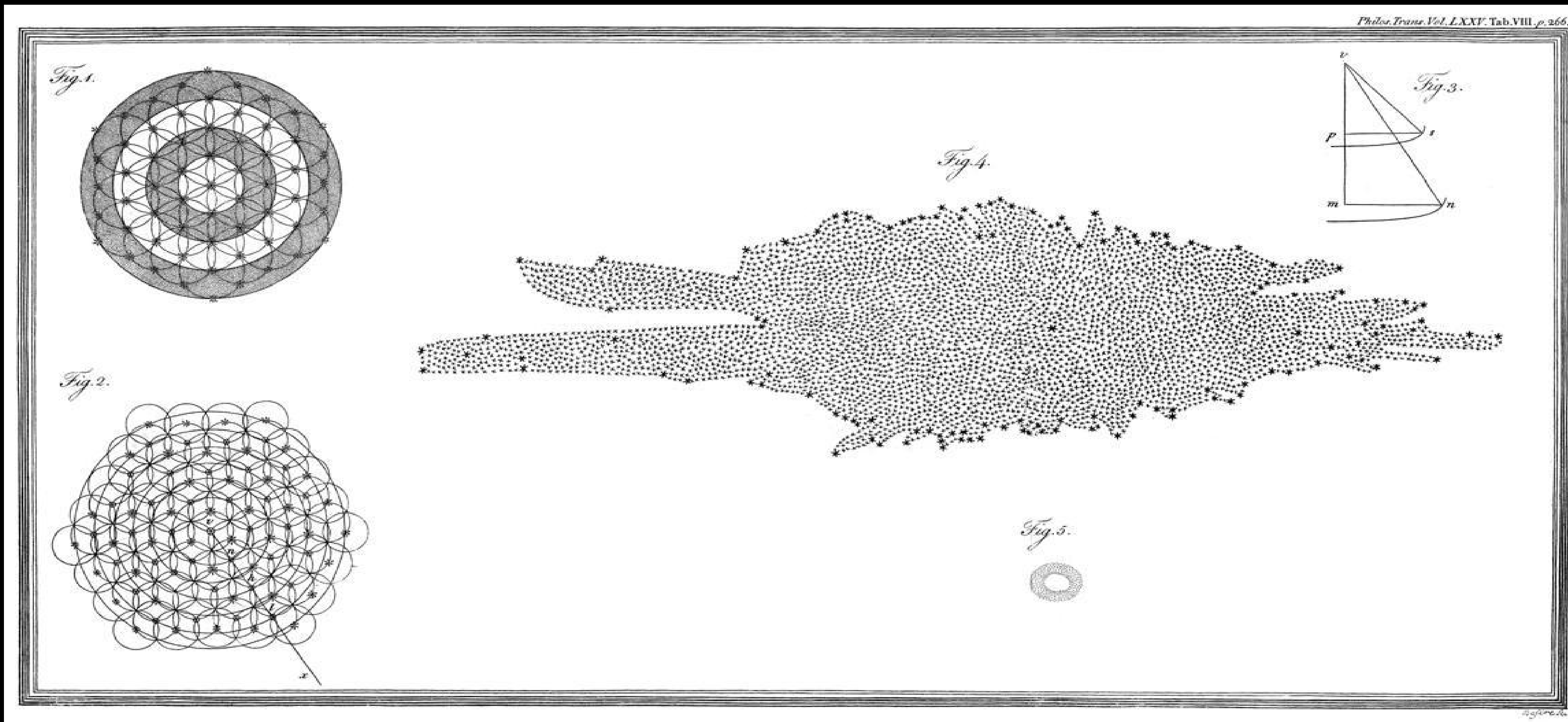
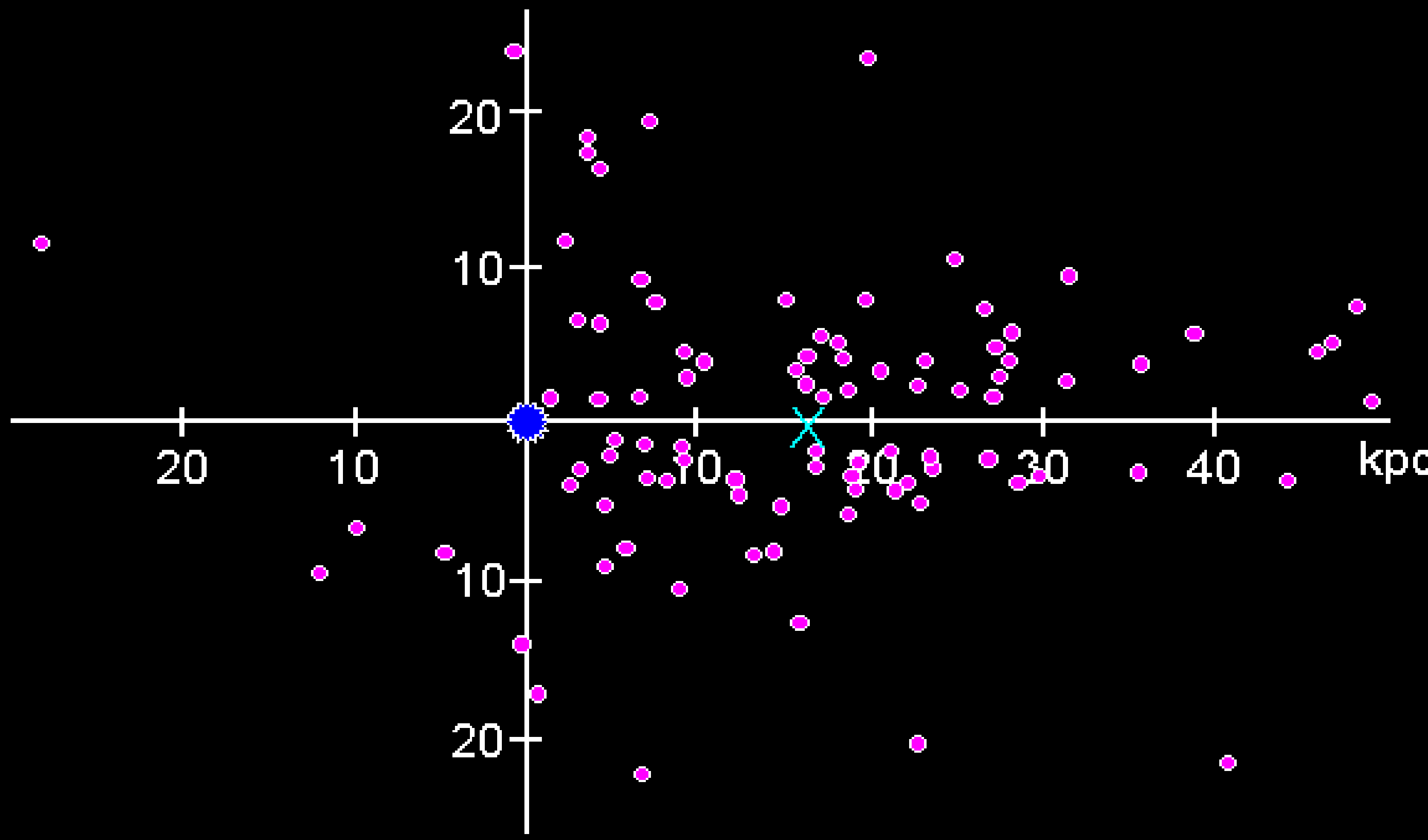
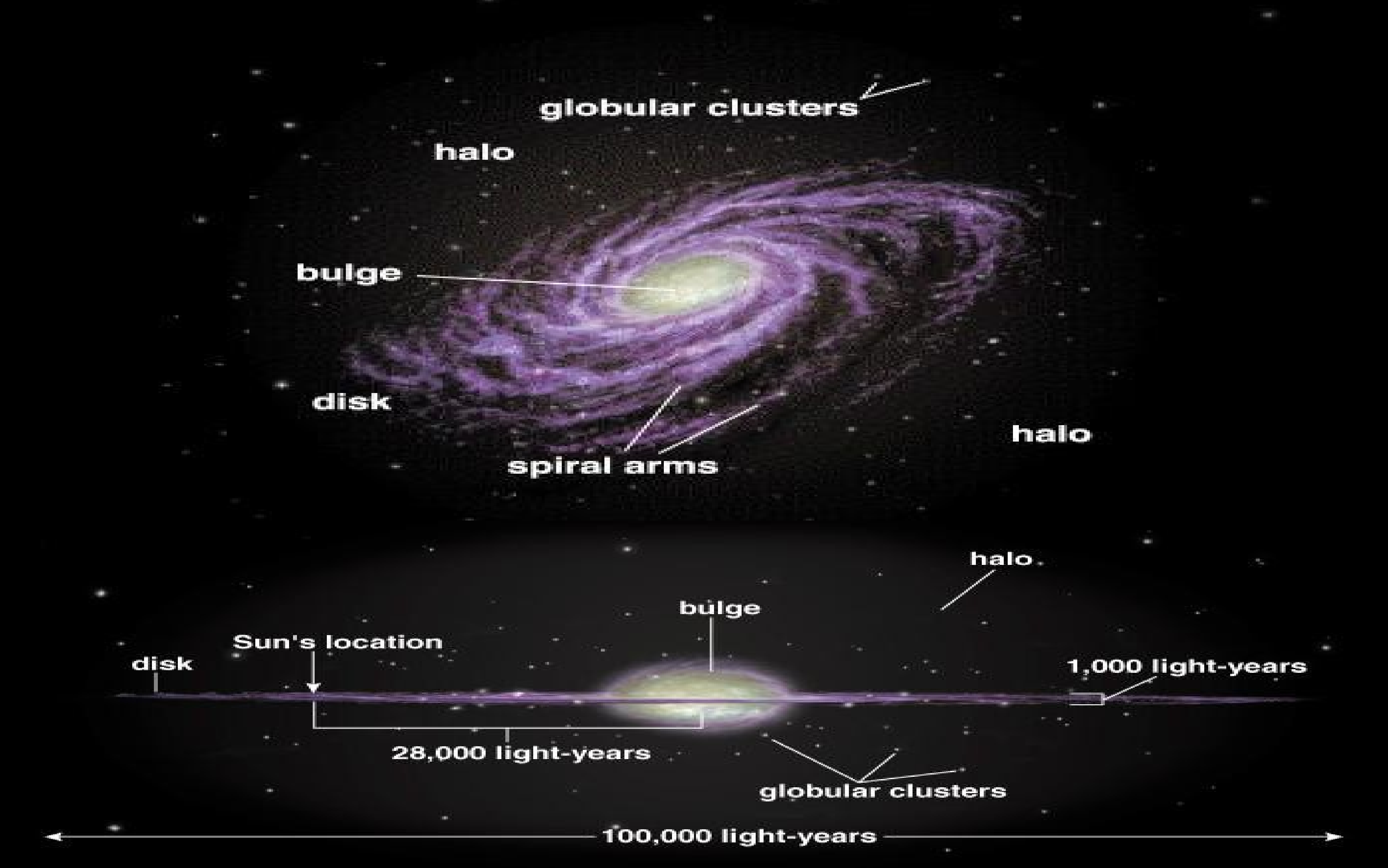
The Milky Way Galaxy

Herschel's Galaxy



Shapley's Globular Cluster Distribution

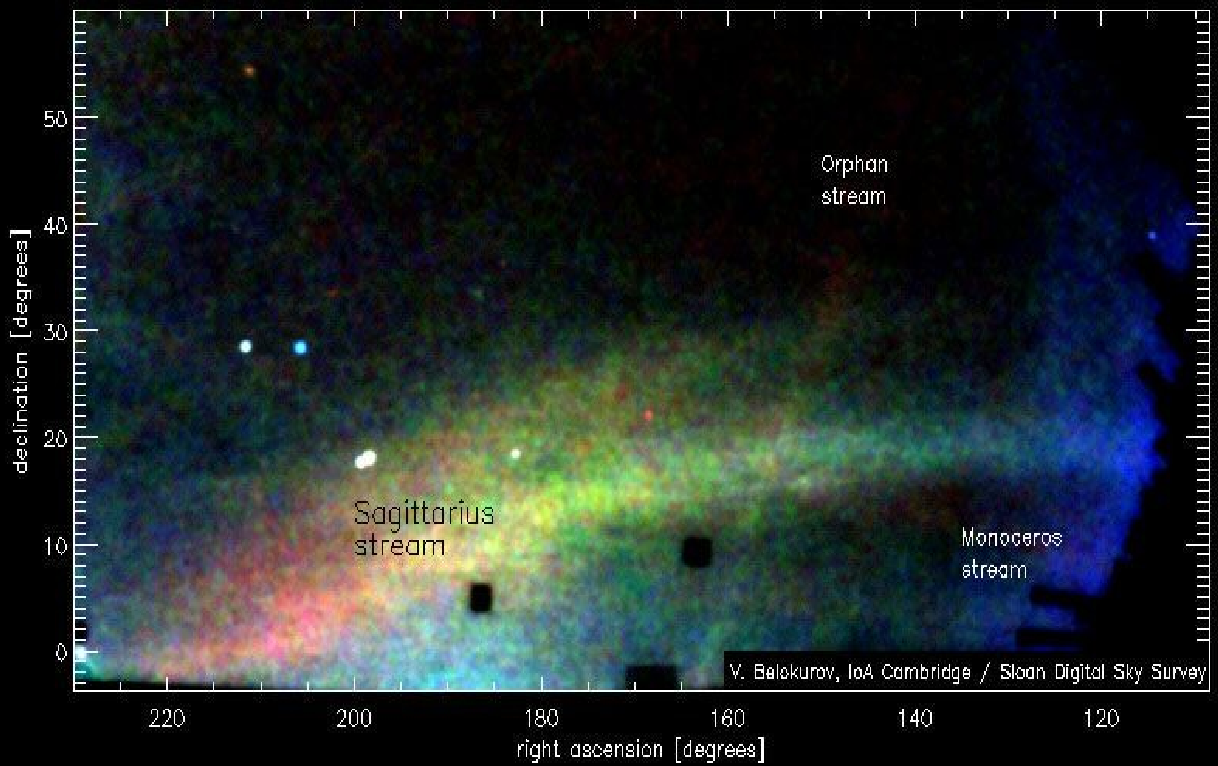


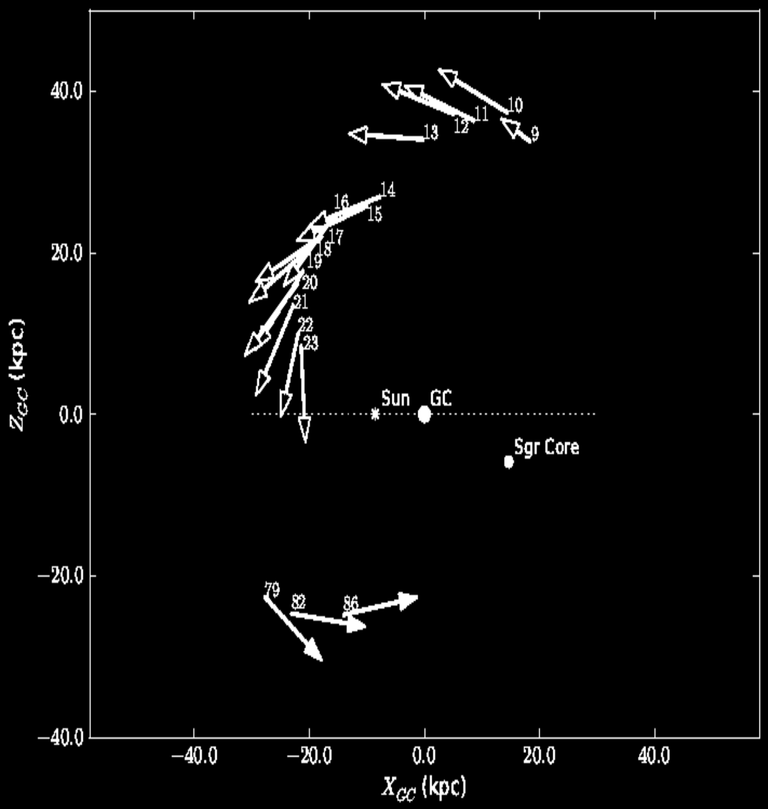

globular clusters
halo
bulge
disk
spiral arms
halo
halo
bulge
Sun's location
disk
1,000 light-years
28,000 light-years
globular clusters
100,000 light-years

The MilkyWay galaxy

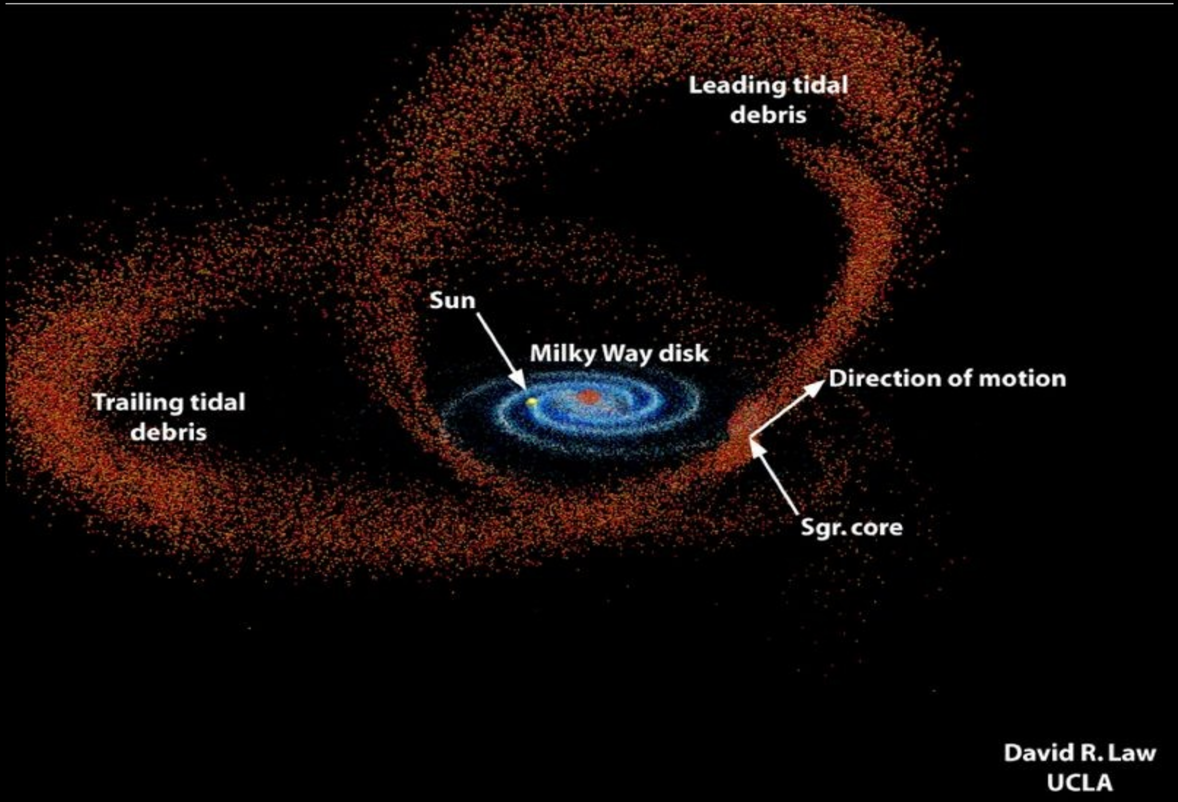
A large SBb (or SBc) spiral galaxy with ongoing star formation

Sagittarius Stream



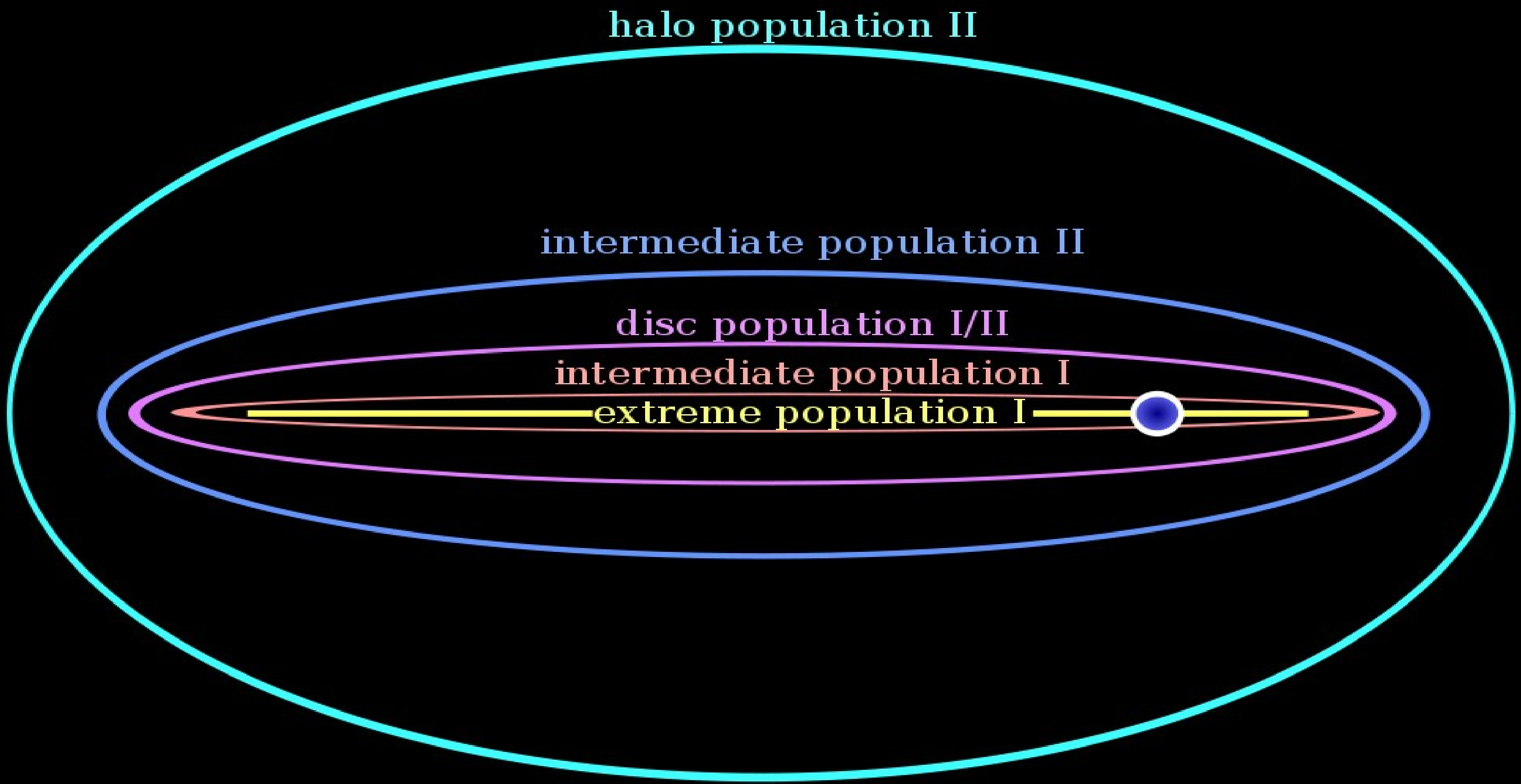


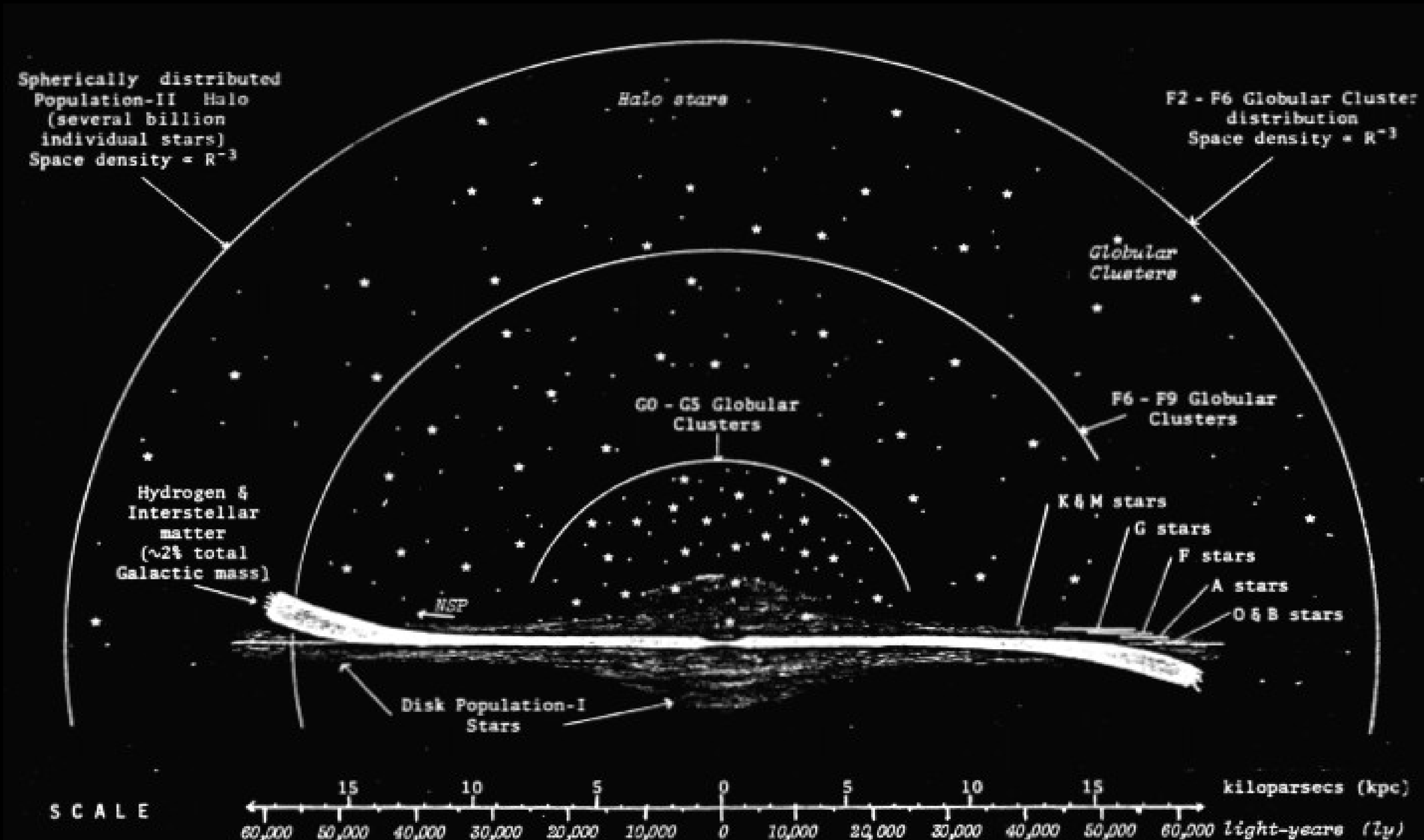
Sagittarius Stream



Sagittarius Stream

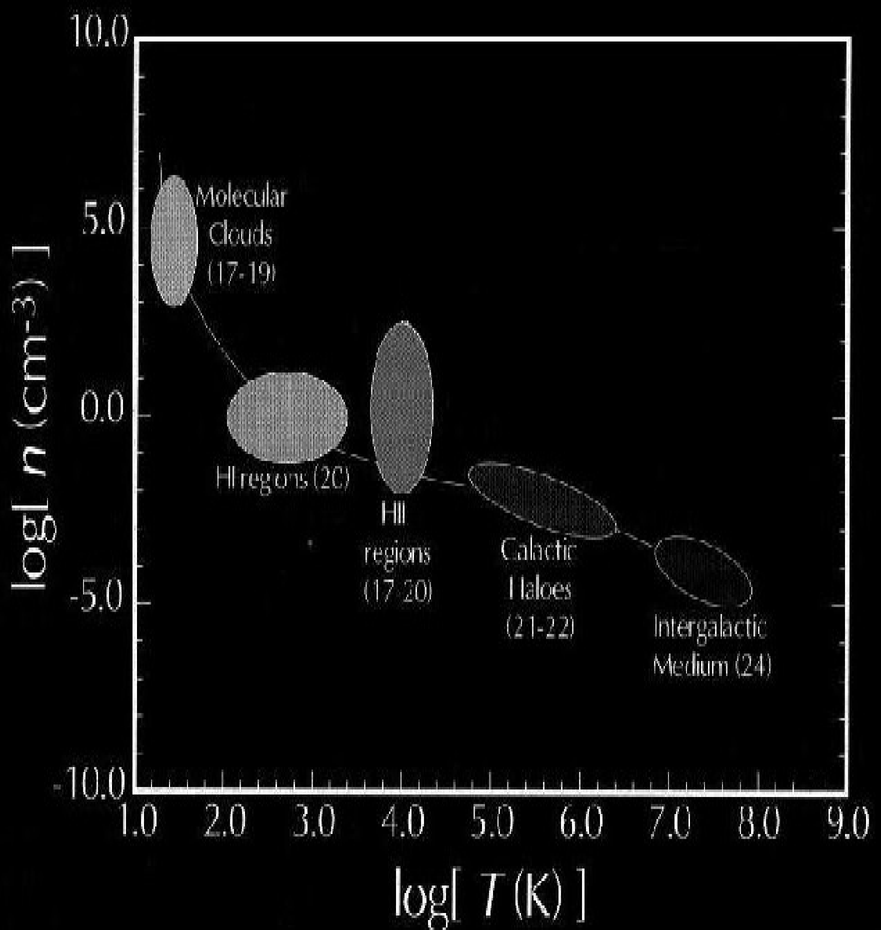
Stellar population





Spherically distributed
Population-II Halo
(several billion
individual stars)
Space density ∝ R⁻³
Halo stars
F2 - F6 Globular Cluste:
distribution
Space density ∝ R⁻³
Globular
Clusters
G0 - G5 Globular
Clusters
F6 - F9 Globular
Clusters
Hydrogen &
Interstellar
matter
(~2% total
Galactic mass)
NSP
K & M stars
G stars
F stars
A stars
O & B stars
Disk Population-I
Stars
SCALE
15 10 5 0 5 10 15 kiloparsecs (kpc)
60,000 50,000 40,000 30,000 20,000 10,000 0 10,000 20,000 30,000 40,000 50,000 60,000 light-years (ly)

