Course of
General Astronomy

Gulu University

Naples FEDERICO II University

2

Light of Stars
or
Physics of Thermal Radiation

Light ?

….. Massless particles called **PHOTONS**

(Their speed is **c=299 792 458** m/s, in the vacuum)

They act as :

- **Particles** **(interacting with matter)**
- **Waves** **(propagating)**

Dualism Wave-Matter :

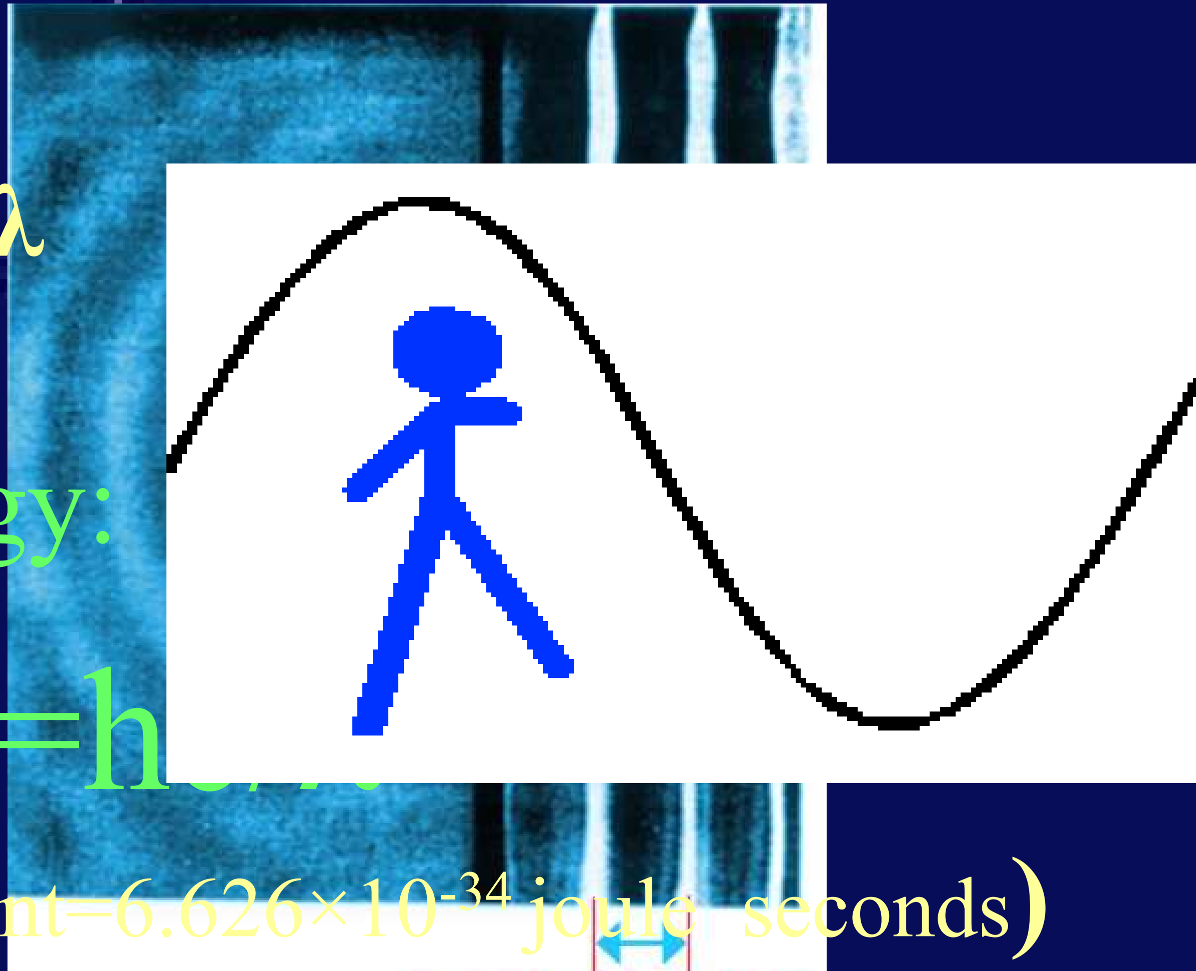
Waves ?

- Wavelength λ
- Frequency $\nu = c/\lambda$

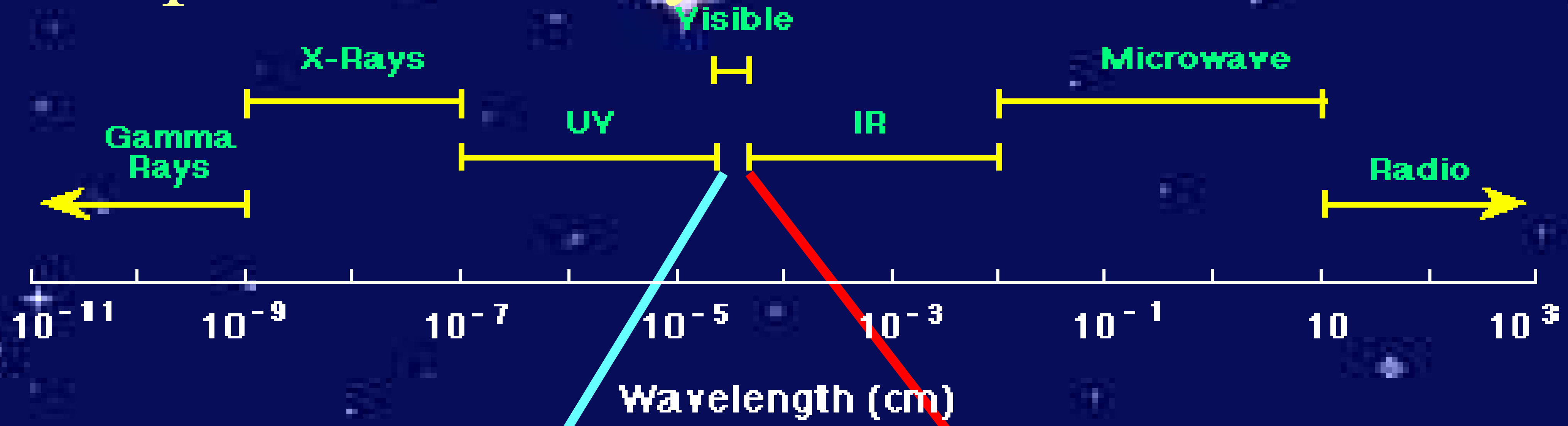
Photon energy:

$$h\nu = hc/\lambda$$

(h=Planck's constant=6.626×10^{-34} joule seconds)

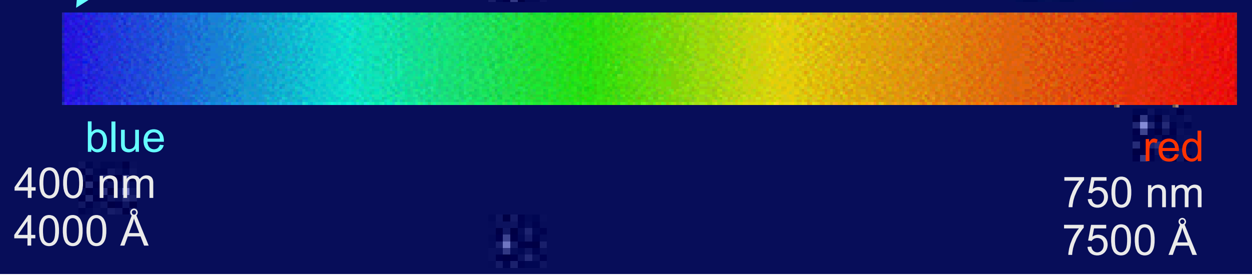


The photons family:



- Ultraviolet
- X Rays
- Gamma Rays

- Radio waves
- Microwave
- Infrared
- Visible



Black Body light:

- Wavelength of the emission maximum

$$\lambda = \frac{2.8979 \times 10^{-3}}{T}$$

λ in meters

T in Kelvin

- overall emitted Flux

$$F = \sigma T^4$$

F in Watt and

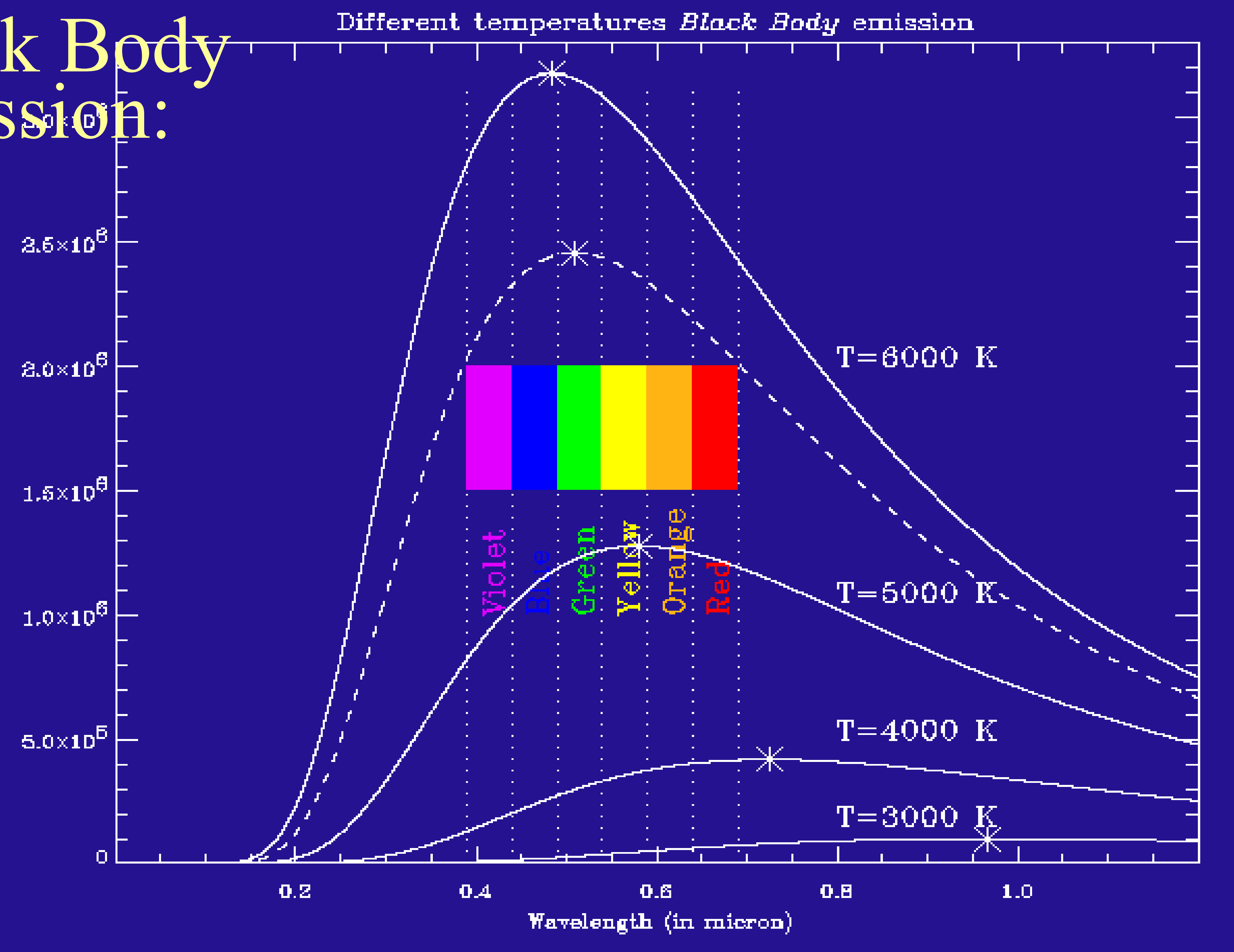
$\sigma = 5.67 \times 10^{-8}$ W K^{-4} m^{-2}

