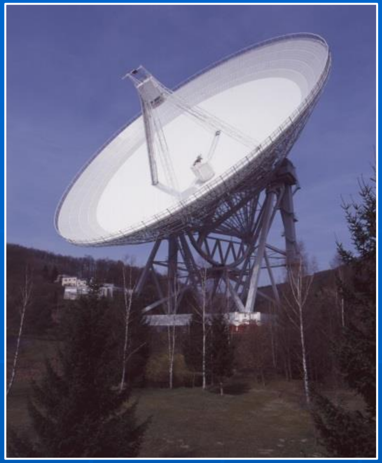
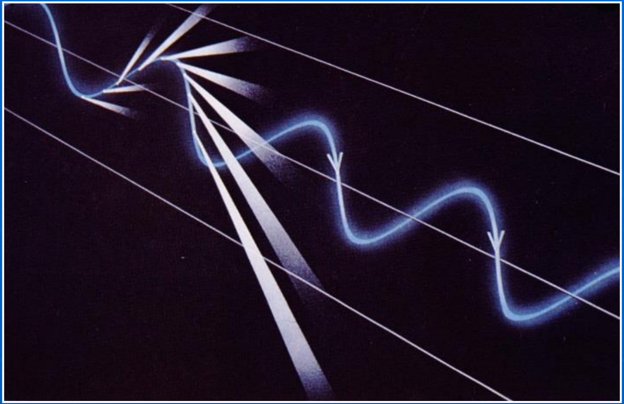




Mapping polarized continuum emission with the Effelsberg Telescope

Rainer Beck

Continuum & polarization mapping: present status

- Single-horn receivers in primary focus (1.4 GHz) or in secondary focus (2.64 and 8.35 GHz)
- Multi-horn receivers in secondary focus (4.85, 10.45, 32 GHz)
- Linearly polarized signals (X and Y) are transformed into circularly polarized signals (Stokes parameters R and L) by a hardware hybrid, turning the phase of one signal by 90°
- A correlator generates signals of linear polarization in Stokes parameters U and Q
- **4 output signals: R, L, U, Q**
- But only one broad frequency channel

Computing Stokes parameters by correlation

(1) Linear input:

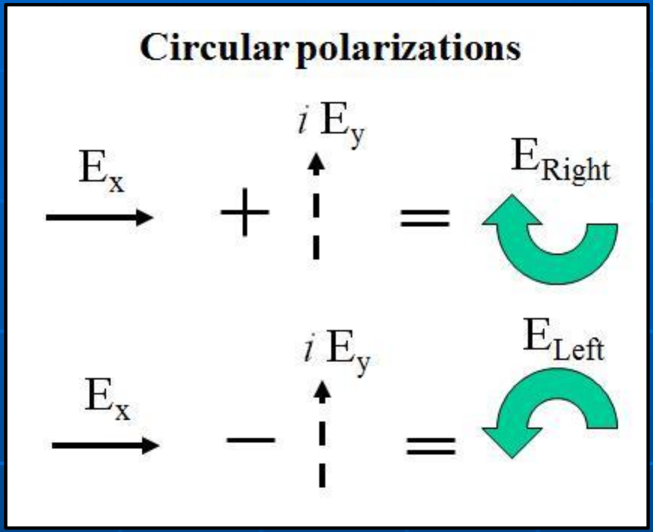
$$
\begin{aligned}
I &= |E_x|^2 + |E_y|^2, \\
Q &= |E_x|^2 - |E_y|^2, \\
U &= 2\mathrm{Re}(E_x E_y^*), \\
V &= -2\mathrm{Im}(E_x E_y^*),
\end{aligned}
$$

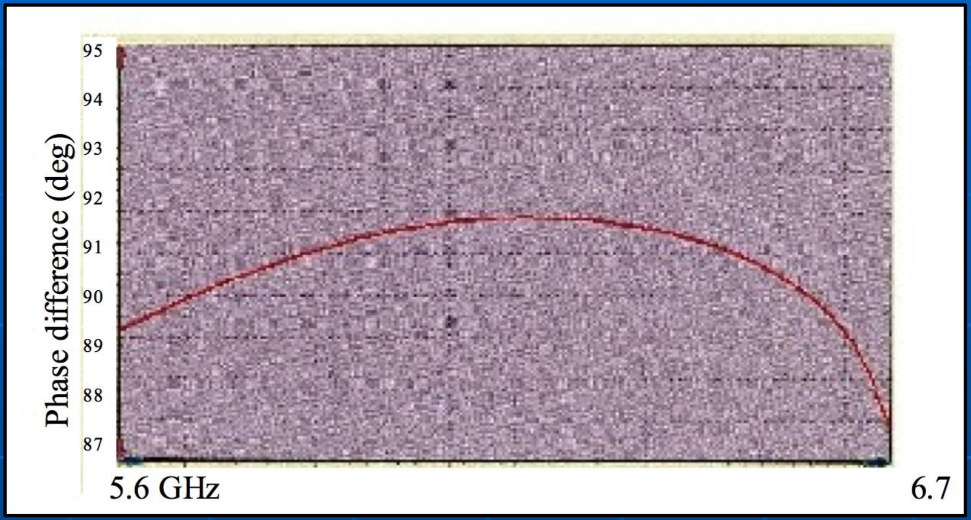
(2) Circular input:

$$
\begin{aligned}
I &= |E_l|^2 + |E_r|^2, \\
Q &= 2\mathrm{Re}(E_l^* E_r), \\
U &= -2\mathrm{Im}(E_l^* E_r), \\
V &= |E_l|^2 - |E_r|^2.
\end{aligned}
$$

