



Max-Planck-Institut  
für  
Radioastronomie

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# Towards Polarization Measurements with LOFAR

Andreas Horneffer  
for the LOFAR Magnetism KSP



# The LOFAR MKSP

- LOFAR Key Science Project on Cosmic Magnetism
- 31 full members & 47 associated members

## Full Members

Rainer Beck, MPIfR Bonn (PI)  
James Anderson, MPIfR Bonn  
George Heald, ASTRON Dwingeloo  
Anna Scaife, Dublin Inst. for Advanced Studies  
Paul Alexander, MRAO Cambridge  
Michael Bell, MPA Garching  
Michiel Brentjens, ASTRON Dwingeloo  
Ger de Bruyn, ASTRON Dwingeloo  
Chris Chyzy, Univ. Kraków  
Ralf-Jürgen Dettmar, Univ. Bochum  
Torsten Enßlin, MPA Garching  
Andrew Fletcher, Univ. Newcastle  
Jörn Geisbüsch, Dominion Radio Observatory  
René Gießübel, MPIfR Bonn  
Marijke Haverkorn, ASTRON Dwingeloo  
Andreas Horneffer, MPIfR Bonn  
Marco Iacobelli, Sterrewacht Leiden  
Henrik Junklewitz, MPA Garching  
Masaya Kuniyoshi, MPIfR Bonn  
Enno Middelberg, Univ. Bochum  
Arpad Miskolczi, Univ. Bochum  
David Mulcahy, MPIfR Bonn  
Aris Noutsos, MPIfR Bonn  
Emanuela Orru, Univ. Nijmegen  
Roberto Pizzo, ASTRON Dwingeloo  
Wolfgang Reich, MPIfR Bonn  
Thomas Riller, MPA Garching  
Carl Shneider, Sterrewacht Leiden  
Charlotte Sobey, MPIfR Bonn  
Carlos Sotomayor, Univ. Bonn  
Alice di Vincenzo, Tautenburg Obs.

## Associated members (42):

Björn Adebahr, Univ. Bochum  
Tigran Arshakian, MPIfR Bonn  
Nadya Ben Bekhti, Univ. Bonn  
Gianni Bernardi, CfA Cambridge  
Dominik Bomans, Univ. Bochum  
Jess Broderick, Univ. Southampton  
Marcus Brügggen, Jacobs Univ. Bremen  
Ettore Carretti, CSIRO Sydney  
John Conway, Onsala Radio Obs.  
Robert Drzazga, Univ. Kraków  
Sven Duscha, ASTRON Dwingeloo  
Jochen Eislöffel, Tautenburg Obs.  
Jamie Farnes, MRAO Cambridge  
Lauranne Fauvet, Univ. Nijmegen  
Luigina Feretti, IRA Bologna  
Katia Ferrière, Univ. Toulouse  
Dave Green, MRAO Cambridge  
Volker Heesen, Univ. Hertfordshire  
Matthias Hoeft, Tautenburg Obs.  
Cathy Horellou, Onsala Radio Obs.  
Marek Jamroz, Univ. Kraków  
Jens Jasche, Univ. Bonn  
Vibor Jelić, ASTRON Dwingeloo  
Wojciech Jurusik, Univ. Kraków  
Jongsoo Kim, Korea Astronomy & Space Science Institute  
Ulrich Klein, Univ. Bonn  
Michael Kramer, MPIfR Bonn  
Marita Krause, MPIfR Bonn  
Martin Krause, MPE Garching  
Halime Miraghaei, MPIfR Bonn  
Katarzyna Otmianowska-Mazur, Univ. Kraków  
Rosita Paladino, IRA Bologna  
Amrita Purkayastha, Univ. Bonn  
Julia Riley, MRAO Cambridge  
Dominic Schnitzler, ATNF Sydney  
Anvar Shukurov, Univ. Newcastle  
Marian Soida, Univ. Kraków  
Ben Stappers, Univ. Manchester  
Fateme Tabatabaei, MPA Heidelberg  
Monica Trasatti, Univ. Bonn  
Marek Urbanik, Univ. Kraków  
Marek Weżgowiec, Univ. Bochum



# DFG Research Unit 1254

- Topic: Magnetization of Interstellar and Intergalactic Media Media – The Prospects of Low-Frequency Radio Observations
- Active since summer 2010
- 10 PhD students & 2 postdocs





# MKSP Activities

## (in the last year)

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- three busy weeks
- first polarization signal found
  - in pulsars with pulsar data
  - in point sources
  - in extended sources
- first version of a detailed commissioning plan



# 1<sup>st</sup> busy week

- Location: ASTRON
- Date: 18.-22. October 2010
- 28 Participants at ASTRON

Rainer Beck	Alice Di Vincenzo	Emanuela Orru
Rene Giessuebel	Matthias Hoefft	Rosita Paladino
Andreas Horneffer	Jana Koehler	Amrita Purkayastha
Masaya Kuniyoshi	Sandra Schumann	Monica Trasatti
Halime Mir Aghaee	Marco Iacobelli	Ger de Bruyn
David Mulcahy	Carl Shneider	Marijke Haverkorn
Aris Noutsos	Wojciech Jurusik	George Heald
Charlotte Sobey	Jongsoo Kim	Roberto Pizzo
Michael Bell	Arpad Miskolczi	
Henrik Junklewitz	Carlos Sotomayor	

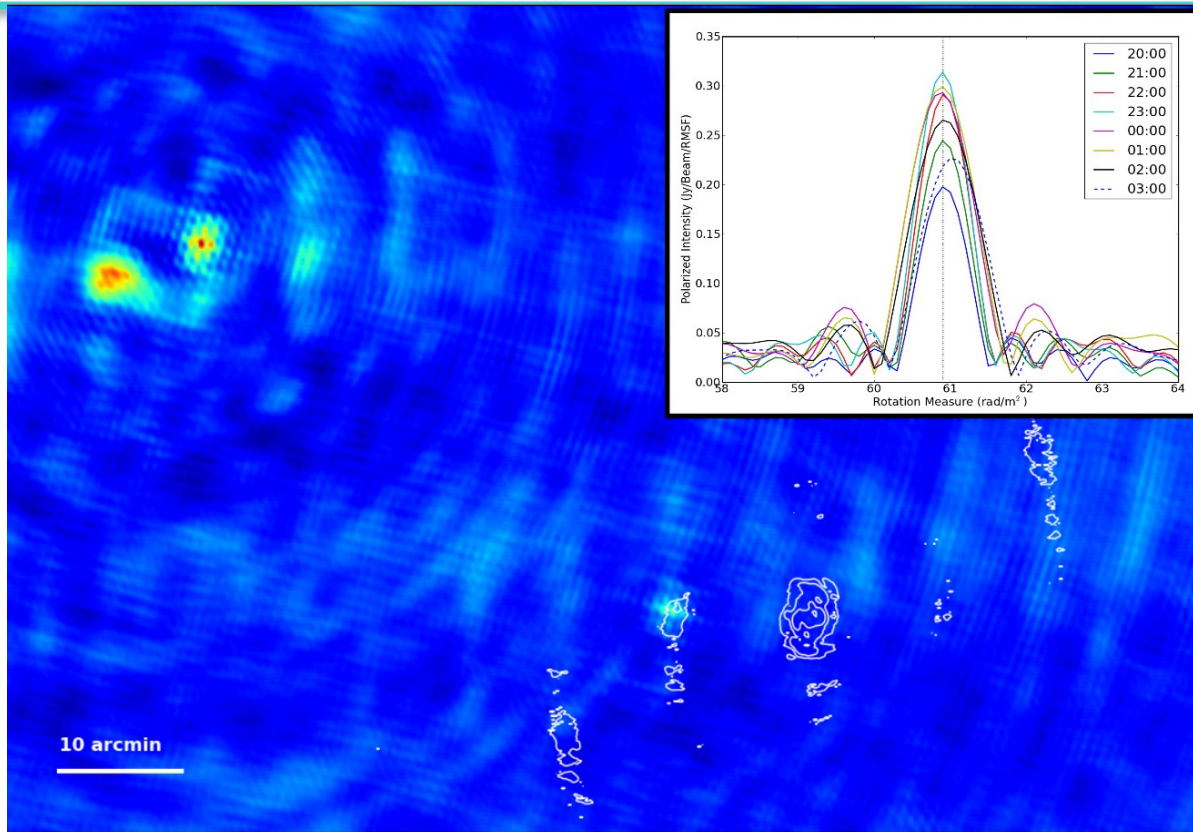


# Goals

- Exercise in imaging: familiarize new members with LOFAR imaging procedures
- Test if we can detect polarization of a highly polarized point source: PSR J0218+42
- If possible track changes in Faraday depth with time, to see effects of the ionosphere.



