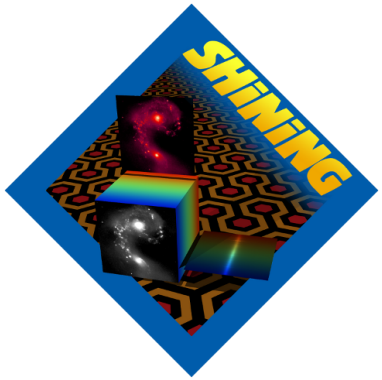

SHINING: studying physical processes in the intersellar media of galaxies

Javier Graciá-Carpio (MPE)

on behalf of the SHINING team:

E. Sturm (PI), 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

SHINING

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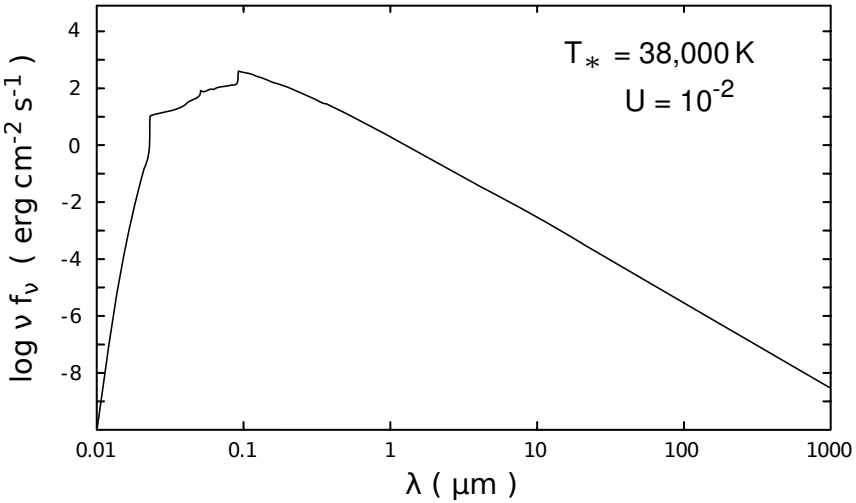
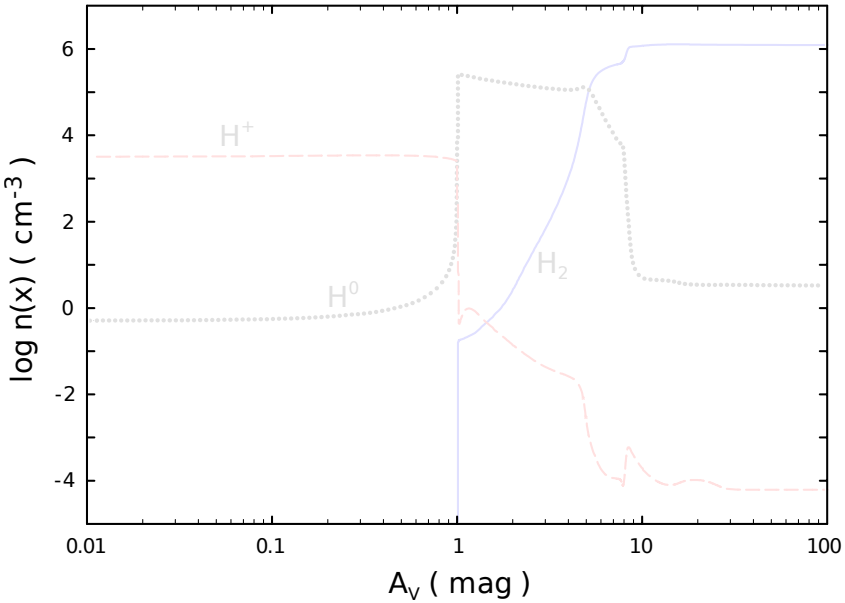
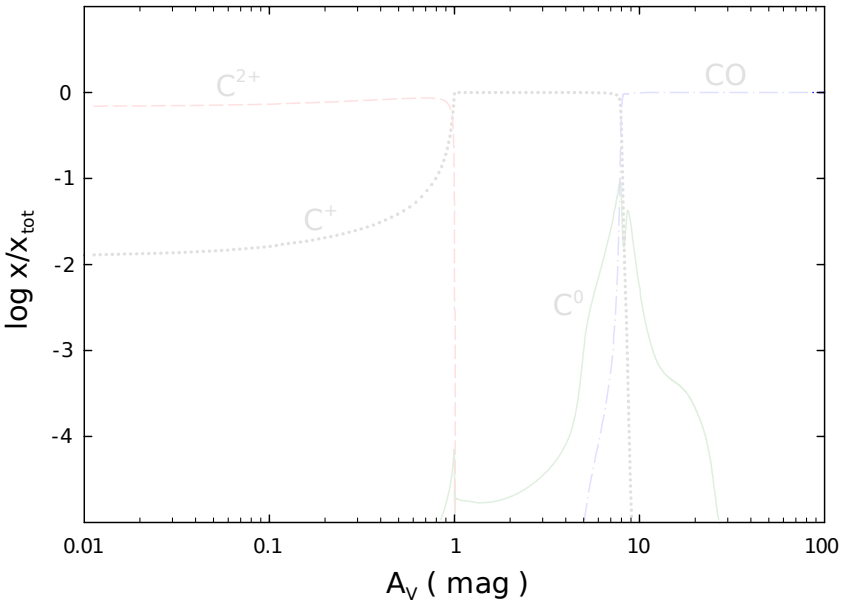
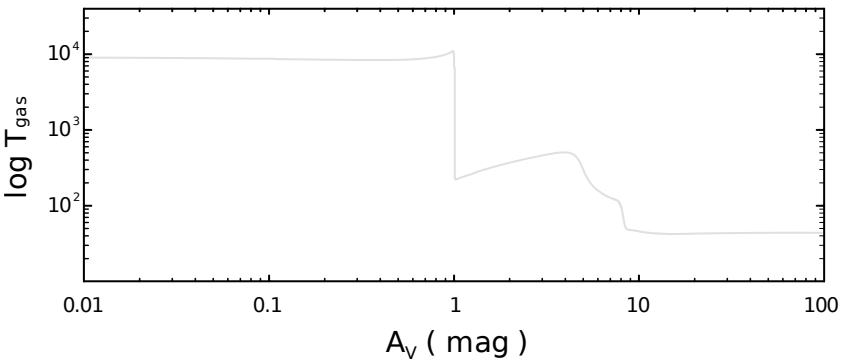
The HII–PDR–molecular cloud connection









