TAROT Robotic Telescopes: Techniques and GRB observations from Swift to SVOM

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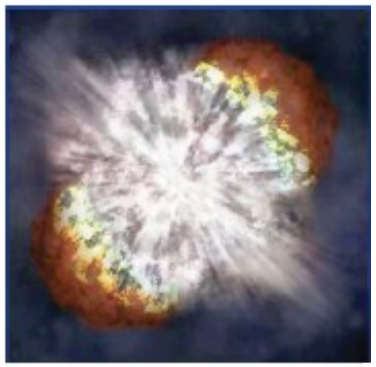
IRAP

Second SVOM scientific workshop :
Surveying the Fast changing Multi-wavelength Sky with SVOM
24 - 28 April 2017
Qiannan, China

GRBs from gamma to optical detectors

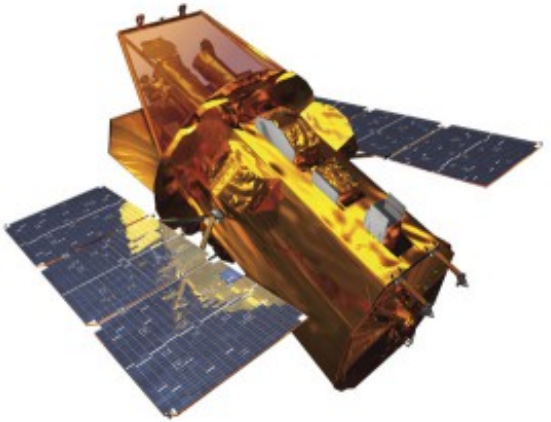
A star explodes



Other wavelengths

Gamma rays

Gamma-ray detection with space telescopes

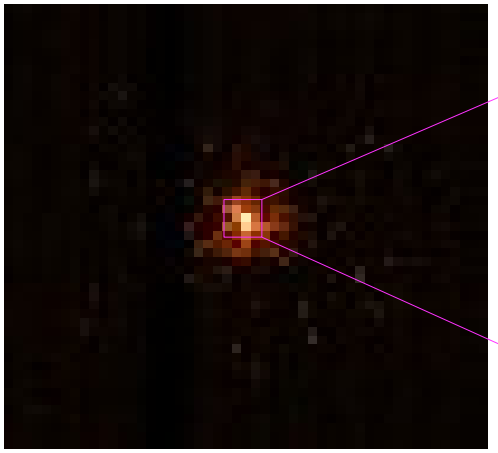


Search and follow-up for the optical counterpart

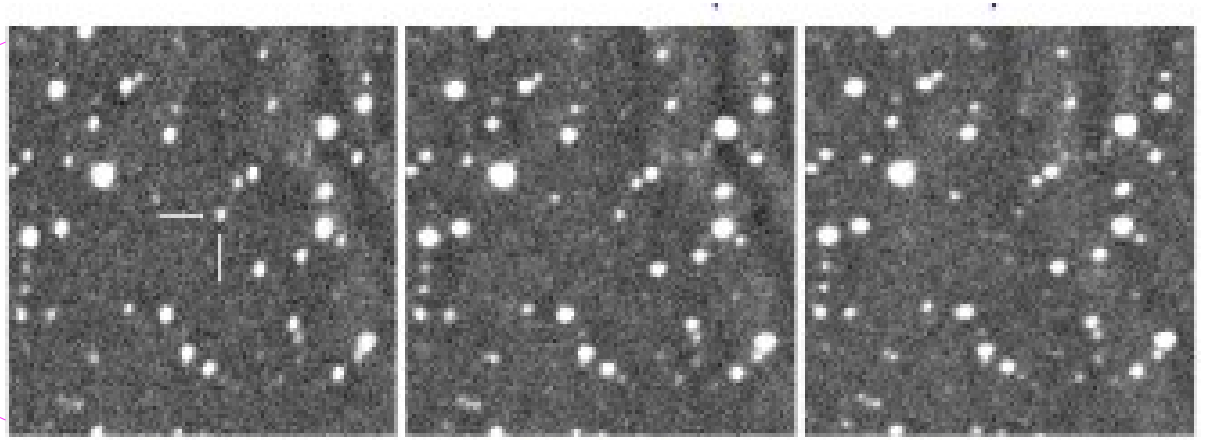
Notice Alert

Find a variable star in a void field of view

Find a variable star in a rich field of view



90 degrees



+8 min

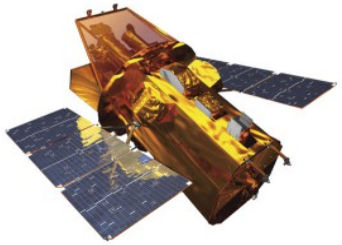
+40 min

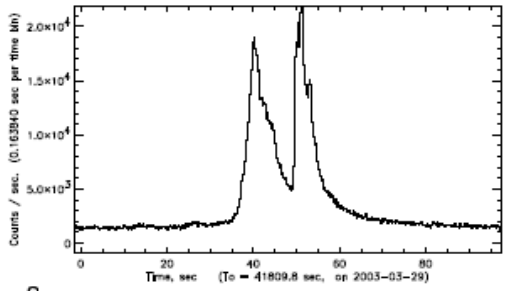
+1h30min

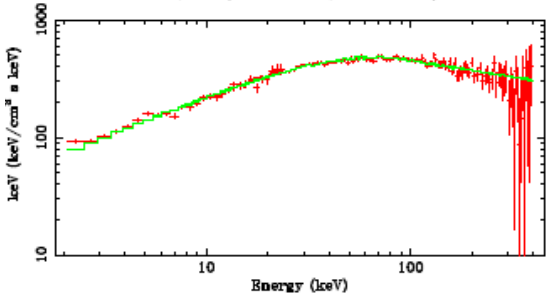
0.1 degree

Light curves + images + spectra

How to derive some GRB parameters





