Ionized Gas Properties in the ISM

Two main phases:

1) Warm Ionized Medium (WIM), including HII regions

   $T \sim 10^4 K$

2) Hot Ionized Medium (HIM)

   $T \sim 10^5 K$

The Warm Ionized Medium (WIM)

The WIM has a temperature of ~10,000 K.

We can separate it into:

1) (Relatively) dense plasma around OB stars, called “HII Regions”
2) Diffuse plasma called the “warm ionized medium” (WIM) or “diffuse ionized gas” (DIG)

HII Regions

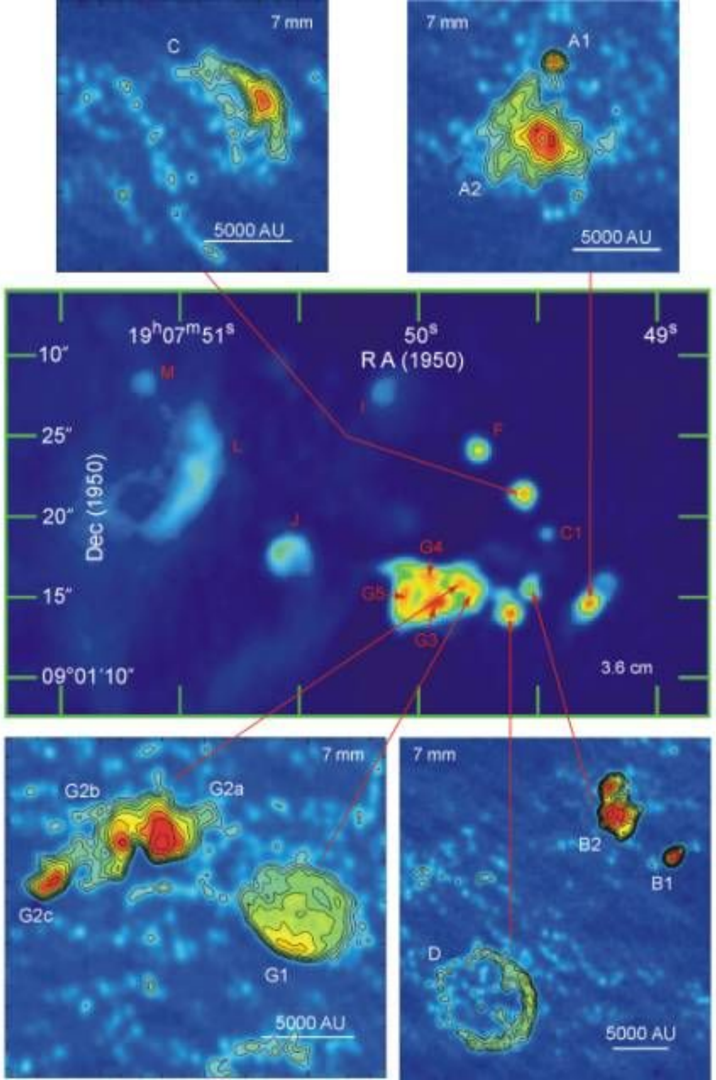
All O-stars, B1, B0 stars create HII regions that we observe.

As we learned in class, HII regions expand as they age.

> The youngest regions are called “hyper-compact.” These are very rare and have ages of ~10^4 years
>
> The next youngest are called “ultra-compact” and have ages of maybe 10^5 years. EM~10^7, size~0.1pc, n_e~10^4 cm^-3
>
> “Classical” HII regions have lifetimes of ~10MYr, sizes of ~1-10pc, and densities of ~10^2 cm^-3

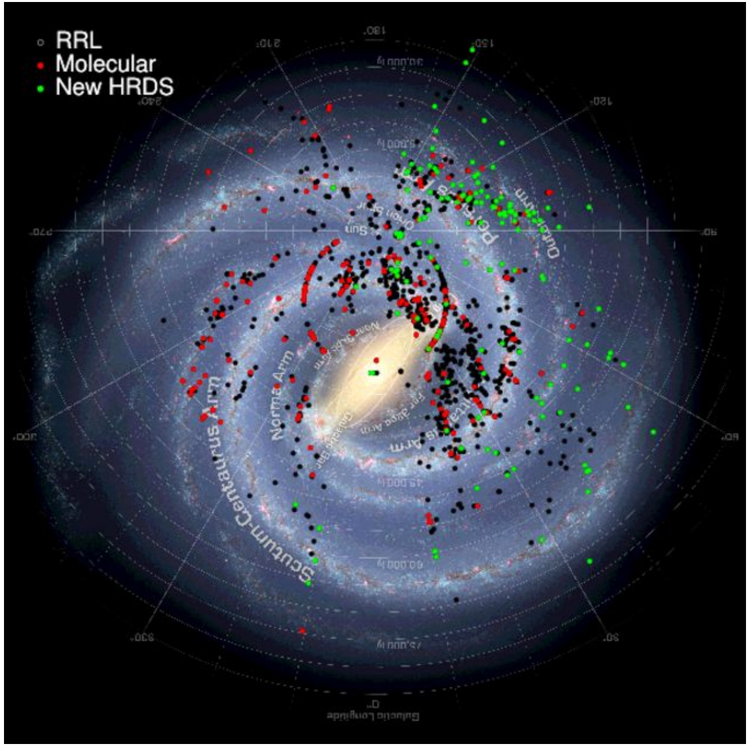
Traced using recombination lines (H-alpha and radio), radio continuum (Bremsstrahlung), collisionally ionized lines (optical/UV), and far-infrared fine-structure lines

