HERMES mission: probing GRBs with small satellites

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Overview

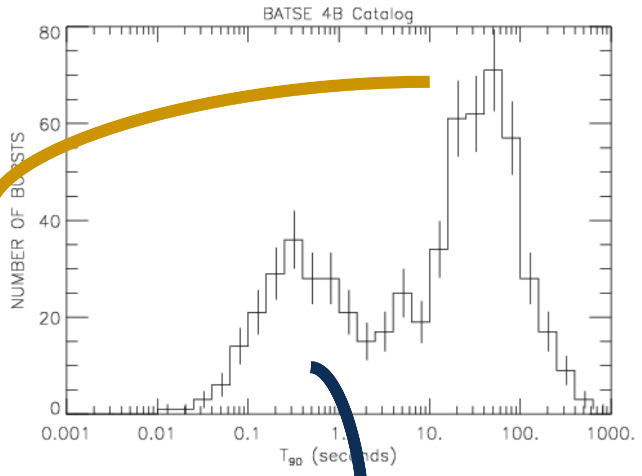
1. Gamma Ray Bursts and multi-messenger astronomy
2. HERMES mission profile and payload
3. Wrap-up

1. Introducing Gamma-Ray Bursts

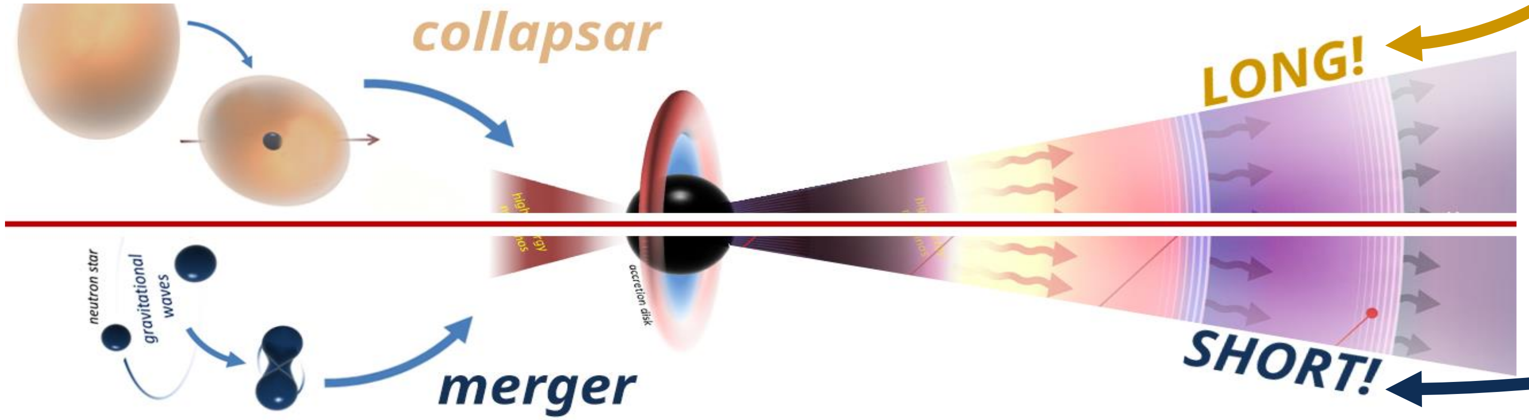
What is a Gamma-Ray Burst?

Most powerful sources of the γ-sky: $F \lesssim 10^{-3}\, erg\, s^{-1} cm^{-2}$.

Short time duration with bimodal distribution.



What cause a Gamma-Ray Burst?



