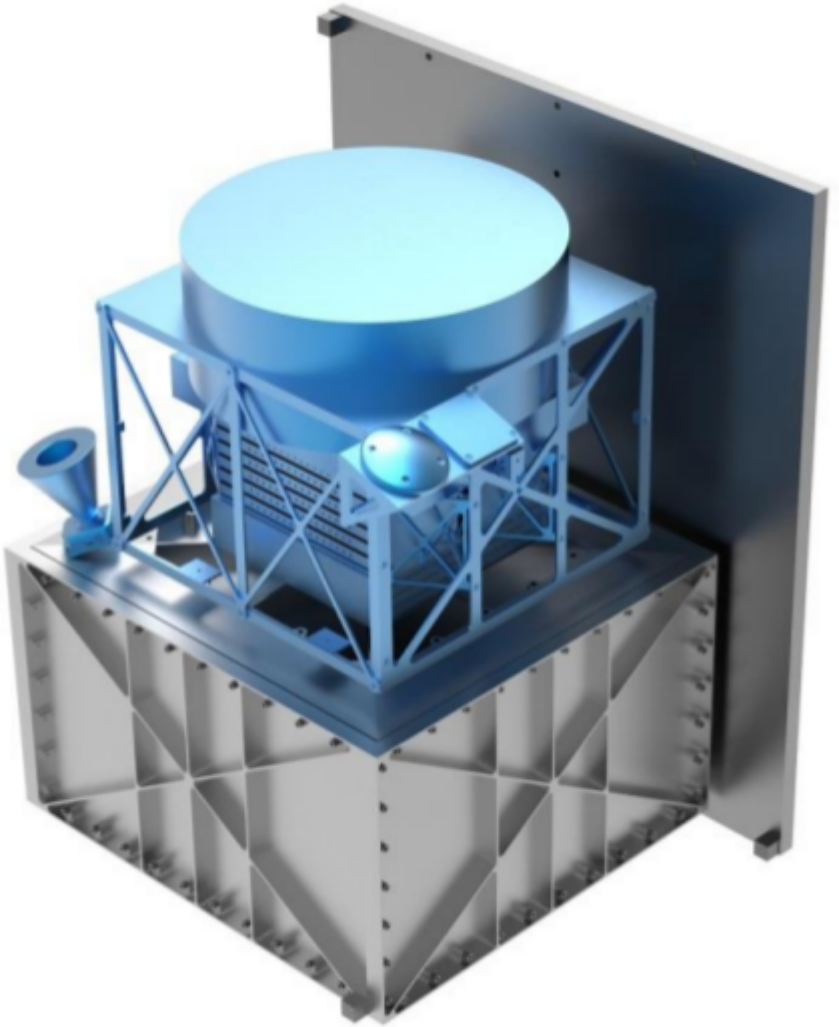
SPHiNX – A GRB polarimeter



Partikeldagarna 2017

- Nirmal Iyer
On behalf of the SPHiNX collaboration

InnoSat – 2

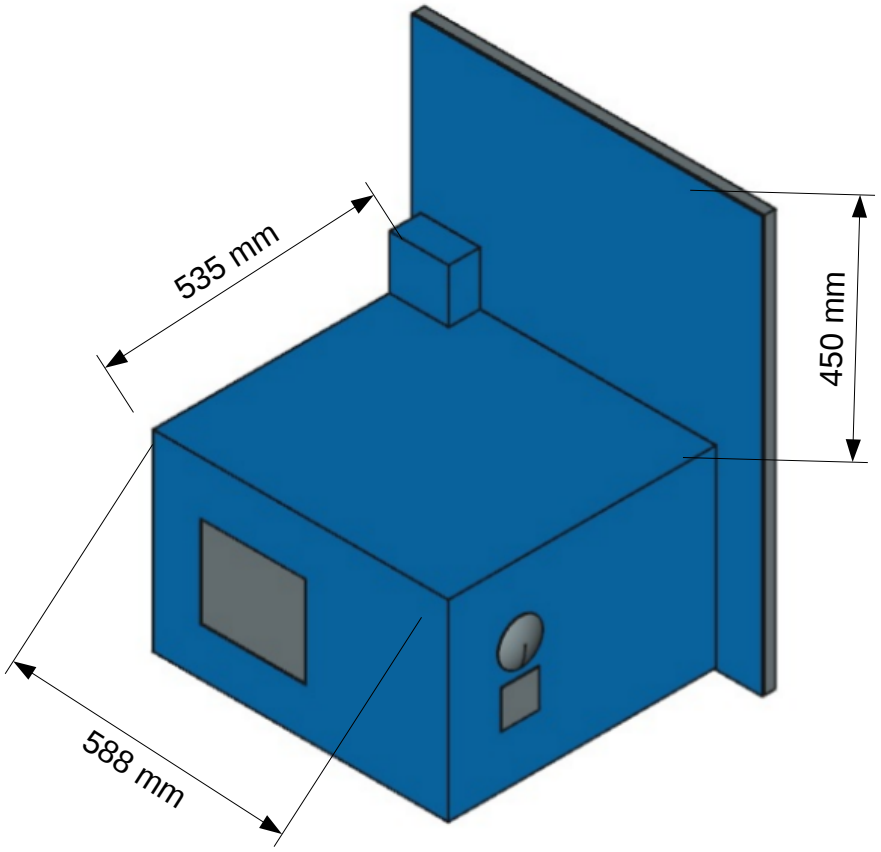
A satellite platform for the next “Innovativa Forskningsatellit”.

- Call for proposal by the Swedish National Space Board (SNSB).
- Satellite platform provided by OHB Sweden

InnoSat – 2

A satellite platform for the next "*Innovativa Forskningsatellit*".

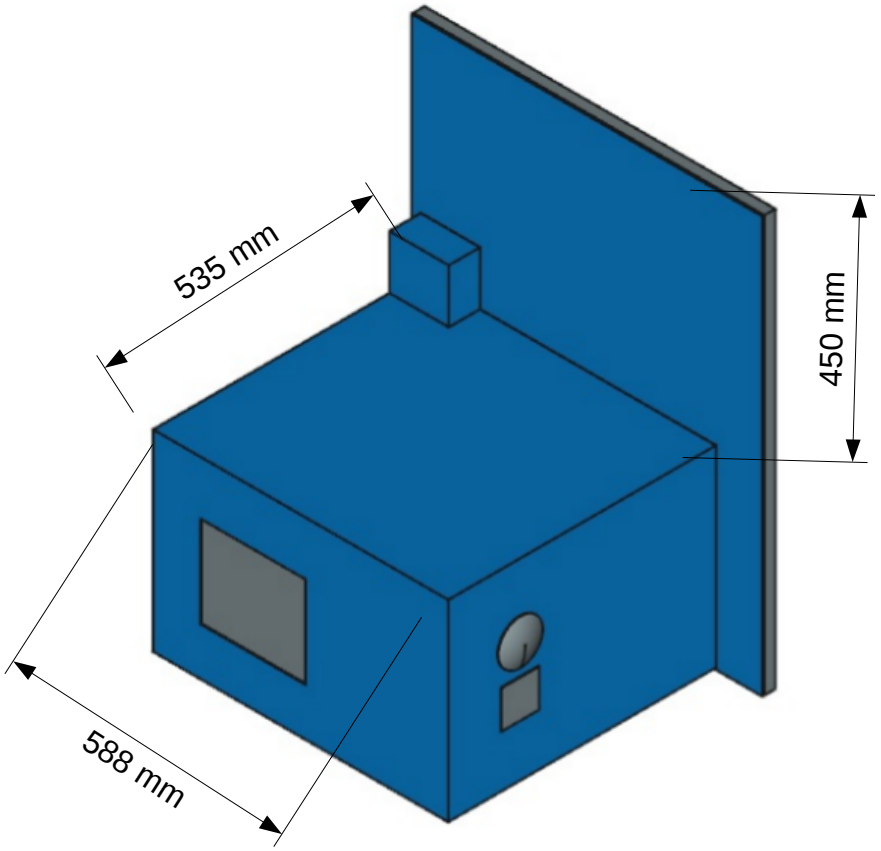
Swedish National Space Board (SNSB)
OHB Sweden



	Standard Platform
Orbit	540 km altitude, 53° inclination
Mass	25 kg
Power	30 W
Data	150 Mbyte / contact
Pointing	
Accuracy	0.1°
Knowledge	0.01°

What '*Innovativa forskning*' can we do ?

- Polarisation studies in high energy X-rays
- Bright sources
- Not very strict pointing constraints



	Standard Platform
Orbit	540 km altitude, 53° inclination
Mass	25 kg
Power	30 W
Data	150 Mbyte / contact
Pointing	
Accuracy	0.1°
Knowledge	0.01°

What '*Innovativa forskning*' can we do ?

- Polarisation studies in high energy X-rays
- Bright sources
- Not very strict pointing constraints

Gamma Ray Bursts !!

	Standard Platform
Orbit	540 km altitude, 53° inclination
Mass	25 kg
Power	30 W
Data	150 Mbyte / contact
Pointing	
Accuracy	0.1°
Knowledge	0.01°

What '*Innovativa forskning*' can we do ?

