COMPTEL reloaded: new initiatives in heritage MeV gamma-ray astronomy

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ABSTRACT

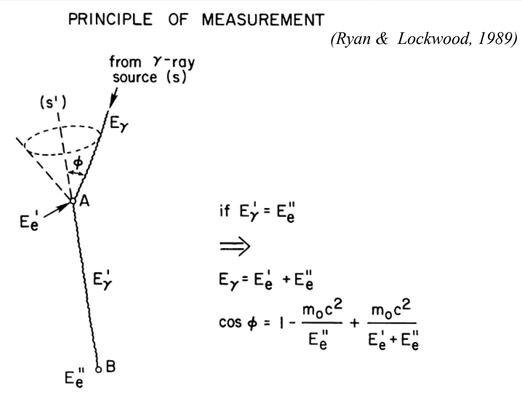
The COMPTEL gamma-ray telescope on NASA's Compton Gamma Ray Observatory (CGRO) operated from 1991 to 2000. It was a double-scatter Compton instrument covering the energy range 0.75-30 MeV, both in continuum and lines. Full-sky maps and a source catalogue were the main outcome of the mission. While the Fermi-LAT instrument has now vastly enhanced our knowledge of the gamma-ray sky at higher energies, the MeV range remains devoid of new missions, so that the heritage COMPTEL data is an essential resource. Data analysis has continued at MPE Garching, with improved event processing and selections. The original skymapping method using Maximum Entropy has been adapted to current technology. A new initiative for skymapping using state-of-the-art Bayesian techniques has been started at MPA Garching; this involves Information Field Theory with the D^{3}PO system.

INSTRUMENT

COMPTEL on CGRO (1991 - 2000)

DETECTION TECHNIQUE

The double-Compton scattering detection technique means that each photon is associated with an annulus on the sky, with known centre, radius and shape; this makes deconvolution essential for imaging. One method is Maximum Entropy (Maxent), which has been used to make all-sky images. The large instrumental background is a further challenge for any COMPTEL analysis.



Original Maxent images (A)

In the original work (Strong et al. 1998) the MEMSYS5 Bayesian 'Classic' Maxent package was used (Skilling, 1989). It employed a template for the instrumental background taken from high Galactic latitudes where the celestial signal is small. In the original work 240 COMPTEL observations were used, and the data and instrumental response were treated in the instrumental coordinate system. Because of the large computing requirements the computation was performed on 240 CPUs of a Cray supercomputer which was state-of-the-art at the time.

