GRIPS

Gamma-Ray Burst Investigation via Polarisation and Spectroscopy

The potential of a future MeV survey

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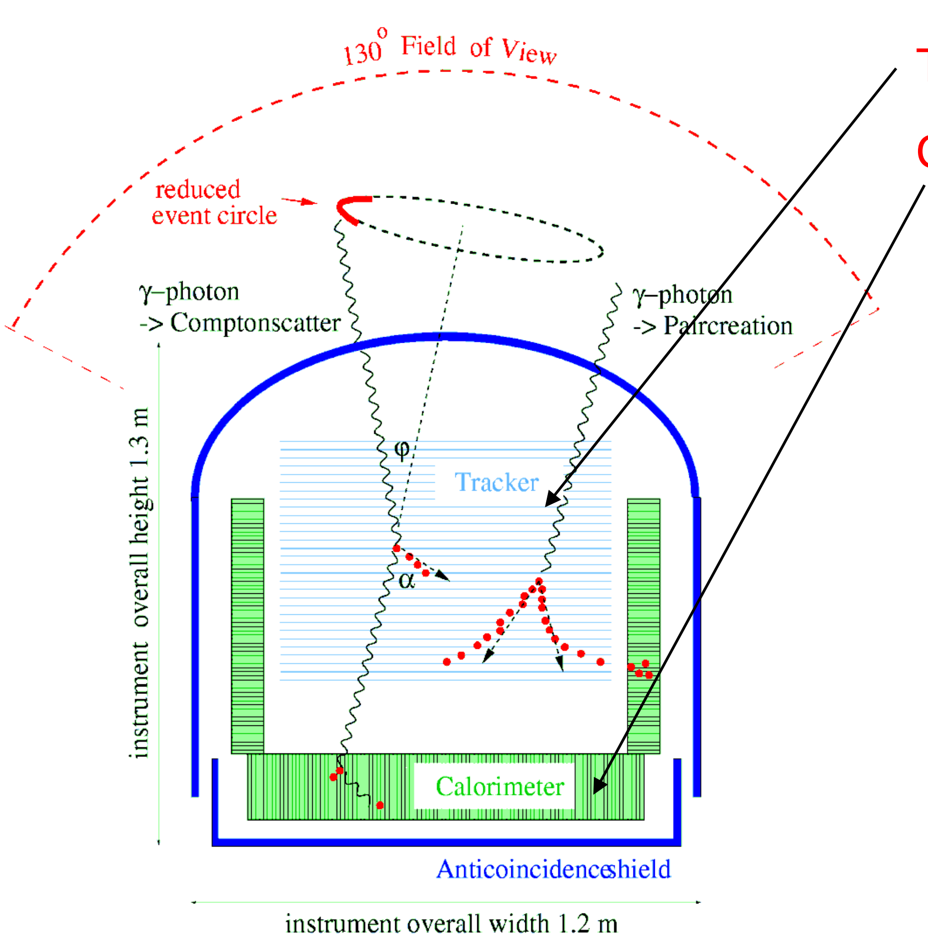
The Telescope Concept

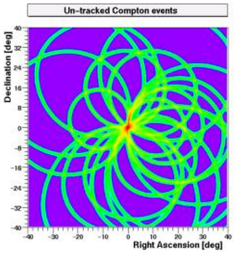


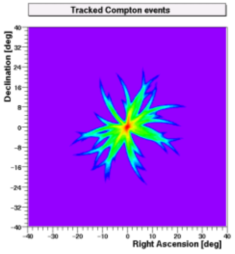
Tracker: double sided Si strip detectors

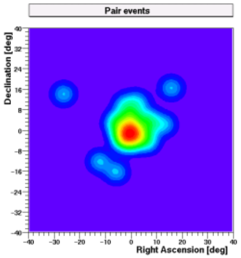
Calorimeter: 3D resolving $LaBr_3$ / Si drift diode

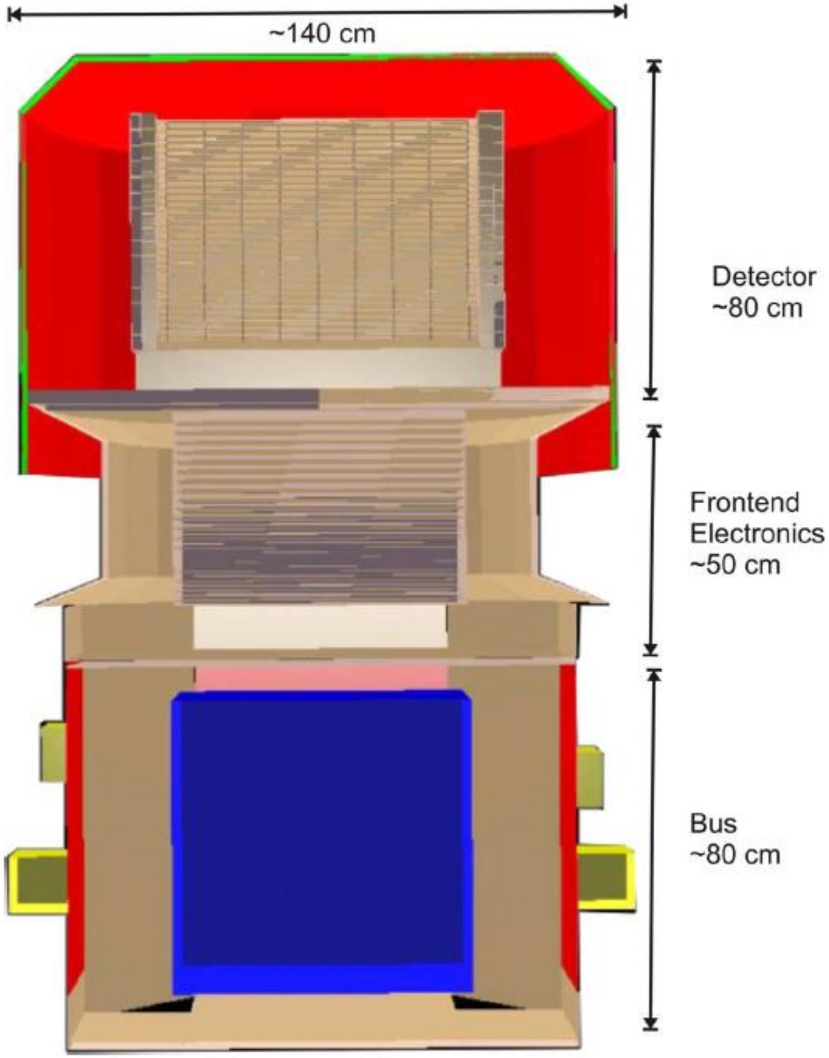
Images

Classical Compton	Tracked Compton	Pairs









1 layer = 4x4 wafers of
10x10 cm^2 each

1 tower = 64 layers
spaced 5 mm (v.1)
3 mm (v.2)

4 towers

~500.000 read-out channels

$LaBr_3$	750 kg
Si (tracker)	50 kg
Ne110	150 kg
Structure+Electr	200 kg
GRM margin	430 kg
eROSITA	660 kg
Gaia bus	510 kg
Contingency	550 kg
Propellant	200 kg
Sum	3500 kg

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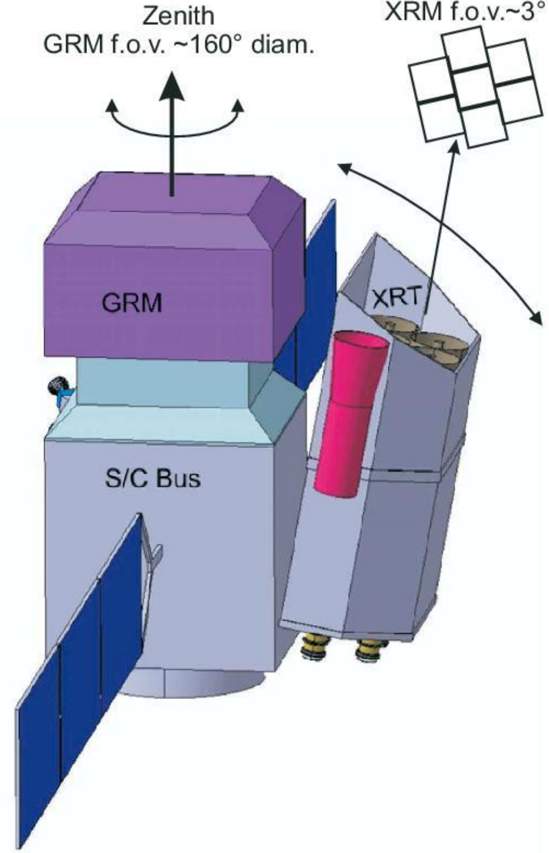
Wealth of Science Topics

- 650-700 GRBs/yr: high-z Universe
- All-sky Survey in 0.2-50 MeV → ~40x more sensitive than COMPTEL
  about 1000(-5000?) sources in 1 yr survey (cp. to 30 COMPTEL sources)
- Polarization of SGRs, bright sources (Crab), AXP flares
- Pulsars
- Nucleosynthesis in all flavours: ^{26}Al, ^{44}Ti, ^{60}Fe
- Solar flares
- Novae (511 line plus conti light curve)
- Origin of 511 keV emission (source class / transport)
- Supernovae: several per yr; few in lifetime to distinguish models
- Diffuse continuum MeV emission
- Discovery space!

Mission Concept

Proposed for ESA's Cosmic Vision 2007
Ranked 4th; only 1-3 selected for study



> LEO, 0 degree, 500 km, zenith pointing
> Gamma-ray Monitor: 160° FOV
> X-ray telescope: 3° FOV
> GRB alerts for follow-up

Instruments/capabilities

Gamma-ray Monitor

Energy range	200 keV–50 MeV
Localisation	1° (radius)
Polarisation	1% (@top 10% GRB)

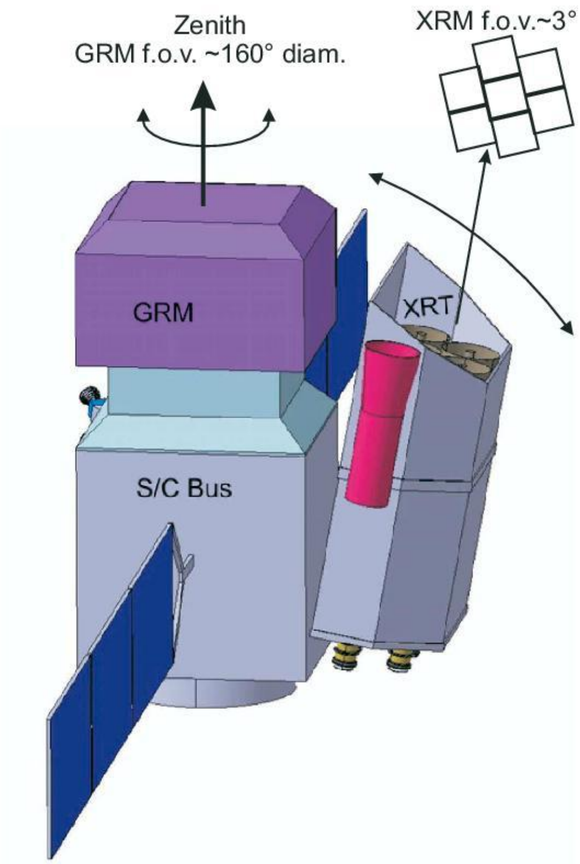
X-ray Monitor

Energy range	0.1-10 keV
Localisation	30″ (radius)

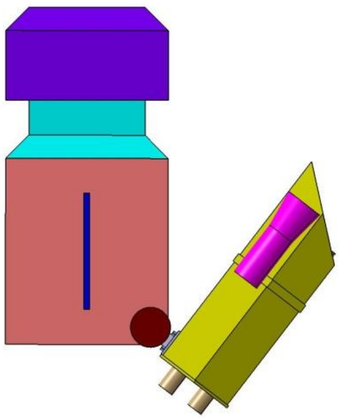
Source detections in 1 yr

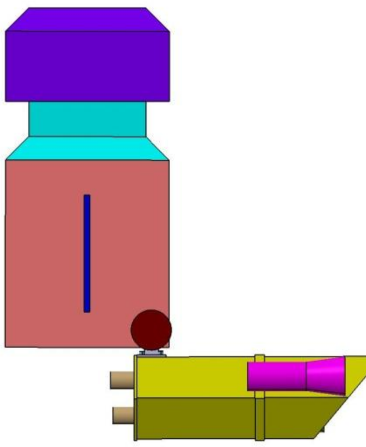
Type	#
GRBs	660
Blazars	820
Other AGN	250
Pulsars/AXP	60
Unidentified	170