Stable signals in Q and U need circular inputs !

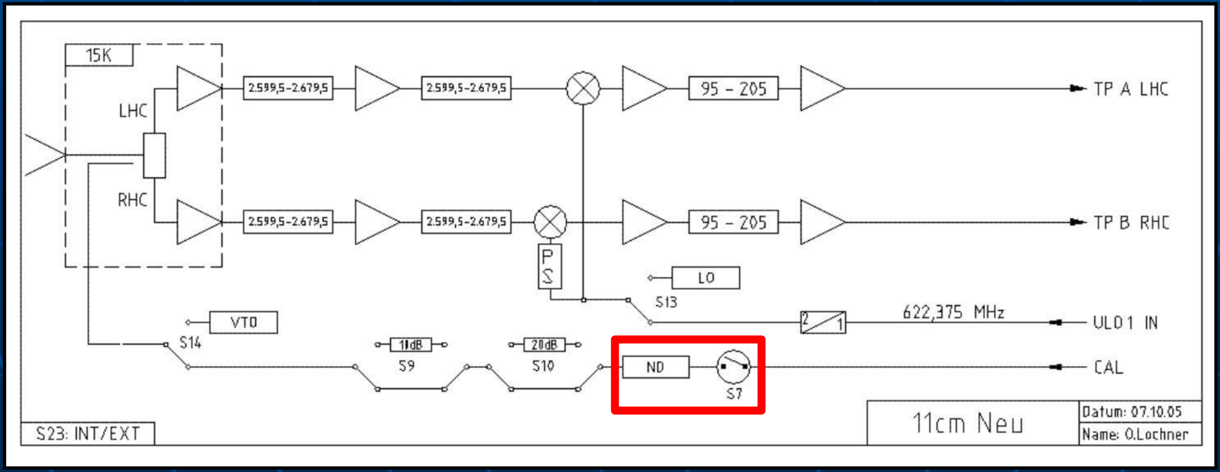
Hybrid





- No perfect phase turning possible (elliptical pol)
- Wide bands ($\Delta\nu/\nu > 2$): hardware hybrid no longer appropriate

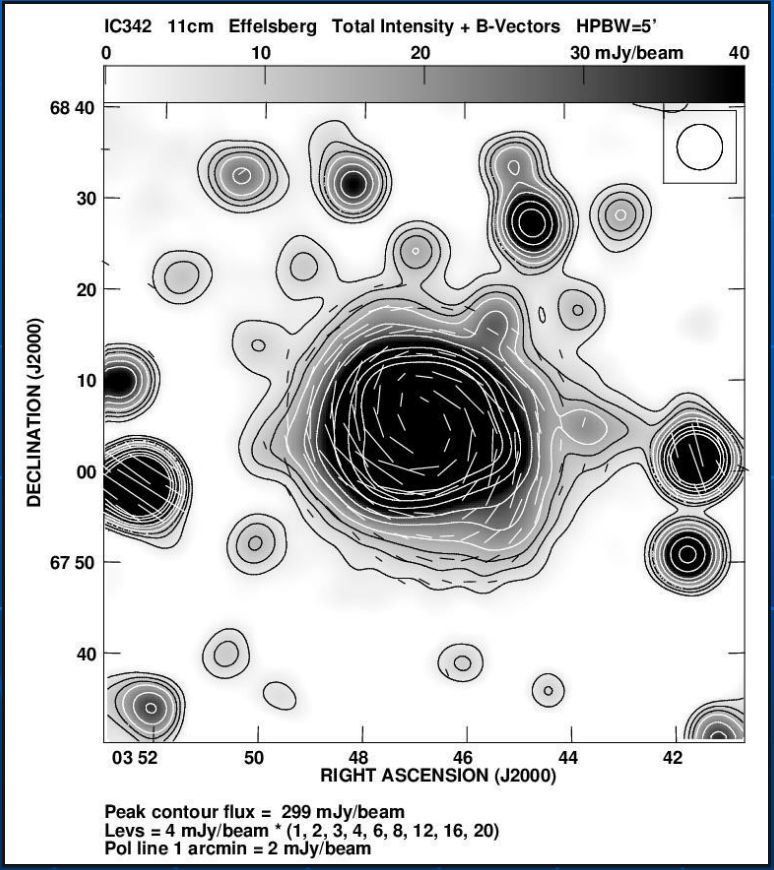
Effelsberg 2.64 GHz (11 cm)
SFK single-horn receiver