The 5 phases of the Interstellar matter



Regions	Density (cm^{-3})	T (K)	ISM Mass Fraction
Molecular clouds	10^3	10 – 30	40-50%
HI cold	1-100	80	40-50%
warm	0.3-1	6000	4-6%
HII warm	0.1 – 1	6000-12000	0.1%
hot	10-2	10^6	

The Interstellar Medium

Interstellar Matter

- Molecular Clouds
- Neutral Hydrogen
- H II regions

Dust

InterStellar Radiation Field

- Stars,
- Dust
- CBM

Magnetic Field

Cosmic Rays

Energy density of the ISM

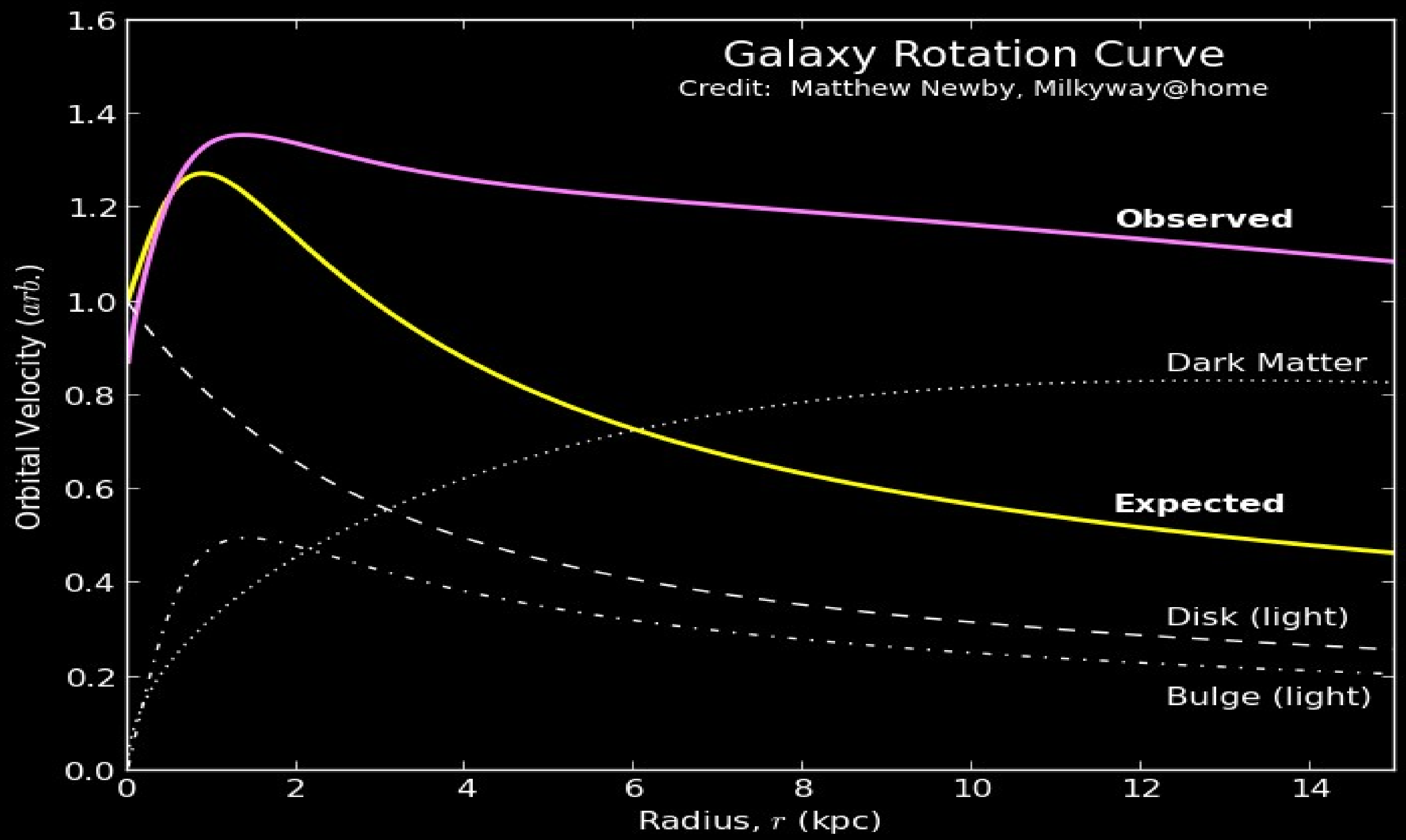
$$U_{ISRF} \sim 1 \text{ eV} / \text{cm}^3$$

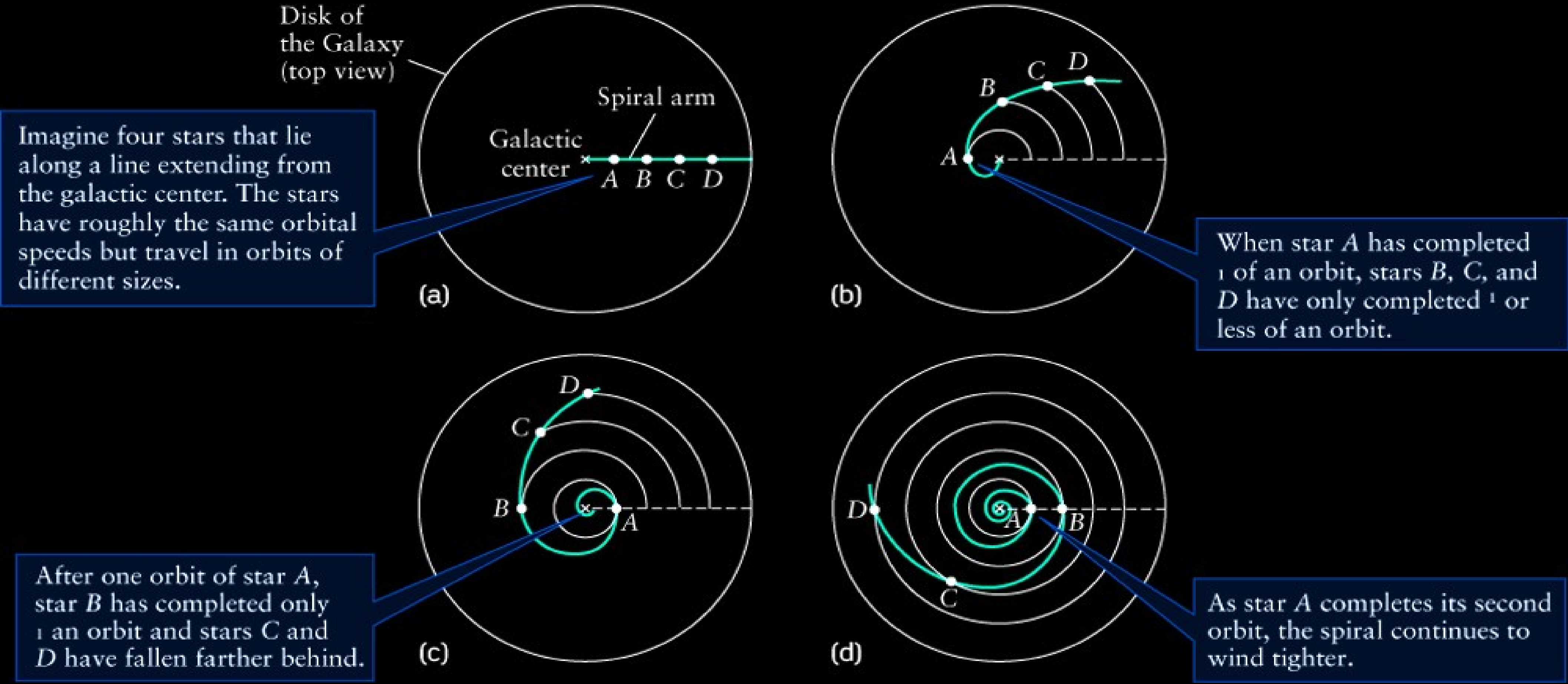
$$U_B \sim 1 \text{ eV} / \text{cm}^3$$

$$E_{CR} \sim 1 \text{ eV} / \text{cm}^3$$

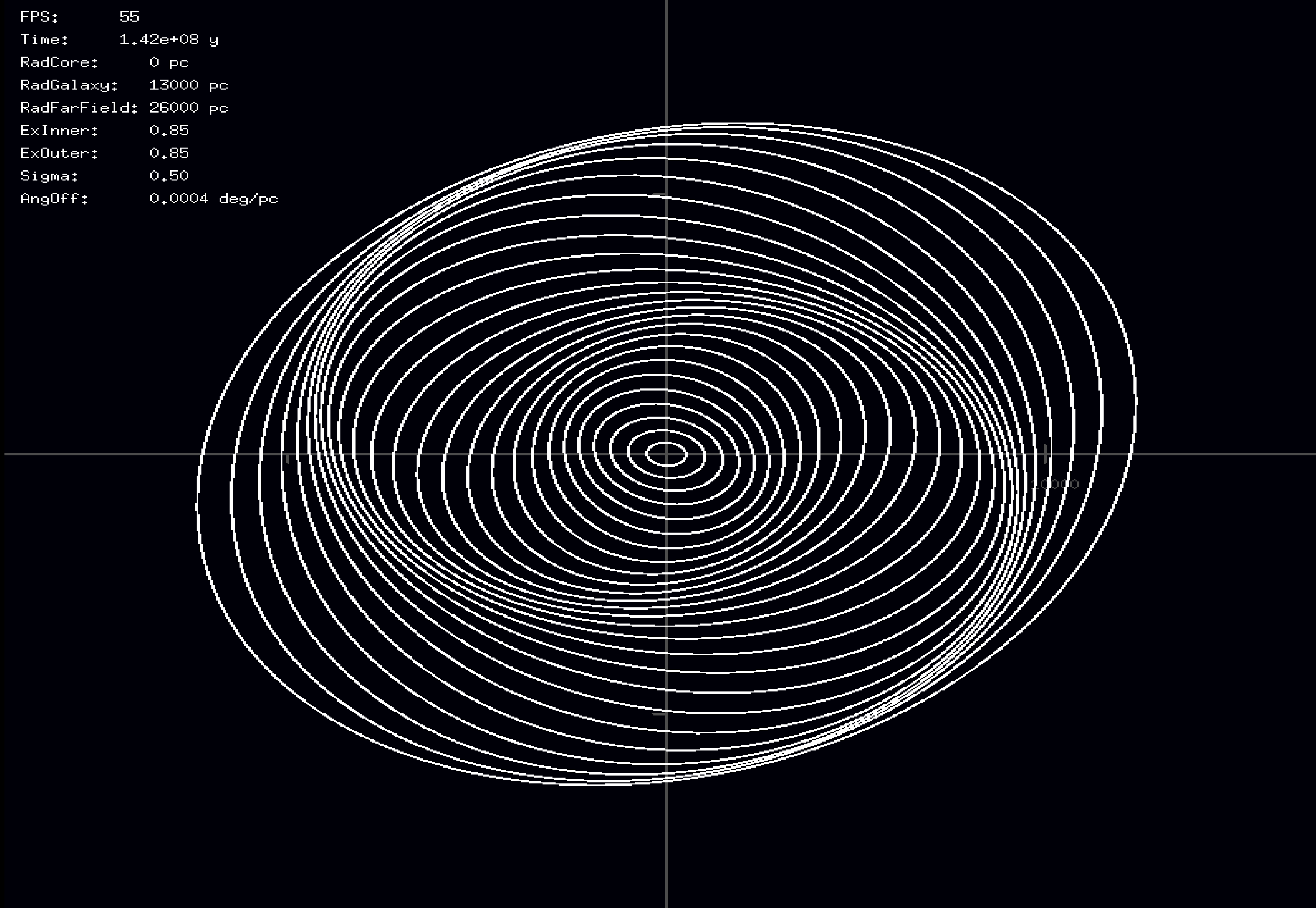
$$E_{gas} \sim 1 \text{ eV} / \text{cm}^3$$

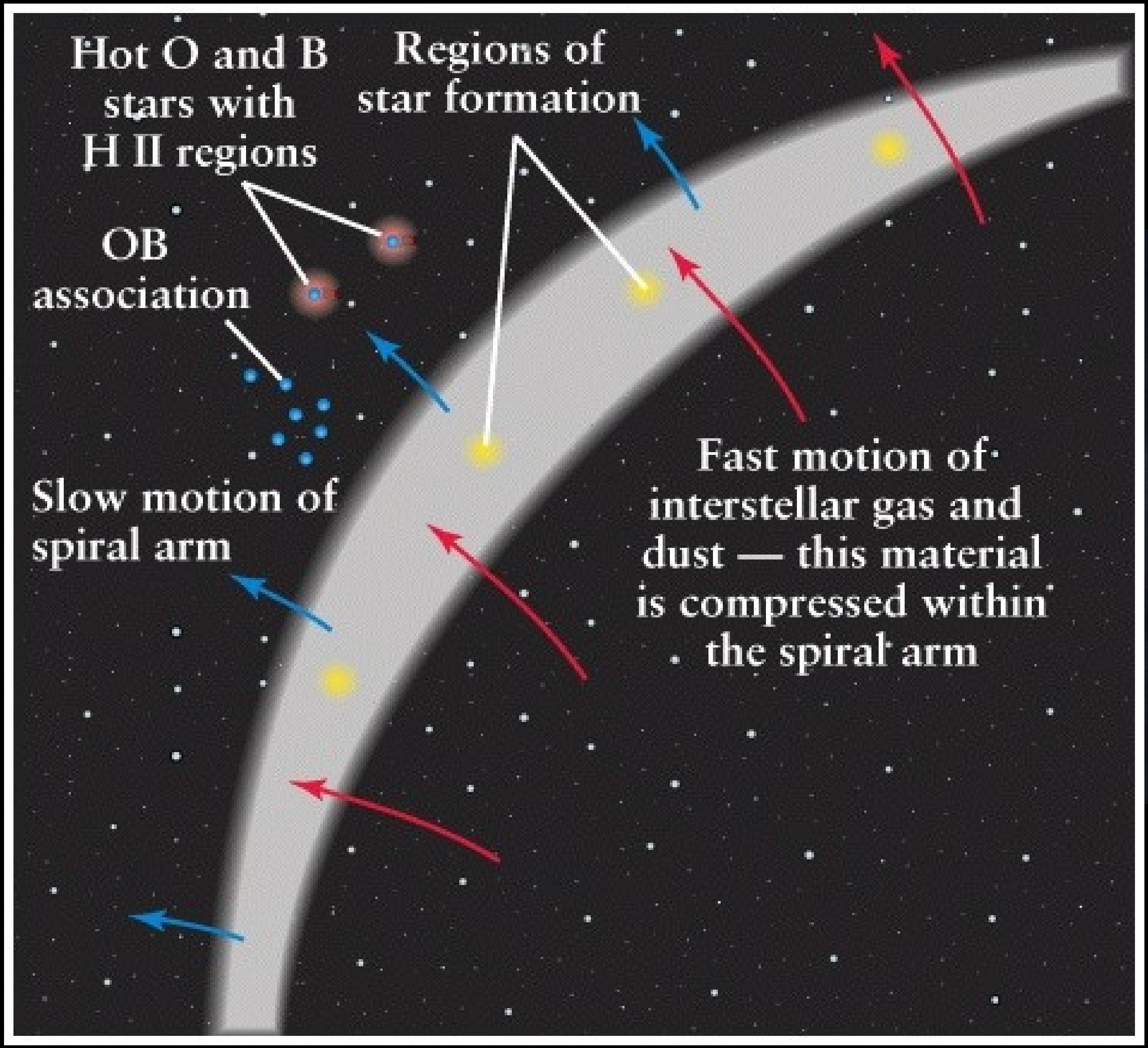
Galactic Rotation Curve

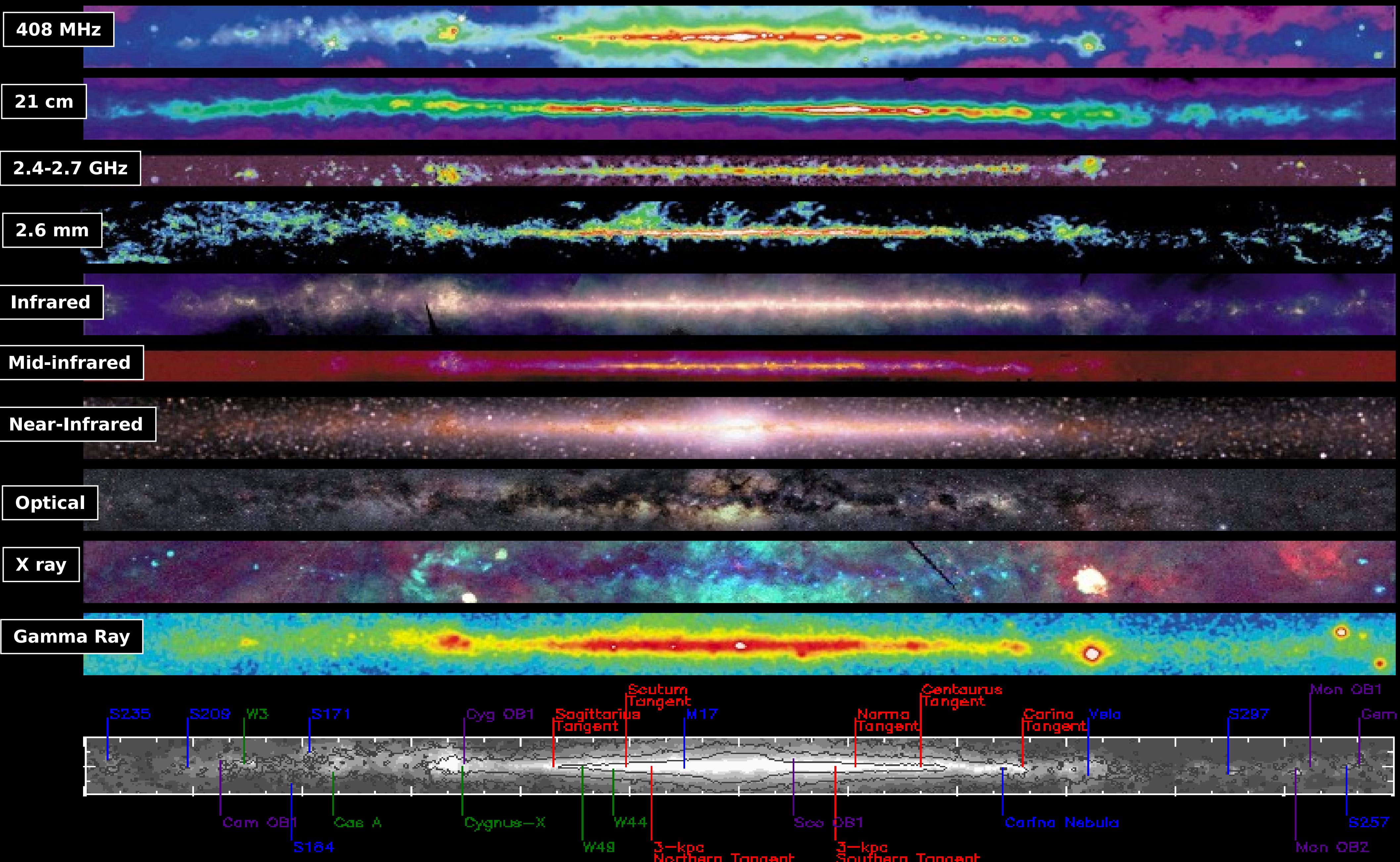




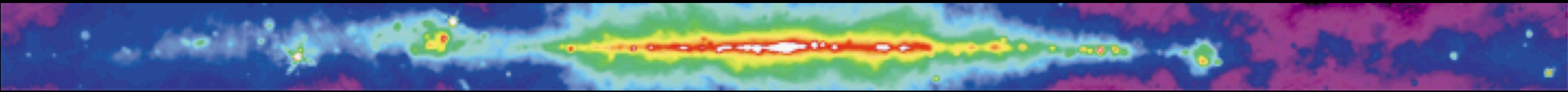
Disk of
the Galaxy
(top view)
Spiral arm
Galactic
center
A B C D
Imagine four stars that lie along a line extending from the galactic center. The stars have roughly the same orbital speeds but travel in orbits of different sizes.
(a)
B C D
A
When star A has completed 1 of an orbit, stars B, C, and D have only completed 1 or less of an orbit.
(b)
D
C
B
A
After one orbit of star A, star B has completed only 1 an orbit and stars C and D have fallen farther behind.
(c)
D
A B
C
As star A completes its second orbit, the spiral continues to wind tighter.
(d)


FPS: 55
Time: 1.42e+08 y
RadCore: 0 pc
RadGalaxy: 13000 pc
RadFarField: 26000 pc
ExInner: 0.85
ExOuter: 0.85
Sigma: 0.50
AngOff: 0.0004 deg/pc


Hot O and B stars with H II regions
Regions of star formation
OB association
Slow motion of spiral arm
Fast motion of interstellar gas and dust — this material is compressed within the spiral arm


408 MHz
21 cm
2.4-2.7 GHz
2.6 mm
Infrared
Mid-infrared
Near-Infrared
Optical
X ray
Gamma Ray
S235
S209
W3
S171
Cyg OB1
Sagittarius Tangent
Scutum Tangent
M17
Norma Tangent
Centaurus Tangent
Carina Tangent
Vela
S297
Mon OB1
Gem
Cam OB1
S184
Cas A
Cygnus-X
W49
W44
3-kpc Northern Tangent
Sco OB1
3-kpc Southern Tangent
Carina Nebula
Mon OB2
S257

Radio Continuum (408 MHz)



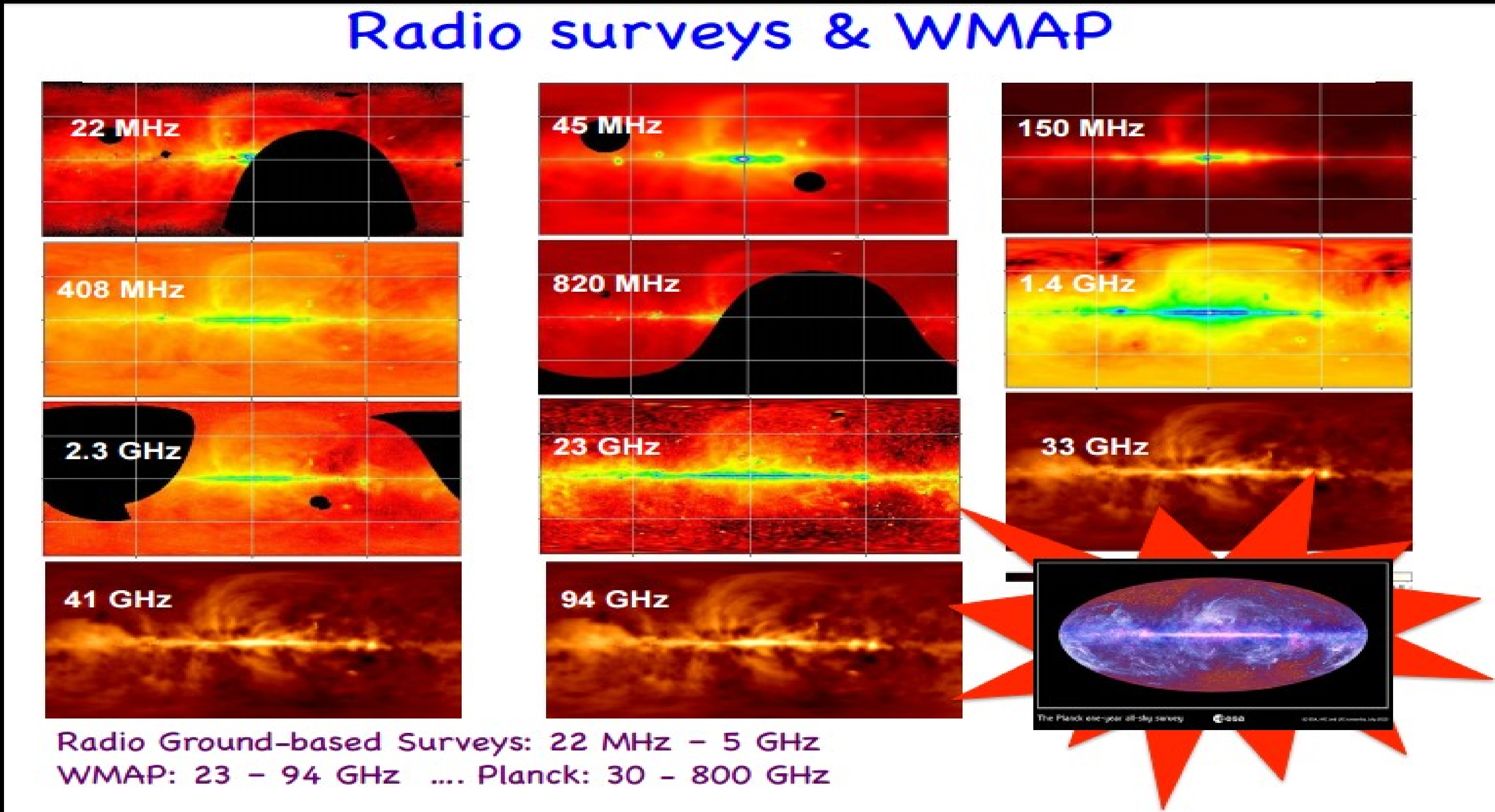
Intensity of radio continuum emission from high-energy charged particles in the Milky Way,from surveys with ground-based radio telescopes (Jodrell Bank Mark I and Mark IA, Bonn 100-meter, and Parkes 64-meter).

At this frequency, most of the emission is from electrons moving through the interstellar magnetic field at nearly the speed of light.

