Laboratoire d'Annecy de Physique des Particules

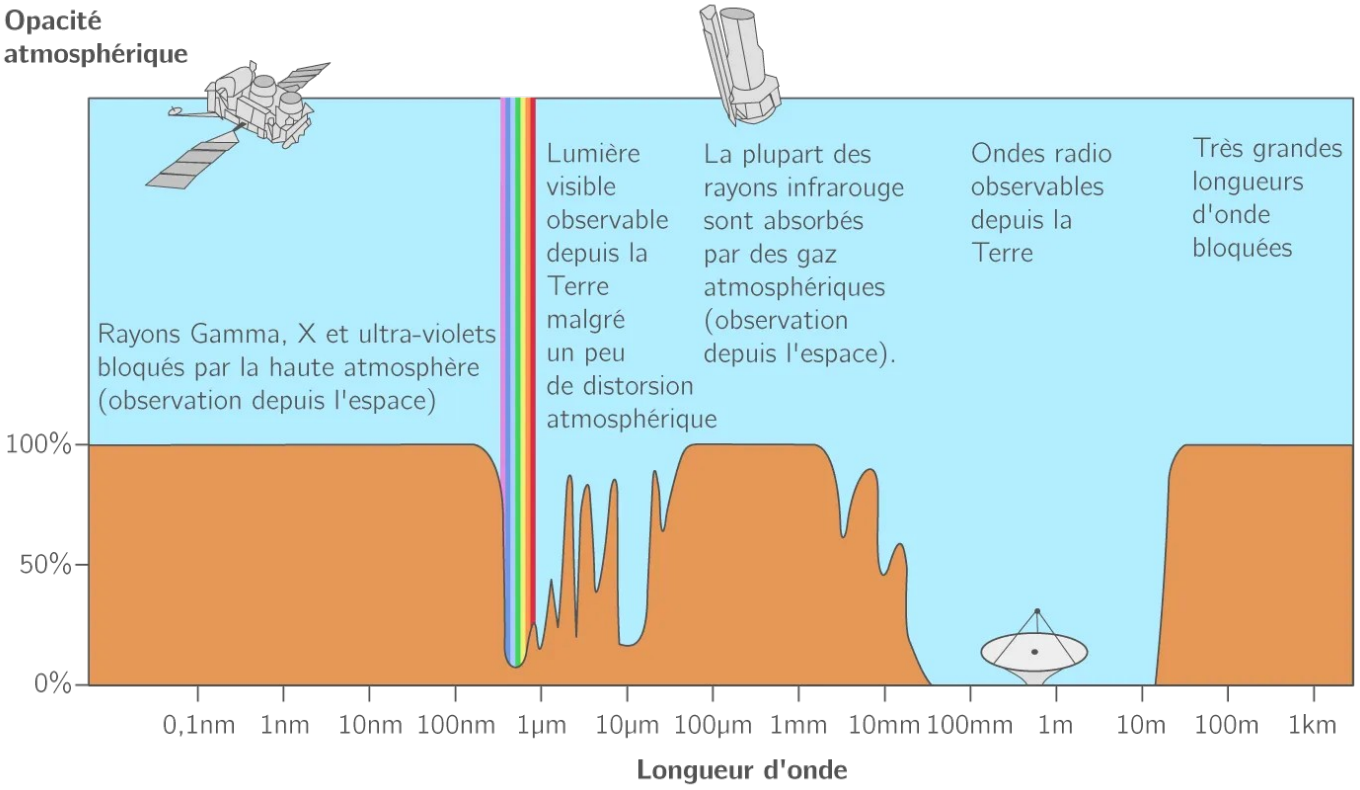
ANIMA SCIENCE

- 30 Avril 2026 -

# L'astronomie Cherenkov : 70 ans d'histoire

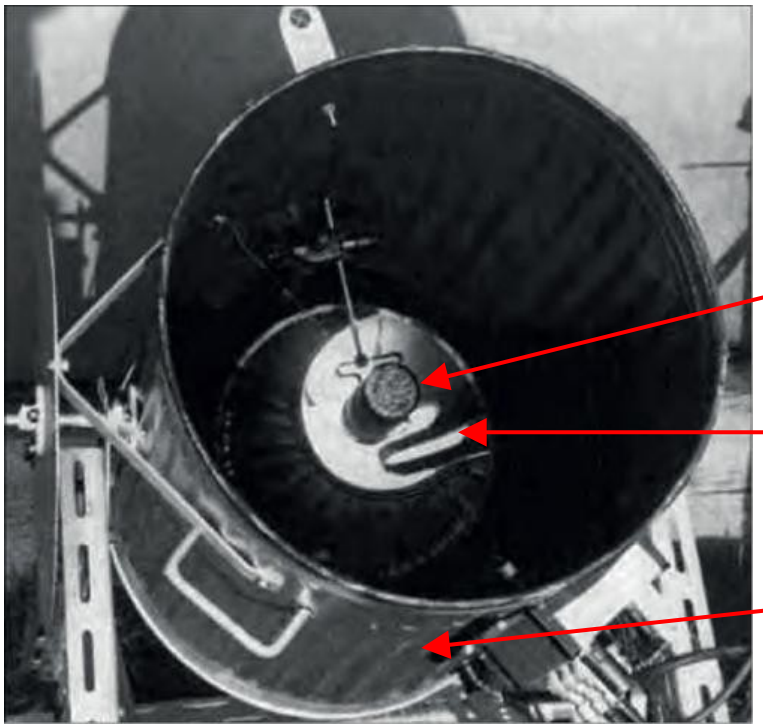
Léo Le Moigne

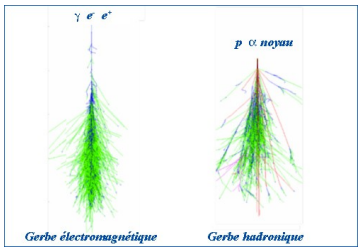
# L’atmosphère : un bouclier naturel



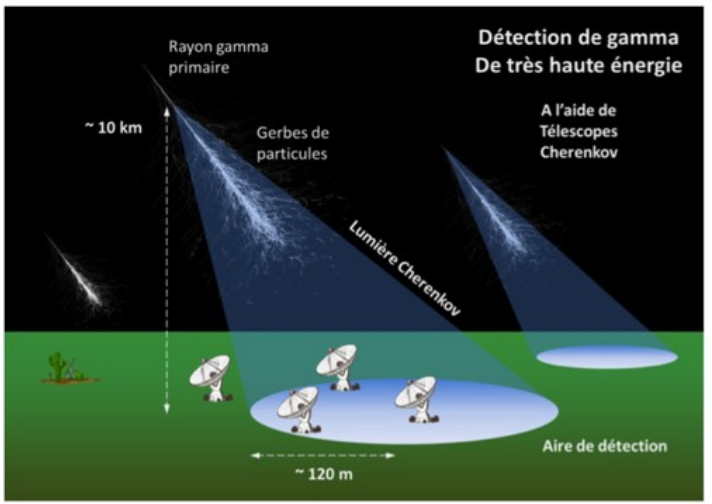
# La lumière Cherenkov

Galbraith & Jelley (1952)




Détection de la lumière Cherenkov produites par des rayons cosmiques, au Pic du Midi !



# Le pari Cocconi

## La Nébuleuse du Crabe comme candidate (ICRC 1960)

AN AIR SHOWER TELESCOPE
AND THE DETECTION OF $10^{12}$ eV PHOTON SOURCES

Giuseppe Cocconi
CERN - Geneva.

1). This paper discusses the possibility of detecting high energy photons produced by discrete astronomical objects. Sources of charged particles are not considered as the smearing produced by the magnetized plasmas filling the interstellar spaces probably obliterates the original directions of movement.

It is proposed that the direction of arrival of the photons, i.e. the direction of their source relative to the earth, be determined by timing on a horizontal plane the arrival of the front of the Air Shower (AS) generated by the photon in the atmosphere.

As shown later, one has to consider photon energies around $10^{12}$eV, that initiate showers whose maximum development is reached at high altitudes. If the measurements are performed at about 1/2 atmosphere (5.5 km above sea level), the electromagnetic cascade is there still in full development and contains $\sim 10^3$ ionizing particles.

