

Water masers in W51A observed with the VLBI Exploration of Radio Astrometry (VERA)

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Summary

We report preliminary results of our multi-epoch observations of water masers in W51A made during 2003 March--2005 May with the VERA. VERA is dedicated for phase-referencing VLBI with dual receiving system to perform 10 microarcseconds-level astrometry for the Galactic water and silicon-monoxide maser sources. With short time separations (1--4 months) of observations during the above period as well as automation of wide-field mapping and proper-motion identifications, internal motions of the clusters of maser features (W51 Main, North, South and West) have been elucidated more clearly than those previously observed (Genzel et al. 1981; Schneps et al. 1981; Imai et al. 2002). Then we found new bipolar outflow traced by water masers in W51 South (e8) and West (possibly W51 Main e2 as well). Some of the observations enable us to perform astrometric analyses that are possible with VERA's dual receiving system to simultaneously observe the masers with the position reference J1924+1540 or J1922+1530. These enable us to compare the coordinates of water masers and their dynamical center with those of methanol maser sources and radio continuum sources (ultracompact (UC) HII regions or blobs of non-thermal jets), and to make diagnostics for evolutionary status of the outflows and their driving massive young stellar objects (MYSOs). Improvement of the fringe-phase tracking in data correlation will lead us to estimate a distance to W51A with trigonometric parallaxes of the water maser features.

* We assume a distance to W51A to be 6 kpc (Imai et al. 2002).
* Multi-epoch maps were aligned by determining a "stationary reference point" (Torrelles et al. 2001) from one pair of maps with a short epoch separation to another.

The map origin for W51 North and West is located at
J2000: $19^{\text{h}}23^{\text{m}}40^{\text{s}}.0886, +14^{\circ}31'04.620''$.

