IMAGING IONOSPHERIC STRUCTURES

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on behalf of the LOFAR-EOR team

Introduction

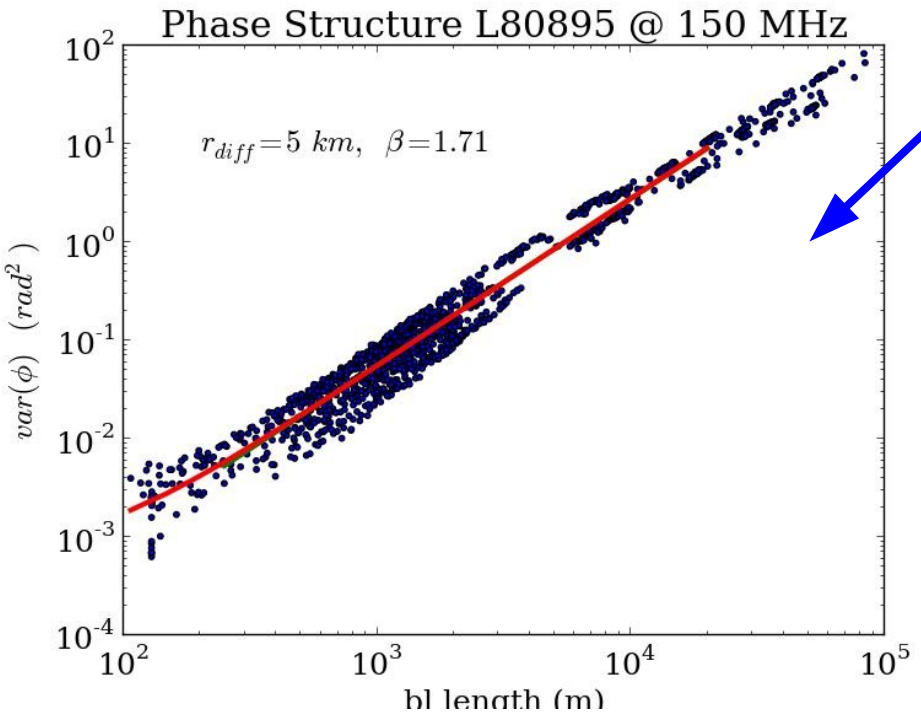
- Gathering ionospheric information from LOFAR data:
  - using calibration phases
  - snapshot images
- Earth magnetic field aligned structures in the ionosphere
  - visible using both methods
- Use snapshot images to visualize moving structures
- all data: LOFAR EOR 3C196 data 2012/2013

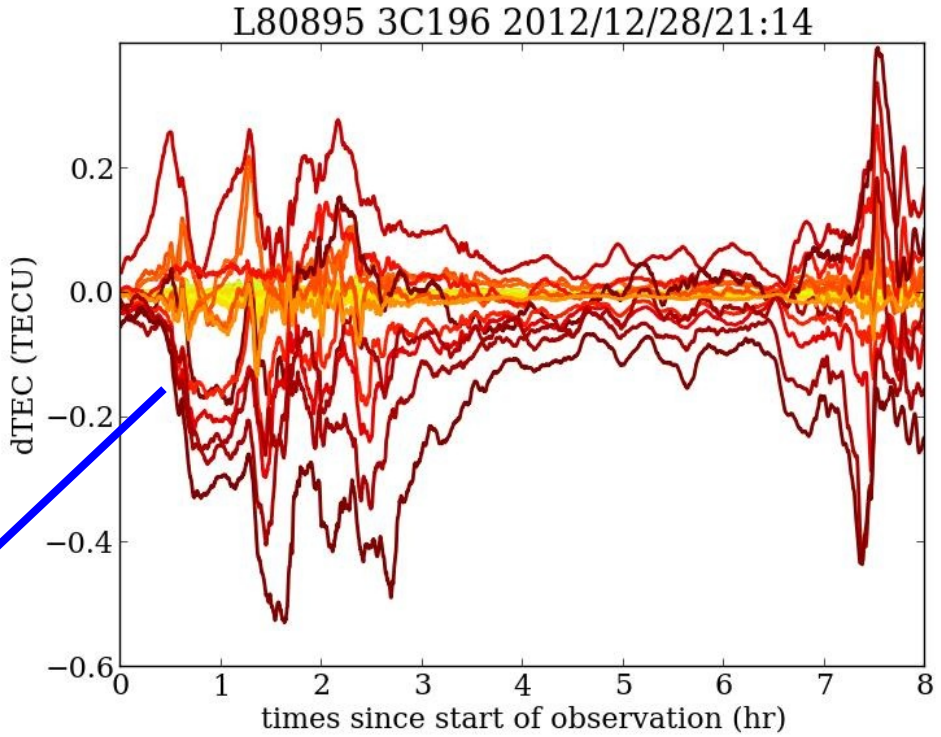
Ionospheric Structure

Calibration phases

large frequency range → 1/ν dependence → ionospheric phases

time average → phase structure function





3C196 observation. dTEC vs. time

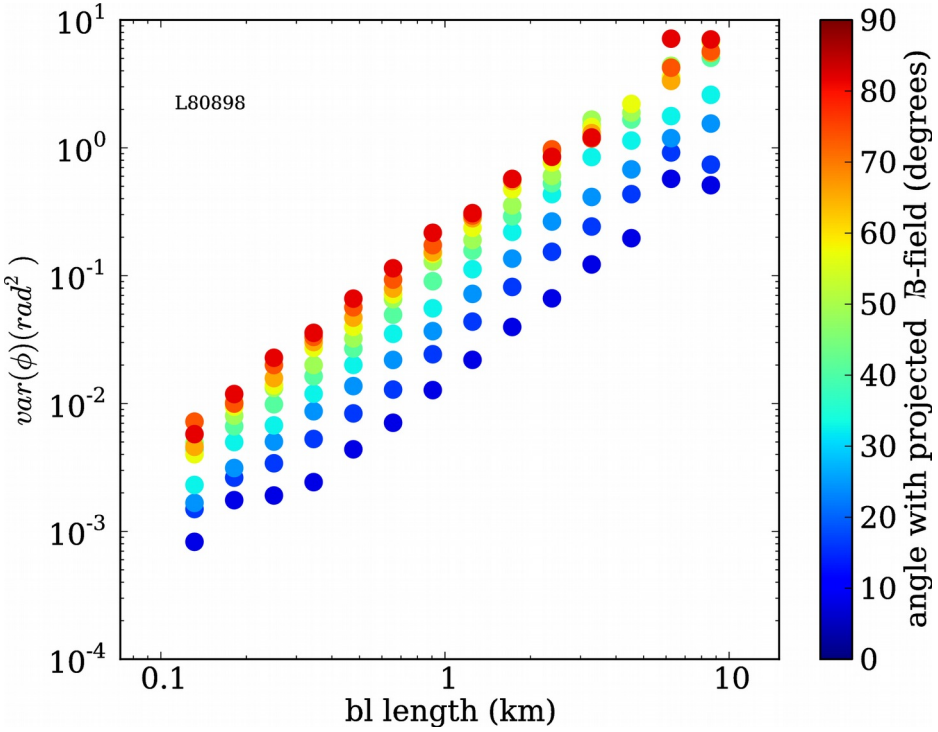
results on 29 EOR 3C196 observations using this technique submitted to Radio Science

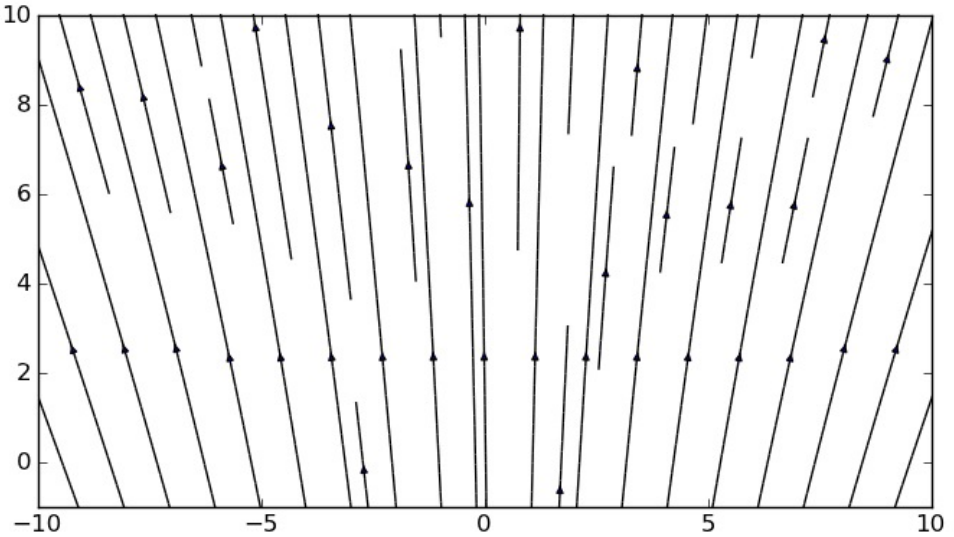
Field Aligned Structure

bandlike structure → orientation of the baseline

Earth magnetic field aligned?

