SPICA Science Workshop 20090601

SPICA Galactic Plane Survey Photometry and Spectroscopy

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SPICA Galactic Plane Survey for the Global Dust Circulation in the Galaxy

Scientific Backgrounds

Global dust grain circulation in the Galaxy not well understood

... Need knowledge on the structure (matter distribution) in the Galaxy

The Galaxy is a spiral galaxy with a bar structure in the center, but

... Spiral pattern still not well defined

... Bar structure not confirmed yet in the far-side

The central structure may have substructures

... The substructure still controversial (Bulge in bulge? Bar in bar?)

Many high mass-loss rate stars are found near the center of the Galaxy

... They may dominate mass and dust return rates in the local space

Issues to be solved

Matter distribution in the Galaxy

- Shapes of the bulge, bar, arms, and disk.

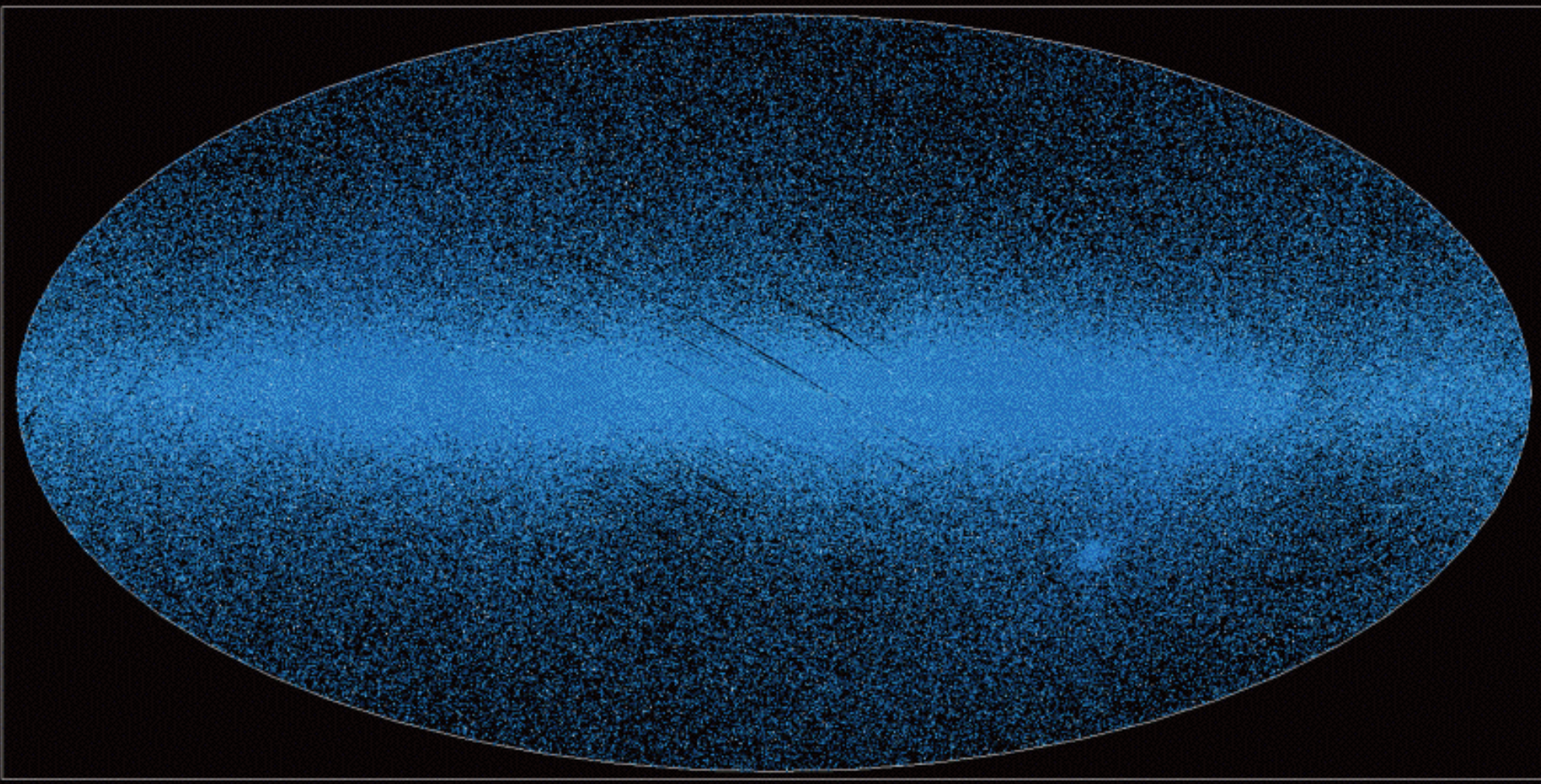
Distributions of kinds of high mass-loss (incl. massive) objects in the Galaxy

- Dominant contributor to the interstellar dust recycling

Dust distribution in the Galaxy

- Ejected dust grains accumulated/destructed over the Galactic history

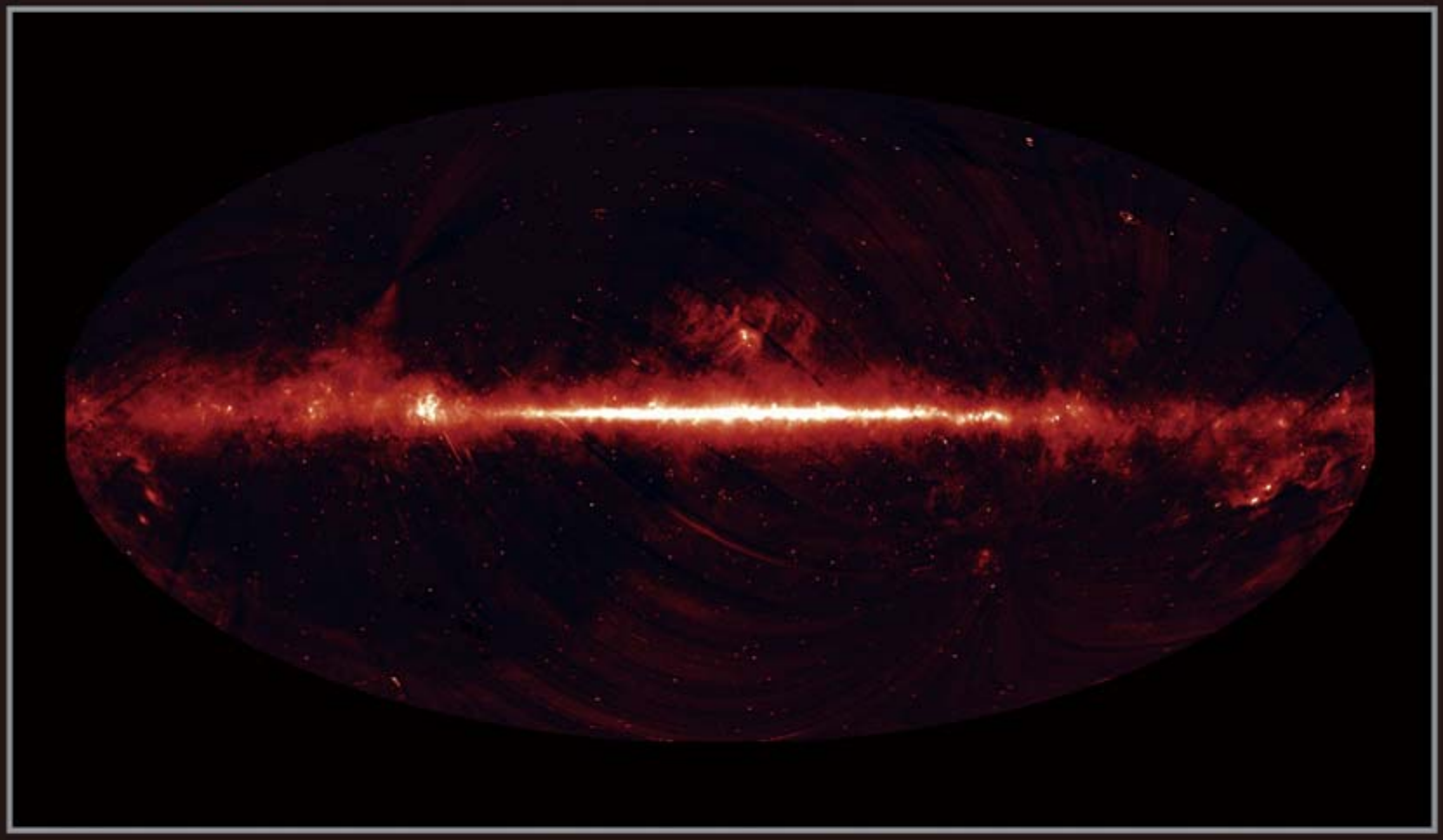
Distribution of AKARI Mid-Infrared (9um) Point Sources



「あかり」近・中間赤外線カメラ（観測波長9μm）

2008年11月19日

Whole Sky Image in the Mid-Infrared at 9um by AKARI



「あかり」近・中間赤外線カメラ（観測波長9μm）

2007年7月11日

Previous Infrared Surveys of the Galactic Plane (I)

#GLIMPSE I & II

*Spitzer; IRAC; 3.6, 4.5, 5.8, and 8.0um

*Angular resolution ranging from 1.4" at 3.6um to 1.9" at 8um.