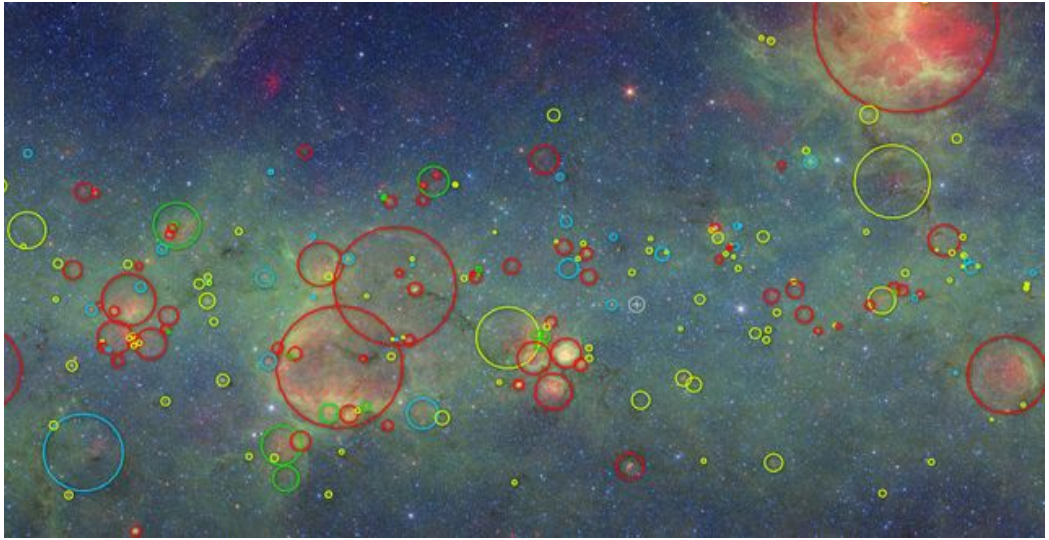
HII Regions



7 mm
C
5000 AU
7 mm
A1
A2
5000 AU
19h07m51s
50s
49s
RA (1950)
10"
25"
20"
15"
09°01'10"
Dec (1950)
M
L
I
F
J
C1
G4
G5
G3
3.6 cm
7 mm
G2b
G2a
G2c
G1
5000 AU
7 mm
B2
B1
D
5000 AU