# Results



M.Bell

- Astron daily image 16. March 2011





# 2<sup>nd</sup> Busy Week

- Location: MPIfR Bonn
- Date: 21. – 25. March 2011
- 20 Participants in Bonn plus 3 remote:

Arpad	Miscolczi	Emanuela	Orru
Björn	Adebahr	Rosita	Paladino
James	Anderson	Amrita	Purkayastha
Rainer	Beck	Sandra	Schumann
Alice	Di Vincenzo	Carl	Shneider
Rene	Gießübel	Charlotte	Sobey
Andreas	Horneffer	Carlos	Sotomayor
Marco	Iacobelli	Monica	Trasatti
Jana	Köhler		
Masaya	Kuniyoshi	Jörn	Geisbüsch
Halime	Miraghaee	Marijke	Haverkorn
David	Mulcahy	Roberto	Pizzo





# Workgroups

## 1. Pulsar Survey

- Pulsar (time series) data for 22 pulsars

## 2. PSR J0218+42

- 10h (imaging) observation of the object of our last BW
  - with station calibration
  - from high till very low elevation
  - including the sunset

## 3. NGC 4631 (edge on galaxy)

- 6h observation

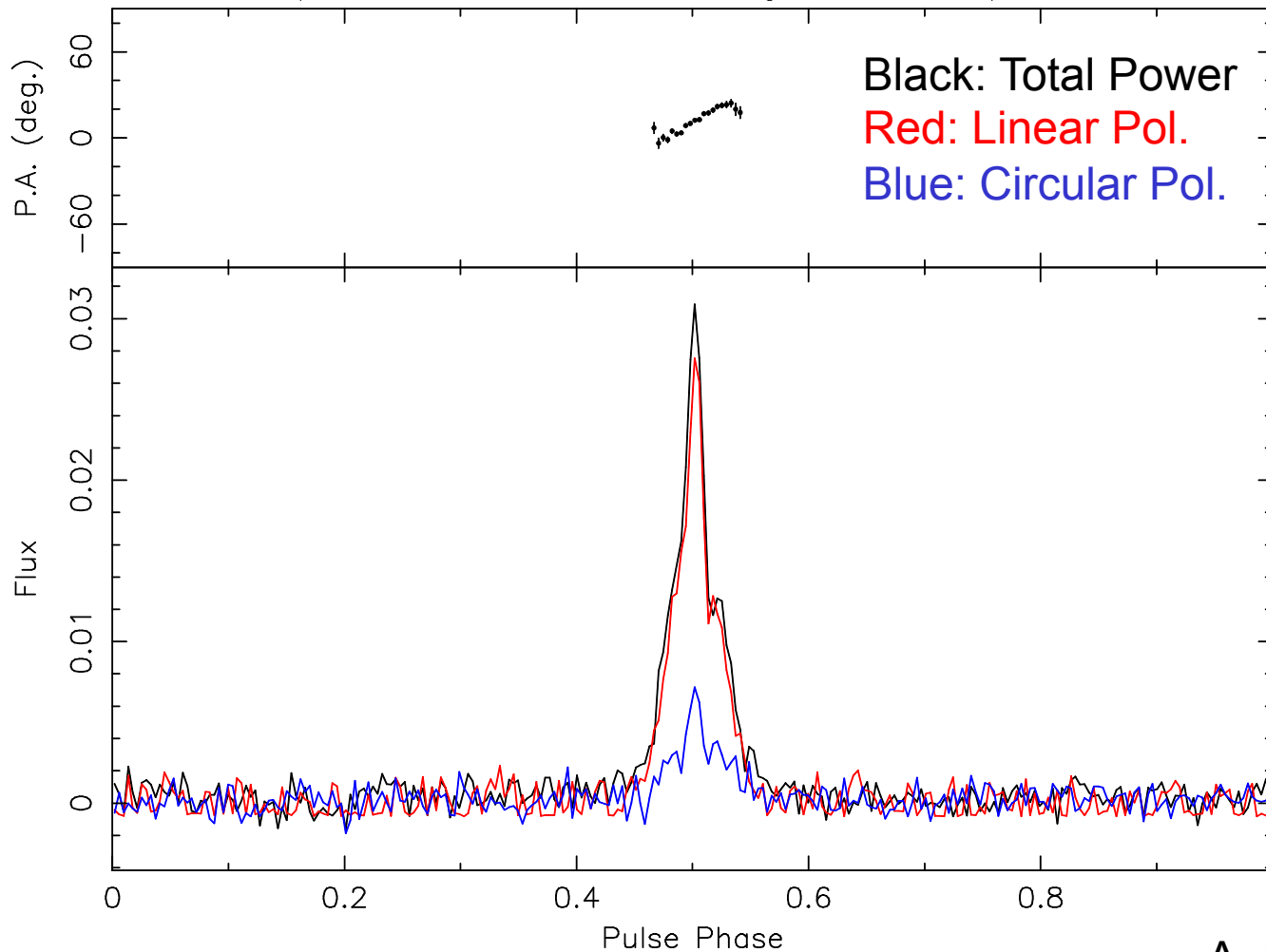
## 4. Fan region

- 6h observation
- strong diffuse polarization and no total intensity



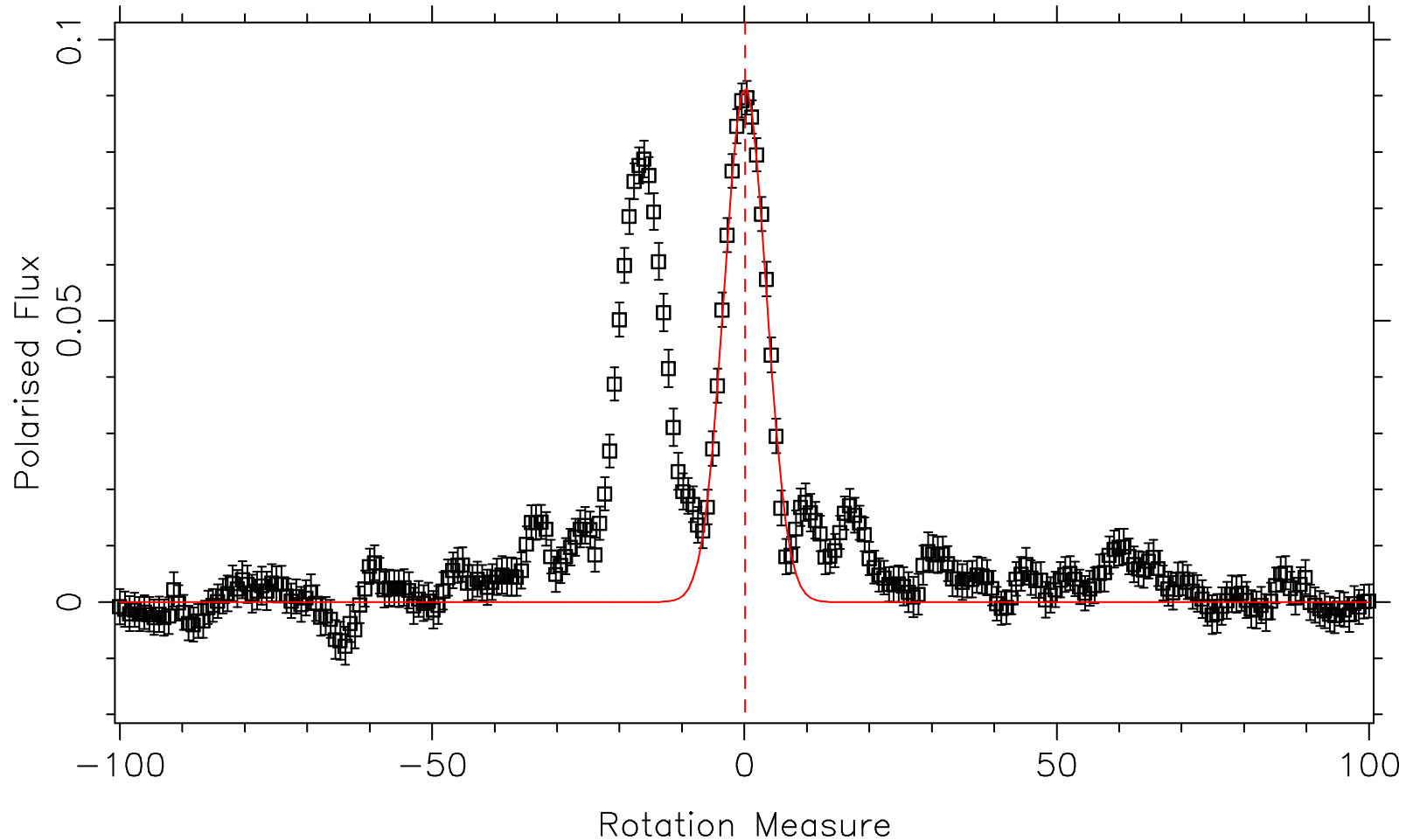
# Results: PSR B1929+10

J1932+1059 B1929+10-L24024.ar.ST  
Freq: 136.322 MHz BW: 6.250 Length: 599.999 S/N: 55.889





