The EM Algorithm for Imaging with Gaps in the Detector Plane

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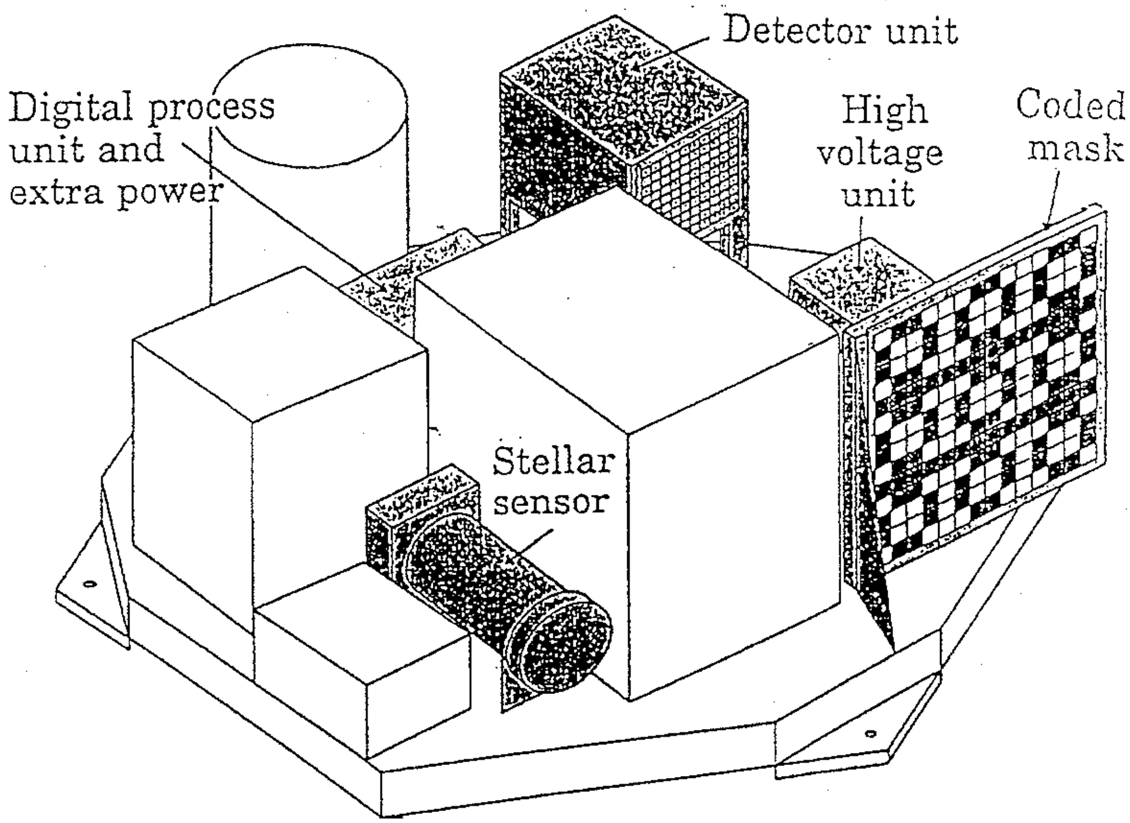
LEGRI Description