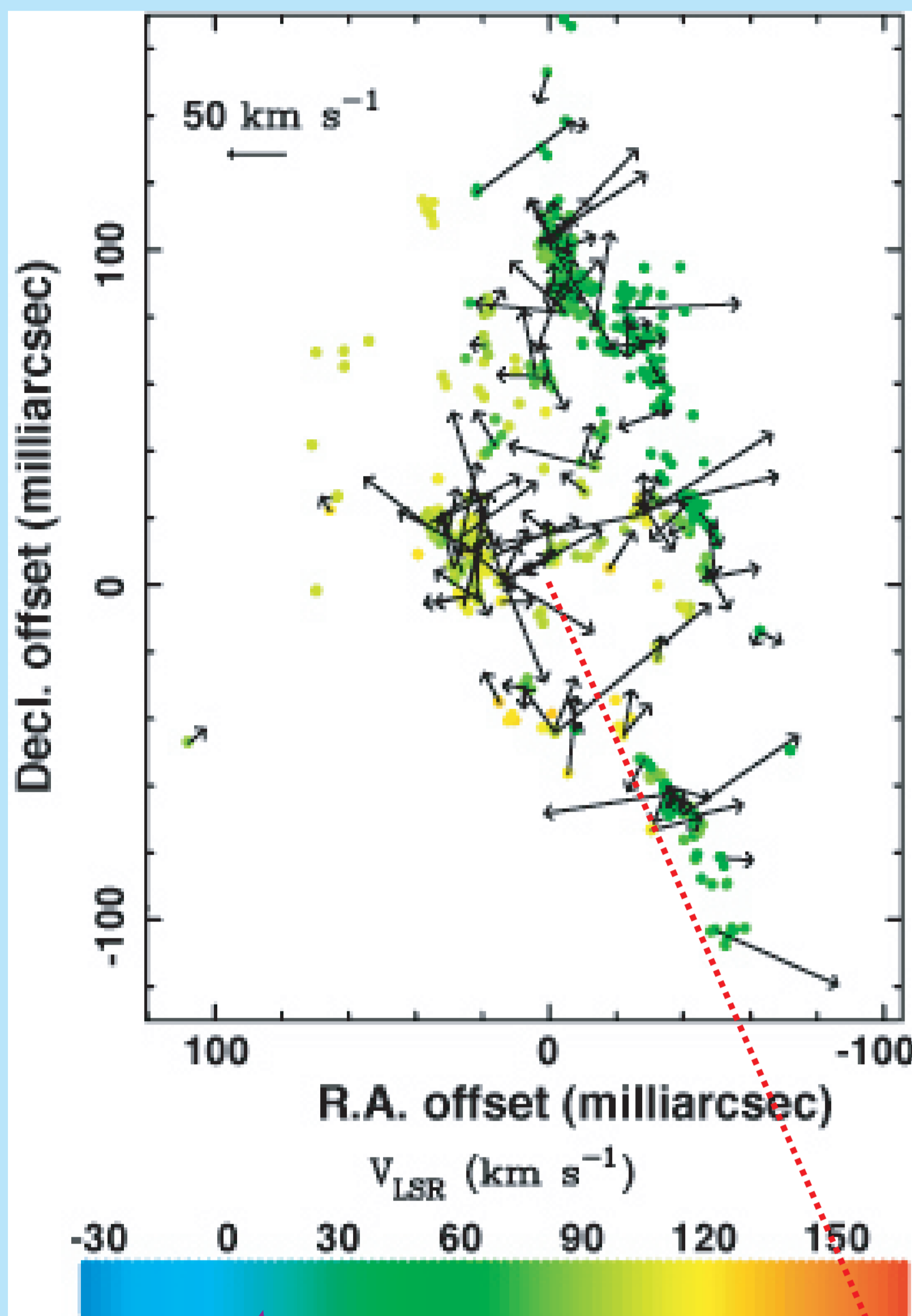


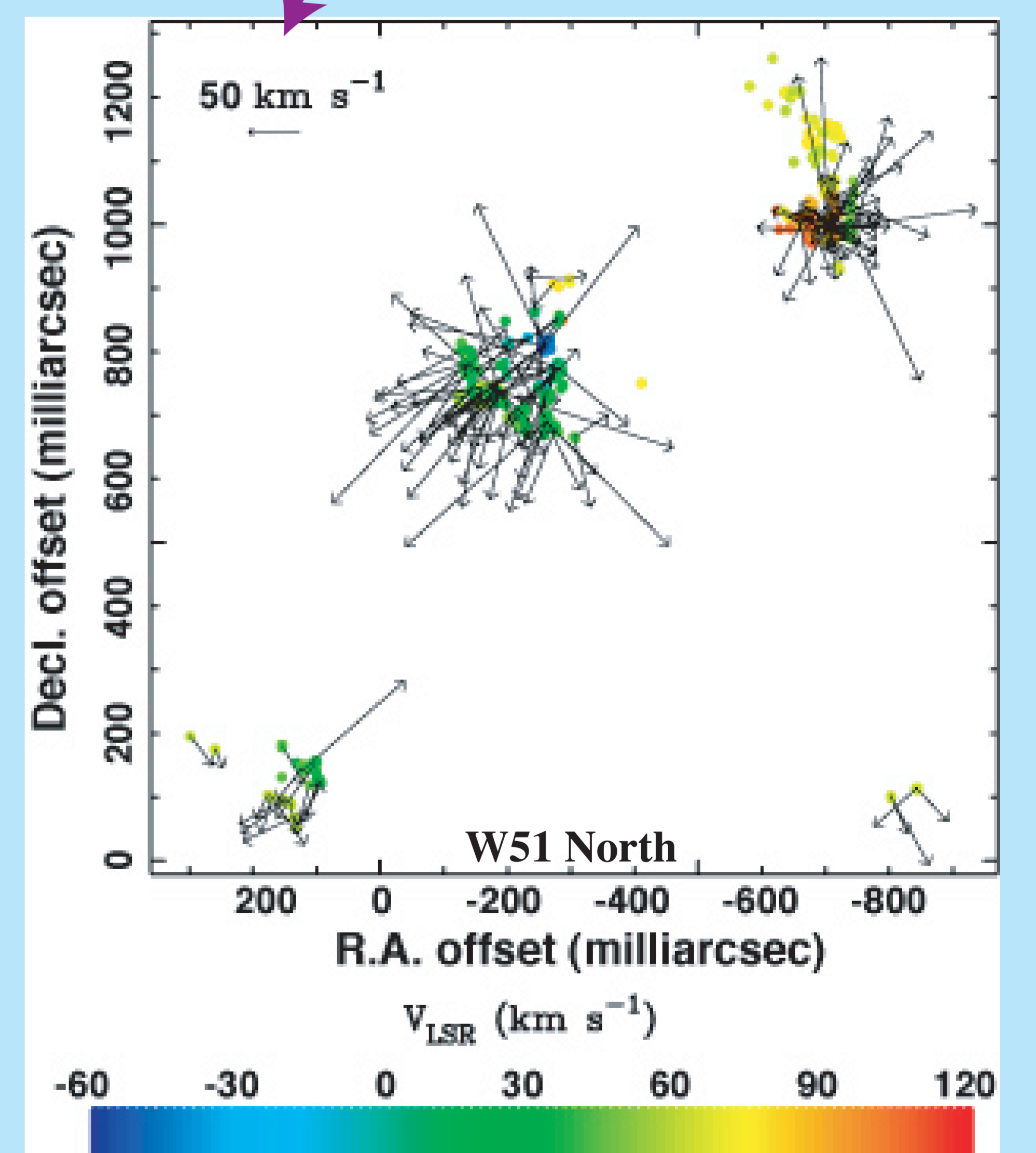
