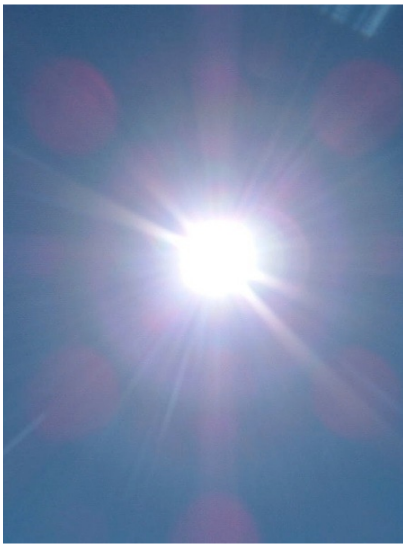
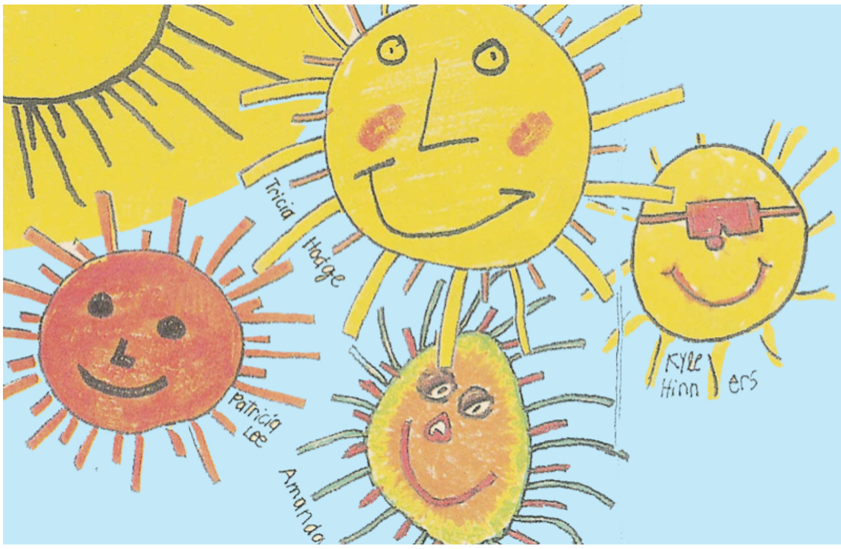
Star formation

Dr Daniel Price

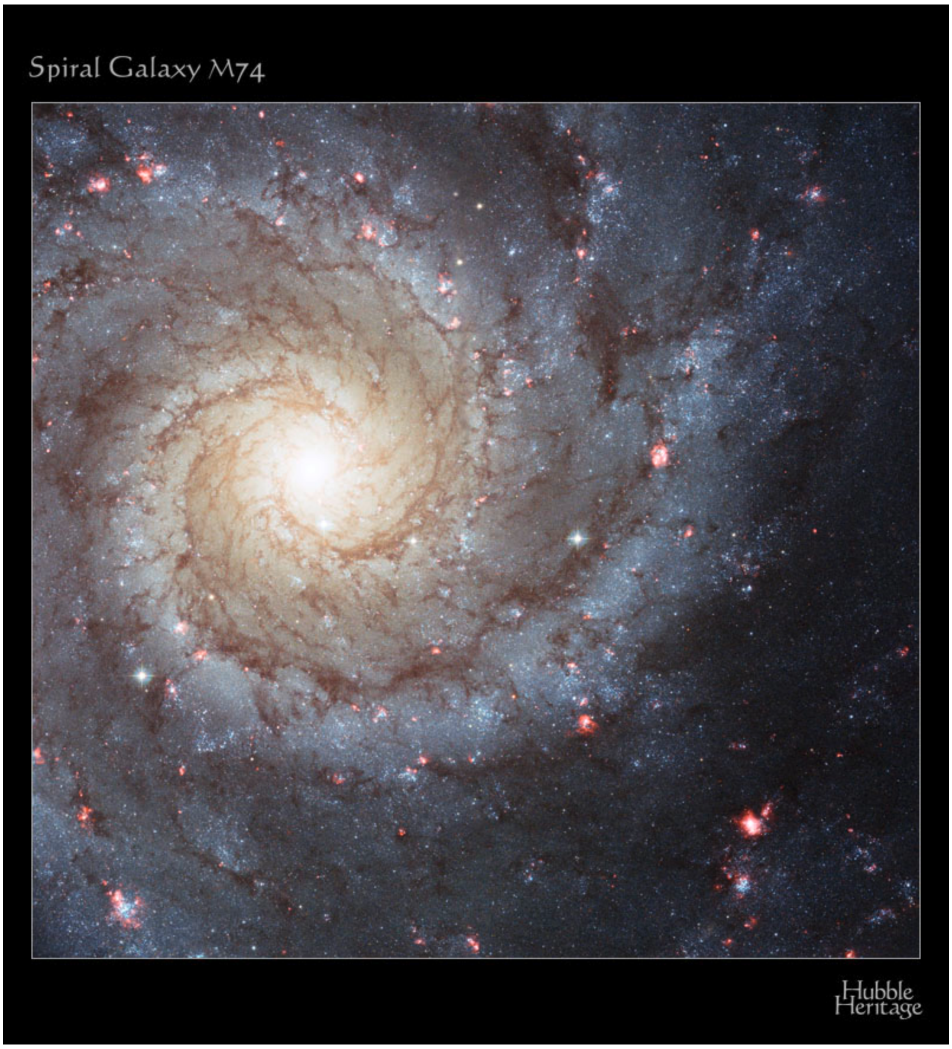
Lecture 7: Star formation intro



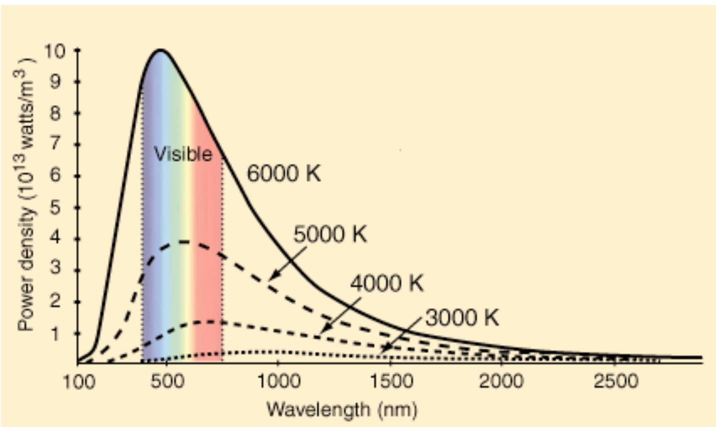


Where did the Sun come from?

What kind of stars are in this galaxy?



Blackbody spectrum (c.f. Lecture 2)



http://hyperphysics.phy-astr.gsu.edu

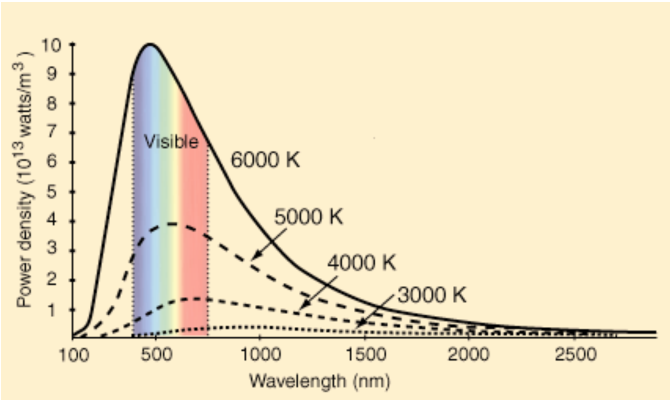
- All substances at some temperature emit thermal radiation in the form of a continuous distribution of wavelengths

Planck Function:

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\left[exp\left(\frac{h\nu}{kT}\right) - 1\right]^{-1}$$