devil in the details

- Gamma Ray Bursts

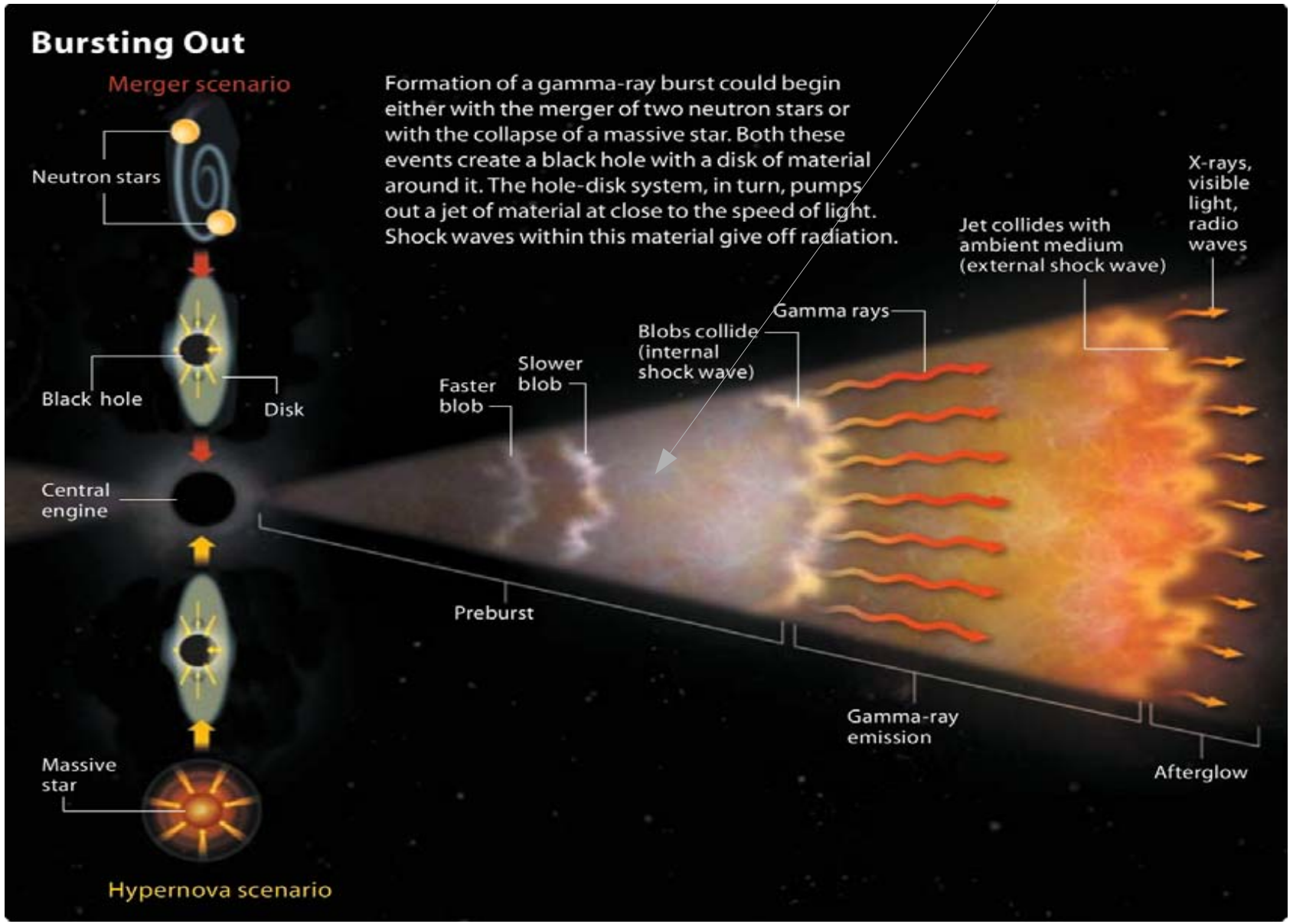
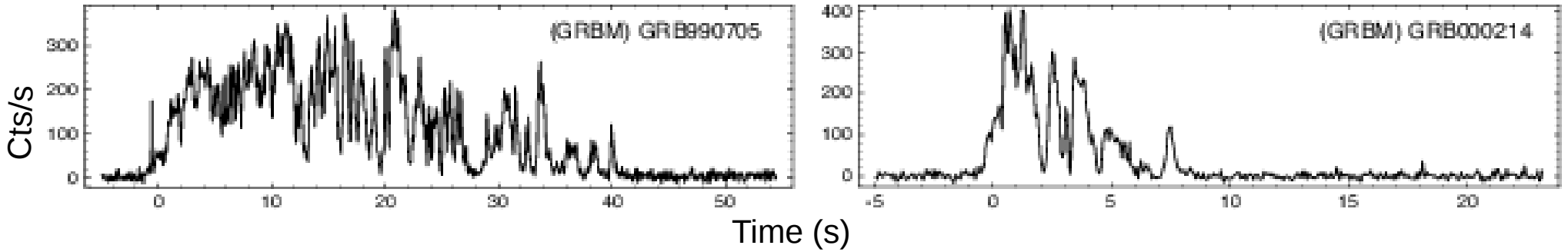


Figure from Gehrels + 2007

What '*Innovativa forskning*' can we do ?

- Prompt emission

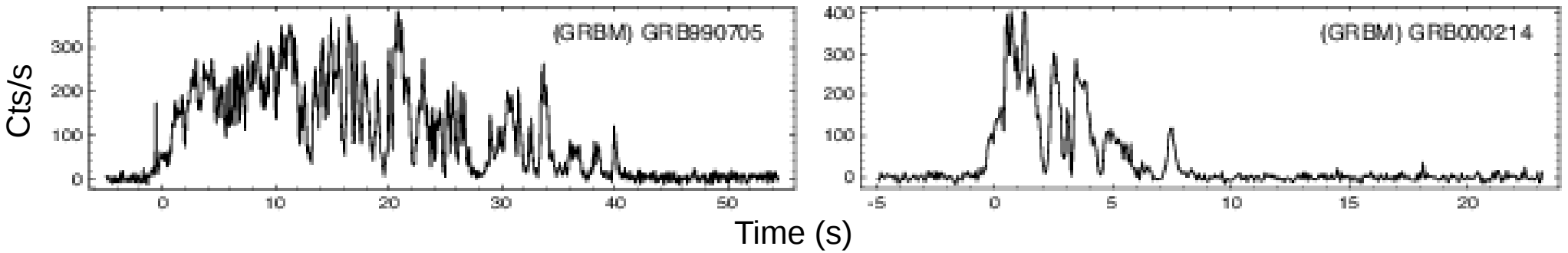
Figure from Borgonovo + 2007



What '*Innovativa forskning*' can we do ?

- Prompt emission

Figure from Borgonovo+ 2007



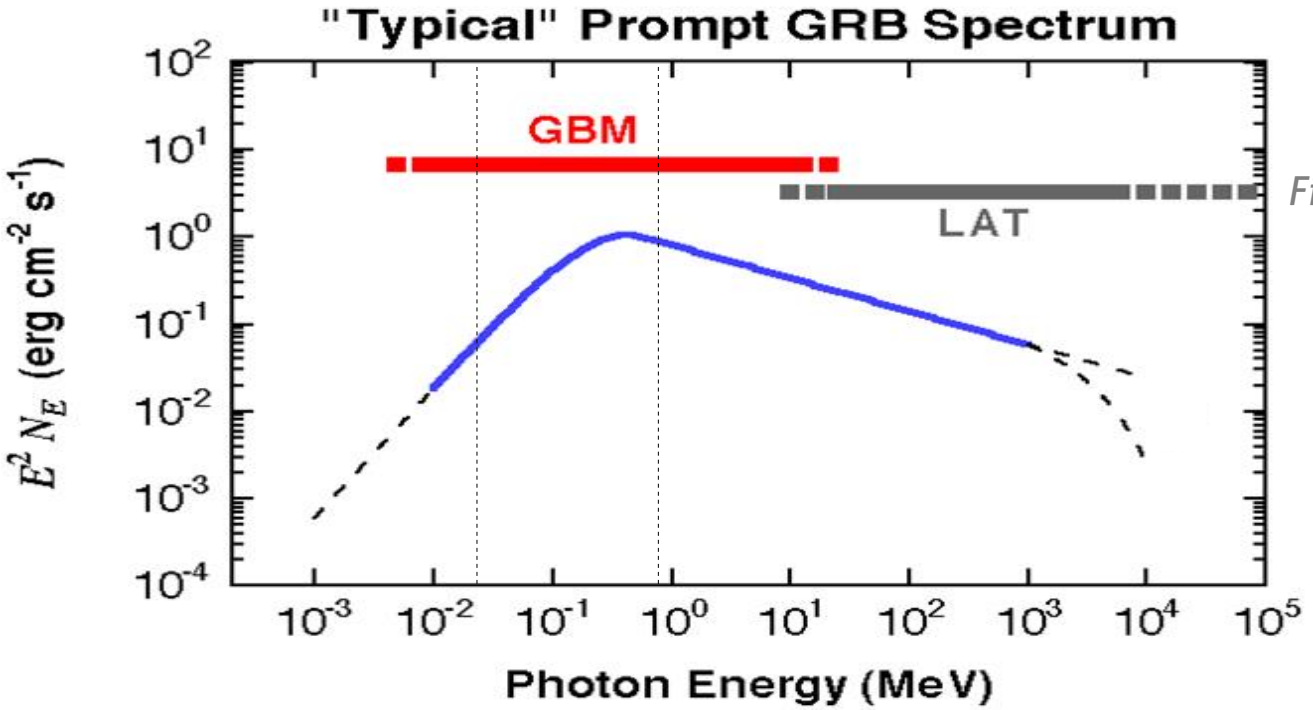


Figure courtesy NASA

- Multiple competing models which explain the gamma ray spectrum and time variations