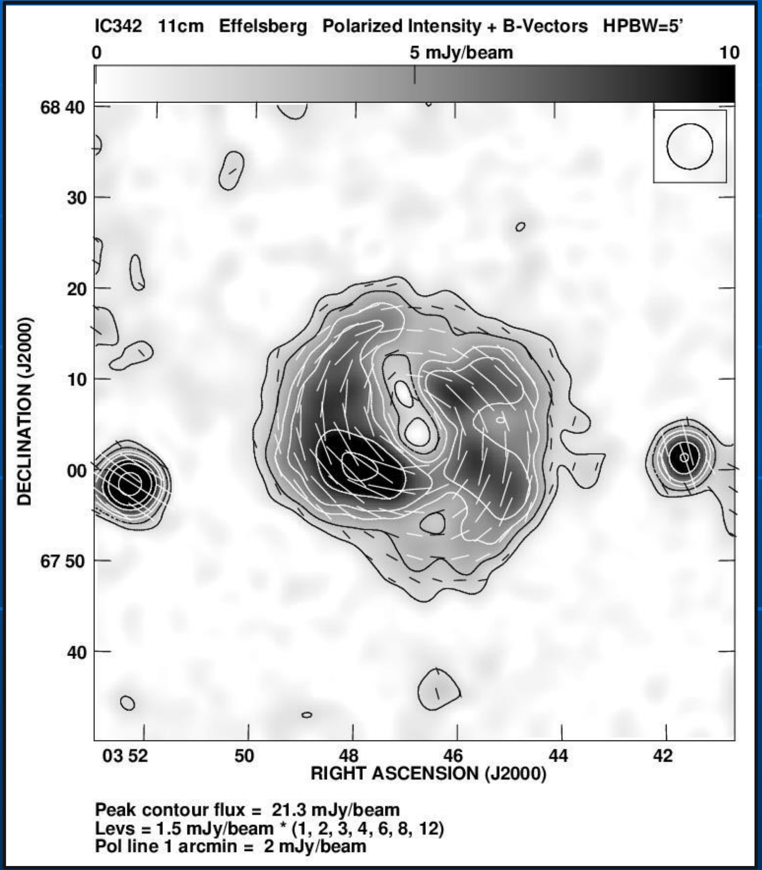


Continuum & polarization mapping: calibration signal

- Noise diode: linearly polarized calibration signal to remove variations in gain and phase
- On/off switching at 32 msec rate
- Signal and calibration signals are separated in 32 msec intervals
- Strong RFI is filtered by comparing adjacent points
- Calibration signal is linearly fitted for each subscan (a single scan in a map) in all 4 signal channels
- Signal/<cal> is averaged to about 3 pixels per beamwidth

