Linear Polarisation of Class I Methanol Masers in Massive SF Regions

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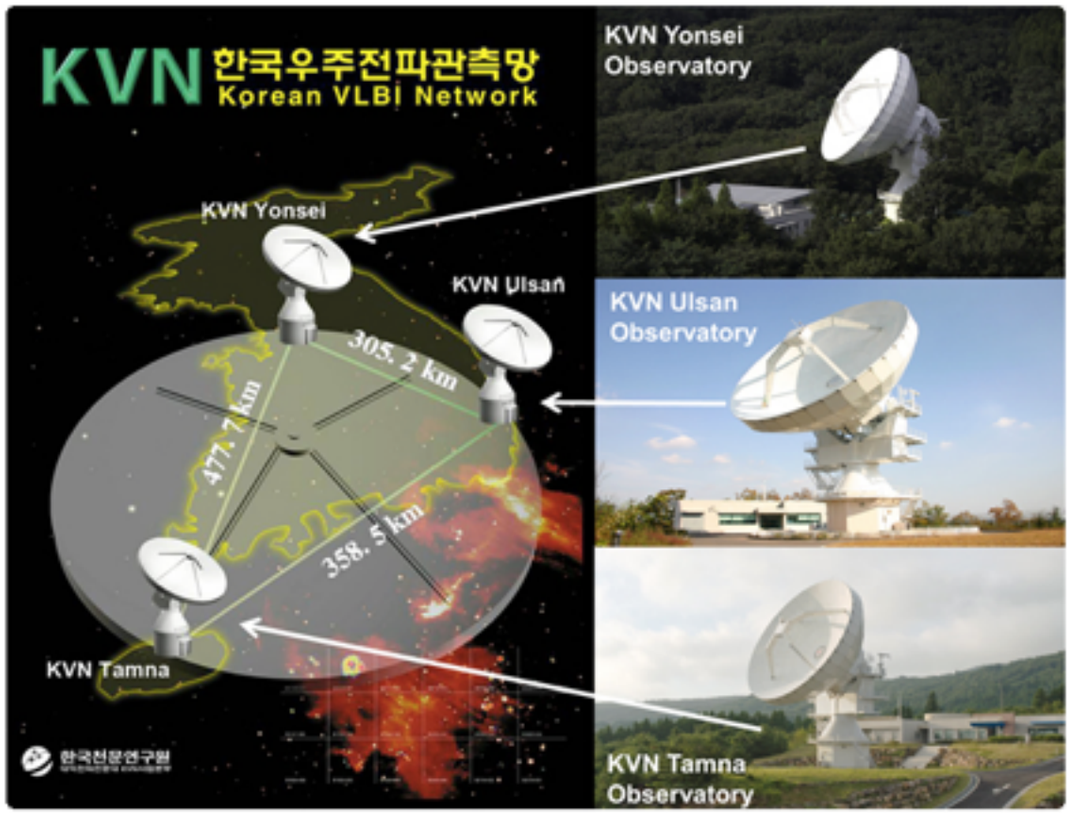
Outline

- Single Dish Polarimetry of Class I methanol masers 44/95GHz (Kang+16)

- Preliminary VLBI polarimetric results of G10.34-0.14



Maser Polarisation

- Masers trace dense regions that can't be traced by dust continuum emission, good to study physical conditions of dense regions near SFRs

- Importance of maser polarisation has been underestimated: Only trace the isolated pockets of compressed field ; not relevant to the larger scale MF. However, more evidences of masers tracing magnetic fields in larger scales (e.g.,Vlemmings+10).

- Polarization observations of Class I methanol masers, tracing dense areas shocked by outflows, have been very rare. (linear/circular, interferometer/ single dish)

- For 44/95GHz Class I methanol masers, only 3 polarisation papers

  - Wiesemeyer+04 : linear : SD(IRAM30m) : 2/14 @95

  - Sarma+11, Momjian+12 : circular : EVLA : 44GHz : OMC2

Purpose of This Study

- To expand the knowledge of polarisation characteristics of Class I methanol maser sources at 44/95GHz.

- Observing many samples of massive SFRs with KVN single dish at 44/95 GHz, simultaneously with full Stokes' parameters.

- Limitations of Single Dish observations :

    - Measured polarisation fractions could be the lower limits due to the depolarisation of multi maser features with different polarisation angles.

    - Measured polarisation angle could be dominated by the strongest feature, may not represent the magnetic field of the system.

Purpose of This Study

- Statistics on polarisation properties
- Both trace outflow regions; ***polarisation angles of 44 and 95GHz*** are expected to be similar.
    - prove this by simultaneous observations at both transitions.
- Wiesemeyer+04 reported two targets with ***high polarisation fraction*** (>30%) in 7 lin-pol-detected Class I / 3 Class II
    - Requires specific conditions of anisotropic pumping or loss mechanism for high J transitions
    - By observing meaningful number of samples, we can verify if conditions producing high pol fraction are as common as they claimed.

Targets & Observations

- 39 Massive star forming regions > 50 Jy from the KVN 44GHz methanol maser survey catalog (Kim+14)

- 2013/8/31 - 2013/12/29

- Freq : 44.06943 and 95.169463 GHz, simultaneously

- KVN Yonsei 21-m telescope

- Dual linear polarization , resolution : 0.1 km/s, 60”@44 and 30” @95

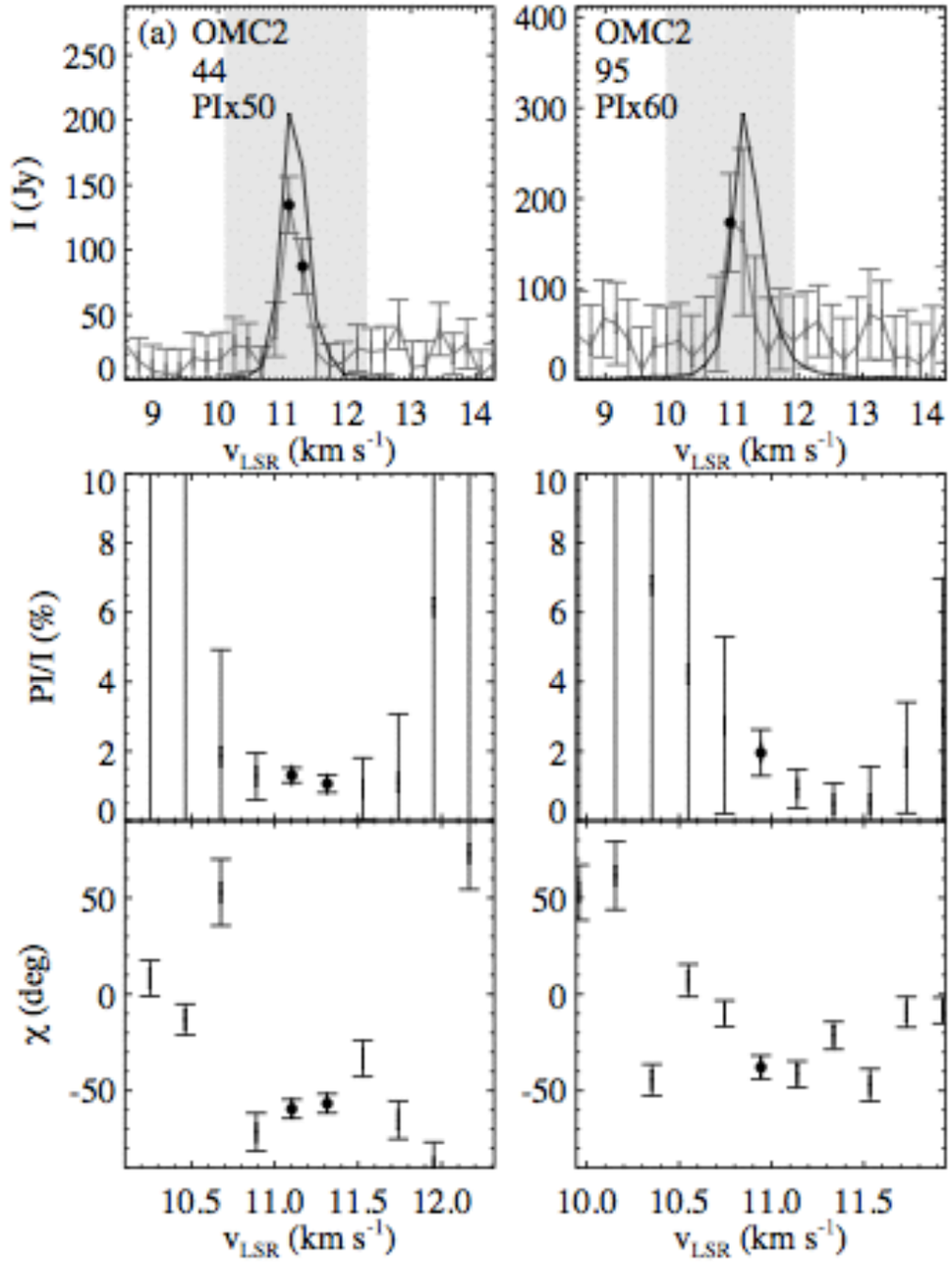
- unpolarized and polarisation angle references : Planets (Venus, Mars, Jupiter) and CRAB : observed each day

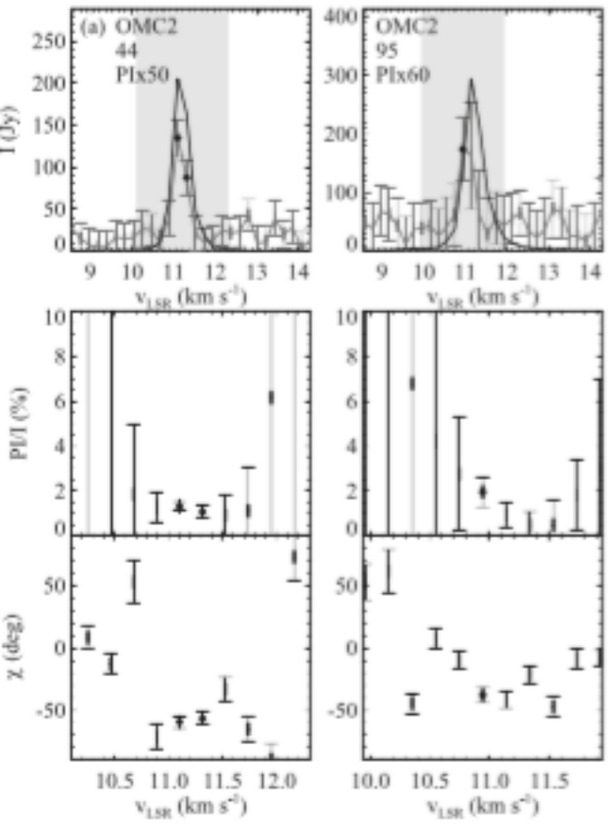
Results

- Polarisation detection rate (~60%)
  - c.f. 71% for Wiesemeyer+04 (10/14@84/95/132)
- ~ 40% are detected at both transitions

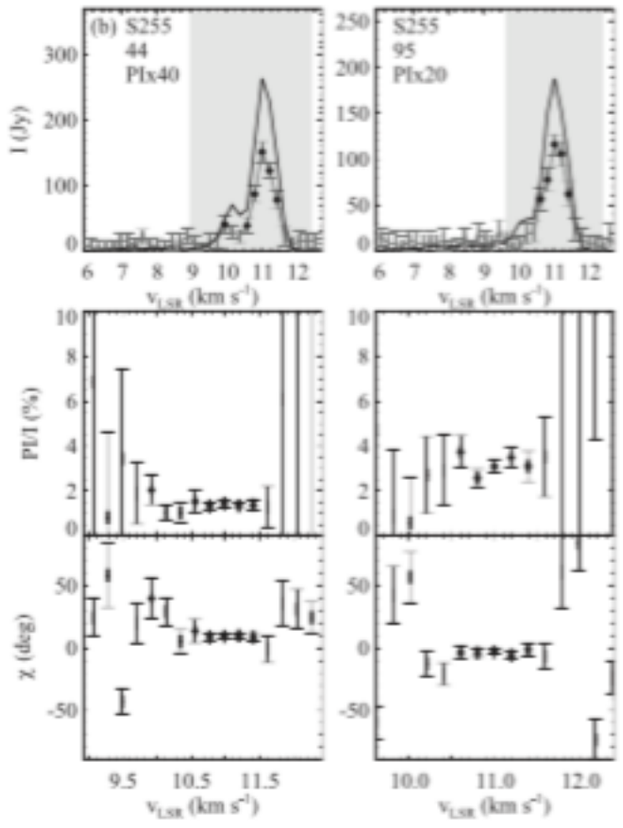
Table 2. Linear Polarization Detection Rates