*Delivered images: 0.6"/pixel, in MJy/sr

*Exposure: 1.2sec integrations x 3 (2 in the first epoch, 1 in the second epoch)

> I: 220 square degrees (| b | < 1deg, | l |= 10-65d, Benjamin et al. 2003)

The average number of sources in each 0.1d x 0.1d bin is

~1400 for the Catalog and ~2200 for the Archive.

Source number in Archive 43E6 (-> about one source per 8"x8" area)

> II: | l | <10deg (| b |<1deg, | l |=10-5deg; | b |<1.5deg, | l |=5-2deg; | b |< 2deg, | l |=2-0d)

(l=-1/+1, b=-0.75/+0.75 is excluded, observed by the GALCEN GO program)

Source number in Catalog (high quality) 19E6 sources

Source number in Archive (less constraints) 24E6 sources (about one per 5"x5")

*Confident measurements

0.5, 0.5, 2.0, and 5.0mJy for 3.5, 4.5, 5.8, and 8.0um (Robitaille et al. 2007)

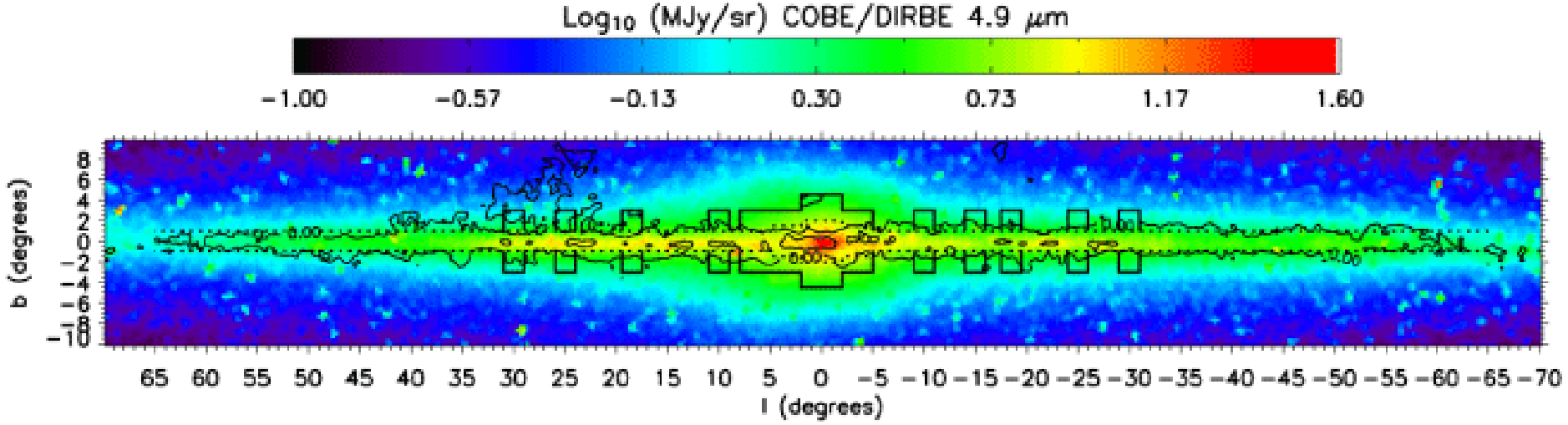
[<-> 14.4, 13.9, 11.9, and 10.3mag 、但し、277.5, 179.5, 116.5, and 63.13 Jy

@ 3.5, 4.5, 5.8, and 8.0um for zero mag.]

*GLIMPSE catalog is more restrictive, limiting magnitude 14.1mag at 3.6um

*Mead et al. (2008)

The counts begin to fall at14mag(3.6 and 4.5um), 12.5mag(5.8um), 12mag(8.0um)



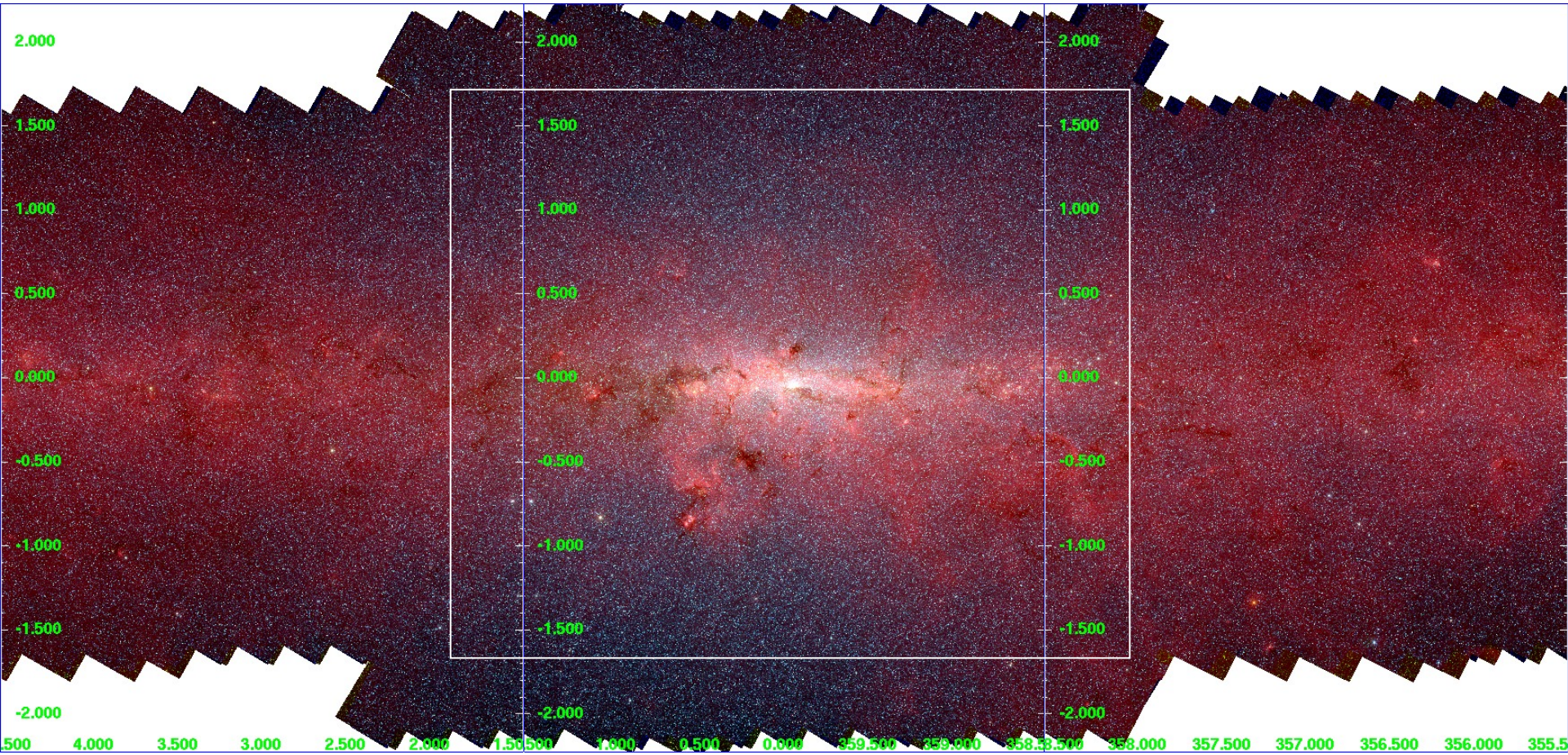
GLIMPSE,GLIMPSEII,GLIMPSE3D areal coverage (GLIMPSE home page)

