COS-B:

the pioneer of high-energy γ-ray astronomy in Europe

Gottfried Kanbach, MPE
for the
CARAVANE COS-B collaboration

1964 

1975 →

ESTEC, Noordwijk
ESOC, Darmstadt

U. Milano
U. Palermo

MPE, Garching

CEN, Saclay

U. Leiden

Mysteries and Discoveries in high-energy physics (up to the mid-1960s)

Cosmic Rays (discovered in 1912):

→ development of new detection techniques for energetic particles
1930s-50s: Rossi, Kolhörster, Auger, Occhialini, Blackett et al.:
Detector arrays, counters, coincidence electronics, imaging in cloud chambers and photographic emulsions

→ C.R.s (mainly energetic nucleons, few electrons, fewer γ-rays) were Nature's free particle beams to discover the 'zoo' of sub-nuclear particles (positrons, mesons, pions, etc.).
After the 1940s accelerators replaced CRs

The big questions up to the mid-1960s) were then

where do cosmic rays come from and how are they accelerated?

How can we find sources of cosmic rays when their trajectories in cosmic magnetic fields are completely scrambled ?

→ the direct observation of high-energy γ-rays, natural by-products in cosmic ray sources, can be used to find these sources.

The challenge was to operate remote detectors in the upper Atmosphere (Balloons) or in space (Satellites)

IL NUOVO CIMENTO Vol. VII, N. 6 16 Marzo 1958

On Gamma-Ray Astronomy.

P. Morrison

Department of Physics, Cornell University - Ithaca, N. Y.

(ricevuto il 22 Dicembre 1957)

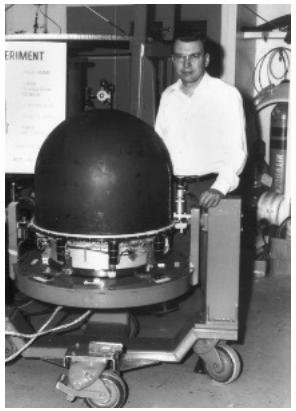
After the beginning of the 'space age' in the 1960's many research groups proposed instruments sensitive to high energy gamma radiation that could be operated remotely.

First balloon flights (short exposures), and later satellites (longer exposures) made it possible. Severe limits on size, weight, telemetry, and instrumental background of these instruments often led to frustration (the predictions were often to optimistic)

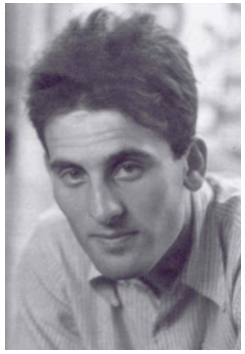
→ Imaging telescopes using pair-creation were the solution

U.S.A. – NASA: groups at MIT and NASA/GSFC

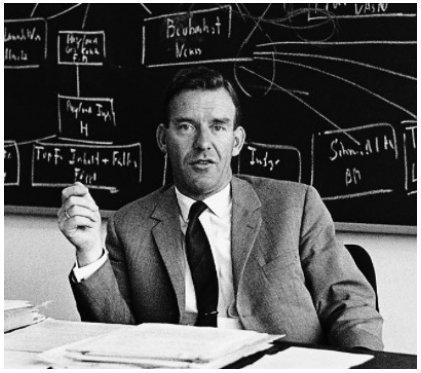
Explorer 11 (1961), OSO-3 (1968), MIT, W.L. Kraushaar et al. -> galactic γ emission
SAS-2 (1972), GSFC, C. Fichtel, et al.
Nanni Bignami as a post-doc at GSFC in 1973/74 at calibrations at DESY.



Europe –ESRO/ESA: the 'founding fathers'



Beppo Occhialini, Università di Milano



Reimar Lüst, MPE, Garching, Monaco

Jacques Labeyrie, CEN Saclay

First the MiMoSa collaboration (S-133 flown on TD-1,1972); Expansion to the CARAVANE collaboration (1968,adding ESTEC, Leiden U., Palermo U.)

The CARAVANE collaboration:

Task:

Develop and build the second generation high-energy gamma-ray telescope -> COS-B

Noordwijk and Leiden

Paris Saclay

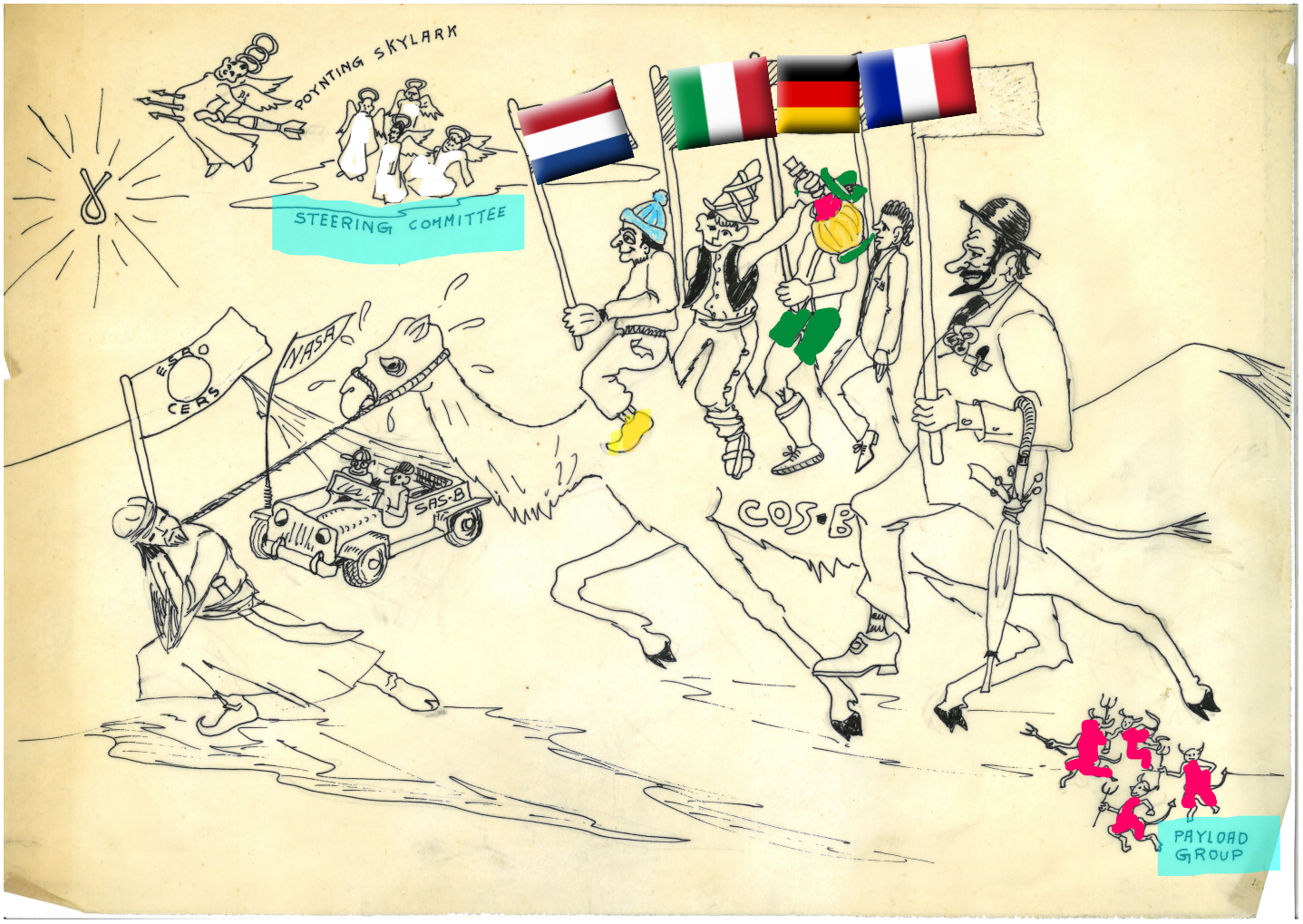
Darmstadt(ESOC),

MPE Garching

Milano

Palermo

COS-B CARAVANE Drawing from Beppo Occhialini's Archive
(unknown artist mid XX century)


POYNTING SKYLARK
STEERING COMMITTEE
ESRO
CERS
NASA
SAS-B
COS-B
PAYLOAD
GROUP

ESRO SP-106, November 1974, Bignami et al.