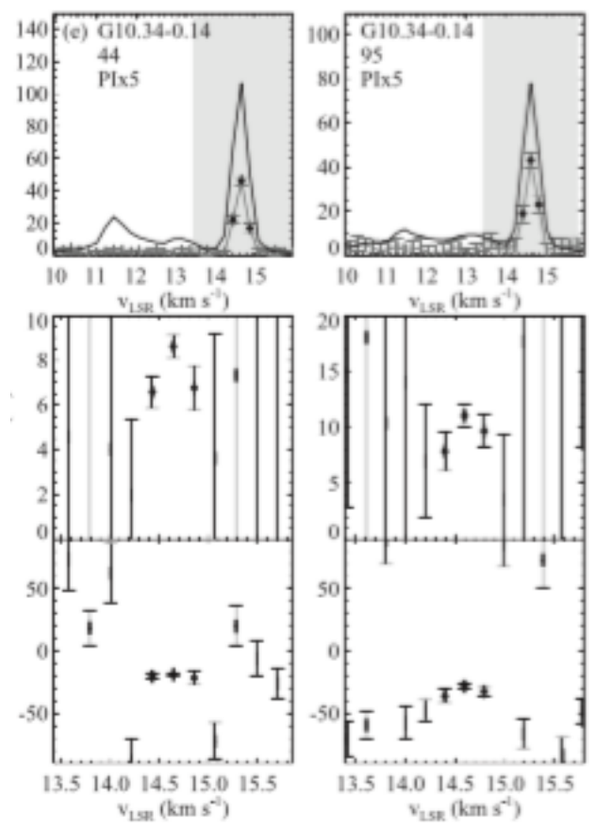
Group	Number
Total Detected	23 (59%)
44	21 (54%)
95	17 (44%)
44 and 95	15 (38%)
44 only	6
95 only	2
Total Observed	39

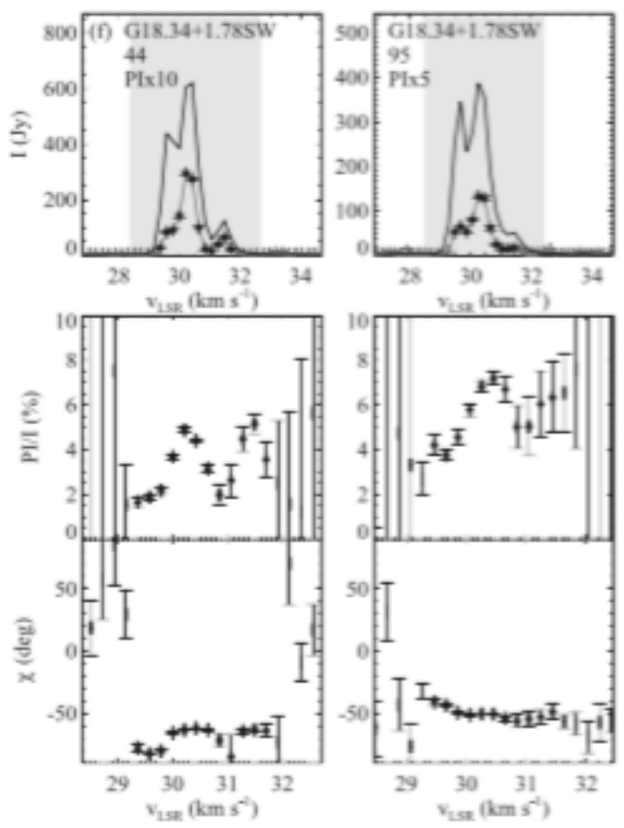


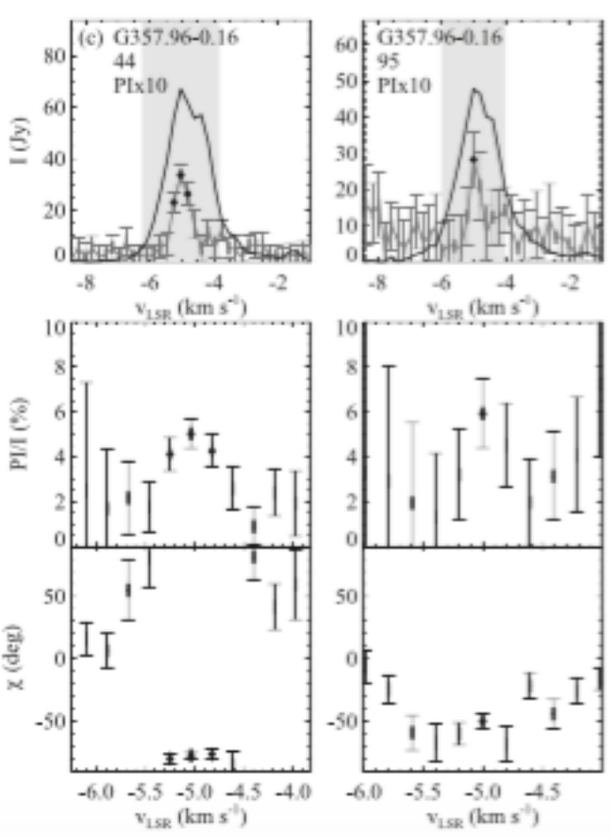

(a) OMC2
44
PIx50
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

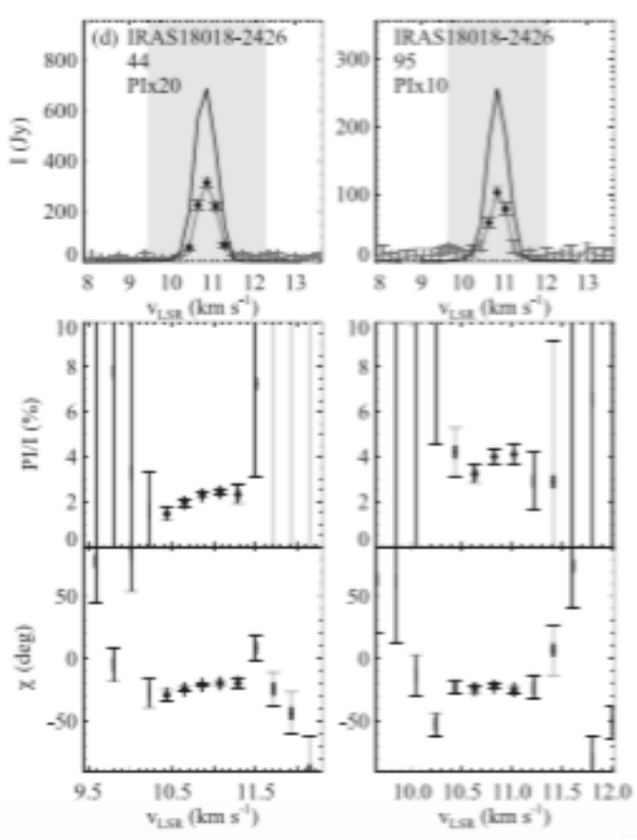
OMC2
95
PIx60
v_LSR (km s^-1)

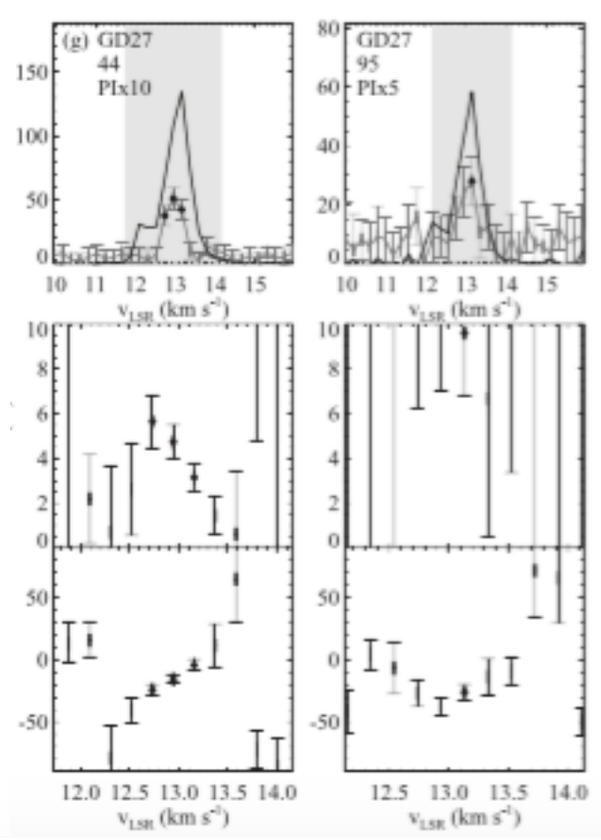

(b) S255
44
PIx40
S255
95
PIx20
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

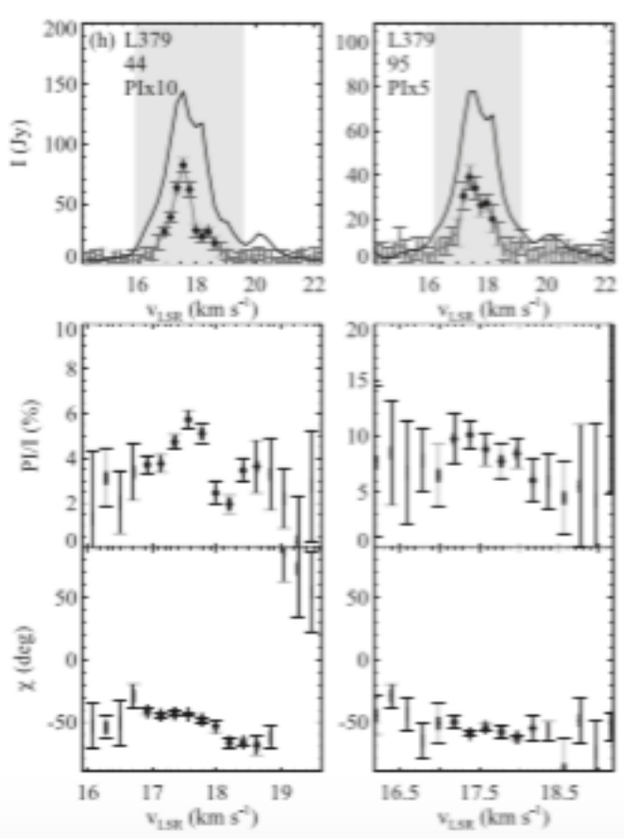

(e) G10.34-0.14
44
PIx5
G10.34-0.14
95
PIx5
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

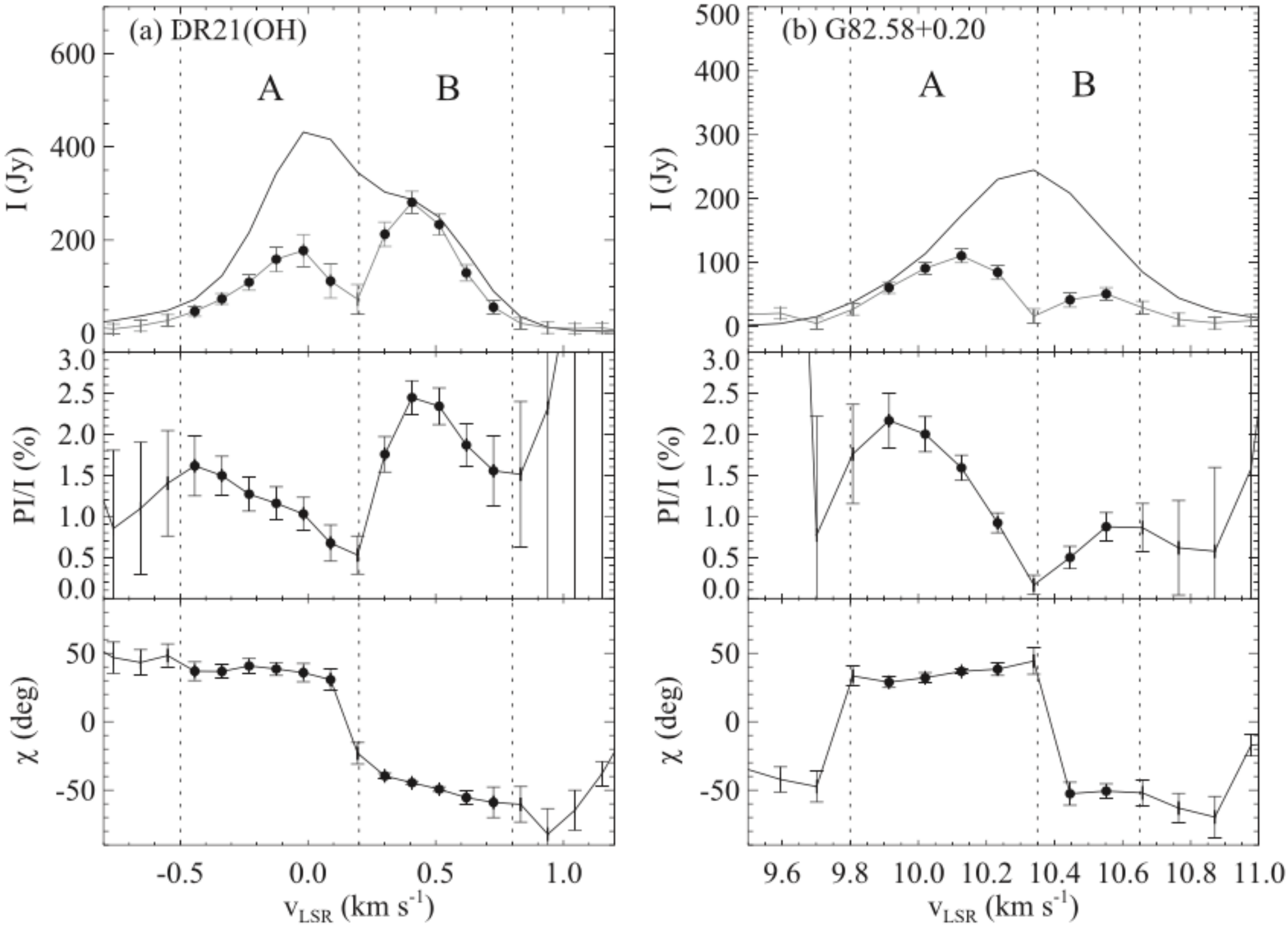

(f) G18.34+1.78SW
44
PIx10
G18.34+1.78SW
95
PIx5
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)


