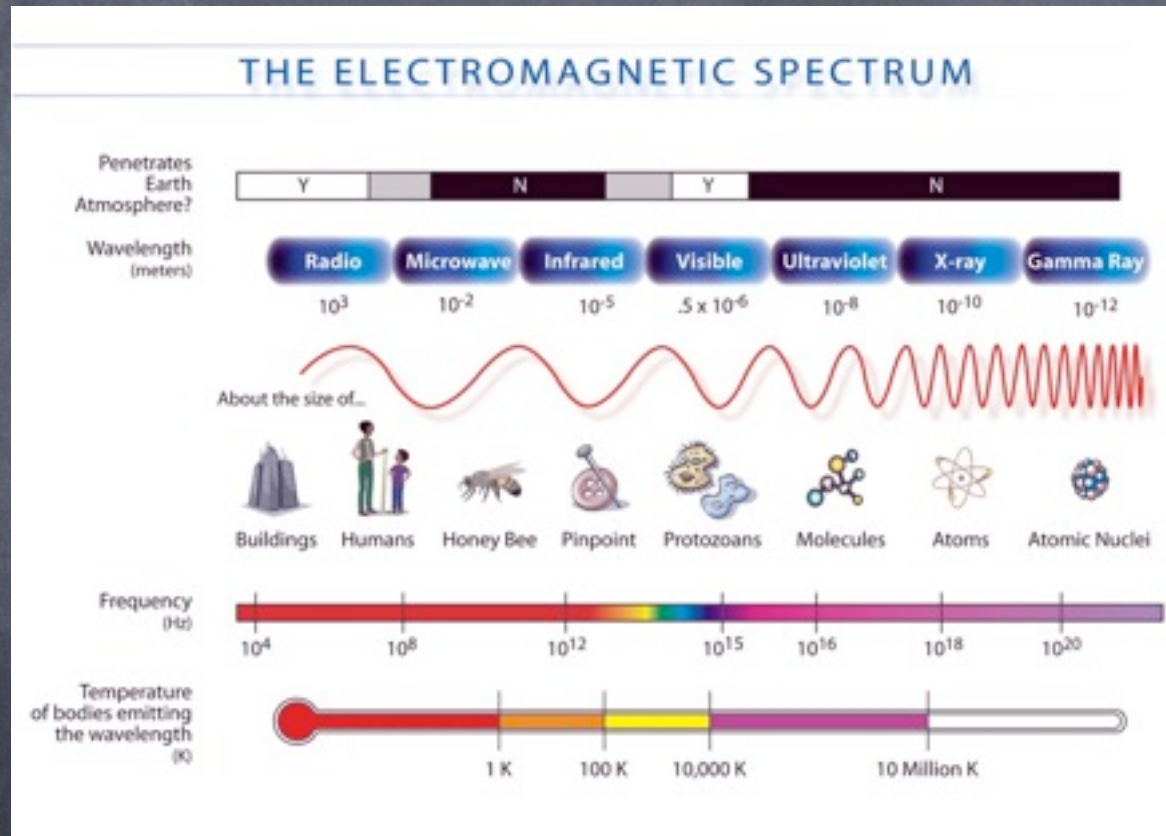


# Multiwavelength Astronomy



NASA



# Thermal Emission

Type of Radiation	Wavelength Range (nanometers [ $10^{-9}$ m])	Radiated by Objects at this Temperature	Typical Sources
Gamma rays	Less than 0.01	More than $10^8$ K	Few astronomical sources this hot; some gamma rays produced in nuclear reactions
X-rays	0.01 - 20	$10^6$ - $10^8$ K	Gas in clusters of galaxies; supernova remnants, solar corona
Ultraviolet	20 - 400	$10^5$ - $10^6$ K	Supernova remnants, very hot stars
Visible	400 - 700	$10^3$ - $10^5$ K	Exterior of stars
Infrared	$10^3$ - $10^6$	10 - $10^3$ K	Cool clouds of dust and gas; planets, satellites
Radio	More than $10^6$	Less than 10 K	Dark dust clouds



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Non-thermal

p-p collisions,  
IC, brems.

