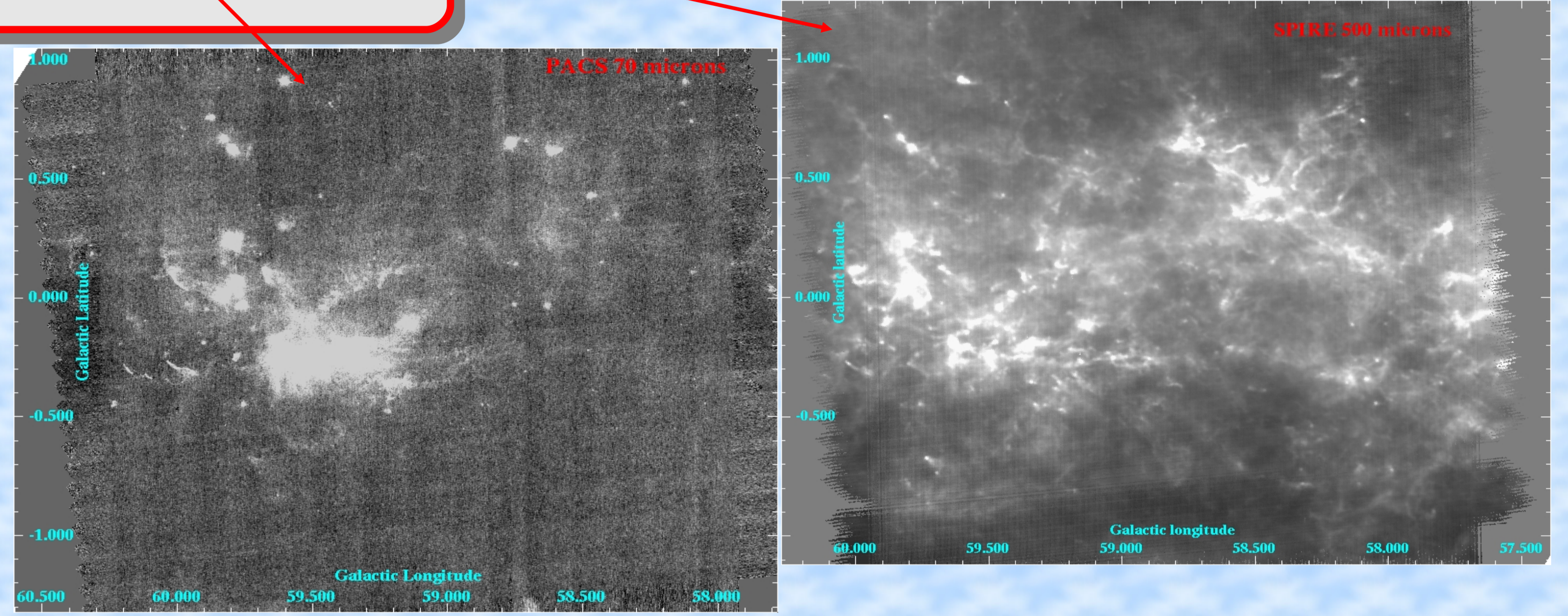


Distance determination for the Hi-GAL Survey

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Context: Hi-GAL is an open time Key-Project of the Herschel satellite that is carrying out a 5-band photometric imaging survey at 70, 160, 250, 350 and 500 μm of the Milky Way Galactic Plane in the longitude range $-60^\circ < l < 60^\circ$ and the latitude range $|b| < 1^\circ$ (Molinari et al. 2010). Our goal is to present the velocity follow-up and the distance determination method for the Hi-GAL compact sources. The field at $l=59^\circ$, observed during the science demonstration phase (SDP), is taken as an example to illustrate our method.