# Results: PSR B1642-03 RM-Synthesis





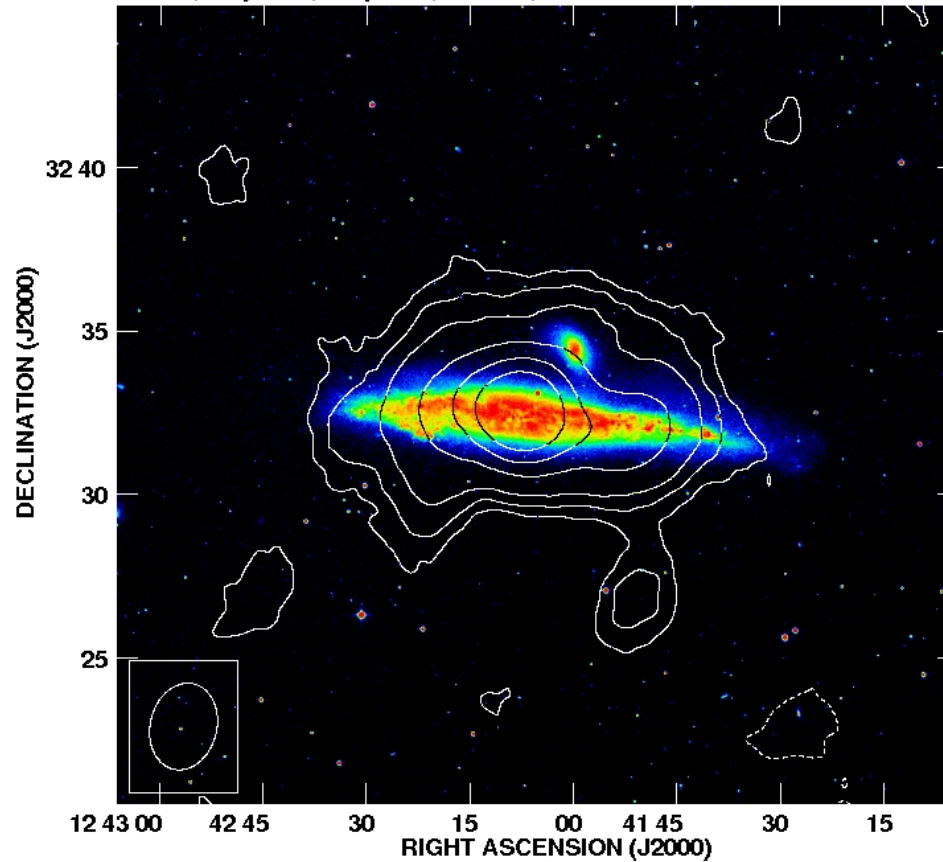
# Results: Pulsar Table

PSRB	OBSID	(L/I)%	ERR	RMfit (rad m <sup>-2</sup> )	ERR	PAfit (rad m <sup>-2</sup> )	ERR	PUBRM (rad m <sup>-2</sup> )	ERR	DATE	TIME (UT)	Az (deg)	Alt (deg)
0136+57	L24052	69	8	93	1	93	2	-90	4	13-03	14:00	343.68	84.39
0525+21	L24050	35	—	38	—	38	3	-39.6	0.2	13-03	18:00	330.21	39.35
0809+74	L24117	13	3	13.5	0.6	14	2	-11.7	1.3	14-03	20:50	354.25	68.16
0809+74	L24116	16	1	12.5	0.5	12	4	-11.7	1.3	14-03	21:40	346.18	66.86
0823+26	L24115	26	1	-5	—	-4	1	5.9	0.3	14-03	21:03	196.45	63.02
0823+26	L24114	25	2	-4	—	-3	1	5.9	0.3	14-03	22:13	226.35	57.45
0834+06	L24113	21	4	-26	—	-26	1	23.6	0.7	14-03	21:16	191.92	42.73
0834+06	L24112	22	4	-26	—	-27	1	23.6	0.7	14-03	22:30	215.51	38.22
0950+08	L24111	69	0.3	-2	—	-2	—	-0.66	0.04	14-03	22:00	181.13	45.03
0950+08	L24110	66	0.1	-2	—	-2	—	-0.66	0.04	14-03	23:00	201.78	43.22
1133+16	L24152	33	4	-4.5	—	-3	1	1.1	0.2	15-03	00:10	192.13	52.48
1133+16	L24151	32	6	-4	—	-2	1	1.1	0.2	15-03	01:20	217.72	47.99
1237+25	L24150	33	—	-0.6	—	-1	2	-0.33	0.06	15-03	01:00	188.52	61.80
1237+25	L24149	29	5	-0.2	0.3	-1	2	-0.33	0.06	15-03	02:00	215.23	58.39
1508+55	L23996	11	1	-1.8	0.4	0	2	0.8	0.7	13-03	04:00	298.10	83.55
1541+09	L24162	28	5	-17	1	-17	3	21	2	15-03	04:13	189.74	46.25
1642-03	L24010	19	1	-16.3	—	-17	1	15.8	0.3	13-03	05:00	181.35	33.83
1642-03	L24009	31	14	-16	3	-17	2	15.8	0.3	13-03	06:00	199.17	32.21
1642-03	L24160	17	2	-16	—	-17	1	15.8	0.3	15-03	05:00	183.71	33.77
1642-03	L24159	33	9	-17	—	-17	1	15.8	0.3	15-03	06:00	201.44	31.79
1919+21	L24006	17	3	16.4	0.4	15	2	-16.5	0.5	13-03	08:00	192.94	58.51
1929+10	L24025	79	2	5.6	—	6	1	-6.87	0.02	13-03	08:13	191.33	47.64
1929+10	L24024	81	3	5.8	0.6	6	1	-6.87	0.02	13-03	09:13	212.08	44.27
1953+50	L24022	9	4	20	2	22	5	-22	2	13-03	09:50	273.87	73.75
2224+65	L24035	18	13	22	2	21	7	-21	3	13-03	12:43	320.85	69.59