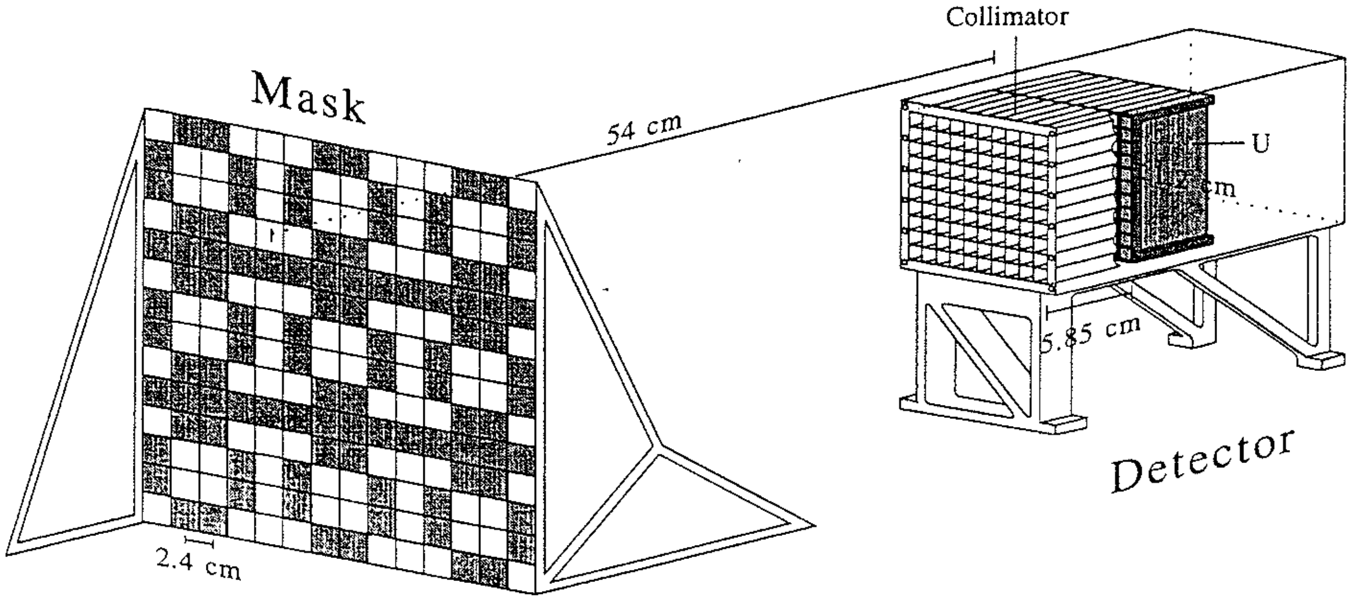
LEGRI on board Minisat 01



Main components:

- Detector Unit
- Mask
- Star Sensor
- High voltage unit
- DPU and extra power unit

The telescope



The Mask

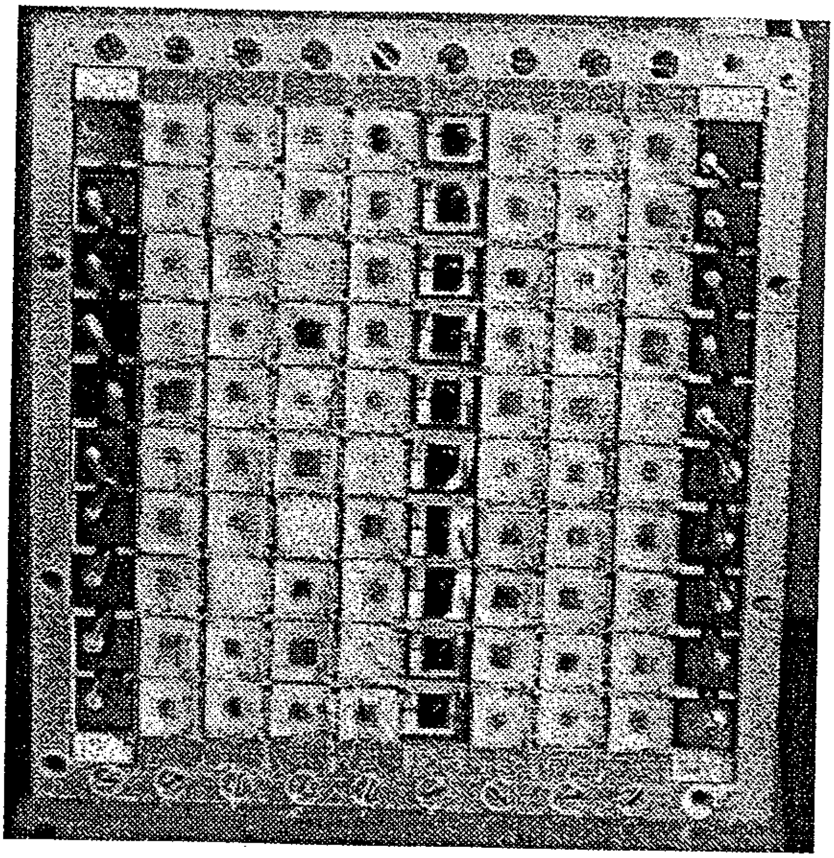
- Pattern: MURA 5x5 in a mosaic (14x14 units)
- Distance between centres 2.4 cm
- Distance mask-detector plane: 54 cm

