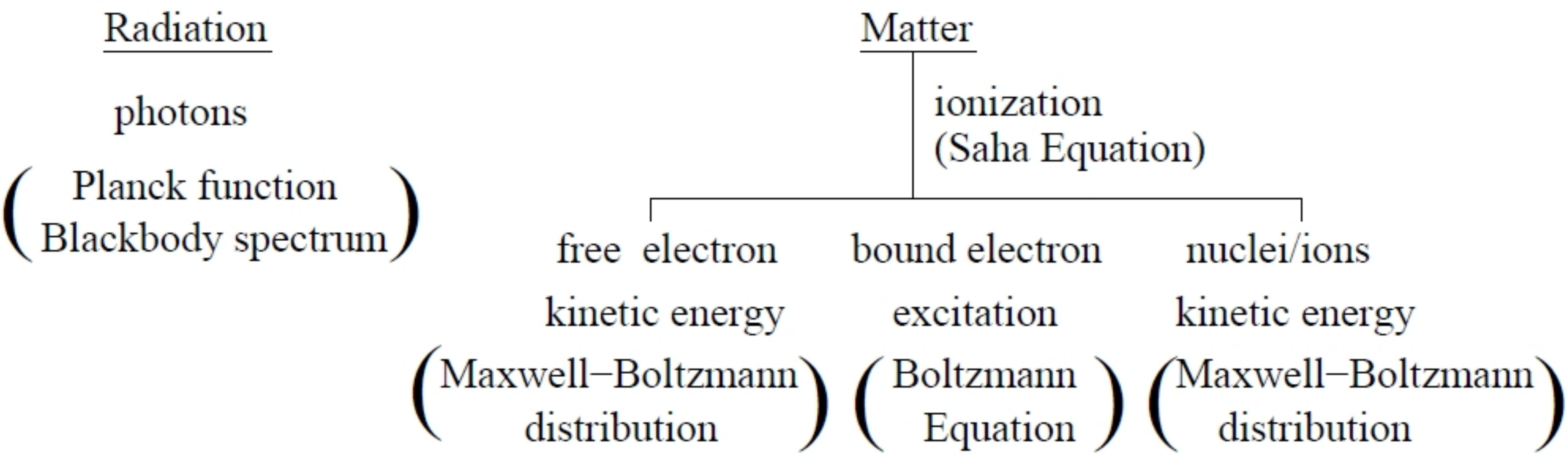
Astronomy 405
Solar System and ISM

Lecture 22
ISM - What is diffuse matter?

March 16, 2013

What's out there? What physical descriptions?



In the interstellar medium (ISM), we do not worry about dark matter or dark energy at scales of pc to kpc.
(1 pc = 3.08×10^{16} m)

Planck Function (Carroll & Ostlie, p.73)

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT}-1}$$

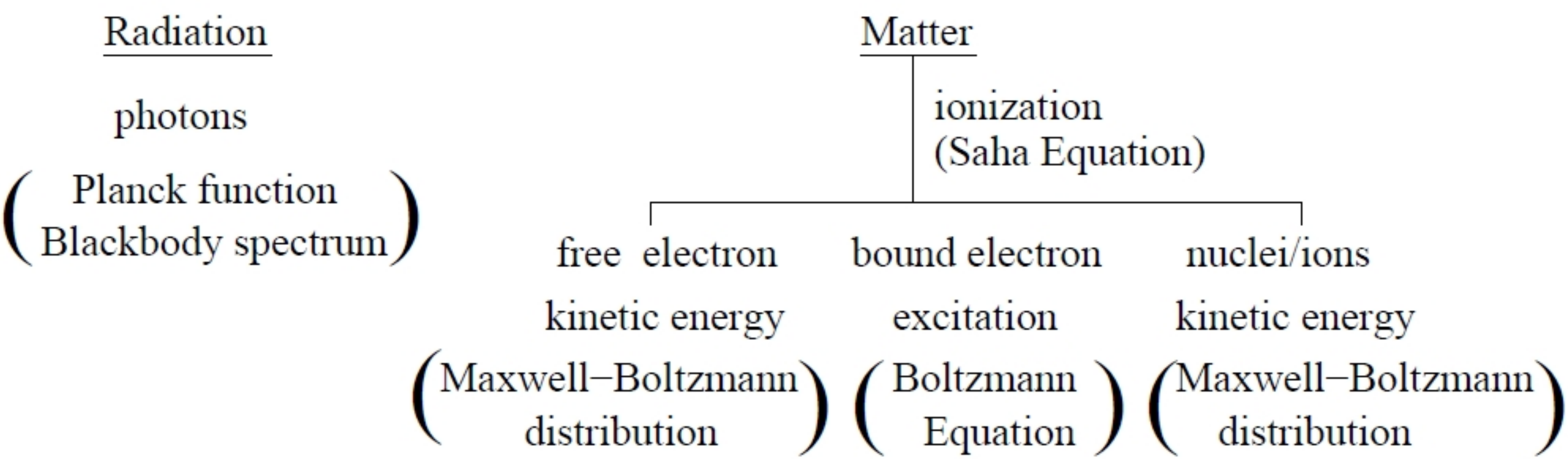
or

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{hc/\lambda kT}-1}$$

Note: $B_\nu(T) \neq B_\lambda(T)$, but $B_\lambda(T)d\lambda = B_\nu(T)\, d\nu$, because:

$$B_\lambda(T)d\lambda = B_\lambda(T)\ \ d\left(\frac{c}{\nu}\right) = \frac{2h\nu^5/c^3}{e^{h\nu/kT}-1}\ \frac{c}{\nu^2}\ d\nu = \frac{2h\nu^3/c^2}{e^{h\nu/kT}-1}\ d\nu = B_\nu(T)\ d\nu$$

What’s out there? What physical descriptions?



