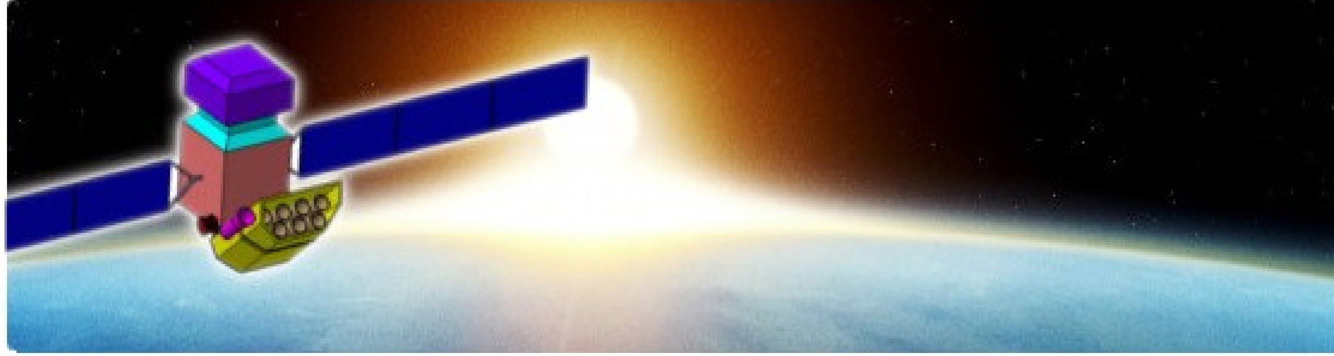


GRIPS: the deep connections to GeV and TeV

O. Tibolla, K. Mannheim, A. Paravac

Institut für Theoretische Physik und Astrophysik,
Universität Würzburg, Germany

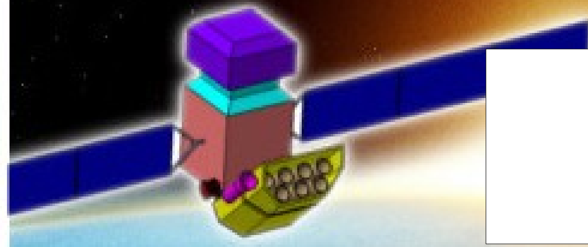
J. Greiner (PI), G. Kanbach

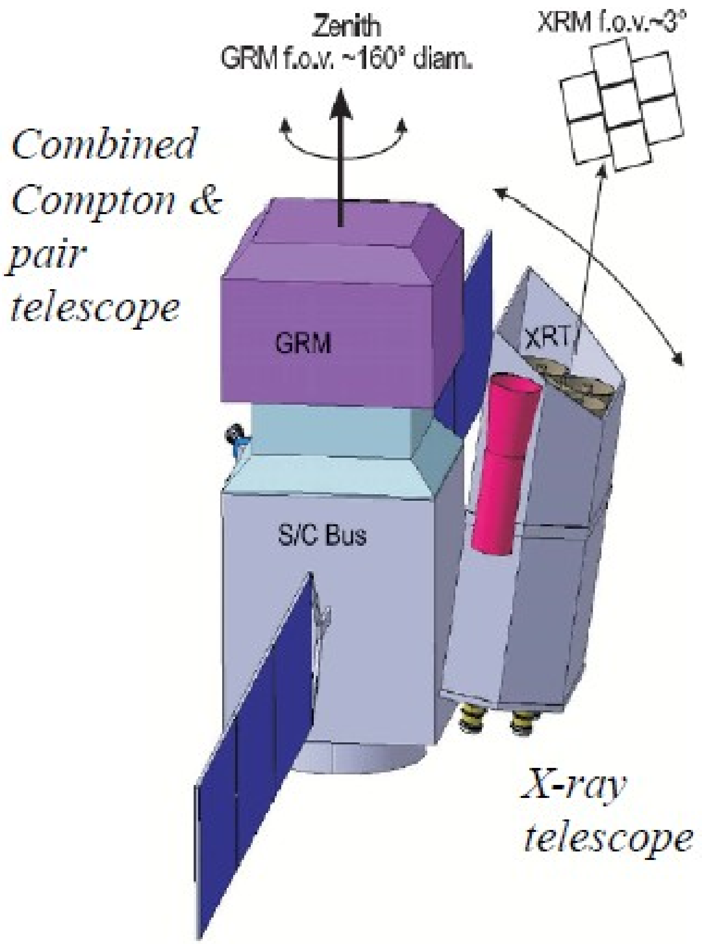
Max Plank Institut für Extraterrestrische Physik, Garching, Germany

SciNeGHE, Trieste, Italy

8th-10th of September 2010

GRIPS





Gamma-Ray Investigations Via Polarization and Spectroscopy.
Ranked 4th in the ESA's Cosmic Vision 2007.