Principal objectives for COS-B:

(i) the investigation of the angular structure and energy spectrum of the gamma emission from the galactic plane, with special emphasis on the Galactic Centre and the resolution of possible point sources in the plane,

Map the Milky Way Galaxy

(ii) the measurement of the energy spectrum and the degree of isotropy of the diffuse radiation from high galactic latitudes,

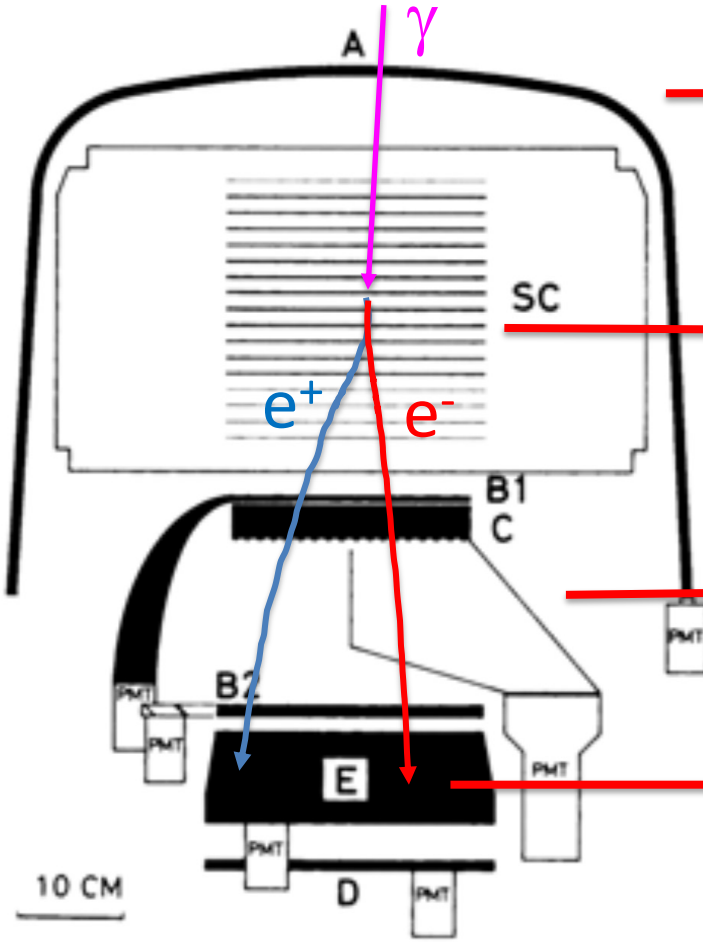
Measure the extragalactic background

(iii) the detailed investigation of gamma-ray sources identified by other experiments or of postulated sources,

Find point sources
'γ stars'

(iv) the search for short period pulsations of gamma-ray emission from sources known to pulsate at longer wavelengths, and for longer period fluctuations.

Find variability in γ sources



CEN Saclay
Anticoincidence

MPE
Sparkchamber

SSD ESTEC
Triggersystem

Huygens Lab.,
Leiden
Calorimeter

Electronics

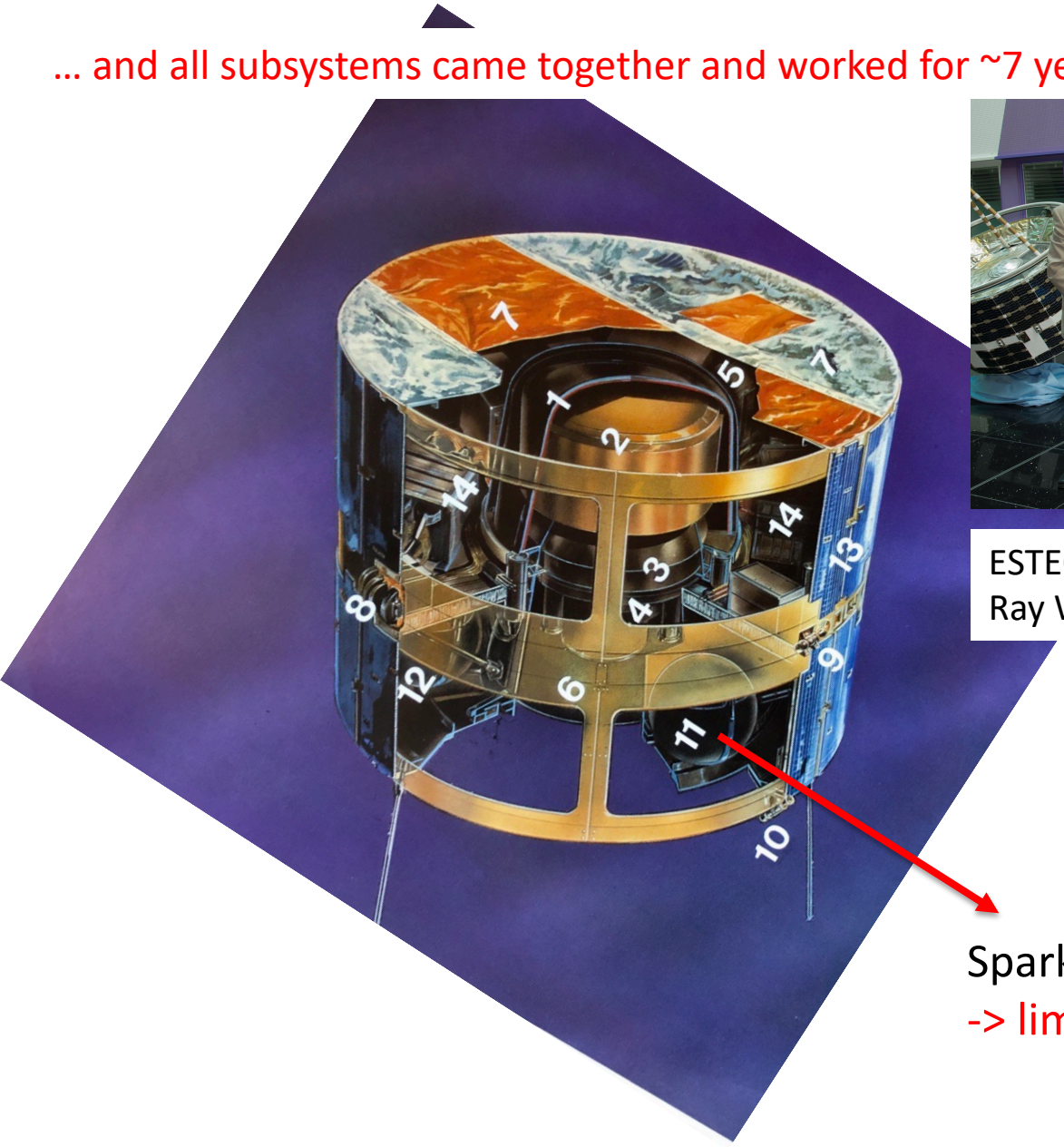
Univ. Milano

PSR Synchronizer

Univ. Palermo

Bignami et al., ESRO SP-106, pp. 307-344, Nov. 1974,
'The mission of ESRO's COS-B satellite for gamma-ray astronomy'