The detector plane

- 10x10 detector units
- Distance between centres 1.2 cm
- Common electronic each row of 10 detectors
- Collimator height: 5.85 cm

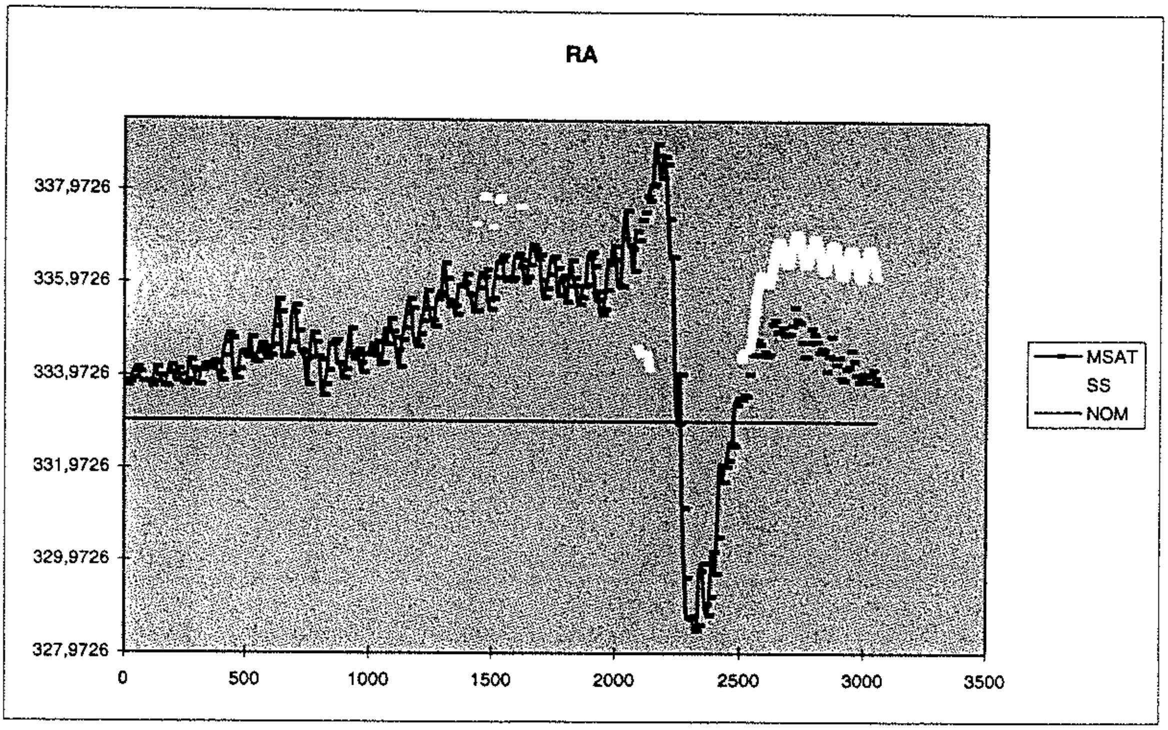
The detector plane

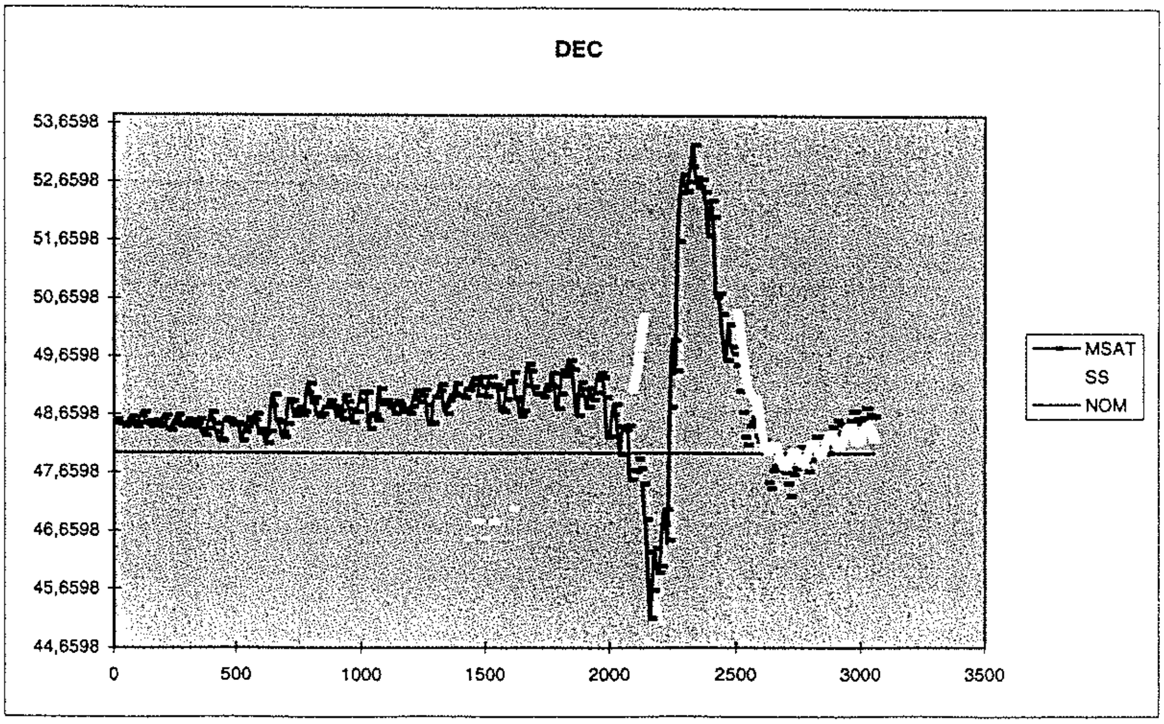
- 80 HgI_2 and 20 Cd(Zn)Te. Solid state detectors.
- Energy range: 20 – 100 keV.
- Operative detectors: 17!!



Movement and pointing

- The satellite moves and the pointing changes. We have to consider it.
- Two ways to know the pointing:
  - The Star Sensor pointing reconstruction.
  - The Minisat 01 pointing reconstruction.





Mathematical Description

Detection and data integration

$$D_{klp} = \left(\sum_{\alpha\beta} O_{\alpha\beta} \Phi_{klp}^{\alpha\beta} + B_{kl} \right) T_p$$

kl = detector unit indexes

p = pointing direction index. Data are integrated in different sets for each pointing direction

$\alpha\beta$ = sky pixel indexes

O = emission intensities from the sky pixels per time unit and area unit

Φ = sky fluxes (how much sees detector kl coming from the sky pixel $\alpha\beta$ during pointing p; =1 everything, =0 nothing –usually something between 0 and 1-)