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Saha Equation (Carroll & Ostlie, p.214)

Ionization stages i and i+1

$$\frac{N_{i+1}}{N_i} = \frac{2Z_{i+1}}{n_\mathrm{e}\, Z_i} \left(\frac{2\pi m_\mathrm{e} kT}{h^2}\right)^{3/2} e^{-\chi_i/kT}$$

χ_i : ionization energy of the ionization stage i

Z: partition function;   g: statistical weight

$$Z = g_1 + \sum_{j=2}^{\infty} g_j\, e^{-(E_j - E_1)/kT}$$

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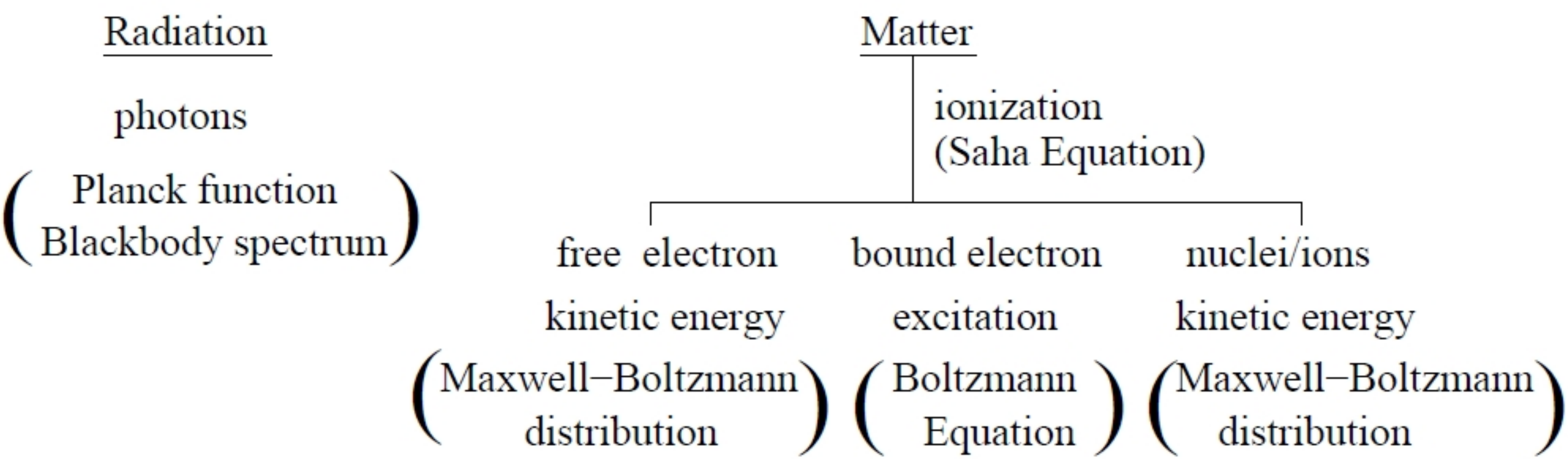

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Maxwell-Boltzmann Distribution

(Carroll & Ostlie, p.206)

$$n_v dv = n \left(\frac{m}{2\pi kT}\right)^{3/2} e^{-mv^2/2kT} 4\pi v^2 dv$$

Number of particles with velocities within *v* to *v*+*dv*

Boltzmann Equation (Carroll & Ostlie, p.212)

$$\frac{N_b}{N_a} = \frac{g_b e^{-E_b/kT}}{g_a e^{-E_a/kT}} = \frac{g_b}{g_a} e^{-(E_b - E_a)/kT}$$

g: statistical weight
E: energy

In the interstellar medium (diffuse matter), densities are so low and interactions between radiation and matter and collisions between particles are so infrequent that thermal equilibrium is no longer valid.

Radiation and matter need to be considered separately.

Ionization

Ionization can be carried out by absorbing a photon or through collision with another particle.

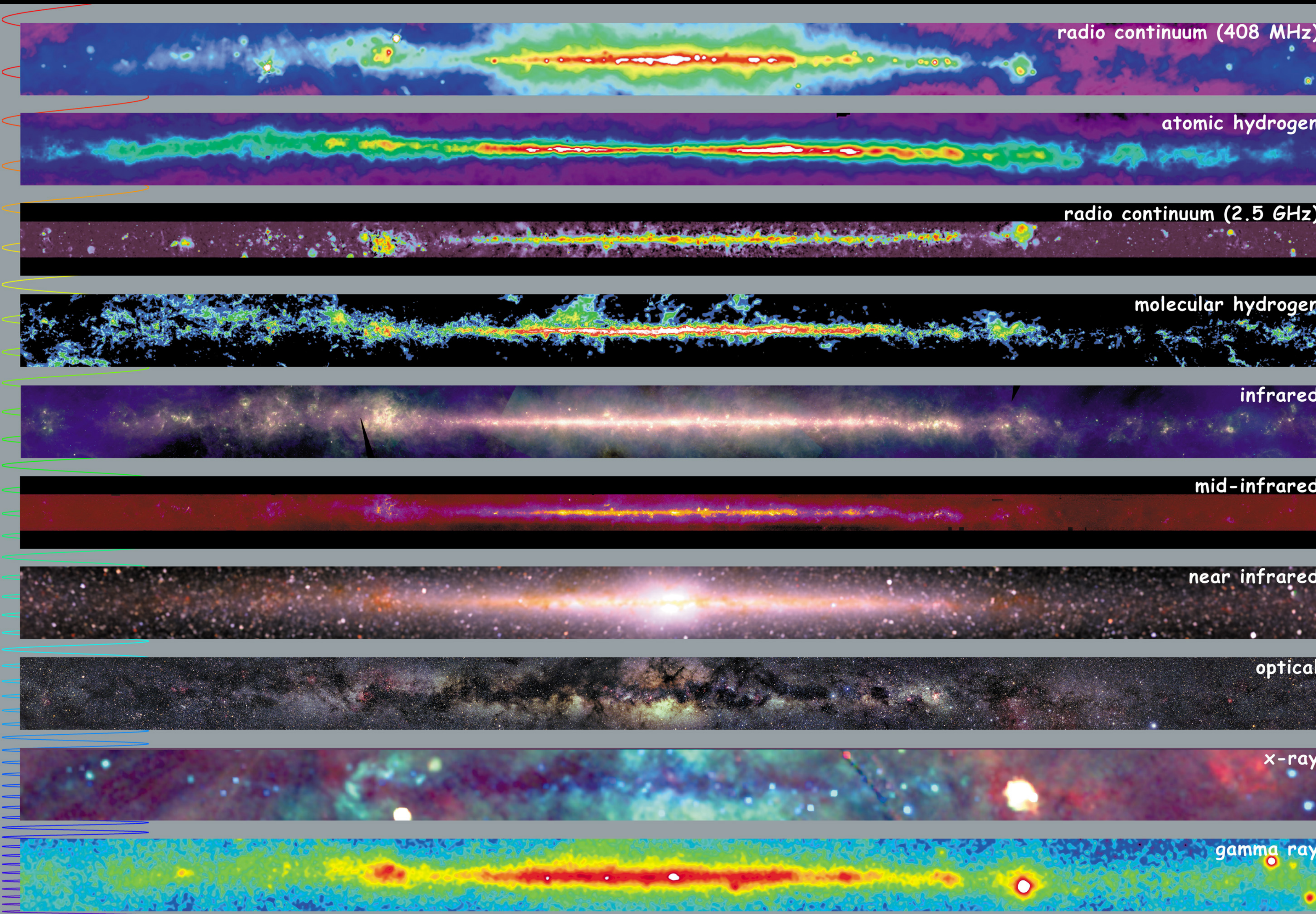
The ionization state is determined by balancing the number of ionizations and the number of recombinations.