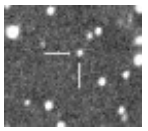


T90 : GRB duration

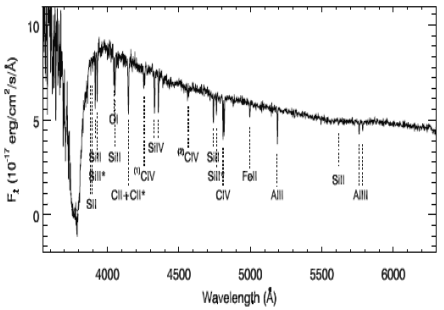
E_{iso}: Isotropic energy

E_{peak}: Peak energy

α,β : Gamma spectrum slopes



R.A, Decl : Accurate position

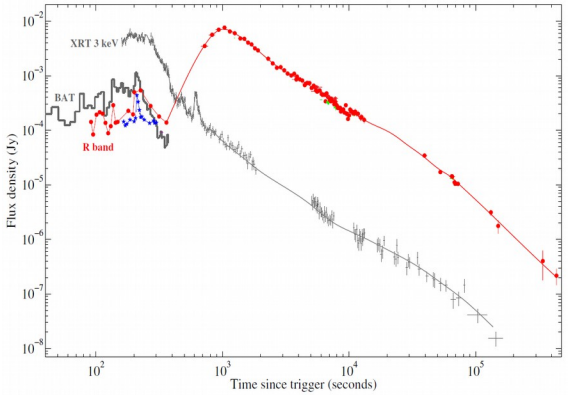


Av : Host extinction

NH : Column density of H

Z : Metallicity

z : Redshift



time

Inputs parameters

Spectra
Light curves

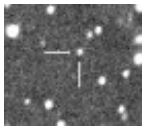
Science

The Swift area

Gamma Ray Burts – Redshifts observation conditions

Senario of redshift determination

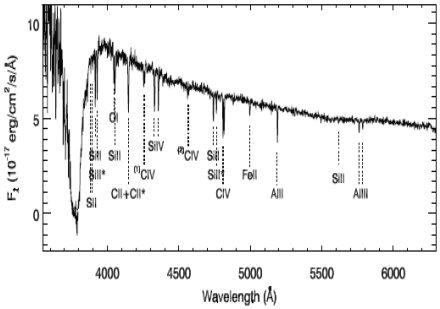





GCN Circular

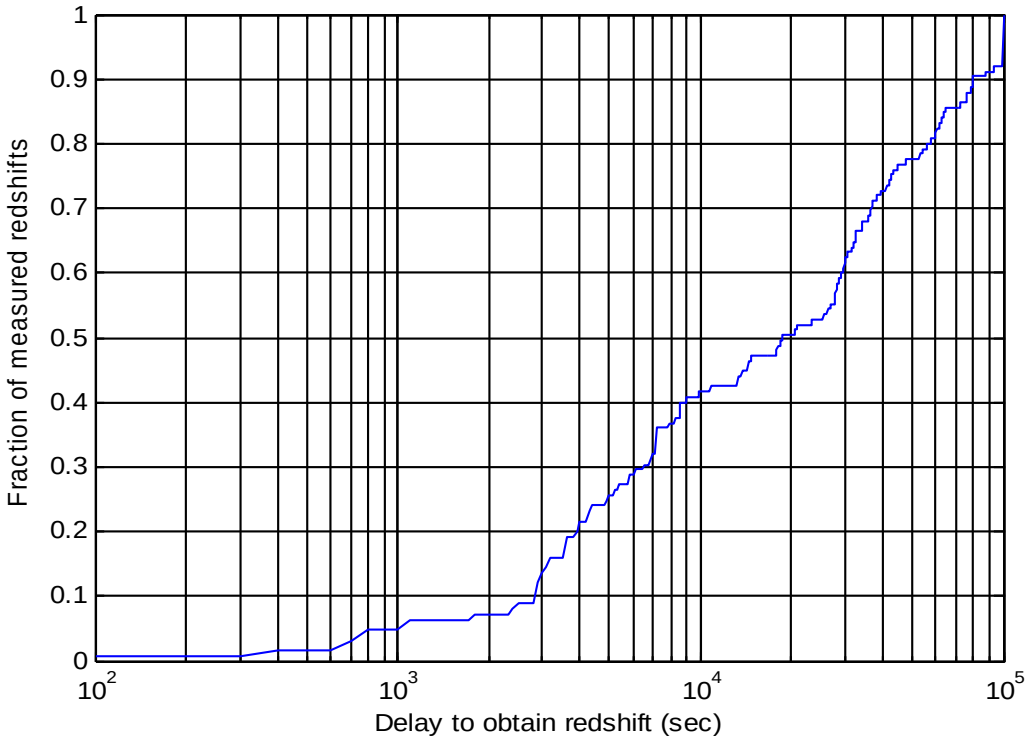
(R.A, Decl.)



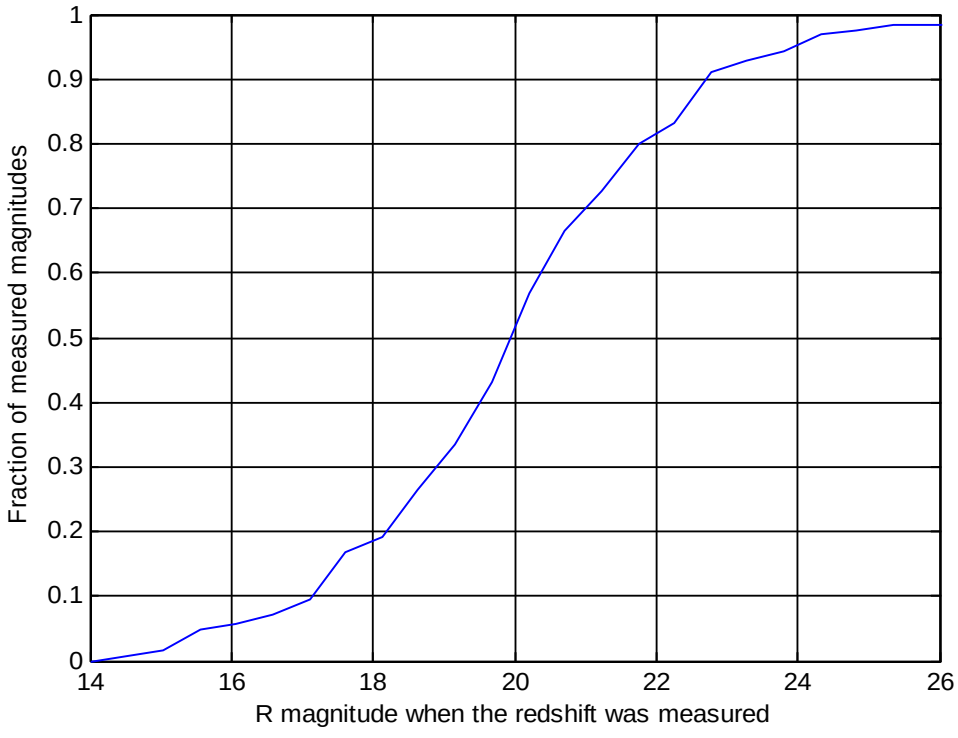


t0 t0+30s t0+5min human check t0+30min t0+31min t0+5h t0+6h

90 % of redshifts are obtained less than 1 day



Median Rmag = 20.5

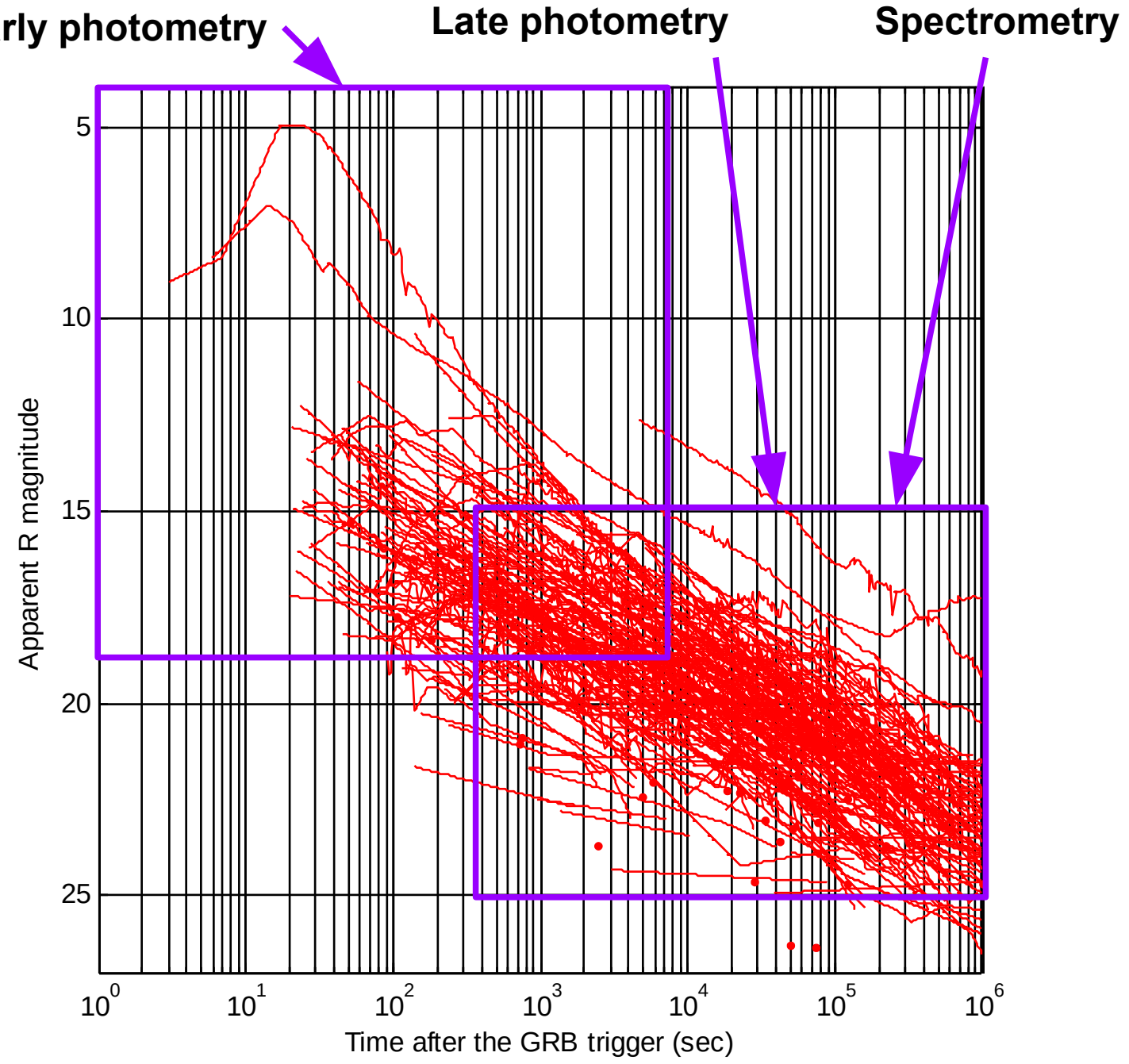


Optical telescopes for GRBs

Photometry follow-up (light curves)