(c) G357.96-0.16
44
PIx10
G357.96-0.16
95
PIx10
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)


(d) IRAS18018-2426
44
PIx20
IRAS18018-2426
95
PIx10
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

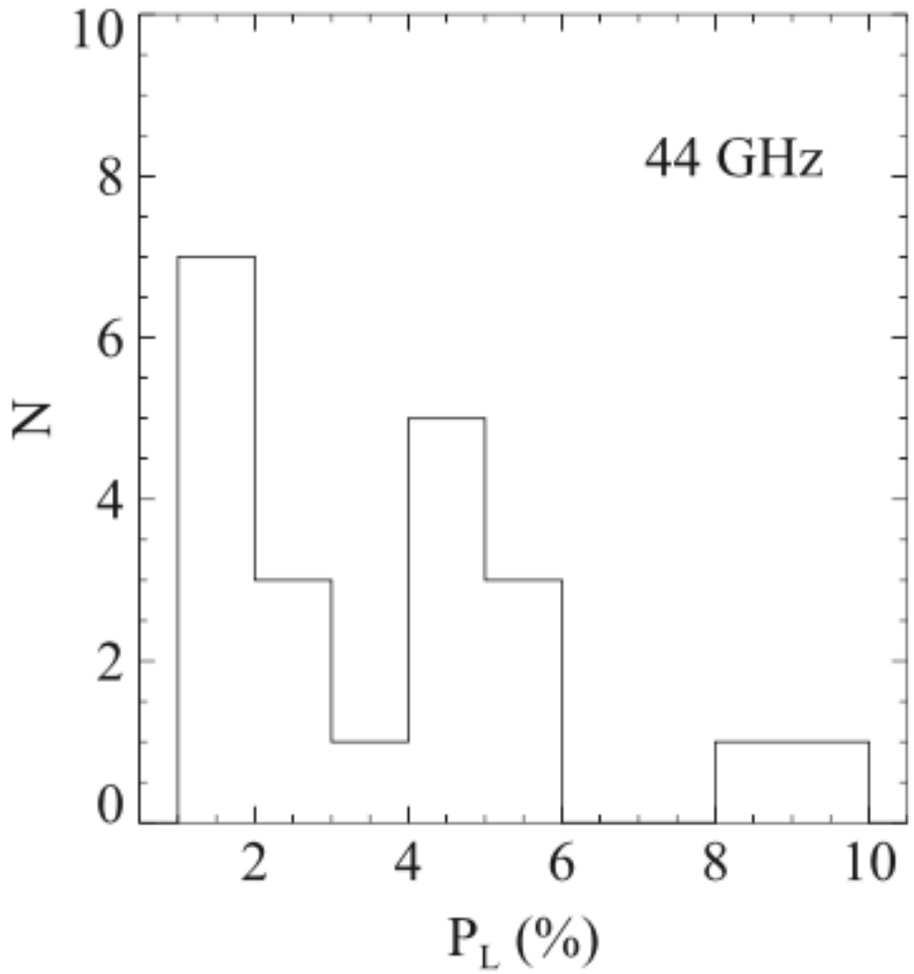

(g) GD27
44
PIx10
GD27
95
PIx5
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

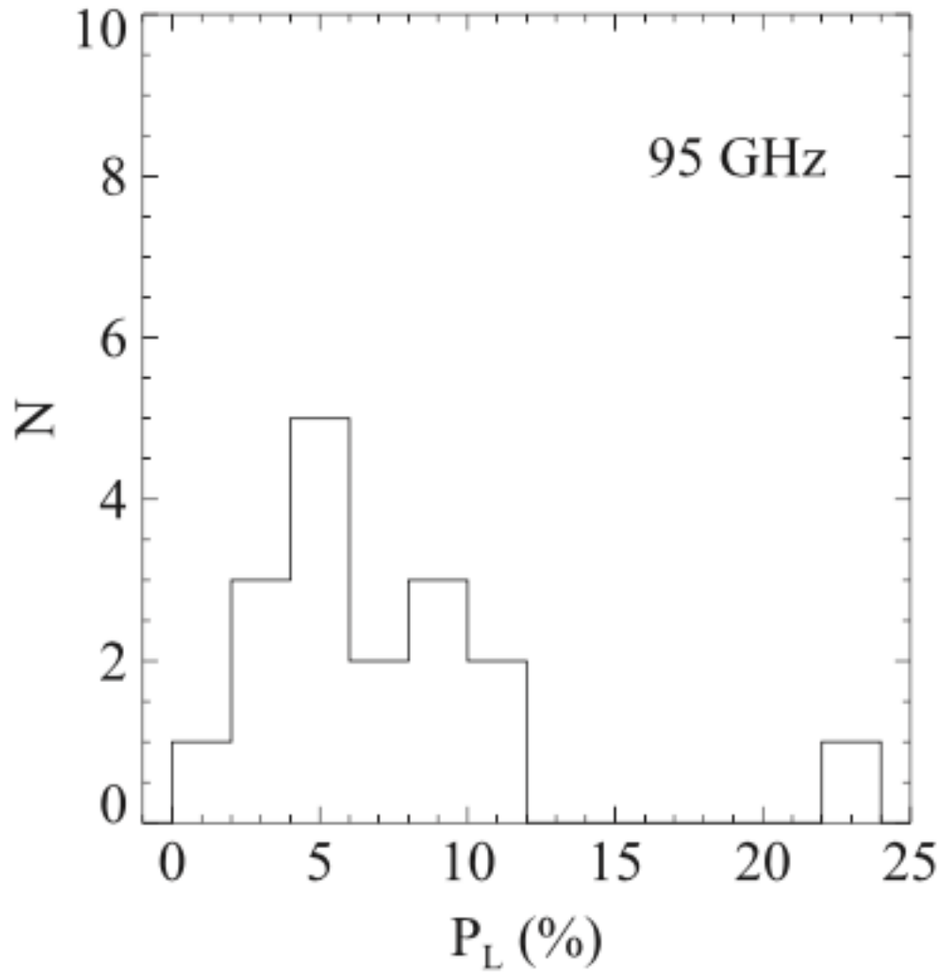

(h) L379
44
PIx10
L379
95
PIx5
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)


(a) DR21(OH)
A
B
I (Jy)
600
400
200
0
PI/I (%)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
χ (deg)
50
0
-50
-0.5
0.0
0.5
1.0
v_LSR (km s^-1)
(b) G82.58+0.20
A
B
I (Jy)
500
400
300
200
100
0
PI/I (%)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
χ (deg)
50
0
-50
9.6
9.8
10.0
10.2
10.4
10.6
10.8
11.0
v_LSR (km s^-1)

Polarisation Fraction

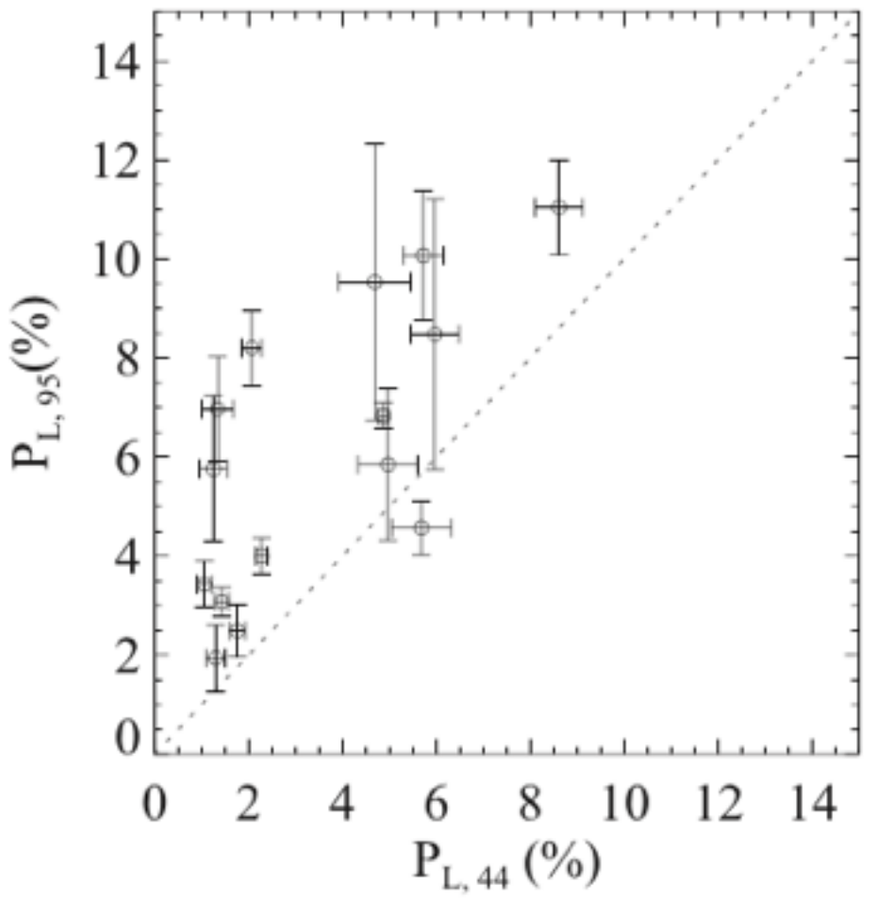
- ~2.7% @ 44 GHz, ~4.8% @ 95 GHz

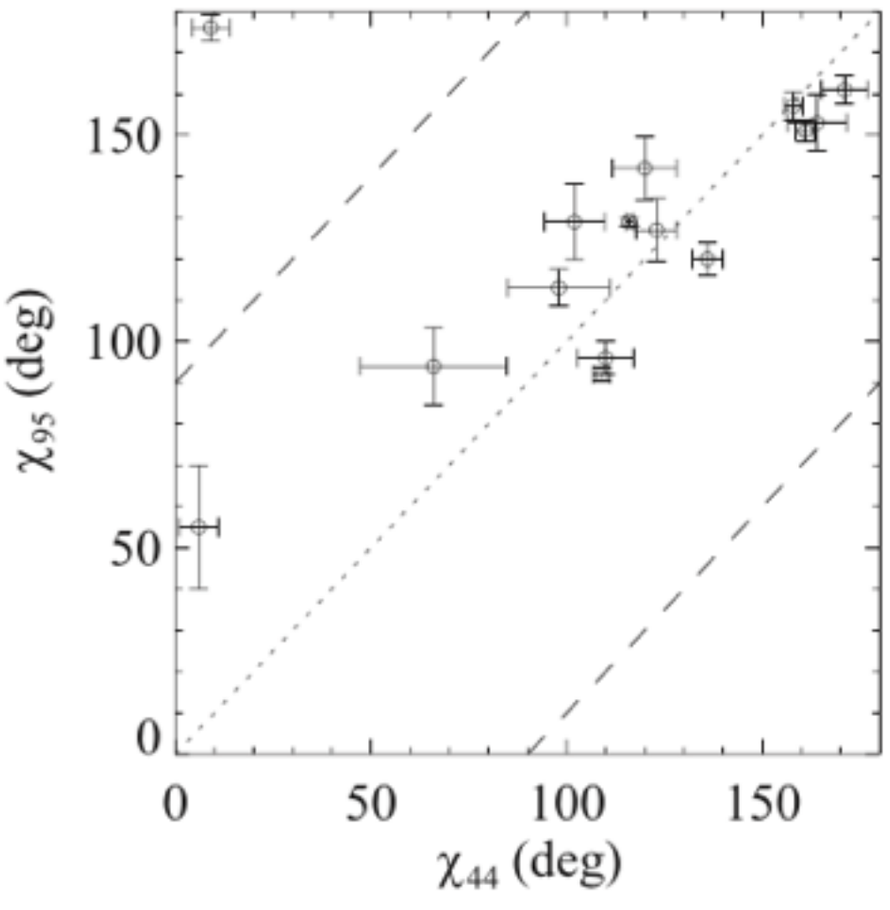




44GHz v.s. 95GHz

- Polarisation fractions of 95 GHz tend to be larger than those of 44GHz
  - RM, beam size, or intrinsic issue (Peres-sanchez+13, Nedoluha+90)
- Polarisation angles tend to be similar





KVN VLBI

- VLBI Polarimetry at 44 GHz for 7 targets in 2014-2017, single and multiple epochs

- G10.34-0.14 : 3 epoch obs (2014-2017). reduced by 2 person, consistent results.