Excitation

Similarly, excitation is carried out by photon or collision. Boltzmann equation is applicable at high energy levels when densities are high.

What is the "temperature" then?

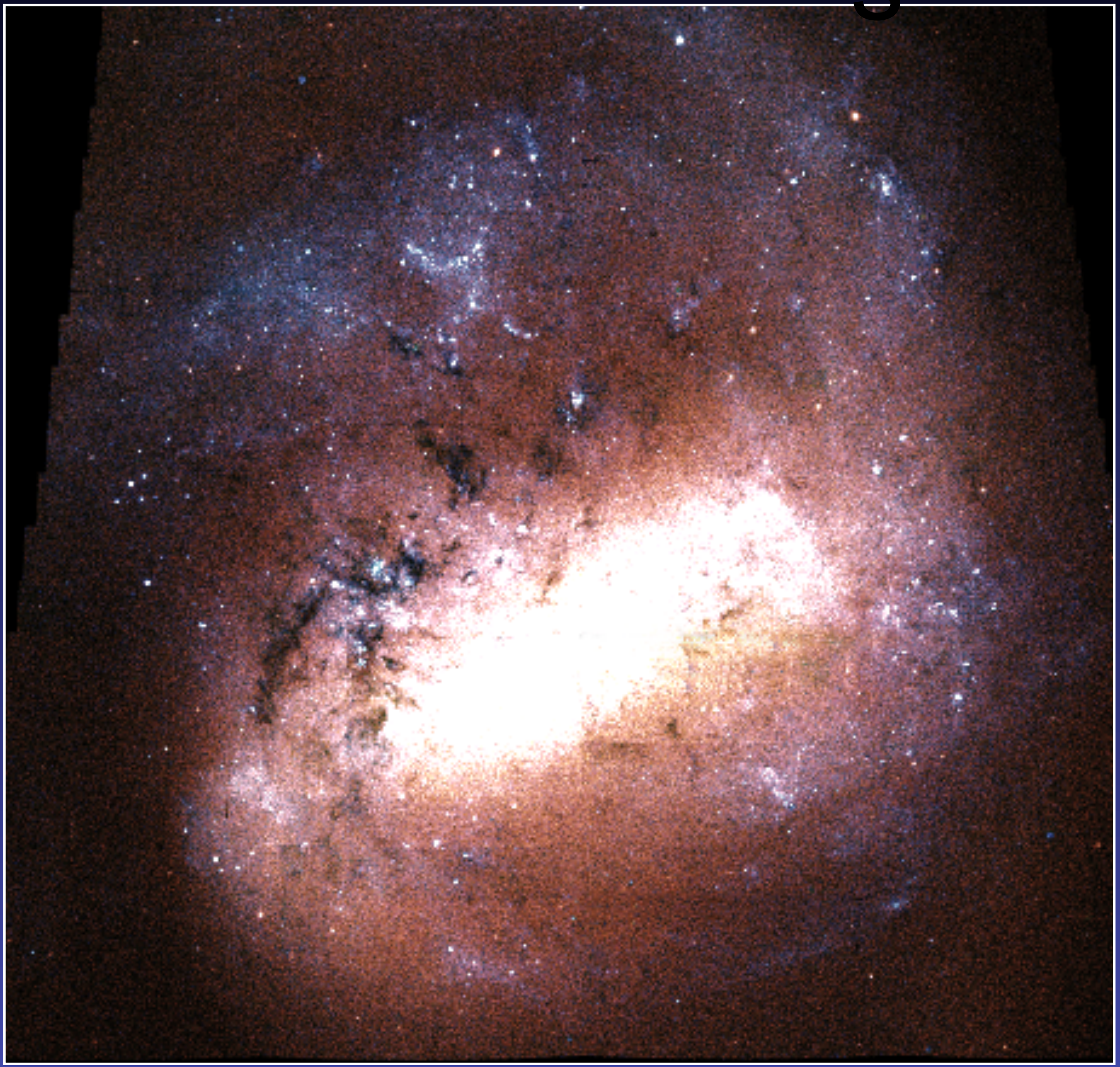
You can count on electrons establishing Maxwell-Boltzmann distribution very quickly. Therefore, electron temperatures or kinetic temperatures are used.

