QUIJOTE view on Fan region

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Outline

• Fan region description.
• QUIJOTE observations.
• Results:
  – Correlation plots in I, Q.
  – Fluxes and SED in intensity.
• Conclusions.
Fan region

- Located in the Galactic plane, in the outer part of the Perseus arm.
- Extended around 25° (gl) x 30° (gb)
- Distance ~ 500 pc
- It contains diffuse emission and some sources.

Table 1. Sources in the Fan region

<table>
<thead>
<tr>
<th>Name</th>
<th>l (deg)</th>
<th>b (deg)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR3C58</td>
<td>130.75</td>
<td>3.12</td>
<td>SN remnant</td>
</tr>
<tr>
<td>W3</td>
<td>133.8</td>
<td>1.2</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>W5</td>
<td>137.5</td>
<td>1.1</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>W4</td>
<td>134.7</td>
<td>0.9</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>LBN0679</td>
<td>141.0</td>
<td>-1.7</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>LBN0679</td>
<td>140.7</td>
<td>2.0</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>Bckgr1</td>
<td>138.65</td>
<td>11.5</td>
<td>Molec. cloud</td>
</tr>
<tr>
<td>Bckgr2</td>
<td>135.5</td>
<td>-7.9</td>
<td>Molec. cloud</td>
</tr>
</tbody>
</table>

Intensity at 13 GHz
QUIJOTE observations

• Nominal observations: diffuse emission.

• Raster observations: sources.
  - Period of observations: 02/April/2013 – 16/Nov/2015.
  - Number of observations = 258, total time ~ 450 hours.
  - Null-tests:
    • Dividing in two periods.
    • Dividing in two halves.
    • RMS is computed in a radius of 2° centered in (l=133.4 deg., b=7.19 deg.).
Results:

1. Correlation plots

- The wide survey is used for computing correlation plots in intensity and in polarization and thus, for characterizing the diffuse emission.

- Correlation plots allow us to infer the spectral index of the whole emission in the region.

- Correlations between WMAP 23, 33 GHz and QUIJOTE 11, 13, 17 and 19 GHz are computed in Stokes’ I and Q.

- To this purpose, we consider a extended region:
Correlation plots in intensity

\begin{align*}
\text{QUIJOTE 11.1} & \quad \beta = 1.8 \pm 0.0 \\
\text{QUIJOTE 17.0} & \quad \beta = 2.0 \pm 0.0 \\
\text{QUIJOTE 12.9} & \quad \beta = 1.8 \pm 0.0 \\
\text{QUIJOTE 18.7} & \quad \beta = 2.5 \pm 0.0
\end{align*}
Spectral index derived from correlation plots in intensity

- Spectral index for WMAP (22 – 33 GHz): -2.09±0.02
- Spectral index (11 – 22 GHz): -1.96±0.11 (11 – 33 GHz): -1.99±0.07
- Spectral index (13 – 22 GHz): -1.94±0.24 (13 – 33 GHz): -2.00±0.15
- Spectral index (17 – 22 GHz): -2.16±0.34 (17 – 33 GHz): -2.11±0.17
- Spectral index (19 – 22 GHz): -2.11±0.28 (19 – 33 GHz): -2.08±0.19
The FAN region in polarization
Stokes Q 22GHz

Centroid of emission
in $b=2.2^\circ$
**QUIJOTE** observations at 11GHz.

All maps show a 40°x40° region, centered around (l,b)=(135°,0°).
We mask the polarized sources in the region.

**Spectral index** in the region $l=[122^\circ, 155^\circ]$, and $b=[-12^\circ, 12^\circ]$, computed using TTplots for Q (or P):

- 22-33GHz: $-2.65 \pm 0.13$
- 11-22GHz: $-2.89 \pm 0.03$
- 11-33GHz: $-2.87 \pm 0.06$

**Flattening between 22 and 33GHz!**

**Fuskeland et al. (2014).** Regions 18 and 19 cover the FAN region. Using WMAP data only they found (no source emission masked):

- 18: $-2.82 \pm 0.11$
- 19: $-2.93 \pm 0.11$
FAN in the wide survey

Scaling the Q 22GHz emission to 11GHz assuming beta=-2.6

Q11

Q22 scaled
FAN in the wide survey

Residuals at Q 11GHz after correcting for the scaled emission (beta=-2.6)

Residual at 11GHz from 22GHz

Residual at 11GHz from 33GHz
* Conclusions on diffuse emission:

- Centroid of the emission seems to be shifted to positive values (above the plane). Hill et al. (2017) attribute this to positive warp of the disc in the Perseus arm (+1º).

- Flattening of the spectral index of the polarised emission between 22 and 33GHz. Two populations of electrons?

- Residuals at 11GHz show diffuse emission in the region. Possible explanation: extragalactic cosmic ray contribution?

- In intensity the emission is compatible with mainly free-free emission.
2. Fluxes and SED

- Raster observations are used for computing the flux in the sources by doing aperture photometry. Flux is computing by considering the pixels of the source and masking everything else.

- Four different regions are considered for computing the background.
Fluxes

• Ancillary data used: Haslam, Reich, HartRAO, Urumqi, WMAP, Planck and DIRBE.

• The SED is fitting to several components: free-free, synchrotron, thermal dust, AME, CMB (see Poidevin’s talk).

• Commander simulations and Finkbainer are used to infer some information about EM, electron temperature, etc.
SED in intensity: W3

- **Fit models:**
  - dash-blue: sync
  - purple: free-free
  - red: AME
  - orange: dust

- **Data points:**
  - yellow: Has, Rei, Har
  - red: QUIJOTE
  - green: WMAP
  - blue: Planck
  - orange: DIRBE
SED in intensity: W4

- **Fit models:**
  - dash-blue: sync
  - purple: free-free
  - red: AME
  - orange: dust

- **Data points:**
  - yellow: Has, Rei, Har
  - red: QUIJOTE
  - green: WMAP
  - blue: Planck
  - orange: DIRBE
SED in intensity: W5

- **Fit models:**
  - dash-blue: sync
  - red: AME
  - orange: dust

- **Data points:**
  - yellow: Has, Rei, Har
  - red: QUIJOTE
  - green: WMAP
  - blue: Planck
  - orange: DIRBE
Conclusions

• First analysis of the spectral energy distribution of the sources of the Fan: W3, W4, W5:
  - We found evidences for AME in molecular clouds W3, W4 and W5 when QUIJOTE frequencies are included (in I).

• Diffuse emission is dominated by free-free emission in intensity while in polarization, we find evidence for a turn-off in the spectral index of the synchrotron:
  - This could be interpreted as two populations of cosmic rays.

THANK YOU FOR YOUR ATTENTION.