Gamma-ray Monitor

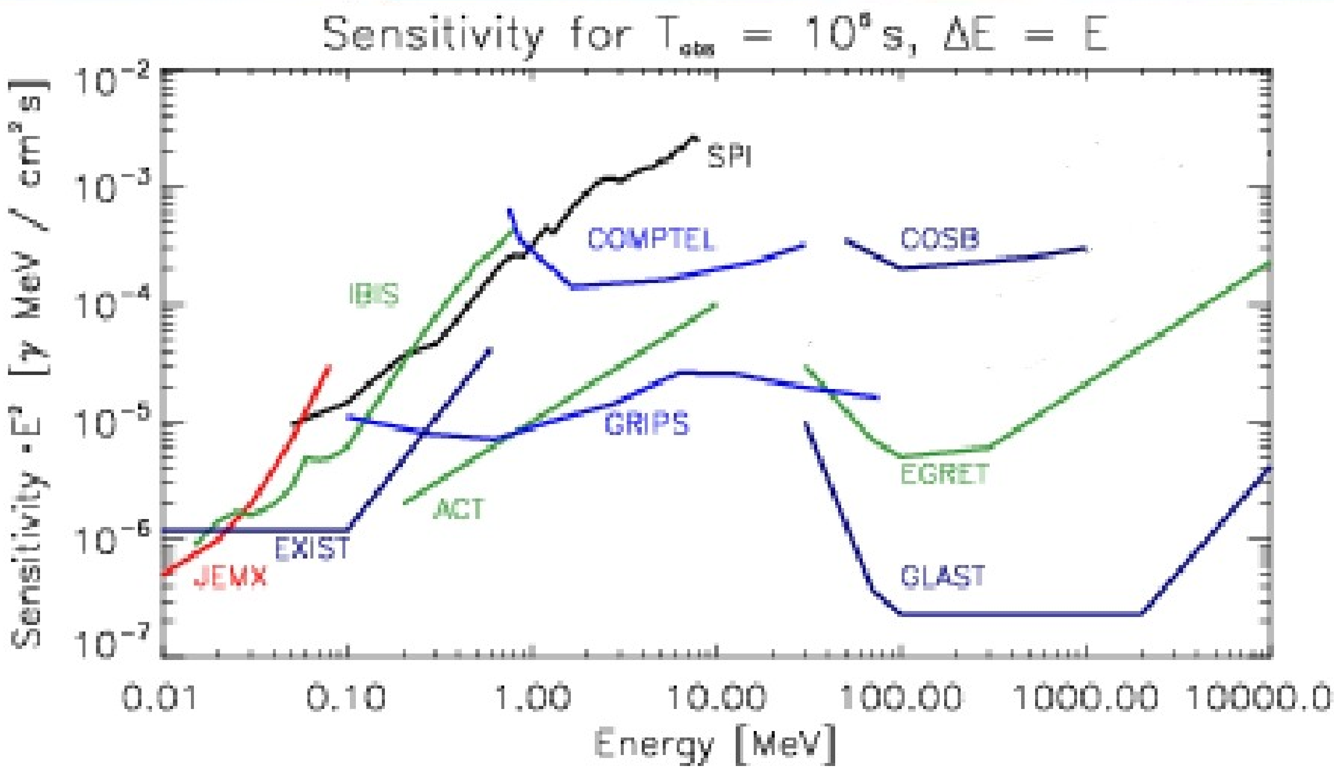
Energy range	200 keV–50 MeV *(extensible)*
Localization	1° (radius)
Polarization	1% (@top 10% GRB)

X-ray Monitor

Energy range	0.1-10 keV
Localization	30'' (radius)

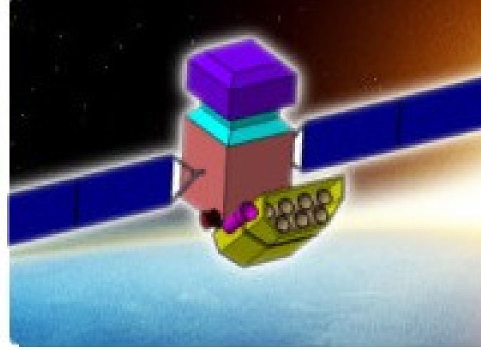
- Described in details in the talk of J. Greiner.
- For urgent questions, see spare slides.

Sensitivity!



- At 1 MeV GRIPS is 40 times more sensitive than Comptel/INTEGRAL → more than 1000 sources in 1 year survey!

- Poorly studied region of the electromagnetic spectrum → complementary with γ-ray and with soft X-ray experiments (bridging the gap..)!



Scientific Purposes:
Gamma-ray Bursts

GRBs science is living a golden age (Swift, Fermi GBM and Fermi LAT).