# Results: NGC 4631 First Image

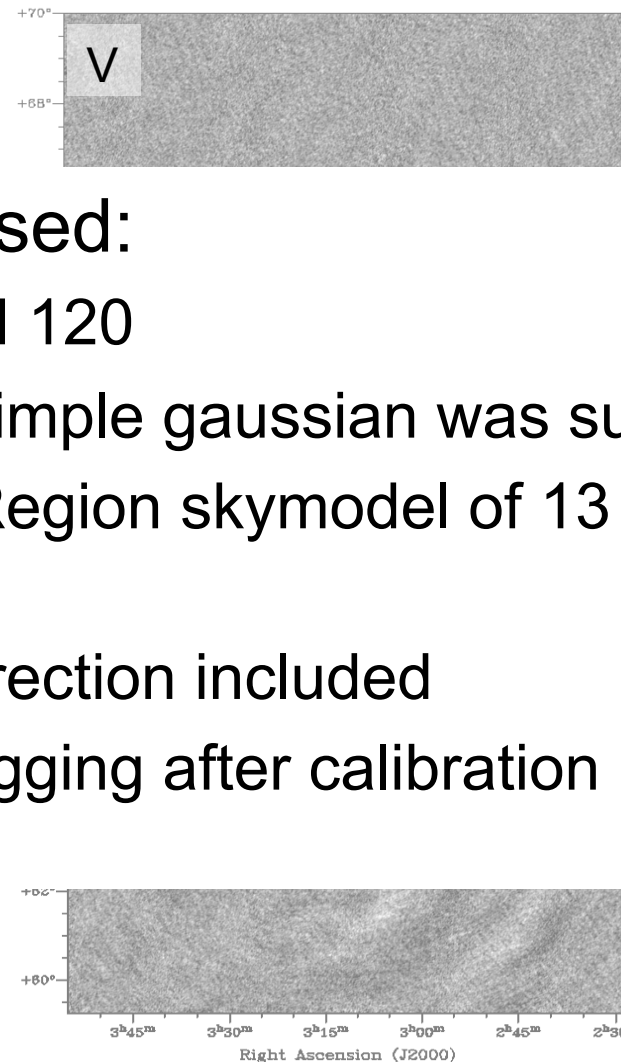
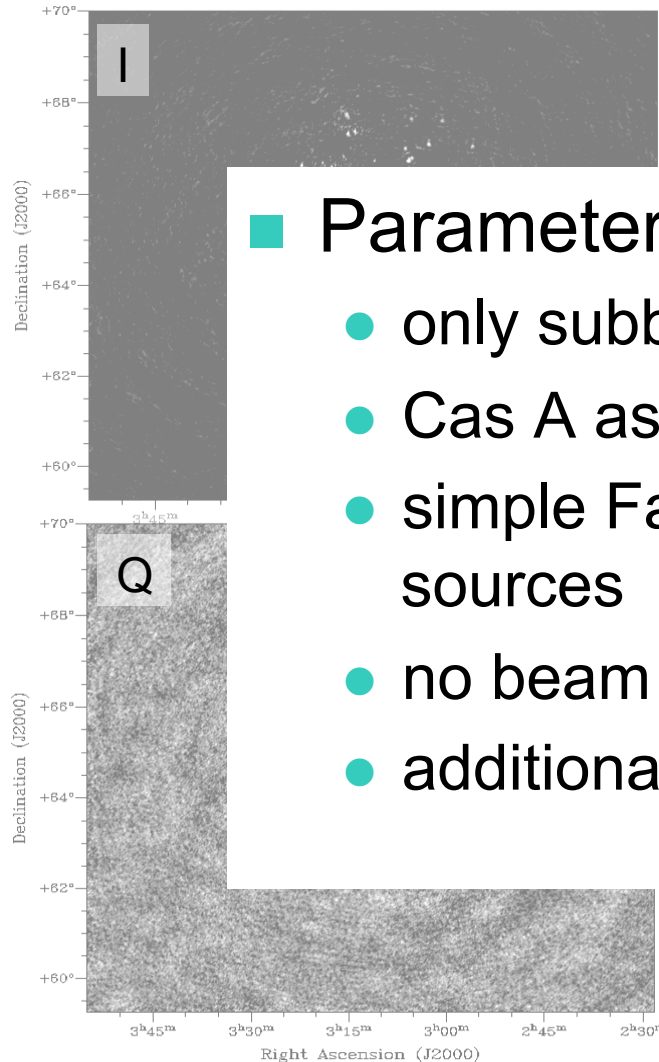
LOFAR MKSP COMMISSIONING  
NGC 4631 at 157 MHz (subband nr. 150)  
Robert, Wojciech, Krzysztof, Krakow, 23.02.2011



Grey scale flux range= 12.72 27.81 Kilo  
Cont peak flux = 3.5229E+00 JY/BEAM  
Levs = 2.200E-02 \* (-5, -3, 3, 5, 8, 16, 24, 32,  
64, 128, 256, 512, 1024)



# Results: Fan Region



## Parameters used:

- only subband 120
- Cas A as a simple gaussian was subtracted
- simple Fan Region skymodel of 13 point sources
- no beam correction included
- additional flagging after calibration

Maps by  
E. Orru &  
R. Pizzo



# 3<sup>rd</sup> Busy Week

- Location: ASTRON
- Date: 6. – 10. June 2011
- 18 Participants in ASTRON plus 3 remote:

Björn	Adebahr	David	Mulcahy
Mike	Bell	Blazej	Wroczynski
Ger	de Bruyn	Aris	Nutsos
Alice	Di Vincenzo	Emanuela	Orru
Rene	Gießübel	Roberto	Pizzo
Marijke	Haverkorn	Thomas	Riller
George	Heald	Charlotte	Sobey
Andreas	Horneffer		
Marco	Iacobelli	James	Anderson
Jana	Köhler	Robert	Drzazga
Masaya	Kuniyoshi	Carlos	Sotomayor





# Datasets

1. NGC 4631
  - 7 hour observation with 3C286 as calibrator
  - same frequency coverage on NGC 4631 and calibrator
2. M51
  - 5 hour observation with 3C295 as calibrator
  - same frequency coverage on M51 and calibrator
3. Double-Double Radio Galaxy
  - 7 hour observation
4. Pulsars
  - some more Pulsars observed
5. PSR J0218+42
  - observation from our last BW
6. Fan Region of the Milky Way
  - observation from our last BW

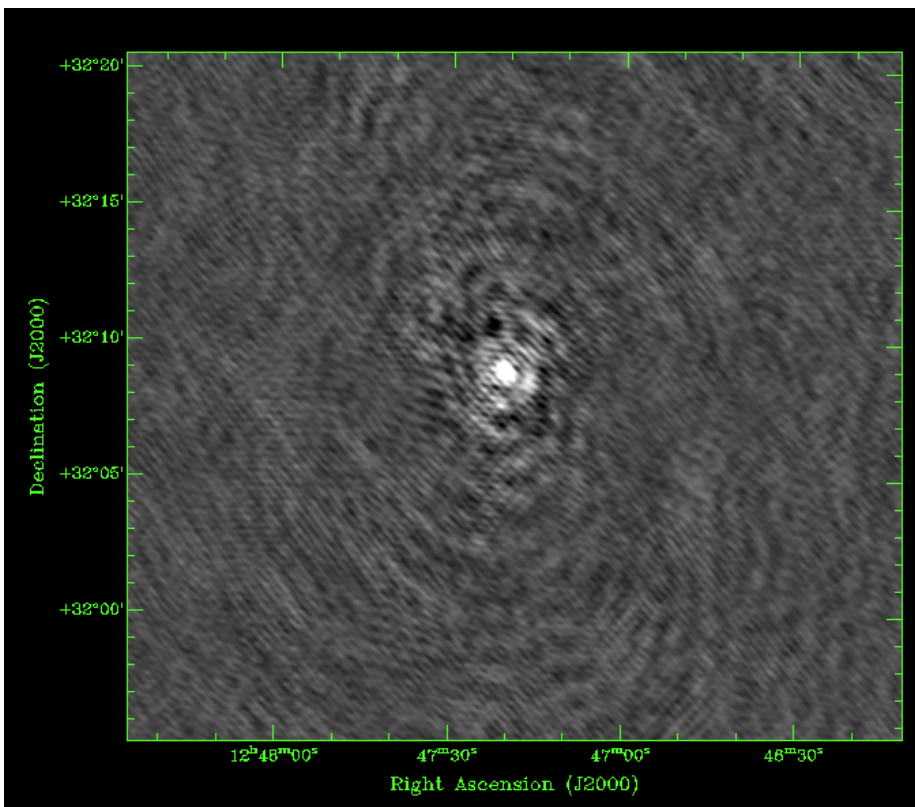


# Workgroups

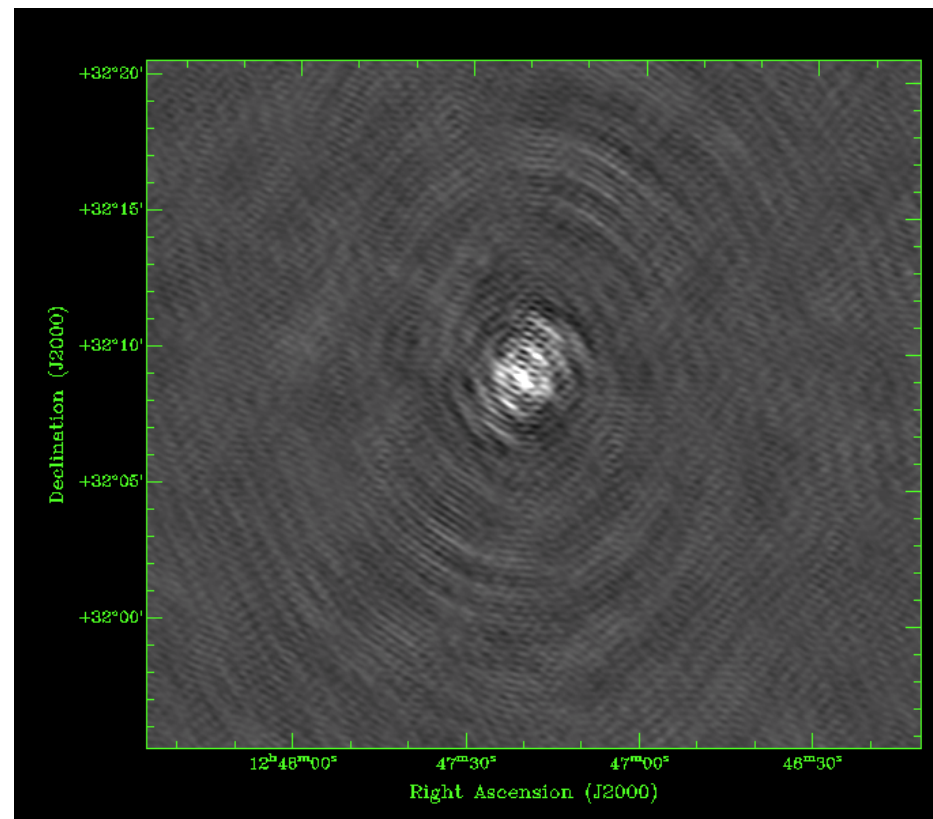
- imaging of NGC 4631 and M51 with selfcal and transfer of gain solutions from calibrator
- imaging of Double Double galaxy
- time resolved RM-Synthesis of pulsars
  - pulsar data
  - PSR J0218 imaging data
- RM-Synthesis of Fan Region data



