Probing the ISM Properties of Galaxies through their FIR Fine-Structure Lines: The SHINING View

Javier Graciá-Carpio (MPE)

 E. Sturm, S. Hailey-Dunsheath, J. Fischer, A. Contursi, A. Poglitsch, E. González-Alfonso,
A. Sternberg, A. Verma, N. Christopher, R. Genzel, R. Davies, H. Feuchtgruber, J. A. de Jong, D. Lutz, L. Tacconi and S. Veilleux

What we knew before Herschel



[Noeske et al. 2007, ApJ 660: L43]

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« Presumably, the regularity and constant dispersion of the Main Sequence out to $z \sim 1$ means that the same physics that regulates SF in local disk galaxies is operating, indicating significant evolution either in the gas supply or SF efficiencies over this interval. »

Indeed...

After many years of hard work from the millimeter community



[Saintonge et al. 2013, astro-ph/1309.3281]



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(for the galactic gang: is like moving from the Taurus GMC to the Orion and W49 GMCs)

SHINING

Far-infrared fine structure lines:

- PDR lines: [C II] 158μm, [O I] 145μm, [O I] 63μm
- HII lines: [N II] 122μm, [O III] 88μm, [N III] 57μm, [O III] 52μm

Sample:

- 9 local starbursts (M 82, NGC 253, M 83, ...)
- 18 Seyfert galaxies (NGC 1068, Cen A, Circinus, ...)
- 28 LIRGs and ULIRGs (NGC 4418, Arp 220, Mrk 231, ...)
- 9 Lyman break analogues
- 5 high-z star forming galaxies (MIPS J142824.0, ...)
- 4 high-z AGNs (IRAS F10214, Cloverleaf, ...)

Integrated properties





[Díaz-Santos et al. 2013, ApJ 774: 68] [Sargsyan et al. 2012, ApJ 755: 171] [Graciá-Carpio et al. 2011, ApJ 728: L7]



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[Brauher et al. 2008, ApJS 178: 280]

- Seyfert & QSO
- Low-mass galaxy
- Lyman break analog
- Unclassified

[Luhman et al. 2003, ApJ 594: 758] [Malhotra et al. 2001, ApJ 561: 766]



- HII galaxy
- LINER
- Seyfert & QSO
- Low–mass galaxy
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- Unclassified
- High–z galaxy

[Graciá-Carpio et al. 2013, in prep.] [Contursi et al. 2013, in prep.] [Farrah et al. 2013, ApJ 776: 38] [Díaz-Santos et al. 2013, ApJ 774: 68] [Sargsyan et al. 2012, ApJ 755: 171] [Graciá-Carpio et al. 2011, ApJ 728: L7] [Brauher et al. 2008, ApJS 178: 280]

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- [Walter et al. 2009, Nature 457: 699]



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A general far-infrared line deficit



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Line emission vs. L_{FIR}/M_{H_2}



$L_{FIR}/M_{H_2} \simeq 1{-}100\,L_{\odot}\,M_{\odot}{}^{-1}$

Line emission vs. L_{FIR}/M_{H_2}





$$L_{FIR}/M_{H_2} \simeq 1 - 100 \, L_{\odot} \, M_{\odot}^{-1}$$

Line emission vs. L_{FIR}/M_{H_2}





$$L_{FIR}/M_{H_2}\simeq 1{-}100\,L_\odot\,M_\odot^{-1}$$

 $L_{FIR}/M_{H_2} \simeq 100\text{--}1000\,L_{\odot}\,M_{\odot}^{-1}$











Spatially resolved properties

NGC 1068 line and continuum maps



NGC 1068 line and continuum maps



Global trends



HII galaxies



Seyfert galaxies



HII galaxies + disks of Seyfert galaxies





Explaining the line deficits



Explaining the line deficits



Conclusions

- We find line deficits in all the fine structure lines, regardless of their origin in the ionized or neutral phase of the ISM.
- Independent of their redshift, galaxies with high SFE and high dust temperatures tend to have weaker lines compared with their FIR continuum.
- We find similar trends when we study the resolved emission for the closest SB and Seyfert galaxies. However, only in few points the line to continuum ratios are as low as those found globally for many luminous and ultraluminous infrared galaxies.
- The FIR emission properties of compact and ultracompact HII regions are quite similar to those in IR luminous galaxies, which might indicate similar excitation conditions.