Metallicity of M33 using Planck data

L. Fauvet
F. Israel, R. Laureijs, R. Leonardi, J. Tauber

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What about M33?

nearby spiral Galaxy with expected low metallicity.

IRAS + ISO + Spitzer

SED

M33 spectrum

Flux Density (Jy)

Frequency (GHz)

Submm continuum to be determined ...

courtesy F.Israel
SED and dust characteristics

Submm continuum: dominated by thermal dust emission

peak of the black body: constraint on the dust grain temperature.

information on the surrounding medium.

slope: constraint on $\beta$ which could be an indicator of the metallicity.

$\Rightarrow$ nature of the dust grains.

strong degeneracy between $\beta$ and $T$.

courtesy F.Israel
Why do we need Planck data?

- data currently available not enough to constrain \( \rightarrow \) peak wavelength : \( T_d \)
  \( \rightarrow \) Rayleigh-Jean slope : \( \beta \)

- \( \beta \) and \( T \) not independents : requires accurate fit on both.

- PCCS (Planck Catalogue of Compact Sources) ?
  
  ➞ contains compact sources \( \sim \) few arcmin.

  ➞ more accuracy needed to solve a specific extended source like M33.

  ➞ especially : gradient expected between the center similar to MW and the arms similar to the LMC.

combined use of Planck data + SPIRE + PACS to conclude
Method (1/3)

data used: 2013 Planck public data release of HFI 100 – 857 GHz

2 complementary approaches:

⇒ full galaxy [square patch of 30 arcmin²].

⇒ 3 restricted area: center, West and East arms.
Method (2/3) : full galaxy photometry

- convolution with 100 GHz channel beam (10arcmin).
- subtraction of CMB.
- removal of the galactic foreground.
- calculation of the flux associated to each patch.
Method (3/3) : photometry of restricted area

- fixed 5 arcmin resolution (30-353 GHz) : average value over the width of the size.
- selected 3 positions along the slice running over the major axis of the galaxy
- west and east arm at 4kpc from center

- constant background subtraction (uncertainties of ½ difference of foregrounds in West and East arms )
- CMB removal
CMB removal and other uncertainties

4 CMB removal method

all show differences at M33 center

⇒ value on M33 position not reliable

⇒ to be take into account as an uncertainty.

Other uncertainties:

• foreground removal based on average calculation: existing gradient?

• instrumental noise
Photometry calculation

- Planck HFI
- SPIRE (total flux [Kramer et al 2011 ])

- consistency of both set but bias due to calibrations and beam correction on SPIRE data have to be taken into account for the all galaxy photometry.

- on restricted area: error bars to be improved.

- power law behaviour.
Fit with modified black body body

\[ F(\nu, \beta_d, T_d) = \left( \frac{\nu}{\nu_0} \right)^{\beta_d} \frac{\exp^{\frac{h\nu}{kT_d}} - 1}{\exp^{\frac{h\nu}{kT_0}} - 1} \]

\( X^2 \) min based comparison method

The SED associated to each area of M33 considered is compared to a modified black body based on Planck law:

\[ F(\nu, \beta_d, T_d) = \left( \frac{\nu}{\nu_0} \right)^{\beta_d} \frac{\exp^{\frac{h\nu}{kT_d}} - 1}{\exp^{\frac{h\nu}{kT_0}} - 1} \]

from this comparison we extracted best-fit values for the 2 parameters \( \beta_d \) and \( T_d \) in those regions, considering the data between 143 and 857 GHz to set the parameters.
Preliminary results

<table>
<thead>
<tr>
<th>$\nu$ (GHz)</th>
<th>Parameter</th>
<th>Center</th>
<th>West arm</th>
<th>East arm</th>
<th>full M33</th>
</tr>
</thead>
<tbody>
<tr>
<td>217 to 545</td>
<td>$\beta_d$</td>
<td>$1.34 \pm 10^{-3}$</td>
<td>$1.23 \pm 0.02$</td>
<td>$1.36 \pm 0.05$</td>
<td>$1.31 \pm 0.16$</td>
</tr>
<tr>
<td>217 to 857 (+spire)</td>
<td>$\beta_d$</td>
<td>$1.33 \pm 10^{-3}$</td>
<td>$1.02 \pm 0.01$</td>
<td>$1.13 \pm 5.10^{-3}$</td>
<td>$1.42 \pm 0.11$</td>
</tr>
<tr>
<td>217 to 545</td>
<td>$T_d$</td>
<td>$23.55 \pm 10^{-3}$</td>
<td>$23.88 \pm 0.01$</td>
<td>$19.72 \pm 0.08$</td>
<td>$22.98 \pm 0.22$</td>
</tr>
<tr>
<td>217 to 857 (+spire)</td>
<td>$T_d$</td>
<td>$23.67 \pm 2.10^{-3}$</td>
<td>$21.38 \pm 0.02$</td>
<td>$19.92 \pm 0.06$</td>
<td>$23.72 \pm 0.15$</td>
</tr>
</tbody>
</table>

Starburst, AGN (high metallicity galaxies)

$\Rightarrow \beta = 1.68 \pm 0.06$

Low metallicity dwarf galaxies [Kramer 2011]

$\Rightarrow \beta = 1.08 \pm 0.12$

MW : $1.63 \pm 0.3$ [Planck 2013 results XXXI]

M33 $\Rightarrow \beta \approx 1.30$ (based only on Planck) on average : medium metallicity

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Conclusions and work ahead ...

• good consistency between Planck and SPIRE (bias due to calibration to be corrected)

• preliminary results: M33 in between high and low metallicity will study of separate area shows different behaviour?

TO BE DONE ...

• LFI data to be used: flat slope at low frequencies?
• PACS data to be add: improvement of constraint on T

• better estimation of the uncertainties

• calibration Herschel/Planck to be understood.

• color correction factor to be apply.

• contamination by radio continuum (synchrotron and free-free) to be estimated

• extension of the work to NGC6822 (another low metallicity galaxy)