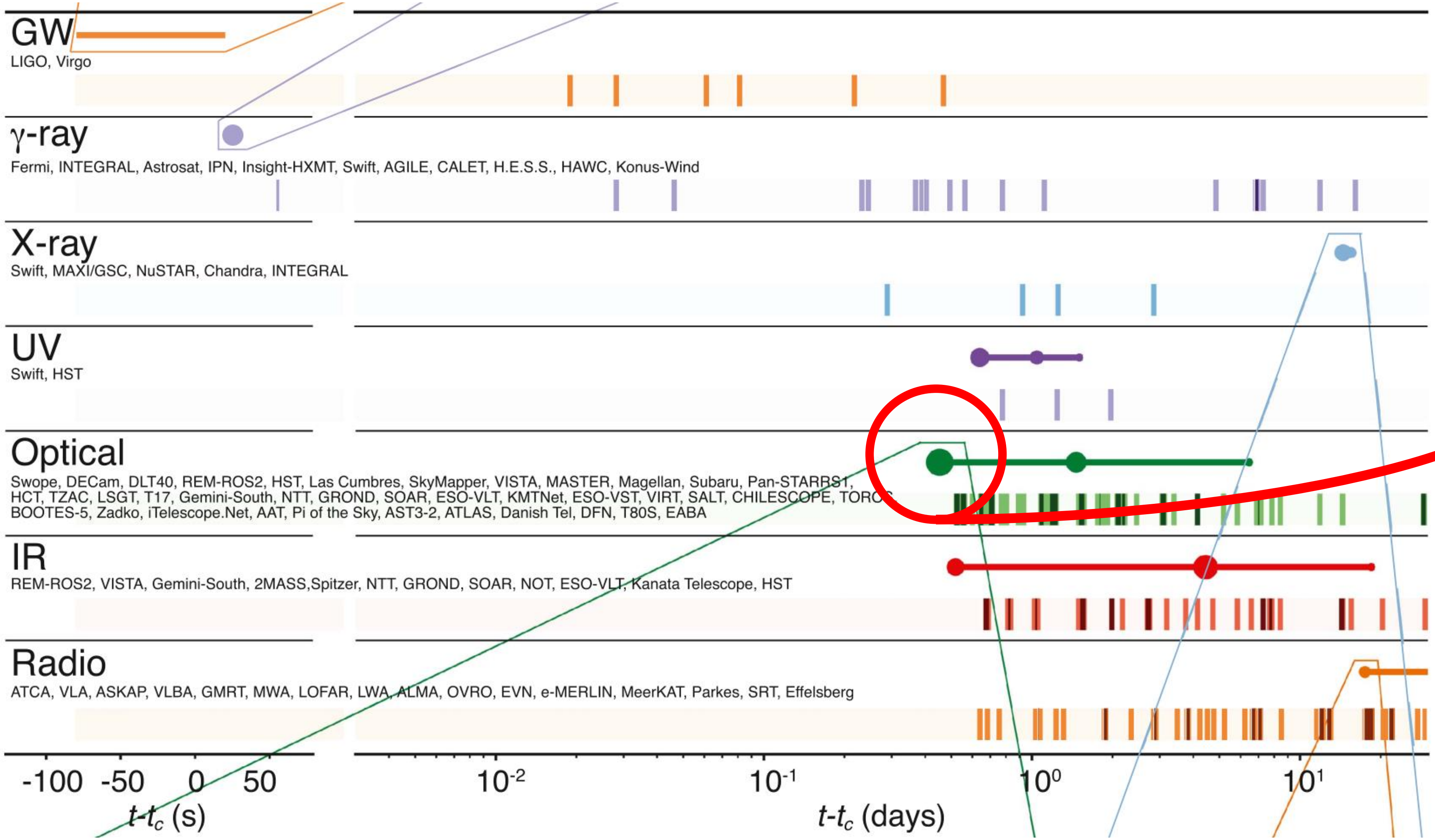
What happened on 17 August 2017?