[Abel et al. 2005, ApJS 161: 65]

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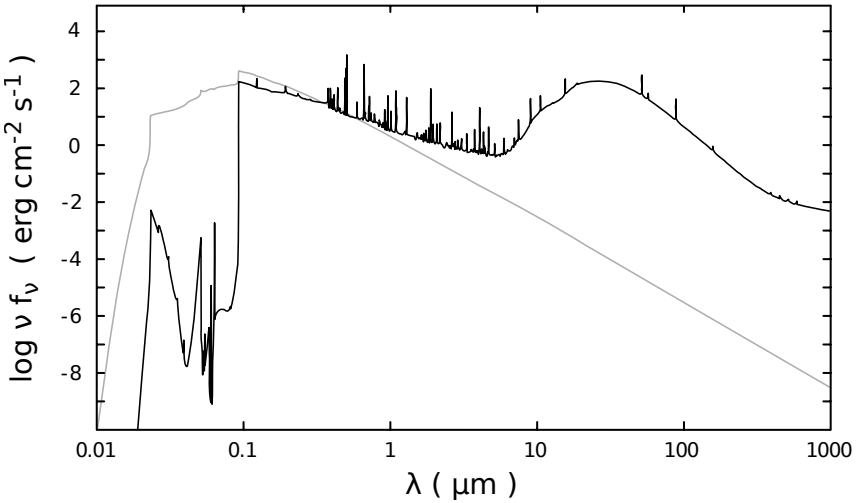