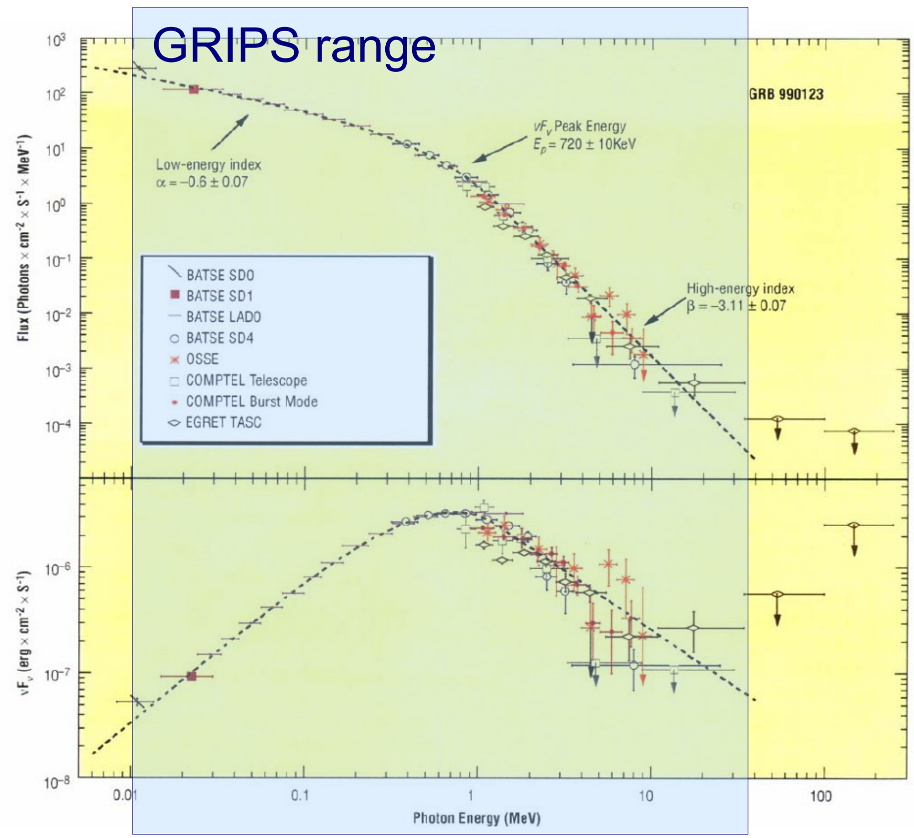
- GRIPS will be a great GRBs monitor (more than 600 GRBs expected per year).

- the νFν energy peak is at MeV

(e.g. Band et al. 1993, ApJ, 413, 281)

- Discovery of high-z GRB as "farthest known objects”

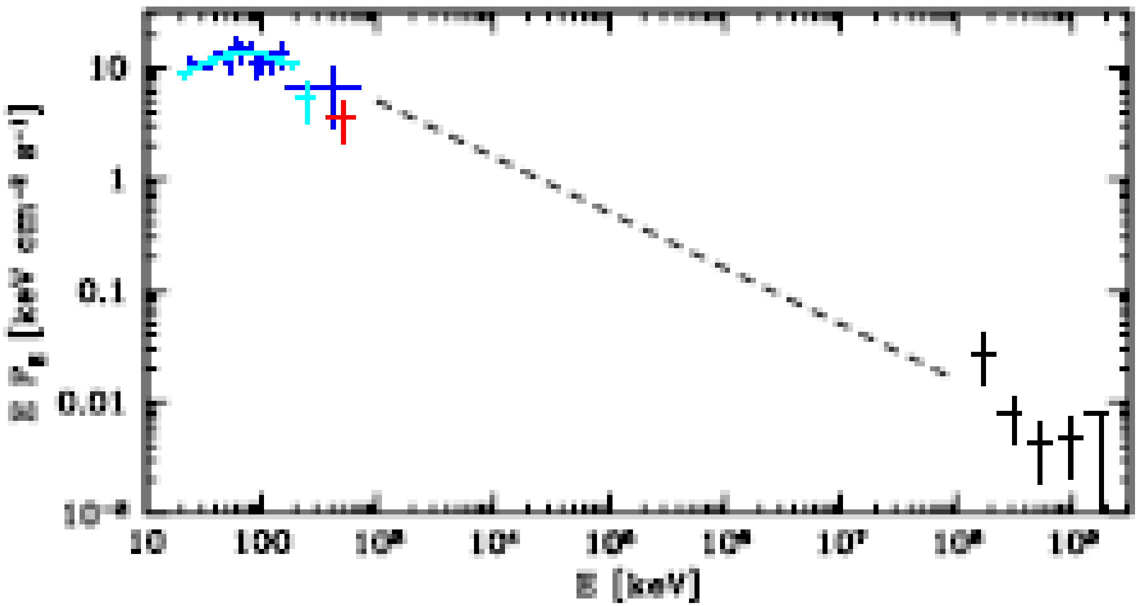
- In the case we would find density columns of 10^{28} cm^{-2} (structure formations at z=20) we could study resonance photon absorptions (PDR, GDR and Delta-R) as predicted by Iyudin et al. (GRB930131), together with LAT (3→325 MeV) (also from AGNs)



Scientific Purposes:
Supra-thermal/Non-thermal

The thermal components finish at maximum at some hundreds of keV...the transition thermal → non-thermal is crucial for many asrophysical HE sources/processes, extragalactic (like in AGNs, jet-disk symbiosis) or Galactic (XRBs).

In particular in the case of Galactic BH-disk systems, we see that the temperature can increase to hundreds of keV...we see as well the non-thermal component from HE observations..what's in between?

