Observation of linearly polarized sources with a linearly polarized horn

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Many extragalactic radio sources have a high degree of linear polarization (ie. 5–10%). When these sources are observed with a linear polarized horn, the measured antenna temperature (and consequently the flux density) will depend on the parallactic angle (and therefore on time). The reason is the apparent rotation of the source's polarization vector over the horn (for an alt-azimuth mounted telescope like Effelsberg).
Following J.D. Kraus (*Radio Astronomy*, chapter 4), the power W received is given by

$$W = \frac{1}{2} A_{eff} \cdot S_{unpol} + A_{eff} \cdot P \cdot \cos^2(\kappa) \tag{1}$$

with $P = p \cdot S_{tot}$ being the polarized flux density of the source, $S_{tot} = S_{unpol} + P$ the total flux density of the source, $A_{eff} = \eta_A \cdot A_{geom}$ the effective aperture of the antenna, and κ the angle between the wave and antenna polarization state.
Taking into account that $W = k \cdot T_A$ and $T_A/S_{obs} = A_{eff}/2k$, one gets

$$S_{obs} = S_{unpol} + 2 \cdot P \cdot \cos^2(\kappa) \qquad . \tag{2}$$

The angle κ could be expressed as $\kappa = q - \chi + \theta_H$ where q is the parallactic angle, χ the polarization angle of the source, and θ_H the angle between the E-vector of the horn and the north.
Therefore, total and polarized flux density and polarization angle of a source could be determined by a least-square-fit, if several measurements at various parallactic angles are made. θ_H can be derived by observing a source with a known polarization angle, eg. 3C286 (see examples below).
However, the situation certainly is more difficult, if a source shows short-timescale variations in either S_{unpol}, P, or χ.

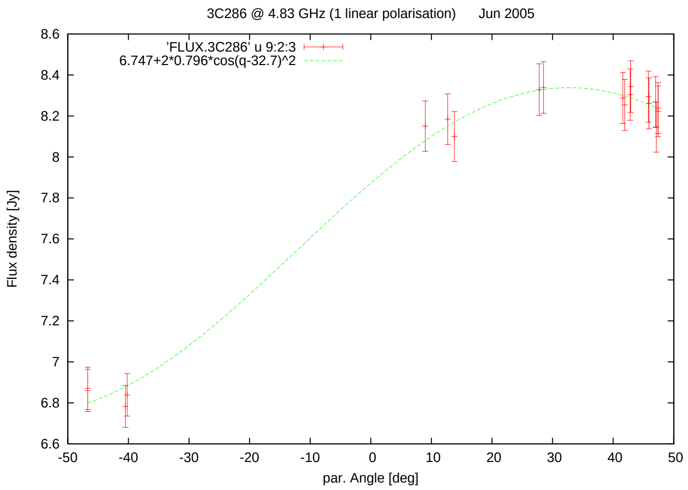
For a receiver with two linear polarizations (like the 1.3cm-primary focus system), we have

$$\begin{aligned} S_{\parallel} &= S_{unpol} + 2 \cdot P \cdot \cos^2(\kappa) \\ S_{\perp} &= S_{unpol} + 2 \cdot P \cdot \sin^2(\kappa) \\ \Rightarrow S_{\Sigma} = \frac{1}{2}(S_{\parallel} + S_{\perp}) &= \frac{1}{2}(2 \cdot S_{unpol} + 2 \cdot P) = S_{tot} \end{aligned} \tag{3}$$

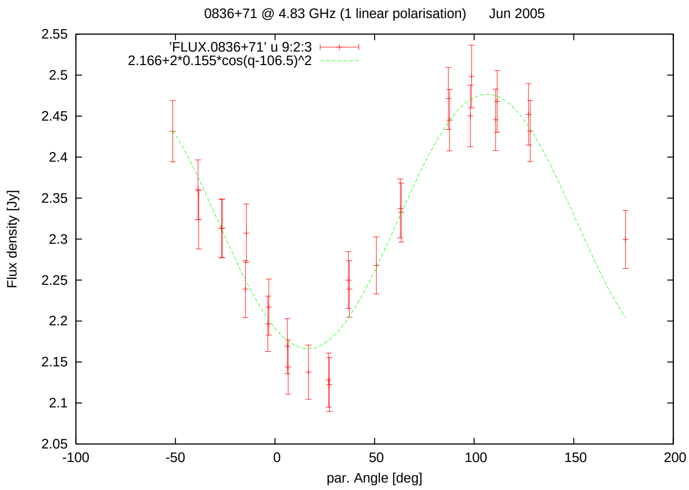
Hence, the sum of both linear polarizations is independent on the parallactic angle, that means, the time dependence has disappeared – unless the source itself exhibits variations in either S_{unpol} and/or P.

