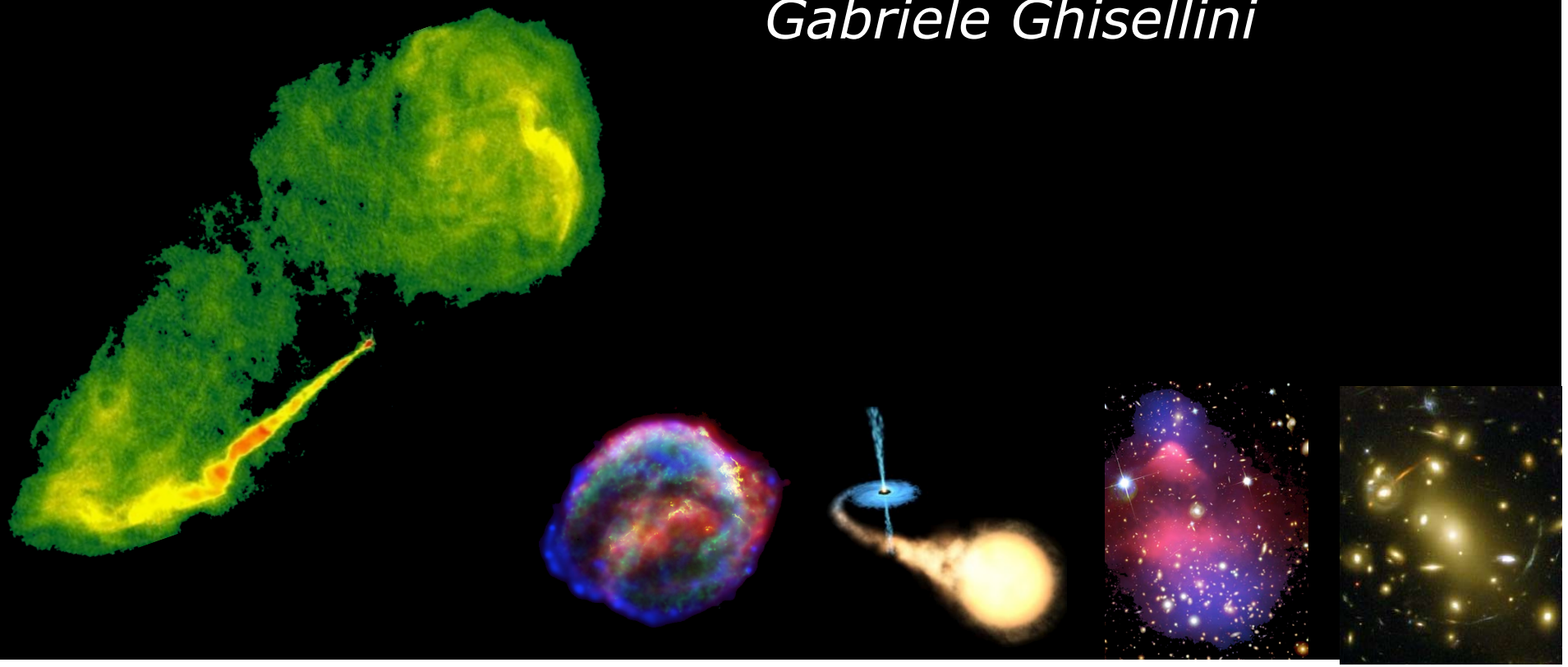
Istituto Nazionale di Astrofisica

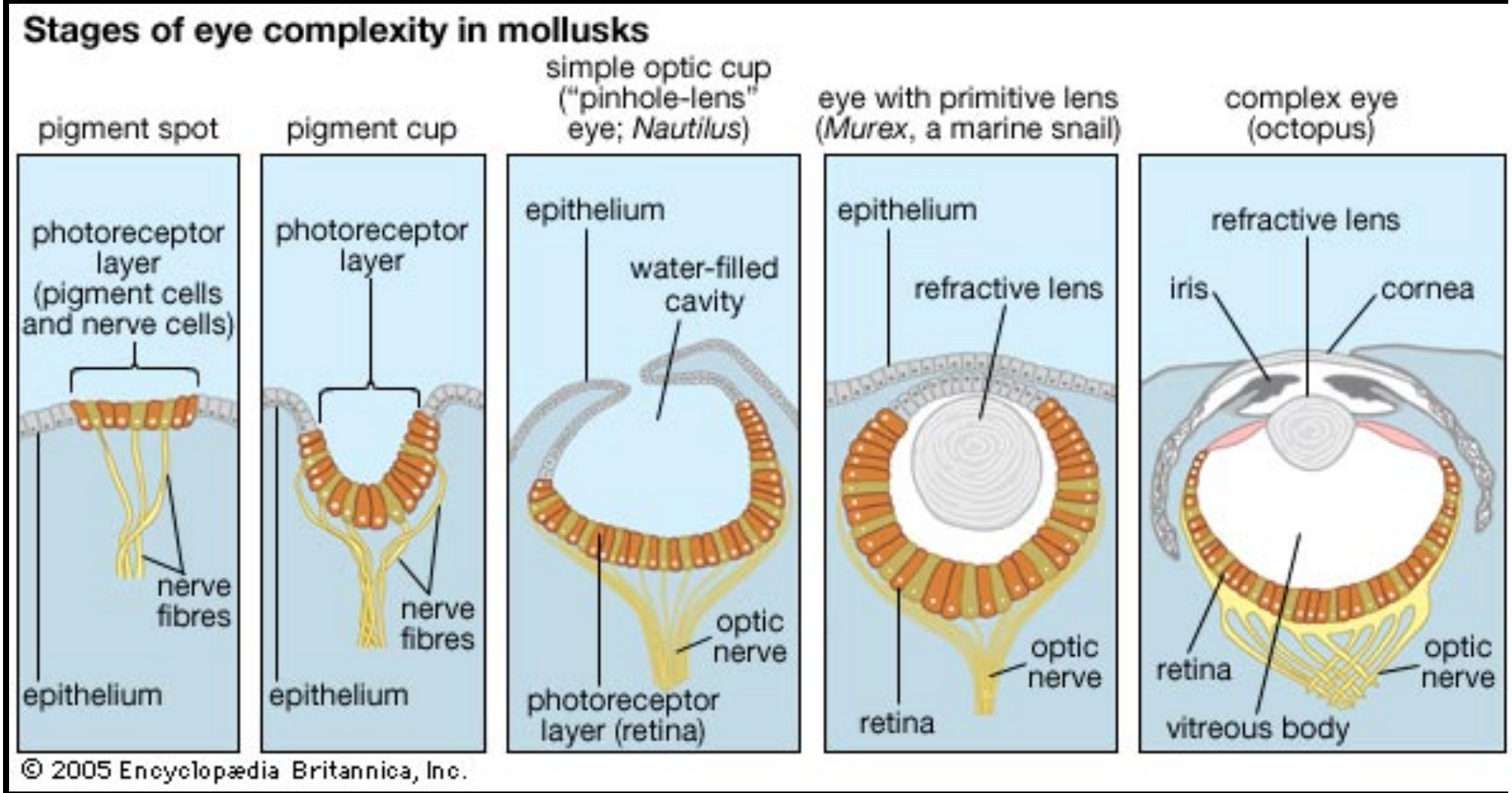
Osservatorio astronomico di Brera

Più veloci della luce: i getti cosmici

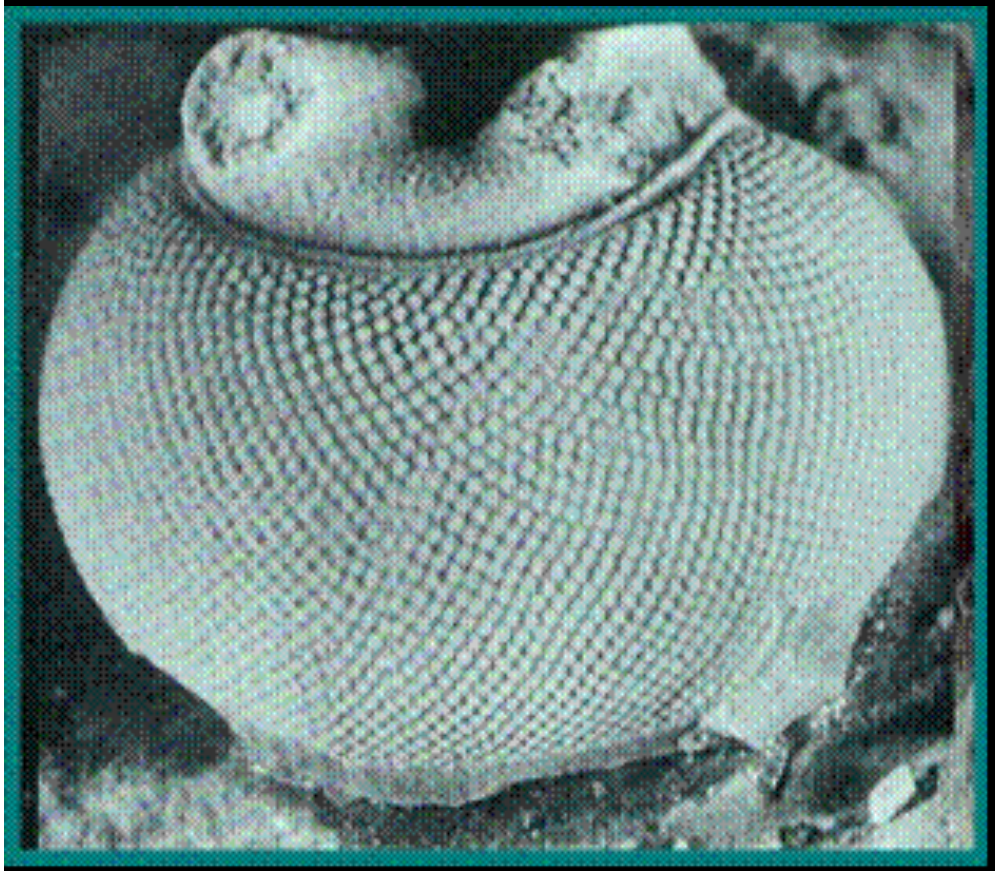
Gabriele Ghisellini

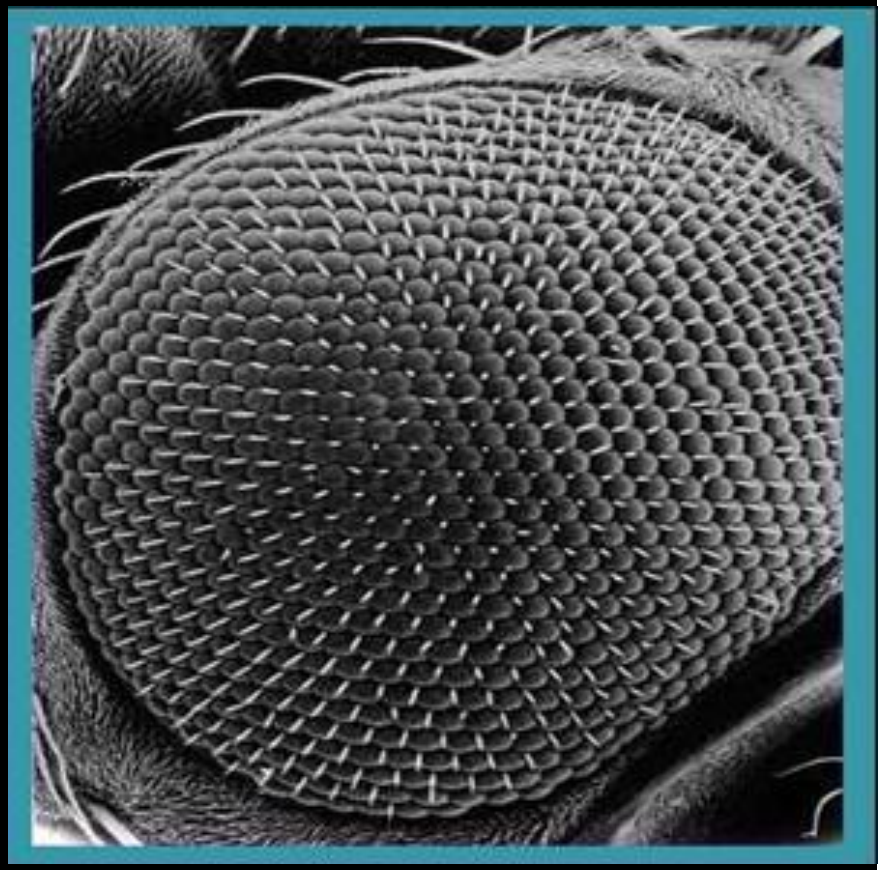


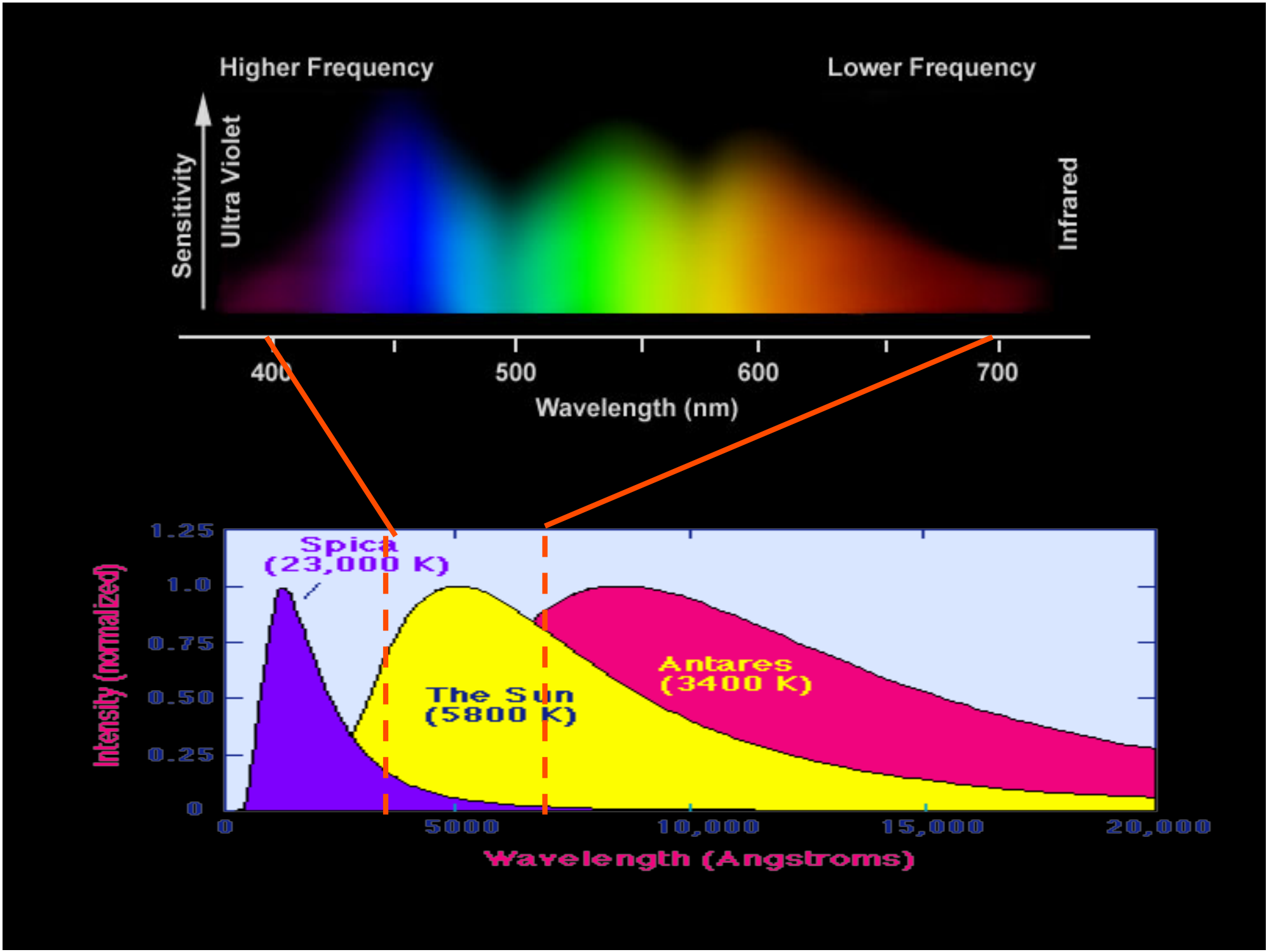
540 milioni di anni fa
Esplosione del Cambriano

