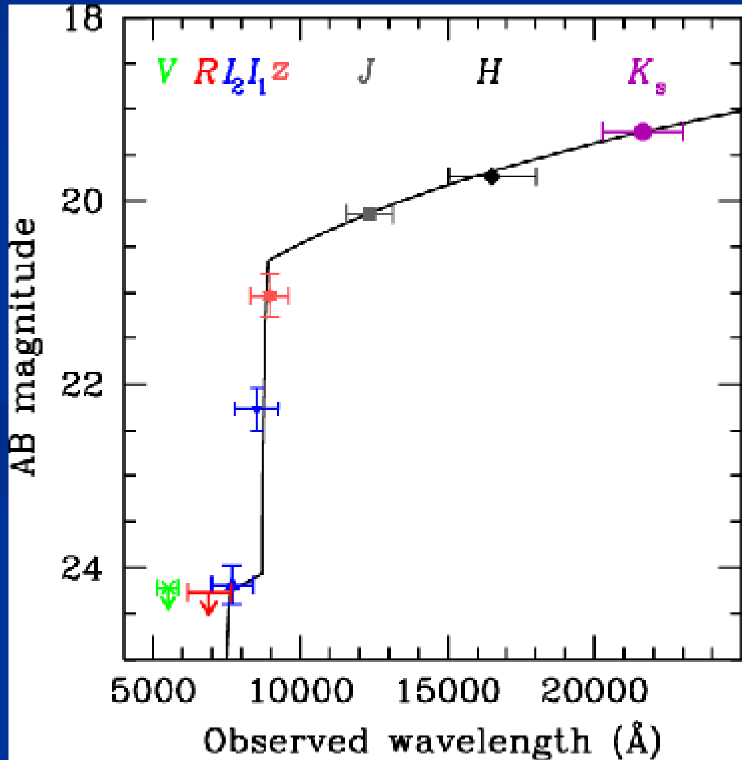


Page et al. (2009)

Cosmic explosions (5)

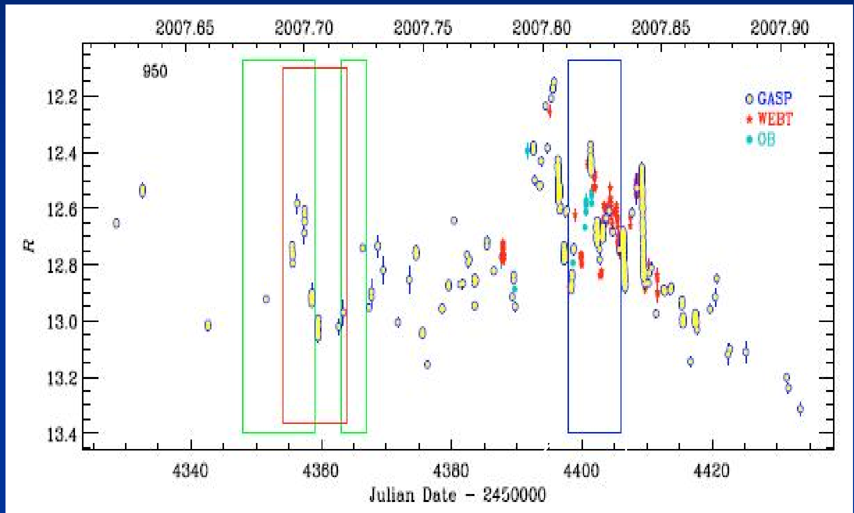
Ultra-high redshift do exist !





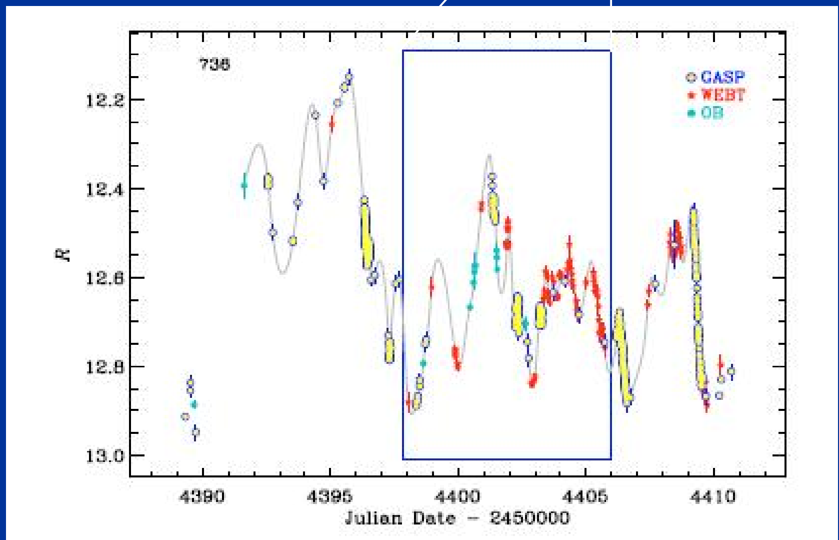
GRB 050904 at z = 6.3 (Haislip et al. 2006, Nature 440, 181, including BOOTES data). See also Cusumano et al. 2005, A&A 443, L1