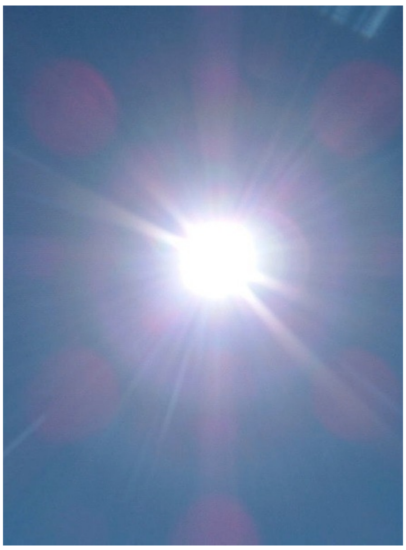
Wien's displacement law

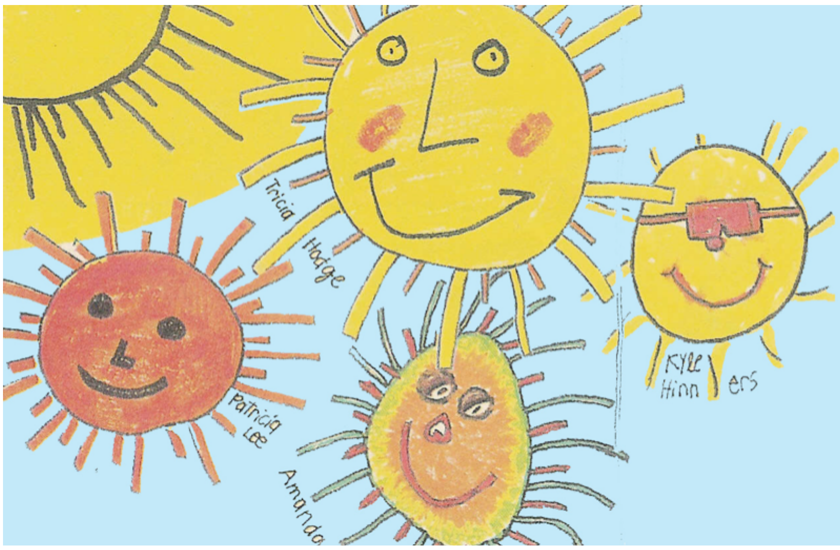
- Peak of blackbody spectrum can be related to temperature of body



$$\lambda_{max} T = b$$

$$b = const = 2.9 \times 10^6 \text{nm K}$$





What is the effective temperature of the Sun?

Hint: yellow = 580nm

$$\lambda_{max} T = b$$

$$b = const = 2.9 \times 10^6 \text{nm K}$$

Temperature of the Sun (roughly)

- 8,000K
- 10,000K
- 3,000K
- 5,000K

Luminosity = surface area x flux

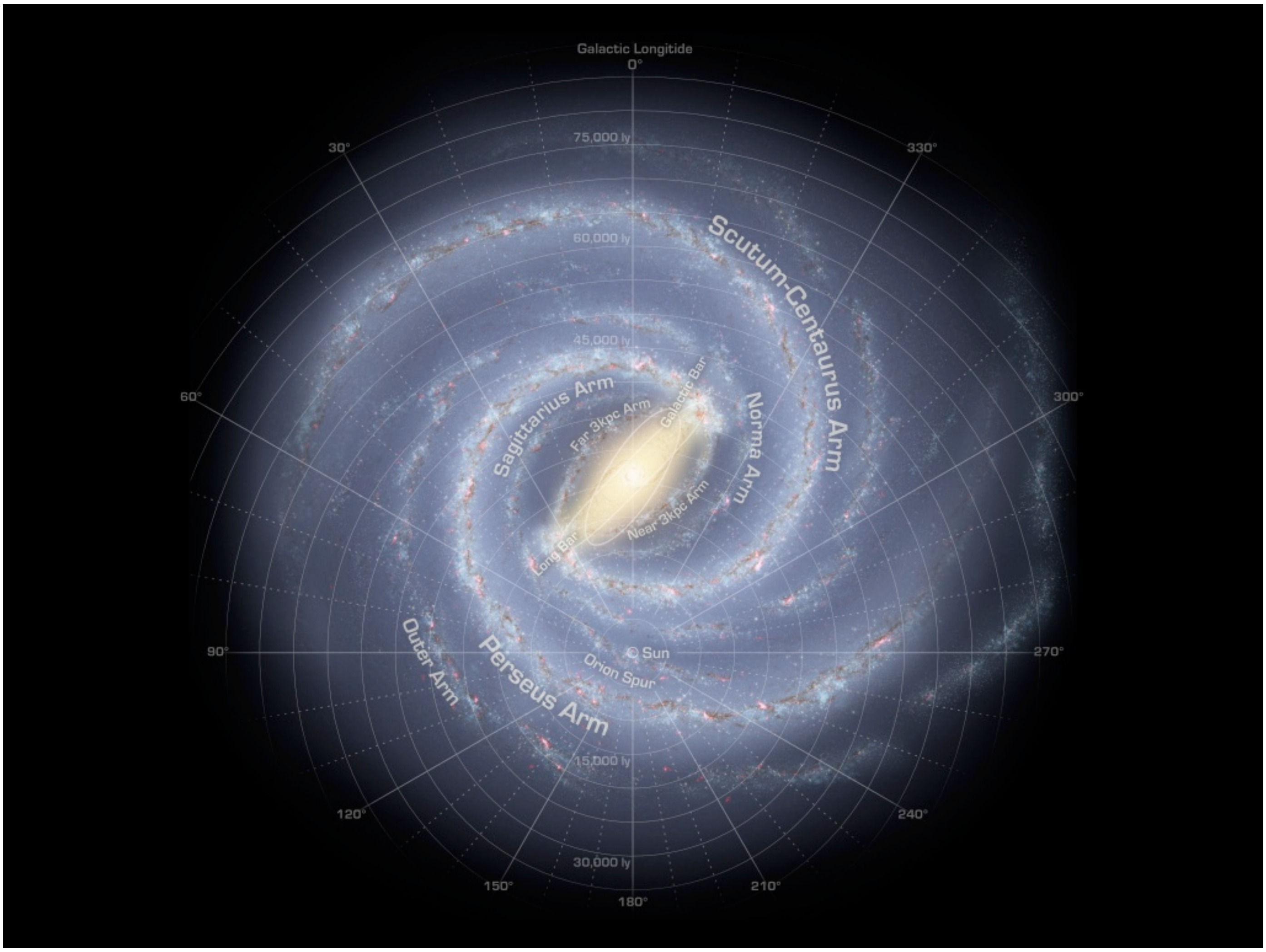
$$L = 4\pi R^2 \sigma T^4$$ for a spherical blackbody

σ = Stefan-Boltzmann constant = 5.67×10^{-5} erg cm^{-2} K^{-4} s^{-1}

Luminosity strongly dependent on T (and R)

Stellar spectral types (Harvard spectral classification)

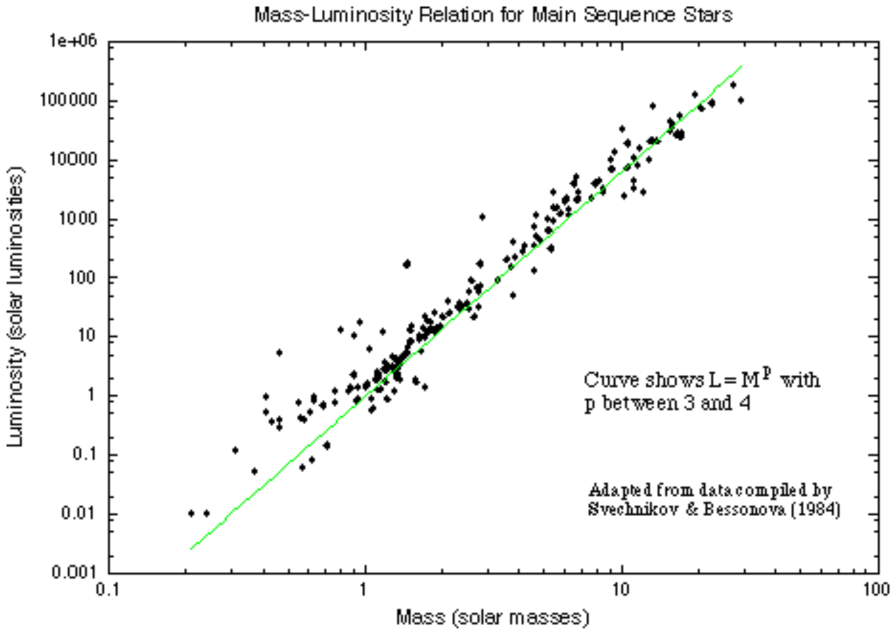
Type	Apparent colour	Temperature	Mass (Msun)	Radius (Rsun)
O	blue	> 30,000 K	> 16	> 6.6
B	blue white	10,000-30,000K	2-16	1.8-6.6
A	white	7,500K-10,000K	1.4-2	1.4-1.8
F	yellow-white	6,000-7,500K	1.04-1.4	1.15-1.4
G	yellow	5,200-6,000K	0.8-1.04	0.96-1.15
K	orange	3,700-5,200K	0.45-0.8	0.7-0.96
M	red	2,400-3,700K	0.08-0.45	< 0.7
L	red brown	1,300-2,400K	0.005-0.08	0.08-0.15
T	brown	500-1,300K	0.001-0.07	0.08-0.14
Y	dark brown	< 500K	0.0005-0.02	0.08-0.14