Hi-GAL $2^\circ \times 2^\circ$ images: PACS + SPIRE
case of $l=59^\circ$

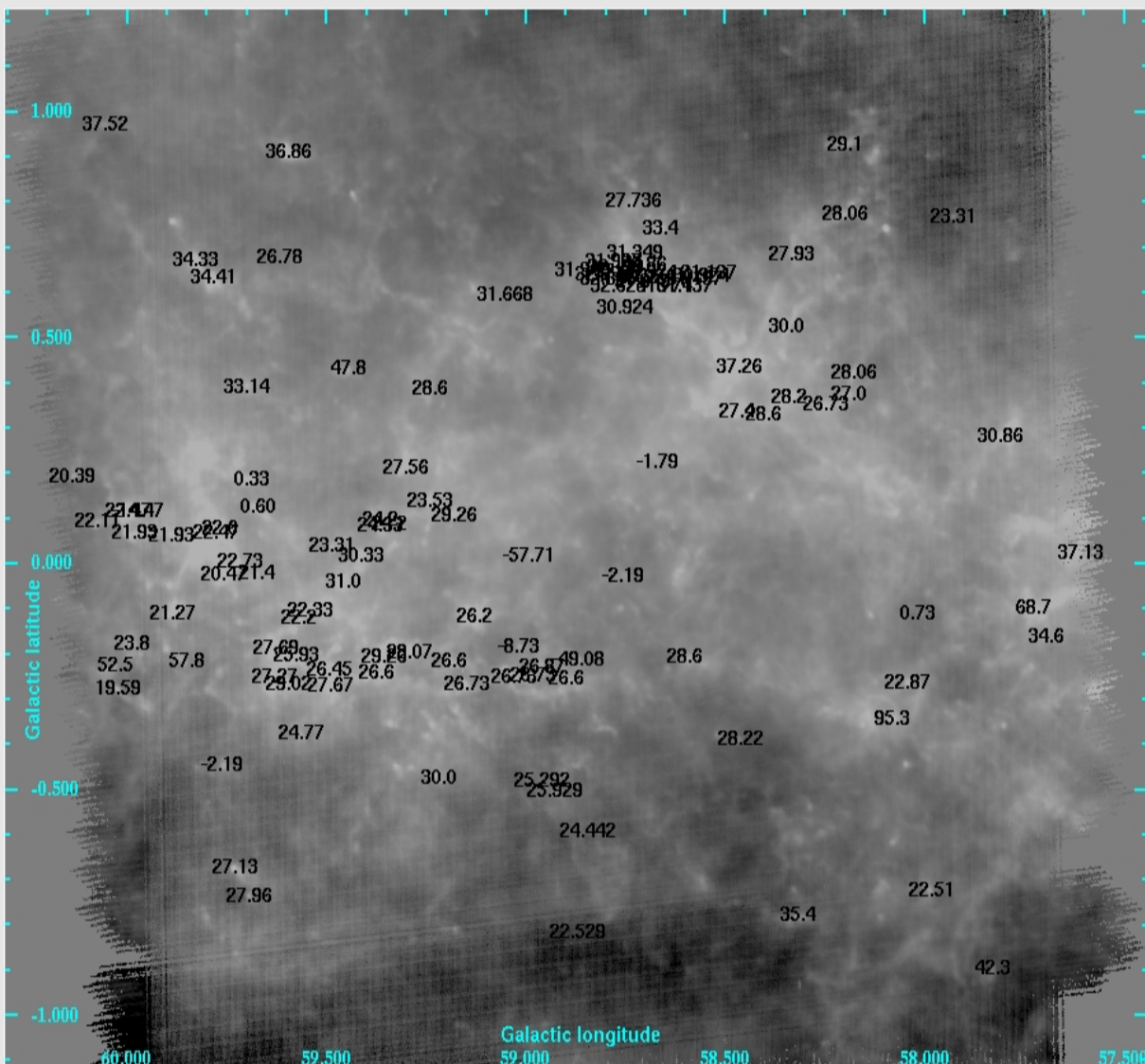


Sources catalogue
(Elia et al. 2010)
2678 compact sources
in $l=59^\circ$ and $l=30^\circ$ SDP
fields

VELOCITY

NH_3 observations
(Medicina, Onsala, Effelsberg Telescopes)
 $^{13}\text{CO} - \text{C}^{18}\text{O}$ line profiles extracted from datacubes (FCRAO, Galactic Ring Survey)

709 Hi-GAL sources with an unambiguous velocity determination (only one line detected in the spectrum)



Rest velocity (km/s) of the Hi-GAL compact sources overlaid on the Spire 500 μm image.