Effelsberg 2.64 GHz (11.1 cm), BW = 80 MHz



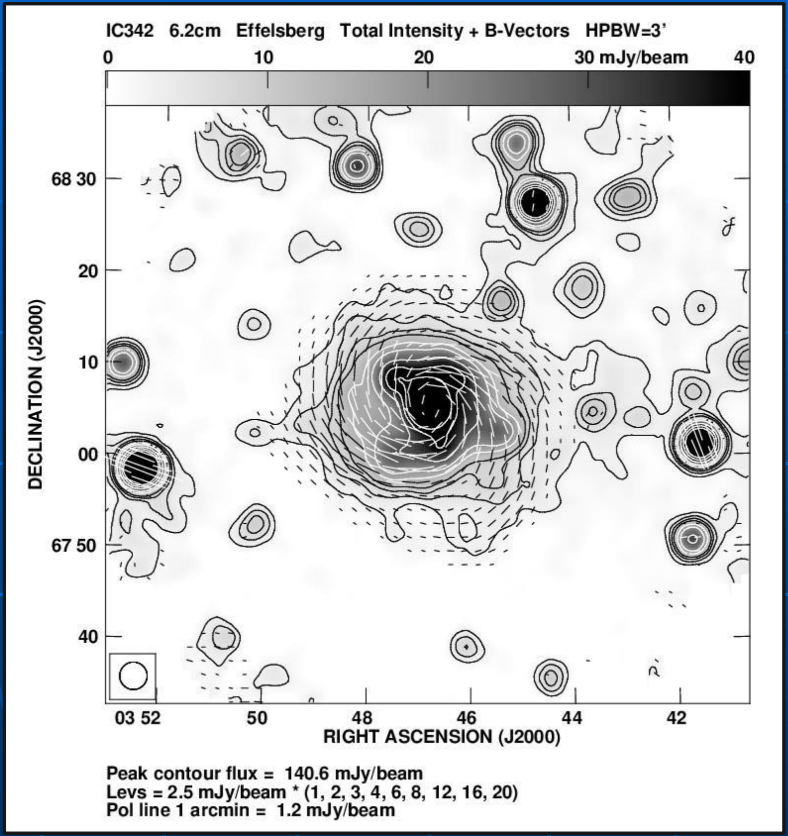


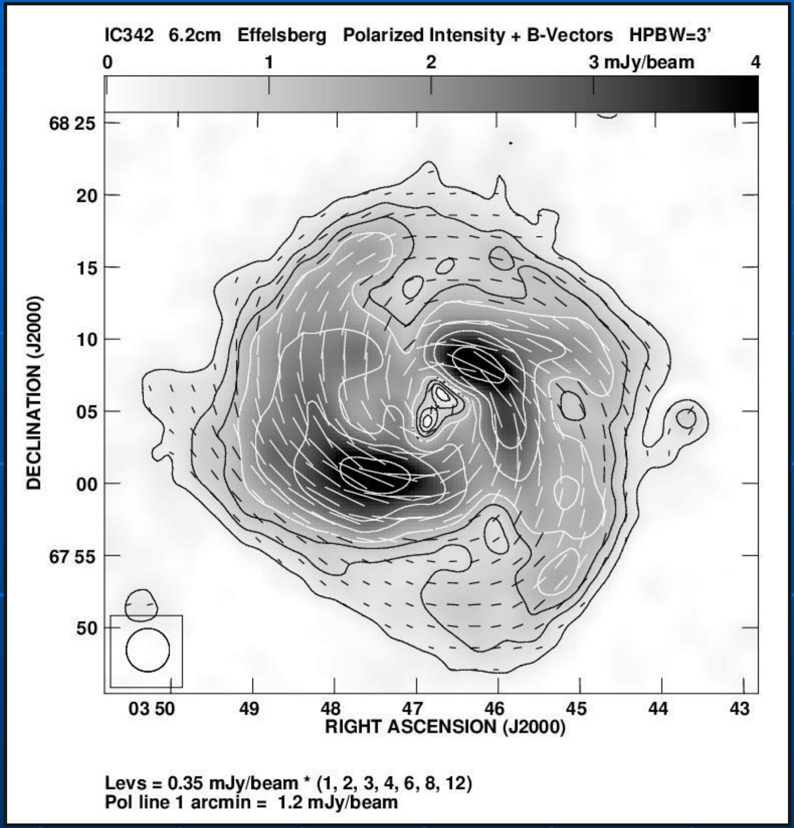
Total intensity:
$\sigma \approx$ 0.8 mJy/ 5´ beam

Q & U:
$\sigma \approx$ 0.45 mJy/ 5´beam

Beck, in prep.