- Flux at different λ (Planck's law)

$$F(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{\Delta}{e^{\frac{hc}{\lambda kT}} - 1}$$

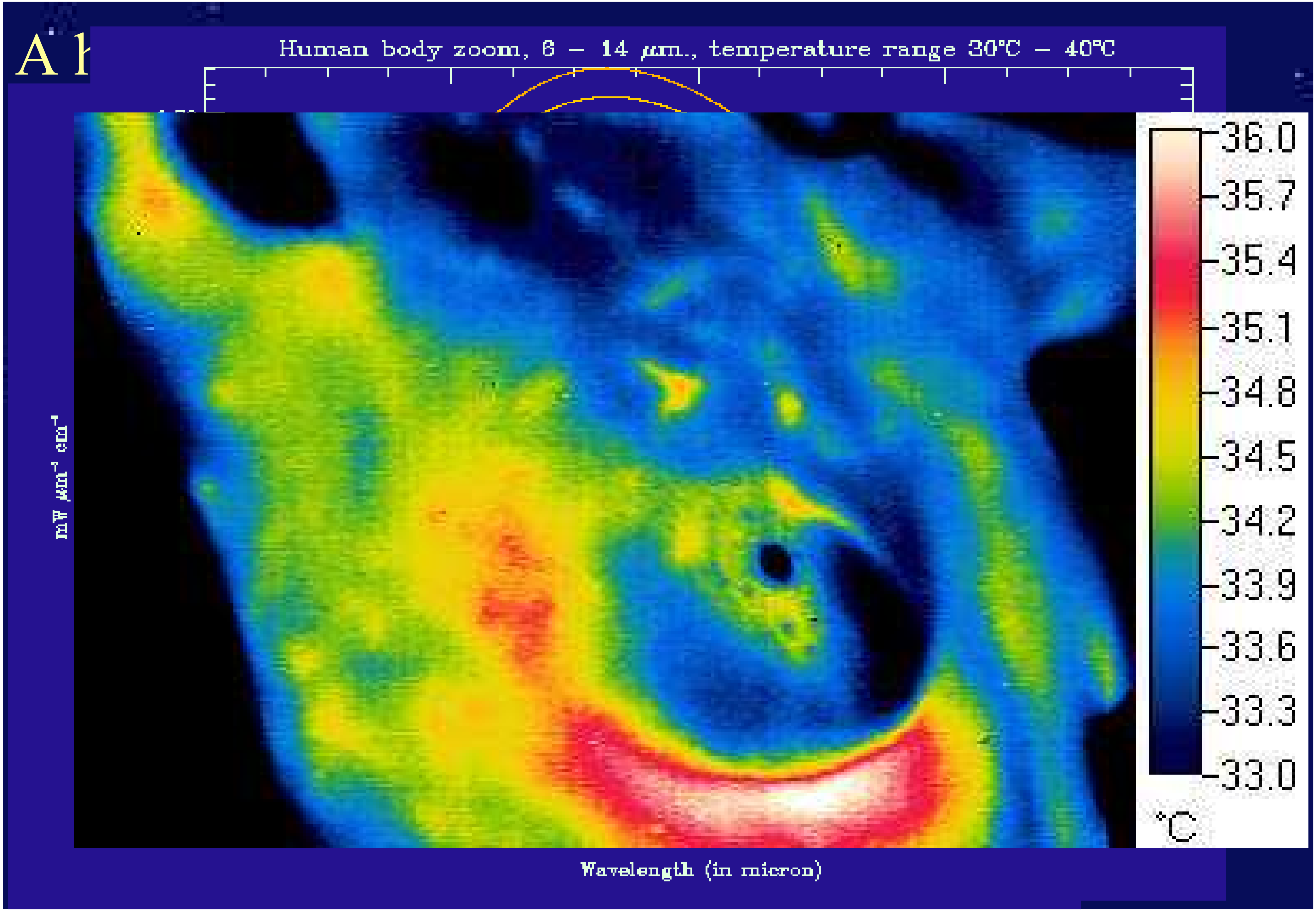
$k = 1.3806 \times 10^{-23}$ j/K

Black Body Emission:



A human …. case: (35 °C = 308.16 Kelvin)

λ_{max}=2.8979×10^{-3}/T = 2.8979×10^{-3}/308.16≈9.41×10^{-6} m =9.41 μm


A h
Human body zoom, 6 – 14 µm., temperature range 30°C – 40°C
mW µm⁻¹ cm⁻²
Wavelength (in micron)
36.0
35.7
35.4
35.1
34.8
34.5
34.2
33.9
33.6
33.3
33.0
°C

A human …. case: (35 ^oC = 308.16 Kelvin)

λ_{max}=2.8979×10^{-3}/T = 2.8979×10^{-3}/308.16≈9.41×10^{-6} m =9.41 μm

F = σT^4 = 5.67×10^{-8} ×308.16^4 ≈ 511 W m^{-2}

(cylinder, height of 1.75 *m*, diameter 0.45 *m*)

L = F×S =511 × 2.45 = 1252 W = 0.3 Cal /sec = 1080 Cal/hour

= 26000 Cal/day

Don't fool yourself : this isn't the way to lose weight !

We are immersed in an environment at T_a

$L_{net} = \sigma(T^4 - T_a^{\,4})\times S$ =216 W=4300 Cal/day

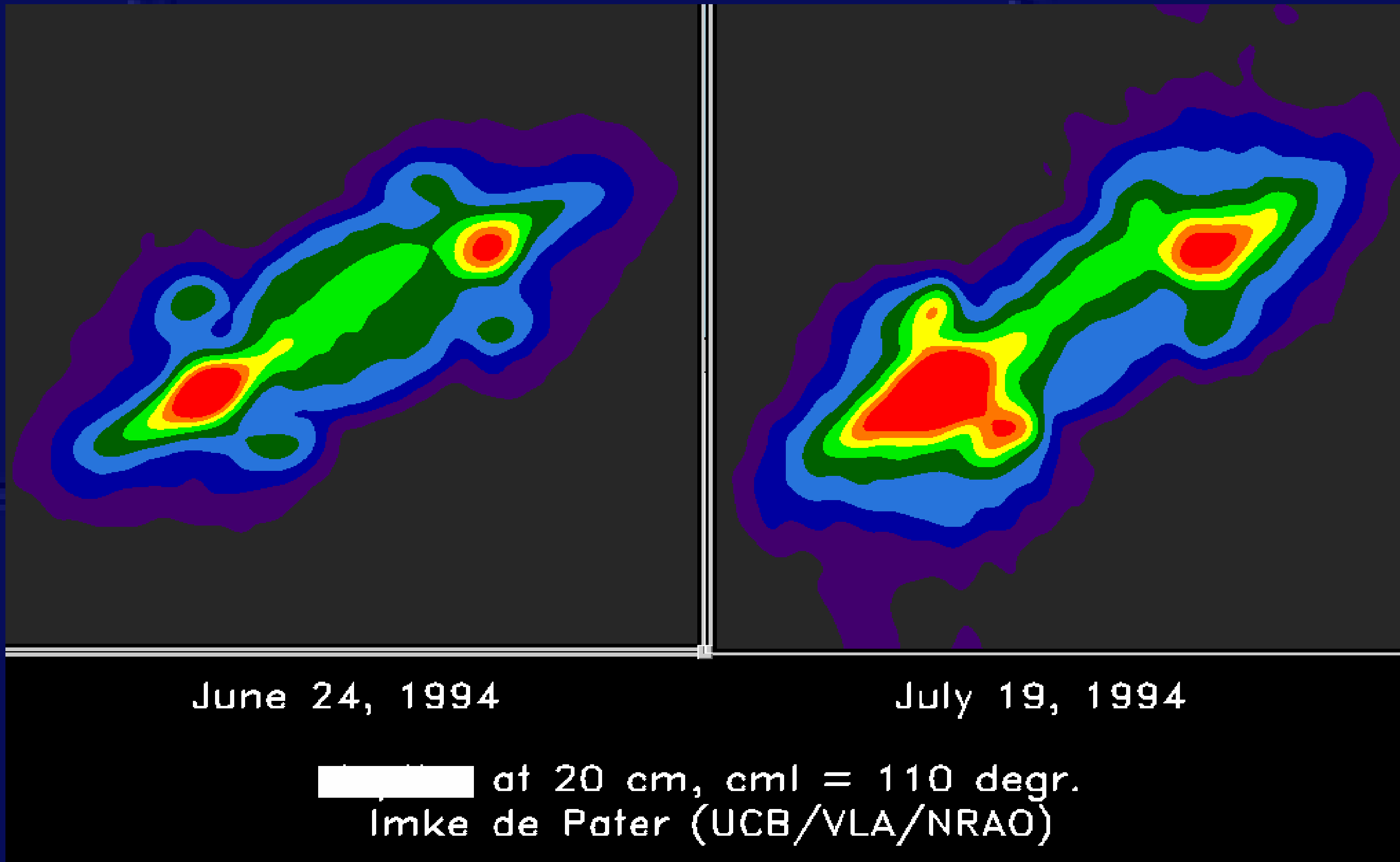
(if we account for hairs and clothes, ≈ 2000)

And now ….. go for Stars !

sorry.. but I was thinking about a different kind of stars !!!

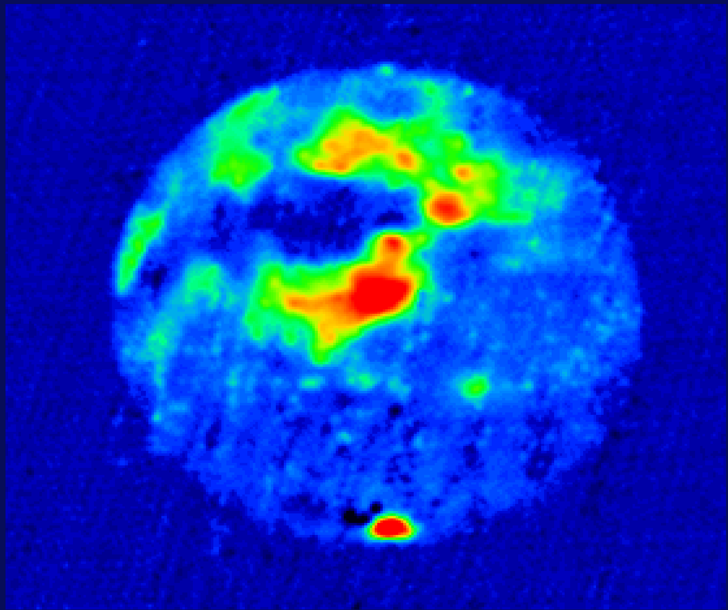
Radio waves:

(is it some sort of …. saurian ?!?)