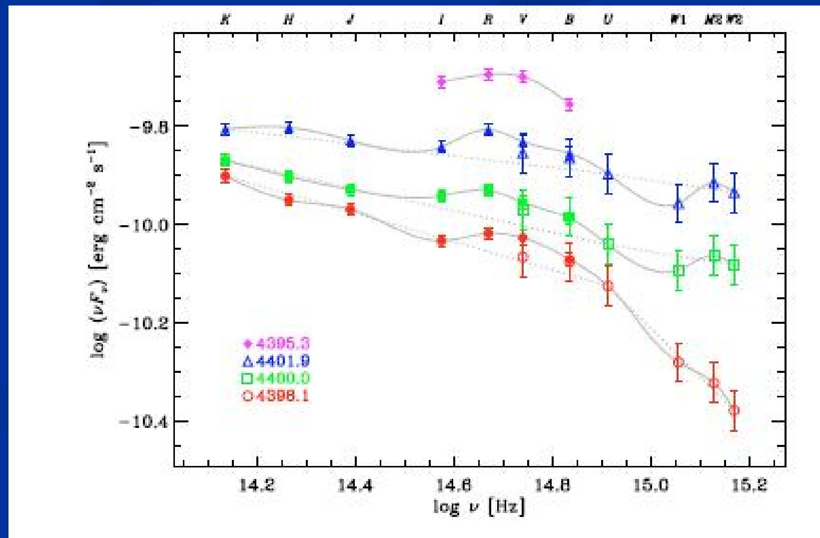
Monitorig of Galactic and Extragalactic sources



Variable stars (GK Persei: the most observed object in the North, Strobl, in prep.)

Blazars (S5 01716+714, Villata et al. 2007, A&A 481, L79)