… and all subsystems came together and worked for ~7 years



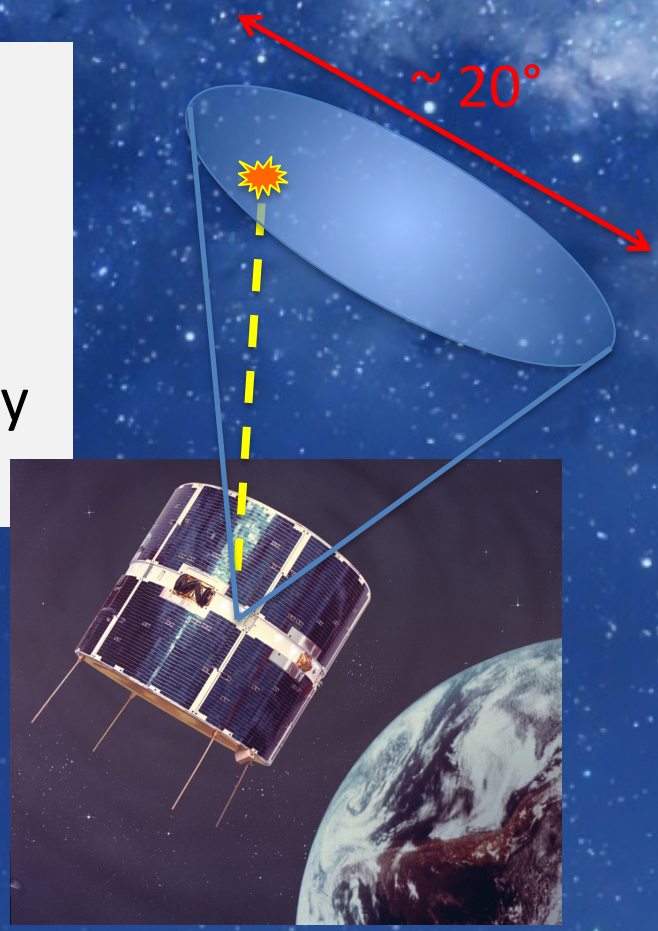
ESTEC 2015
Ray Wills, Gottfried Kanbach, Wolfgang Voges

Sparkchamber gas supply 12 refills
-> limitation for instrument lifetime

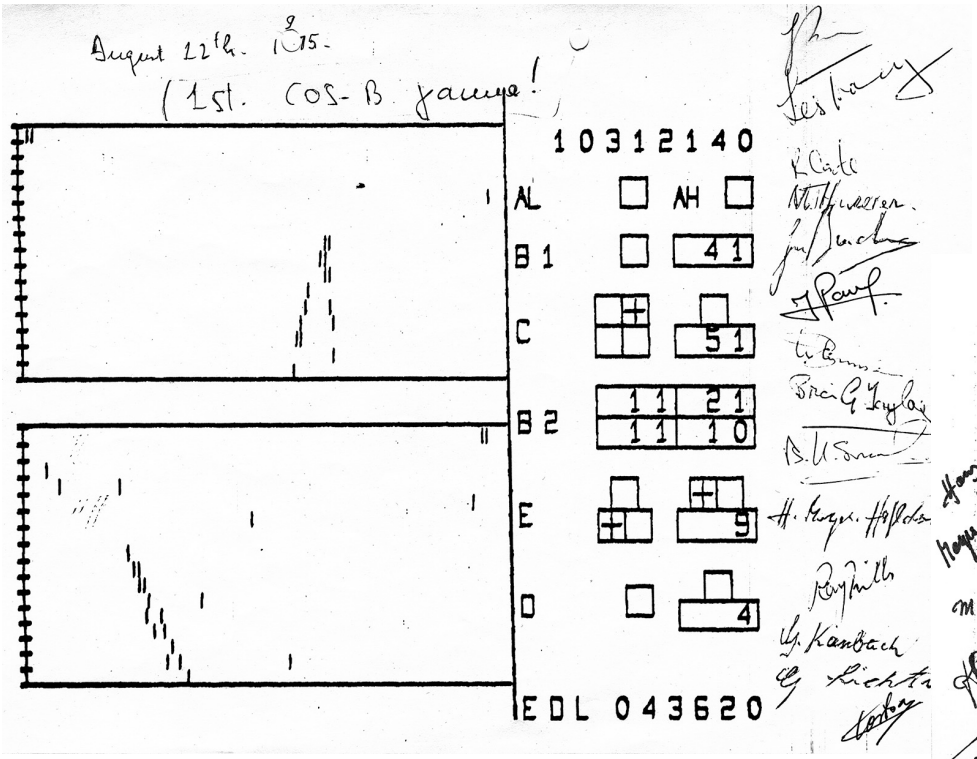
In Orbit: Aug 9, 1975 - Jan 18, 1986
Operations: Aug 22, 1975 - Apr 25, 1982
65 viewing periods, duration 2 weeks to 2 months

Energy range: 30 MeV – 5 GeV
Effective area: ~50 cm^2 , f.o.v. ~20°
Angular resolution: ~ 1 degree

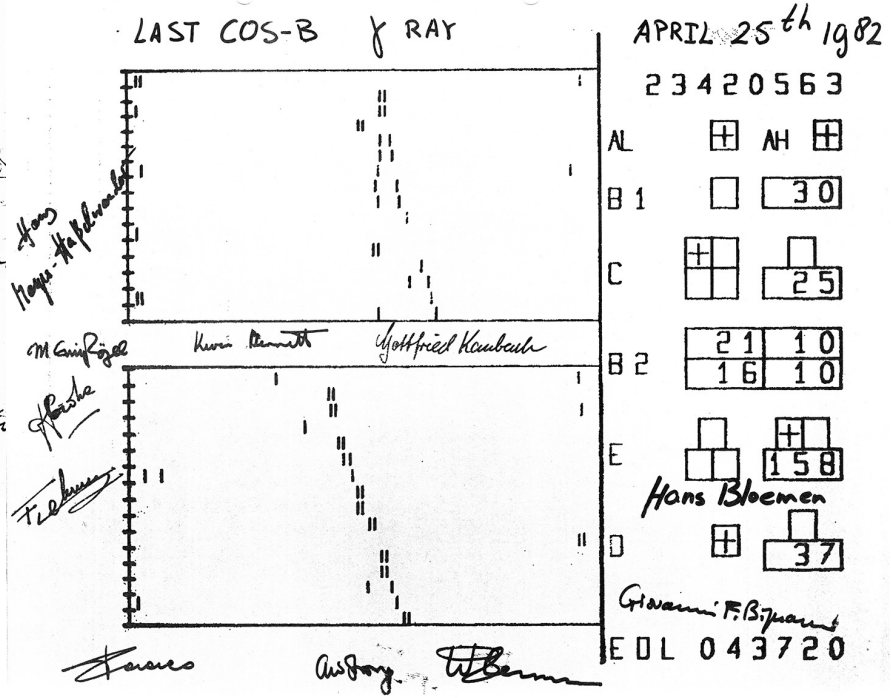
Typical src flux: 10^{-6} γ/cm^2s -> 4 cts/day
Observation periods ~1 month