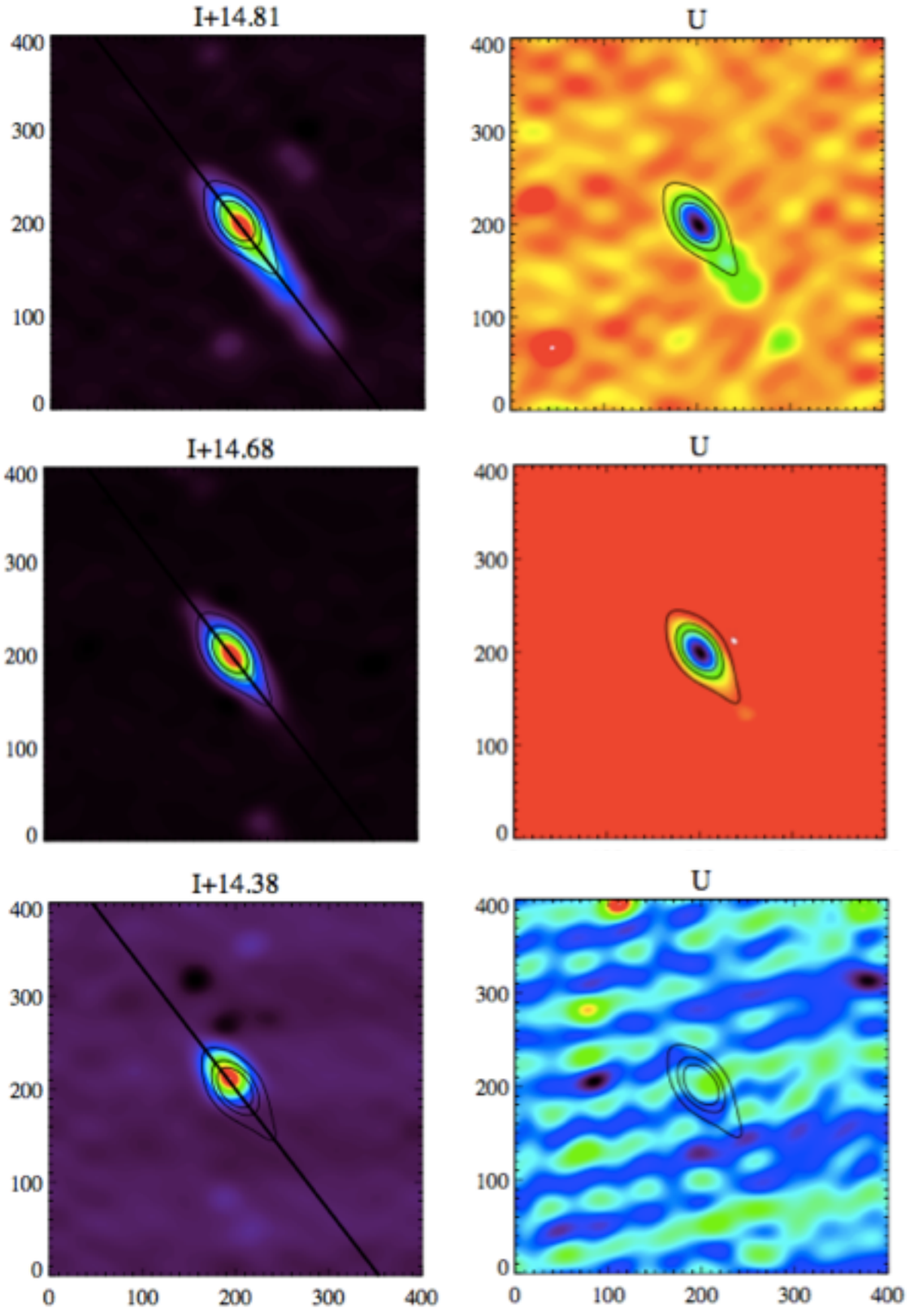
- Velocity resolution ~ 0.01km/s, beam ~ 2x3mas

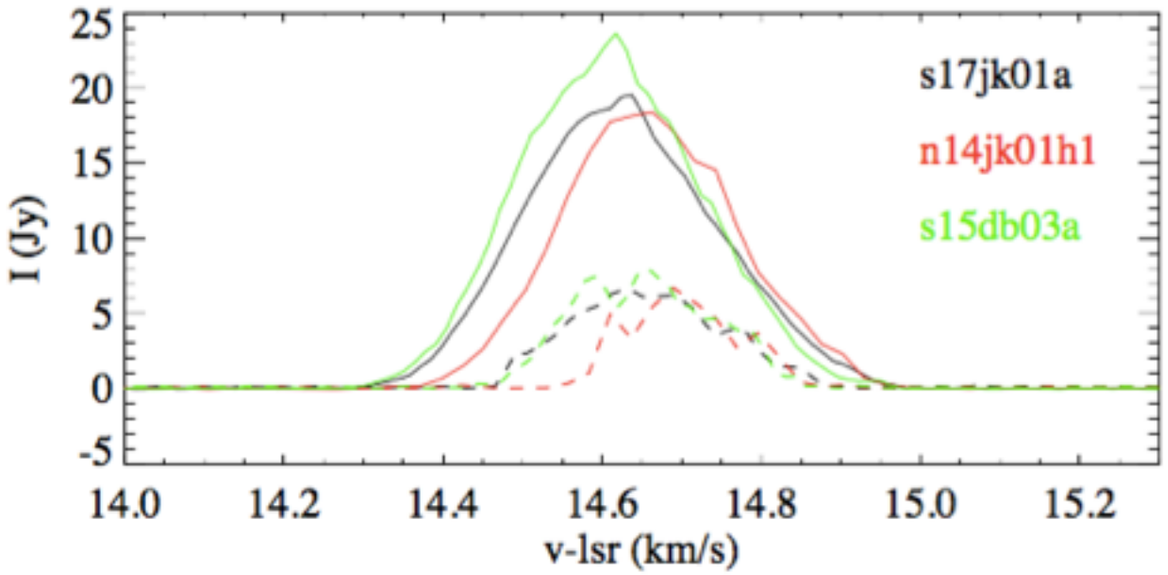
- D-term correction using 3C84, OJ287, 3C454.3

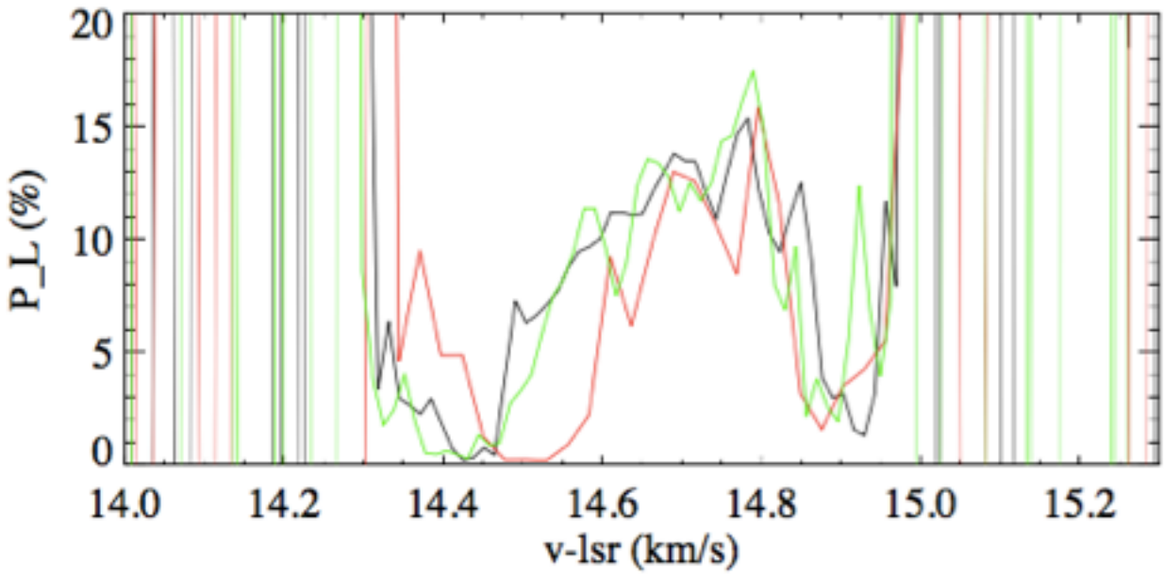
- Polarisation angle correction : single dish polarisation of other calibrators using Crab a day before.

I

PI


I+14.81
U
I+14.68
U
I+14.38
U
0
100
200
300
400


I (Jy)
v-lsr (km/s)
s17jk01a
n14jk01h1
s15db03a


P_L (%)
v-lsr (km/s)

Summary & Future Works

- We have detected linear polarisation emission towards 23 massive SFRS. *The linear polarisation of the 44 GHz methanol maser transition was first detected in this study.*

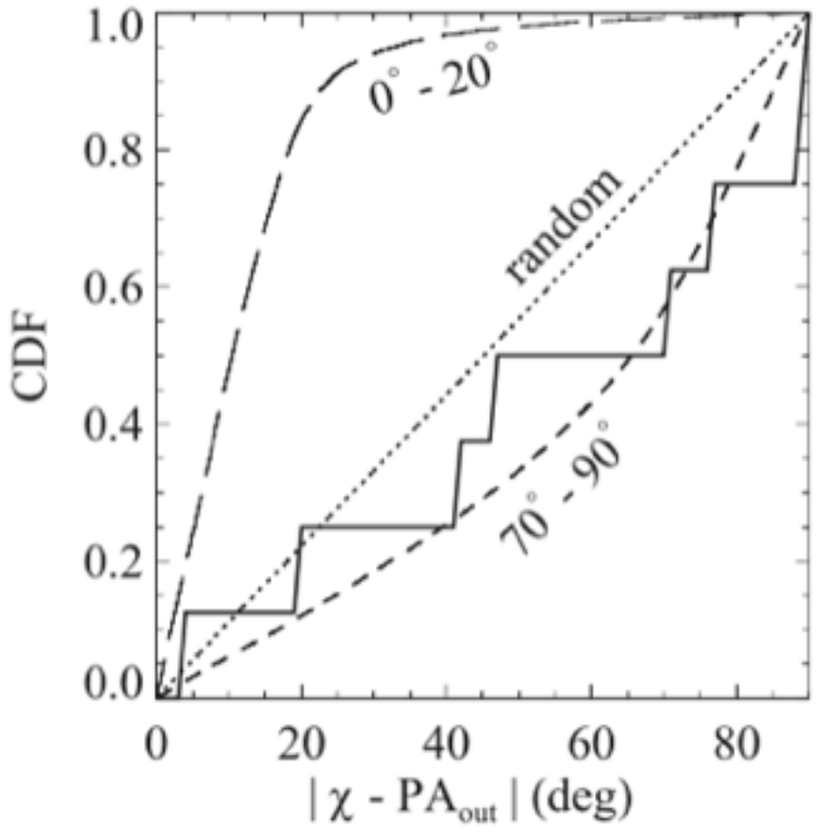
- Polarisation fractions and angles of 44/95 are generally well correlated.