Effelsberg 4.85 GHz (6.3 cm), BW = 500 MHz



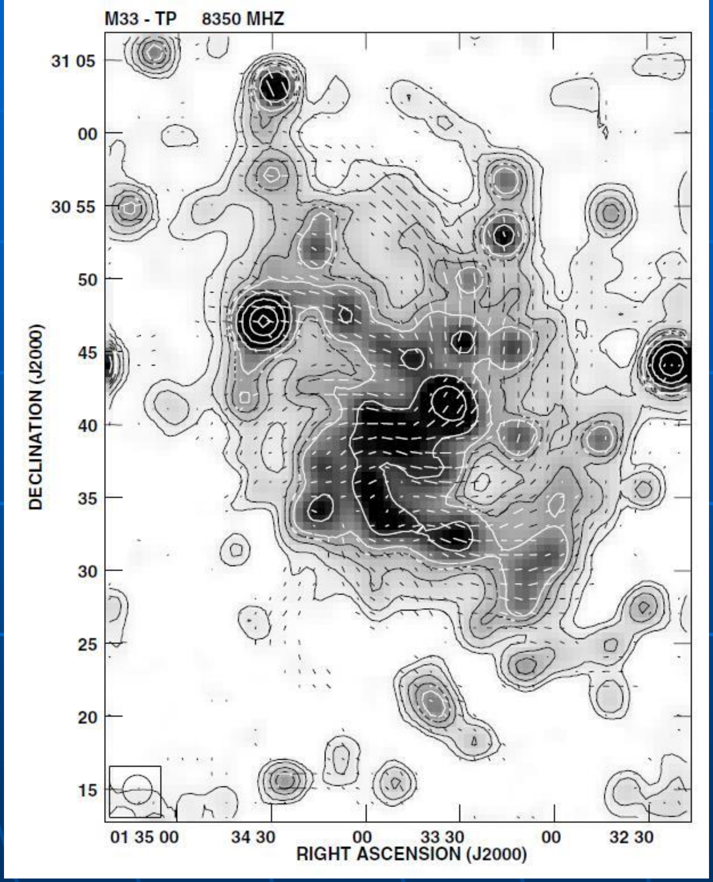


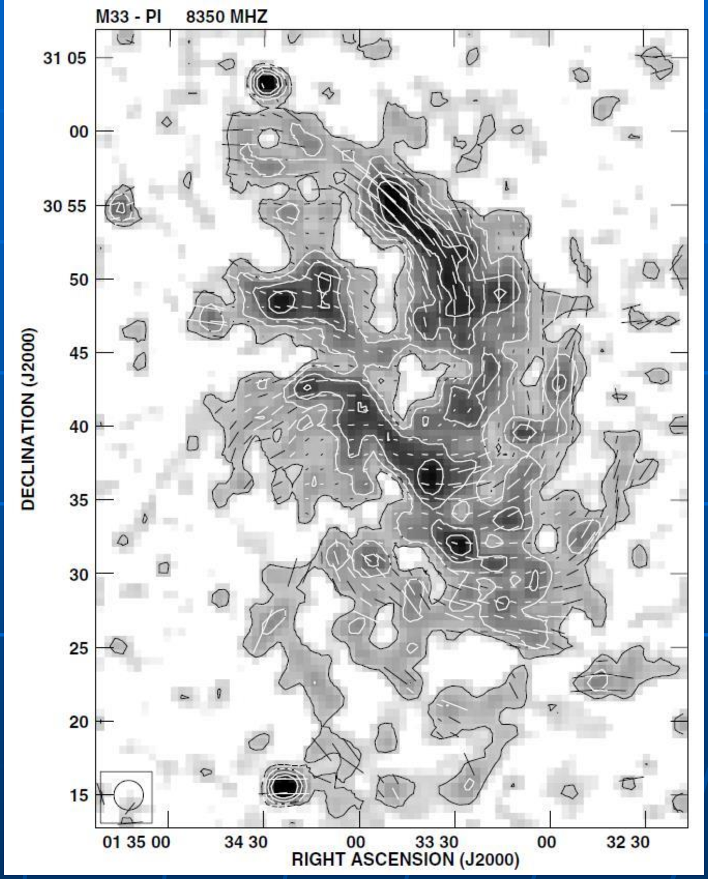
Total intensity:
σ ≈ 0.5 mJy/ 3´ beam

Q & U:
σ ≈ 0.07 mJy/3´ beam

Beck, in prep.

Effelsberg 8.35 GHz (3.6 cm), BW = 1100 MHz





Total intensity:
σ ≈ 0.5 mJy/ 2´ beam

Q & U:
σ ≈ 0.04 mJy/2´beam

Tabatabaei et al. 2008

Effelsberg is the world's most sensitive radio telescope to map diffuse polarized emission

- $\sigma \approx 0.07$ mJy/ 3′ beam (Q&U at 4.85 GHz, 29h on-source to map a field of ≈1 deg^2)
- This corresponds to a surface brightness of diffuse emission of 0.5 μJy/ 15″ beam
- JVLA C-band D-array (3 GHz bandwidth): more than 100h on-source needed, FoV only ≈0.02 deg^2
- JVLA cannot see large-scale emission

→ Effelsberg is more sensitive to diffuse emission than the JVLA

Present-day limits to measure magnetic field strengths with the Effelsberg telescope

Lowest detectable total intensity: $S_{min} \approx 1.5$ mJy/3′ beam (confusion limited):

Equipartition strength of the total field, 1000 pc pathlength, spectral index -0.8: $\approx 6\ \mu G$
100 pc pathlength: $\approx 11\ \mu G$

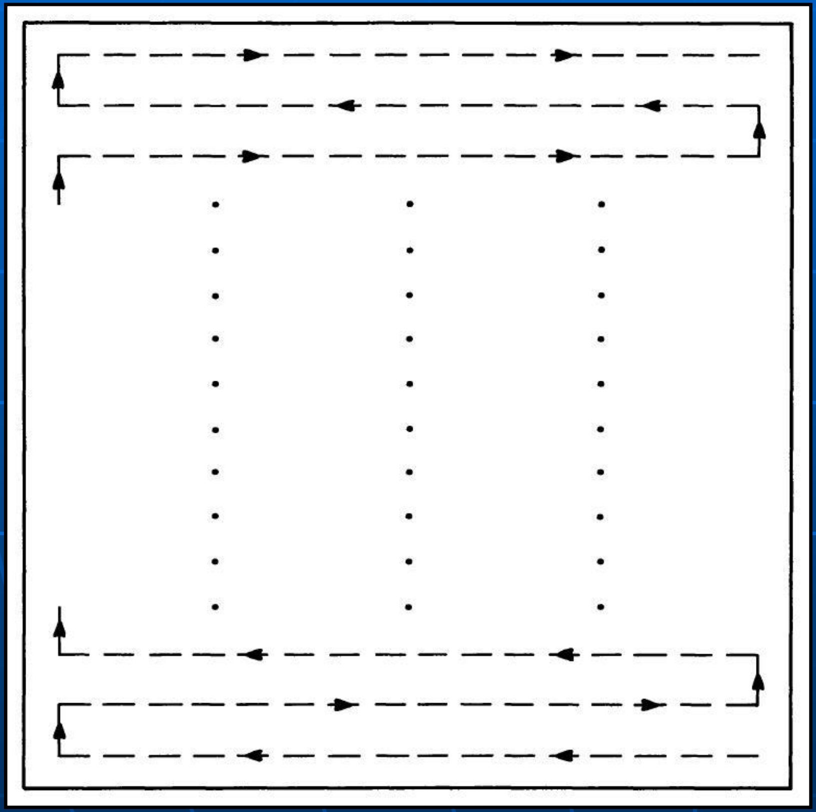
Lowest detectable polarized intensity: $S_{min} \approx 0.2$ mJy/3′ beam (NOT confusion limited):