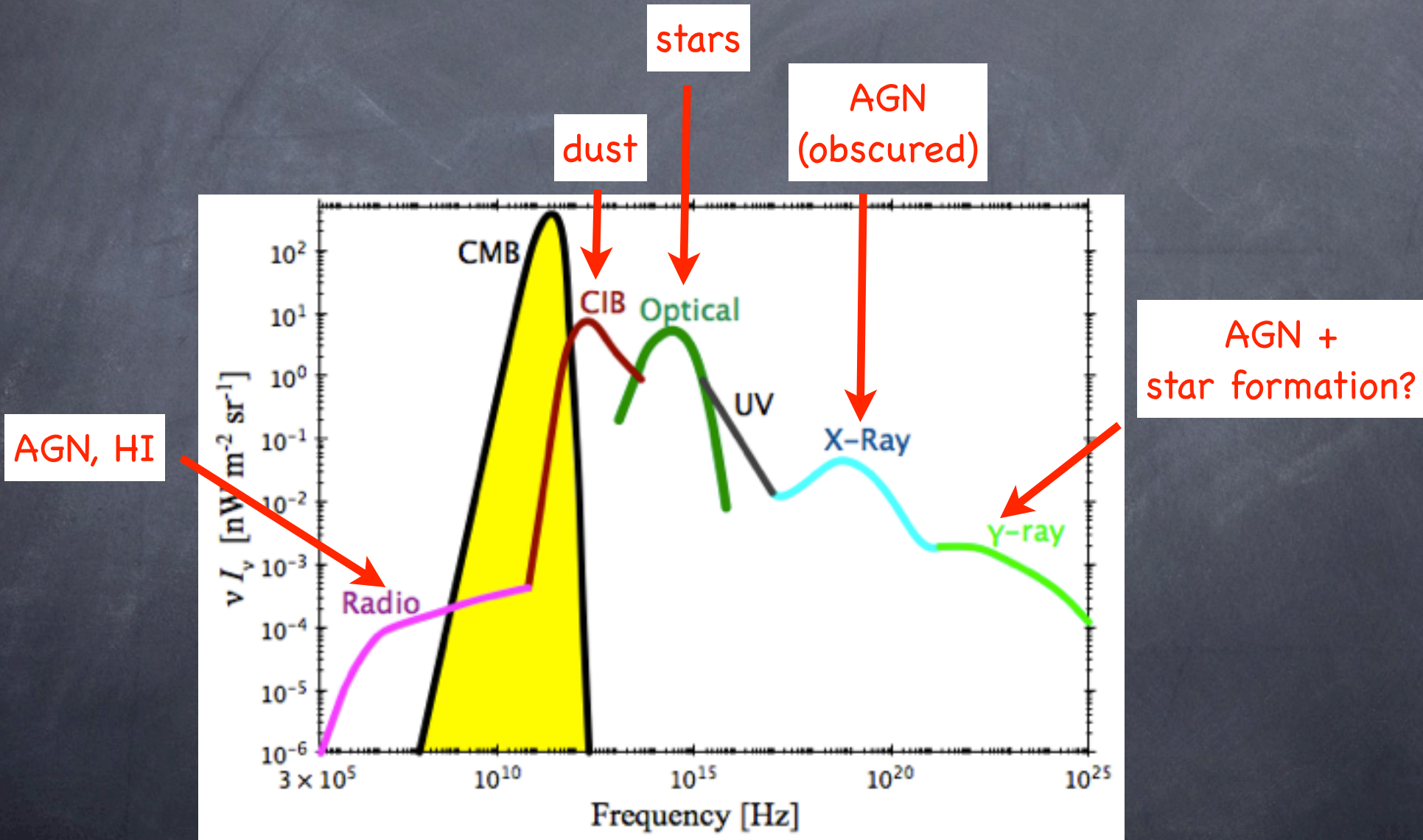
IC, synchrotron

synchrotron (e.g.  
AGN jets)

synchrotron



# Multiwavelength Cosmos





# Centaurus A – Peculiar Galaxy

Distance: 11,000,000 ly light-years (3.4 Mpc)