Gamma trigger
t0 : t0+300s

Swift
INTEGRAL
FERMI



Light curves from GRBase

Optical telescopes for GRBs

Classification of telescopes

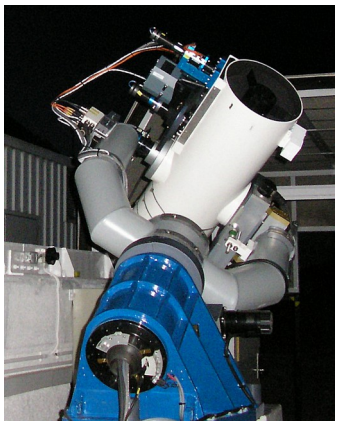
Gamma trigger
t0 : t0+300s

Swift
INTEGRAL
FERMI

Early photometry
t0+30s : t0+2h

MASTER
MITSuME
Rotse
TAROT
UVOT
TNT
PROMPT
REM

Small diameters
20 cm to 1 meter
Rapid slewing
Autonomous



Late photometry
t0+3min : t0+1week

GROND
Shajn
NOT
RATIR
P60
Tautenburg
Faulkes
Liverpool
RTT150

Medium diameters
1 to 4 meters
Standard slewing
Human check

Spectrometry
t0+1h : t0+1day

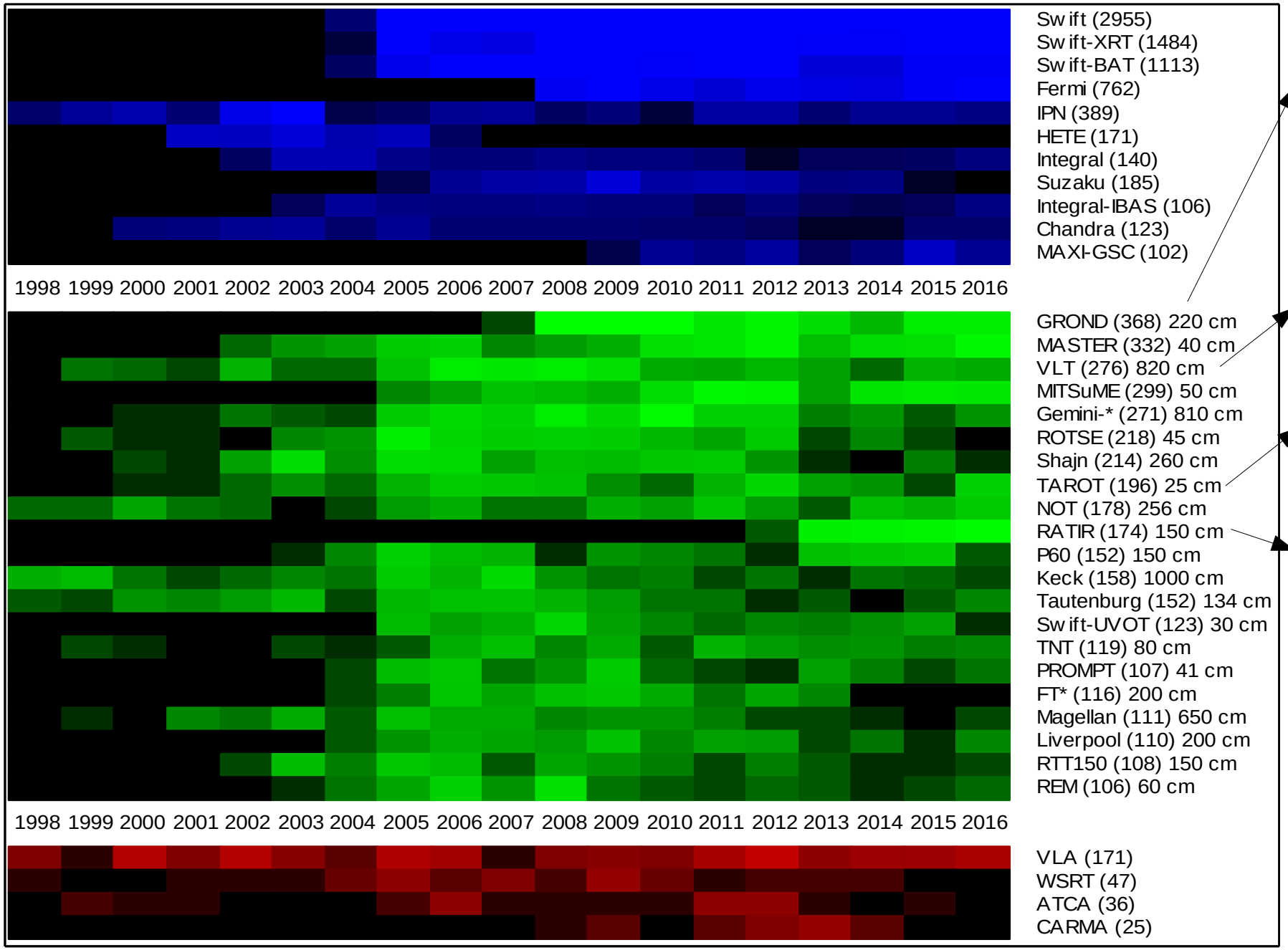
VLT
Gemini
Keck
Magelan

Large diameters
4 to 11 meters
Slow reactivity
Human manual

Optical telescopes for GRBs

Gamma ray burts Coordinate Network Circular production

GCN circular productions



TAROT + Zadko – Heterogeneous telescope network

TAROT Calern (France)
D = 25 cm
FoV = 2° x 2°
Slew < 10 s

TAROT La Silla (Chile)
D = 25 cm
FoV = 2° x 2°
Slew < 10 s

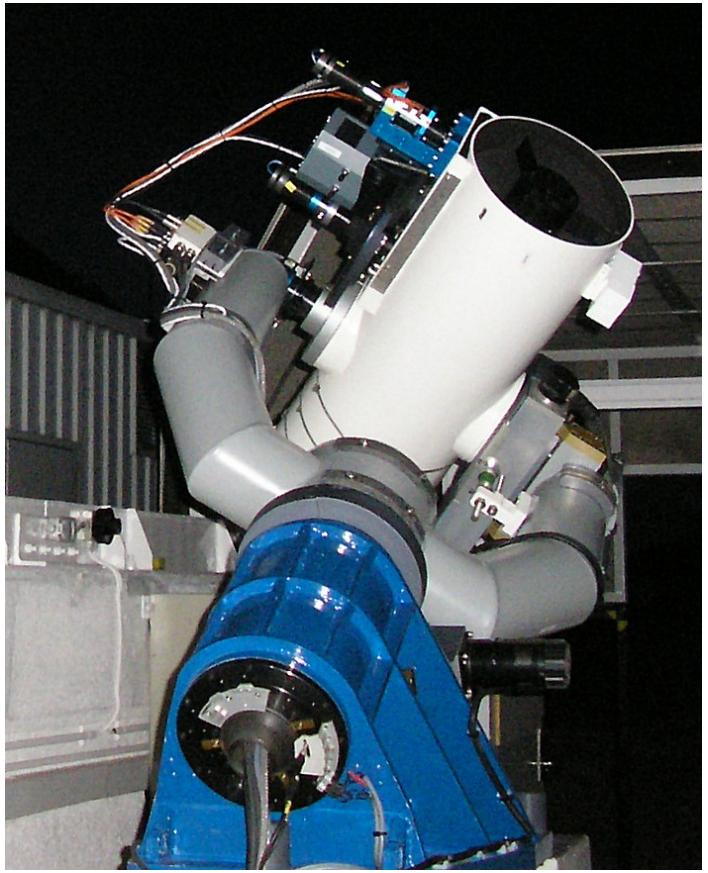
CADOR computers (France)
Web acces and 30 TB storage