GLIMPSE Catalog and Archive Source Information

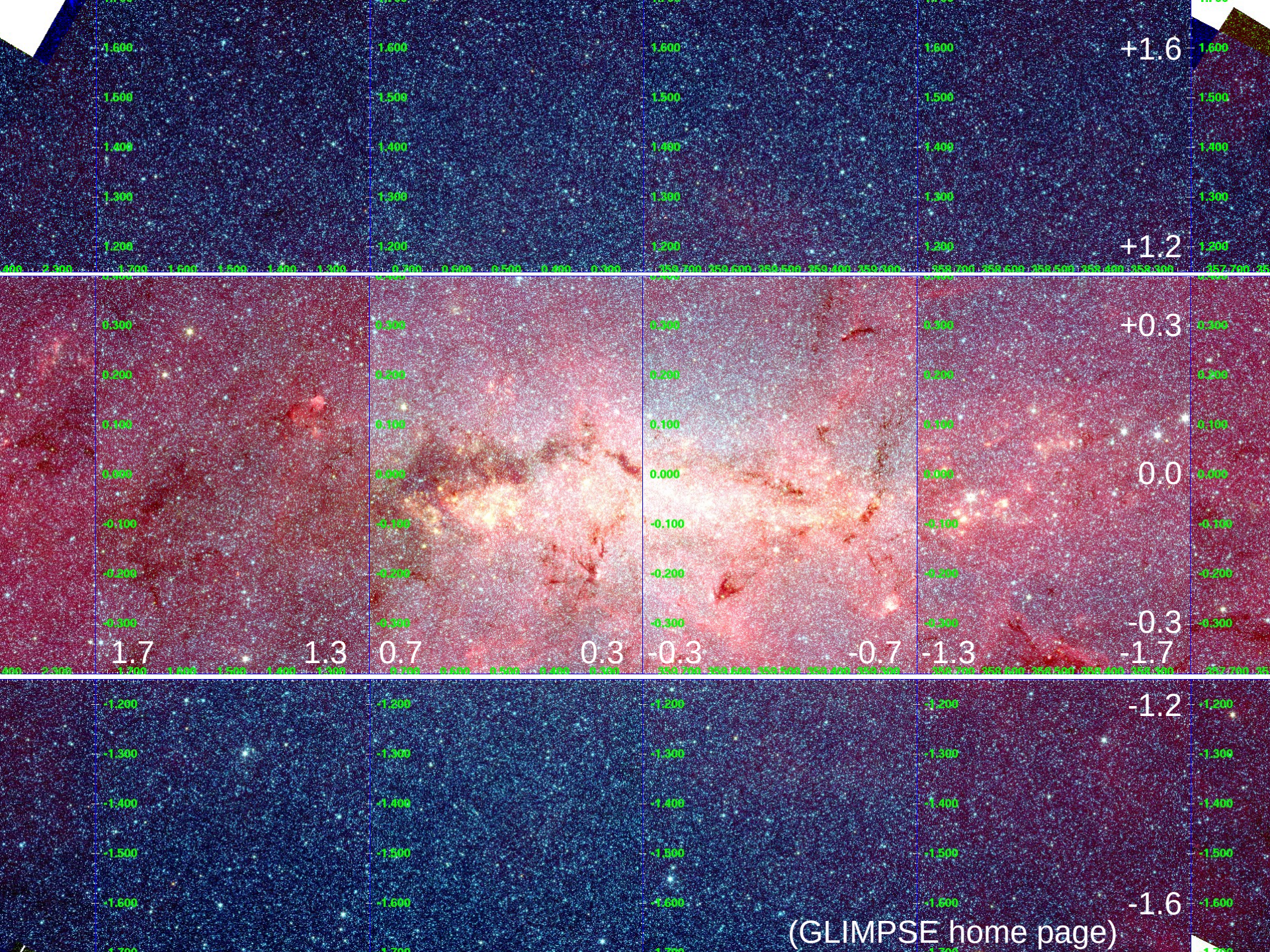
IRAC Band	λ[a] (μm)	S_0[a] (Jy)	$A_{[\lambda]}/A_K$[b]	m_{sel}[c] (mag)	m_{br}[c] (mag)	m_{sens}[d] (mag)	Catalog Sources (×10⁶) North	Catalog Sources (×10⁶) South[e]	Archive Sources (×10⁶) North	Archive Sources (×10⁶) South[e]
1	3.55	277.5	0.56 ± 0.06	14.2	7.0	13.3–13.6	14.775	14.255	21.420	22.044
2	4.49	179.5	0.43 ± 0.08	14.1	6.5	13.3–13.6	14.768	14.250	19.797	19.423
3	5.66	116.5	0.43 ± 0.10	11.9	4.0	11.7–12.3	5.768	5.291	6.095	5.594
4	7.84	63.13	0.43 ± 0.10	9.5	4.0	11.0–12.4	4.426	3.959	4.749	4.268

[a] Vega isophotal wavelengths and IRAC zero magnitudes from M. Cohen (2005, unpublished).
[b] Extinction from Indebetouw et al. (2005).
[c] GLIMPSE Point Source Catalog selection limits and brightness cutoff limits from Meade et al. (2005).
[d] The "effective" Catalog sensitivity limit varies over the longitude range $|l| = 10°$ to $|l| = 65°$.
[e] The southern Catalog and Archive are still missing ~1% of the survey area.

Benjamin et al. 2005

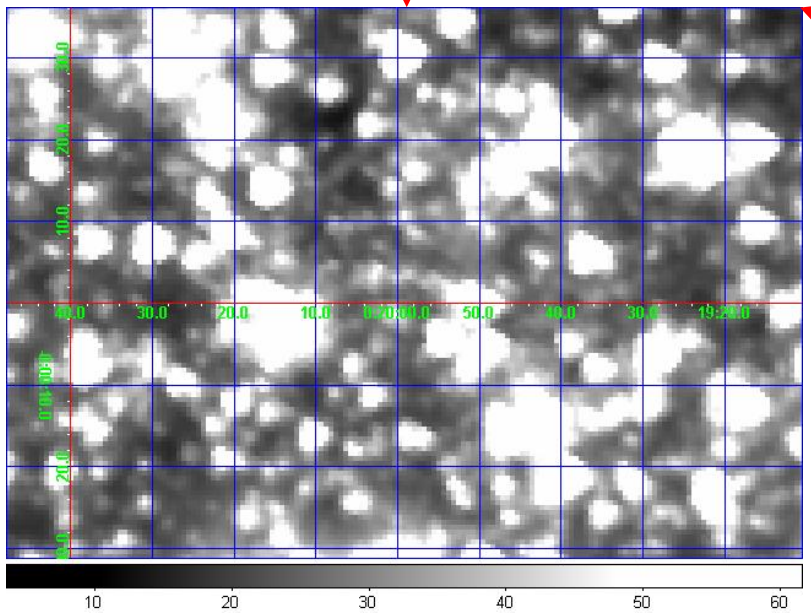


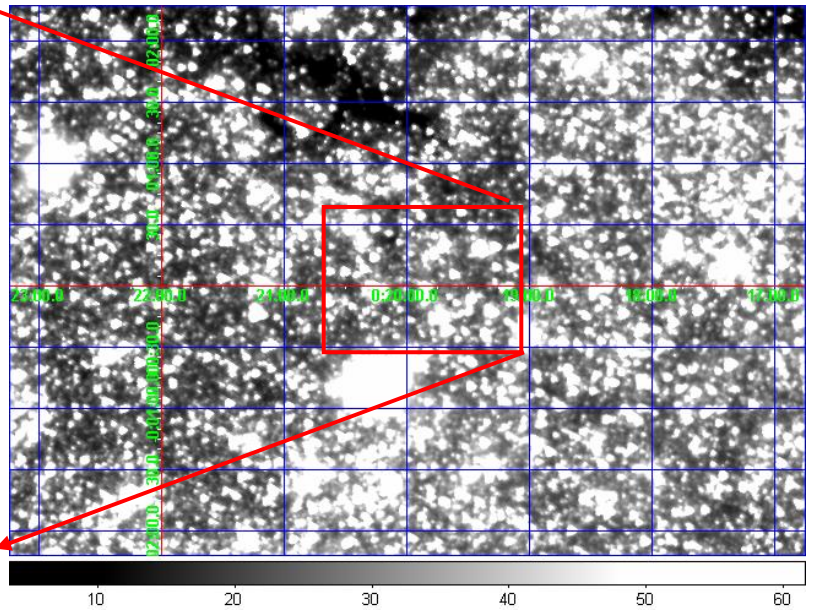
Mosaicked image of the region L=-5d ~ +5d observed by GLIMPSEII (GLIMPSE home page) (Mead et al. 2008)


+1.6
+1.2
+0.3
0.0
-0.3
-1.2
-1.6
1.7
1.3
0.7
0.3
-0.3
-0.7
-1.3
-1.7
(GLIMPSE home page)