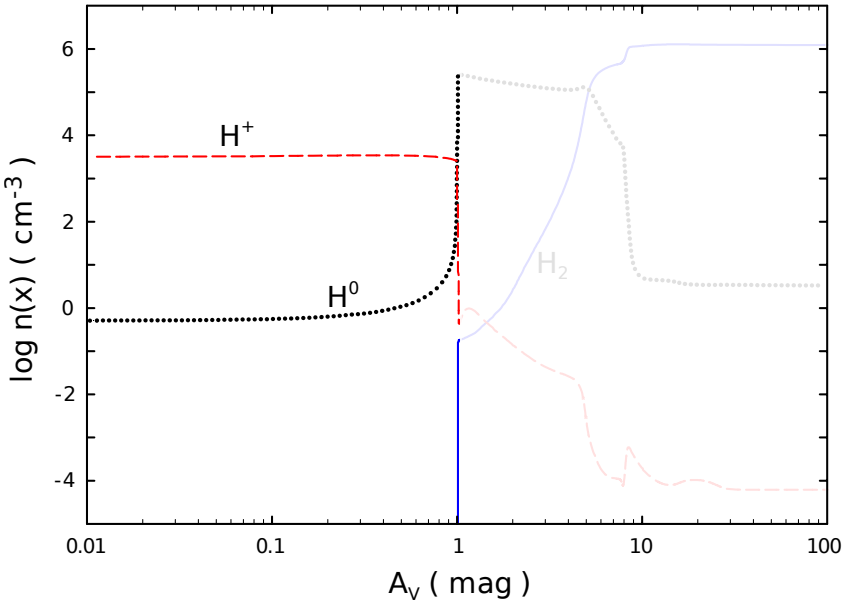

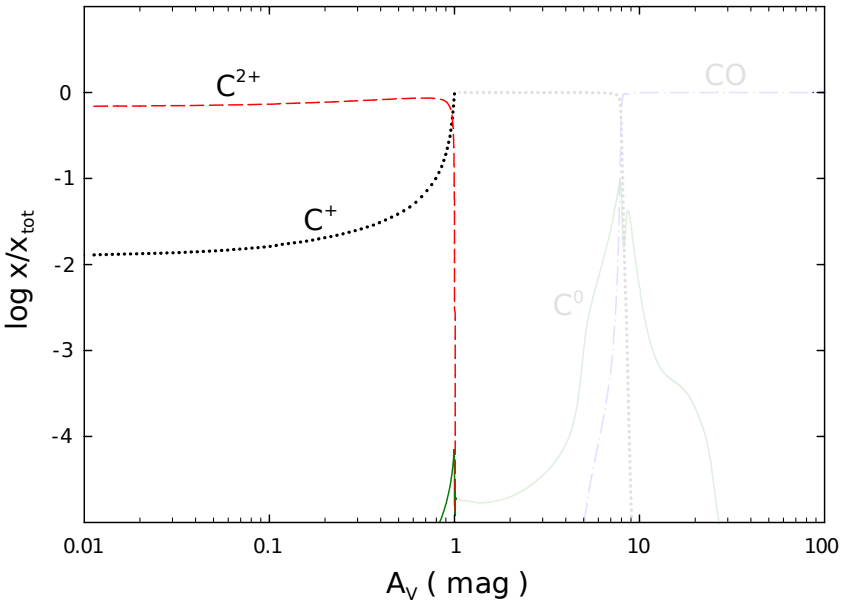

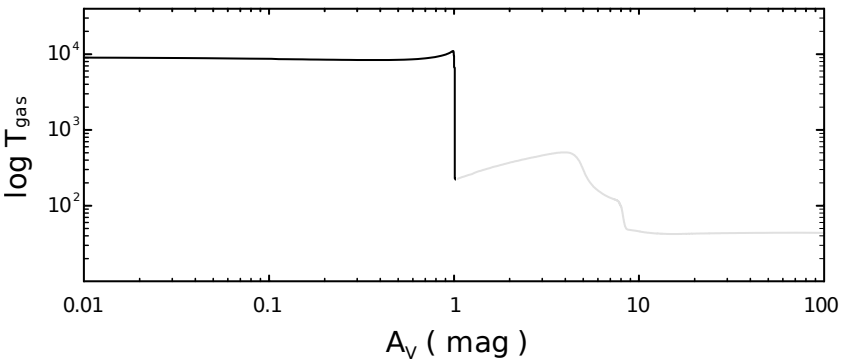

[Abel et al. 2005, ApJS 161: 65]

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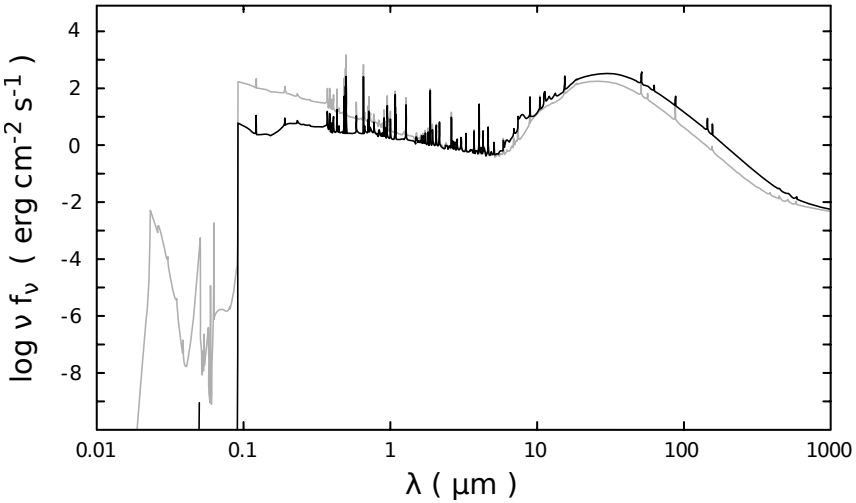