# NGC 4631: Difference WENSS - Caltrans



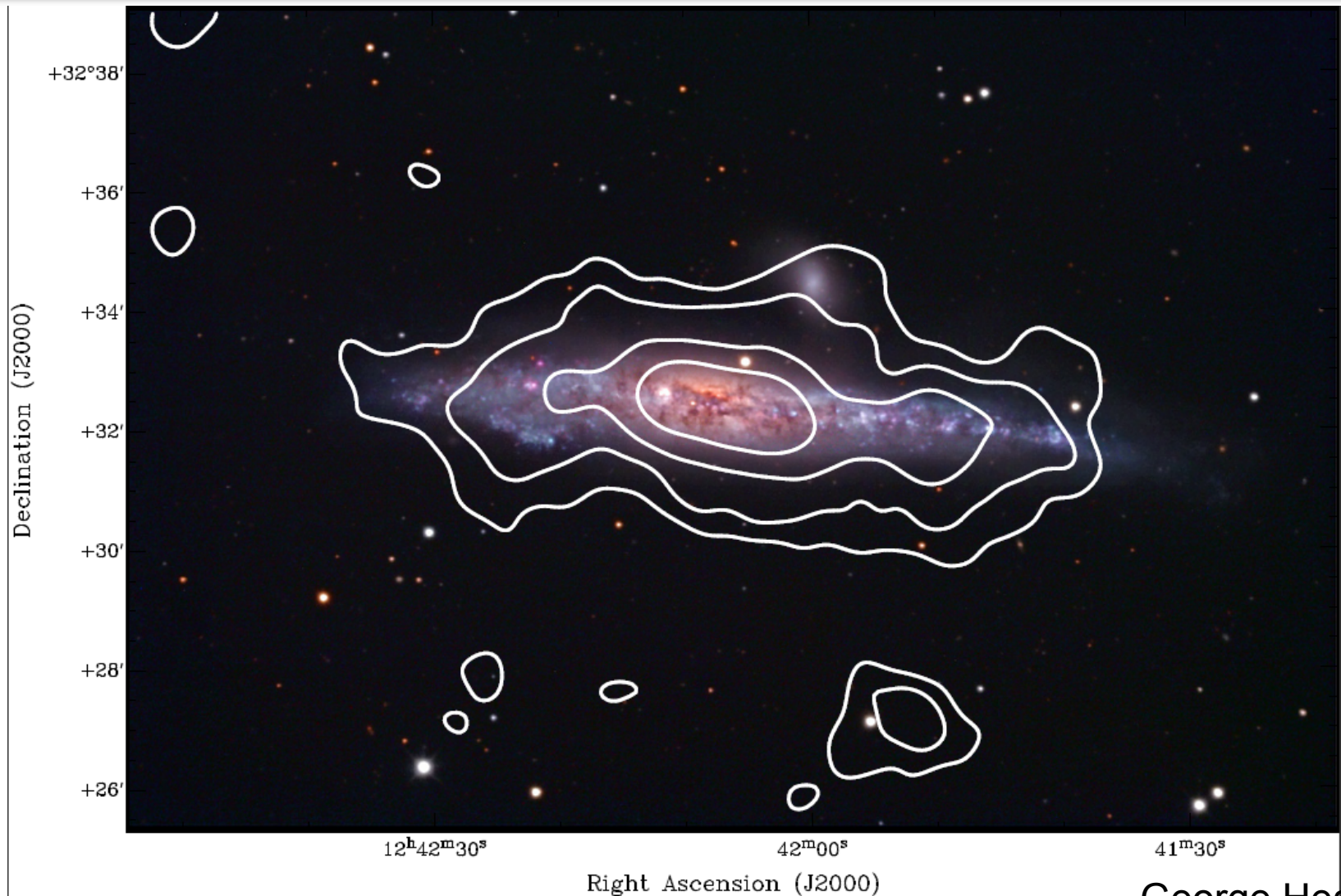
Solution Transfer



WENSS Selfcal



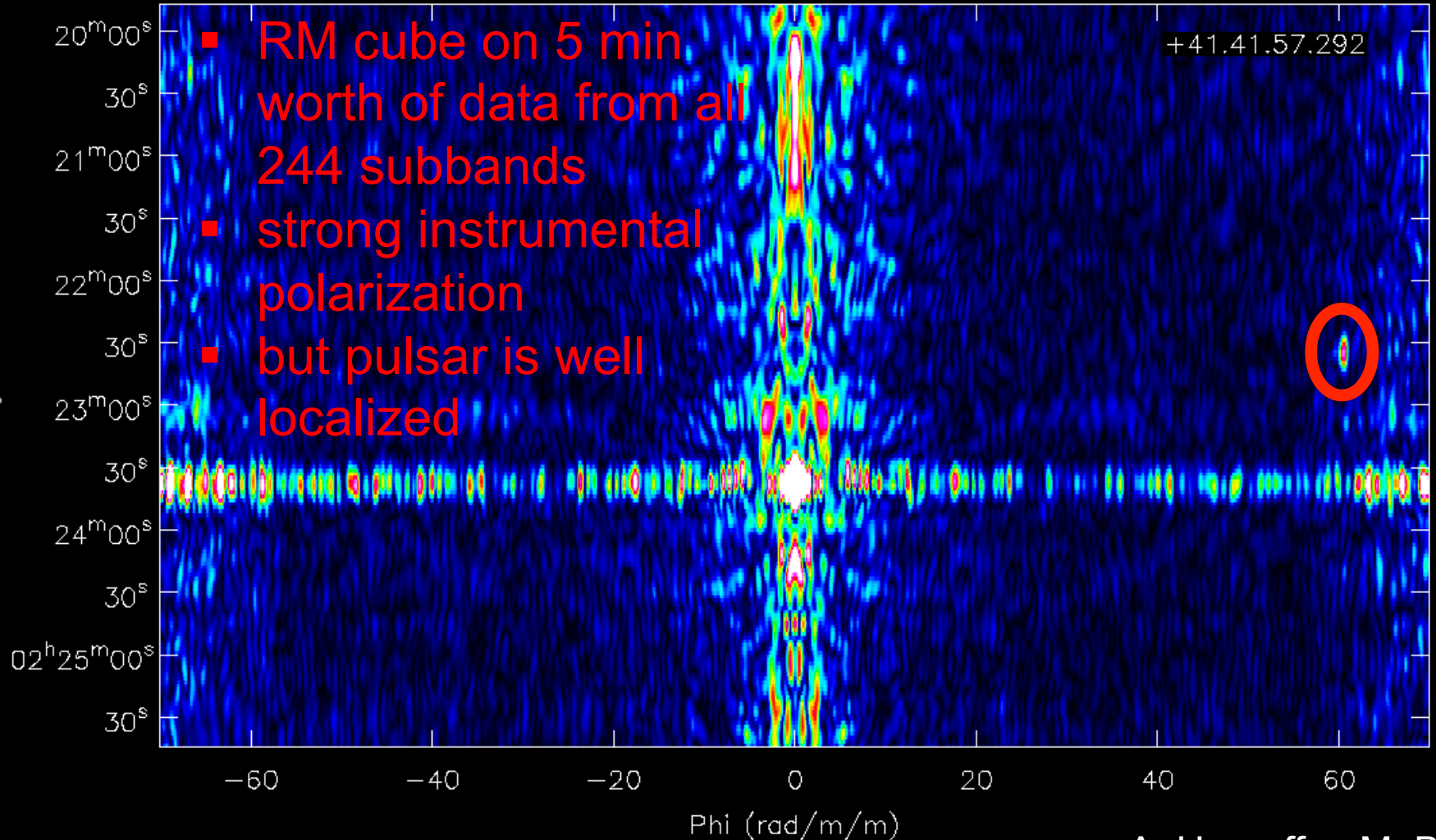
# NGC 4631: After Transfer and Scrubbing