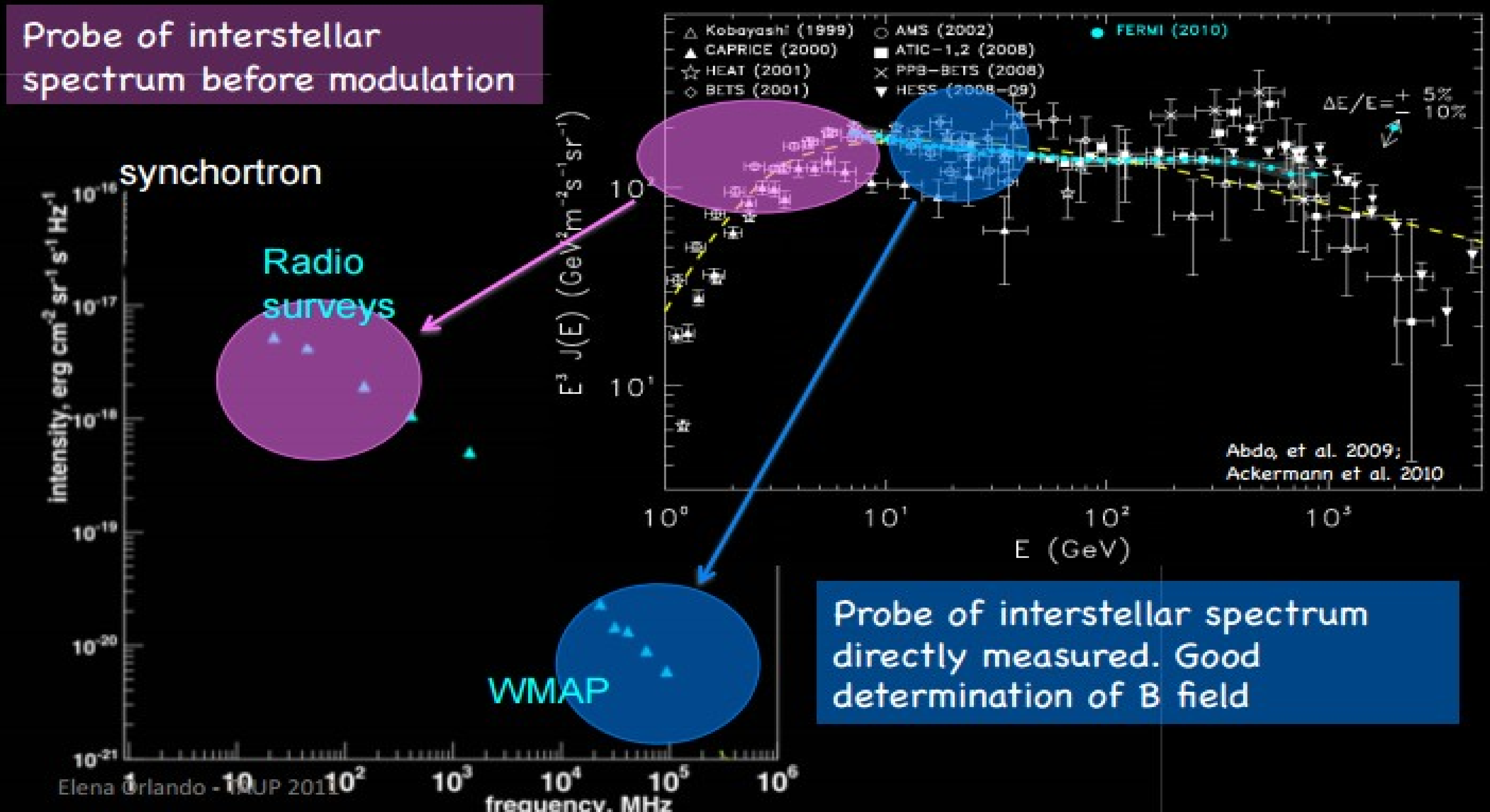
Shock waves from supernova explosions accelerate electrons to such high speeds, producing especially intense radiation near these sources.

Emission from the supernova remnant Cas A near 110° longitude is so intense that the diffraction pattern of the support legs for the radio receiver on the telescope is visible as a cross shape.

Radio emission of the Galaxy

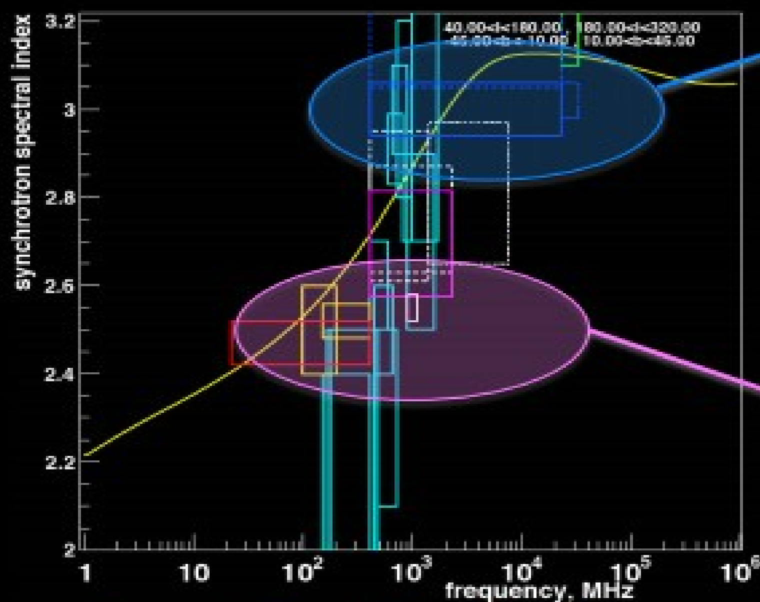


Radio emission of the Galaxy



Radio emission of the Galaxy

Synchrotron spectral index measurements ...



Strong, Orlando & Jaffe A&A accepted (arXiv:1108.4822)

β~3.0 → P~3.0

β=2+(p-1)/2
(p=ambient e- spectrum)

β~2.5 → p~2.0

... need of a break in interstellar e-

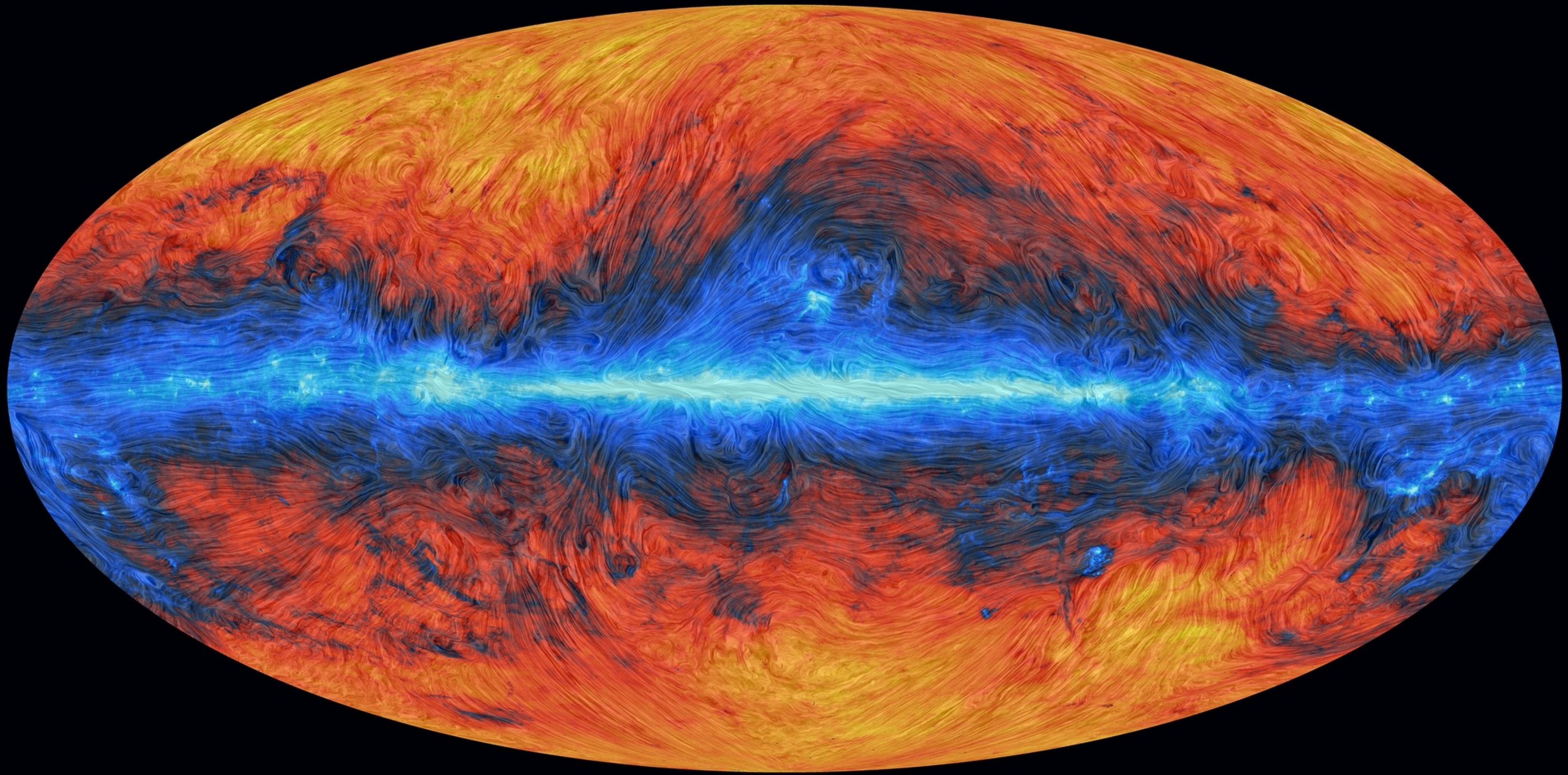
The magnetic field

Ordered, large-scale magnetic field
B = 2 - 6 microGauss

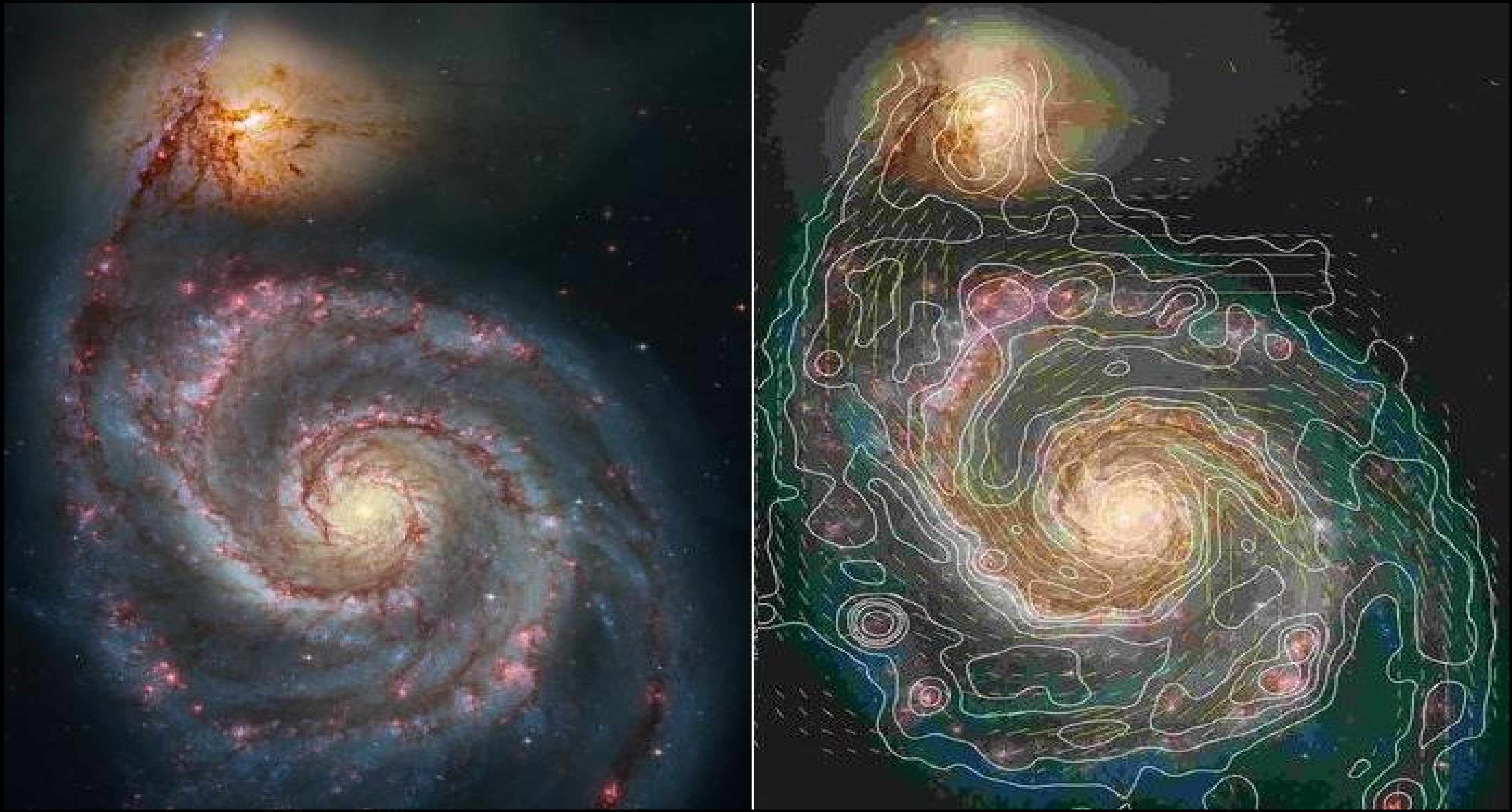
Explored with:

- **Radio continuum**
- **Starlight polarization**
- **Faraday Rotation**
- **Zeeman splitting**

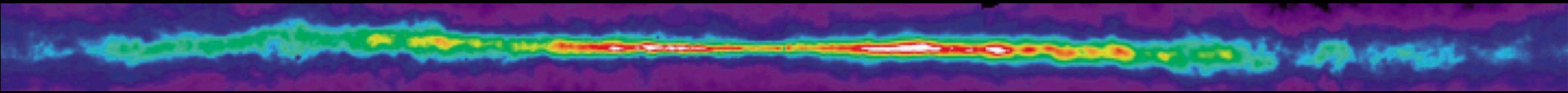
The magnetic field



The magnetic field



Atomic Hydrogen (1.4 GHz)

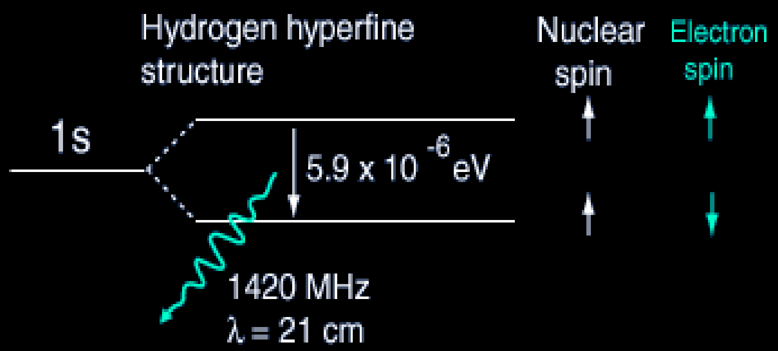


Column density of atomic hydrogen,derived on the assumption of optically thin emission, from radio surveys of the 21-cm transition of hydrogen.

The 21-cm emission traces the "cold and warm" interstellar medium, which on a large scale is organized into diffuse clouds of gas and dust that have sizes of up to hundreds of light-years.

Most of the image is based on the Leiden-Dwingeloo Survey of Galactic Neutral Hydrogen using the Dwingeloo 25-m radio telescope; the data were corrected for sidelobe contamination in collaboration with the University of Bonn.

Neutral Hydrogen (HI)



Ground level of neutral hydrogen ($1^2S_{1/2}$) is split into two sublevels

F = J + I = 0,1

Tiny energy separation (t = 1.1 10^7 years)

Radio emission at 1420.4 MHz or 21 cm

Spin temperature T_S

Neutral Hydrogen Survey

Leiden-Dwingeloo survey at 21 cm

(Hartmann et al 1997)

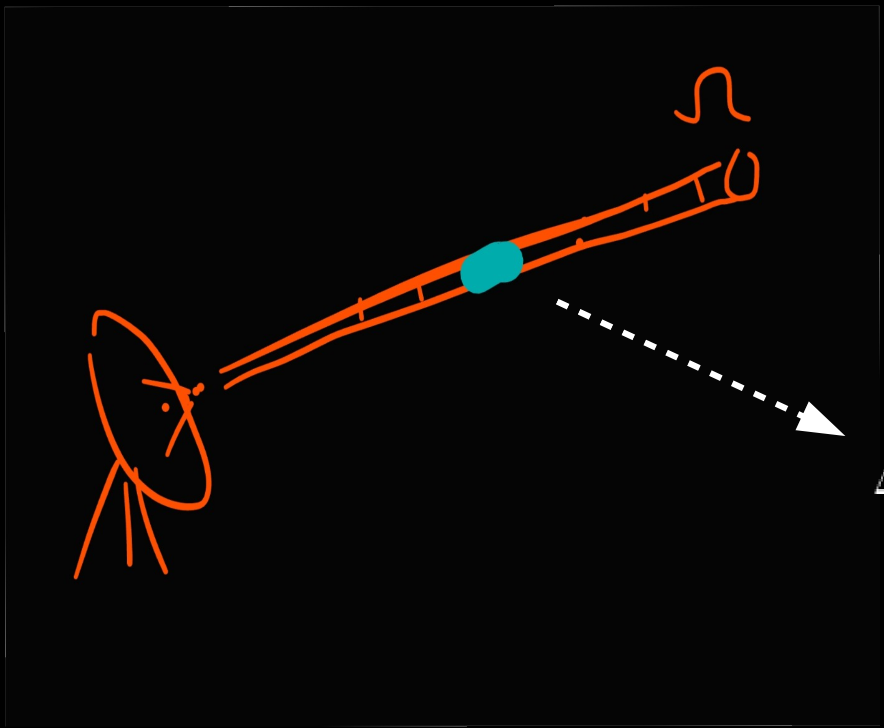
Spatial resolution: 30’

Velocity resolution: 1.03 km/s

Velocity range: -450,400 km/s

Sensitivity: 0.07° K

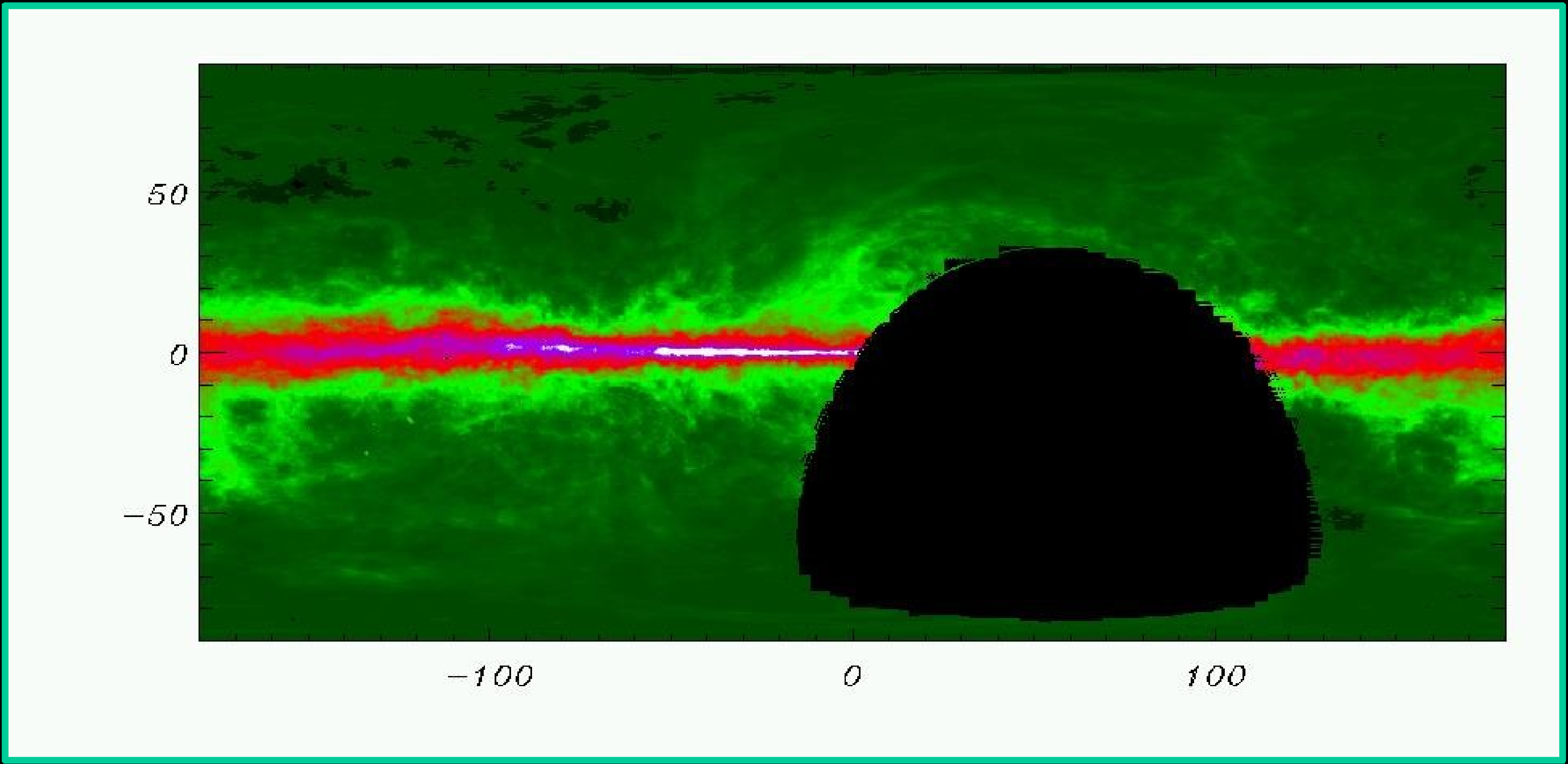
Intensity vs column density



$$\Delta F = \frac{\Delta L}{4\pi r^2} = \frac{\epsilon(r)\,\Delta V}{4\pi r^2} = \frac{\epsilon(r)\,\Omega r^2\,dr}{4\pi r^2} = \epsilon(r)\,\frac{\Omega}{4\pi}\,dr$$

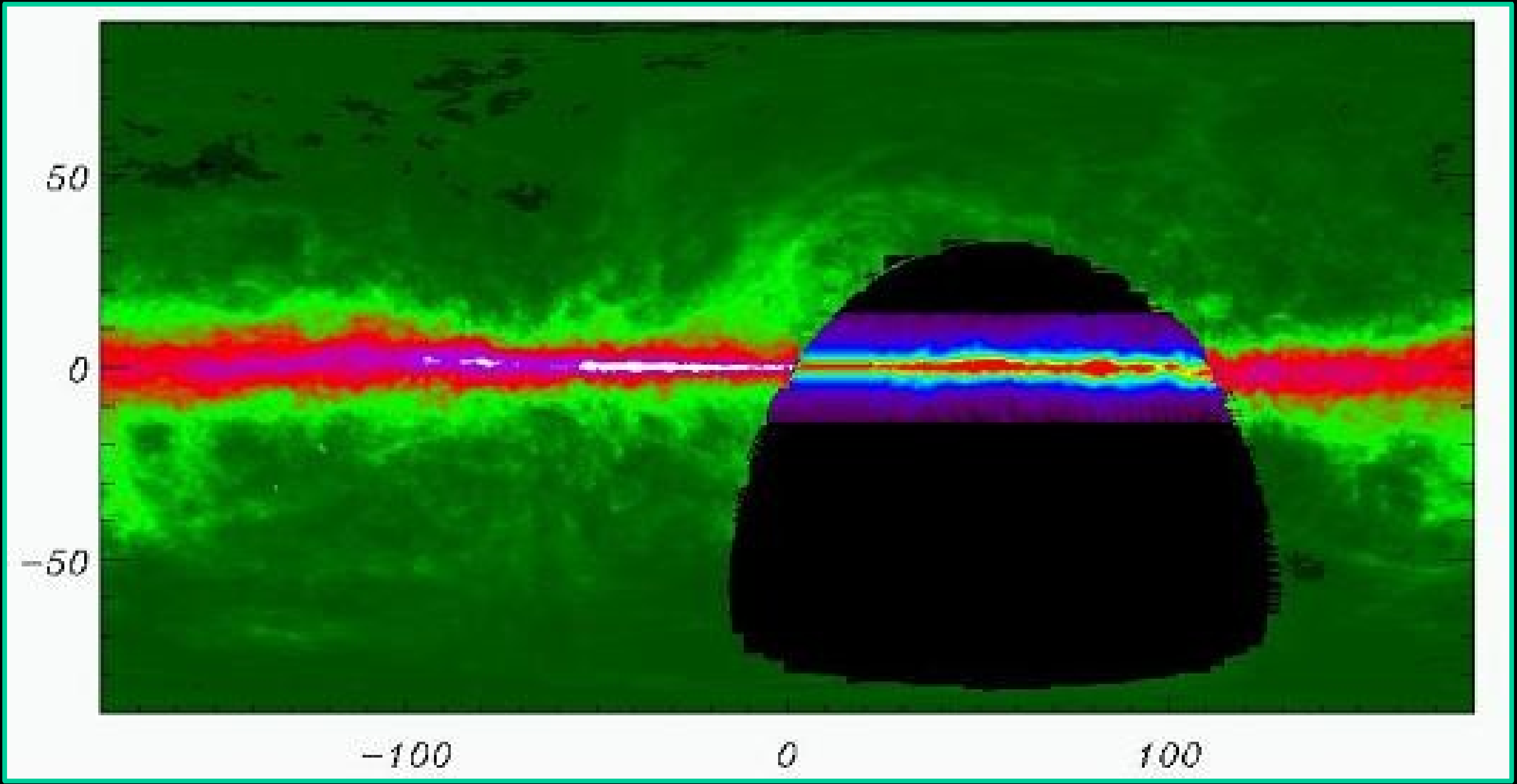
$$I = \frac{F}{\Omega} = \frac{1}{4\pi}\int_0^\infty \epsilon(r)\,dr = \frac{3}{16\pi\,\tau}\int_0^\infty n_{HI}(r)\,dr$$

Neutral Hydrogen



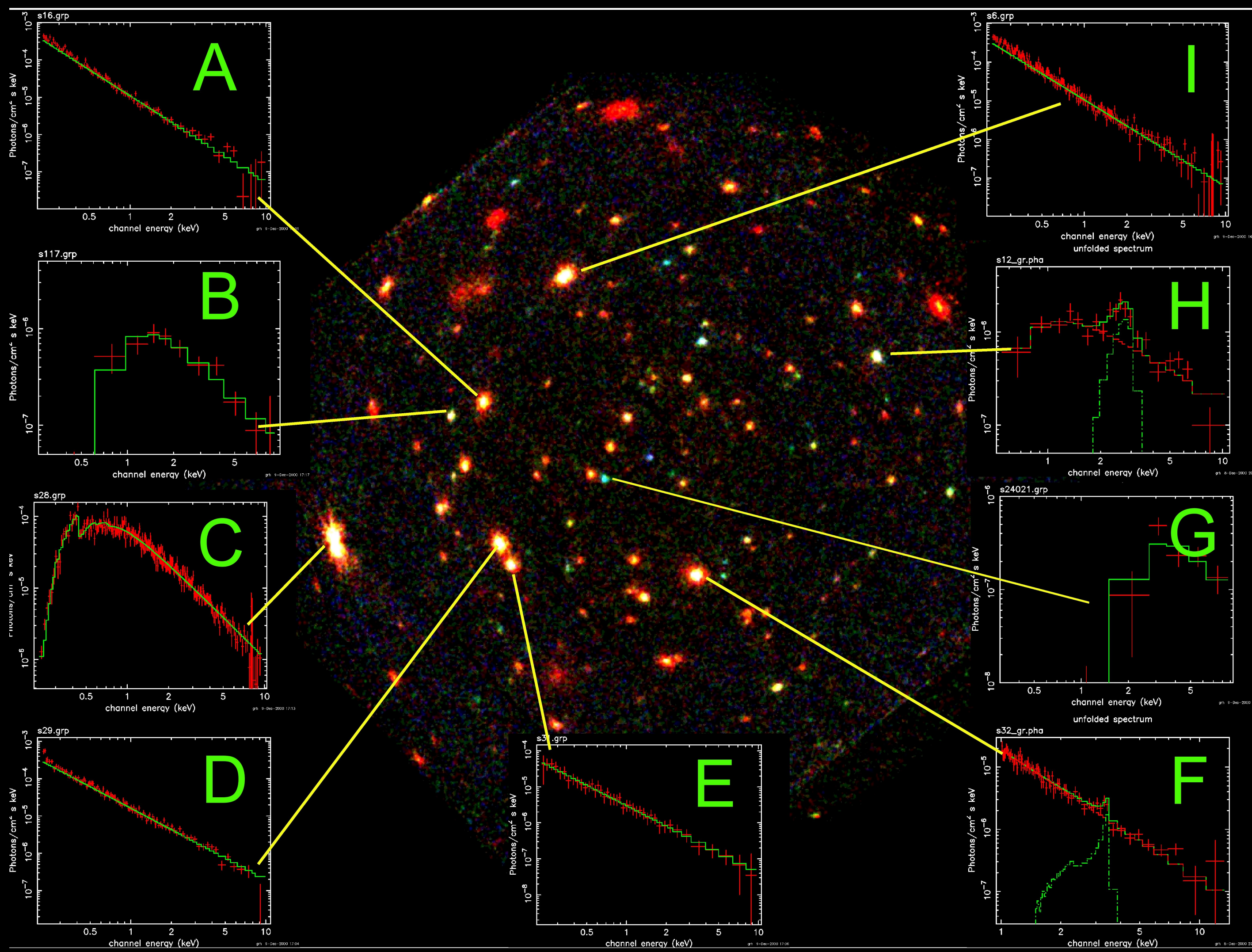
Leiden-Dwingeloo survey at 21 cm (Hartmann et al 1997)