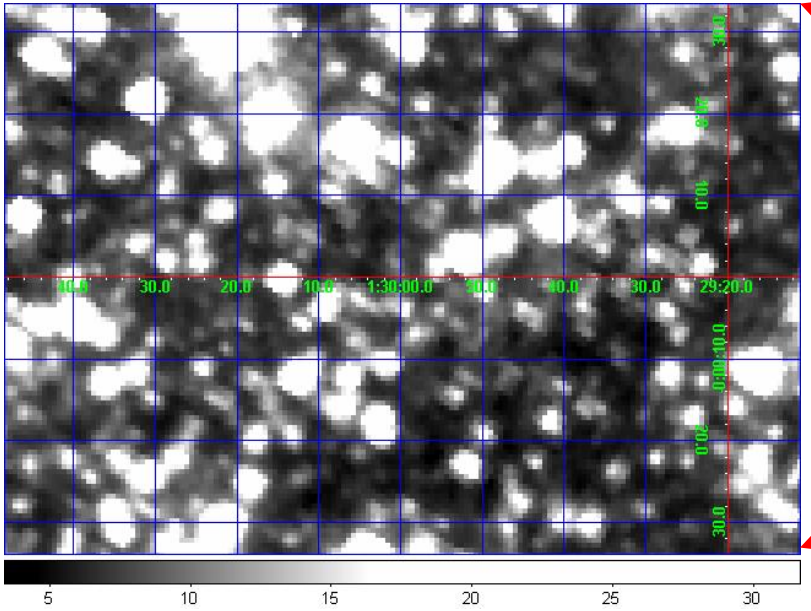
Galactic Plane near G. C. @3.6um

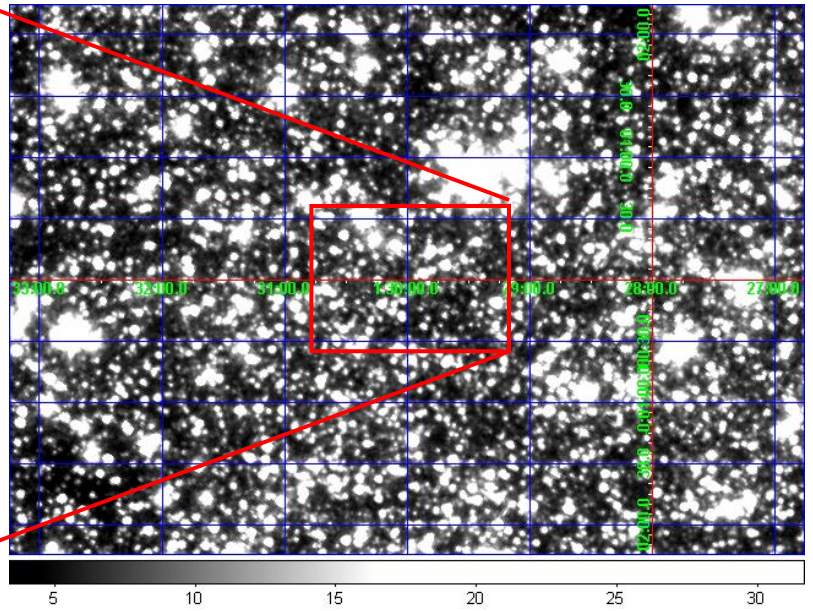
Spitzer GLIMPSEII (0.6”/pixel,10” grid) ⇔SPICA PSF~0.7”@12um