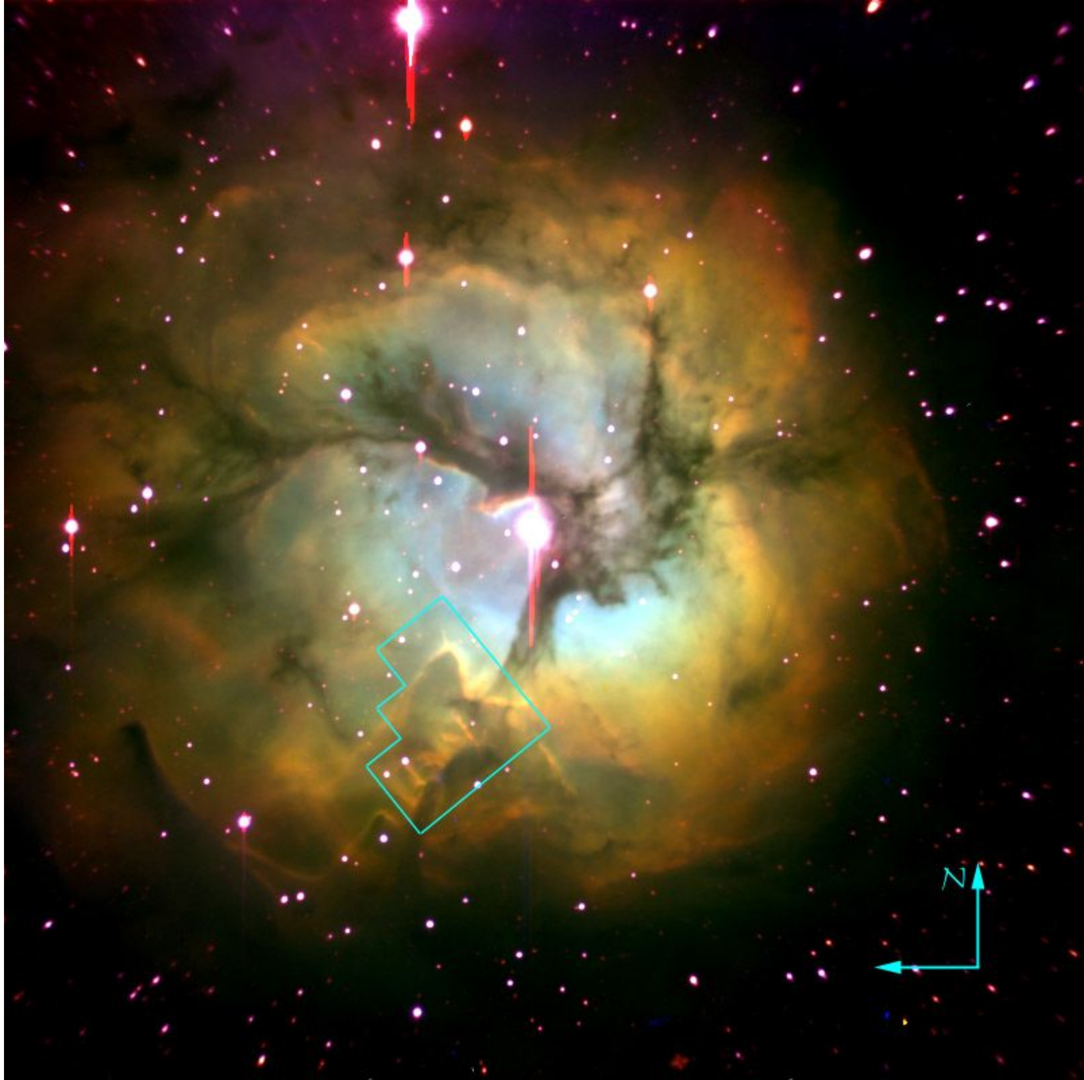
Total Galactic population is ~10,000





Orion

Trifid

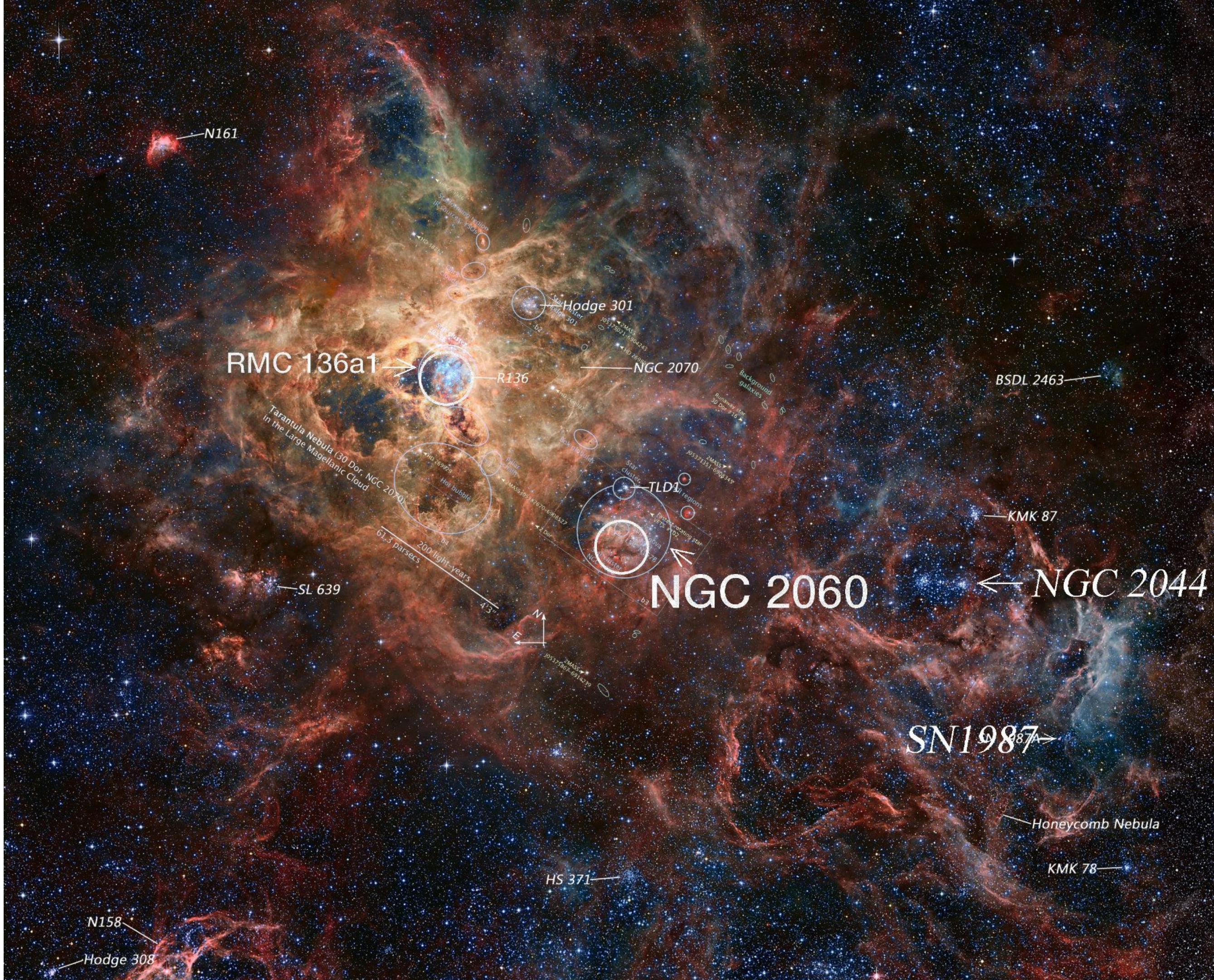


RCW120