Neutral Hydrogen

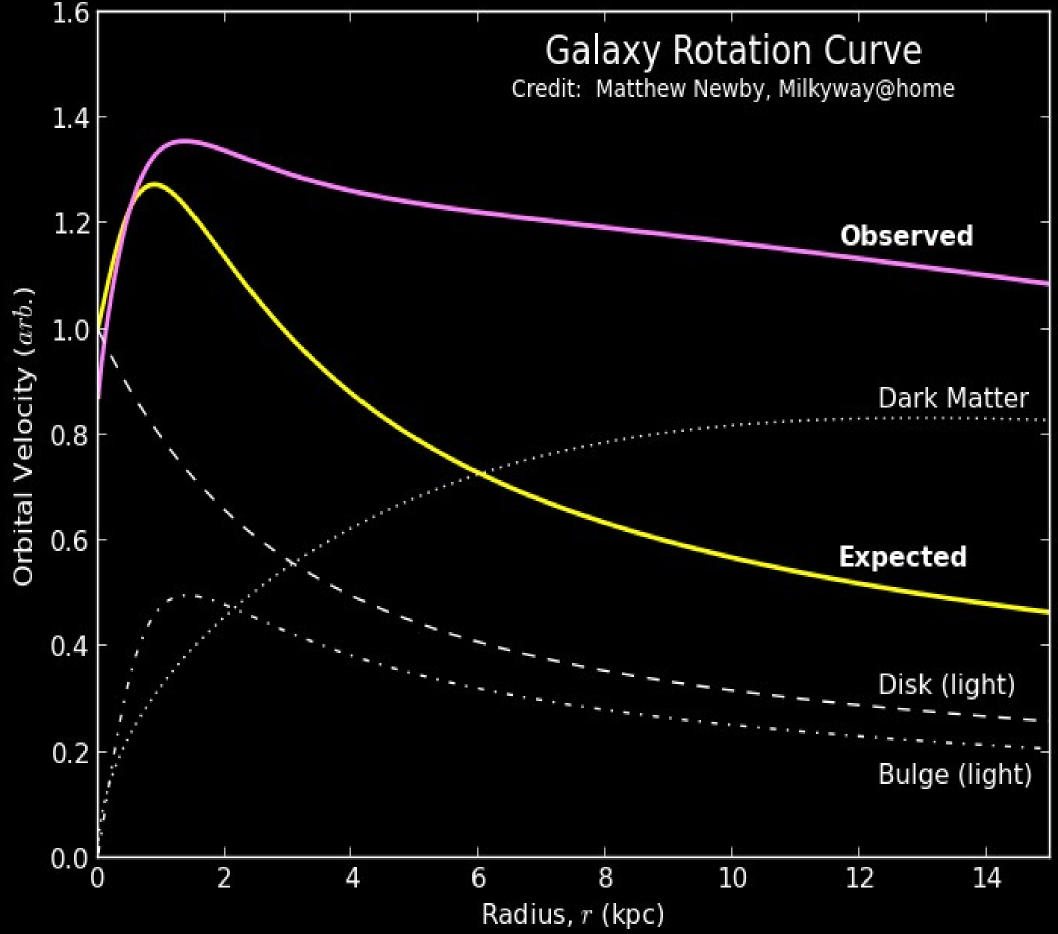


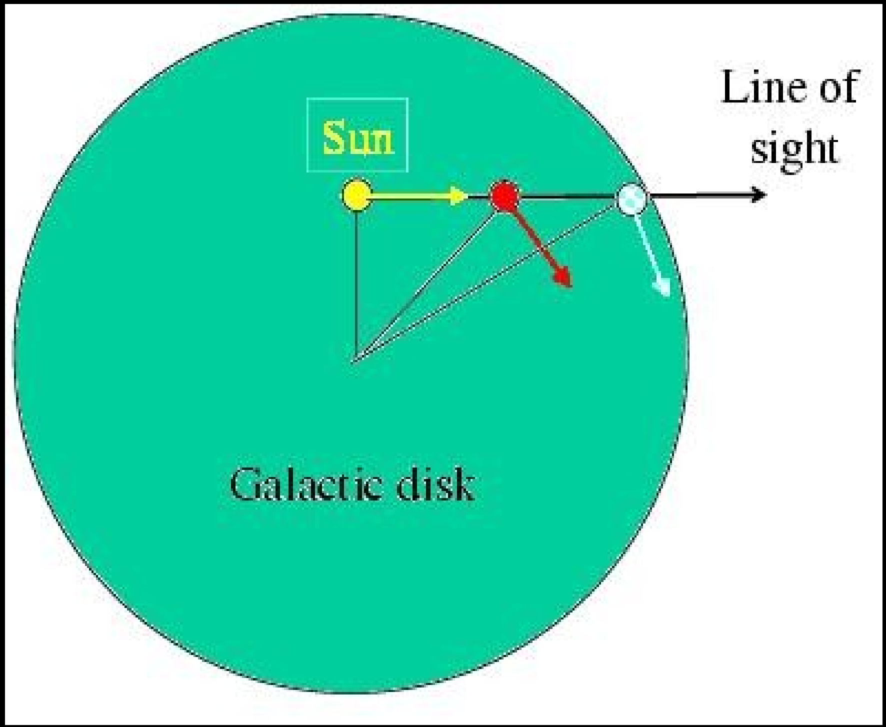
Leiden-Dwingeloo survey + Parkes (Kerr et al 1986)

Lockman Hole

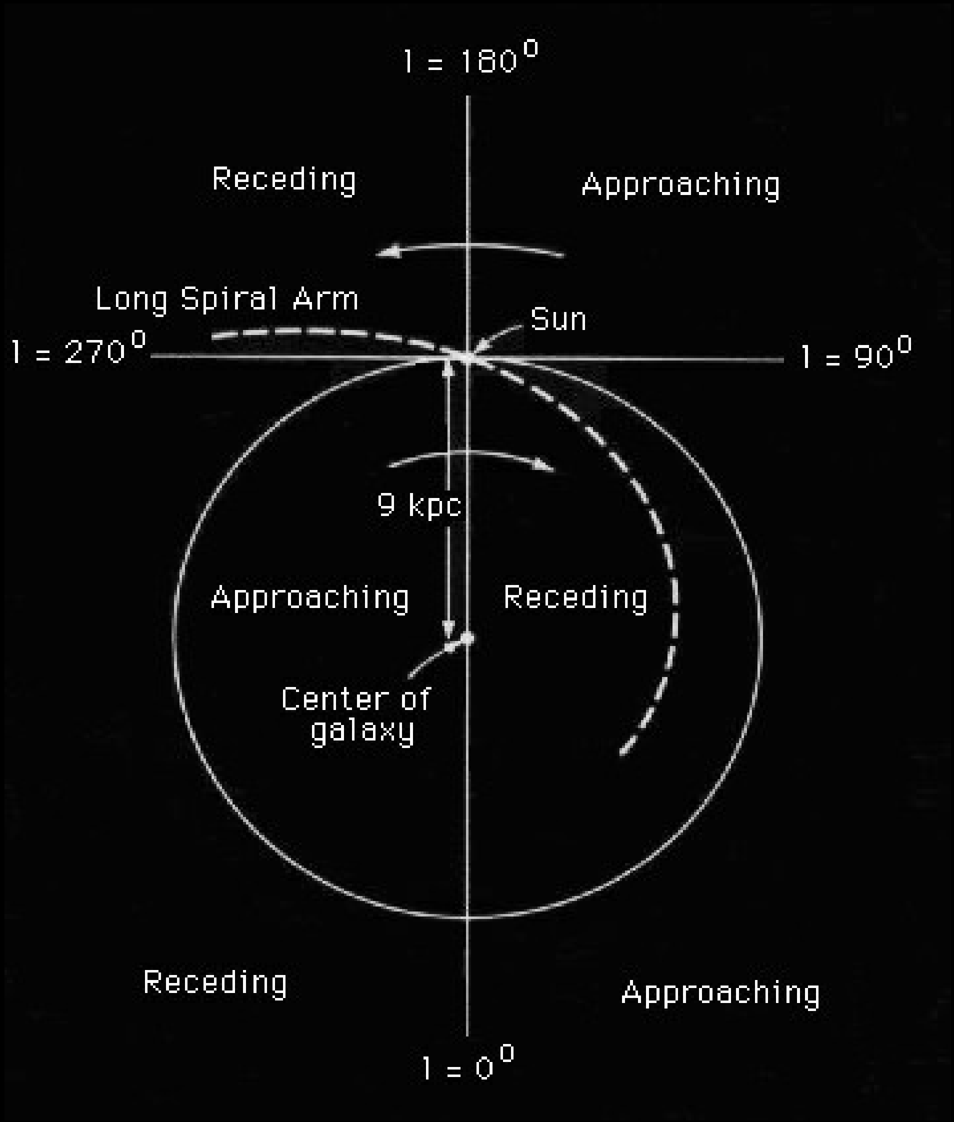


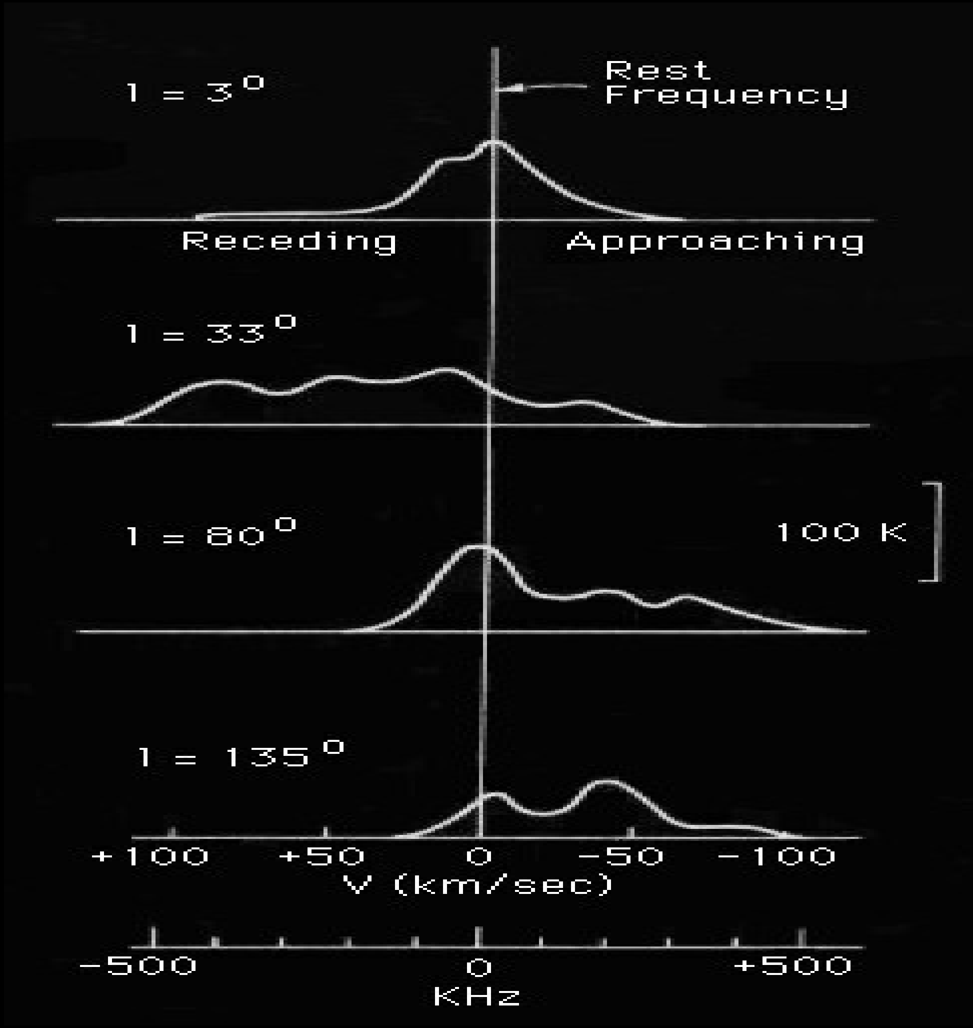
Radio Data deprojection



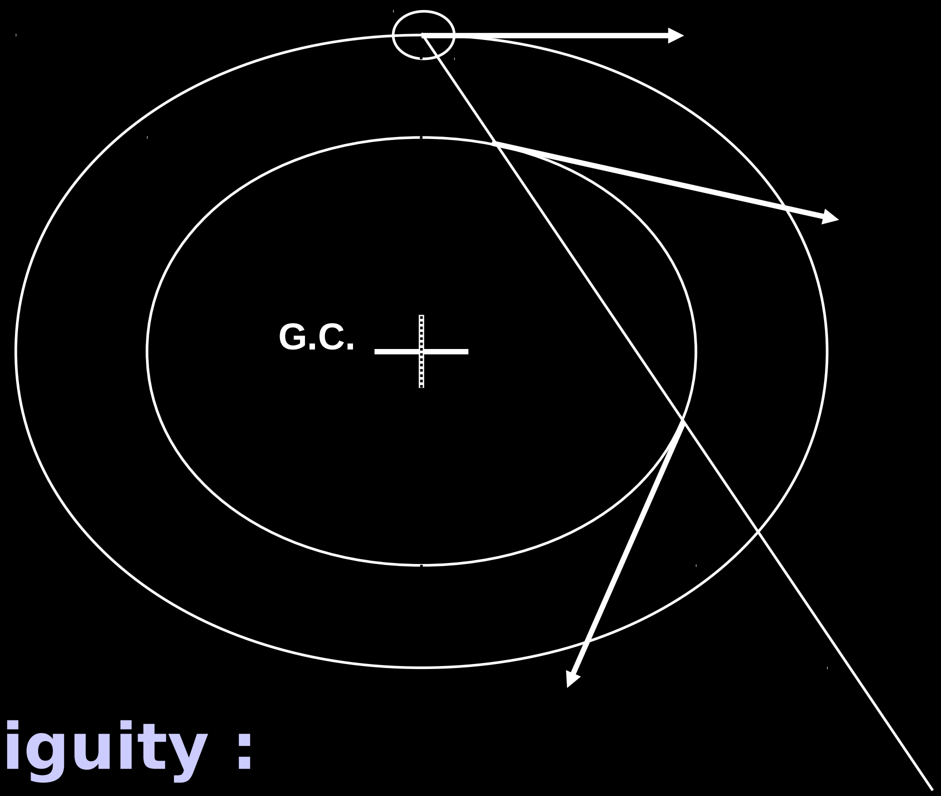


Radio Data deprojection





Near-Far distance ambiguity:



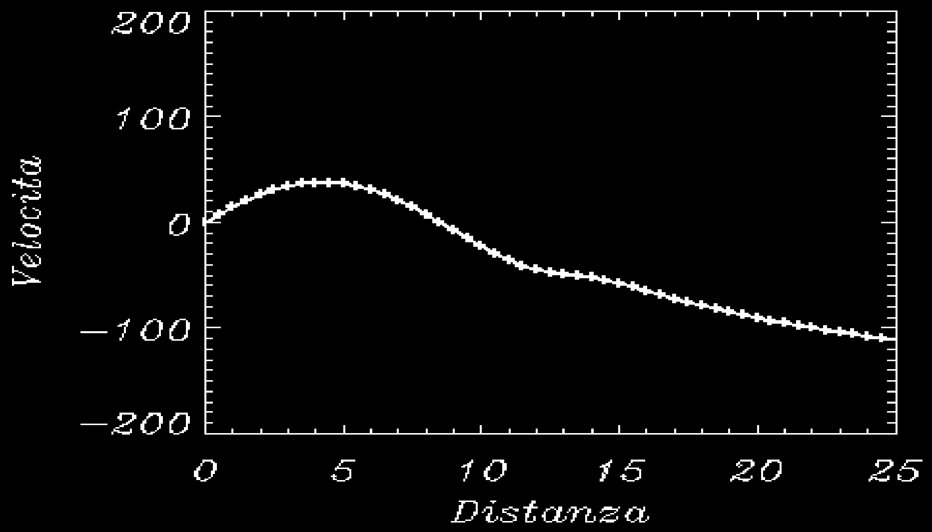
Dinamical ambiguity :

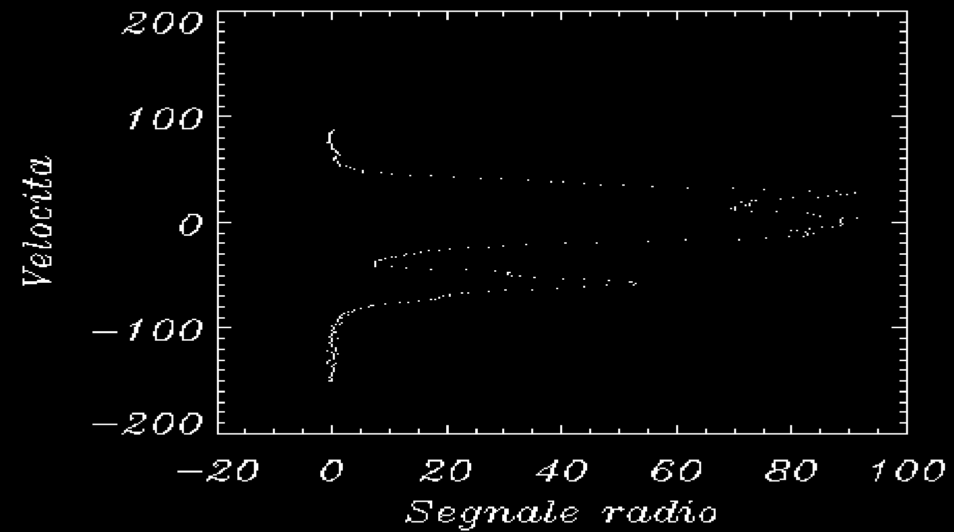
$$w.f. \propto e^{-\frac{1}{2}\frac{z}{Z_{gas}}}$$

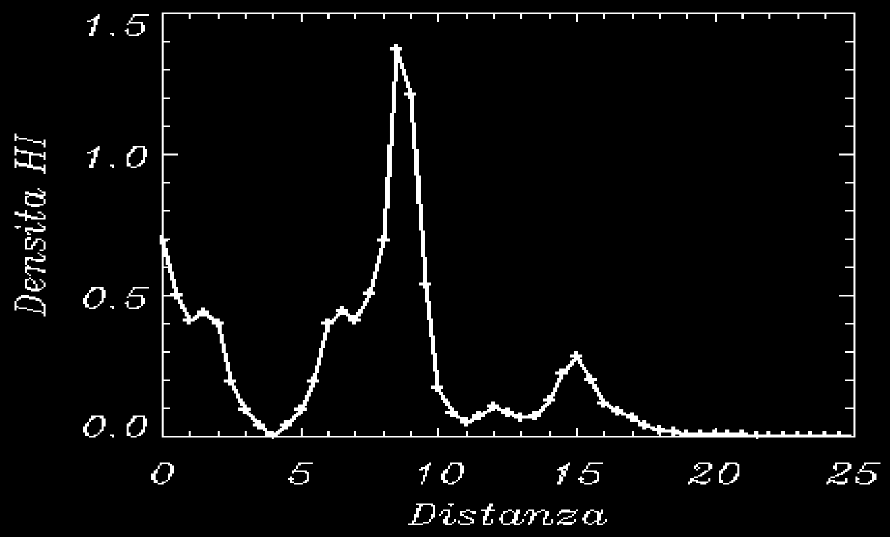
$Z_{gas} = 100\ pc$ for HI

$Z_{gas} = 60\ pc$ for H_2

Radio Data deprojection



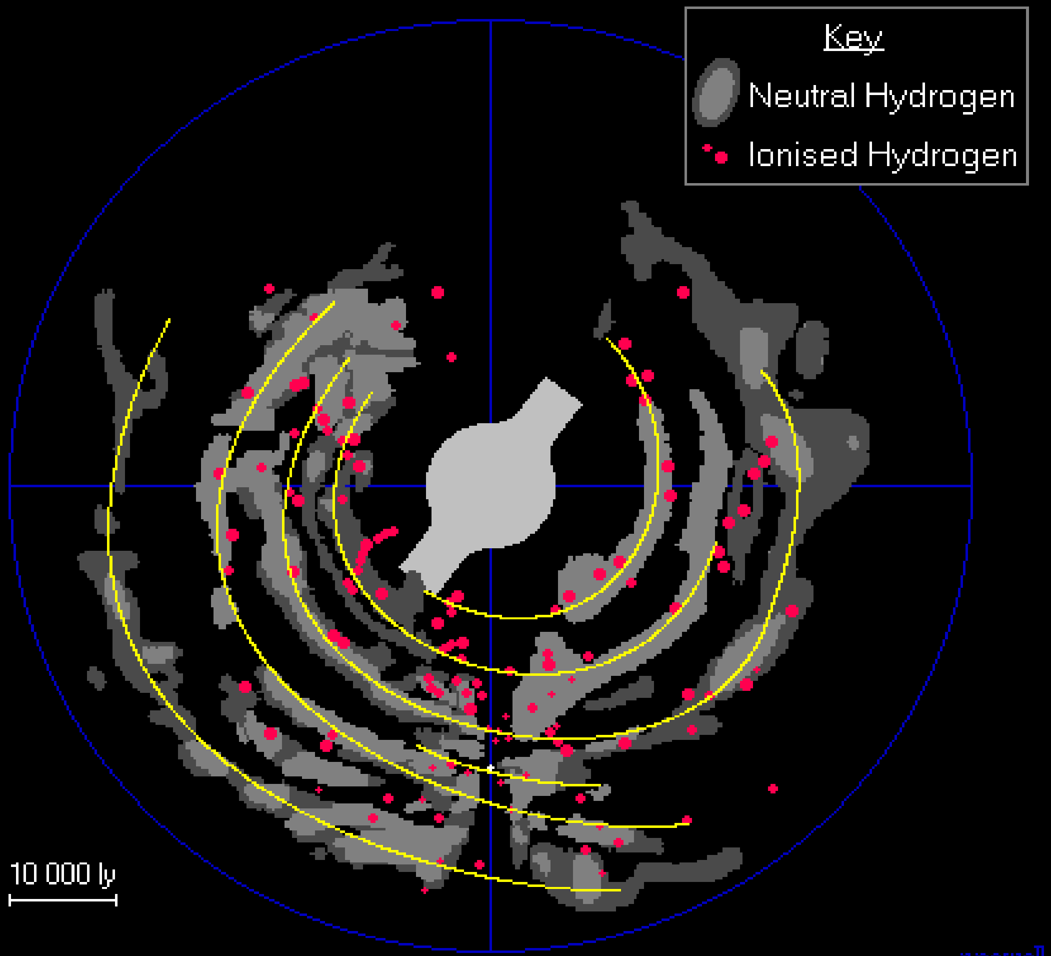




Lat. 0.00000

Long. 60.0000

Neutral Hydrogen (HI)



Two phase medium in pressure balance

Cold (100 K)

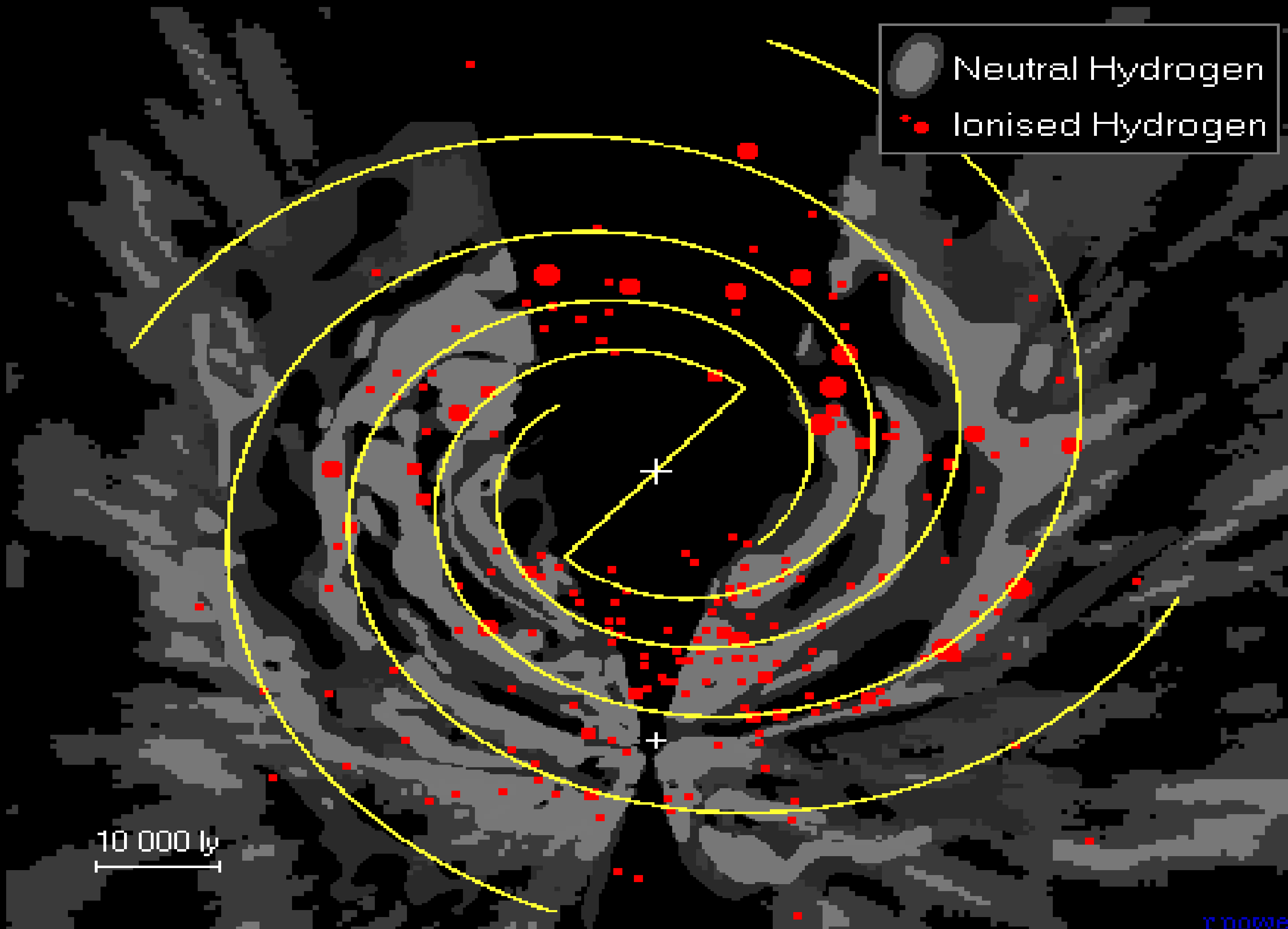
Mass

Dense sheet

No grav. Bound

n = 20–60 cm^{-3}

Warm (6000 K)



Neutral Hydrogen
Ionised Hydrogen
10 000 ly
r powell

Astronomy & Astrophysics manuscript no. ms
October 9, 2014

The observed spiral structure of the Milky Way* **

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ABSTRACT

Context. The spiral structure of the Milky Way is not yet well determined. The keys to understanding this structure are to increase the number of reliable spiral tracers and to determine their distances as accurately as possible. HII regions, giant molecular clouds (GMCs), and 6.7 GHz methanol masers are closely related to high mass star formation, and hence they are excellent spiral tracers. The distances for many of them have been determined in the literature with trigonometric, photometric and/or kinematic methods.
Aims. We update the catalogs of Galactic HII regions, GMCs, and 6.7 GHz methanol masers, and then outline the spiral structure of the Milky Way.
Methods. We collected data for more than 2500 known HII regions, 1300 GMCs, and 900 6.7 GHz methanol masers. If the photometric or trigonometric distance was not yet available, we determined the kinematic distance using a Galaxy rotation curve with the current IAU standard, R_0 = 8.5 kpc and Θ_0 = 220 km s^{-1}, and the most recent updated values of R_0 = 8.3 kpc and Θ_0 = 239 km s^{-1}, after velocities of tracers are modified with the adopted solar motions. With the weight factors based on the excitation parameters of HII regions or the masses of GMCs, we get the distributions of these spiral tracers.
Results. The distribution of tracers shows at least four segments of arms in the first Galactic quadrant, and three segments in the fourth quadrant. The Perseus Arm and the Local Arm are also delineated by many bright HII regions. The arm segments traced by massive star forming regions and GMCs are able to match the HI arms in the outer Galaxy. We found that the models of three-arm and four-arm logarithmic spirals are able to connect most spiral tracers. A model of polynomial-logarithmic spirals is also proposed, which not only delineates the tracer distribution, but also matches the observed tangential directions.

