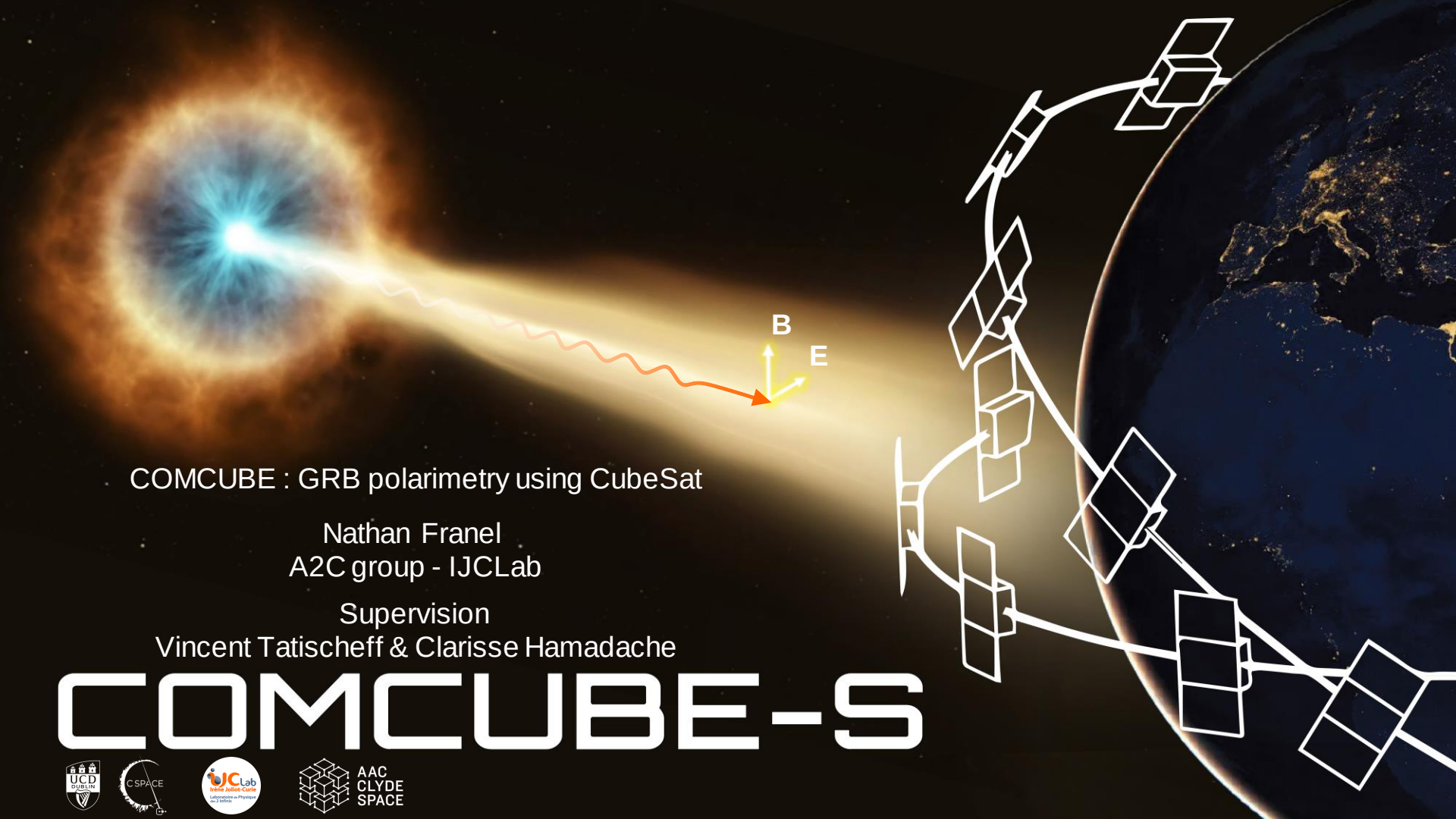


COMCUBE : GRB polarimetry using CubeSat

Nathan Franel
A2C group - IJCLab

Supervision
Vincent Tatischeff & Clarisse Hamadache

# COMCUBE-S

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# 1 Scientific context

## Gamma-ray Bursts

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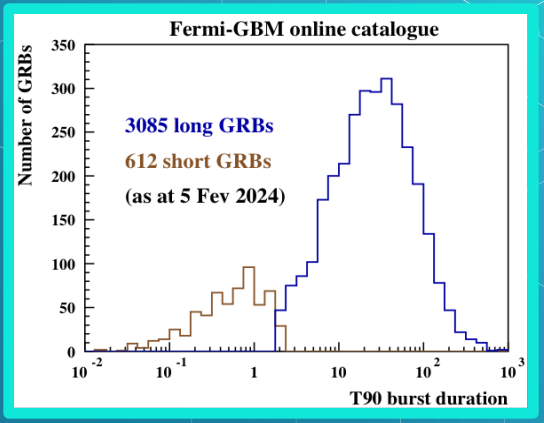
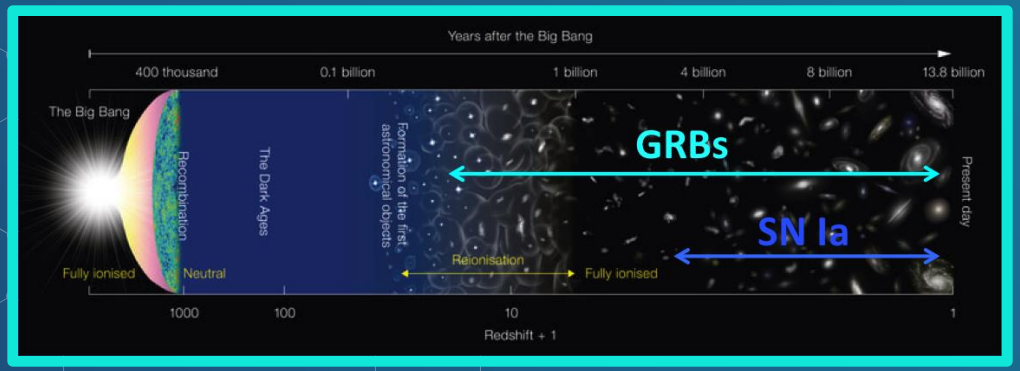
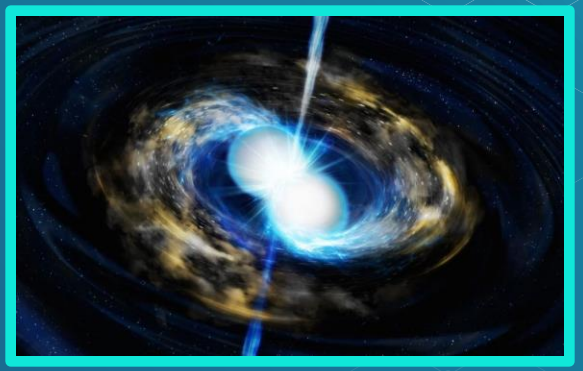
# Gamma-ray bursts

- **Brightest, most violent explosions in the Universe**
- Roughly once per day at cosmological distances, detectable in the very first galaxies, up to redshift z > 10
- Death of very massive stars (long GRBs, $T_{90}$ > 2s) or the merger of compact objects (short GRBs)
- Could become **new standard candles in cosmology** if the physics of **ultra-relativistic jets** ($\Gamma$ > 100) was better understood



