Expansion of methanol maser rings

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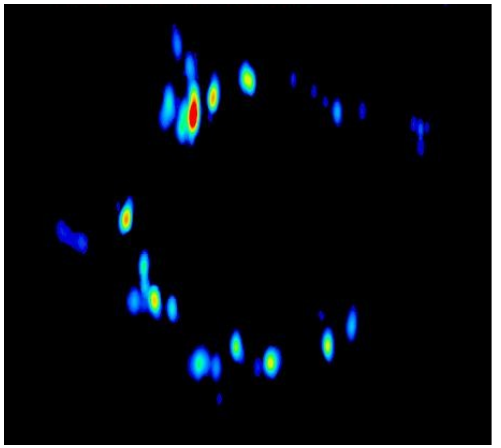
G23.657-0.127



Introduction

- **“Long, long time ago...”**

  In 2003 we started the EVN project to image the 6.7 GHz methanol masers discovered using the 32 m Toruń antenna (Szymczak et al. 2000, 2002). In general, targets were relatively weak: F_{peak} from 1 to 23 Jy.

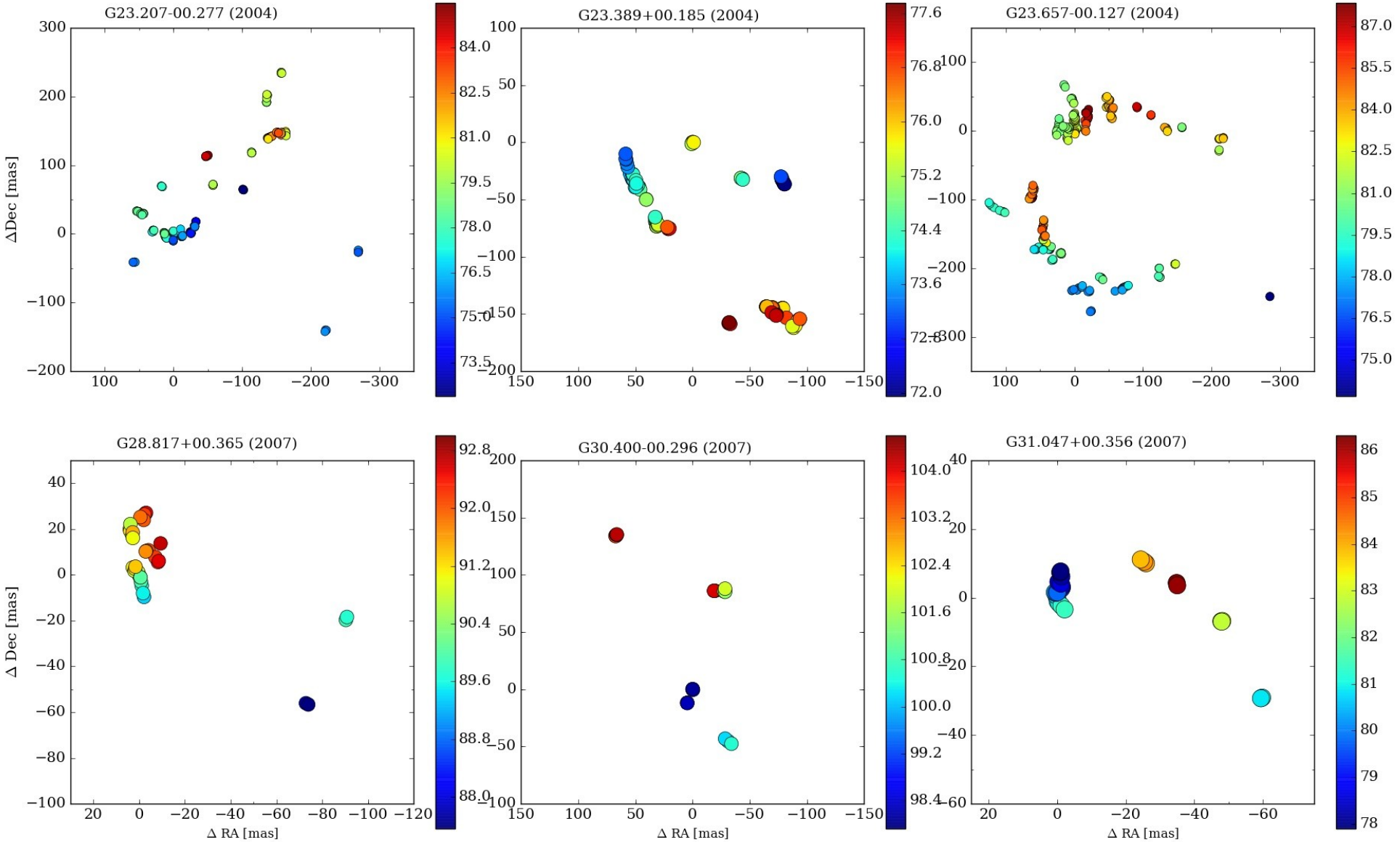
- **In the second run, November 2004, we used eight EVN antennas and obtained high-quality images of six sources. Two of them revealed the ring-like morphology (Bartkiewicz et al. 2005, 2009).**

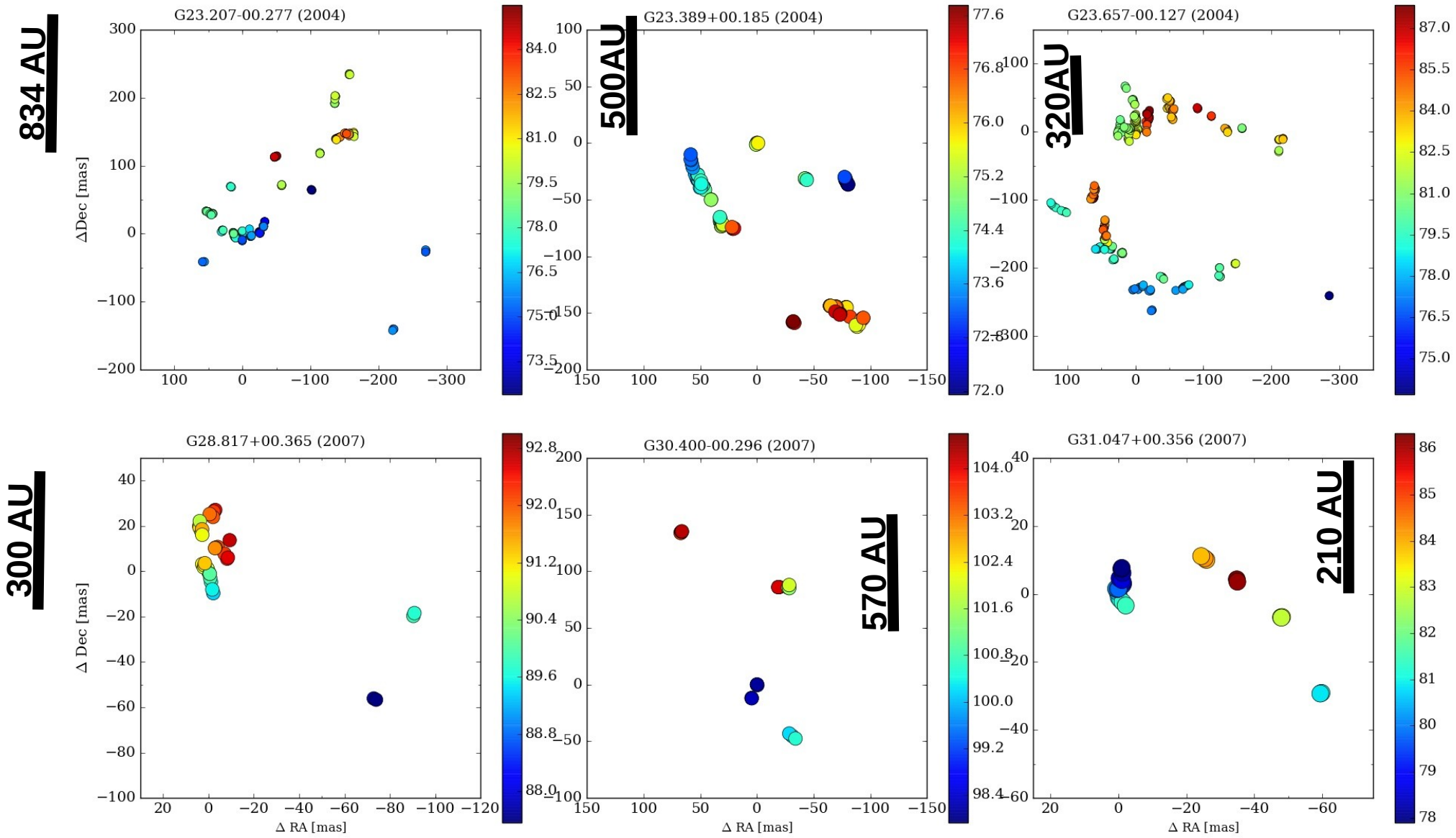
- **In the whole sample of 63 sources (EVN observations made in the period from 2003 to 2010) we detected 11 methanol rings (18%) with a few cases of arcs. (P.51 by Sarniak – mas structures)**

