Optical Counterparts of High-Energy Sources by ESA Gaia

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Abstract

The ESA satellite in development Gaia to be launched in 2011 will focus on highly precise astrometry of stars and all objects down to limiting magnitude 20. Albeit focusing on astrometry related matters, the satellite will also provide photometric and spectral information and hence important inputs for various branches of astrophysics.

Within the Gaia Variability UnitCU7 and related work package Specific Object Studies there has been a sub-work package accepted for optical counterparts to celestial high-energy sources, a category which includes the optical counterparts (i.e. optical transients and optical afterglows, including counterparts of XRFs and yet hypothetical orphan afterglows) of GRBs.

Although the sampling of photometric data will not be optimal for this type of work, the strength of Gaia in such analyses is the fine spectral resolution (spectro-photometry) which will allow the correct classification of GRB-related triggers. The possibilities to detect and to analyze optical transients and optical afterglows of GRBs by Gaia is presented and discussed.

Gaia: Design Considerations

Astrometry (V < 20):
- completeness to 20 mag (on-board detection) ⇒ 109 stars
- accuracy: 10–25 μarcsec at 15 mag (Hipparcos: 1 milliarcsec at 9 mag)
- scanning satellite, two viewing directions
  ⇒ global accuracy, with optimal use of observing time
- principles: global astrometric reduction (as for Hipparcos)
- non-negligible fraction of OTs and OAs of GRBs will be within the detection limit

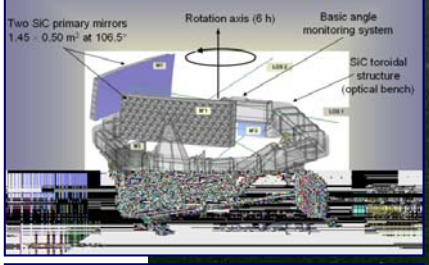
Photometry (V < 20):
- astrophysical diagnostics (low-dispersion photometry) + chromaticity ⇒ ΔT_{eff} ~ 200 K, log g, [Fe/H] to 0.2 dex, extinction

Radial velocity (V < 16–17):
- application: third component of space motion, perspective acceleration dynamics, population studies, binaries spectra: chemistry, rotation
- principles: slitless spectroscopy using Ca triplet (847–874 nm)

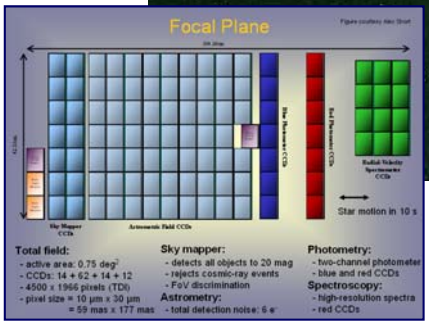
Gaia: Complete, Faint, Accurate

	Hipparcos	Gaia
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	20 mag
Bright limit	0	6 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance	1 kpc	1 Mpc
Quasars	None	5 x 10^5
Galaxies	None	10^6 – 10^7
Accuracy	1 milliarcsec	7 μarcsec at V = 10 10-25 μarcsec at V = 15 300 μarcsec at V = 20
Photometry	2-colour (B and V)	Low-res. spectra to V = 20
Radial velocity	None	15 km/s to V = 16-17
Observing	Pre-selected	Complete and unbiased

Payload and Telescope



Focal Plane



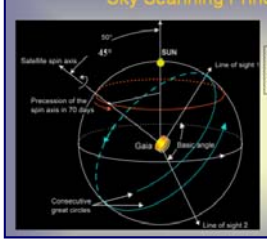
On-Board Object Detection

Requirements:
- unbiased sky sampling (mag, color, resolution)
- no all-sky catalogue at Gaia resolution (0.1 arcsec) to V~20

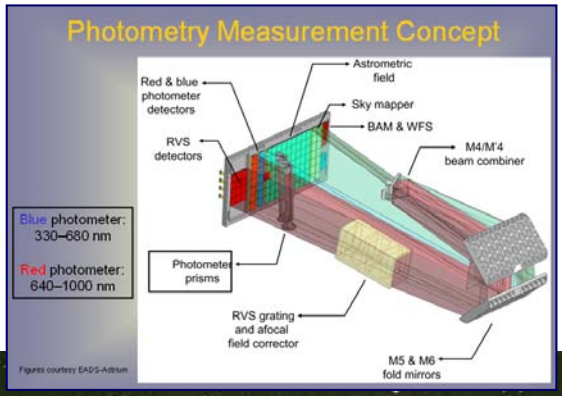
Solution: on-board detection:
- put catalogue or observing programme
- detection efficiency to V~21 mag
- alse-detection rate, even at high star densities

Will therefore detect:
- variable stars (eclipsing binaries, Cepheids, etc.)
- supernovae: 20,000
- microlensing events: ~1000 photometric; ~100 astrometric
- Solar System objects, including near-Earth asteroids and KBOs
- fraction of OTs and OAs of GRBs

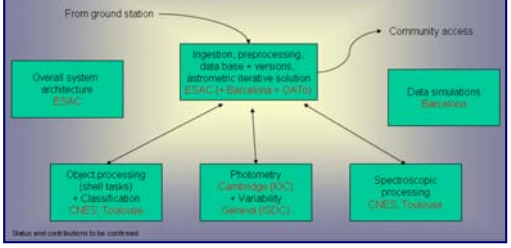
Sky Scanning Principle



Photometry Measurement Concept



Data Processing Concept (simplified)



Participation of Ondřejov HEA team

Natural extension of participation in INTEGRAL ISDC (since 1997).