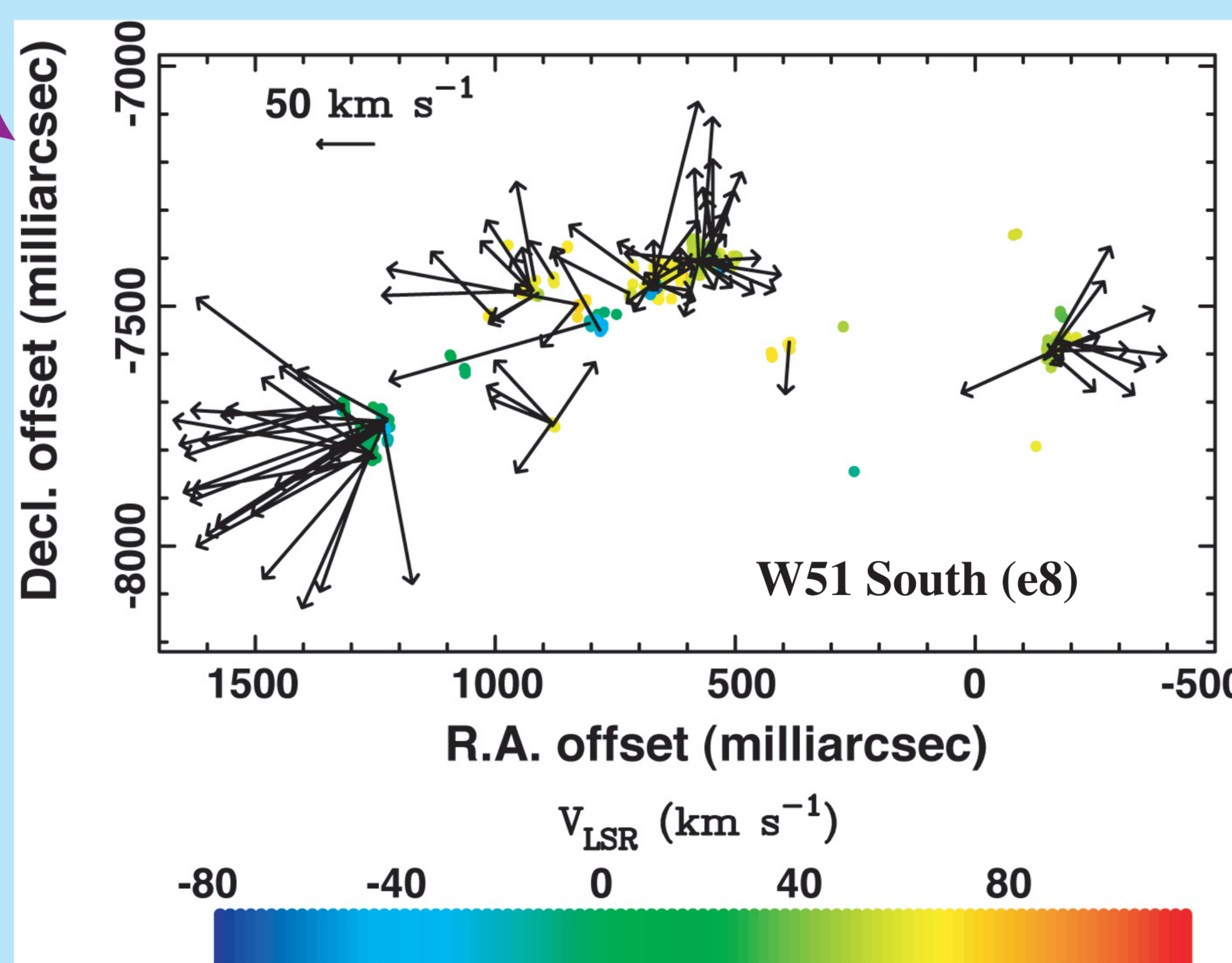
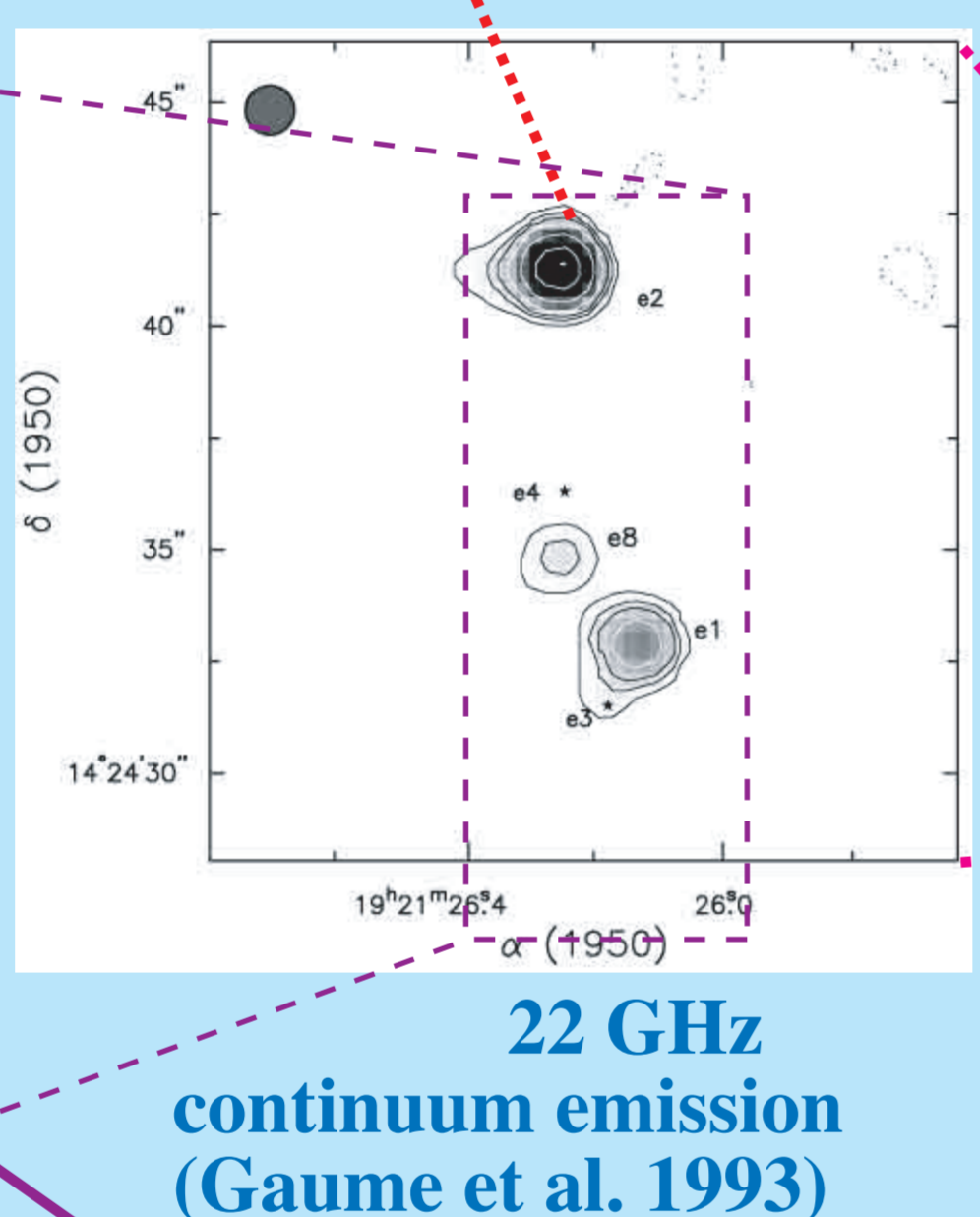