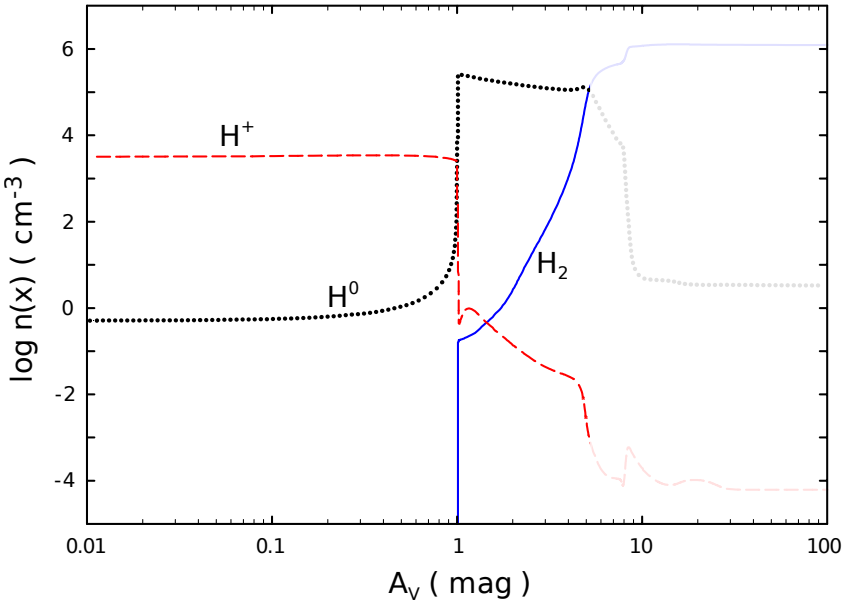

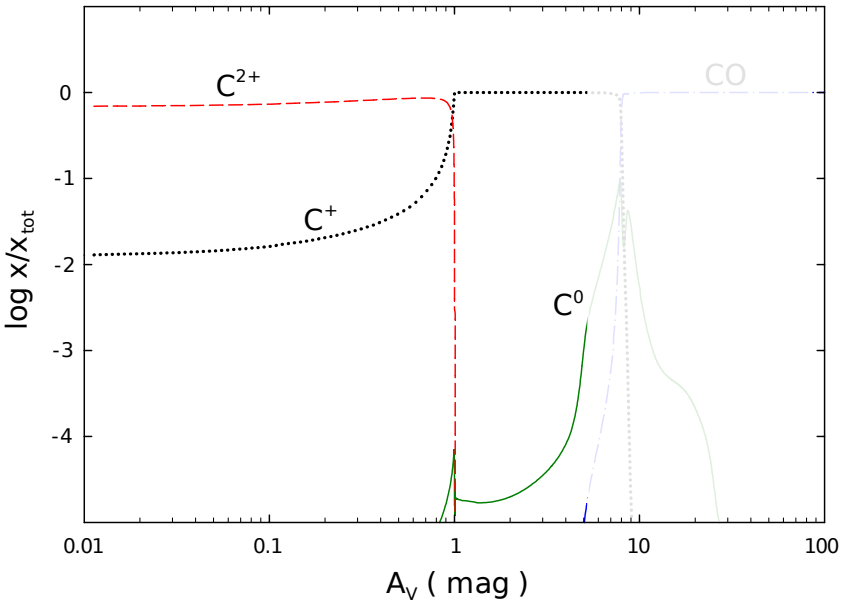

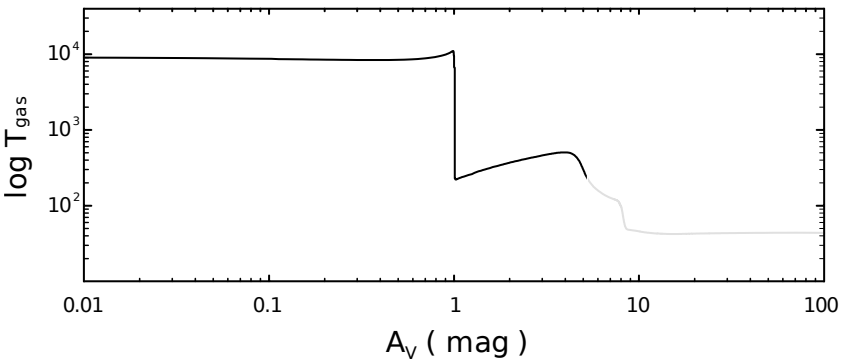

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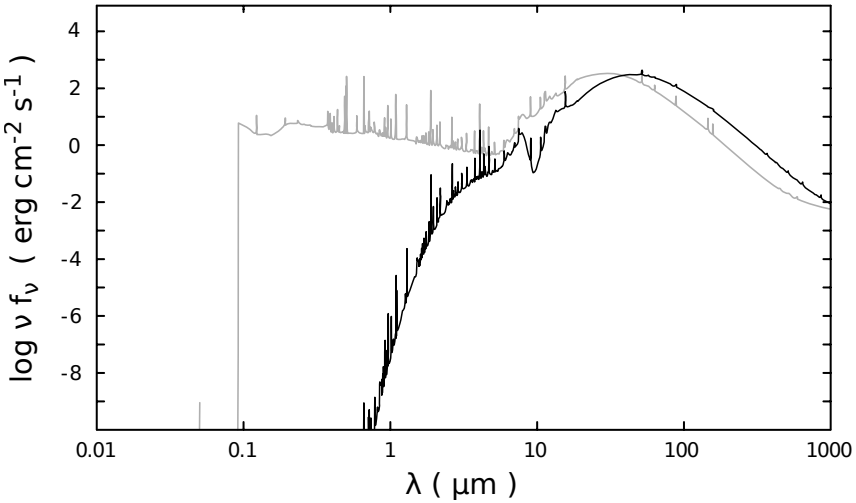