GRIPS: ESA CV2007



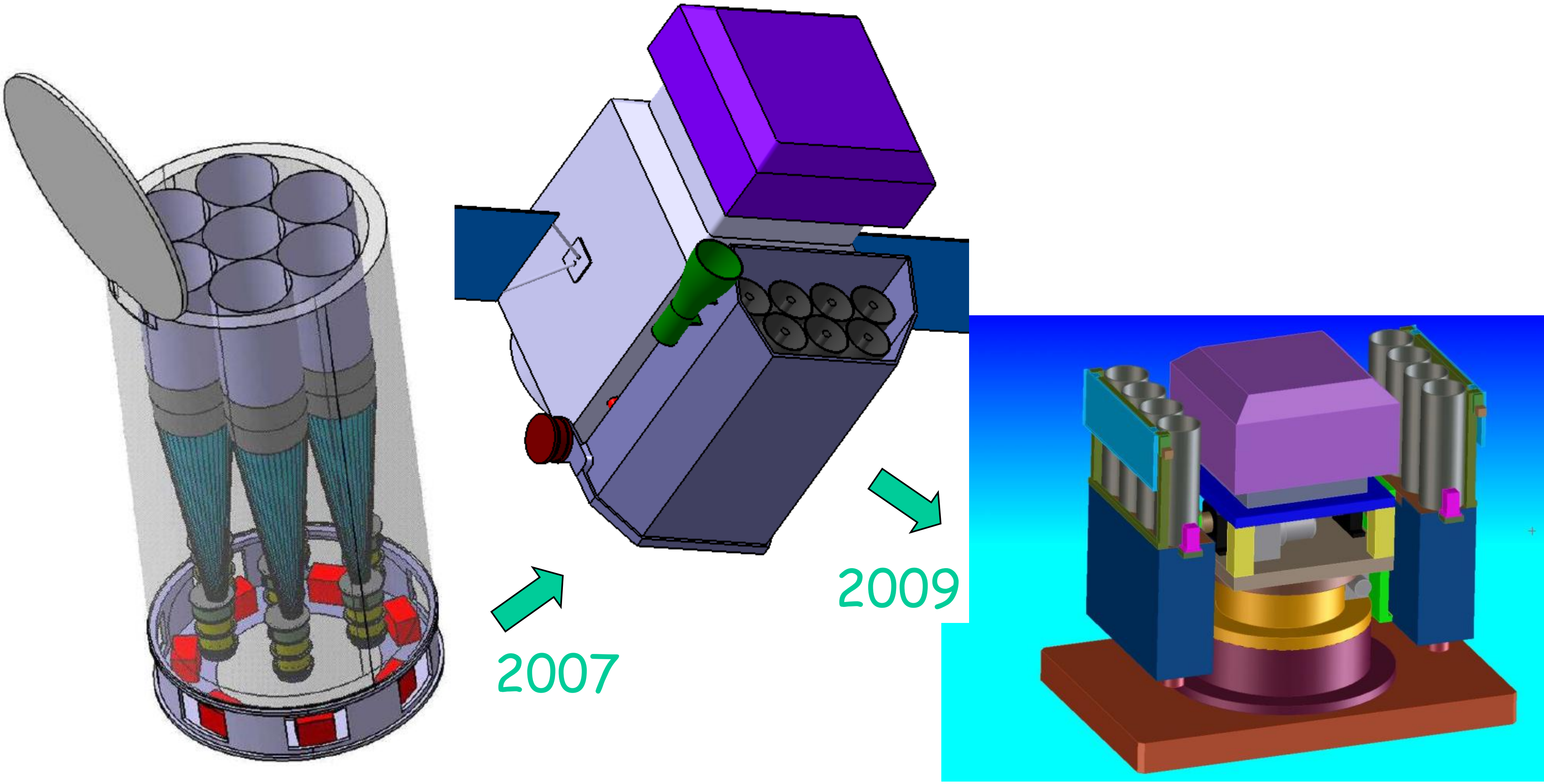
- 1-satellite version with XRT on a hinge mechanism
- follow-up requires X-ray telescope – thus the XRT is crucial for fast and precise positions (e.g. for JWST)
- Alternative (like Swift): fixed XRT, re-pointing satellite: Earth blockage would compromise the gamma-ray survey!





GRIPS - X-Ray Monitor:

a Grazing Incidence X-ray telescope based on eROSITA



Re-configuration of 7 eROSITA telescopes to fit satellite on launcher

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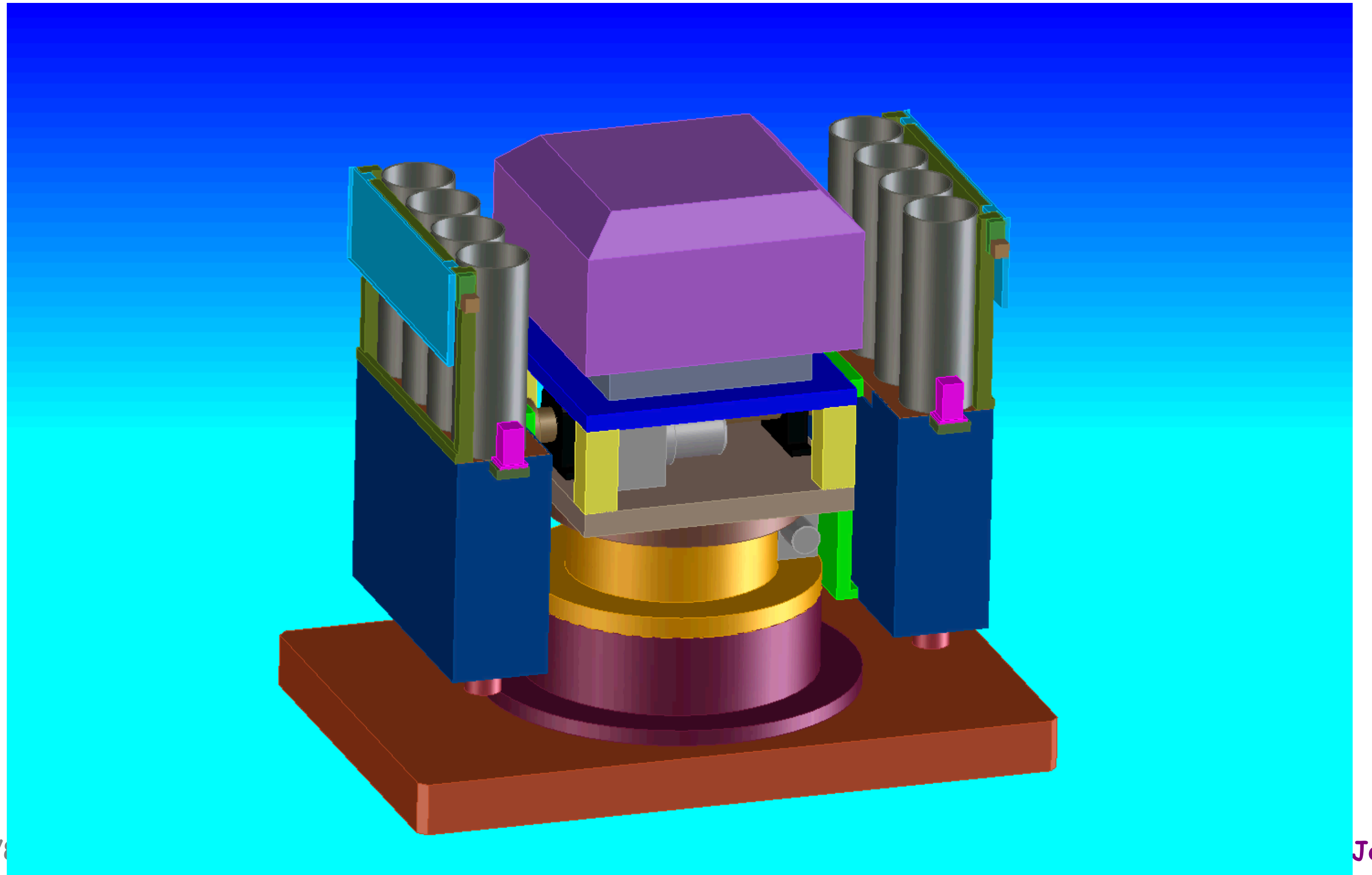
GRIPS: ESA CV2010

- 1-satellite version:
- TRL high, since many components (twisted harness, slip rings, momentum wheel, scan drive…) have been flown already
- BUT: Moving/Stopping 3 tons in seconds is technically challenging



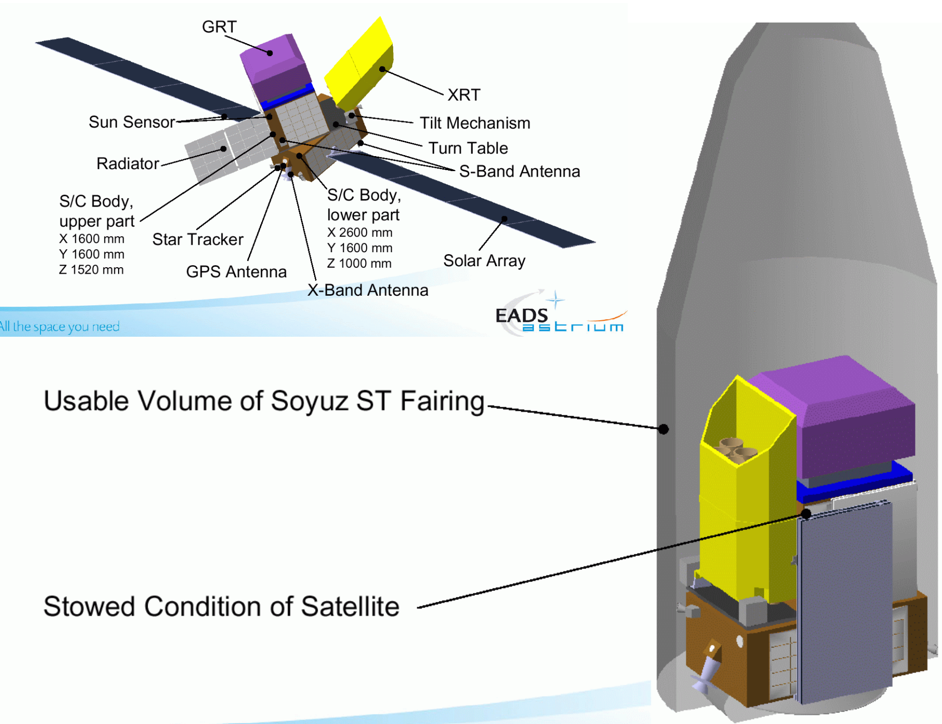
Mission concept

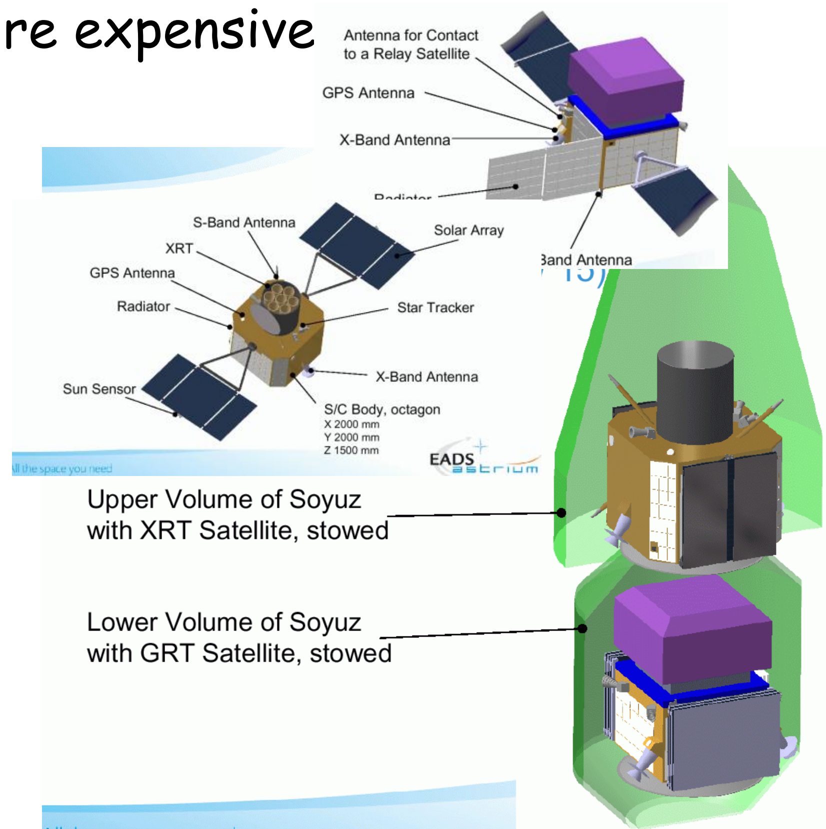
1-satellite option

- Technically feasible
- Technology all TRL3 or higher
- Most serious problem: Large solar panels (26 m^2)