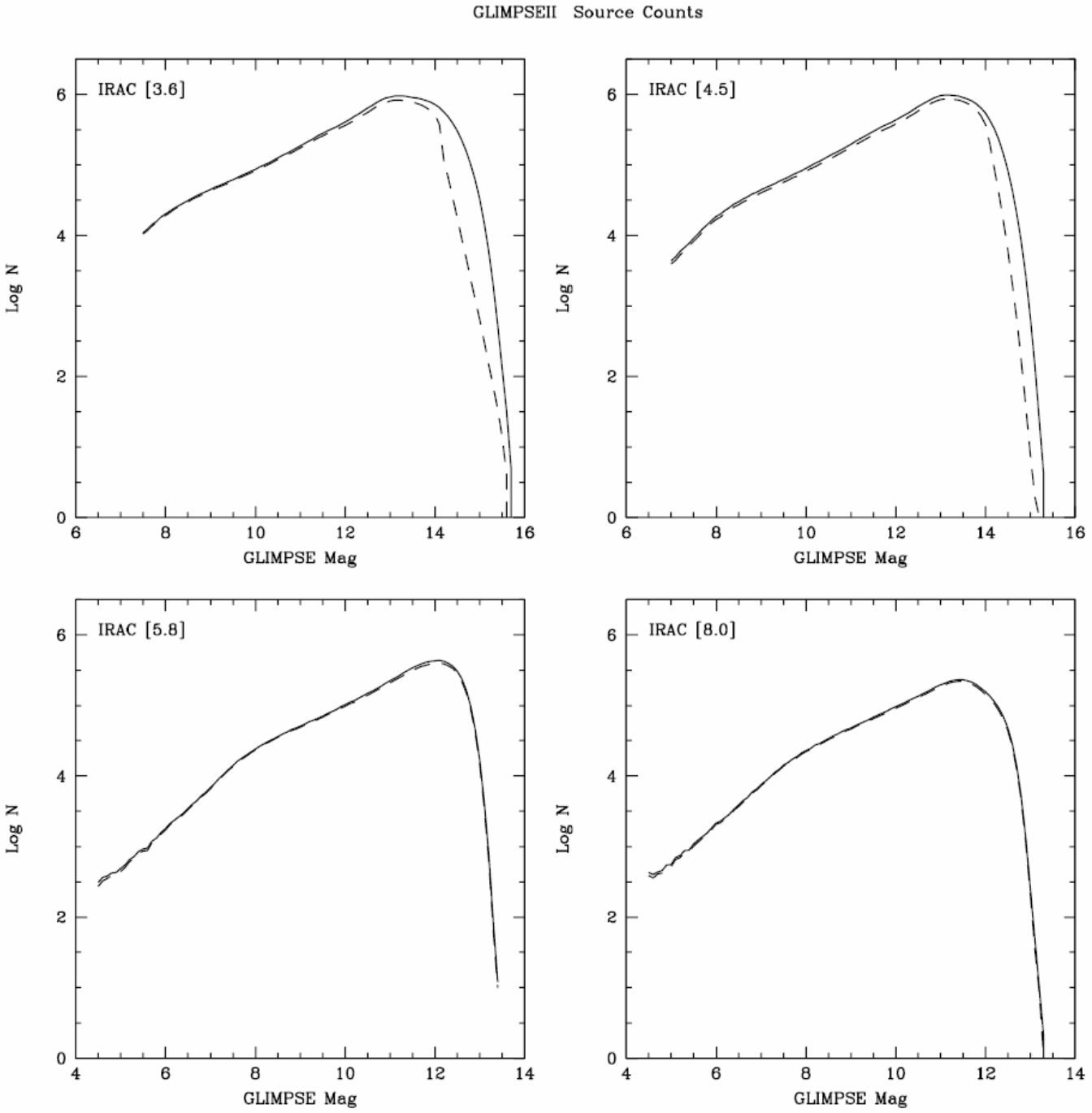


L=+0:20:00
B=00:00:00





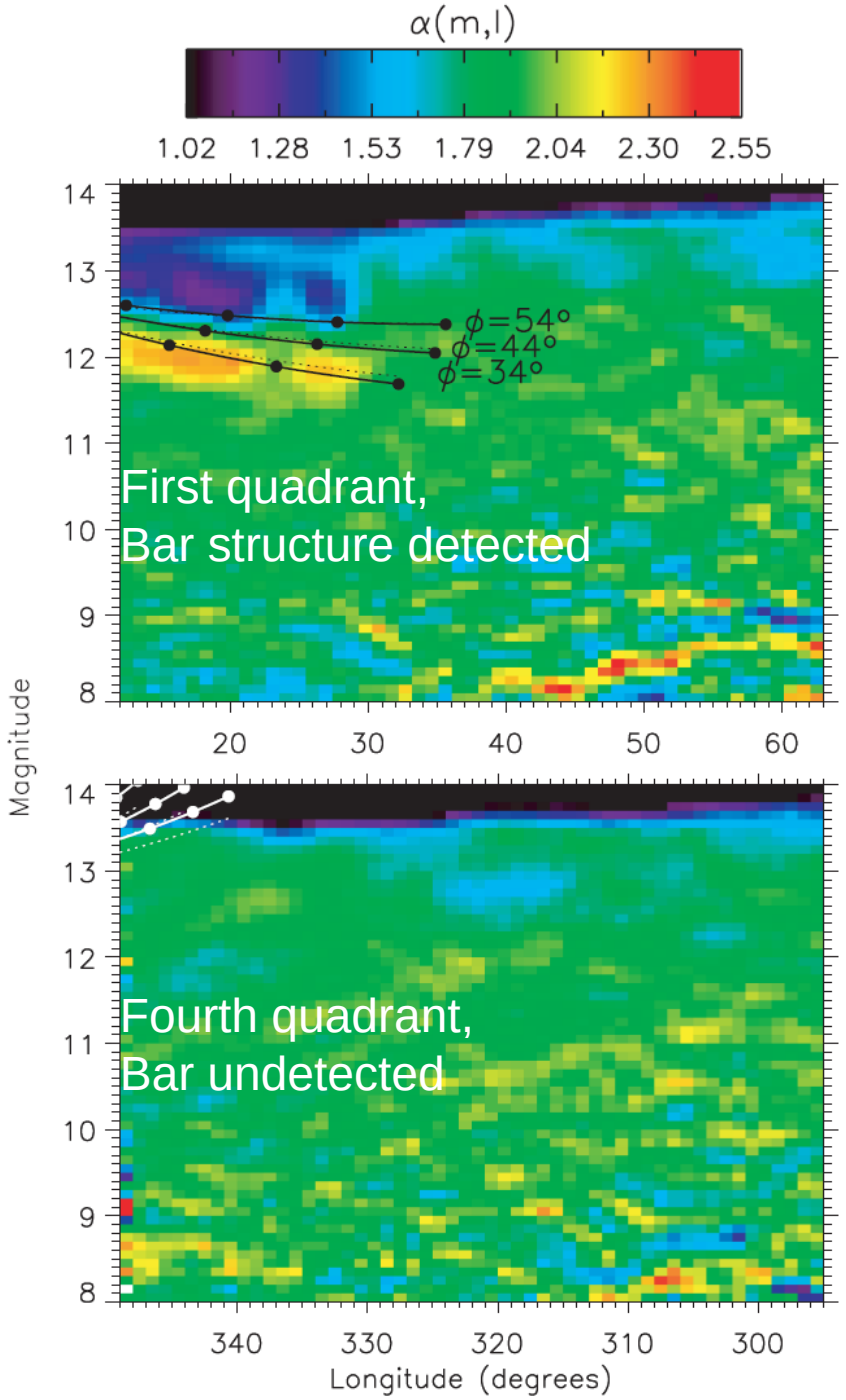
L=+1:30:00
B=00:00:00



GLIMPSEII
Source Counts
(Luminosity Function)

+ Differential
+ Entire region
+ Solid line: Archive
+ Dashed line: Catalog
+ 0.1mag bin

(Mead et al. 2008)



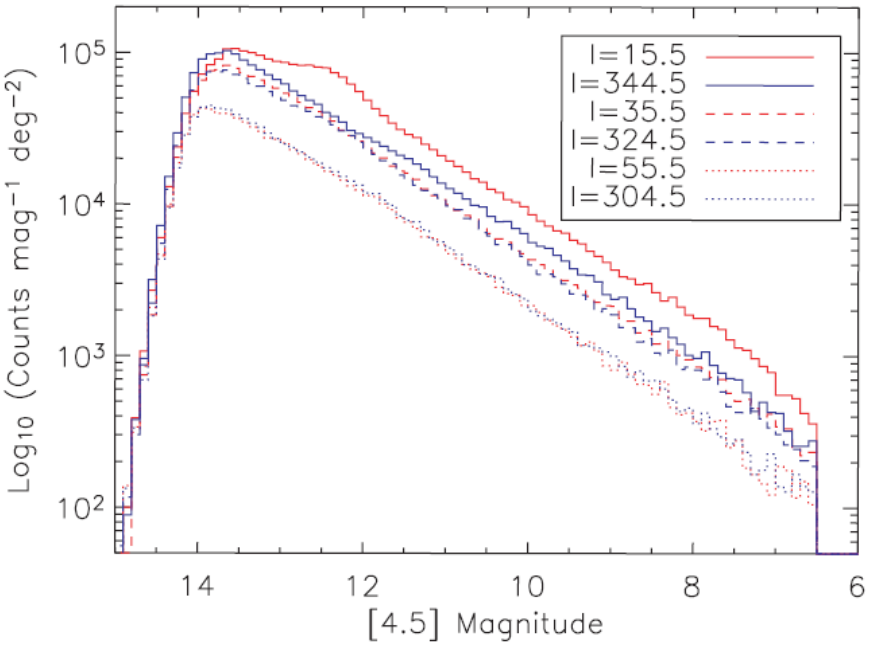


FIG. 4.—Power-law exponent of counts as a function of flux density, plotted as a function of apparent magnitude and Galactic longitude. The position of the ~12 mag hump seen toward $l = 15.^{\circ}5$ in Fig. 3 is seen here to vary consistently in both longitude and magnitude. The locus of magnitude and longitude of a model bar, consisting of stars of absolute magnitude $M_{[4.5]} = -2.15$, foreground extinction $a_{[4.5]}(r) = 0.05$ mag kpc^{-1}, and three different position angles ϕ, are shown in black in the top panel and in white in the bottom panel. The circles indicate $R = 3$, 4, and 5 kpc points along the bar. The dotted lines show the same position angles for zero extinction, with $M_{[4.5]} = -1.8$.

(Benjamin et al. 2005)

Next Step by SPICA

Resolving Source Confusion

Resolve and detect red clump giants to the other edge of the Galaxy
=> Galactic Structure will be investigated

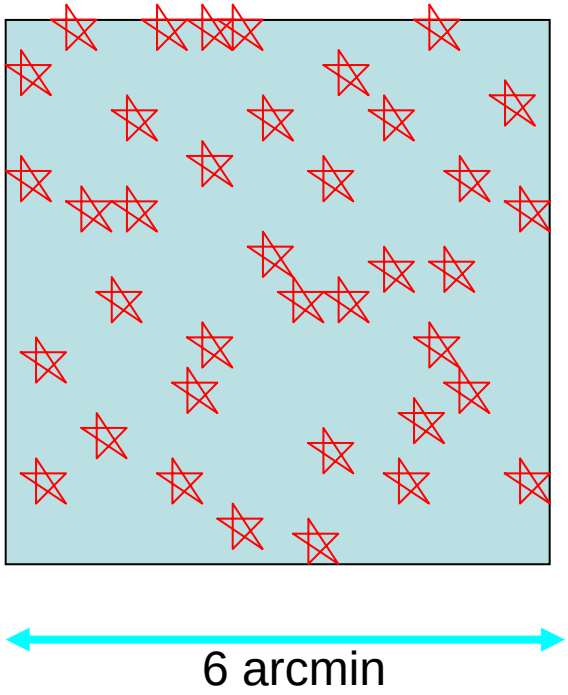
Simple estimates:

* M_[4.5]=-2 assumed for red clump giants (corresponding to K2-K3 giants)
* To detect stellar bar in the fourth quadrant at L~ 350deg. => Reach m_[4.5] >14
* To detect global structure to 20kpc by source count => Reach m_[4.5]>14.5
  => The GLIMPSE source counts (luminosity function) tells us to detect sources in regions as crowded as 10^6.5 star mag^-1 deg^-2
  => Need of counting 10^8 sources in the GLIMPSEII region without confusion
  => 10^8 sources / 2deg x 20deg = 0.2 source arcsec^-2 or 5 arcsec^2/source
  => 2.2" x 2.2"/source expected <=> 5"x5"/srouce in GLIMPSEII
  => Need of an angular resolution twice or more better than Spitzer

Tolerance for the Bright End of Sources

* Bright ends of GLIMPSE : 7, 6.5, 4, and 4mag @3.6, 4.5, 5.8, and 8.0um
* How near do we want to study sources with high precision?
* Red clump giants at the distance of the Galactic Center should be seen as
  =>12.5mag at 8 kpc, and 11.0mag at 4 kpc, if absolute magnitude is -2 mag.
* Relatively arbitrary requirements:
  7 mag (1.0Jy) at K-band, 8 mag (40mJy) at 8um
  => 7 mag at all bands