Zadko (Australia)
D = 1 m
FoV = 23 x 23 arcmin
Slew ~ 60 s

TAROT Reunion (France)
D = 18 cm
FoV = 4° x 4°
Slew < 5 s

TAROT – Small telescopes optimized for GRBs

Autonomous. No human presence



Chile 2006 (74 GRB alerts)

SATELLITE
gamma

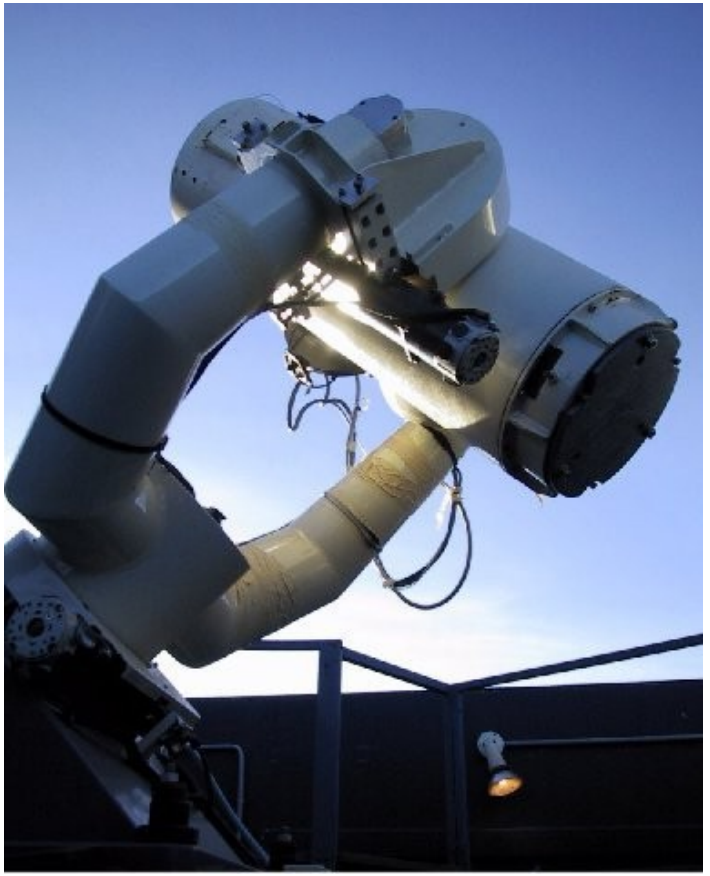
↕ ~15 sec

GCN

↕ 1 sec

Tel. Robotics
optics

↔ ~10 sec ↔ ~10 sec



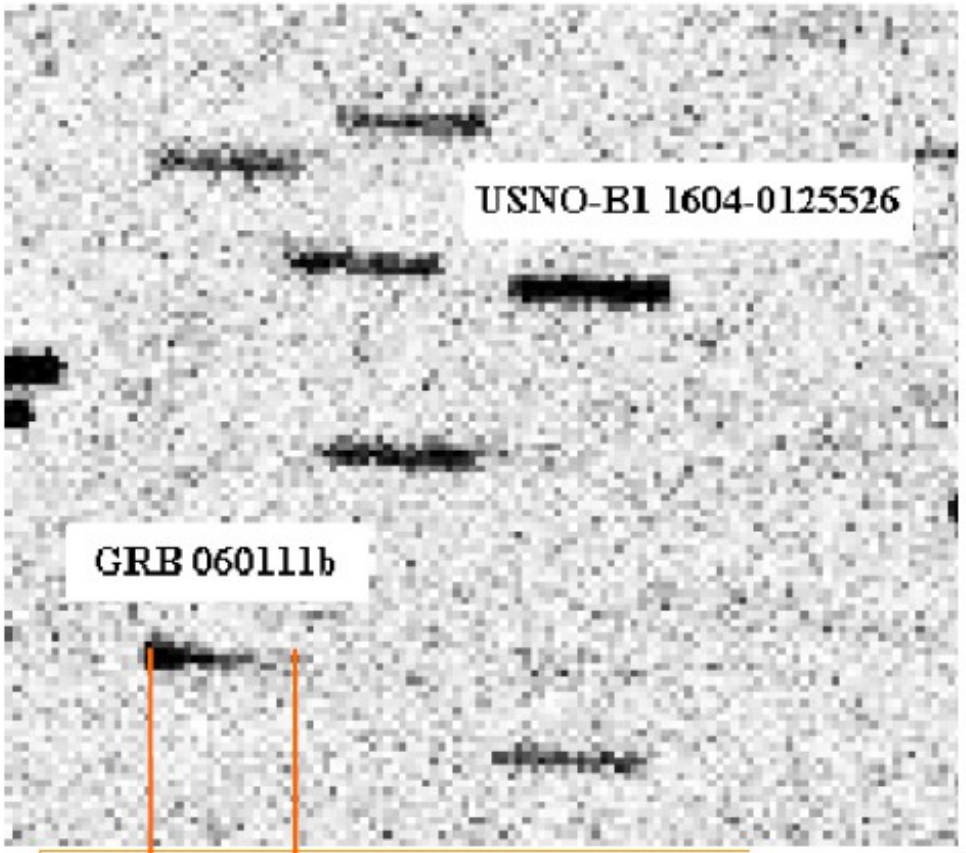
Calern 1998 (100 GRB alerts)

26 papers in refereed journals
196 GCN circulars

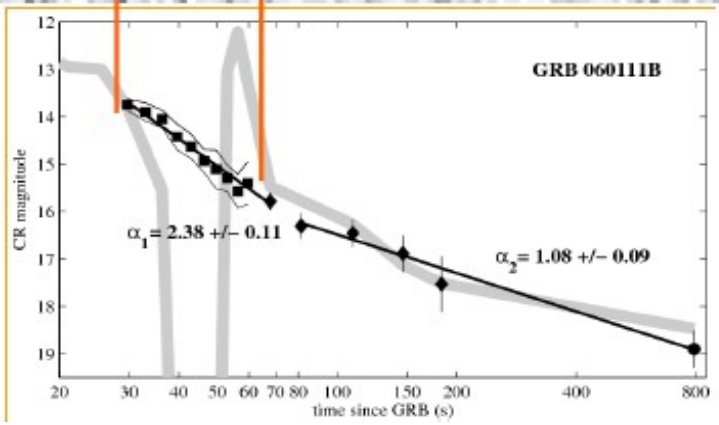
181 alerts, 58 optical emissions seen. 36 GRB observed during prompt emission, 11 optical transient seen during prompt emission.
32% optical emissions seen. 20% GRB observed during prompt emission, 6% optical transient seen during prompt emission.