First γ ray: Aug. 22, 1975

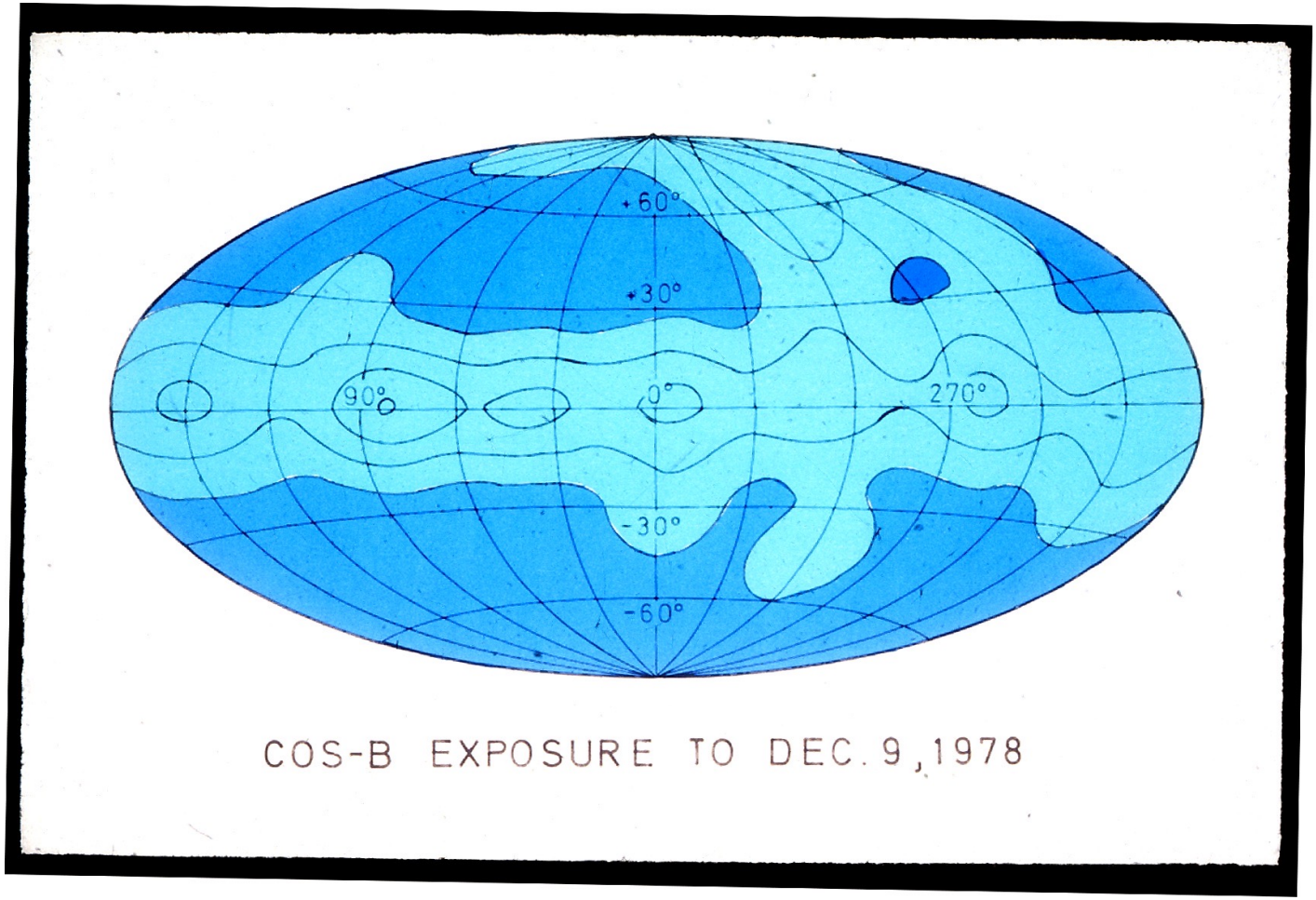


Last γ ray: Apr. 25, 1982



COS-B Sky coverage 1975-1982 (~210.000 gamma rays)

65 viewing periods of typical duration 1 month



The COS-B Data Reduction Group (DRG) working hard …

Lino Buccheri, Nanni Bignami, Livio Scarsi, Boudewijn Swanenburg

… with tables full of results

Nanni Bignami, Jacques Paul, Lino Buccheri, Wim Hermsen, Livio Scarsi

Nanni Bignami Jacques Paul

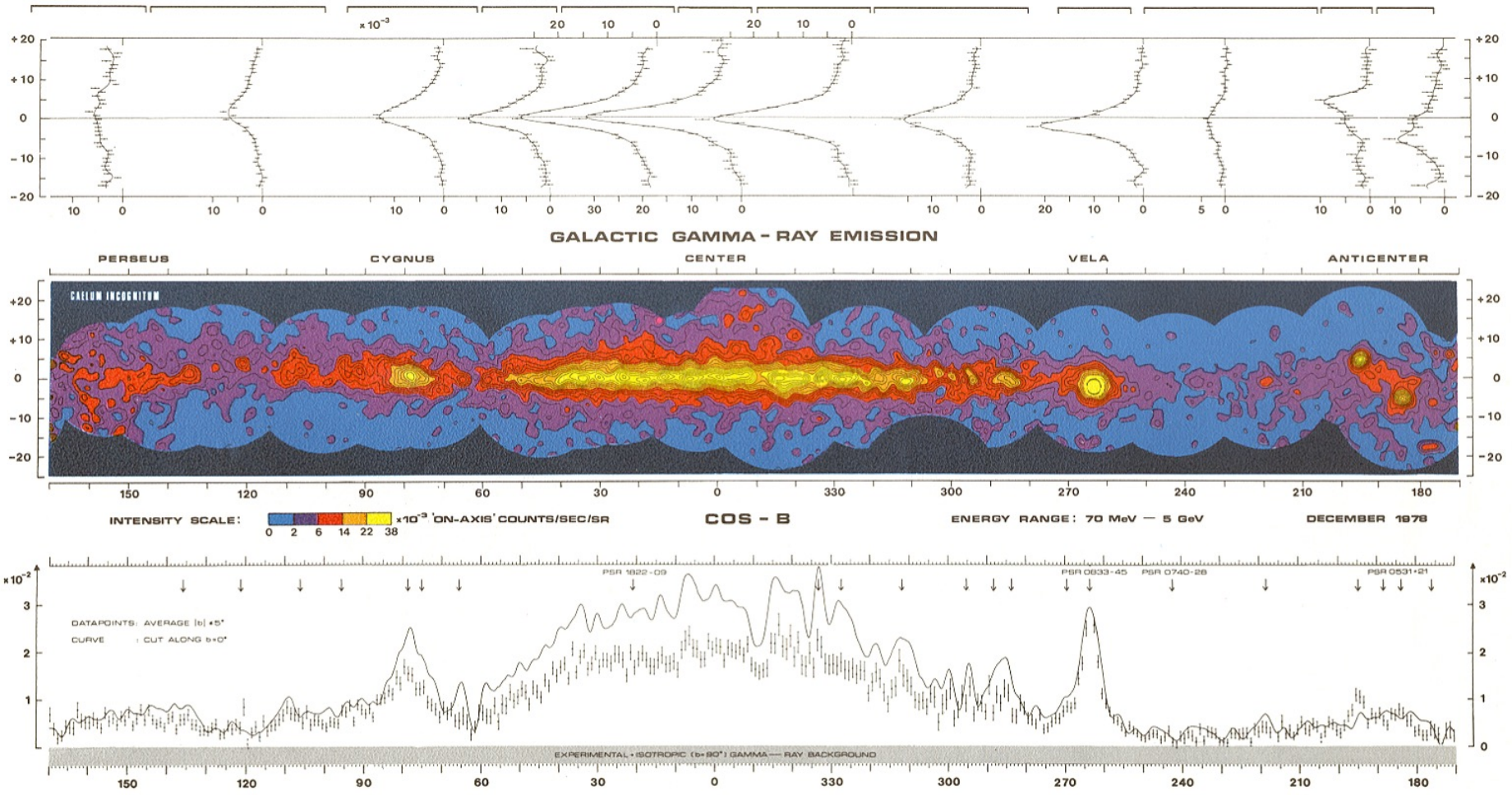
…but also play hard
(Mondello beach)