Mid-IR Imaging Survey with MIRACLE

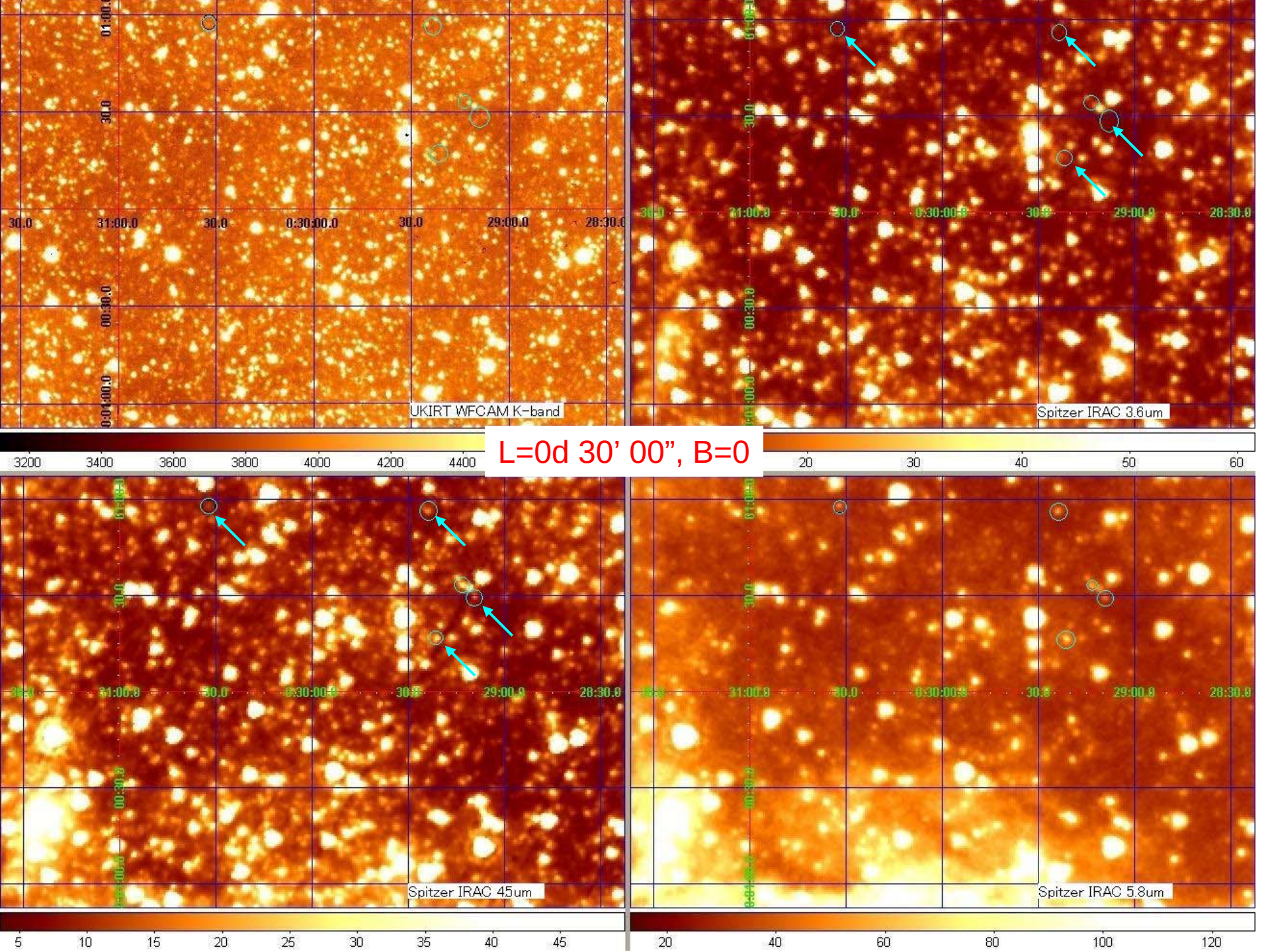


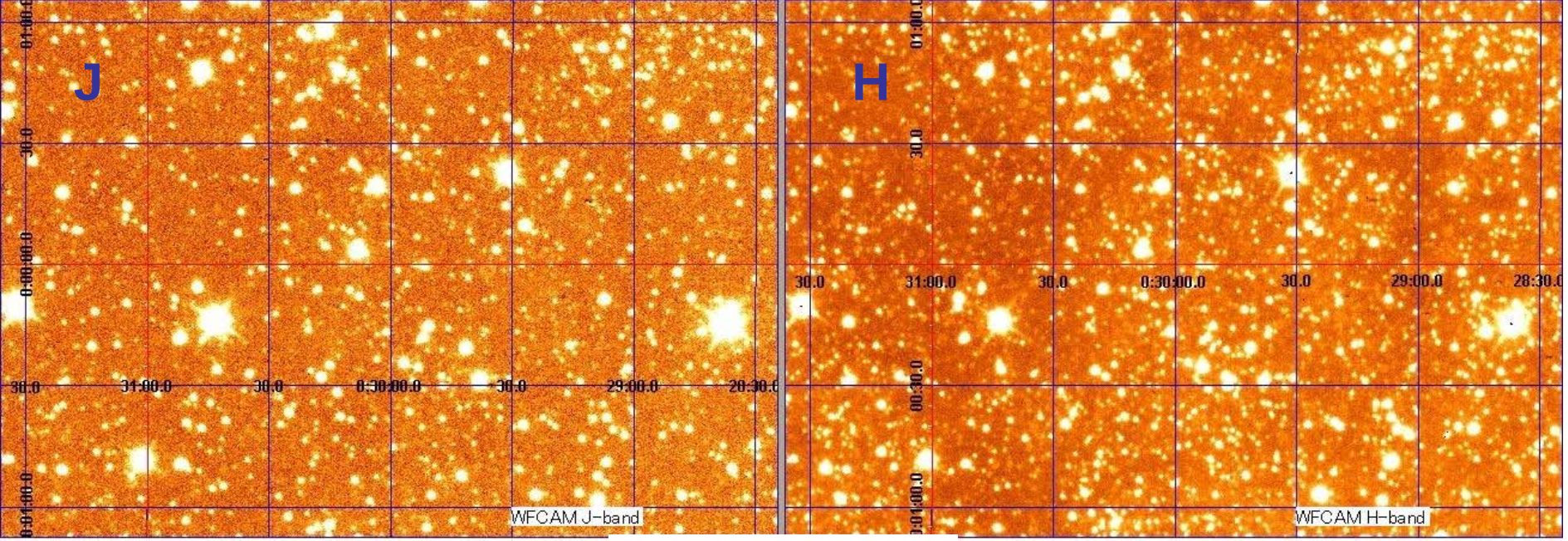
Observing Time for One Sweep:
- Integ. time 1 sec x 3 shots = 3 sec
- Survey area -90<l<90, -2<b<2
- Total pointings (4 x10) x (180 x10)= 72,000
- Total Integ. time 60 hours / sweep /band)
- Observing bands ~5um and ~7um (+ L and N hopefully)

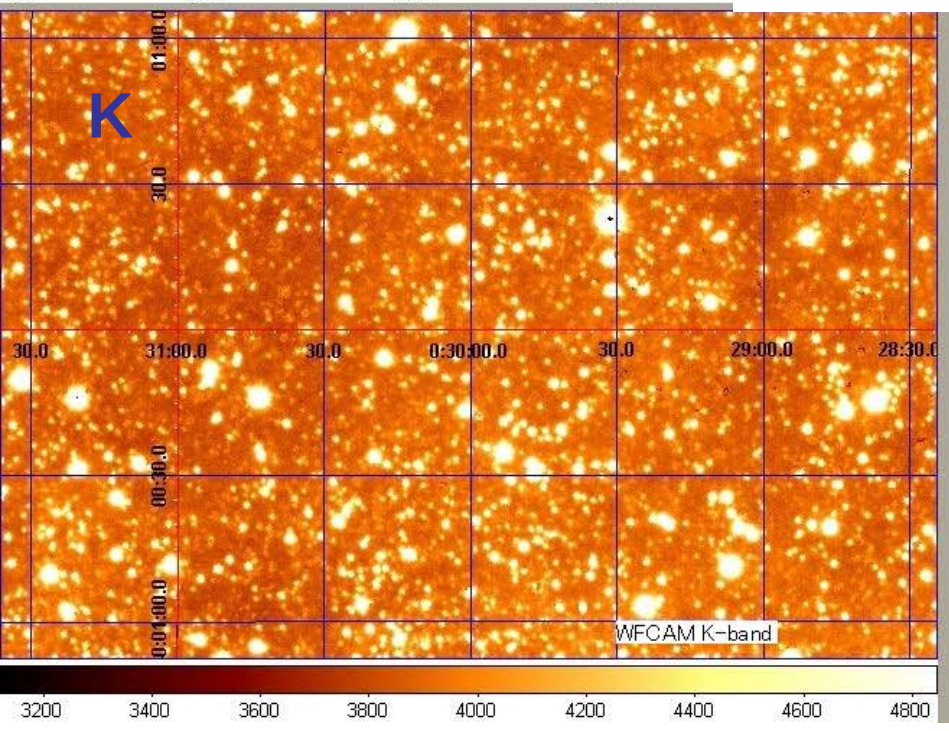
Sensitivity :
- 15.9 mag @5um with S/N=5 for 3 sec integ./sweep
- #Based on sensitivity plot of SPICA=>
- #0.4uJy, 5 sigma for 1 hour @ 5um
- # =>15.9 mag for 5 sigma and 3 sec.