Hi-GAL sources associated with HII regions from velocity and spatial considerations

HII regions

- => Stellar distance for optical HII region, if exciting stars identified (e.g. Forbes 1989)
- => Maser parallax distance of star-forming region (e.g. Xu et al. 2009)
- => Near/far distance determination: HI absorption/emission, Self-absorption methods (e.g. Anderson & Bania 2009)
- => Near/far distance determination: H_2CO or OH absorption lines velocity (e.g. Sewilo et al. 2004)

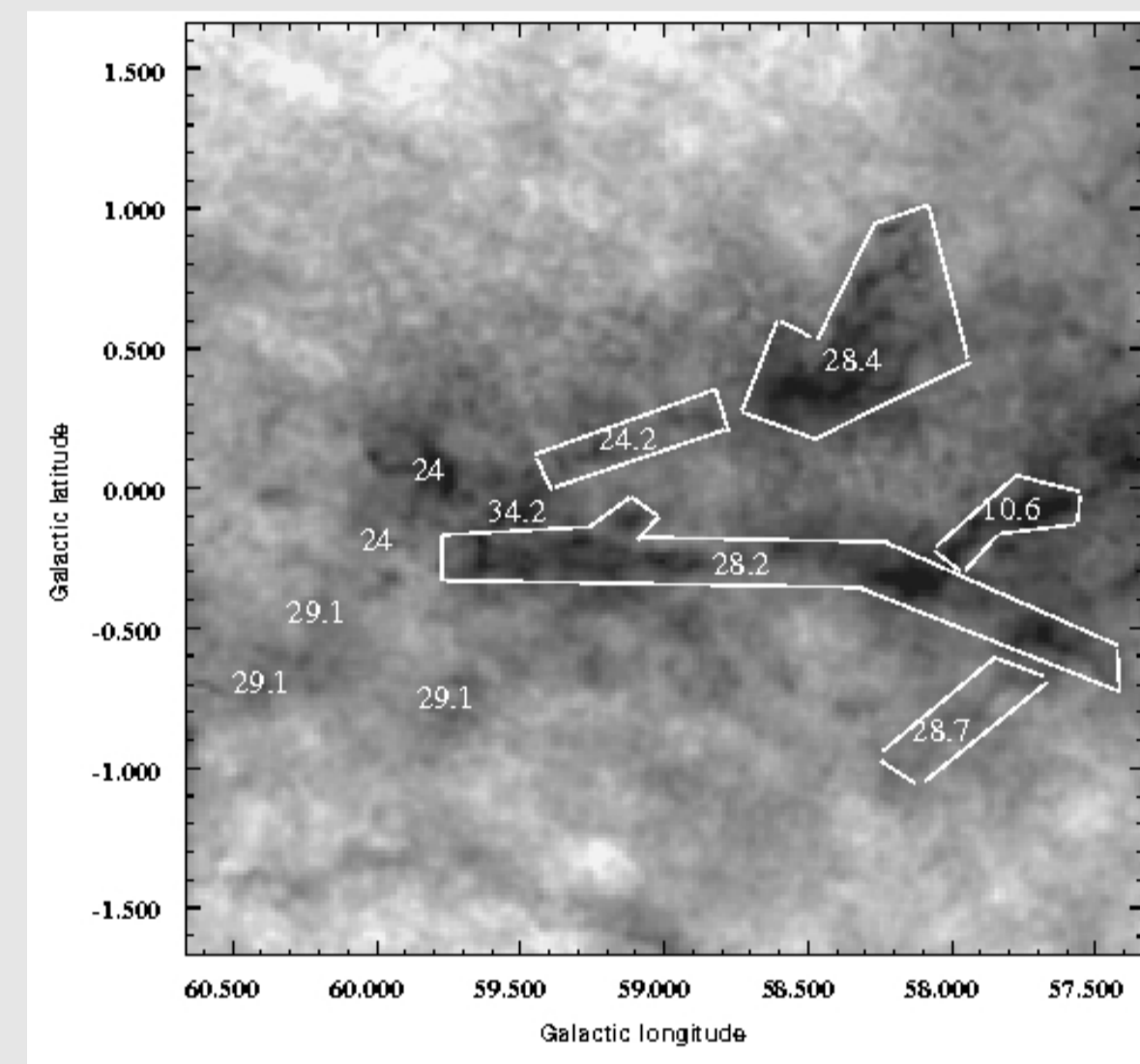


Star-forming complexes

- => Giant Molecular Clouds (e.g. Dame et al. 1986)
- + HII regions + molecular clouds (e.g. Roman-Duval et al. 2009)

Extinction map
2 MASS + Besançon model
(Schneider et al. 2010)

