PROCEEDINGS OF SCIENCE

[CII] as a star formation rate tracer in M31: Is [CII]/TIR the best photoelectric heating efficiency proxy?

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The [CII] 158μm line is typically the brightest far-IR emission line from star-forming galaxies. To use this line as a tracer of star-formation and a diagnostic of the ISM conditions, we must understand details of the heating mechanisms generating it and contributing to the total observed emission, especially the photoelectric (PE) heating mechanism.

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1. Introduction

The [CII]/TIR is the most commonly used observational proxy for photoelectric (PE) heating efficiency. The ratio has been found "deficient" in many galaxies on global and sub-galactic scales [1, 2]. The most commonly used explanation is grain charging lowering the PE yield. The fact that we observe the [CII]/TIR changing by a factor of ~ 3 in M31 (see overview of the SLIM fields in Figure 1; [3]), while [CII] is closely tracing SFR raised our suspicions on how good the $\varepsilon_{PE}^{dust} = [CII]/TIR$ approximation of the PE efficiency is.

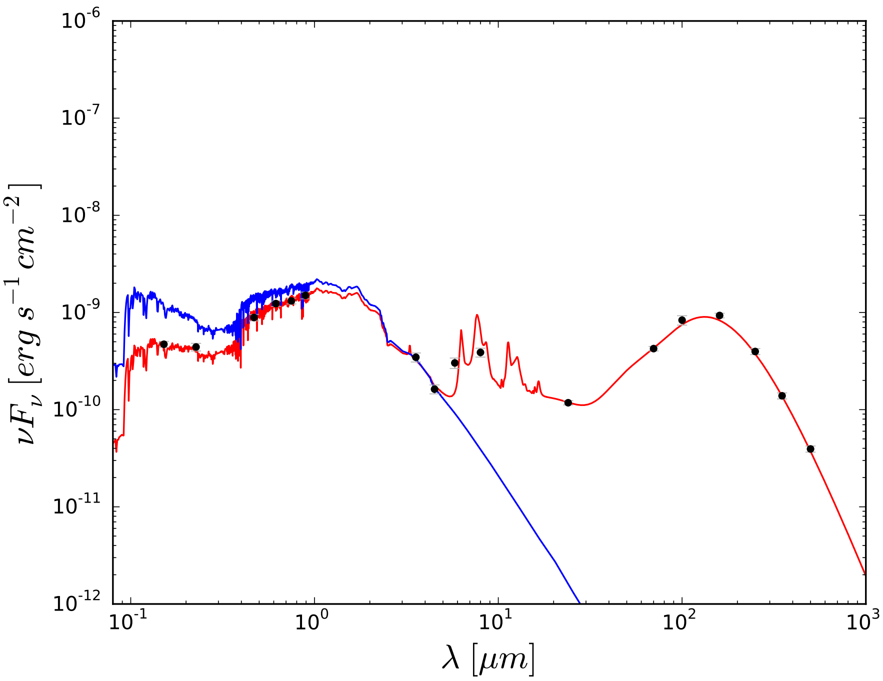

Figure 1: An example SED fitting using MAGPHYS in SLIM field 3. Red shows the best fit to the data (black points), blue represents estimated intrinsic stellar spectrum.

Theoretically the PE heating efficiency is defined as the ratio of gas heating to the grain FUV absorption rate [4], and finds theoretical values 0.1 - 5%.

$$\varepsilon_{PE}^{TH} = \frac{\Gamma_{gas\ heating}}{\Gamma_{grain\ FUV\ absorption}} \tag{1.1}$$

2. Methodology & Results

We use MAGPHYS [5] SED fitting (e.g. in Figure 1) to estimate the energy input from stars into the ISM in the energy range where photons are energetic enough to eject photoelectrons, i.e. UVatt (6 - 13.6eV). We introduce a new PE efficiency proxy, which is closer to the theoretical definition than [CII]/TIR:

$$\varepsilon_{PE}^{UV} = \frac{[CII]}{UV_{att}} \tag{2.1}$$

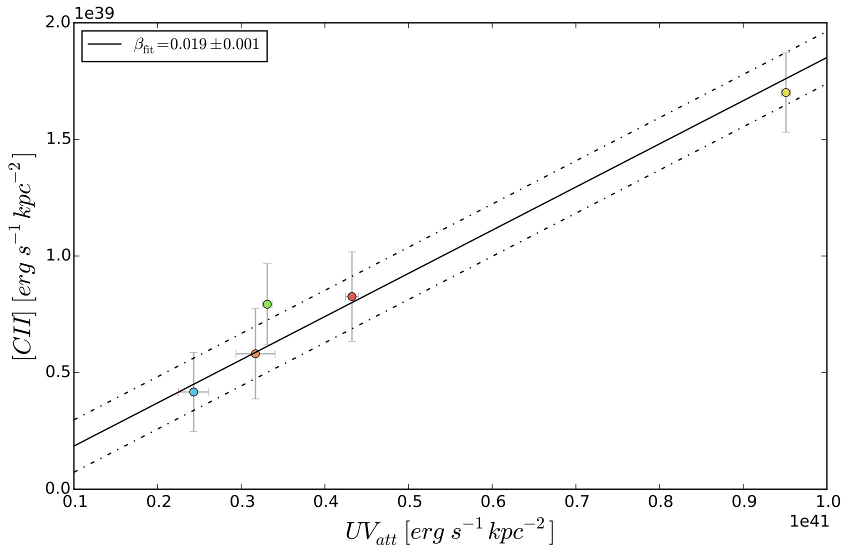

Figure 2: Observed [CII] emission in the SLIM fields versus predicted attenuated FUV emission based on MAGPHYS SED fitting. Infered PE efficiency is $1.9 \pm 0.1\%$.