TAROT & Zadko – Early observations

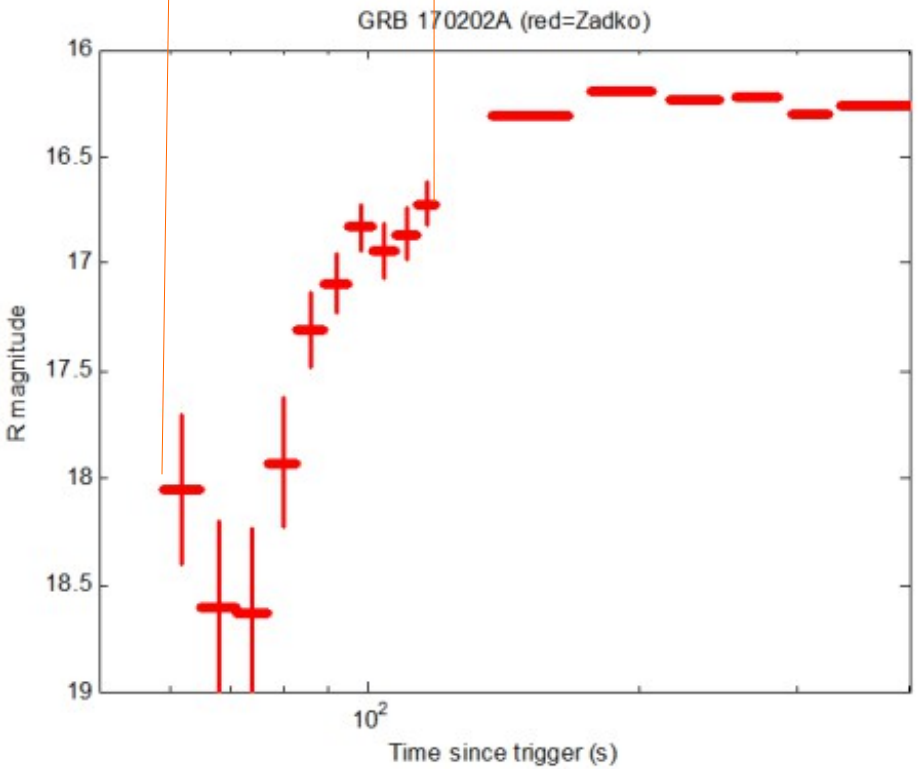
The trail technique to keep a good temporal resolution during the first minute



(Klotz et al. 2006 A&A 451, L39)



Klotz et al. 2017 GCNC 20580



How to prepare optical observations after 2020 ?

The secrets of the success of an optical robotic telescope

Fluids
- Electric power reliability (UPS)
- Computer reliability
- Network reliability (+ easy access)

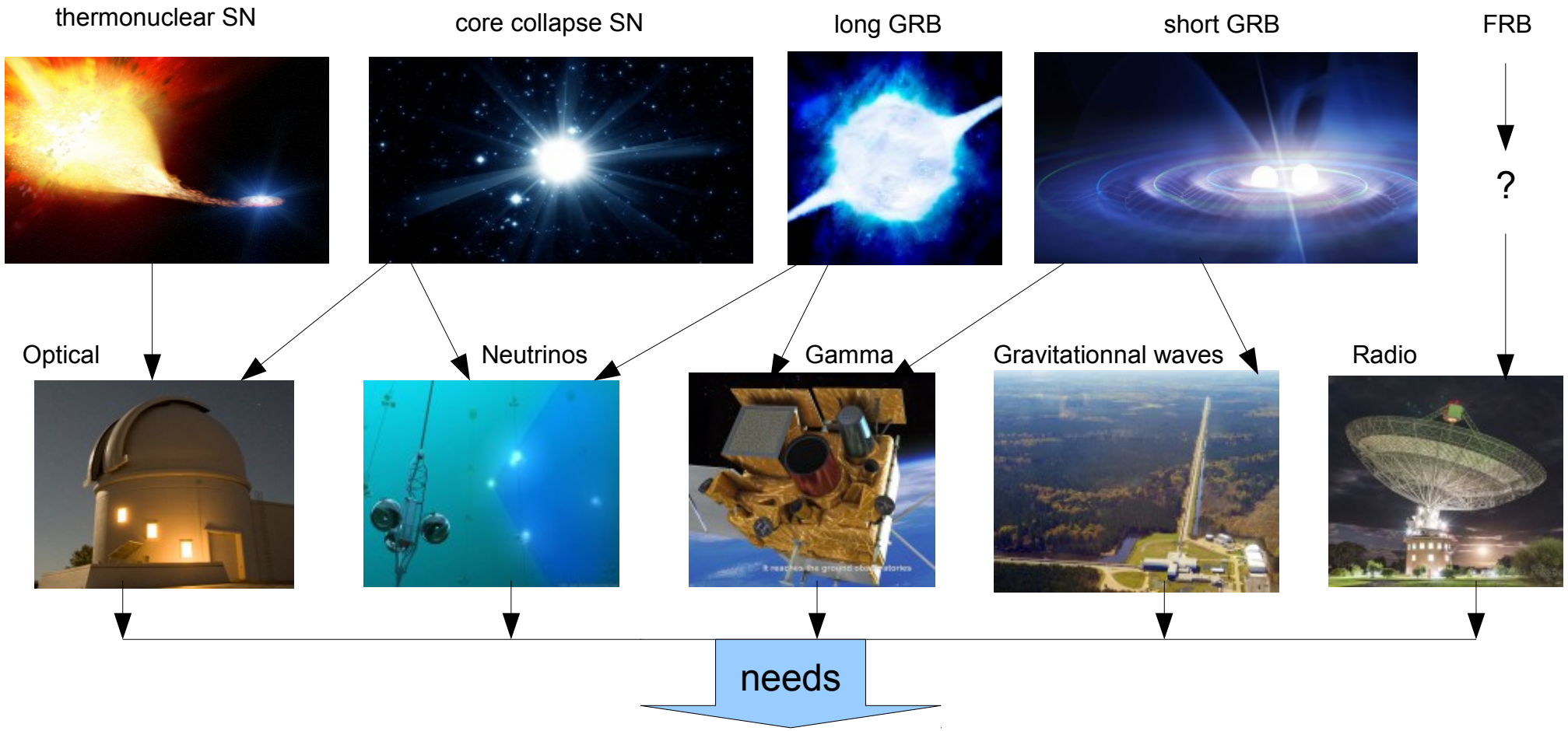
Security
- Security (meteo, etc.) managed by a Programmable Logic Controller (not by computer)
- Redundant security devices

Hardware
- Roof reliability
- Rapid slewing mount with limited flexions
- Use motors with absolute encoders
- Use industrial motor controlers

Software
- Software based on agents instead of one executable
- Daily check procedure (electronics, pointings, detector response)
- Feed routine observations by a web service (or a web form)
- Quick look of images from a simple web page
- Web tool to do maintenance (manual mode)

How to prepare optical observations after 2020 ?

New triggers : Multiwavelength + multimessagers



Rapid observation of cataclysmic events => Fast slewing mounts

Large fields of view => Small focal length optics
Network of telescopes

Detectivity => Large aperture

How to prepare optical observations after 2020 ?

An example : SVOM F-GFT (expected in 2020)

Rapid observation
of cataclysmic events => Fast slewing mounts

GRBs
FRBs

Detectivity => Large aperture

RATIR
Large aperture
Detectivity multiband
Near infrared

TAROT
Fast slewing

Ground Follow-up Telescope
France + Mexico
@ San Pedro Martir (Mex.)