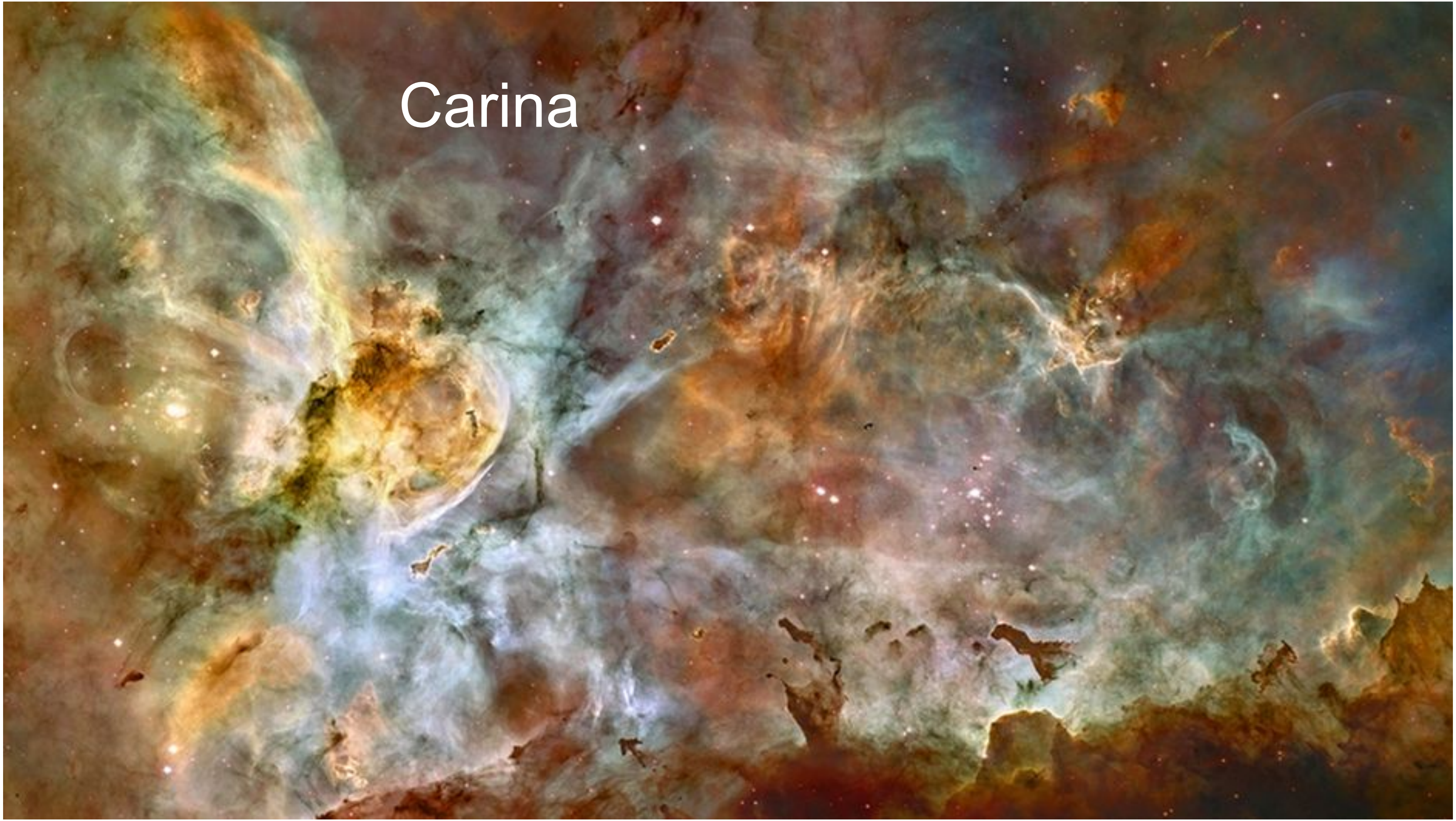
M16 (Eagle Nebula)

M17 (Omega Nebula)

30 Dorados (Tarantula Nebula)



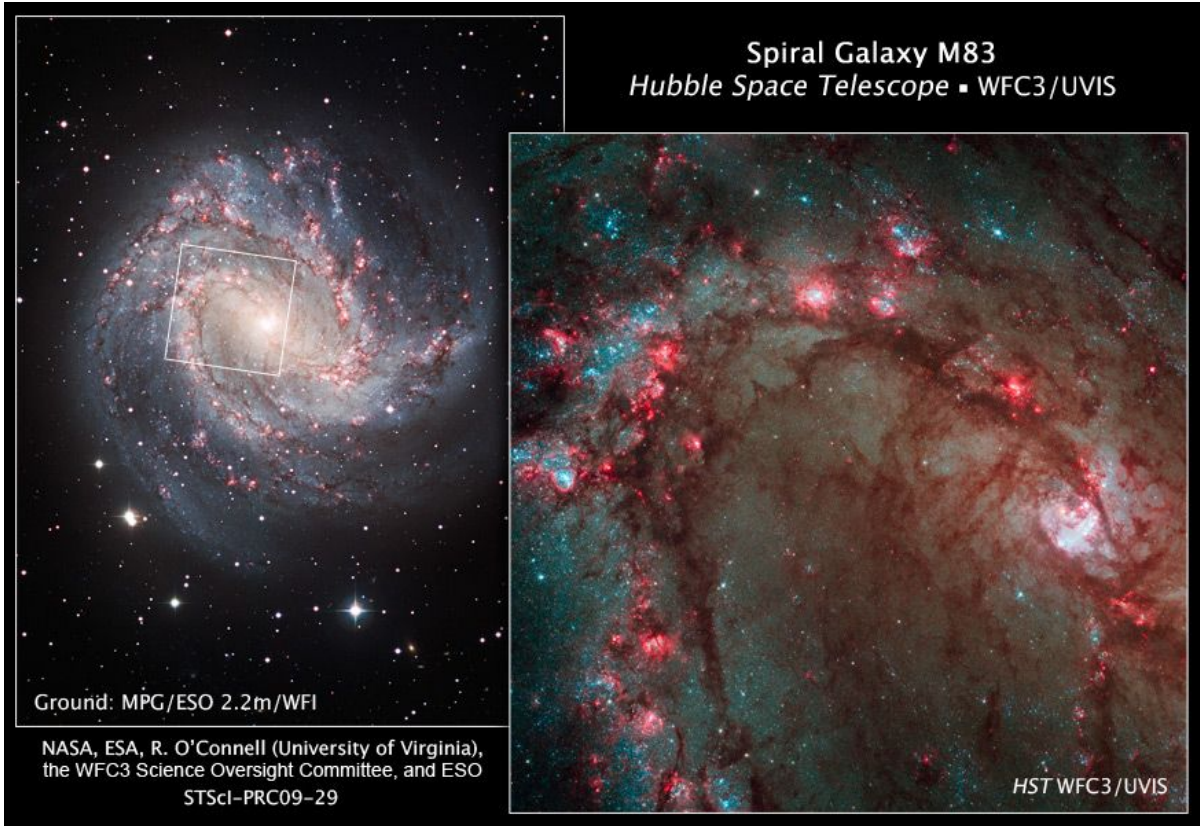
NGC6334 (Cat's Paw)