T_p = integration time for pointing p

Taking into account the changes of pointing (rotantions + translations):

$$\Phi_{klp}^{\alpha\beta} = \Phi_{kl}^{(\alpha-\alpha_p)\cos(roll_p)+(\beta-\beta_p)\sin(roll_p) \quad -(\alpha-\alpha_p)\sin(roll_p)+(\beta-\beta_p)\cos(roll_p)}$$

The EM algorithm

- g(D|O) = probability of obtaining the data D given the parameter set O
- we look for O^{max} that maximices g(D|O) → good estimator of sky intensities
- EM carries out that maximization via and iterative and indirect way:

  We define a bigger (and fictitious) data space D_t (D is a subset of D_t) and its asociated $f(D_t|O)$. Then
  n-th iteration:
  - E step: form $E(\log f(D_t|O) \mid D, !\tilde{O}^n)$
  - M step: maximize it with respect to O keeping $\tilde{O}^n$ constant → it gives $\tilde{O}^{n+1}$

    Property: $g(D|\tilde{O}^{n+1}) \geq g(D|\tilde{O}^n)$

Final form:

$$\tilde{O}_{\alpha\beta}^{n+1} = \tilde{O}_{\alpha\beta}^{n} \frac{\sum_{klp} \Phi_{klp}^{\alpha\beta} \left(\frac{D_{klp}}{\tilde{D}_{klp}} \right)}{\sum_{klp} \Phi_{klp}^{\alpha\beta}}$$