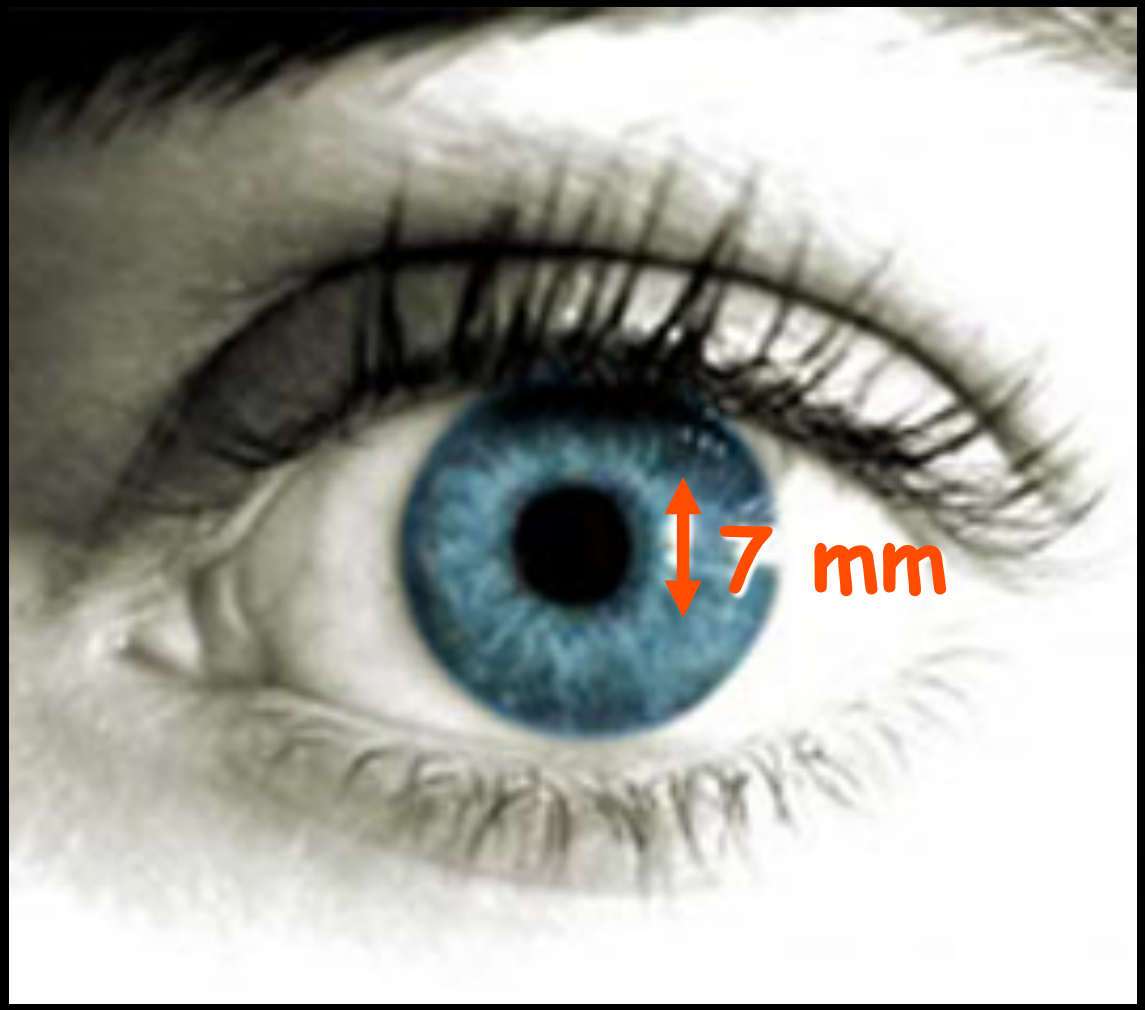


(c) MixroAngela

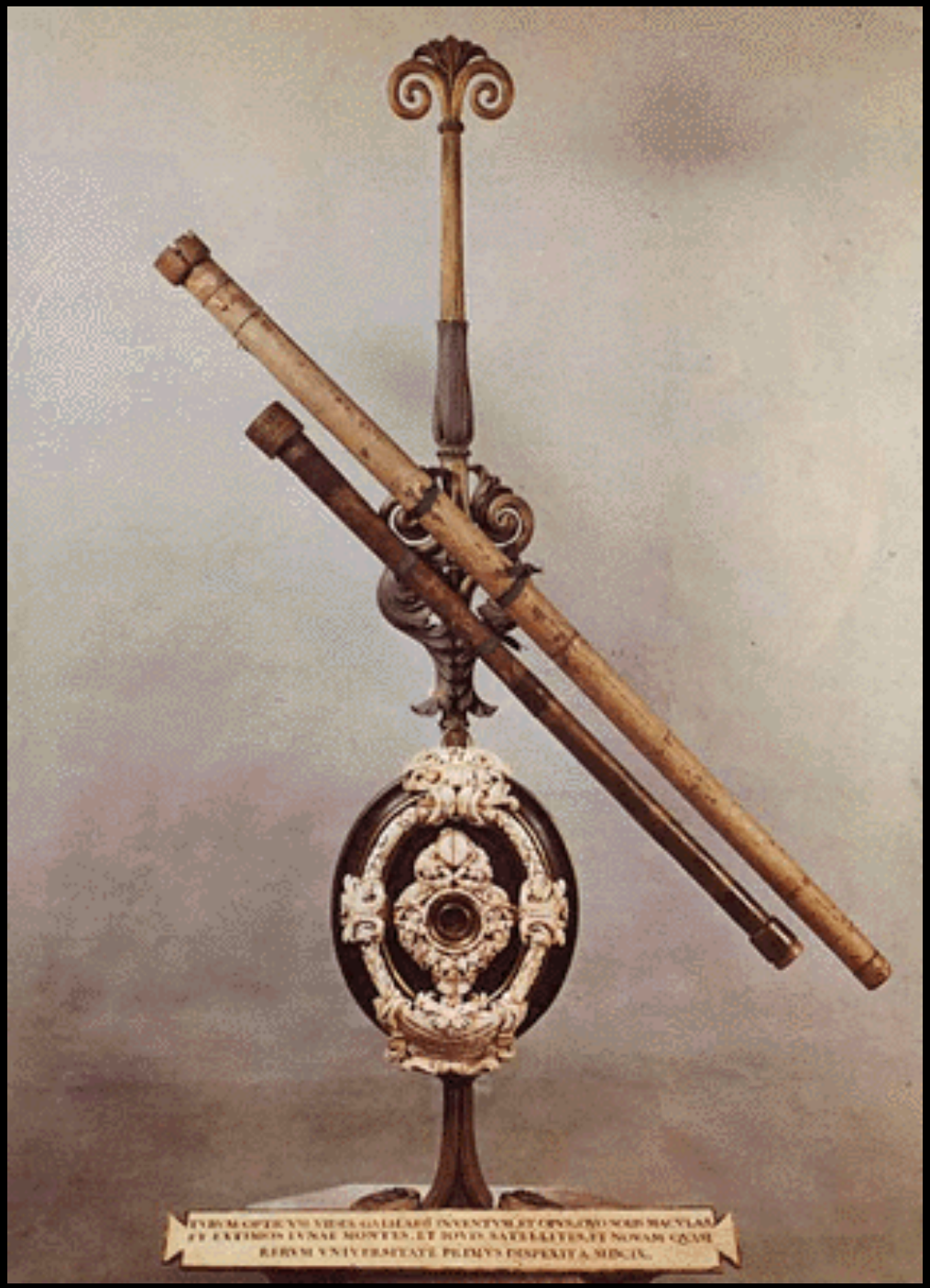





Higher Frequency
Lower Frequency
Sensitivity
Ultra Violet
Infrared
400
500
600
700
Wavelength (nm)
Spica
(23,000 K)
The Sun
(5800 K)
Antares
(3400 K)
Intensity (normalized)
1.25
1.0
0.75
0.50
0.25
0
0
5000
10,000
15,000
20,000
Wavelength (Angstroms)



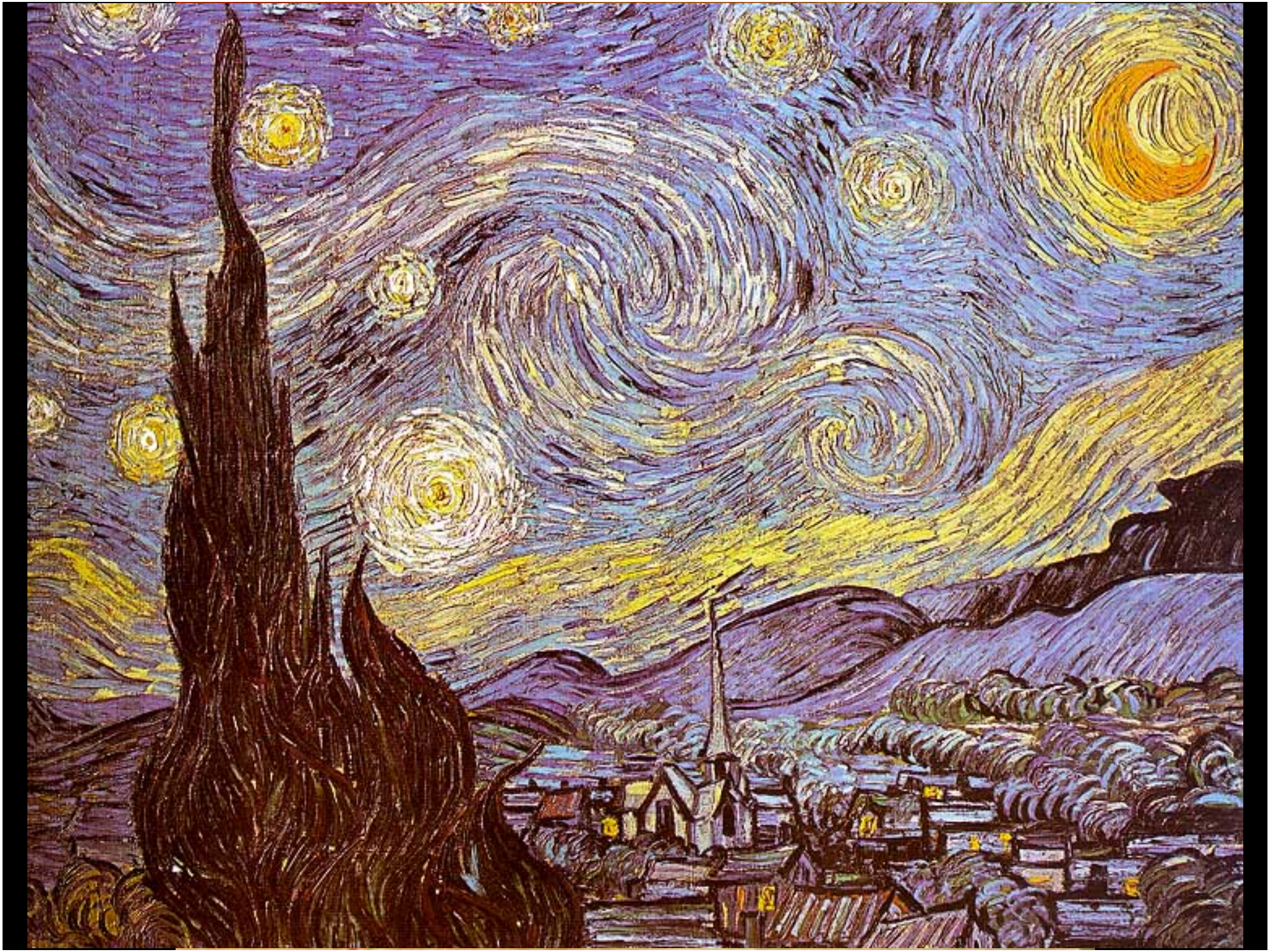
Per 2 milioni di anni… (=24 ore)

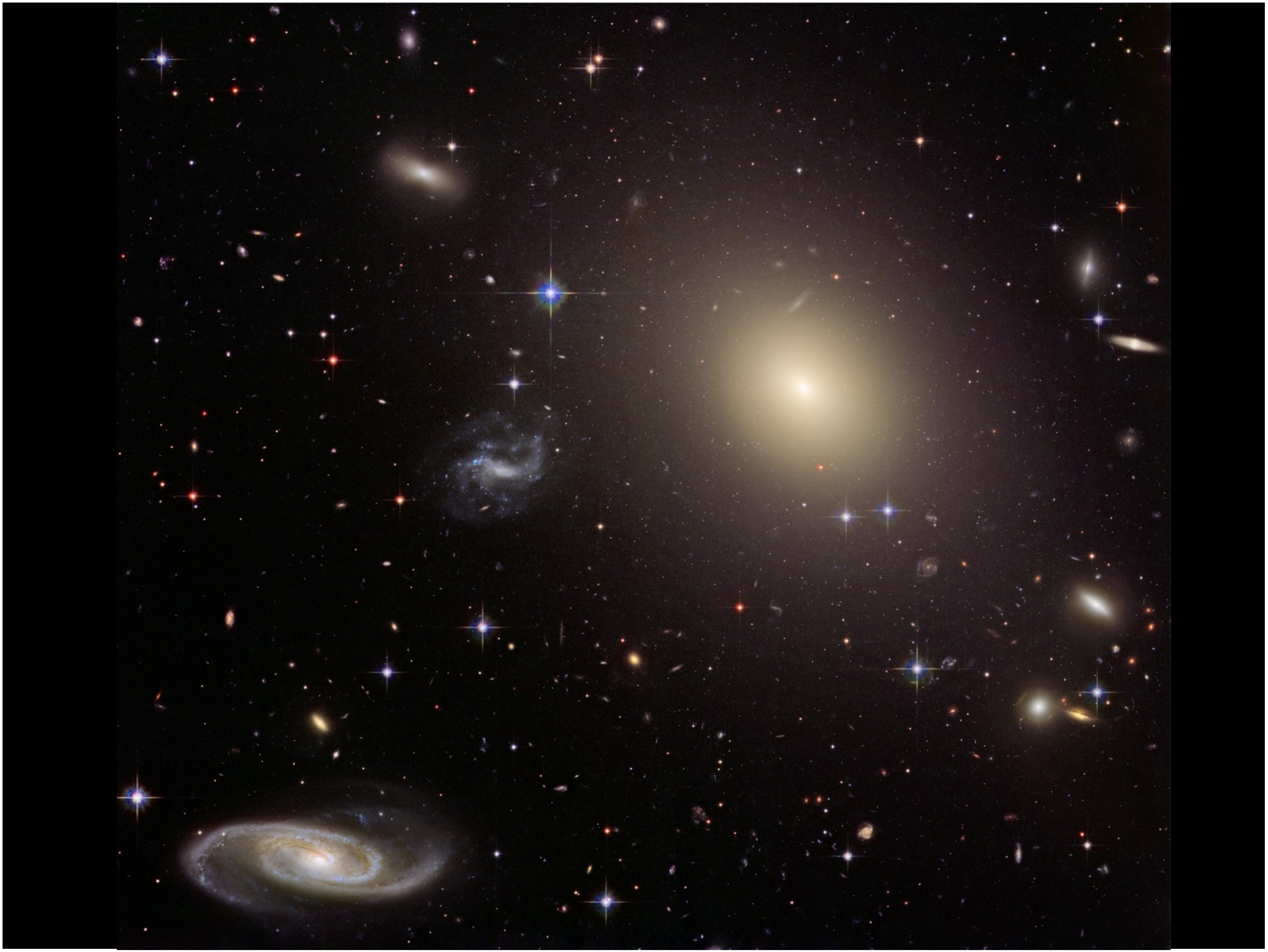


~1610

37 mm

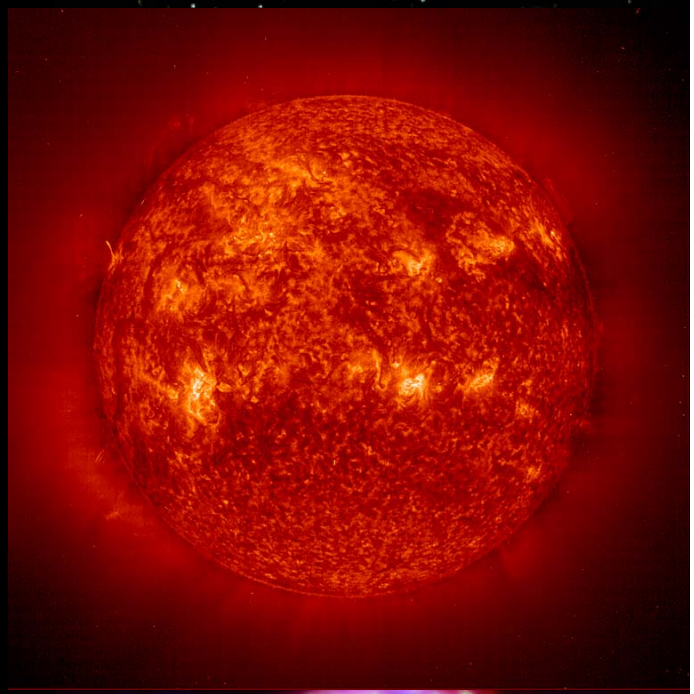
21.6 sec alla mezzanotte

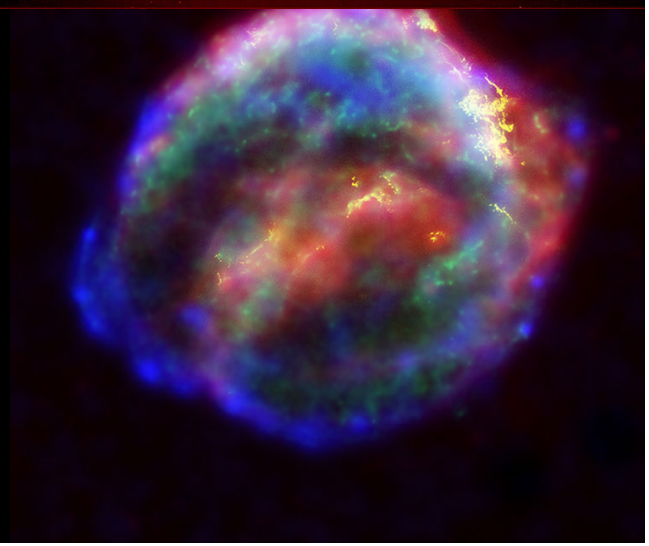


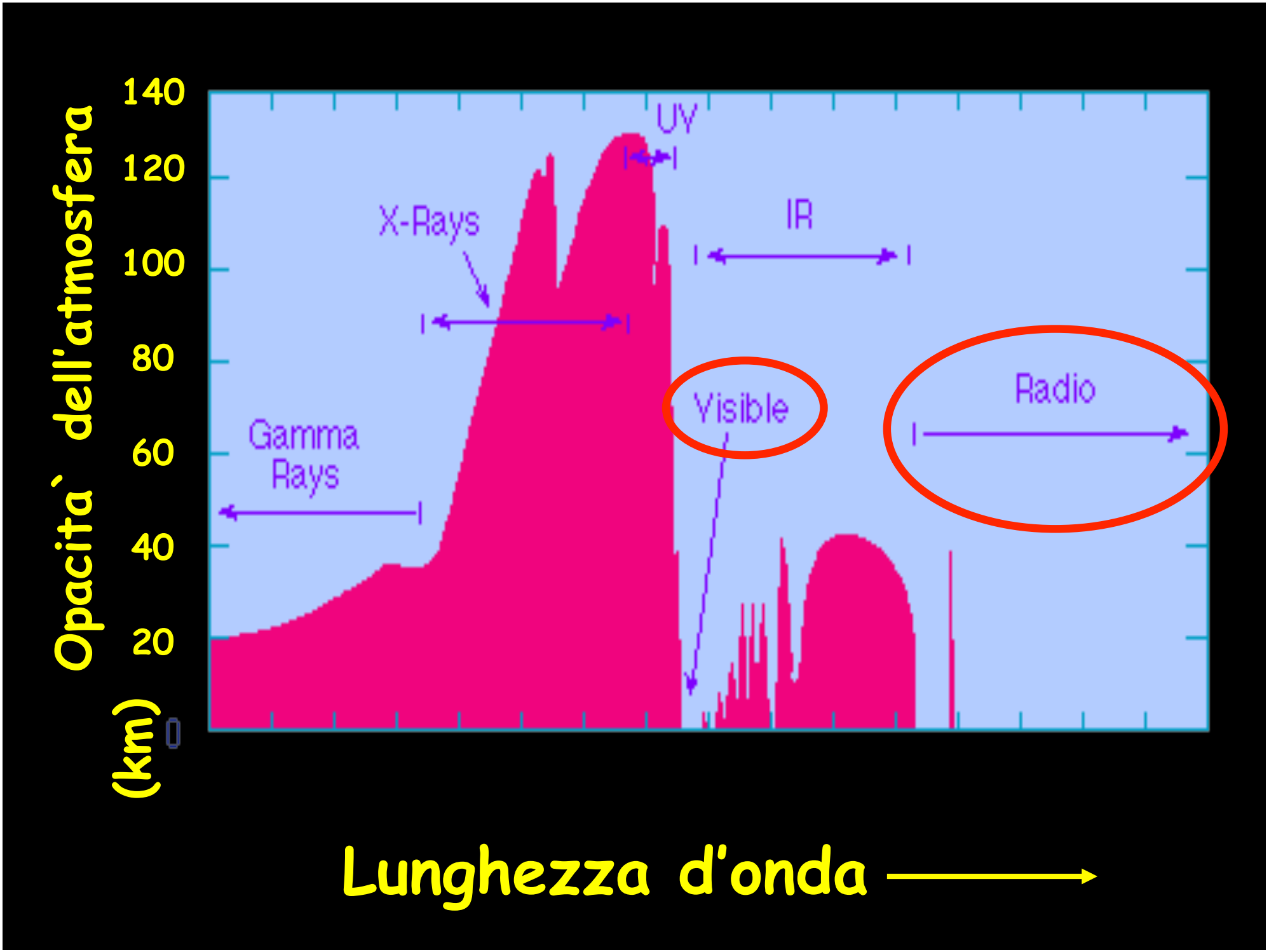


Un Universo "tranquillo"