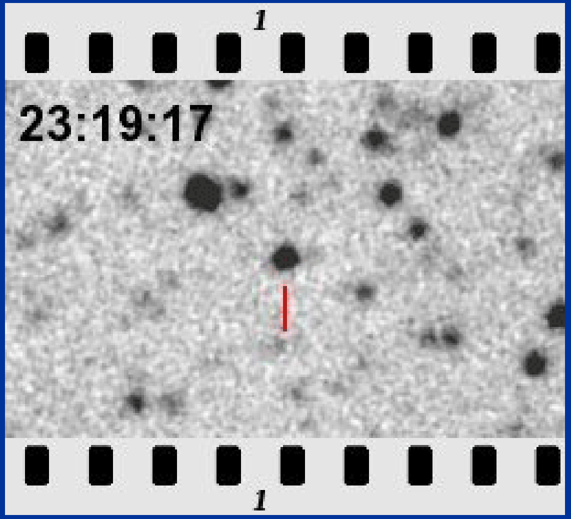




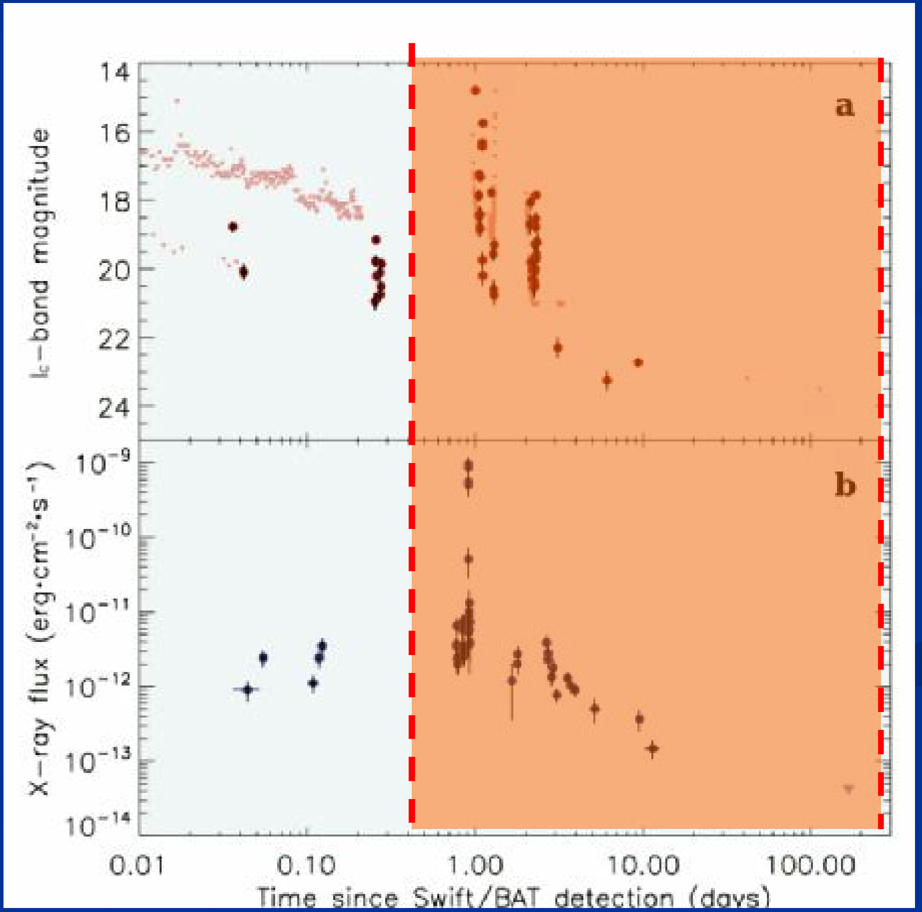
Bizarre Objects in the Galaxy

SWIFT J1955+2604: Early light curve / early flares

"Rapid flaring in a new Galactic source: a missing link between magnetars and dim isolated neutron stars?" ***(C-T et al. 2008, Nature, 405, pp. 506-509)***

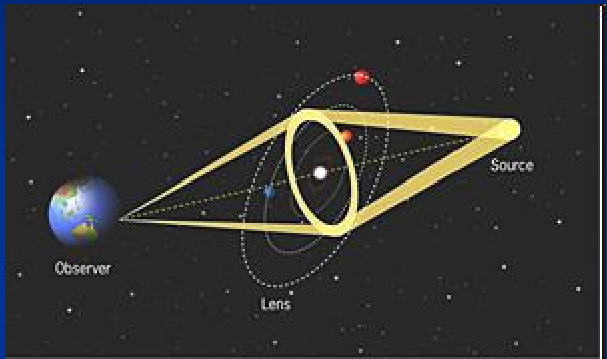


We recorded ~40 flare episodes, up to I~14.8, on timescales of ~20sec to 7 min and amplitudes up to 7 mag.

