Astr 102: Introduction to Astronomy

Fall Quarter 2009, University of Washington, Željko Ivezić

Lecture 4:

The Electromagnetic Spectrum

Understanding Stellar and Galaxy Properties, and Cosmology

Four blocks: introduction to astrophysical tools, stars, galaxies, cosmology.

The goals of this class are:

- Understanding the formation and evolution of stars using simple physical principles
- Understanding the formation and evolution of galaxies
- Understanding the cosmological evolution of the Universe

Physics that we need to know

Before we start with astrophysics, you need to be familiar with these terms:

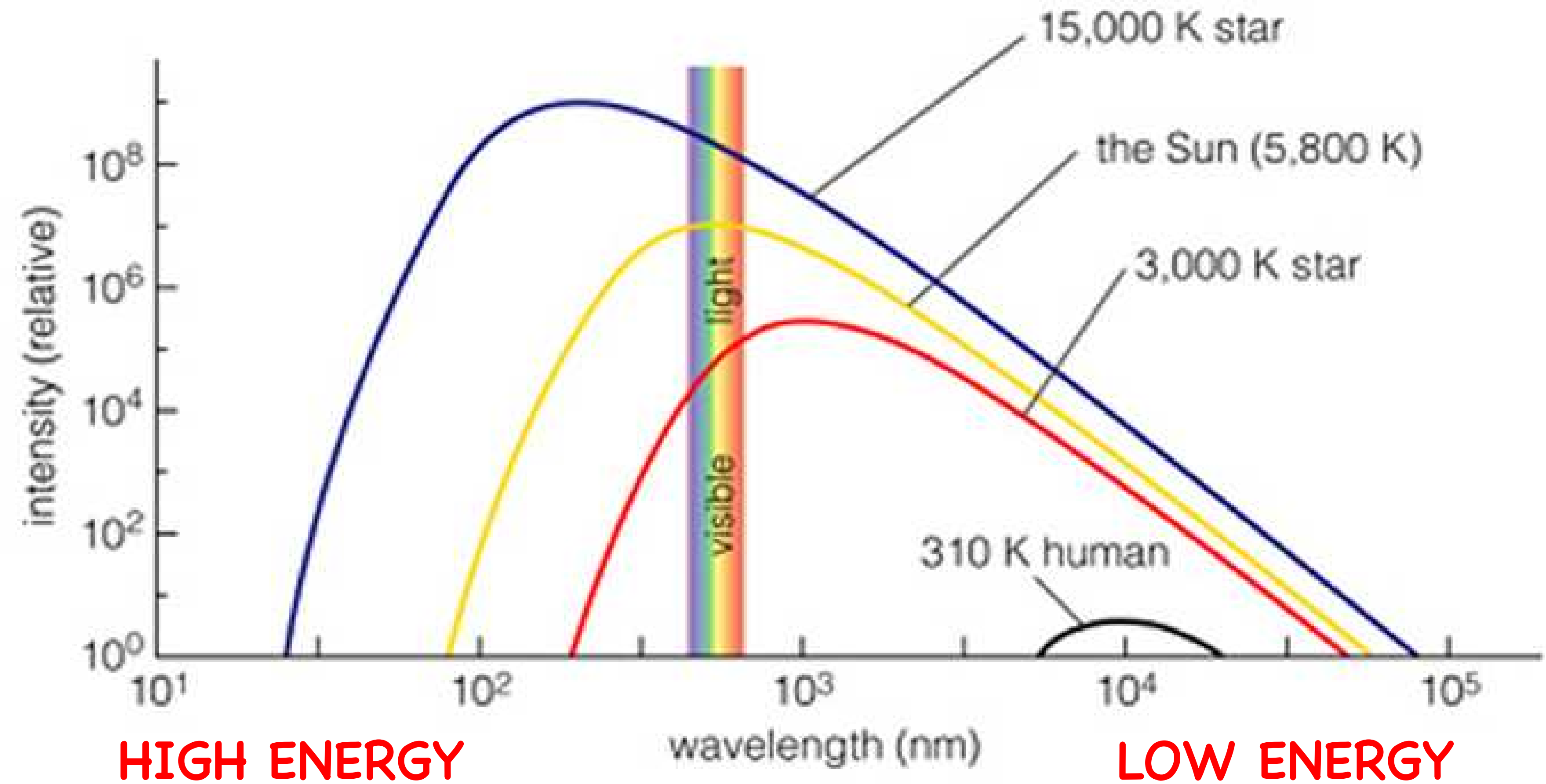
- scientific notation
- definition and units: distance, time, velocity, acceleration, angular size, mass, momentum, angular momentum, force, energy, power, temperature
- states of matter: solid, liquid, gas, ions
- the four forces of nature: gravity, electromagnetic force, weak and strong nuclear force
- light: dual wave/particle nature, interaction with matter

- energy transfer mechanisms: conduction, convection, radiation

- thermal radiation: Planck function

Thermal radiation distribution:

- If its hotter, its BLUER.
- If its hotter, there's MORE of it →

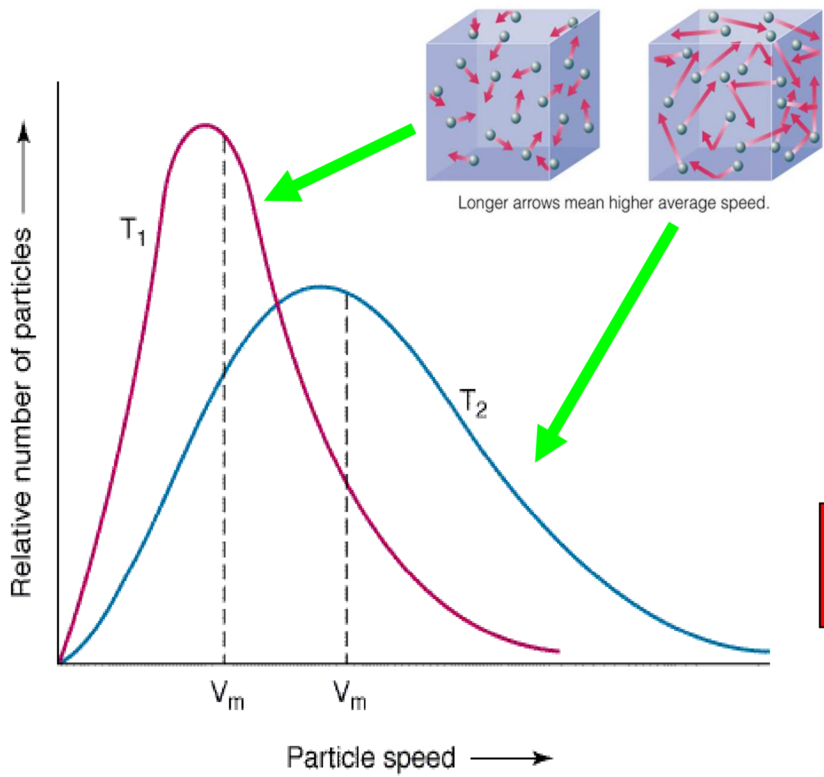


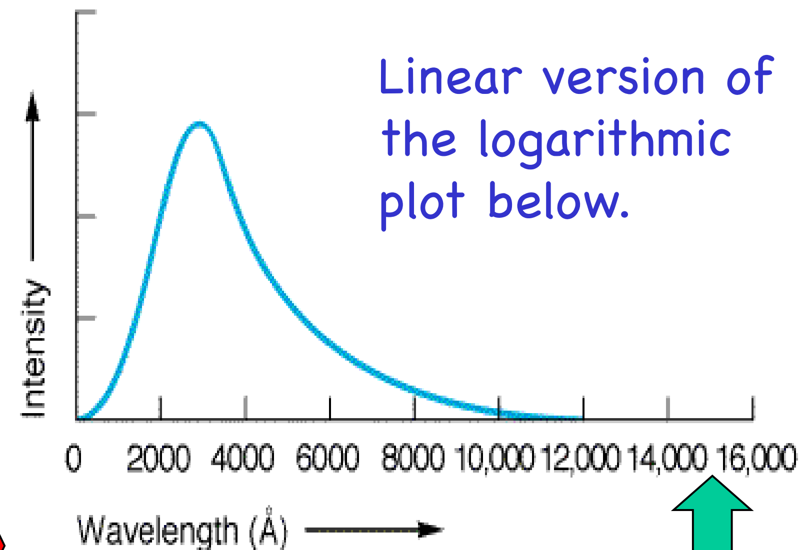
HIGH ENERGY LOW ENERGY

(Log-log plot)

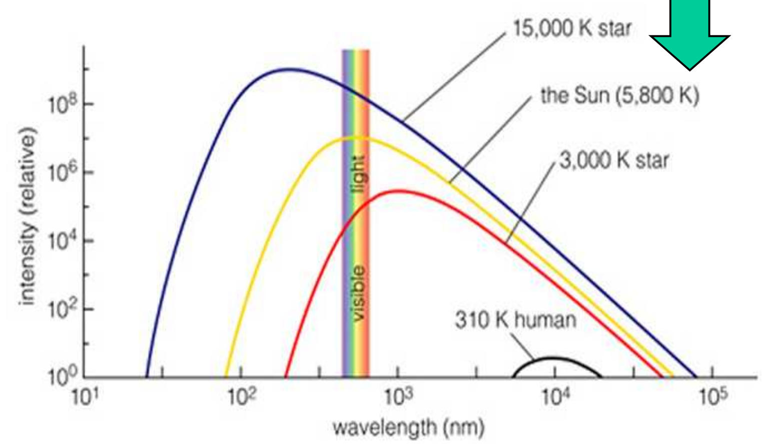
Thermal radiation distribution:

- This spectral shape is closely related to the distribution of particle velocities.





Linear version of the logarithmic plot below.



P.S. Note that the plots on the right have energy decreasing to the right, whereas the left hand plot is opposite

Planck Function

Describes how much electromagnetic power is emitted at a given wavelength (or frequency) by a black body of a given temperature:

$$I_\nu(\nu, T) = 4\pi \left(\frac{h\nu^3}{c^2}\right) \left(\frac{1}{\exp\left(h\nu/kT\right) - 1}\right) \tag{1}$$

This form gives power per per unit area of emitting surface, and per unit frequency (the unit is W m^{-2} Hz^{-1}).