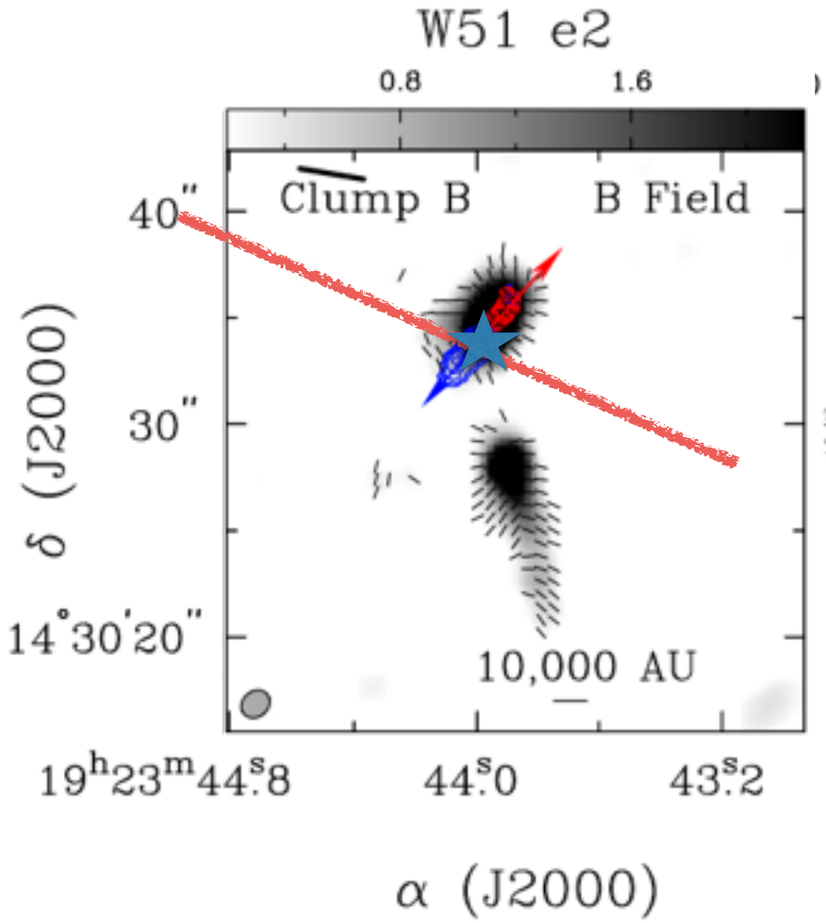
- No high polarisation fraction (>30%) has been detected. It may not be as common as Wiesemeyer+04 suggested.

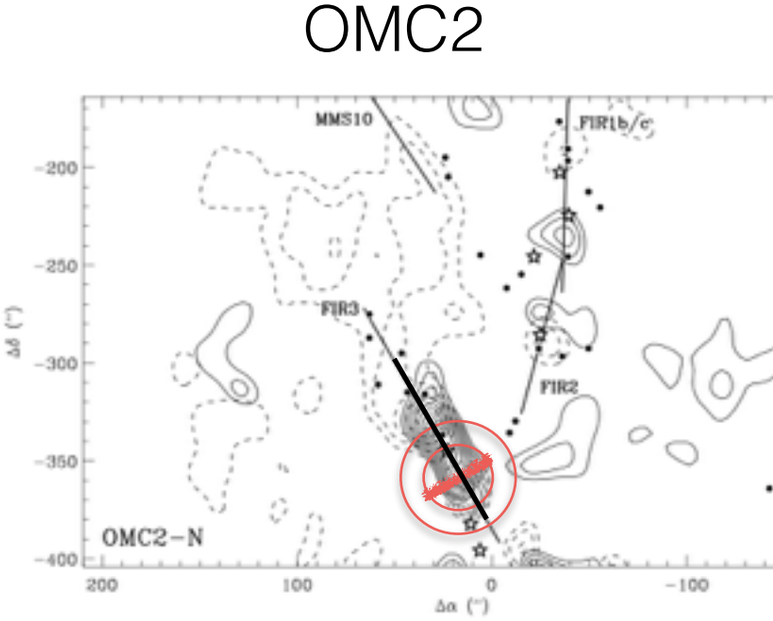
- KVN VLBI follow-up of G10.34 in multi-epochs show consistent polarisation results, successful performance of KVN polarisation system.

- ALMA 95GHz maser polarisation data is delivered. JVLA 44GHz maser polarisation is approved.