Lifetime of the Sun

- 10 Myr
- 10 Gyr
- 100 Myr
- 100 Gyr

Luminosity-mass relation



$$L \propto M^p$$

$$p \approx 3.5$$

blatantly nicked from Nick Strobel's Astronomy Notes: www.astronomynotes.com

Lifetime of a 10 solar mass star

- Assume available energy proportional to mass
- Luminosity = Energy consumption rate = dE/dt
- Lifetime t = E/(dE/dt)
- Work out the relative lifetime compared to the Sun

Lifetime of a 10 solar mass (B-type) star

- 300 Myr
- 10 Gyr
- 30 Myr ←
- 1 Myr

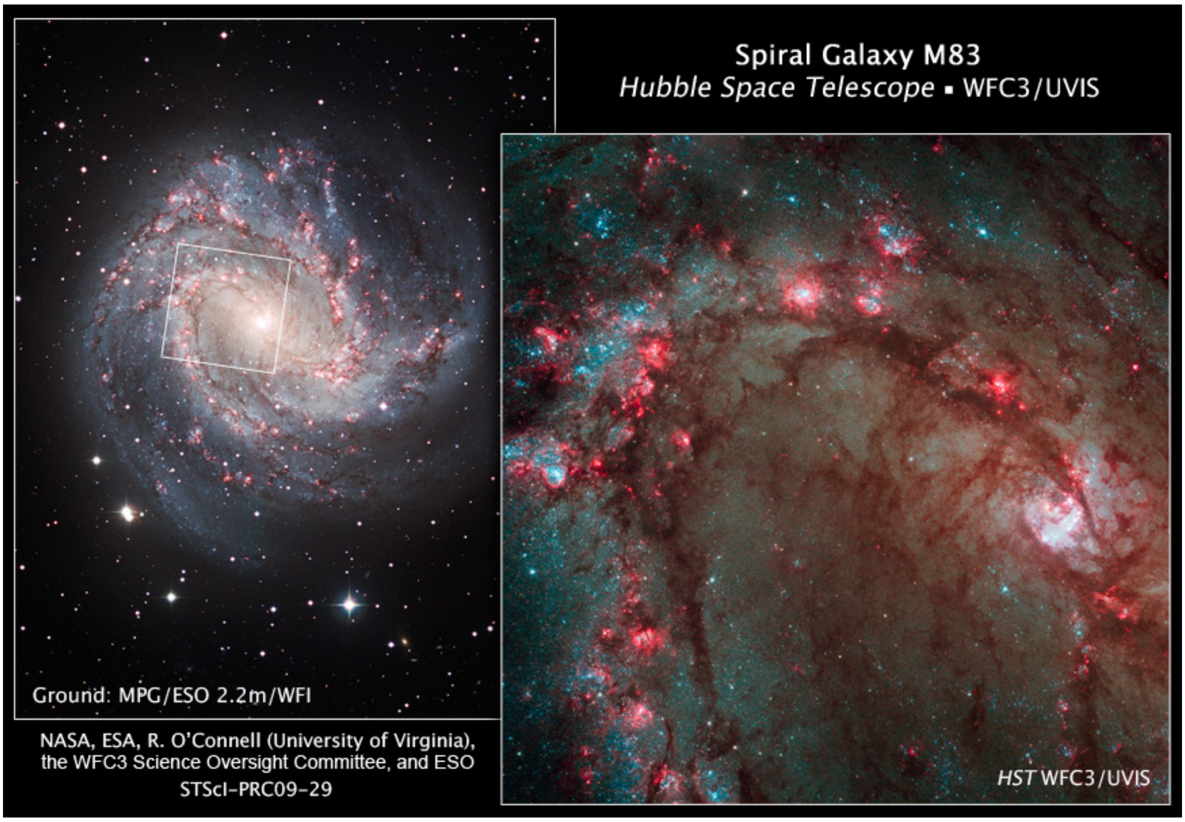
Orbital period of the Sun around the Milky Way

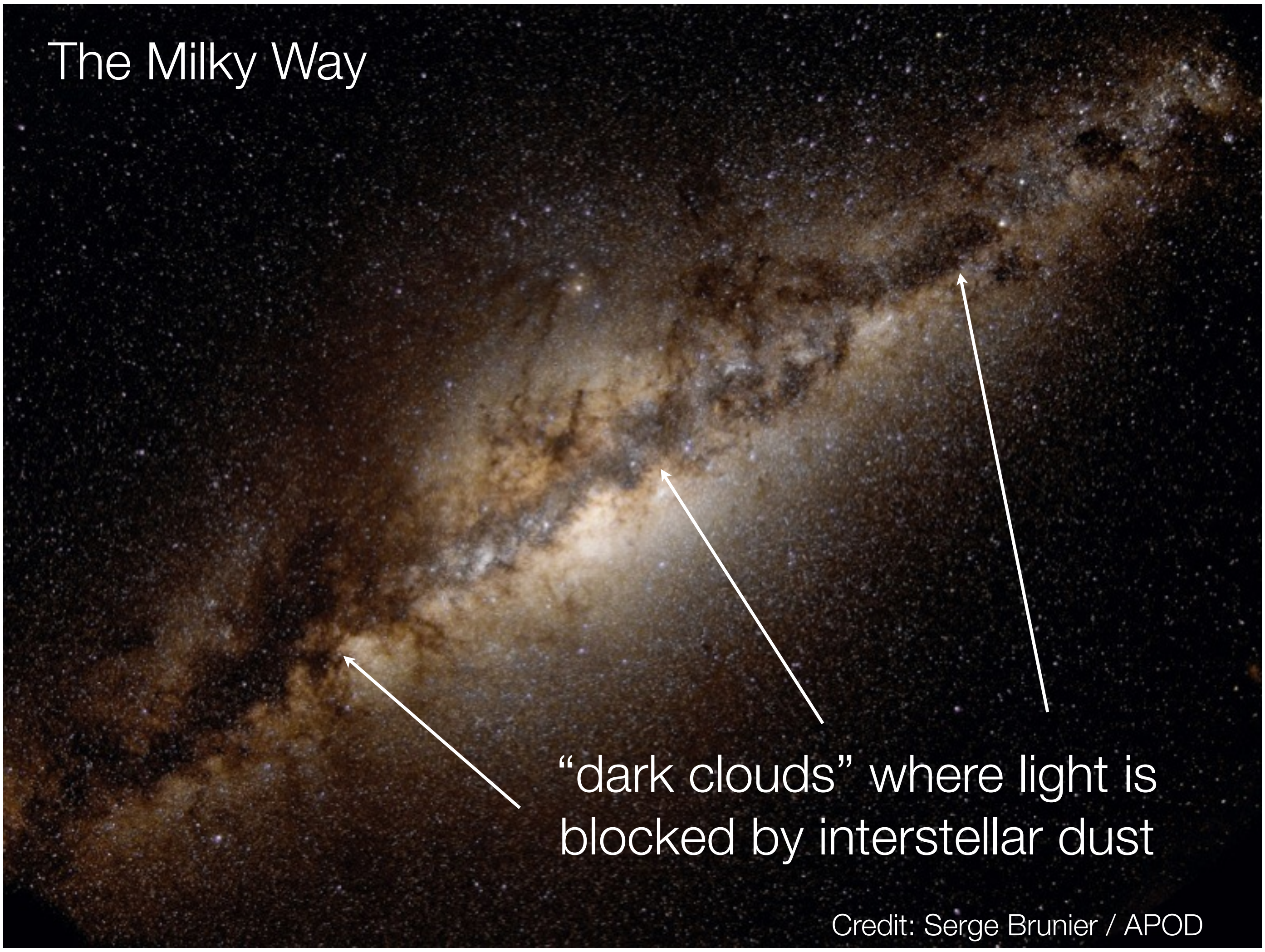
- 23 Myr
- 23,000 yr
- 230 Myr ←
- 2.3 Gyr

So where do the blue stars come from?