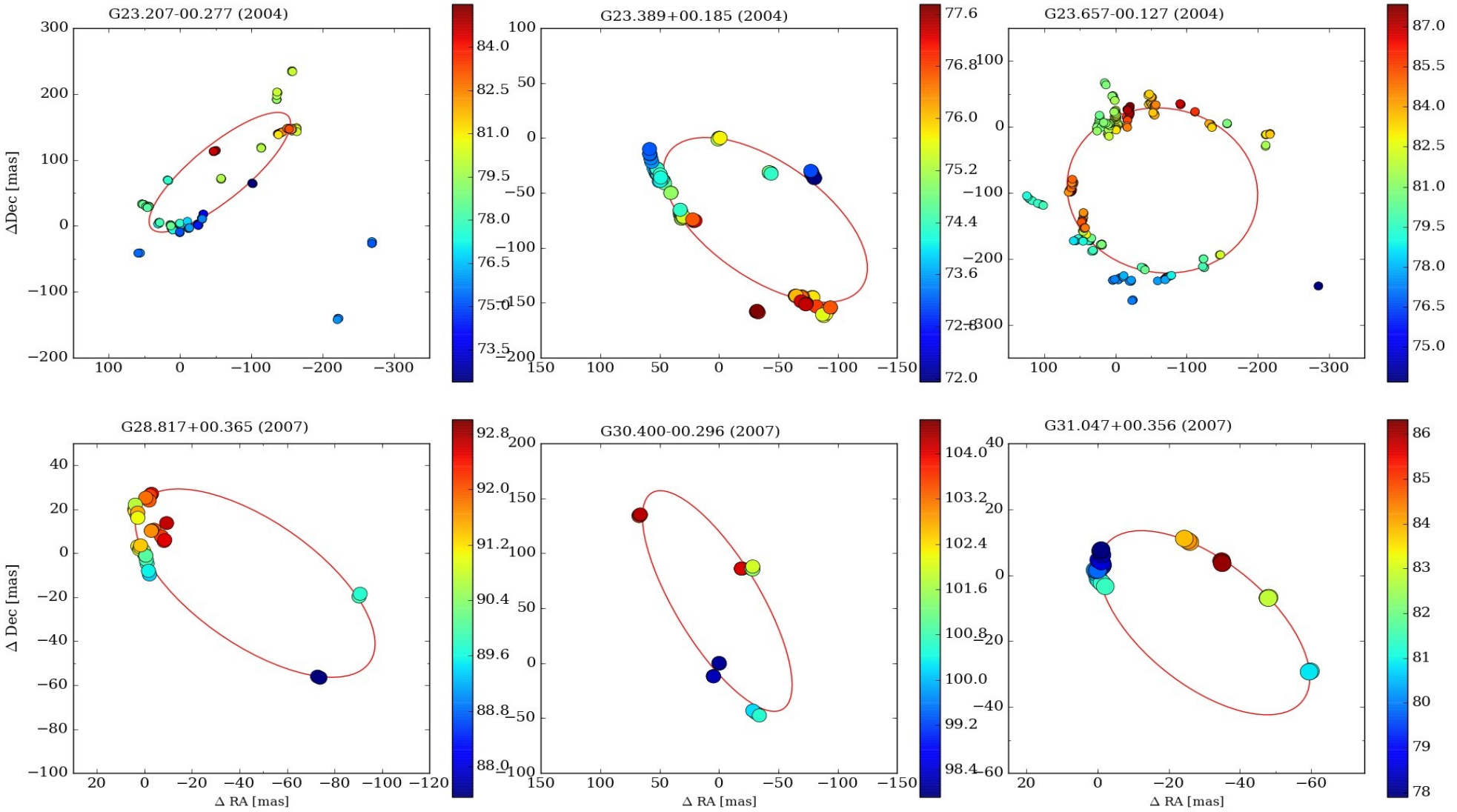
What are these rings?

- **In general, rings do not coincide with the 22 GHz water masers, do not show H II regions at the cm range (VLA data, Bartkiewicz et al. 2009, 2011).**
- **Towards four rings we obtained the NIR and MIR images with high angular resolution (De Buizer et al. 2012a). As stated during the last IAU maser symposium in 2012: "*The infrared emission does not seem to support the scenario where methanol maser rings trace circumstellar disks around young massive stars.*" (De Buizer et al. 2012b)**

  Therefore, we started the most direct studies to answer the above question: the proper motion studies. After ~8 years we have repeated the observations with the same network, observations were done in 2013. Assuming a rotating or an expanding motion of 10 km/s, an expected shift of a single maser spot would be 0.6 mas per year.


G23.207-00.277 (2004)
G23.389+00.185 (2004)
G23.657-00.127 (2004)
G28.817+00.365 (2007)
G30.400-00.296 (2007)
G31.047+00.356 (2007)
ΔDec [mas]
Δ Dec [mas]
Δ RA [mas]


834 AU
G23.207-00.277 (2004)
ΔDec [mas]
500AU
G23.389+00.185 (2004)
320AU
G23.657-00.127 (2004)
300 AU
G28.817+00.365 (2007)
Δ Dec [mas]
Δ RA [mas]
570 AU
G30.400-00.296 (2007)
Δ RA [mas]
210 AU
G31.047+00.356 (2007)
Δ RA [mas]


G23.207-00.277 (2004)
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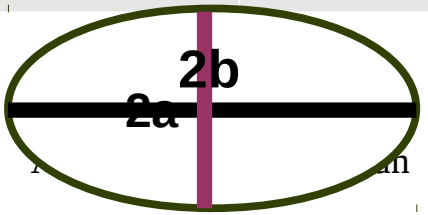
G28.817+00.365 (2007)
G30.400-00.296 (2007)
G31.047+00.356 (2007)
ΔDec [mas]
Δ Dec [mas]
Δ RA [mas]