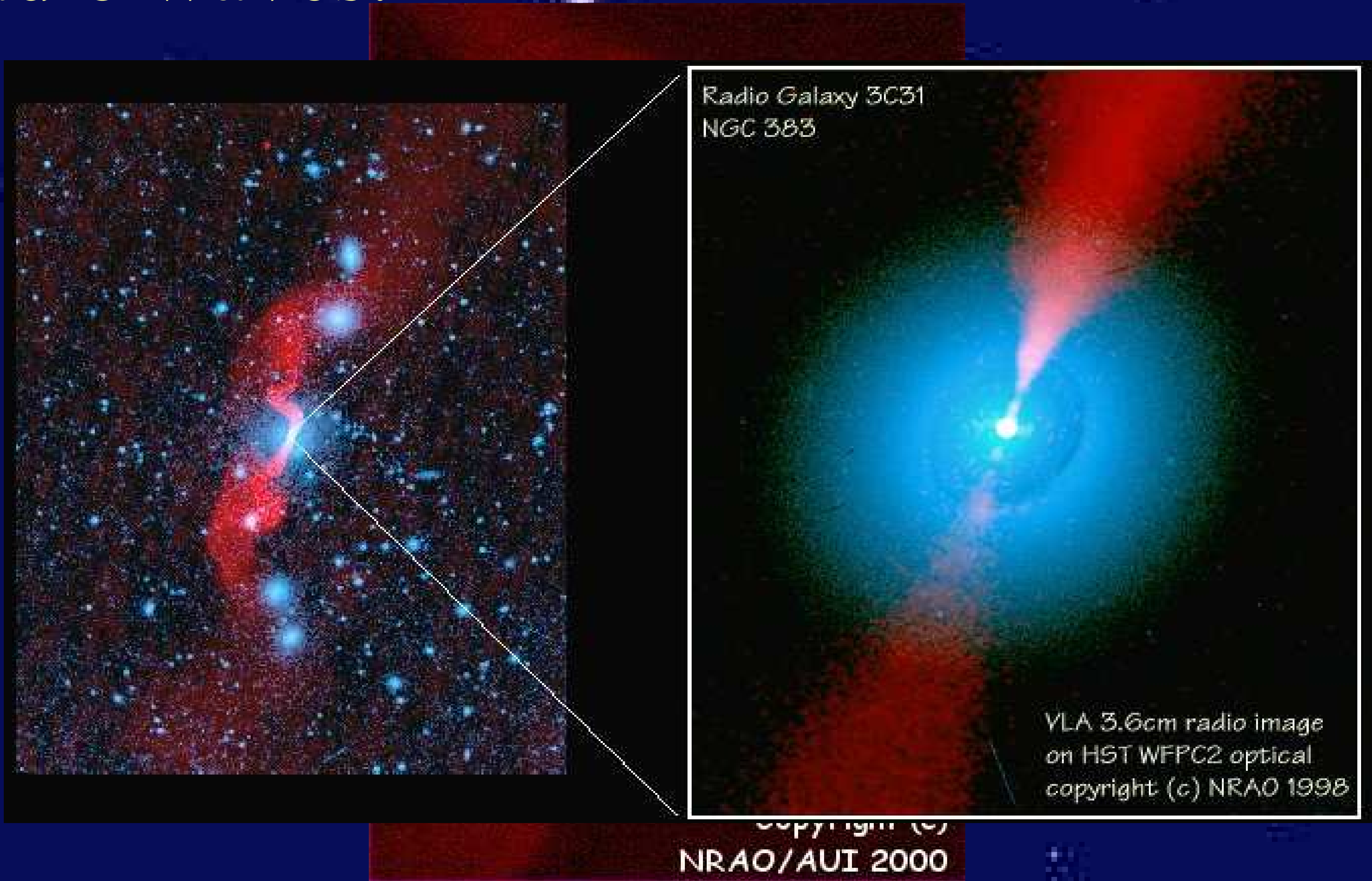
Radio waves:

Do you know this planet ?



Radio waves: The telescope for the radio light (radiotelescope)

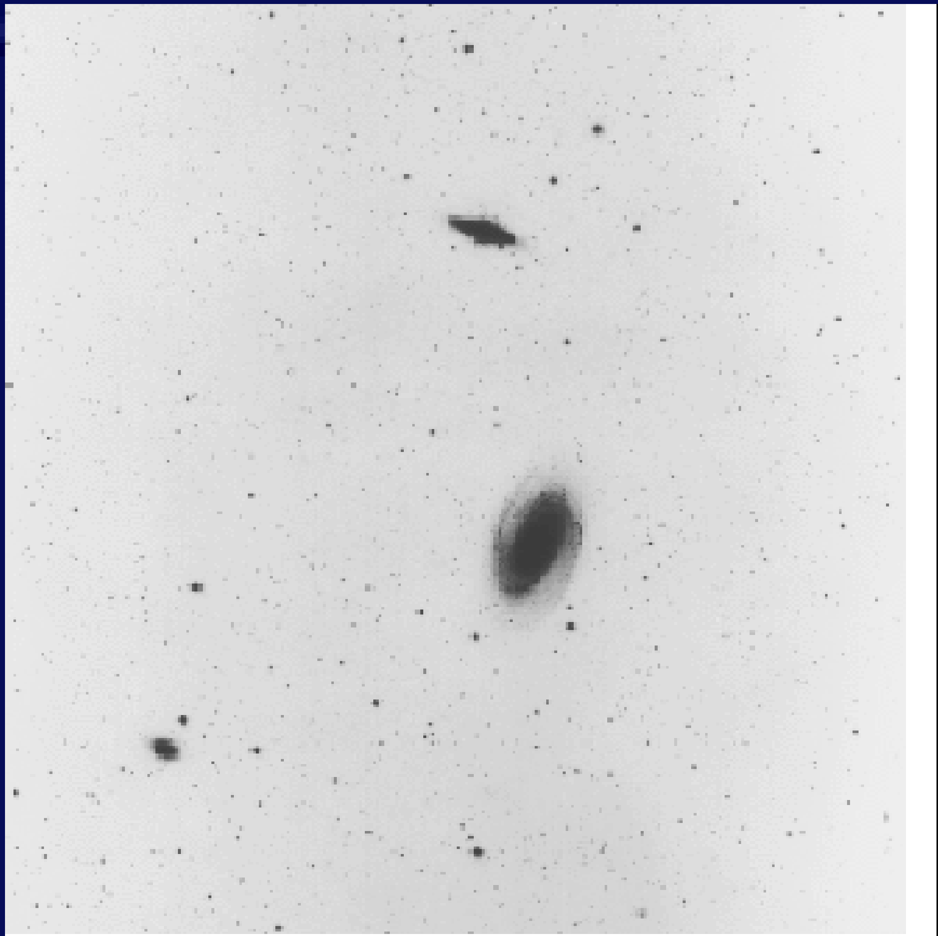
Radio waves: *radio galaxy* … and the visible image!



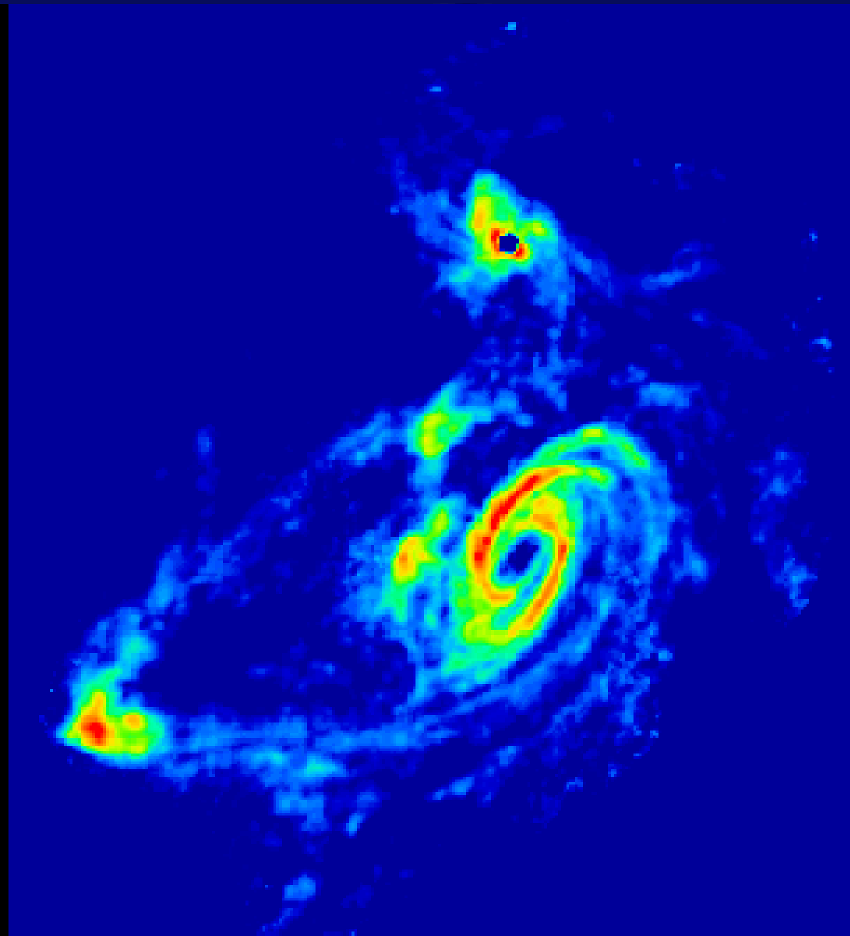
Radio waves:

Tidal interactions in M81 group

Stellar light distribution

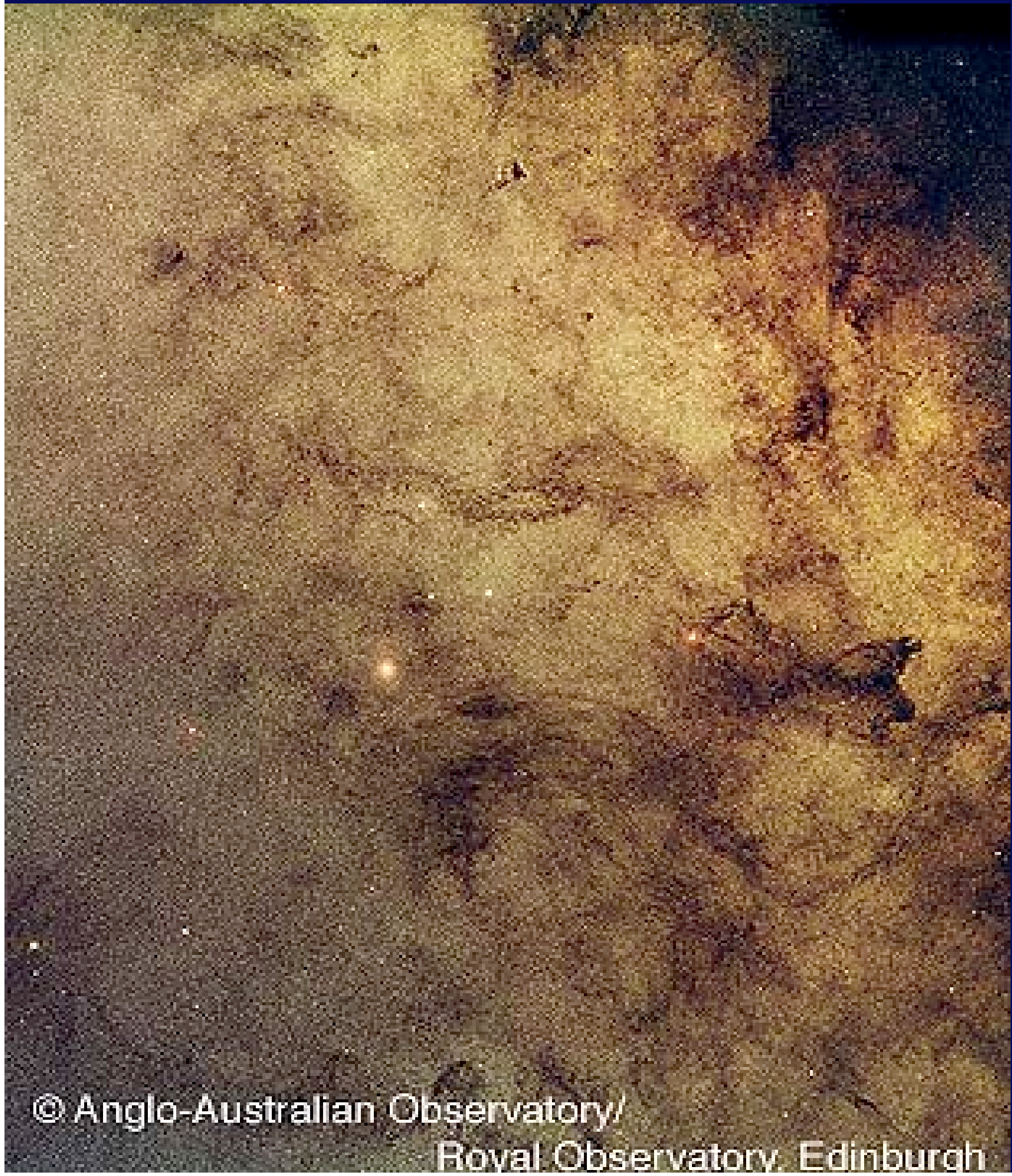


Hydrogen distribution (21 cm emission)