projected field lines along LOS single ionospheric height





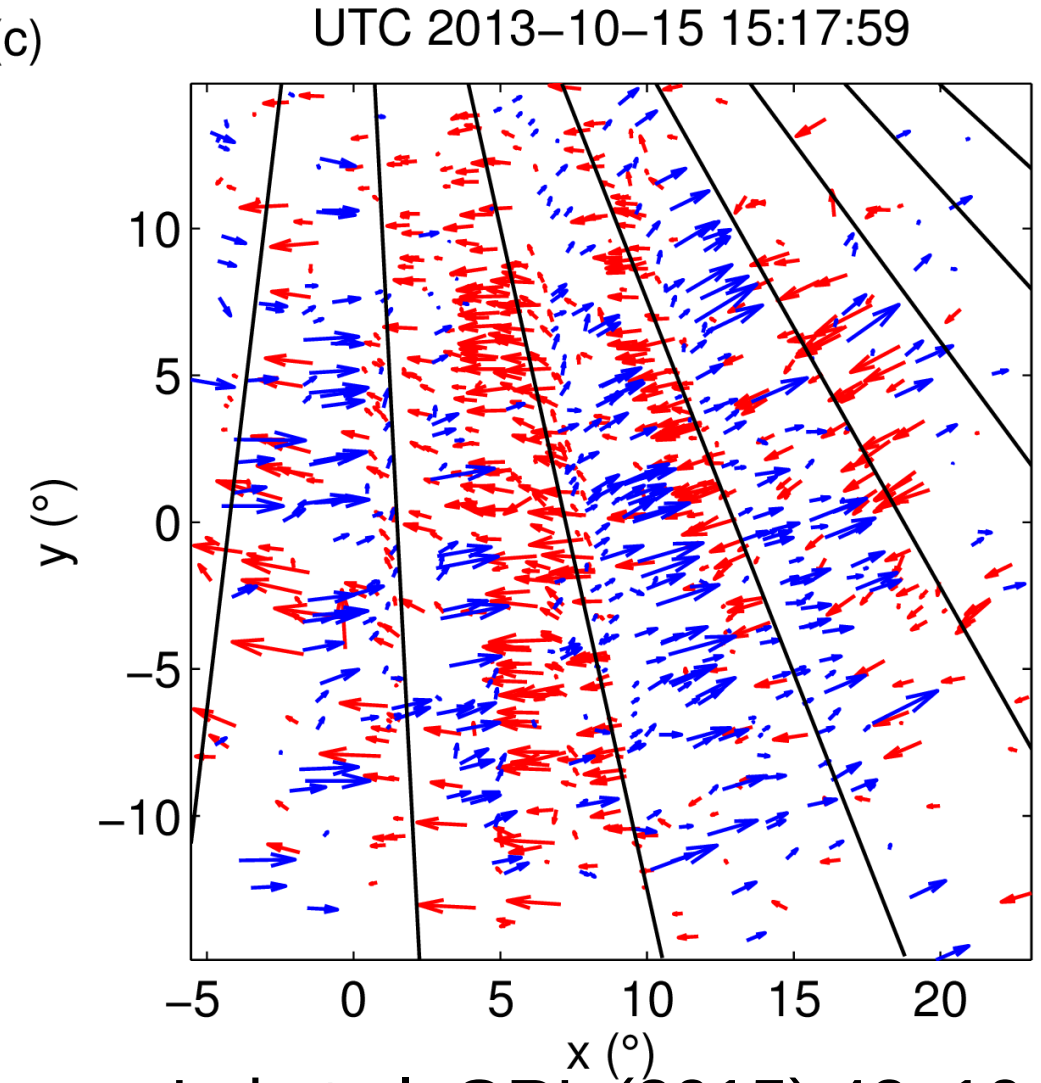
Earth magnetic field lines along viewing angle (NS/EW beam angle, zenith = 0,0)

perspective view → time dependent orientation
bin data in according to angle wrst projected field lines
field aligned structure observed in ~ 50 % of the observations

Earth magnetic field : WMM

Loi et al. GRL 2015

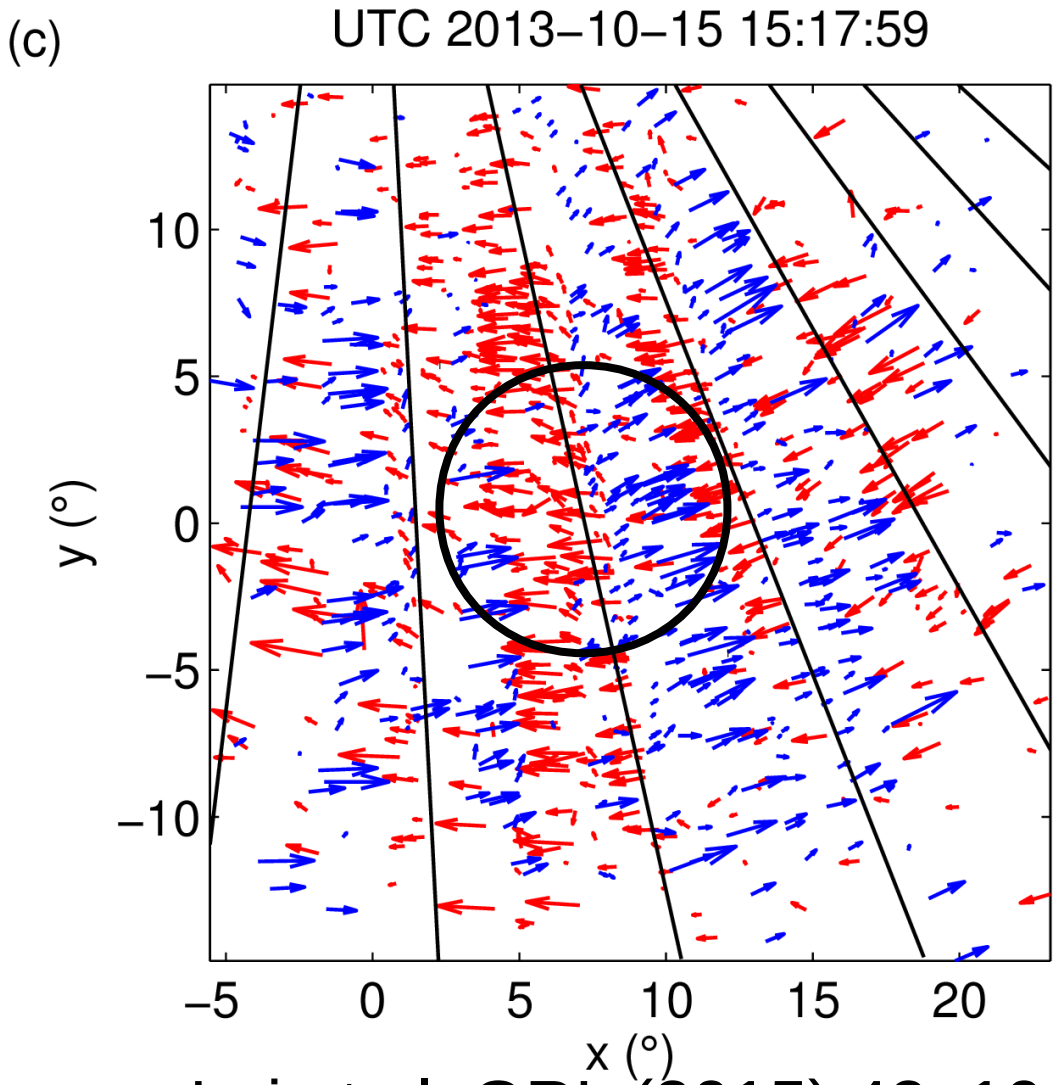
Real-time imaging of density ducts between the plasmasphere and ionosphere



Loi et al, GRL (2015) 42, 10

MWA data
snapshot images of source shifts
ionospheric gradient → position shift
elongated slowly moving field aligned structures