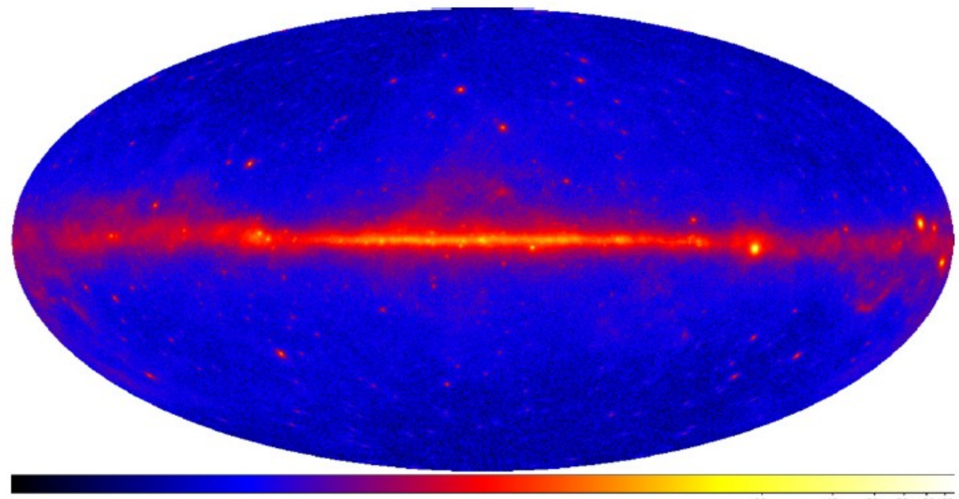


(e.g. Cyg X1 from *Malzac et al. (2009), A&A, 492, 527*)

Scientific Purposes:
SFRs, Galaxy history and SN

The experience with Fermi LAT tells us how important is to have a good knowledge of the ISM in our Galaxy and especially of the young-active regions.

GRIPS in fact is a great instrument for studying the history of our Galaxy. There are in fact 2 unique lines produced after SN explosions that are visible in its energy range:
^{26}Al (half-life of 700000 yrs) and
^{44}Ti (half-life of 60 yrs); both detected by COMPTEL (e.g. *Chen & Gehrels, ApJ, 514, L103*).



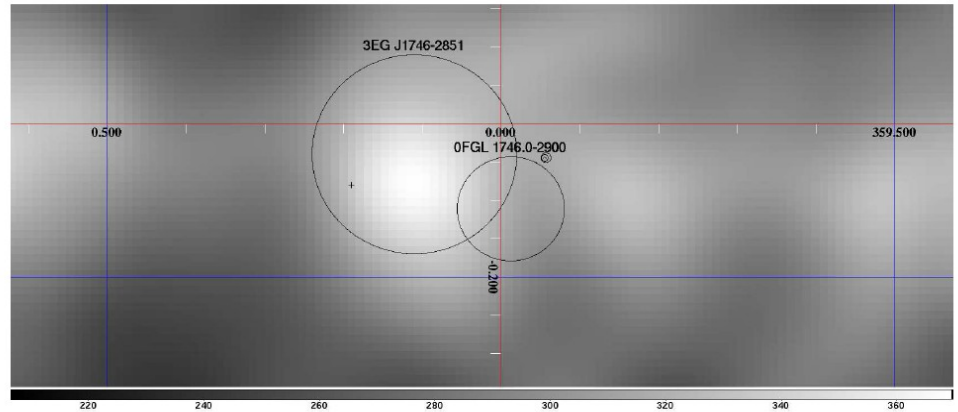
(e.g. Fermi LAT *First year Catalog*)

Moreover, regarding SN, another important radioactive line lies in GRIPS energy range, ^{56}Ni $\rightarrow$ distinguish progenitor and explosion scenarios (within 200 Mpc)

Scientific Purposes:
Dark Matter (GC)

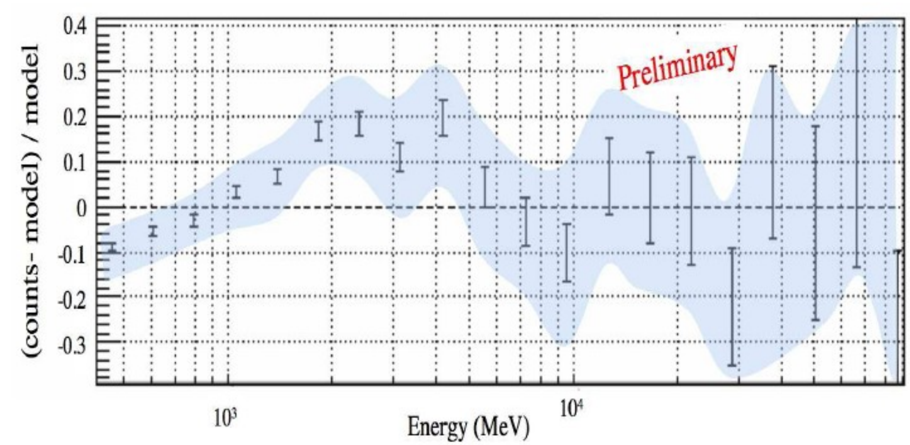
The rest mass of the electrons, 511 keV, is in the energy range of GRIPS. It allows us to map the positron annihilation from regions such as the Galactic Center, or, more in general from the bulge..