The best
optical telescope
for GRB
photometry

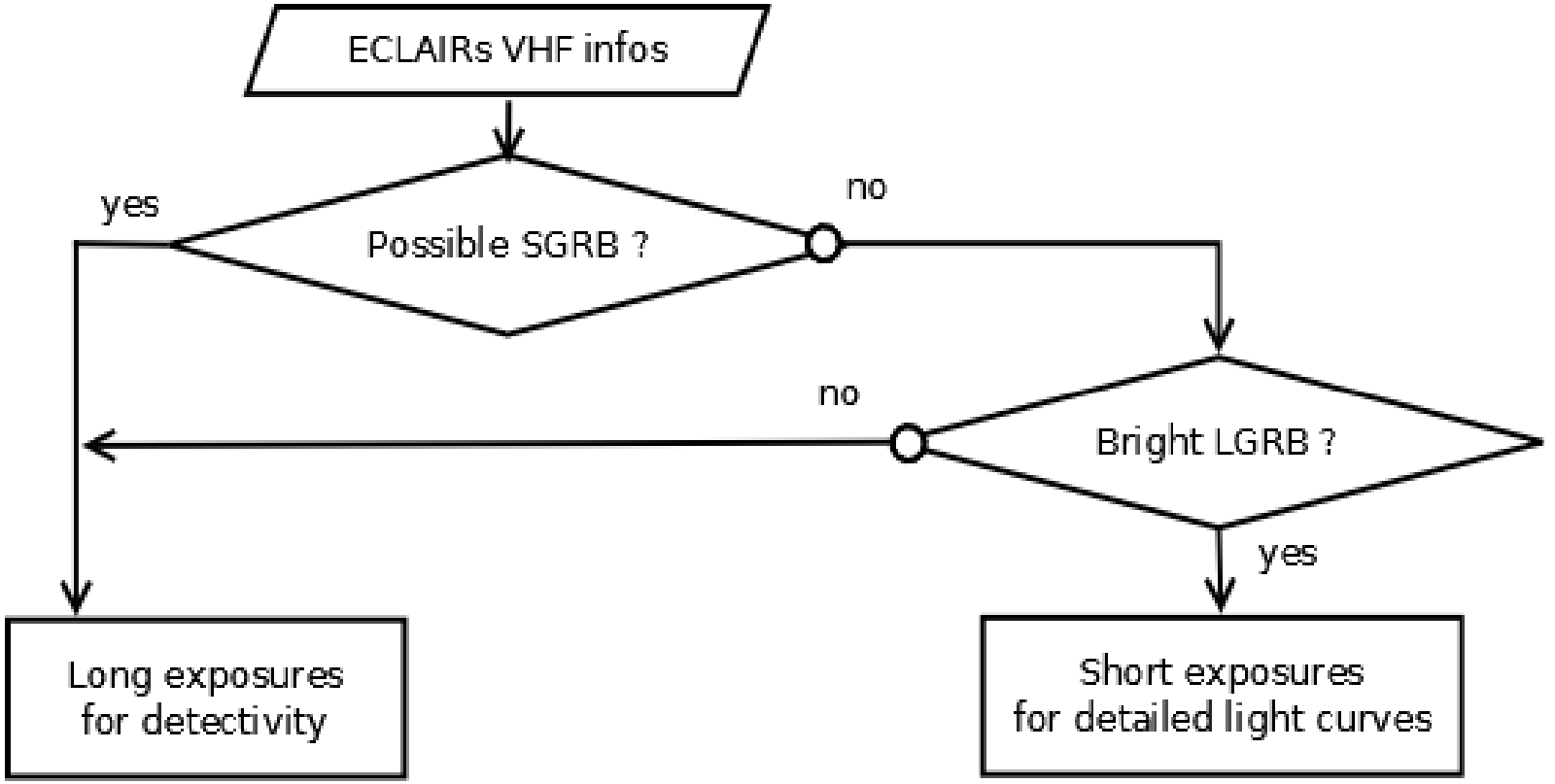
rapid localization
high redshifts
prompt emission
faint emissions

Price : ~3 M€ / unit

How to prepare optical observations after 2020 ?

An example : SVOM F-GFT (expected in 2020)

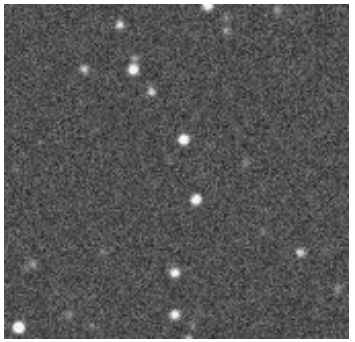
The GFTs need some ECLAIRs informations
in the first VHF message
to optimize observation strategy



How to prepare optical observations after 2020 ?

An example : SVOM F-GFT (expected in 2020)

The GFT can provide a estimation of the redshift



Phot-z
Photometry in 4 bands

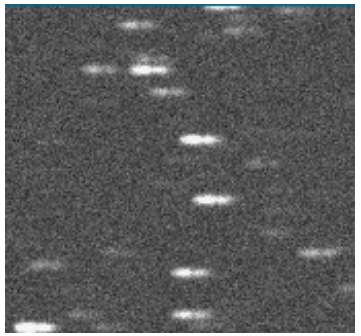
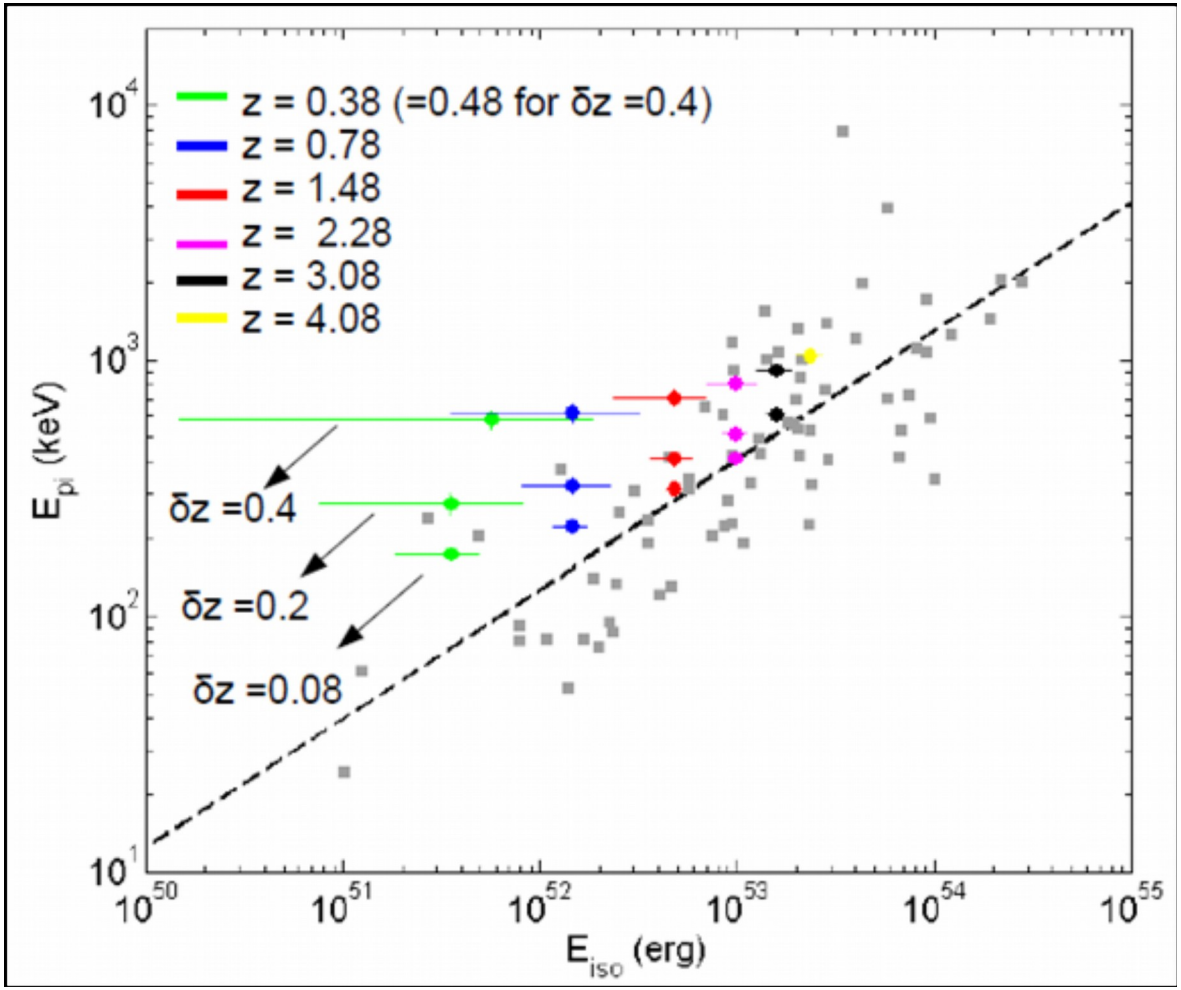


Photo-z ++
Very low dispersion R~10
prism in the filter wheel



The challenge to obtain
an optical spectra during the prompt emission

How to prepare optical observations after 2020 ?