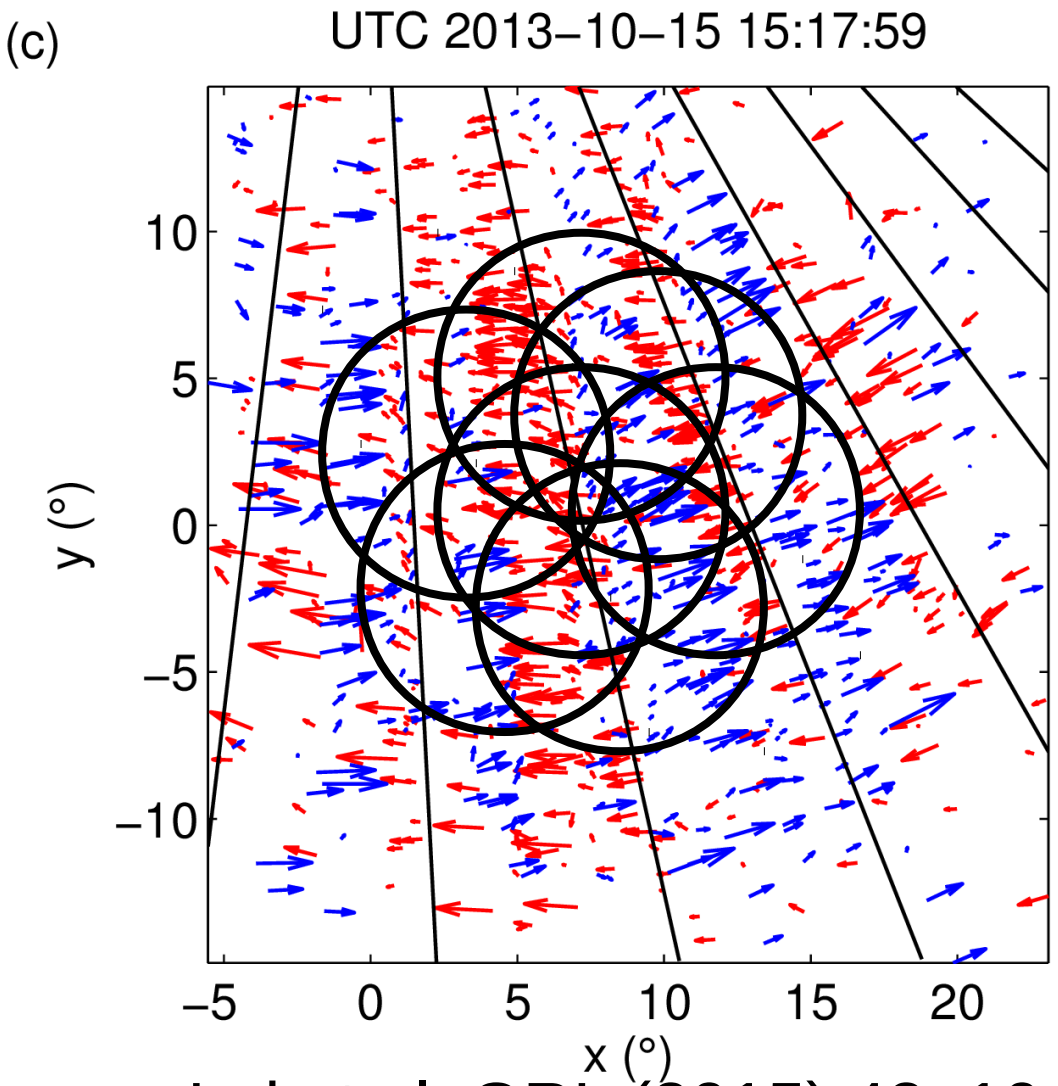
HBA beam



Loi et al, GRL (2015) 42, 10

Do we observe the same structures with LOFAR?
single beam: too small FOV

flanking fields



Loi et al, GRL (2015) 42, 10

Do we observe the same structures with LOFAR?
single beam: too small FOV
multiple beams
standard observing mode for EOR: 1 central beam + 6 flanking fields
18 SB each