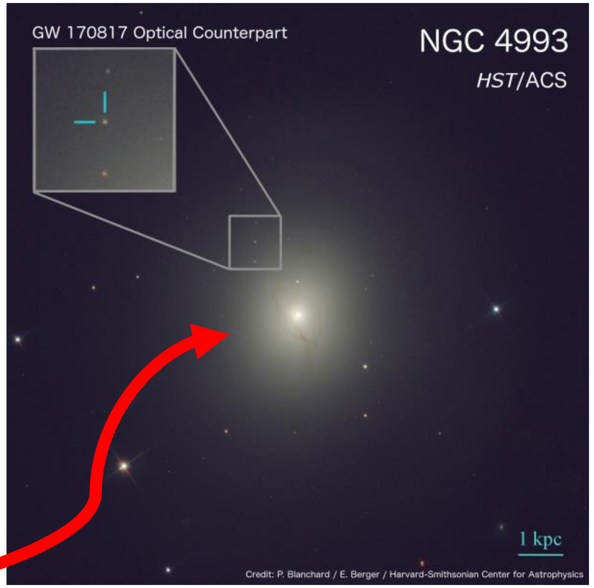
Combined EM-gravitational observations result in:

- For the first time a direct observation supports association between short GRBs and a binary neutron star coalescence event.
- Most complete characterization of BNS coalescence event to date.

17 August 2017 marks a milestone for multi-messenger astronomy.

17 August 2017: the key to success

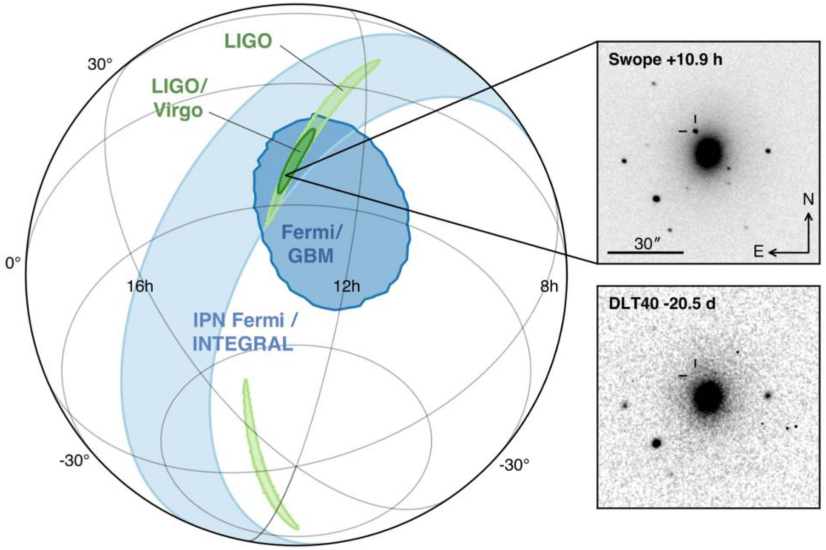




Quick identification of an optic counterpart to the event **at 40 MPc** in galaxy NGC4993!

The next decade of MMA

Timely **identification of the optic counterpart** has been possible thanks to the **closeness** of the event and the combined Ligo/Virgo – GBM $\sim 30\,\mathrm{deg}^2$ **accuracy**.



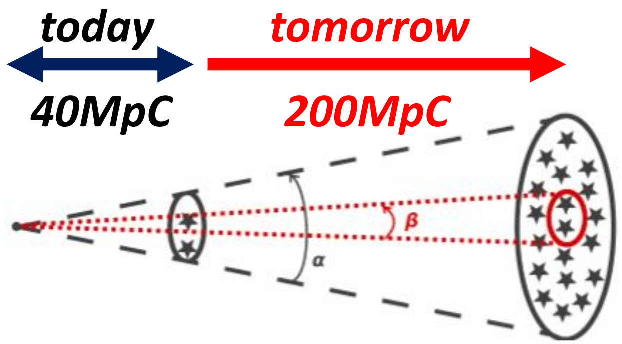


Figure 1.4: Number of sources in a patch of sky grows with the third power of the distance.

These accuracies will not be enough to support gravitational interferometers in the next decade.

We need an all-sky burst monitor with arcmin localization capability!

2. HERMES: scientific motivations

1. **All-sky arcmin to arcsec localization** of a sizeable ($> 100yrs^{-1}$) population **of GRBs with fast data dissemination**.
2. **Inquesting radiation mechanisms** studying GRB emission on a wide band of energies.
3. **Probing inner-engine activity** sampling lightcurves at fine time resolution.