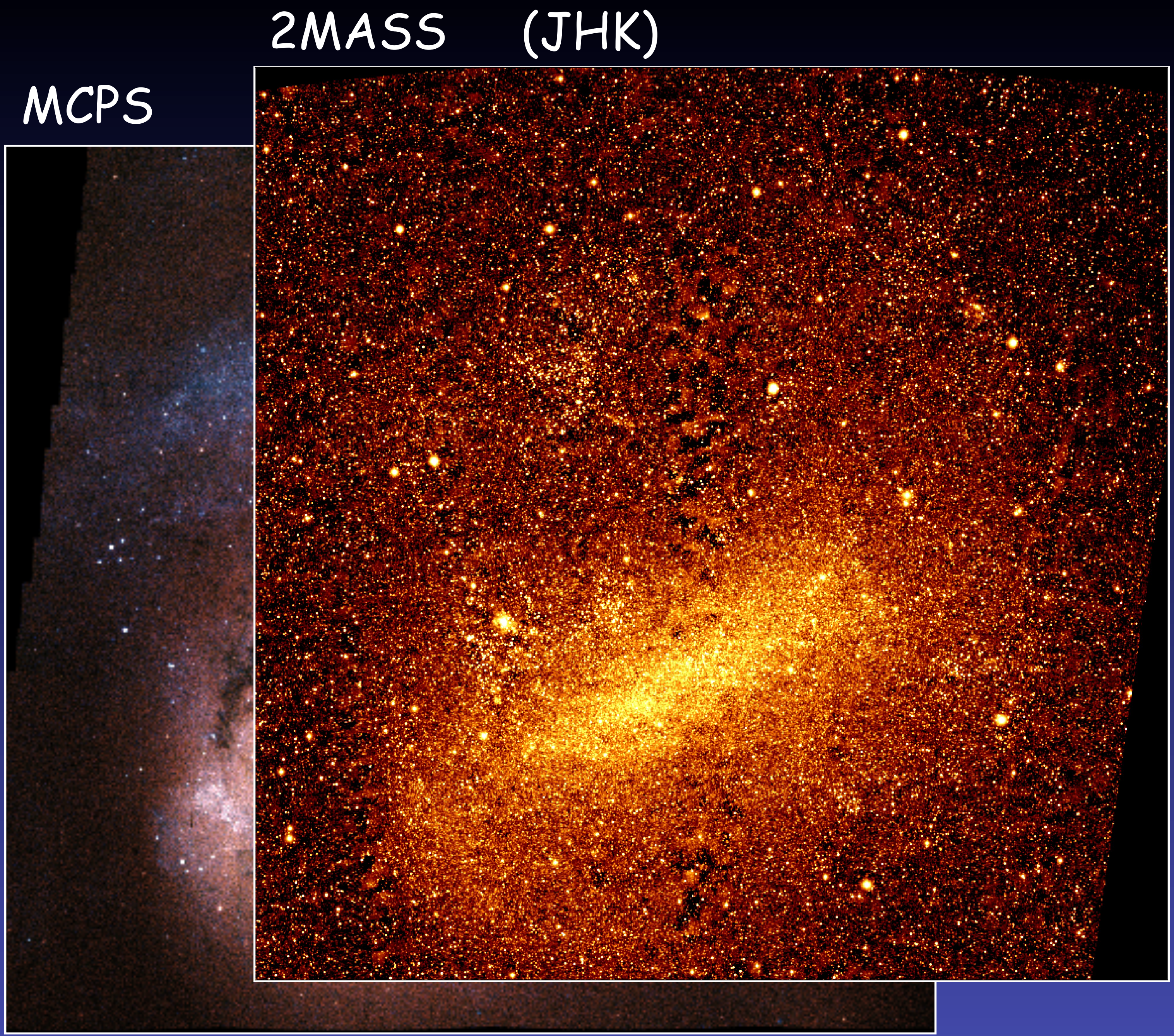


http://adc.gsfc.nasa.gov/mw

Multiwavelength Milky Way

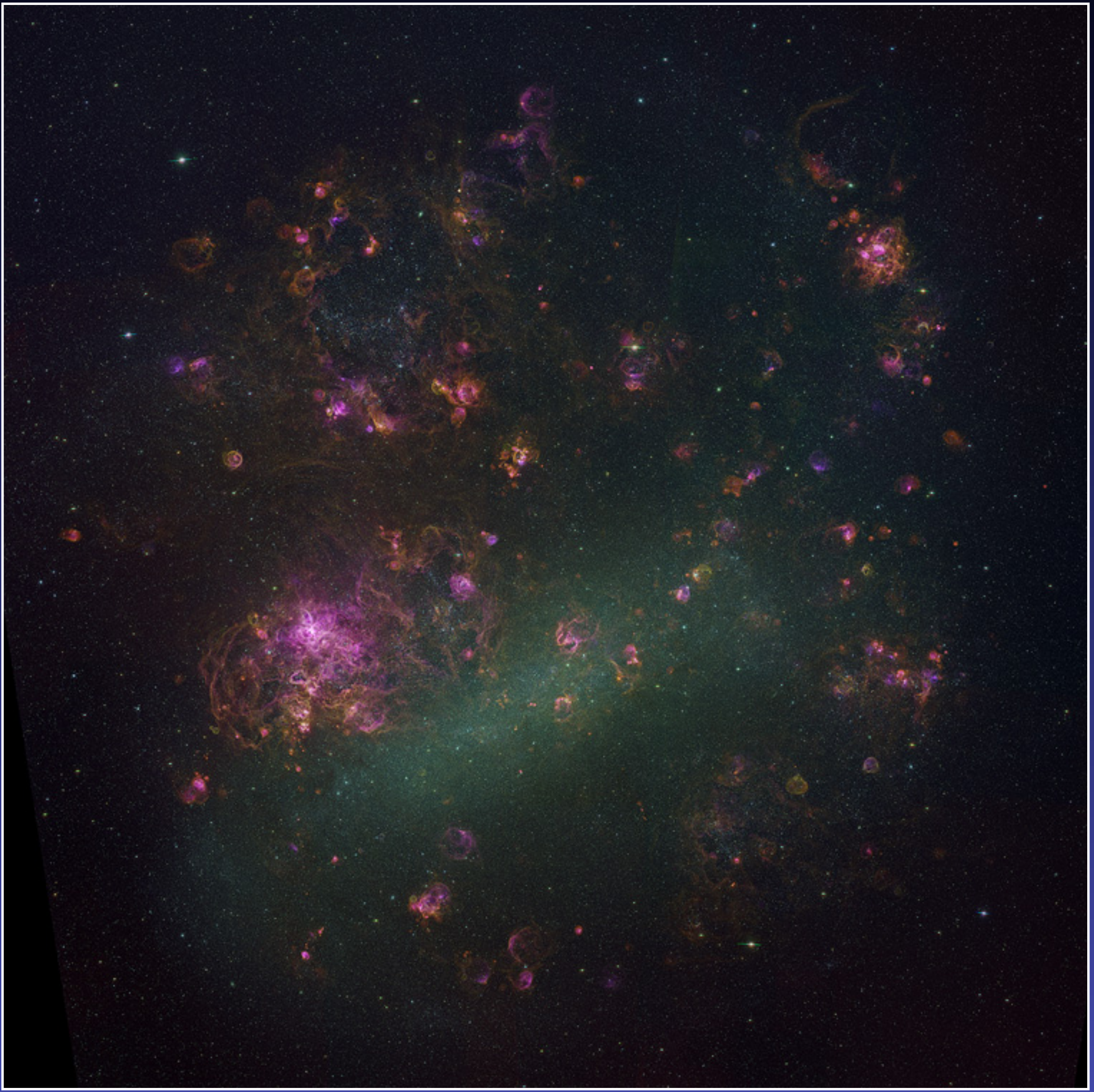
MCPS (UBVI)