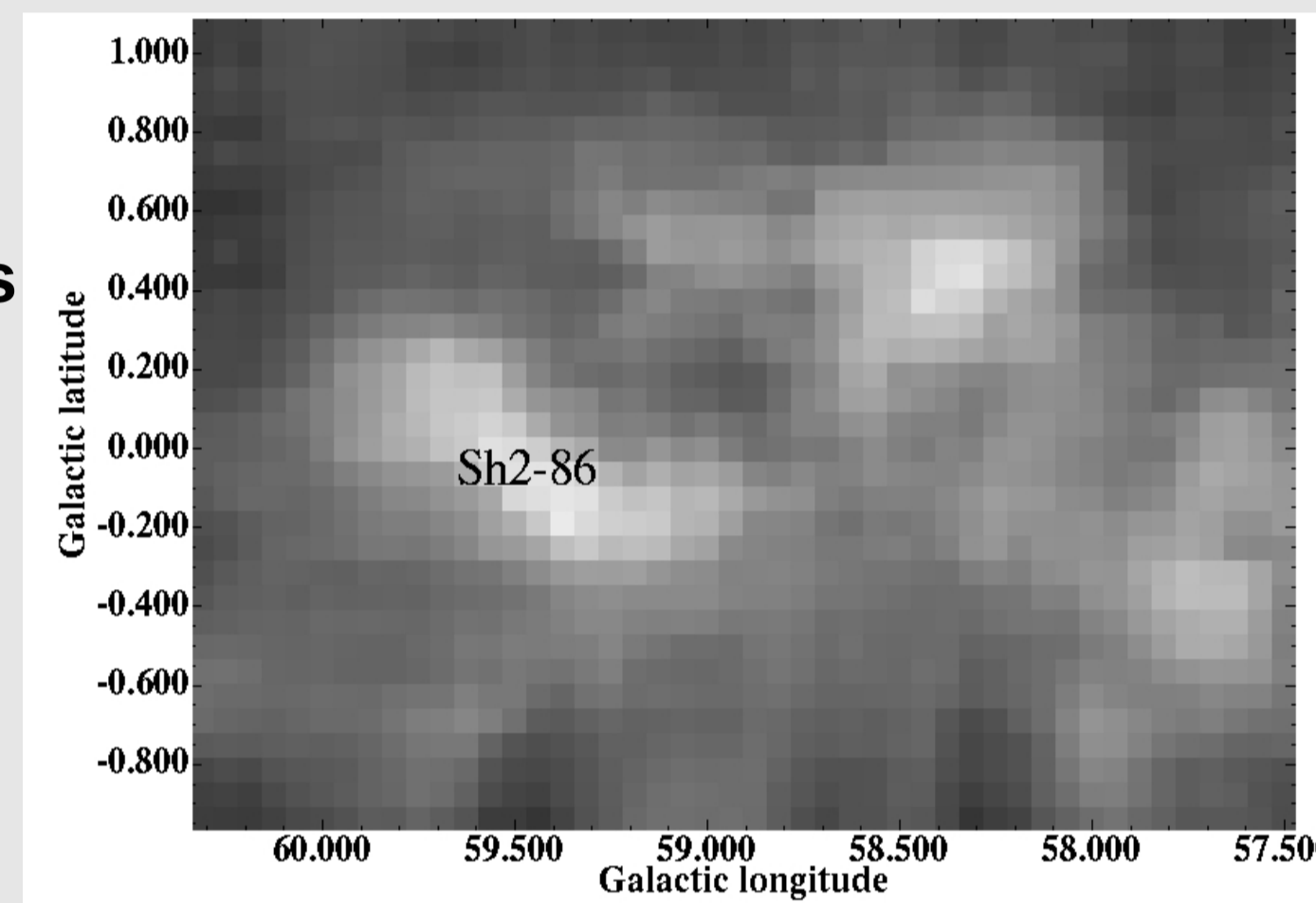
Comparison with ^{13}CO datacube
=> Velocity of the extinction features



The values are velocity at the positions of the numbers or in the delimited areas. Extinction range: ~ 2 (white pixels) to > 15 mag (black pixels)