..and technological requirements

1. **Large number of detectors** separated by a **large baseline distance** of several thousands km.
   Detectors collecting area of $50\ cm^2$ and total collecting area $\sim 0.5 - 1\ m^2$.

$\otimes$ ***time and € constraints*** → **CubeSats in LEO orbit**

2. **Wide energy range** of detectors covering at least the band between 5 and $300\ keV$, with ideal range spanning between **3 $\boldsymbol{keV}$ and 1 $\boldsymbol{MeV}$.**

3. Temporal **resolution of detectors** $\sim$ **1** μs.

$\otimes$ ***Si – detector expertise*** → **State-of-Art detectors**

How to localize GRBs

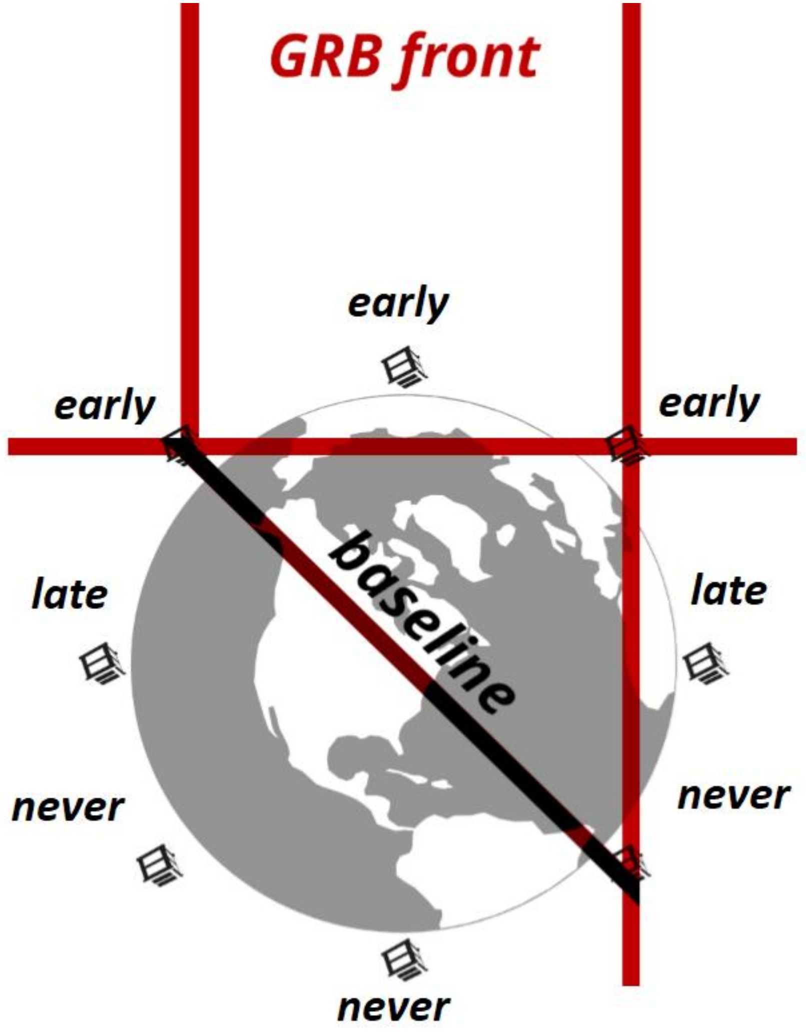
Traditional approach (VELA, IPN..).
Measure time delay between the arrival of GRB light signals on N units separated by d baseline.

$$\sigma \sim c \cdot \frac{\sqrt{\sigma_{cc}^{2} + c^{-1} \cdot \sigma_{\vec{r}}^{2} + \sigma_{t}^{2} + \sigma_{sys}^{2}}}{d \cdot \sqrt{N-3}}$$

LEO $\Longrightarrow$ $d \sim 7000\text{km}$.
GPS $\Longrightarrow$ $\sigma_t \sim 10\,\text{ns}$ and $c^{-1} \cdot \sigma_{\vec{r}} \sim 30\text{ns}$.

$$\sigma \sim 2.4\,\text{deg} \cdot \frac{\sqrt{\sigma_{cc}^{2} + \sigma_{sys}^{2}}}{\sqrt{N-3}}$$

For $\sigma_{SYS}, \sigma_{CC} \sim 50\ \mu s$ and $N = 60$ we get $\sigma{\sim}1$ arcmin.