Variability Survey:
- 10 sweeps over 1000days -> 600 hrs in total / band

Products:
- Point source catalog of one billion sources
- Red clump giants at the other edge of the Galactic disk
- Census of long period variables with heavy mass-loss
- Diffuse emission maps


UKIRT WFCAM K-band
Spitzer IRAC 3.6um
L=0d 30’ 00”, B=0
Spitzer IRAC 45um
Spitzer IRAC 5.8um

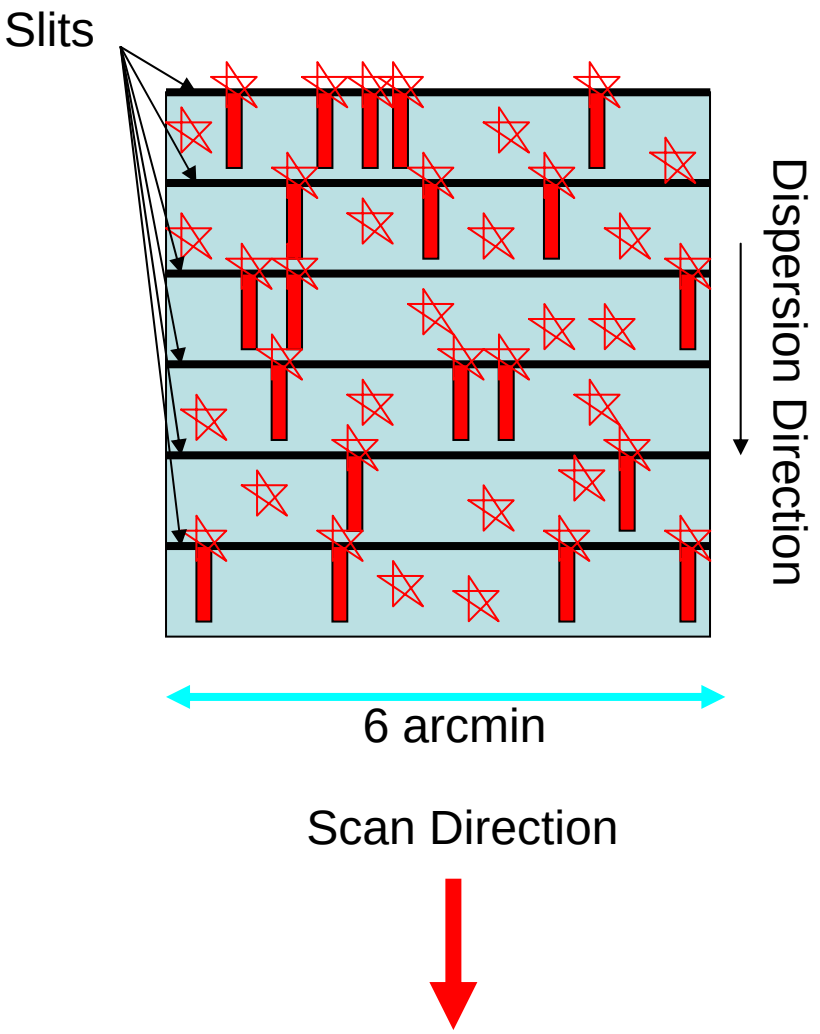




UKIRT/WFCAM, DR4
GPS：K<18.08

WFCAM/VISTA Survey
Deepest K~21

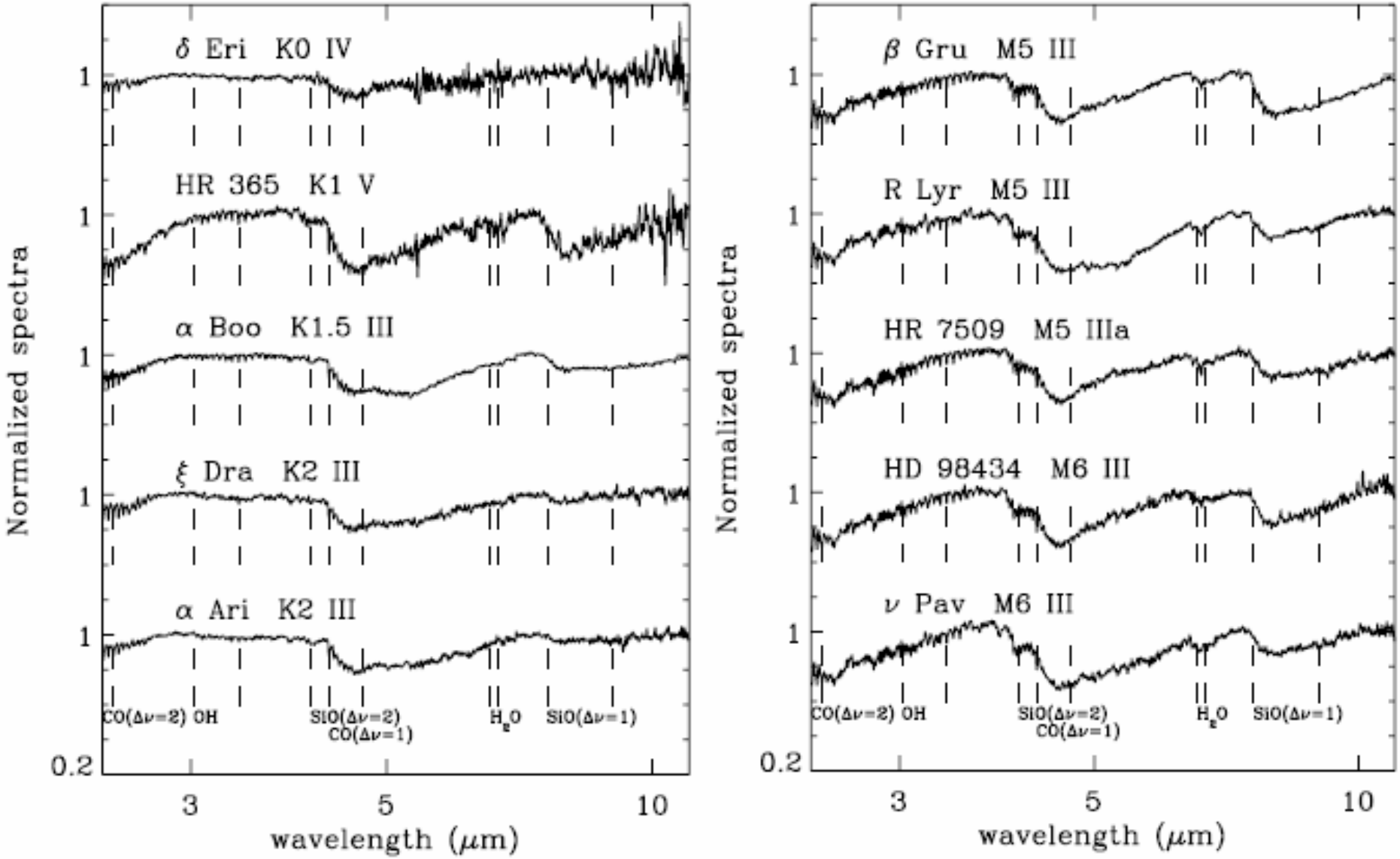
Mid-IR Spectroscopic Survey with MIRACLE



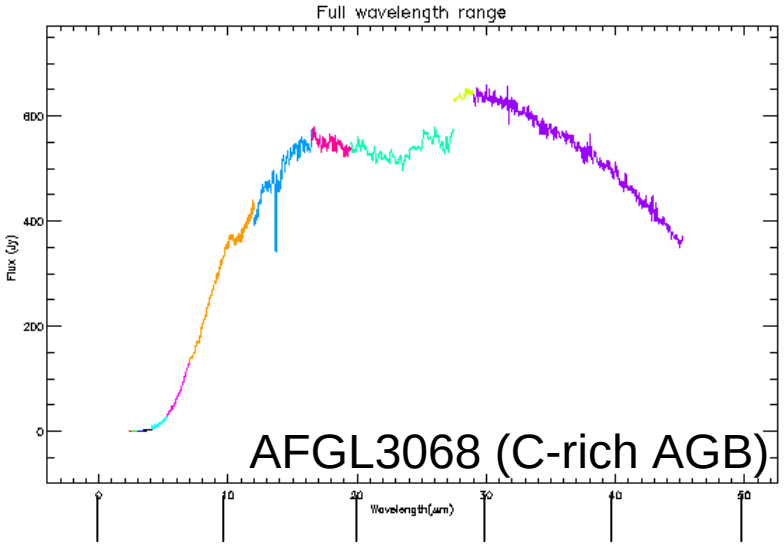
Observing Time:
- Pointing: step by 6 arcminutes
- Scan: step by 1 arcsecond
  length of 60” by 60 steps
- Integ. Time: 3sec/slit position
  => 180 sec/pointing
- Survey area: -60 < L < 60, -1 < B < 1
- Total N of pointings: 2x10x120x10 = 24,000
- Total Integ. Time: 72000min＝1200hrs=50d

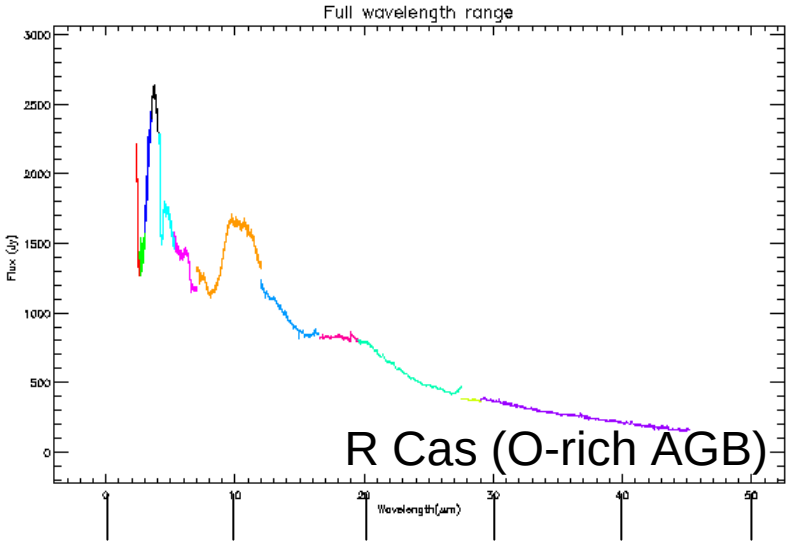
Sensitivity:
- 13.5 mag @ 5um
- S/N >5 for 3 sec, R～100,
- #Based on sensitivity plot of SPICA=>
- #Continuum: 5uJy, 5 sigma,1-hour@5um