Carina

Overall HII Region Distribution

Should be concentrated in spiral arms

Scale height is ~30pc



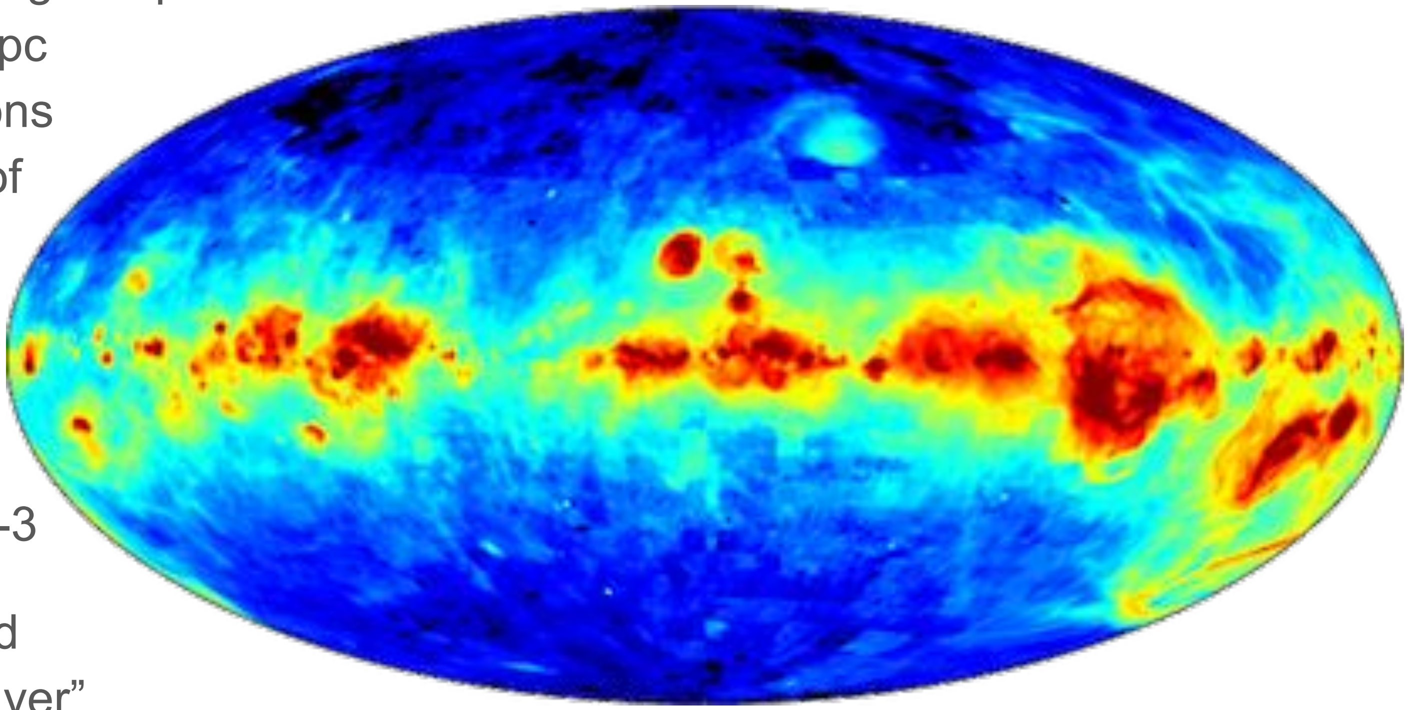
Warm Ionized Medium

Mostly traced using H-alpha
Scale height ~1kpc
Caused by photons
    leaking out of
    HII regions

A bit hotter than
    HII regions

Density ~0.1cm^-3

Sometimes called
    “Reynolds layer”



WIM

Must be caused by photons leaking out of HII regions (Haffner et al., 2009)

Ratios of [SII]/Hα, [NII]/Hα enhanced at high altitude compared to HII regions so additional heating must be present

shocks

turbulent mixing layers in bubbles (Slavin, Shull & Begelman 1993)

galactic fountain clouds?