2-satellite option

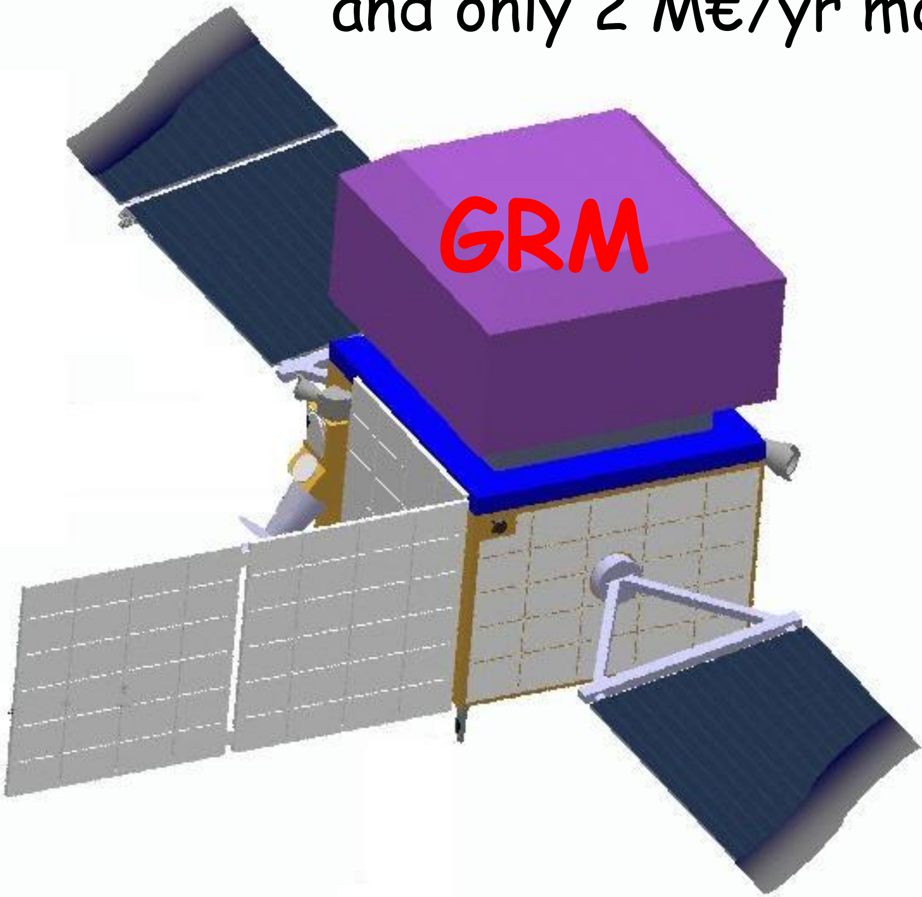
- Technically preferred over 1-sat
- Compatible with Soyuz launch
- Operation costs only marginally more expensive

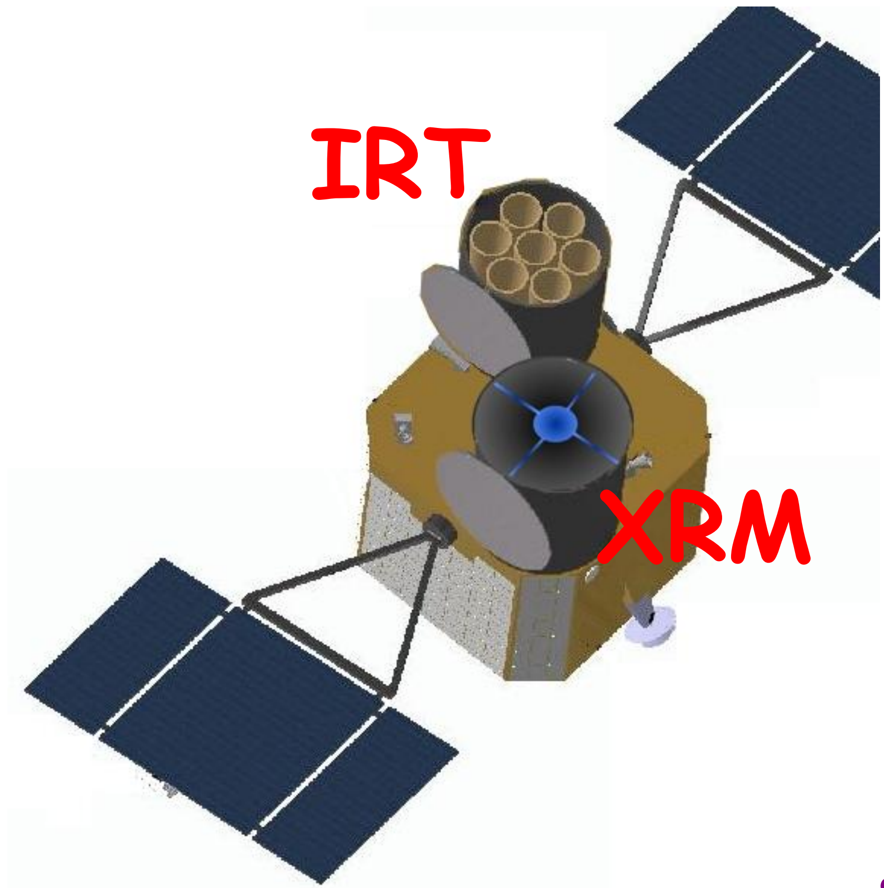




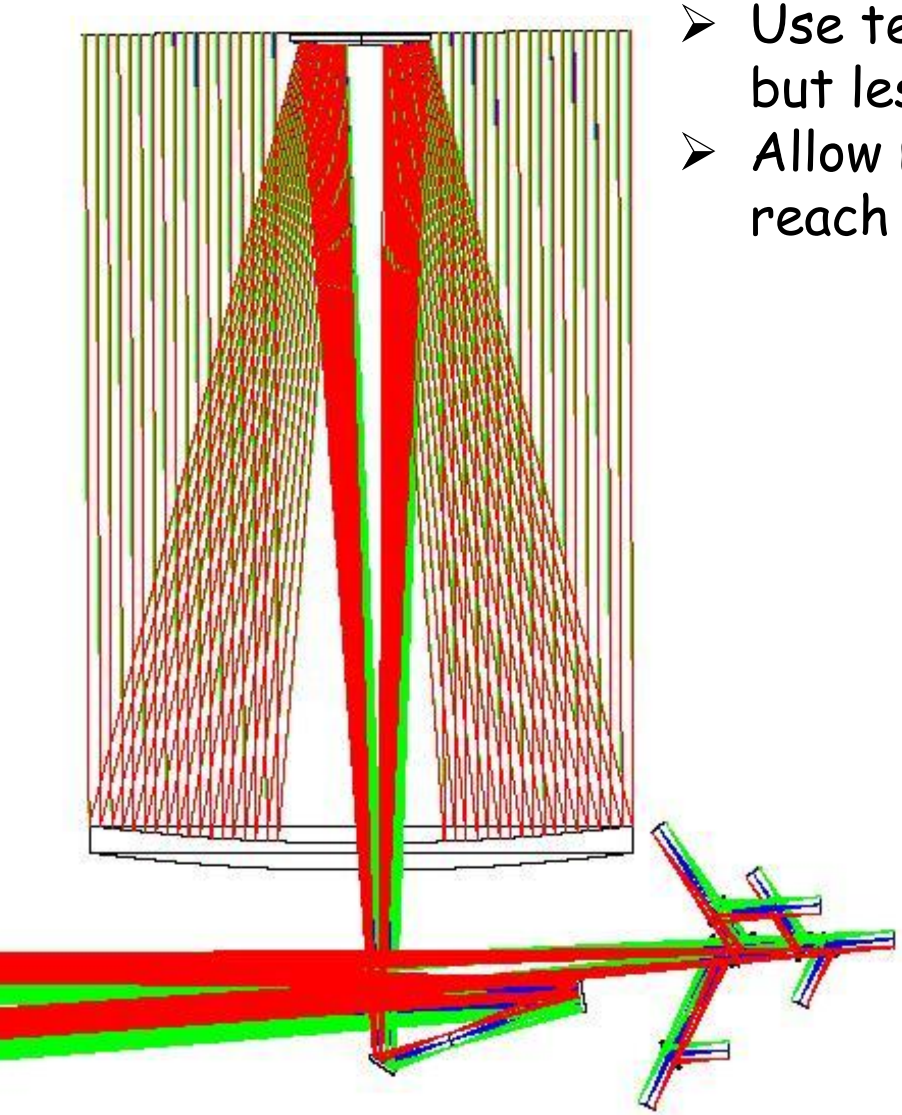
GRIPS: ESA CV2010

- 2-satellite version: distance 500-2000 km
- Pro/cons studied by EADS: is technically simpler, and only 2 M€/yr more for configuration flight

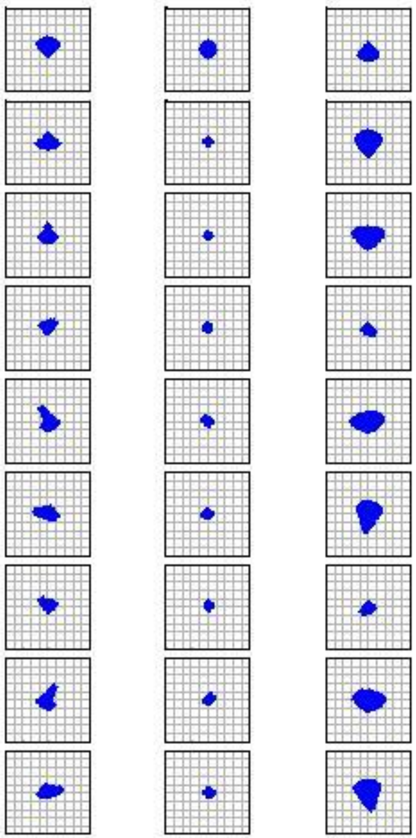




GRIPS – Infrared telescope



- Use telescope system designed for EUCLID, but less demanding optical quality
- Allow multi-filter imaging up to L/M band to reach redshift-measurements up to z~30



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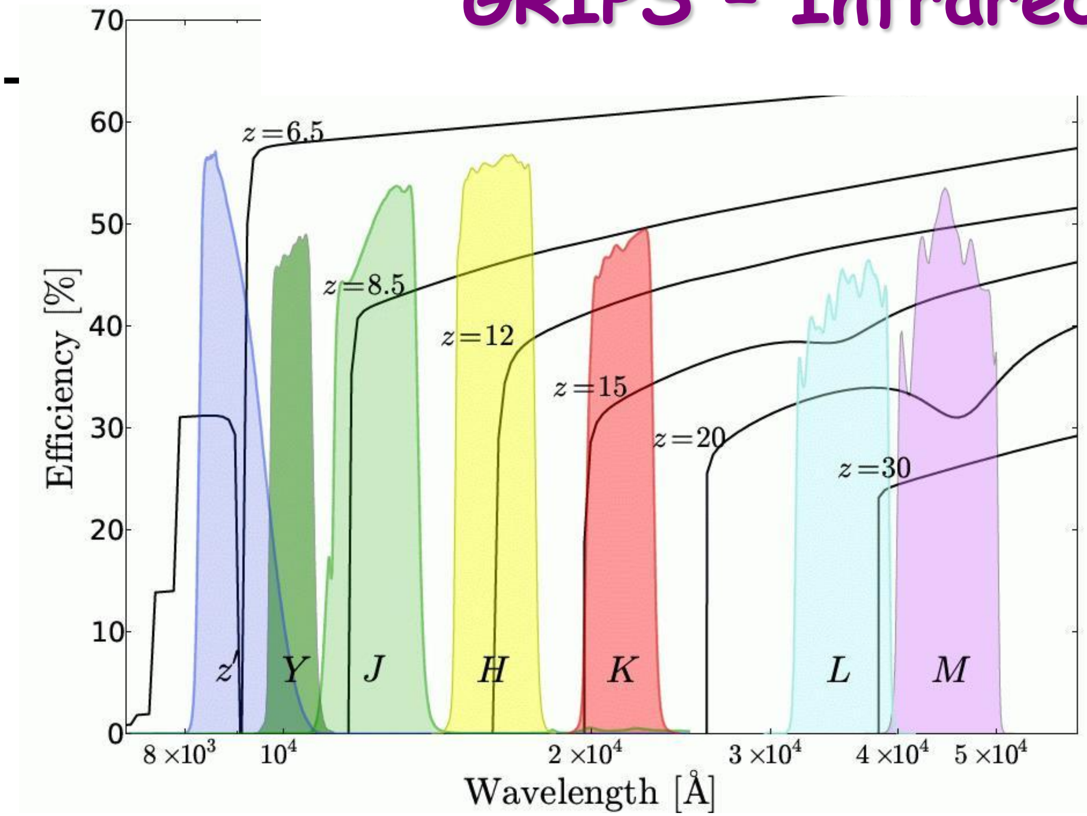
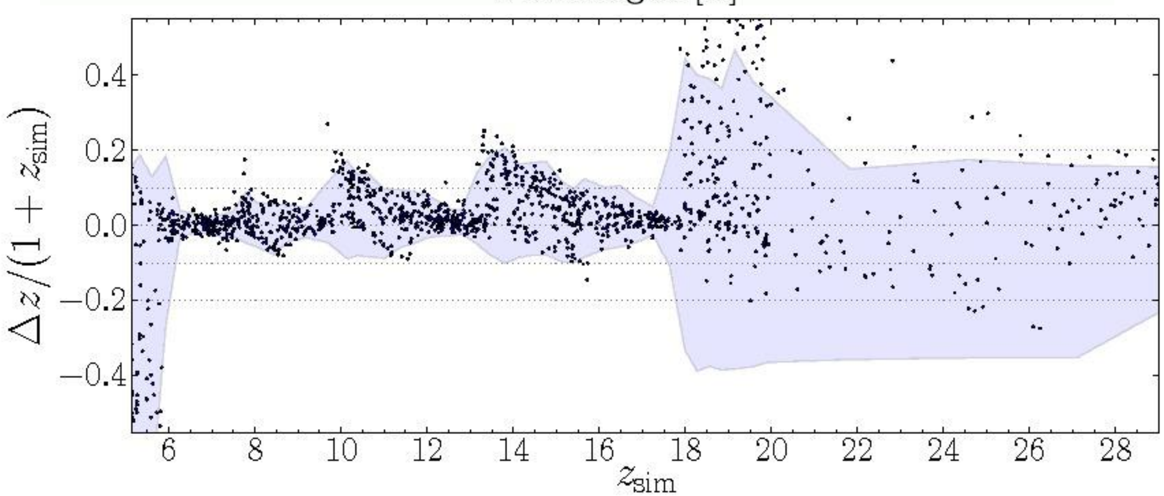
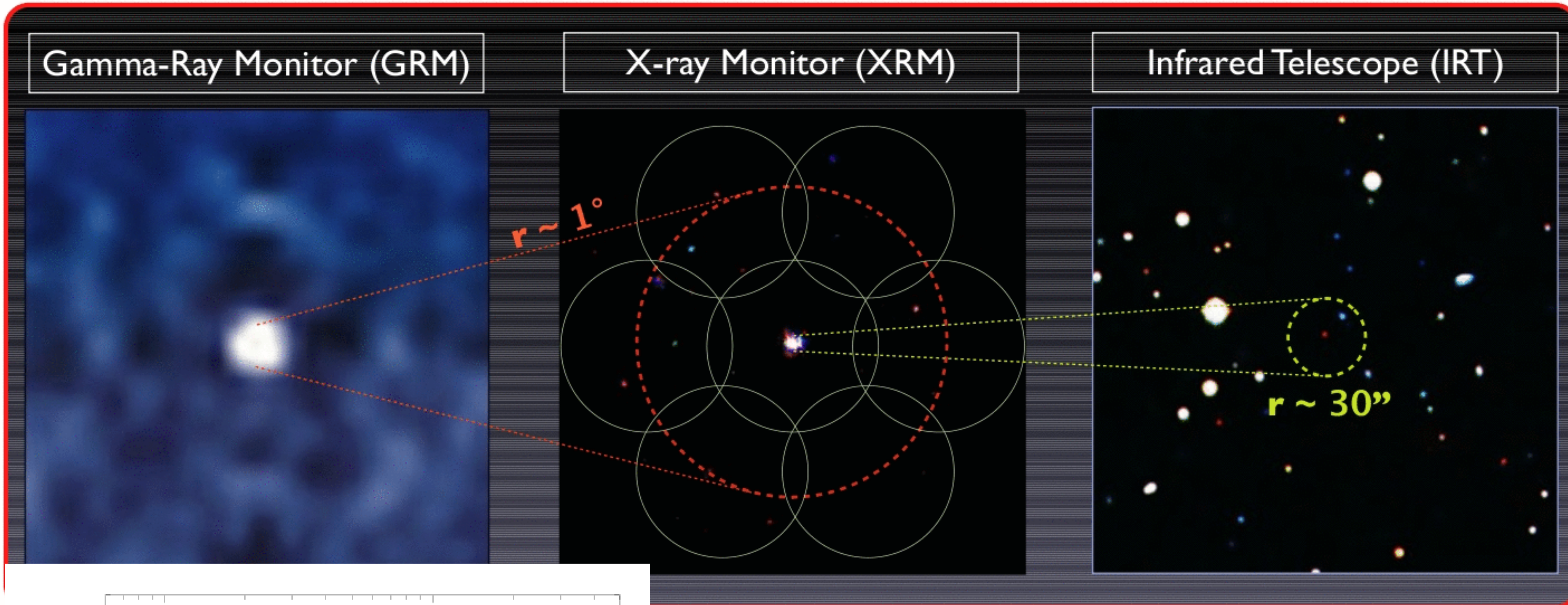
GRIPS – Infrared telescope II