- La maggior parte della luce visibile fatta da stelle che vivono miliardi di anni. Il motore (fusione di idrogeno in elio) e' nel centro della stella.
- Nel sole, la luce prodotta nel centro impiega circa centomila anni ad uscire.
- Ci sono eccezioni: le supernovae, per esempio.






Opacita` dell'atmosfera
140
120
100
80
60
40
20
0
(km)
UV
X-Rays
IR
Visible
Radio
Gamma
Rays
Lunghezza d'onda

Guglielmo Marconi e la radio ~1895

4.8 sec alla mezzanotte

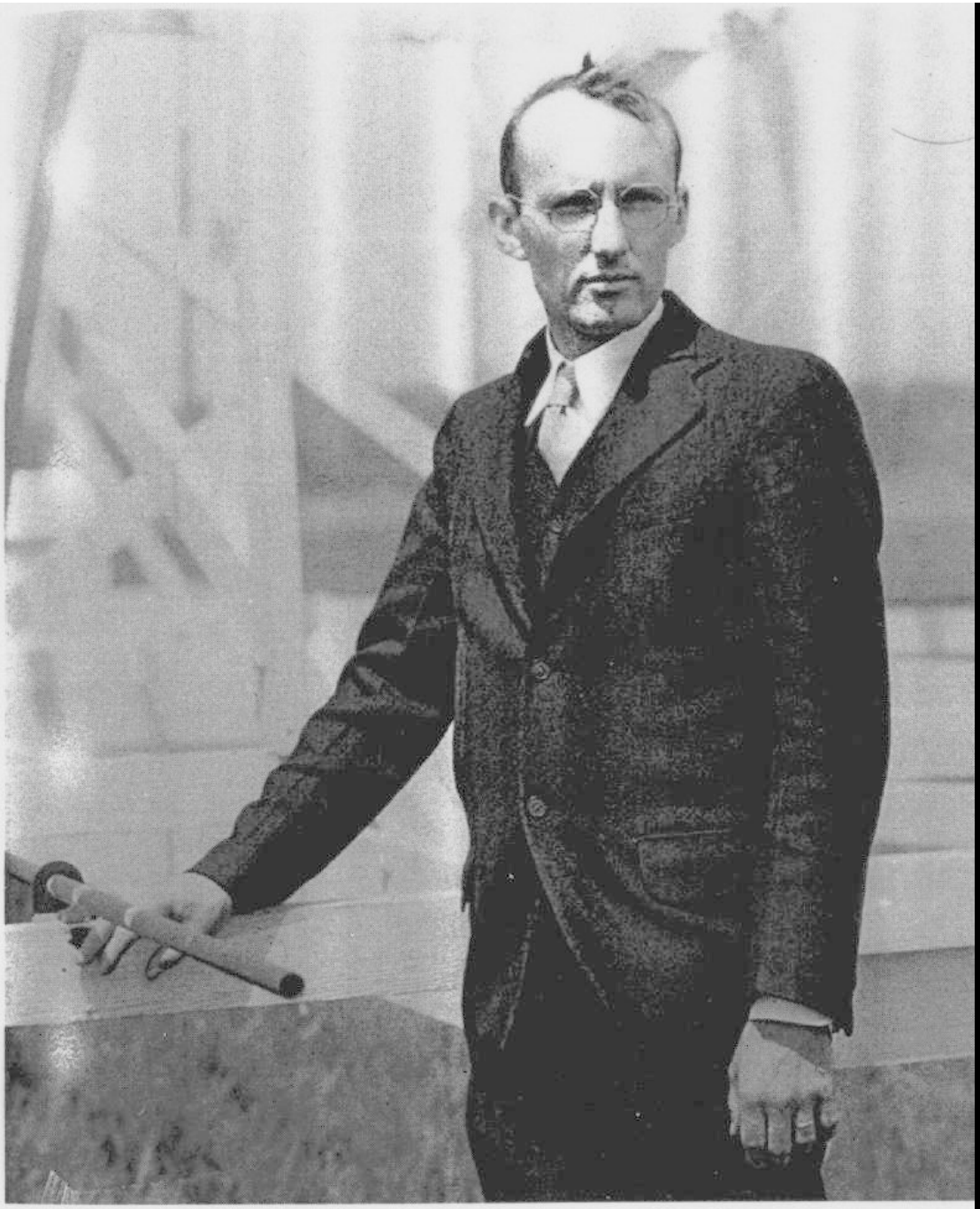
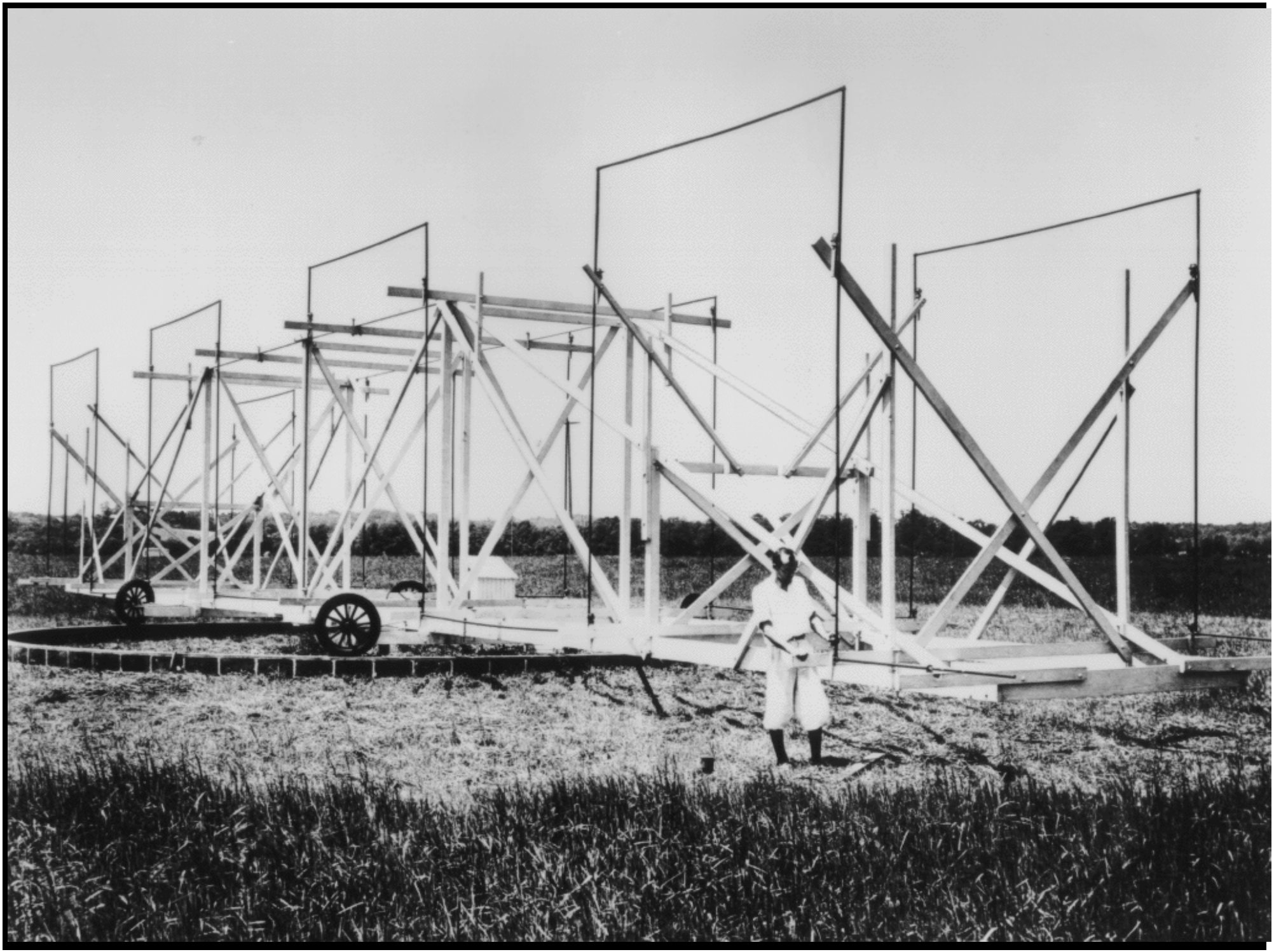


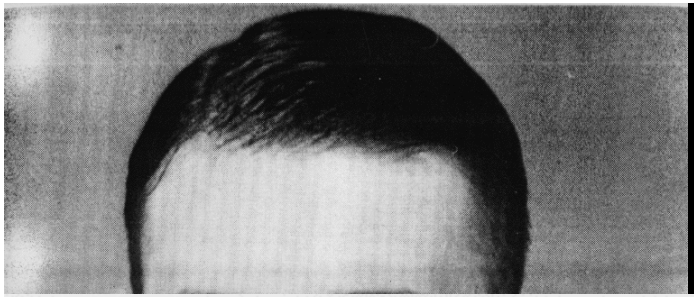
FIG. 1—Karl Guthe Jansky, about 1933.

Karl Jansky

1933 circa

3.2 sec alla mezzanotte





Grote Reber

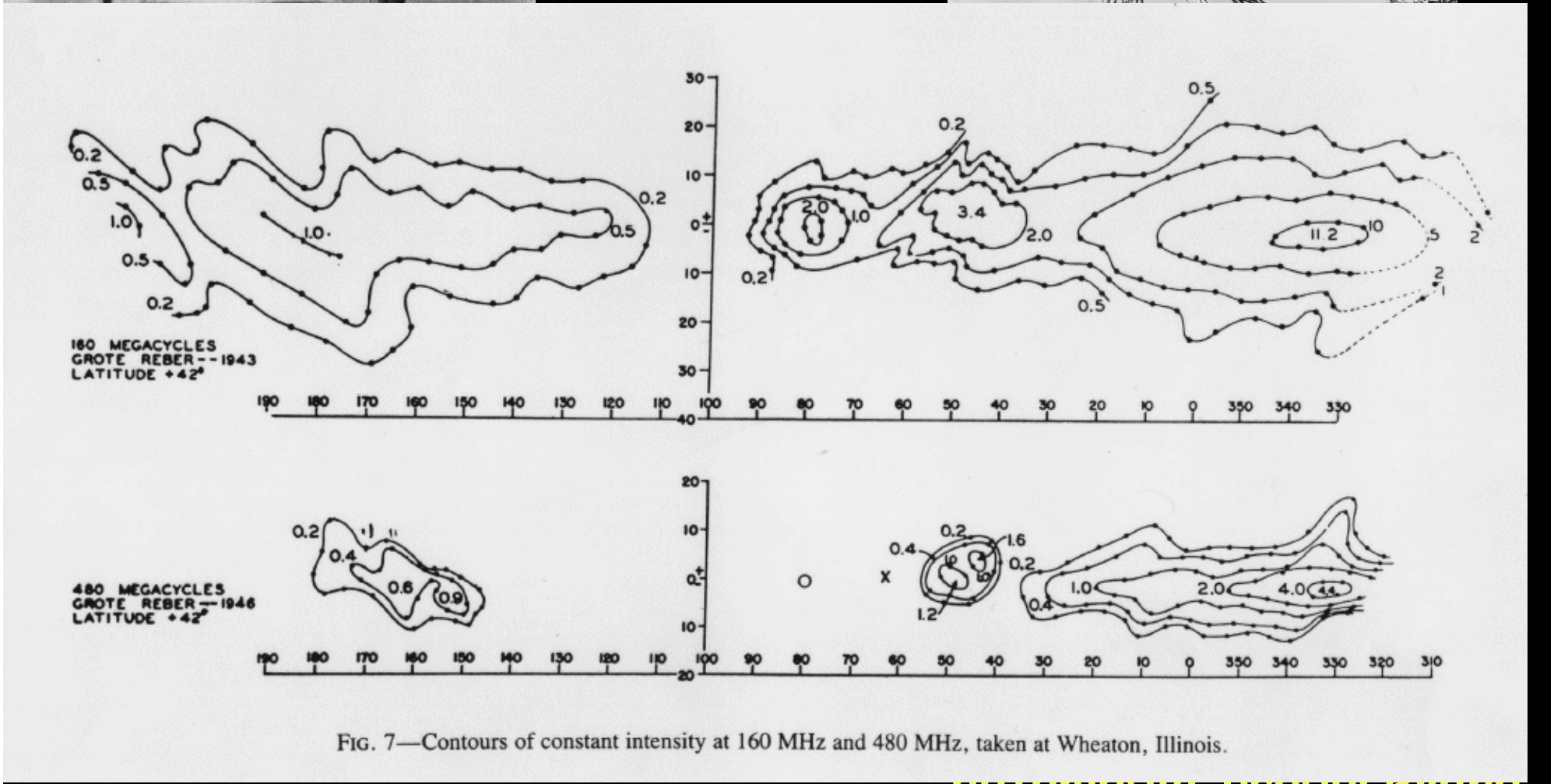
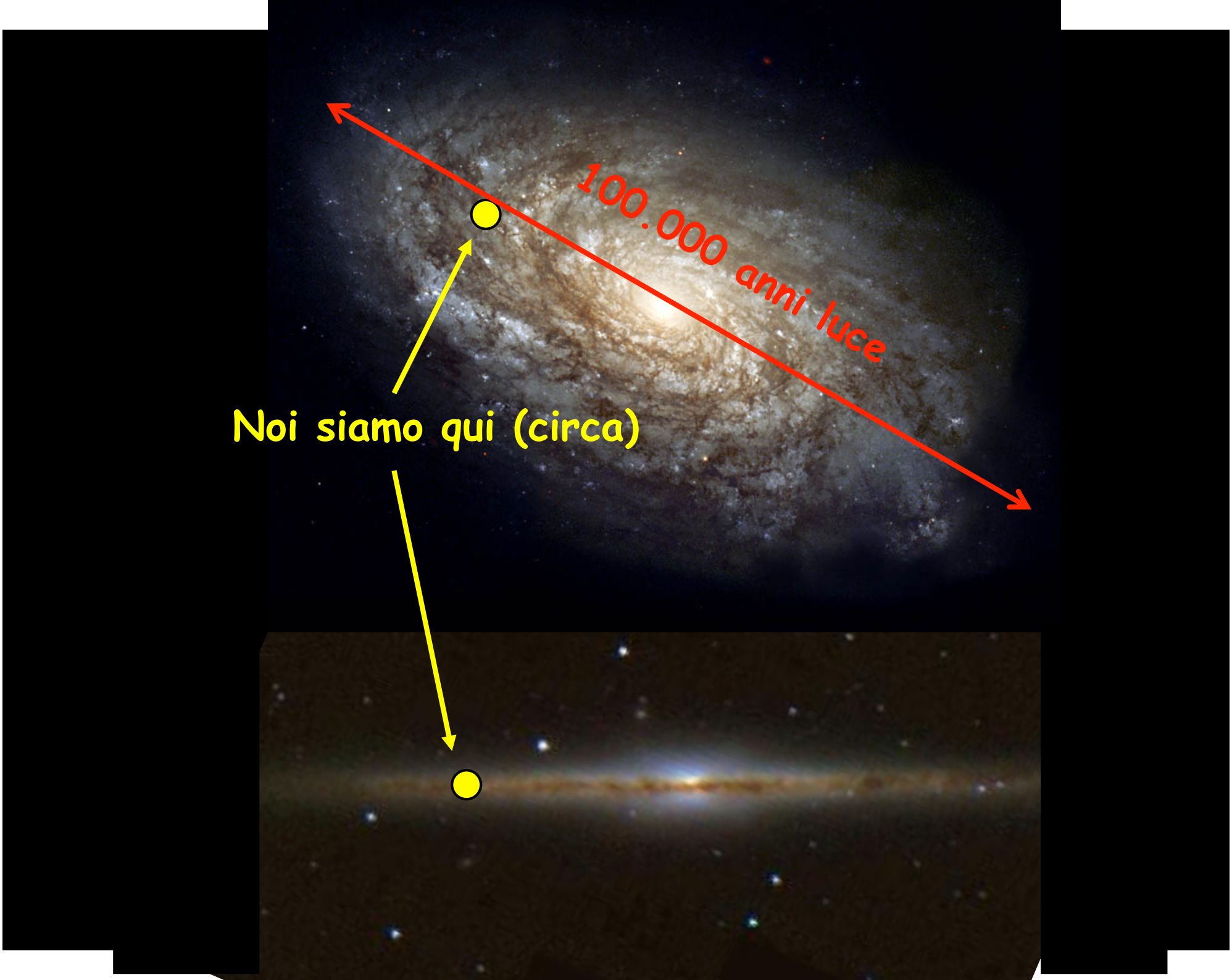