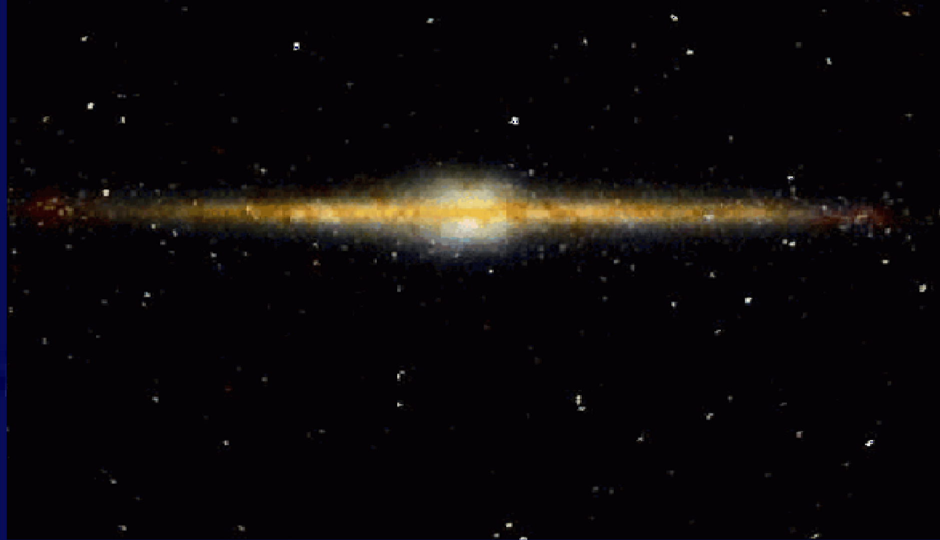
Radio waves: The Milky Way Center

in visible light … and radio

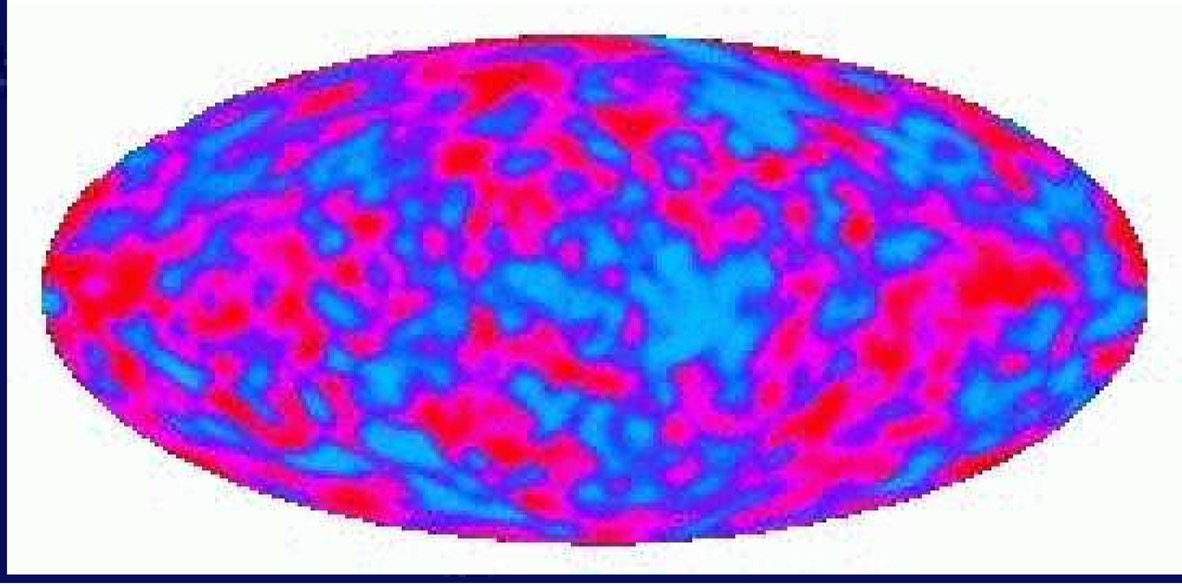


Microwaves:

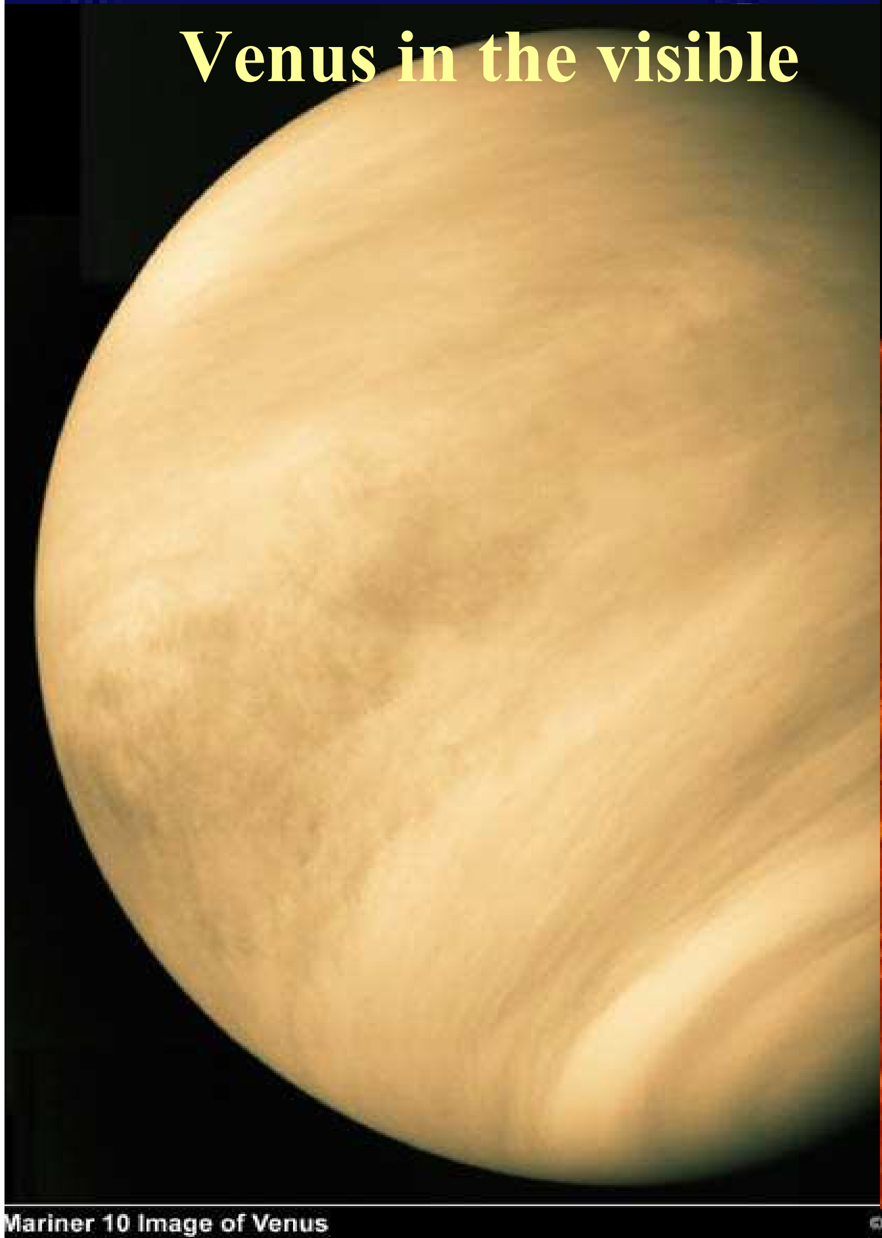
The Milky Way (our galaxy)

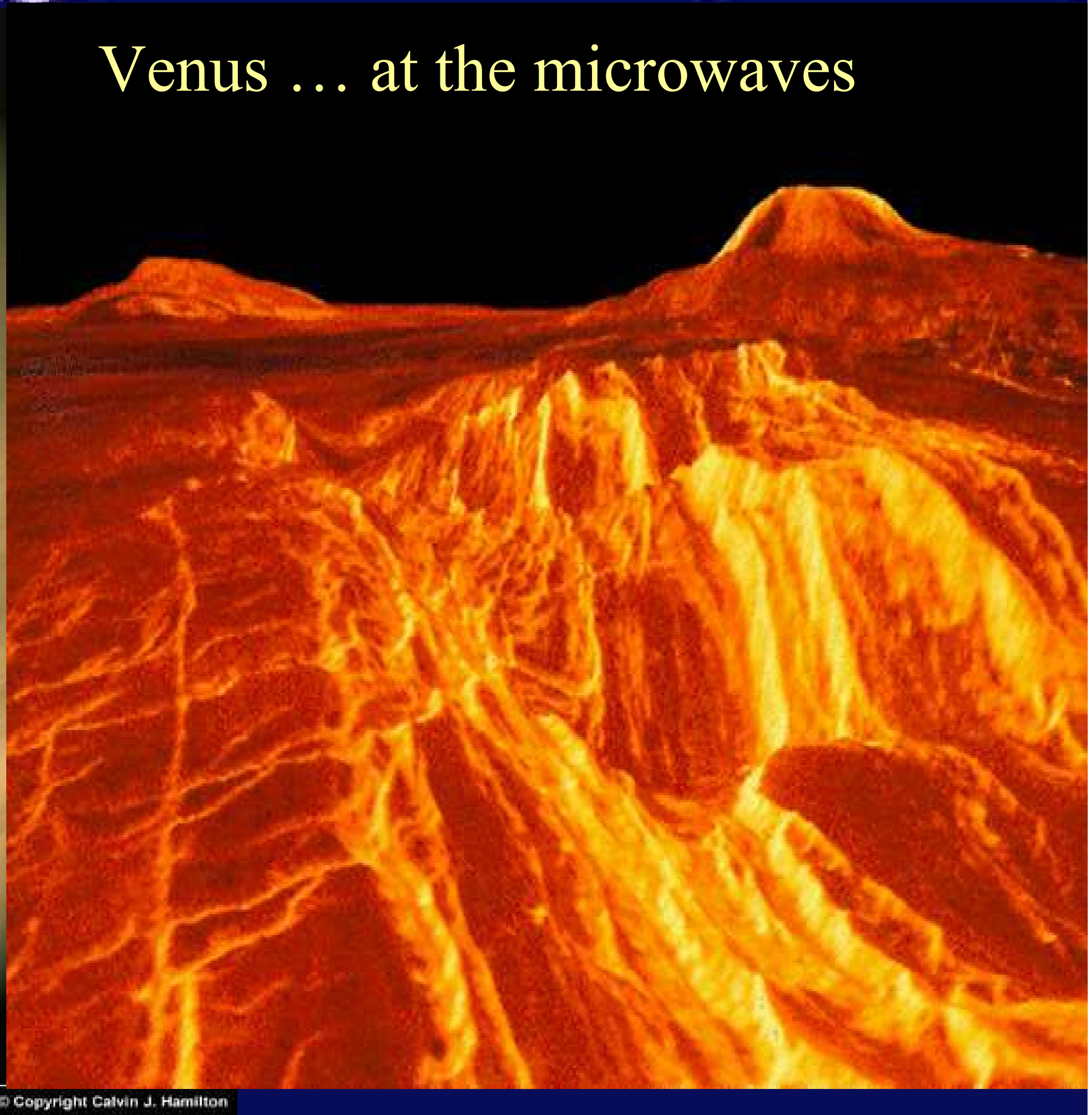


Cosmic Background Radiation Anisotropy



Microwaves:


Venus in the visible
Mariner 10 Image of Venus


Venus … at the microwaves
© Copyright Calvin J. Hamilton

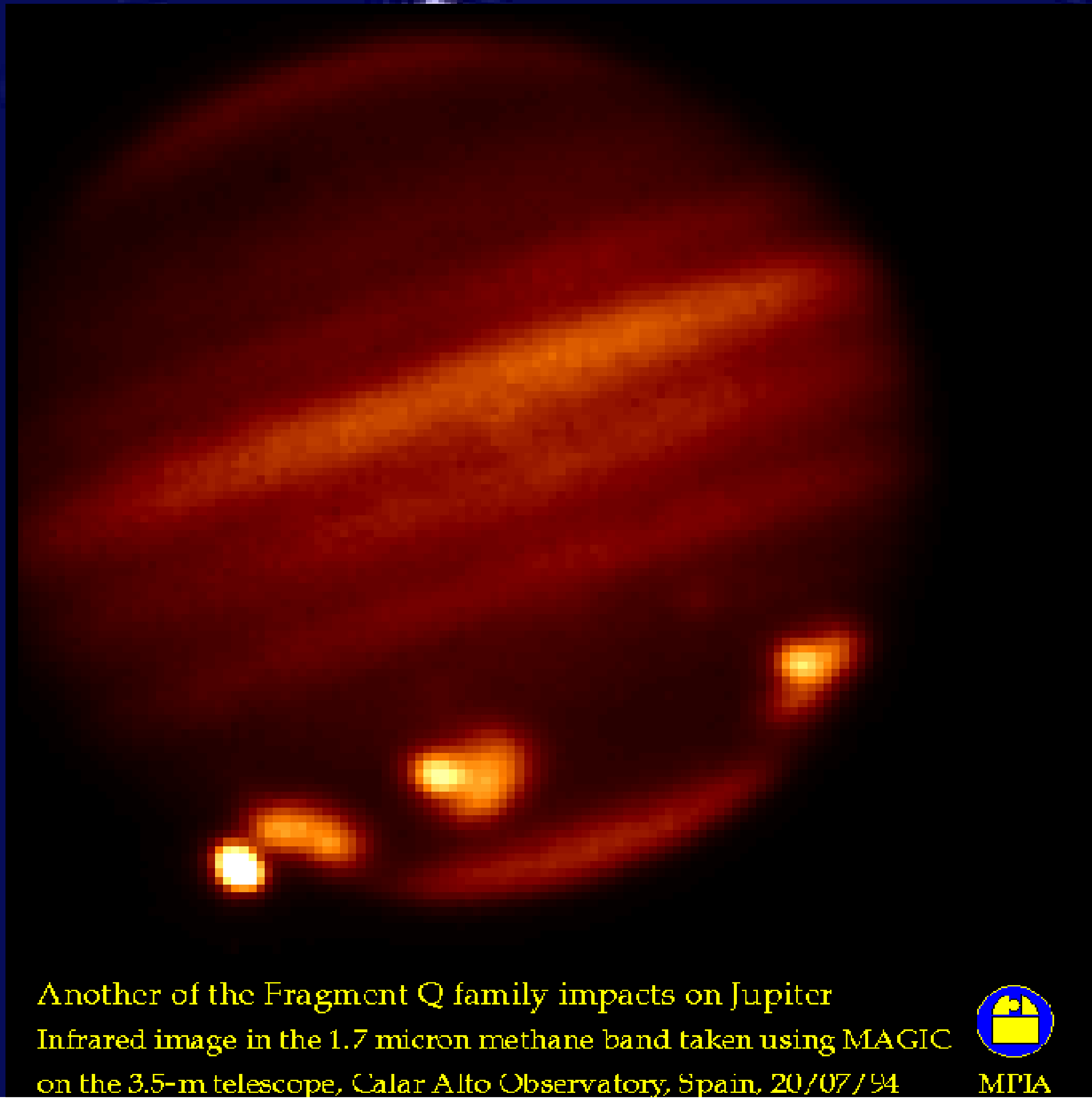
Infrared:

SL9 impacts on Jupiter

in the visible (Galileo probe)

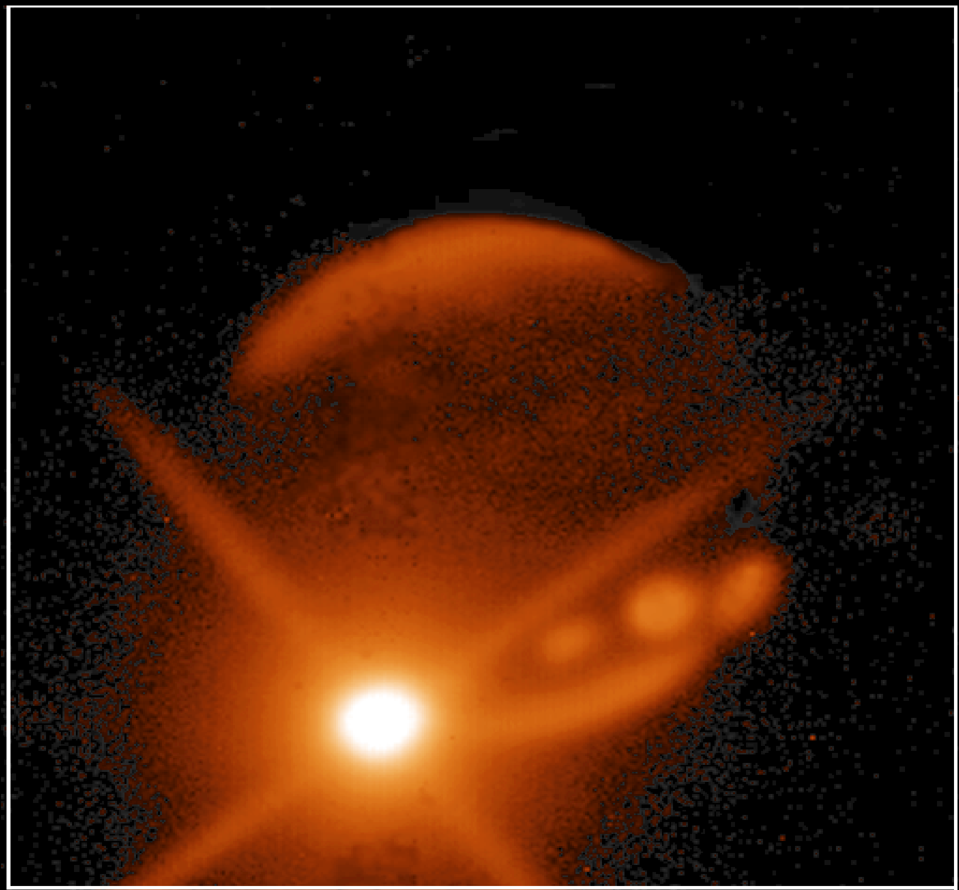
Infrared:

SL9 impacts on Jupiter



Infrared:

SL9 impacts on Jupiter

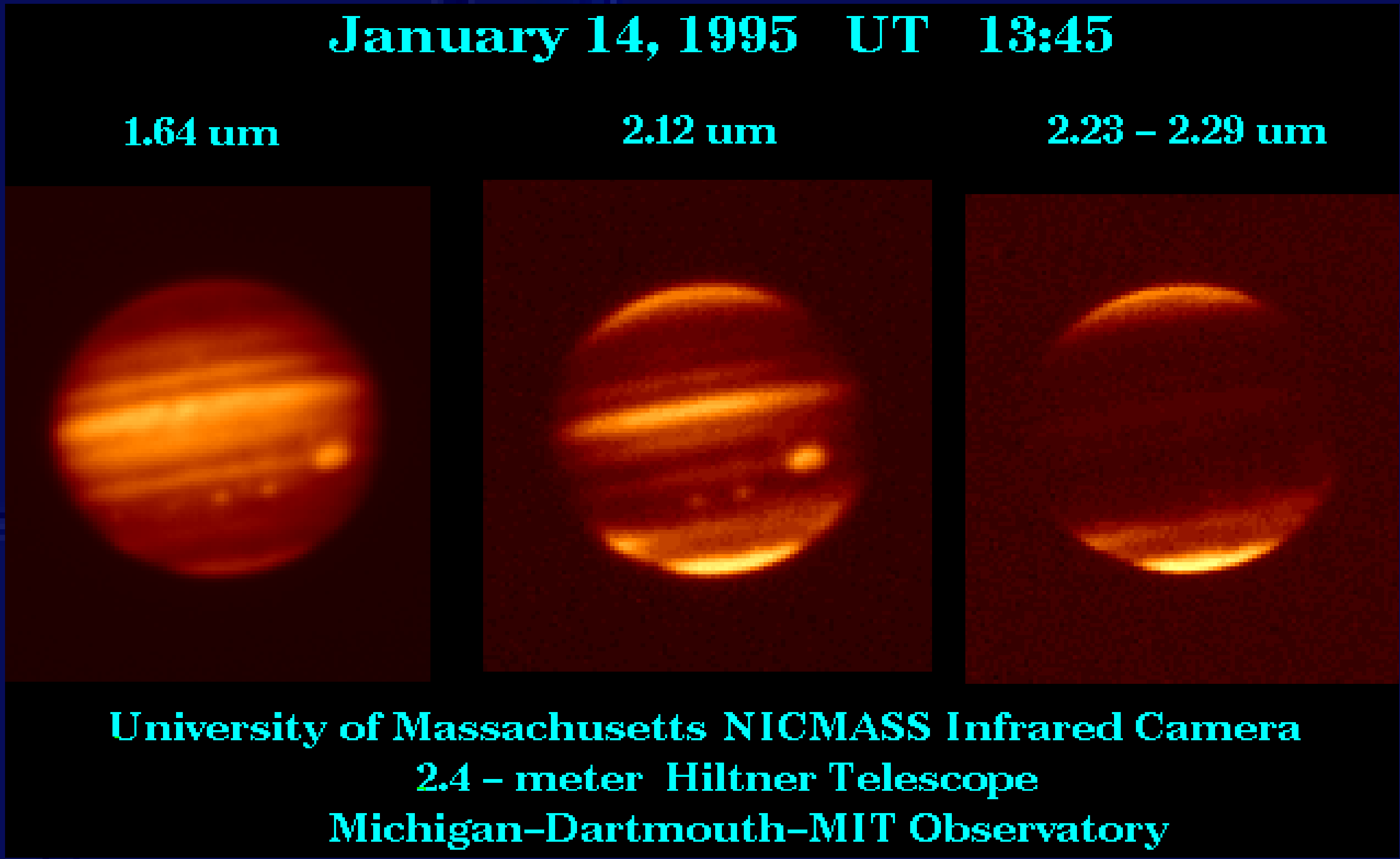


Impact of Fragment K of Comet Shoemaker-Levy on Jupiter.
The scars of three previous impacts can be seen on the planetary disk.

Image from Peter McGregor and Mark Allen, ANU 2.3m telescope.
Instrument: CASPIR at 2.34μm. Colour image Mt Stromlo Observatories.