Here, $h = 6.63 \times 10^{-34}$ Js is the Planck constant, and $c = 2.998 \times 10^8$ m/s is the speed of light (roughly 200,000 miles/second!).

Also, the power per unit wavelength (see the plots on previous slides) is

$$I_\lambda(\lambda, T) = \frac{\nu}{\lambda} I_\nu(\nu, T) \tag{2}$$

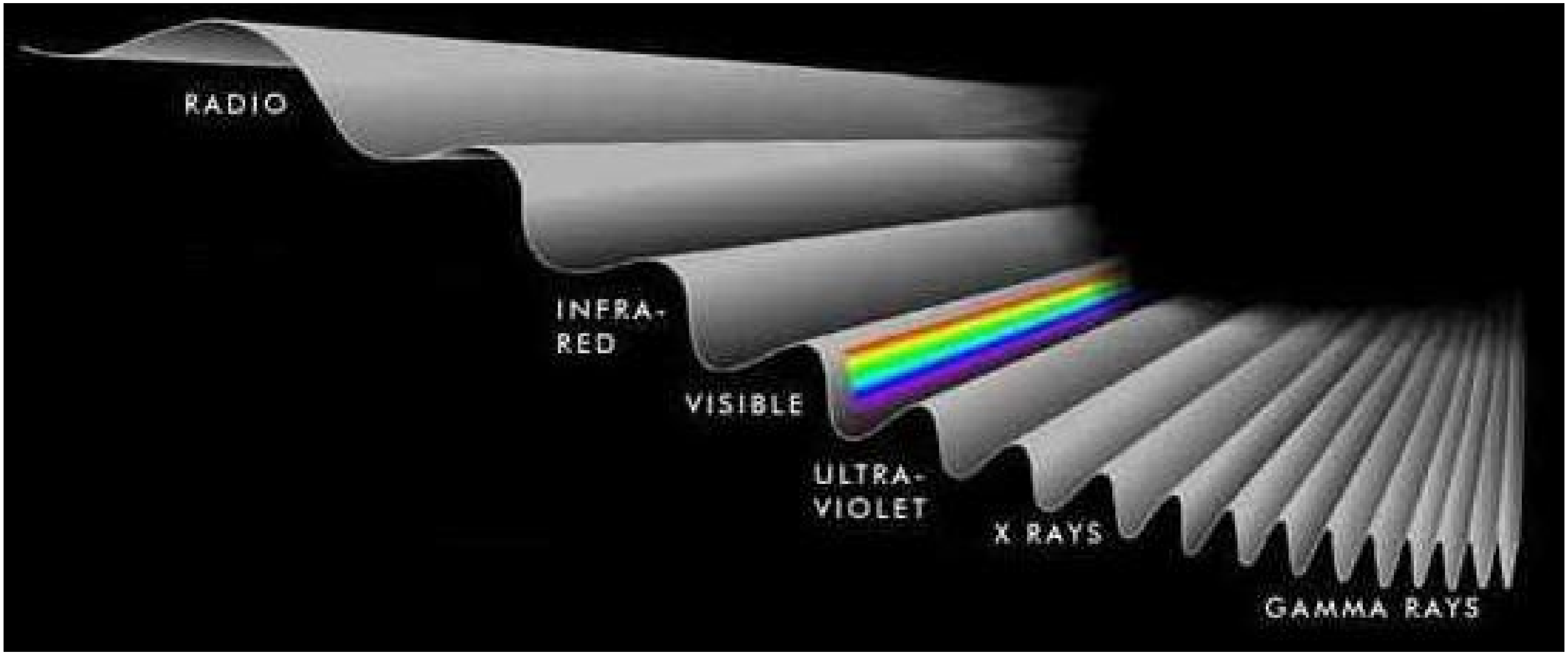
with $\nu\lambda = c$ (true for any wave).

From Planck function, we can derive:

- the Stefan-Boltzmann law: $F = \sigma T^4$, and

- the Wien's law: $T\lambda_{\text{max}} = C$, with $C \approx 3000$ K μm.