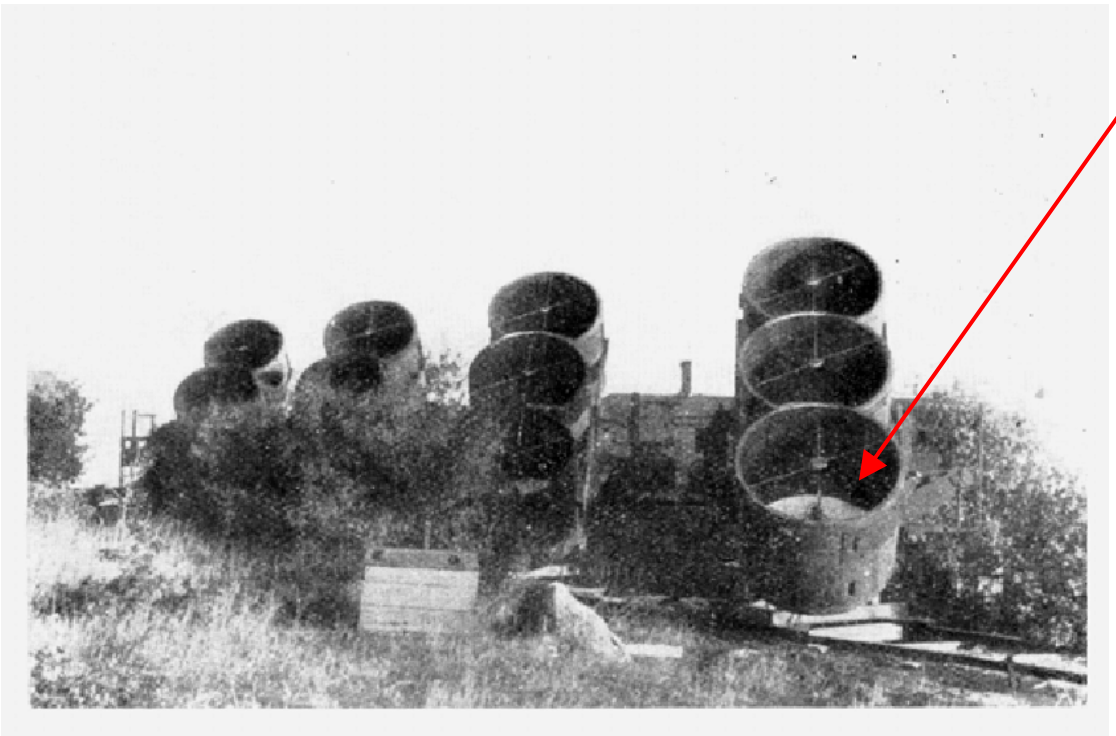
3). The possibility of detecting a point source depends on the ratio signal to background. An estimate of such a ratio for all detectable showers is at present impossible, since little is known about the energy spectrum of the photon sources. We shall estimate the signal to background ratio only for that energy band in which lie the photons coming from those astronomical objects, like the Crab Nebula, that are known to emit polarized light, i.e. synchrotron radiation.

Avant même la première détection de sources en rayons X !

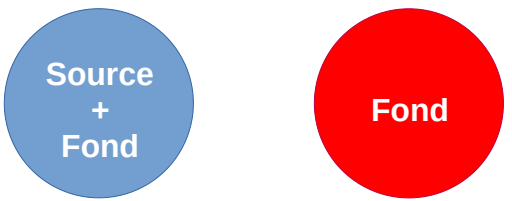
Une émission au-delà du TeV détectable via lumière Cherenkov ?

# Le défi de Chudakov

Réseau de télescopes Cherenkov construit en Crimée (1959 - 1963)



12 miroirs paraboliques d'1,5 m




→ pas d'excès visible

un échec qui laissera Chudakov sceptique quant aux chances de réussite

# La poursuite

Beaucoup de tentatives pendant les décennies qui suivirent :

- multiples miroirs pour recherche de coïncidence temporelle
- interféromètres
- multiples PMT
- …

Chou blanc (hors détections louches)

# Le coup de génie

Hillas (1985), basé sur le design proposé par Weekes (1981)