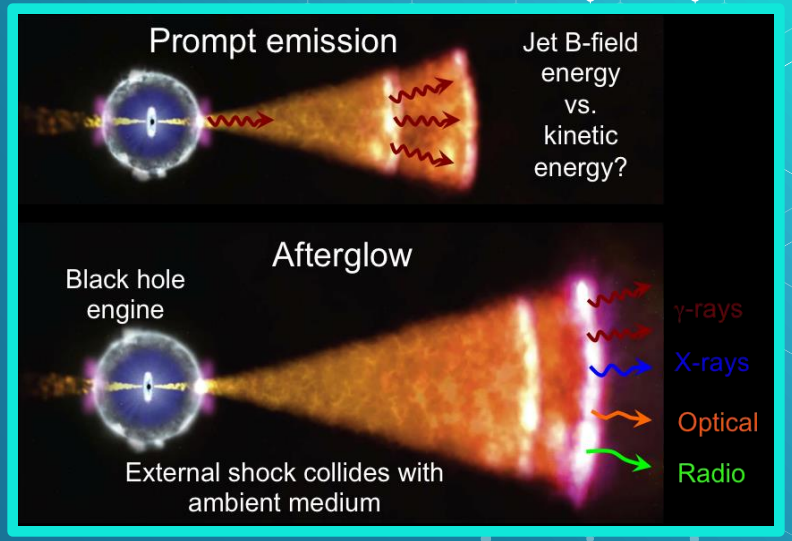



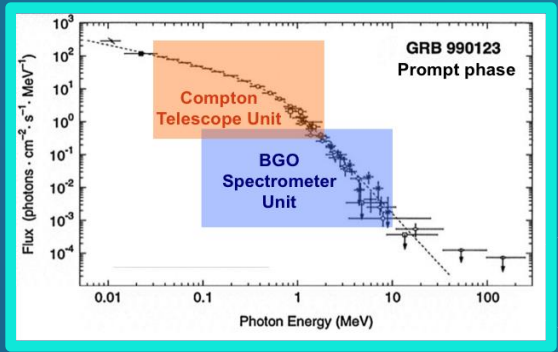



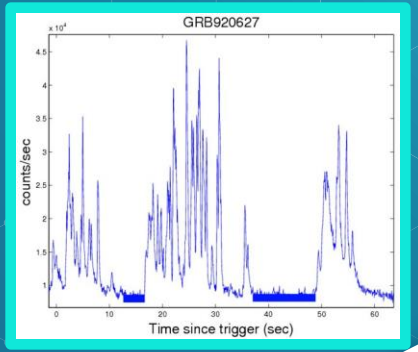
# GRB prompt emission

- Four main models for GRB prompt emission:
  - Non-thermal synchrotron radiation in ordered magnetic fields
  - Non-thermal synchrotron in turbulent magnetic fields
  - Inverse Compton scattering in a thermal photon field
  - Photospheric radiation

Spectral and light-curve information is insufficient for understanding the plasma composition, the B-field origin & the main energy dissipation process in GRB jets



# GRB polarimetry


- **Linear polarisation** of GRB prompt emission
  - Over the duration of the burst
  - Even better : time resolved measurement
    - → Magnetic fields carried by jets and their geometry
    - → Emission mechanism
  - **Very complicated measurements**
    - GRB spectra peak around ~100 keV : atmosphere absorbs this light
      - → Use of detectors in low orbit
    - Uncertainties are considerable

2

# The COMCUBE-S project

## Measurement principle and mission

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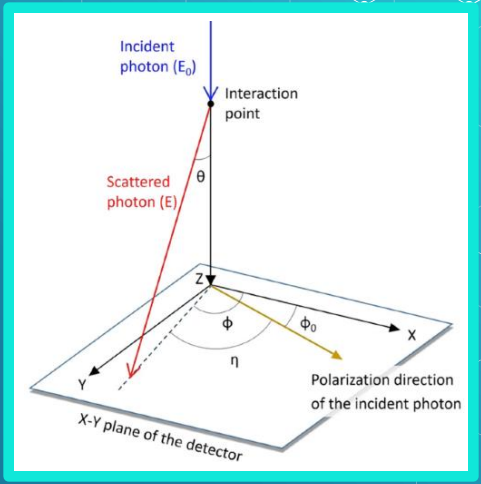
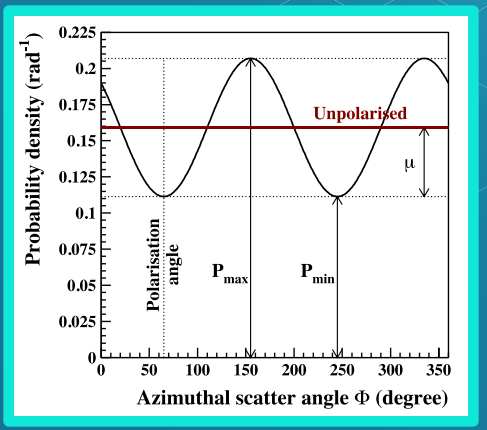
# Compton Polarimetry

- Polarisation information can be recovered using the Compton effect.
  - Linearly polarised photons tend to scatter perpendicularly to the incident polarisation vector.
- The scattering angle distribution gives the polarisation information.