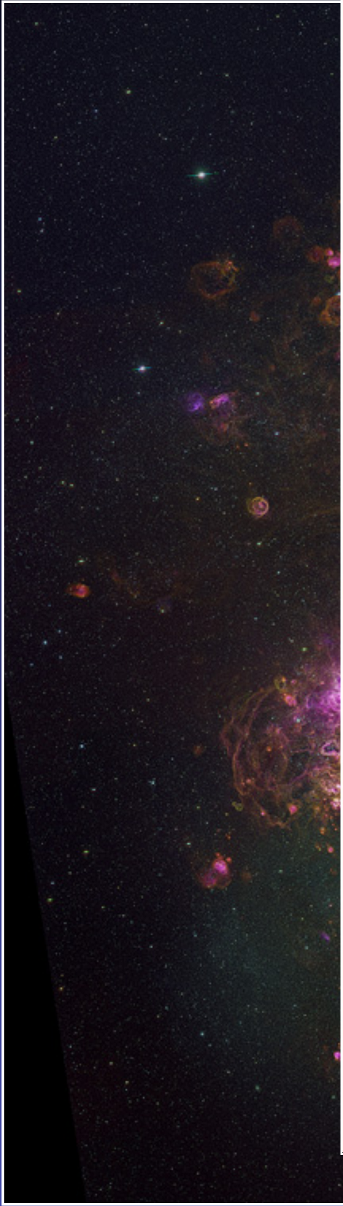


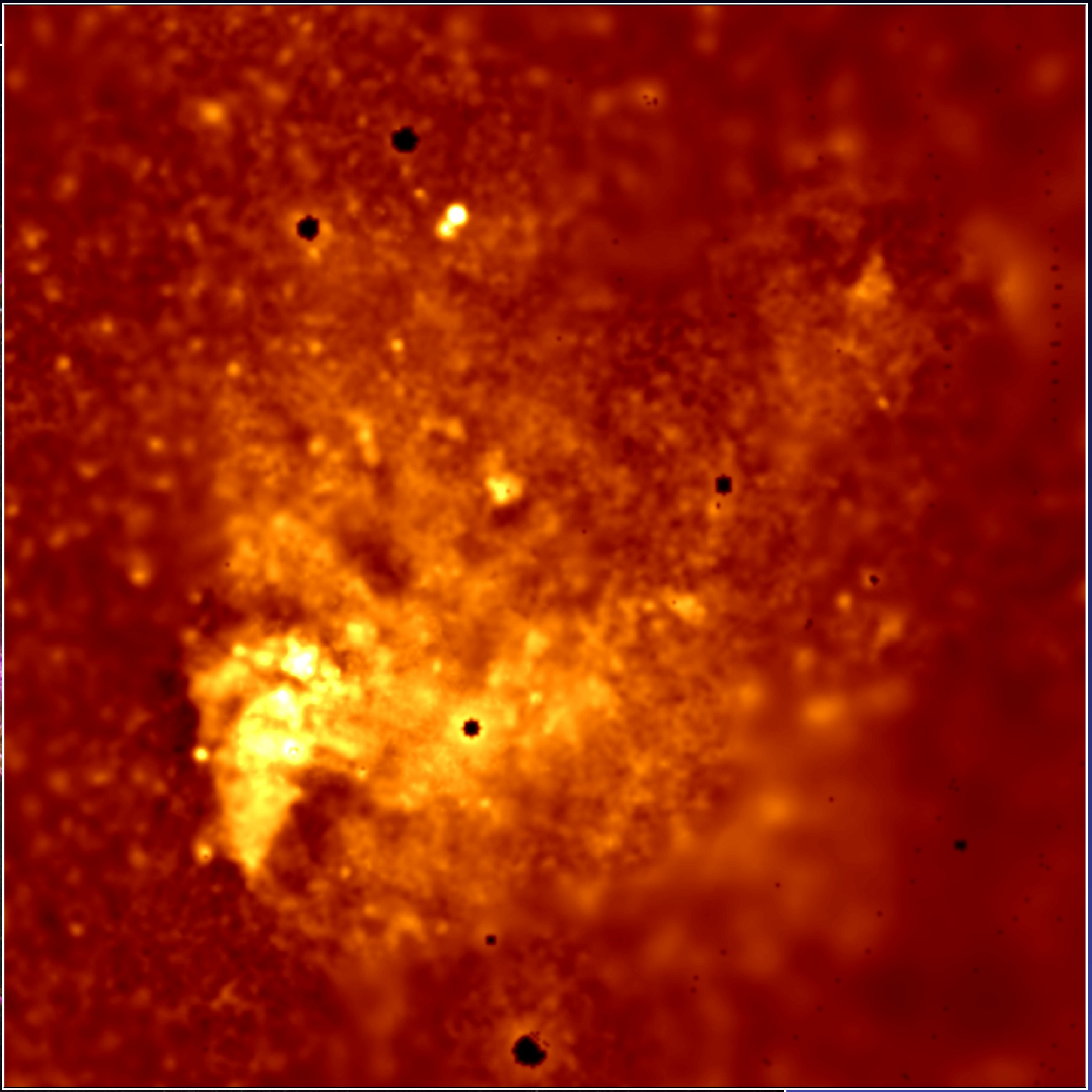

2MASS (JHK)
MCPS