So where do the blue stars come from?

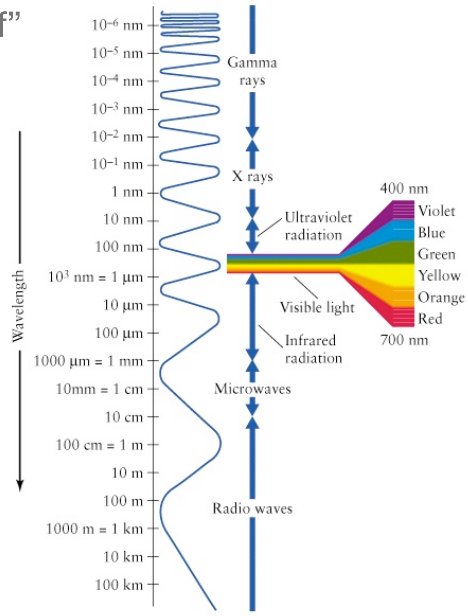
- From the Big Bang
- From merging with another galaxy
- They were born close to where they are ←
- The magical sky fairy sprinkled them there


Spiral Galaxy M83
Hubble Space Telescope ▪ WFC3/UVIS
Ground: MPG/ESO 2.2m/WFI
NASA, ESA, R. O'Connell (University of Virginia), the WFC3 Science Oversight Committee, and ESO
STScI-PRC09-29
HST WFC3/UVIS


The Milky Way
"dark clouds" where light is blocked by interstellar dust
Credit: Serge Brunier / APOD

Interstellar dust

- consists mostly of Silicon, Carbon ("household fluff" produced by stars)
- sublimates (ie. melts) at T > 1000K
- at what wavelength do we expect blackbody emission?



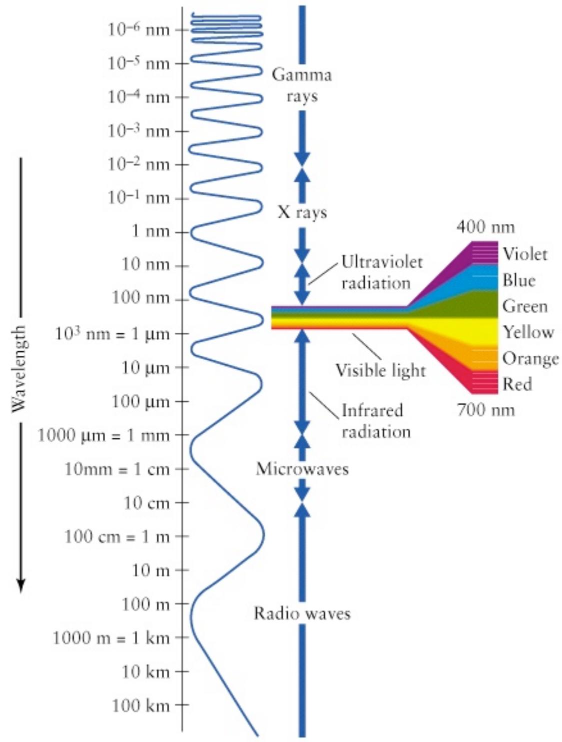
Recall:

$$\lambda_{max} T = b$$

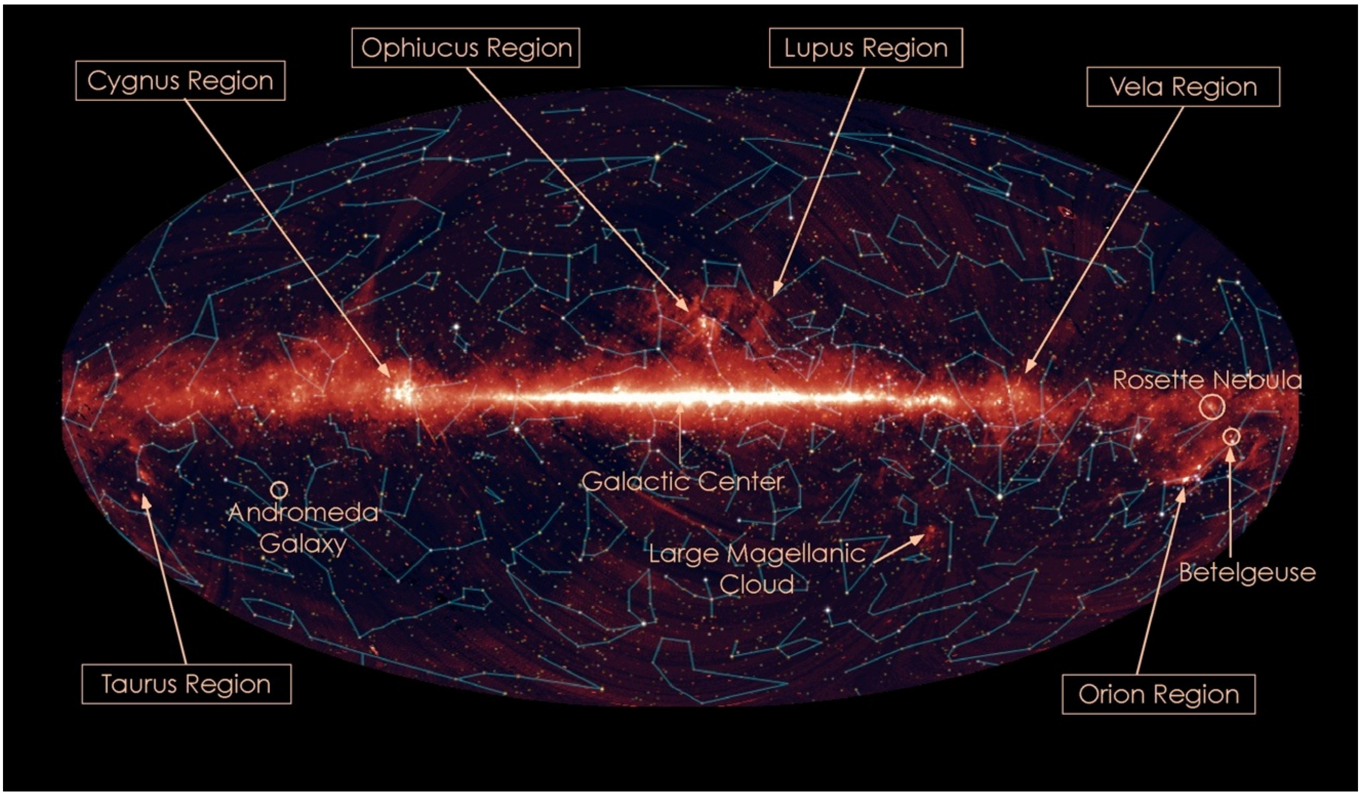
$$b = const = 2.9 \times 10^{6} \text{nm K}$$

At what wavelength do you predict emission from dust?