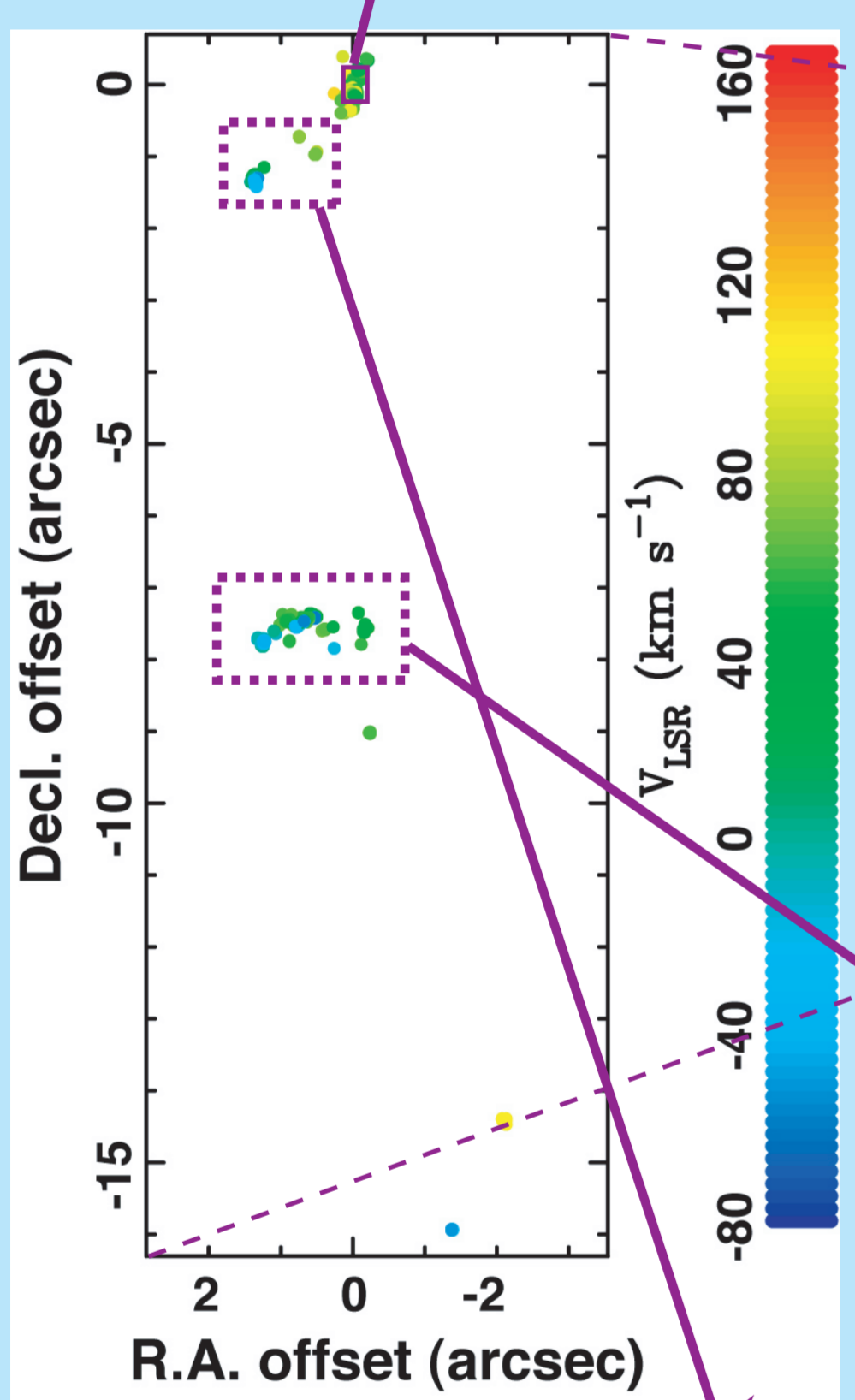
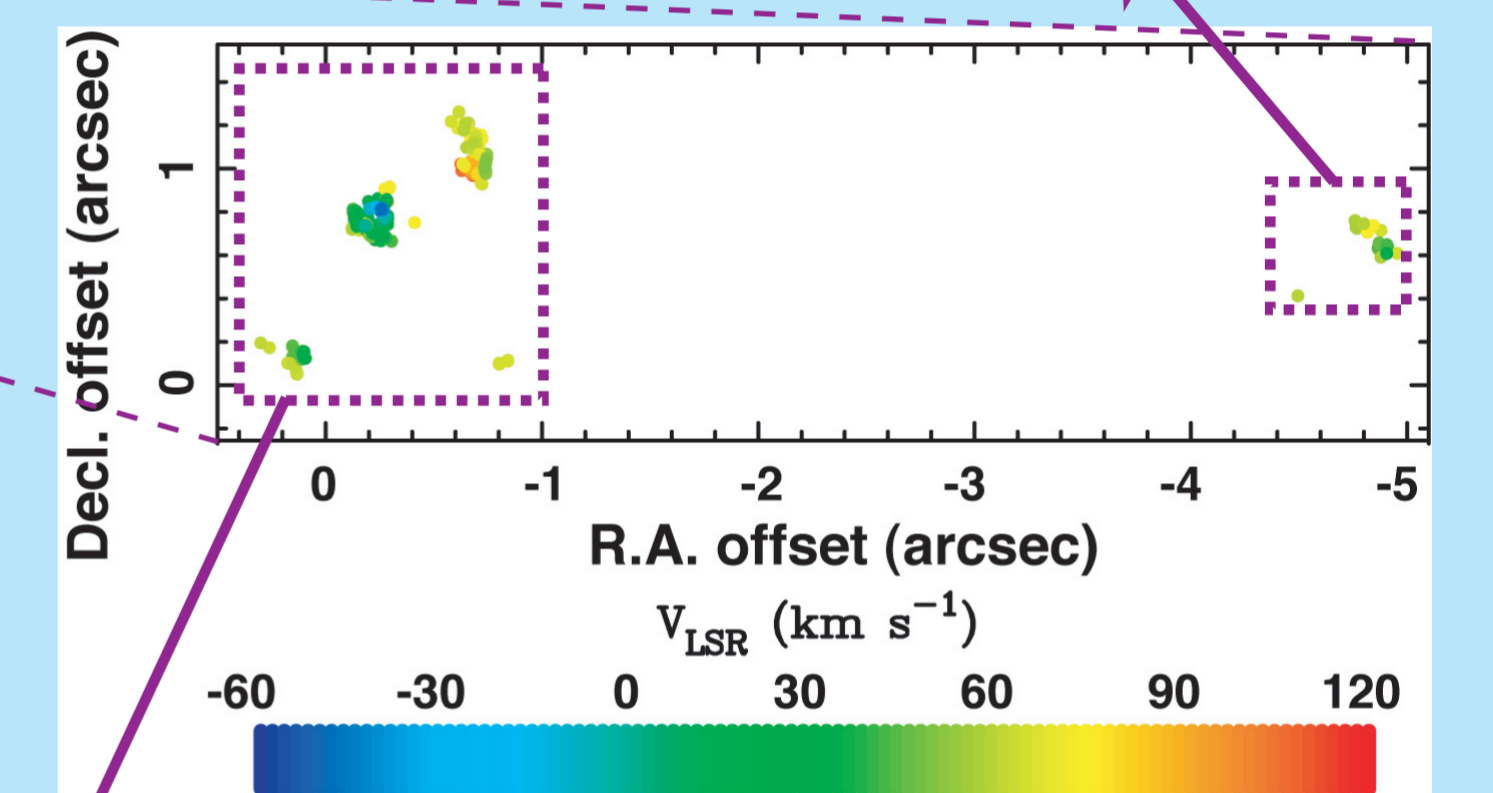