Examples:

• 6.5cm-receiver – 4.83 GHz, Jun 2005,
3C286 (expected values: $S_{tot} = 7.50$ Jy, $p = 11.0\,\%$, $\chi = 33$ deg):



$$
\begin{aligned}
S_{unpol} &= 6.747\,\mathrm{Jy} \\
P &= 0.796\,\mathrm{Jy} \\
\chi - \theta_H &= 32.^\circ 7 \\
\Rightarrow \quad S_{tot} &= 7.543\,\mathrm{Jy} \\
p &= 10.6\% \\
\theta_H &= 0.^\circ 3 \qquad (4)
\end{aligned}
$$

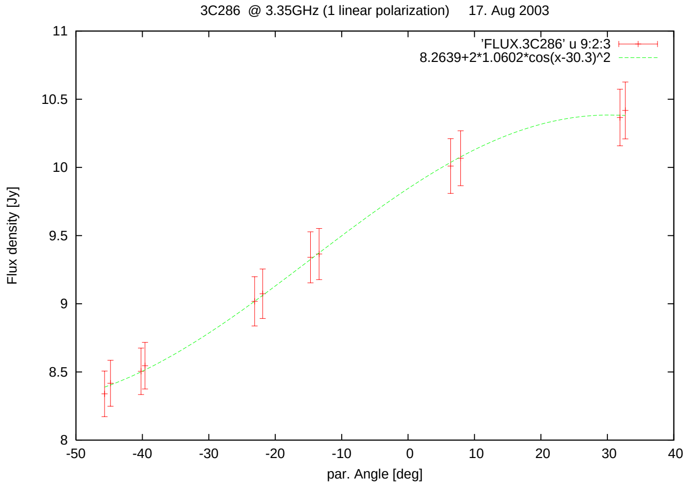


For 0836+710, we get (well in agreement with other measurements, e.g. with the 6cm-secondary focus system):

$$
\begin{aligned}
S_{unpol} &= 2.166\,\mathrm{Jy} \\
P &= 0.155\,\mathrm{Jy} \\
\chi - \theta_H &= 106.^\circ 5 \\
\Rightarrow \quad S_{tot} &= 2.321\,\mathrm{Jy} \\
p &= 6.7\% \\
\chi &= 106.^\circ 8 \qquad (5)
\end{aligned}
$$

- 9cm-receiver – 3.35 GHz, Aug 2003,

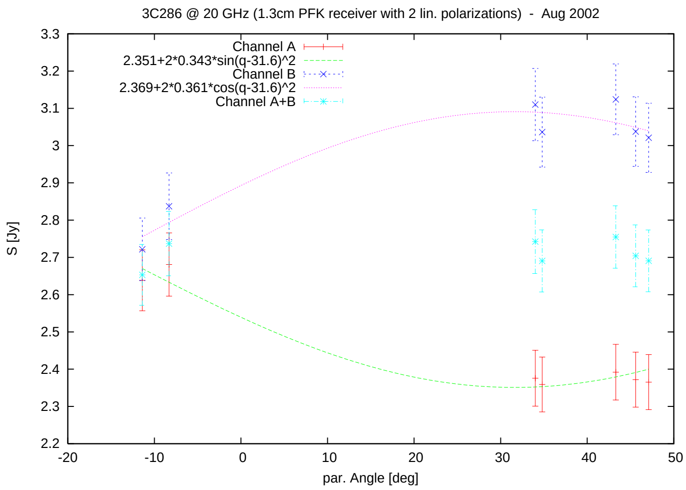
3C286 (expected values: $S_{tot} = 9.35$ Jy, $p = 11.0\,\%$, $\chi = 33$ deg):



$$\begin{aligned} S_{unpol} &= 8.264\,\mathrm{Jy} \\ P &= 1.060\,\mathrm{Jy} \\ \chi - \theta_H &= 30.^\circ 3 \\ \Rightarrow \quad S_{tot} &= 9.324\,\mathrm{Jy} \\ p &= 11.4\% \\ \theta_H &= 2.7^\circ \end{aligned} \tag{6}$$

- 1.3cm-receiver – 20.0 GHz, Aug 2002,

3C286 (expected values: $S_{tot} = 2.70$ Jy, $p \simeq 11.0\,\%$, $\chi = 33$ deg):



$$\begin{aligned} S_{unpol} &= 2.360\,\mathrm{Jy} \\ P &= 0.352\,\mathrm{Jy} \\ \chi - \theta_H &= 31.^\circ 6 \\ \Rightarrow \quad S_{tot} &= 2.712\,\mathrm{Jy} \\ p &= 13.0\,\% \\ \theta_H &= 1.4^\circ \end{aligned} \tag{7}$$