Analyse multi-messagers photon/neutrino avec le télescope ANTARES

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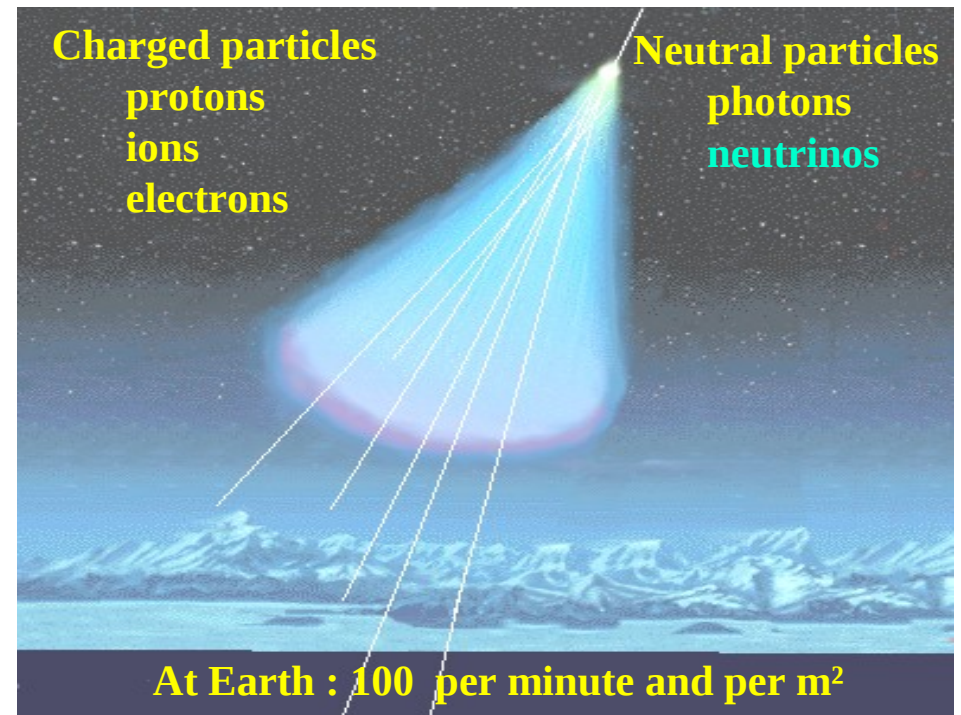
Visite L3 PC

16 avril 2014

Parcours

- **Licence** "physique et sciences pour l'ingénieur", parcours physique, Université de Strasbourg

  - Stage L2 : "Étude des distributions de rayons cosmiques détectés par le télescope ANTARES", IPHC. (T. Pradier)

- **Master** recherche "Physique", parcours astrophysique & physique des corpuscules, Université Bordeaux 1

  - Stage M1 : "Étude des distances des pulsars", CENBG, équipe astroparticules. (D. Smith & D. Dumora)

  - Stage M2 : "Analyse d'observations Herschel de proto-étoiles massives", LAB. (J. Braine)

- **Doctorat** en astroparticules (2ème année) :
  "Analyse multi-messagers photon/neutrino avec le télescope ANTARES"

Cosmic rays

Cosmic rays were discovered a century ago by Victor Hess and we still do not know their origin ...
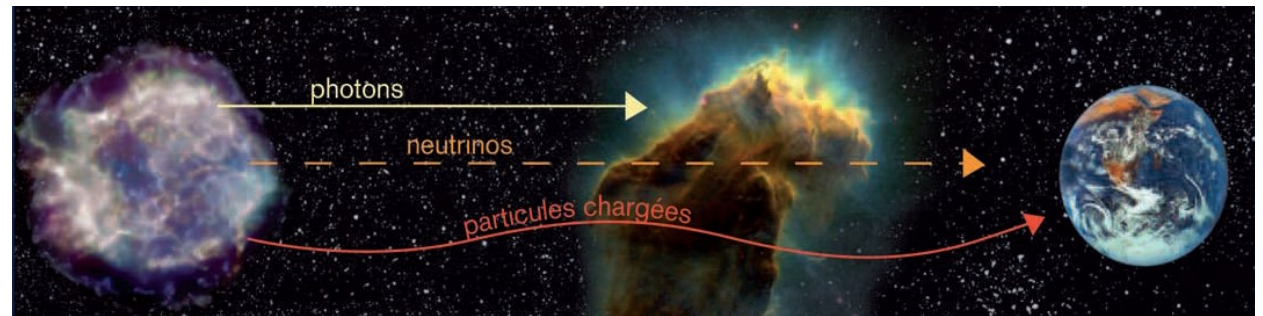
Cosmic rays interact with the upper atmosphere and produce large particle showers ...