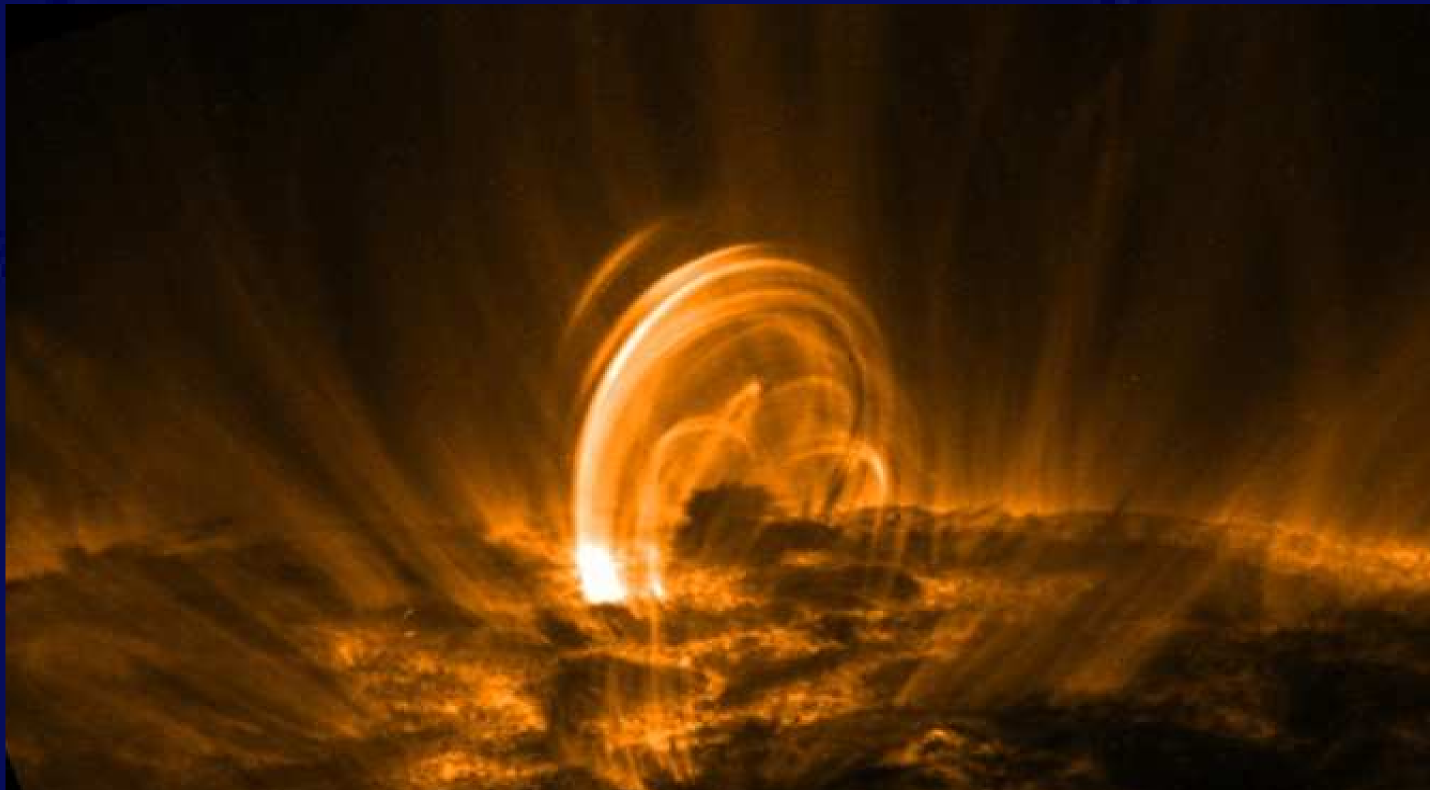
Infrared:

SL9 impacts on Jupiter

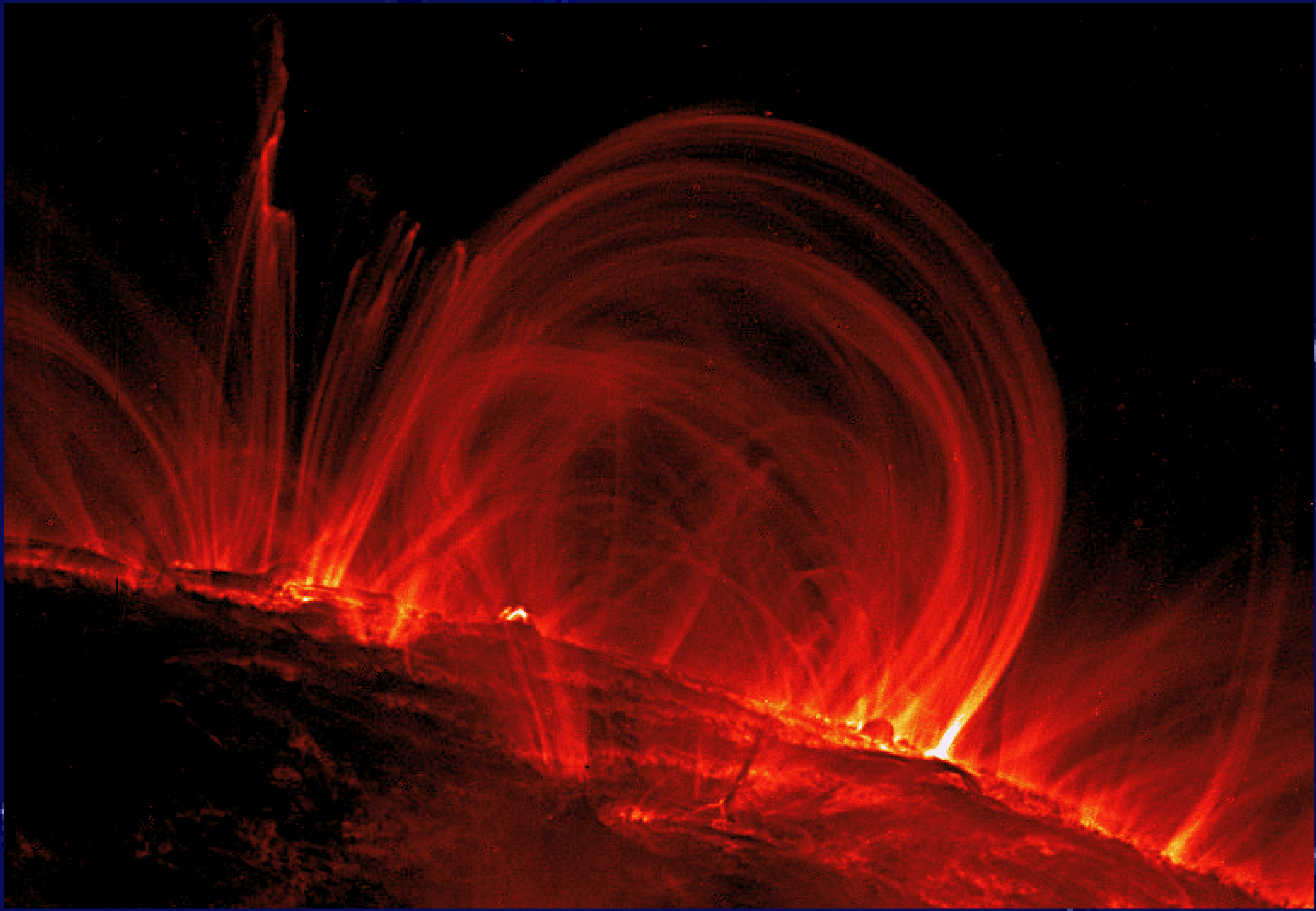


Ultraviolet:

loops in the solar corona

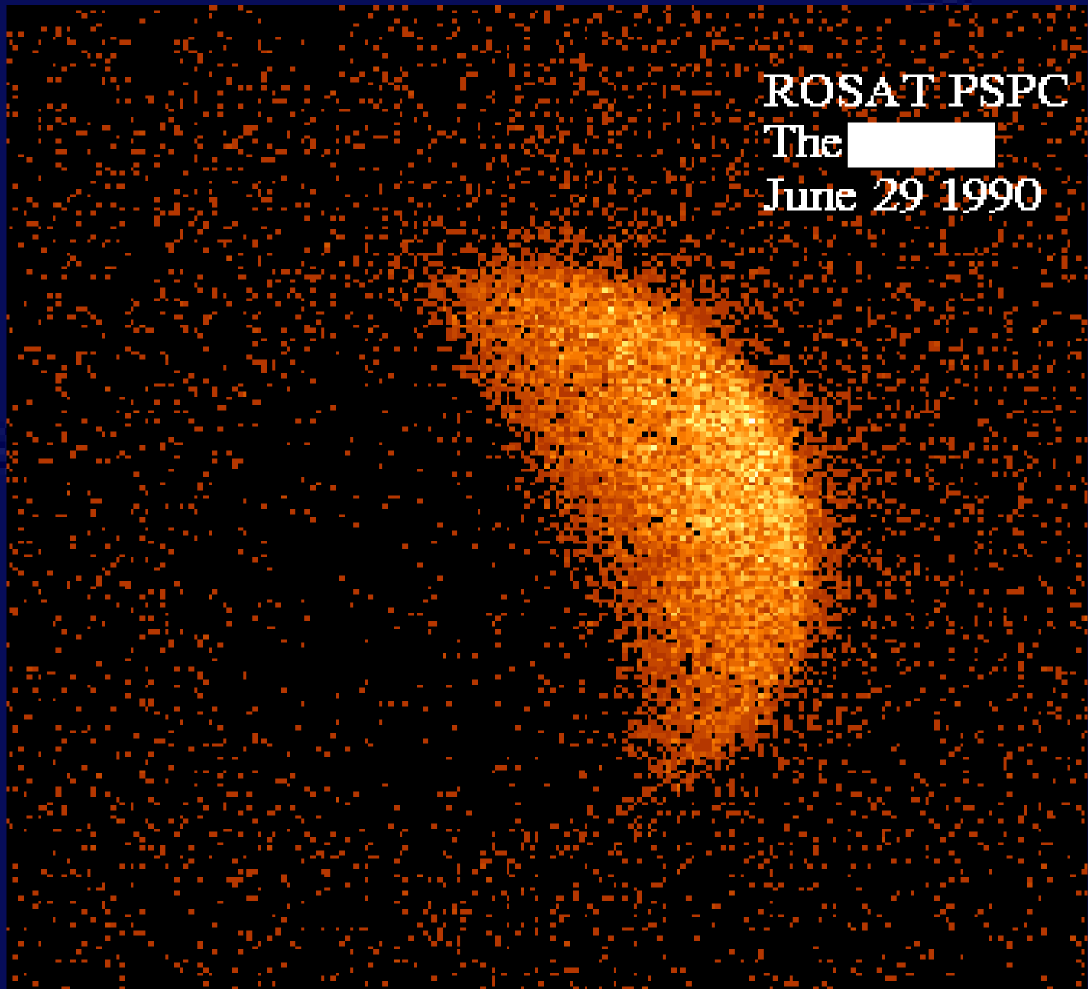


Ultraviolet: more loops in the solar corona

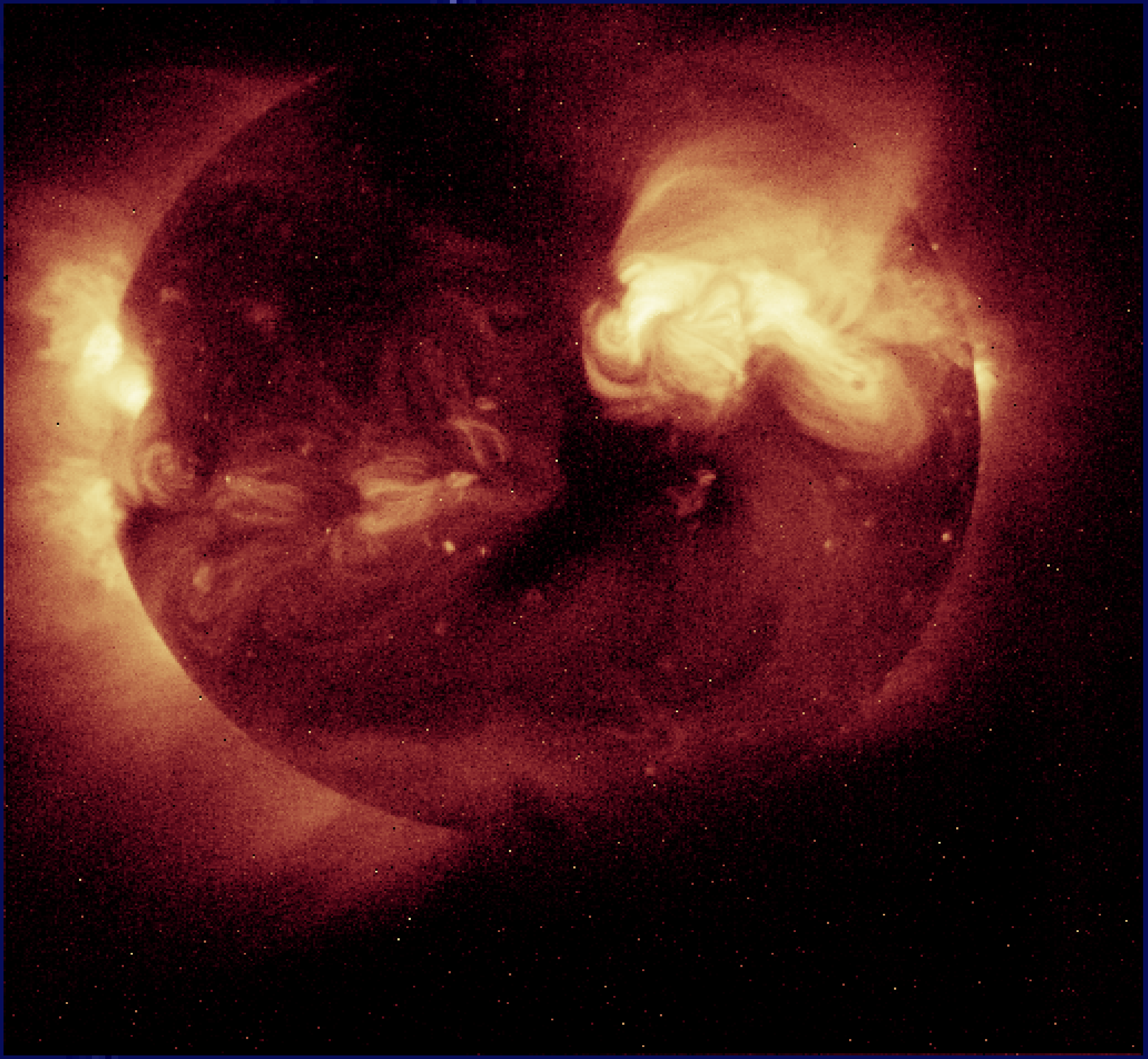


X Rays:

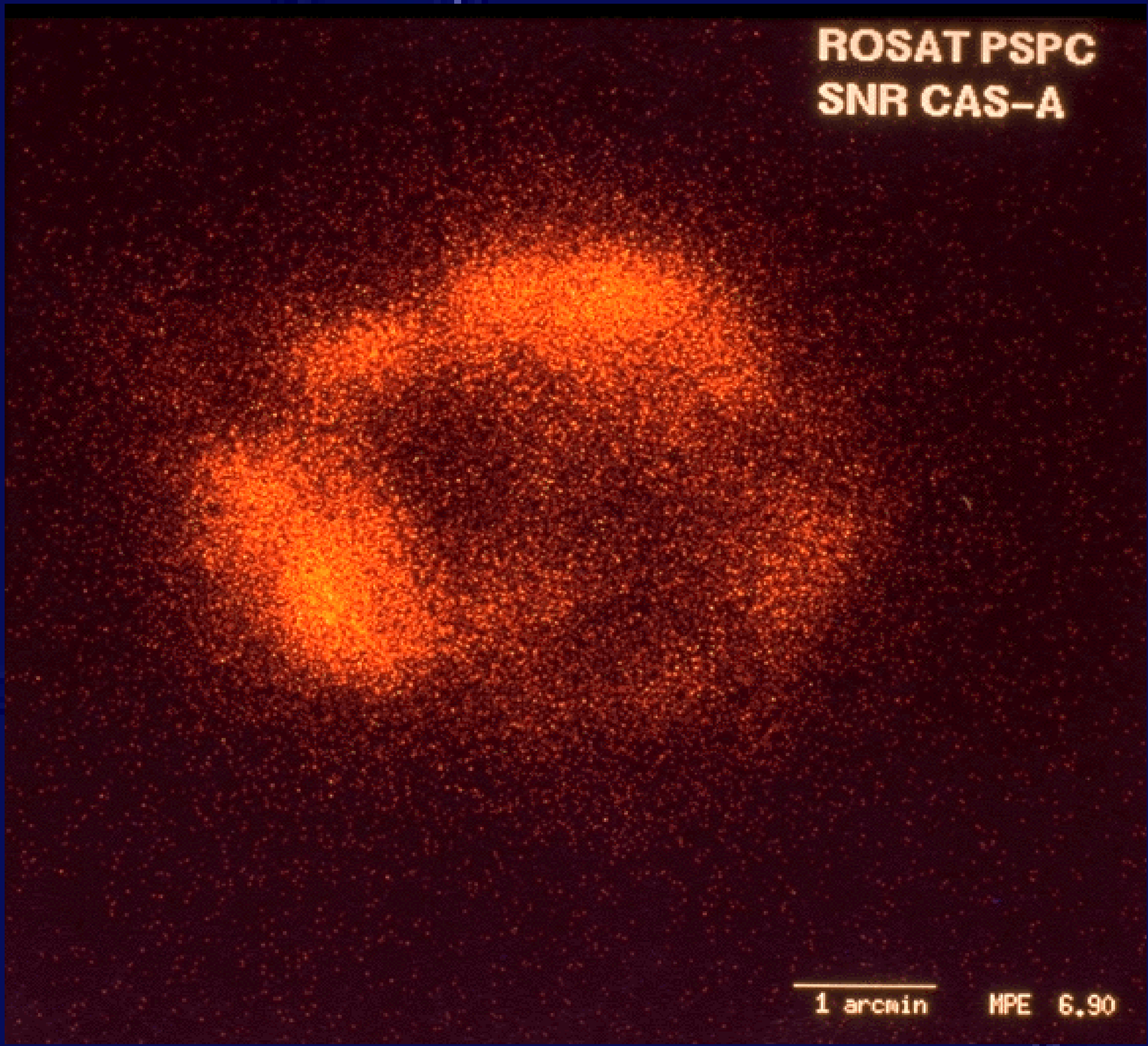
Make a guess!