FIG. 7—Contours of constant intensity at 160 MHz and 480 MHz, taken at Wheaton, Illinois.

automobili producevano troppe interferenze

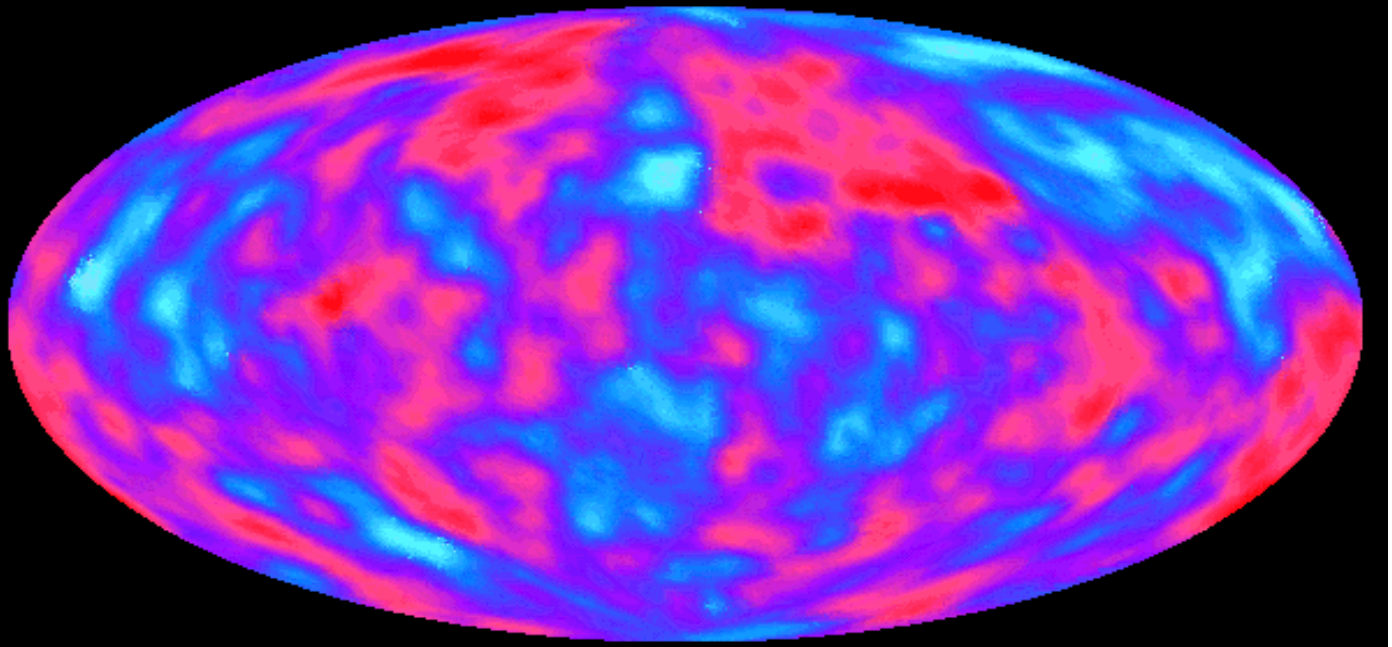

100.000 anni luce
Noi siamo qui (circa)

Anni '50: sviluppo della radioastronomia

- Sviluppo del radar durante la II guerra mondiale
- Materiale elettrico in saldo

2.5 secondi alla mezzanotte

Radiazione cosmica di fondo



Penzias e Wilson

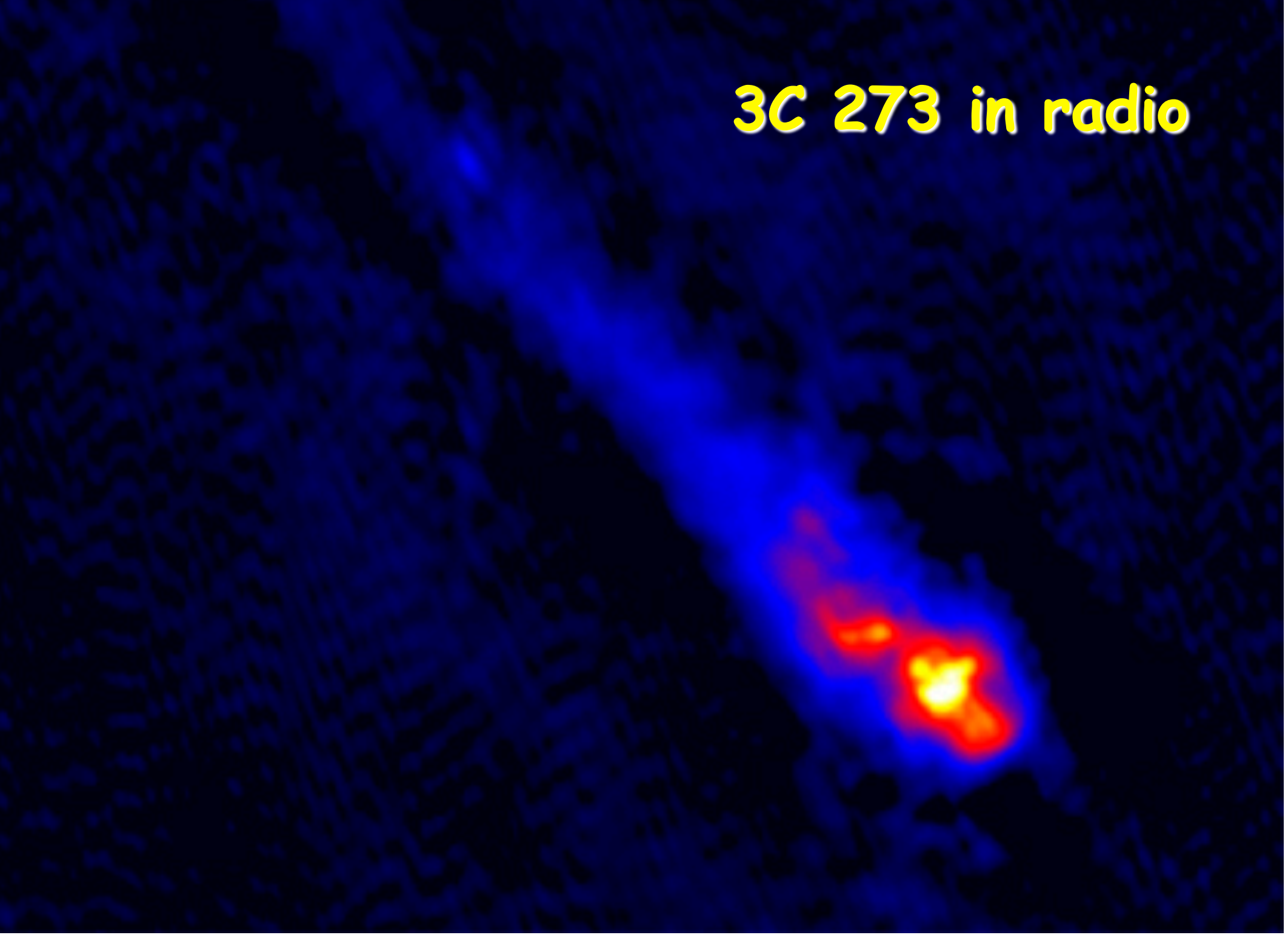
$$\Theta = 57^{0} \frac{\text{lunghezza d'onda}}{\text{diametro}}$$

Se λ=10 cm e il diametro e' 1000 cm:

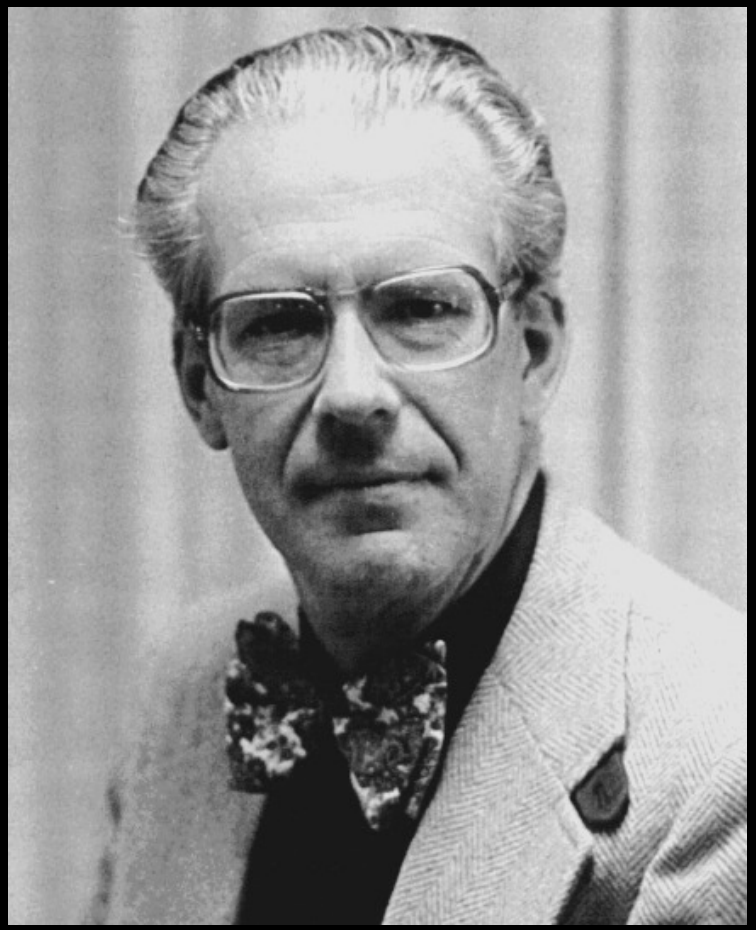
$\Theta \sim 0.5$ gradi =
diametro della Luna

"Sorgenti doppie" (piu' puntolino in mezzo?)

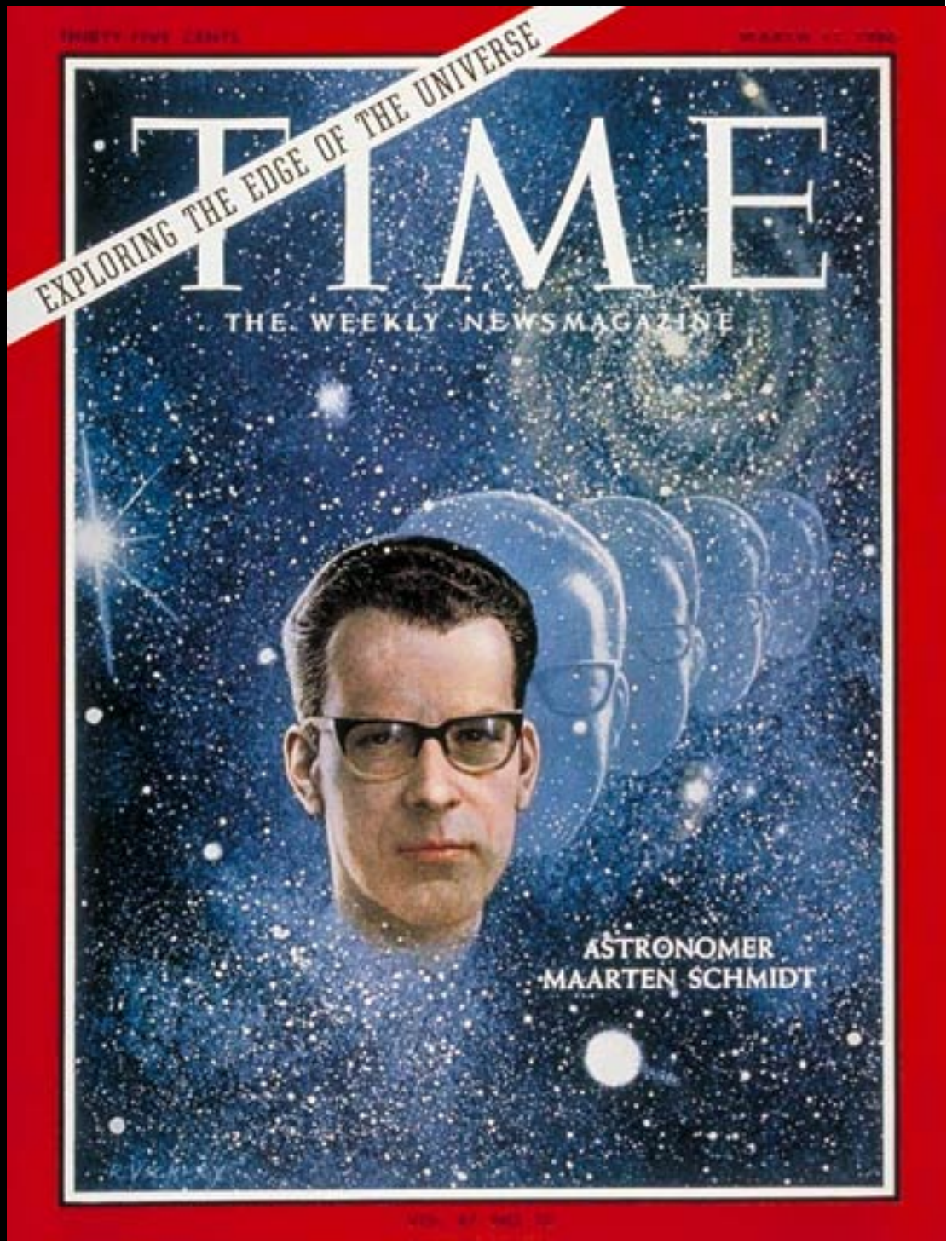
"Sorgenti
doppie" (piu' puntolino
in mezzo?)


3C 273 in radio

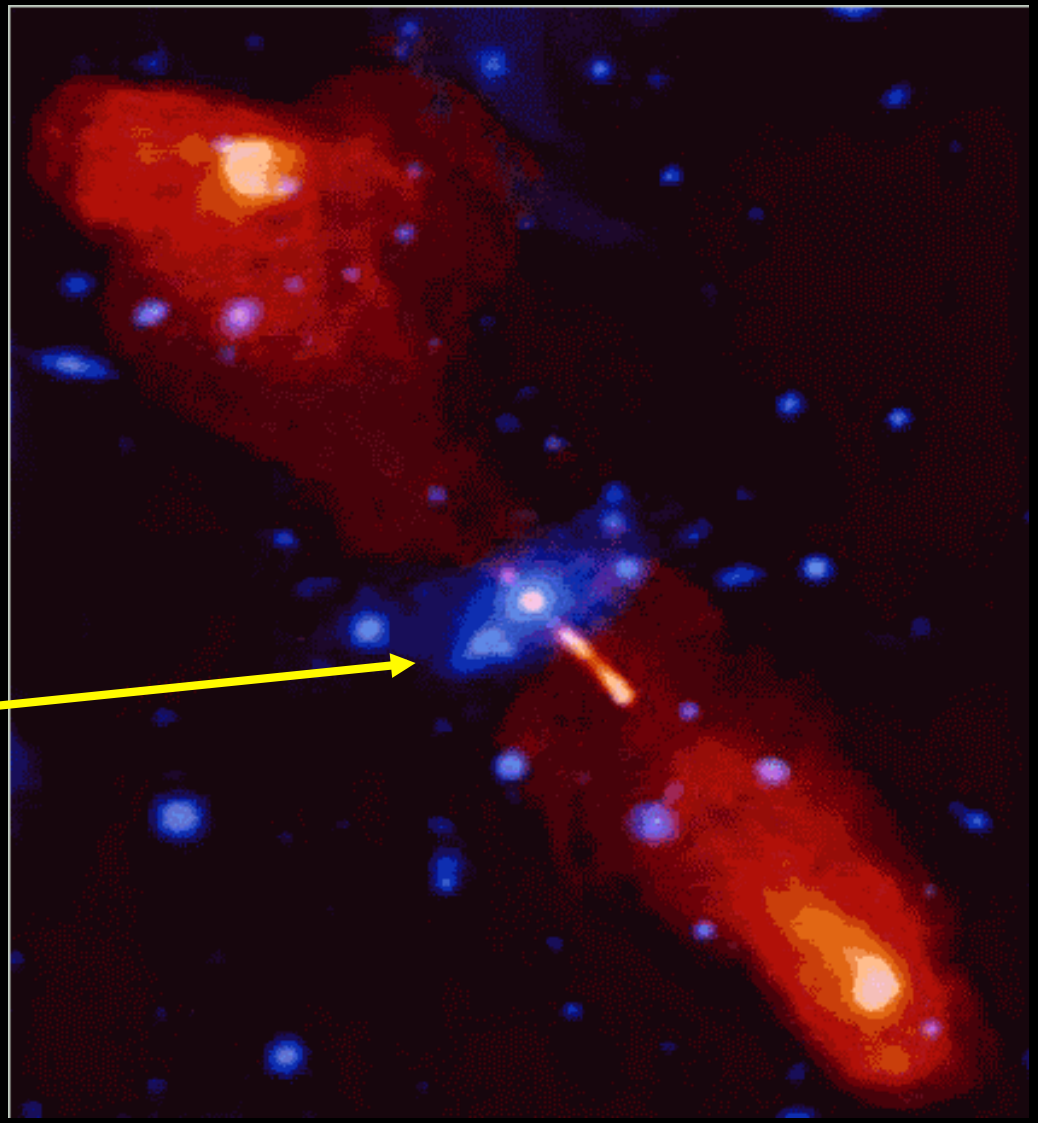
Mistero: righe sconosciute nello spettro, aspetto stellare (12 magnitudine), variabile.