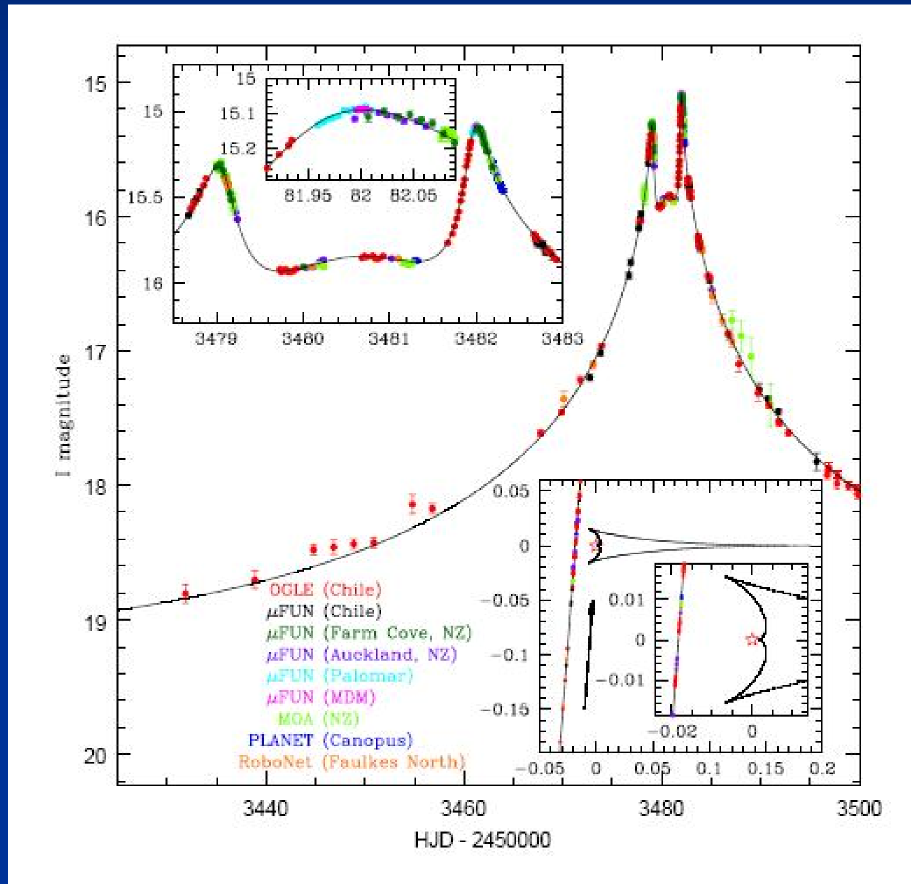


Microlensing Research

Global Network most essential



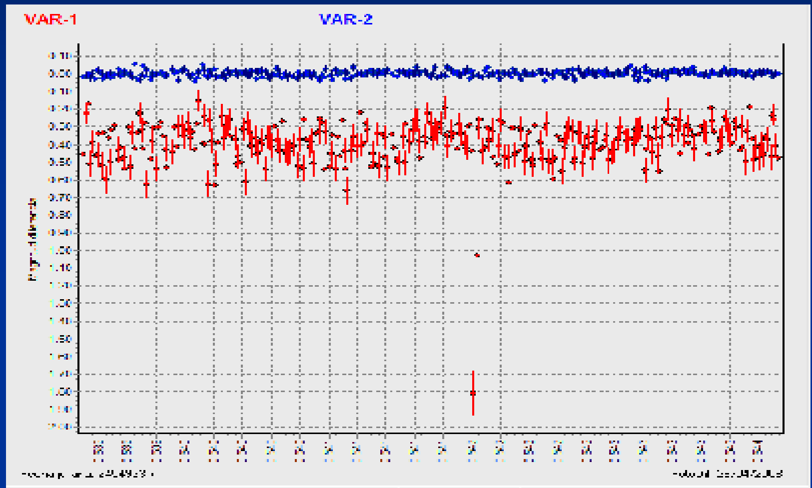
A 3x Earth mass planet (Bennet et al. 2008)

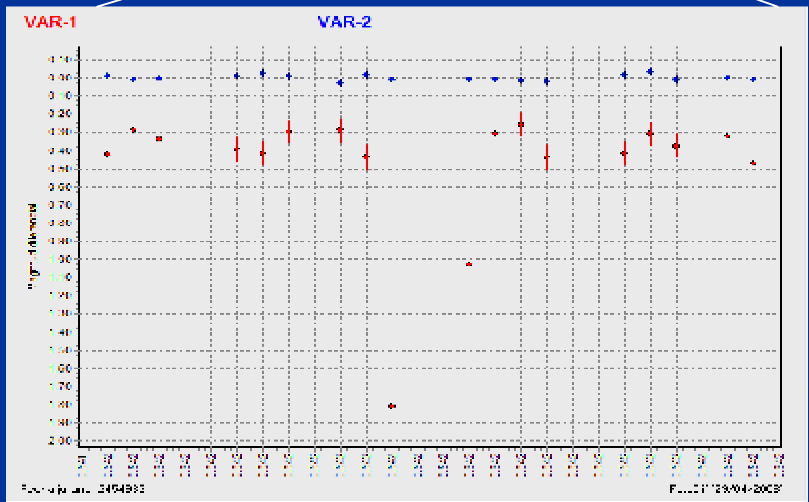


Jovian mass planet. < 1%
Precision photometry requested.
Udalski et al. (2008)

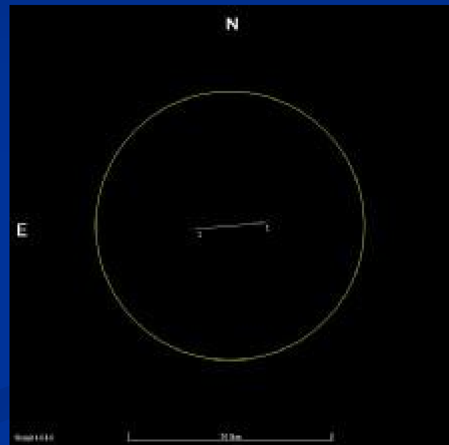
Stellar ocultations by asteroids

Different geographic locations most essential





207 Hedda



Casas et al. (2009)

Conclusions

- Robotic Telescopes (RTs) like TAROT and BOOTES are opening a new field in Astrophysics in terms of optimizing the observing time, providing pre-reduced data. The big advantange is that they can be placed in remote locations where human life conditions will be hostile (Antartica now, the Moon in the near future). Technological development is involved and some RAOs are moving towards *intelligent* RAOs.

- GRBs are the *most energetic* phenomenon in the Universe, with 10^{51} erg released in few s after the event. Rapid observations (within s) from RTs may detect the most distant objects in the Universe. μlensing events and search for extrasolar planets are also goals and a network of RAOs provide a **unique opportunity** to achieve them.

- The BOOTES Network that started in 1998 as a Spanish-CZ initiative is, finally, **expanding worldwide**. Potentially it can be considered as an important ground-based support for *SVOM*.

Workshop on Robotic Autonomous Observatories

Málaga, Spain, 18-20 May 2009
www.iaa.es/astrorob2009
e-mail: astrorob@iaa.es

Again in 2011 (30 May - 3 June).
Stay tuned !

SOC

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