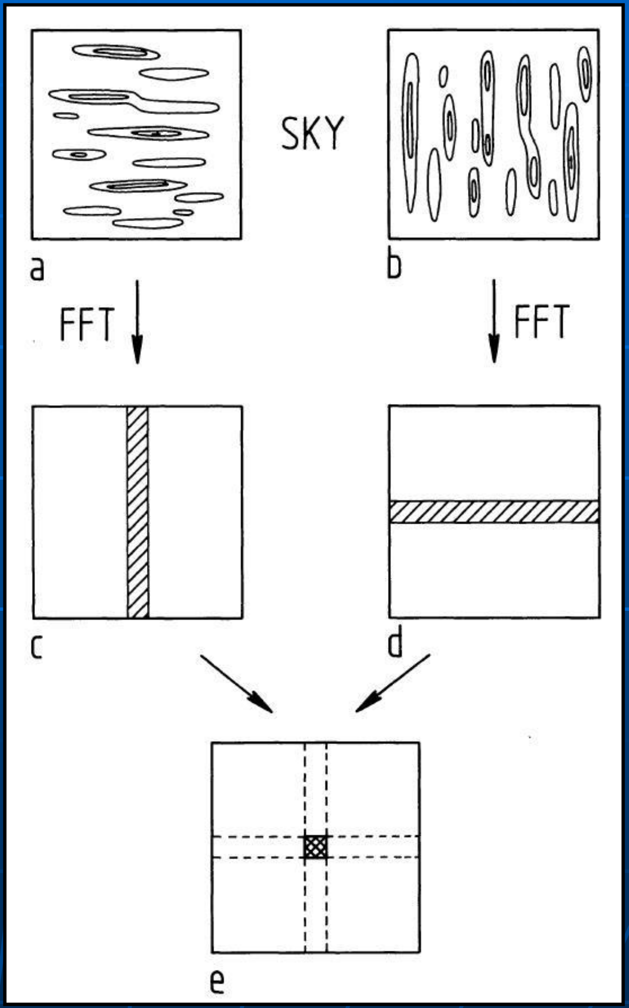
Equipartition strength of the ordered field, 1000 pc pathlength, spectral index -0.8: $\approx 2.5\ \mu G$
100 pc pathlength: $\approx 4.5\ \mu G$

Reasons for the success of the Effelsberg systems

- Sensitivity (low system temperatures)
- Low degree of instrumental polarization
- Absolute gain stability by fast switching of the cal signal
- Relative gain stability between R and L
- Phase stability between Q and U
- Removal of quadratic terms of the correlator by using a 180° phase shift
- Dedicated software to reduce scanning effects

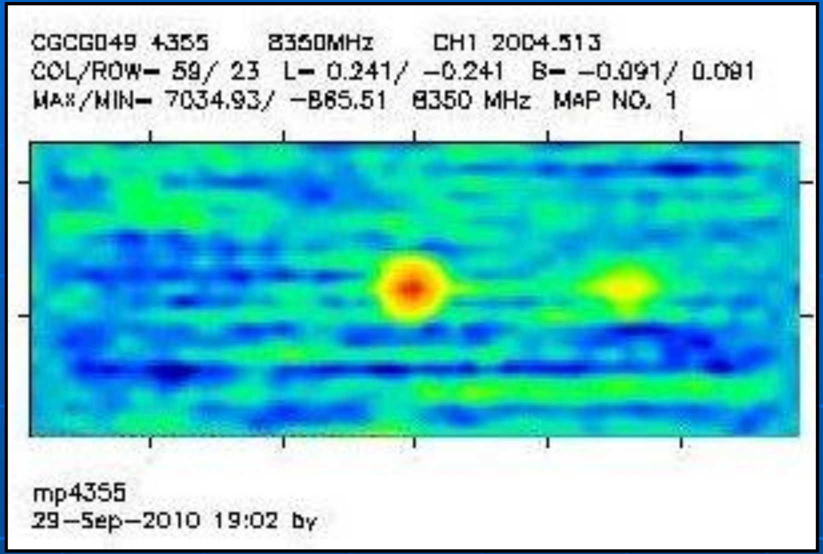
Suppressing scanning noise: Scanning in different directions