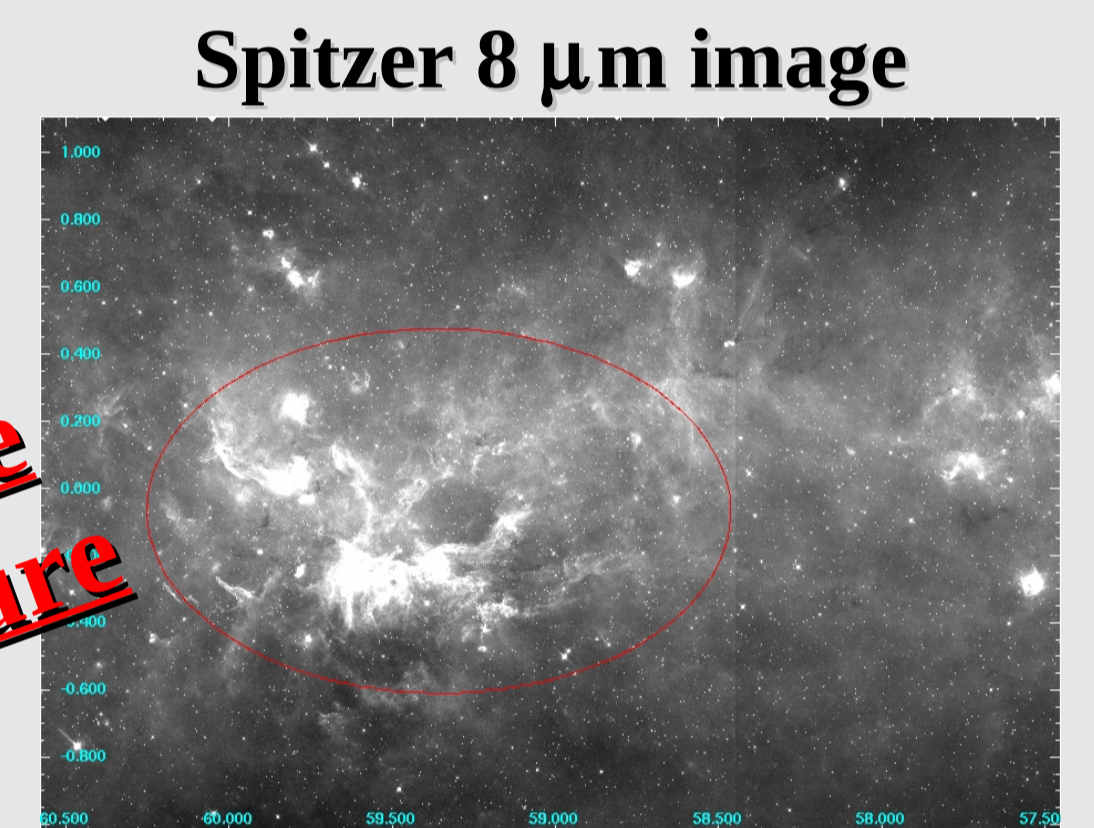
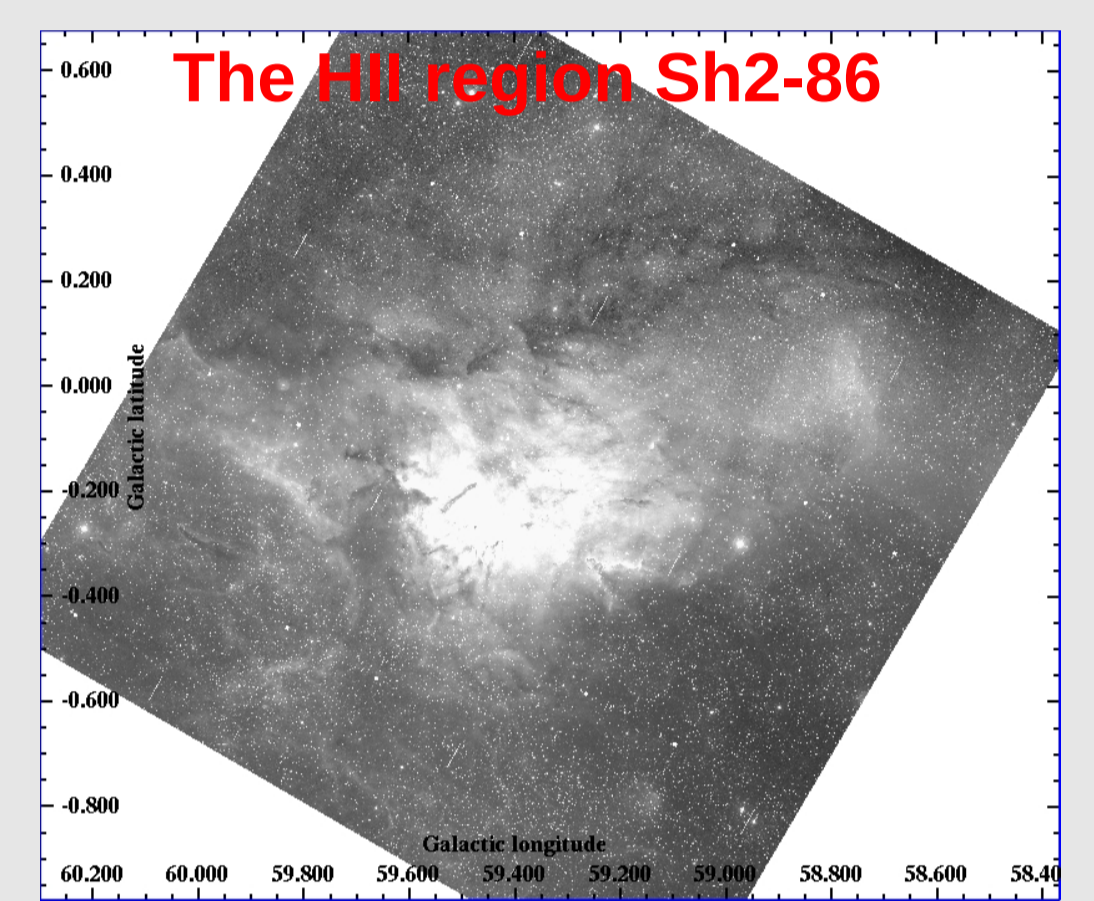
EXTINCTION