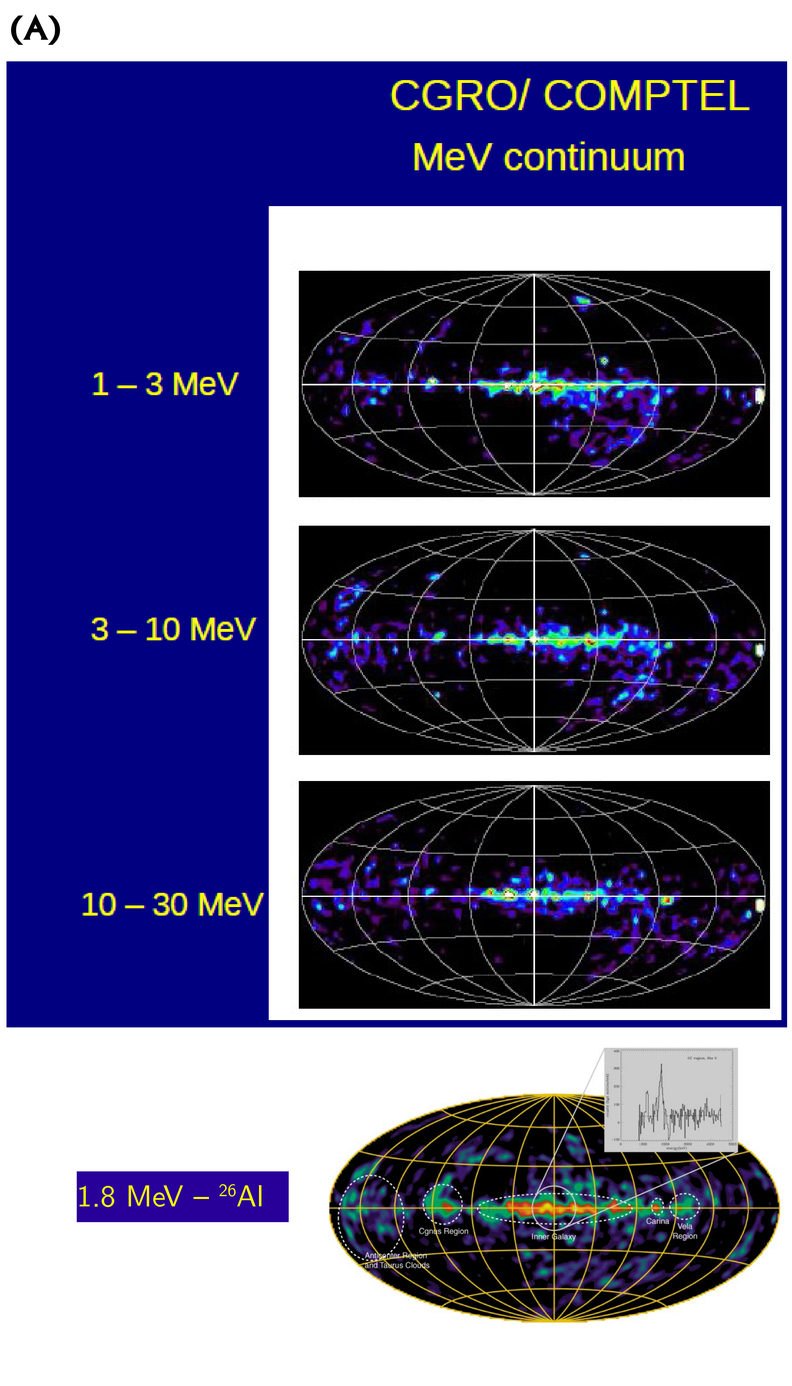
Classic Maxent

Entropic prior on image:

$$\Phi(S) \propto \exp(\alpha S)$$

Posterior of image:

$$\begin{aligned} \Pr(h, \alpha, \boldsymbol{D}) &= \Pr(\alpha)\ \Pr(h \mid \alpha)\ \Pr(\boldsymbol{D} \mid h) \\ &= \Pr(\alpha)\ \frac{\exp(\alpha \mathcal{S}(h) - \mathcal{L}(h))}{Z_{\mathcal{S}}(\alpha)\ Z_{\mathcal{L}}}. \end{aligned}$$



New Maxent images (B)

In view of the importance of the COMPTEL data, we have recently revisited imaging with current software and hardware technology. The original code was adapted to use the *HEALPix* sky representation for a uniform sky coverage both in data and image space instead of the original straight (l,b) system. This also allows fast convolution/correlation on the sphere, replacing the original "brute-force" method. This already gives an enormous speed gain, and running in on a multicore machine produces images in hours (compared to weeks on the original Cray implementation). A finer pixelization (0.5° instead of the original 1°) is hence possible. The *HEALPix* format enhances the value of the images and the speed allows investigation of more imaging parameters, data selection etc.

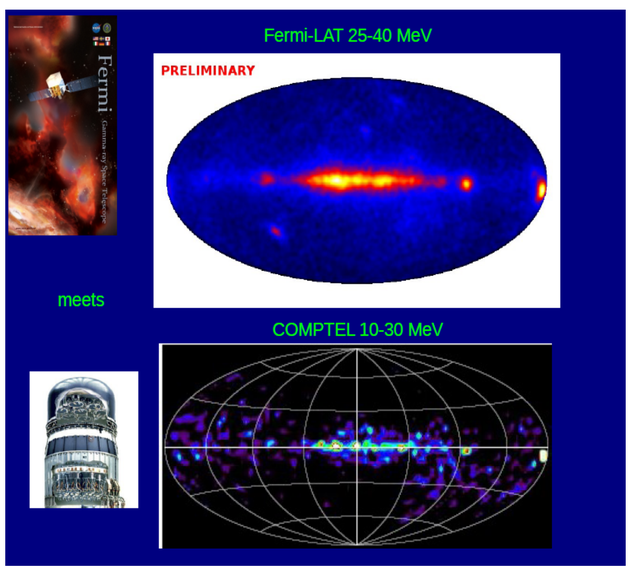
The new images are fully consistent with the original ones, with the Galactic plane clearly visible, and in addition the well-known sources including the Crab, Vela, Cyg X-1, LS5039, 3C273, 3C279, PKS0528+134 and the Galactic Centre. (Note: the excess at lower right is due to Earth atmospheric emission)

In addition we have produced a 1.8 MeV ^{26}Al line map which can be compared with the standard Maxent image (Plüschke et al. 2001).

Comparison with Fermi-LAT

Fermi-LAT energy range extends to lower energies with Pass 8, and this allows a comparison with COMPTEL.

(from A. Strong on behalf of Fermi-LAT Collaboration, talk at MeV Conference, APC Paris 2012)



OUTLOOK

New COMPTEL photon data processing

COMPTEL data analysis continues at MPE (Collmar & Zhang 2014). The event processing and selection is also under study at MPE with improved time-of-flight calculation and other enhancements to reduce the instrumental background. More observations are also now available than for the skymaps shown above. This new data will be used to generate updated images in the near future.

Future methods

While Maxent has been very successful for image COMPTEL data, further advances in data analysis have been made in the last decade. Information Field Theory (IFT) as implemented in the NIFTY and D^{3}PO software has been applied to Fermi-LAT data (Selig et al. 2015), see talk 'Gamma-ray analysis with D^{3}PO' at this symposium. Application of this method to COMPTEL is in progress.

References

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