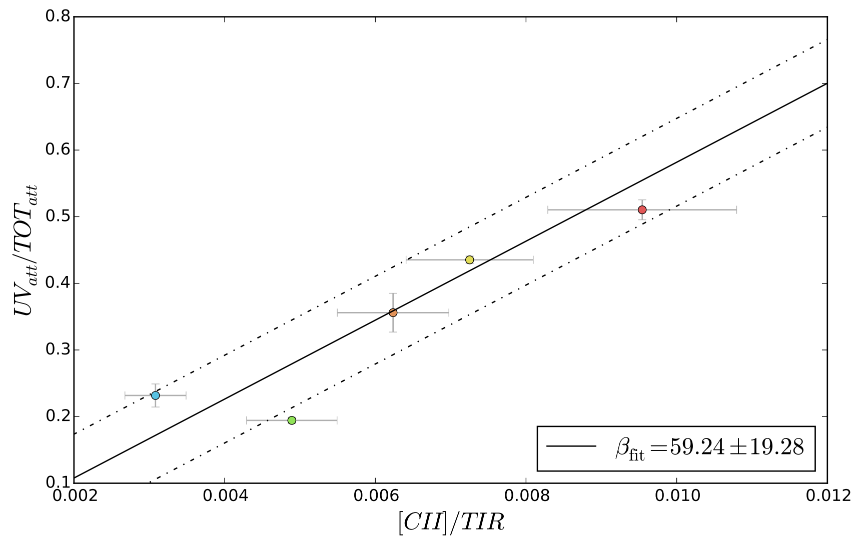

Figure 3: Observed [CII]/TIR versus infered UVatt over TOTatt based on MAGPHYS SED fitting.

We find one constant PE heating efficiency $\varepsilon_{UV} \sim 1.9\%$, that can predict reasonably well the observed [CII] emission in all of the SLIM fields (see Figure 2). If that is the case, the factor of ~ 3 gradient across the disk in [CII]/TIR (see Figure 9 in [3]) is not related to the PE efficiency. That raises the question: what else drives the [CII]/TIR gradient in the disk?

We find that the [CII]/TIR radial decline is related to the gradient in the UV_{att}/TOT_{att} in the SLIM fields (see Figure 3). UV_{att}/TOT_{att} estimates of the fraction of stellar energy that can contribute to gas heating over the total absorbed stellar energy.

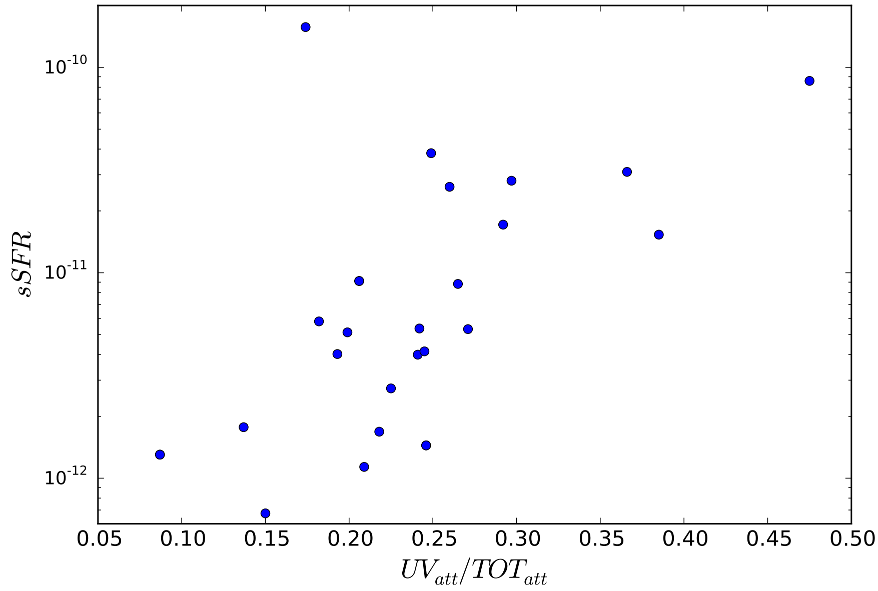

Figure 4: Specific star formation rates (SFR per unit stellar mass) plotted against UV_{att}/TOT_{att}.

3. Conclusions

1) We can predict [CII] emission in the SLIM fields in the disk of M31 based on the estimated fraction of the stellar energy that contributes to gas heating ($\varepsilon_{UV} \times UV_{att}$) with a constant PE heating efficiency ($\varepsilon_{UV} \sim 1.9\%$).

2) The PE heating efficiency constancy is also supported by the fact that [CII] works as a SFR tracer in each SLIM field despite the factor of 3 gradient in the [CII]/TIR found between these fields.

3) In Figure 4 we show that UV_{att}/TOT_{att} (and therefore [CII]/TIR) is correlated with sSFR, which can be explained by the fact that the relative change in the absorbed stellar hardness is controlled by the SFH and the recent SF.

References

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