Extinction versus distance
2 MASS + Glimpse + Besançon model
(Marshall et al. 2009)



Extinction map (A_V) for distances between 1.7 and 2.2 kpc. The extinction feature corresponding to the HII region Sh2-86 is identified. Extinction range: -0.4 (black pixels) to -1.9 mag (white pixels)

H α - IPHAS image



The red ellipse shows the extension of the H α emission of Sh2-86.

NEAR distance favoured IF source associated with an extinction feature

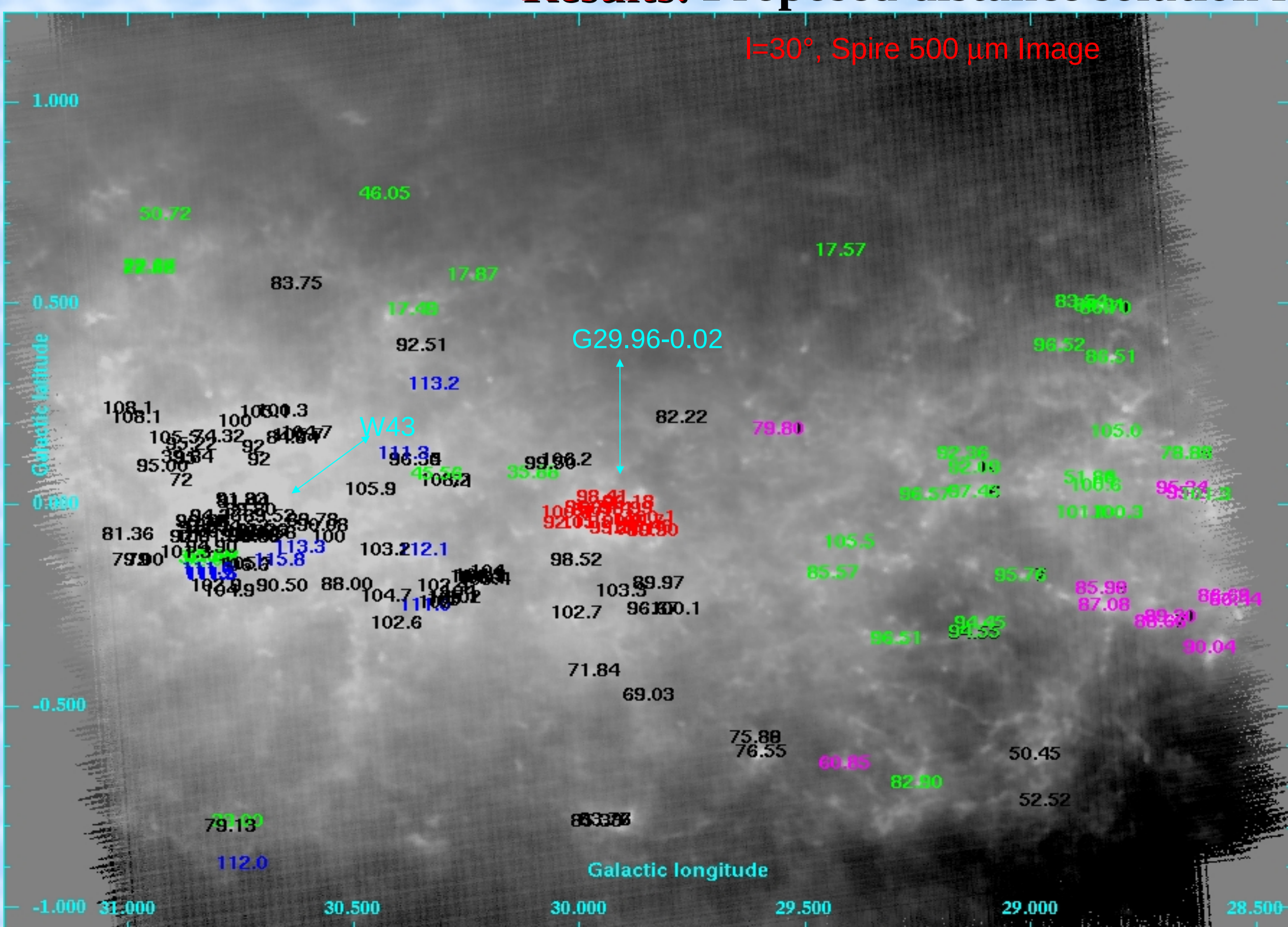
Stellar or maser parallax distance favoured w.r.t. Kinematic distance