Synchrotron / Inverse Compton / Photospheric

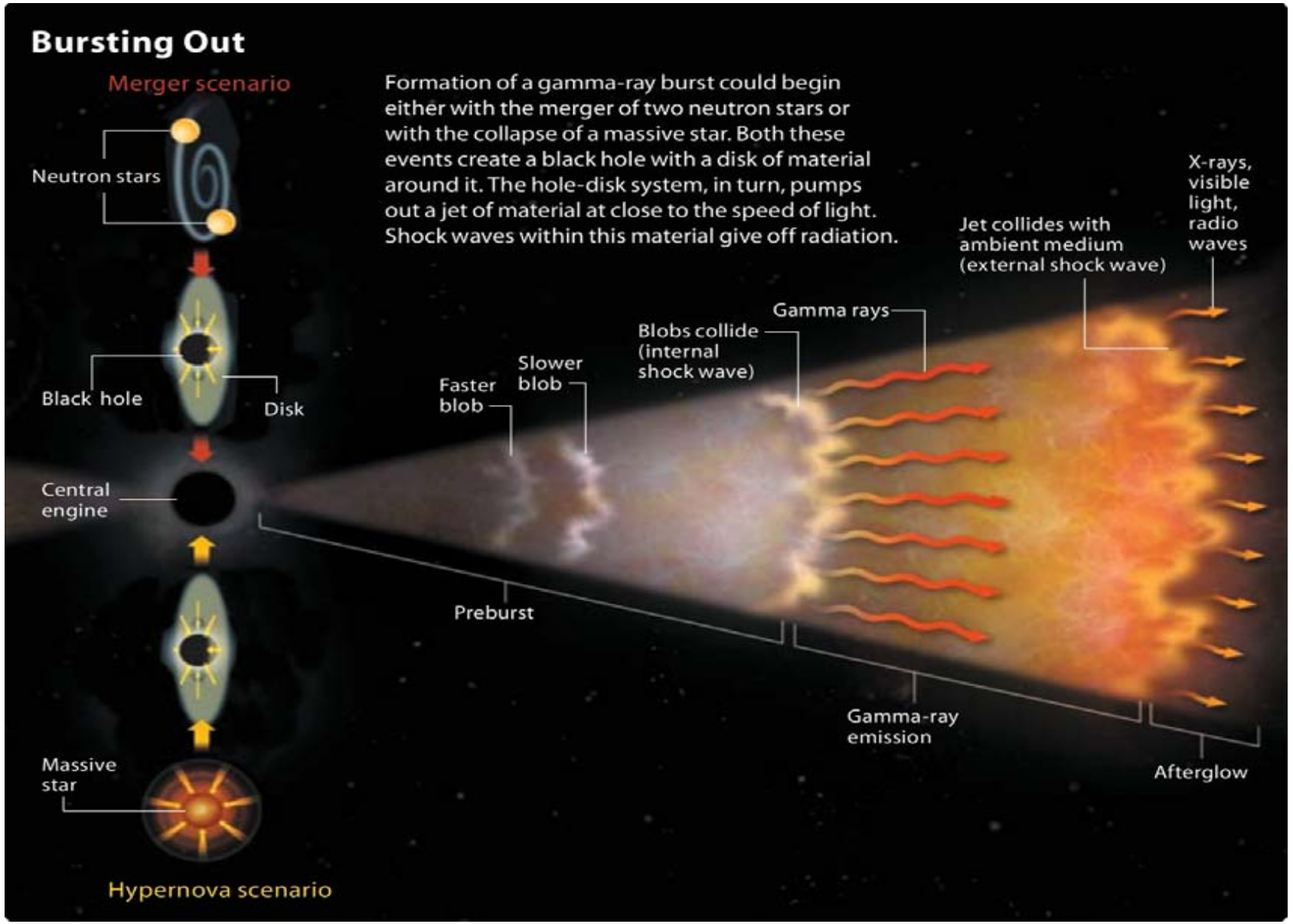


Figure from Gehrels+ 2007

Polarisation studies of Prompt emission

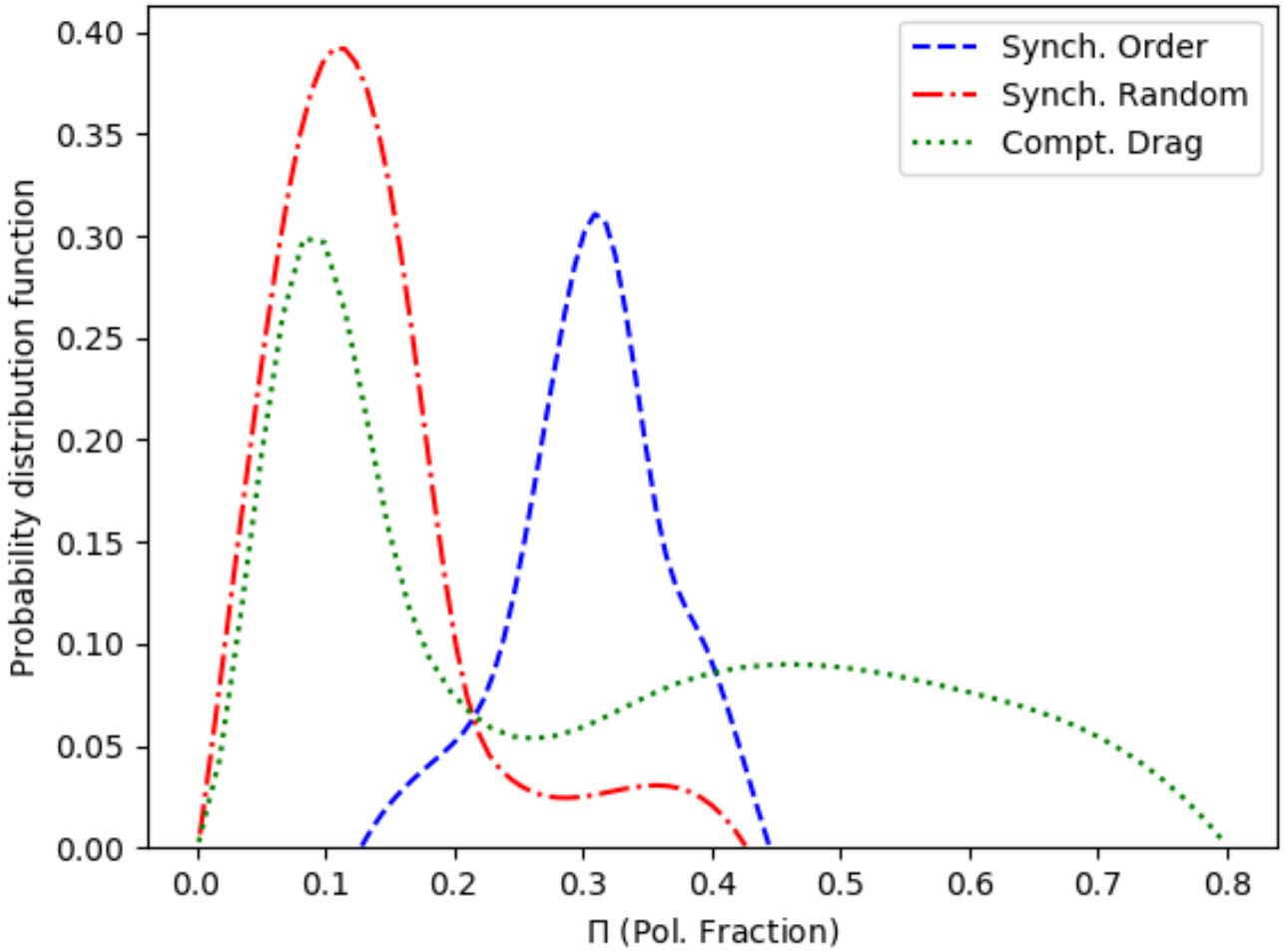


Figure made from data in Toma+ 2009

Science Case

- Polarisation measurements of the prompt gamma ray emission to learn more about the emission mechanisms

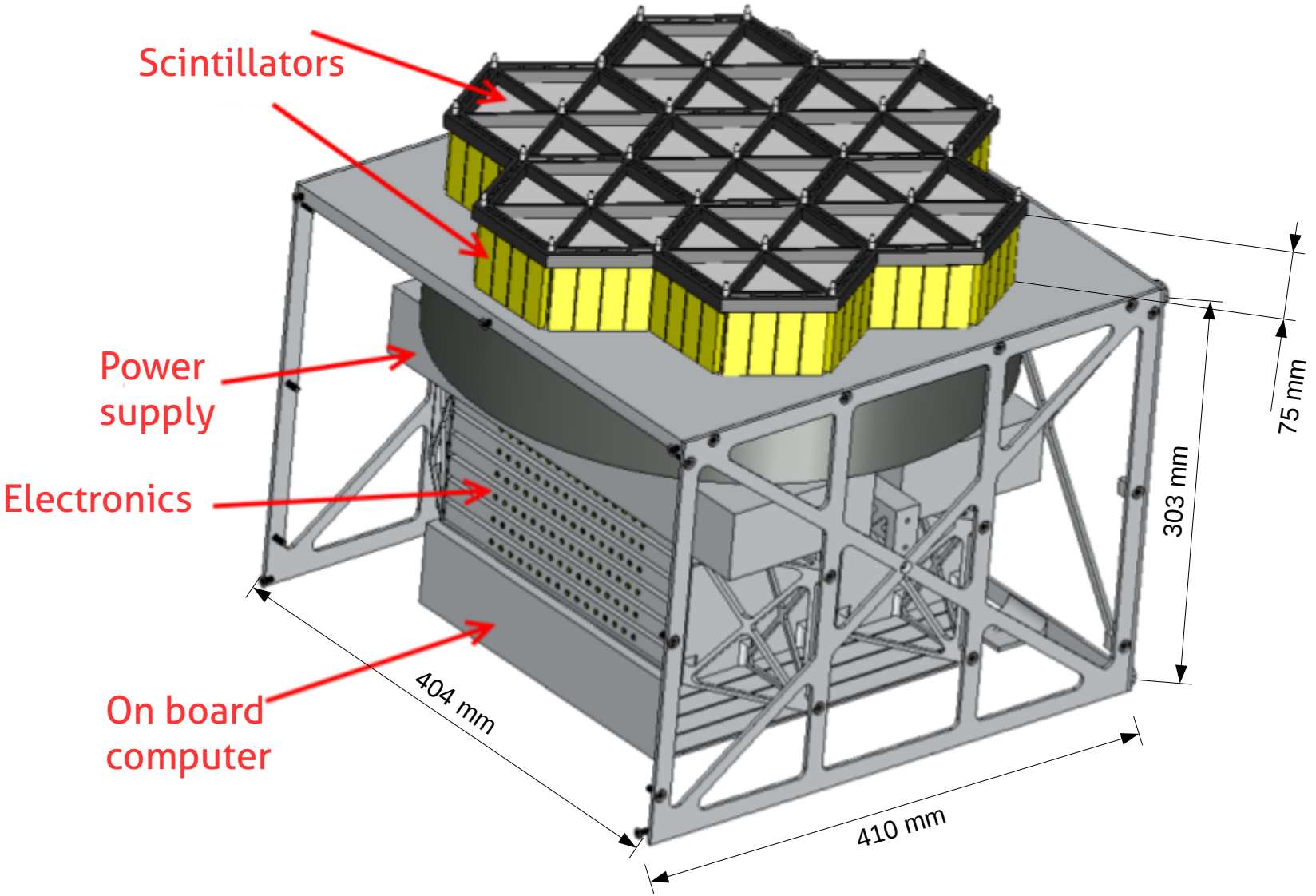
Satellite Opportunity

- InnoSat-2 platform provided by SNSB

Can we put the two together ??