Febbraio 1963:
Maarten Schmidt misura la distanza di 3C 273 (z=0.16): ~2 miliardi di anni luce.



Grandi distanze vuol dire…
grandi dimensioni e grandi energie….

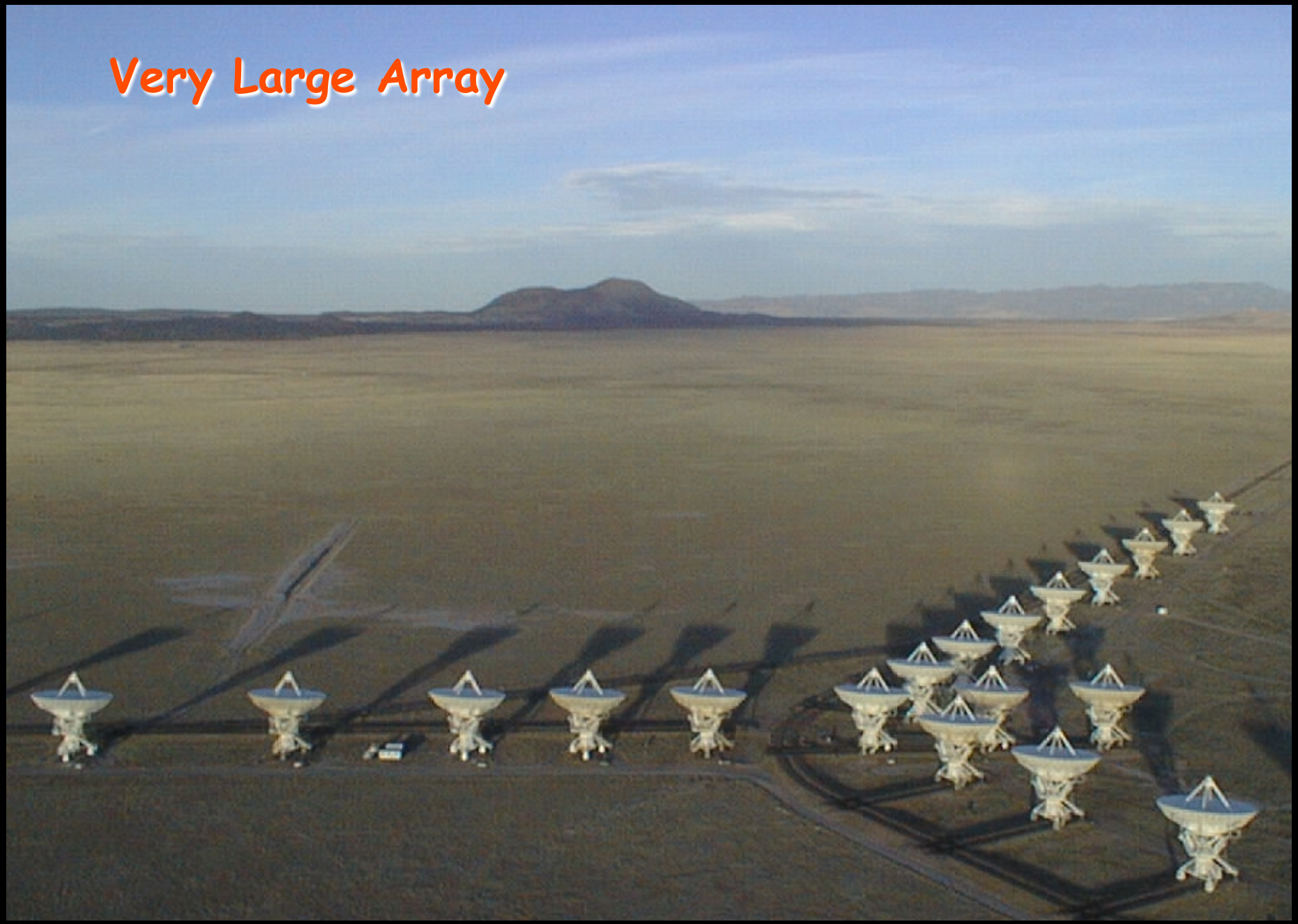


Galassia
(circa 100
miliardi di stelle
come il sole)

Quanta energia c'e' nei lobi radio?

Tanta.
Quanta ne viene prodotta da tutte le stelle di una galassia per un miliardo di anni

Chi la porta li'?
Chi la fa?


Very Large Array

Very Long Baseline Interferometry

Bologna
Noto

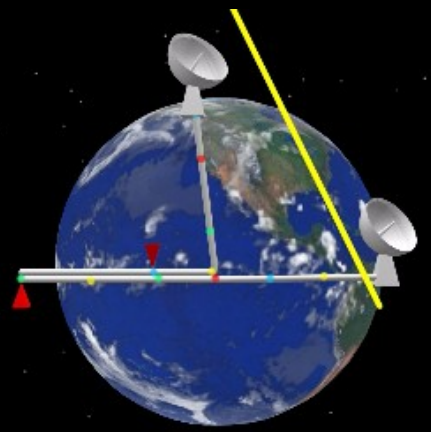
Prime osservazioni nel 1971: 1.5 secondi alla mezzanotte…

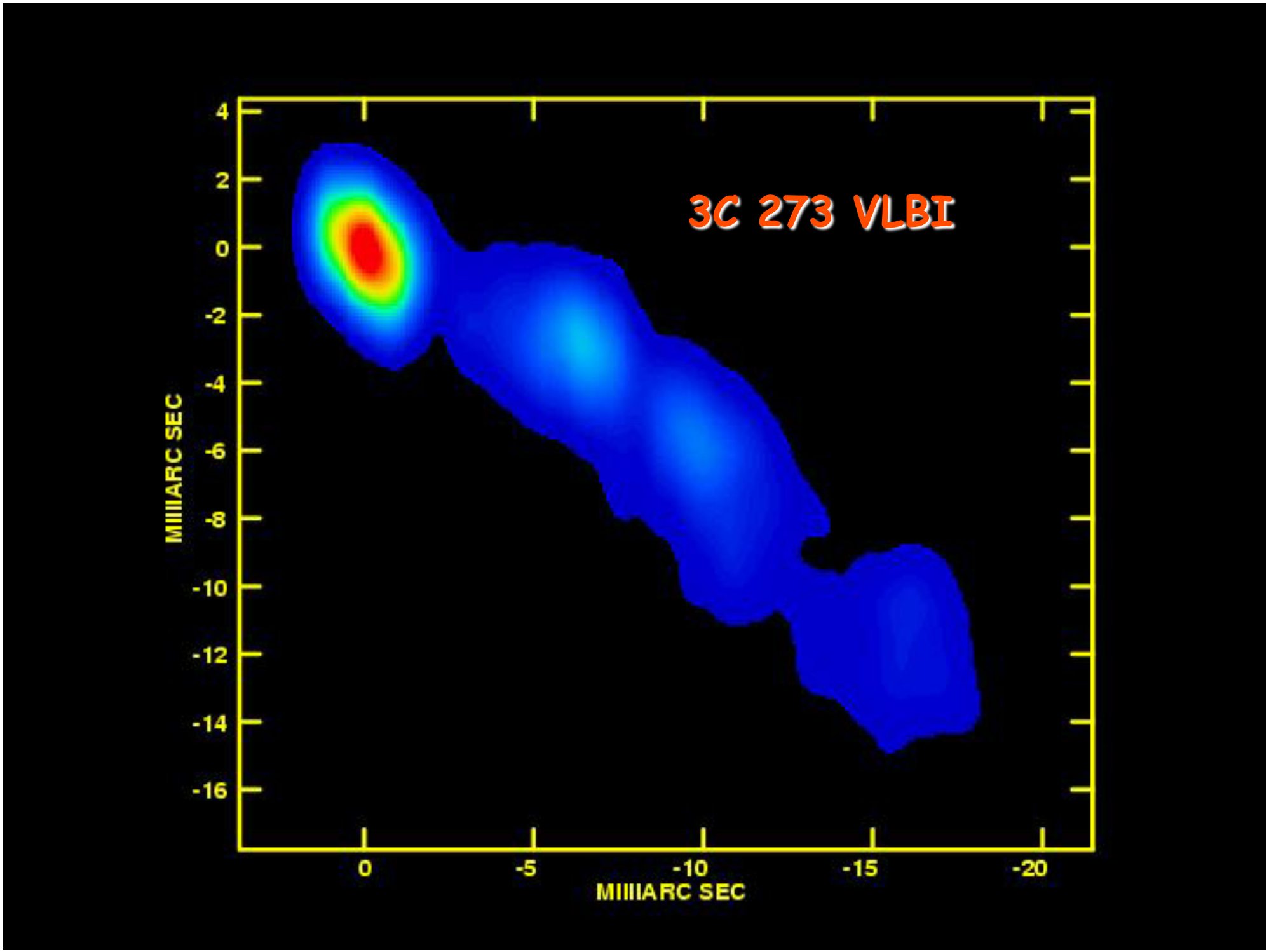
$$\Theta = 57 \frac{\text{lunghezza d'onda}}{\text{distanza}}$$

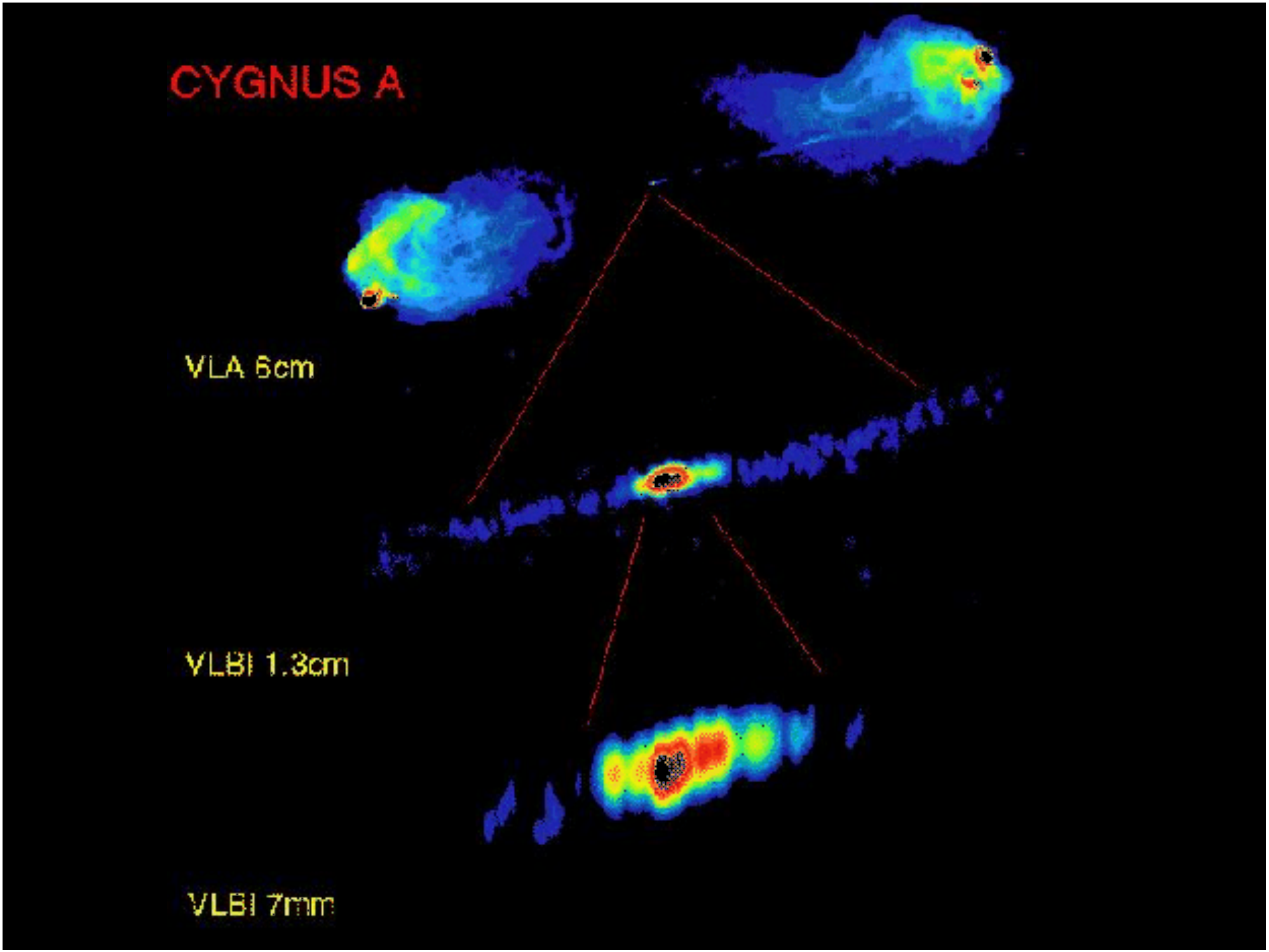
Se λ=1 cm e la distanza e' 5000 km:

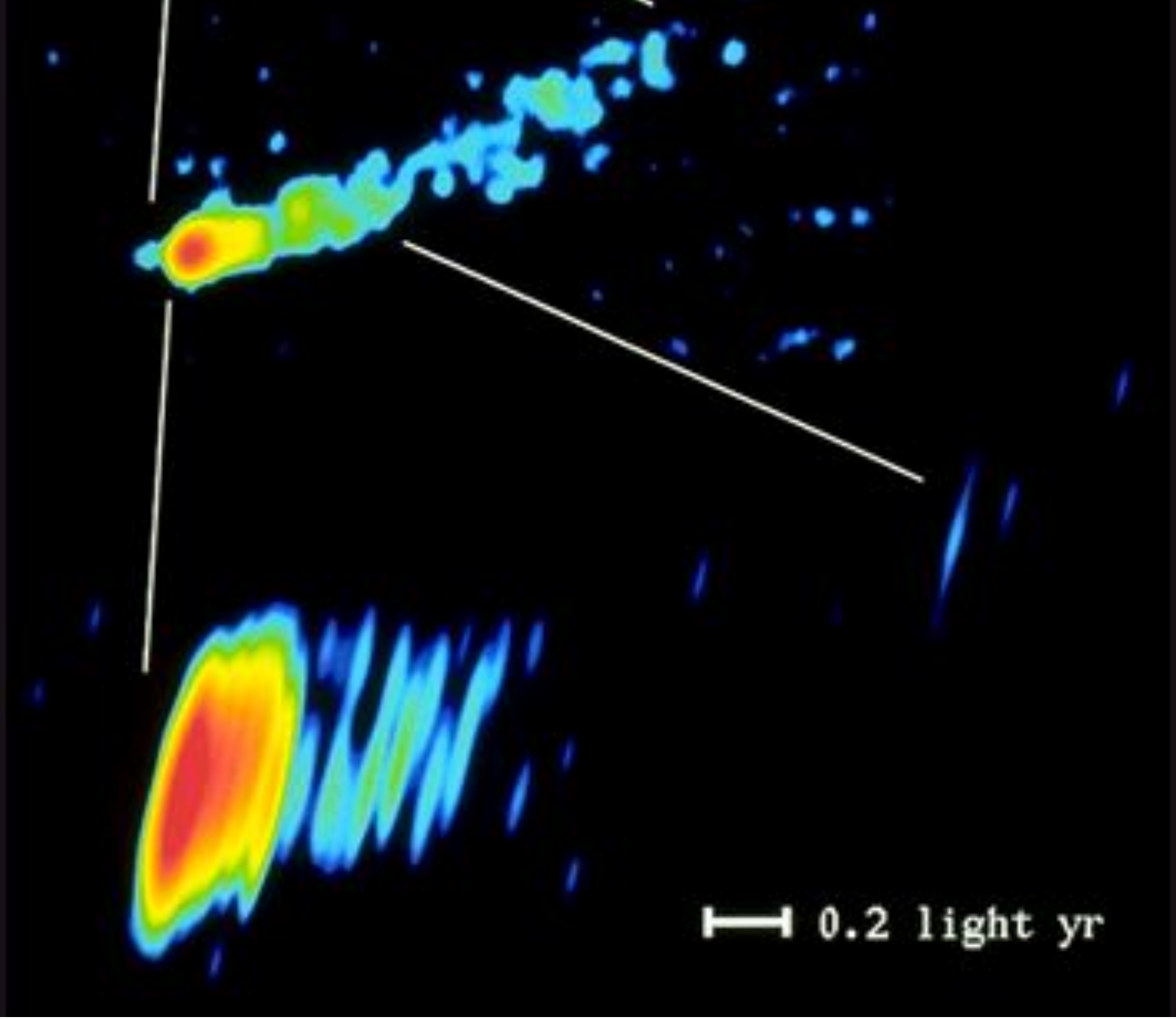
$\Theta \sim 0.0005''$ =

1 euro alla distanza di 10.000 km, o un bambino sulla Luna, o 2 anni luce alla distanza di un miliardo di anni luce...