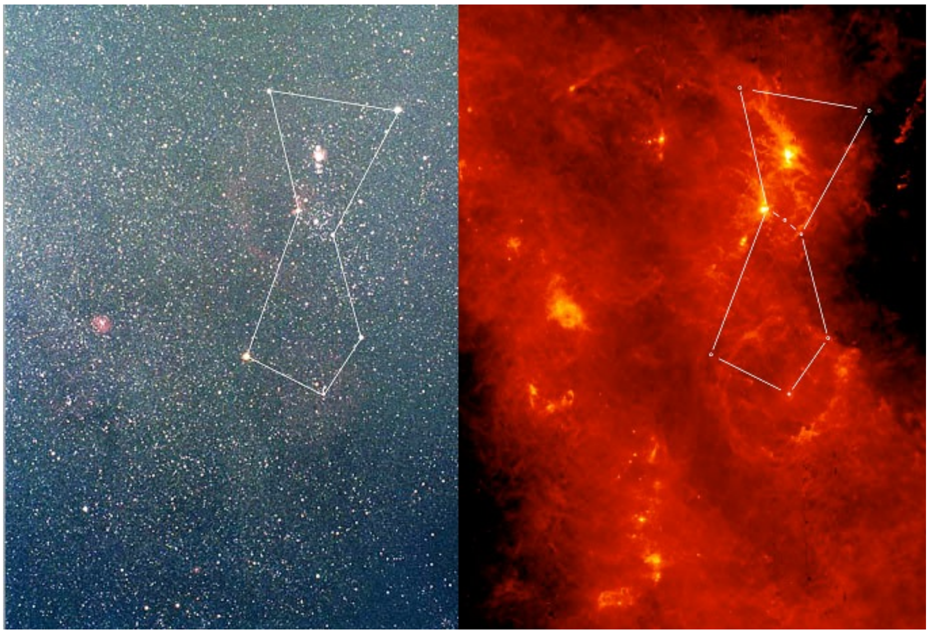
- Optical
- Infrared
- X-ray
- Microwave

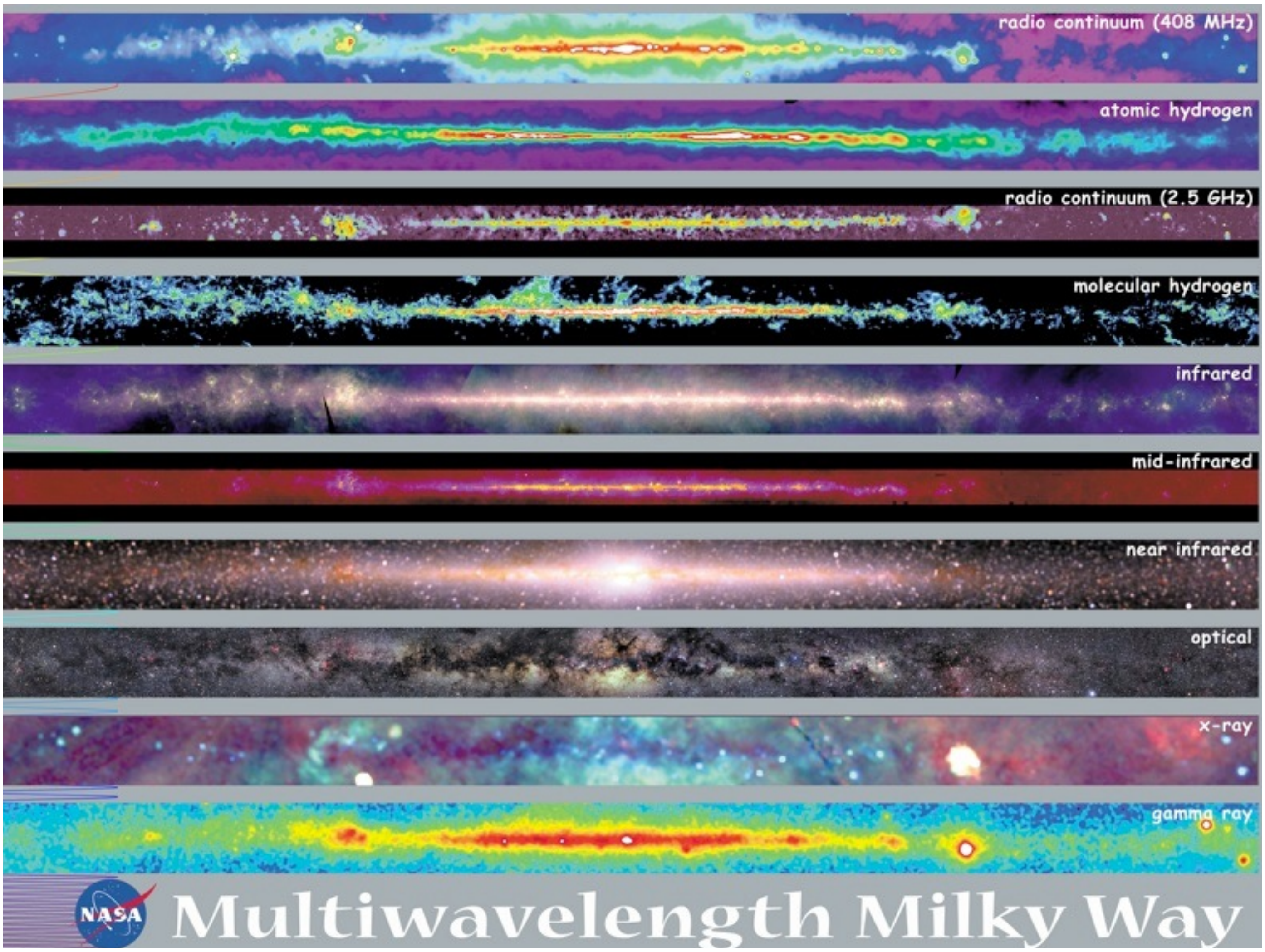


The Milky Way in Infrared



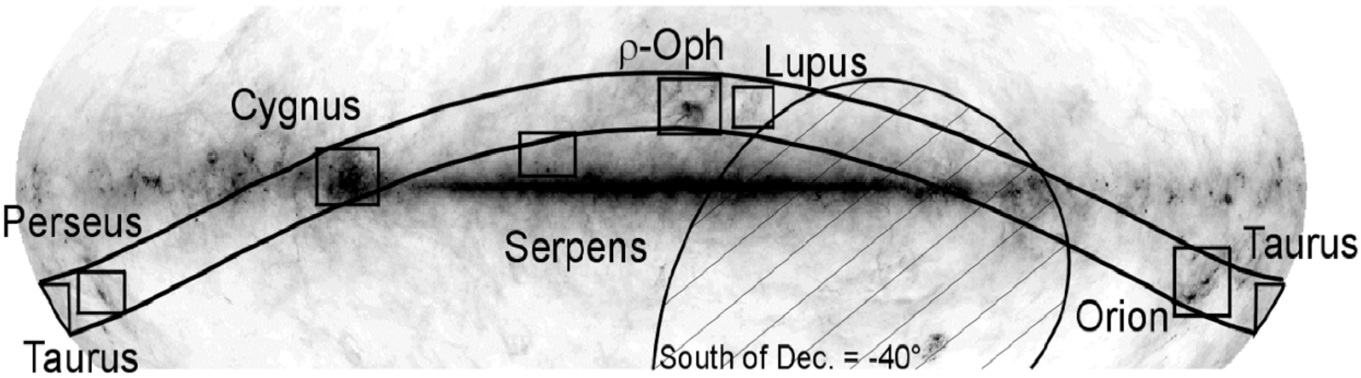
Orion





Gould's belt

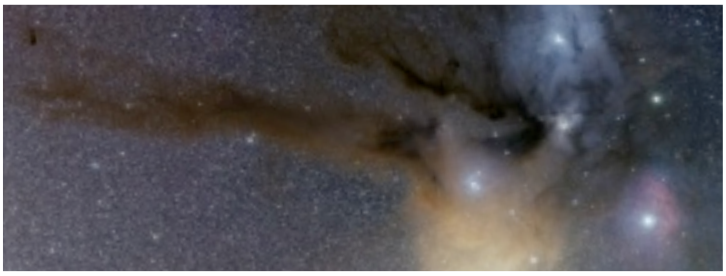
described by Benjamin Gould in 1879 as a collection of bright and massive stars that formed a ring in a projection on the sky