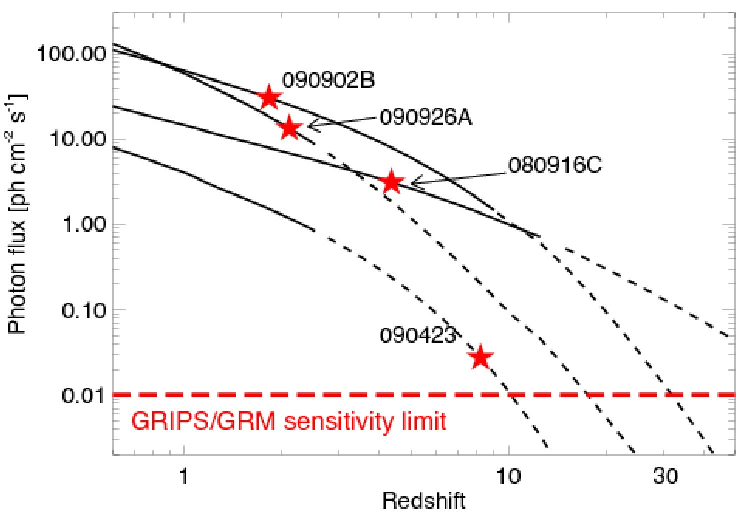




- Concept based on ground-based 7-channel imager GROND, operated since May 2007 in Chile
- L/M band allows to reach redshift-measurements up to z~30
- Redshift accuracy is about 20% for most of the range – good enough for follow-up spectroscopy with e.g. JWST

GRIPS measurement sequence





- GRM detects GRBs up to z~35
- XRM improves localizations of GRBs from 1° to 30 arcsec
- IRT improves localizations of GRBs down to 1 arcsec, and provides photometric redshift if z>7

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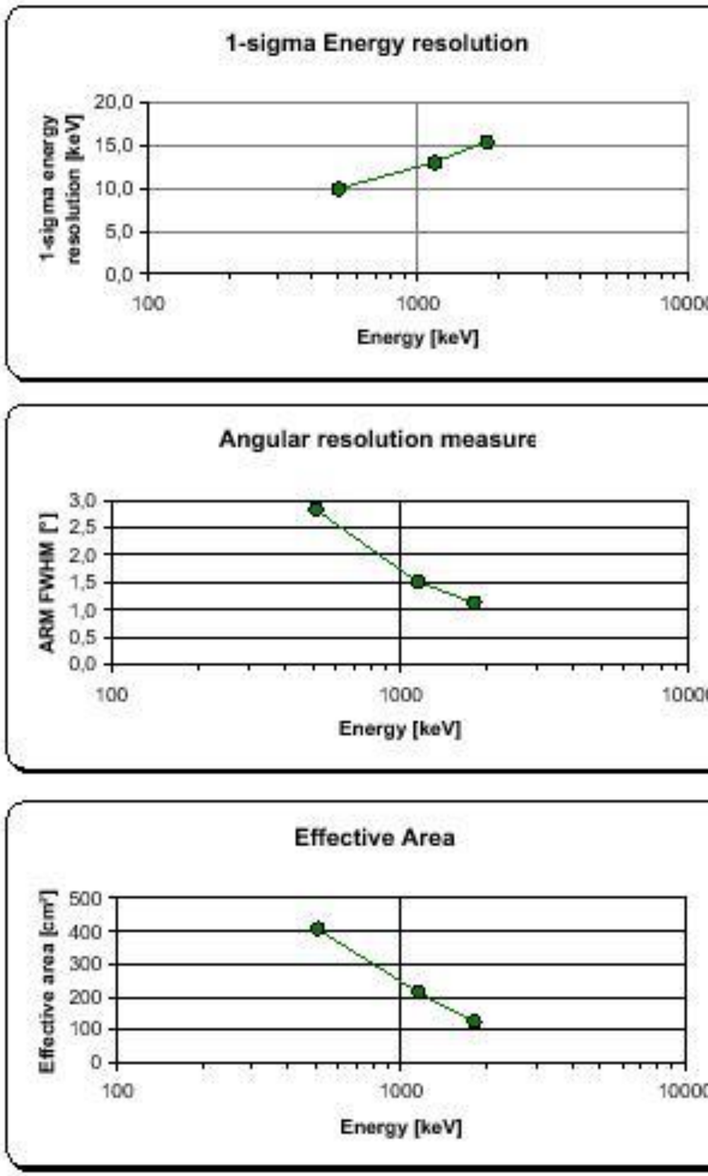
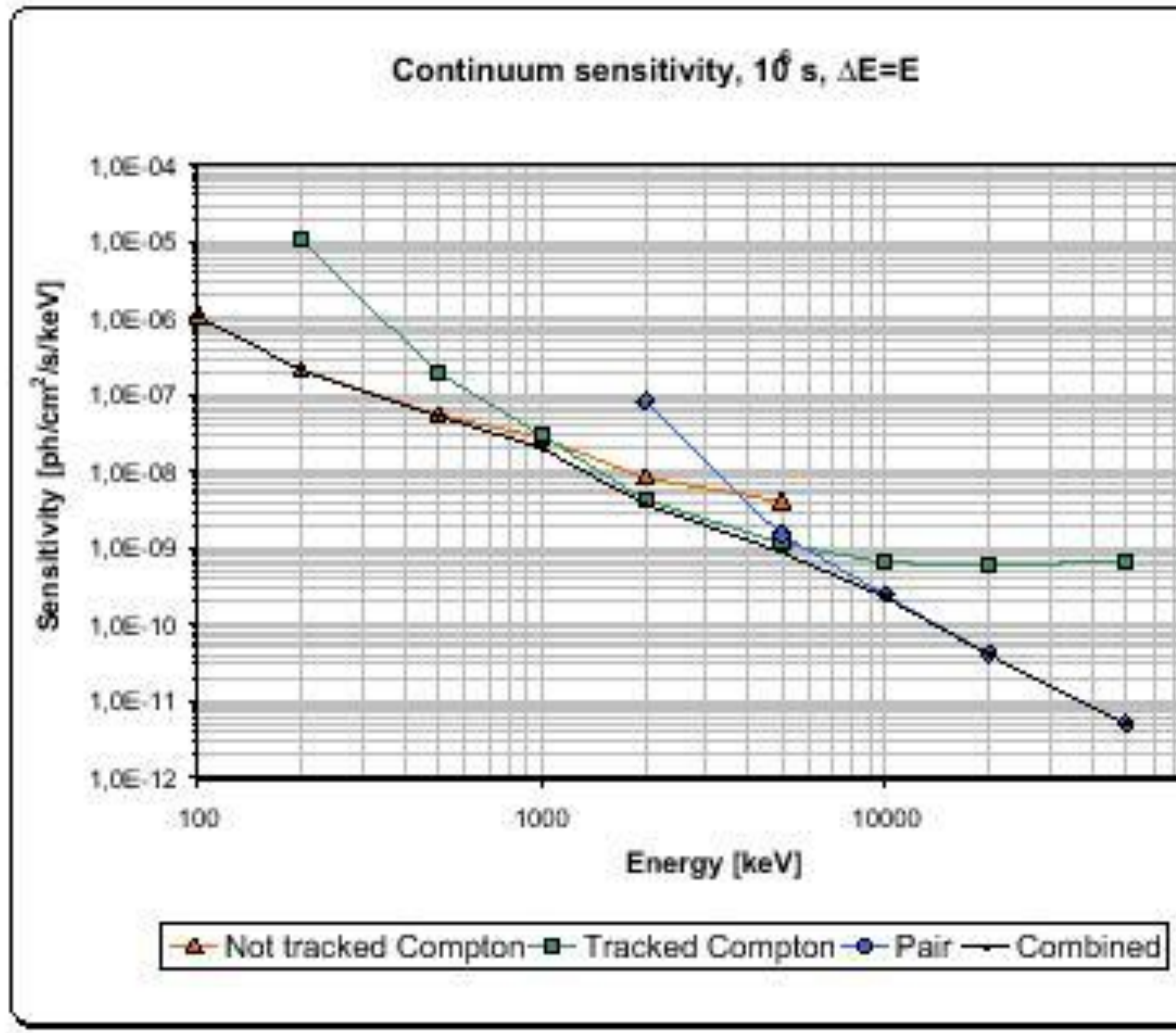
GRIPS capabilities