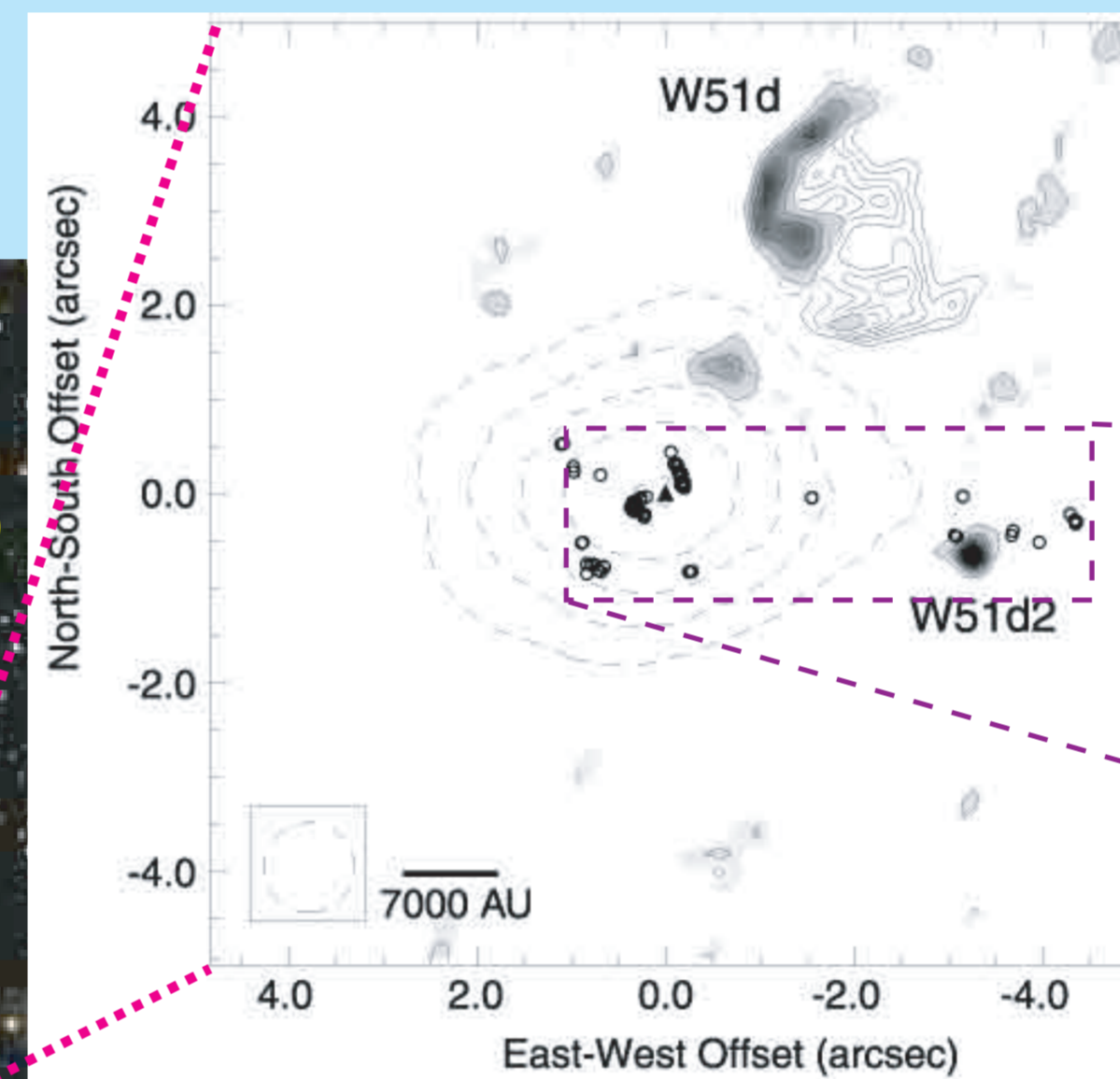
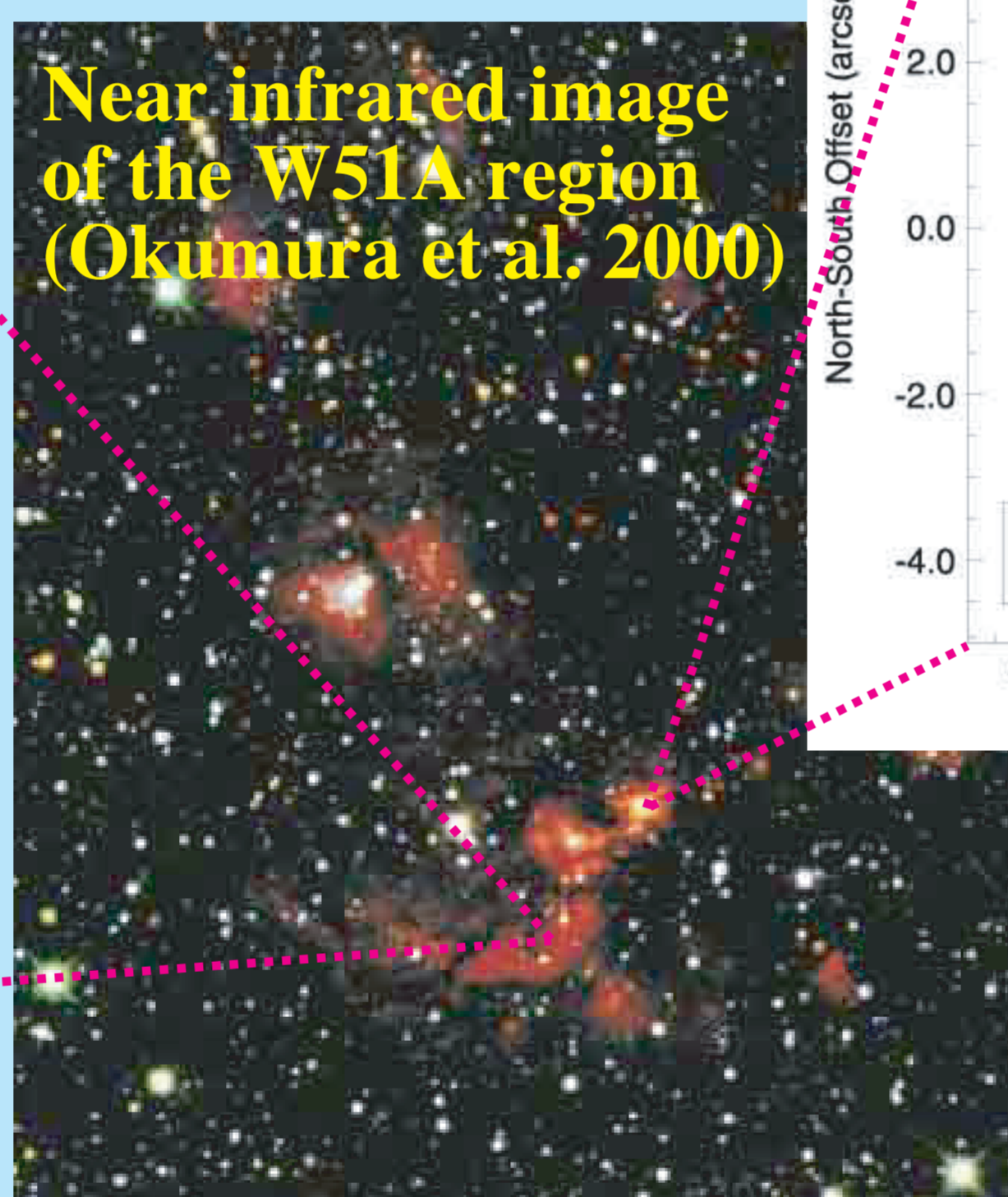