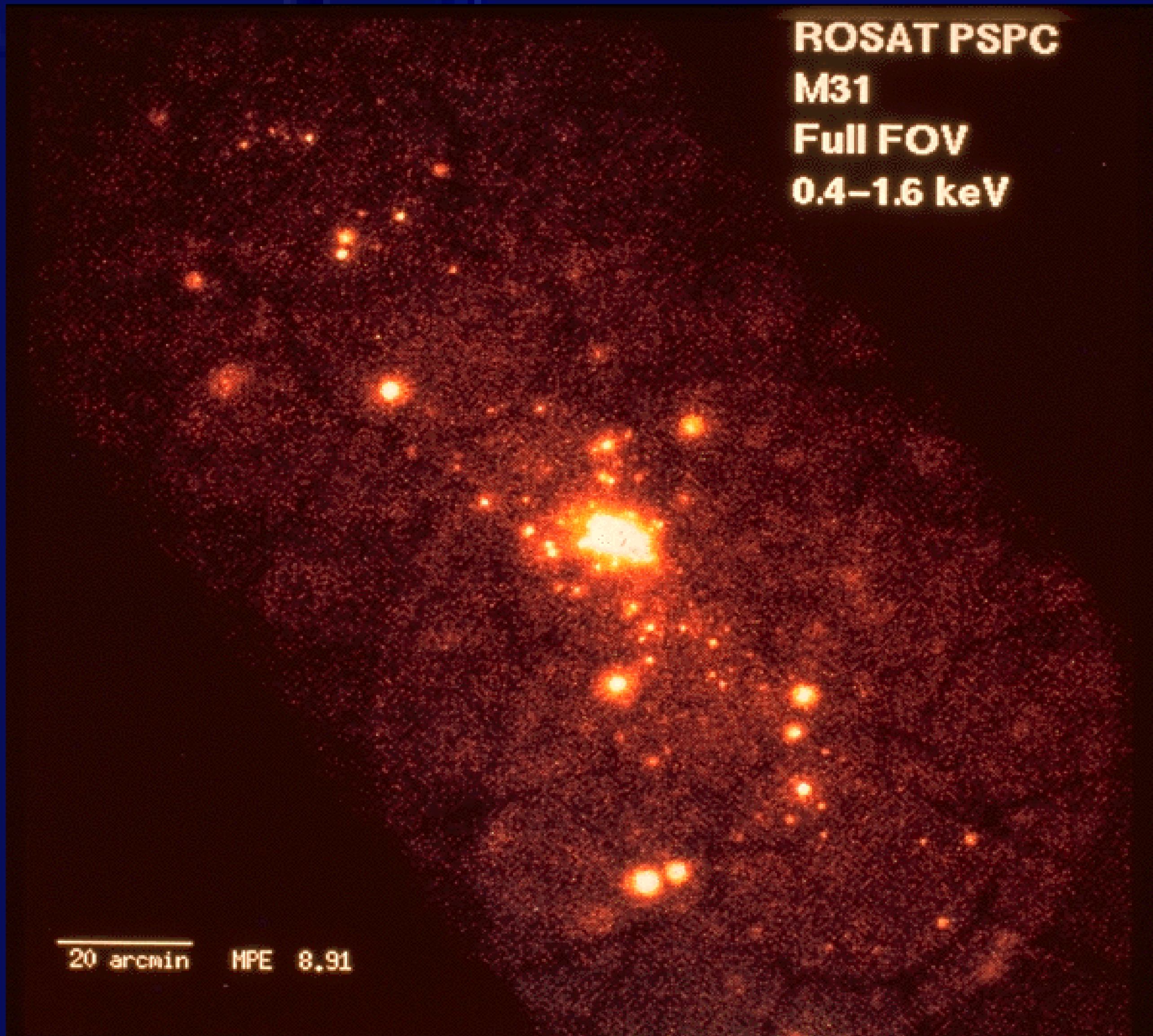
X Rays: The SUN



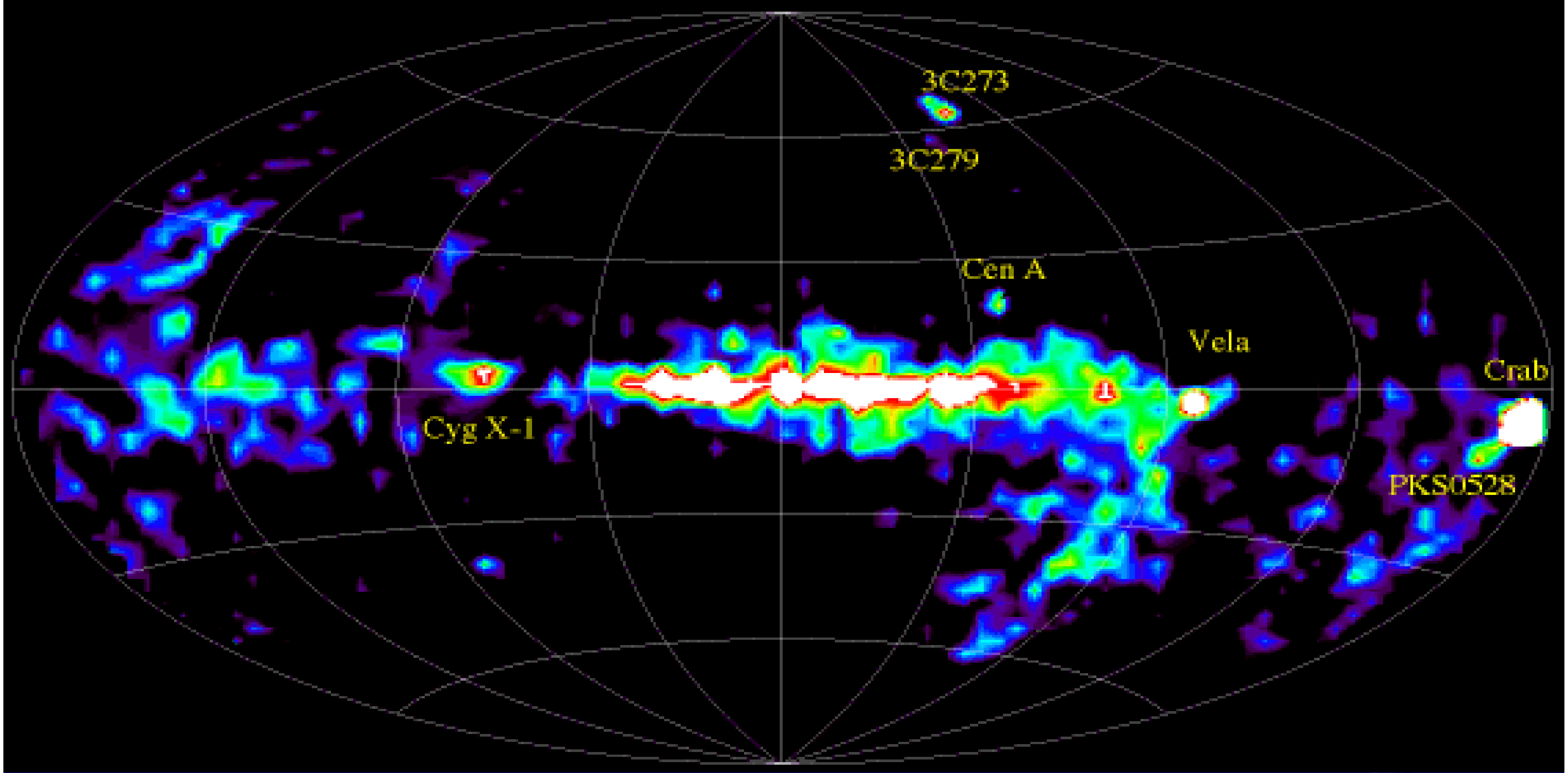
X Rays: Supernova remnants



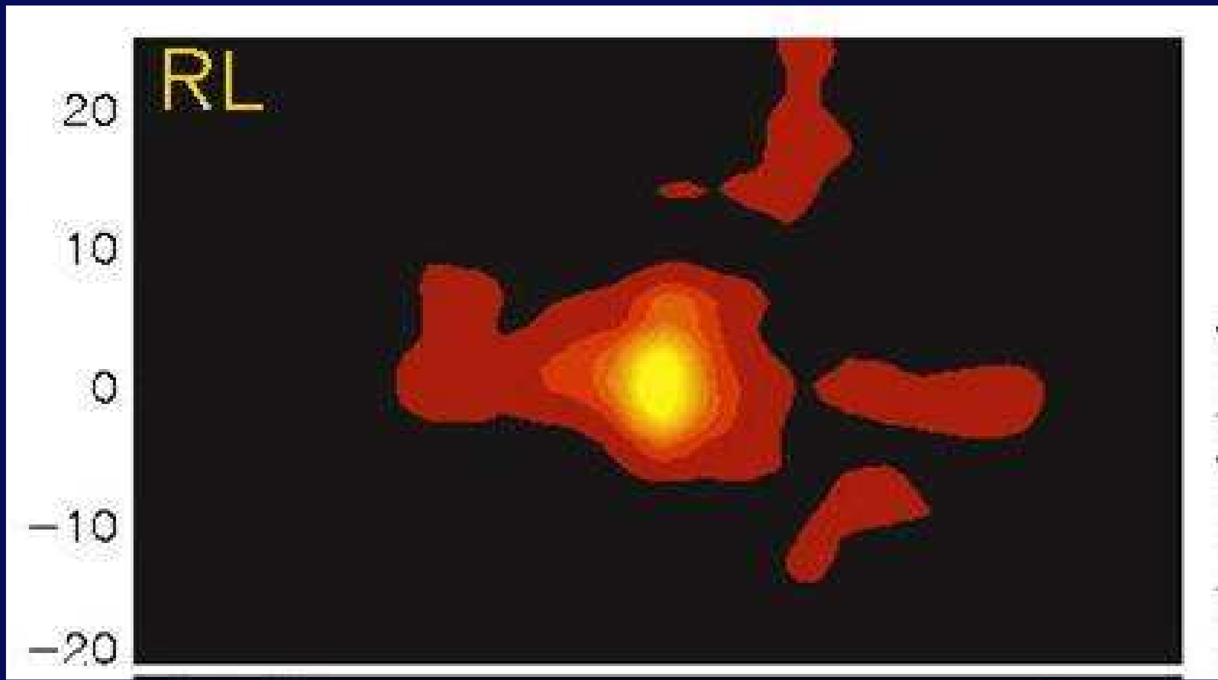
X Rays: Andromeda Galaxy



Gamma Rays: the whole Universe



Gamma Rays: the Milky Way center



The Stars: (T* and R* are surf. temperature and radius)

•Overall Flux at star surface (emitted power by 1 m^2 of star)

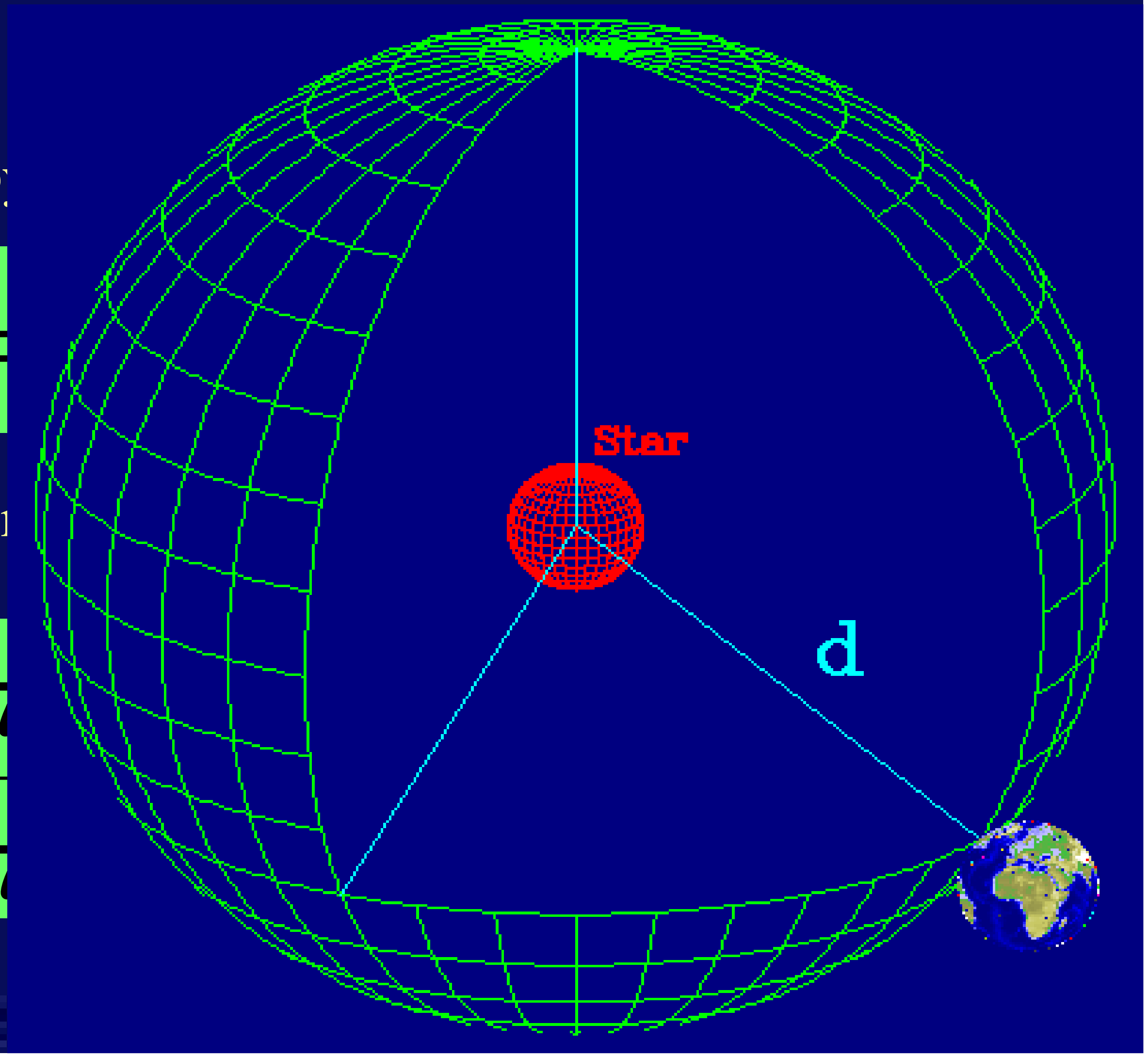
$$F_* = \sigma T_*^4$$

•Total Luminosity (emitted power b

$$L_* = 4\pi R_*^2 F_* =$$

•Total Flux at Earth (received power

$$f = \frac{L_*}{4\pi d^2} = \frac{4\pi}{4\pi}$$



How can we get the stars temperature ?

• f can be measured

but … for T_* we need R_* and d !!!!

For the SUN:

$T_\odot$ =5800 K

$R_\odot = 6.96\times10^8$ m

$L_\odot = 3.8\times10^{26}$ w

d $= 1.49\times10^{11}$ m

$f_\odot = 1.36$ Kw

Maybe … we can do it:

If we observe the star through a blue filter:

$$f_B = \frac{R_*^2}{d^2} \frac{2\pi hc^2}{\lambda_B^5} \frac{\Delta_B}{e^{\frac{hc}{\lambda_B kT_*}} - 1}$$

If we observe the star through a yellow filter:

$$f_G = \frac{R_*^2}{d^2} \frac{2\pi hc^2}{\lambda_G^5} \frac{\Delta_G}{e^{\frac{hc}{\lambda_G kT_*}} - 1}$$

Maybe … we can do it:

Their ratio is :

$$\frac{f_B}{f_G} = \frac{\lambda_G^5}{\lambda_B^5}\frac{\Delta_B}{\Delta_G}\frac{e^{\frac{hc}{\lambda_G k T_*}}-1}{e^{\frac{hc}{\lambda_B k T_*}}-1}$$

We have the stars Thermometer !!

Now you can read correctly this image:

Why different colors for the stars ??