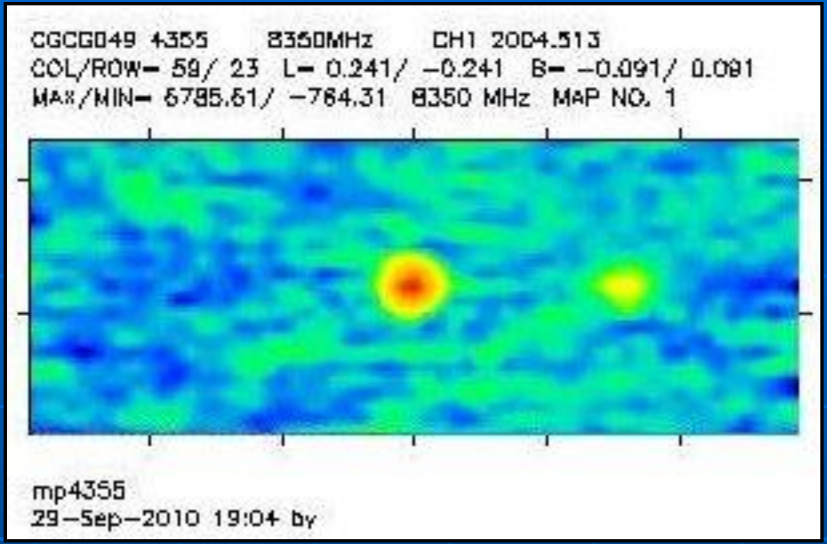




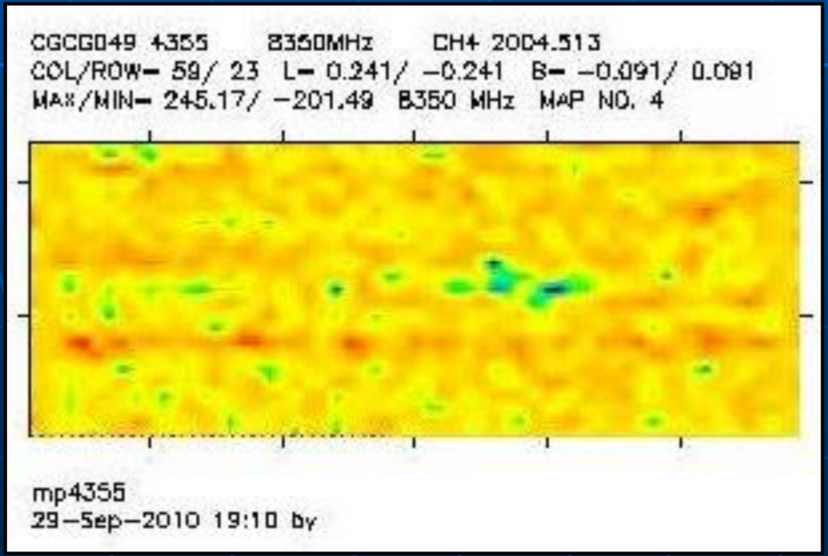
Suppressing scanning noise (8.35 GHz)