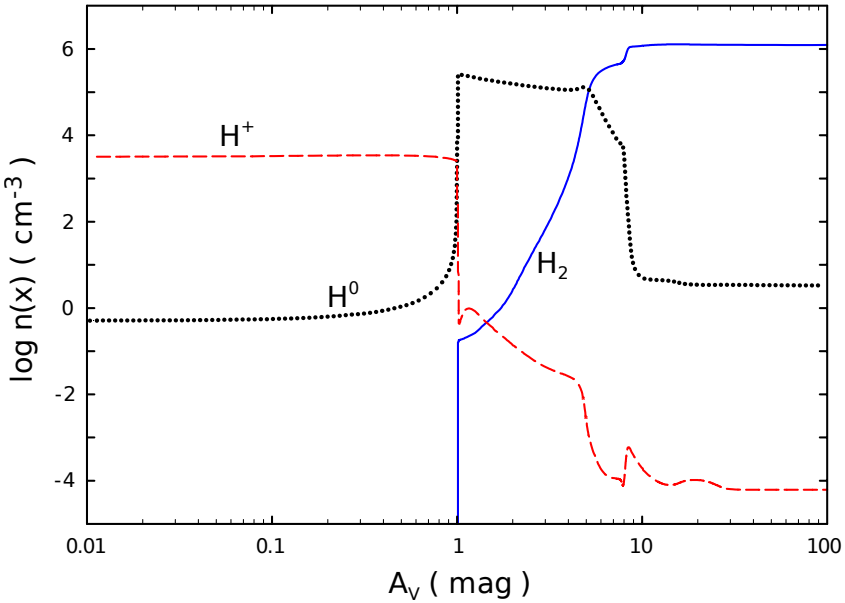
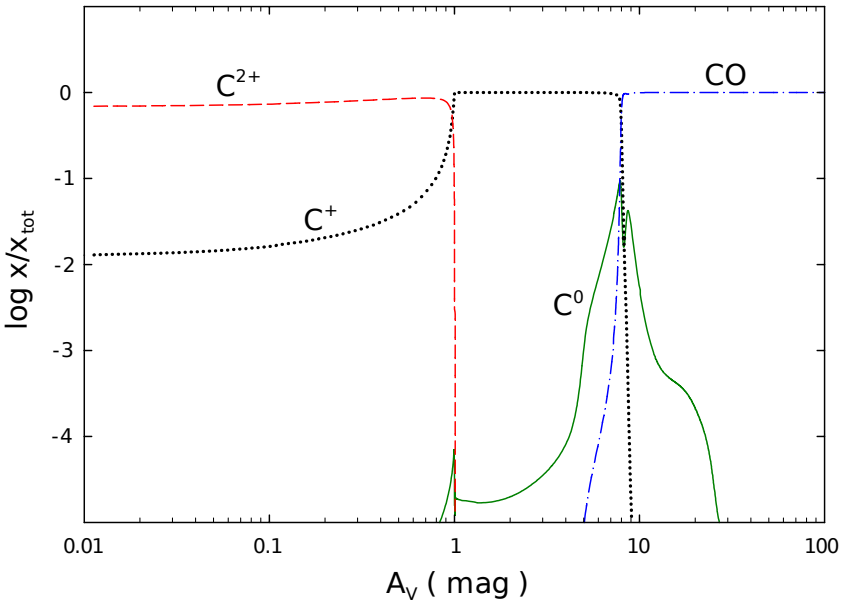
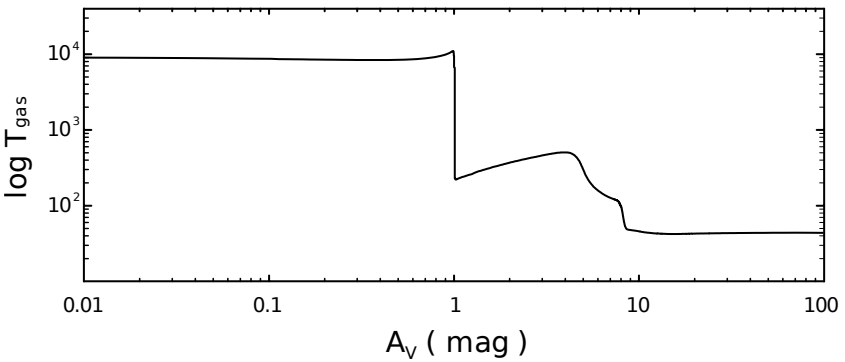
The HII–PDR–molecular cloud connection