This would be crucial also in order to evaluate the DM component in those regions, that, as seen by LAT (see A. Morselli talk), are not easy to study at all.
(having the π_0 bump at 68 MeV would be useful as well; and this is not difficult to implement in the current configuration of the instrument)



(Cohen-Tanugi, Pohl, Tibolla & Nuss ICRC 2009 proc)

(Vitale & Morselli Fermi Symposum proc)



Scientific Purposes:
MeV Blazars

There are two types of flat-spectrum radio quasars (FSRQs): those with steep γ-ray spectrum (MeV blazars) and those with flat γ-ray spectrum (GeV blazars). The two types of blazars are thought to be two aspects of the same phenomenon (e.g. *Sikora et al. 2002, ApJ, 577, 78*) and it has been predicted that:

- variability timescales of MeV blazars should be longer than variability timescales of GeV blazars.

- both type of blazars can appear in the same object.

...contemporary observations by Fermi LAT and GRIPS will be able to answer this questions.

(moreover, *Ajello et al. 2009* and *Kneise & Mannheim 2008*, point out that we can explain ~16% of Extragalactic MeV-GeV background → need for a numerous faint population > 10 MeV)

Scientific Purposes:
Origin of CRs

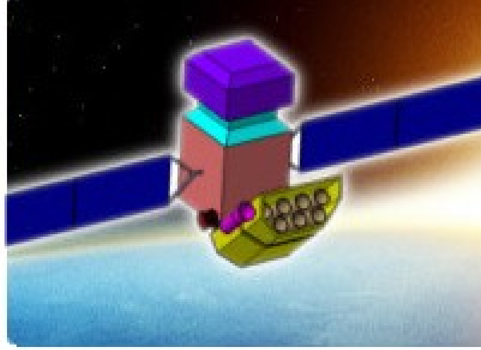
One of the most important achievement of GRIPS will regard CRs, ~98% hadrons and ~2% leptons...discovered ~1 century ago by Domenico Pacini and Victor Hess, their origin is still unknown.

While the leptons acceleration has been proven (e.g. by X-rays and Radio observations of SNRs or PWNe), the “smoking gun” for the hadronic acceleration is still missing. The SN explosions are thought to be the responsible of the hadronic component of CRs (since 1964, Ginzburg et al.) and the recent discoveries at TeV (IACTs) and GeV (Fermi LAT) energies seem to support this, however there is not yet the final proof of it.

GRIPS can provide this proof in 2 ways:

- distinguishing between hadronic and leptonic emission from the continuum spectrum.

- studying the nuclear de-excitation lines.

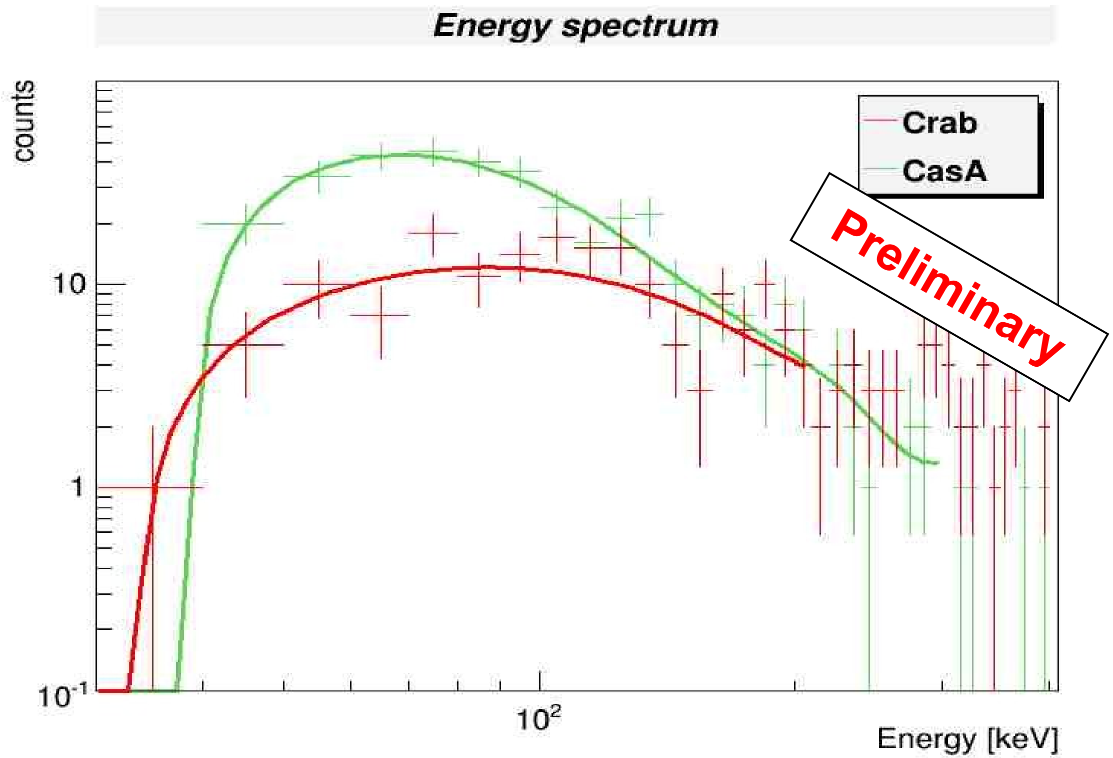


Scientific Purposes:

CRs: continuum

Leptonic and hadronic processes have different signatures in the GRIPS energy range. GRIPS is able to detect the sources that are thought to be responsible of CRs acceleration and to precise measure their spectra.