Imaging Structures

ionosphere: linear gradient → position shift

higher order term → distorted source

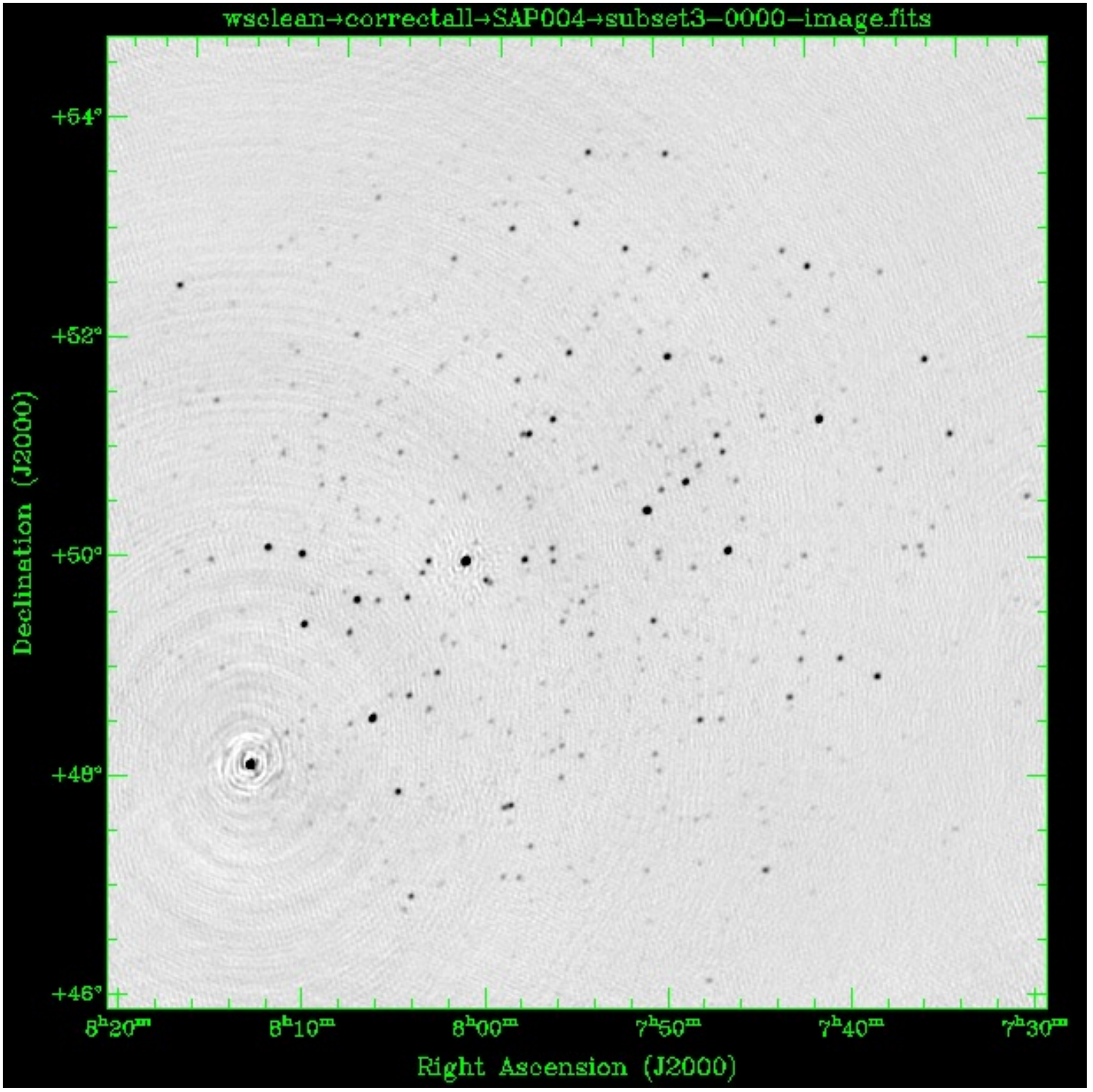
use only short baselines: CS only

$\Delta\theta = C/\nu^2 \nabla_\perp \mathrm{TEC}$

I. correct all with calibration gains of central field

- subtract 3C196 from central field

II. image corrected data (wsclean) → extract sources for reference (pybdsm)



wsclean: combine SBs to create 3 images with different frequency

~ 4 SB each, due to missing files

Imaging Structures

ionosphere: linear gradient → position shift

higher order term → distorted source

use only short baselines: CS only

$\Delta\theta = C/\nu^2 \nabla_\perp \mathrm{TEC}$

I. correct all with calibration gains of central field
   - subtract 3C196 from central field

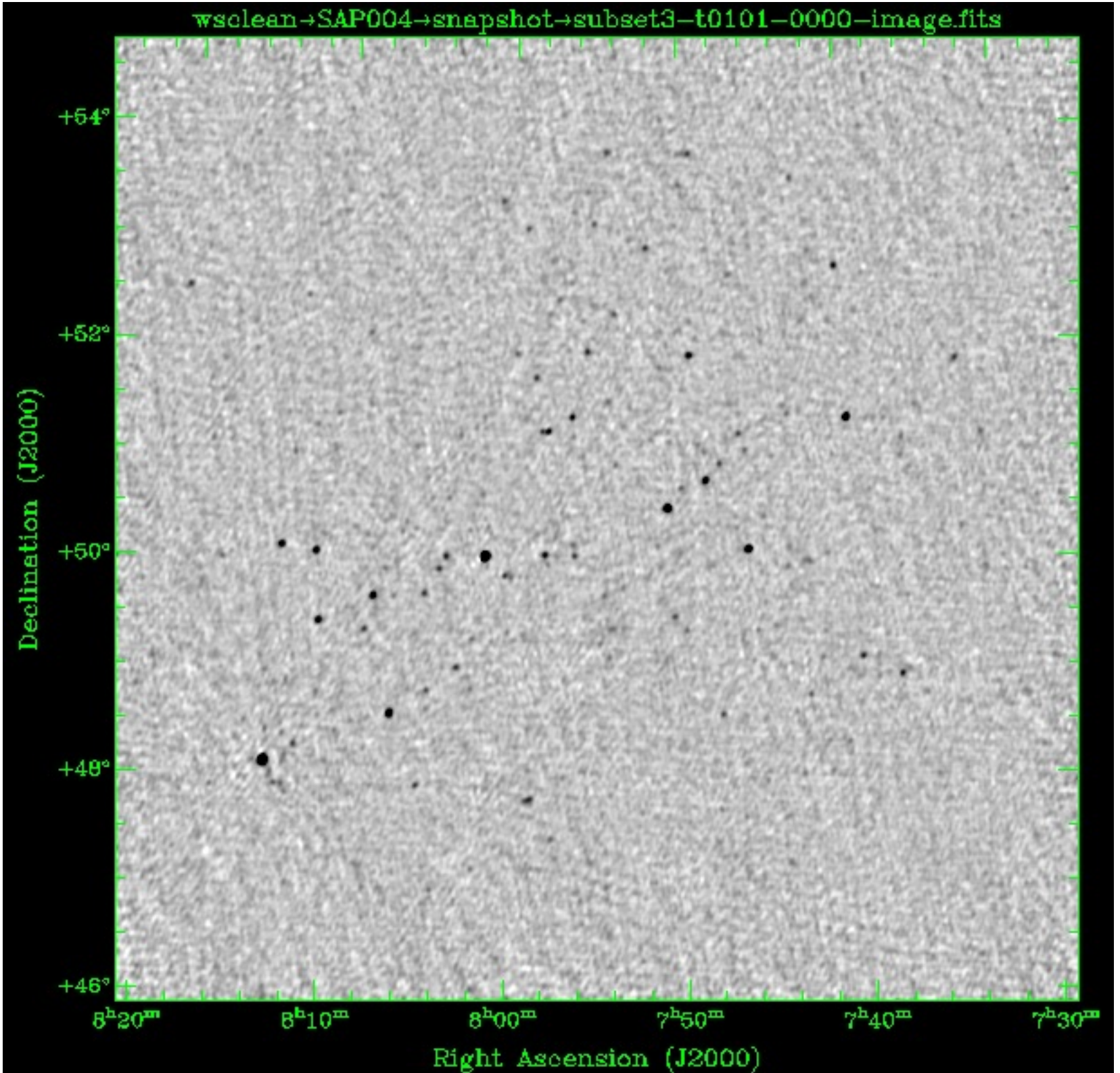
II. image corrected data (wsclean) → extract sources for reference (pybdsm)

III. remove TEC-phases from calibration gains, correct all

Imaging Structures (2)

IV. 1 minute snapshot images (wsclean)

- 3 frequencies



1 minute snapshot image

SAP004

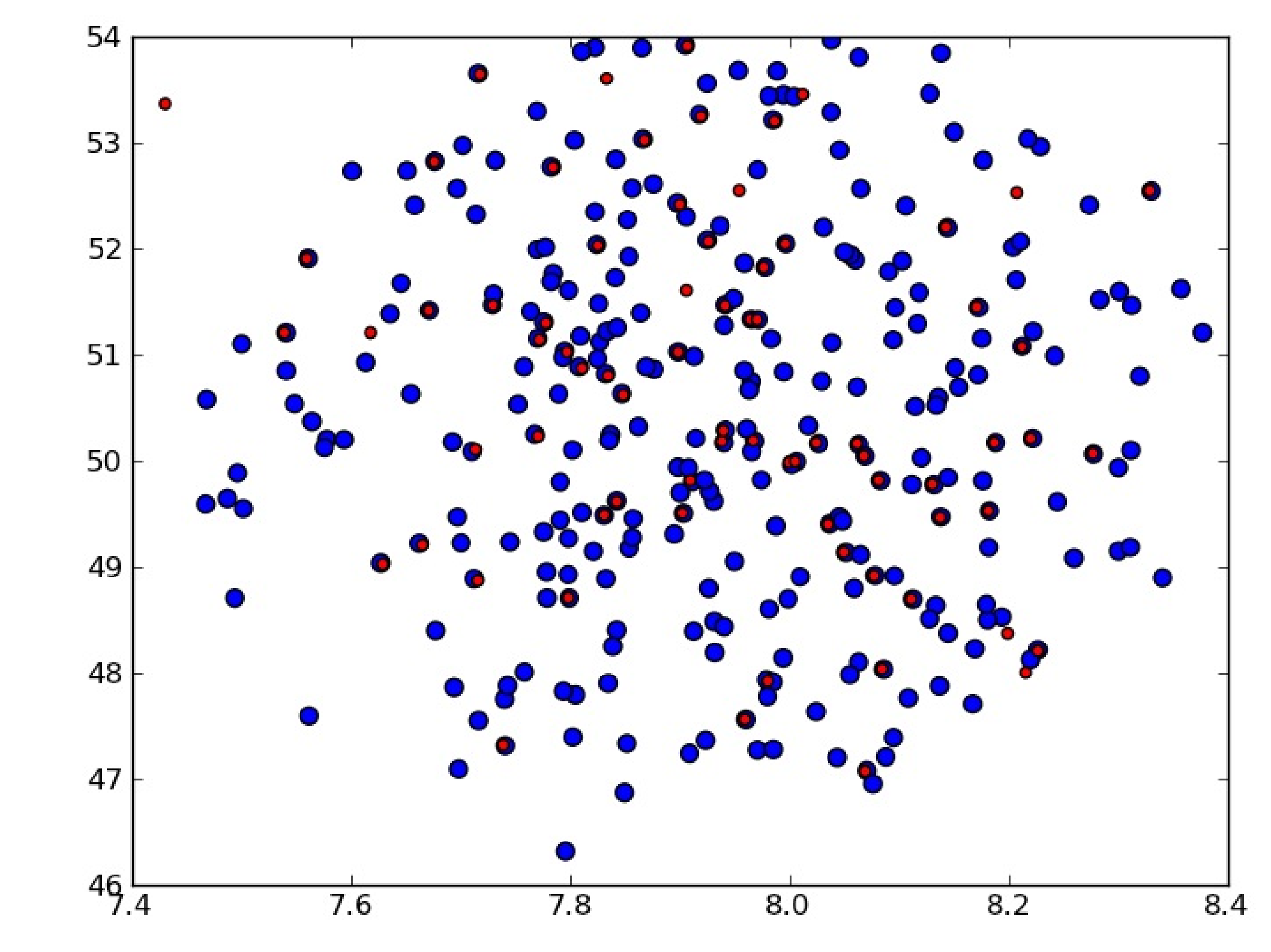
L86767

Imaging Structures (2)

IV. 1 minute snapshot images (wsclean)
- 3 frequencies

V. source extraction (pybdsm)
- default values
- about 400 sources (including double matches)

VI. match with reference sources


54
53
52
51
50
49
48
47
46
7.4
7.6
7.8
8.0
8.2
8.4

Imaging Structures (2)

IV. 1 minute snapshot images (wsclean)
- 3 frequencies

V. source extraction (pybdsm)
- default values
- about 400 sources (including double matches)

VI. match with reference sources

VII. image source position shifts

Selected 5 observations:

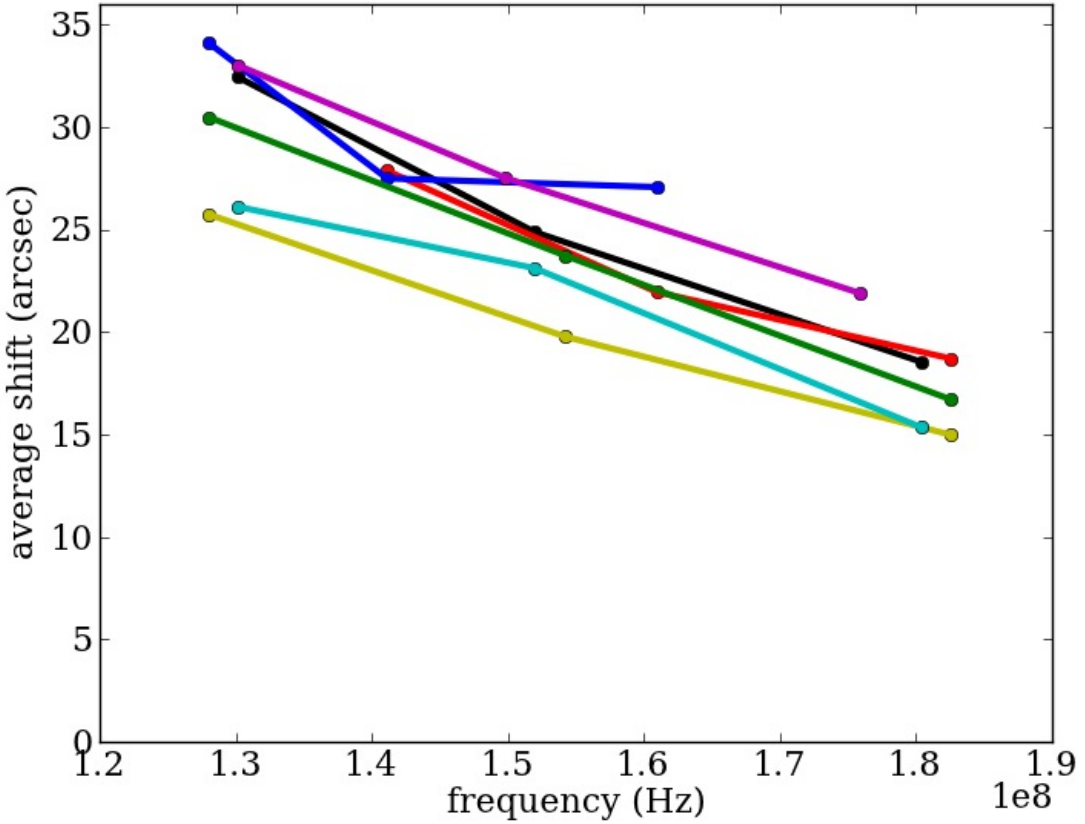
4 with field aligned structure function

1 other

processed on new eor cluster dawn

frequency dependence

average position shift bright sources



images were dividing all SBs in 3 groups, using the

-joinchannels

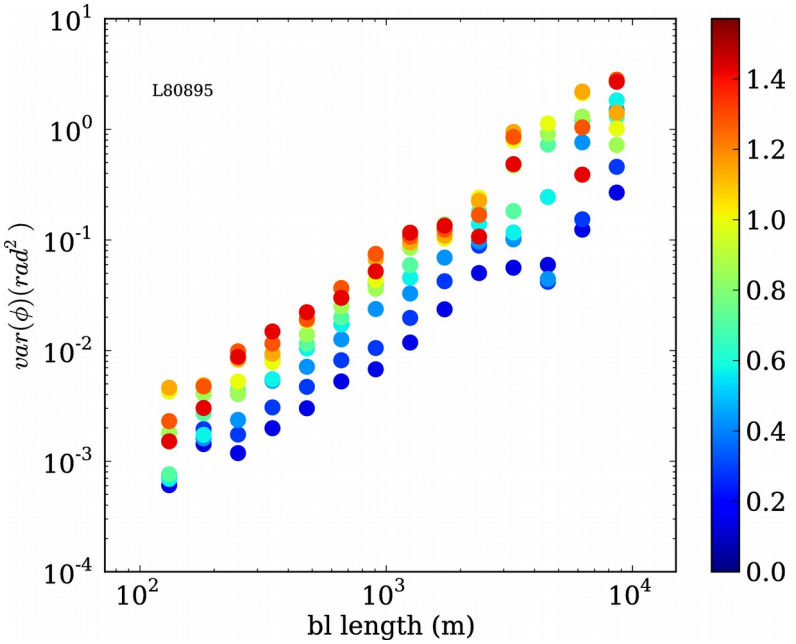
-channelsout

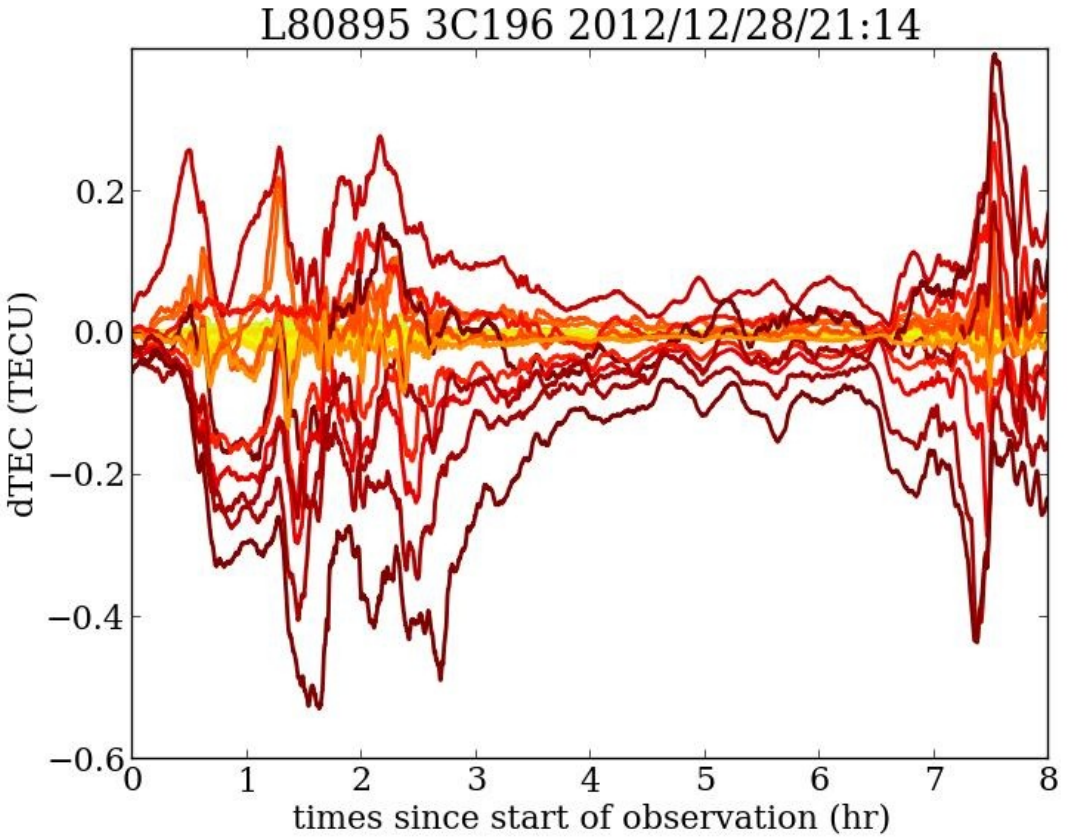
options in wsclean

missing data:

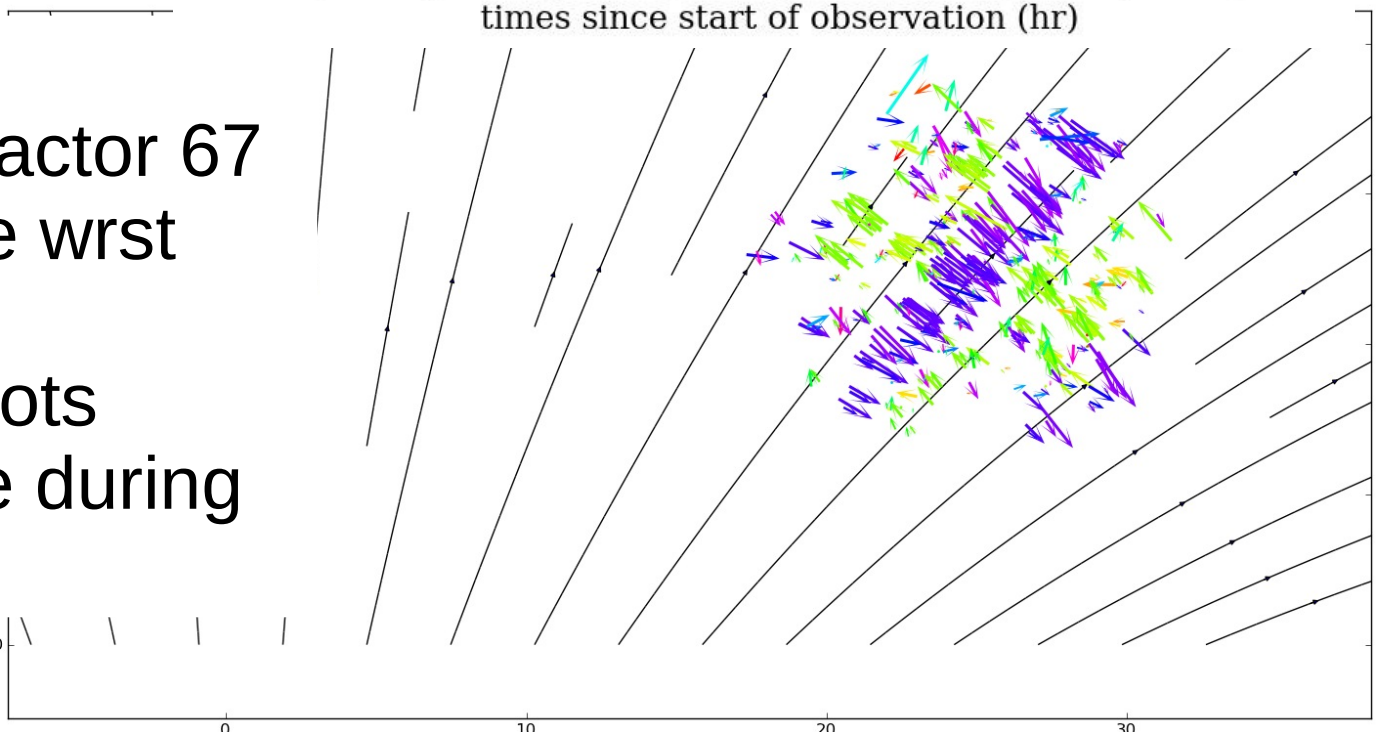
~4SB per image

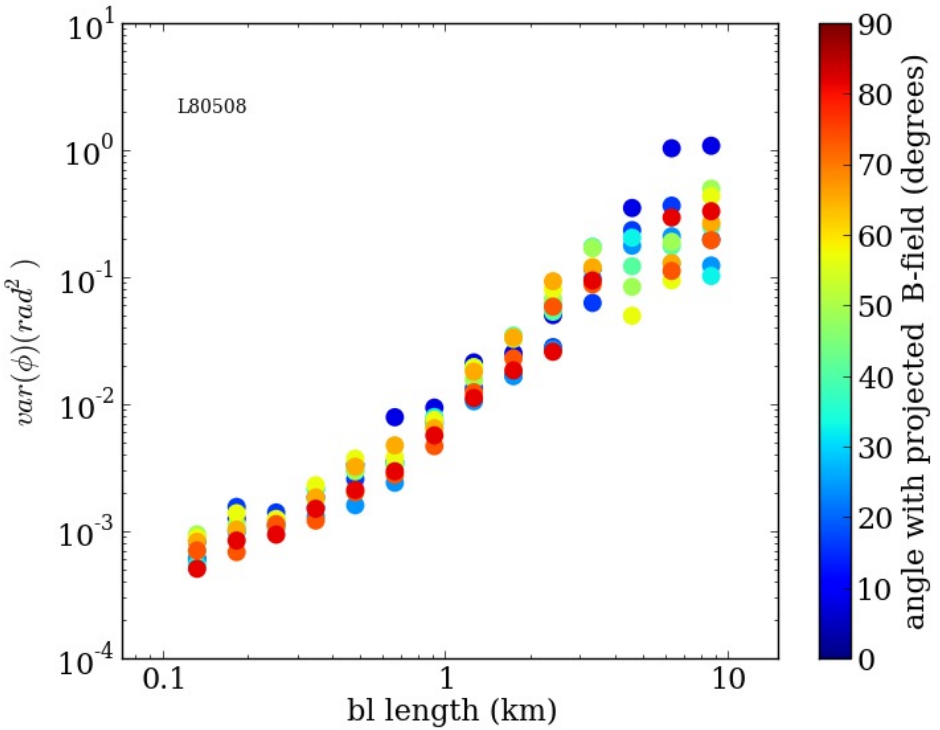
ionosphere: shift ~ $1/\nu^2$

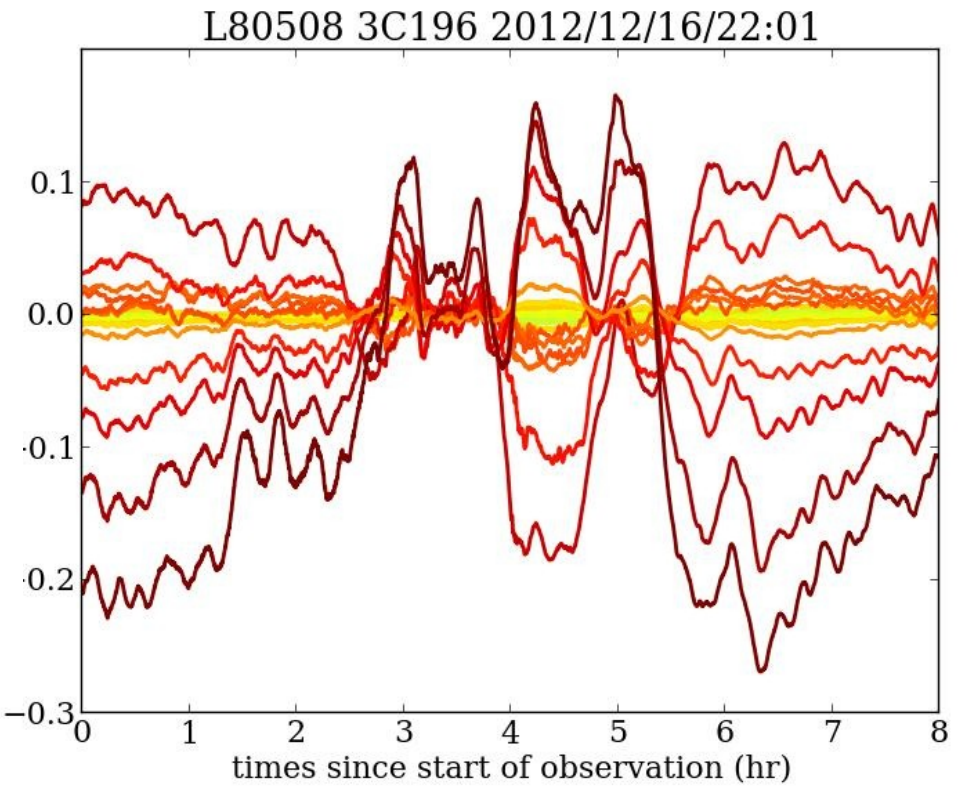


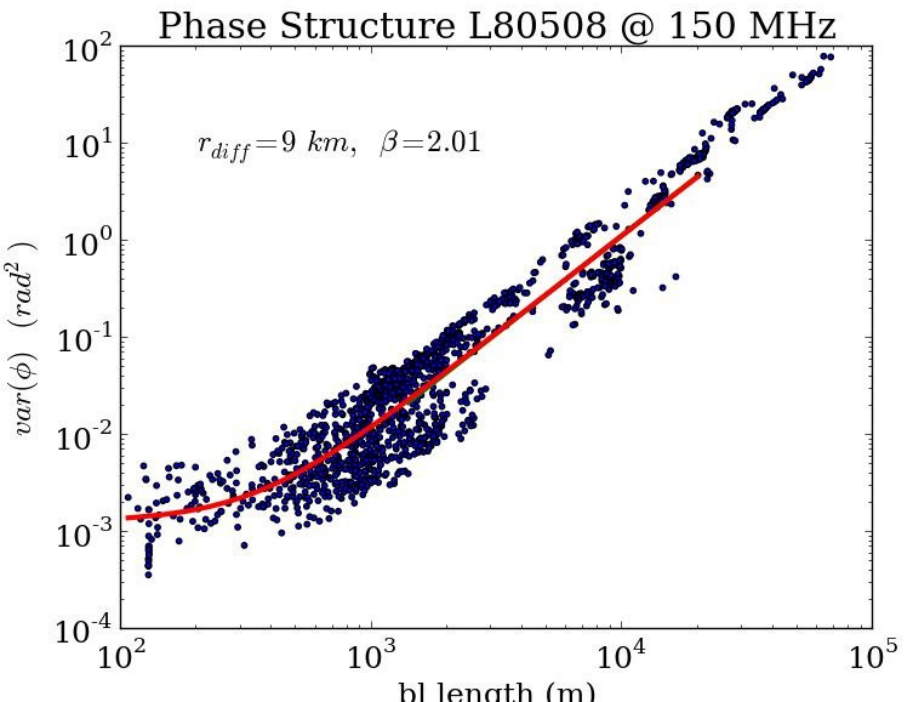


L80895
arrows scaled with factor 67
color indicates angle wrst local field lines
2 (1 minute) snapshots
structure only visible during first hour