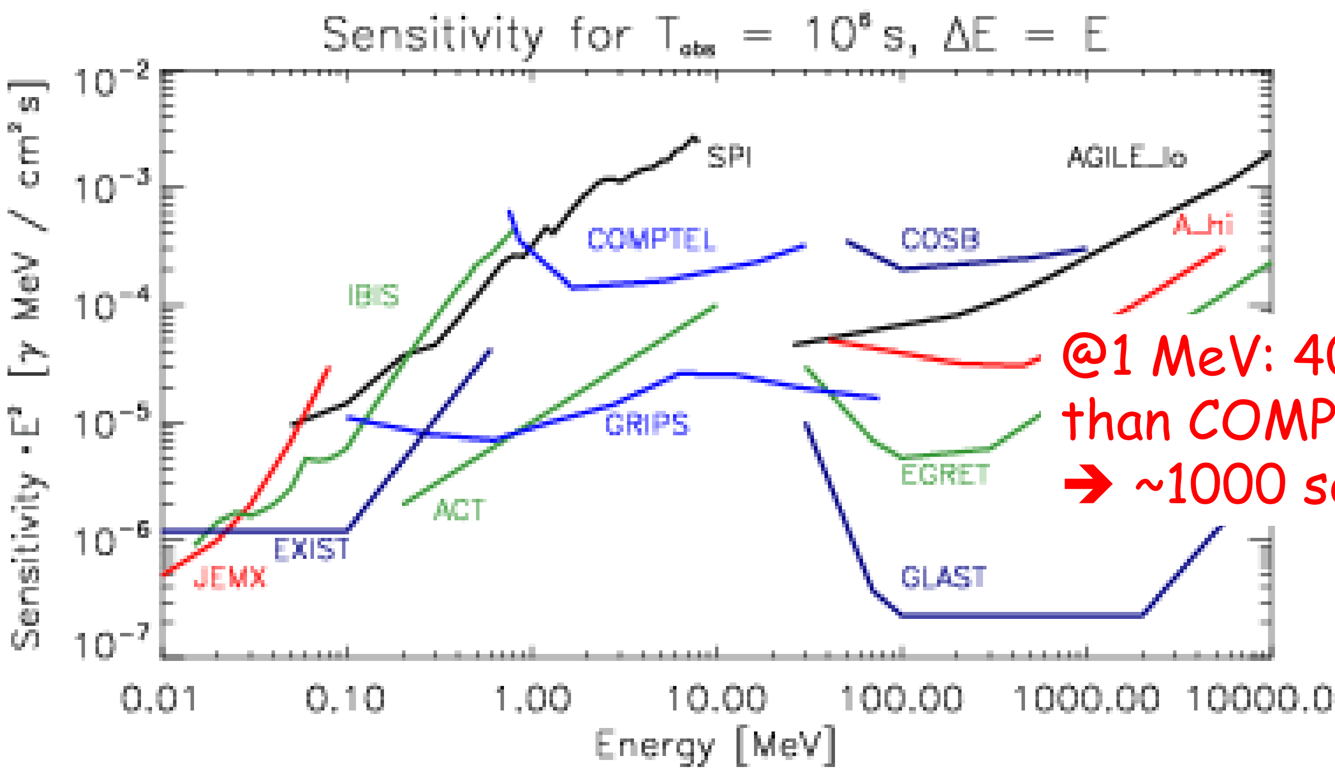
Localizations: 0.5-1° radius

Performance parameters for different norrow line sources





GRIPS sensitivity in context



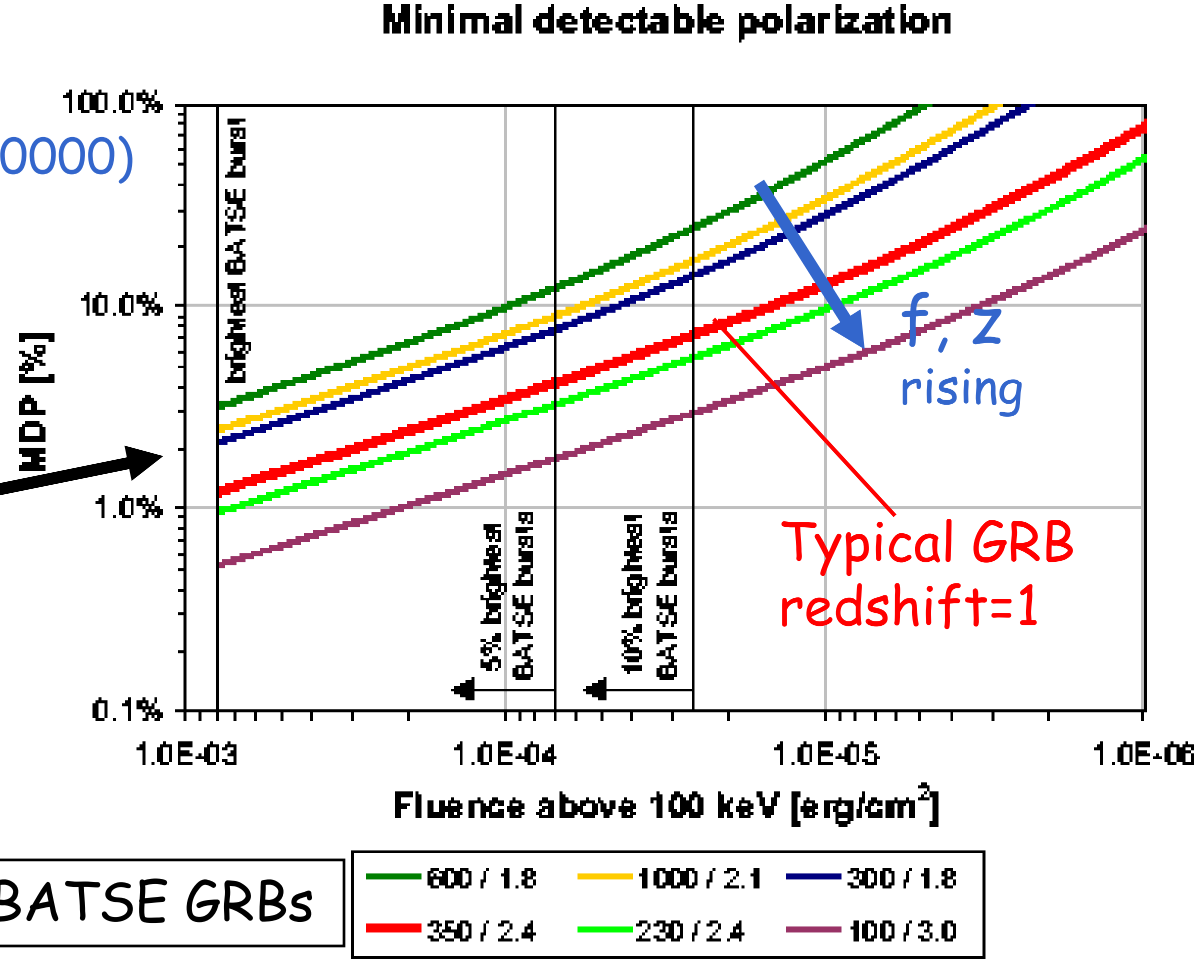
@1 MeV: 40x more sensitive than COMPTEL/INTEGRAL
➔ ~1000 sources in 1 yr survey

- more sensitive than EXIST above 200 keV
- similar sensitivity to Laue lens (GRI): ~20% diffraction efficiency is just compensated by focusing. Also much wider energy coverage and not the ambiguity of line energy / sky position as the lens.

Perfect to measure Polarisation

Polarisation sensitivity best at 200-500 keV: f=flux(200-500)/flux(200-50000)

- in Gamma-Ray Bursts
- in SGRs, AXP flares
- Pulsars
- other bright sources



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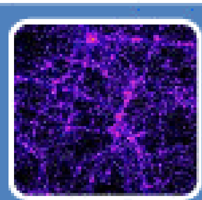
- Novae (511 line plus conti light curve)
- Origin of 511 keV emission (source class / transport)
- Supernovae: several per yr; few in lifetime to distinguish models
- Diffuse continuum MeV emission
- Discovery space!

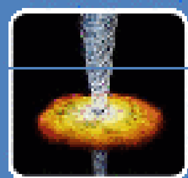
Encounter the superlatives with GRIPS



Highest redshifts

3.1, 3.2

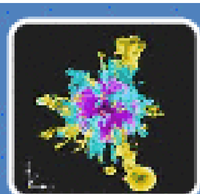
- Find first massive stars through GRBs
- Pinpoint first massive DM halos with MeV blazars



Beyond the thermal regime

3.1, 3.2, 3.5, 3.6

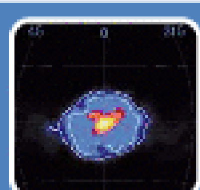
- Study accretion and jets near spinning black holes
- Injection of cosmic rays from the thermal pool



Extreme explosions

3.1, 3.3

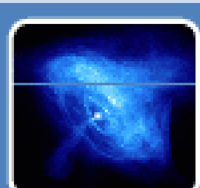
- Decipher the explosion mechanisms of SNe and GRBs
- Formation of elements and isotopes



Antimatter

3.4

- Trace the sources of positrons
- Identify signatures of elusive dark matter



Strongest magnetic fields

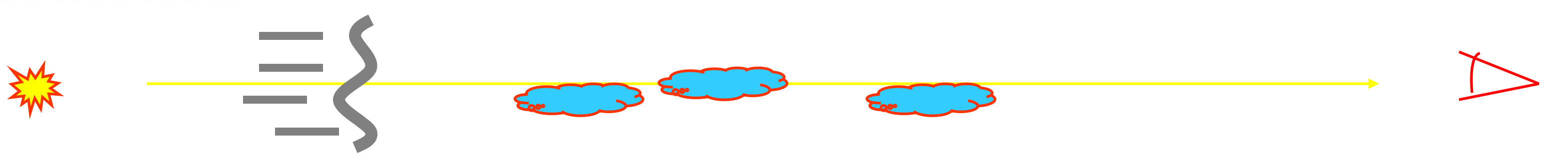
3.6

- Discriminate radiation mechanisms in pulsars
- Understand supercritical fields in magnetars

GRBs as light beacons

- Long-duration GRBs are caused by explosion of massive stars
- Thus: Long-duration GRBs follow the star formation rate
- If rapidly identified: unique probes of early universe, including cosmic chemical evolution, re-ionization
- GRBs are ideal light beacons to study early universe
  - ☆ Bright
  - ☆ Not affected by dust extinction – unbiased sample
  - ☆ Simple spectrum (power law)
  - ☆ No pre-GRB ionization of surrounding

Star formation



GRB **Re-ionization** **absorbers** **observer**

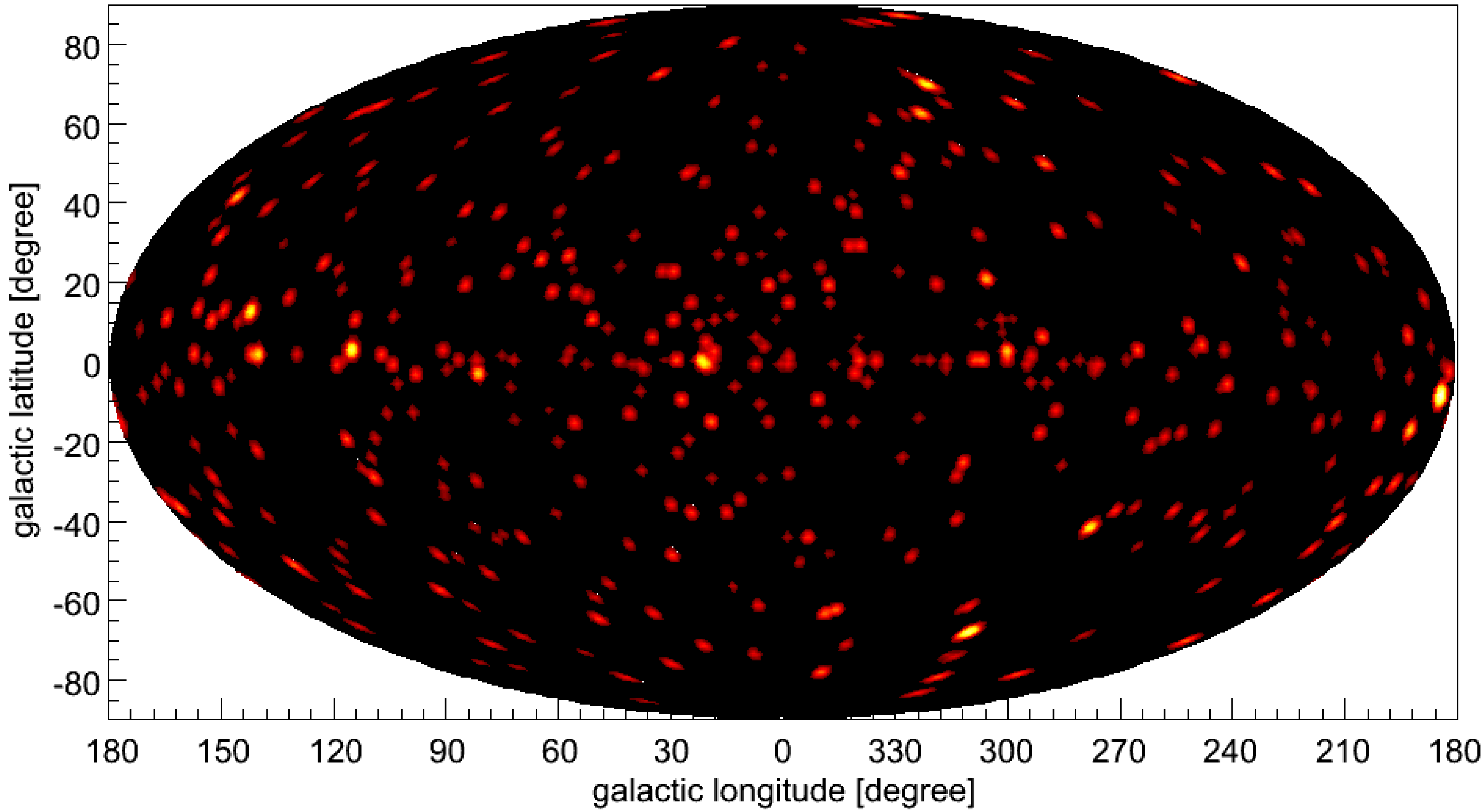
GRB science topics

- Emission mechanism: is it synchrotron or inverse Compton?
  - polarisation in 200-1000 keV can tell
  - also spectral components below/above ~MeV
- short GRBs – 150/yr expected
  - nearby shorts ($z<0.1$/~300 Mpc) are promising candidates for gravitational waves detectable with A-LIGOII
- high-redshift Universe:
  - with 660 GRBs/yr: expect 30/yr at $z>5$, 3/yr at $z>10$ (as compared to 5 GRBs at $5<z<8.2$ in last 14 yrs) [requires X-ray telescope]
  - When and how did the first (Pop III) stars form & evolve?
  - Did re-ionization begin at z ~15 (WMAP) and reach, say, 50% by z ~10?
  - What is SFR(z) and Z(z)? Did dwarf-irregulars really power the EoR?