Key words. Galaxy: disk – Galaxy: structure – Galaxy: kinematics and dynamics – HII regions – ISM: clouds

e Data

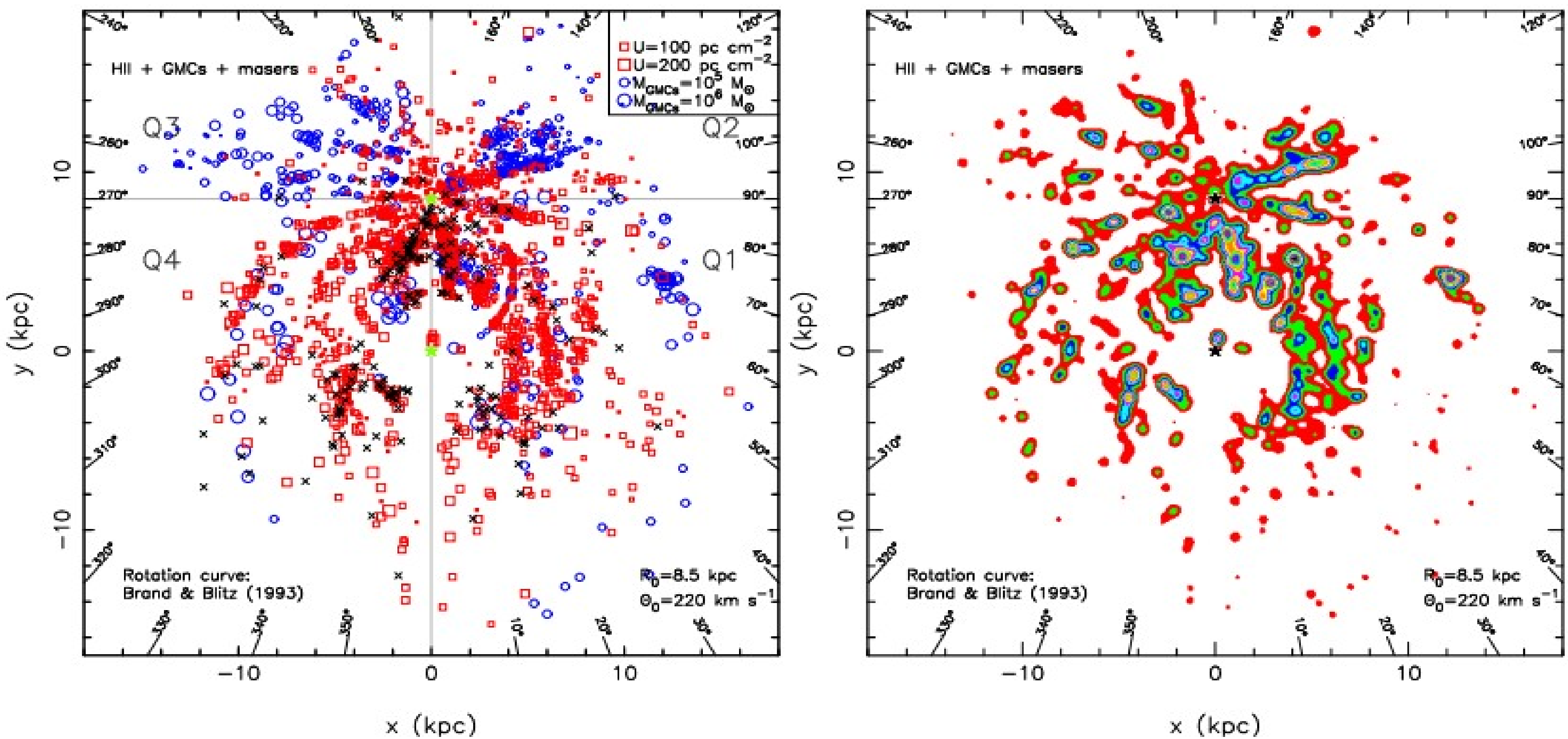
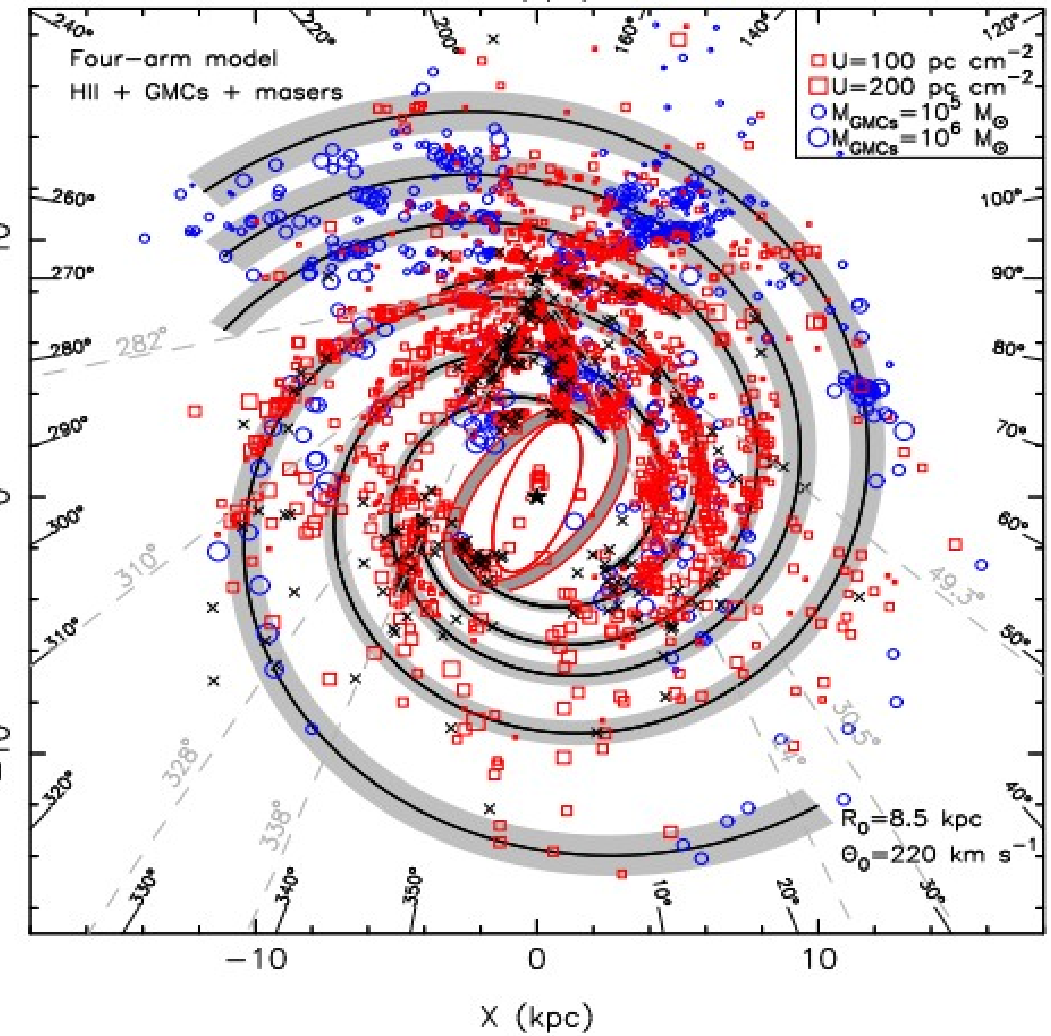


Fig. 15. *Left*: distributions of HII regions, GMCs, and 6.7 GHz methanol masers projected into the Galactic plane. The symbols are the same as those in Fig. 2. The kinematic distances are estimated using the rotation curve of BB93. *Right*: color intensity map of spiral tracers. The IAU standard R_0 = 8.5 kpc and Θ_0 = 220 km s^{-1} and standard solar motions are adopted in deriving the kinematic distances if no photometric or trigonometric distance is available.



In polar coordinates (r, θ), the ith arm can be given as logarithmic form:

$$\ln \frac{r}{R_i} = (\theta - \theta_i) \tan \psi_i, \tag{3}$$

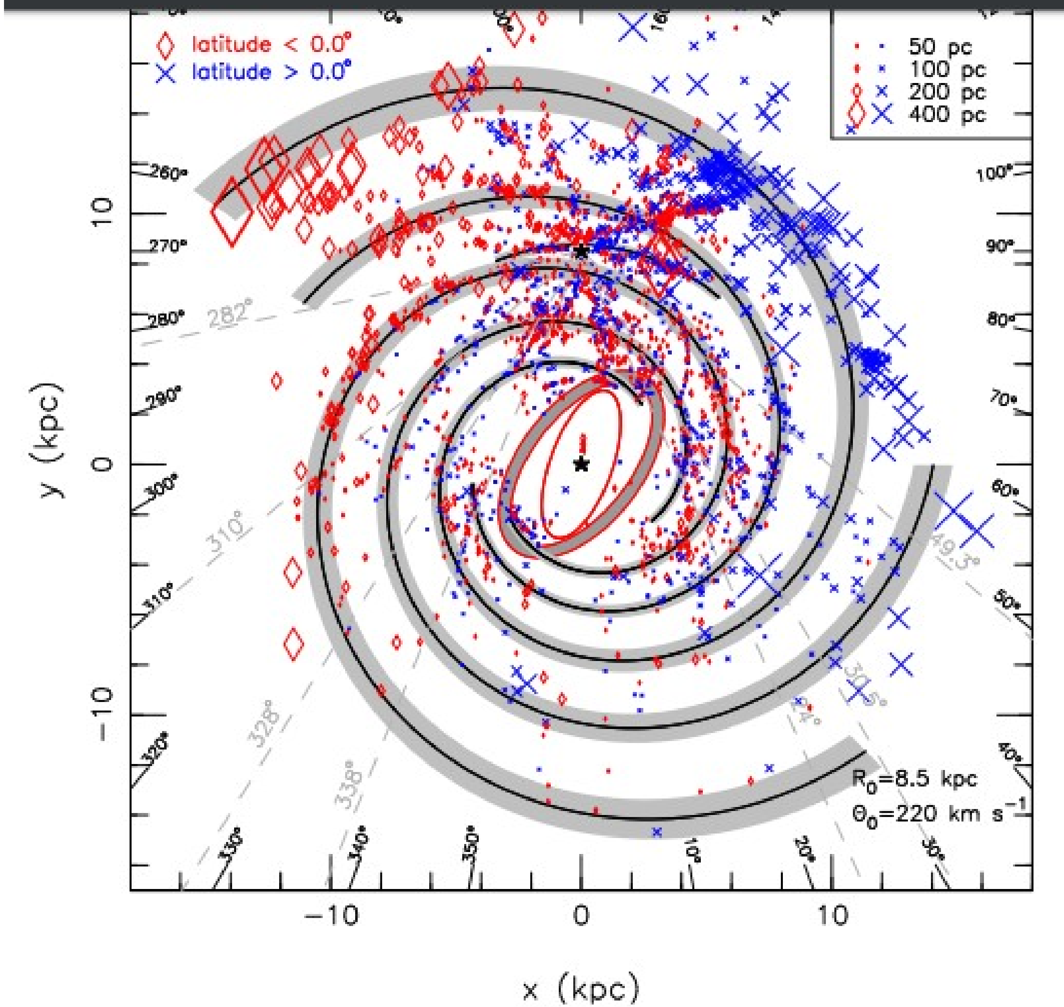
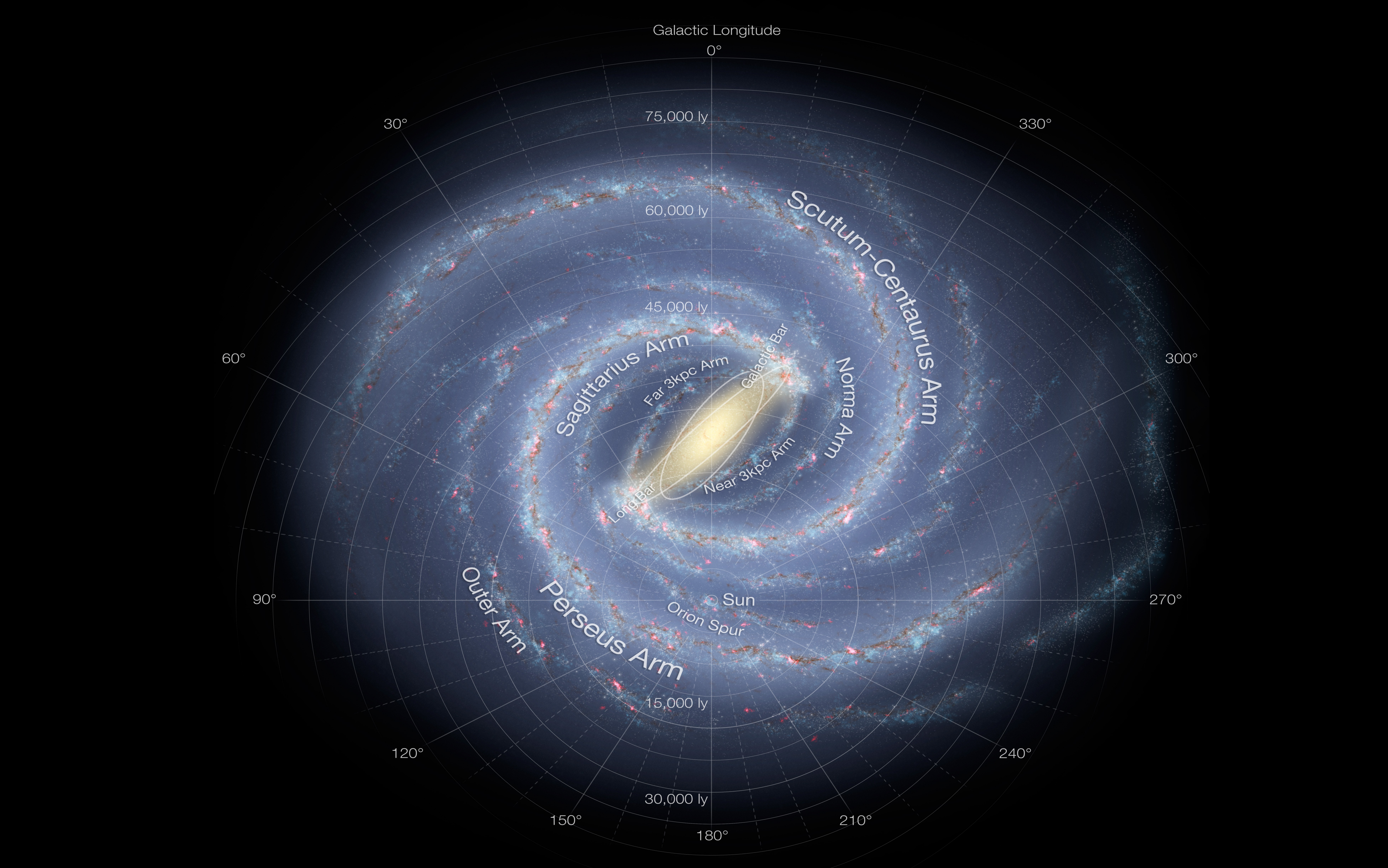
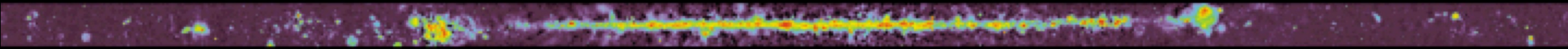


Fig. 16. Evidence of Galactic warp as shown by the distributions of HII regions, GMCs, and 6.7 GHz methanol masers. Note that the diamonds here indicate the tracers of $b < 0.0°$, and the blue crosses indicate the tracers of $b > 0.0°$. The symbol size is proportional to the offset from the Galactic plane. The outlines are the best-fitted four-arm model (see the *upper right panel* of Fig. 10).



Galactic Longitude
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
180°
210°
75,000 ly
60,000 ly
45,000 ly
15,000 ly
30,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Far 3kpc Arm
Galactic Bar
Norma Arm
Near 3kpc Arm
Long Bar
Outer Arm
Perseus Arm
Sun
Orion Spur

Radio Continuum (2.4 - 2.7 GHz)



Intensity of radio continuum emission from hot, ionized gas and high-energy electrons in the Milky Way, from surveys with both the Bonn 100-meter, and Parkes 64-meter radio telescopes.

Unlike most other views of our Galaxy presented here, these data extend to latitudes of only 5° from the Galactic plane.

The majority of the bright emission seen in the image is from hot, ionized regions, or is produced by energetic electrons moving in magnetic fields.

The higher resolution of this image, relative to the 408 MHz picture above, shows Galactic objects in more detail.

Note that the bright "ridge" of Galactic radio emission, appearing prominently in the 408 MHz image, has been subtracted here in order to show Galactic features and objects more clearly.

Ionized Hydrogen (HII)

Two phase medium in pressure balance

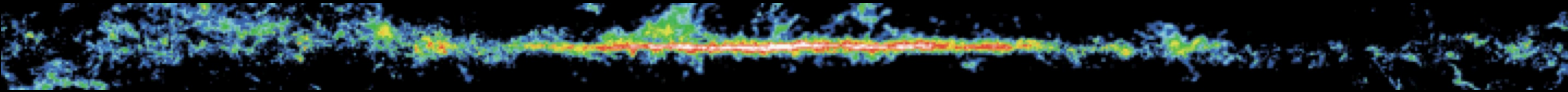
Warm (6000-12000 K)

- **Photoionized by hot young stars**
- **$n = 1\ cm^{-3}$**

Hot (10^6 K)

- **$n = 10^{-2}\ cm^{-3}$**
- **Buoyancy**
- **Local bubble**

Molecular Hydrogen (115 GHz)



Column density of molecular hydrogen inferred from the intensity of the J =1-0 spectral line of carbon monoxide, a standard tracer of the cold, dense parts of the interstellar medium.

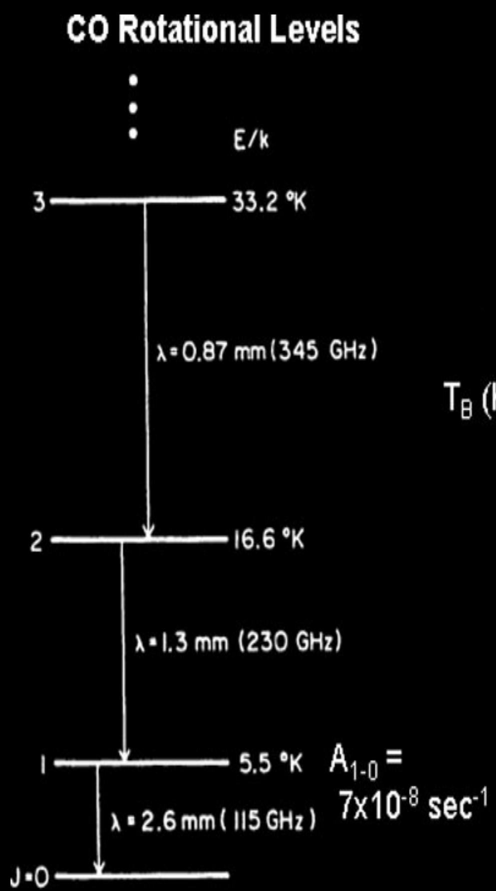
Such gas is concentrated in the spiral arms in discrete "molecular clouds."

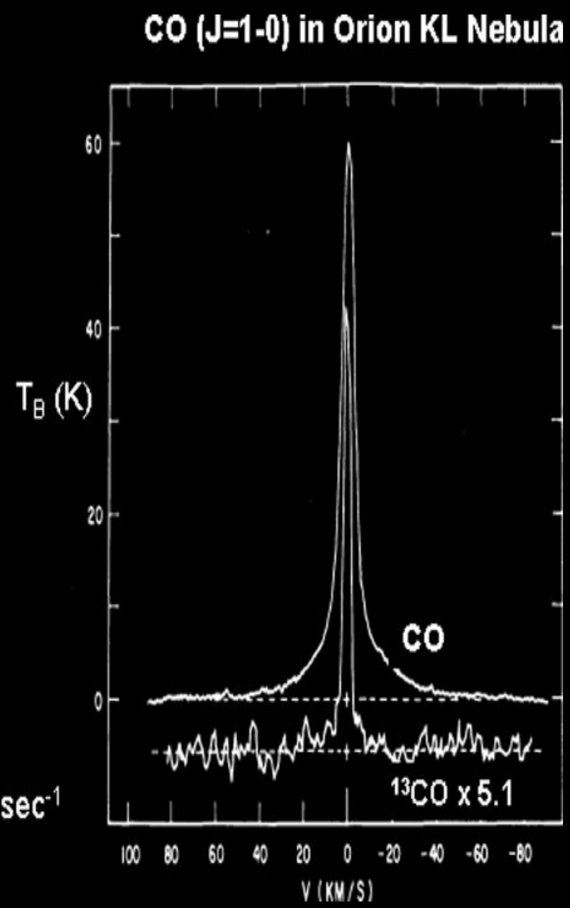
Most molecular clouds are sites of star formation.

The molecular gas is pre-dominantly H_2, but H_2 is difficult to detect directly at interstellar conditions and CO, the second most abundant molecule, is observed as a surrogate.

The column densities were derived on the assumption of a constant proportionality between the column density of H_2 and the intensity of the CO emission.

CO emission





H_2 is homopolar → No vibrational or rotational emission

CO is the abundant molecule after H_2

CO emits strong line radiation at 2.6 mm (J 1→0)

CO tracer of H_2

n_{H2} proportional to L_{CO}

CO Survey

(Dame et al. 2001)

CO observation

J 1→0 115 GHz

31 survey combined

Spatial resolution: 12’ or more
Velocity resolution: 0.65 km/s

Sensitivity: 0.62° K

$X = n_{HI} / I_{CO} = 1.8\ 10^{20}\ cm^{-2}\ K^{-1}\ km^{-1}\ s$

Hydrogen distribution

HI density :

$$n_{HI} = \frac{1.83}{\Delta r} \int_{\Delta v} T_S \ln\left[1 - \frac{T_b(v)}{T_S}\right] dv \qquad atom\ cm^{-3}$$

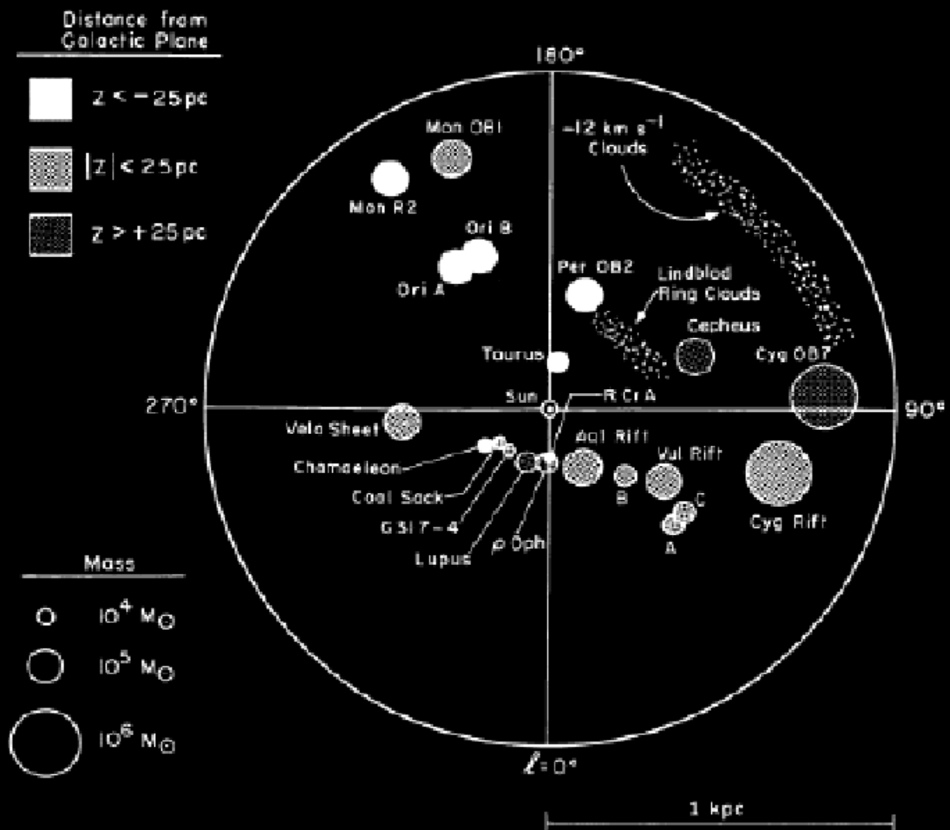
$T_S = 125\ K$

Molecular Clouds density :

$$n_{H_2} = \frac{2X}{\Delta r} \int_{\Delta v} T_b(v)\, dv \qquad atom\ cm^{-3}$$

$X = 1.8\ 10^{20}\ H_2\, cm^{-2}\, (K\ km\ s^{-1})^{-1}$

The molecular clouds



Concentrated in *Giant Clouds* (10^4 -10^8 Msol) self graviting with n > 10^3 cm^{-3}

Optically thick (dust, H_2)

Along spirala arms

Small scale thickness (120 pc)

CO Survey →Molecular Clouds

Infrared (12–100 microns)

Composite mid-and far-infrared intensity observed by the Infrared Astronomical Satellite (IRAS) in 12, 60, and 100 micron wavelength bands.

The images are encoded in the blue, green, and red color ranges, respectively.

Most of the emission is thermal, from interstellar dust warmed by absorbed starlight, including star-forming regions embedded in interstellar clouds.

The display here is a mosaic of IRAS Sky Survey Atlas images.

Emission from interplanetary dust in the solar system, the "zodiacal emission," was modeled and subtracted in the production of the Atlas.

DUST

Cold Dust (15-25 K) associated to the HI regions and molecular clouds. Heated by both old and young stellar population

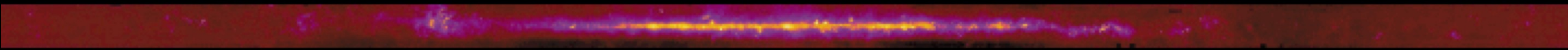
Warm dust (30-40 K) associated to HII regions. Heated by OB stars

Hot dust (250-500 K)

very small grains (5 A) heated by ISRF

normal grains (1 micron) heated by M giants

Mid-Infrared



Mid-infrared emission observed by the SPIRIT III instrument on the Midcourse Space Experiment (MSX) satellite.

Most of the diffuse emission in this wavelength band is believed to come from complex molecules called polycyclic aromatic hydrocarbons, which are commonly found both in coal and interstellar gas clouds.

Red giant stars, planetary nebulae, and massive stars so young that they remain deeply embedded in their parental molecular gas clouds produce the multitude of small bright spots seen here.

Unlike most of the other maps, this map extends only to 5° above and below the Galactic plane.

Near Infrared (1.25-3.5 microns)

Composite near-infrared intensity observed by the Diffuse Infrared Background Experiment (DIRBE) instrument on the Cosmic Background Explorer (COBE) in the 1.25, 2.2, and 3.5 micron wavelength bands.

The images are encoded in the blue, green, and red color ranges, respectively.

Most of the emission at these wavelengths is from relatively cool giant K stars in the disk and bulge of the Milky Way. Interstellar dust does not strongly obscure emission at these wavelengths; the maps trace emission all the way through the Galaxy, although absorption in the 1.25 micron band is evident toward the Galactic center region.