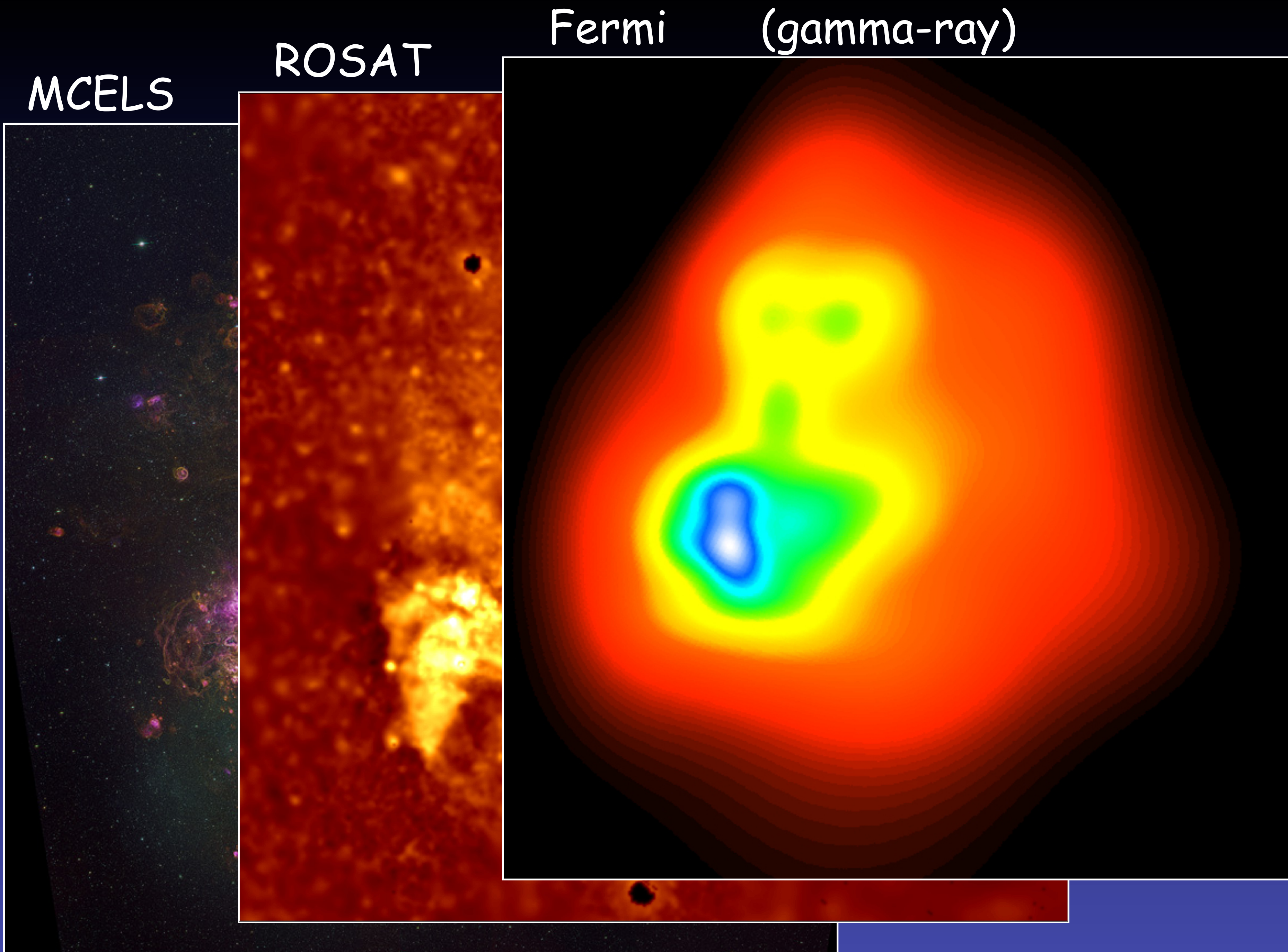

SAGE (3.6, 4.5, 5.8, 8.0, 24 μm)
2MASS
MCPS

MCELS (Hα, [O III], [S II])