Proper motion studies - method

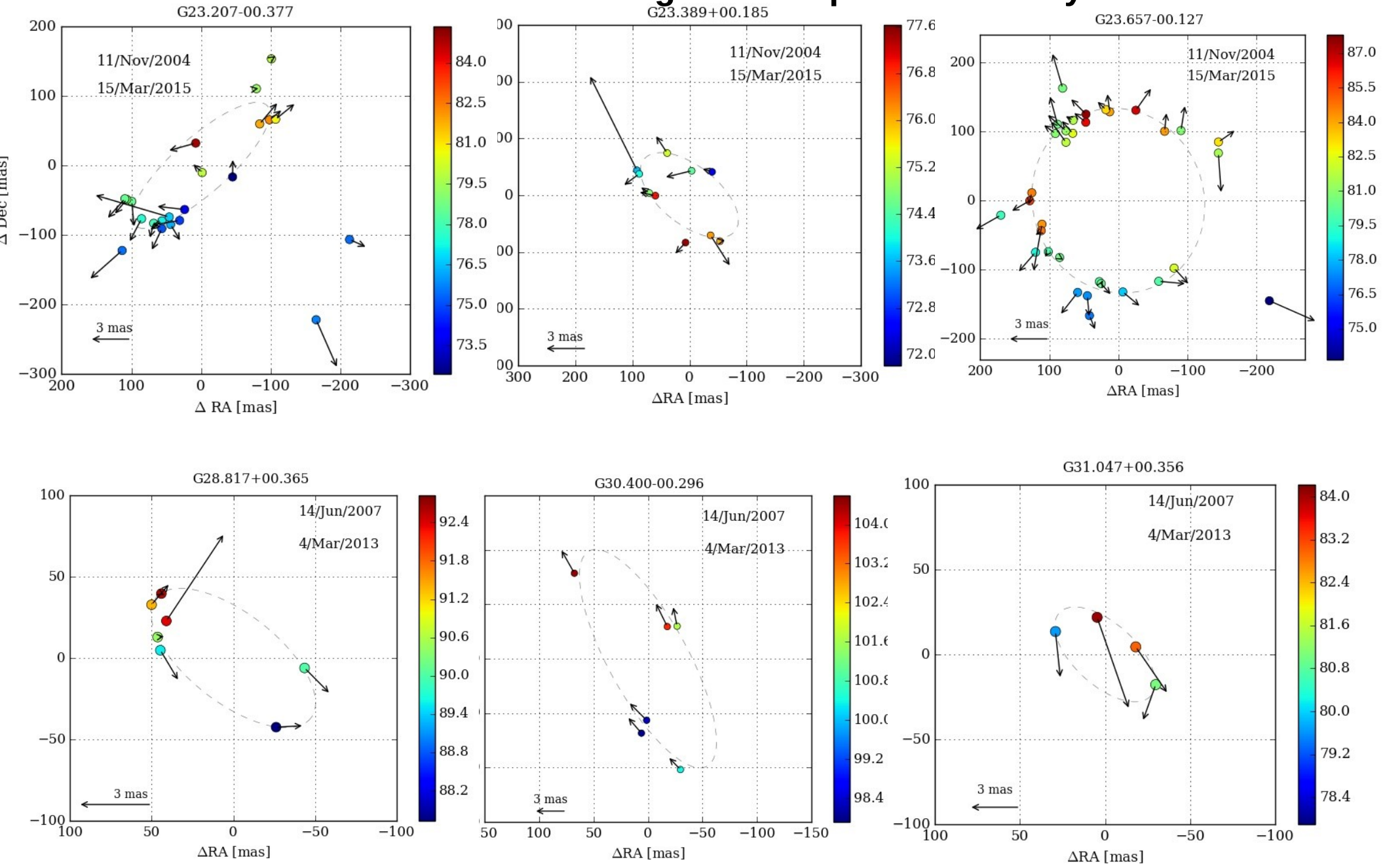
- **Data calibration for both epochs were done in the same way, i.e. phase-referenced to the brightest maser spots in the first epoch.**
- **Measurement of all spots with the same limits, i.e. 5 times the rms on the single channel map.**
- **Selection of spots appearing at both epochs.**
- **Grouping of maser spots into maser clouds (close in space and in the velocity domain) in each epoch.**
- **First approach to obtain the "absolute motions": fitting (flux-weighted) ellipses to the maser cloud distributions and removed the shift between the centres of the best fitted ellipses from both epochs.**
- **Estimation of a motion vector within each cloud.**

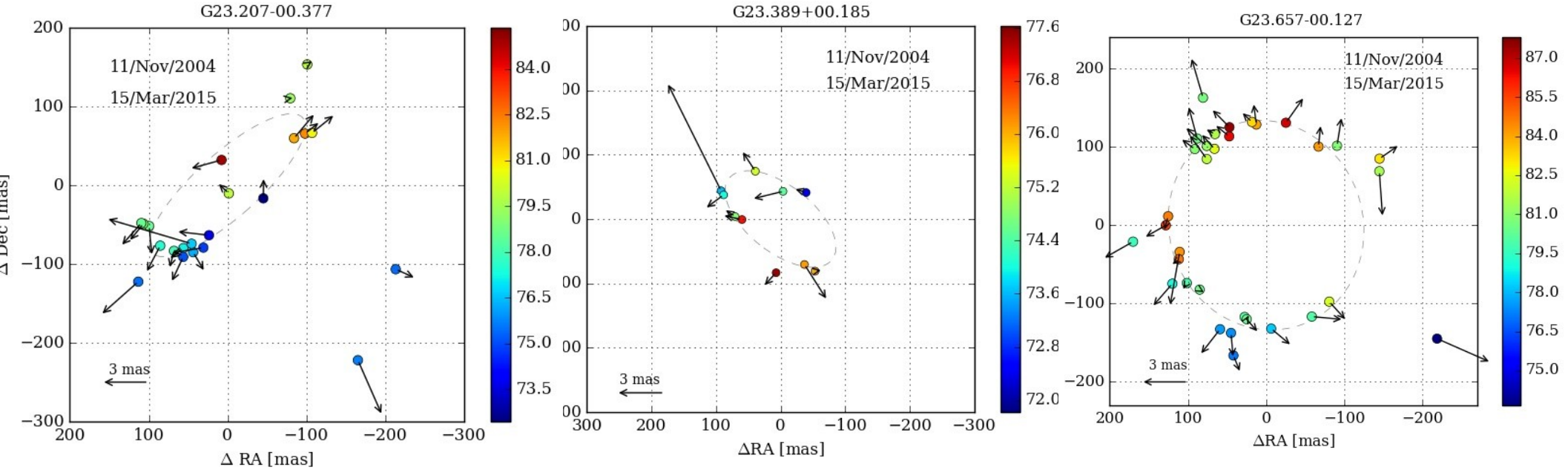
Name epoch	**$a_{\text{first epoch}}$**	**$b_{\text{first epoch}}$**	**$\Delta a_{\text{second epoch}}$**	**$\Delta b_{\text{second epoch}}$**	**Distance [kpc]**
G23.207-0.377 2004 – 2015	128.33	40.07	+1.4 mas	+0.8 mas	4.17 (BeSSeL)
G23.389+0.185 2004 – 2015	101.84	51.41	+3.3 mas	-0.23 mas	5.0 (BeSSeL)
G23.657-0.127 2004 – 2015	134.88	123.94	+1.2 mas	+1.3 mas	3.19 (Bart+09)
G28.817+0.365 2007 – 2013	60.21	27.511	-0.7 mas	+0.15 mas	4.9 (D_{near})
G30.400-0.296 2007 – 2013	112.78	36.40	+0.4 mas	+0.6 mas	5.7 (D_{near})
G31.047+0.356 2007 – 2013	36.38	18.23	-3.0 mas	-2.1 mas	5.2 (BeSSeL)

Name	$a_{\text{first epoch}}$	$b_{\text{first epoch}}$	$\Delta a_{\text{second epoch}}$ V [km/s]	$\Delta b_{\text{second epoch}}$	Distance [kpc]
G23.207-0.377	128.33	40.07	+1.4 mas 2.7 km/s	+0.8 mas	4.17 (BeSSeL)
G23.389+0.185	101.84	51.41	+3.3 mas 7.5 km/s	-0.23 mas	5.0 (BeSSeL)
G23.657-0.127	134.88	123.94	+1.2 mas 1.7 km/s	+1.3 mas	3.19 (Bart+08)
G28.817+0.365	60.21	27.511	-0.7 mas	+0.15 mas	4.9 (D_{near})
G30.400-0.296	112.78	36.40	+0.4 mas	+0.6 mas	5.7 (D_{near})
G31.047+0.356	36.38	18.23	-3.0 mas	-2.1 mas	5.2 (BeSSeL)

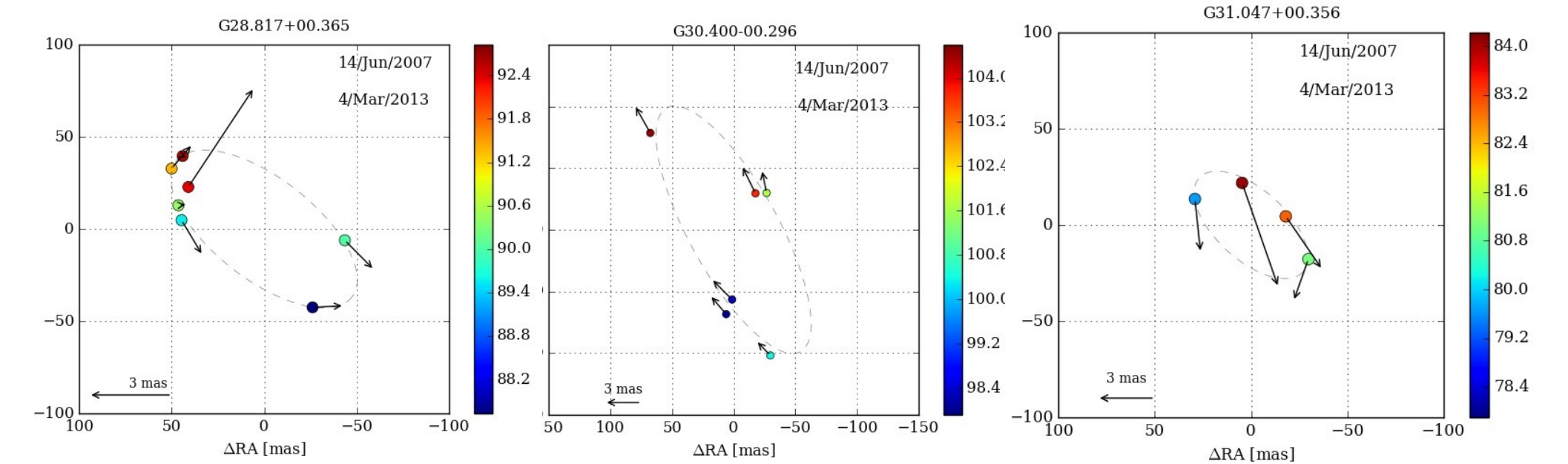


Results: motion vectors after shifting fitted ellipses to overlay their centres:

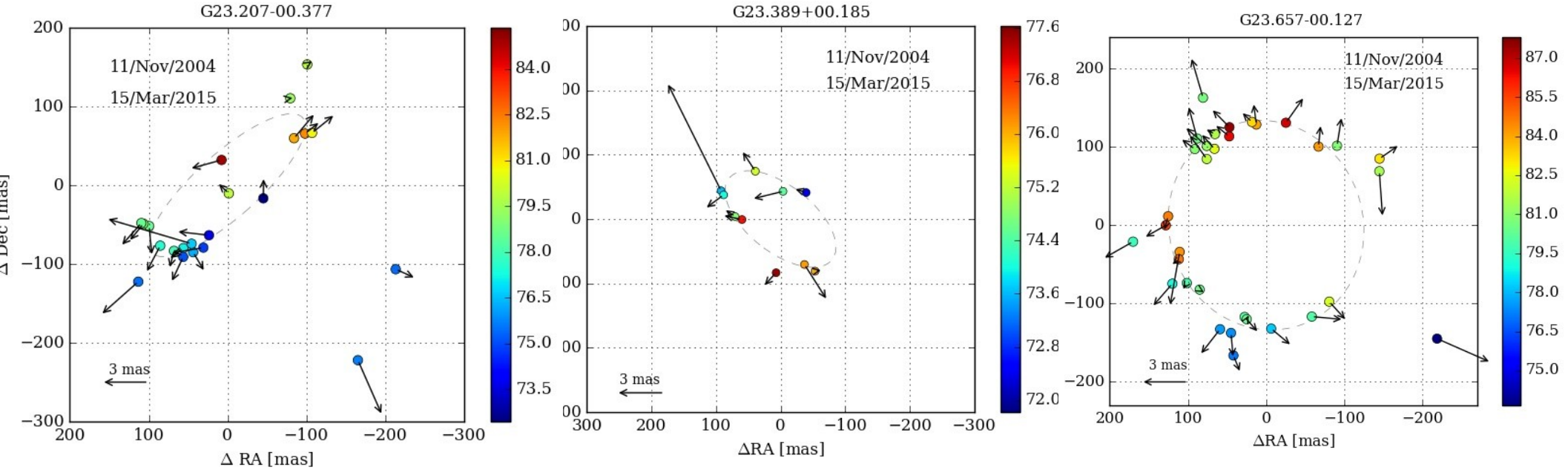




Non-variable 6.7 GHz methanol sources (Szymczak et al. MNRAS submitted).



Periodic variable source (P.44 by Olech)



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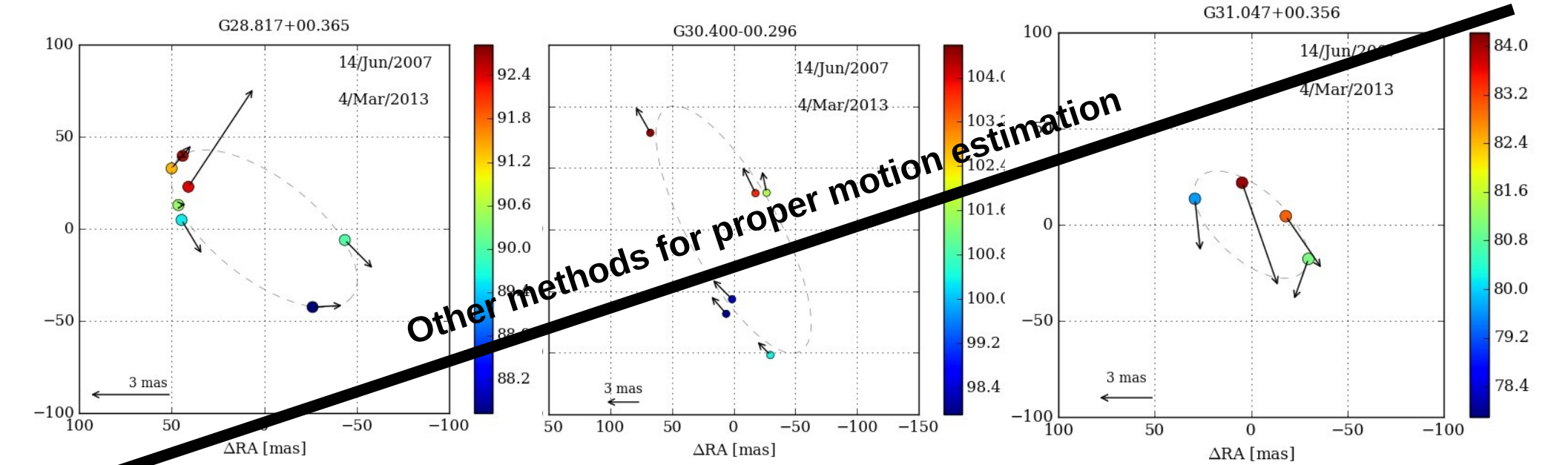
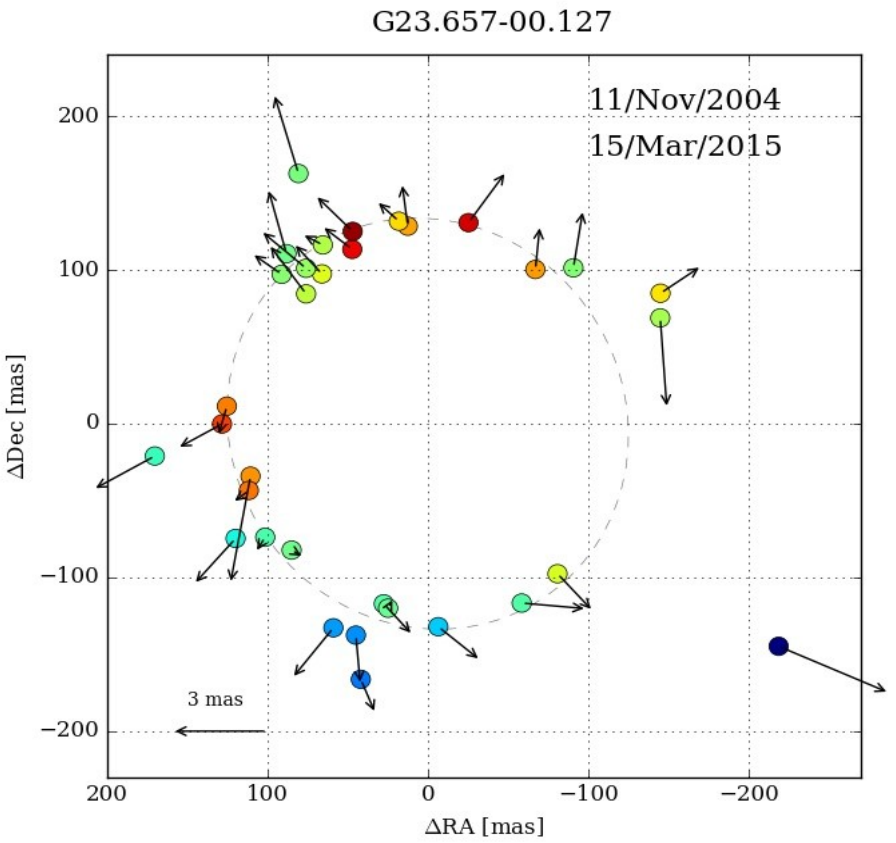
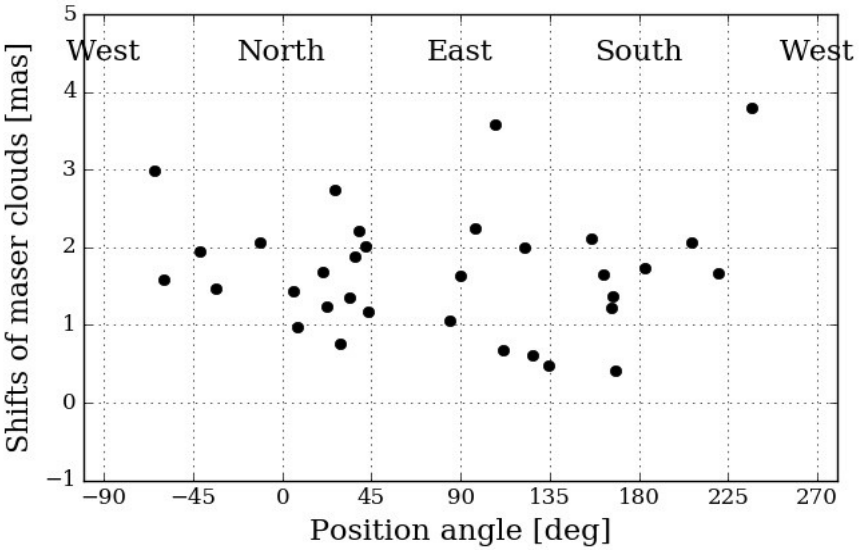
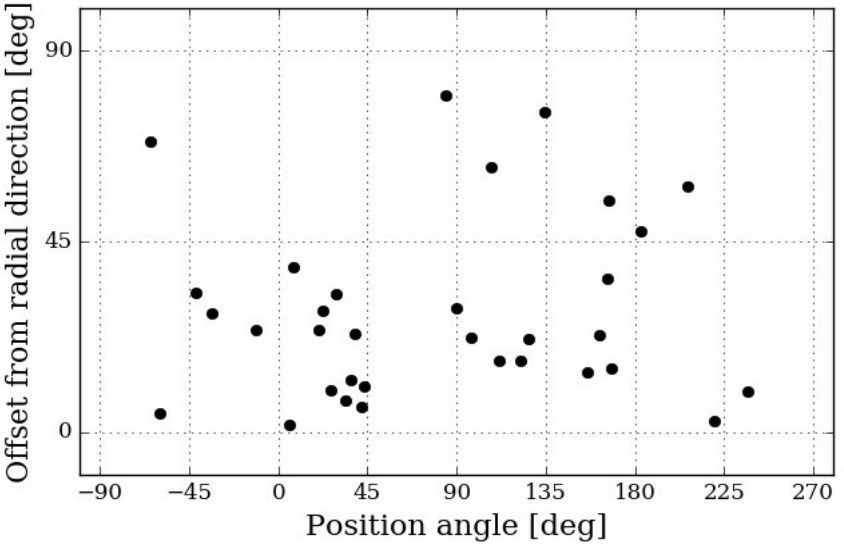