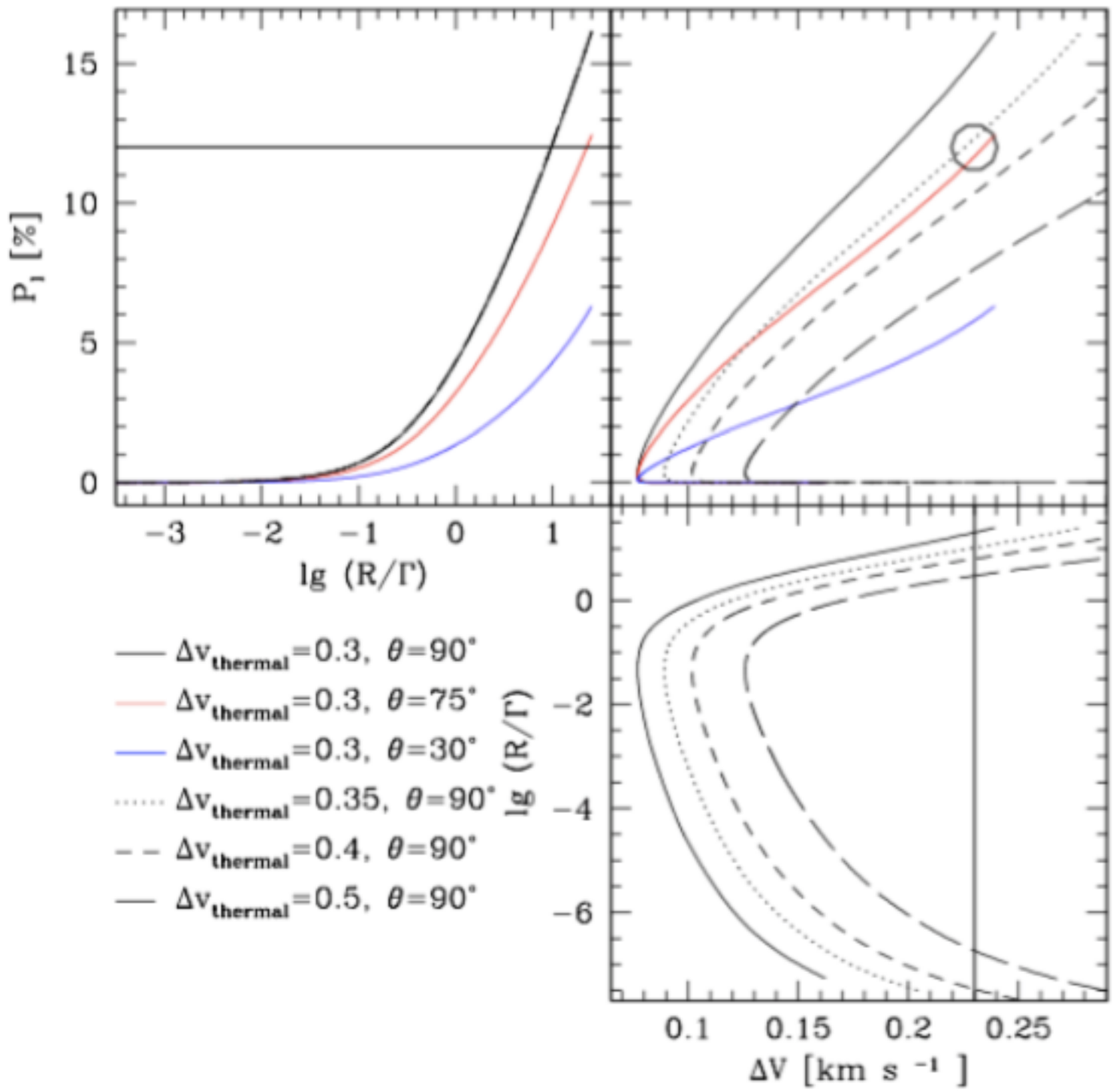
Masers and Outflows



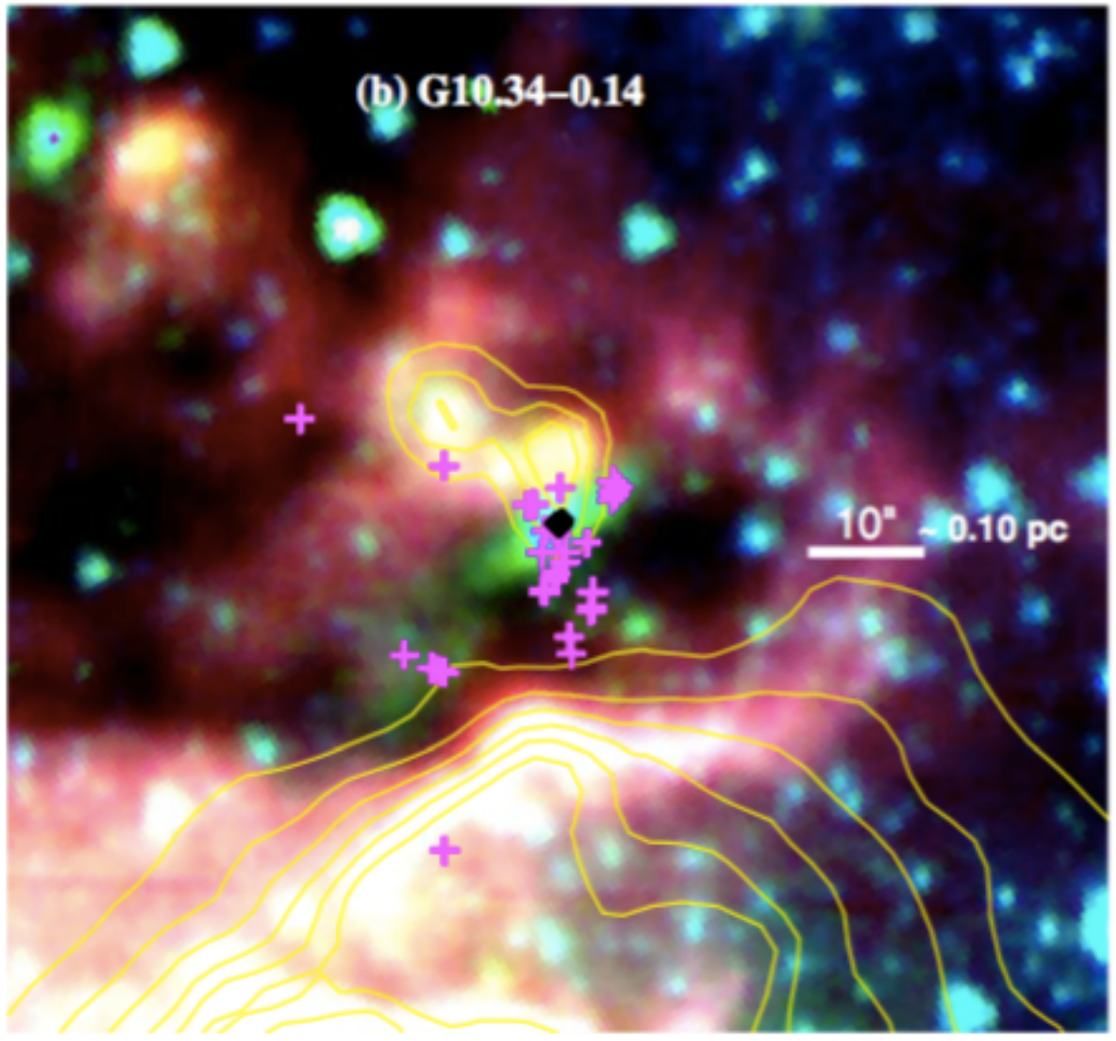




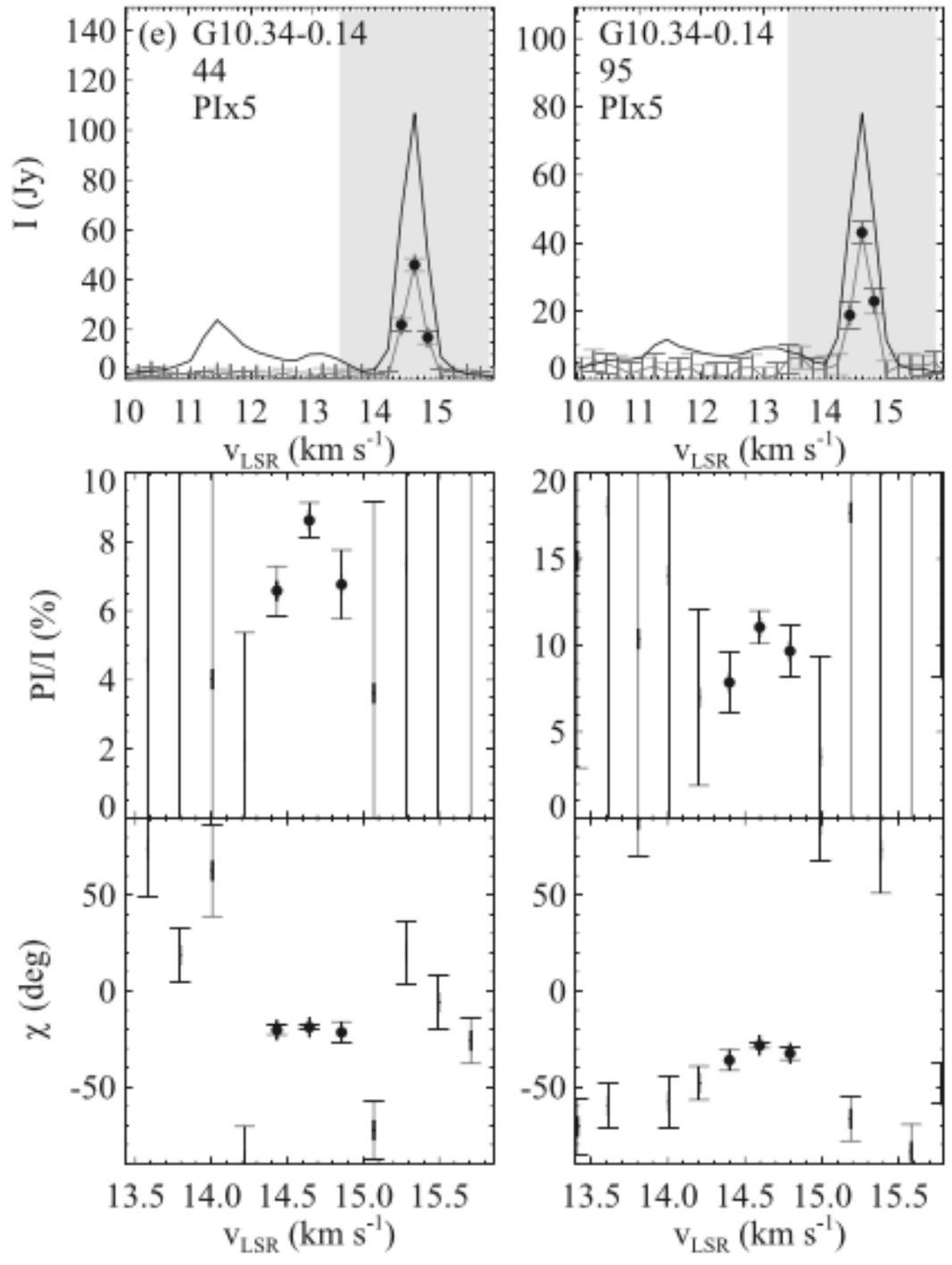
Source Name	$\lvert\chi - \mathrm{PA_{out}}\rvert$	Reference
OMC2	90° ± 9°	Williams et al. (2003)
S255N	42° ± 5°	Wang et al. (2011)
NGC2264	20° ± 10°	Schreyer et al. (2003)
G49.49−0.39 (W51 e2)	71° ± 19°	Shi et al. (2010)
DR21W	89° ± 4°	Garden et al. (1991)
DR21(OH)	4° ± 3°/77° ± 3°	Zhang et al. (2014)
DR21	47° ± 8°	Garden et al. (1991)

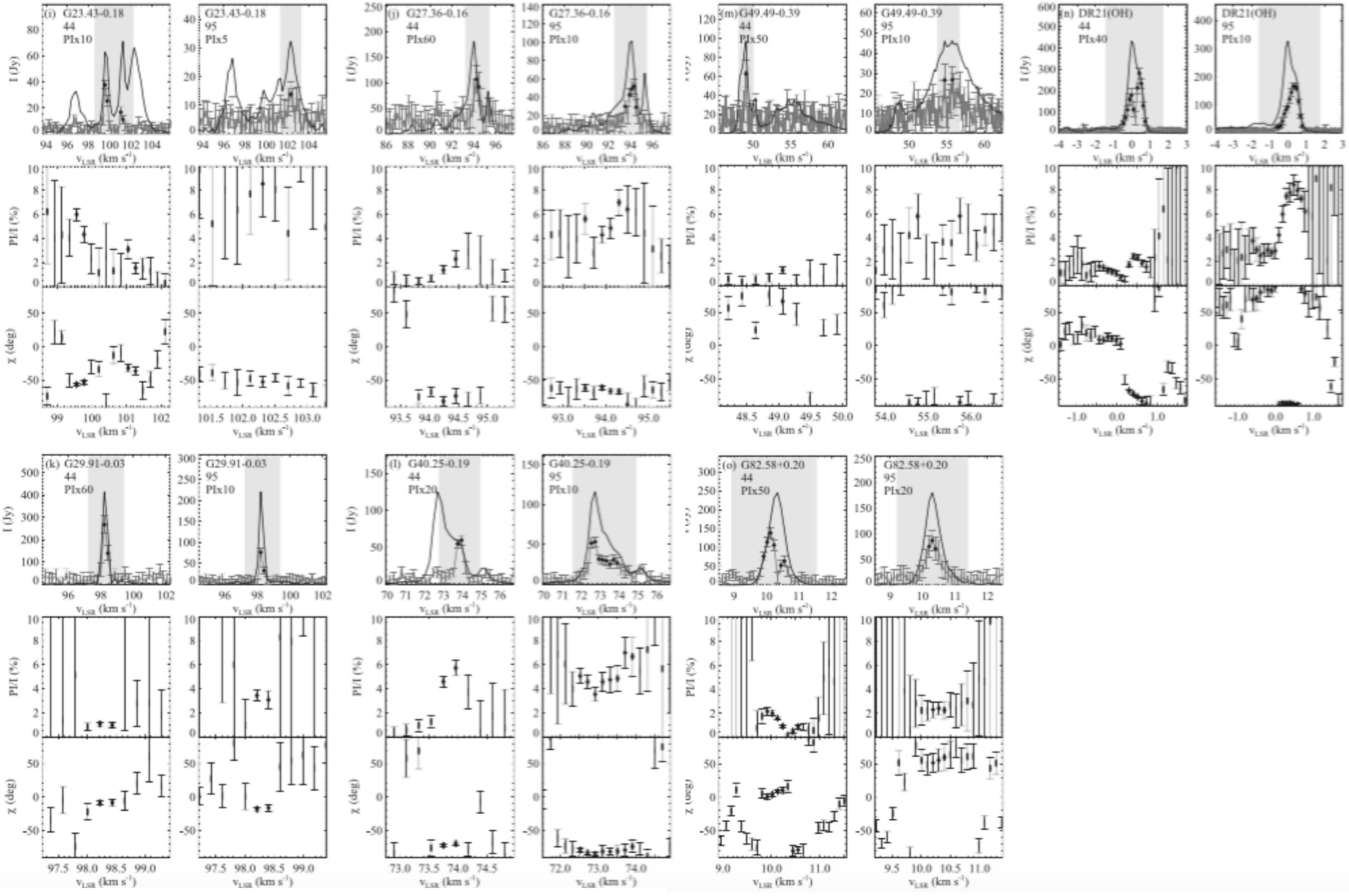

15
10
5
0
P_l [%]
−3
−2
−1
0
1
lg (R/Γ)
0
−2
−4
−6
lg (R/Γ)
0.1
0.15
0.2
0.25
ΔV [km s $^{-1}$]
$\Delta v_{thermal}$=0.3, θ=90°
$\Delta v_{thermal}$=0.3, θ=75°
$\Delta v_{thermal}$=0.3, θ=30°
$\Delta v_{thermal}$=0.35, θ=90°
$\Delta v_{thermal}$=0.4, θ=90°
$\Delta v_{thermal}$=0.5, θ=90°