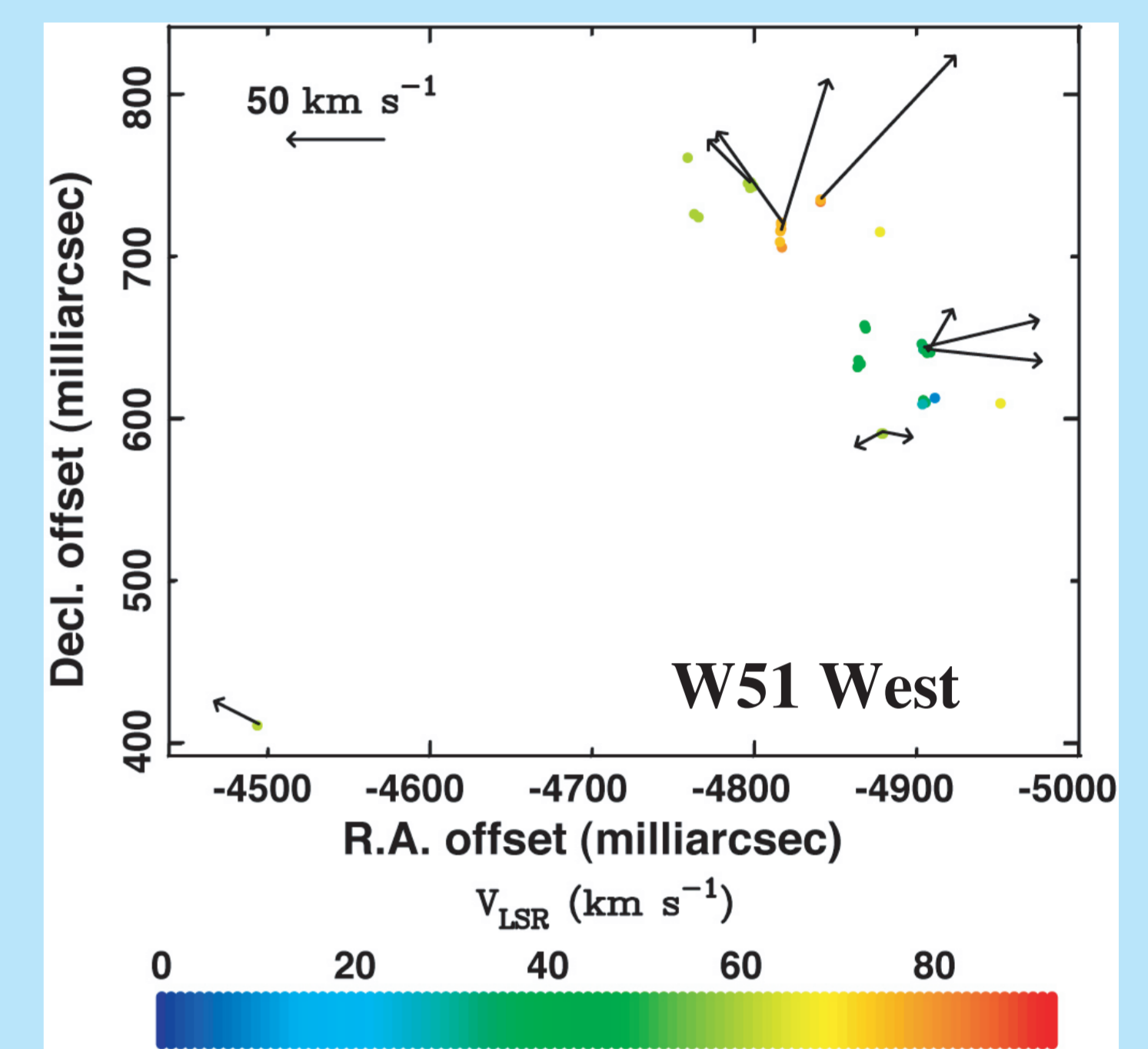
Table: Status of VERA observations toward W51A