Interstellar Radiation Field

Cosmic Background Radiation

Model of the Interstellar Radiation Field

Far Infrared (dust)

Near Infrared (late stars)

Optical/UV (OB stars)

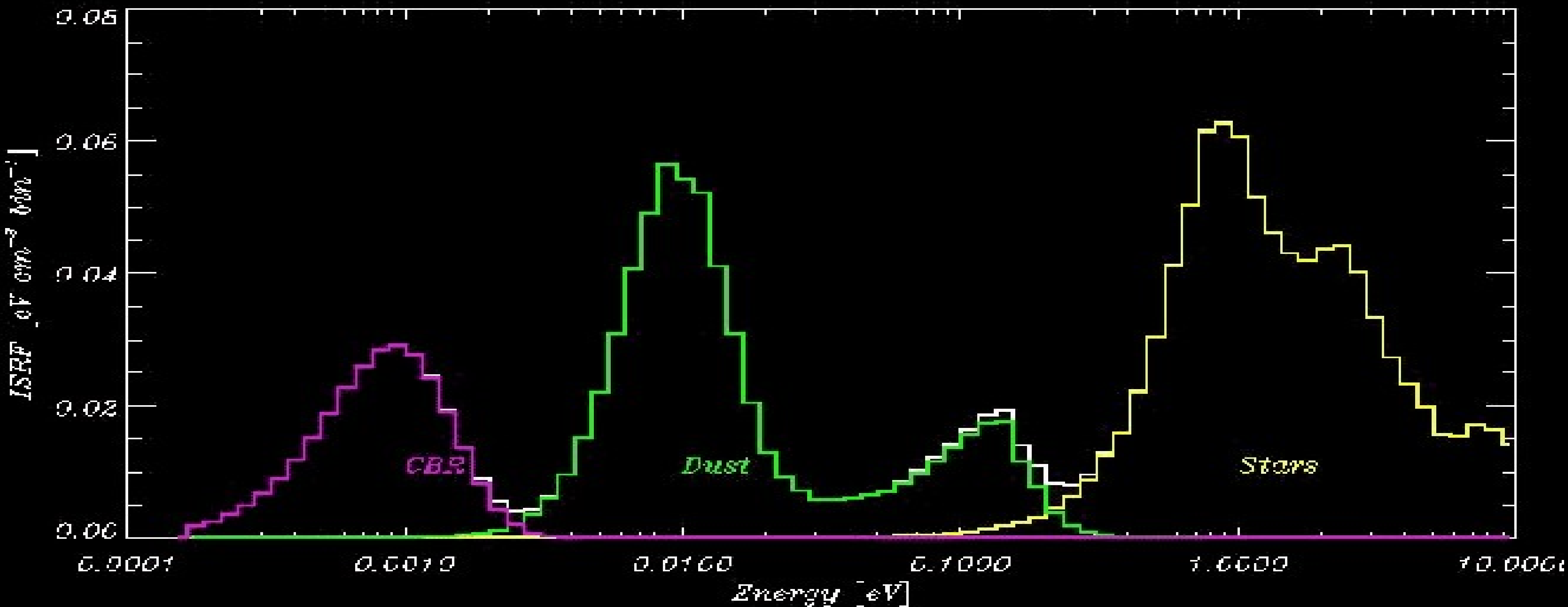
ISRF model :

$$ISRF(\vec{r}, \nu) = \int_{MW} \frac{\varepsilon(\vec{r}', \nu)}{|\vec{r} - \vec{r}'|^2} e^{-\int k(\vec{r}', \nu)\, ds}\, dV'$$

$\boldsymbol{\varepsilon}$ from COBE/DIRBE emissivities + detailed stellar model

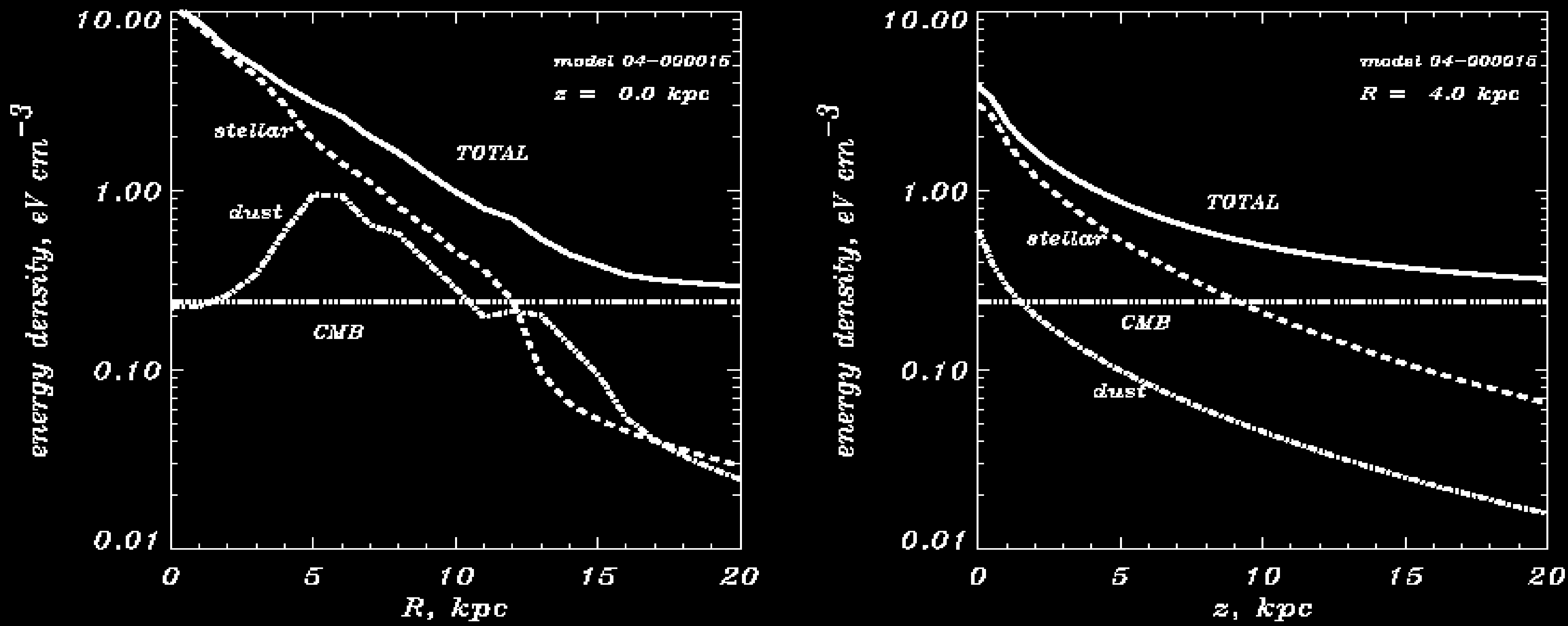
k from extinction curves, grain albedo

The Interstellar Radiation Field



Strong, Moskalenko, & Reimer (2000)

The Interstellar Radiation Field



Strong, Moskalenko, & Reimer (2000)

Optical (400-600 nm)

Due to the strong obscuring effect of interstellar dust,the light is primarily from stars within a few thousand light-years of the Sun, nearby on the scale of the Milky Way.

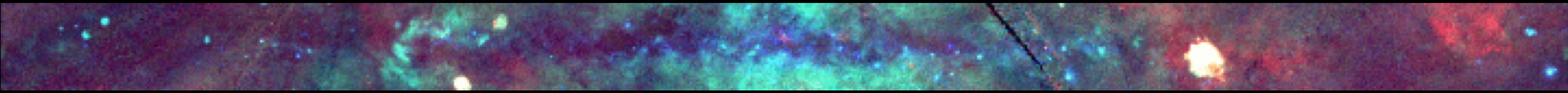
The widespread bright red regions are produced by glowing, low-density gas.

Dark patches are due to absorbing clouds of gas and dust.

Stars differ from one another in color, as well as mass, size and luminosity. Interstellar dust scatters blue light preferentially, reddening the starlight somewhat relative to its true color and producing a diffuse bluish glow. This scattering, as well as absorption of some of the light by dust, also leaves the light diminished in brightness.

The panorama was assembled from sixteen wide-angle photographs taken by Dr. Axel Mellinger using a standard 35-mm camera and color negative film. The exposures were made between July 1997 and January 1999 at sites in the United States, South Africa, and Germany.

X Rays (0.25-1.5 keV)



Composite X-ray intensity observed by the Position-Sensitive Proportional Counter (PSPC) instrument on the Röntgen Satellite (ROSAT).

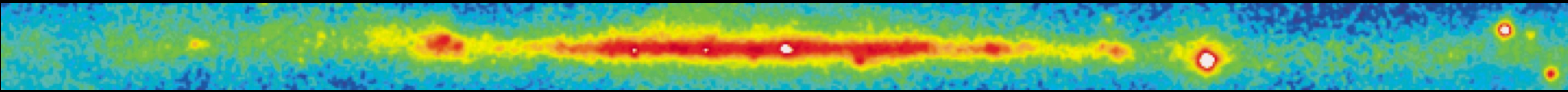
Images in three broad, soft X-ray bands centered at 0.25 , 0.75, and 1.5 keV are encoded in the red, green, and blue color ranges, respectively.

In the Milky Way, extended soft X-ray emission is detected from hot, shocked gas.

At the lower energies especially, the interstellar medium strongly absorbs X-rays, and cold clouds of interstellar gas are seen as shadows against background X-ray emission.

Color variations indicate variations of absorption or of the temperatures of the emitting regions. The black regions indicate gaps in the ROSAT survey.

Gamma Rays (E>300 MeV)



Intensity of high-energy gamma-ray emission observed by the Energetic Gamma-Ray Experiment Telescope (EGRET) instrument on the Compton Gamma-Ray Observatory (CGRO).

The image includes all photons with energies greater than 300 MeV. At these extreme energies, most of the celestial gamma rays originate in collisions of cosmic rays with hydrogen nuclei in interstellar clouds.

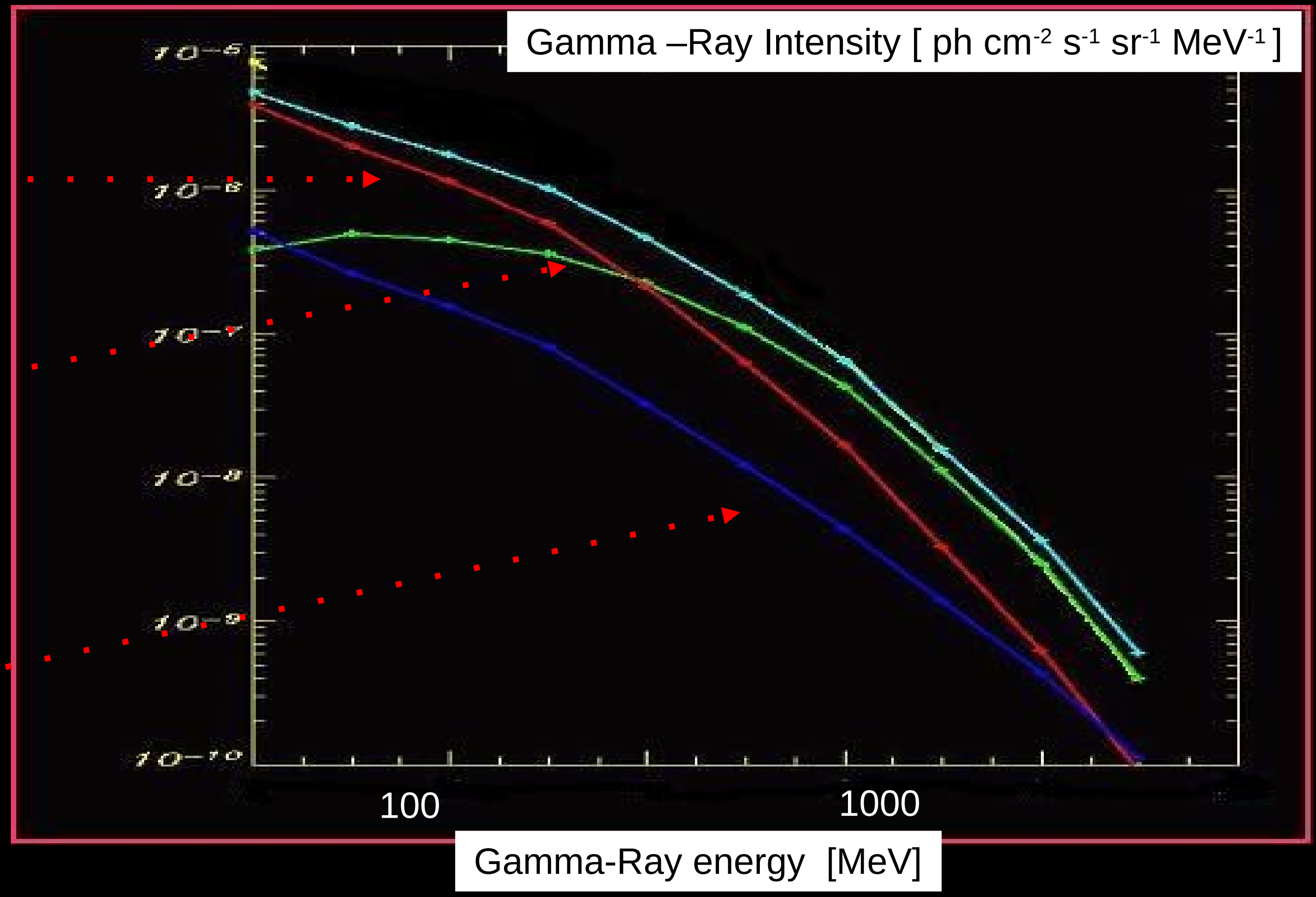
The bright, compact sources near Galactic longitudes 185°, 195°, and 265° indicate high-energy phenomena associated with the Crab, Geminga, and Vela pulsars, respectively.

Gamma-Ray Spectrum

Electron Bremsstrahlung

π^o decay

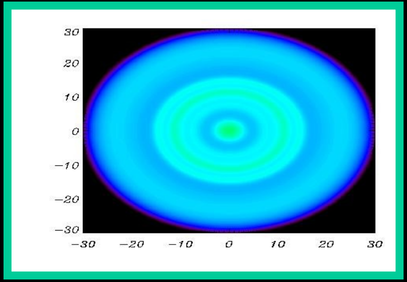
Inverse Compton



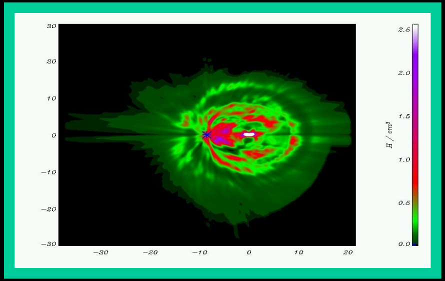
$$I(E) = \frac{1}{4\pi} \int_0^\infty [q_{pp}(E) + q_{br}(E)]\, n_H + q_{IC}(E)\, n_{ph}\, dr$$

Gamma rays / CR connections

CR distribution

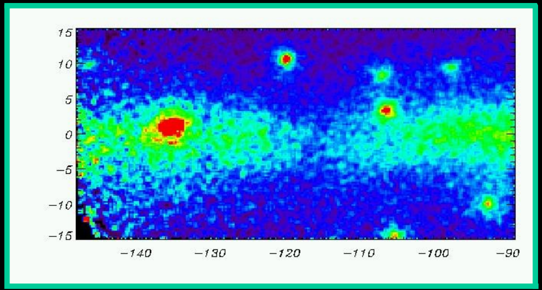


Targets distribution

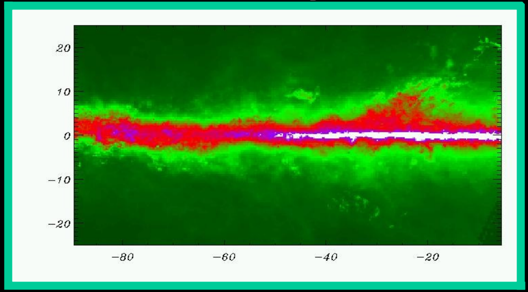


Integrating along the line of sight

Gamma Ray Data

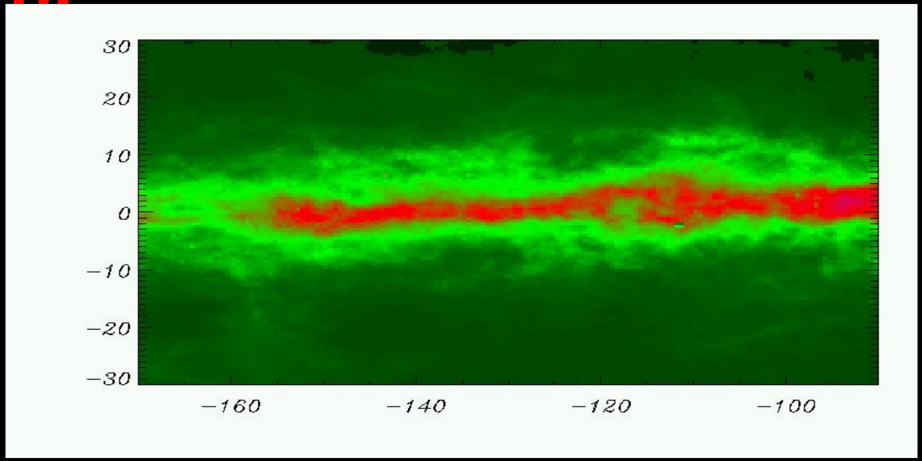


Gamma Ray model

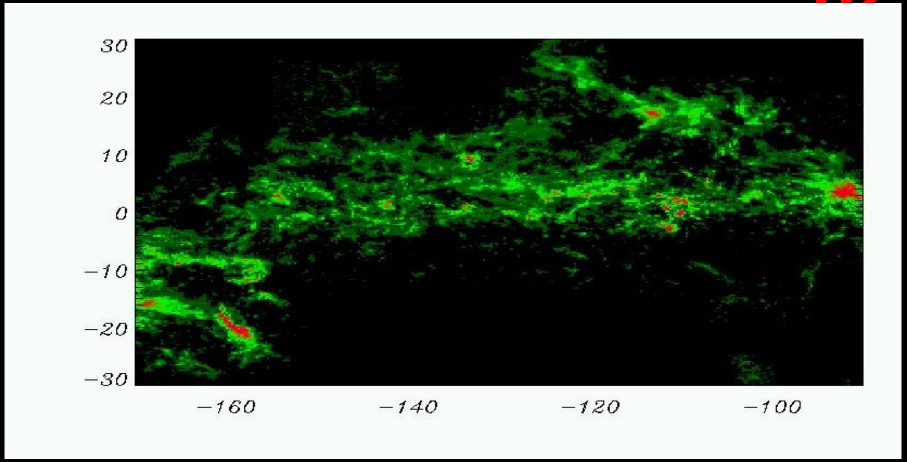


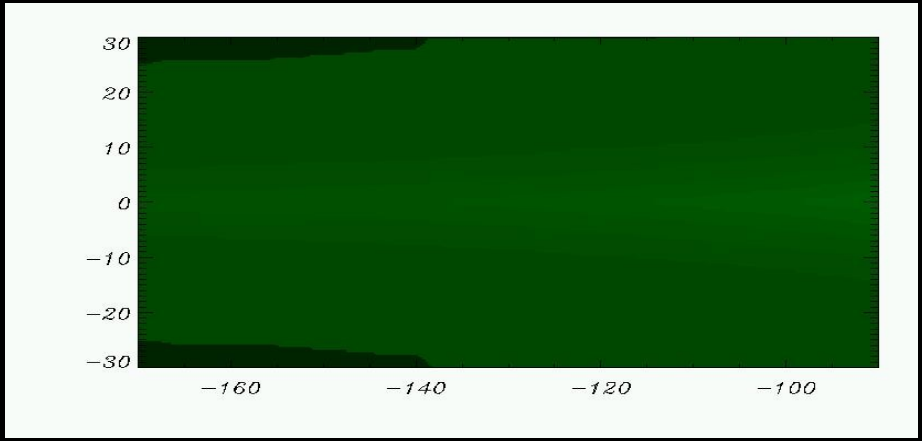
The γ-ray emission model (II quadrant)

HI



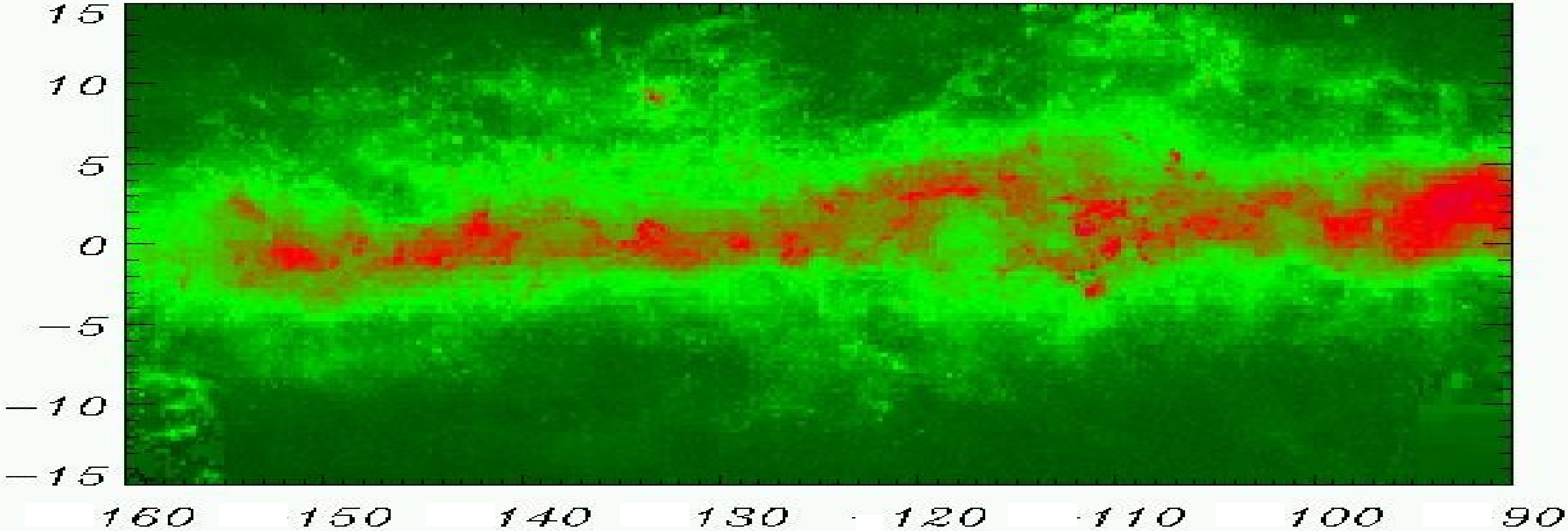
H2



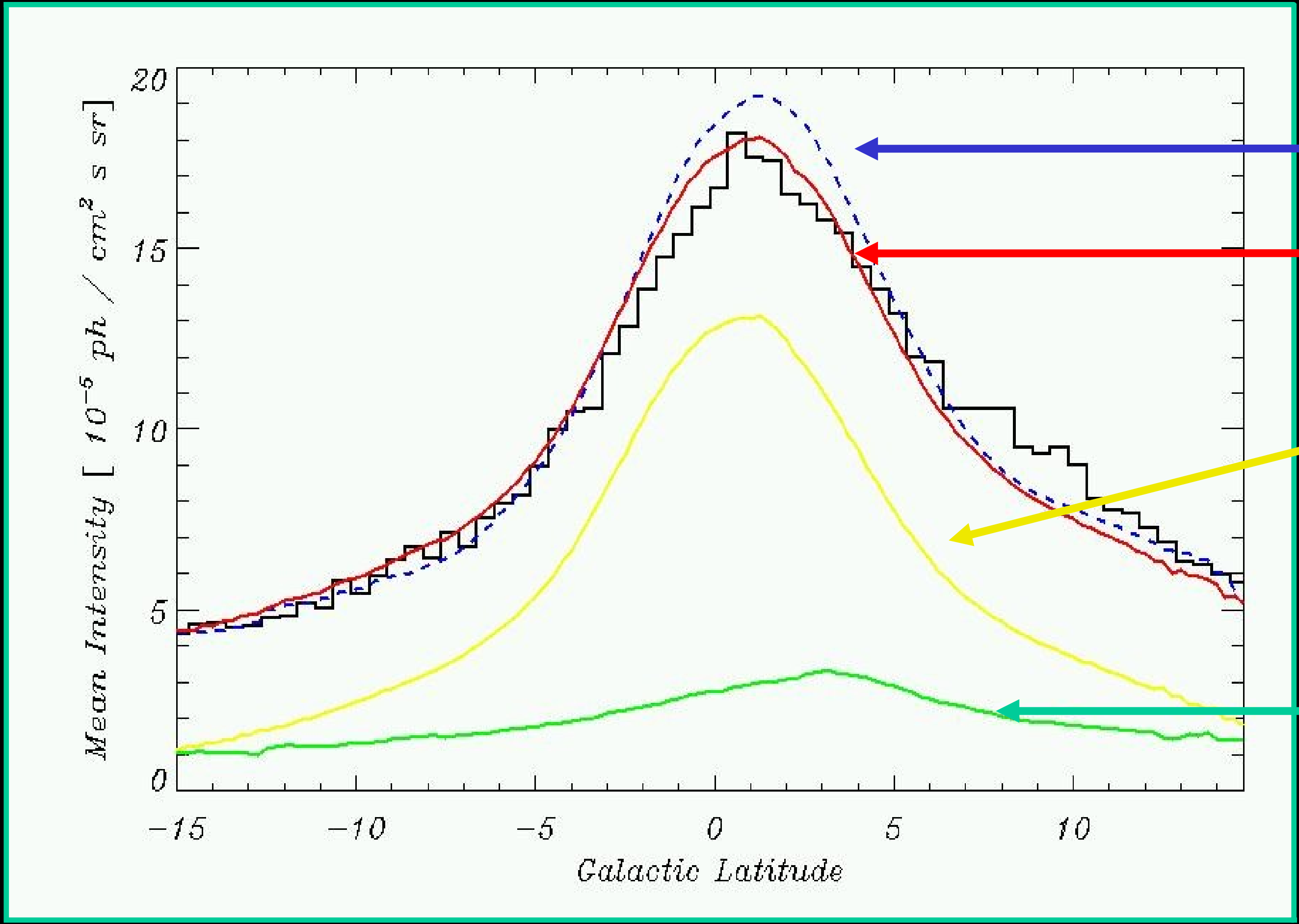


ISRF

The γ-ray emission model (II quadrant)



Model vs. Observations
(II quadrant)



EG. model

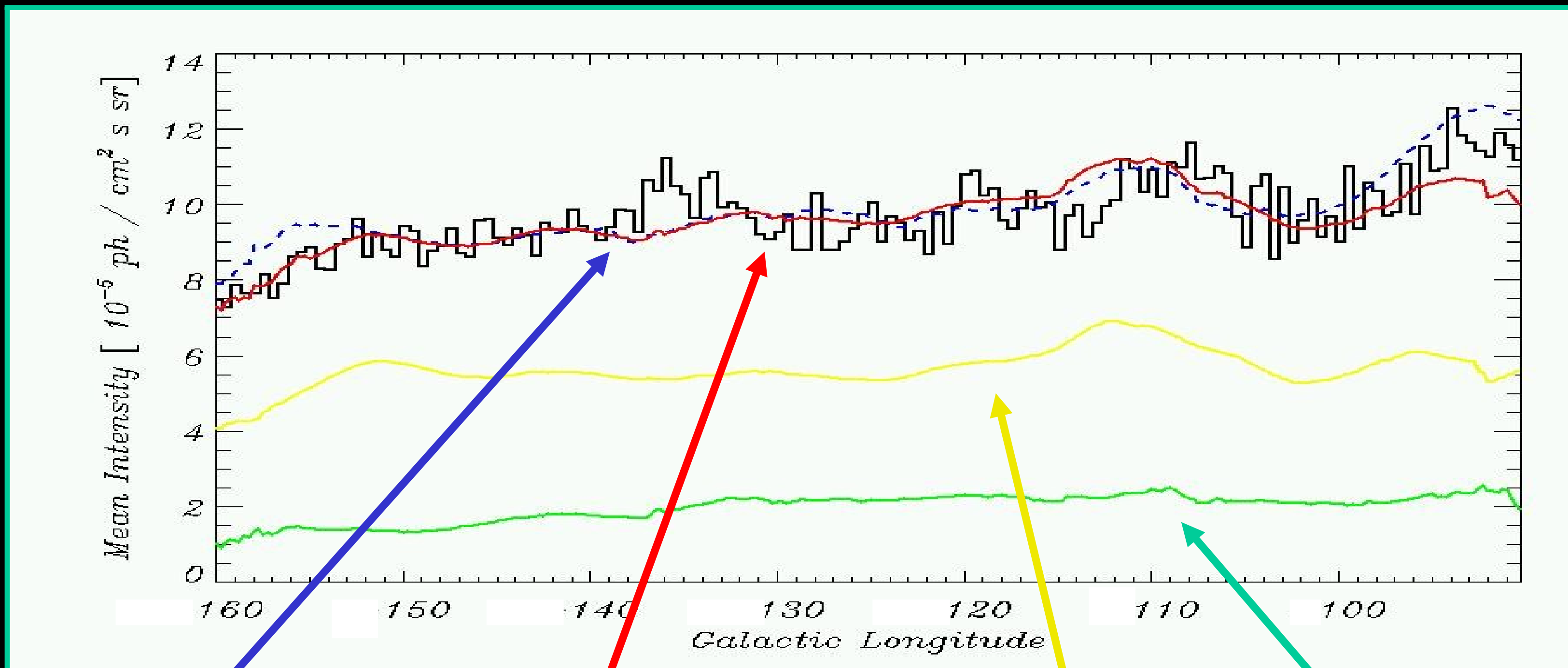
AG. model

Emission from HI regions

Emission from molecular clouds

Model vs. Observations

(II quadrant)