More details: http://en.wikipedia.org/wiki/Planck's_law

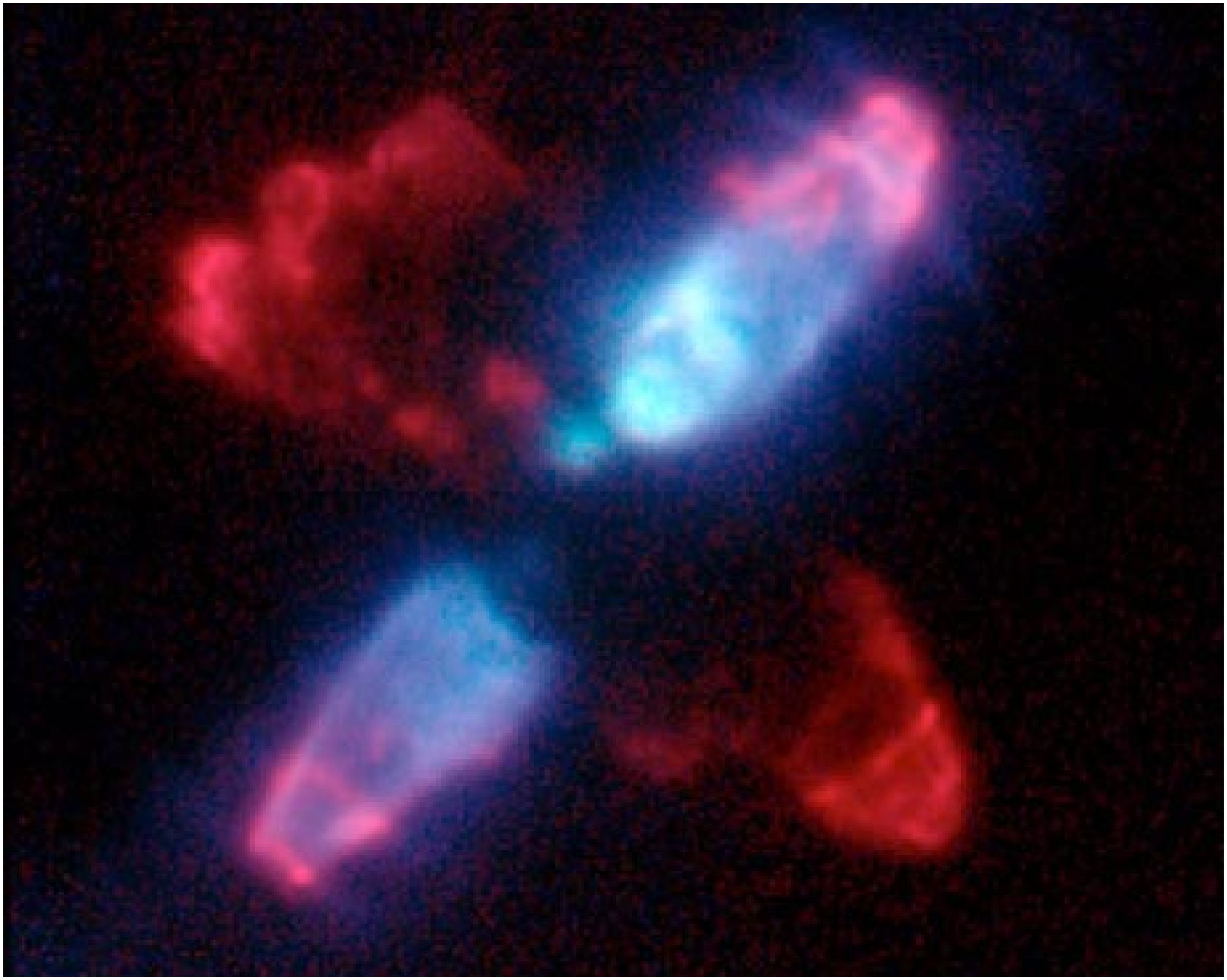


Electromagnetic Radiation

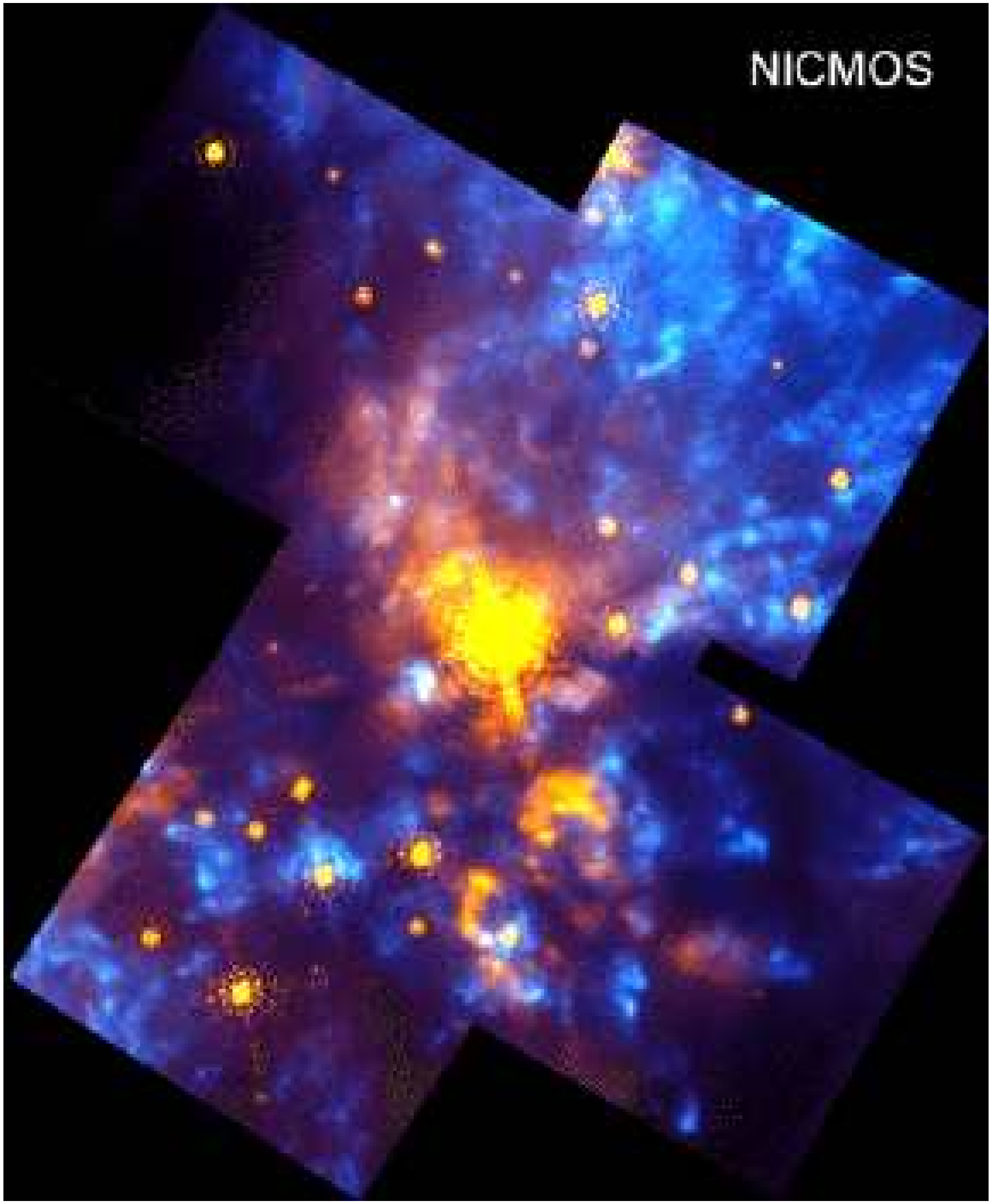
Astronomers care for every photon: from radio to gamma rays!

Why do astronomers care for every photon? That is, why are the wavelengths other than visual important? After all, the Planck function radiation is described by 2 numbers (temperature and flux)!

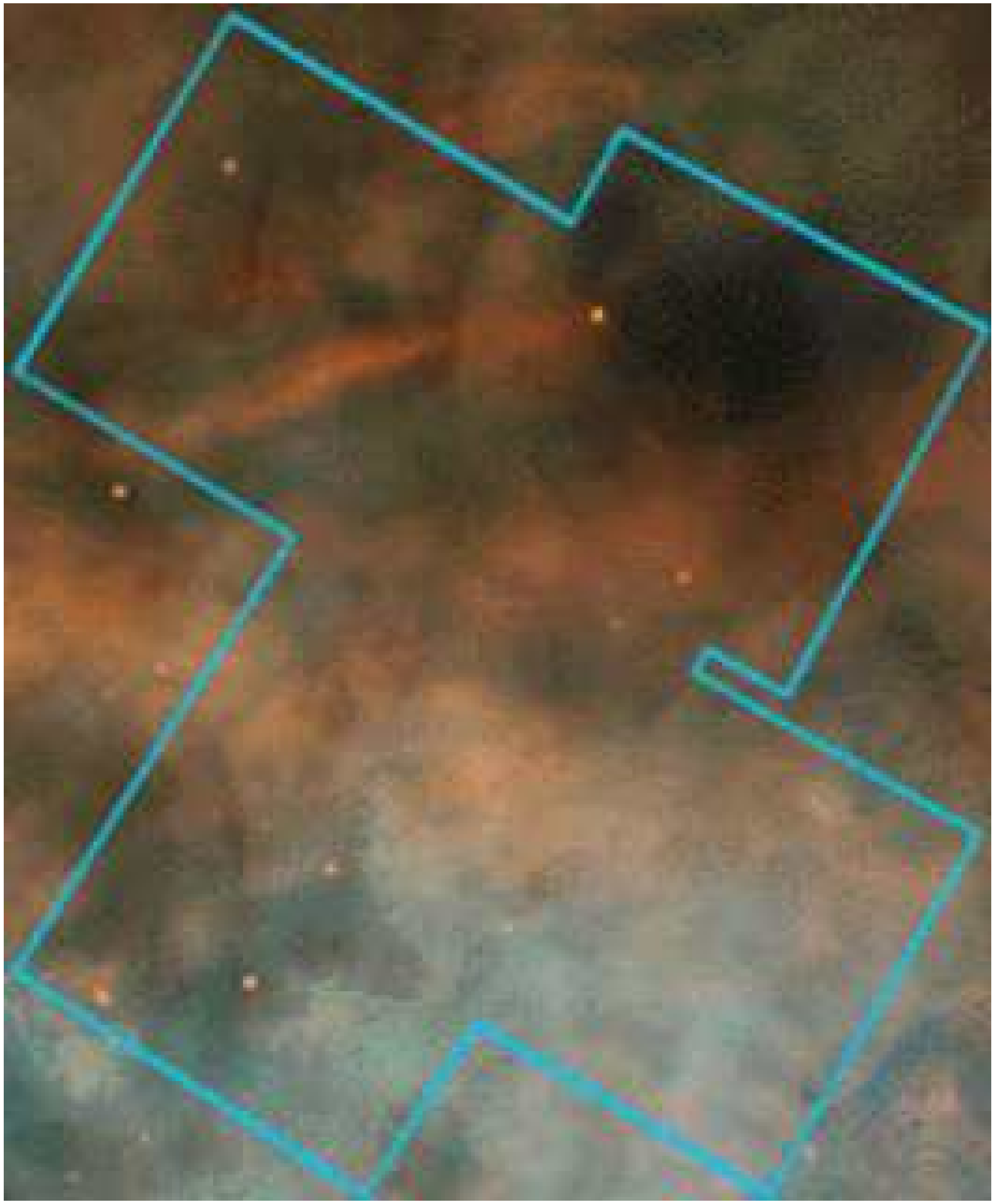
- **Radiation from astronomical sources is NOT Planckian**