Image Size = 15 x 14 arcmin

Visual Magnitude = 7.0



gamma-ray:  
Fermi



X-Ray: Chandra



Ultraviolet: GALEX



Visible: DSS



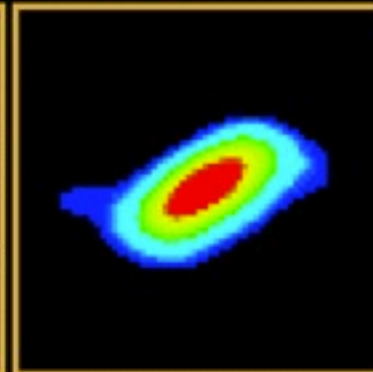
Visible: Color ©AAO



Near-Infrared: 2MASS



Mid-Infrared: Spitzer



Far-Infrared: IRAS



Radio: VLA

NASA's Cool Cosmos site

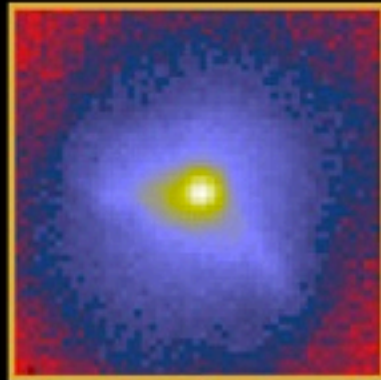
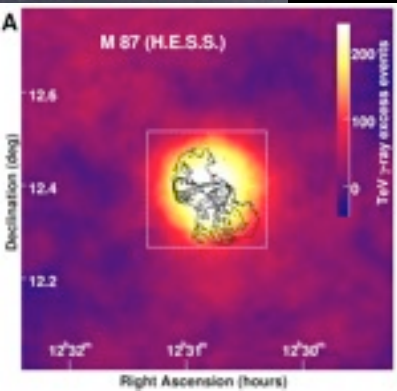


# M87 – Giant Elliptical Galaxy

Distance: 6,000,000 light-years (18 Mpc)

Image Size = 13 x 13 arcmin

Visual Magnitude = 8.6



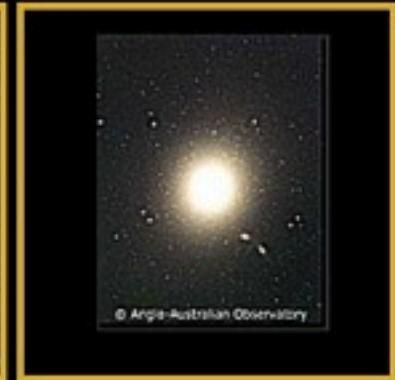
X-Ray: ROSAT



Ultraviolet



Visible: DSS

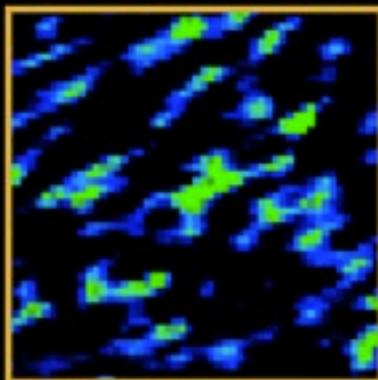


Visible: Color © AAO

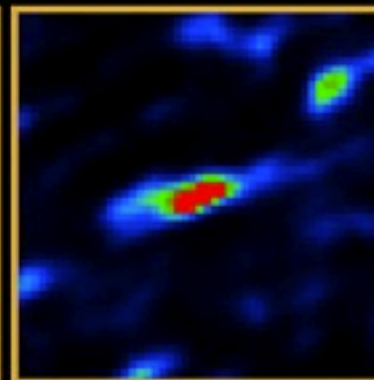
gamma-ray:  
HESS



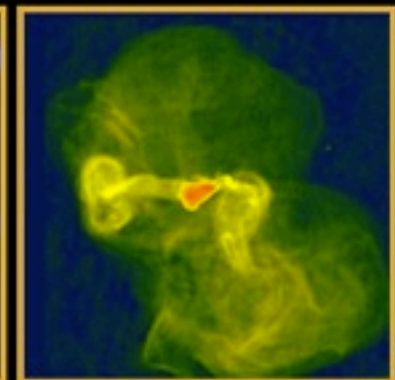
Near-Infrared: 2MASS



Mid-Infrared: IRAS



Far-Infrared: IRAS



Radio: NRAO

NASA's Cool Cosmos site

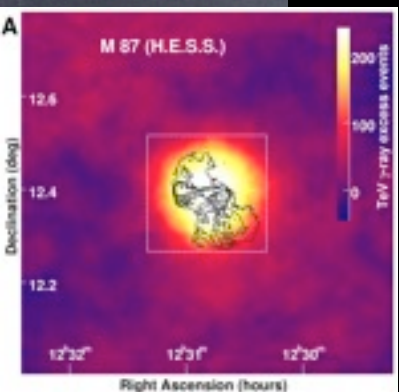


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Distance: 6,000,000 light-years (18 Mpc)