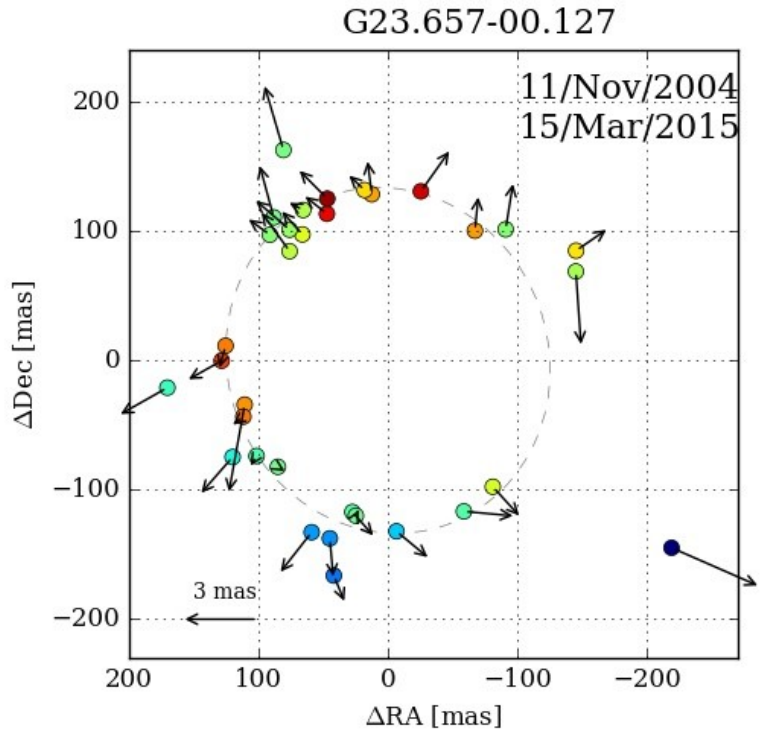
Other methods for proper motion estimation

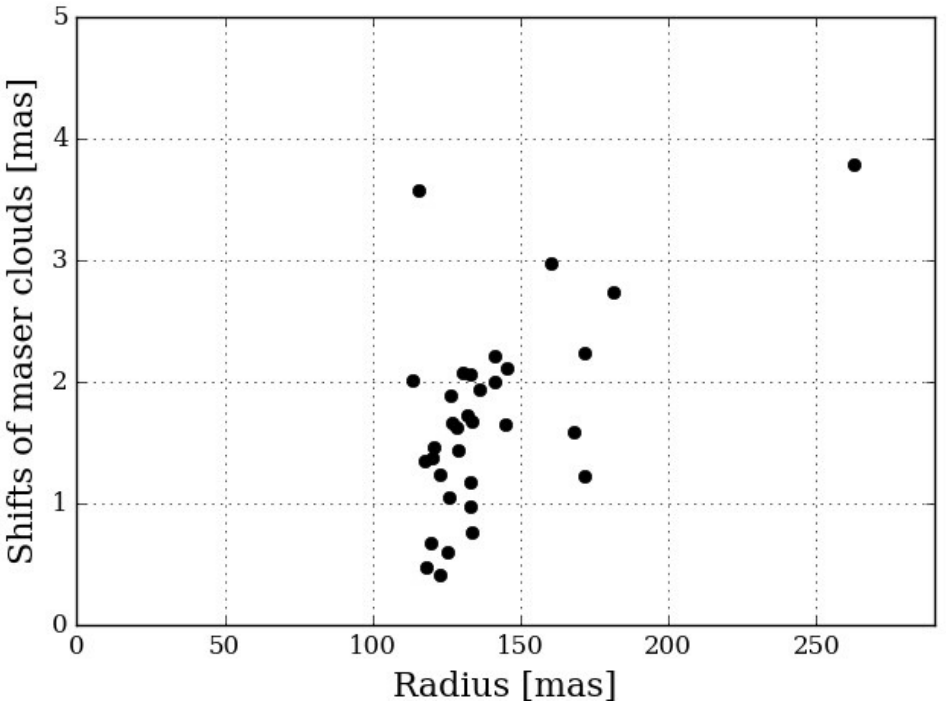
A special case of G23.657-0.127:

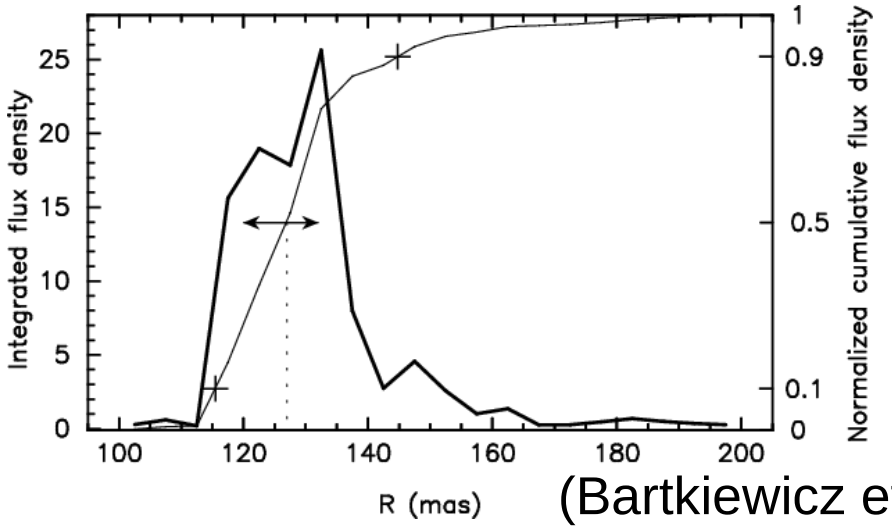






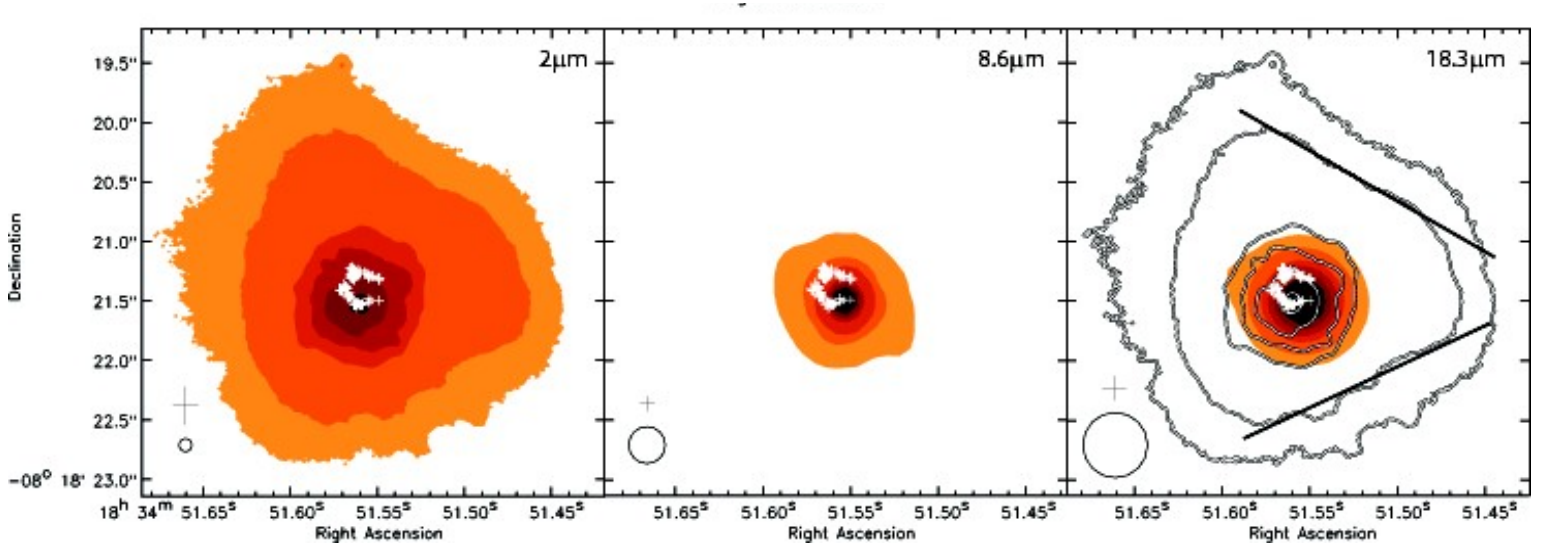


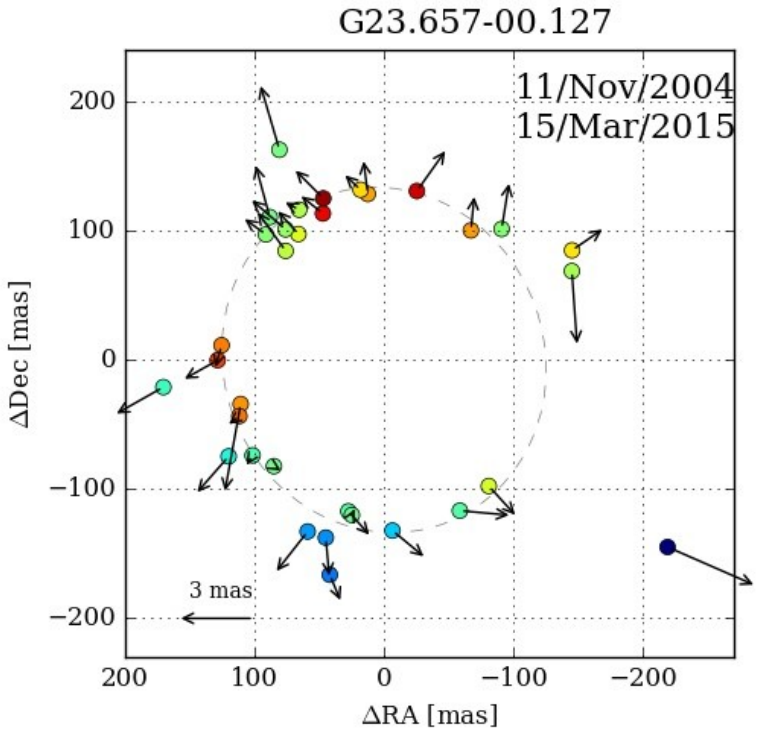


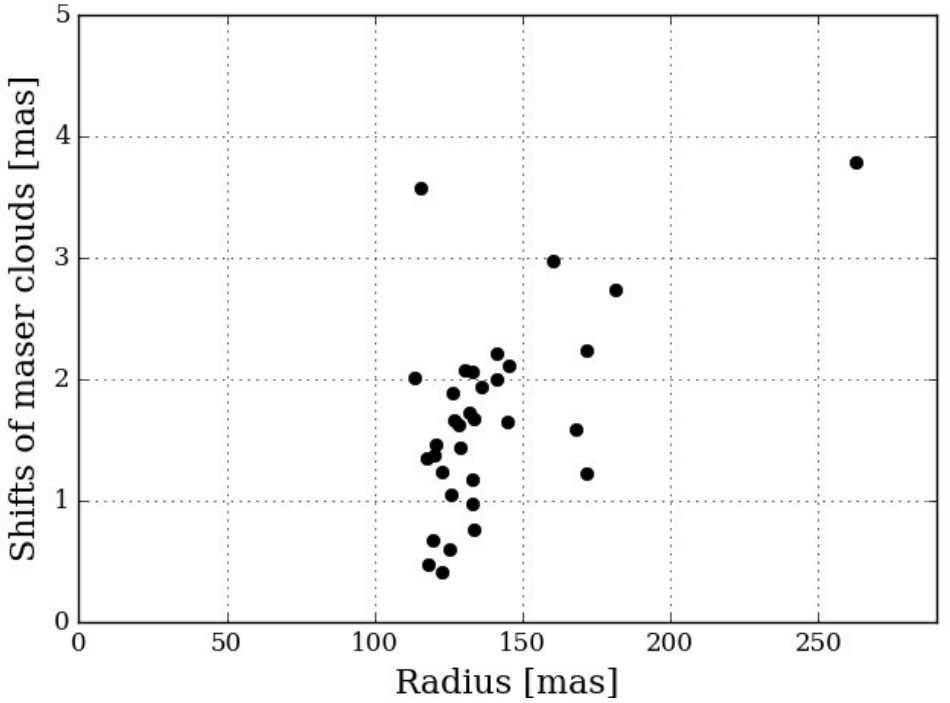


(Bartkiewicz et al. 2005)

(De Buizer et al. 2012)