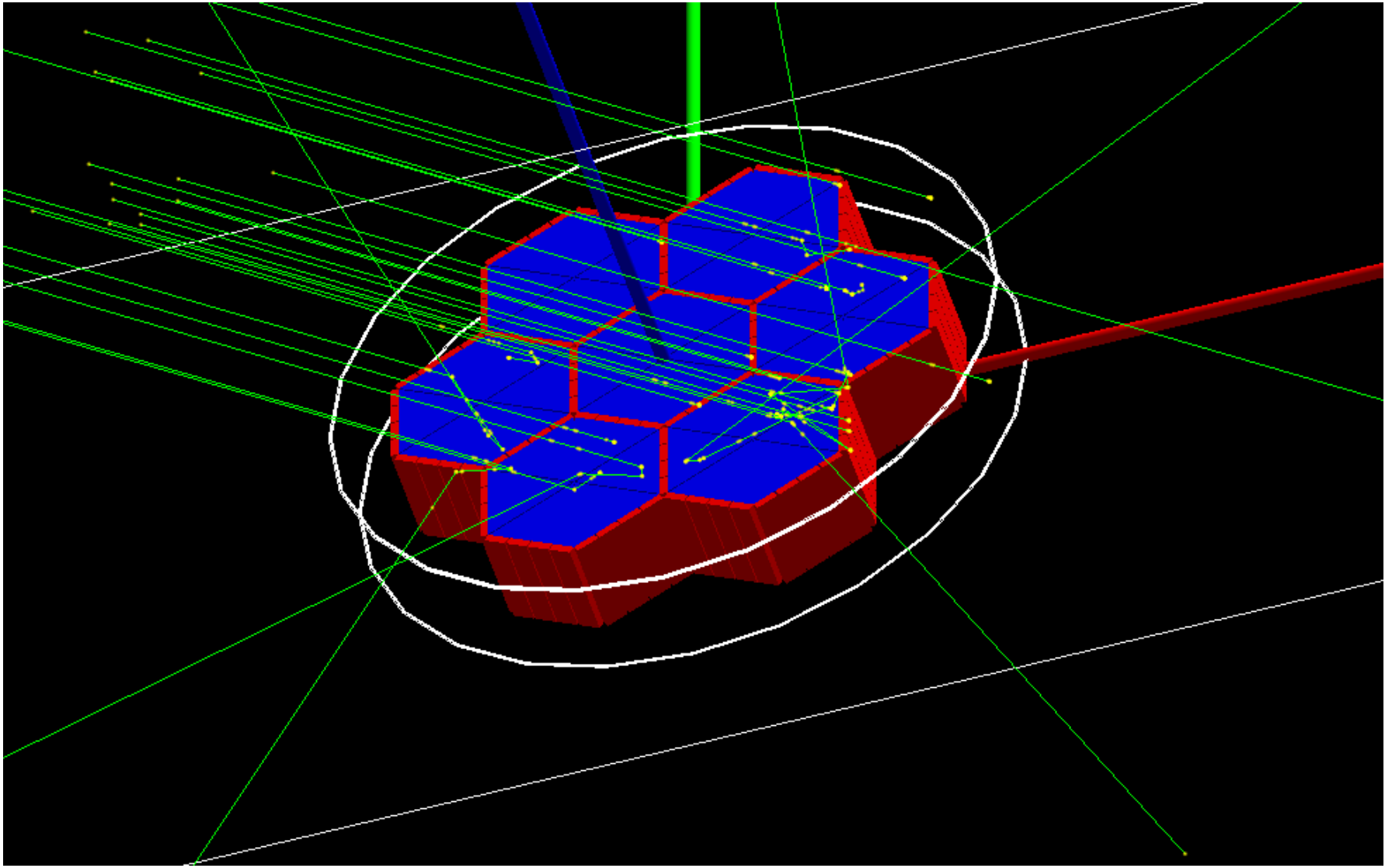
Can we put the two together ??

- SPHiNX (Satellite Polarimeter for High eNergy X-rays)



Can we put the two together ??

- Monte Carlo simulations - Geant4



Monte Carlo simulations – Geant4

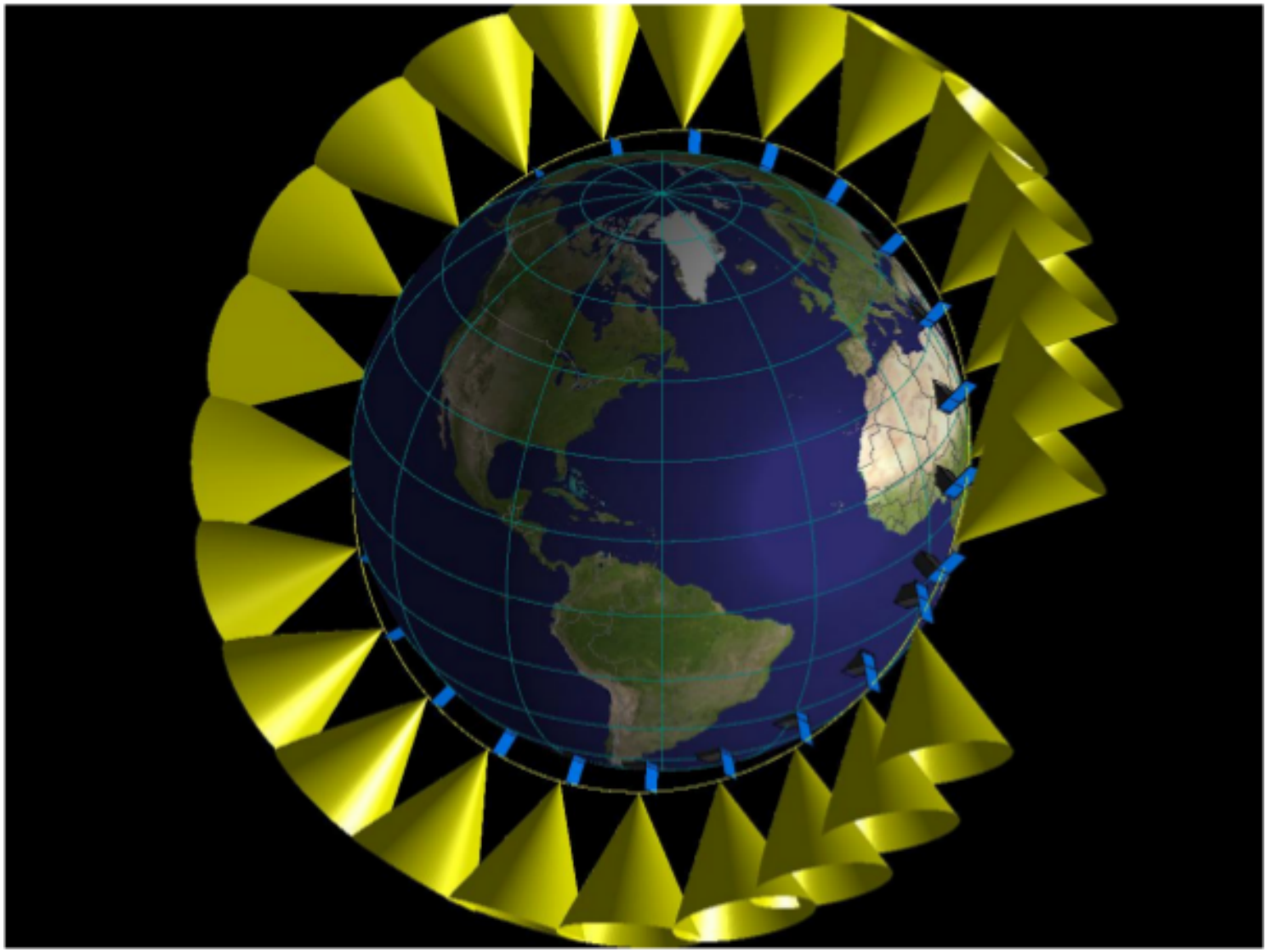
- Source photons
  - Spectrum and duration from *Fermi*,
  - polarisation fraction – 100%, polarisation angle – random value

- Background photons (unpolarised) / particles –
  - Cosmic X-ray Background spectrum
  - Albedo photons from Earth's atmosphere
  - Trapped and albedo particles (protons, electrons and positrons)

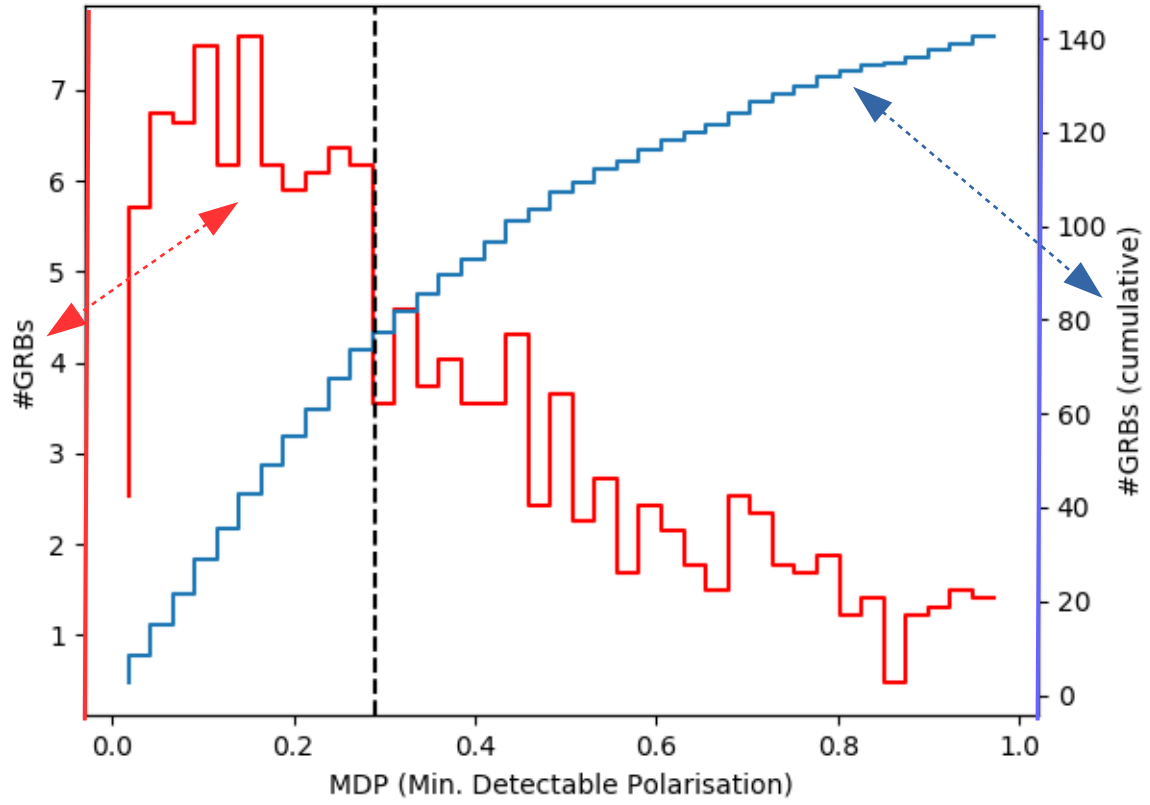
- Analyse modulation curves to get performance for 100% case

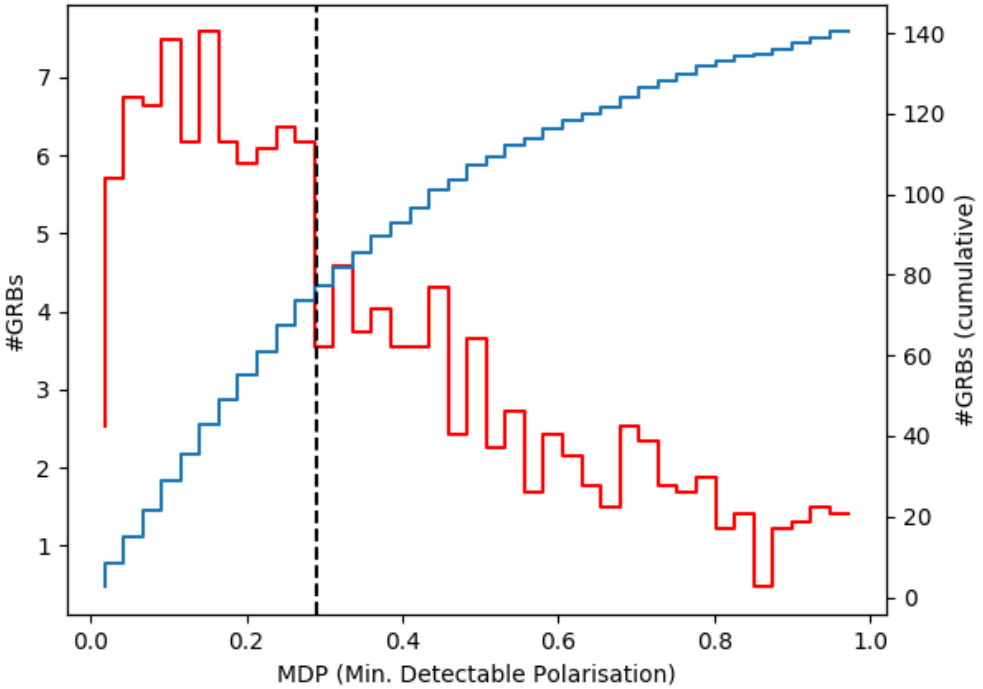
- Extrapolate the performance to the polarisation fraction in different models.