Charged particles
protons
ions
electrons

Neutral particles
photons
neutrinos

At Earth : 100 per minute and per m²

Neutrino astronomy

Neutrinos are unique messengers to study the high energy Universe:
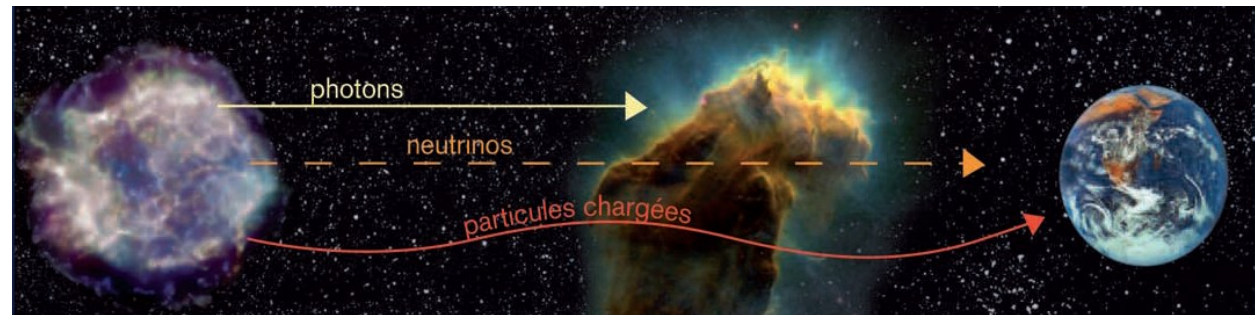
- Electrically neutral

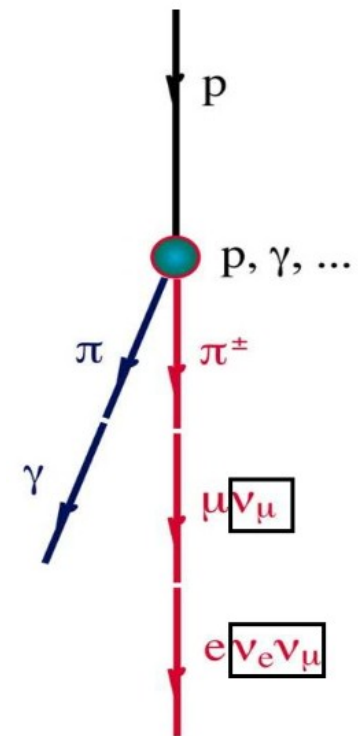- No absorption

- Weakly interacting

Neutrino astronomy

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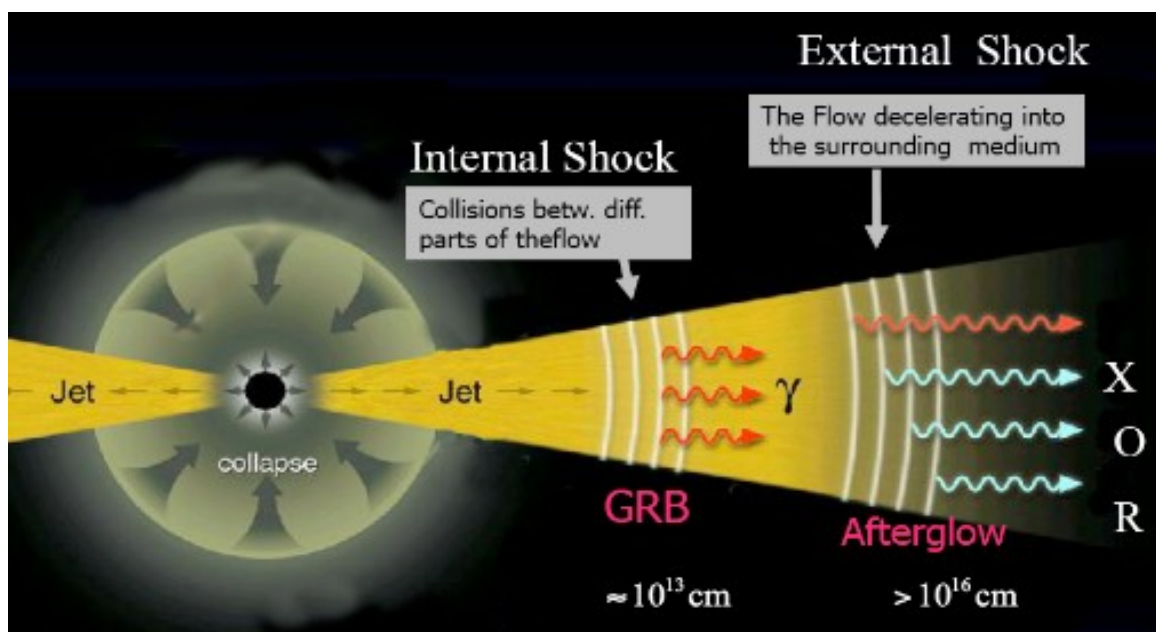
- No absorption

- Weakly interacting

Cosmic neutrinos:

➜ Neutrinos possibly produced in interactions of high energy nucleons with matter or radiation

➜ If **hadronic mechanisms**:
   High energy nucleons + hadrons ⟶ *mesons + hadrons*
   ⟶ *neutrinos and photons*

➜ Simultaneous emitters of neutrinos and gamma-rays

➜ Detection from a cosmic source would be a direct evidence of hadronic scenario

Example of sources
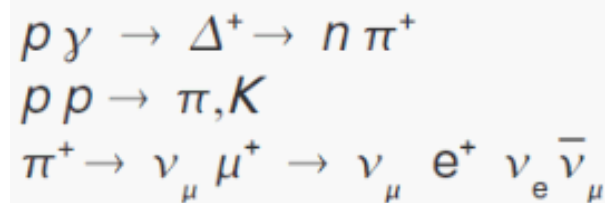
- High energy neutrinos from gamma-ray bursts and supernovae