Wim Hermsen

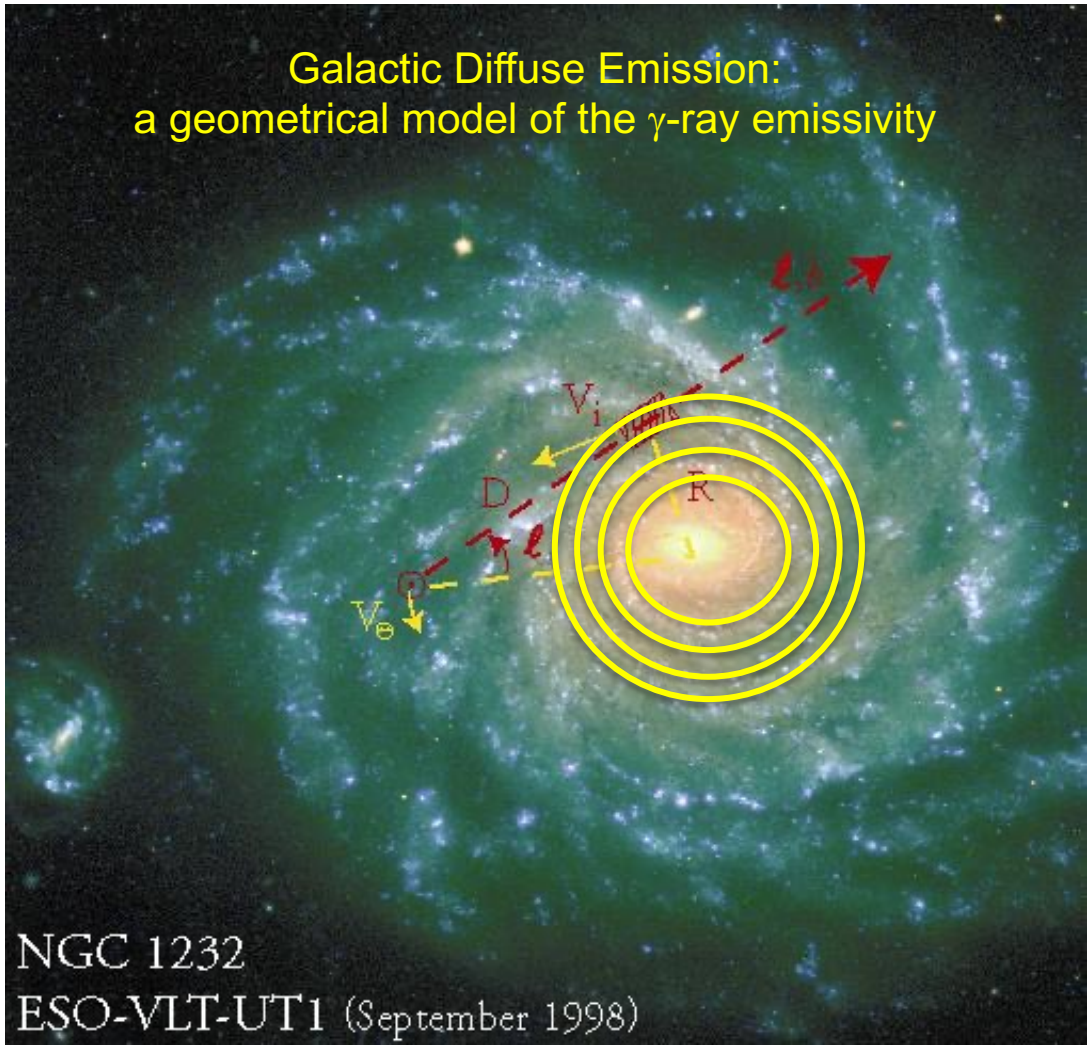
Giselher Lichti

After 5 years of COS-B: time to have a party

The whole Milky Way 70 MeV – 5 GeV



Modeling the galactic survey



Physics of γ-ray production

High energy cosmic rays interacting with the interstellar medium and photon fields make gamma-rays:

p+N → π^o → 2γ

e+N → γ Bremsstrahlung

e+phot → γ inverse Compton

Model Input:

- Cosmic ray density and spectra
- Interstellar medium
- Starlight

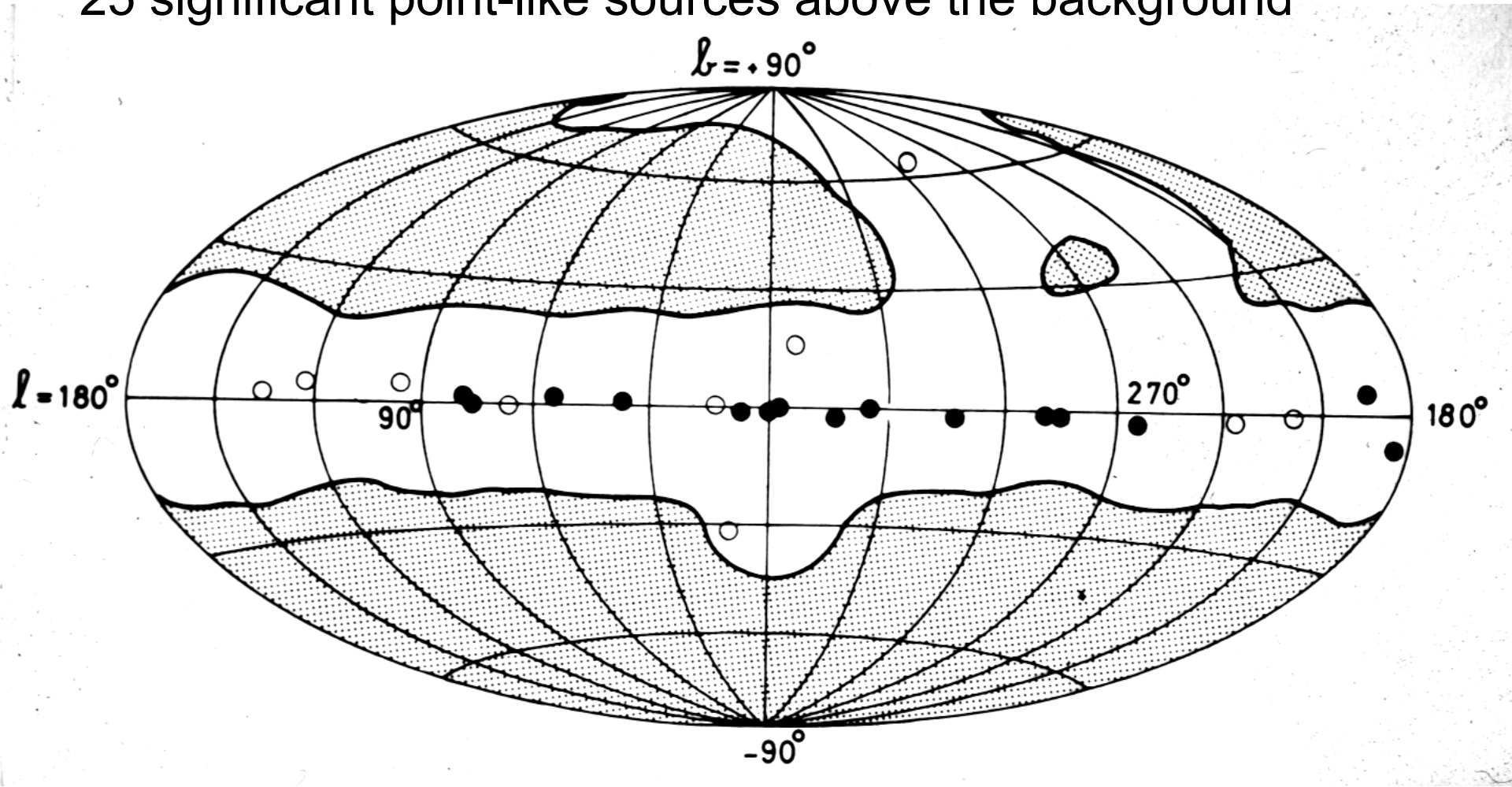
Model Output:

Galactic emissivity distribution

Gamma-ray map → diffuse background

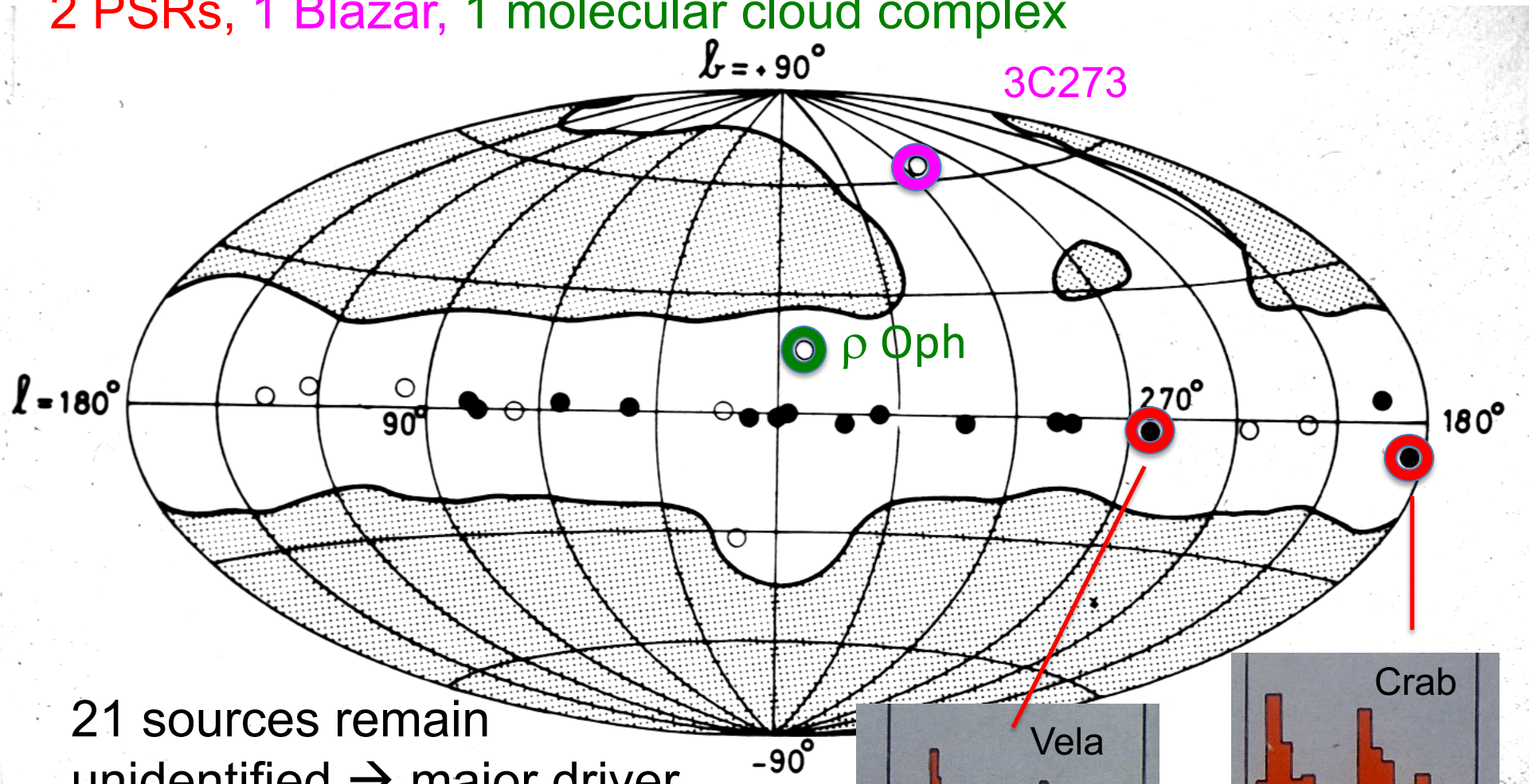
2nd COS-B (2CG) catalogue of gamma-ray sources (>100 MeV) (Swanenburg et al., 1981)

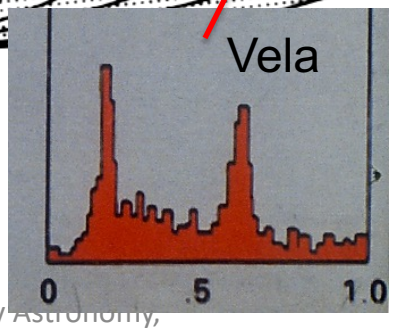
25 significant point-like sources above the background



COS-B: high confidence identifications:

2 PSRs, 1 Blazar, 1 molecular cloud complex



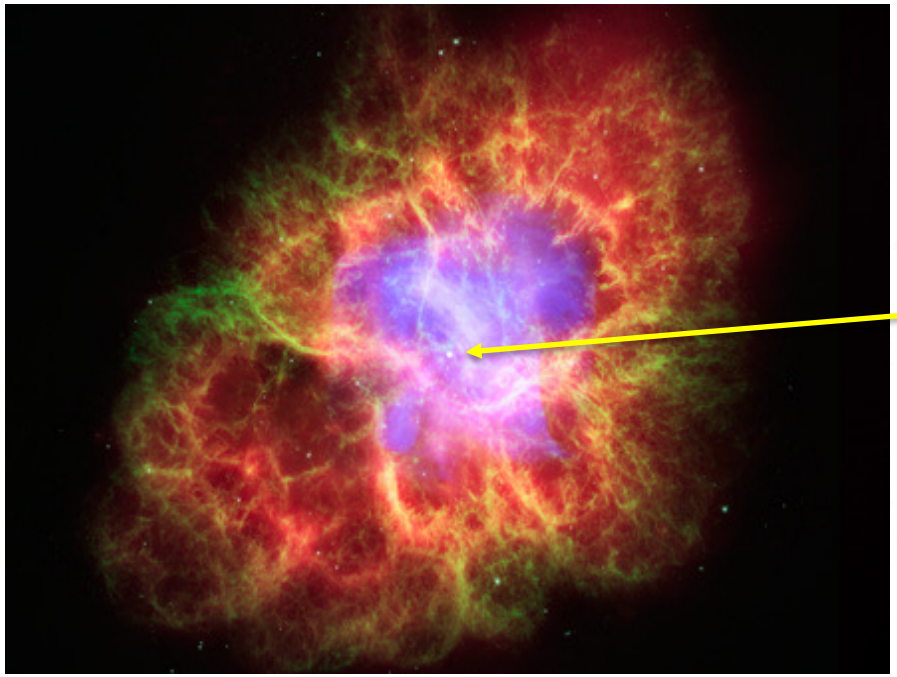


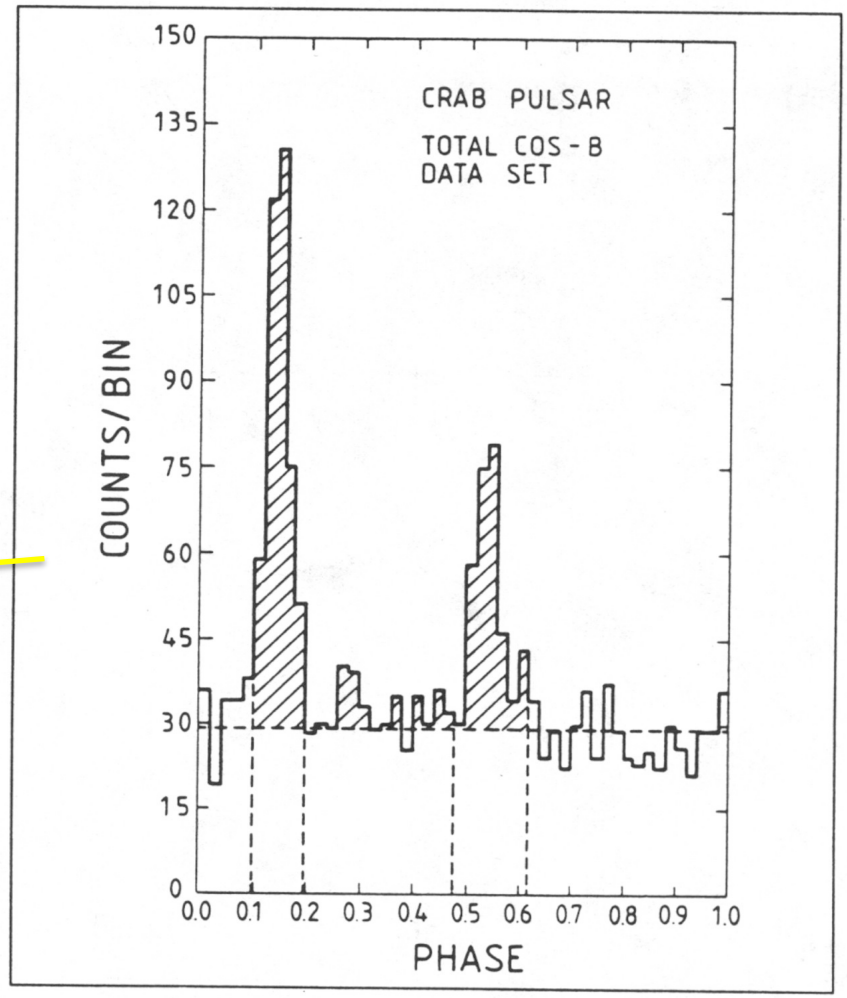
21 sources remain unidentified → major driver for next generation telescopes on CGRO

Crab Pulsar

COS-B (>50 MeV)
(Wills et al., , Nature, 296, 723, 1982

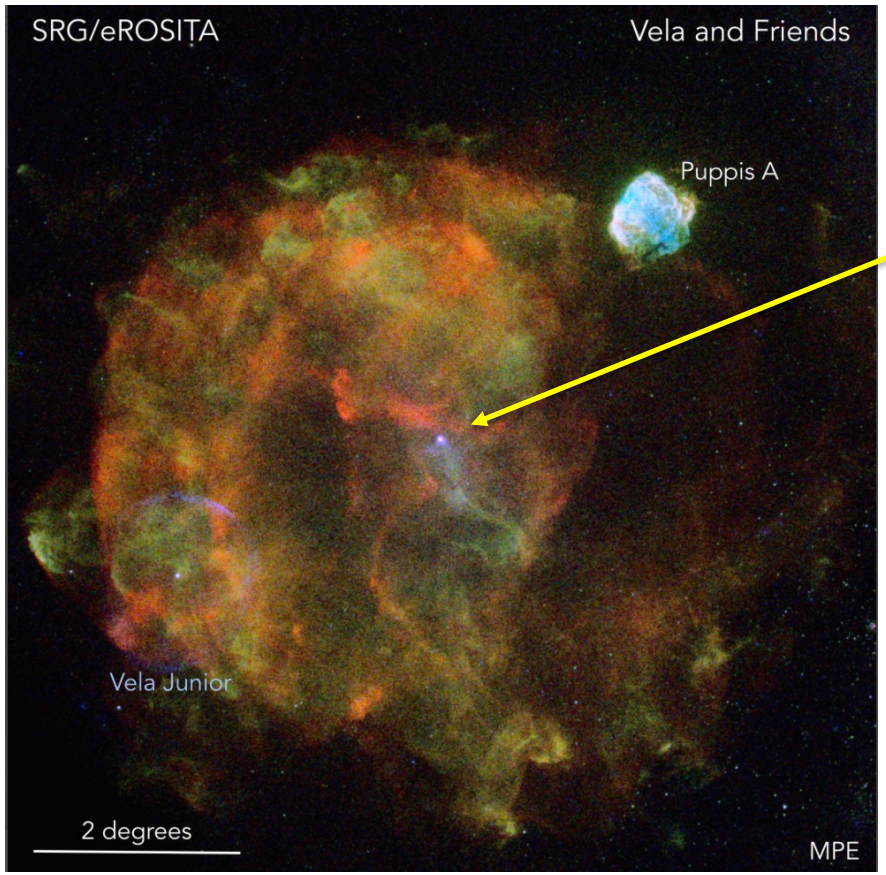
Crab Nebula: Remnant of a stellar explosion (Supernova) year 1054;
Distance ~ 6000 Ly
Period: 33.5 ms / 30 rotations/sec