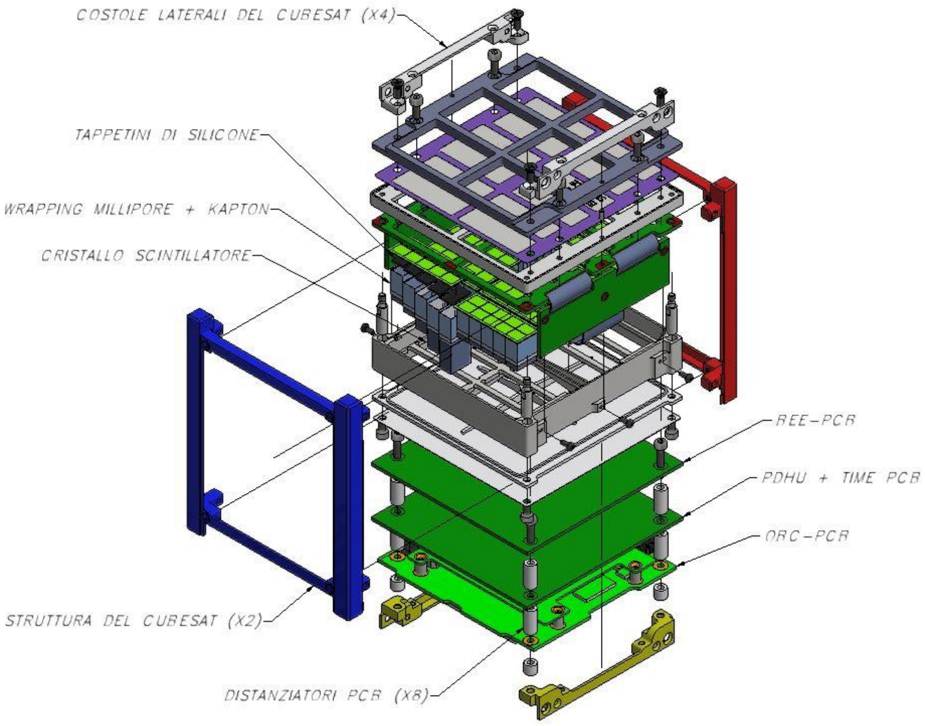


Wide-band energy detectors

Great detectors in small s/c come with..

Constraints!

- Wide energy band.
- Compact ⟷ 3U CubeSat
- Efficient ⟷ $4\ W$ for the entire SC
- Light-weight ⟷ $6\ kg$ for the entire SC
- Undemanding ⟷ No ATCS



Fine timing GRB lightcurves

Flux in band $50 - 300\ keV \sim 10\ ph\ s^{-1} cm^{-2}$.

HERMES S/C detector surface $\sim 50\ cm^2$.

Detector efficiency $\lesssim 1$.