OG 9.5-3

CERENKOV LIGHT IMAGES OF EAS PRODUCED BY PRIMARY GAMMA RAYS AND BY NUCLEI

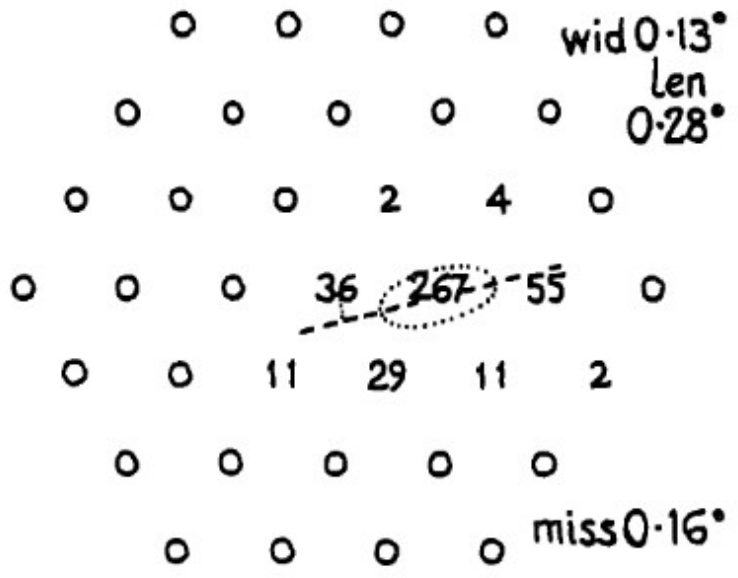
A. M. Hillas
Physics Department
University of Leeds, Leeds LS2 9JT, UK.

ABSTRACT

It is shown that it should be possible to distinguish very effectively between background hadronic showers and TeV gamma-ray showers from a point source on the basis of the width, length and orientation of the Cerenkov light images of the shower, seen in the focal plane of a focusing mirror, even with a relatively coarse pixel size such as employed in the Mt. Hopkins detector.

...

showers. If the appearance of the Cerenkov flashes differs for the two classes of shower, much of the background might be rejected. In another paper, Cawley et al. (1) describe the modification of the 10m reflector at the Whipple Observatory (Mt. Hopkins, Arizona) to record details of each Cerenkov image on a 0.5° grid, using 37 photomultipliers in the focal plane of the focusing mirror. (A central photomultiplier is surrounded by a ring of 6 others, then by a further ring of 12, and another of 18 – the whole forming a hexagonal grid pattern.) Predictions of the response of this system to air showers will be presented. Even though the r.m.s.



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Discrimination sur la nature de la particule incidente possible grâce à la forme de l'image !

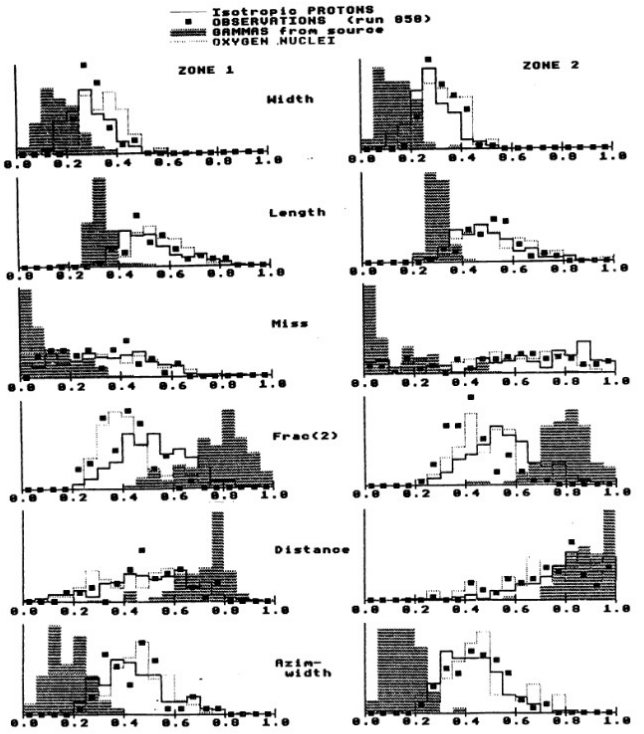
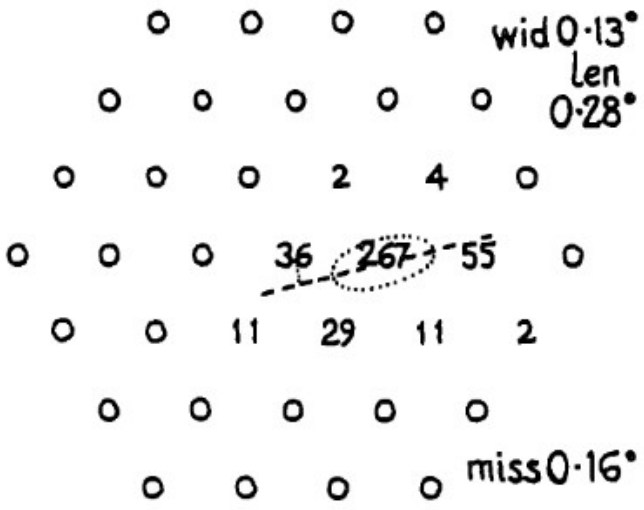