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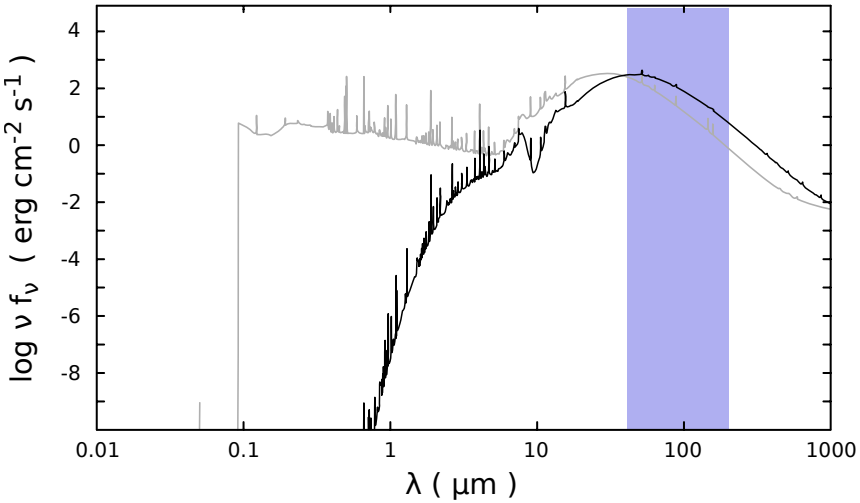
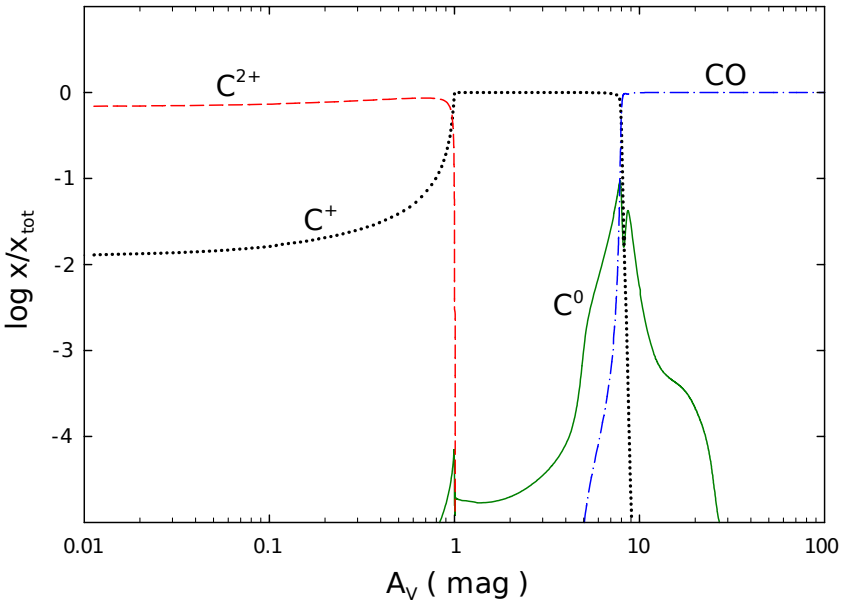
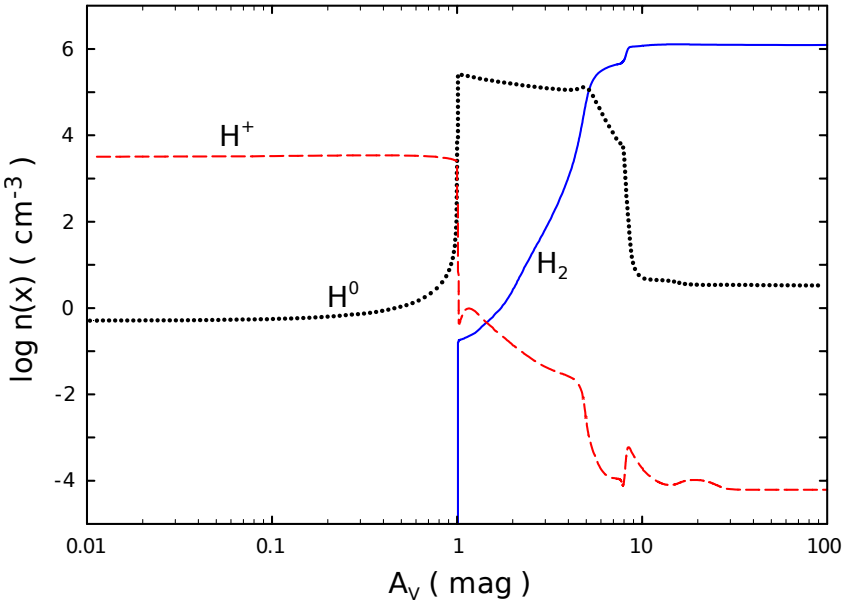
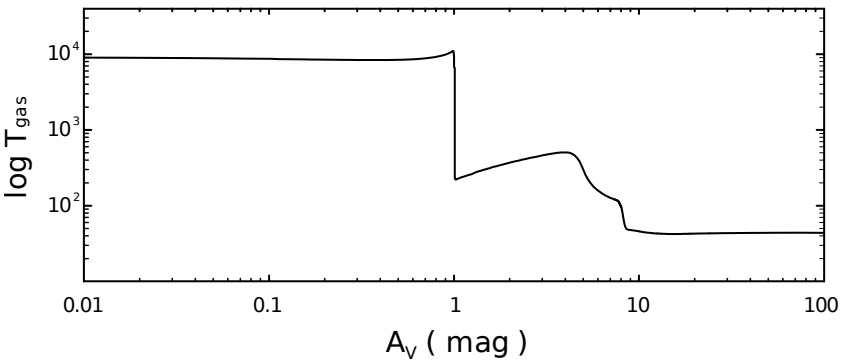








[Abel et al. 2005, ApJS 161: 65]

SHINING

Far-infrared fine structure lines:

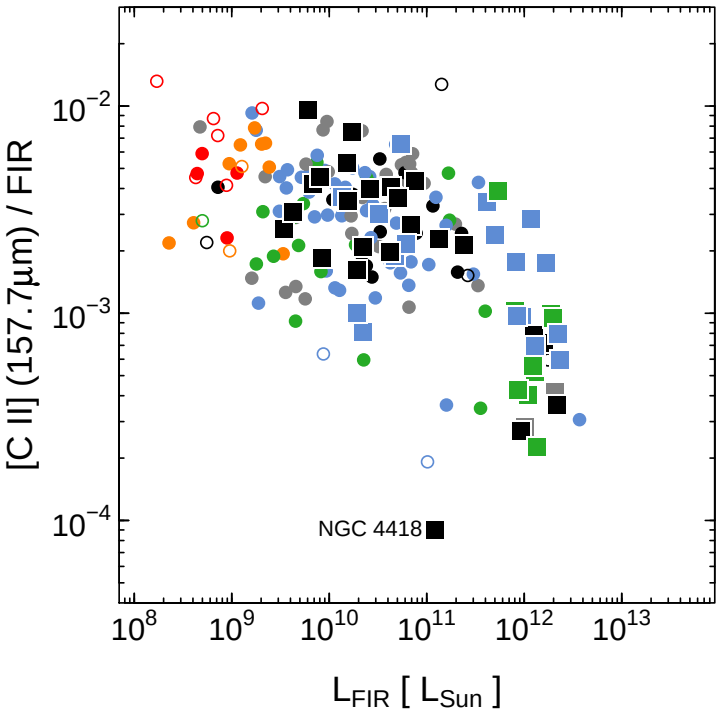
- PDR lines: [C II] 158μm, [O I] 145μm, [O I] 63μm
- HII lines: [N II] 122μm, [O III] 88μm, [N III] 57μm, [O III] 52μm

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, ...)
- 5 high-z star forming galaxies (MIPS J142824.0, ...)
- 4 high-z AGNs (IRAS F10214, Cloverleaf, ...)

Integrated properties

The [CII] line deficit vs. SFR $\propto L_{FIR}$



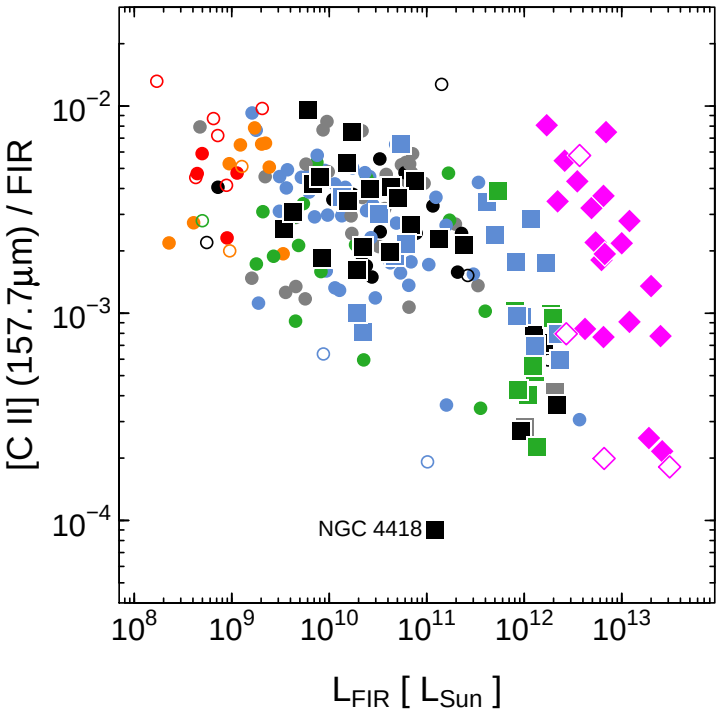
- HII galaxy
- LINER
- Seyfert & QSO
- Low−mass galaxy
- Elliptical
- Unclassified

[Graciá-Carpio et al. 2011, ApJ 728: L7]

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

[Malhotra et al. 2001, ApJ 561: 766]

The [CII] line deficit vs. SFR $\propto L_{FIR}$



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[Ivison et al. 2010, A&A 518: L35]

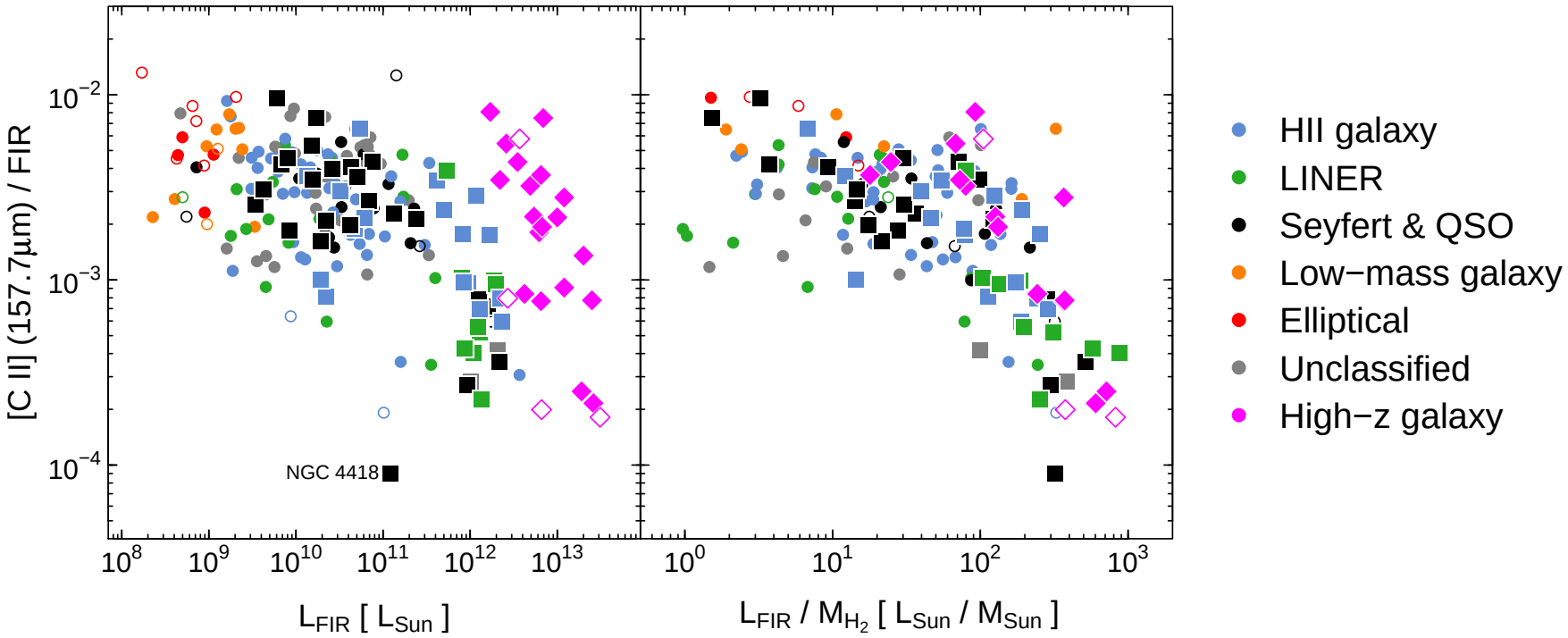
[Stacey et al. 2010, ApJ 724: 957]