Example: spectra of the Crab Nebula and Cassiopeia A extracted from the simulation of 1 minute (!!) of GRIPS observations.



Note: it would be extremely nice to have the 511 keV and the 68 MeV in the same instrument...

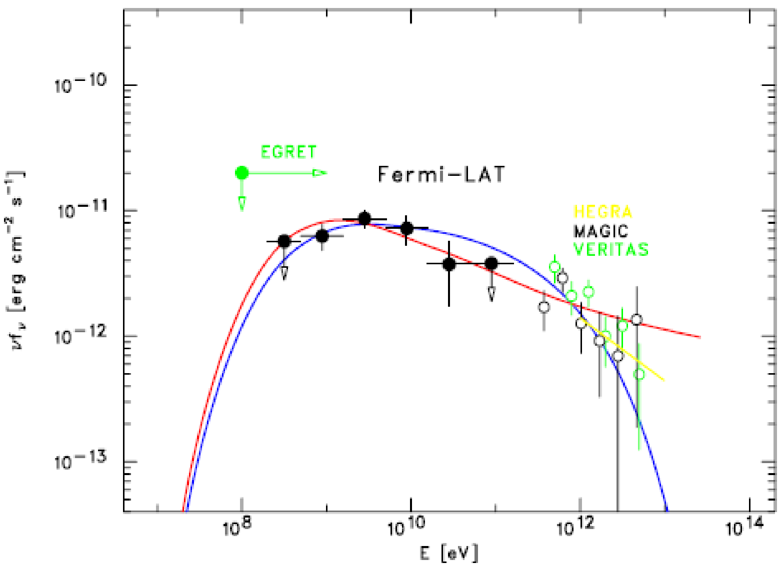
Scientific Purposes:
Nuclear de-excitation lines

The "<u>hadronic fingerprint</u>" can arrive from the study of the de-excitation lines of heavier nuclei.

Exemplary case - Carbon line at 4.4 MeV from Cas A

Prediction from hadronic fit ($p + A \rightarrow \pi_0 + A$) to GeV-TeV data:

Proton power law $Q_p = Q_0\, p^{-2.3}$ with total energy $W_p = \int_{10\,MeV} Q_p\, p\, dp = 4 \times 10^{40}$ erg/s (*Abdo et al. 2010*).
Note that this would correspond to ~2% of the SNR kinetic energy (less than what expected in the Ginzburg scenario, *Voelk & Biermann 1988, ApJ, 333, L65* and *Drury, Markiewicz & Voelk, A&A, 225, 179*).



(*Abdo et al. (2009), ApJ, 710, L92*)

Scientific Purposes:
^{12}C in Cas A (2)

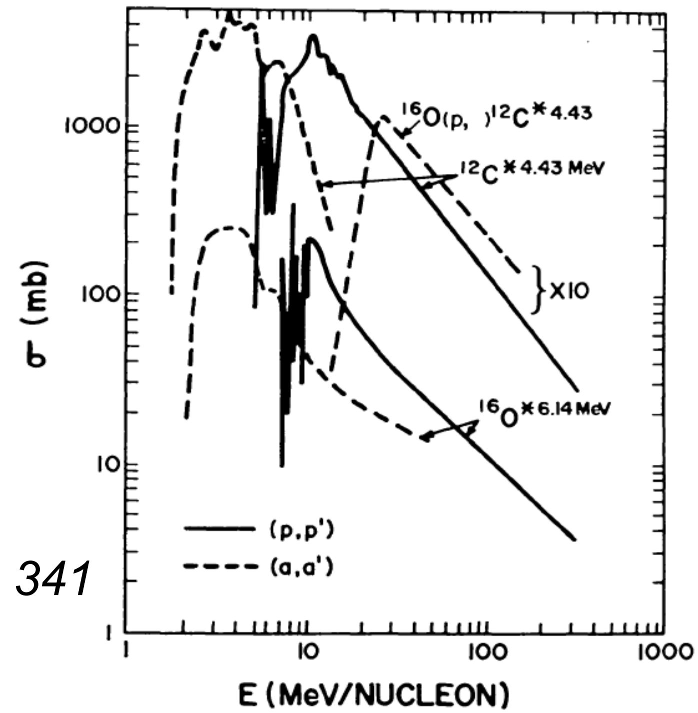
According to *Vink & Laming (2003)*, electrons with a similar slope produce the hard X-rays via synchrotron emission: IC suppressed owing to a strong magnetic field B > 0.5mG (for leptonic GeV-TeV fits, 0.1 mG is needed).

Heavy ion enriched plasma composition with $n_C = 10\ cm^{-3}$ at reverse shock.