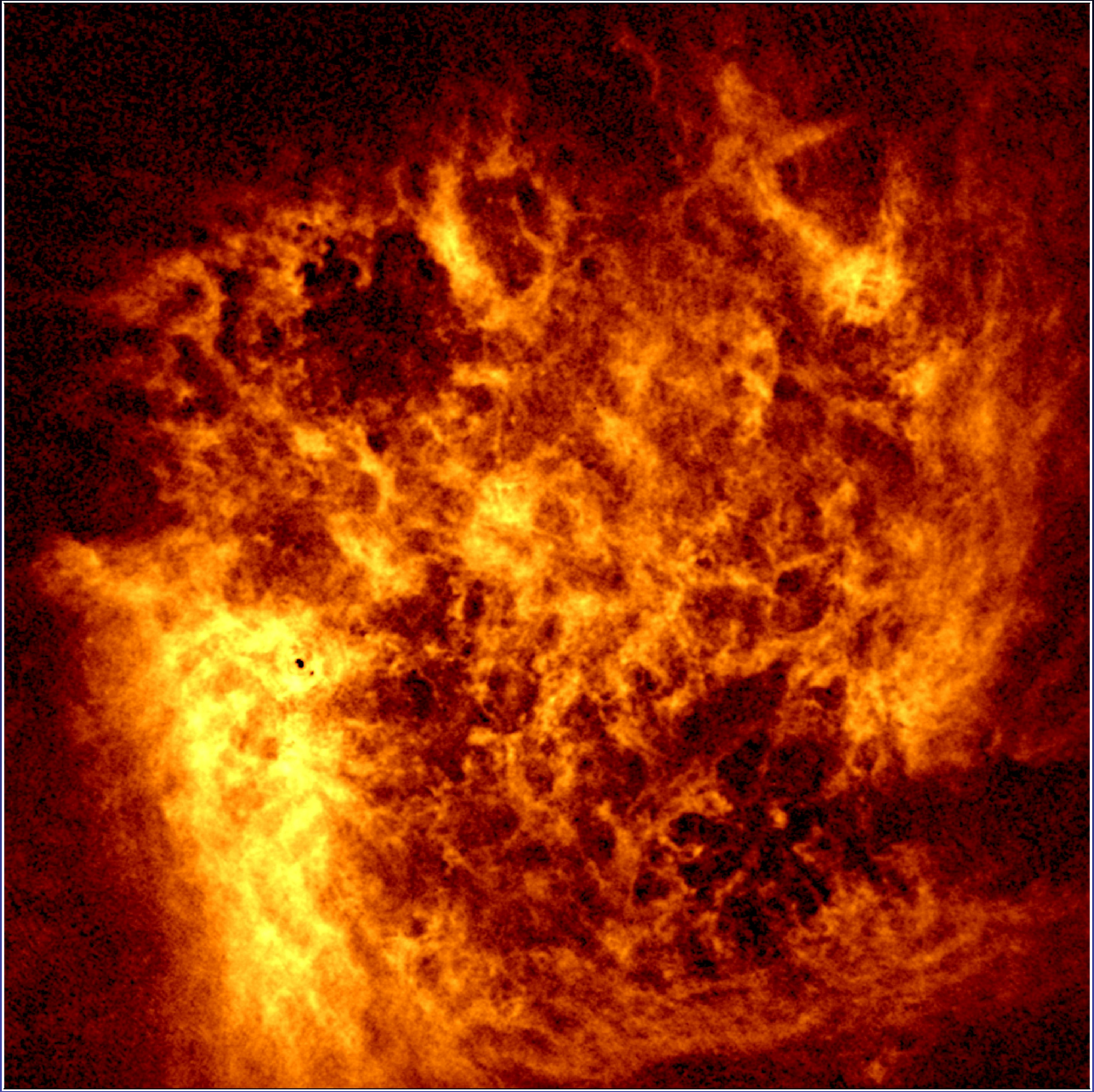



MCELS


ROSAT (X-ray, 0.1-2.4 keV)