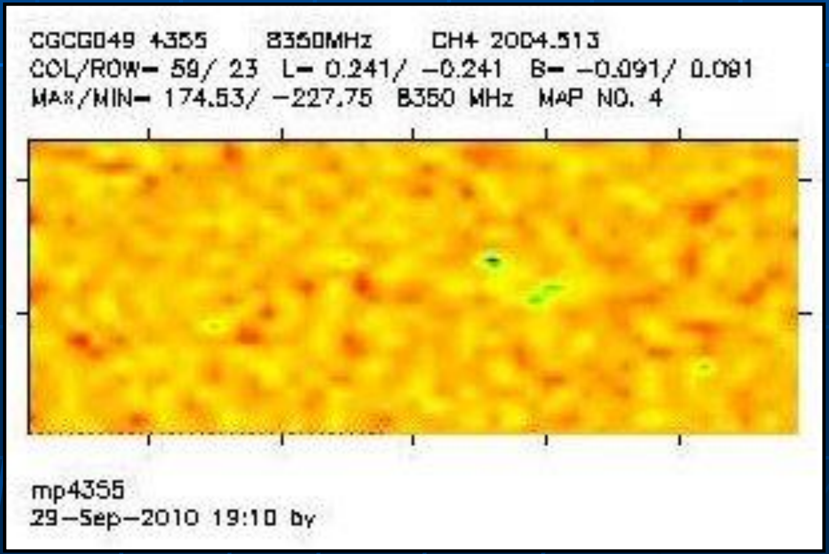
I



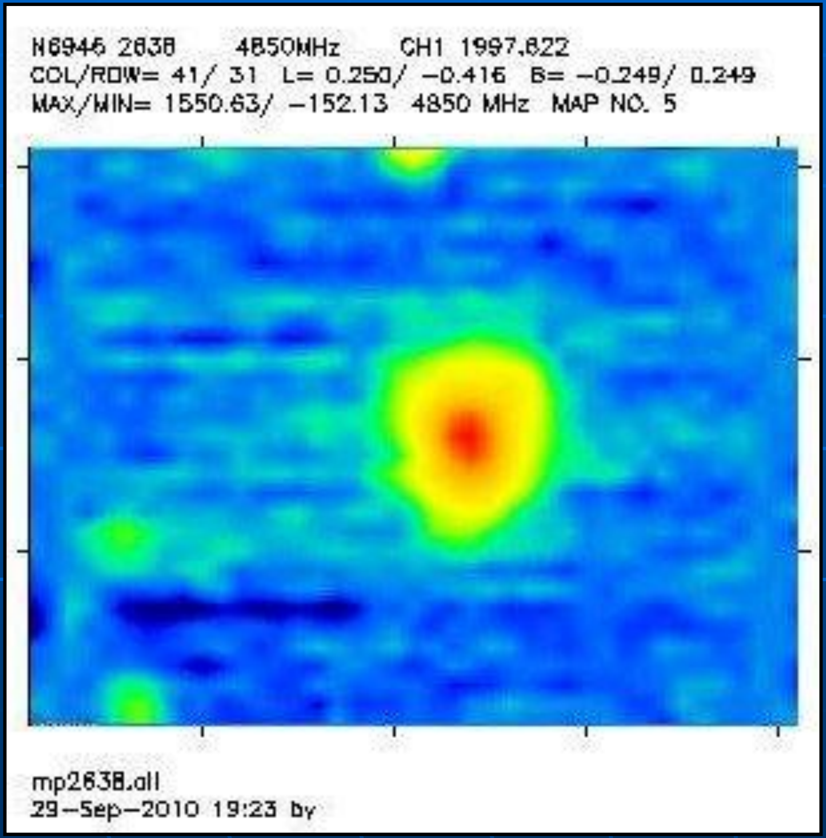


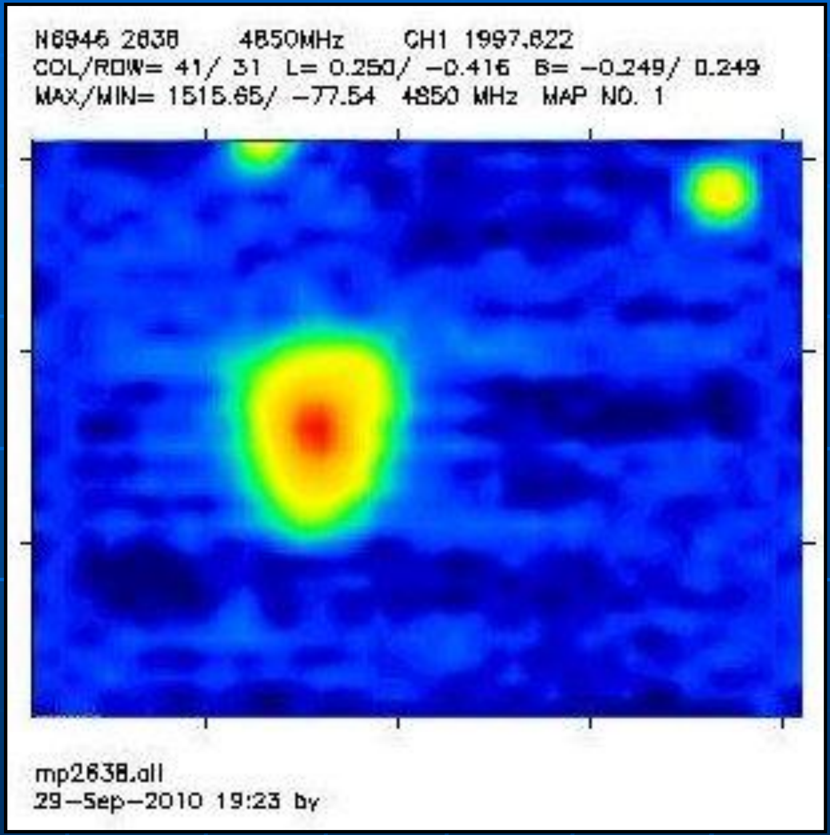
Q





Suppressing scanning noise: Dual-horn observations (4.8 GHz)





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Continuum & polarization mapping: the future

- New wide-band receivers allow even higher sensitivity
- Transformation from linear to circular polarization is crucial, but hardware hybrids cannot be used in the new wide-band systems
  $\rightarrow$ Digital conversion (see e.g. Das et al. 2011)
- Switched calibration signal is crucial for stability (but blank / sync information needed)
- Digital correlation of many frequency channels for two signal inputs (R and L)
- Multi-channel polarimetry allows to apply *RM* Synthesis and to compute *Faraday spectra*)
- Improved software for scanning removal, cleaning, etc: *NOD3*