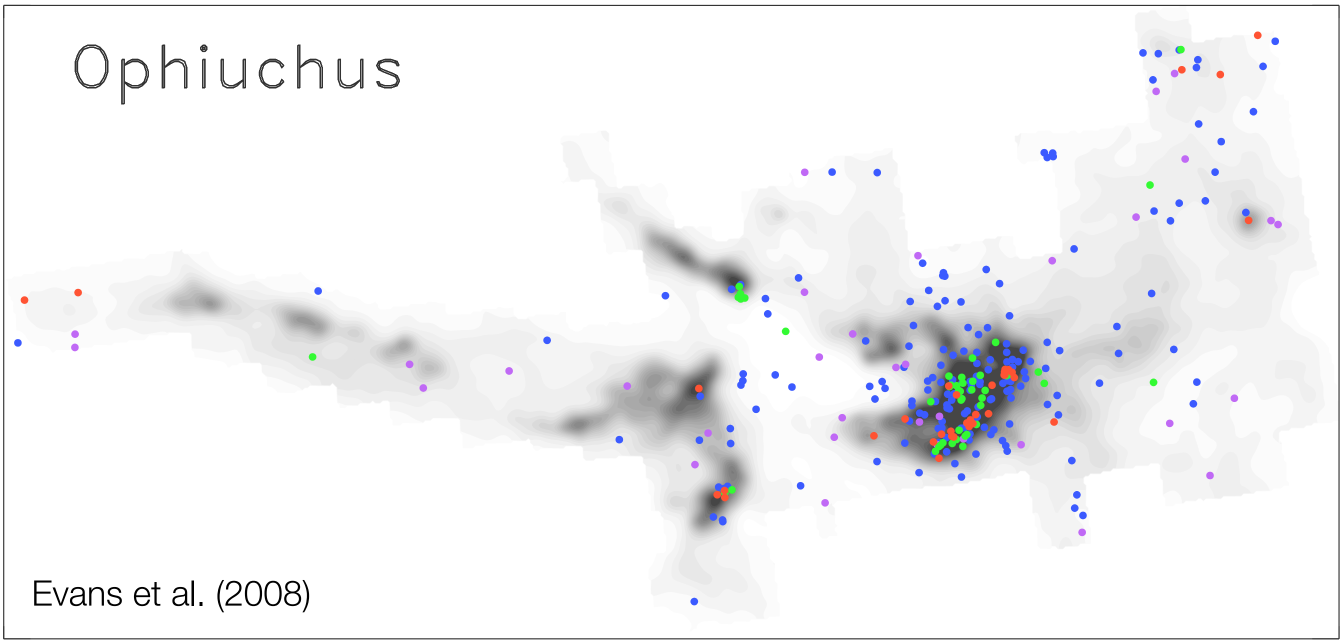


"Most star formation within 0.5 kpc lies in Gould's Belt, a ring around the sky containing star-forming molecular clouds centred on a point 200 pc from the Sun and tilted at 20 degrees to the Galactic Plane"

JMCT Gould's belt legacy survey (sub-mm): http://www.jach.hawaii.edu/JCMT/surveys/gb/

Extinction mapping





Evans et al. (2008)

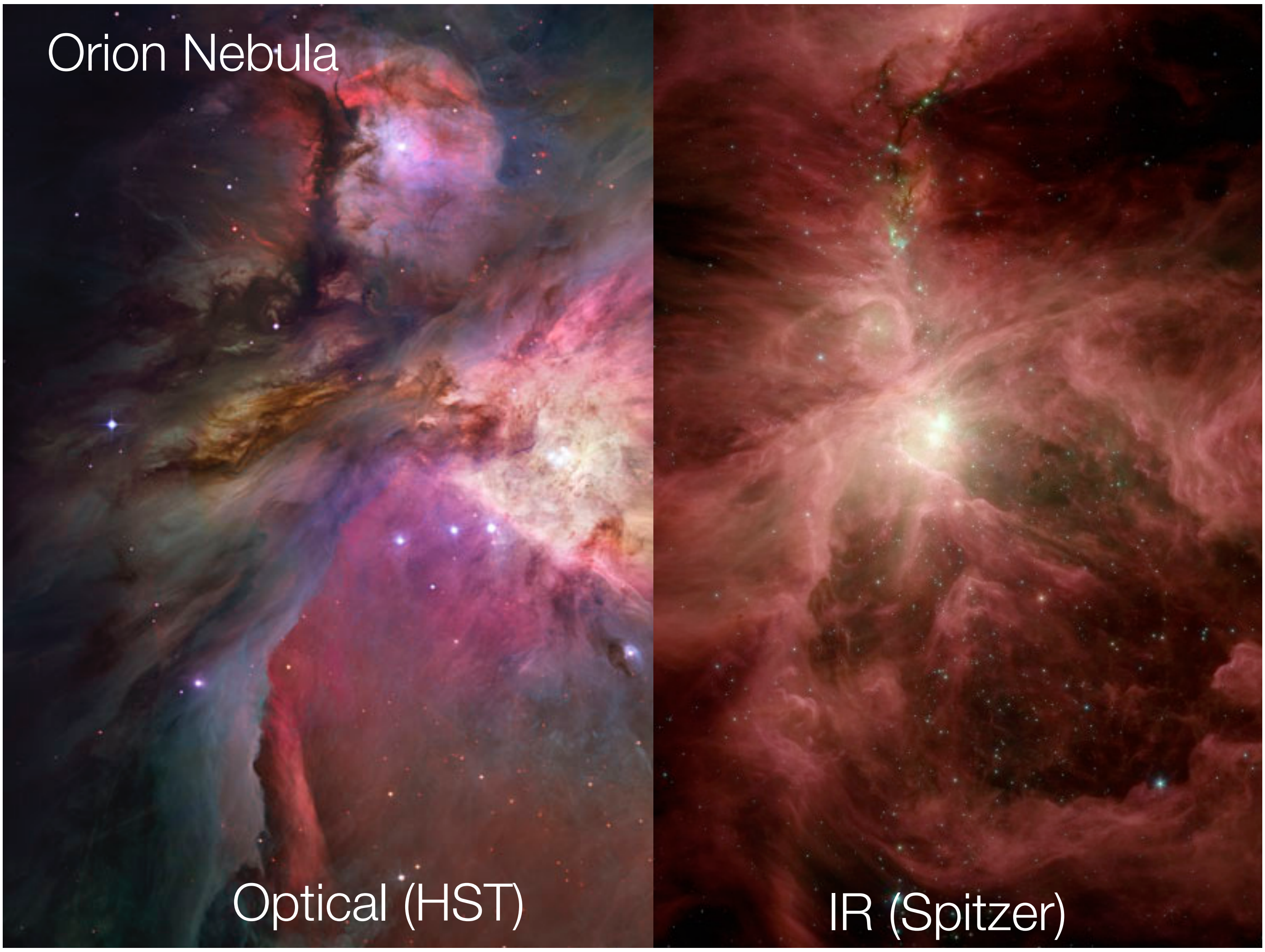
(Nearby) Molecular clouds: in numbers

TABLE 1
FACTS ABOUT CLOUDS

Evans et al. (2008)