GRB neutrinos:
relativistic jets (Fireball model)
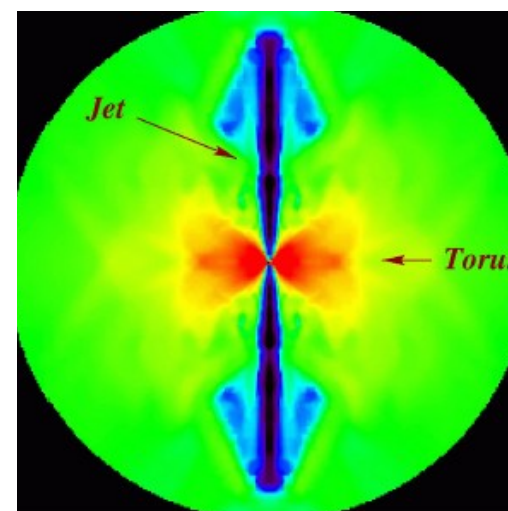$\Rightarrow$ 10 TeV–10 PeV neutrino
Meszaros & Rees, Waxman

$$p\,\gamma \rightarrow \Delta^+ \rightarrow n\,\pi^+$$
$$p\,p \rightarrow \pi, K$$
$$\pi^+ \rightarrow \nu_\mu\,\mu^+ \rightarrow \nu_\mu\,e^+\,\nu_e\,\bar{\nu}_\mu$$
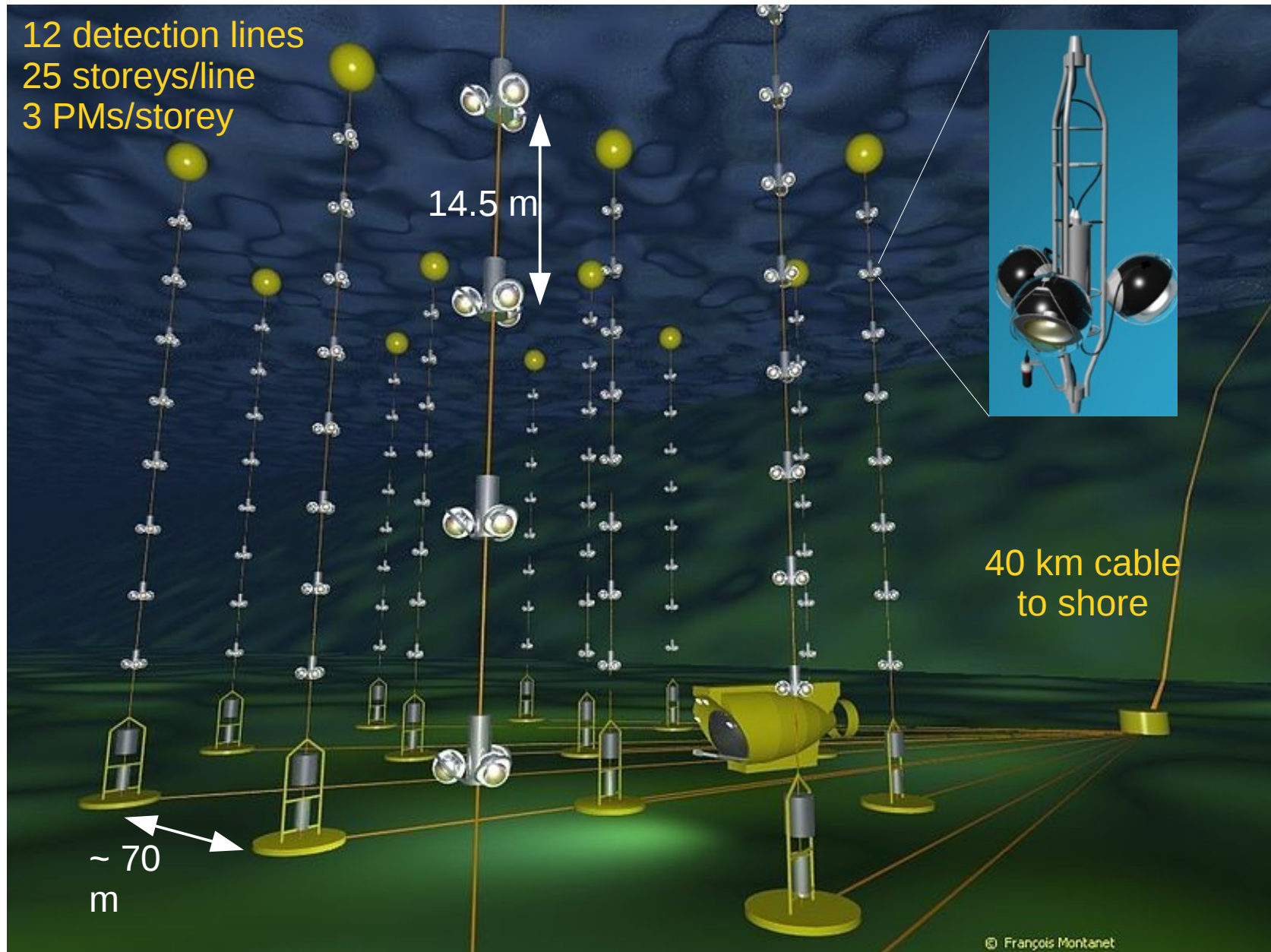
SN neutrinos:
connection GRB-SN (chocked jet, midly relativistic)
$\Rightarrow$ 100 GeV-10 TeV neutrino
Razzaque & al,, Ando & Beacom