# MDP/SNR

2 main quantities to assess the performance of the instrument

MDP : Minimum Detectable Polarisation for a given instrument and a given source

$$MDP = \frac{4.29\sqrt{S+B}}{\mu_{100} S}$$

→ Number of GRBs detectable with enough sensitivity

SNR : Signal to Noise Ratio

$$SNR = \frac{S}{\sqrt{B}}$$

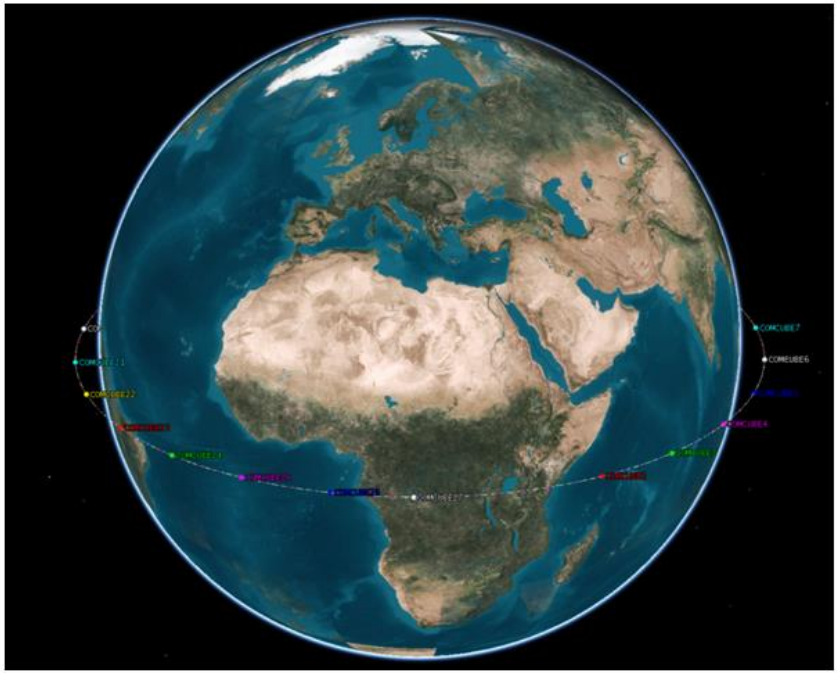
→ Number of GRBs that trigger the detectors

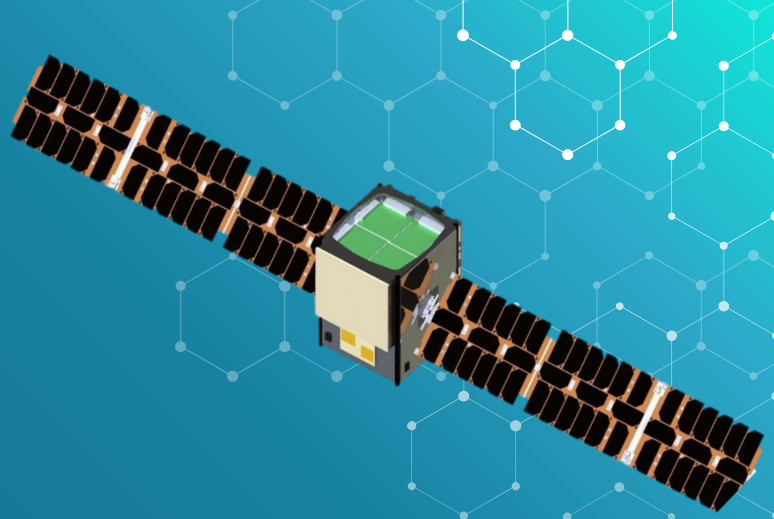
With : S the signal count from the source, B the background count, $\mu_{100}$ the modulation factor ( ~ polarimeter efficiency)

# COMCUBE-S - An ESA proposal

| | | |
|---|---|---|
| Clyde Space<br>Space specialized company | University College Dublin | IJCLab |
| Spacecraft, communication | Science payload, science objectives, performance estimation | |

# Mission baseline





- Constellation of 27 COMCUBE CubeSat
  - 12 Units (20cm x 20cm x 30cm)
  - Powered with solar panels
  - Equatorial orbit & equally spaced
  - Energy range : 30-1000keV

Selected for phase A study !