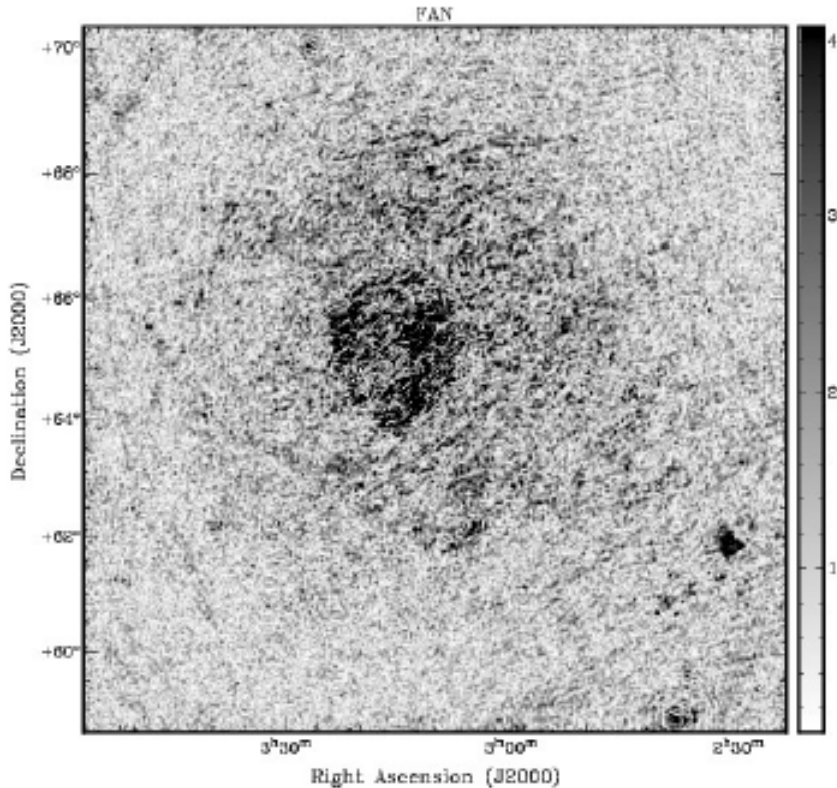
# PSR 0218: RM-Synthesis



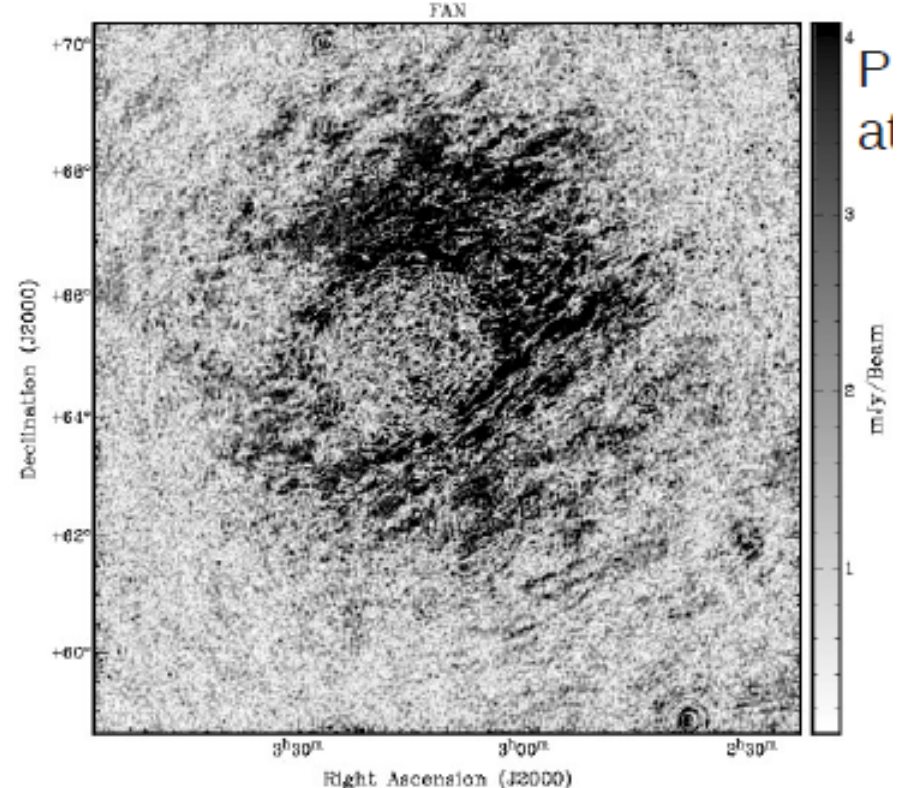


# Fan Region: WSRT Results

FD = -6 rad/m/m



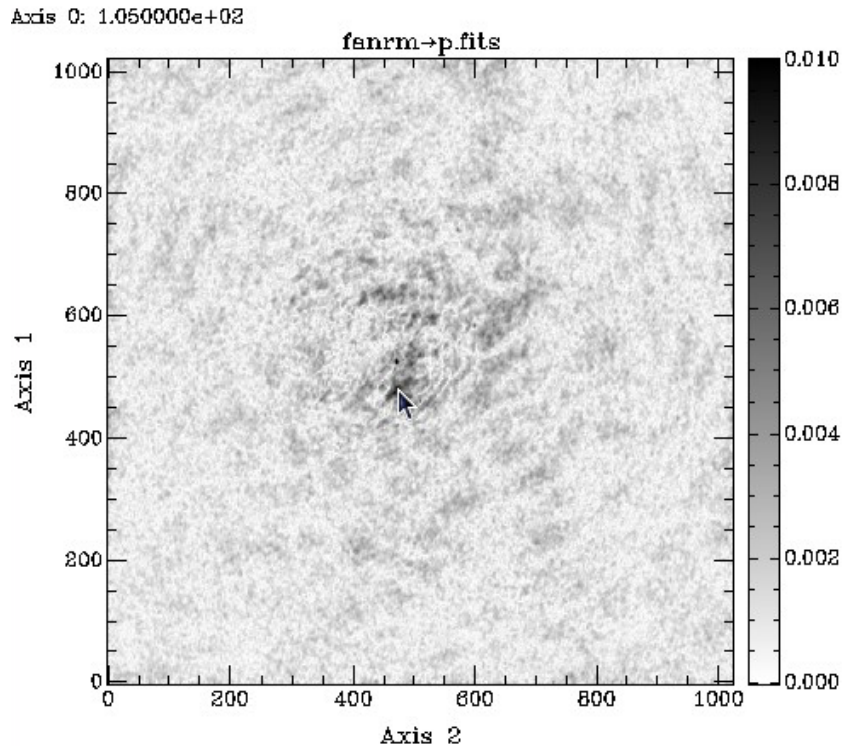
FD = -2 rad/m/m



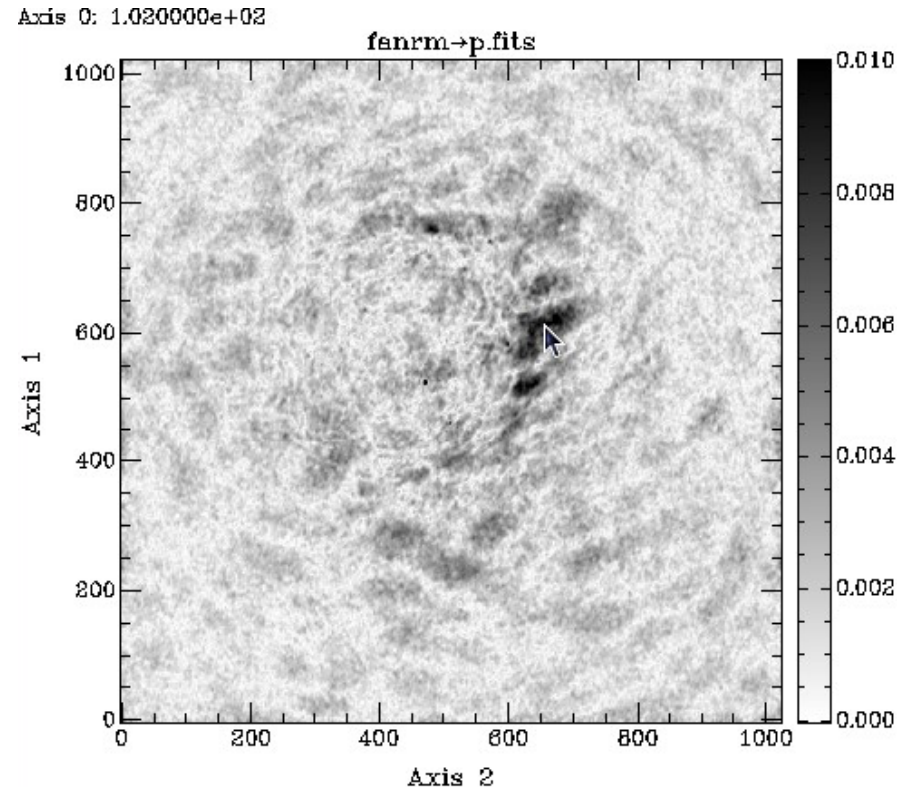


# Fan Region: LOFAR Results

FD = -5 rad/m/m



FD = -2 rad/m/m







# More on Results

- Pulsars → Talk by Charlotte Sobey
- Galaxies → Talk by David Mulcahy
- Fan Region → Talk by Emanuela Orru

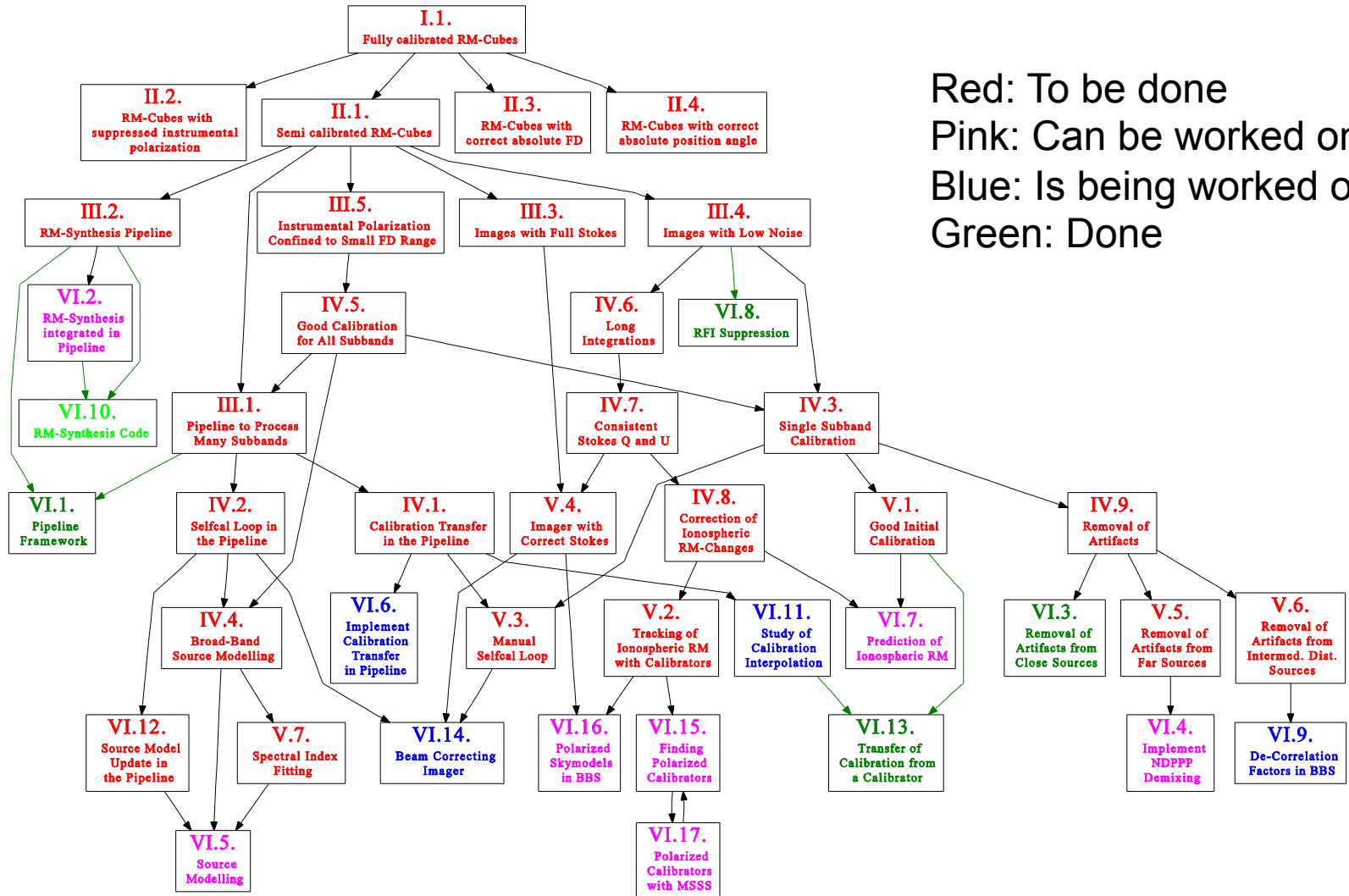


# Commissioning Plan

- Get an overview of what needs to be done.
  - Made a start: List of steps to get RM-Cubes with limited calibration and field of view.
- Streamline the commissioning process:
  - Show how the tasks interact.
  - Targeted development of capabilities.