Products:
- Low resolution spectra of 1 million sources
- Complete diffuse emission map of the GP
- Census of luminous very red objects



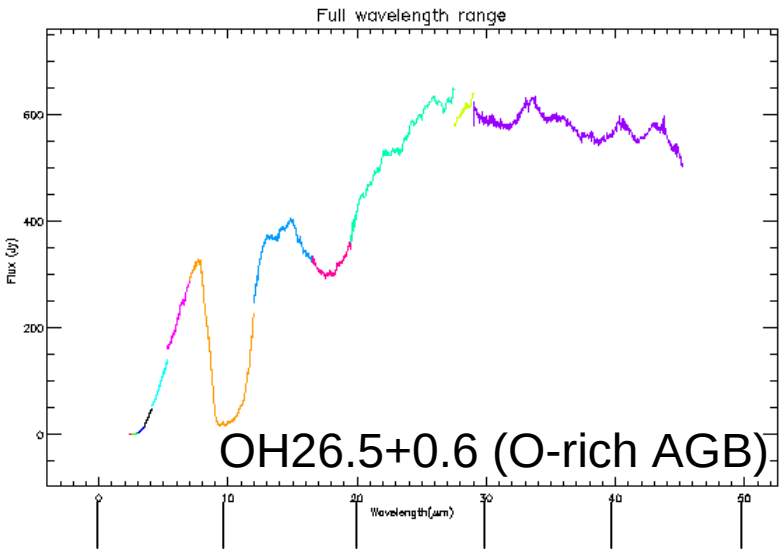
Heras et al. A&A 394, 539–552 (2002)

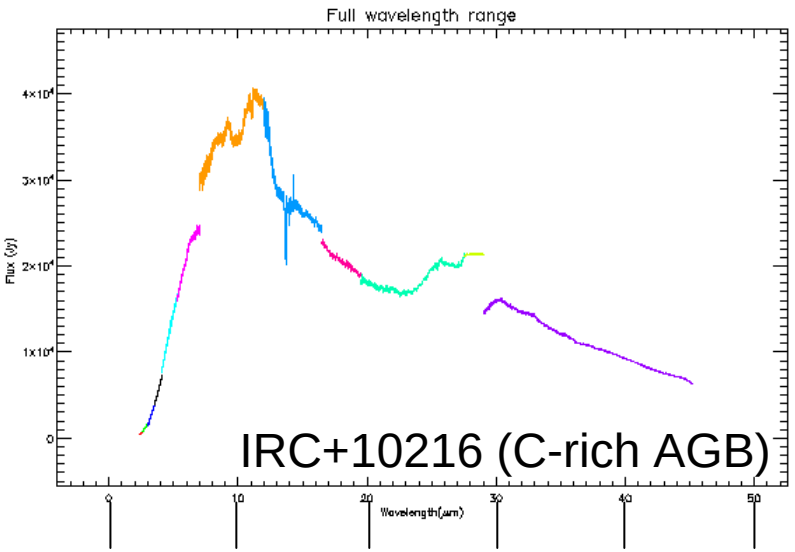




0 10 20 30 40 50 (um)

0 10 20 30 40 50 (um)

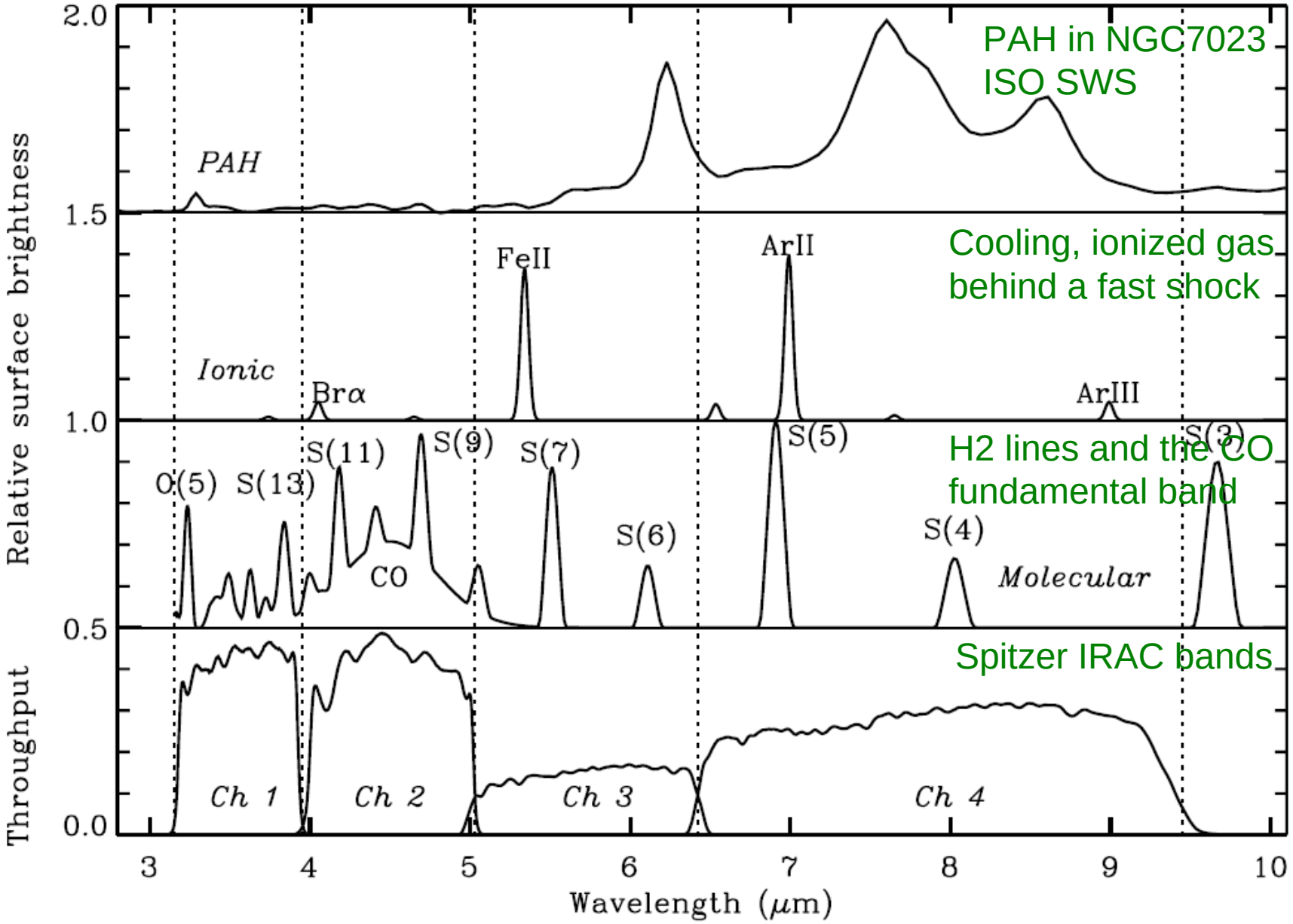




0 10 20 30 40 50 (um)

0 10 20 30 40 50 (um)

Taken from ISO Archive



Reach et al. 2006, AJ, 131, 1479–1500

Summary:

Galactic Plane Survey with SPICA/MIRACLE

Products:

Imaging (600hrs)

* Point source catalog of one billion sources down to ~16mag at M.
* Red clump giants at the other edge of the Galactic disk
* Census of long period variables with heavy mass-loss
* Diffuse emission maps

Spectroscopy (1200hrs)

* Low resolution spectra of 1 million sources down to ~13mag at M
* Complete diffuse emission map of the Gal. Pln.
* Census of luminous very red objects including massive objects

Relevant NIR surveys (WFCAM/VISTA)

* Deeper two-color diagram than those with NIR surveys available
* Extinction correction available to the largest number of sources
* Cool objects invisible in K surveys are seen in L, M, and N bands

Find answers to the questions

* Matter distribution in the Galaxy
  - Shapes of the bulge, bar, arms, and disk.
* Distributions of kinds of high mass-loss (incl. massive) objects in the Galaxy
  - Dominant contributor to the interstellar dust recycling
* Dust distribution in the Galaxy
  - Ejected dust grains accumulated/destructed over the Galactic history

=> Details of the dust circulation in the Galaxy