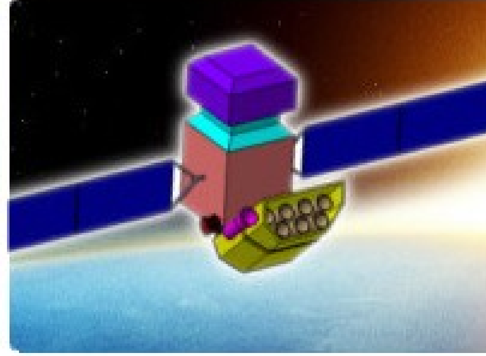
^{12}C excitation and (quasi spontaneous) de-excitation line emission at 4.43 MeV:

$$\frac{dN}{dE}\left({}^{12}C \rightarrow {}^{12}C^{*}\right) = \int_{10\,\mathrm{MeV}} Q_{\mathrm{p}}(p)\frac{d\sigma(p)}{dp} n_{\mathrm{C}}\, c\, dp$$

with cross section:
$d\sigma/dp \approx 3000\delta(p - 10\ \mathrm{MeV})$mb
(*Ramaty, Kozlovsky & Lingenfelter 1975, SpSRv, 18, 341* on a solar flare of August 1972)



GRIPS MISSION



Scientific Purposes:
^{12}C in Cas A (3)

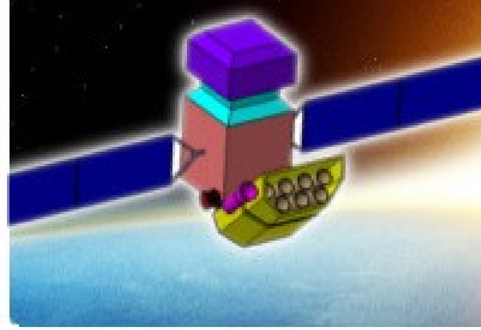
Using d = 3.4 kpc for the distance to Cas A, this yields the line flux at 4.43 MeV:

$$F_{4.43} = \frac{1}{4\pi d^2}\frac{dN}{dE} \approx 4 \times 10^{-8}\ \mathrm{cm^{-2}s^{-1}keV^{-1}}$$

Considering now a line width of ΔE = 100 keV , we obtain the flux that we was searching for and we can compare it with the upper limit by COMPTEL of the flux in the range (3-10) MeV for the continuum (*Strong et al. 2000*)

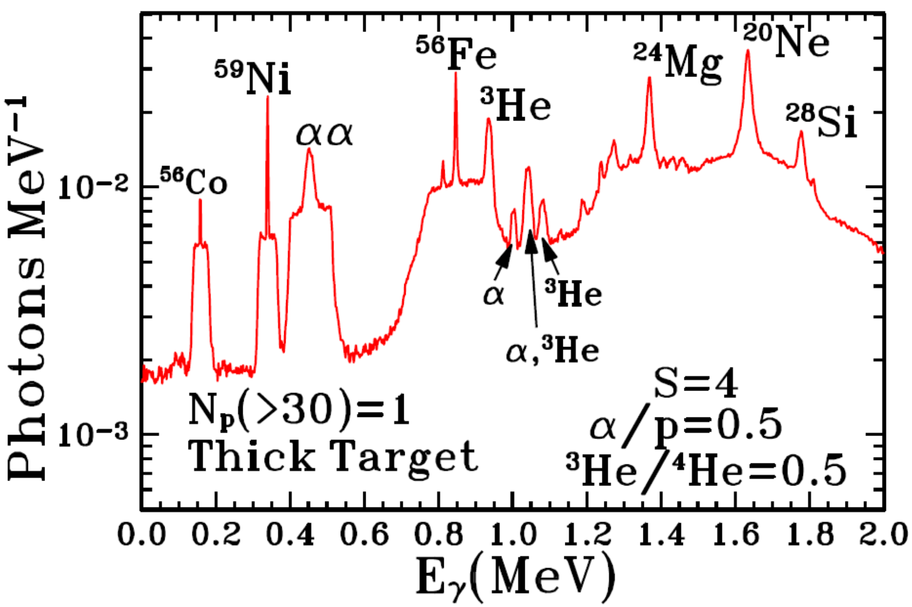
$$\Phi_{3-10} = 4 \times 10^{-6}\ \mathrm{cm^{-2}s^{-1}} < \Phi_{\mathrm{u.l.}} = 1.4 \times 10^{-5}\mathrm{cm^{-2}s^{-1}}$$

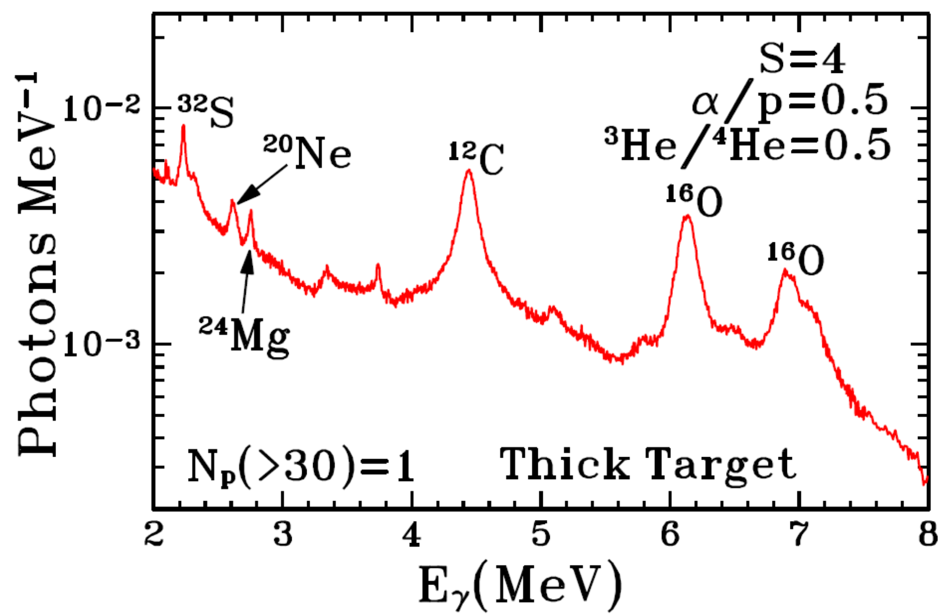
Clearly detectable by GRIPS!