  - Well defined tasks that can be carried out by a student and included in their thesis.



# Commissioning Plan: Task Graph





# Current Major Topics

- Calibration
  - Transfer of calibration to different subbands and/or times
  - Prediction of Ionospheric RM
- Software
  - Test new capabilities/features (RM in BBS, imager)
  - Include RM-Synthesis into the pipeline
  - Close the selfcal loop
- Other
  - Get list of polarization calibrators



# Summary

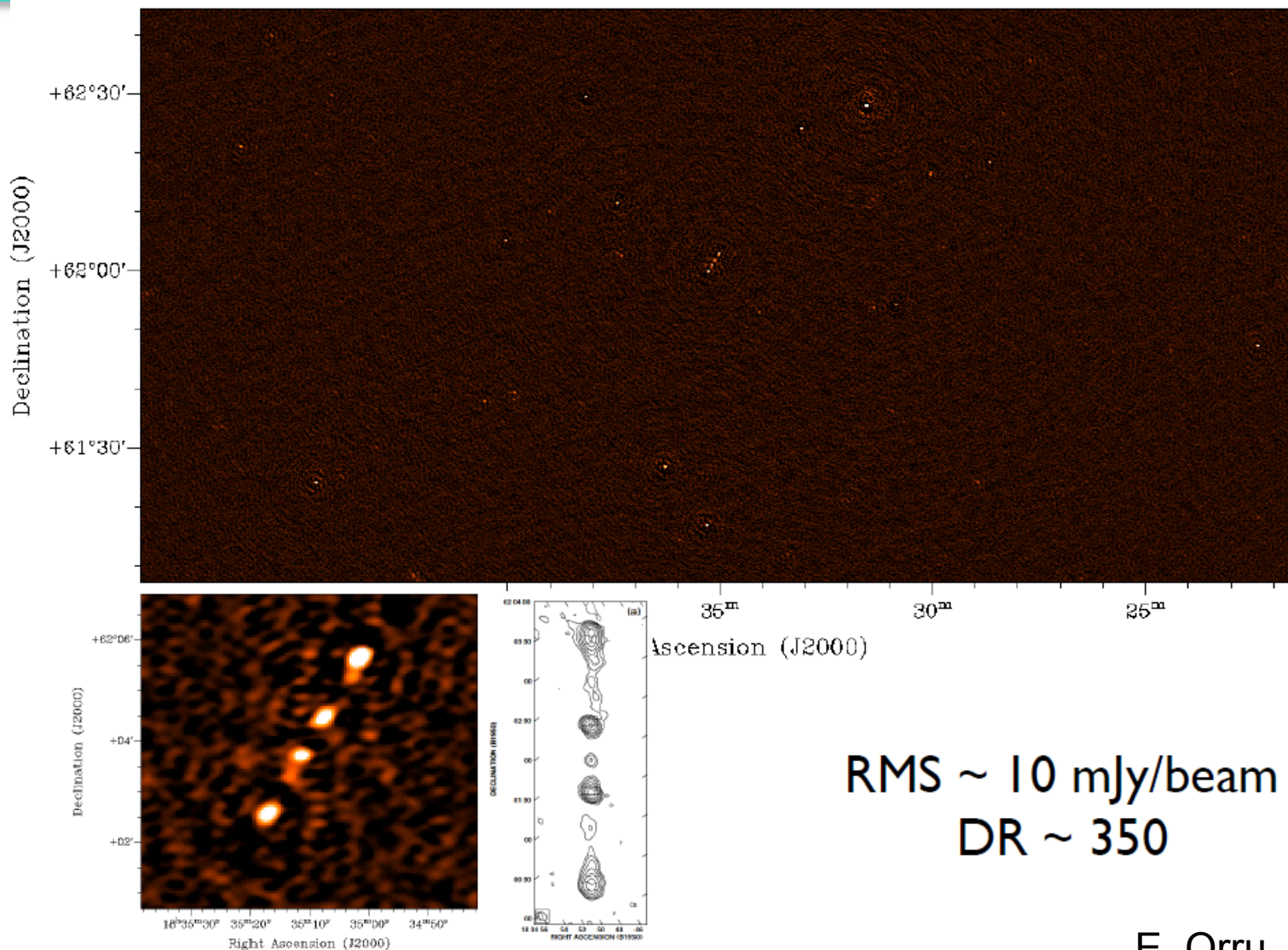
- Lots of activities in the MKSP
- First polarization detections:
  - In Pulsars
  - In imaging data
  - Diffuse polarization in the Milky Way
- Not all activities were streamlined, some duplication of efforts.
  - New commissioning plan with list of more or less clear cut tasks
  - Need students to concentrate on commissioning while working on a task.