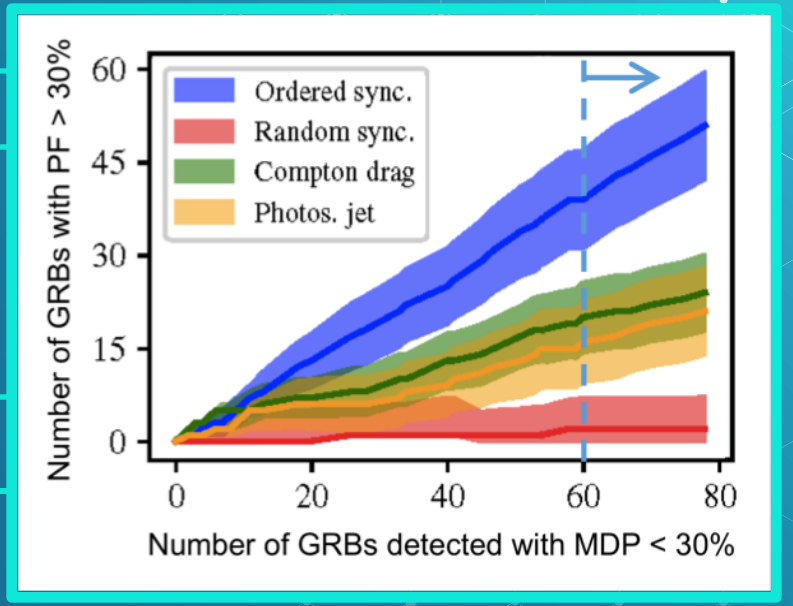
# Science objectives

Goals :

Improve our understanding of astrophysical jets :

- Measure more than 60 GRBs with a minimum detectable polarisation of at least 30%
- Measure time resolved polarisation

Cover the whole sky for fast detection of transient events



3

# GRB simulations

## Estimation of performances

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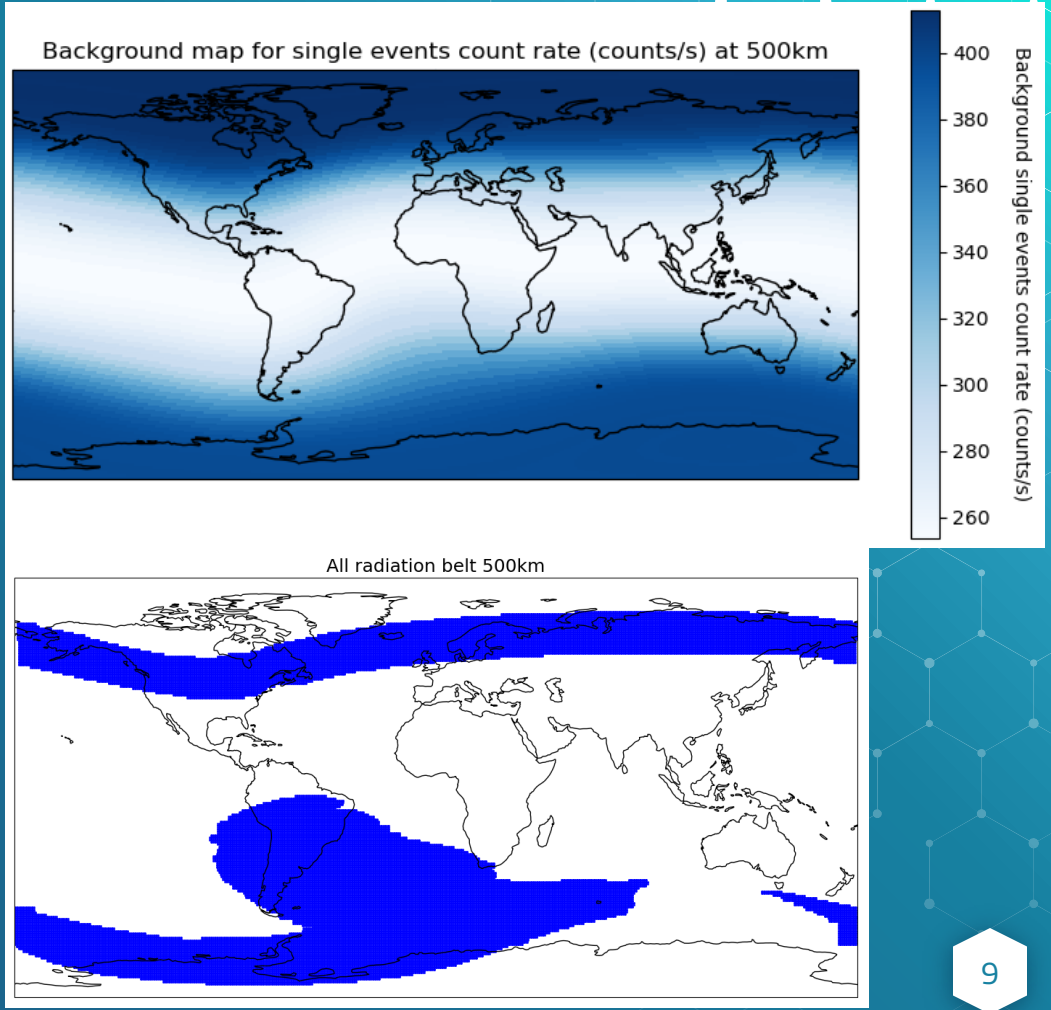
# Background