The ANTARES telescope

12 detection lines
25 storeys/line
3 PMs/storey

14.5 m

40 km cable to shore

~ 70 m

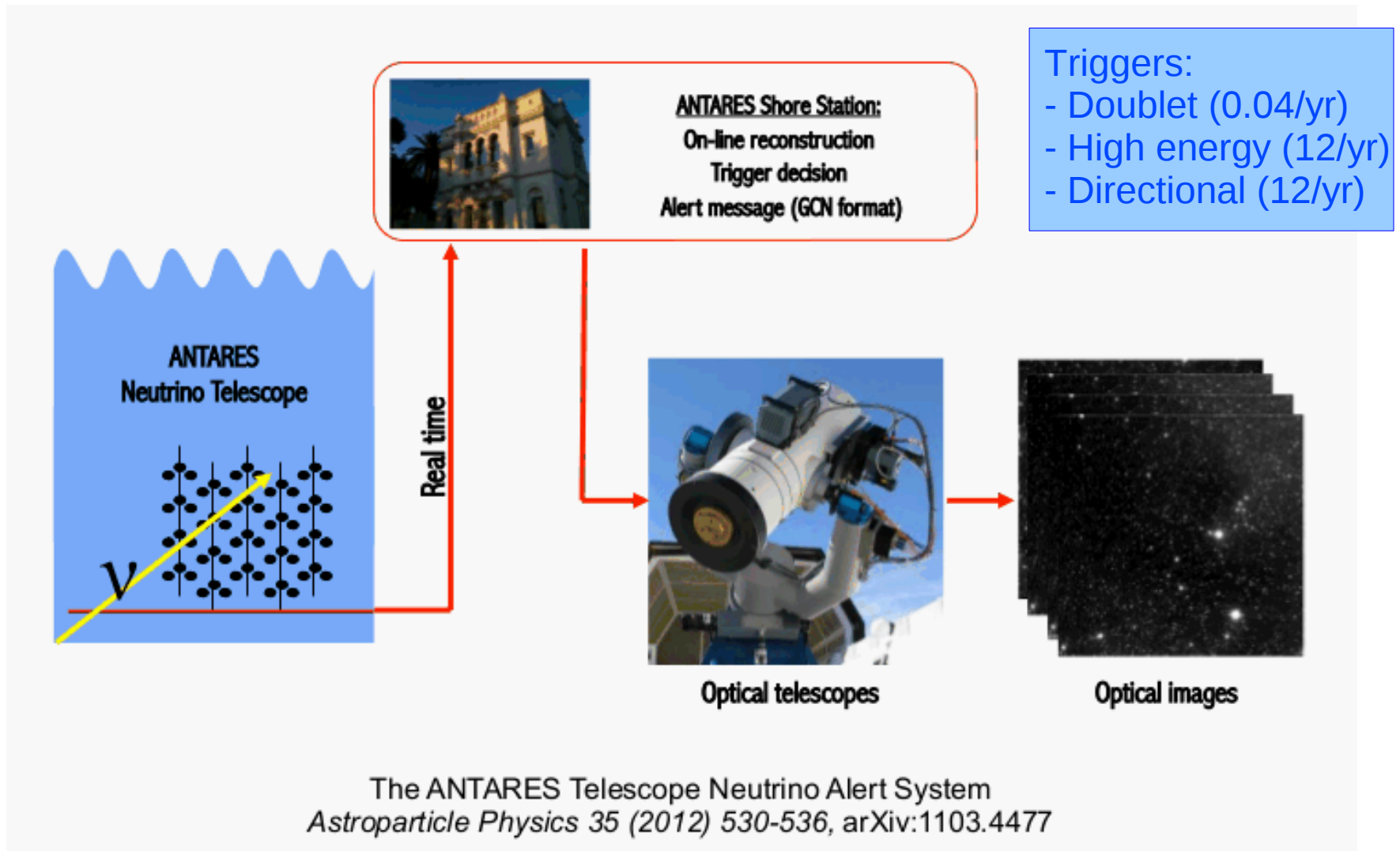© François Montanet

Detection principle

The ANTARES neutrino telescope detects Cherenkov light created by a muon coming from the interaction of a neutrino with the Earth
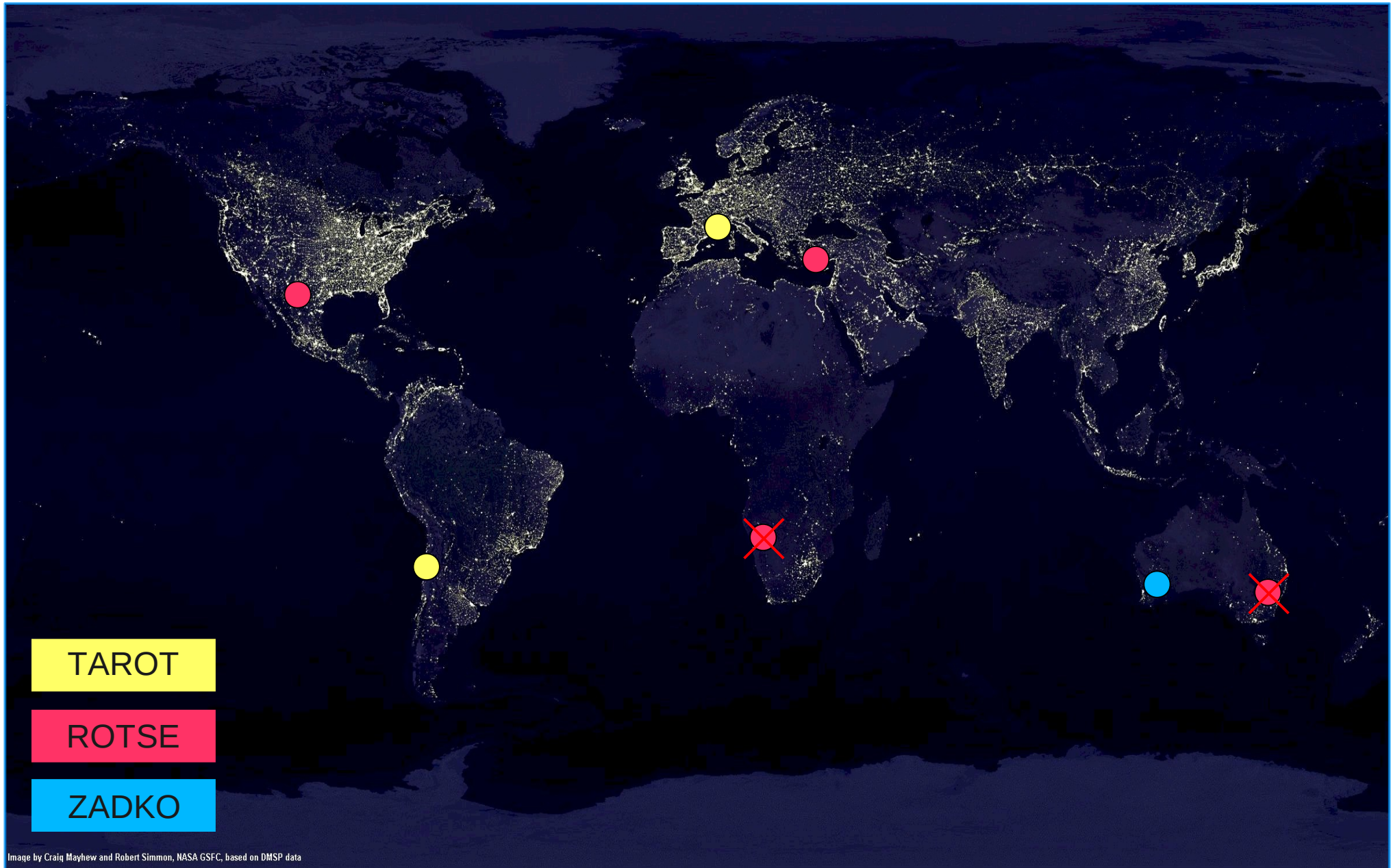
We are looking for upgoing events !

TAToO

- Optical follow-up: search for an optical counterpart
- Transient sources: GRBs, SNe

ANTARES Neutrino Telescope

ν

Real time

ANTARES Shore Station:
On-line reconstruction
Trigger decision
Alert message (GCN format)

Triggers:
- Doublet (0.04/yr)
- High energy (12/yr)
- Directional (12/yr)

Optical telescopes