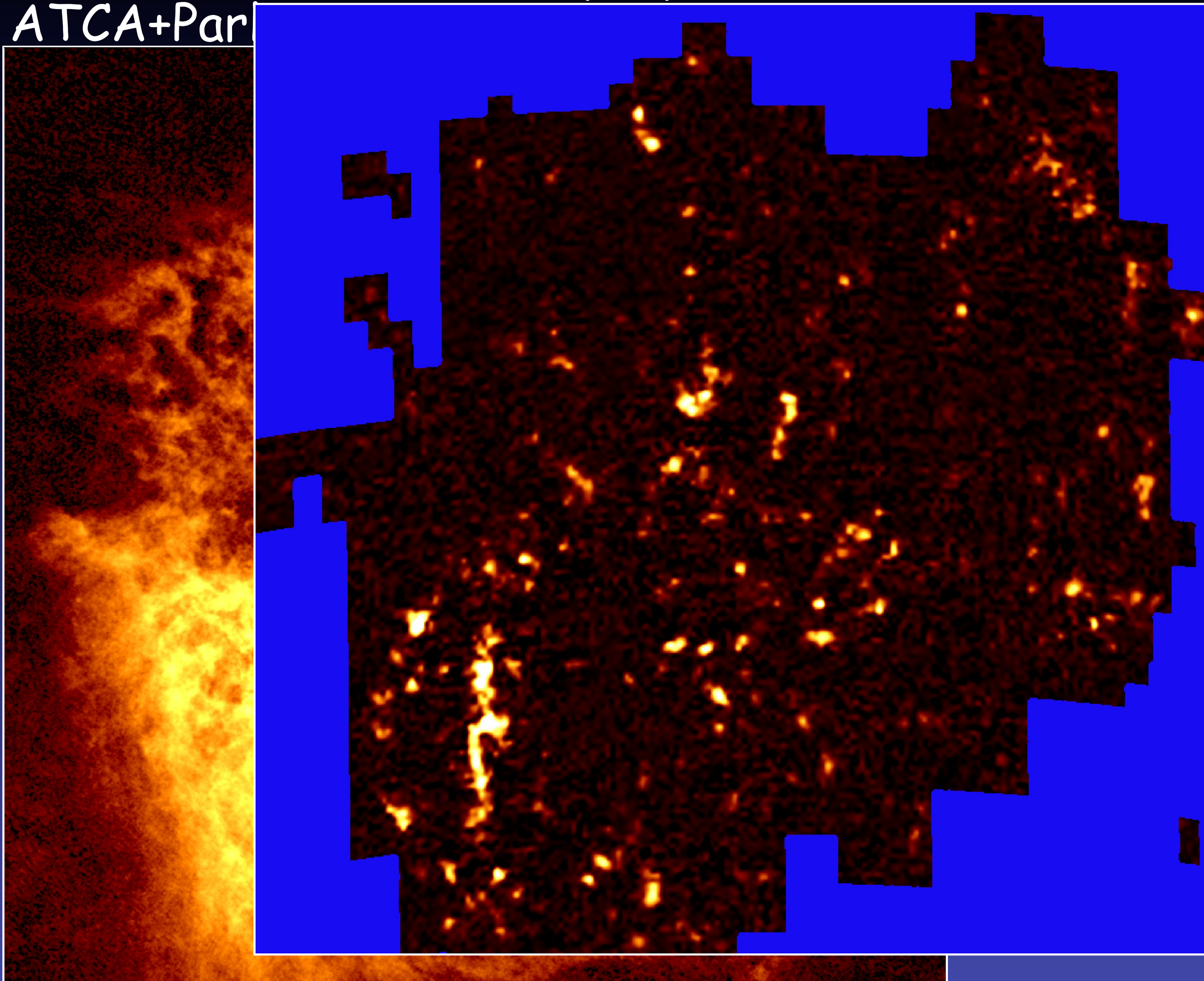

MCELS
ROSAT
Fermi (gamma-ray)

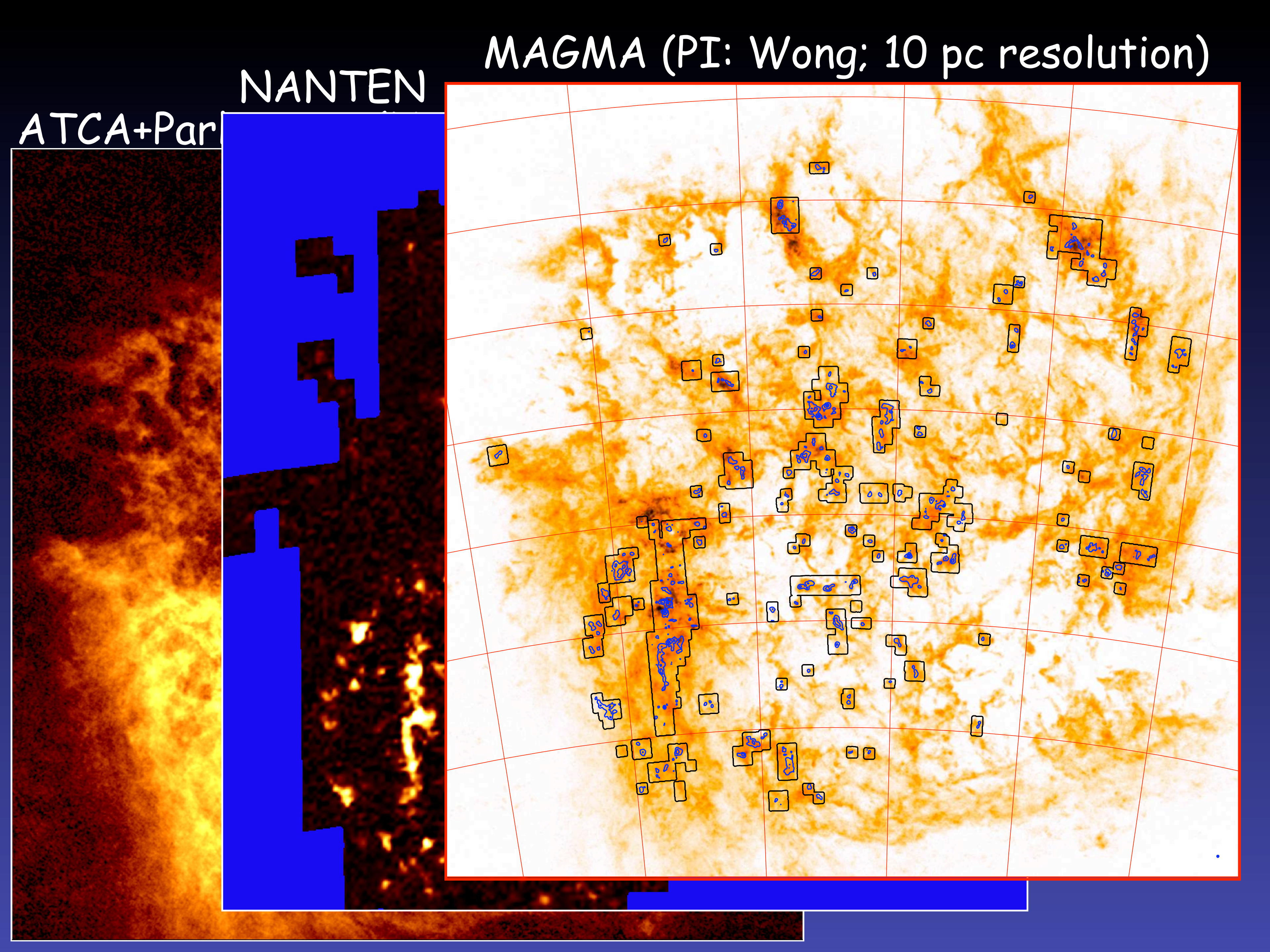
ATCA+Parkes (H I)



NANTEN (CO)

ATCA+Par




MAGMA (PI: Wong; 10 pc resolution)
NANTEN
ATCA+Par

Radiation Field

Radio -- thermal emission from ionized gas,
line emission from molecular, atomic, ionized gas

Far-IR -- luke-warm dust emission

Near-IR -- emission from cool stars,
warmer dust emission

Optical -- star light (OBAFGKM)
line emission from ionized ISM

X-ray -- emission from hot plasma > 10^6 K

Gamma-ray -- supernovae,
accreting compact objects (BH, NS binaries)
cosmic rays interacting with ISM