G10.34-0.14 VLBI Results



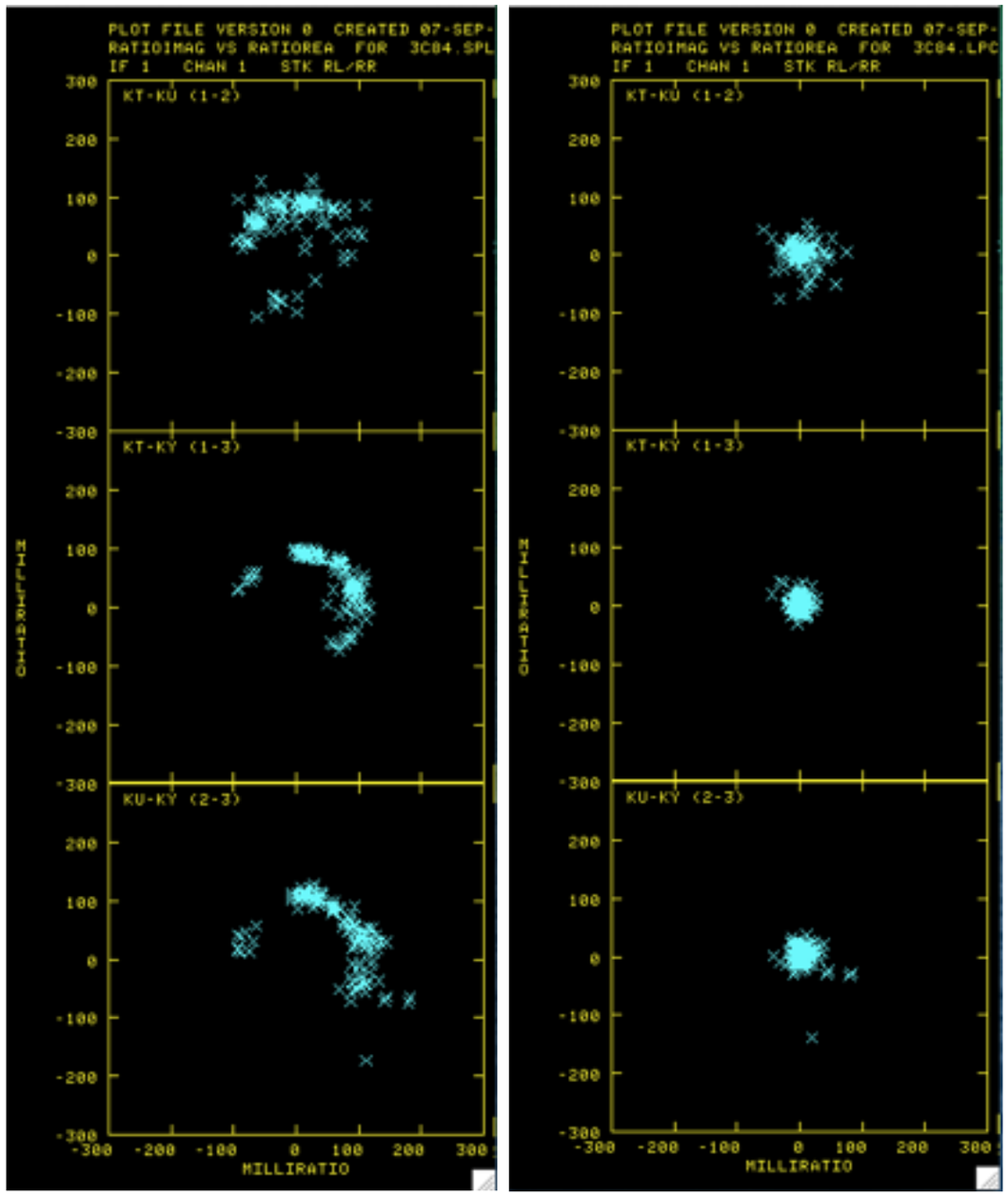
Cygnowski+09

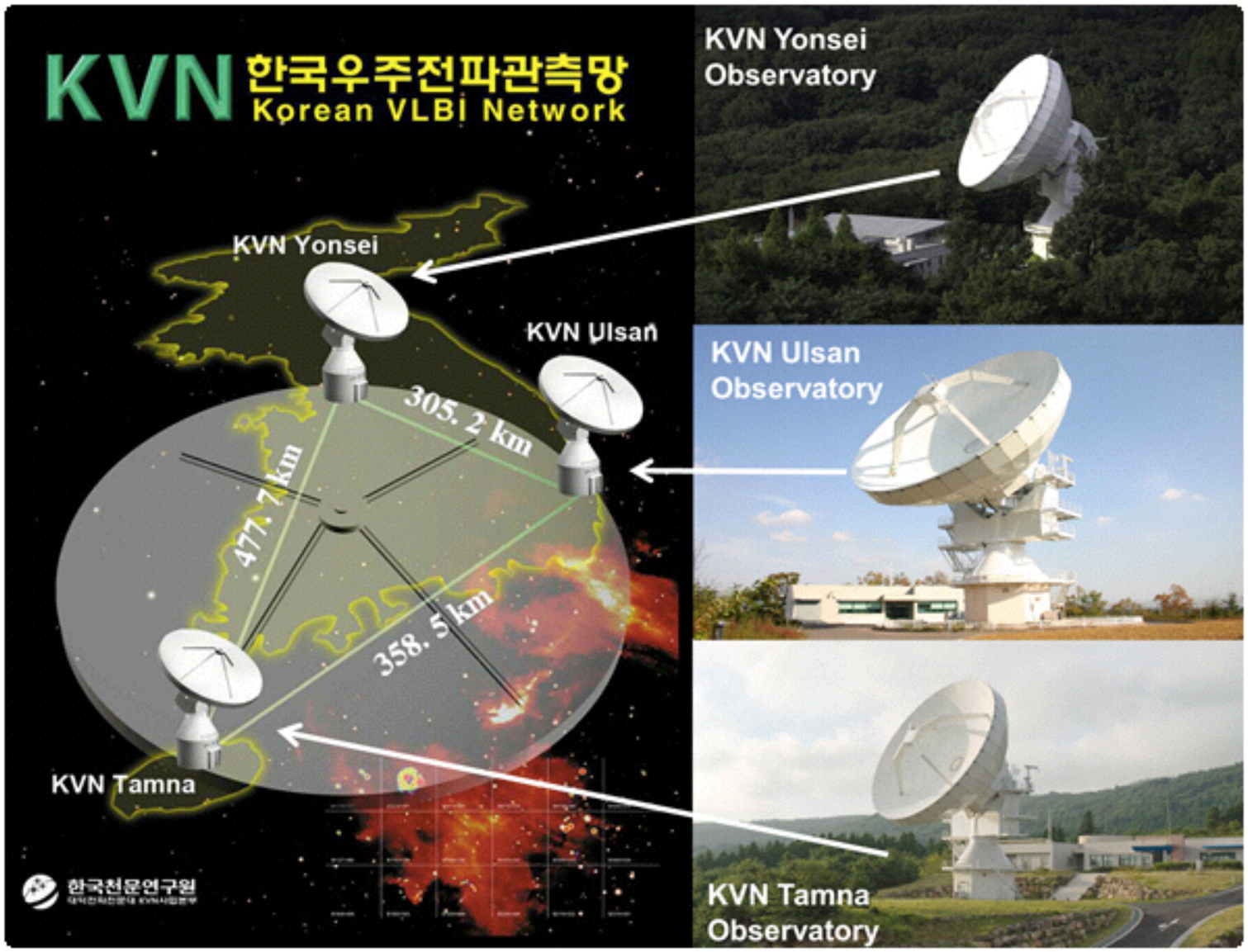


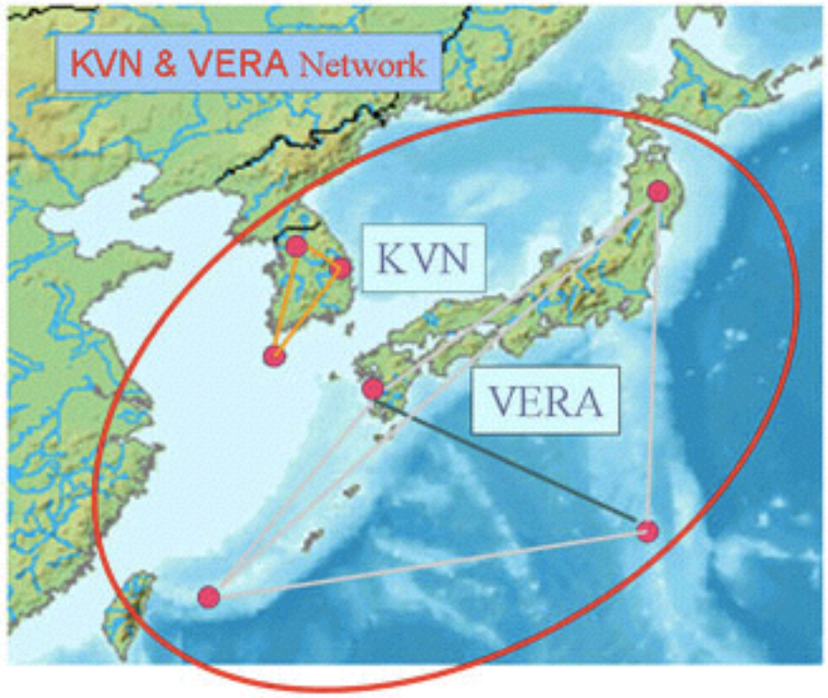

(i) G23.43-0.18
44
PIx10
G23.43-0.18
95
PIx5
(j) G27.36-0.16
44
PIx60
G27.36-0.16
95
PIx10
(m) G49.49-0.39
44
PIx50
G49.49-0.39
95
PIx10
(n) DR21(OH)
44
PIx40
DR21(OH)
95
PIx10
(k) G29.91-0.03
44
PIx60
G29.91-0.03
95
PIx10
(l) G40.25-0.19
44
PIx20
G40.25-0.19
95
PIx10
(o) G82.58+0.20
44
PIx50
G82.58+0.20
95
PIx20
I (Jy)
PI/I (%)
χ (deg)
v_LSR (km s^-1)

KVN VLBI

- 7 sources are observed in VLBI mode.
- G10.34-0.14 (EGO
- Observations date : 2014-2017


PLOT FILE VERSION 0 CREATED 07-SEP-
RATIOIMAG VS RATIOREA FOR 3C84.SPL
IF 1 CHAN 1 STK RL/RR
KT-KU (1-2)
KT-KY (1-3)
KU-KY (2-3)
MILLIRATIO
MILLIRATIO
PLOT FILE VERSION 0 CREATED 07-SEP-
RATIOIMAG VS RATIOREA FOR 3C84.LPC
IF 1 CHAN 1 STK RL/RR
KT-KU (1-2)
KT-KY (1-3)
KU-KY (2-3)
MILLIRATIO
MILLIRATIO


KVN 한국우주전파관측망
Korean VLBI Network
KVN Yonsei
KVN Ulsan
KVN Tamna
305. 2 km
477. 7 km
358. 5 km
KVN Yonsei
Observatory
KVN Ulsan
Observatory
KVN Tamna
Observatory
한국천문연구원


KVN & VERA Network
KVN
VERA

Flux Distribution

- Brighter maser features tend to have higher linear polarisation detection rates.

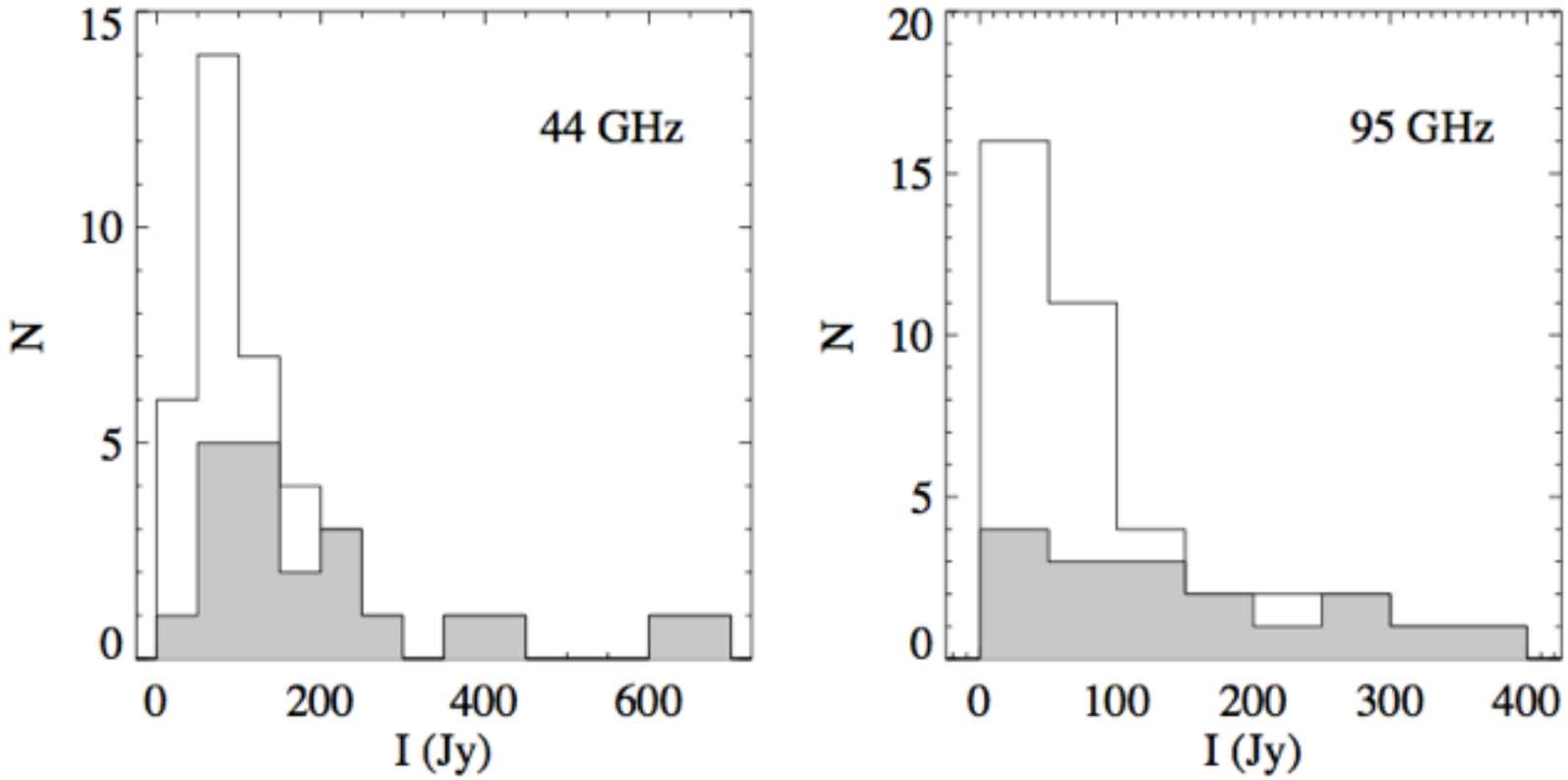


Fig. 1.— Number density distributions of the sources with the polarized emission (grey filled area) and of all observed sources (solid line) at 44 (left) and 95 GHz (right).