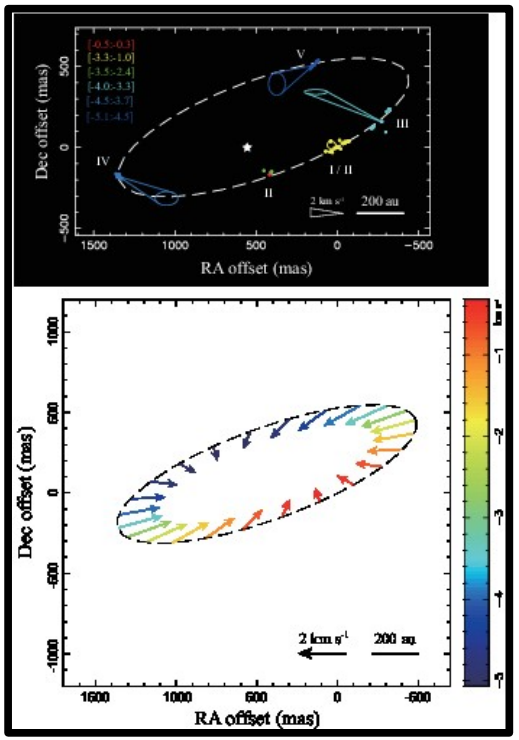




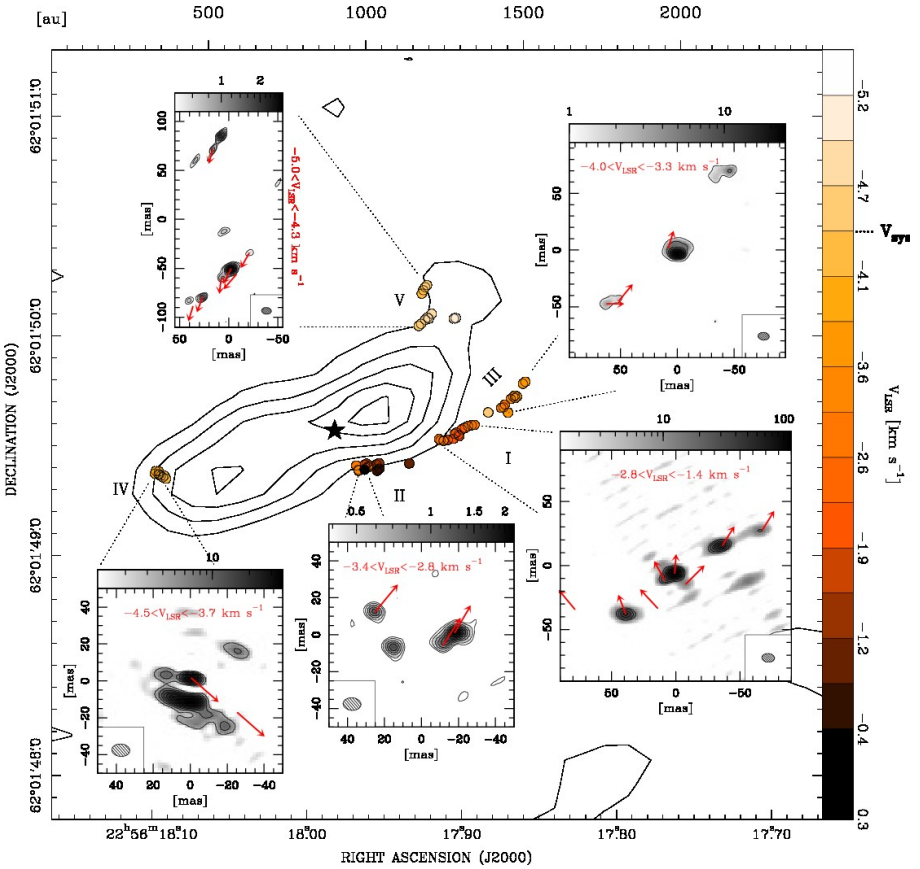


What are these rings? - comparison

- We do not notice a sign of an infall like in Cep A (talk by Alberto Sanna).



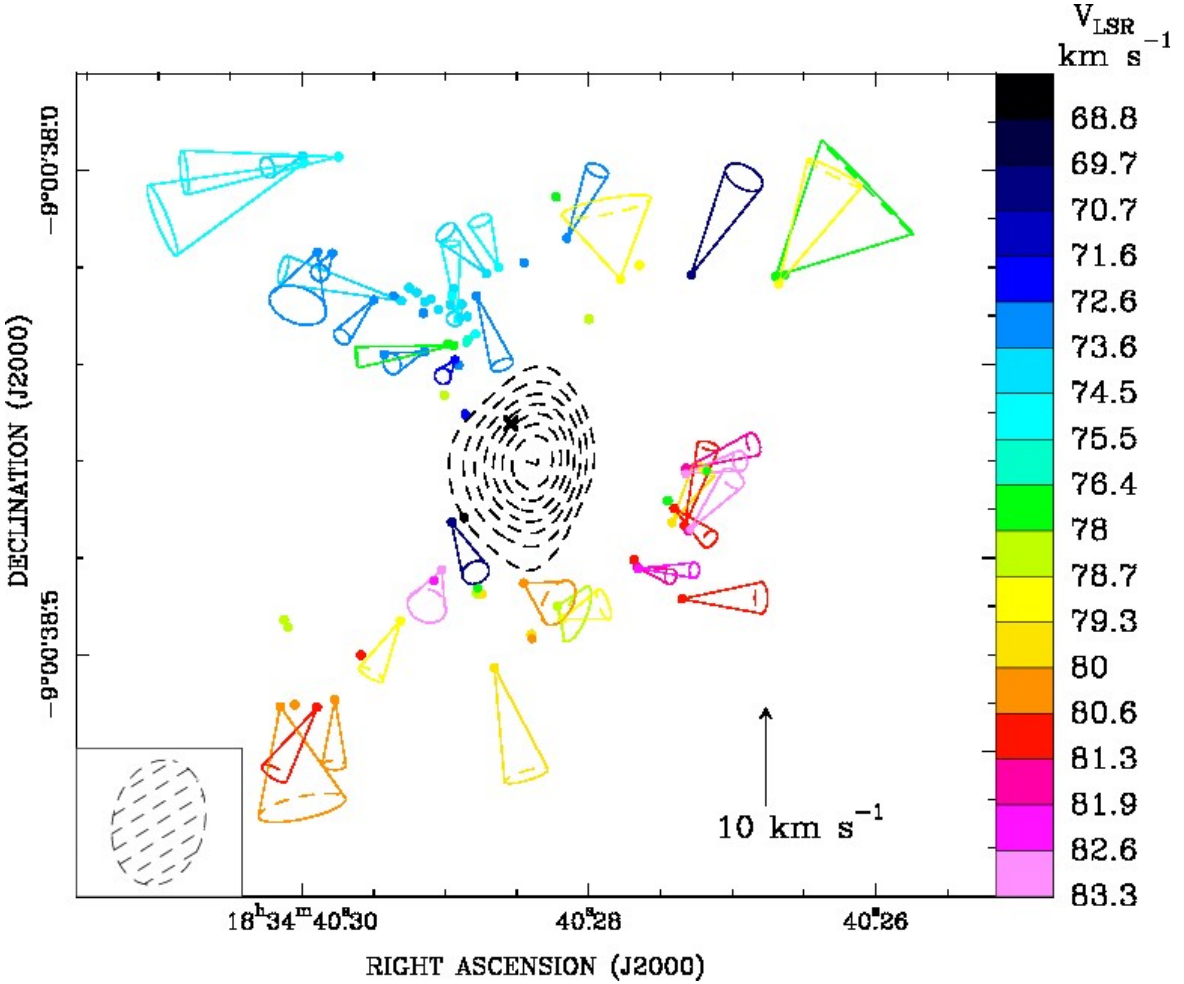
Sugiyama et al. 2014



Sanna et al. 2017

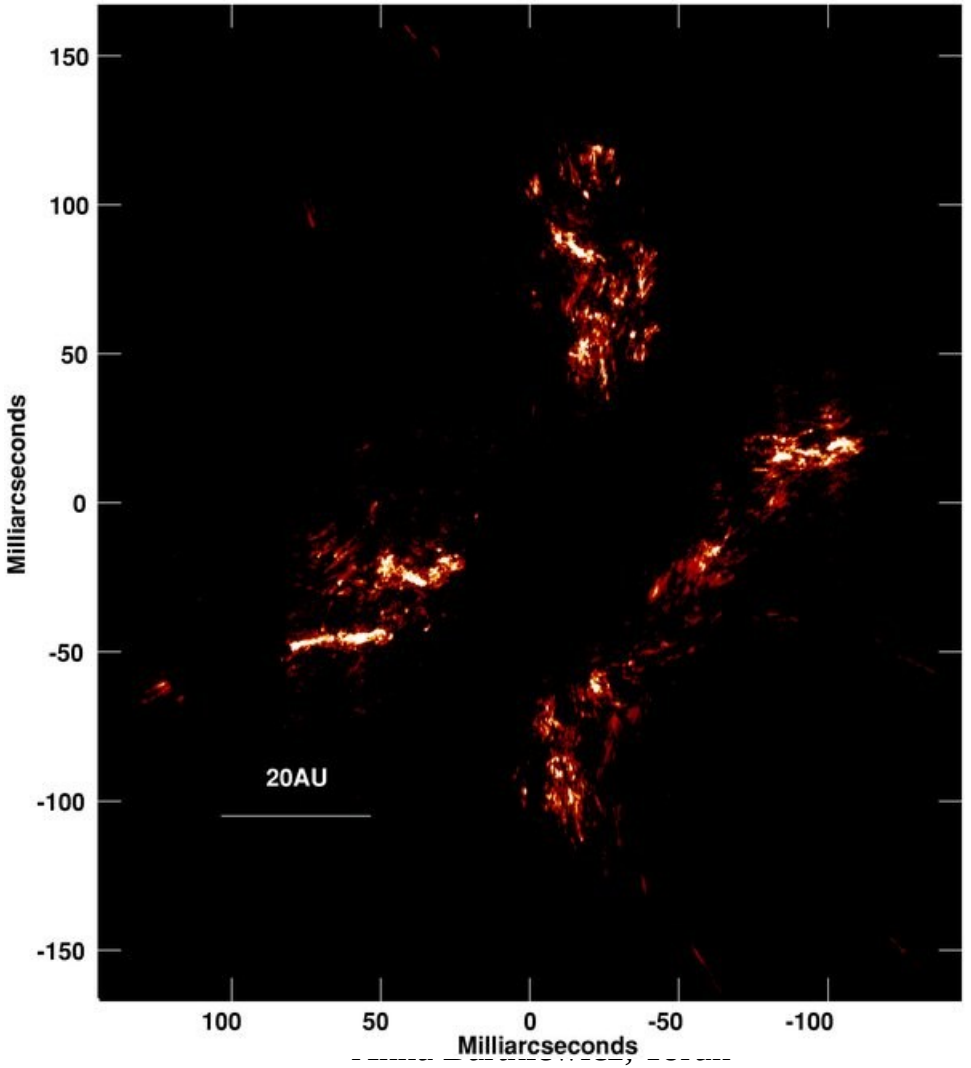
What are these rings? - comparison

- There is rather an expansion and possible rotation as in G23.01 (Sanna et al. 2010).