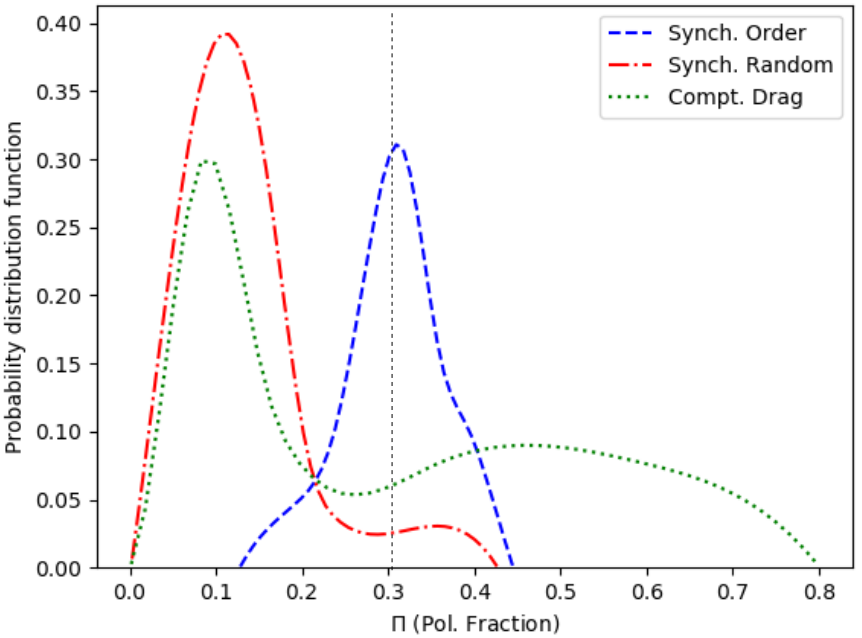
- Results from the proposed design
  - We expect to detect / see ~ 200 GRBs in the two year mission lifetime

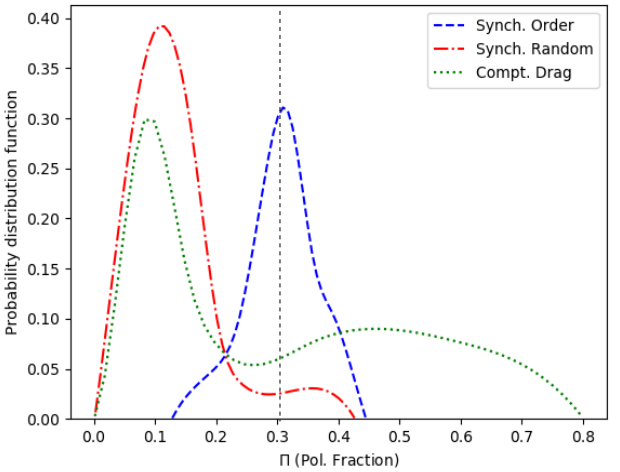


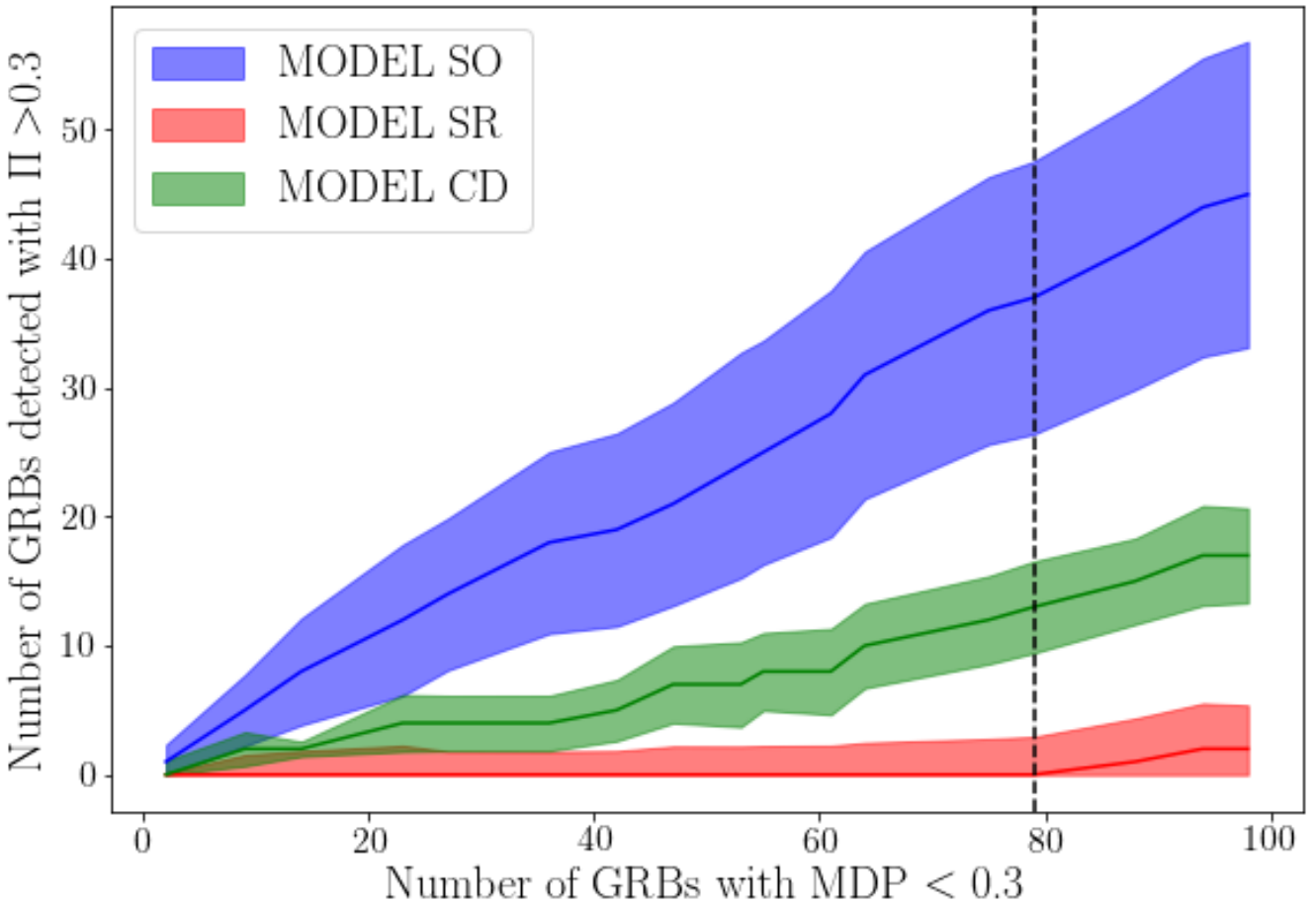
- Results from the proposed design
  - We expect to detect / see ~ 200 GRBs in the two year
  - The sensitivity (minimum detectable polarisation fraction) for these 200 GRBs gives ~ 80 GRBs with MDP < 0.3 !

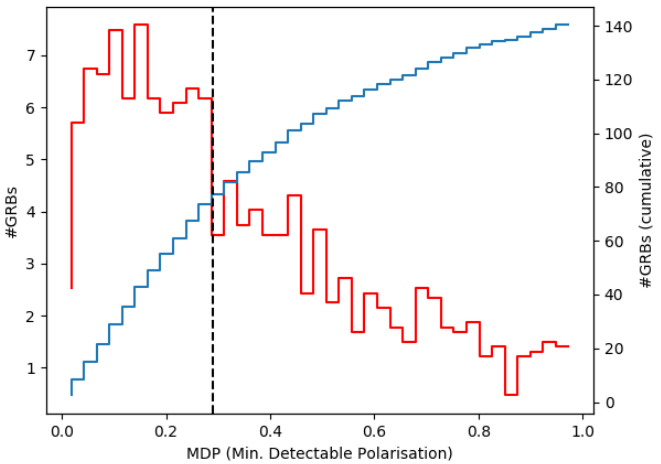


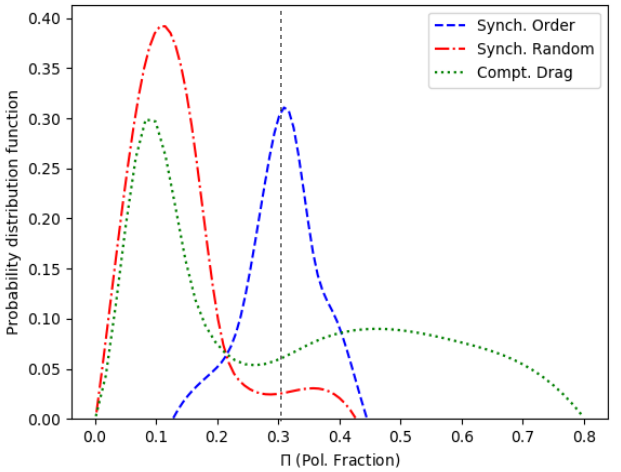

#GRBs
#GRBs (cumulative)
MDP (Min. Detectable Polarisation)
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140