Observation code	Recording system	Participating telescopes				Correlation tracking center		Map of water masers		VERA astrometry
		Mizusawa	Iriki	Ogasawara	Ishigaki	W51M	W51N	W51M&S	W51N&W	
r03076a	DIR1000	o	o	o	Δ	X	X	X	X	X
r03233a	DIR1000	o	o	o	o	o	X	o	X	X
r03295a	DIR2000	o	o	o	o	o	X	X	X	X
r03280a	DIR1000	o	o	o	Δ	o	o	o	o	X
r03295a	DIR2000	o	o	X	o	o	X	X	X	X
r03354a	DIR2000	o	o	o	o	X	X	X	X	X
r04063a	DIR2000	o	o	o	o	Not yet	Not yet	Not yet	Not yet	Not yet
r04118b	DIR2000	o	o	o	o	Not yet	Not yet	Not yet	Not yet	Not yet
r04148b	DIR2000	Δ	o	o	o	o	X	Not yet	X	Trial
r04202a	DIR1000	Δ	o	o	Δ	o	o	o	o	X
r04271a	DIR1000	o	o	o	o	o	o	o	o	Trial
r04298a	DIR1000	o	o	o	X	o	o	o	o	Trial
r04325a	DIR1000	o	o	o	o	o	o	o	o	Trial
r05041b	DIR2000	o	o	o	o	o	o	Not yet	Not yet	Not yet
r050132b	DIR2000	o	o	o	o	Not yet	Not yet	Not yet	Not yet	Not yet