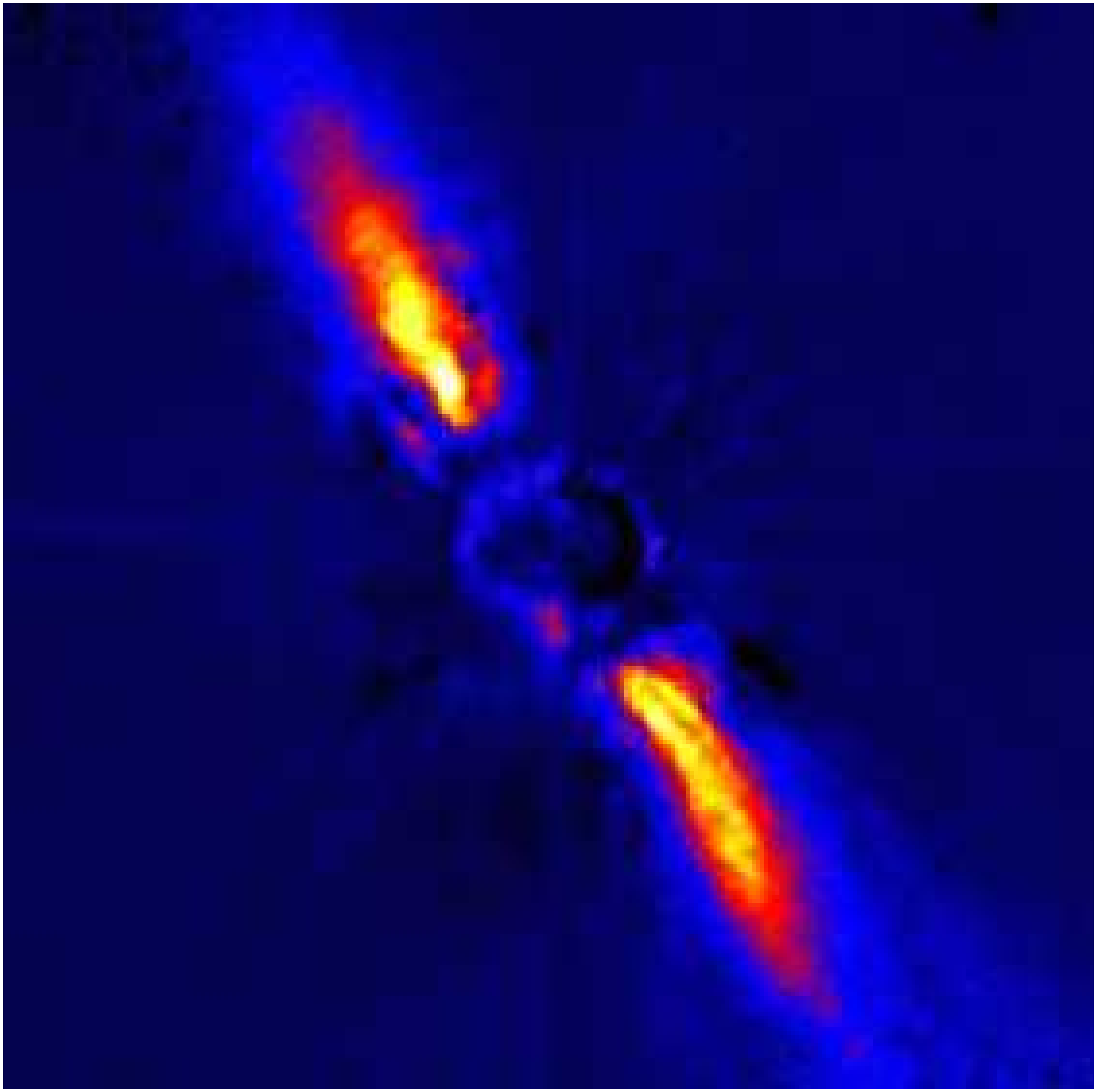
Multiple components



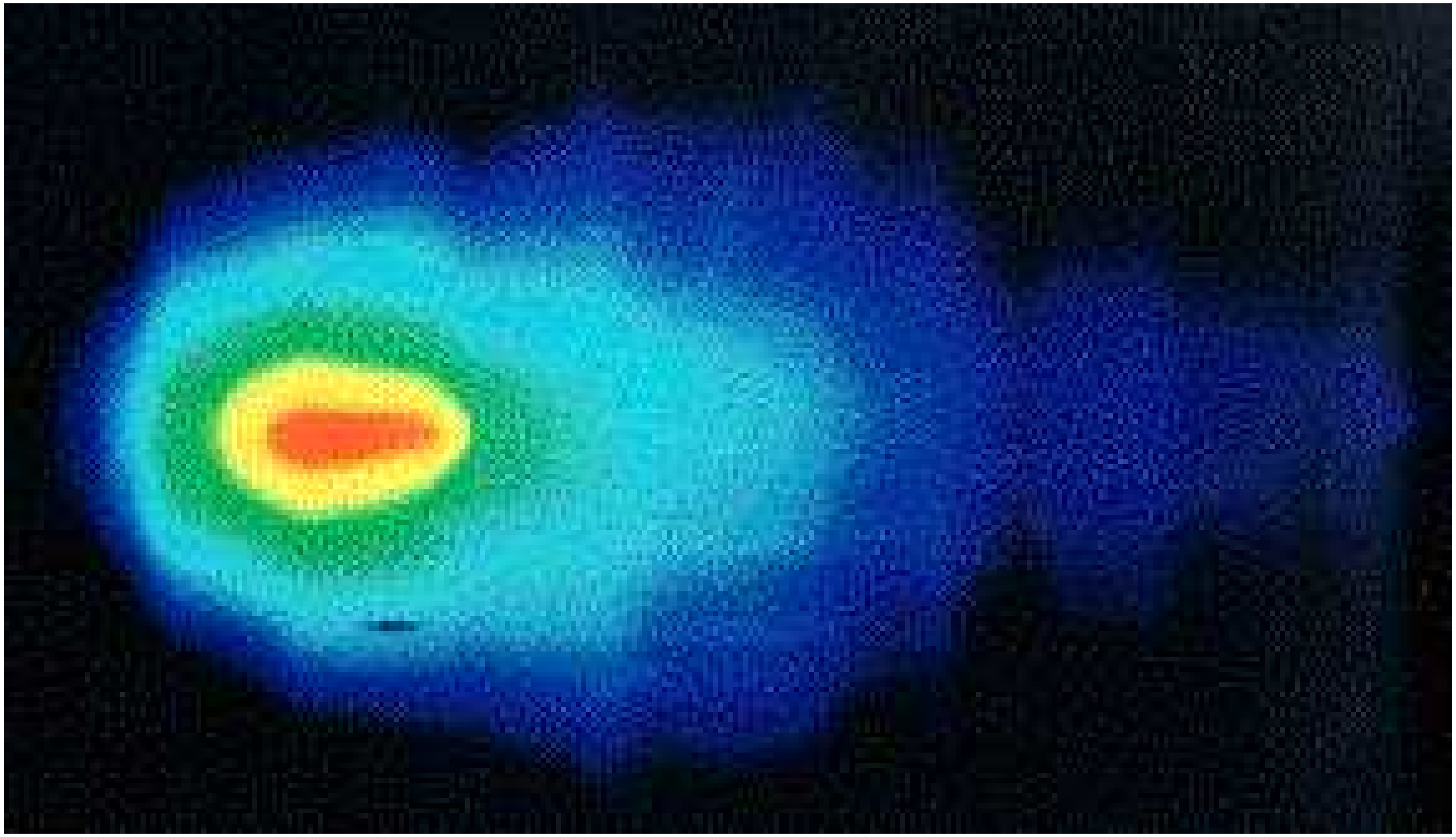
Bright in infrared,



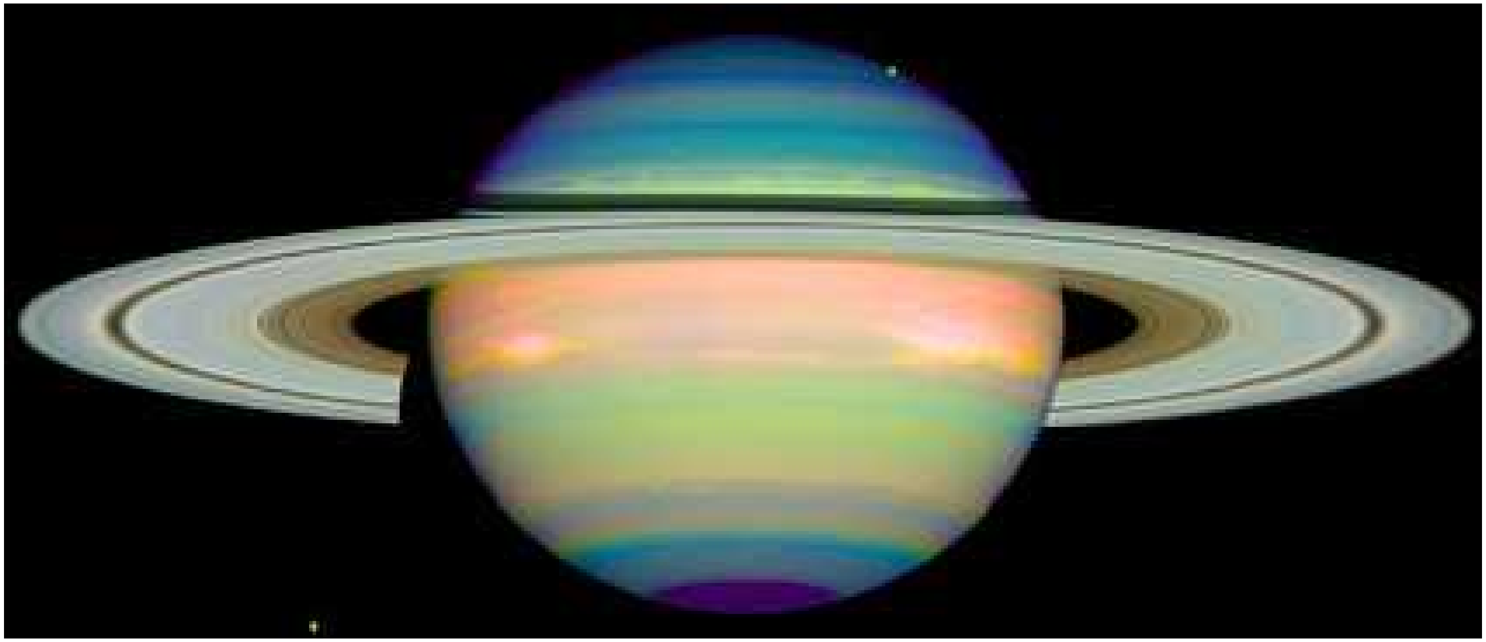
...and invisible in optical



Circumstellar disk (the star is masked)