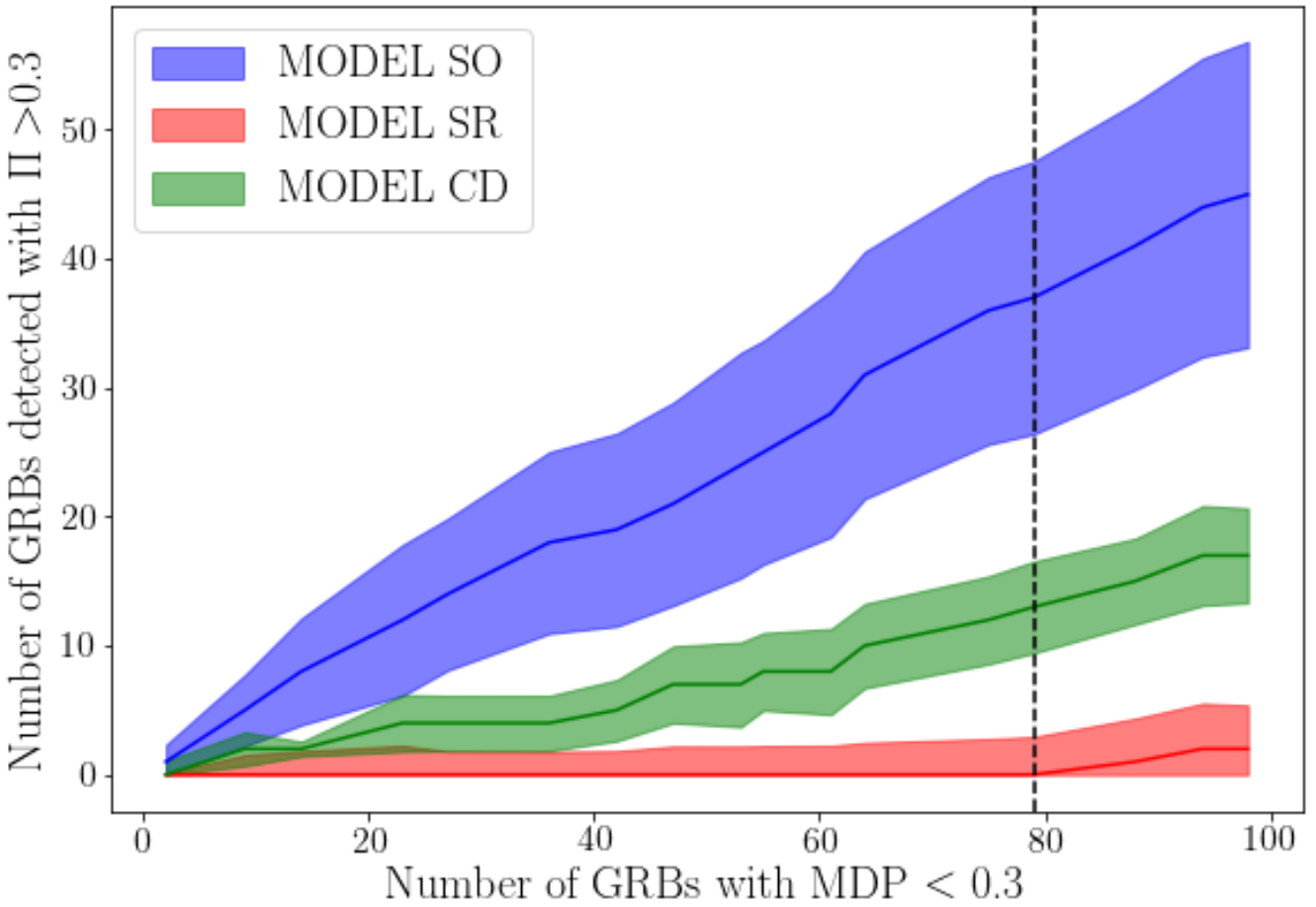

Synch. Order
Synch. Random
Compt. Drag
Probability distribution function
Π (Pol. Fraction)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Synch. Order
Synch. Random
Compt. Drag
Probability distribution function
Π (Pol. Fraction)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


MODEL SO
MODEL SR
MODEL CD
Number of GRBs detected with Π >0.3
Number of GRBs with MDP < 0.3
0
10
20
30
40
50
0
20
40
60
80
100


#GRBs
#GRBs (cumulative)
MDP (Min. Detectable Polarisation)

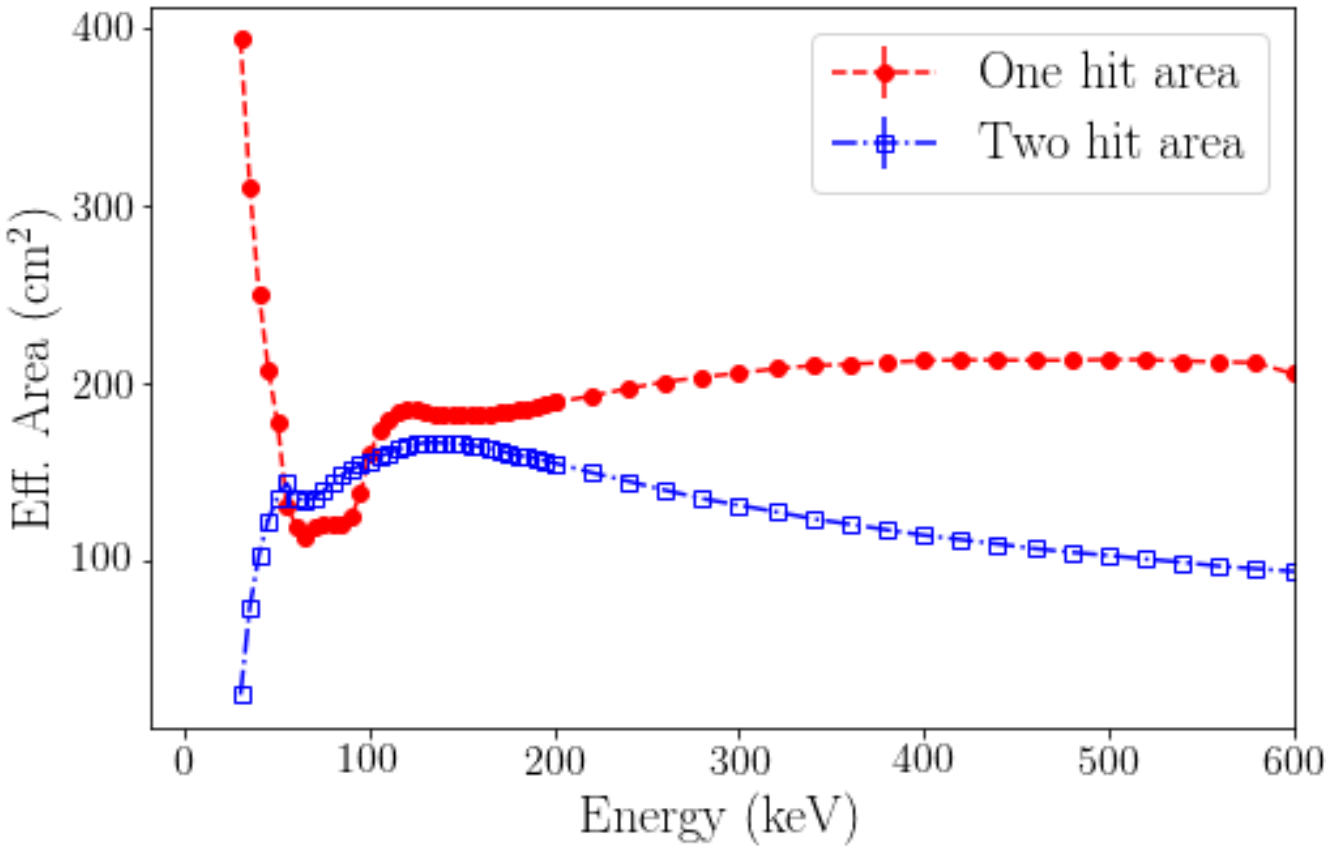

Synch. Order
Synch. Random
Compt. Drag
Probability distribution function
Π (Pol. Fraction)


MODEL SO
MODEL SR
MODEL CD
Number of GRBs detected with Π >0.3
Number of GRBs with MDP < 0.3

And we can do more !

Additional diagnostics

- Simultaneous spectral measurement - correlations
- Simultaneous lightcurve measurements
- Time and energy binned polarisation
- Prompt localisation