EG. model

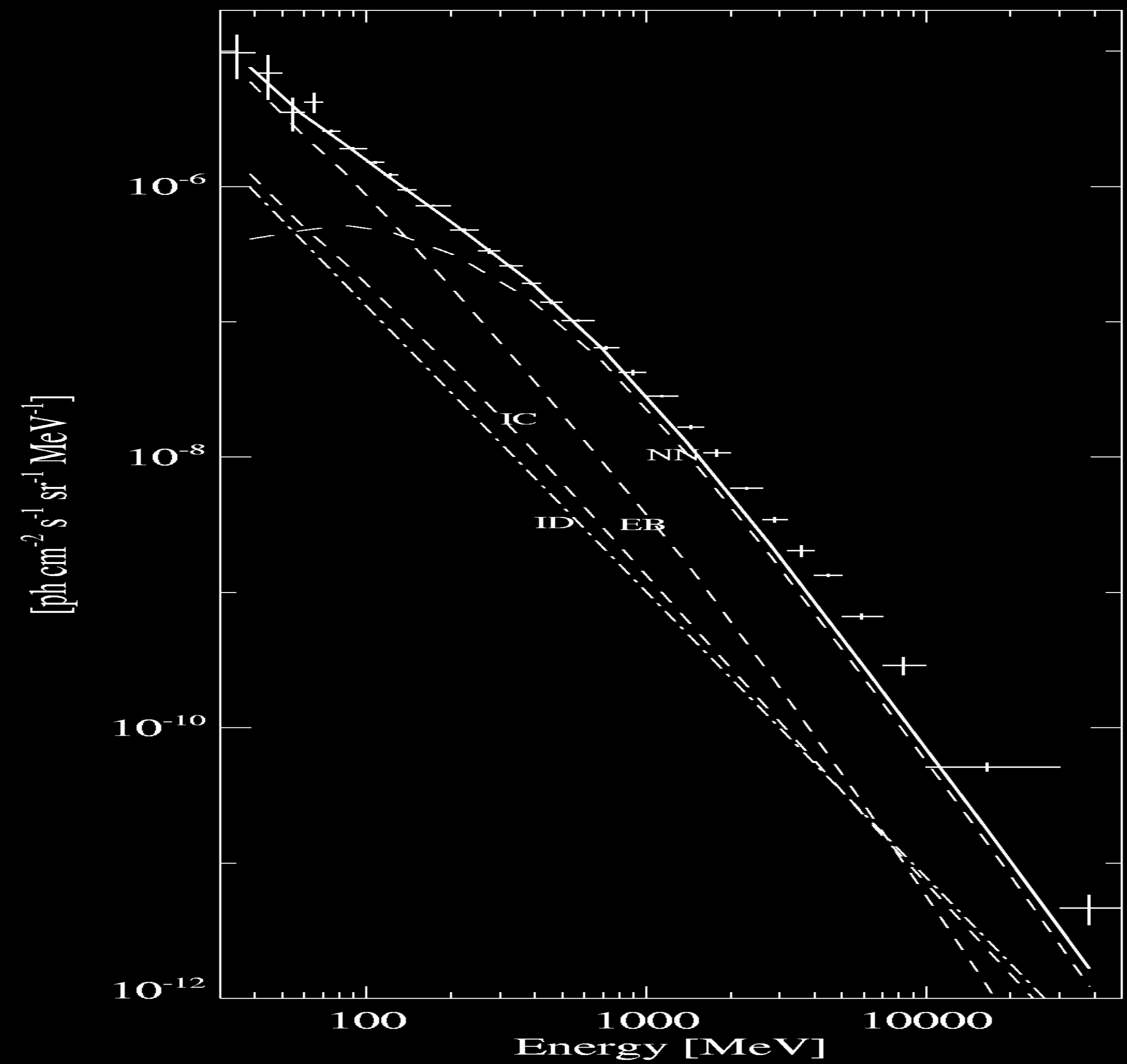
AG. model

Emission from HI regions

Emission from molecular clouds

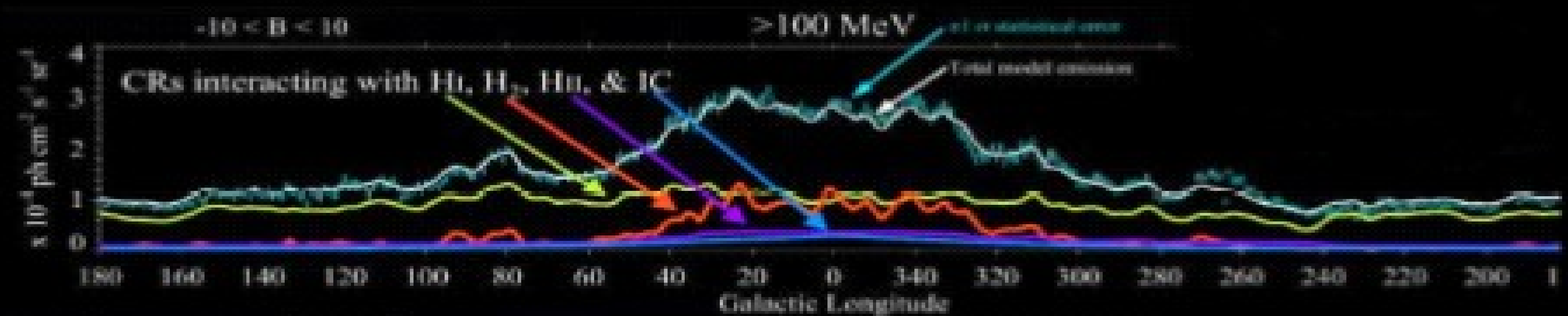
Results from EGRET

π^0 bump in the inner Milky Way (Hunter et al. 1997)



Results from EGRET

Spatial correlation between gaz and γ-rays



Observations (EGRET):

- large scale spatial distribution well modelled by combination of ISM phases (assuming $I \propto \rho^2$)
- fraction of unresolved point sources is small (unless distributed like the interstellar gas)
- spectrum does not vary (within relatively small uncertainties) in the Galaxy
- deviations from perfect fit

Implications:

- Gamma-Rays probe galactic CR and ISM distributions
- CR electron-to-proton ratio roughly constant throughout Galaxy
- assumption of dynamic balance ($I \propto \rho^2$) between ISM and CR is reasonably correct
  (large matter density implies larger magnetic fields, allowing for larger CR energy density)

Galactic diffuse gamma rays

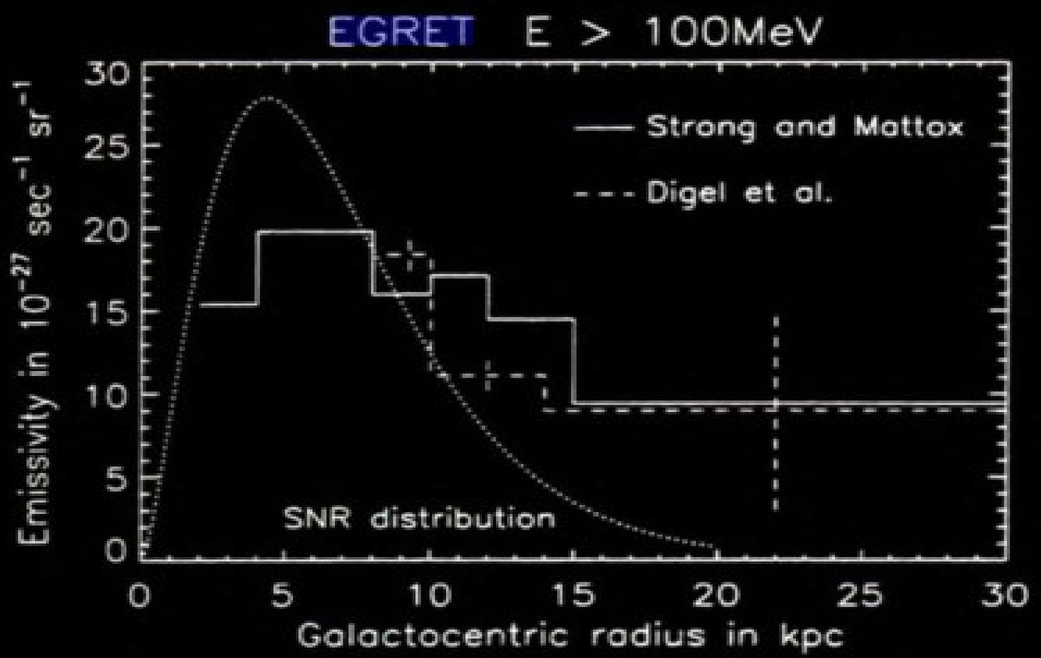
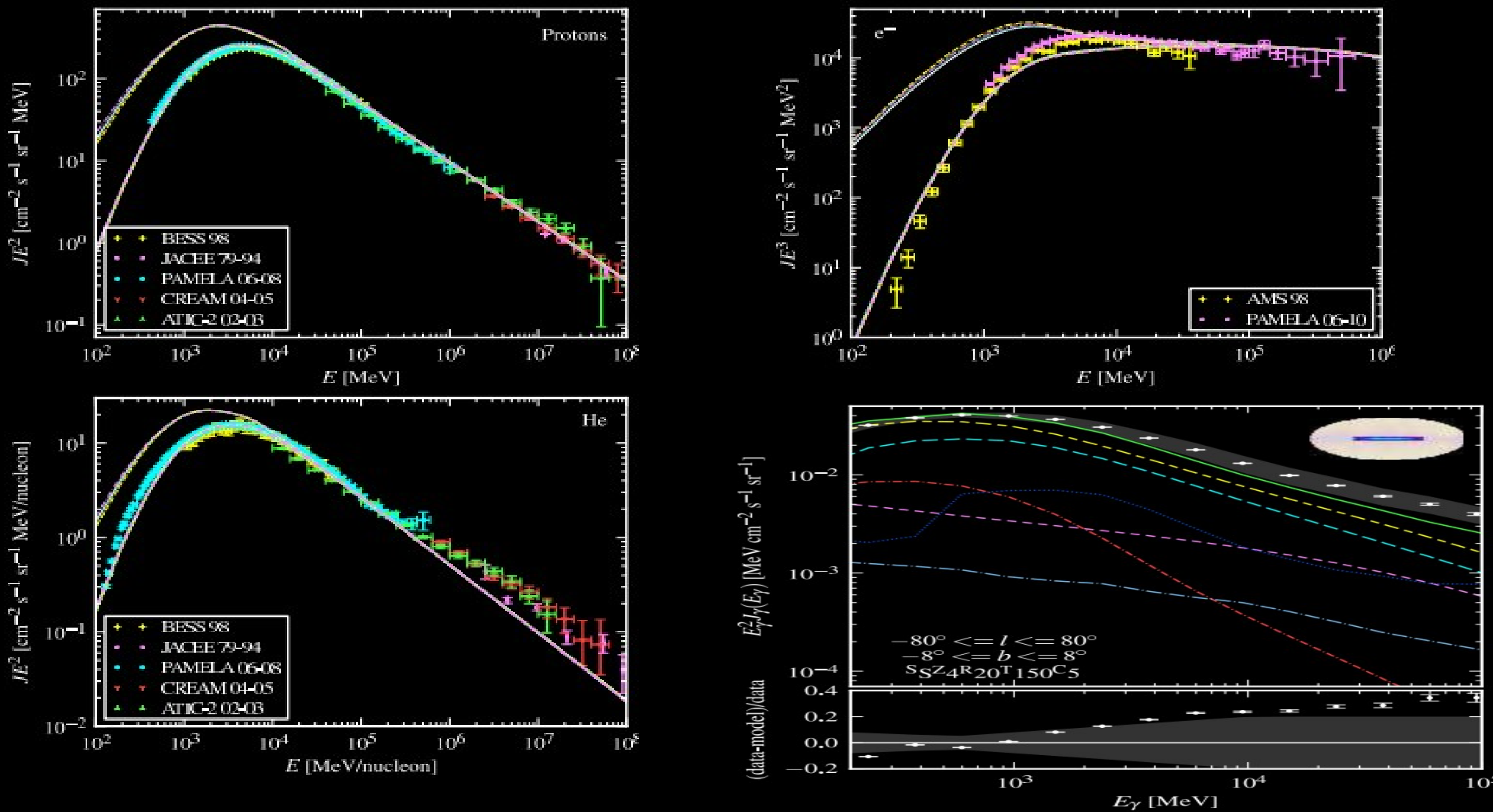


Fig. 6.10. A comparison between the γ-ray emissivity gradient (**solid histogram**) to the distribution of SNR as possible acceleration sites (**dotted line**). The statistical uncertainties of the gradient are typically below 10%. The obvious discrepancy implies that either SNR are not accelerating the bulk of GeV cosmic rays, or diffusive re-acceleration is operative, or galactic cosmic rays are confined on a scale of many kpc's. Note that locally derived emissivities (**dashed histogram**) can differ significantly from the global trend. From Strong and Mattox (1996 [528])

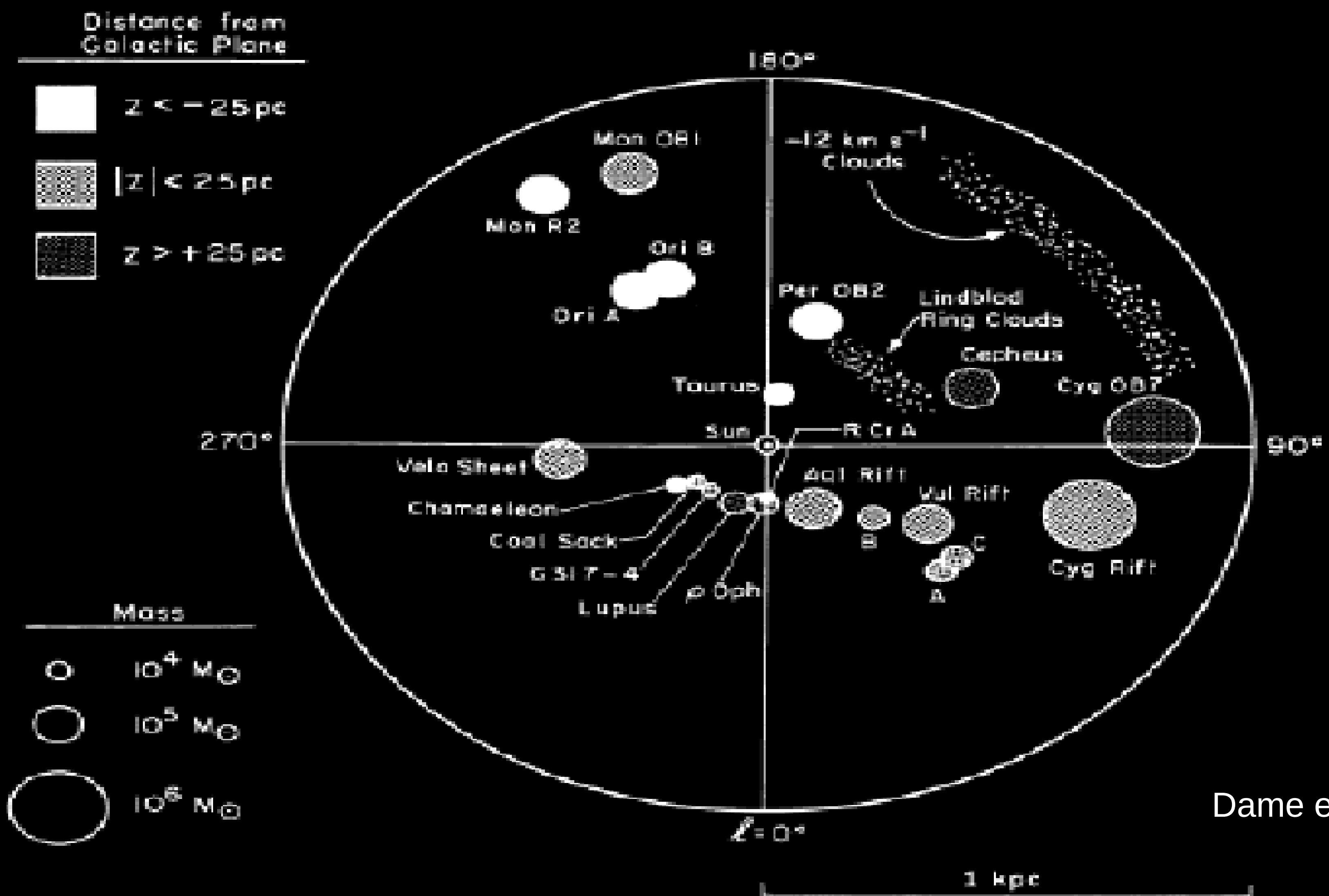
Galactic diffuse gamma rays



Fermi–LAT Observations of the Diffuse γ-ray Emission: Implications for Cosmic Rays and the Interstellar Medium

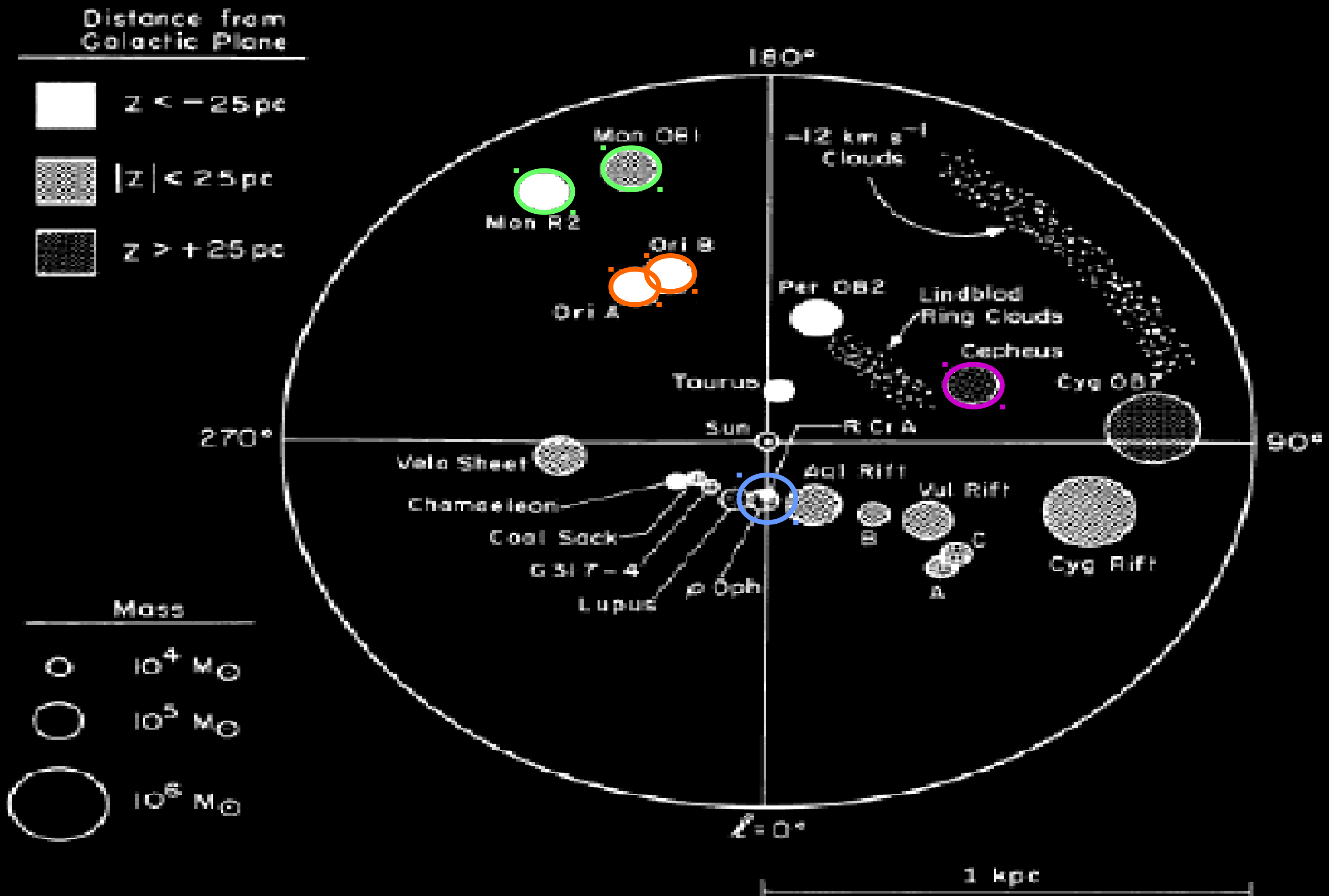
M. Ackermann[1], M. Ajello[2], W. B. Atwood[52], L. Baldini[3], J. Ballet[4], G. Barbiellini[5,6],

Molecular Clouds in gamma rays



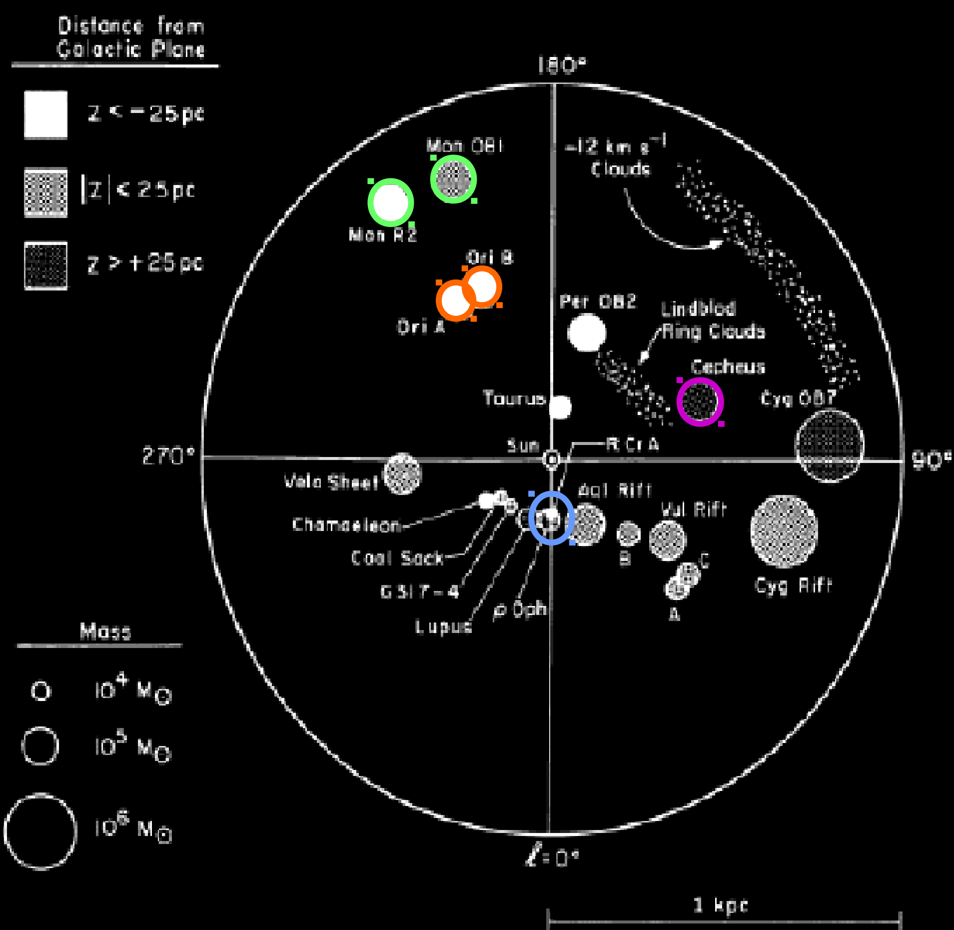
Dame et al. (1987)

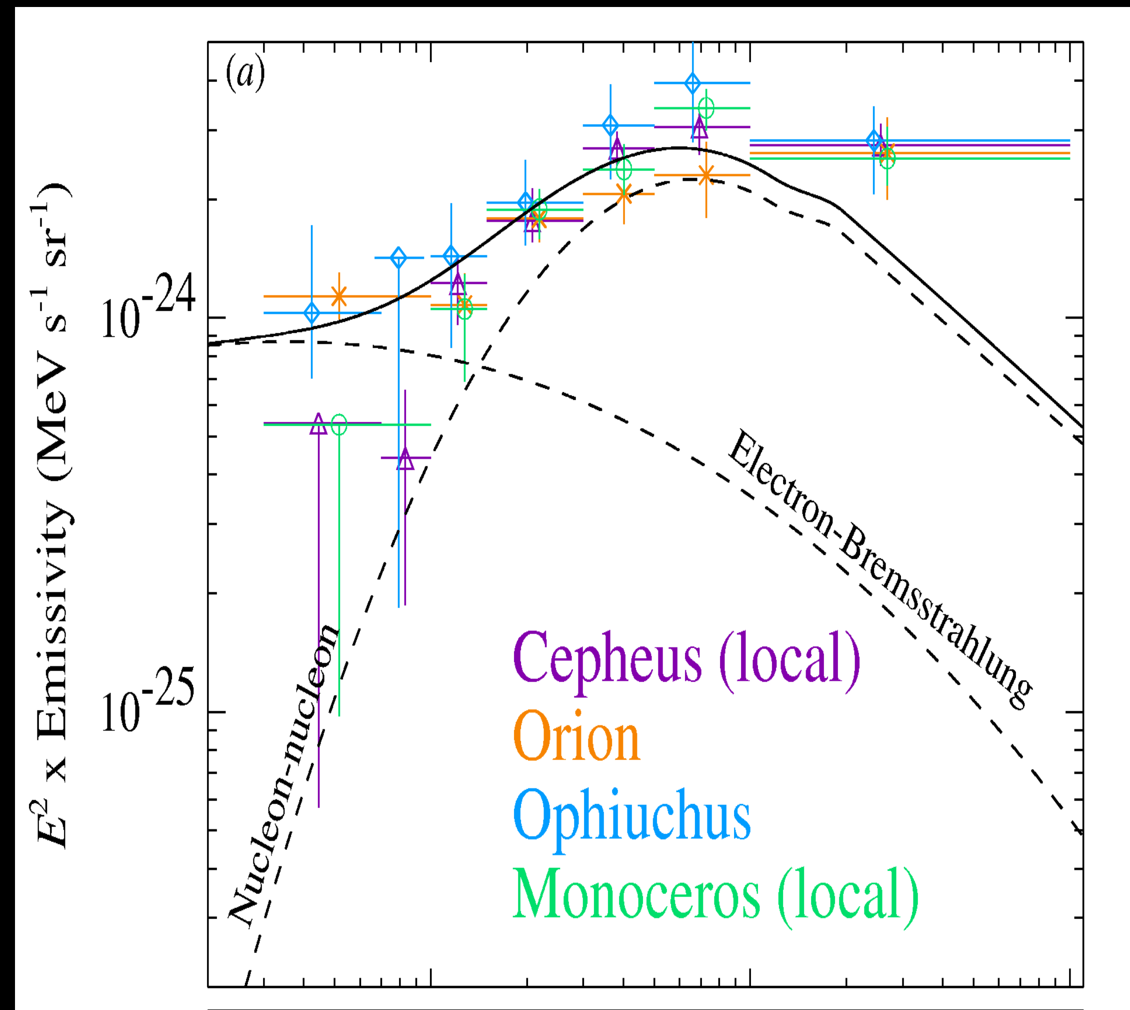
Molecular Clouds in gamma rays



Molecular Clouds in gamma rays

Digel et al. (1996 & 2001)





CRs in Molecular Clouds

Yang et al.: Giant Molecular Clouds as observed with LAT

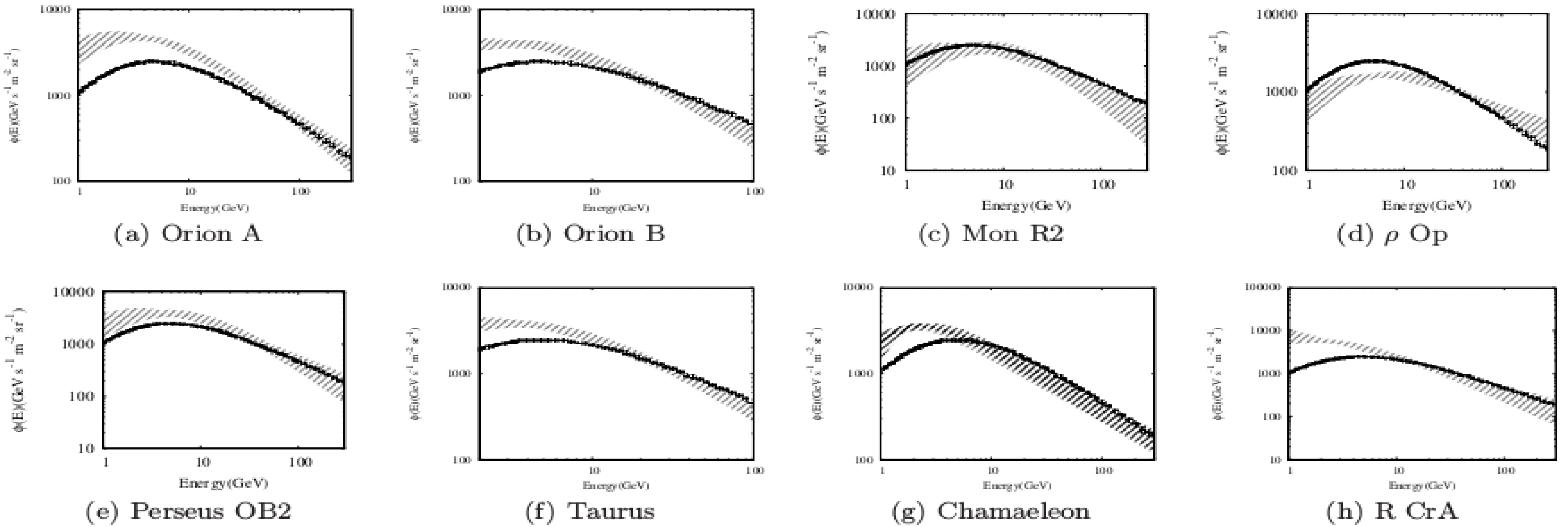


Fig. 5. Energy spectra of CR protons in different clouds derived from the γ-ray data. It is assumed that the interactions of CR with the ambient gas are fully responsible for the observed γ-ray fluxes. The shaded regions represent 1σ fits for the proton spectra. For comparison, the measurements of CR protons by PAMELA are also shown (black crosses).