Table A.2. Star-forming complexes in the $l=59^\circ$ field.

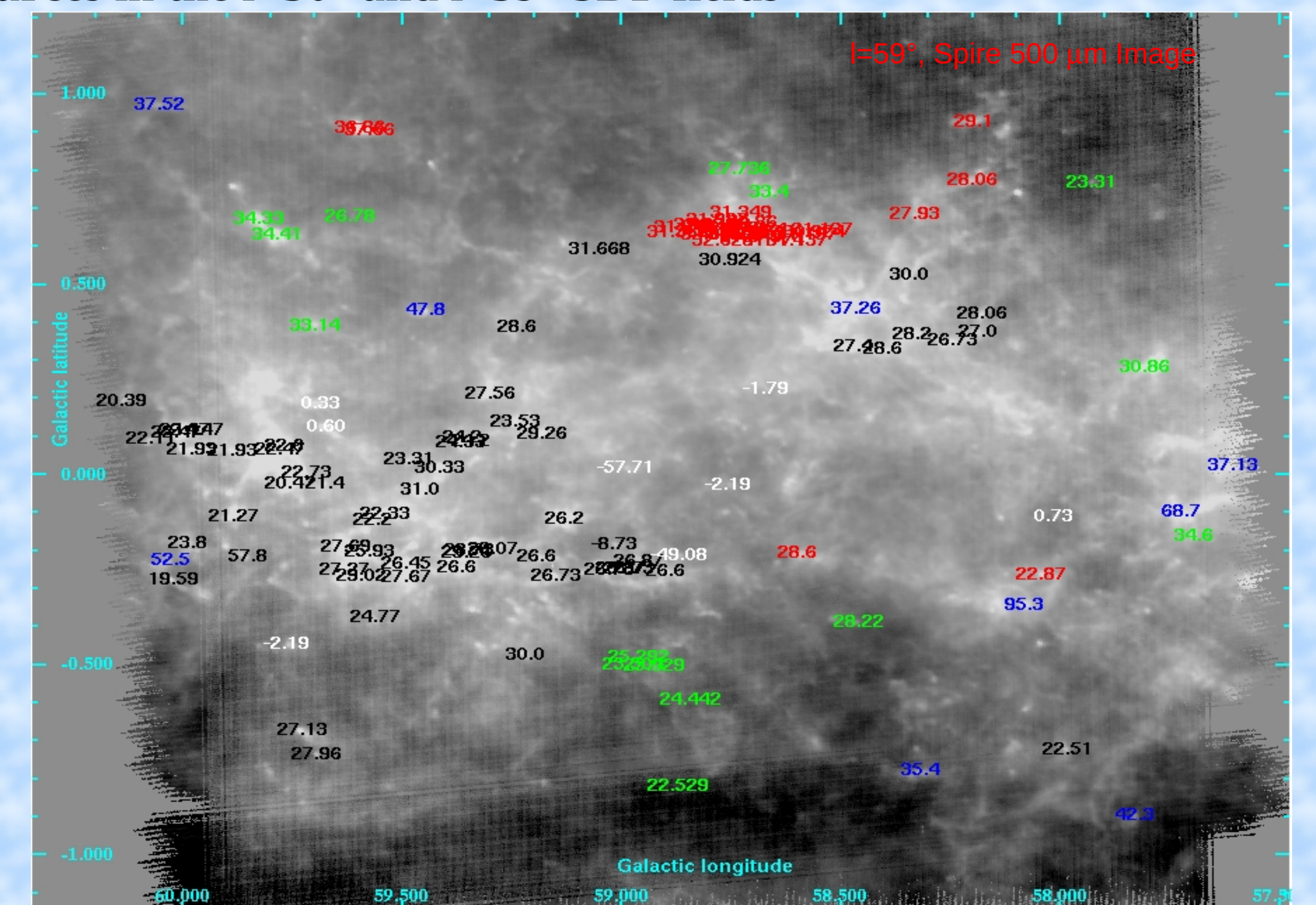
Complex number	Dist. (kpc)	optical HII reg.	source ident.	$V_{\text{H}\alpha}$ km s $^{-1}$	$V_{\text{rad,tan,comb}}$ km s $^{-1}$	$V_{\text{Molecular}}$ km s $^{-1}$	V_{Abs} km s $^{-1}$	Near/far
1			57.541-0.276		2.8	8.8		
0.5 (8.7)	4.6		Bx N 56.8+0.0(0.63,4.8)					F ^{a,c}
Far			Wat57.55-0.27		6.3		2/10.4/31.1	F ^c
2			59.796+0.237		-6.0; -2.8	-7.	42.	
3			Bx W 57.2+0.0(0.61,8.2)					
3			Wat58.77+0.65		30.01		32.5	
4			Wat59.60+0.92		46.4		37.3	
4		Sh2-86	59.529-0.181	26.4; 27.9	29.4	26.8		F ^c
2.3/6.2/4.2		Sh2-87	60.888-0.127	17.9	18.6	22.7		
		Sh2-88	61.470+0.90	19.3; 19.8	27.3	22.9	22/6	T ^a
		Sh2-89	62.941+0.084	12.7	19.2	25.6		
		Sh2-90	63.176+0.460	22.5; 18.0	15.3; 19.4	22.2		
		Bx O 60.0+0.0(0.31,9)				24.5		
		Sol245 59.30-0.20				28		N ^b
		Sol246 60.00+0.10				22		F ^b
		Sol247 60.90-0.10				23		F ^b
		Sol248 61.50+0.10				22		F ^b
		Sol249 63.10+0.40				20		F ^b
		Wat59.36-0.21			26.6		29	
		Mas59.78+0.06				27		