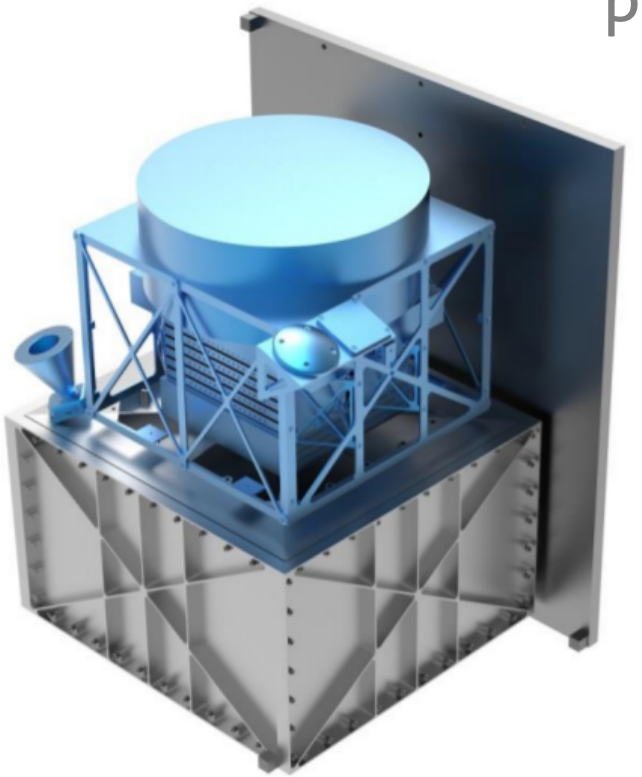


Science Case

- Polarisation measurements

Satellite Opportunity

- InnoSat-2 platform provided by SNSB

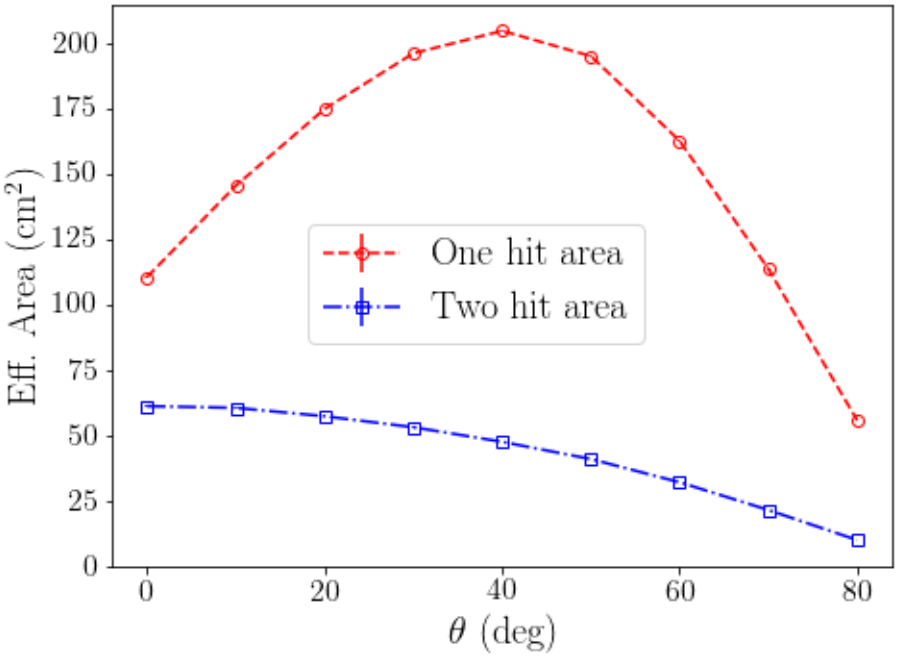


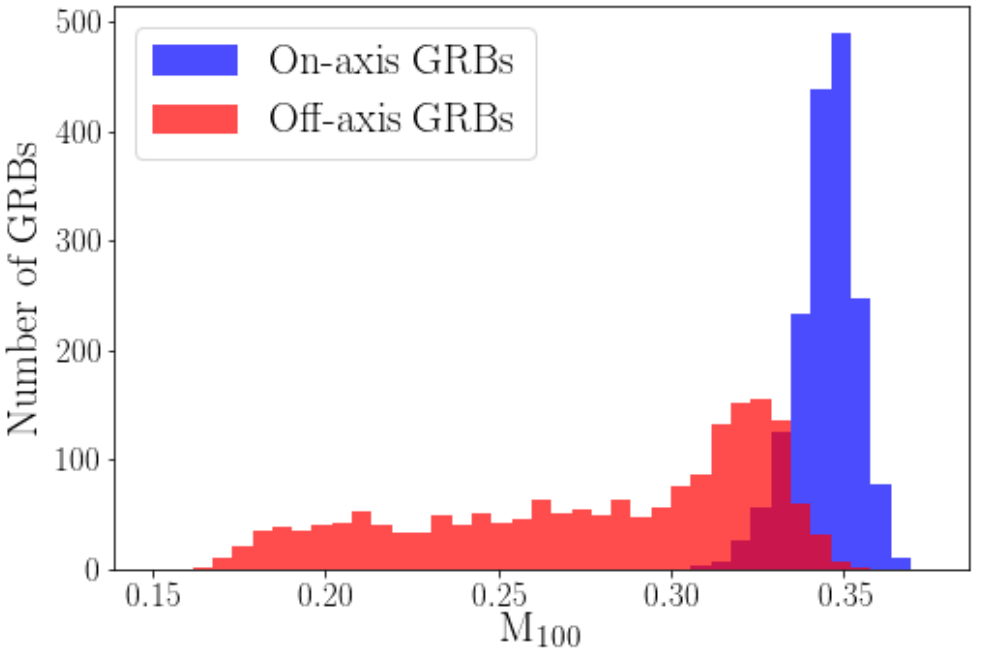
SPHiNX (Satellite Polarimeter for High eNergy X-rays)

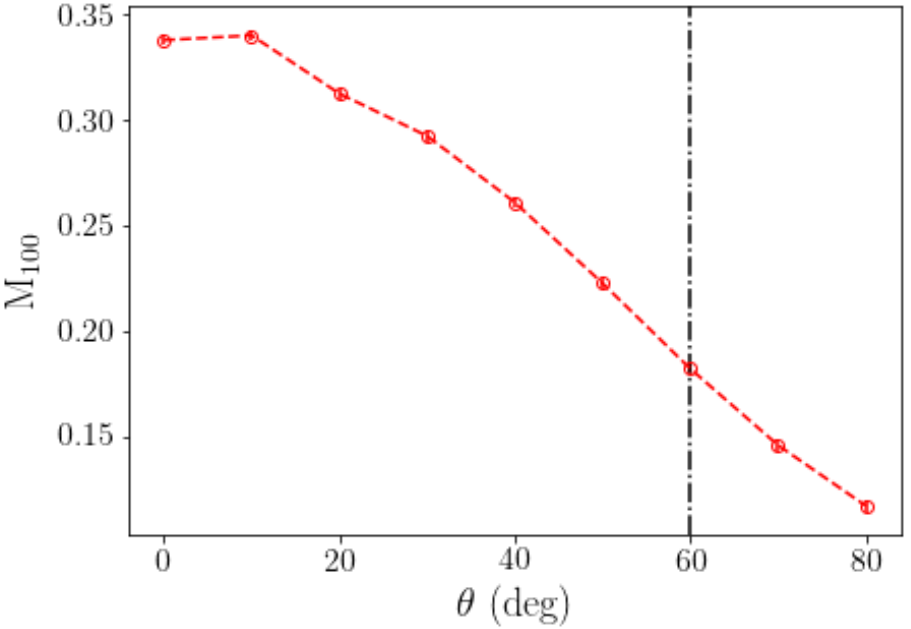
- Proposal Phase A/B1 submitted to SNSB.
- Three competing missions – DICE, SIW and SPHiNX

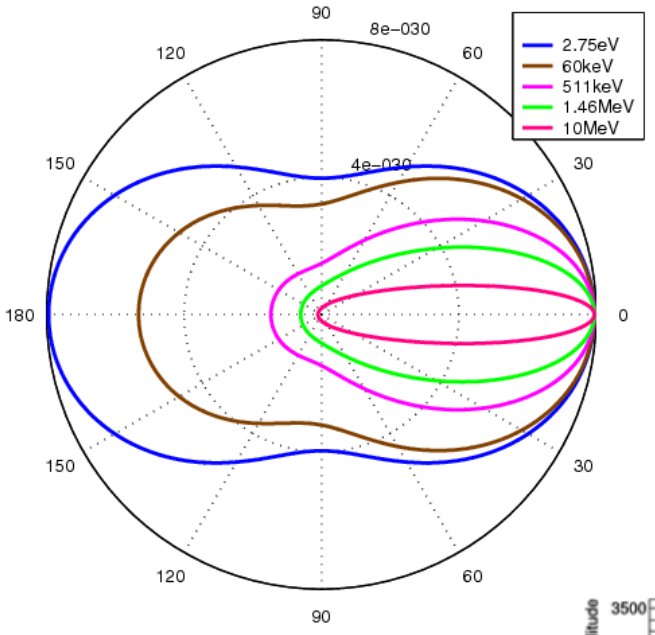
Stop here

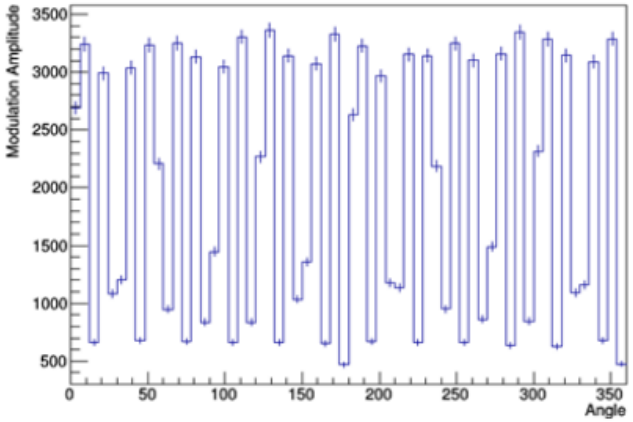
Backup Slides

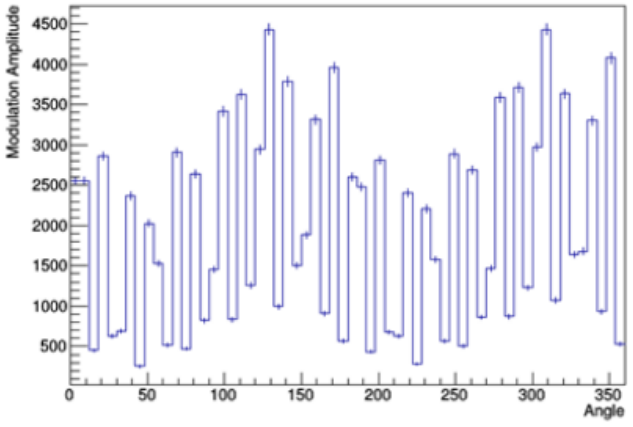


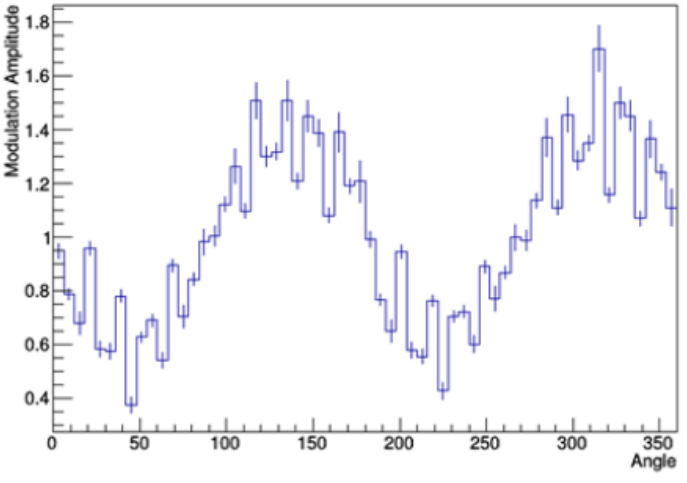




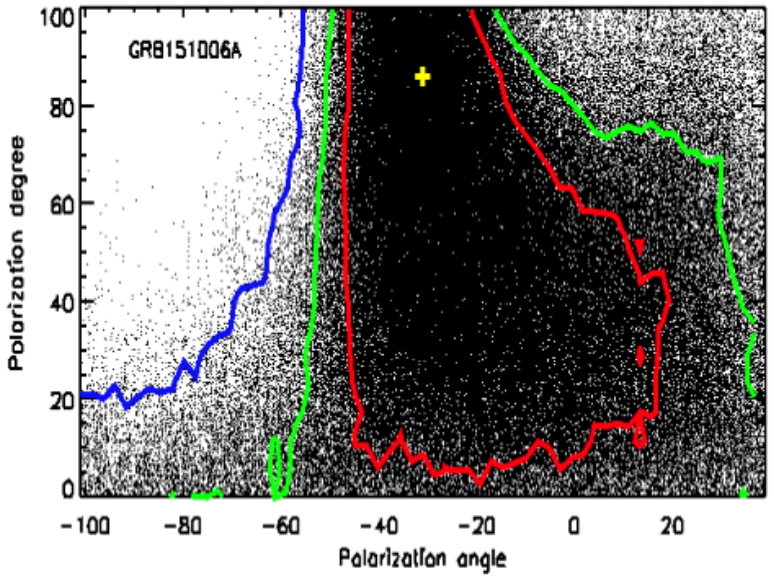

90
120
60
150
30
180
0
150
30
120
60
90
8e−030
4e−030
2.75eV
60keV
511keV
1.46MeV
10MeV