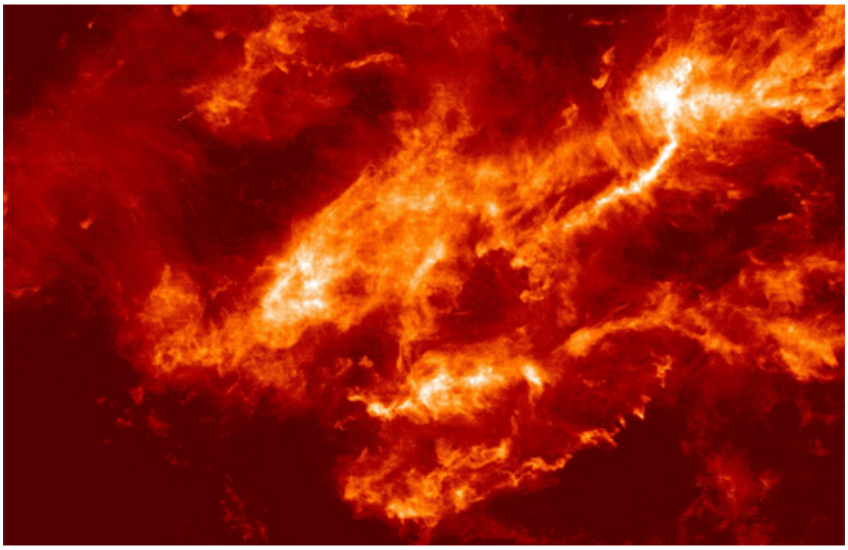
Cloud	Solid angle (deg^2)	Distance (pc)	Area (pc^2)	Δv (km s^{-1})	Mass[a] ($M_\odot$)	$\langle n \rangle$[b] (cm^{-3})	t(cross) (Myr)	Refs
Cha II	1.038	178 ± 18	10.0 ± 2.0	1.2	426 ± 86	345	3.7	1, 2
Lupus	3.101	150 ± 20[c]	28.4 ± 6.5	1.2	816 ± 188	381	4.7[d]	3, 4
Perseus	3.864	250 ± 50	73.6 ± 29.4	1.54 ± 0.11	4814 ± 1925	196	7.8	5, 6
Serpens	0.850	260 ± 10	17.5 ± 1.4	2.16 ± 0.01	2016 ± 155	707	2.7	7, 6
Ophiuchus	6.604	125 ± 25	31.4 ± 12.6	0.94 ± 0.11	2182 ± 873[e]	318	8.4	8, 6
Total	15.457	...	160.9 ± 51.9	...	10254 ± 3228	389	...	

- mostly consist of molecular hydrogen, but also other molecules e.g. carbon monoxide, ammonia, NH_3, methanol, water.
- size ~ 0.1pc - 100pc (0.3ly - 300ly)
- density ~ 10^3 -10^4 particles/cm^3 ~ 10^{-21}-10^{-20} g/cm^3
- size + density implies mass ~ 10 to 10^6 Msun
- temperature ~ 10K
- lifetime? (1 million - 10 million yrs)
- formation?



Taurus Molecular Cloud

T-Tauri and surrounds (optical)
credit: NOAO



Taurus molecular cloud in ^{12}CO emission
Goldsmith, Heyer, Narayanan, Snell, Li & Brunt (2008)

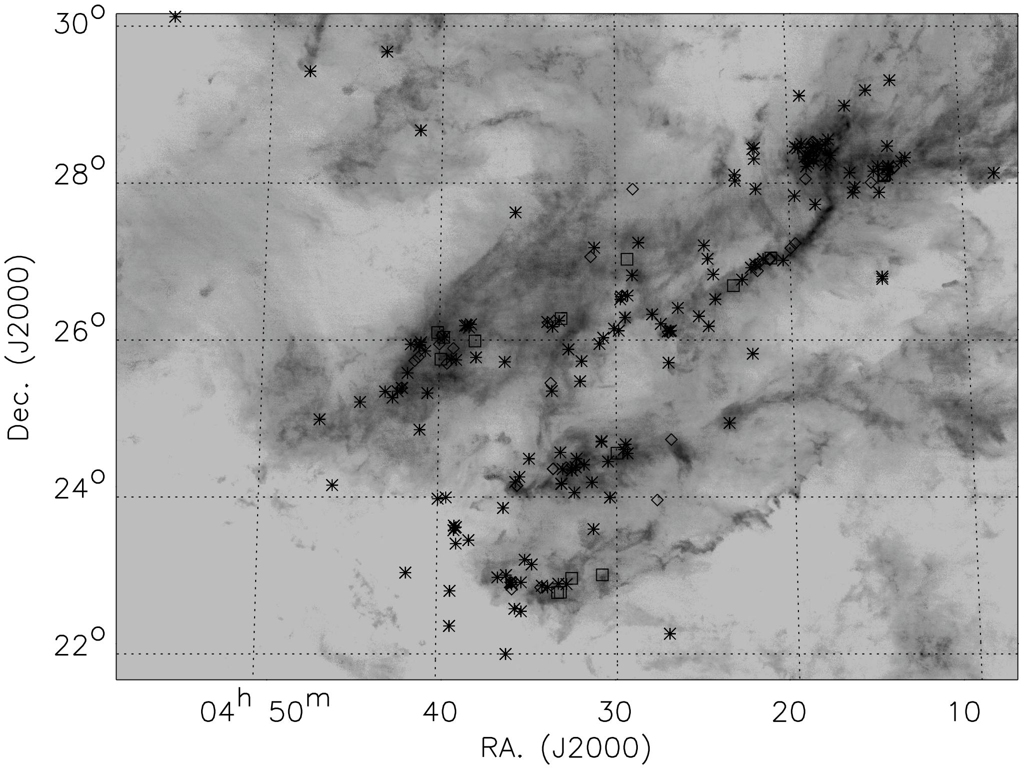
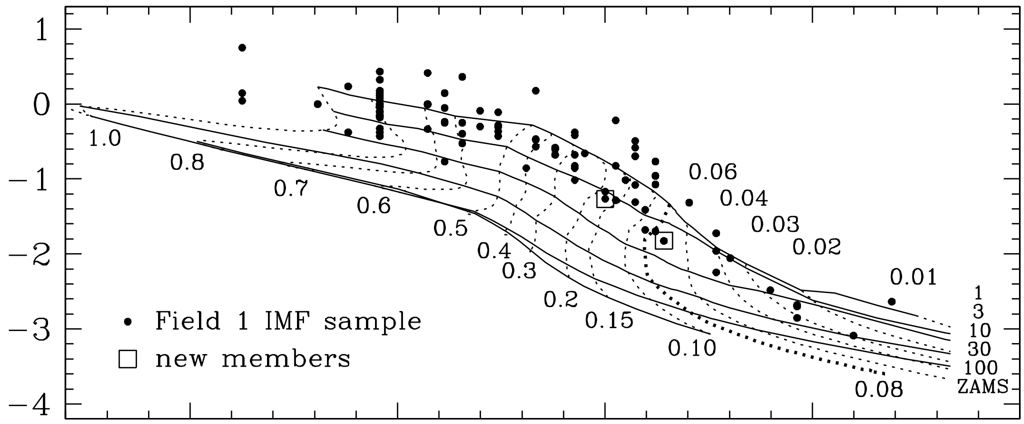


Fig. 14.— Locations of young stars in Taurus superimposed on map of the H_2 column density. The stellar positions are from Kenyon (2007). The diamonds indicate diffuse or extended sources (of which there are 44 in the region mapped), the squares indicate Class I or younger stars (18), and the asterisks indicate T-Tauri stars (168). It is evident that the diffuse and younger sources are almost without exception coincident with regions of relatively large column density, while the older stars show a much larger probability of being found in regions of lower column density.

Hertzsprung-Russell diagram (for Taurus MC)

log Luminosity

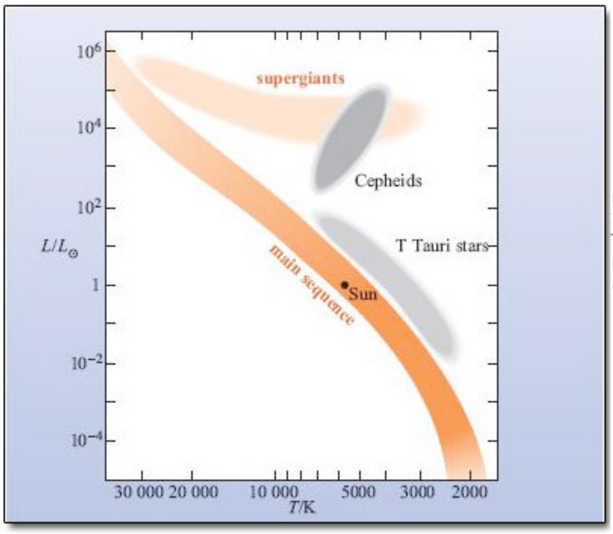


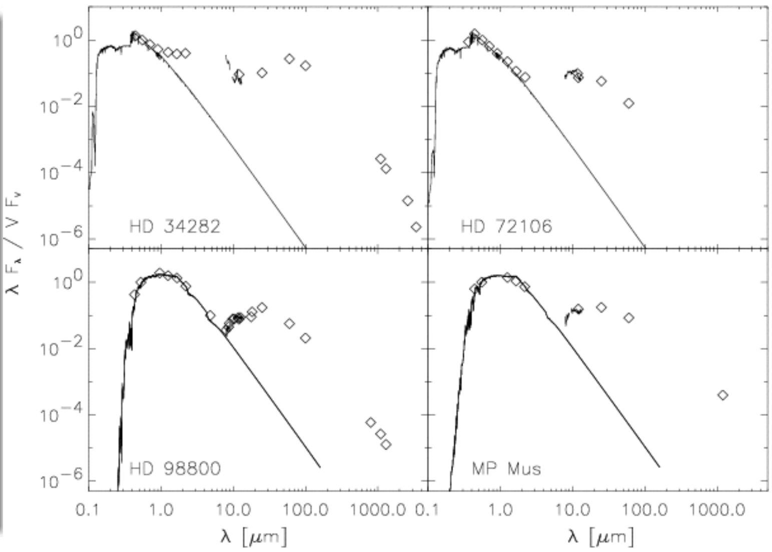
← log Temperature

Why do young stars lie above the main sequence?