Optical images

The ANTARES Telescope Neutrino Alert System
Astroparticle Physics 35 (2012) 530-536, arXiv:1103.4477

Follow-up with telescopes

TAROT

ROTSE

ZADKO

Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data

Follow-up with telescopes

TAROT Calern

- Two 25 cm telescopes
- Fov 1.86°x1.86°
- Slewing time ~ 10s

TAROT

ROTSE

ZADKO

Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data

Follow-up with telescopes

- Four 45 cm telescopes
- Fov 1.85°x1.85°
- Slewing time ~ 10s

ROTSE 3a

TAROT

ROTSE

ZADKO

Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data

Follow-up with telescopes

Zadko
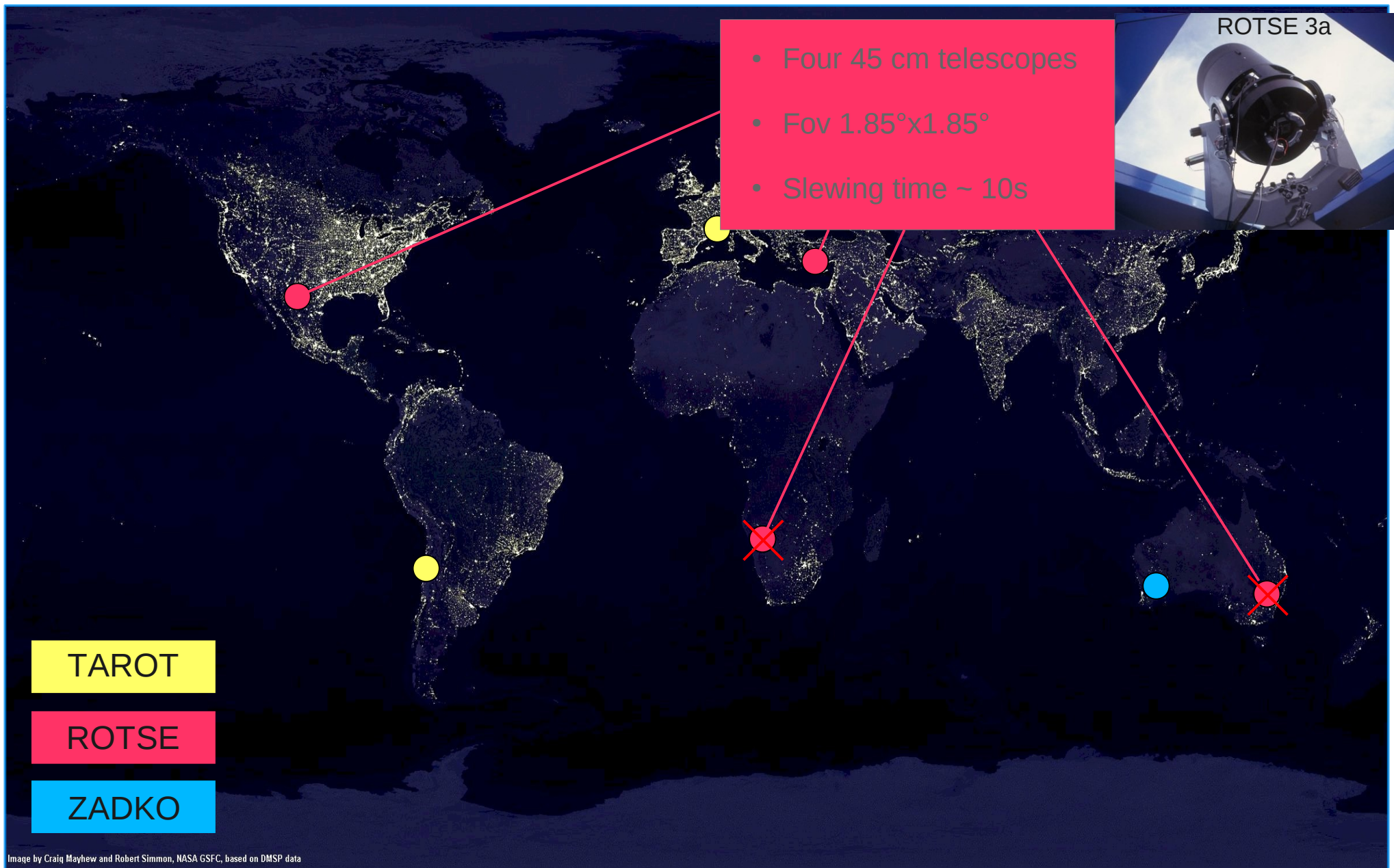
- One-metre telescope
- Fov 23 x 23 arcmin
- Max. Slew speed 3°/s