Focus on Gaia CU7 Variability Processing Unit. R. Hudec member of Gaia CU7.

Two sub-work packages on CVs and Optical counterparts of High energy sources proposed, accepted, and allocated to R. Hudec

Additional participation in image processing – recently algorithms designed for scanned Schmidt spectral plates – simulation of Gaia data

Participation in Gaia CU7 DPC Data Processing Center as a natural continuation of participation in INTEGRAL ISDC. Participation in software development in a team, Java, object oriented programming

Robotic Telescopes run with the same RTS2 operating software: BART, BOOTES1, BOOTES2, BOOTES-IR, FRAM, WATCHER, D 50cm CCD Telescope (from 2007). Also small and private observatories may attend.

Collaborative efforts of several Czech Institutions

Gaia and GRBs: Photometry

There will be a variety of OTs detected by Gaia

The real OTs and OAs of GRBs can be, among these, recognized according to their characteristic power-law fading profie

However, the sampling provided by Gaia, is not optimal for these goals, hence not always we can expect realiable and confirmed detection of OT of GRB based only on photometry by Gaia

Gaia and GRBs: Spectroscopy

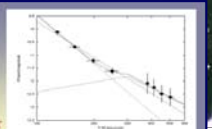
The primary strength of Gaia for GRB study is the fine spectro-photometry

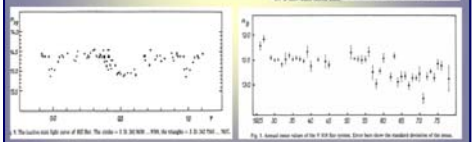
The OAs of GRBs are known to exhibit quite typical colors, distiguishing them from other types of astrophysical objects (Simon et al. 2001, 2004)

Hence a realiable classification of OTs will be possible using this method

Some examples

LMXRB
HMXRB
Optical Afterglows and
Optical Transients of GRB





Motivation of the Gaia CU7 Sub-workpackage on Optical Counterparts of High-Energy Sources

Most of HE sources (including OAs and OTs of GRBs) have also optical emission, mostly variable and accessible by Gaia

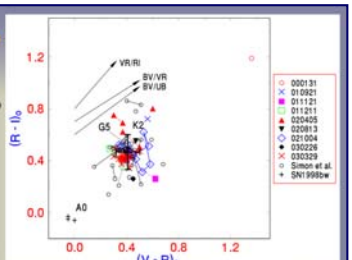
Monitoring of this variable optical emission provides important input to understanding the physics of the source

Multispectral analyses

The idea is to focus on sources not included in other categories of variable sources (eg. not on AGNs, CVs, etc.) covered by other sub-workpackages

Specific colors of OAs of GRBs

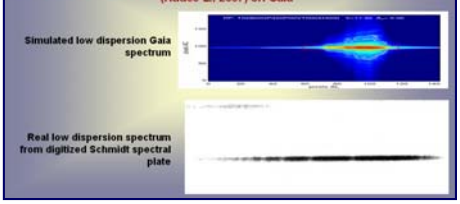
(Simon et al., 2001, 2004)



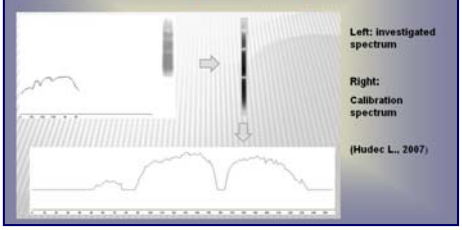
V-R vs. R-I diagram of OAs of GRBs ($t-T_0$ <10.2 days) in *observer frame*, corrected for the Galactic reddening. Multiple indices of the same OA are connected by lines for convenience. The mean colors (centroid) of the whole ensemble of OAs (except for GRB000131) are marked by the large cross. The colors of SN1998bw are shown only for comparison. The representative reddening paths for E_{B-V}=0.5 are also shown. Positions of the main-sequence stars are included only for comparison.

Variability studies based on low dispersion spectra

Application of algorithms developed for digitized astronomical archival plates (Hudec L., 2007) on Gaia



Automatic classification of stellar objective prism spectra on digitised plates, a simulation and a feasibility study for low-dispersion Gaia spectra



References

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Hudec, L., Algorithmes for automated spectral classification of stars, Bc. Thesis, Faculty of Mathematics and Physics, Charles University, Prague, 2007.
Simon V. et al., A&A 377, 450, 2001.
Simon V. et al., Baltic Astronomy 13, 253, 2004.