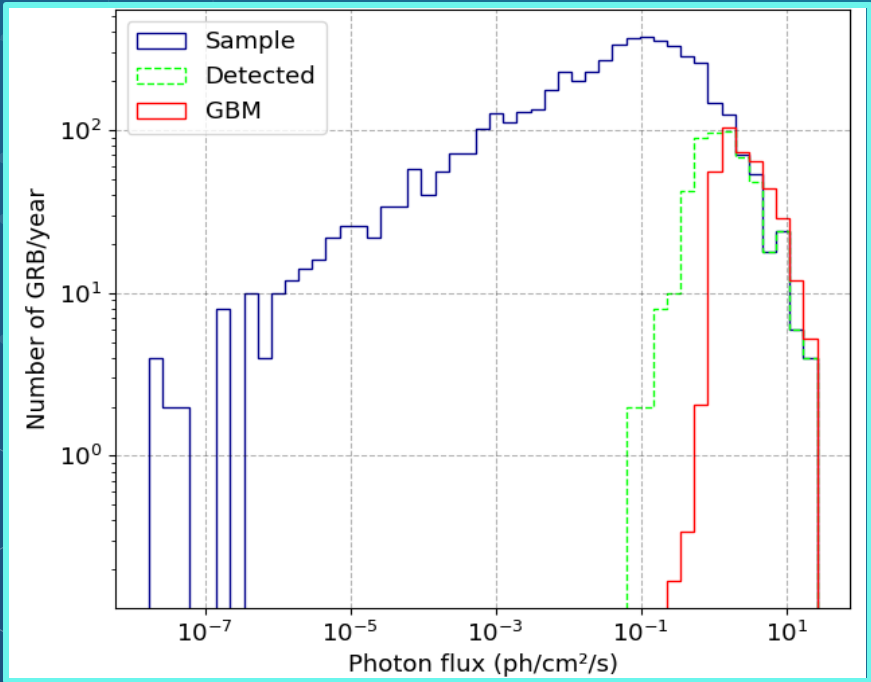
Low Earth orbite background at 500km
→ Less background at low latitude

Non operation zones due to excessive fluxes of trapped protons and electrons.
Based on NASA's AP8 and AE8 models.
→ Less radiations at low latitude

Equatorial orbit is prefered as both backgro und and radiation belts are weaker



# Samples used




We use Fermi GBM sample to simulate the GRBs using the software MEGAlib.

As detection capabilities are better than the ones of GBM, synthetic GRBs are also used to simulate fainter bursts

Synthetic sample are developped with distributions from previous missions to estimate GRB :

- Duration (T90)
- Redshift
- Number of GRB/year at this redshift
- Luminosity
- Spectrum
- Light curve