# Spare Slides



# Double-Double: Image



RMS ~ 10 mJy/beam  
DR ~ 350





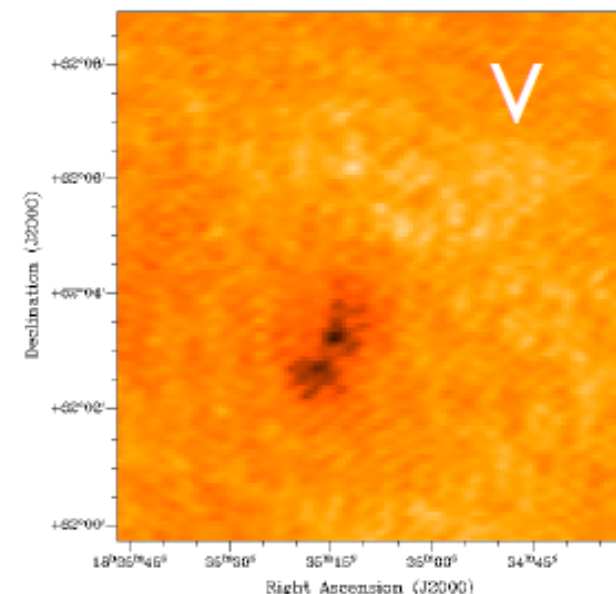
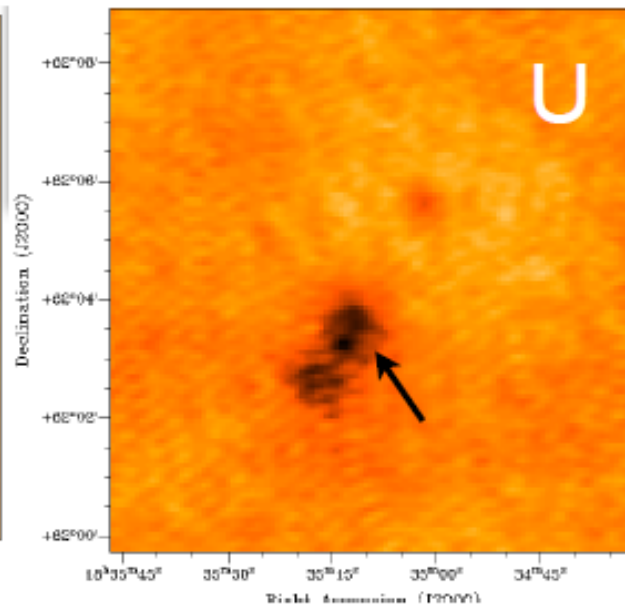
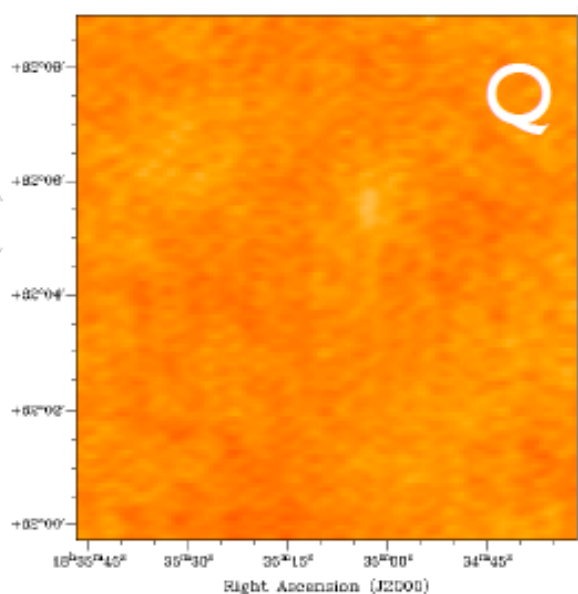
# Double-Double: Polarization

- expect  $\sim 5\%$  polarization at FD 58 rad/m/m
- selfcal with model from NewStar with IQUV but no RM

?

4%

3%

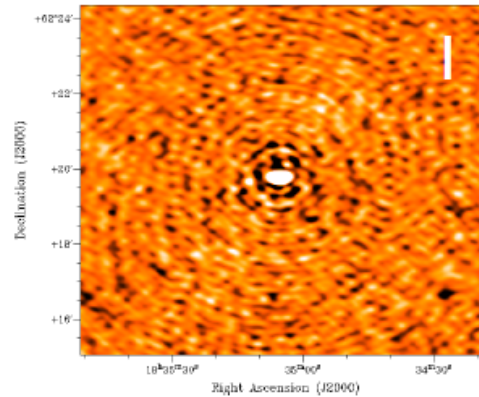




# Injected Polarized Source

TEST: INJECTED ONE POLARIZED SOURCE

$I=100$  Jy  $Q=10$  Jy  $U=0.01$  Jy  $V=0.001$

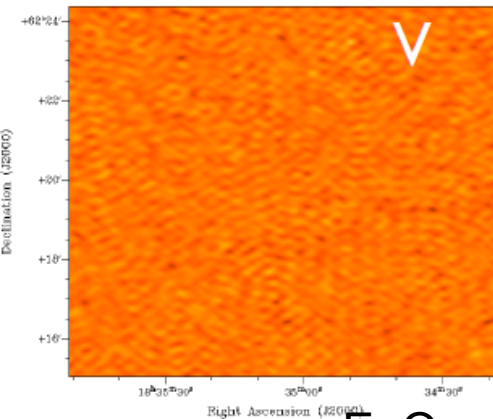
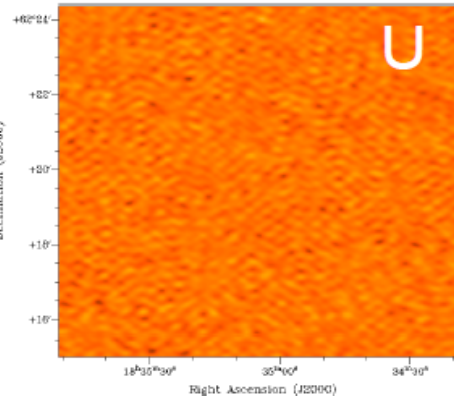
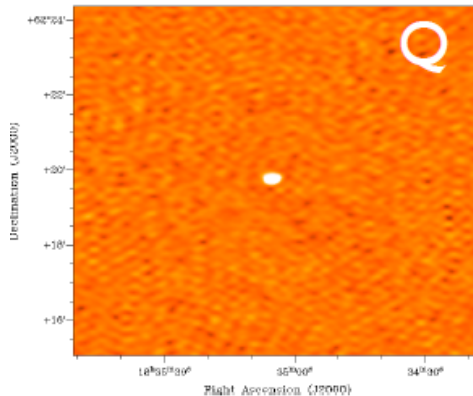


82 Jy

7%

?

?





# PSR 0218: Beam-Correction

- beam-correction increases signal from pulsar
- beam-correction does not fix wrong sign of RM
- little effect on instrumental polarization