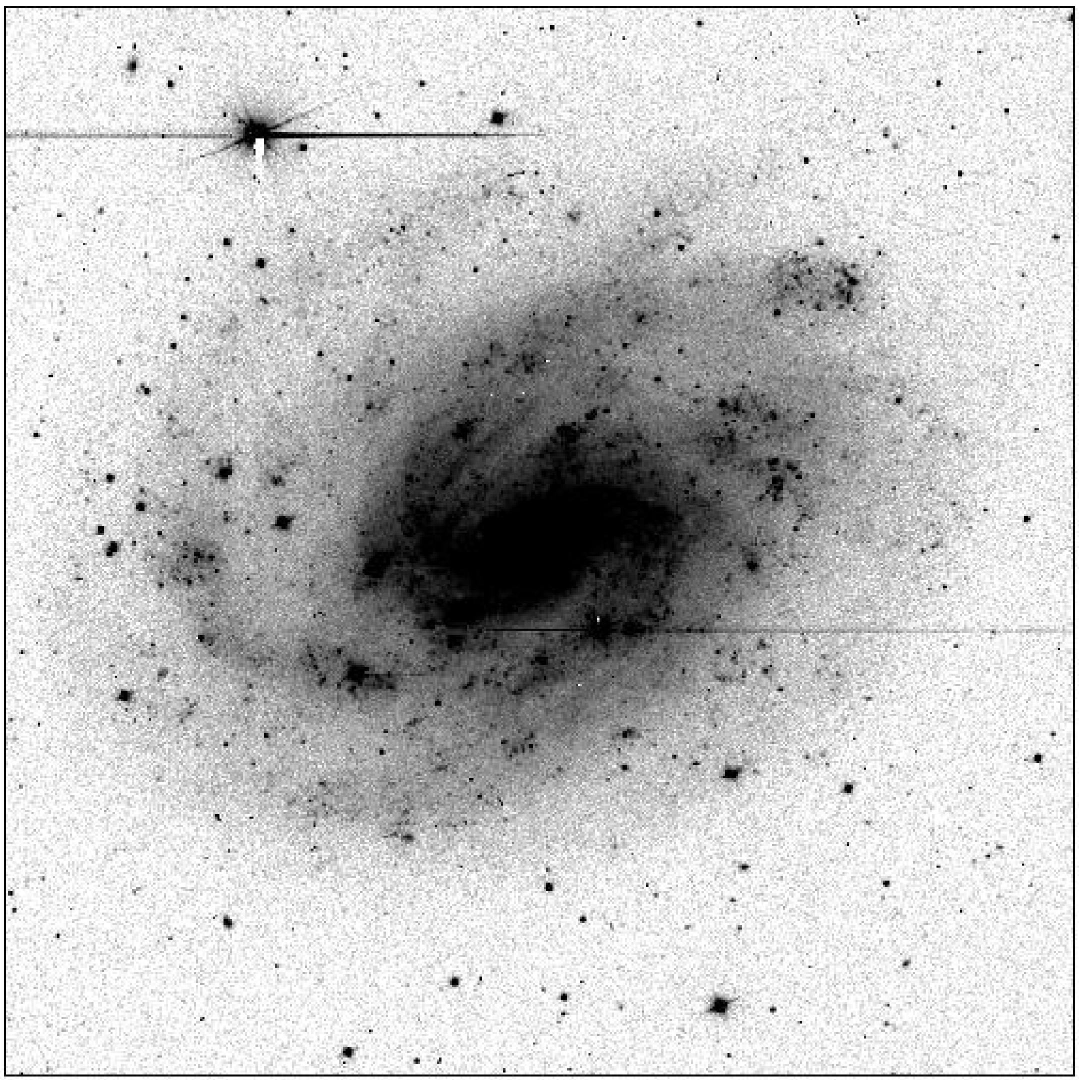


Comet

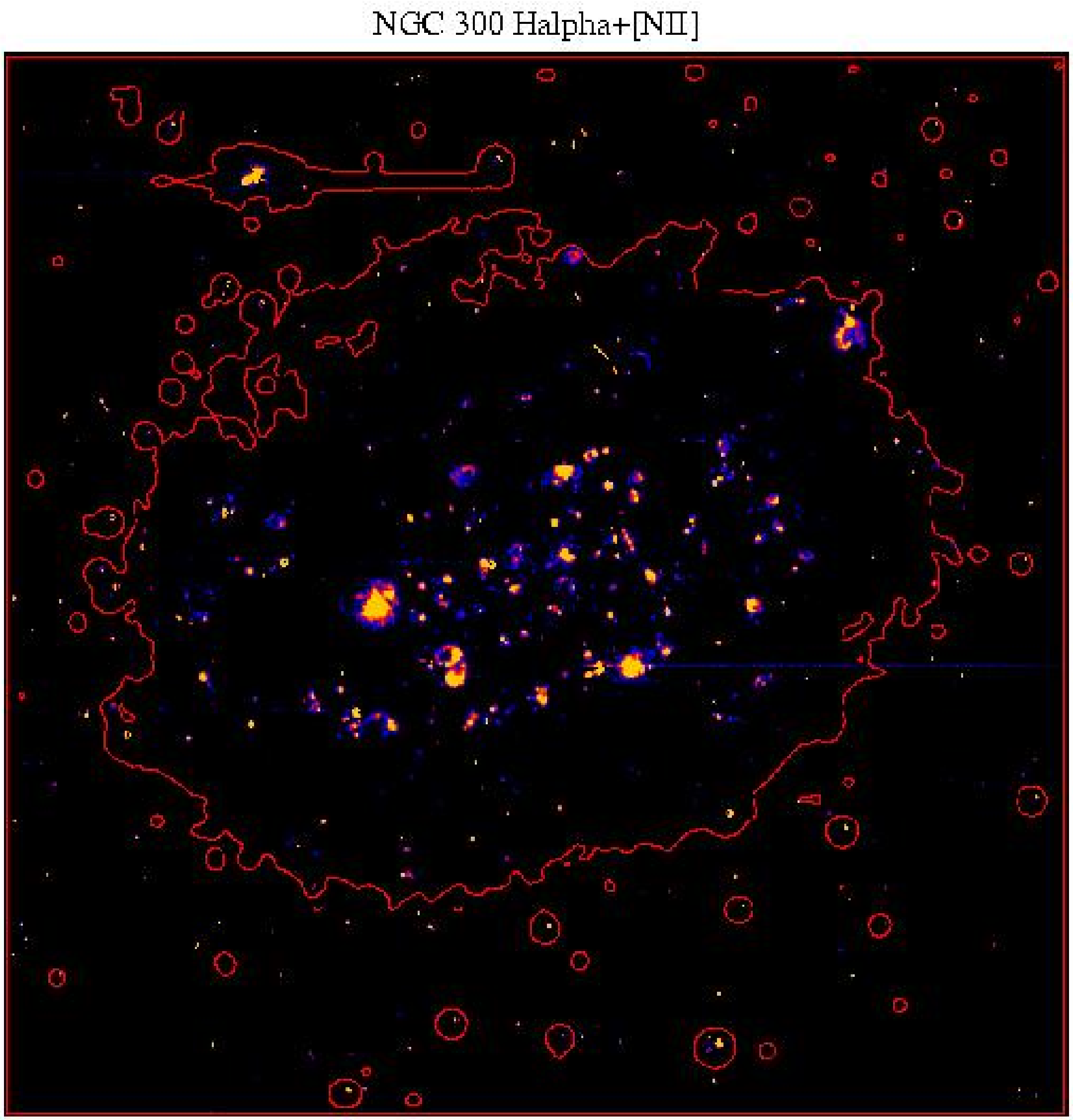


Saturn

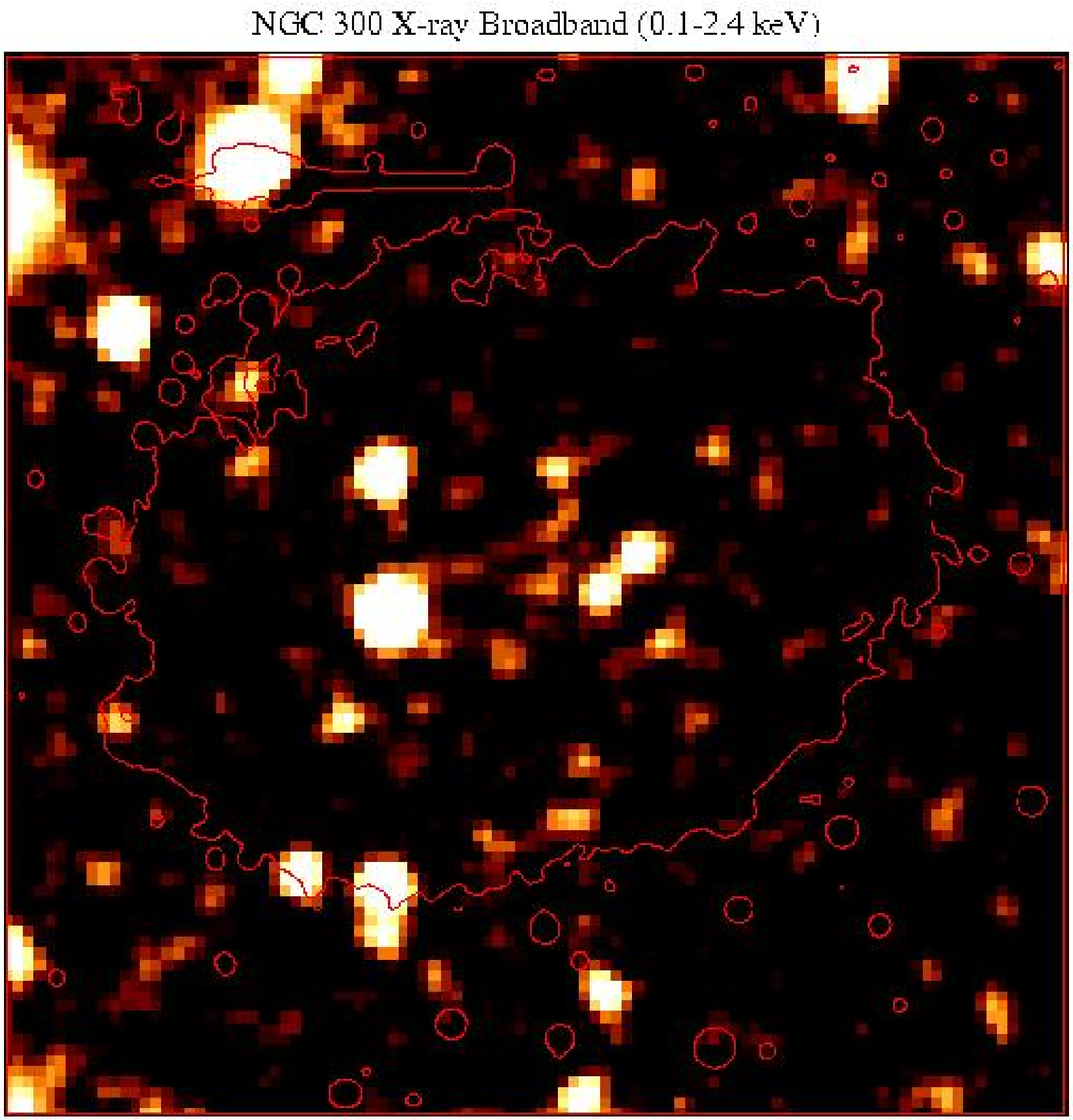
- Radiation from astronomical sources is NOT Planckian
  - Radiative transfer effects (e.g. circumstellar dust)
  - Non-thermal processes (e.g. synchrotron emission)