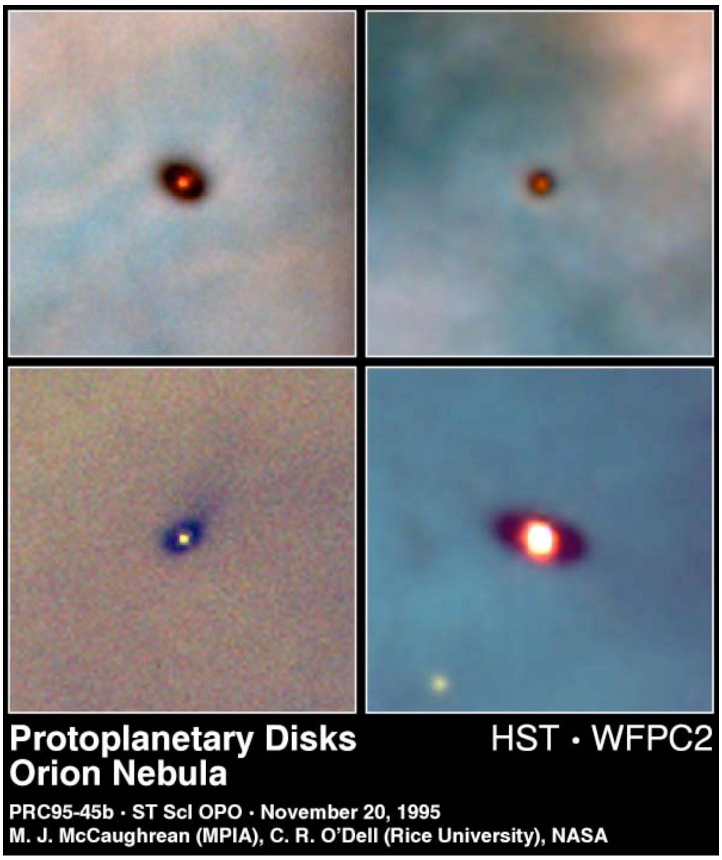
- They are hotter than main sequence stars
- They are bigger than main sequence stars
- They are cooler than main sequence stars
- They are smaller than main sequence stars

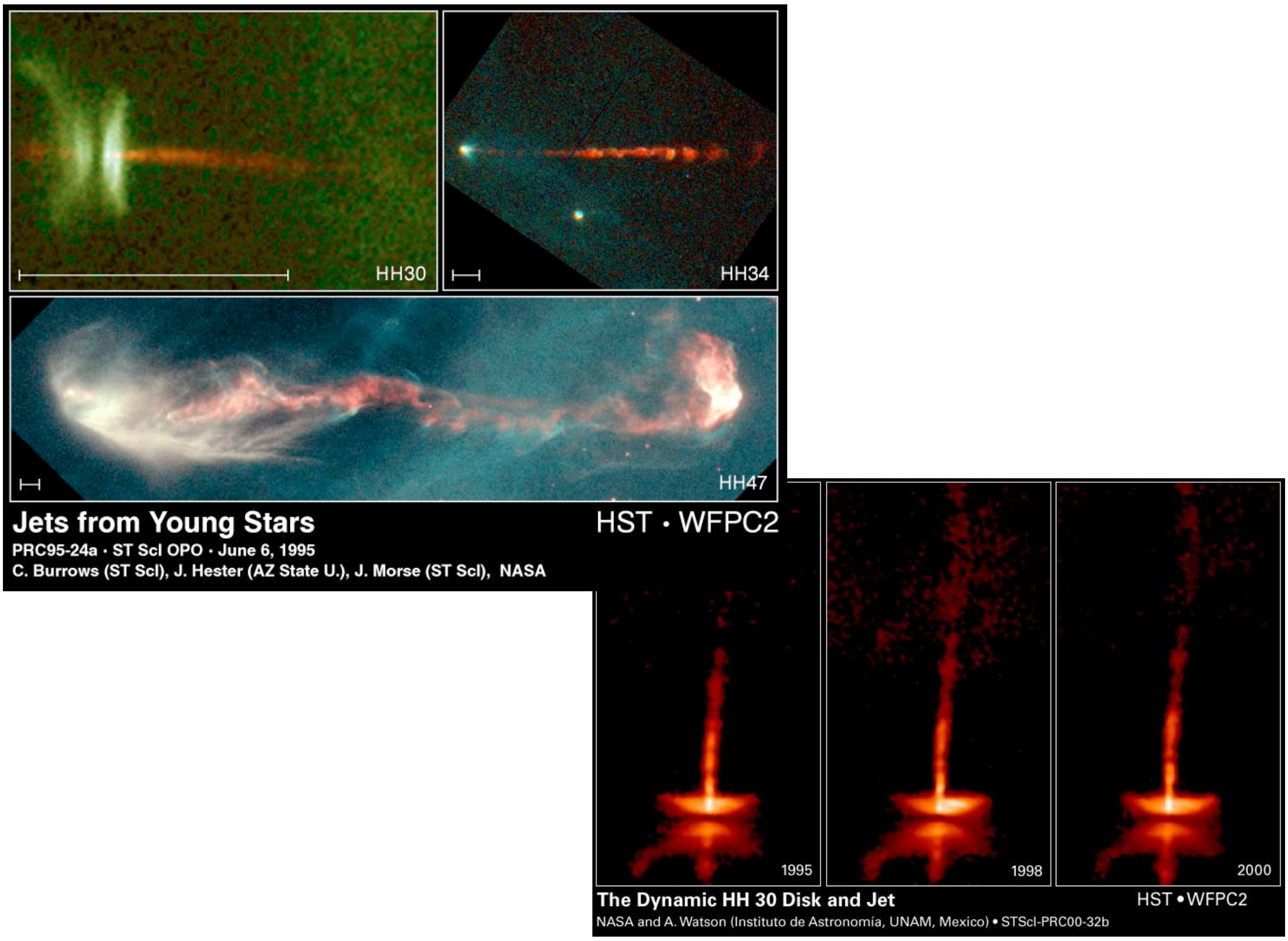
T-Tauri stars





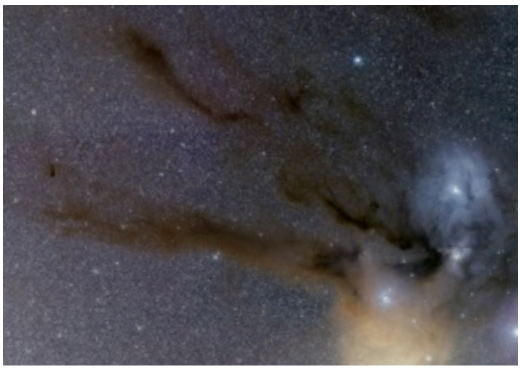
Why is there a “bump” on top
of the blackbody curve?





Molecular cloud appearance and structure is strongly dependent on mass of stars formed

Taurus



Ophiuchus

Orion

most massive star ~ 1 M_{Sun}

most massive star ~ 3 M_{Sun}

most massive stars ~ 15-30 M_{Sun}