Column 9 references: a) Watson et al. (2003); b) Solomon et al. (1987); c) Kuchar & Bania (1994).

Results: Proposed distance solution for the 709 Hi-GAL sources in the $l=30^\circ$ and $l=59^\circ$ SDP fields



Velocity of the Hi-GAL sources. The colors correspond to: Black: probable association with W43 for sources around 94 km/s (~ 5.8 kpc) and association with Sh2-65 for sources around 51 km/s (3.3 kpc), Blue: tangent distance (~ 7.4 kpc), Green: far or tangent distance (e.g. ~ 12.4 kpc for sources ~ 20 km/s, ~ 7.5 kpc for sources ~ 95 km/s), Magenta: Near distance (~ 5.3 kpc) and Red: probable association with G29.96-0.02 (near distance, ~ 6.2 kpc).



Velocity of the Hi-GAL sources. The colors correspond to: Black: sources probably associated with Sh2-86 (2.1 kpc), Red: near distance (~ 3 kpc) but not associated with Sh2-86, White: objects with negative velocity (no distance ambiguity, ~ 13.5 kpc) or velocity close to 0 km/s (far distance favoured, ~ 9.5 kpc), Blue: objects with forbidden velocity; tangent distance adopted (~ 4.3 kpc), and Green: far distance (~ 6 kpc).