Image Size = 13 x 13 arcmin

Visual Magnitude = 8.6



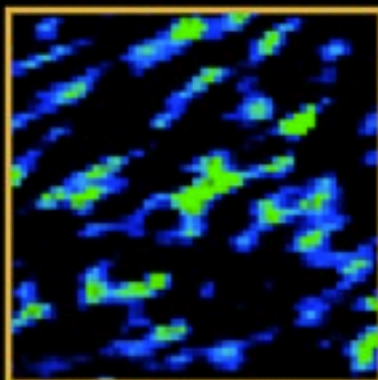
gamma-ray:  
HESS

Chandra

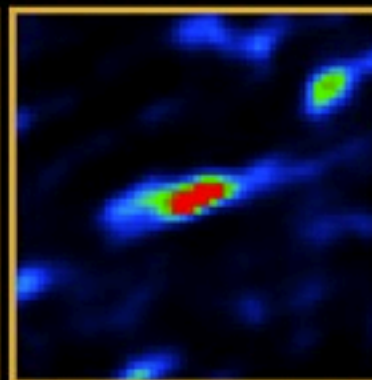
Ultraviolet Image  
Not Available



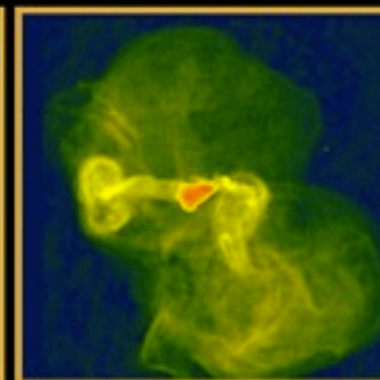
Near-Infrared: 2MASS



Mid-Infrared: IRAS



Far-Infrared: IRAS



Radio: NRAO

NASA's Cool Cosmos site

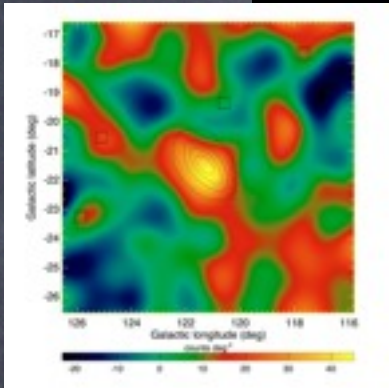


# M31 – The Andromeda Galaxy

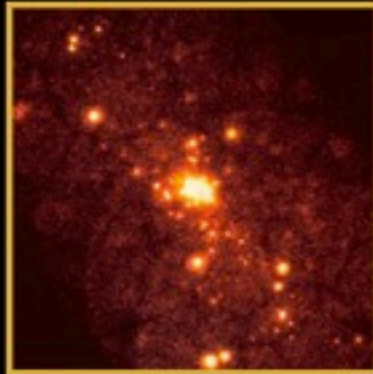
Distance: 2,900,000 light-years (900 kpc)