# Detection results

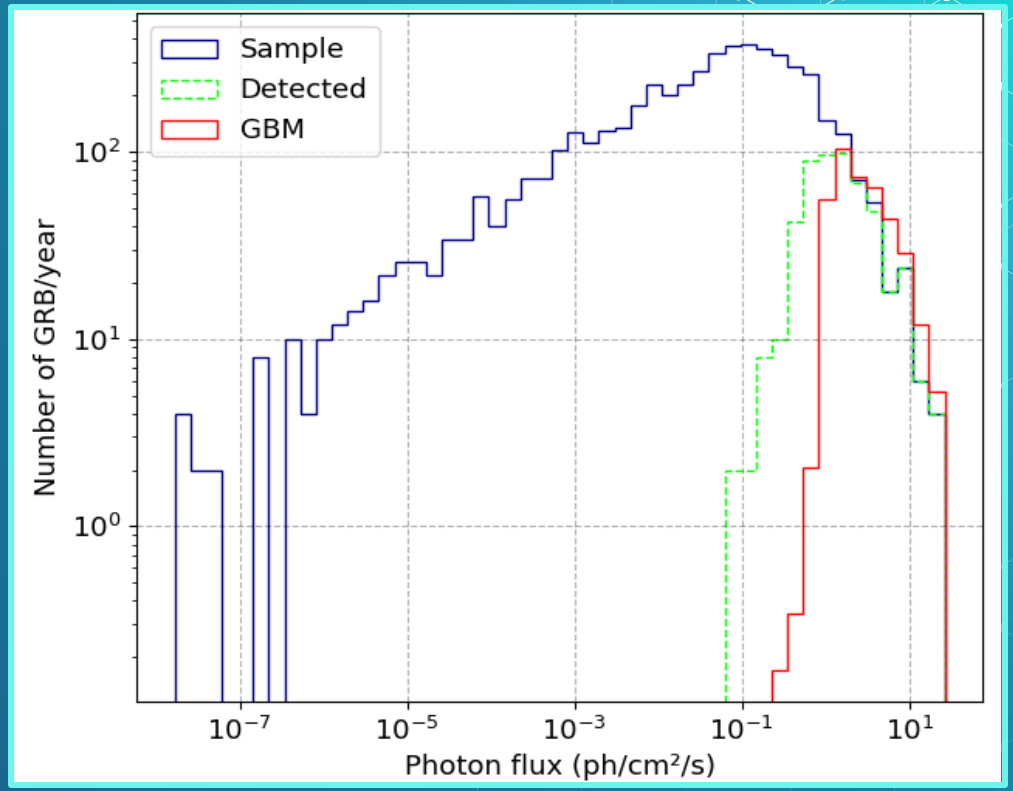
Study with GBM bursts :

- 2293 simulated
- 2290 detected

GRB detection rate ~ 380/year

Study with synthetic sample :

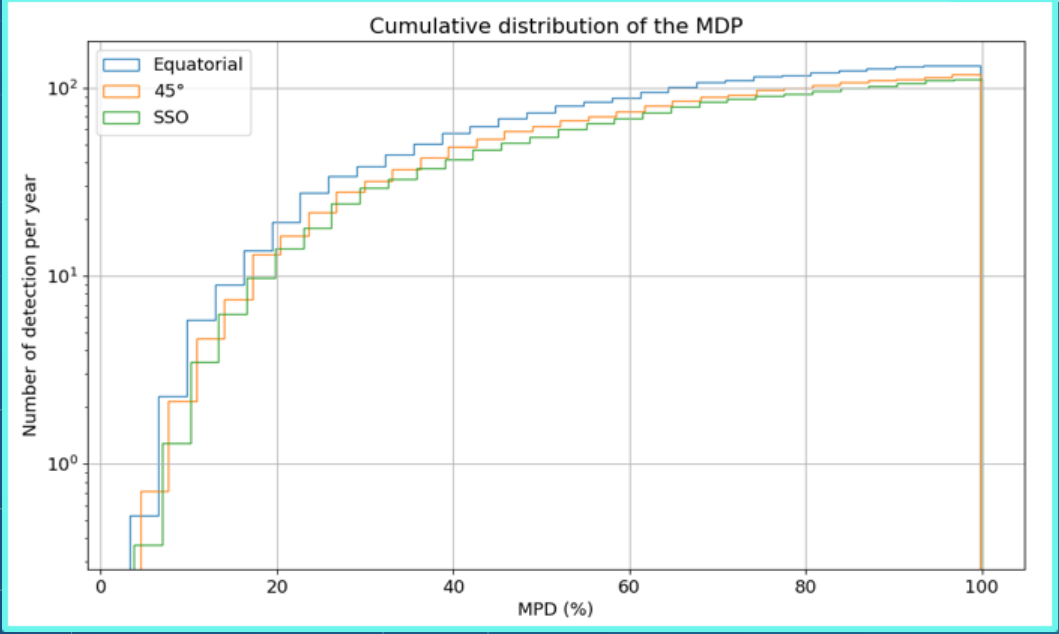
GRB detection rate ~ 520/year



# Polarisation results

| | $i = 0°$ | $i = 45°$ | $i = 97.4°$ (SSO) |
|---|---|---|---|
| All S/C working | 35.6 | 28.2 | 24.9 |
| 1 S/C off | 34.9 | 27.3 | 23.5 |
| 2 S/C off | 33.0 | 24.8 | 21.7 |
| 3 S/C off | 28.7 | 21.5 | 19.9 |
| 5 S/C off | 18.5 | 14.1 | 11.6 |