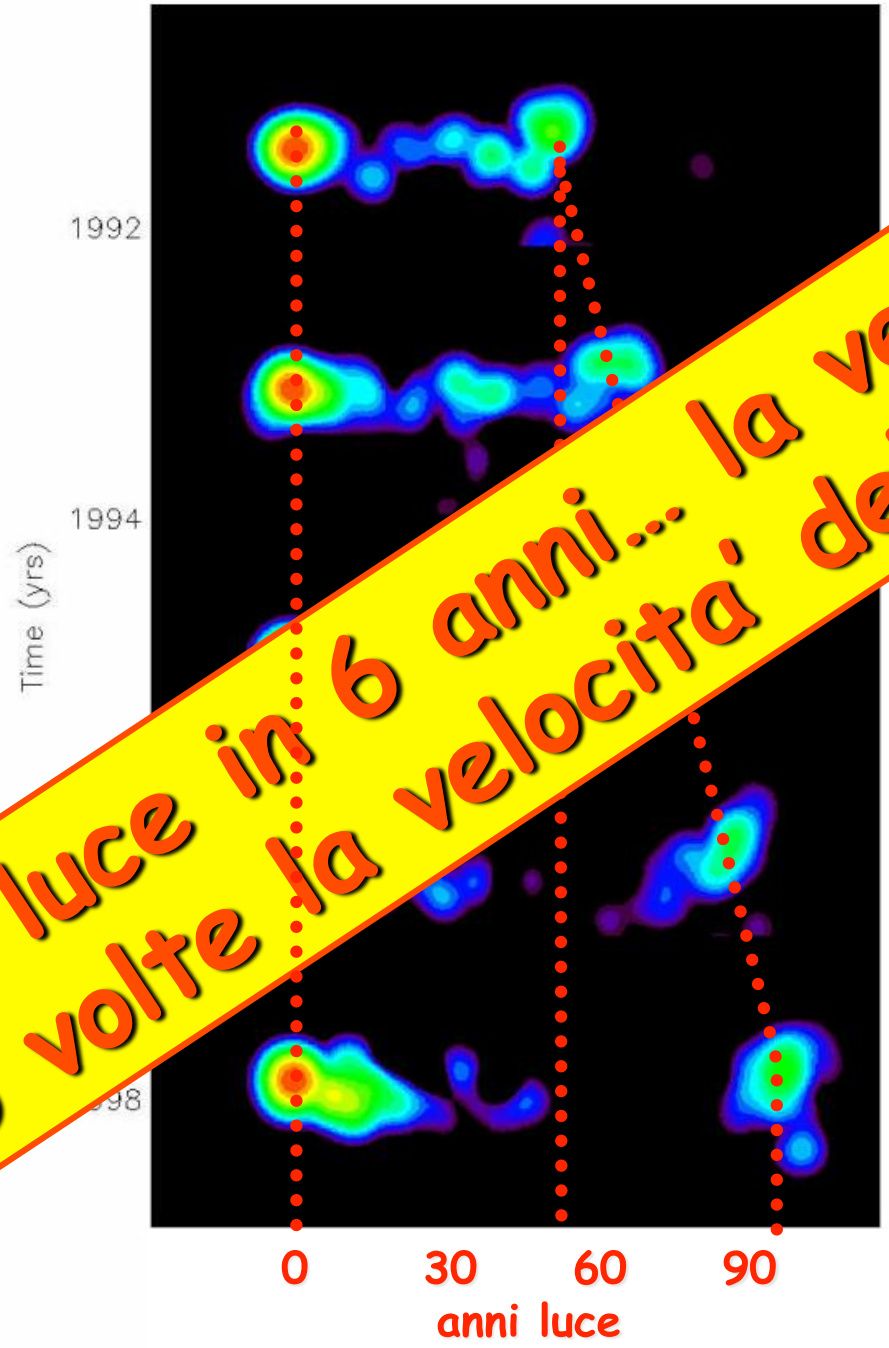



3C 273 VLBI
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
MIIIIARC SEC
0
-5
-10
-15
-20
MIIIIARC SEC

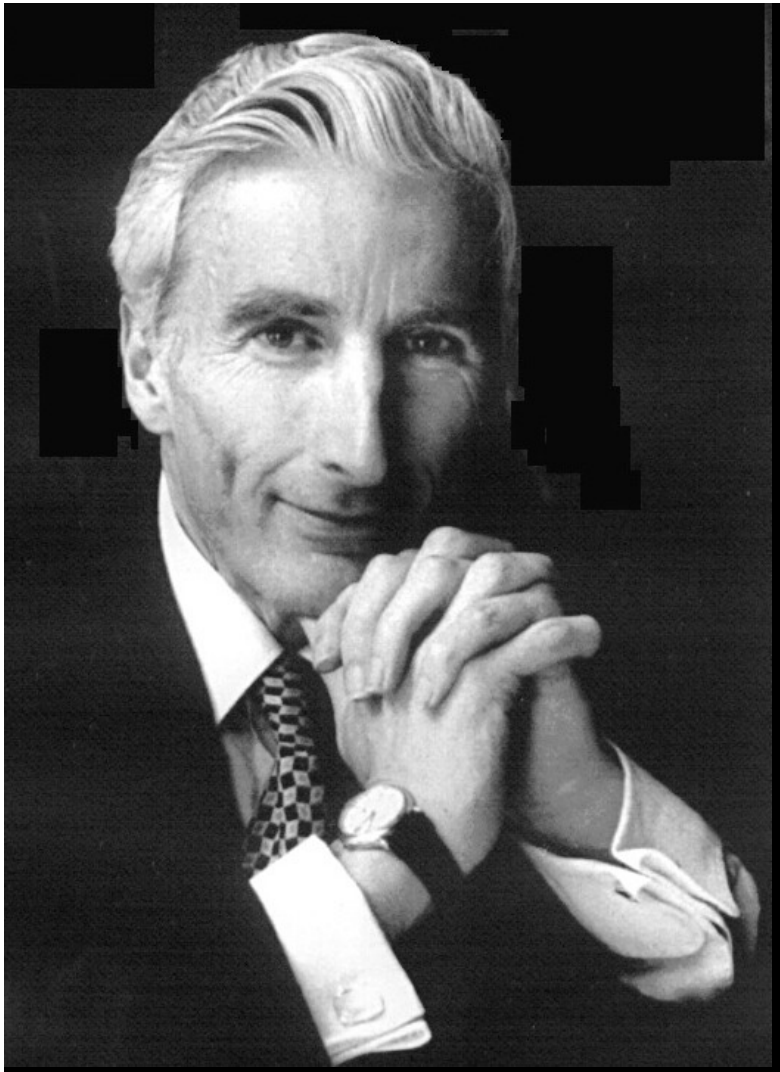

CYGNUS A
VLA 6cm
VLBI 1.3cm
VLBI 7mm


0.2 light yr

3C 279

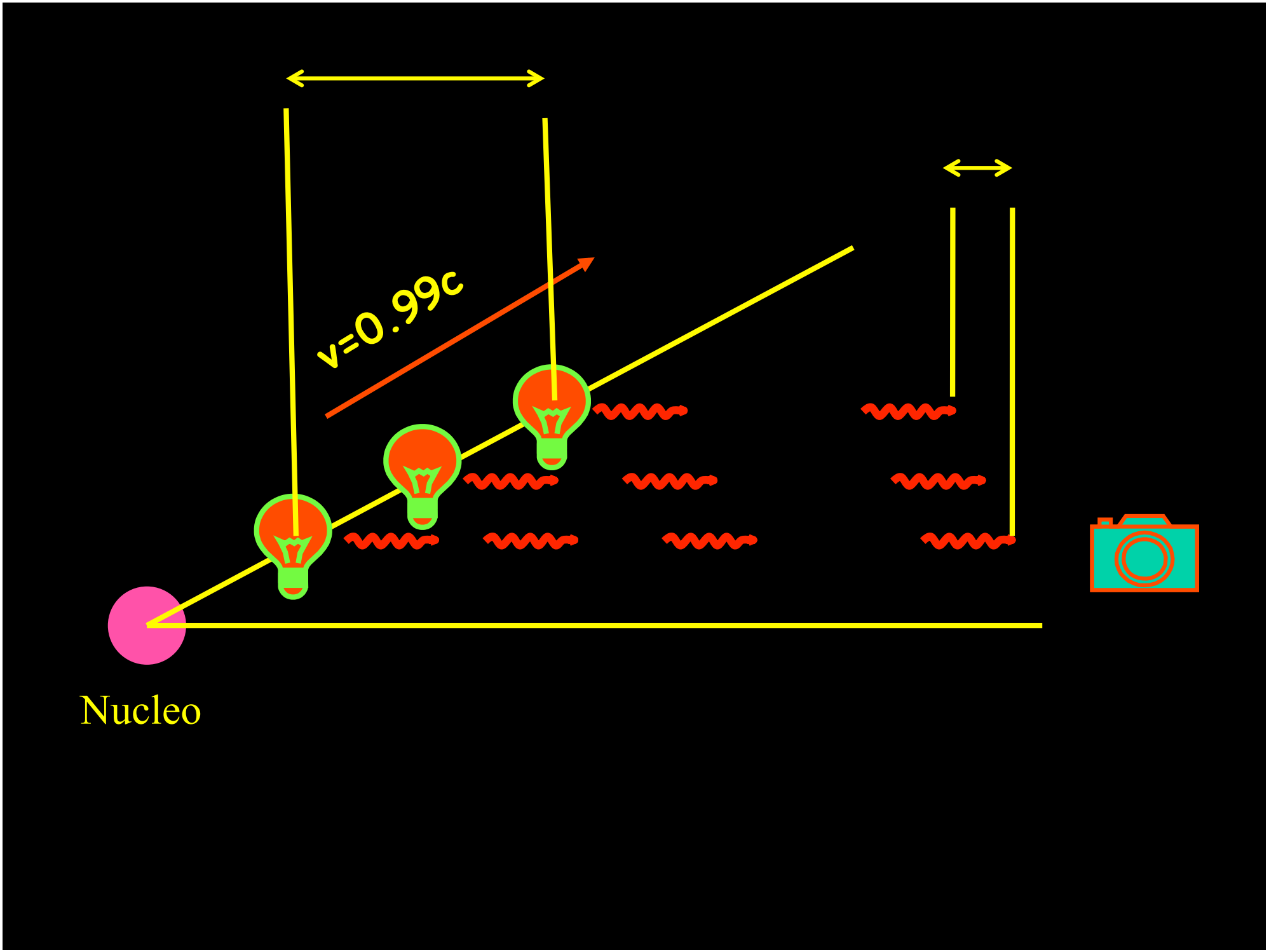


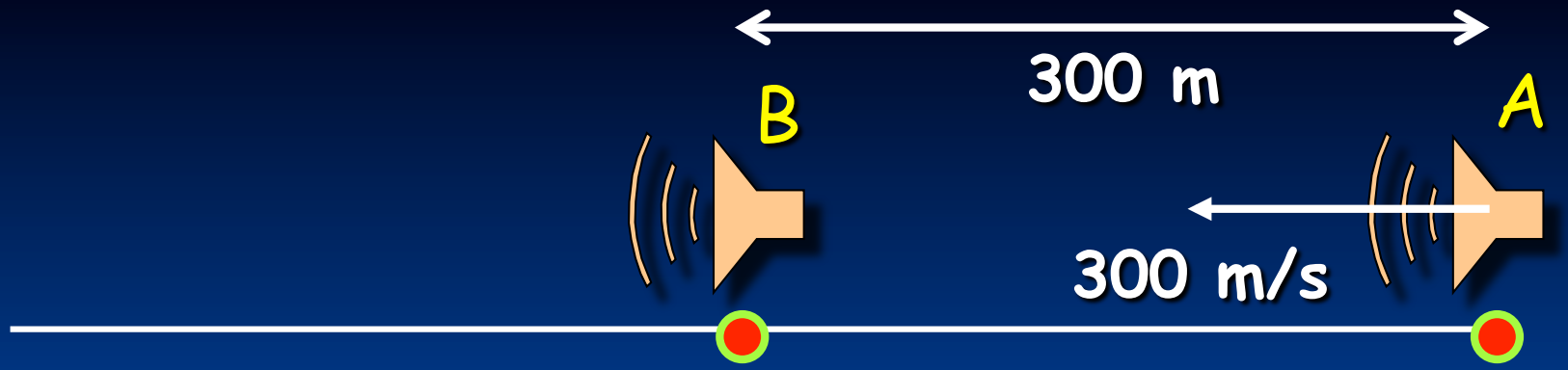
35 anni luce in 6 anni... la velocita' e' ~6 volte la velocita' della luce...



Lord Martin Rees

Da studente di dottorato, a 24 anni, predice il moto superluminale. Era il 1966, 5 anni prima della scoperta di questo fenomeno.


v=0.99c
Nucleo

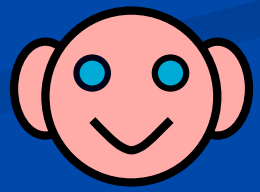


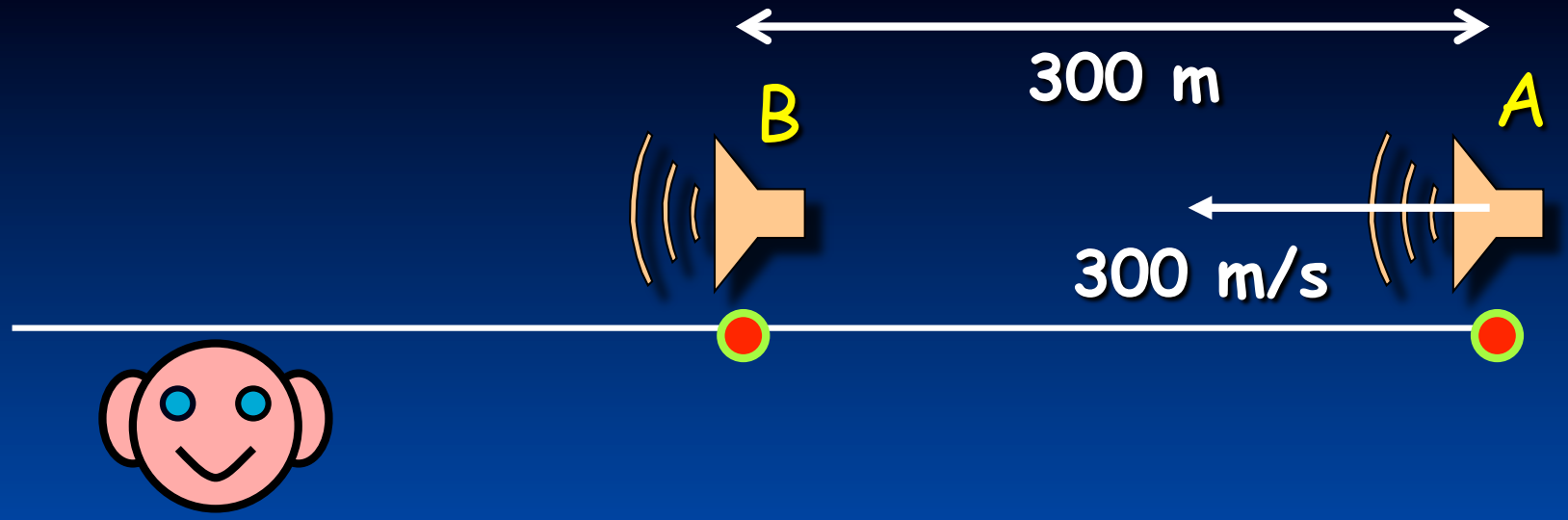
Velocita' del suono: 330 m/s

Velocita' del treno: 300 m/s

Dopo quanto tempo
sento il secondo suono?

~1 secondo!





Dopo quanto tempo sento il secondo suono?

0.1 secondi!

Penso: in 0.1 secondi il treno ha fatto 300 metri…. Quindi la sua velocita' e' 3 km/s !