Polarization Fraction Distribution

- ~4% @ 44 GHz, ~7% @ 95 GHz

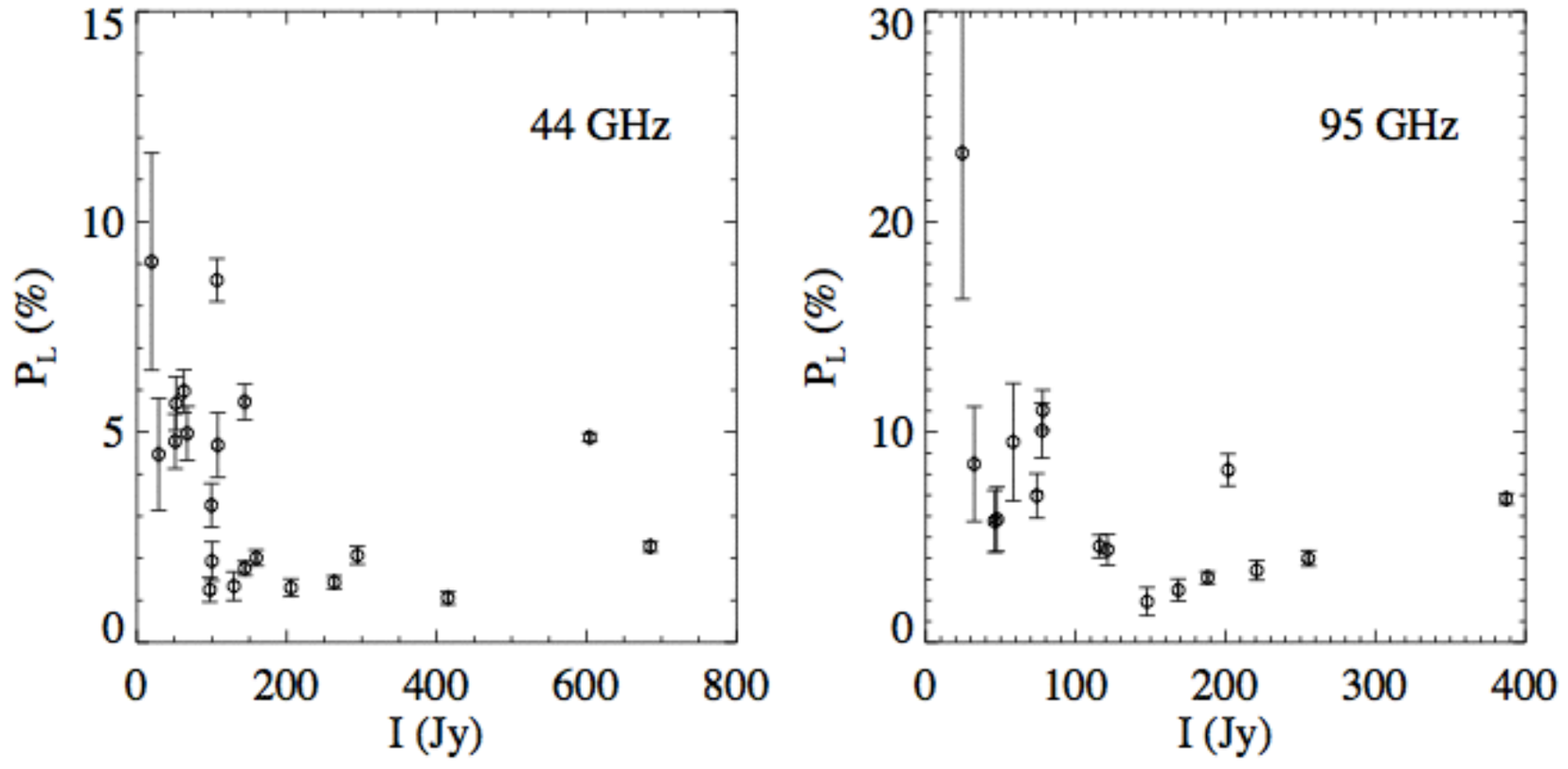
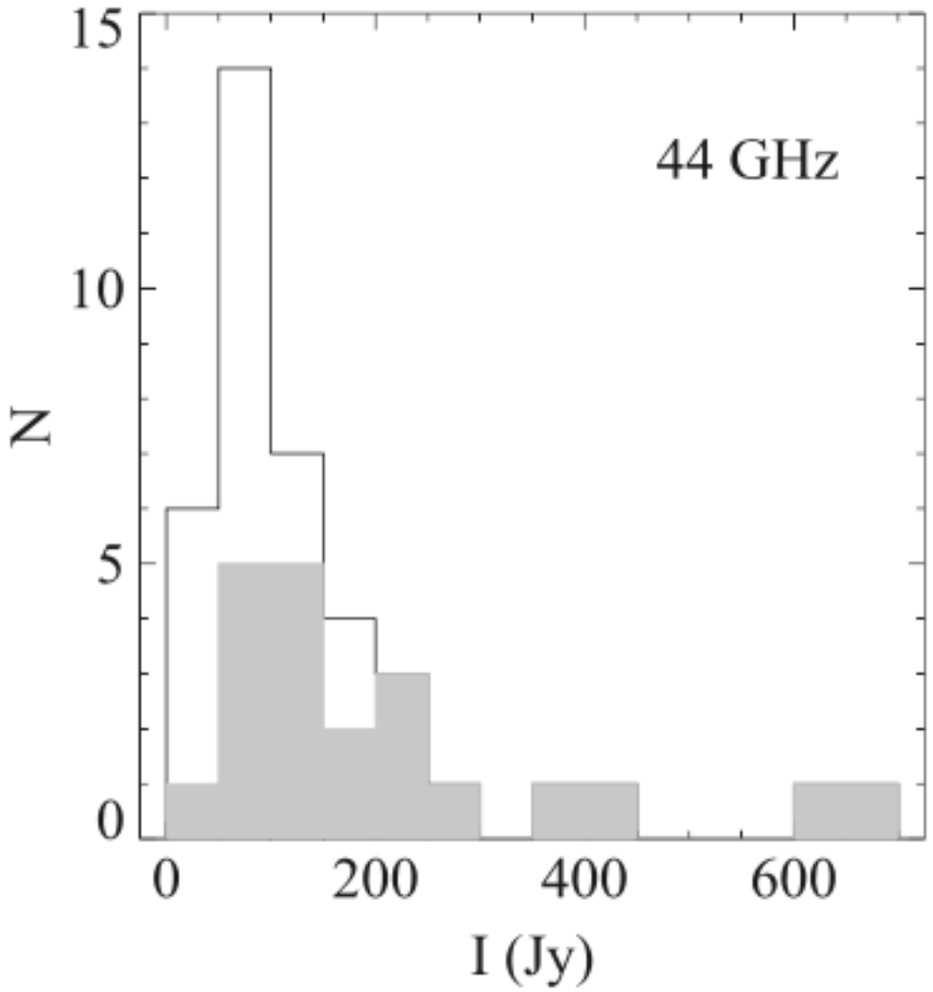
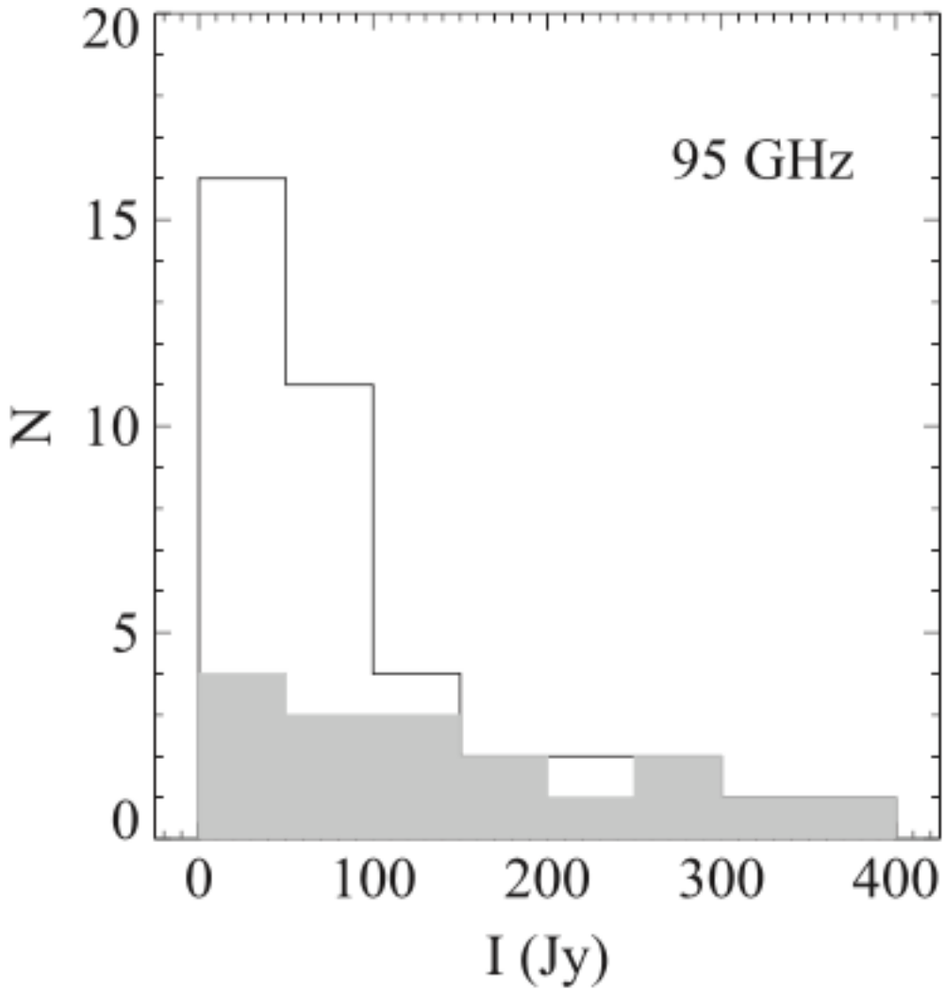
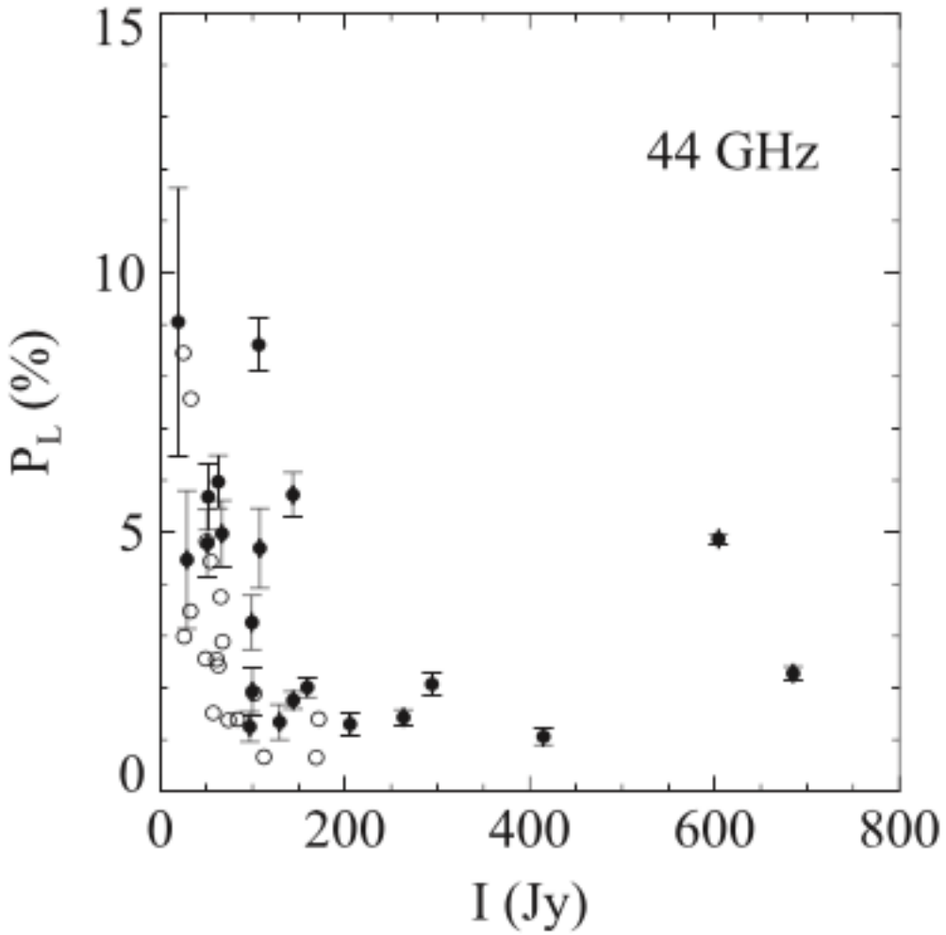
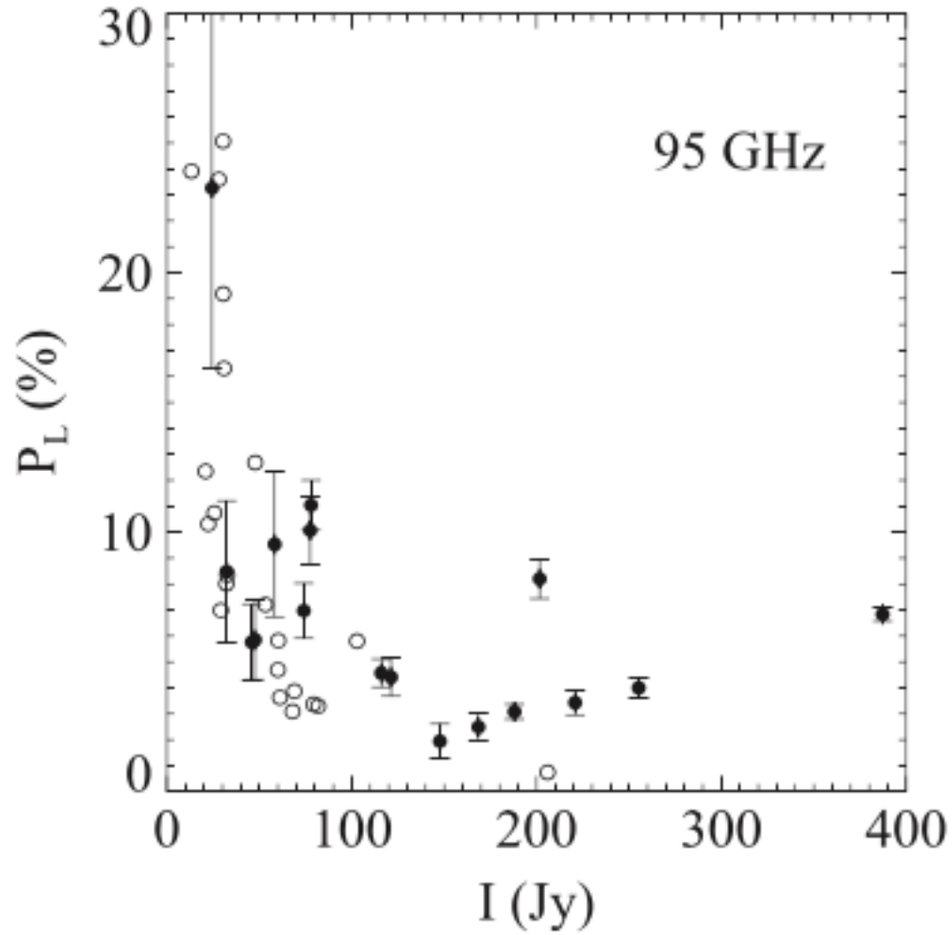


Fig. 3.— Polarization fraction P_L vs. total flux I at 44 (left) and 95 GHz (right). Errors of 1σ are presented.


44 GHz
N
I (Jy)
0
5
10
15
0
200
400
600


95 GHz
N
I (Jy)
0
5
10
15
20
0
100
200
300
400


44 GHz
P_L (%)
I (Jy)
0
5
10
15
0
200
400
600
800


95 GHz
P_L (%)
I (Jy)
0
10
20
30
0
100
200
300
400