TAROT

ROTSE
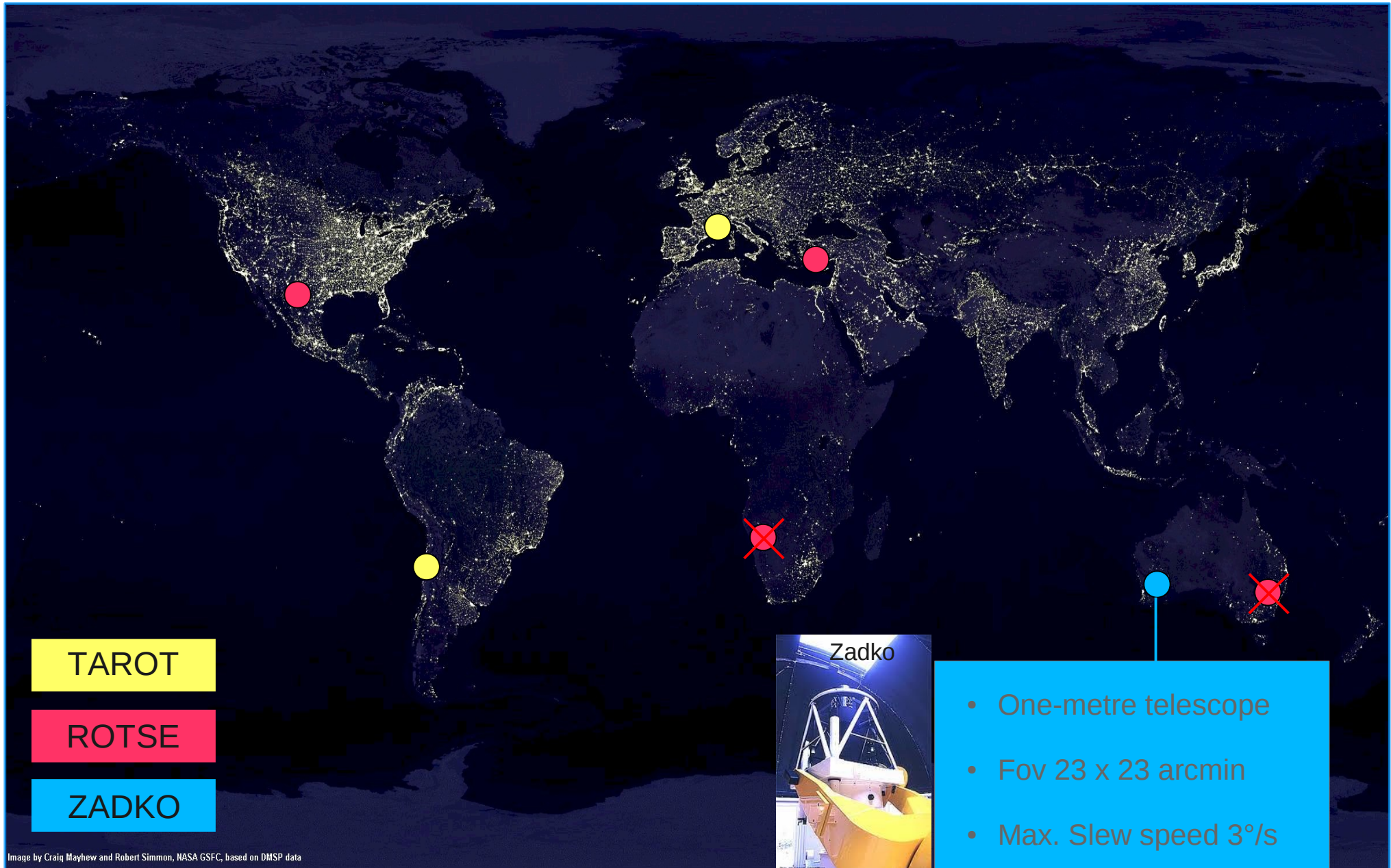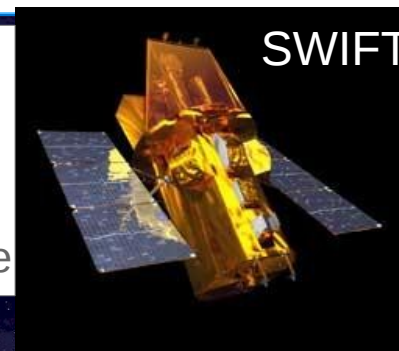
ZADKO

Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data

Follow-up with telescopes

- X-ray follow-up
- Fov 23.6 x 23.6 arcmin
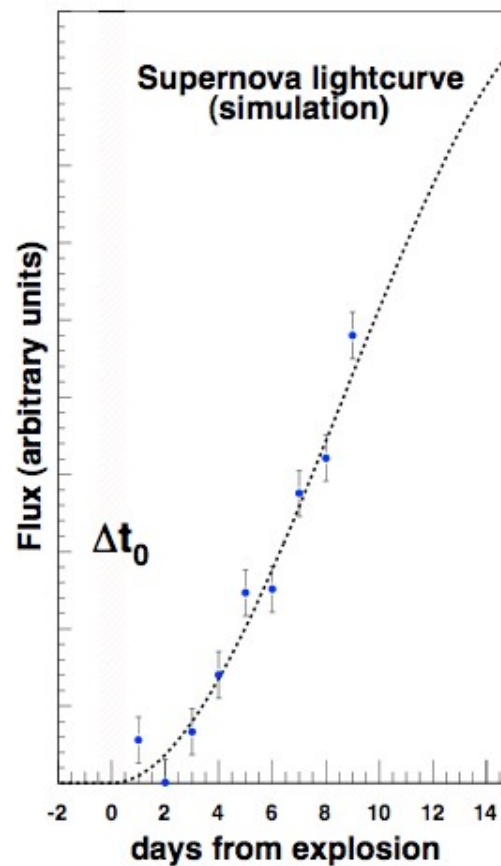- 0.3-10 keV energy range

SWIFT

TAROT

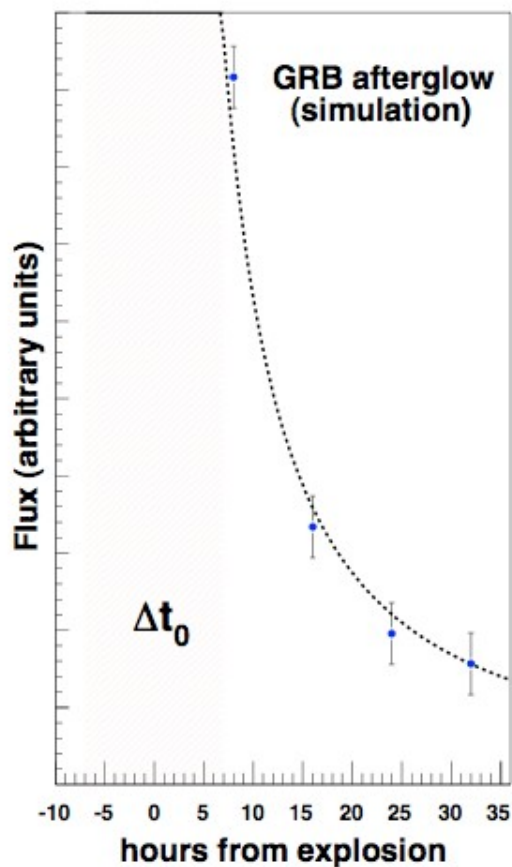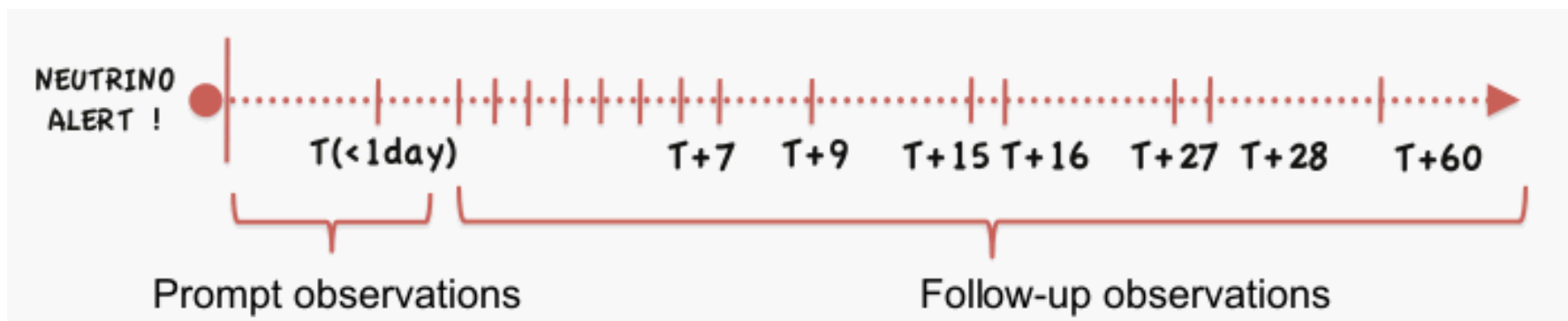ROTSE