Image Size = 2.5 x 2.5 degrees

Visual Magnitude = 3.4



gamma-ray:  
Fermi



X-Ray: ROSAT



Ultraviolet: GALEX



Visible: DSS



Visible: © Jason Ware



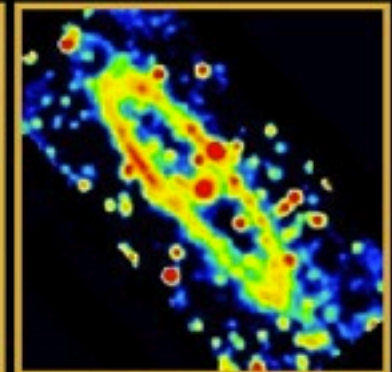
Mid-Infrared: IRAS



Mid-Infrared: Spitzer



Far-Infrared: ISO



Radio: Effelsberg

NASA's Cool Cosmos site

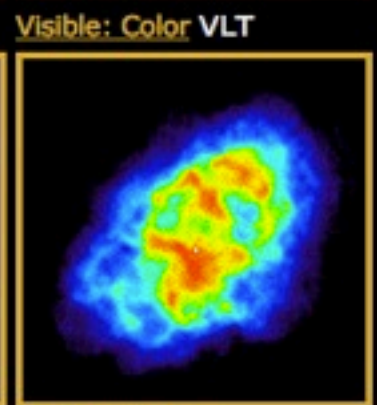
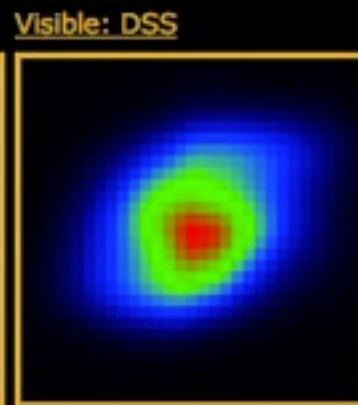
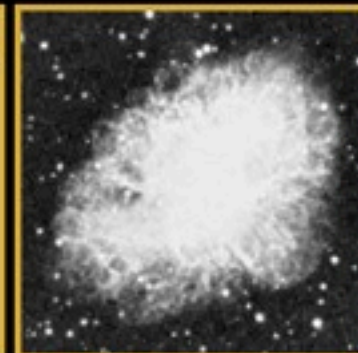
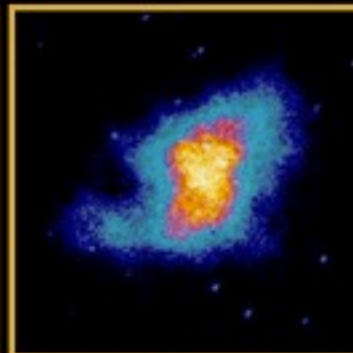
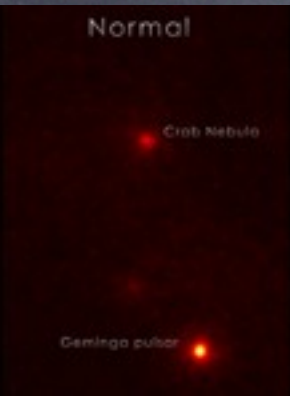


# M1 – The Crab Nebula

Distance: 6300 light-years (1.9 kpc)