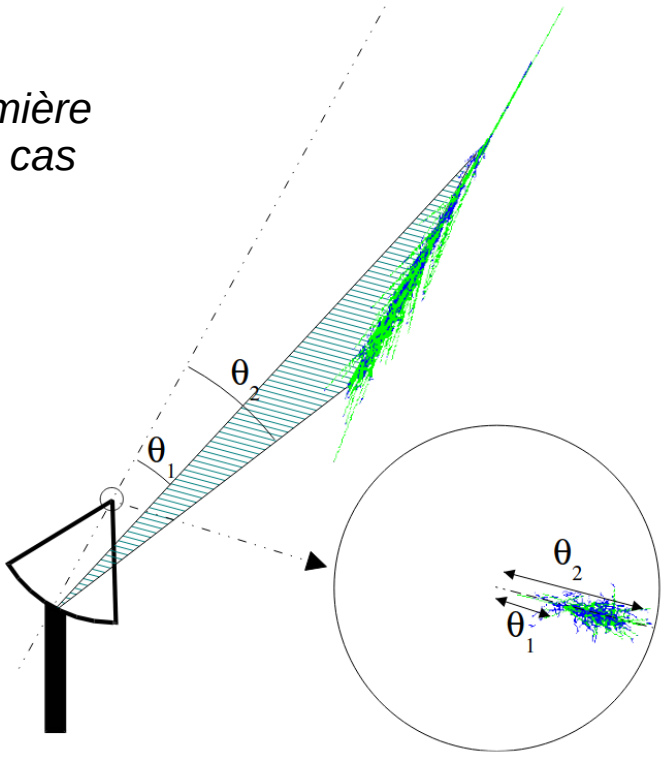

Figure 2: histograms of image characteristics. (vertical showers)

# Le coup de génie

Hillas (1985), basé sur le design proposé par Weekes (1981)



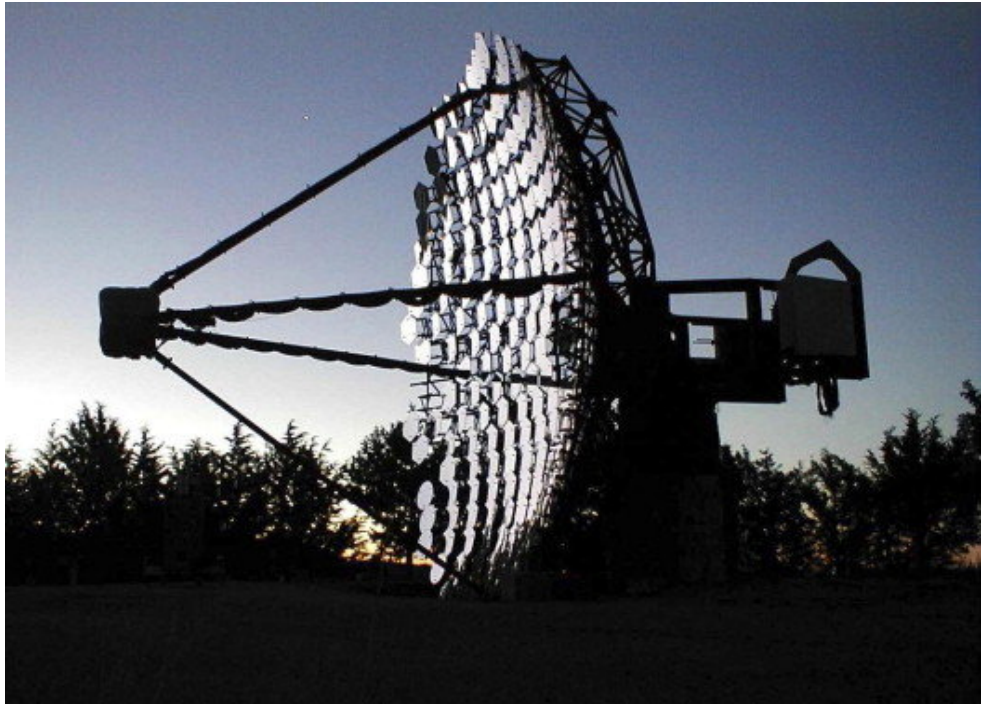

*Résultat de la simulation de la lumière collectée par les 37 PMT, dans le cas d'un rayon gamma de 2 TeV*




Détermination de la direction d'arrivée de la particule incidente avec le grand axe de l'ellipse

# Whipple 10 m : à jamais le premier

Une évolution technologique



Nouveau design de caméra :
**37 photo-multiplicateurs**

→ imager la gerbe au lieu de simplement collecter de la lumière

Observation pendant 28 min suivie par un scan OFF avec le même angle zénithal

# Whipple 10 m : à jamais le premier

Weekes et al. (1989) : détection de la nébuleuse du Crabe !