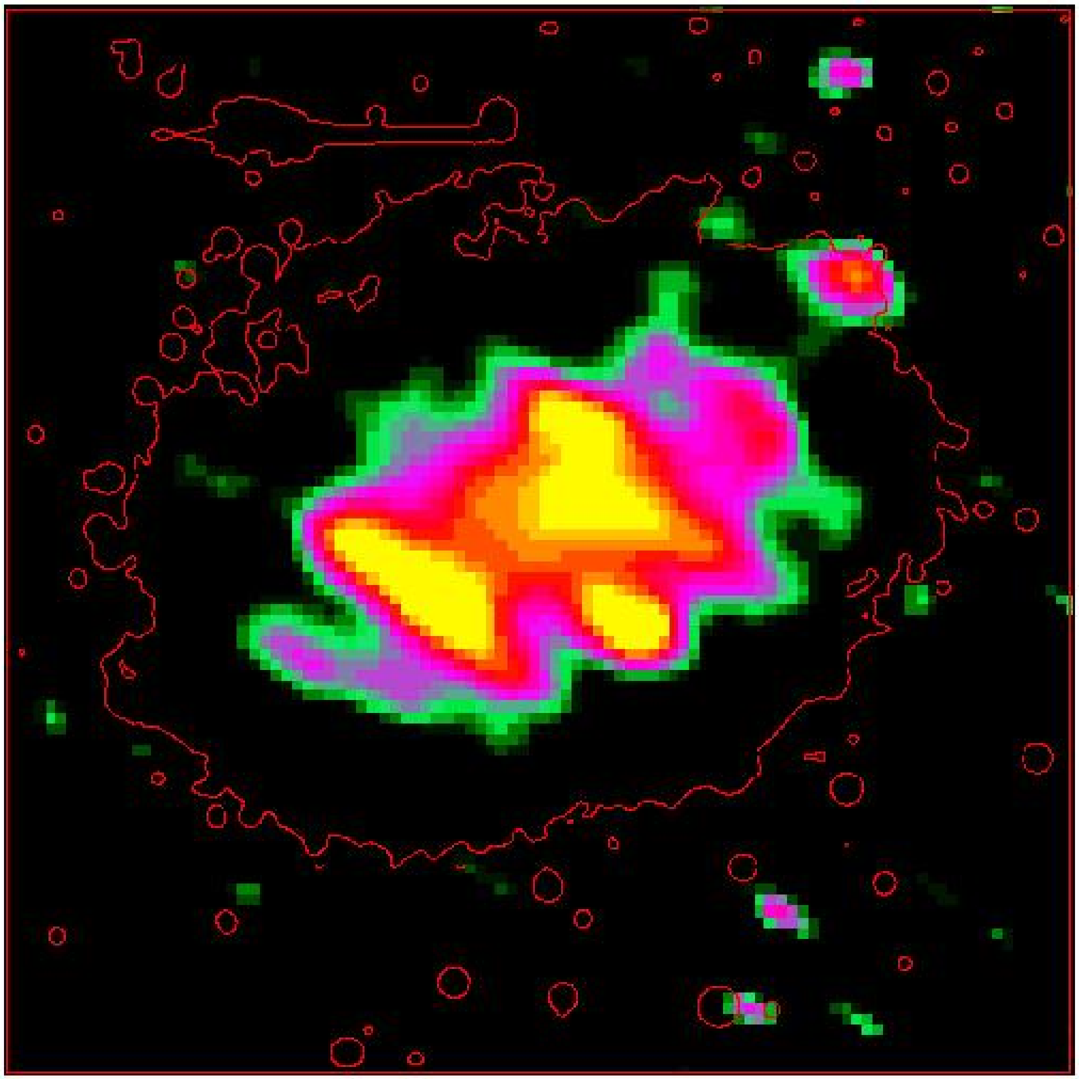
Optical Continum Emission



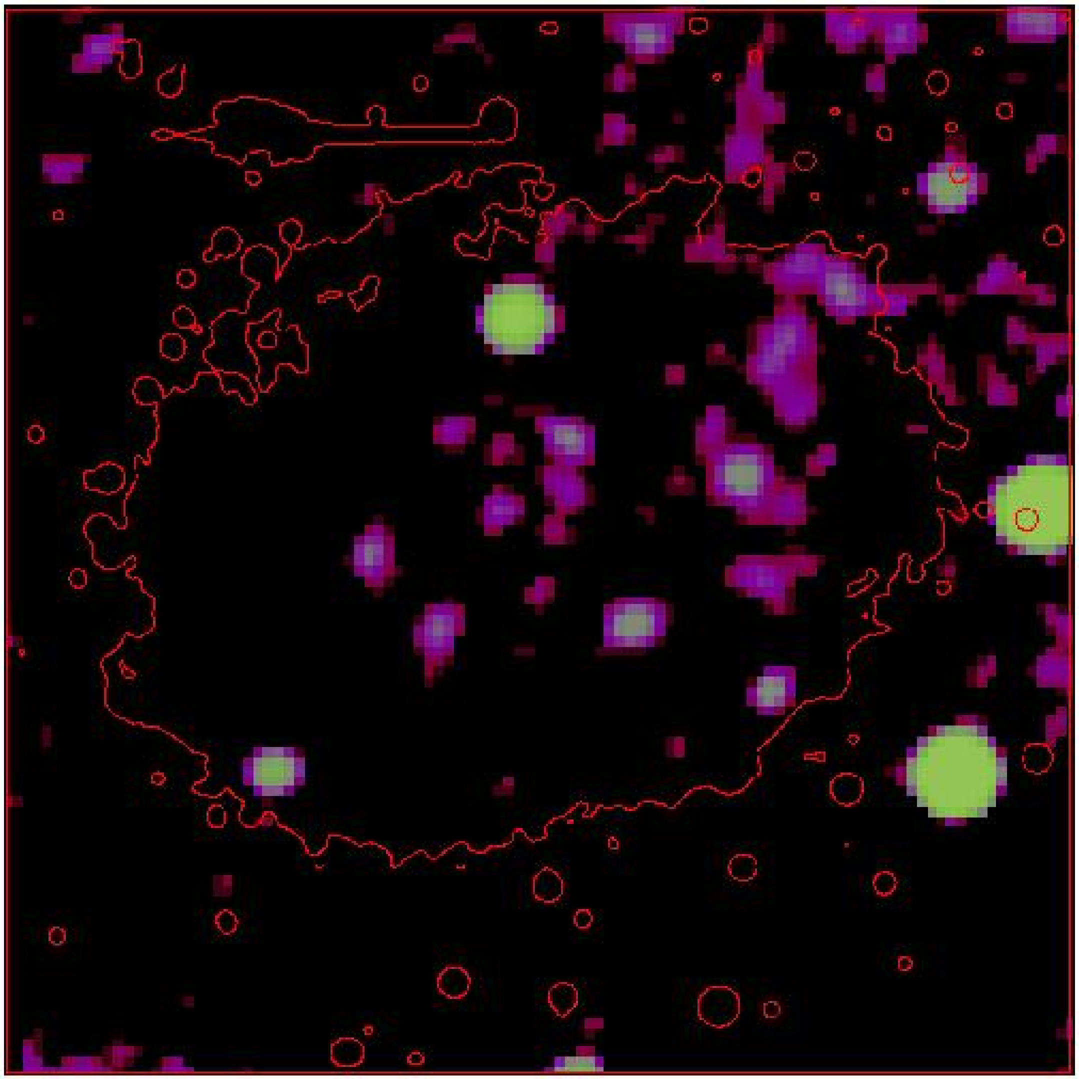
Optical Line Emission



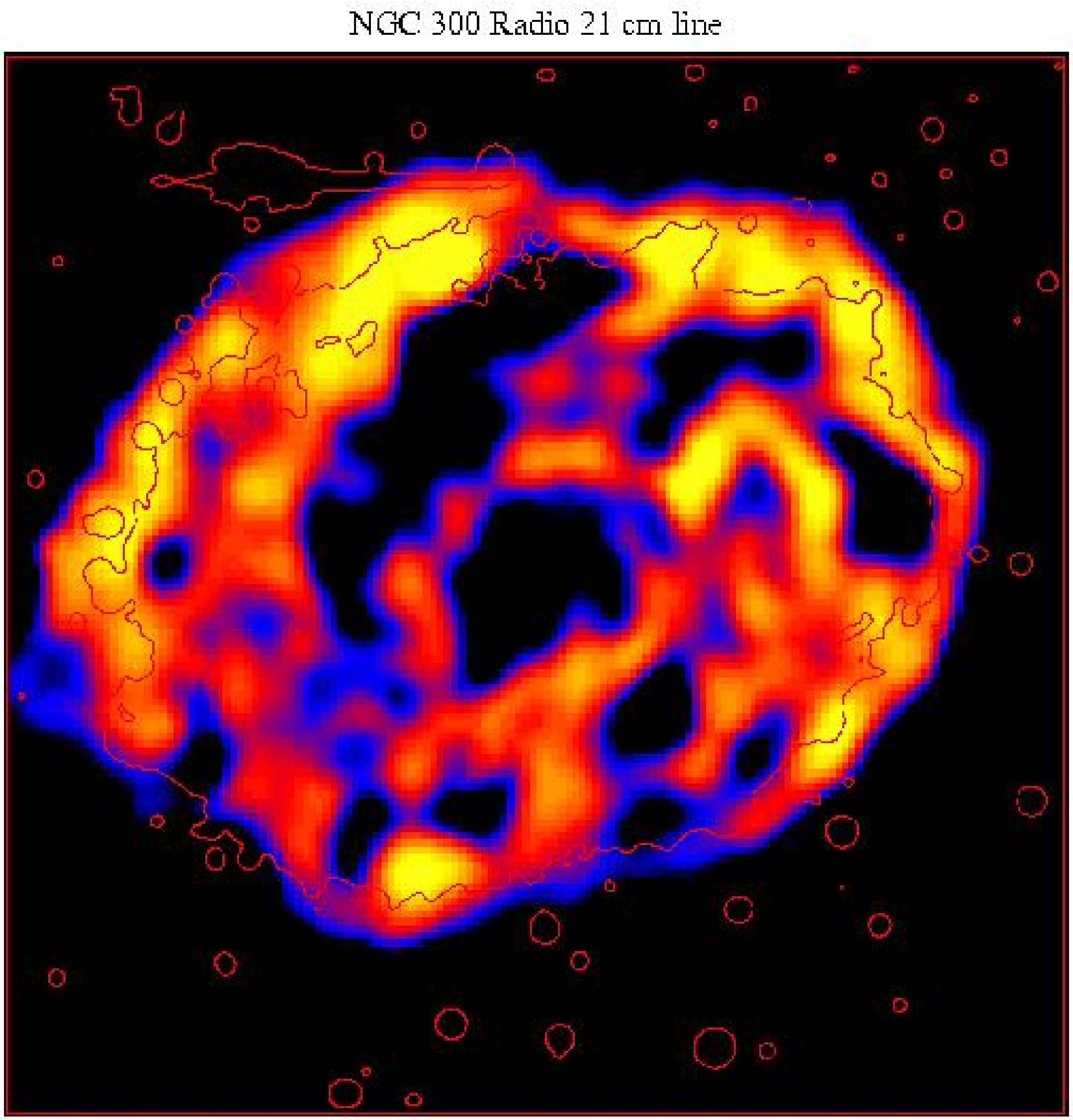
Soft X rays



Infrared (60 μm) Emission



Radio Continuum (6 cm) Emission



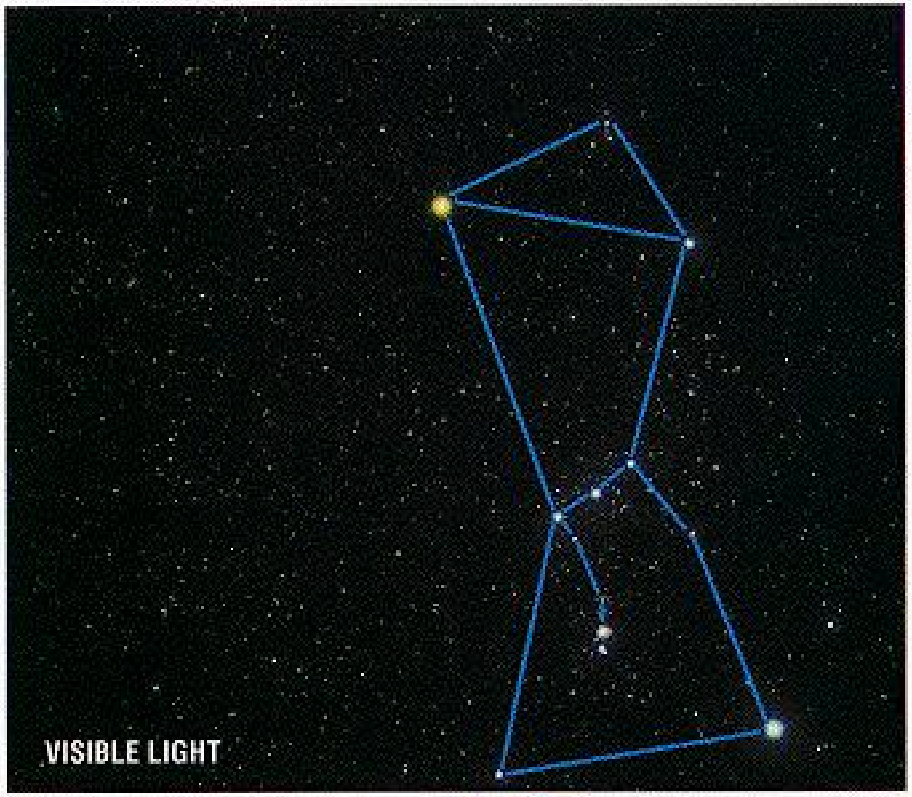
Radio Line (21 cm) Emission

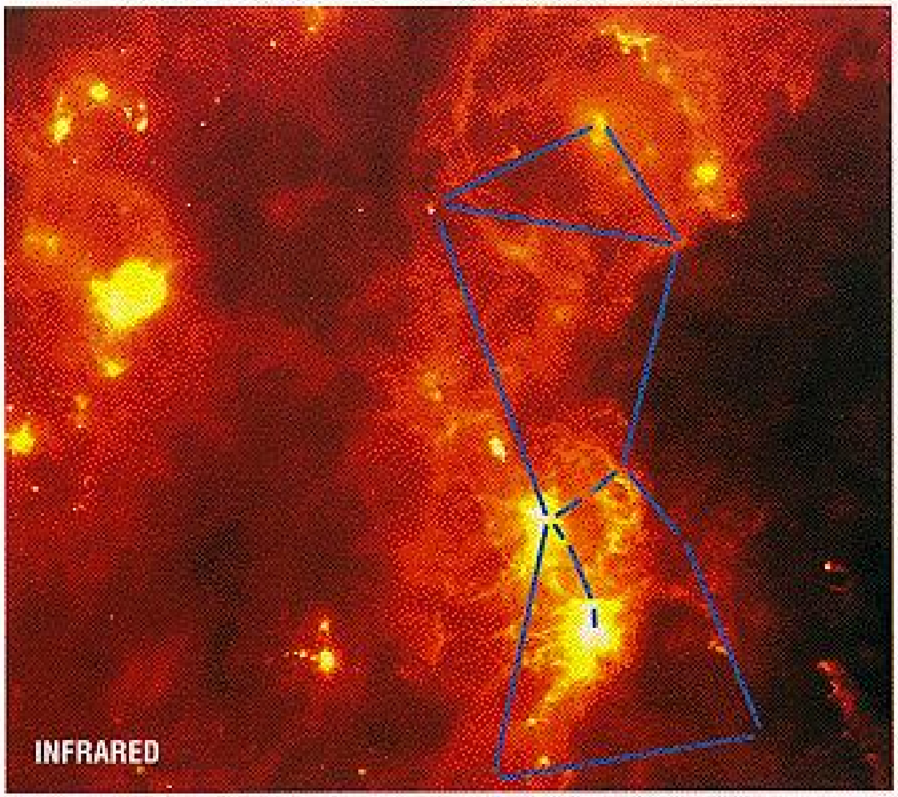