ZADKO
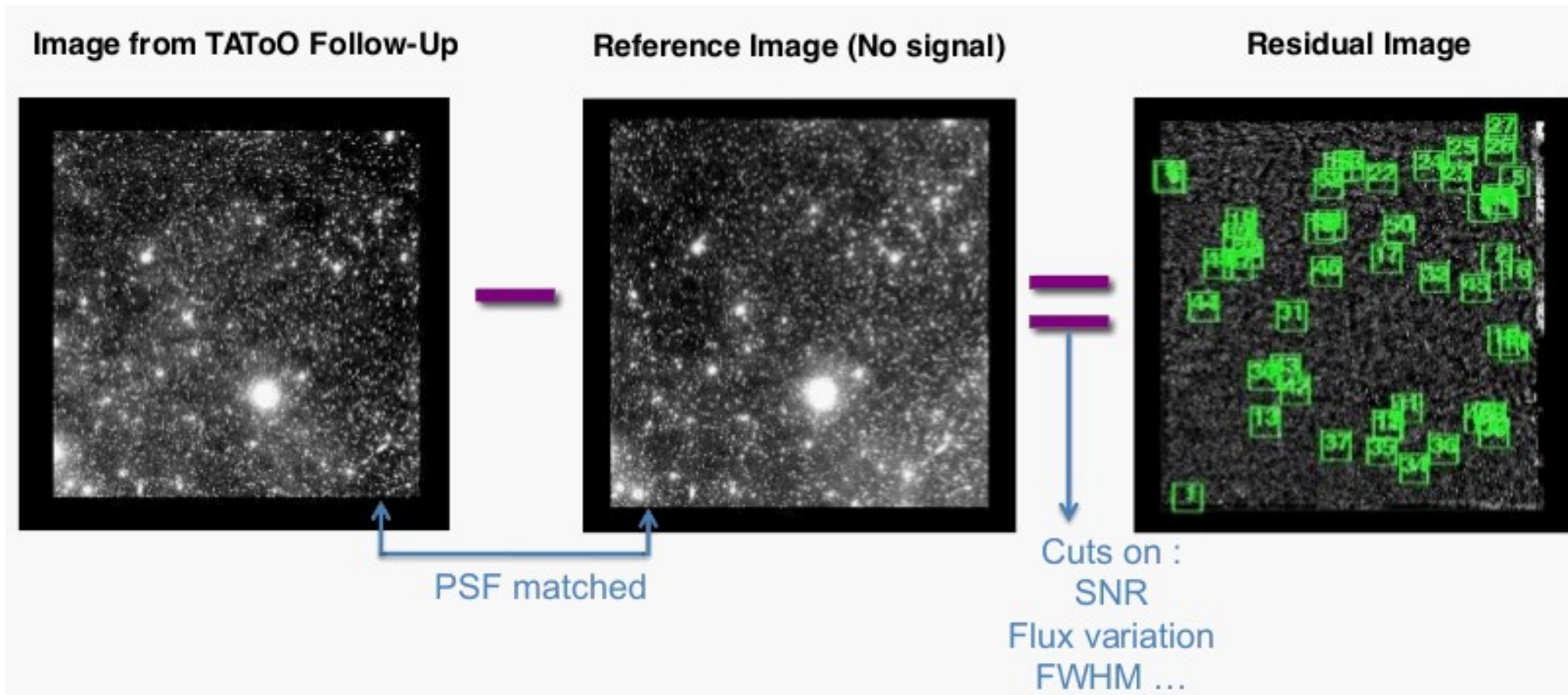
Image by Craig Mayhew and Robert Simmon, NASA GSFC, based on DMSP data

Optical follow-up strategy

- Analysis based on the image subtraction:

Image from TAToO Follow-Up — Reference Image (No signal) — Residual Image

PSF matched

Cuts on :
SNR
Flux variation
FWHM …

- Development of a new pipeline for image analysis

Alerts

- Since 2009, 127 alerts:

GWGC local galaxies

Prompt analysis

Hypothesis: neutrino emission simultaneously with photons
➡ No transient optical counterpart associated with a neutrino detection
➡ Upper limits on transient sources magnitude

Alert	Delay (days)	U.L. Mag S/N=5	Galactic extinction
ANT100123A	0.64	12	0.2
ANT100302A	1.01	15.7	0.2
ANT100725A	8.7e-4	14.5	0.3
ANT100922A	4.7e-2	14.0	0.5
ANT101211A	0.50	15.1	0.1
ANT110409A	3.0e-3	18.1	6.7
ANT110529A	5.2e-3	15.6	1.2
ANT110613A	7.8e-4	17.0	2.3
ANT120730A	2.4e-4	17.6	0.2
ANT120907A	2.9e-4	16.9	0.2
ANT121010A	2.8e-4	18.6	0.1
ANT121206A	3.1e-4	16.9	0.2

Based on only detected light curves [kann2010]

Conclusion

- ANTARES is a deep-sea neutrino telescope to observe the Universe

- TAToO: multi-messenger approach enhances the sensitivity to
  transient sources

- Image analysis:

  - New pipeline

  - Prompt analysis done: no candidate, upper limits on transient
    sources magnitude

  - Follow-up analysis to be done: search for a SN candidate