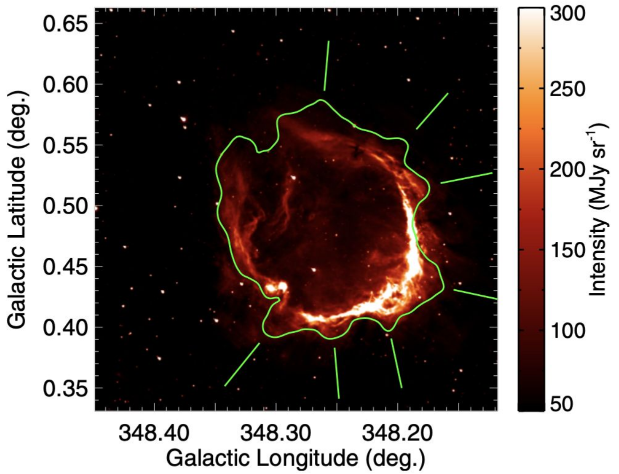
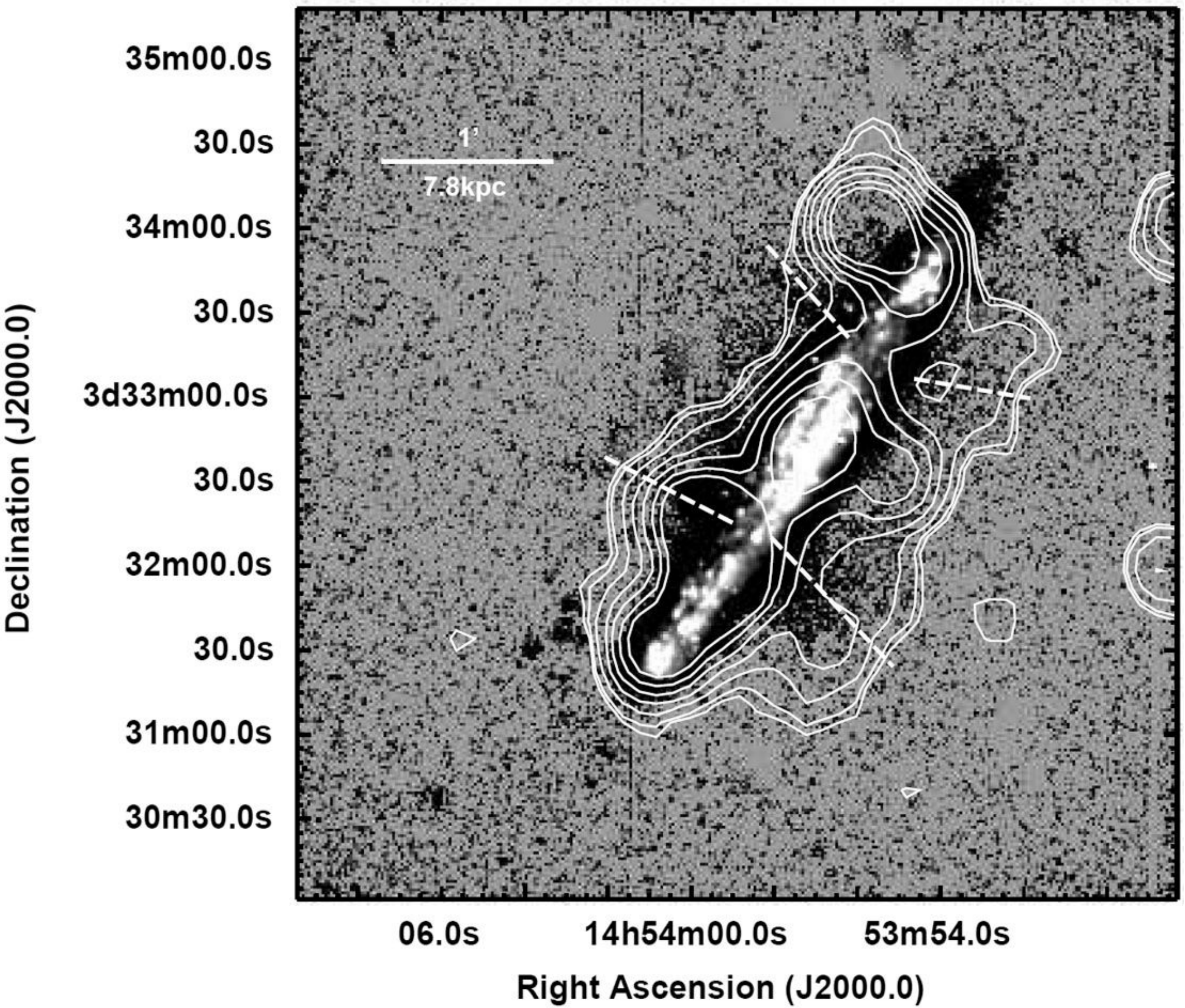
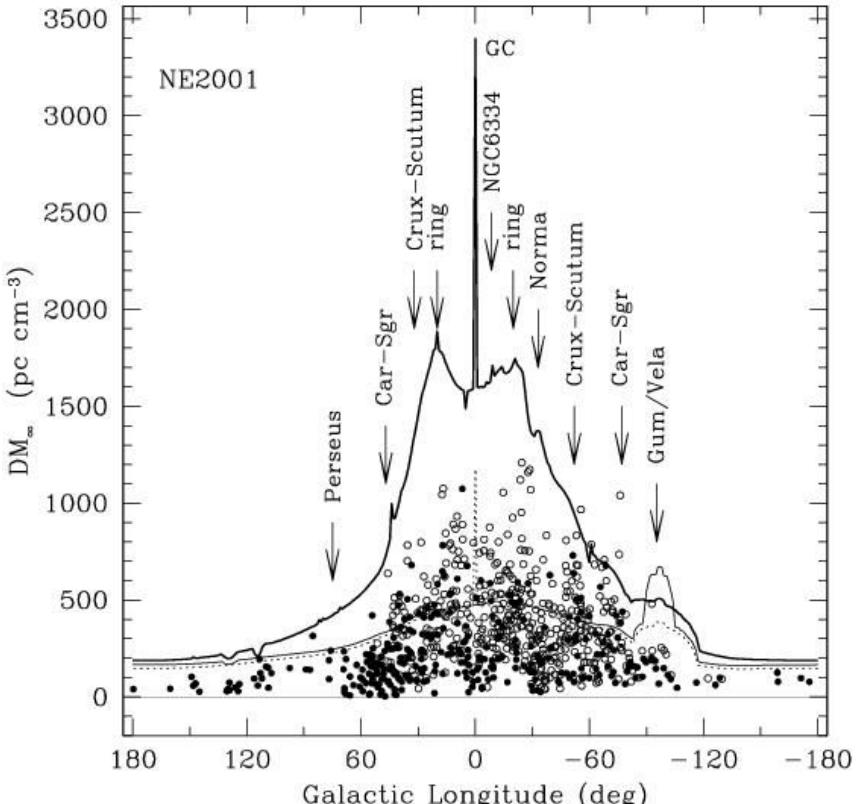