But $\sum_{kl} \longrightarrow \sum_{kl}$ = useful detectors

Results

- LEGRI background noise level ≈ 0.6 counts/s cm^2
- Crab Nebulae pulsar intensity ≈ 0.4 photons/s cm^2
- Significance level in ~40000 s

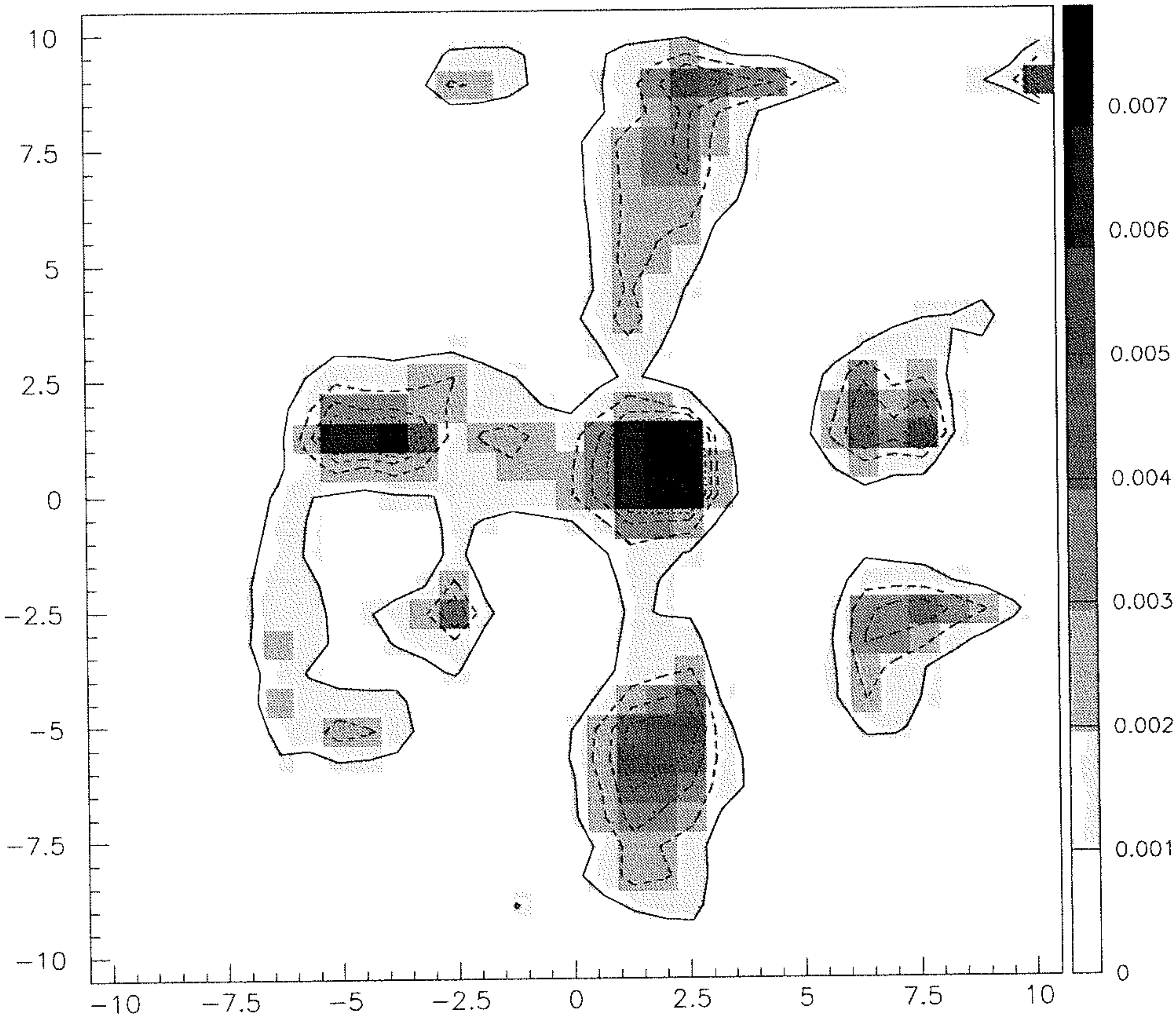


Imagen Reconstruida