GRIPS (5 years): based on simulated Fermi catalogue.

Effectively based on EGRET sources!

→ IF the EGRET catalog contained more faint/soft sources, we would also see more sources with GRIPS!



Number of sources that can be detected with the sensitivity of GRIPS

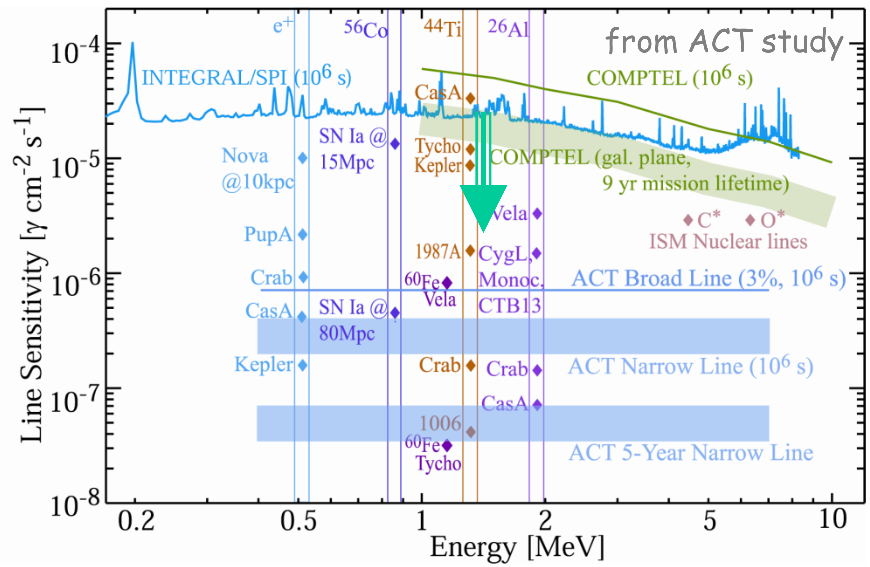
	(1 yr exposure)	(5 yrs exposure)	
Type	#	total #	new
GRBs	660	3300	3300
Blazars	820	950	300
Other AGN	250	300	0?
Pulsars/AXP	60	90	0?
Unidentified	170	230	60

Based on extrapolations of KNOWN source spectra!
Prior Fermi-launch!

Exploration Depth of this Energy Band

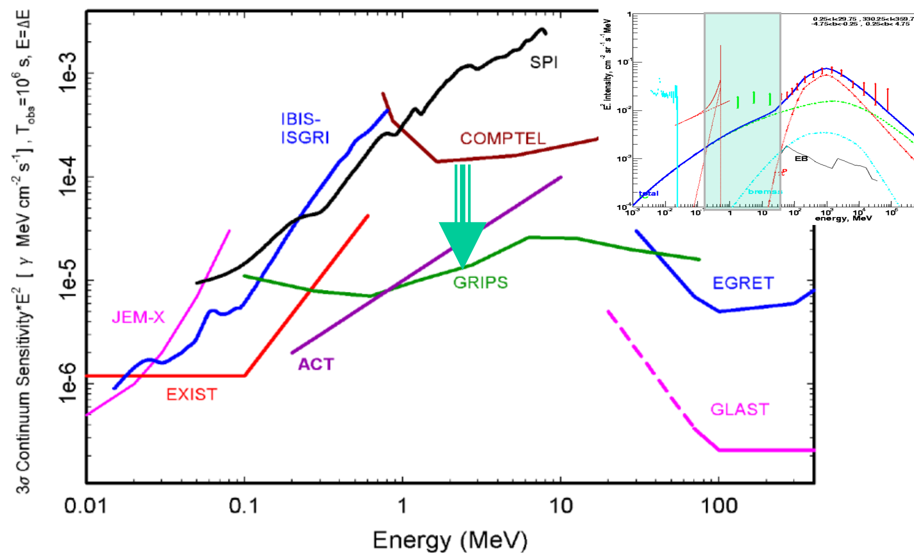
☆ Spectroscopy (Lines)

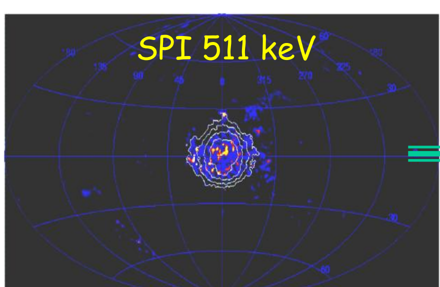
- Radioactivities in SNe, Novae
- Positron Annihilation
- Nuclear Interactions (LECRs)
- *from "one key source" to a sample*

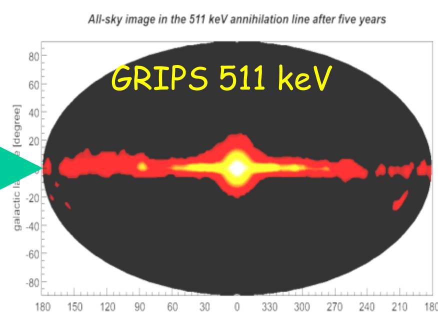


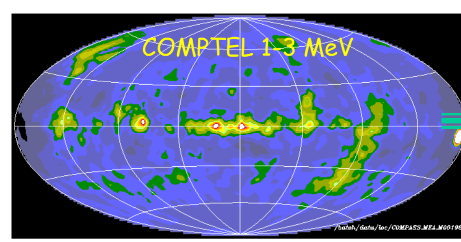
☆ Non-thermal Continua

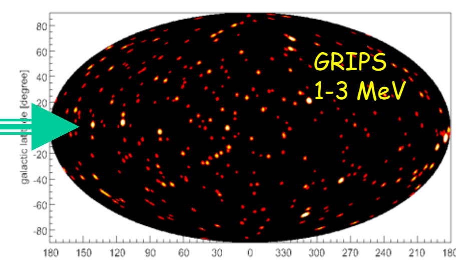
- Particle Acceleration
  - from thermal pool; 'Fermi in detail'
  - in strong fields (B,G)
- Jet Sources, MeV Blazars
- *constraints from a new E band*







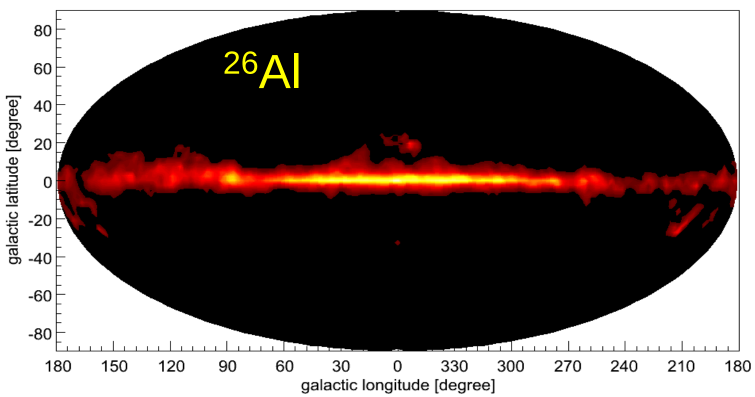




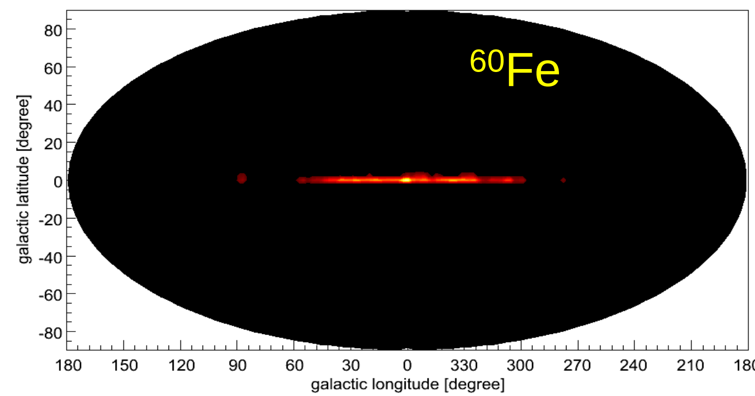
Summary

GRIPS will be a huge leap forward in GRB science
and in galactic and extragalactic MeV astronomy +++

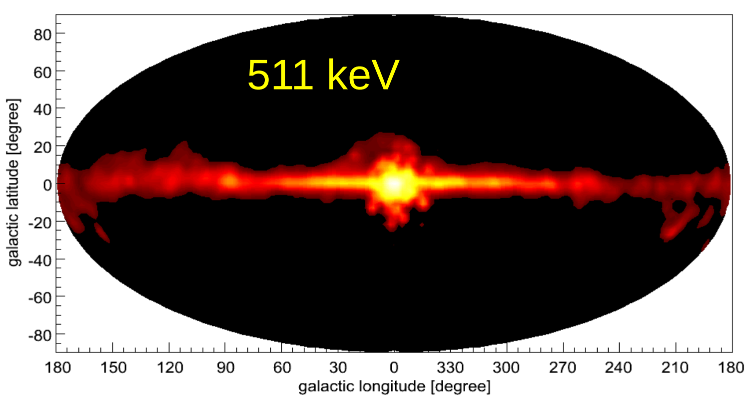
All-sky image in the ^{26}Al line after five years

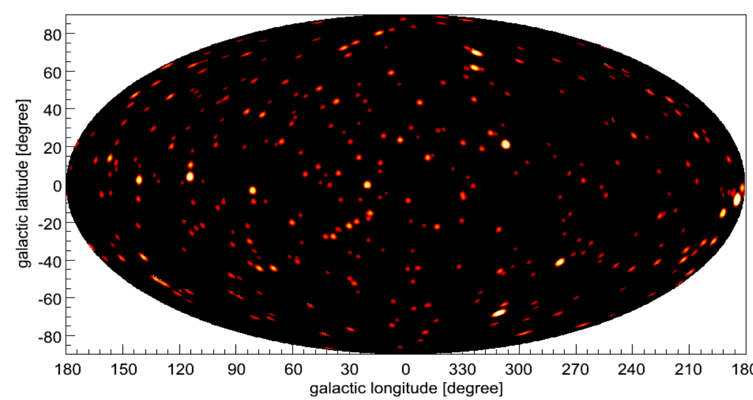


All-sky image in the ^{60}Fe lines after five years



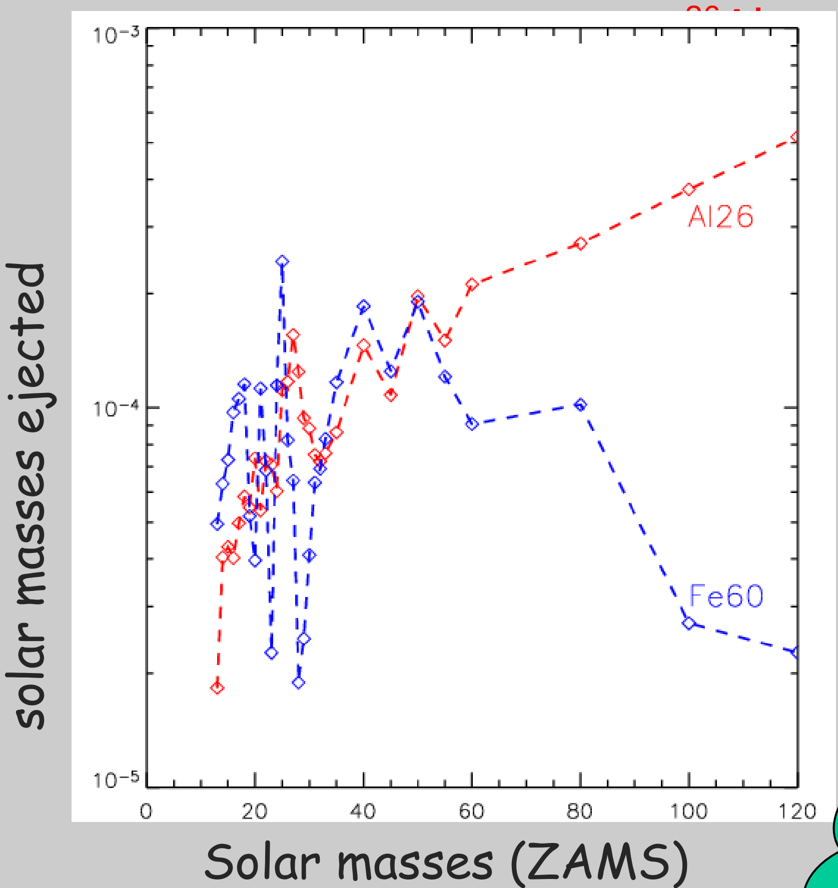
All-sky image in the 511 keV line after 5 years





Revised/Updated/New Massive-Star Nucleosynthesis

Woosley & Heger, PRL'07:

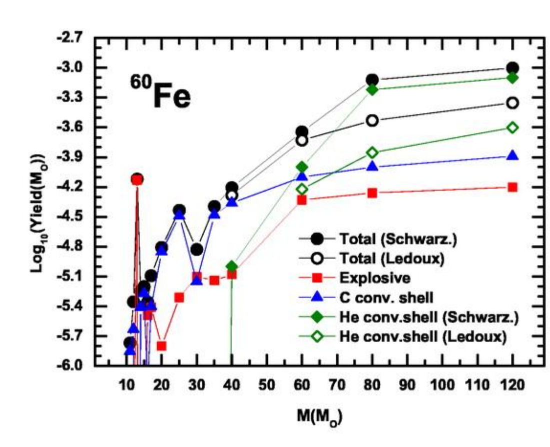


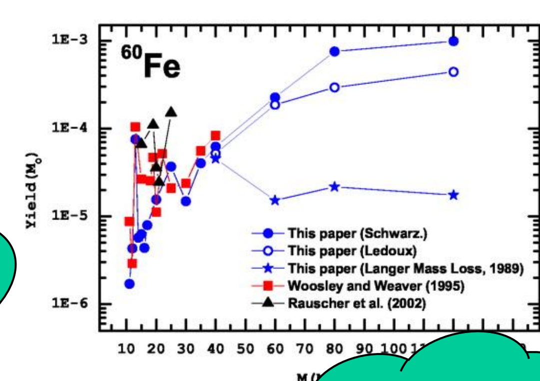
Woosley & Heger 2007:

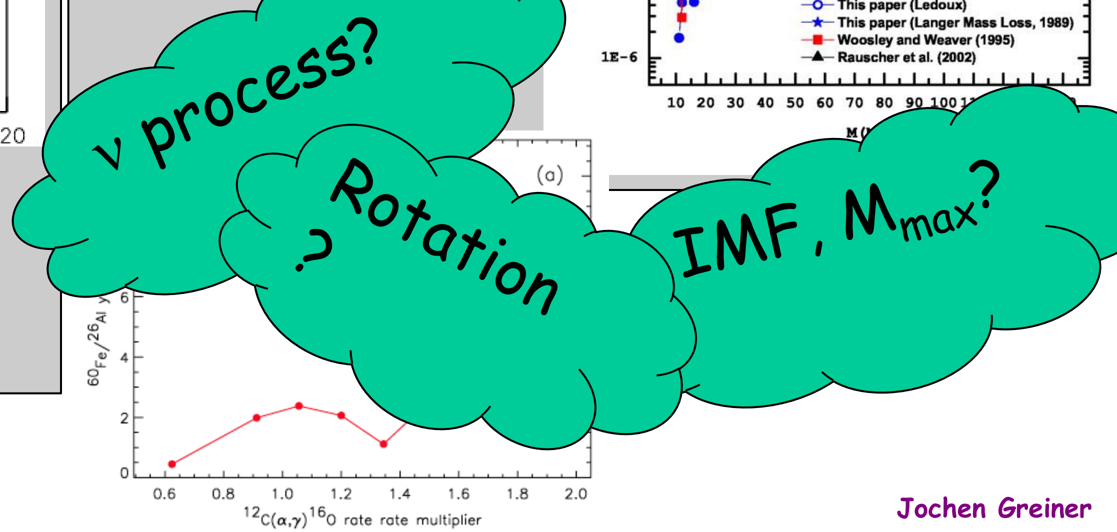
- He Core Evolution through SN
- Including ν Process

Limongi & Chieffi 2006:

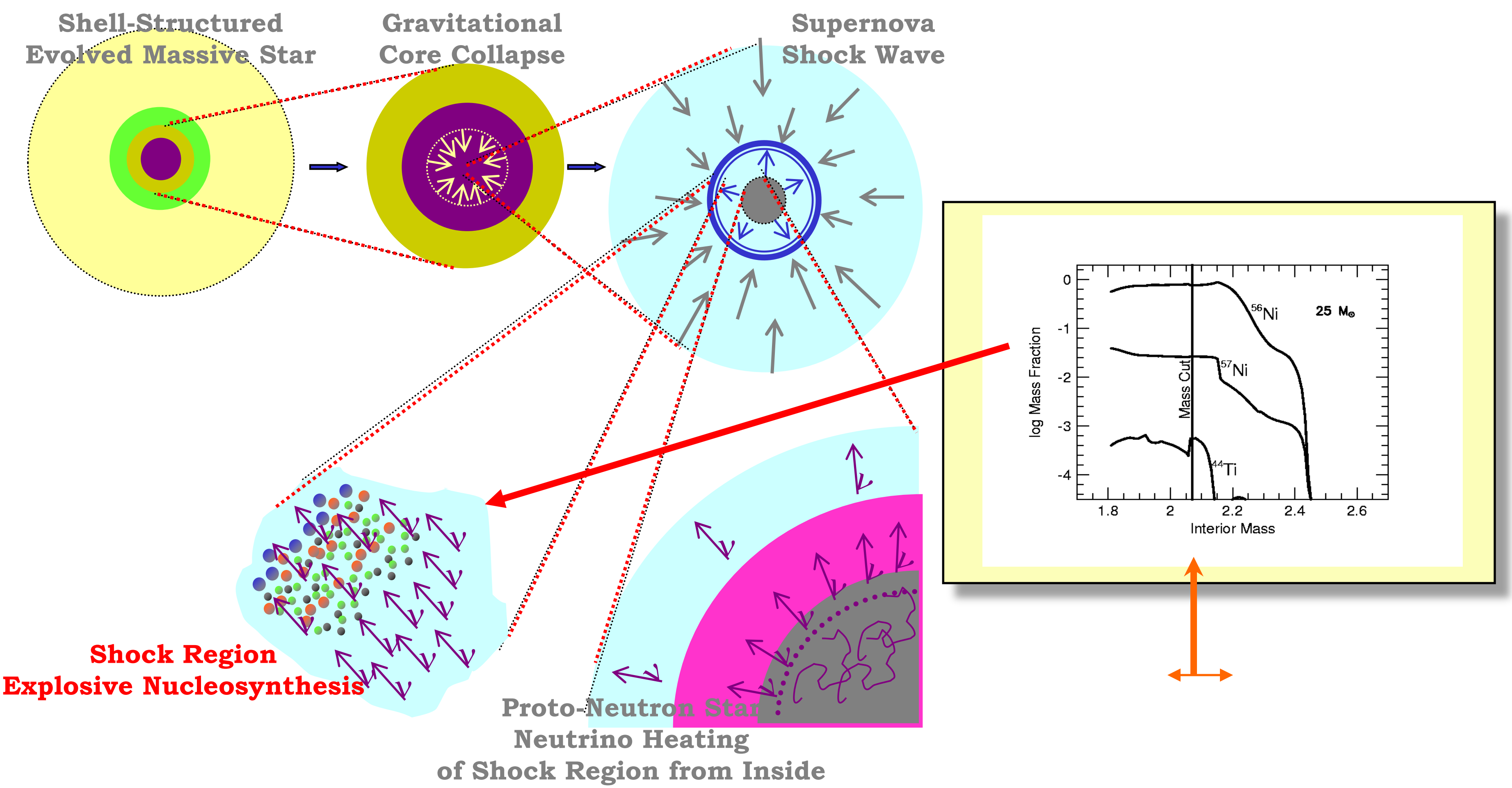
- MS Evolution through SN
- Test Various Convection & Mixing & Mass Loss Models
- High-End Masses Very Variable for ^{60}Fe
- Agree with Gamma-Ray Constraints for Latest Models and M_{upper}=80M







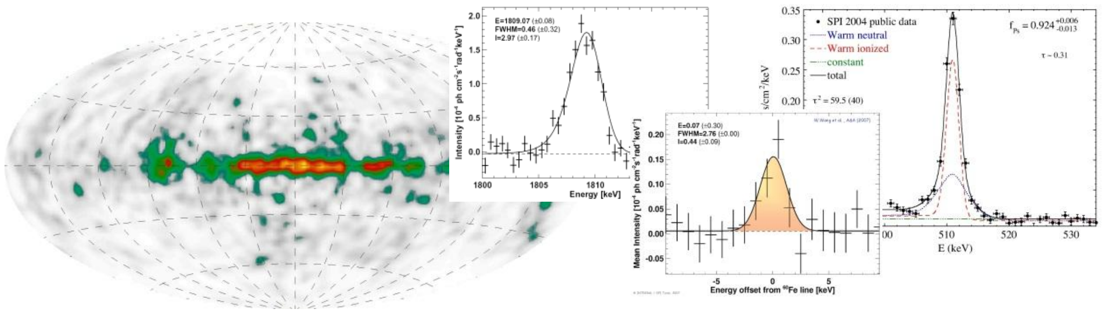
Nucleosynthesis in CC-Supernova Models and ^{44}Ti

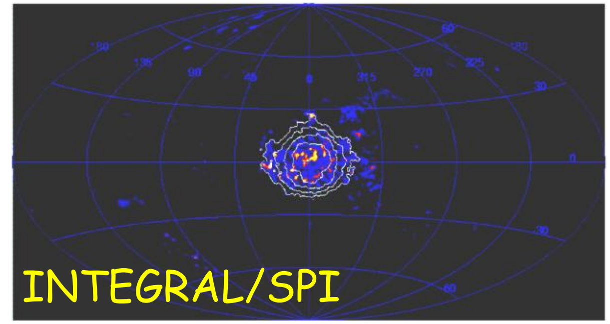


- ^{44}Ti Produced at r < 10^3 km from α-rich Freeze-Out,
  => Unique Probe (+Ni Isotopes)

From All-Sky to Specific-Source Studies

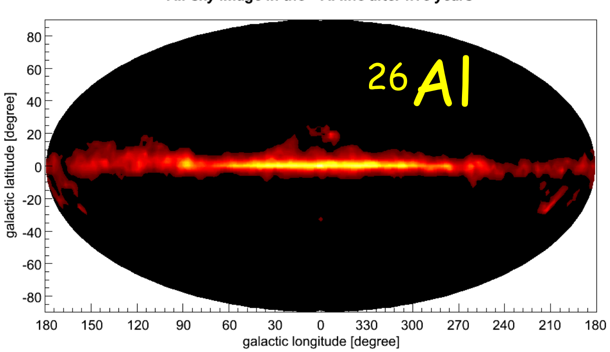
☆ Current Gamma-Ray Line Surveys Can Only See Brightest Emission:



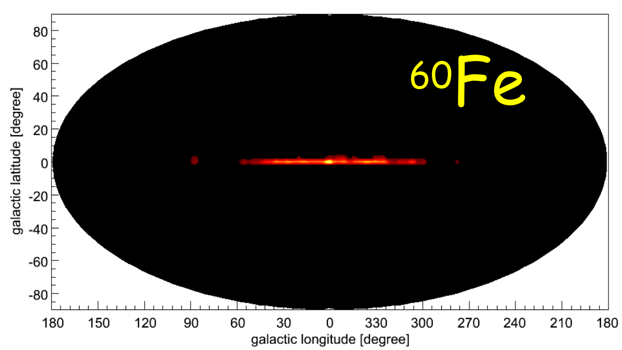


☆ GRIPS Will Provide Localized Results:

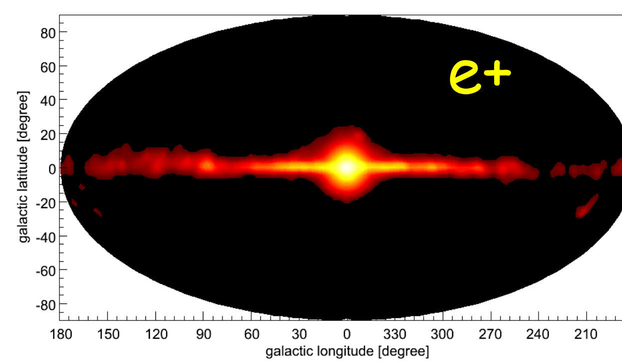
All-sky image in the ^{26}Al line after five years