Why do astronomers care for every photon?

- Radiation from astronomical sources is NOT Planckian
  - Radiative transfer effects
  - Non-thermal processes (e.g. synchrotron emission)
- Dust Obscuration (end emission!)

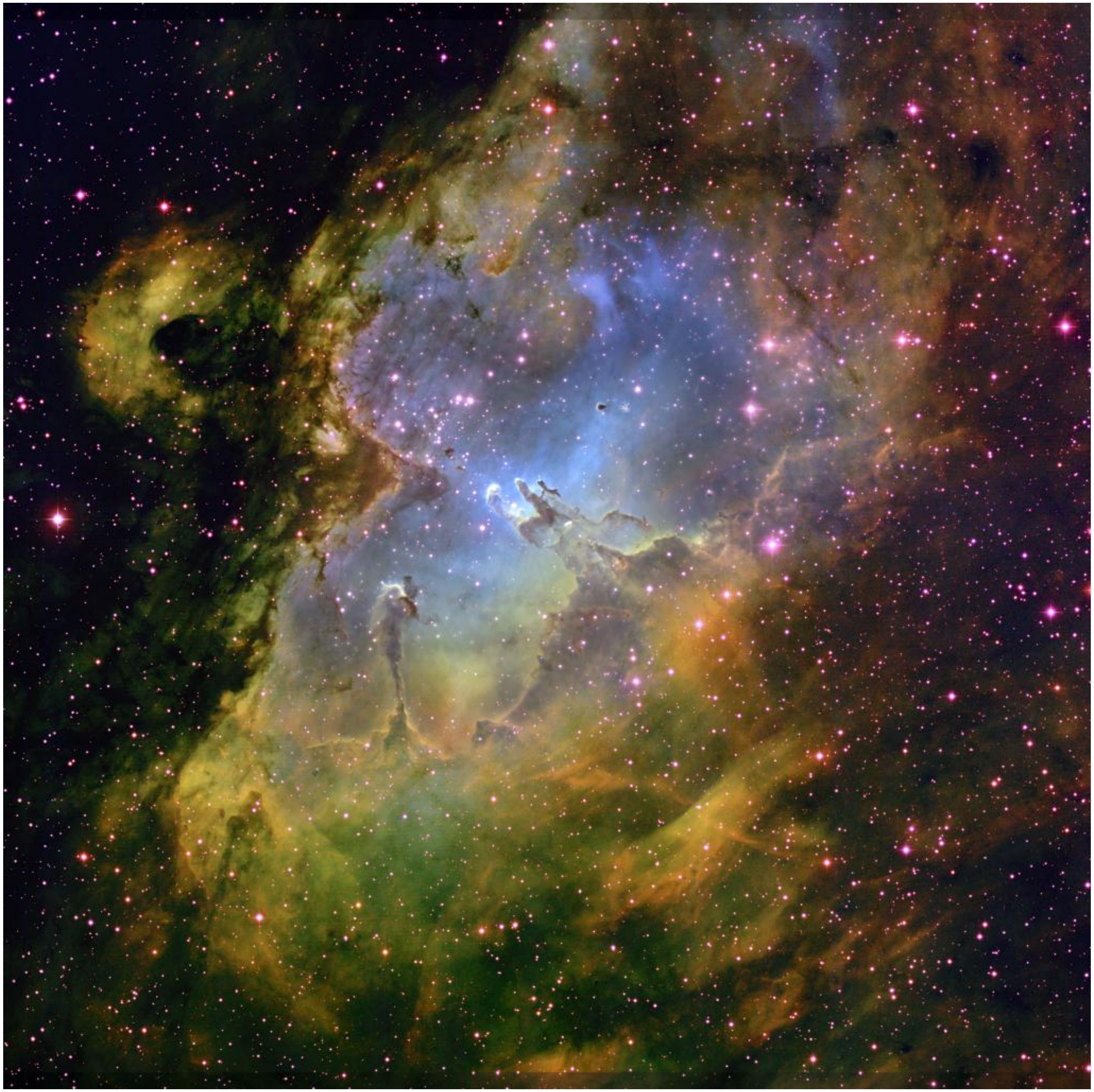
Optical – Near-IR (1 μm)– Far-IR (100 μm)

- Dust obscures optical radiation, and re-emits it at infrared wavelengths.