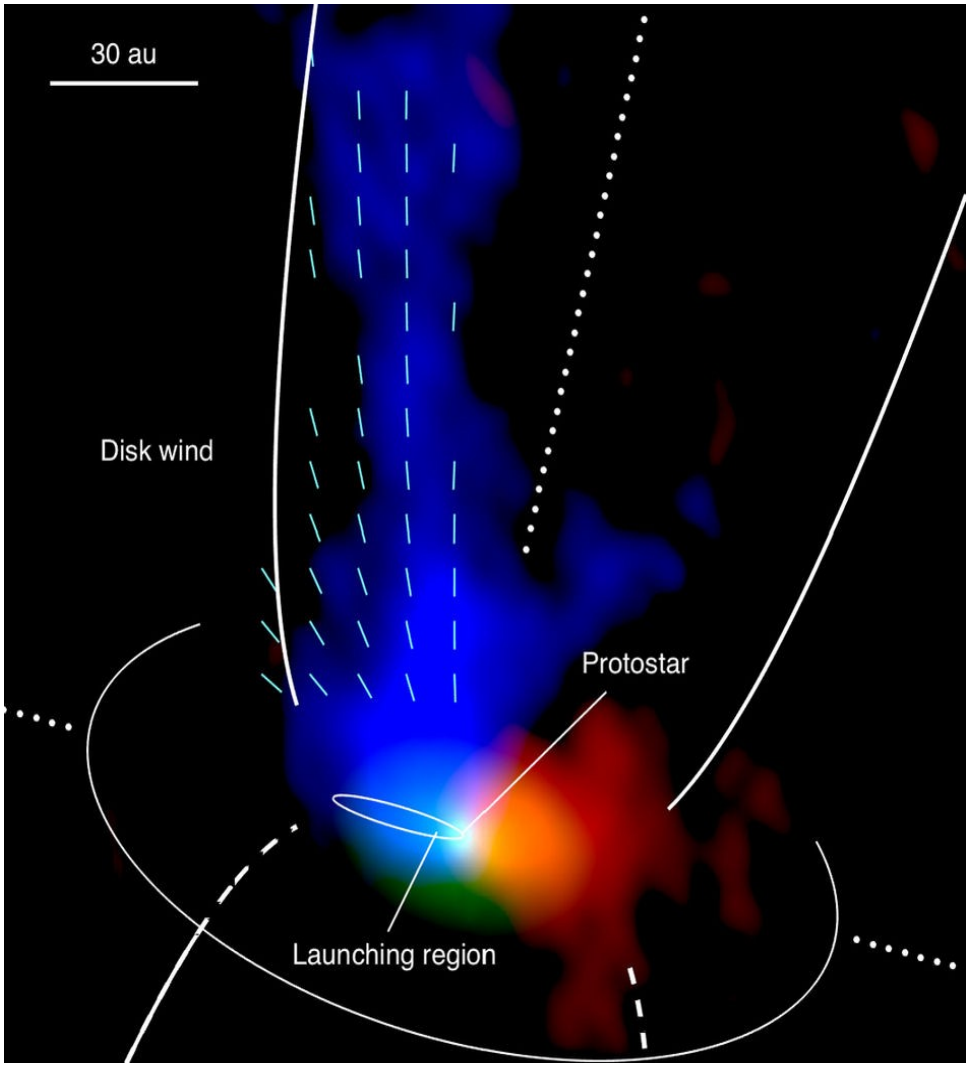


What are these rings? - comparison

- It may be similar to SiO motions (Matthews et al. 2010).



They may be related to an extended disk wind as seen by ALMA (CO lines) in TMC1A protostellar system (Bjerkeli et al. 2016).



Summary

- We plan to detect the central sources using JVLA and ALMA.
- We propose that the methanol maser rings may be a part of a disk wind close to the central sources (rings are relatively small in sizes).

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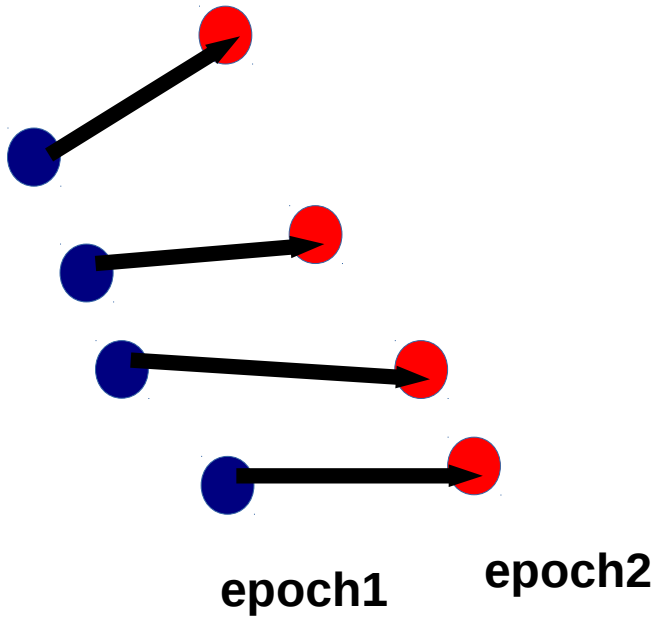
Thank you!

Motion vector:
for each cloud we plotted a vector **corresponding to the sum of shifts between a spot from epoch1 and a spot from epoch2.**



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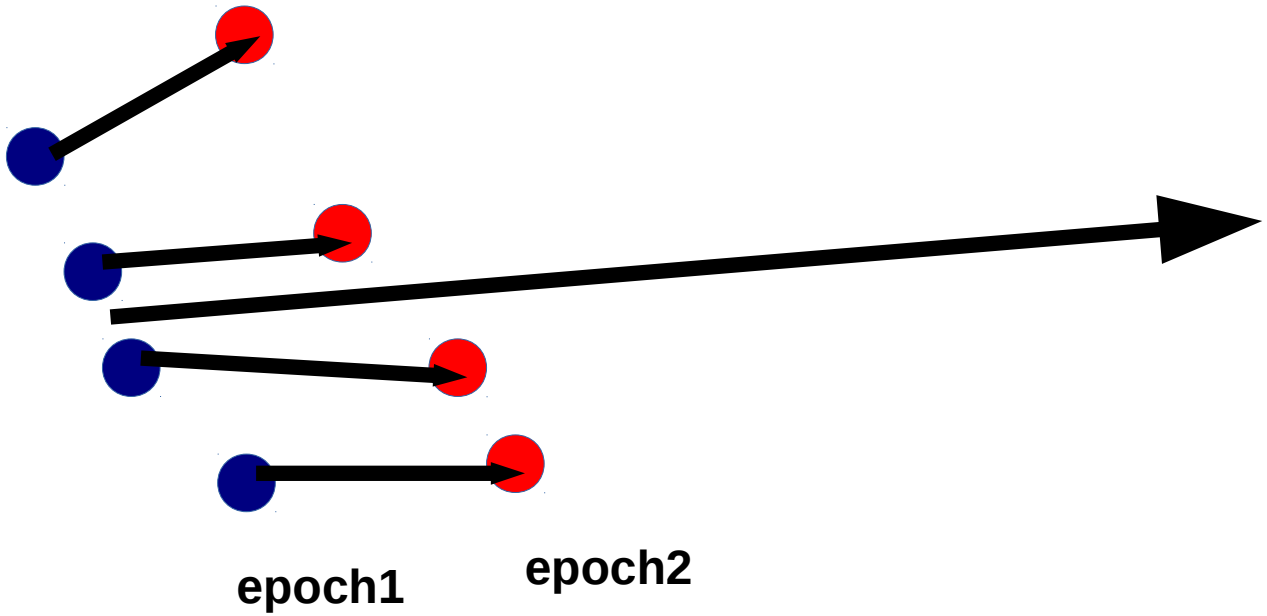

Motion vector:
for each cloud we plotted a vector **corresponding to the sum of shifts between a spot from epoch1 and a spot from epoch2. Next, we divided its length by a number of pairs epoch1 – epoch2.**