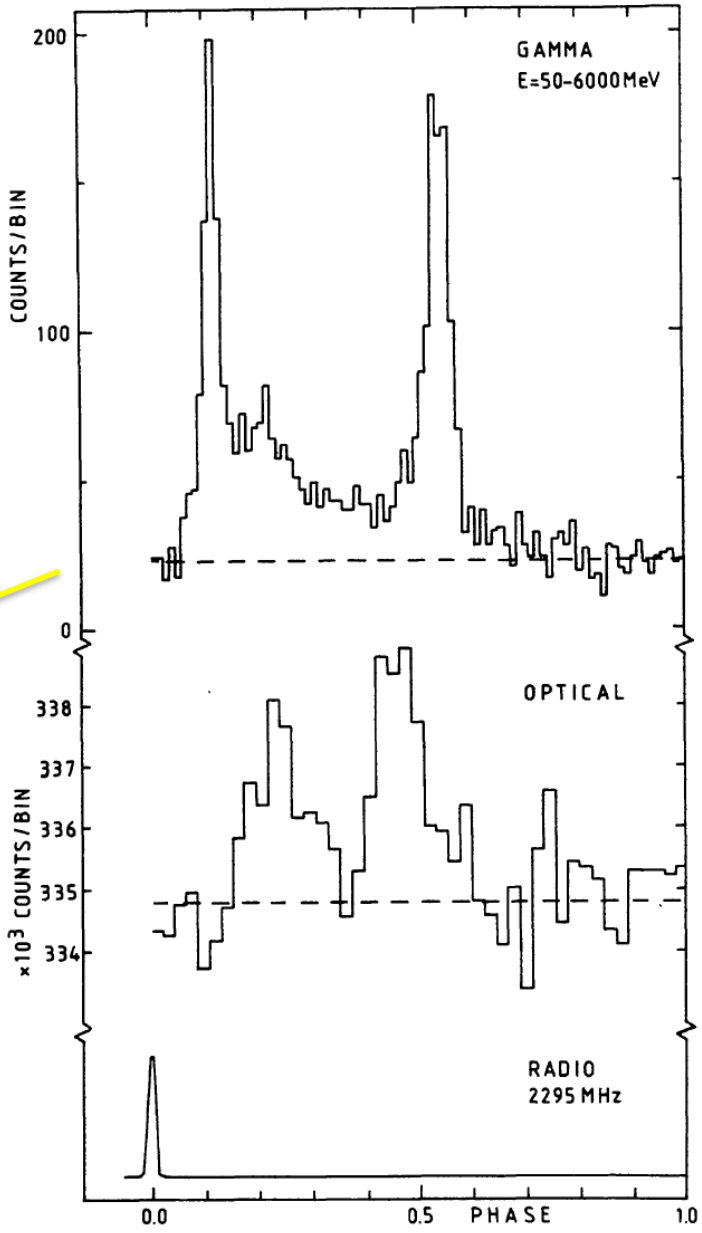




Vela Pulsar

X-ray SNR image by eROSITA survey
Distance ~ 960 Ly
Period: 89.33 ms / 11 rotations/sec

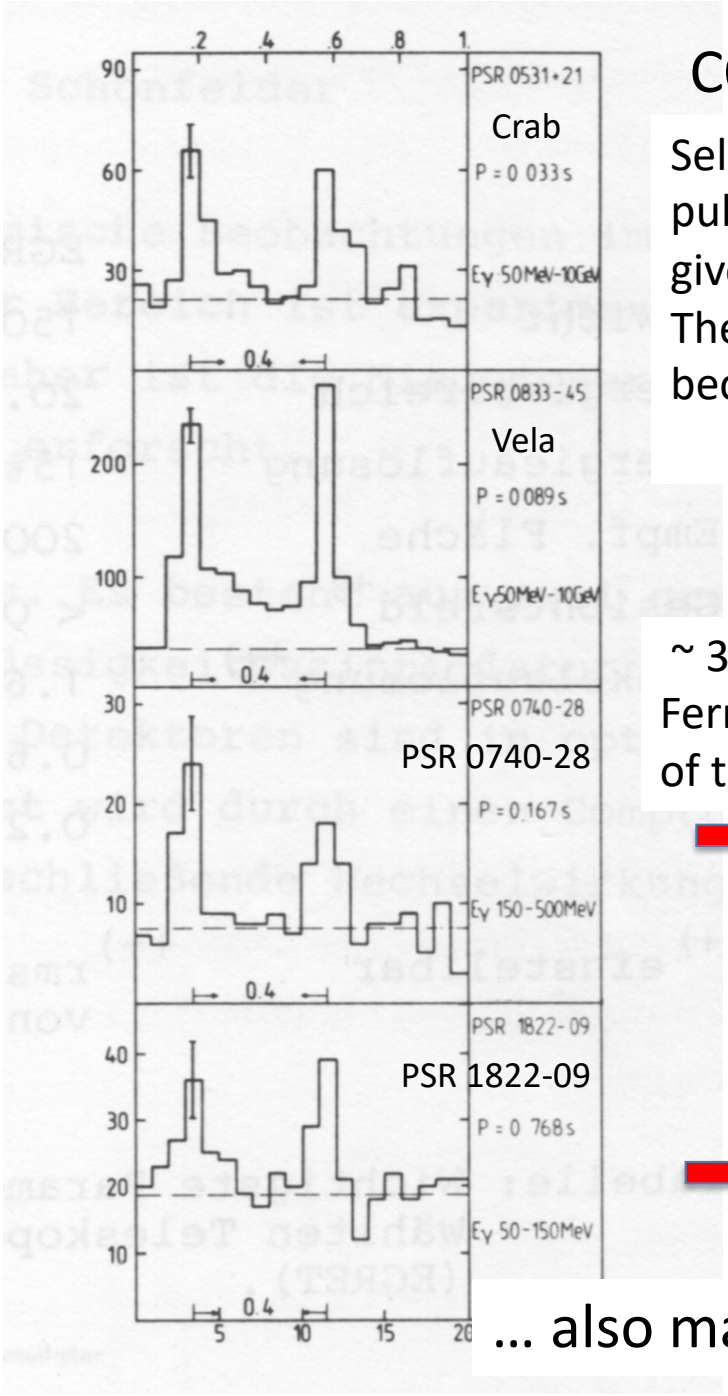




(Kanbach et al., A&A, 90, 163, 1980)

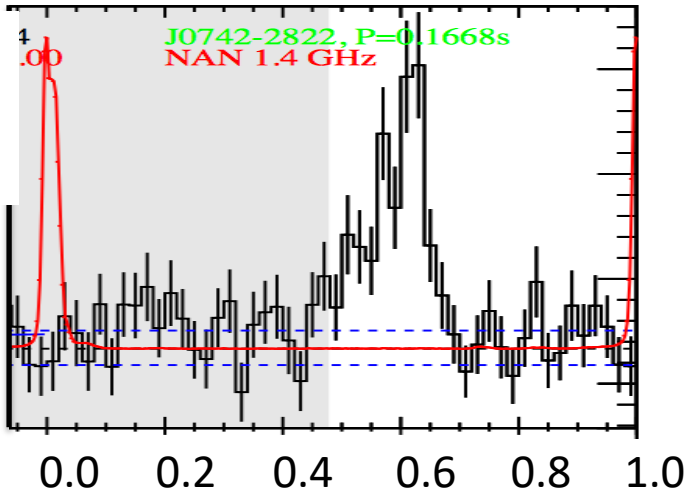
COS-B search for other radio pulsars:

Selection of high rotational energy loss, small distance pulsars. Search pulsations over wide P,Pdot ranges given by old radio ephemerides. Two new candidates! The collaboration did not publish this result because new radio data showed some inconsistencies



~ 35 years later: Fermi detects one of the suspects!

PSR J0742-2822, Period 0.1668s
Fermi LAT > 100 MeV
Radio 1.4 GHz



Not detected by Fermi

… also many negative ‘blind’ searches in Geminga

COS-B 10 year anniversary and transfer of final data base to ESA DG Palermo 1985

M. Sommer, W. Voges, R. Lüst, K. Pinkau, H. Mayer-Hasselwander

COS-B summary:

- Map the Milky Way Galaxy: emissivity distribution & fine structure ✓
- Measure the extragalactic background: X – instrumental background too high
- Find point sources ‘γ stars’: 25 detected ✓
- Find variability in γ sources ✓

Extras:

- Details of gamma-ray pulsars
- Hints for more pulsars (some later confirmed)
- First extragalactic gamma-ray source
- Detection of emission from molecular clouds / SNR

ADS search for ‘COS-B’ since 1970 results in > 580 publications

The pioneering COS-B results will remain a lasting heritage to the efforts of the CARAVANE collaboration and their central group in MILANO