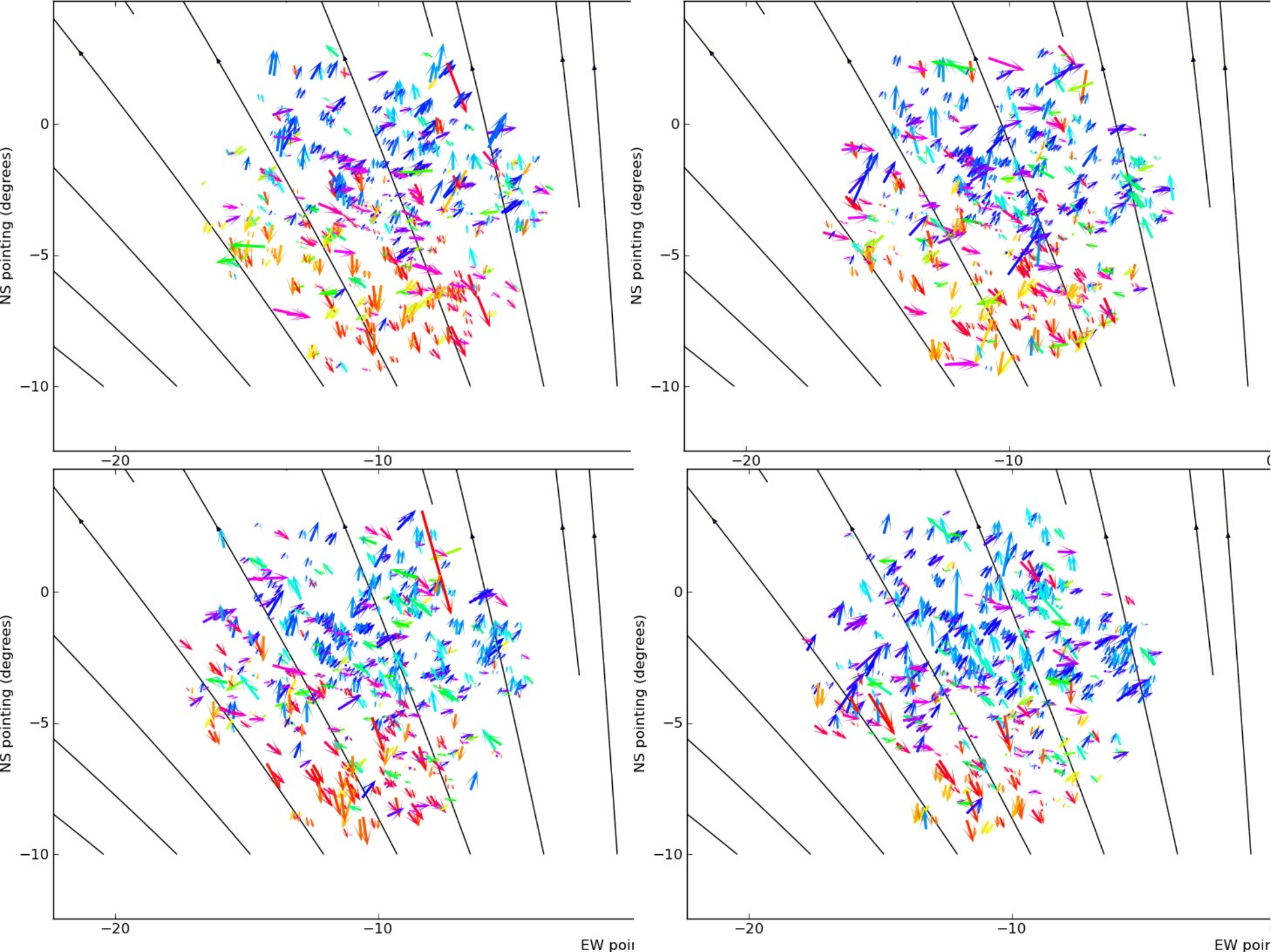


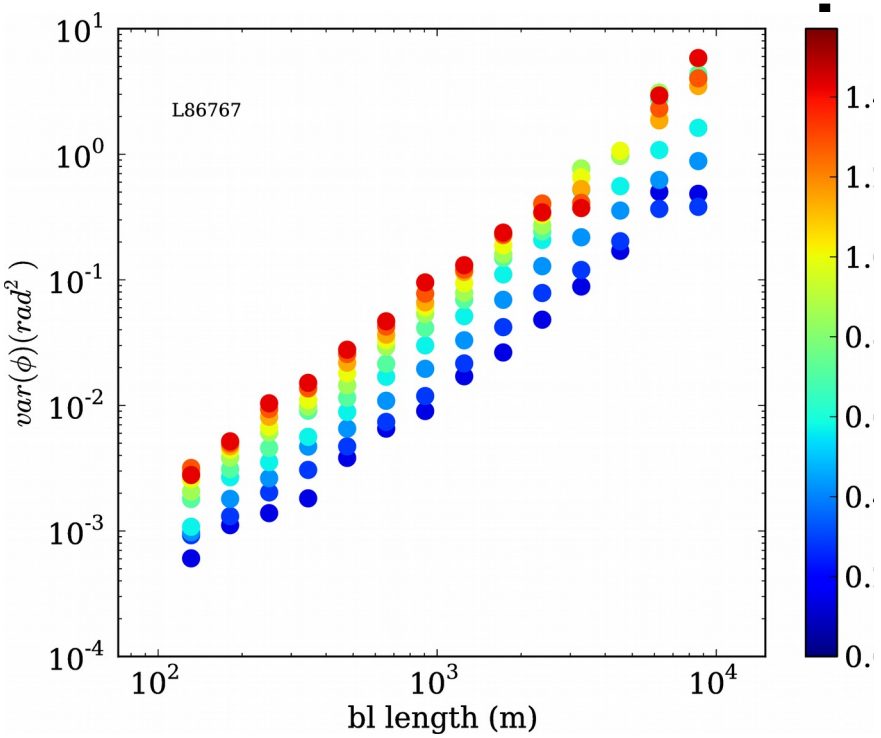


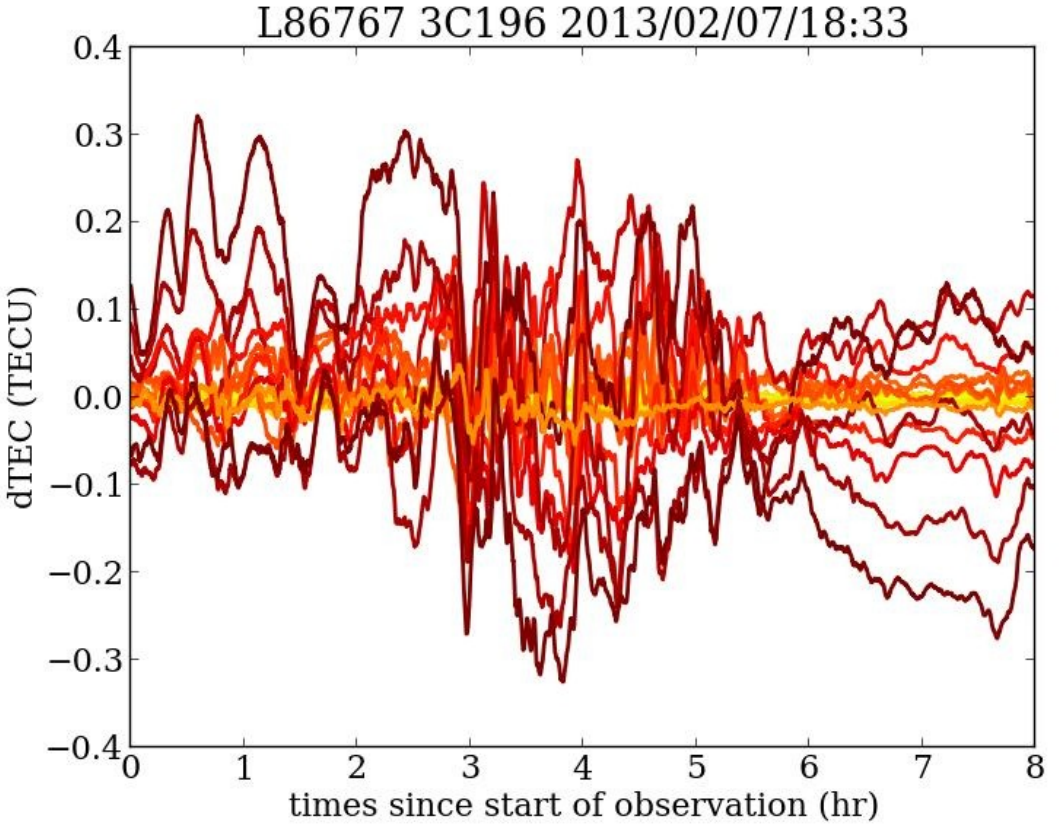


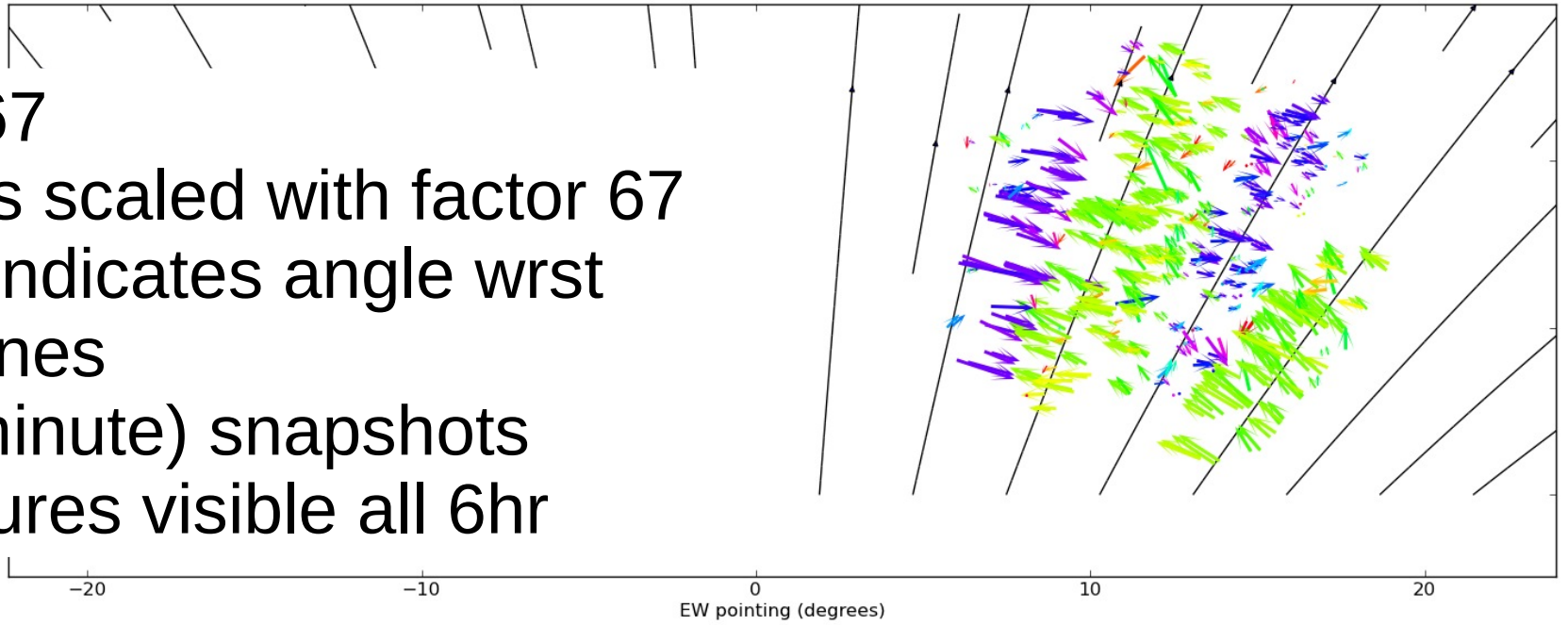


NO field aligned structures larger scale

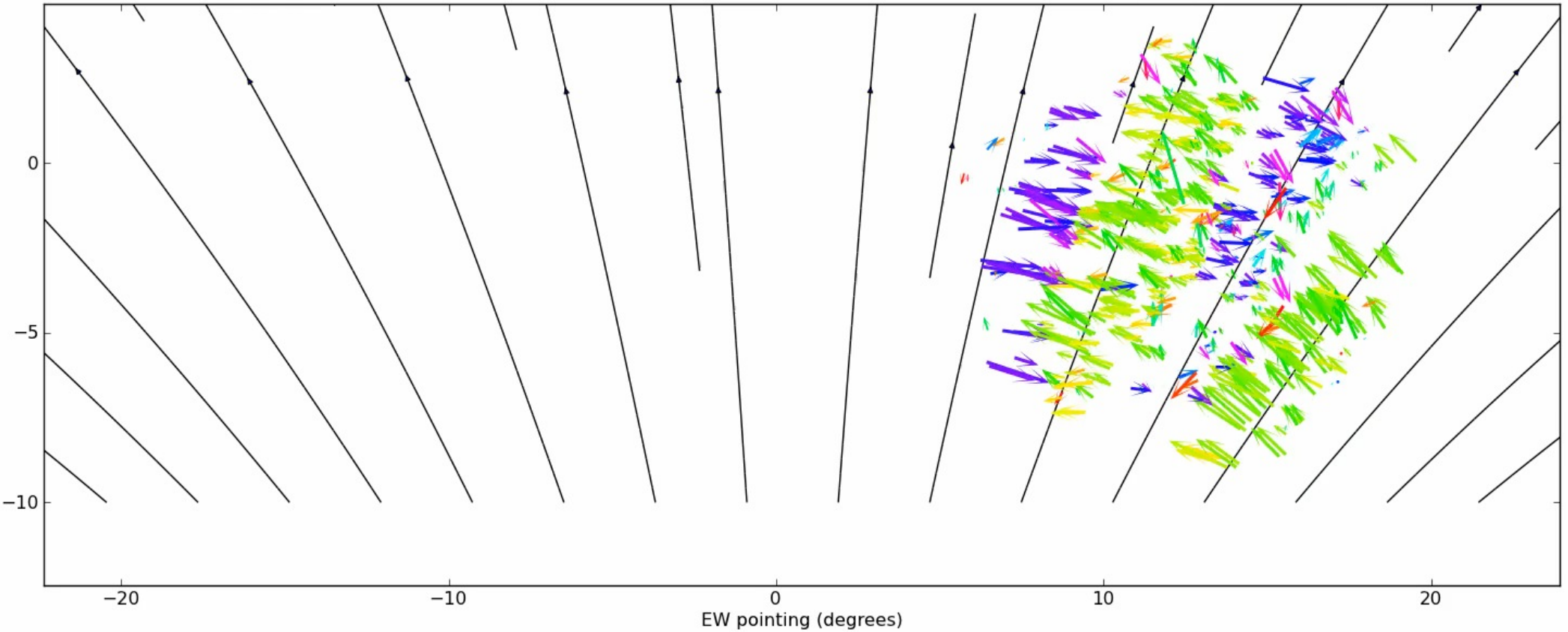

NS pointing (degrees)
0
−5
−10
−20
−10
NS pointing (degrees)
0
−5
−10
−20
−10
NS pointing (degrees)
0
−5
−10
−20
−10
EW poi
NS pointing (degrees)
0
−5
−10
−20
−10
EW poi



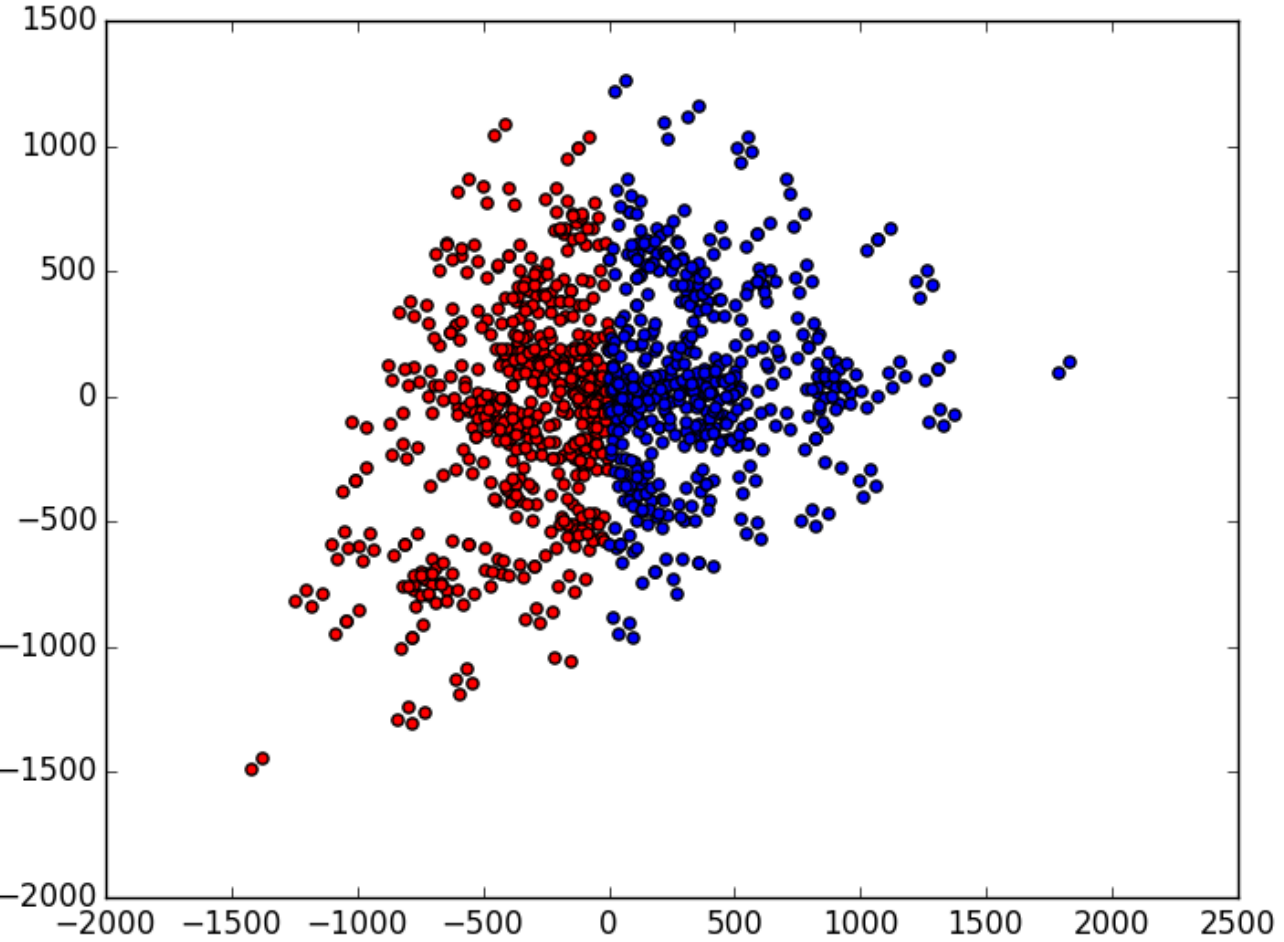




L86767
arrows scaled with factor 67
color indicates angle wrst field lines
2 (1 minute) snapshots
structures visible all 6hr


0
−5
−10
−20
−10
0
10
20
EW pointing (degrees)

measure height via parallax



divide baselines in E and W

E-W=730 m

create snapshotimages with both

cross correlate to get parallax shift

ongoing

Conclusion and Outlook

- Two ways of visualizing ionosphere:
  - TEC phases from calibration solutions
    - all baselines
  - source position shifts in snapshot images
    - short baselines
- Earth magnetic field aligned structures observed in structure function of ~50% of the observations
- density ducts?
  - clear structures in snapshot movies of 1 out of 4 (2 out of 5)
  - hints in short intervals of 2 more observations
- height via parallax measurement ongoing:
  - use nearby remote stations for better stereo angle