Image Size = 6.5 x 6.5 arcmin

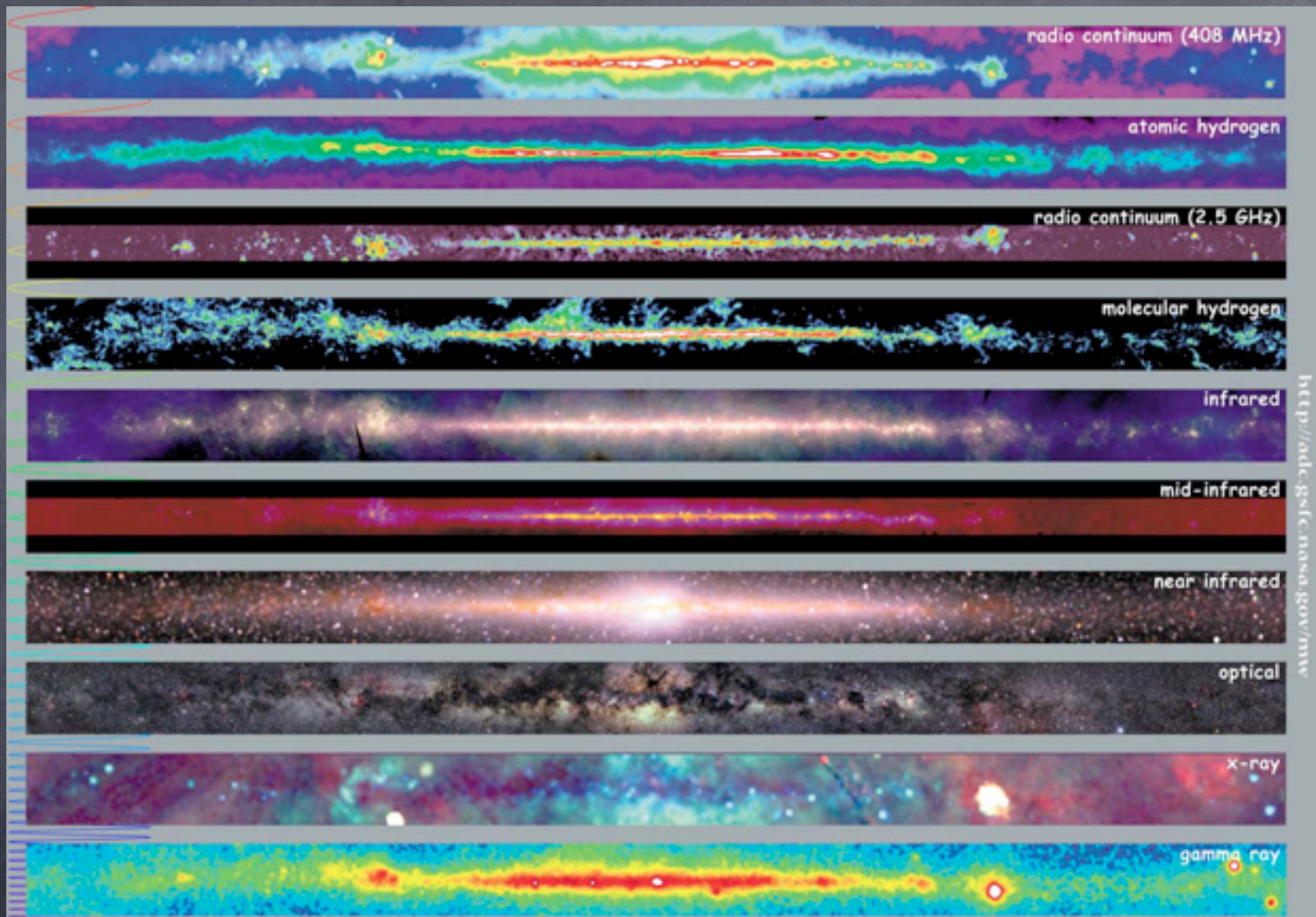
Visual Magnitude = 8.4



gamma-ray:  
Fermi

NASA's Cool Cosmos site





<http://adc.gsfc.nasa.gov/mw>



# Multiwavelength Milky Way



# Low(ish) Energy

	UV	Optical	IR	Radio/ Microwave
sources of emission	massive stars, WHIM, Ly $\alpha$	many	dust, cool objects, molecules	AGN, pulsars, SNR, cold gas (HI, CO), CMB, clusters
detectors	microchannel plates	CCDs	HgCdTe etc. arrays, bolometers	Heterodyne receivers, bolometers
major telescopes	GALEX, HST	many	Spitzer, Herschel, ground	VLA, VLBI, Arecibo, GBT, Planck, etc.



# Low(ish) Energy

	UV	Optical	IR	Radio/ Microwave
optics	similar to optical	reflectors of varying design	similar to optical	reflecting dish, antenna
best spatial resolution	0.04"	0.04"	0.05" (near), 1" (mid)	a few milliarcsecs



# High Energy

	X-ray	Hard X-ray	Gamma-ray ~GeV	Gamma-ray ~TeV
sources of emission	AGN, clusters, SNR, binaries, stars	AGN (obscured), shocks, similar to soft X-ray	AGN, pulsars, SNR, GRBs, galaxies	AGN, SNR, pulsars, starburst galaxies
detectors	CCDs	CZT, etc. arrays, scintillators	Si trackers, scintillators	photo-multipliers
major telescopes	Chandra, XMM, Suzaku	NuSTAR, Integral, Swift	Fermi	HESS, VERITAS, MAGIC



# High Energy

	X-ray	Hard X-ray	Gamma-ray ~GeV	Gamma-ray ~TeV
optics	grazing angle	coded mask, grazing angle	pair conversion	optical reflectors (ACTs)
best spatial resolution	0.5"	12' (MeV) 10" (<80 keV)	0.1-0.2 degrees	2'