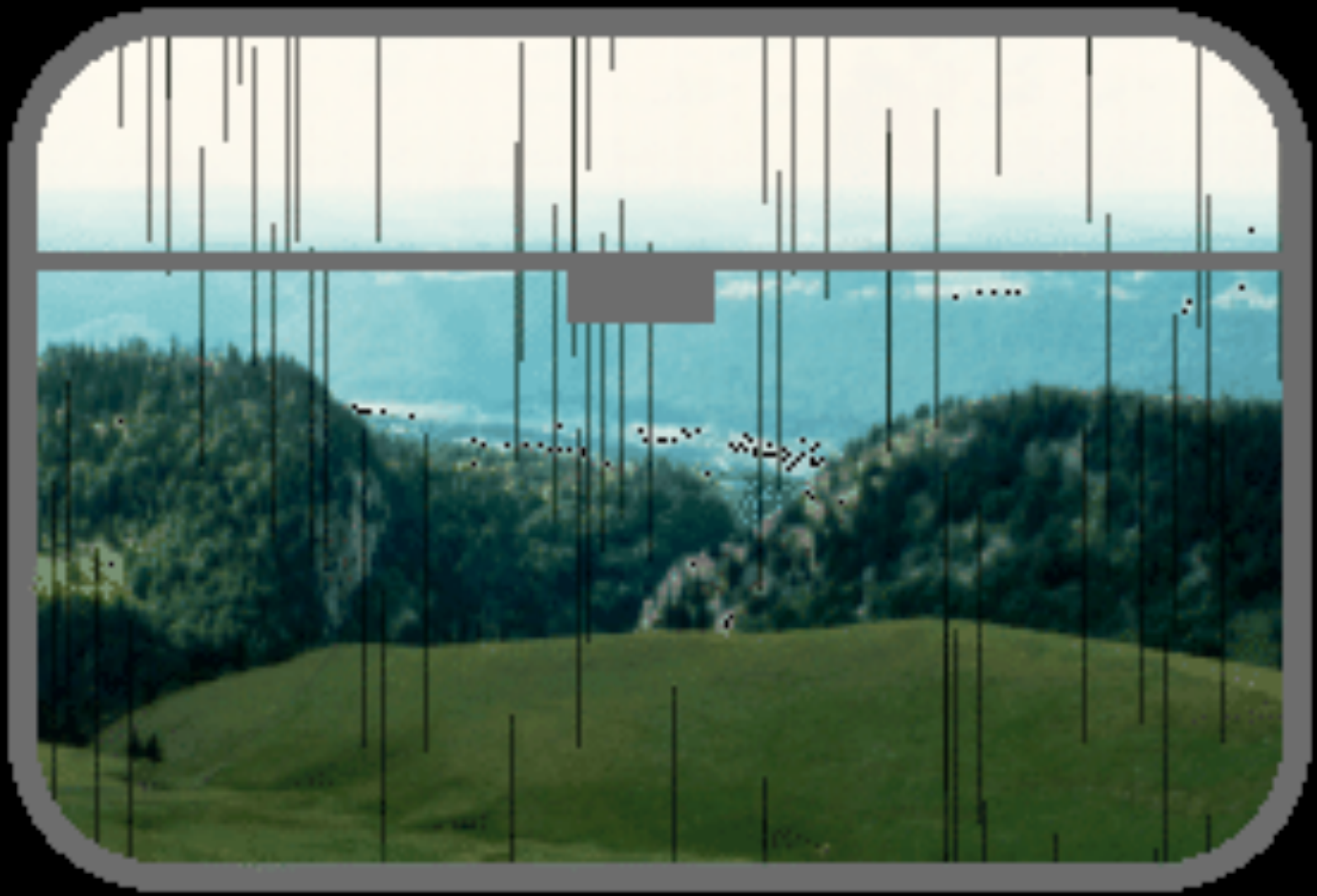
Nucleo

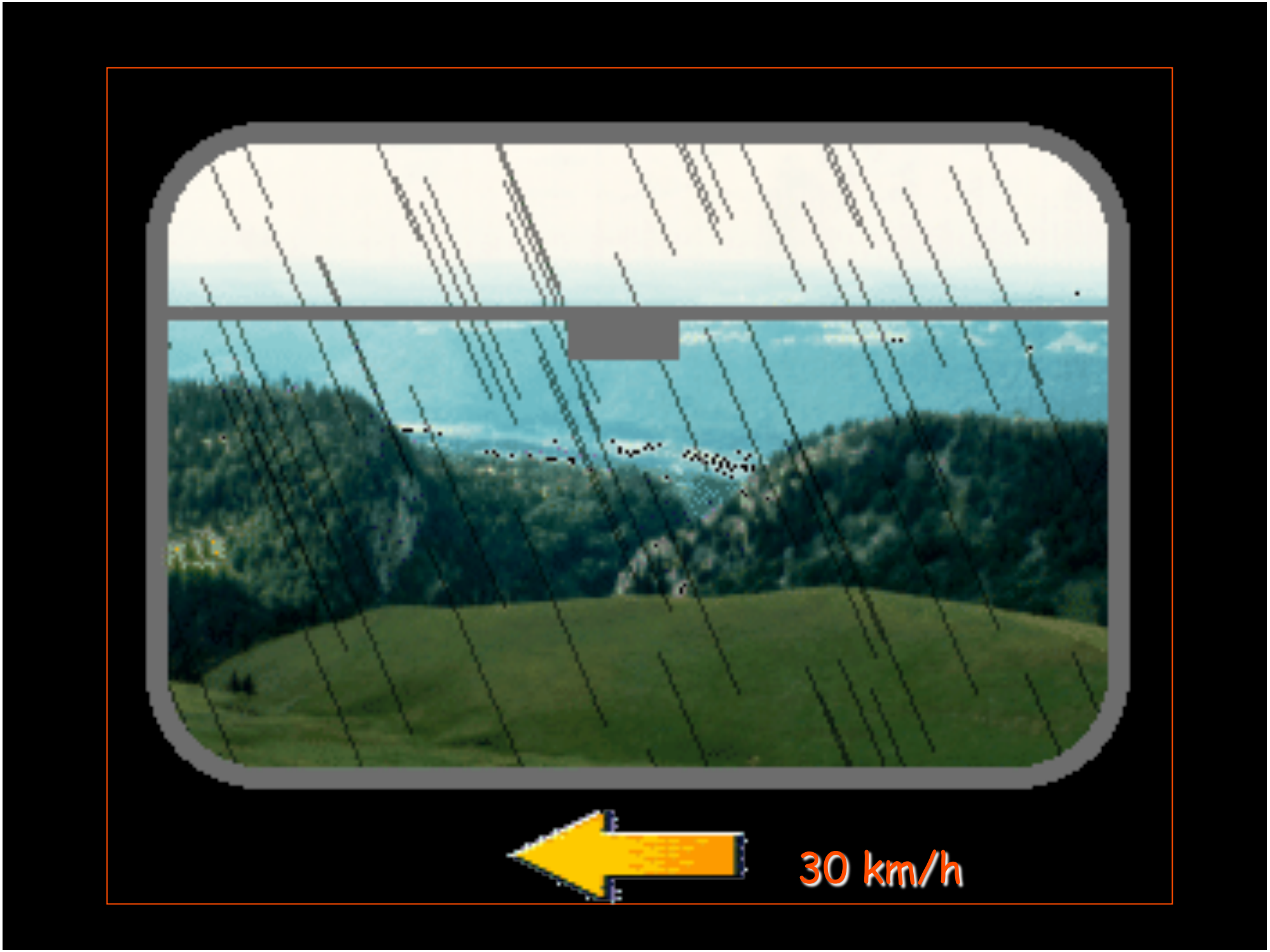
スクリーン（天球面）

Ricetta per sorgente superluminal

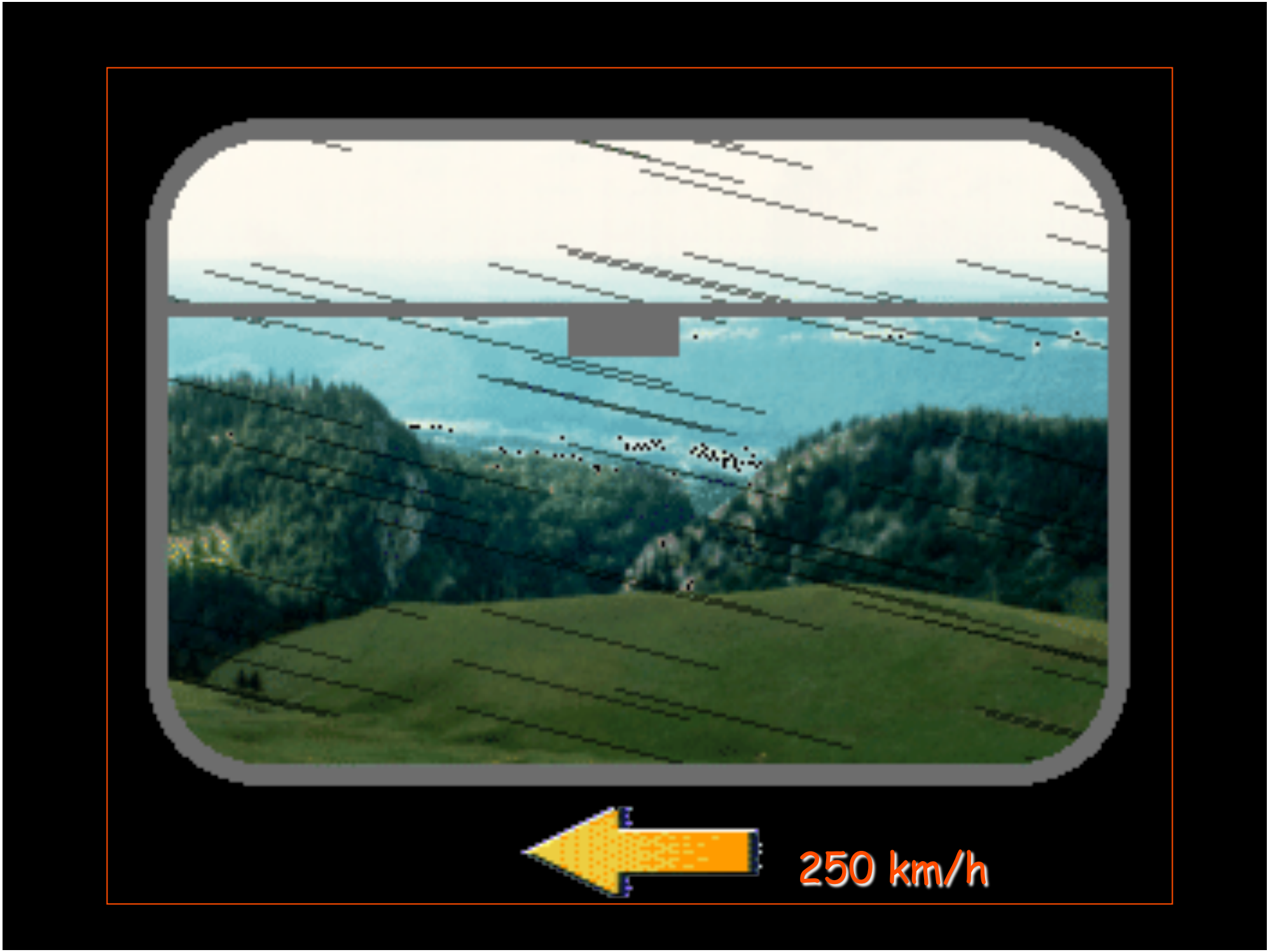
- Velocita' vicina alla velocita' della luce (ma non superiore!). Velocita' tipiche raggiungono il 99.5 per cento di c.
- Piccolo angolo di vista (ma non zero!)