TAROT Reunion a prototype of low cost reliable small robotic telescope

Rapid observation
of cataclysmic events => Fast slewing mounts

Large fields of view => Small focal length optics
Network of telescopes

Neutrinos
Gravitational waves
Supernovae
Early GRBs

Wide FoV = 4° x4°
Limiting mag. = 17 in 120s
No maintenance
Very high speed mount

Price : ~80 k€ / unit

Robotic telescope observations when there is no event

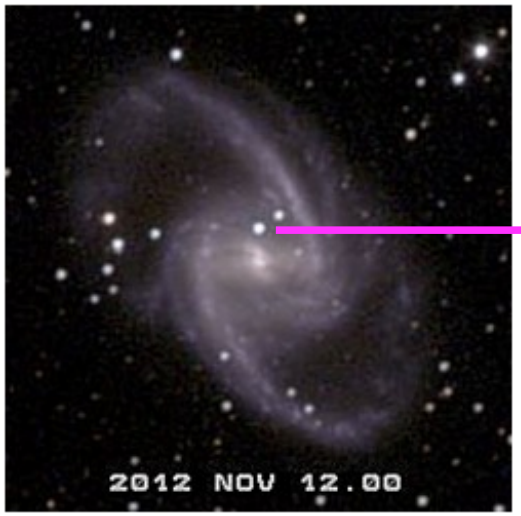
TAROT supernovae

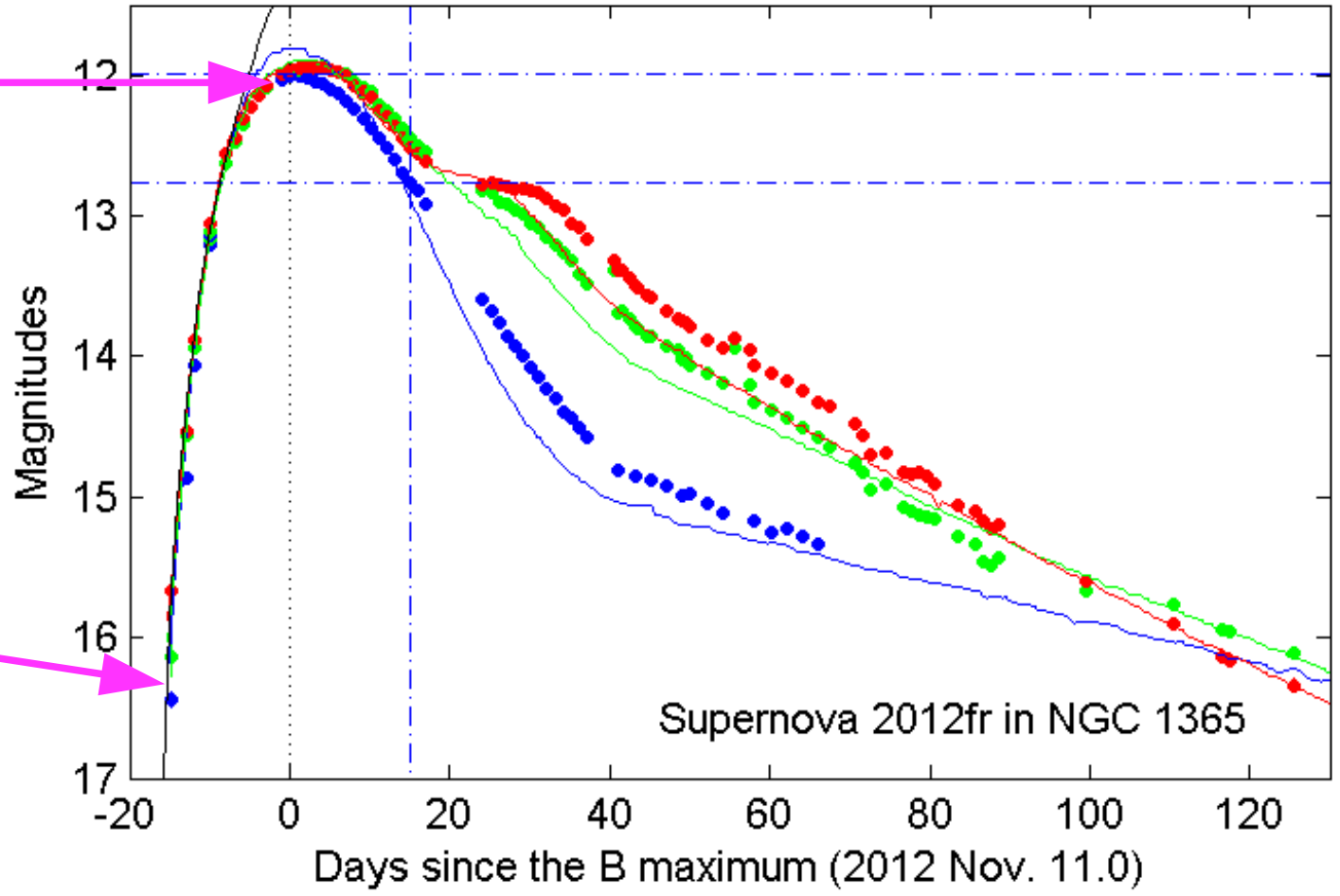
Discovery of 15 nearby supernovae since 2007

→ Early observations (less than 3 days after the explosion)

→ Photometry follow-up (SNIa calibration if Cepheids)

→ Searching for shock breakouts



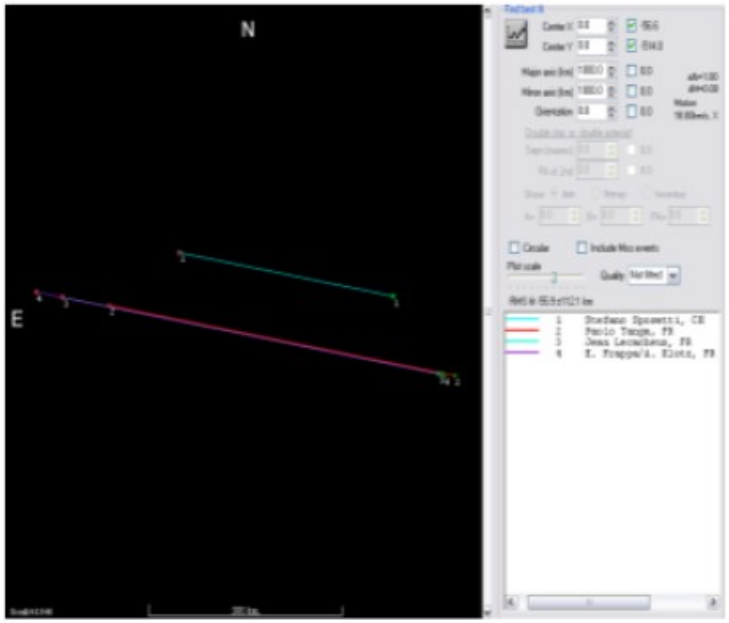


Robotic telescope observations when there is no event

TAROT occultation of stars by minor planets

92 positive occultations since 2004

→ Measure duration of the disapearance of a star
→ Combine durations from various observatories
→ Determine the shape at a kilometric precision