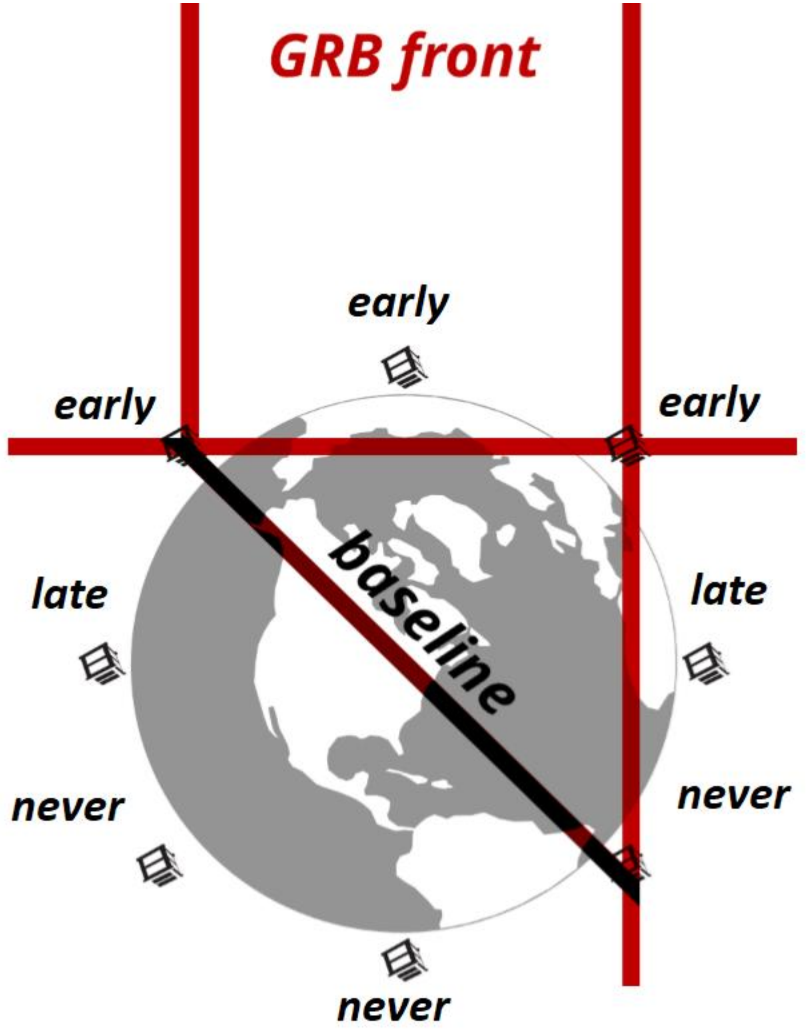
Cross-correlating signals: $5\ ph\ ms^{-1}$ with $N \sim 10$.

BUT we are mounting **wide-band detectors**, so:

Flux in band $5 - 50\ keV \sim 10\ ph\ s^{-1} cm^{-2}$.

Henceforth $N \rightarrow \frac{N}{2} \sim 5$.