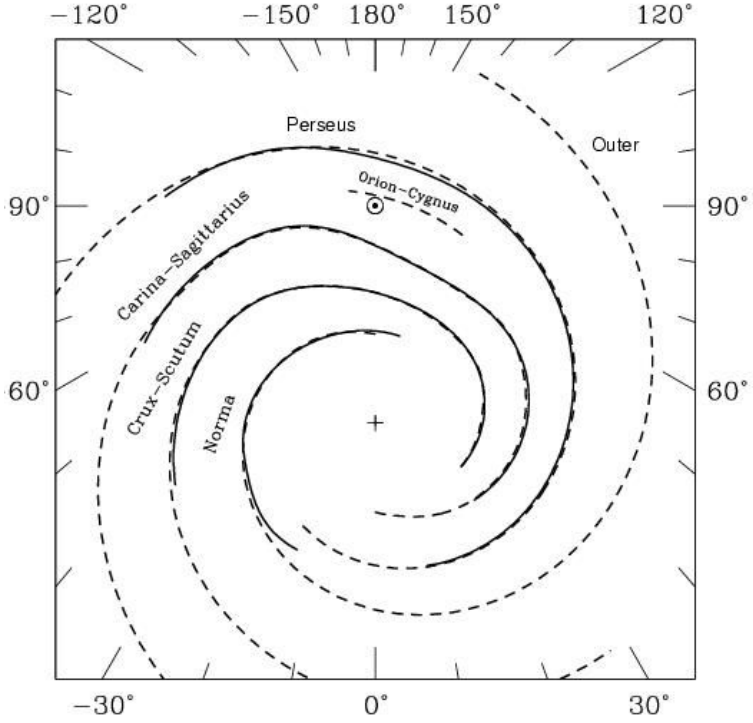
Figure 13. Temperature enhancements outside the PDR of RCW 120. The image is of GLIMPSE 8.0 μm data and the green outline shows the boundary of 22 K *Herschel* dust temperatures from Anderson et al. (2012) (hotter dust is inside this boundary). We mark the locations of significant temperature enhancements outside the PDR with green lines. These enhancements coincide with discontinuities in the PDR seen at 8.0 μm.

WIM in external galaxies
Correlated with star formation



Also seen from pulsar dispersion measures…..