Code: r[YY][DOY][x], where YY is final two digit number of the observation year, DOY the day of the year, x sublabel for observations made in the same day.
DIR1000: 128Mbps recorder, DIR2000: 1024Mbps recorder
o: Available, Δ: partially available, X: Inavailable

Preliminary astrometry of the map origin for W51 Main/South with VERA (2003--2004)
J2000: $19^{\text{h}}23^{\text{m}}43^{\text{s}}.8886 \pm 0^{\text{s}}.0003$
 $+14^{\circ}30'35.820'' \pm 0.008''$
(B1950: $19^{\text{h}}21^{\text{m}}26^{\text{s}}.23, +14^{\circ}24'42.4''$)

22 GHz continuum emission (grey scale), ammonia emission (dashed contour), water masers (open circle) and silicon-monoxide (filled triangle) masers (Figure from Eisner et al. 2002)



Comments on individual water maser sources

W51 Main: New astrometry with VERA locates the water masers $\sim 1.2''$ south from those at which previous observations (Forster et al. 1978) did. There exists another possible flow collimated in NE--SW direction or an expanding shell in the southern region ($Y < -40$ mas) as well as that found by Leppanen et al. (1998) in the northern region ($Y > 50$ mas).

W51 Main (e2): A blue-shifted group of water masers is located close to the UCHII region W51 e2 and methanol masers. One outflow is newly but marginally found in NW--SE direction, which is perpendicular to alignment of methanol masers (Phillips and van Langevelde. 2005), but the existence of a physical link between these sorts of maser emission is still unclear.

W51 South (e8): A bipolar outflow is found more clearly than that found by Imai et al. (2002). A dynamical center of the outflow is located closer to the center of an ammonia emission core (Zhang and Ho 1997) than to the UCHII region W51 e4. Another cluster of water masers is located $\sim 8''$ south from this cluster, but where few water maser features were detected.

W51 North: We believe in only one driving source of an outflow in this region even if there are three major clusters of water masers (Imai et al. 2002). In fact, the dynamical center of the flow is located at silicon-monoxide maser source and ammonia emission core (Eisner et al. 2002). However, fast random motions (> 100 km/s) are also found. Doubtful proper motions in crowded regions should be omitted by adding more epochs of observation to identify maser proper motions more reliably.

W51 West: One bipolar outflow is newly discovered in the spatio-kinematics of the water masers. The proper motions have a bias in NW direction, which may be oriented by a systemic bulk motion of the outflow with respect to the cluster in W51 Main by $(V_X, V_Y) = (-14, 25)$ [km s $^{-1}$]. The outflow is aligned in NE--SW direction. Methanol masers are located $\sim 1''$ (6000 AU) east from the water masers (Phillips and van Langevelde 2005) but they may not physically linked with the water masers.

Coexistence of multiple driving sources of water maser clusters: Within $\sim 70''$ (~ 2.1 pc @ 6 kpc), where a single giant molecular cloud may exist (56 km s $^{-1}$ could, Okumura et al. 2001), there are at least 5--6 MYSOs exhibiting outflows traced by water masers. These MYSOs were likely to born simultaneously within an expected duration of water maser emission ($< 10^5$ years, e.g. Genzel and Downes 1977). Some water maser sources exhibit a spatio-kinematics indicating a bipolar outflow and may be associated with UCHII regions or methanol maser sources, while others are not (e.g. W51 Main). These support a hypothesis proposed by Torrelles et al. (2003) that spatio-kinematics of water masers trace evolutionary status of the maser sources rather than difference in ambient physical conditions around the sources.