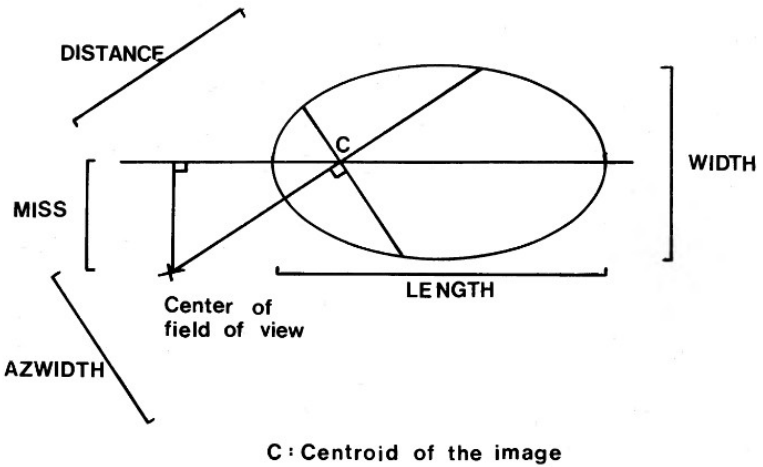



TABLE 4

*Azwidth* DISCRIMINATION

| Epoch | ON | OFF | All (%) | Difference | OFF (%) | Significance |
|---|---|---|---|---|---|---|
| No Selection (All) | | | | | | |
| 1986–1988..... | 652,974 | 651,801 | 100.0 | +1173 | 0.2 | +1.03 |
| *Azwidth* Selection | | | | | | |
| 1986–1988..... | 9092 | 7929 | 1.2 | +1163 | 14.7 | +8.91 |

Probabilité que les évènements dans la région de la source ne soient dues qu'au fond :
**0.00000000000000003**

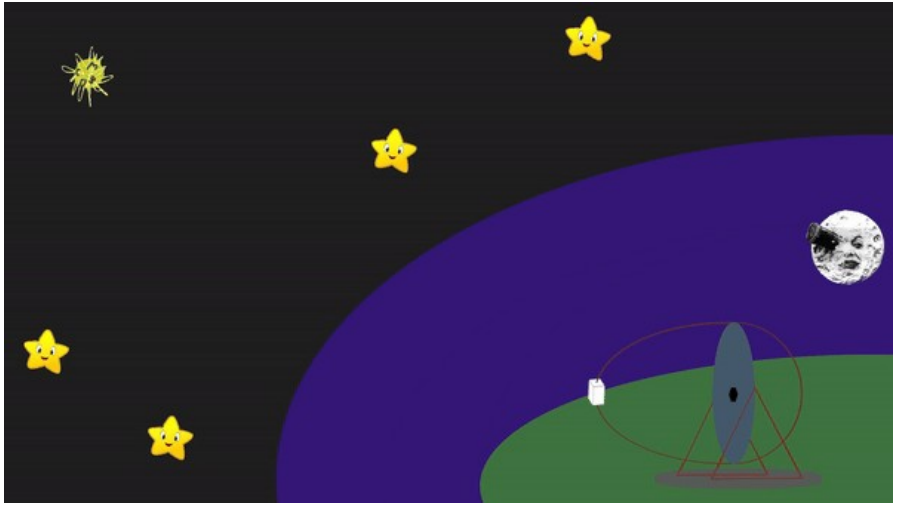
# Une nouvelle ère

Beaucoup de détections suivirent celle de la Nébuleuse du Crabe :

- Markarian 421, en 1992 (Whipple)
- Markarian 501, en 1996 (Whipple)
- 3C66A, en 1998 (Crimea)
- 1 ES 2344+514, en 1998 (Whipple)
- PKS 2155-304, en 1999 (Durham Mark 6)
- ...

# La nouvelle génération

Jusqu’aux LST !



# La nouvelle génération

Jusqu’aux LST !