NE2001

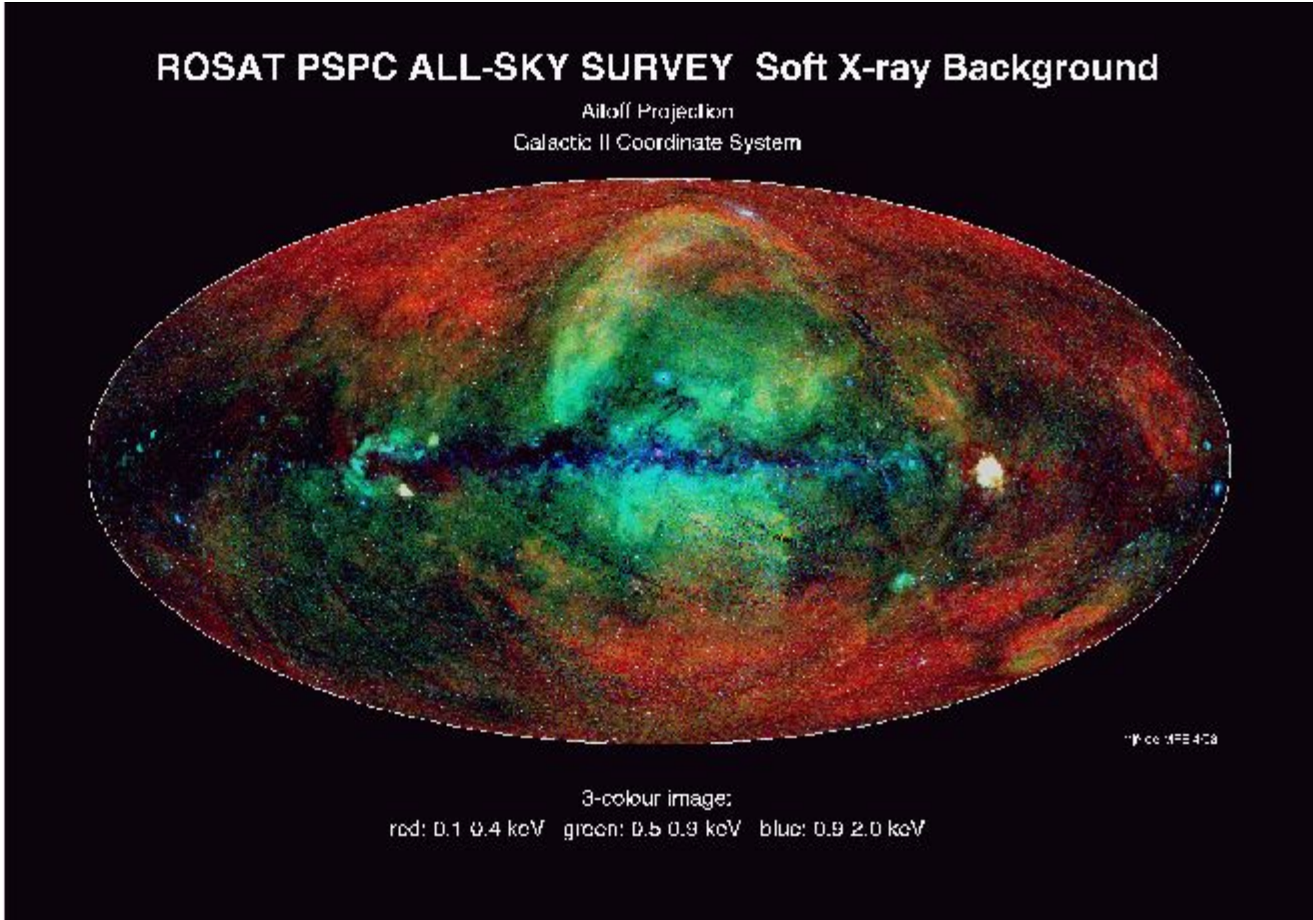
Hot Ionized Medium (HIM)

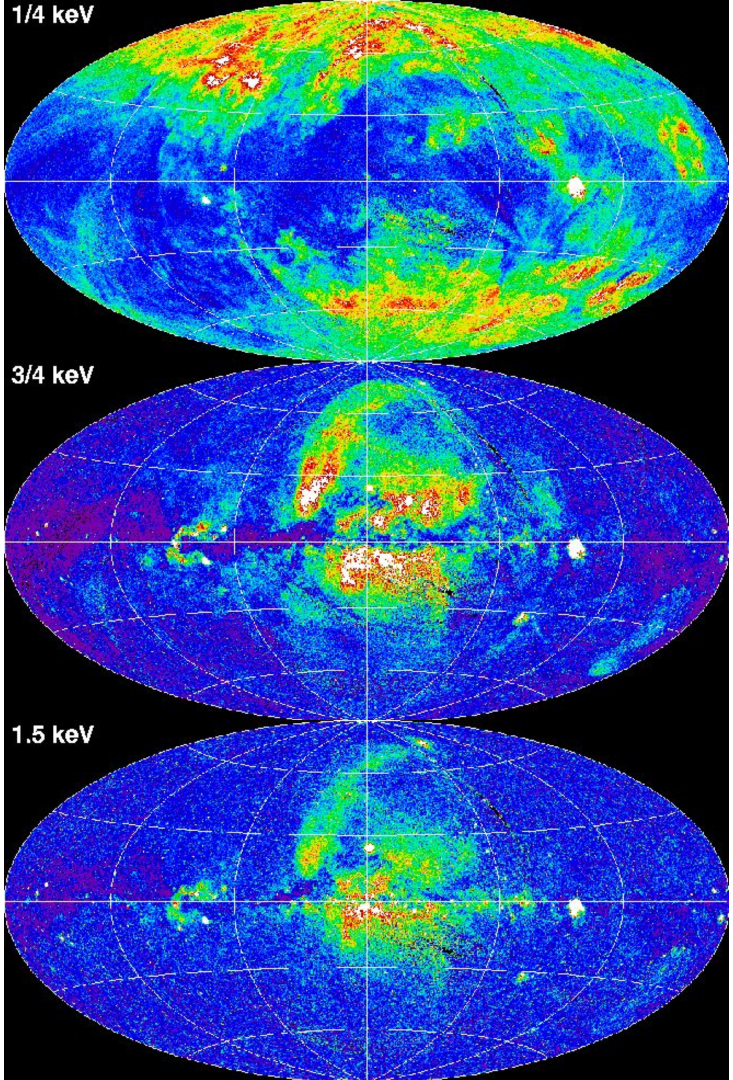
$N_e \sim 10^{-3}$

$T \sim 10^5$

Scale height 5-10kpc

Probably produced by SNR




1/4 keV
3/4 keV
1.5 keV

HIM lines

Important UV lines are listed below:

Species	Lines (Å)	IP (eV)	T_{max} (K)
Si IV	1402.7, 1393.8	33.5/45.1	60,000 K
C IV	1550.8, 1548.2	47.9/64.5	100,000 K
S VI	944.5, 933.4	72.5/88.0	200,000 K
N V	1242.8, 1238.8	77.5/97.9	180,000 K
O VI	1037.6, 1031.95	113.9/138.1	300,000 K

The ionization potentials (IP) listed are those required to create/destroy this ionic state.