→ **Mission modularity!**



HORIZON 2020

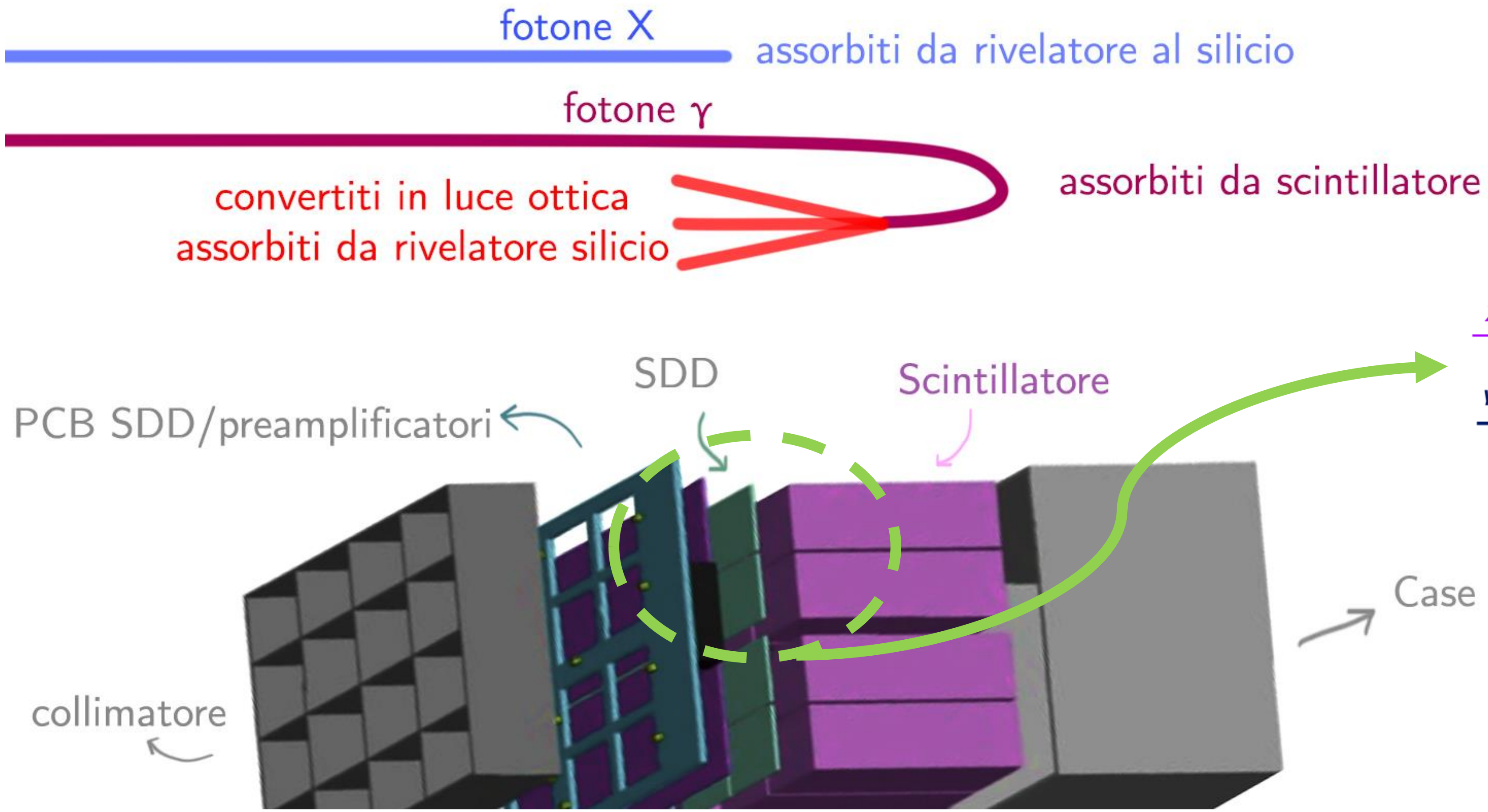
Silicon Drift Detectors

SDD = Silicon Drift Detector

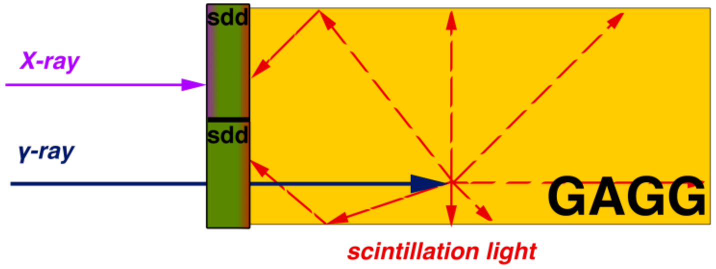
Remarkable features:

- Efficient in soft-X at standard thickness $450\ \mu m$.
- Low noise: $< 10\ e^{-}\ rms, 25\ pA\ cm^{-2}$ at room temp.
- Efficient: \w VEGA-like ASICs,$\sim mW$ per channel.
- Decent radiation hardness
- Slower when compared to other Si-detectors.

Payload at work



note!



Discrimination between X and γ photons is achieved through segmented design

Wrap-up

HERMES will provide the **all-sky GRB monitor** much needed in order to support the next decade of multi-messenger observations.

Beside this supportive role, HERMES will be able to do – possibly breakthrough! - **new science** on its own.

This will be possible within **CubeSat** framework and **on tight** (*t* and $) **budget**, exploiting an innovative detector and intrinsic highly **modular architecture**.

The first 6 HERMES units have been funded by H2020 programme and ASI and are expected to launch in 2021 on equatorial LEO orbit.