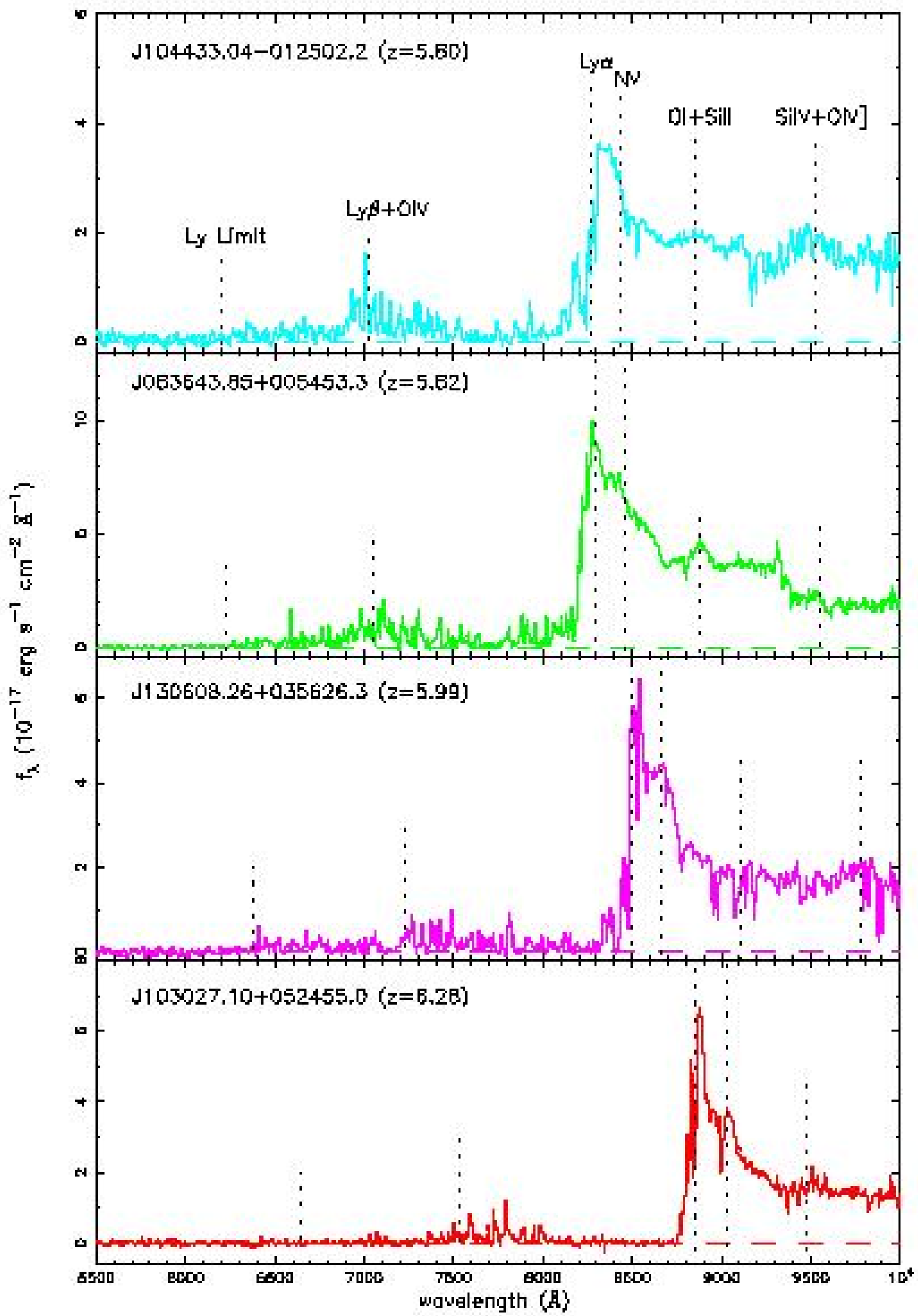


Again, an infrared view can be VERY different from optical view.



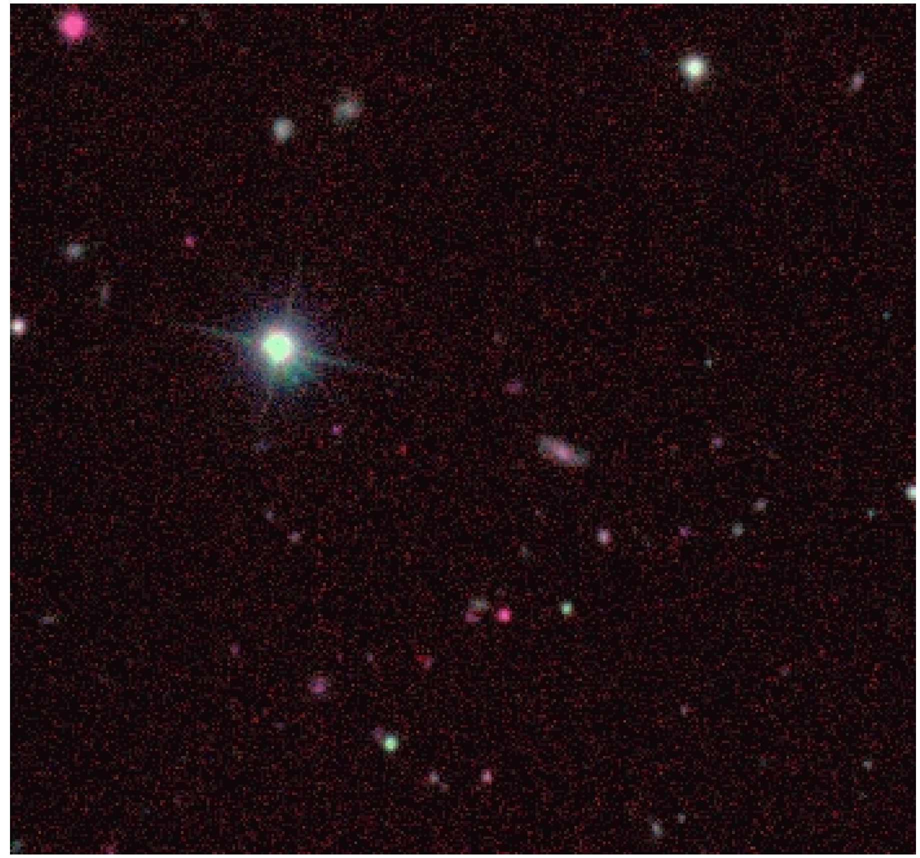
Why do astronomers care for every photon?

- Radiation from astronomical sources is NOT Planckian
  - Radiative transfer effects
  - Non-thermal processes (e.g. synchrotron emission)
- Dust Obscuration (end emission!)
- Cosmological Reddening


J104433.04−012502.2 (z=5.80)
Lyα
NV
OI+SiII
SiIV+OIV]
Lyβ+OIV
Ly Limit
J083643.85+005453.3 (z=5.82)
J130608.26+035626.3 (z=5.99)
J103027.10+052455.0 (z=6.28)
wavelength (Å)

A quasar at $z \approx 6.28$

gri



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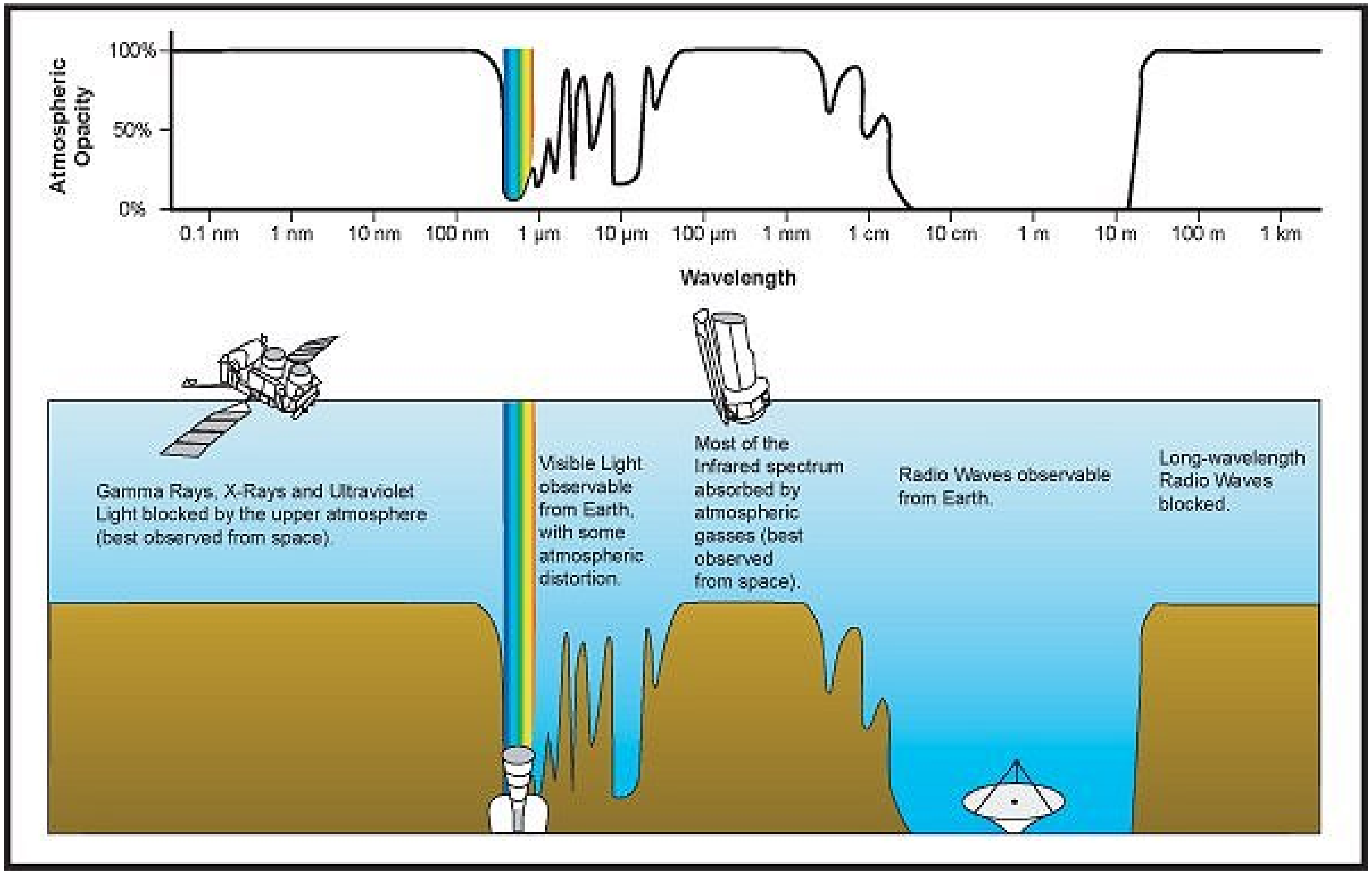
Hint: Look between the star and the galaxy, and down a little



Atmospheric water absorbs infrared radiation, except in a few 1-2 and 100 μm windows.

Can we get at least some photons at the ground level?

Yes, if you go high and dry.

Next time: sections 1.1 and 1.2!