All-sky image in the ^{60}Fe lines after five years

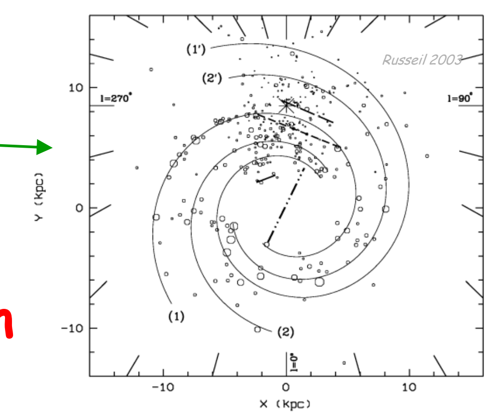


All-sky image in the 511 keV annihilation line after five years



☞ ^{26}Al to ^{60}Fe to Positron Yields per Massive-Star Group

☞ We Know ~ 500 Star-Forming Complexes;
Gamma-Rays will also see Embedded SFR's

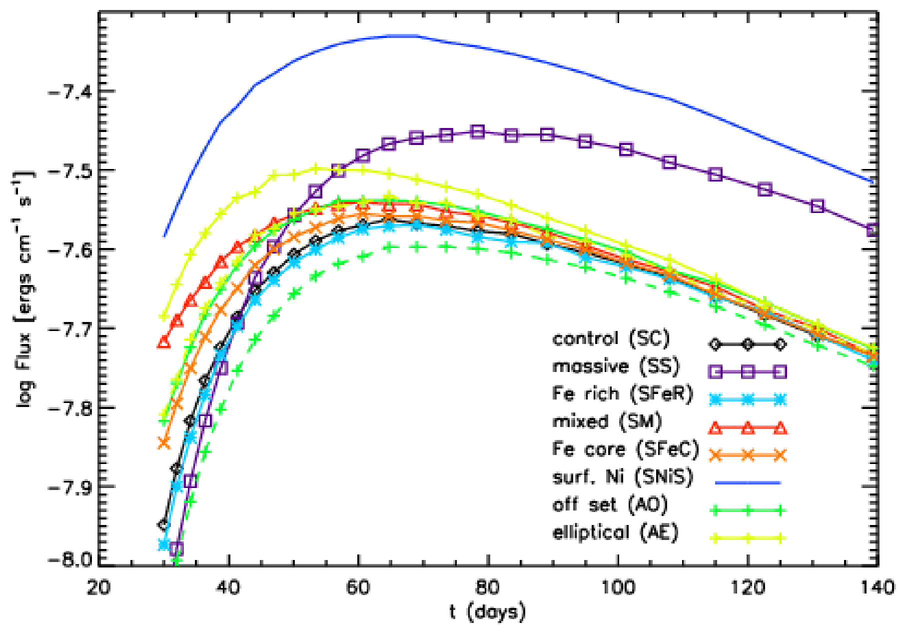


☆ From All-Sky to Many Specific Sources
→ Study the Conditions for Pop I Star Evolution

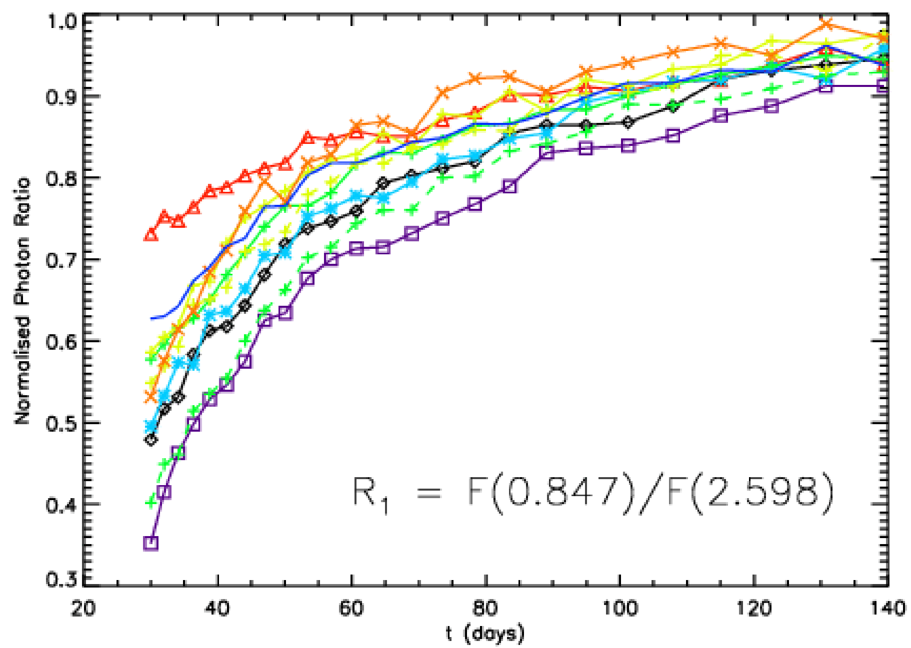
Type Ia SN
Identifying the progenitors and probing the explosion physics

Measure γ-ray line light curves and profiles in nearby (< 200 Mpc) SN Ia: 2-5/yr

- Distinguish progenitor scenarios direct measurement of ^{56}Ni mass (single / double degenerate)
- Distinguish explosion scenarios measure line shape evolution

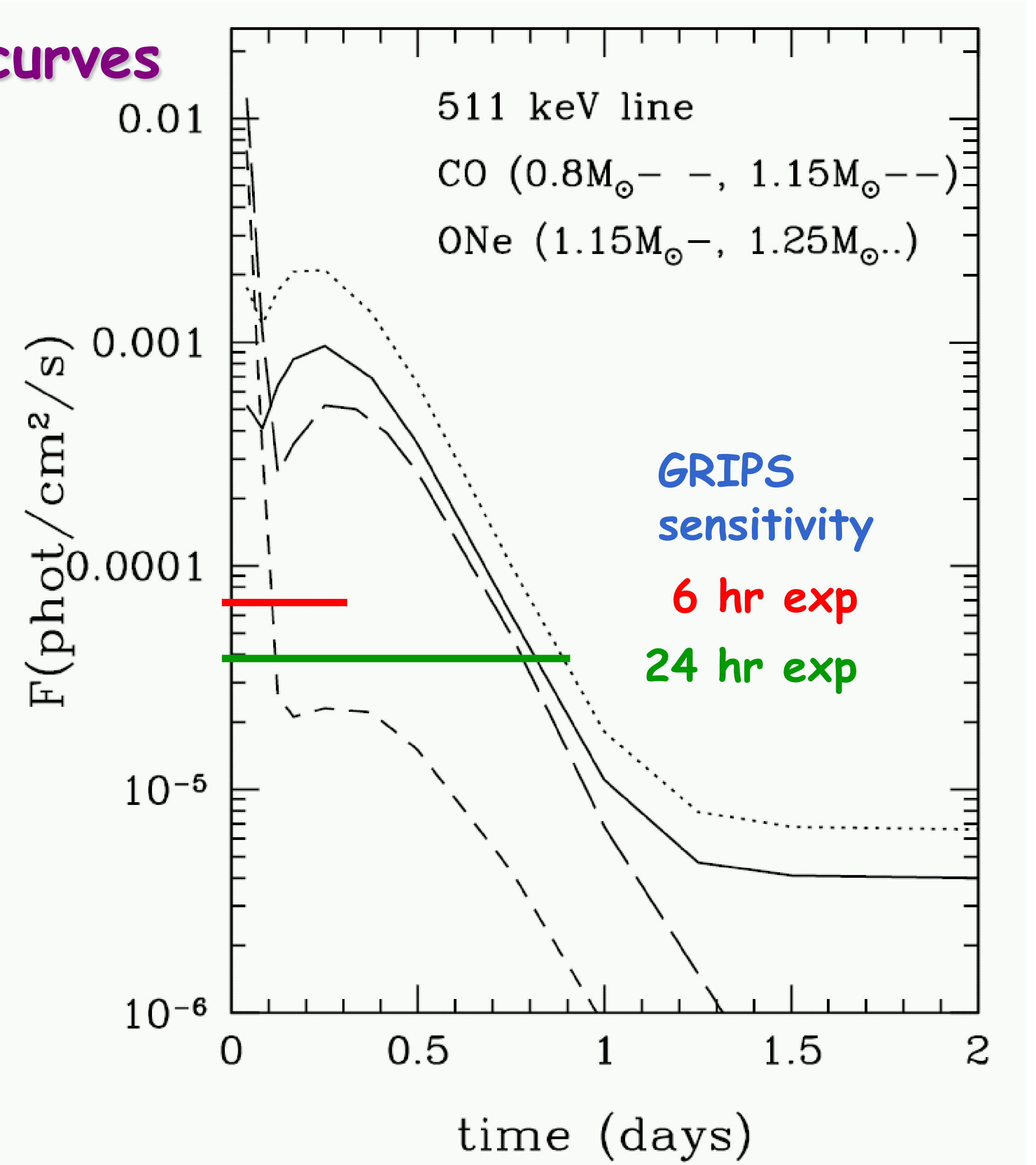


Simon & Mazzali (2008)



Novae: 511 keV light curves

- All-sky monitor allows to detect them within <1hr
- Light curves within first day

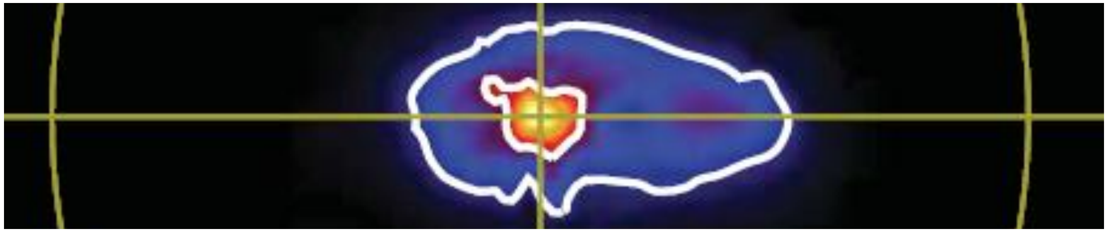


Novae at 1 kpc distance (Hernanz et al 2007)

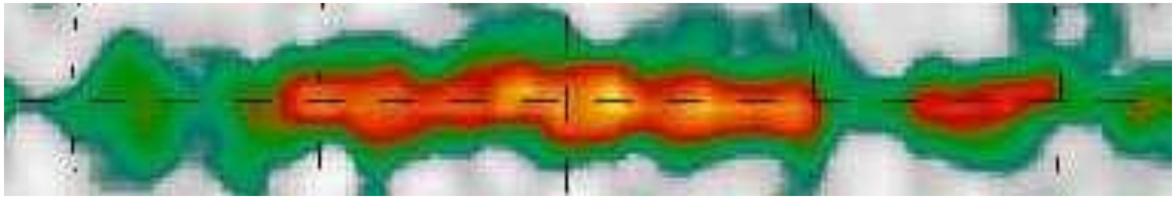
What are the Positron Sources??

☆ Identify Each of the KNOWN Types of Sources

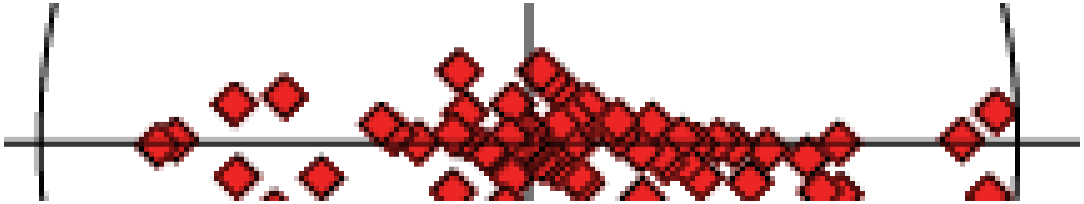
- Individual Sources?
- Morphology of Galactic-Disk Emission
- Assemble a Sky Model for the Known Integrated Emission, e.g.:



- Positron Annihilation



- ^{26}Al Radioactivity



- Binary Systems (LMXBs)

☆ See if Significant Residual (bulge) Emission Remains

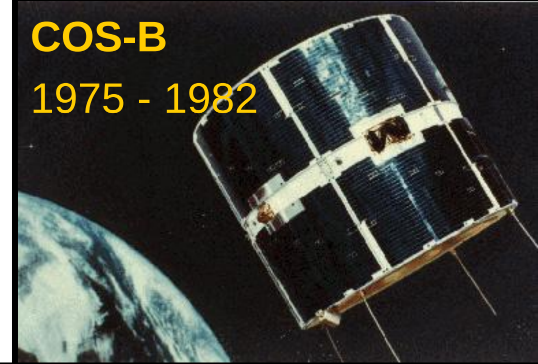
☆ An Unexpected / New Type of Sources? (e.g. DM?)

Perspectives

- wealth of scientific topics with guaranteed progress
  - 650-700 GRBs/yr: high-z Universe
  - All-sky Survey in 0.2-50 MeV → ~40x more sensitive than COMPTEL
    about 1000(-5000?) sources in 1 yr survey (cp. to 30 COMPTEL sources)
  - Polarization of SGRs, bright sources (Crab), AXP flares
  - Pulsars
  - Nucleosynthesis in all flavours: ^{26}Al, ^{44}Ti, ^{60}Fe
  - Solar flares
  - Novae (511 line plus conti light curve)
  - Origin of 511 keV emission (source class / transport)
  - Supernovae: several per yr; few in lifetime to distinguish models
  - Diffuse continuum MeV emission
  - Discovery space!
- unique capabilities: polarisation & nuclear lines
- re-proposed for ESA CV2010, but 'politically' ignored
- with MPE stepping out, we need to re-organize

  GRIPS collaboration (www.grips-mission.eu) presently includes ~50 scientists from 10 countries, but we need a new German flagship

Heritage: MPE History in γ-rays



- Missionen mit MPE Beteiligung:
  - ☆ COS-B
  - ☆ Ulysses: HUS
  - ☆ CGRO: COMPTEL / EGRET
  - ☆ *INTEGRAL:* IBIS / SPI
    - ☞ Spektrometer SPI
  - ☆ *Fermi:* LAT / GBM
    - ☞ Fermi Gamma-ray Burst Monitor

Various levels of arguments

Science

- New science (world leadership)
- gravitational wave and neutrino telescopes need external trigger for "classification" of transient event

Common sense under conditions of reduced resources

- Synergy in detector development with nuclear physics and astro-particle communities

Politics/Management

- Old division between space-based (solely MPIs) and ground-based big projects breaks down
- (Karl:) Germany is country of nuclear physics / education