Scientific Purposes:
Conclusion on the lines

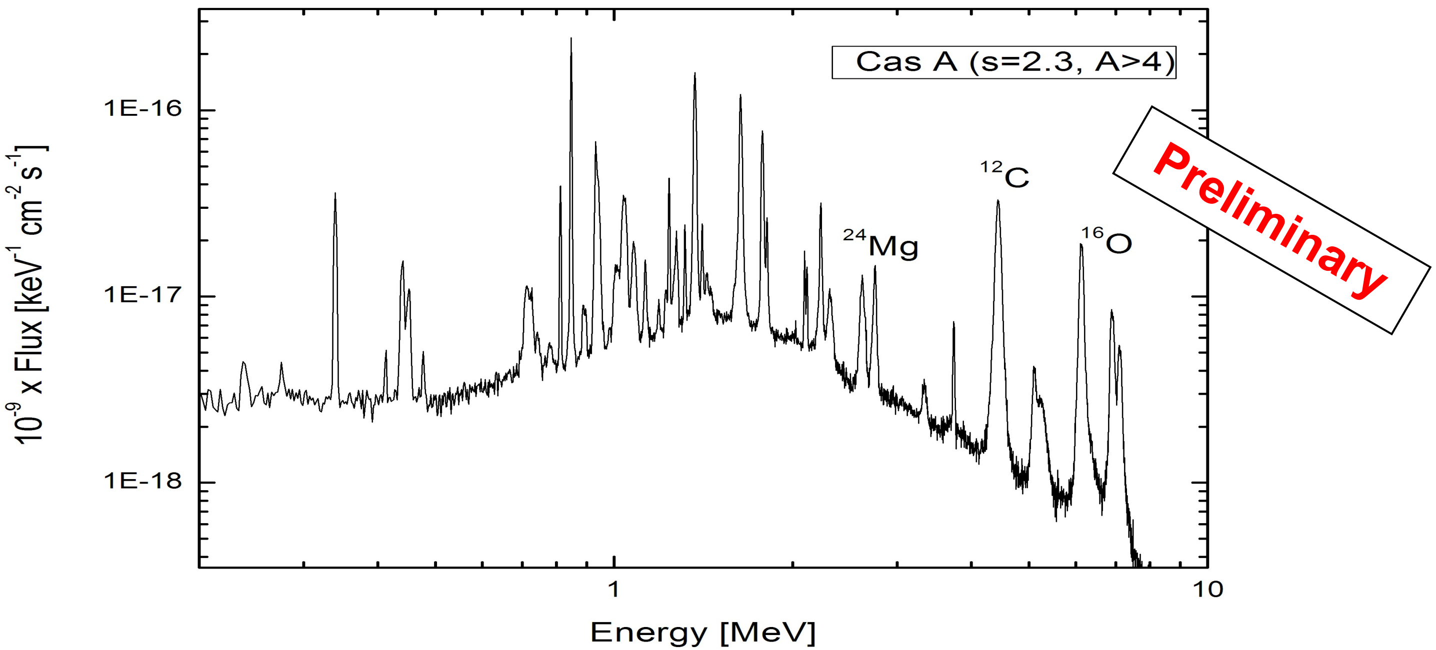
Let's zoom around the ^{12}C line... Using the Ramaty/Koslovsky code, we computed the nuclear de-excitation line spectrum.
With GRIPS we will be able to:
   1- probe the hadronic acceleration in SNRs in independent ways (e.g. continuum spectrum, ^{12}C and ^{16}O lines).
   2- studying the elements abundances by studying the line ratios.





Scientific Purposes:
"Last minute test"

Using the Ramaty/Koslovsky code, we computed the nuclear de-excitation line spectrum for Cas A aboundancies.
Good agreement!...on-going work...



Conclusions

- In order to close the gap between GeV and keV we need a much more sensitive instrument: GRIPS (200 keV – 50 MeV extensible) is 40 times more sensitive than COMPTEL/Integral.

...complementing Fermi (GeV) and IACTs facilities (TeV):

- many GRBs (~600 p.y.) at MeV, wth the possibility of doing hadronic physics
- supra-thermal / non-thermal process variety (diskjet/shocks)
- star formation variety & history in the Galaxy (+ extragalactic SN Ia)
- 511 keV positron annihilation from bulge & disk (DM contribution?)
- MeV-dominated sources (e.g., MeV blazars)
- accretion in the strong-gravity regime (BH,NS)
- testing the high cosmic ray production efficiency (>10%)
- *surprises? ...this is a poorly-explored window...*

Thanks for your attention!

“If 10 years ago I could do an experiment from hundreds of keV to hundreds of MeV, I would have done it instead of GLAST”

W. Atwood