Case of the TNO (50000) Quaoar

http://www.euraster.net/tarot/

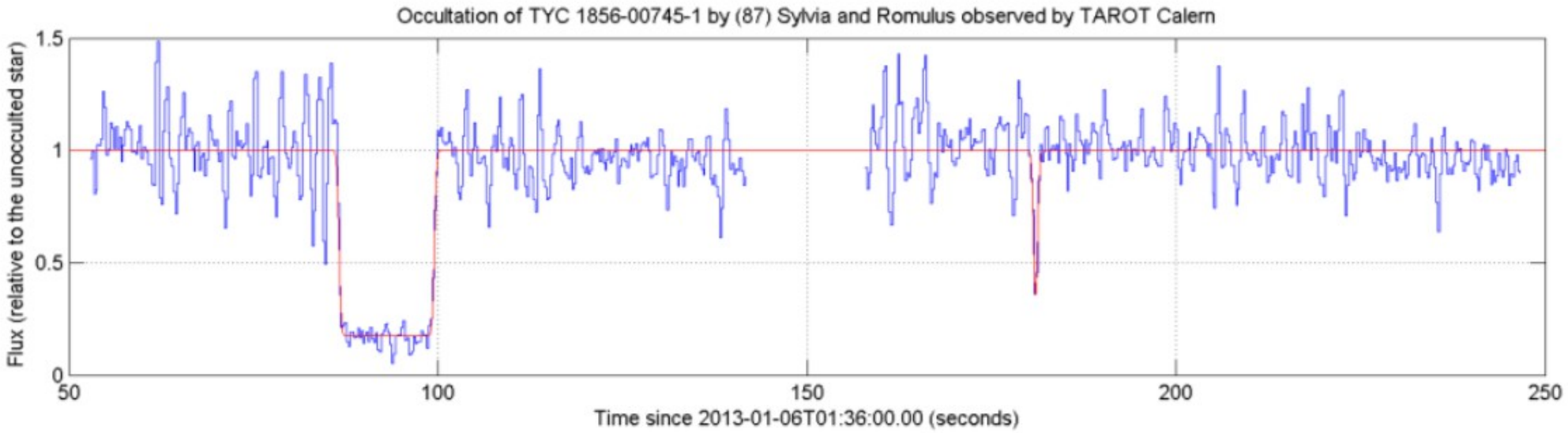
Robotic telescope observations when there is no event

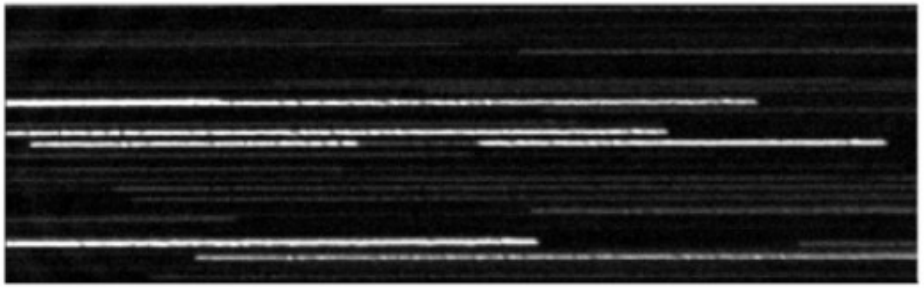
TAROT occultation of stars by minor planets

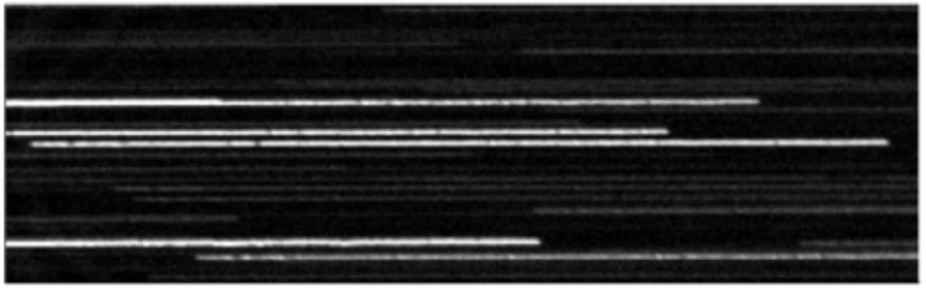
92 positive occultations since 2004

→ Determine the shape at a kilometric precision

→ In case of double body, help to determine the density







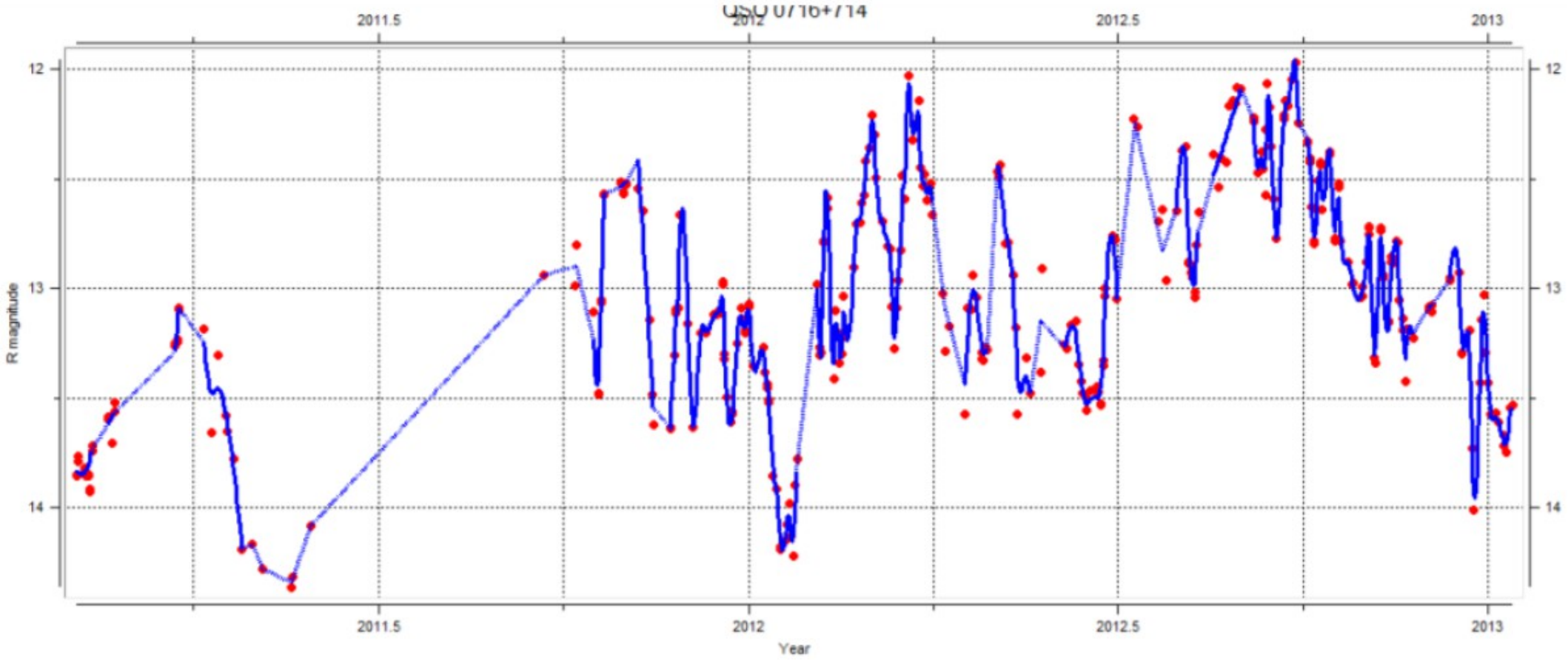
Robotic telescope observations when there is no event

TAROT photometry follow-up of quasars

14 quasars photometry follow-up since 2011

→ Determine their activity for the reference frame of GAIA

→ Eliminate the too active quasars to limit noises of the absolute celestial frame



How to prepare optical observations after 2020 ?

CONCLUSIONS

Understanding GRBs in multiwavelength

- 1/4 of GRBs is not compatible with the standard theory (fireball)
- Collect more data with a good time sampling → dedicated telescopes (GFT, GWAC)
- Lack of alternative non standard models to explain observations

The design of telescopes for GRB must include new messengers (GW, neutrino, FRB)

Participate to research on GW optical counterparts

- Scan >100°^{2}
- Small focal length telescopes → large field of view (>4°)
- Aperture diameter is limited by the price !

Participate to research on neutrinos optical counterparts

- Error box of about 2 degrees.
- New neutrino detector KM3NET → search on electronic neutrinos (no Earth noise)

Participate to research on FRB optical counterparts

- Error box of about 0.5 degree.
- Follow the Parkes pointings (public in april 2018).