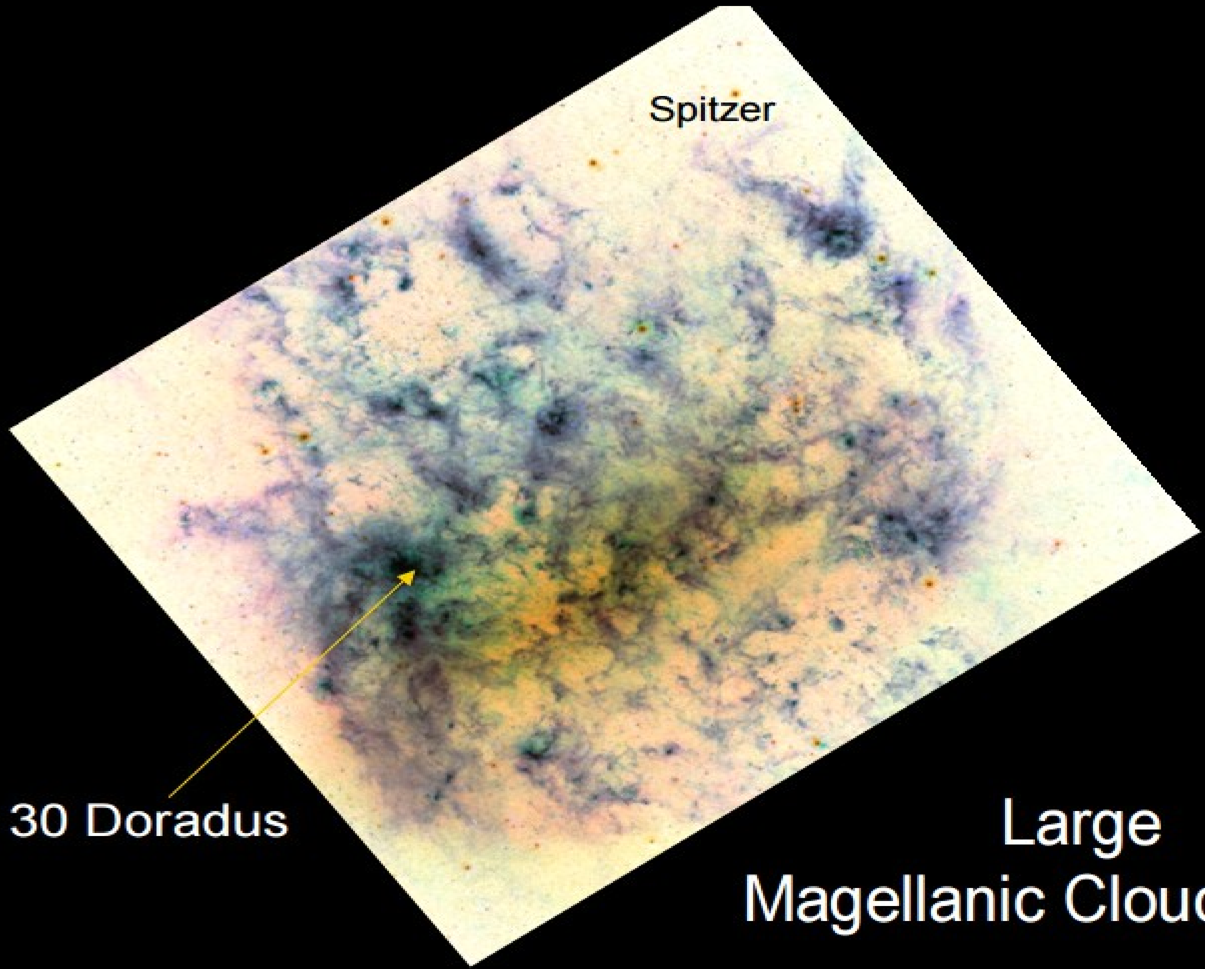
CRs in Molecular Clouds

Yang et al.: Giant Molecular Clouds as observed with LAT

Table 2. Spectral characteristics and statistic test (TS) value of the GMC listed in Table 1 obtained from the LAT data. The individual χ^2/d.o.f. of the spectral representation tested are also quoted with the corresponding probabilities in brackets (see text for more details).

#	Region	TS	Flux at 3 GeV [10^{-9} GeV^{-1}cm^{-2}s^{-1}]	E_b [GeV]	χ^2/d.o.f. (BPL)	χ^2/d.o.f. (KPL)	χ^2/d.o.f. (TPL)
1	ρ Oph	11648	7.7 ± 0.8	4.7 ± 2.3	10.7/9 (0.30)	22.2/11 (0.024)	13.9/11 (0.24)
2	Orion B	6107	3.0 ± 0.6	3.6 ± 1.3	10.8/9 (0.29)	27.9/11 (2.3×10^{-3})	13.1/11 (0.29)
3	Orion A	22021	5.9 ± 0.7	4.3 ± 1.2	11.0/10 (0.35)	40.1/12 (4.9×10^{-5})	14.0/12 (0.30)
4	Mon R2	1607	1.3 ± 0.2	3.0 ± 0.7	10.5/10 (0.39)	29.4/12 (3.4×10^{-3})	13.4/12 (0.34)
5	Taurus	5670	9.8 ± 1.5	4.7 ± 1.5	10.5/10 (0.39)	36.9/12 (2.3×10^{-4})	16.5/12 (0.17)
6	R CrA	2315	1.2 ± 0.8	0.9 ± 0.8	5.1/9 (0.82)	7.4/11 (0.76)	15.0/11 (0.18)
7	Chamaeleon	2917	2.0 ± 0.5	2.0 ± 0.9	9.2/9 (0.42)	24.0/11 (0.01)	12.0/11 (0.36)
8	Perseus OB2	6410	3.8 ± 0.3	4.9 ± 2.1	11.7/10 (0.30)	20.8/12 (0.05)	17.3/12 (0.14)

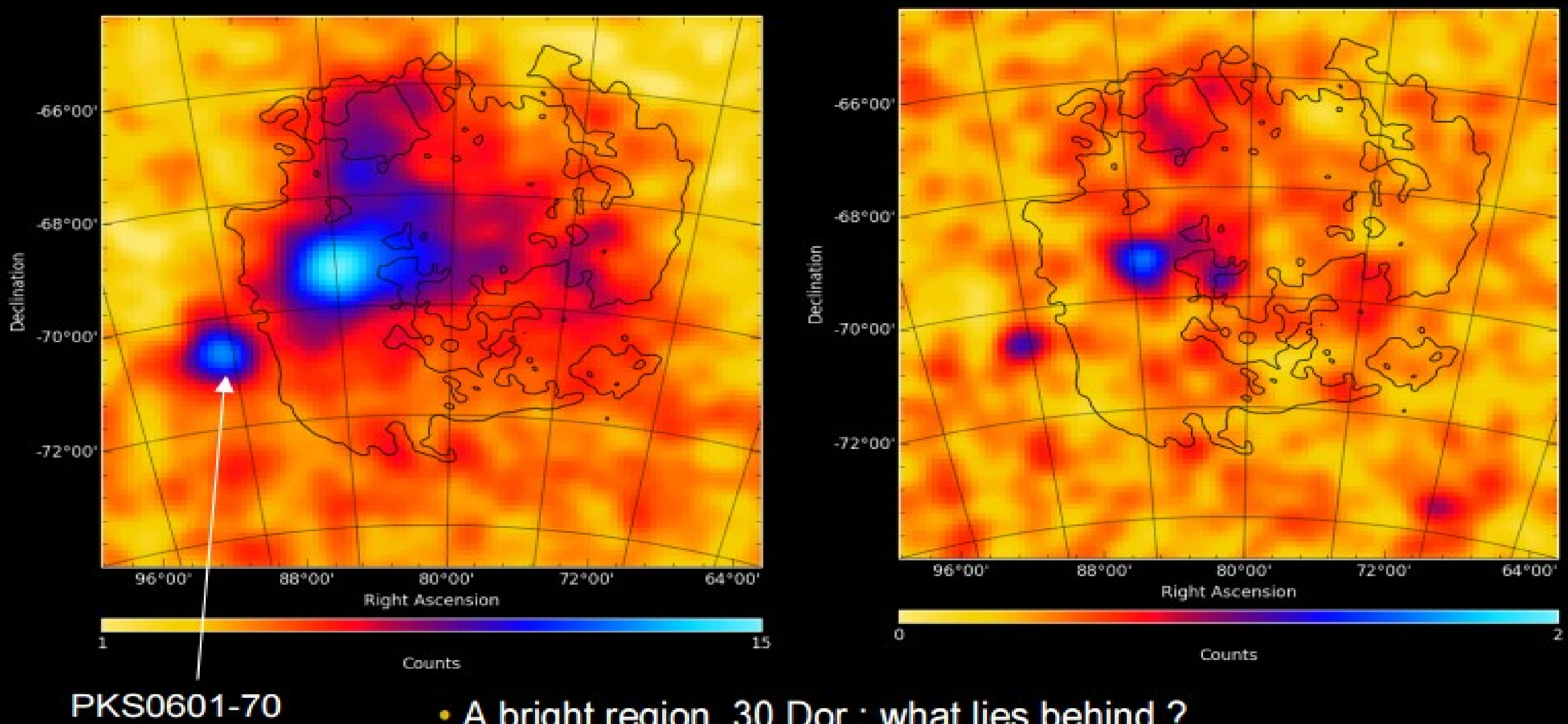
LMC diffuse gamma rays



Large
Magellanic Cloud (LMC)

LMC diffuse gamma rays

LMC: counts maps 800MeV-8GeV and 8-80GeV (smoothing with gaussian of 0.2°)



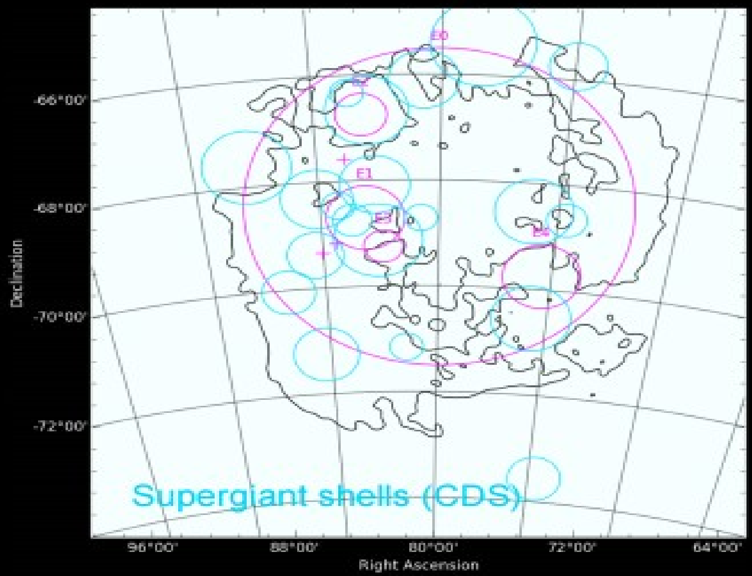
- A bright region, 30 Dor : what lies behind ?
- Extended emission not filling the galaxy or following the gas
- A few hard sources

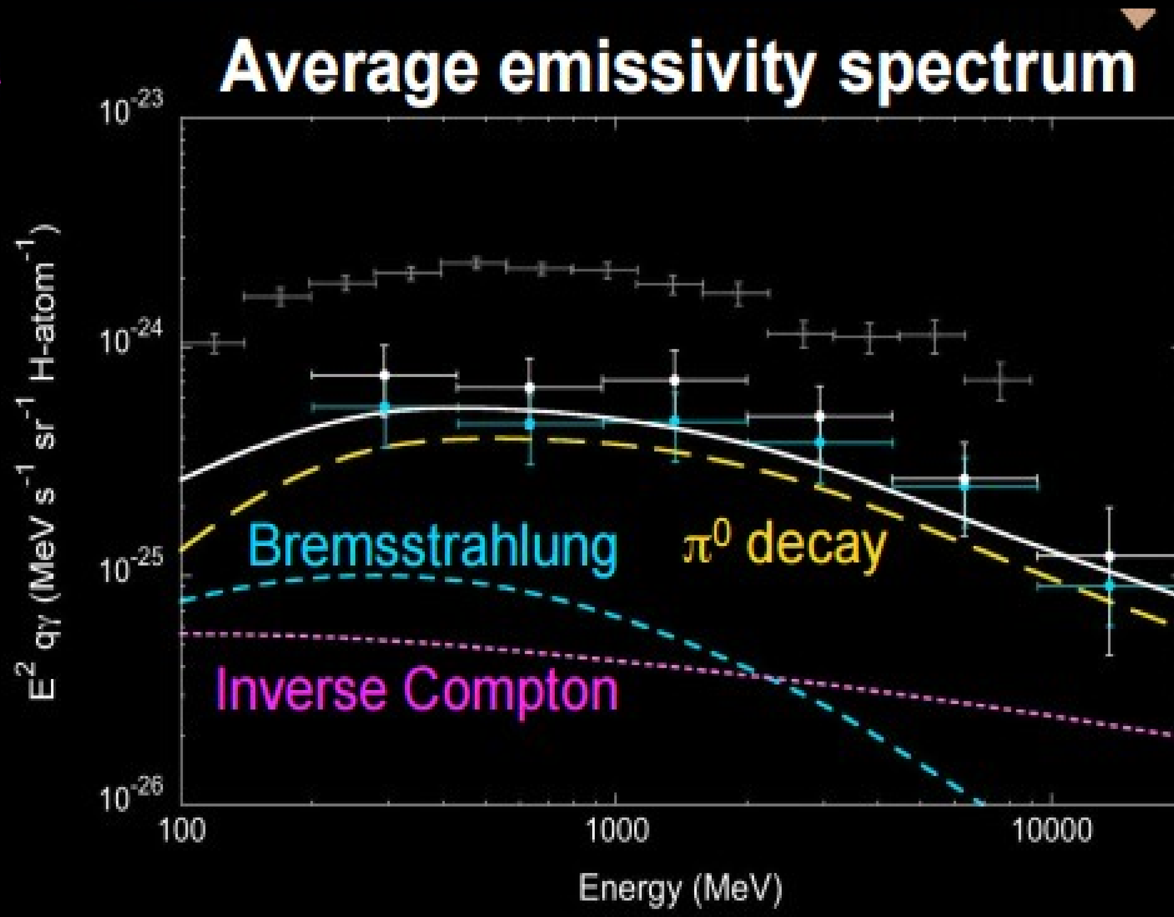
LMC diffuse gamma rays

LMC: cosmic-ray population

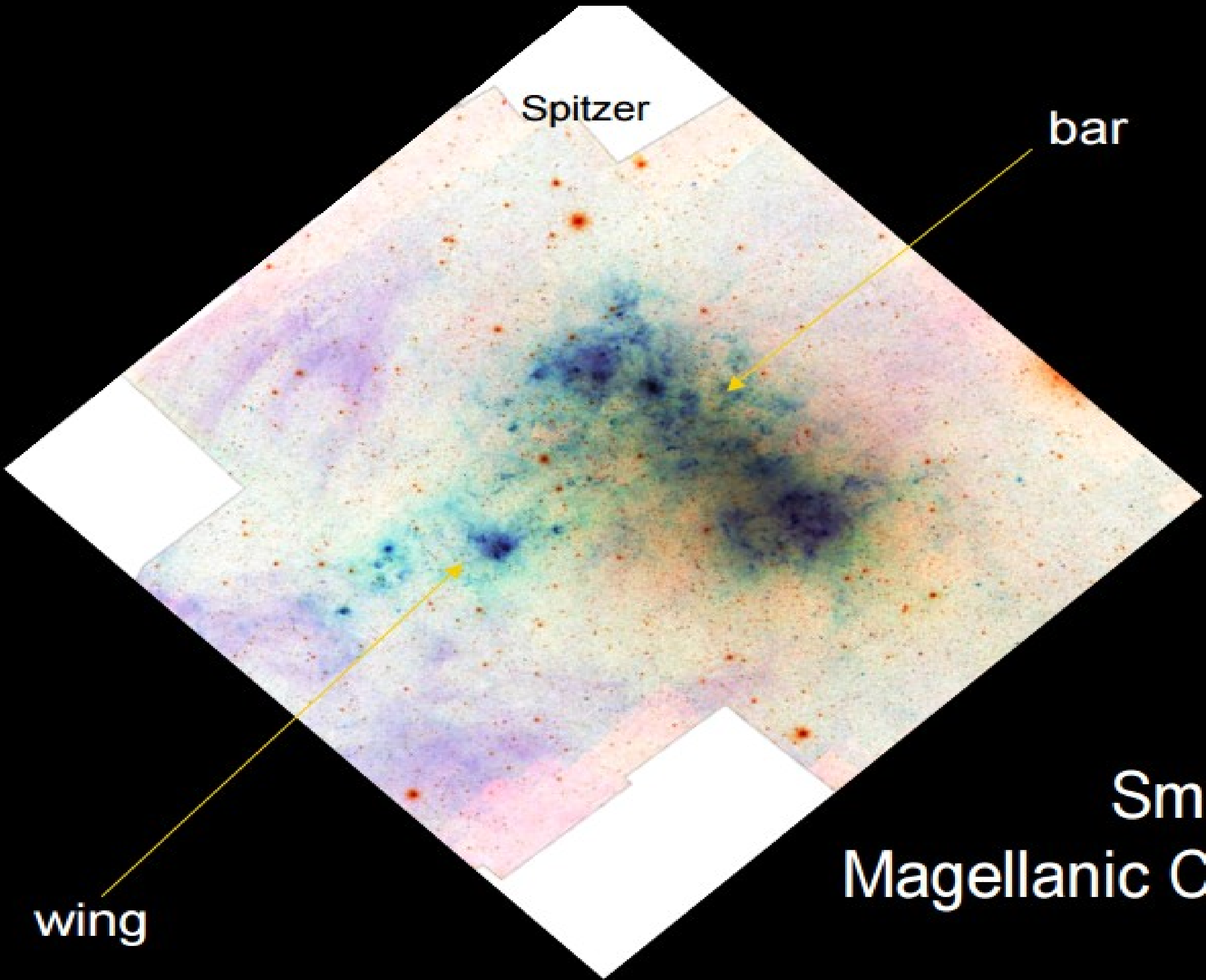
An inhomogeneous distribution

- CR sea has 1/3 the local CR density
- CR enhancements by factors 2-8
- No CR enhancement in 30 Dor…
- … but >0.5° offset from it
- Correlation with cavities and shells





SMC diffuse gamma rays

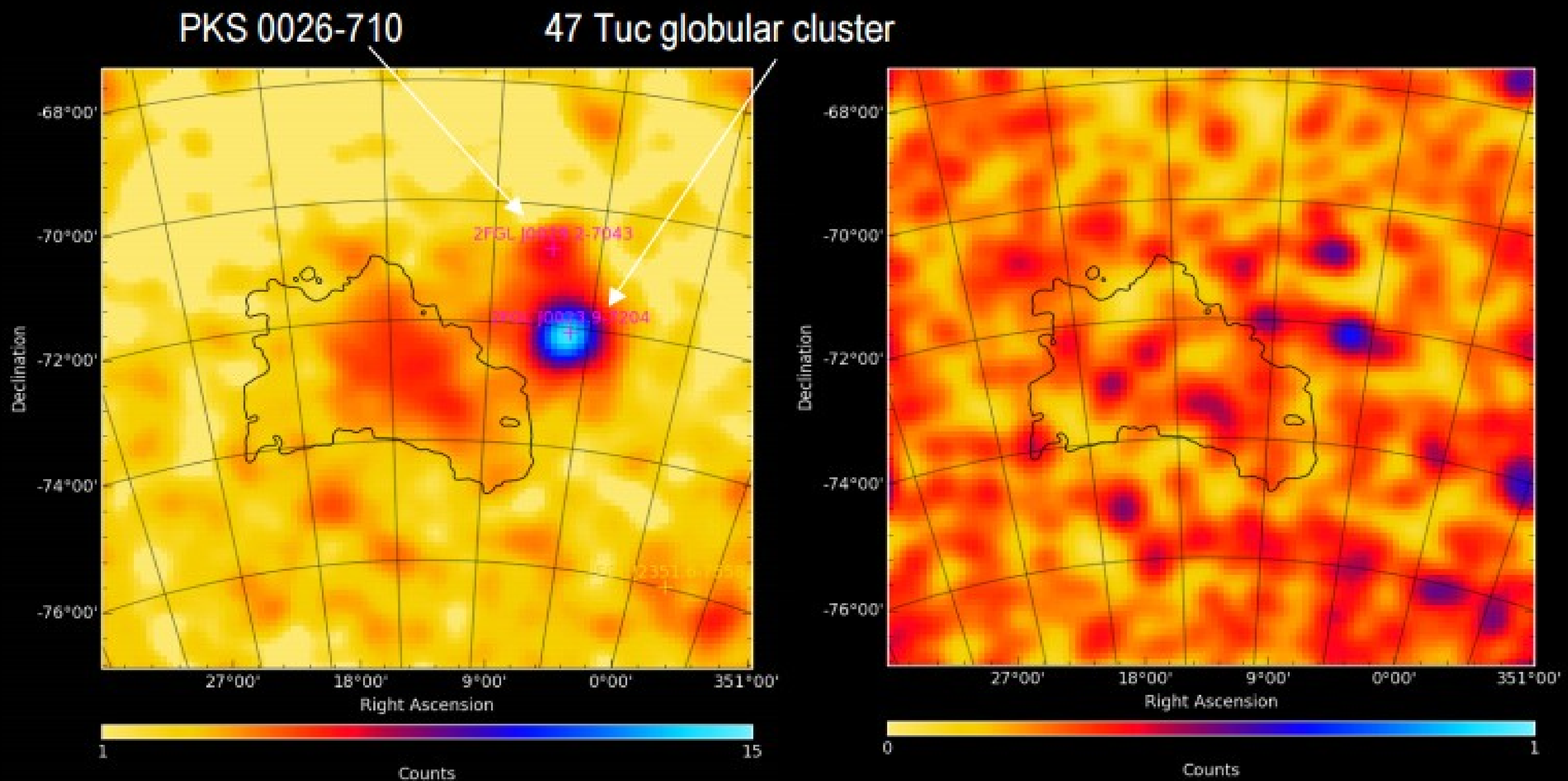


Small
Magellanic Cloud (SMC)

SMC diffuse gamma rays

SMC: counts maps

800MeV-8GeV and 8-80GeV (smoothing with gaussian of 0.2°)



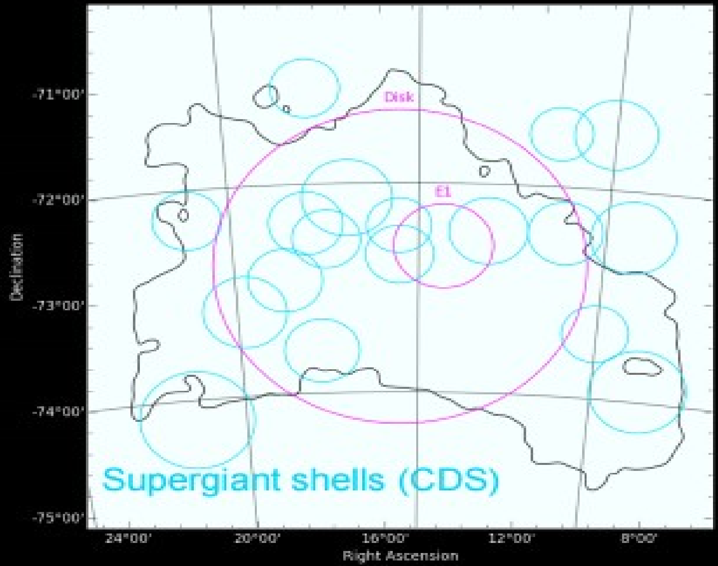
- Extended emission following the bar of the SMC
- No hard sources within SMC boundaries

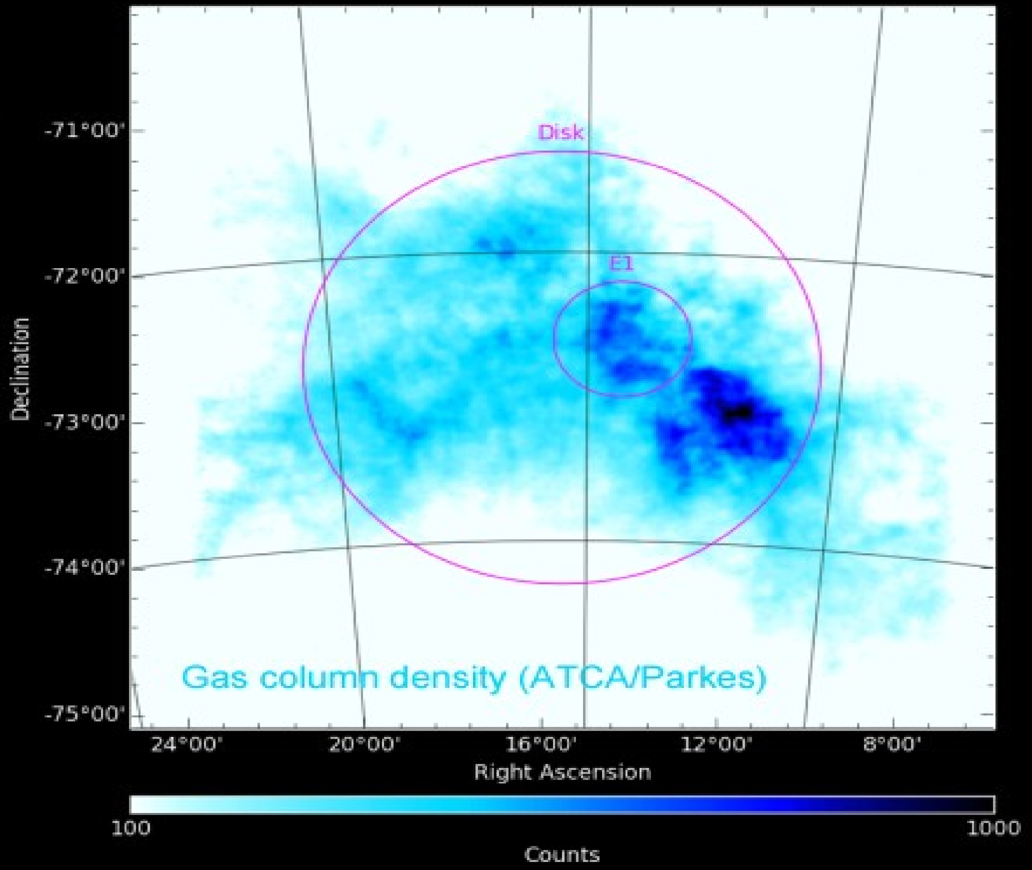
SMC diffuse gamma rays

SMC: cosmic-ray population

Global picture differs from LMC

- No point-like source in SMC
- CR sea has ~5% the local CR density
- CR enhancement in the bar by ~4
- No obvious correlation with cavities
  …or star forming regions
  (but geometry is different)





CR in other galaxies