Modulation Amplitude
Angle

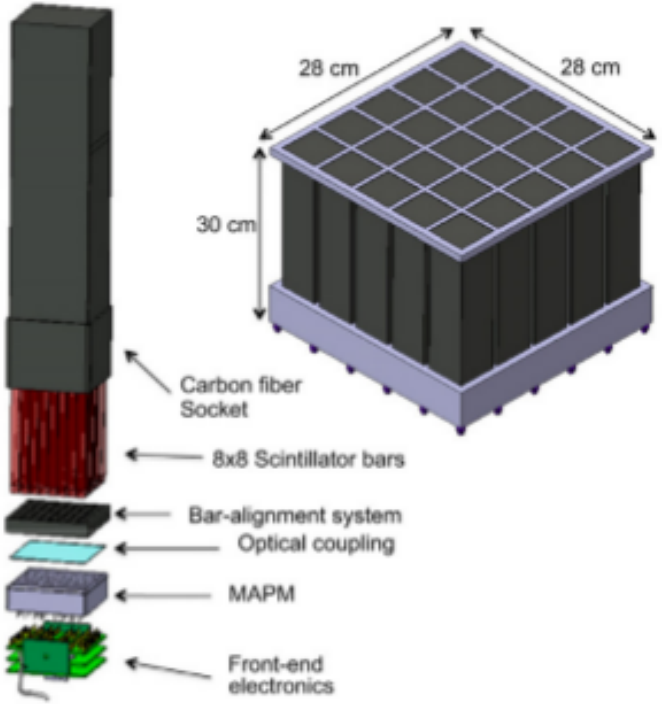

Modulation Amplitude
Angle


Modulation Amplitude
Angle

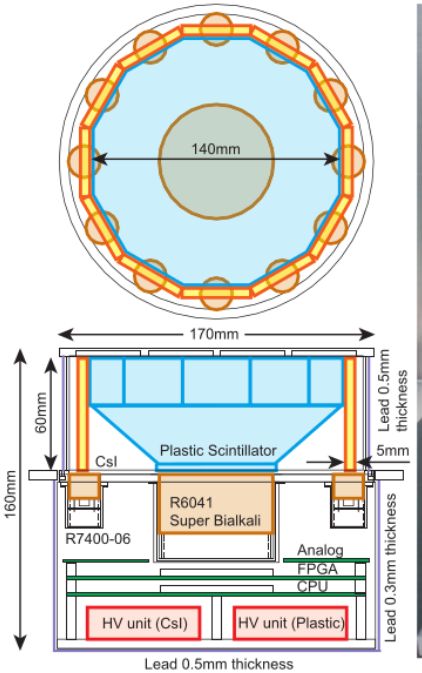
AstroSat measurement

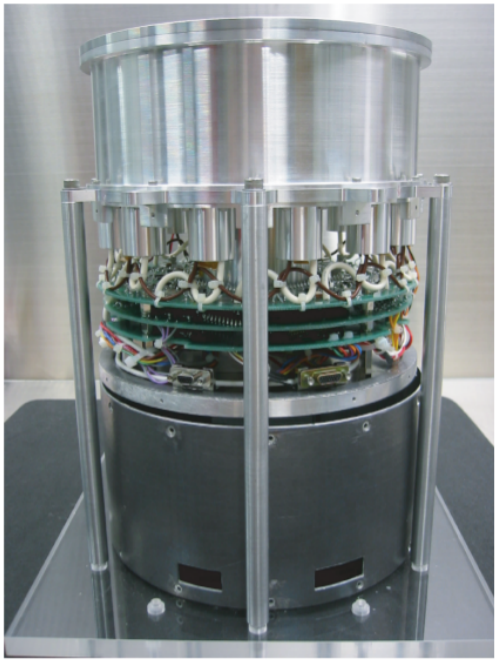


POLAR



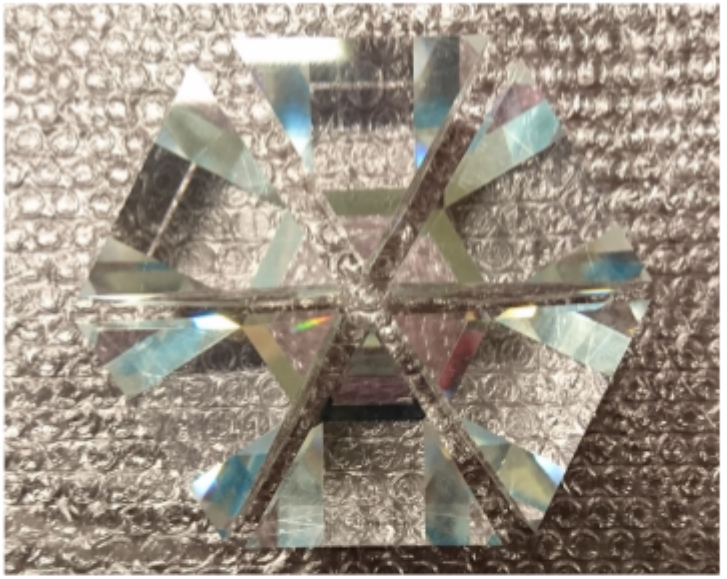
GAP





Backup Slides

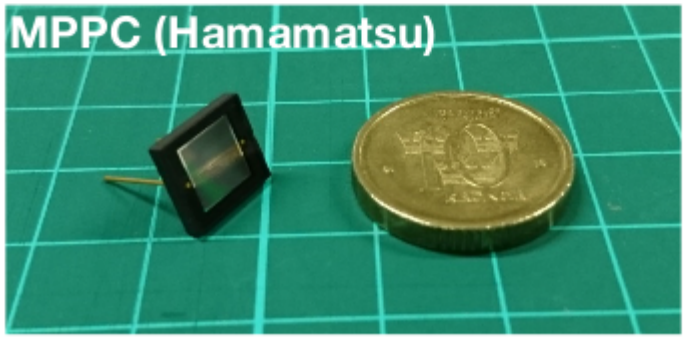
Plastic scintillator (Eljen Technology)

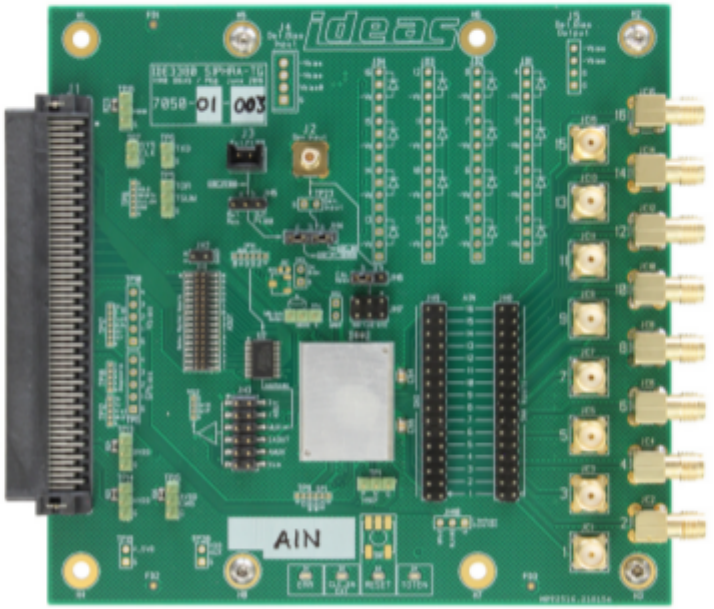


GAGG scintillator (C&A)

Photomultiplier (Hamamatsu)

MPPC (Hamamatsu)





SiPHRA ASIC (IDEAS)
Incoming: x-ROC ASIC (weeroc)

PHVS (KTH)

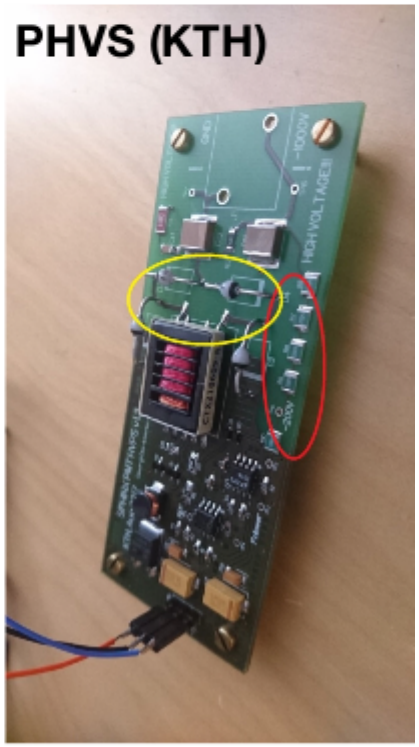


Table 1
GRB polarization measurements.

Pub Date	GRB	Instrument	Energy (keV)	Π	Refs.
2004	GRB 021206	RHESSI	150–2000	80% ± 20%	Coburn and Boggs (2003)
2004	GRB 021206	RHESSI	150–2000	< 4.1%	Rutledge and Fox (2004)
2004	GRB 021206	RHESSI	150–2000	41^{+57}_{-44}%	Wigger et al. (2004)
2005	GRB 930131	CGRO/BATSE	20–1000	(35–100%)[a]	Willis et al. (2005)
2005	GRB 960924	CGRO/BATSE	20–1000	(50–100%)[a]	Willis et al. (2005)
2007	GRB 041219a	INTEGRAL/SPI	100–350	98% ± 33%	Kalemci et al. (2007)
2007	GRB 041219a	INTEGRAL/SPI	100–350	96% ± 40%	McGlynn et al. (2007)
2009	GRB 041219a	INTEGRAL/IBIS	200–800	43% ± 25%[b]	Götz et al. (2009)
2009	GRB 061122	INTEGRAL/SPI	100–1000	< 60%	McGlynn et al. (2009)
2011	GRB 100826a	IKAROS/GAP	70–300	27% ± 11%[c]	Yonetoku et al. (2011b)
2012	GRB 110301a	IKAROS/GAP	70–300	70% ± 22%	Yonetoku et al. (2012)
2012	GRB 110721a	IKAROS/GAP	70–300	80% ± 22%	Yonetoku et al. (2012)
2013	GRB 061122	INTEGRAL/IBIS	250–800	> 60%	Götz et al. (2013)
2014	GRB 140206a	INTEGRAL/IBIS	200–800	> 48%	Götz et al. (2014)
2016	GRB 151006a	Astrosat/CZTI	100–300	–	Rao et al. (2016)

[a] Albedo polarimetry.
[b] Variable Π.
[c] Variable position angle.