Number of GRB with MDP <=30% per year




- Best performance for an equatorial orbit.
- With a constellation of 27 satellites :
  - Detection of more than 35 GRB/year with a MDP<= 30%

With a 2 years mission we could constrain the GRB emission models

# Conclusion

- COMCUBE-S may lead to an ESA funded mission (~100M€)

  Now in phase A

- Learn about GRB jet physics & full sky monitoring of transient events

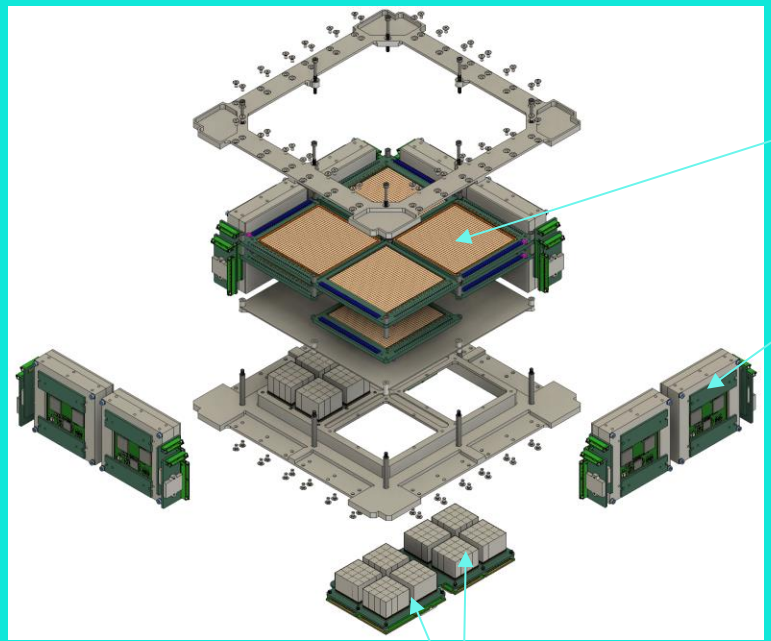
  Use for cosmology and studying transient objects with a multi-messenger approach

- 27 satellites in equatorial orbit would give a better sensitivity than Fermi GBM

- New technology for gamma ray polarisation measurement in space

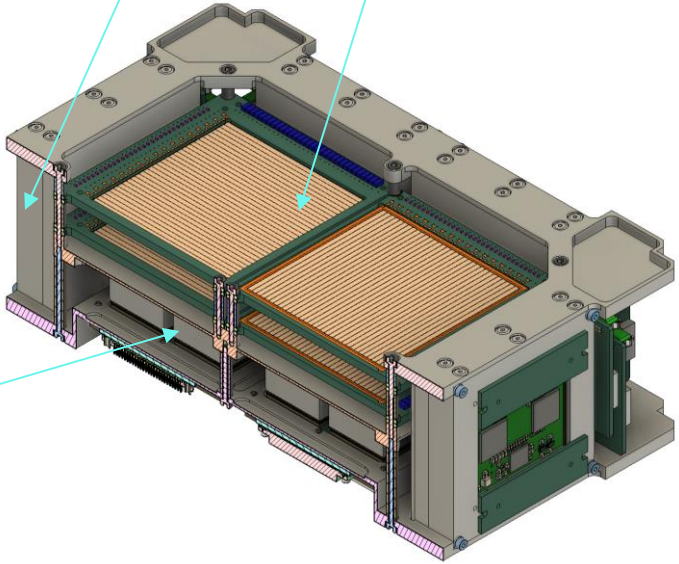
# Backup : Science payload

## Compton polarimeter



IJCLab/CEA DSSSD

IJCLab scintillator



UCD scintillator