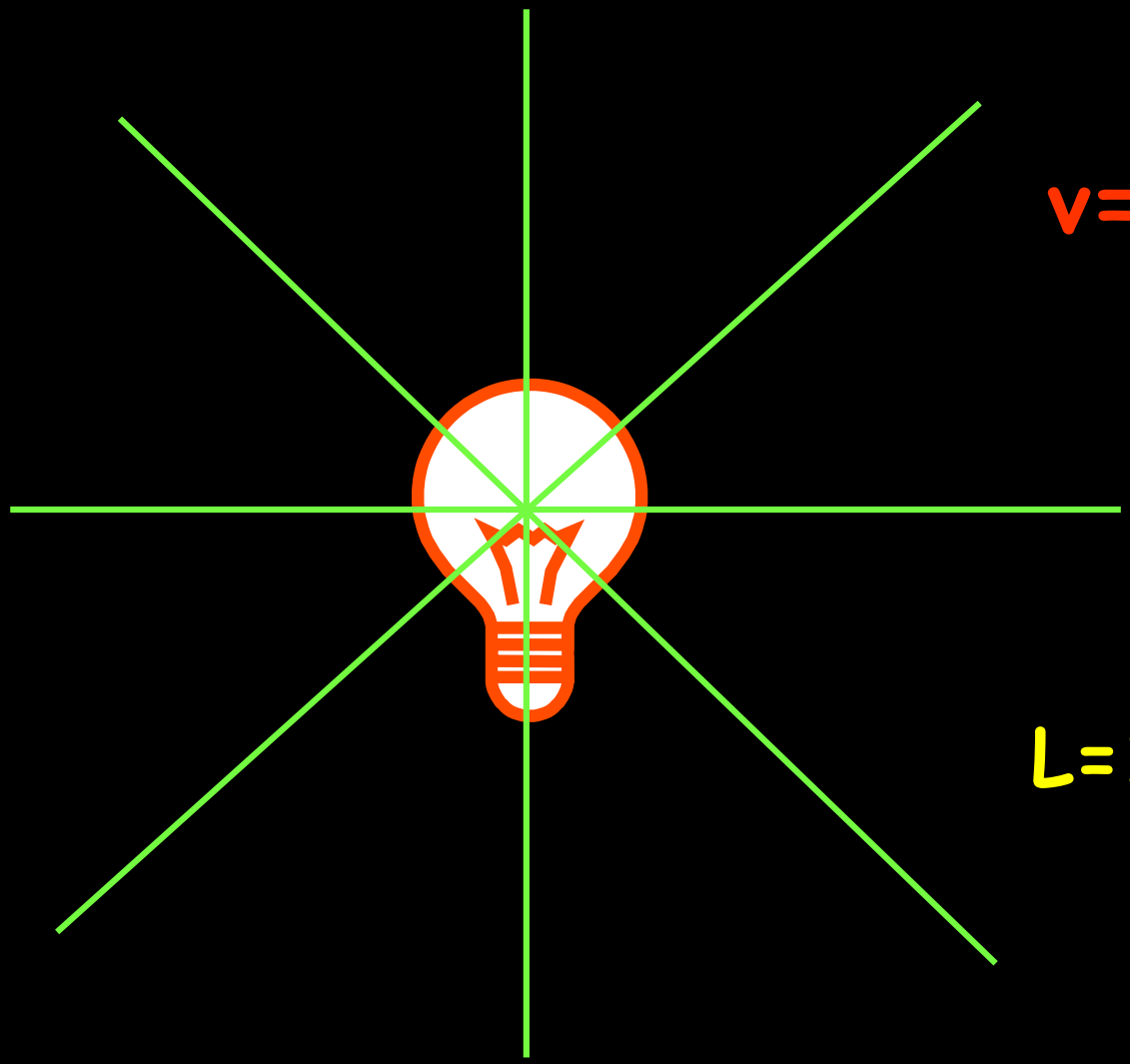
Effetti della relativita' speciale


0 km/h


30 km/h

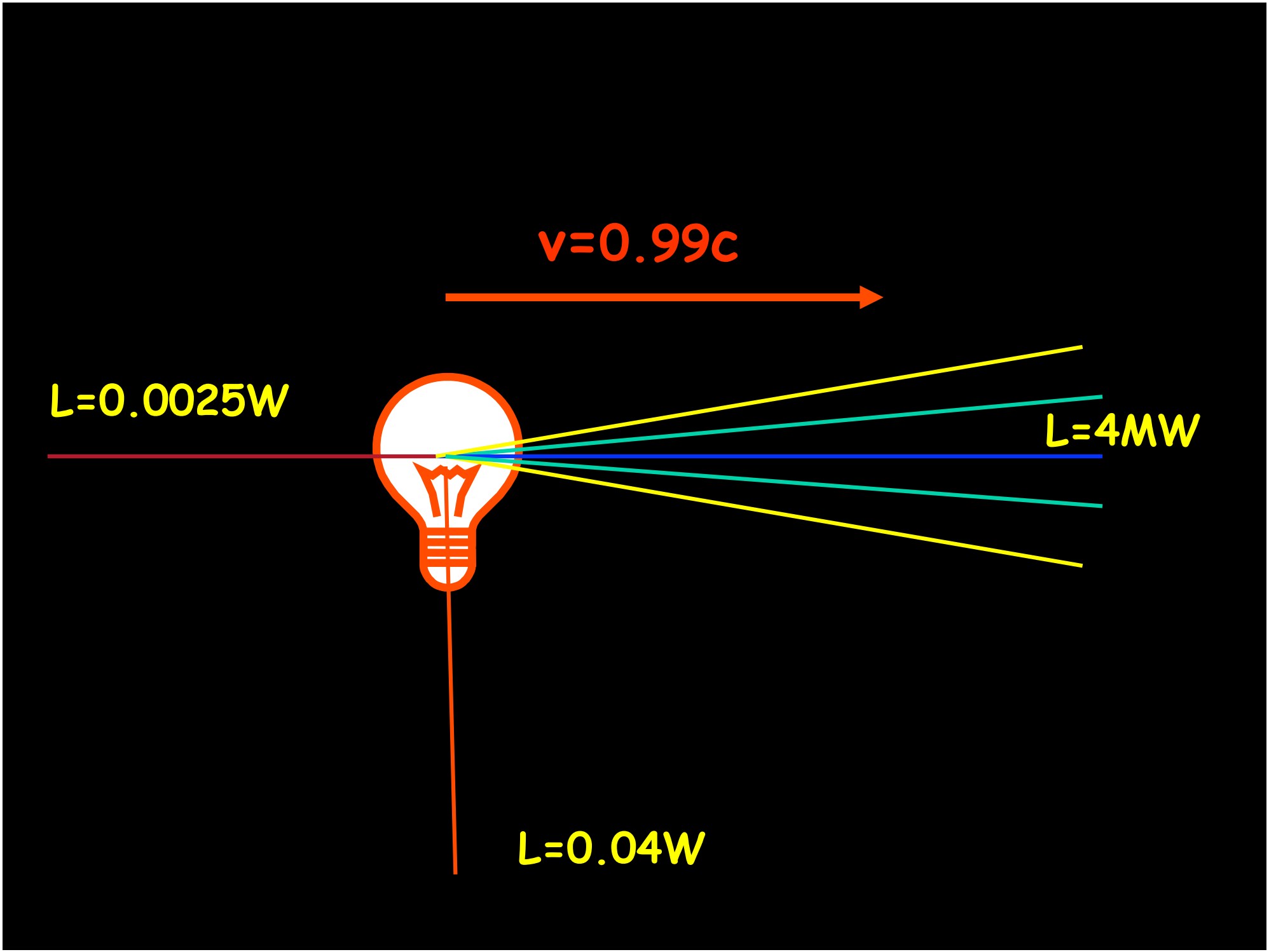
60 km/h

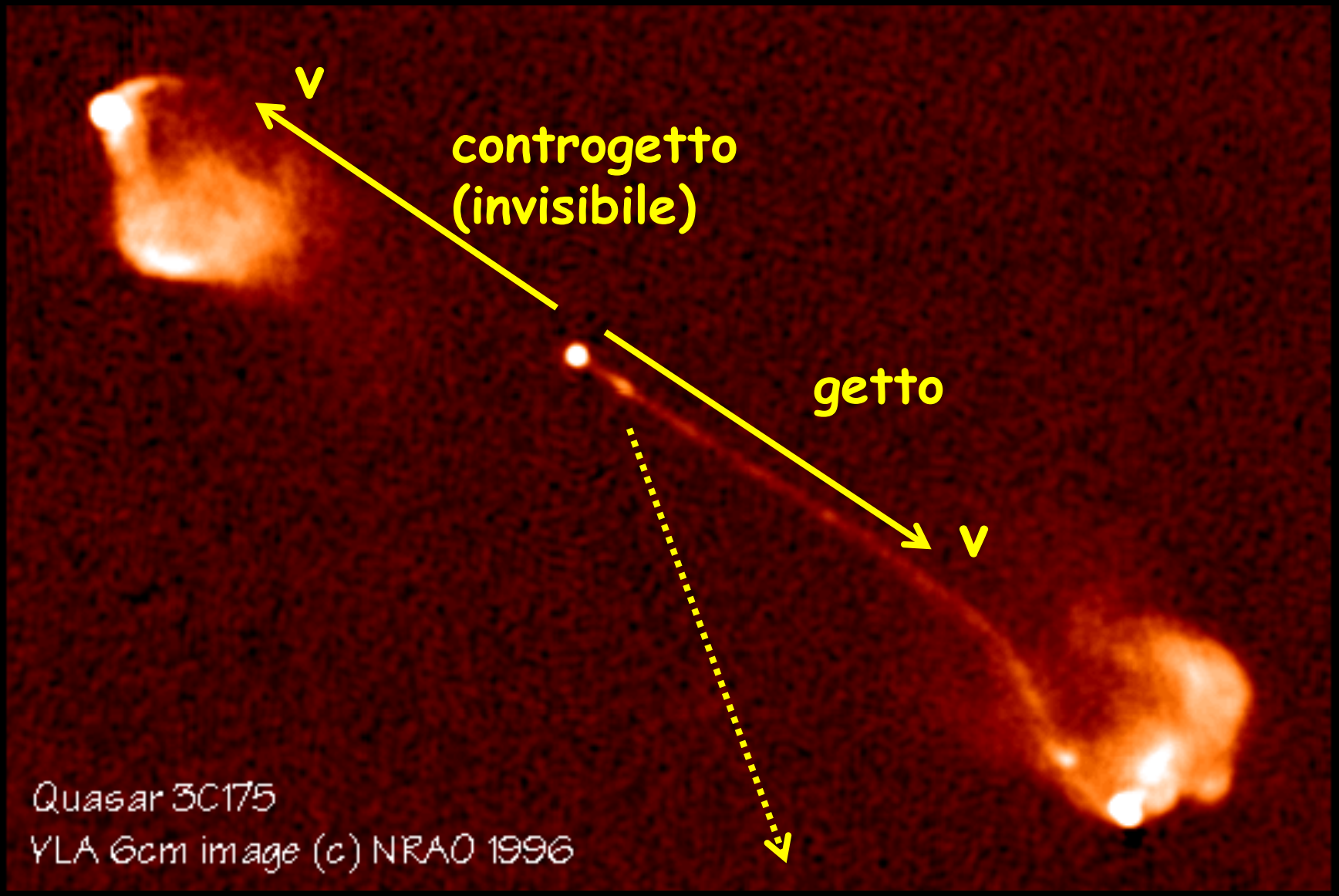

250 km/h

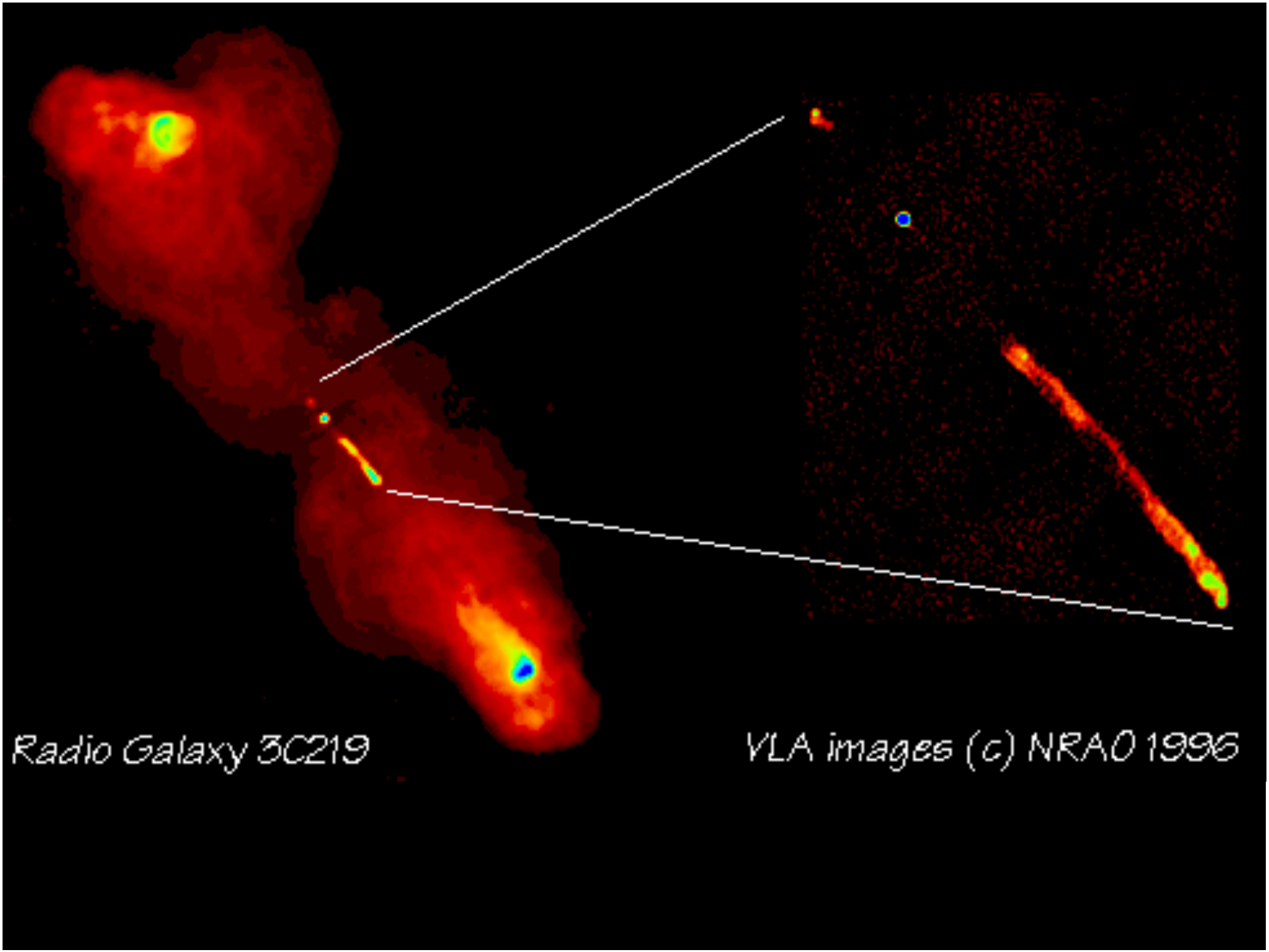


v=0

L=100 W

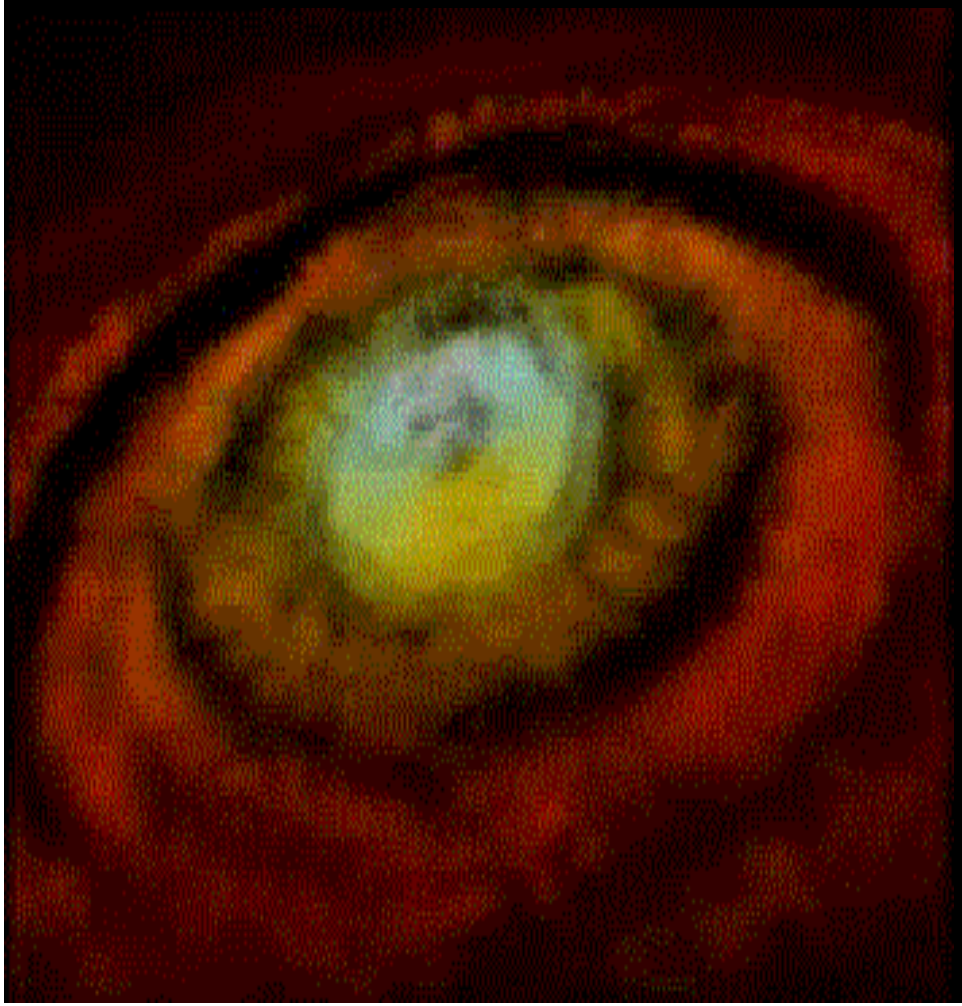

v=0.99c
L=0.0025W
L=4MW
L=0.04W

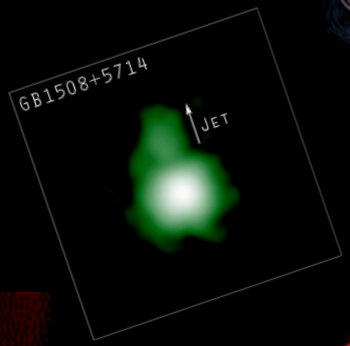

v
controgetto
(invisibile)
getto
v
Quasar 3C175
VLA 6cm image (c) NRAO 1996

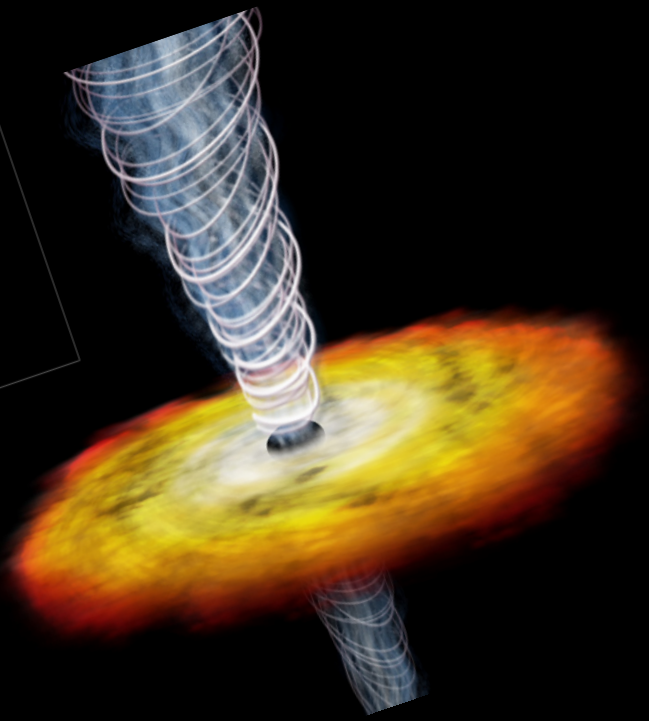

Radio Galaxy 3C219
VLA images (c) NRAO 1996

Quindi…

- C'e' della materia emittente, nei getti, che si muove quasi alla velocita' della luce.
- I getti riforniscono di energia i lobi, e li' l'energia si accumula, e i lobi diventano sempre piu' grandi.
- Queste strutture possono essere piu' grandi di 10 volte una galassia come la nostra.
- Riescono a mantenere la direzione per centinaia di milioni di anni.
- Sono dei motori formidabili, molto molto efficienti.
- Ma cosa e' il motore?

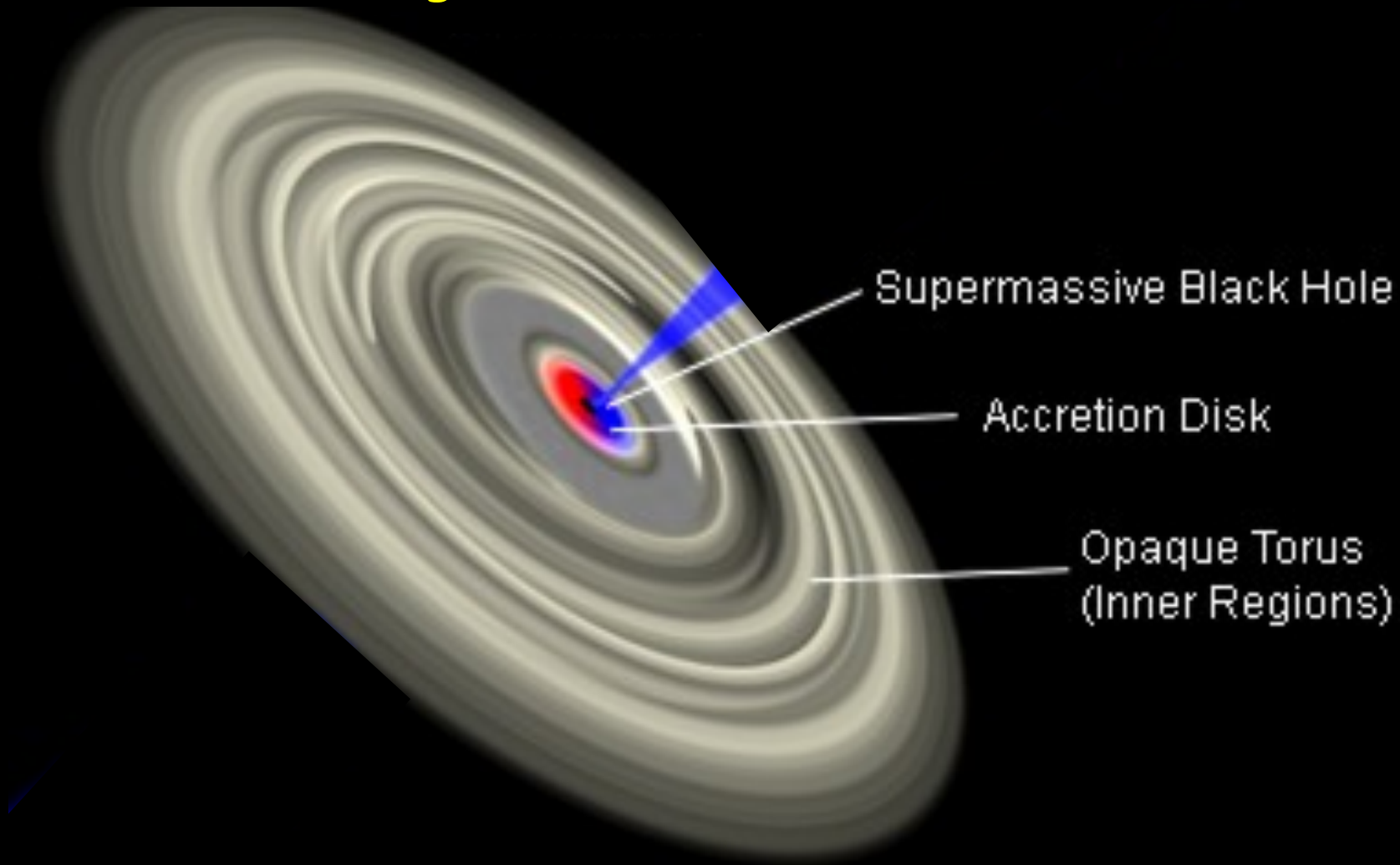






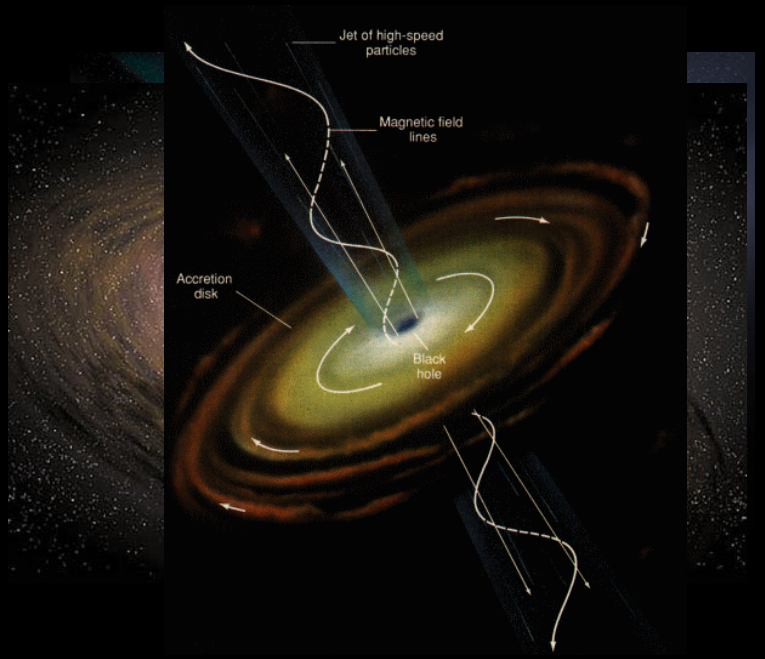
Buco nero di almeno 100 milioni di masse solari, che accresce materia. Cadendo, la materia libera energia gravitazionale

Quasi tutte le galassie, nel loro centro, ospitano un buco nero massiccio (piu` di un milione di masse solari). Circa l'1 per cento accresce materia, e si rende visibile.
L'1 per mille forma i getti.



Motore? Buco nero, ma come?

- Tante idee, poche certezze
- Da dove viene l'enegia necessaria? Dalla rotazione del buco nero o dalla materia che cade nel buco nero?
- Perche' il grosso della materia cade e circa l'1% viene espulsa?



Conclusioni

- Guardare il mondo "con altri occhi" ci ha fatto scoprire un universo diverso dal solito
- Materia che si muove a c, buchi neri da miliardi di masse solari, motori formidabili