[Hailey-Dunsheath et al. 2010, ApJ 714: L162]

[Maiolino et al. 2009, A&A 500: L1]

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

The [CII] line deficit vs. SFE $\propto L_{FIR}/M_{H_2}$



[Graciá-Carpio et al. 2011, ApJ 728: L7]

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

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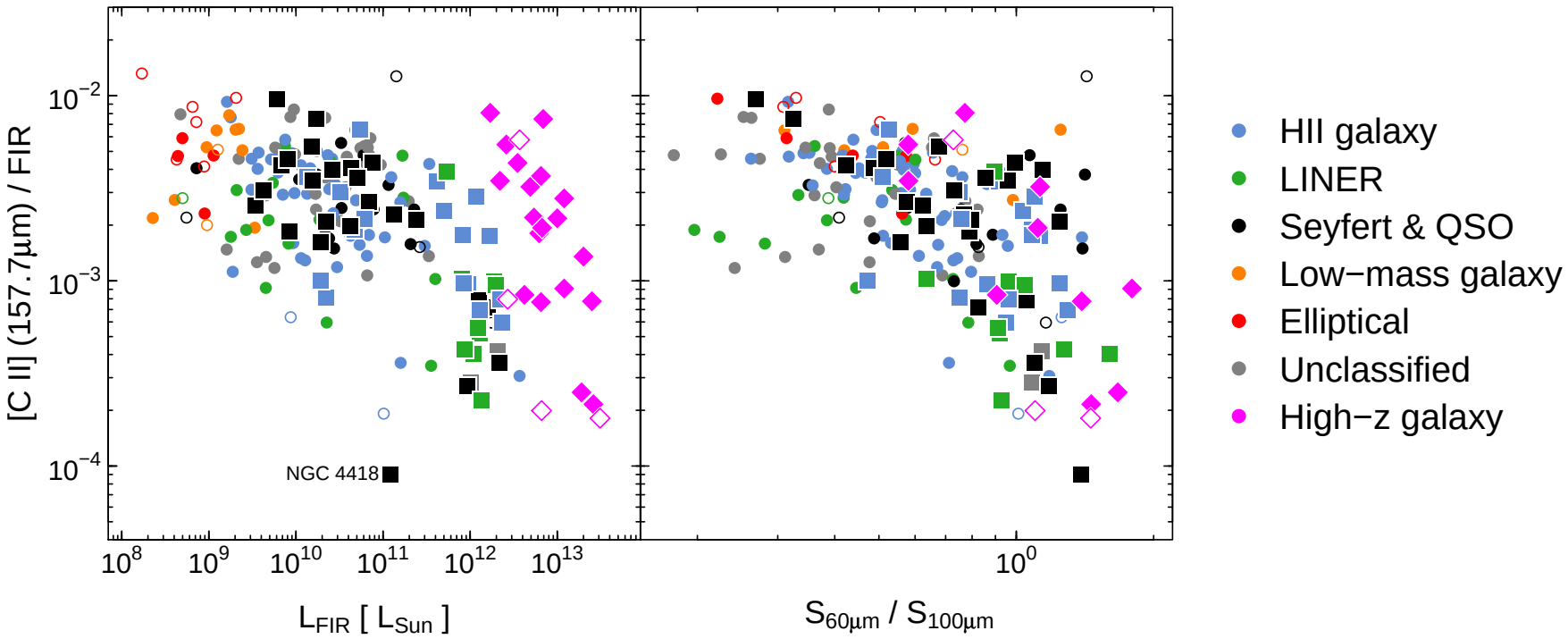
[Hailey-Dunsheath et al. 2010, ApJ 714: L162]

[Maiolino et al. 2009, A&A 500: L1]

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

The [CII] line deficit vs. $T_{dust} \propto S_{60\mu m}/S_{100\mu m}$



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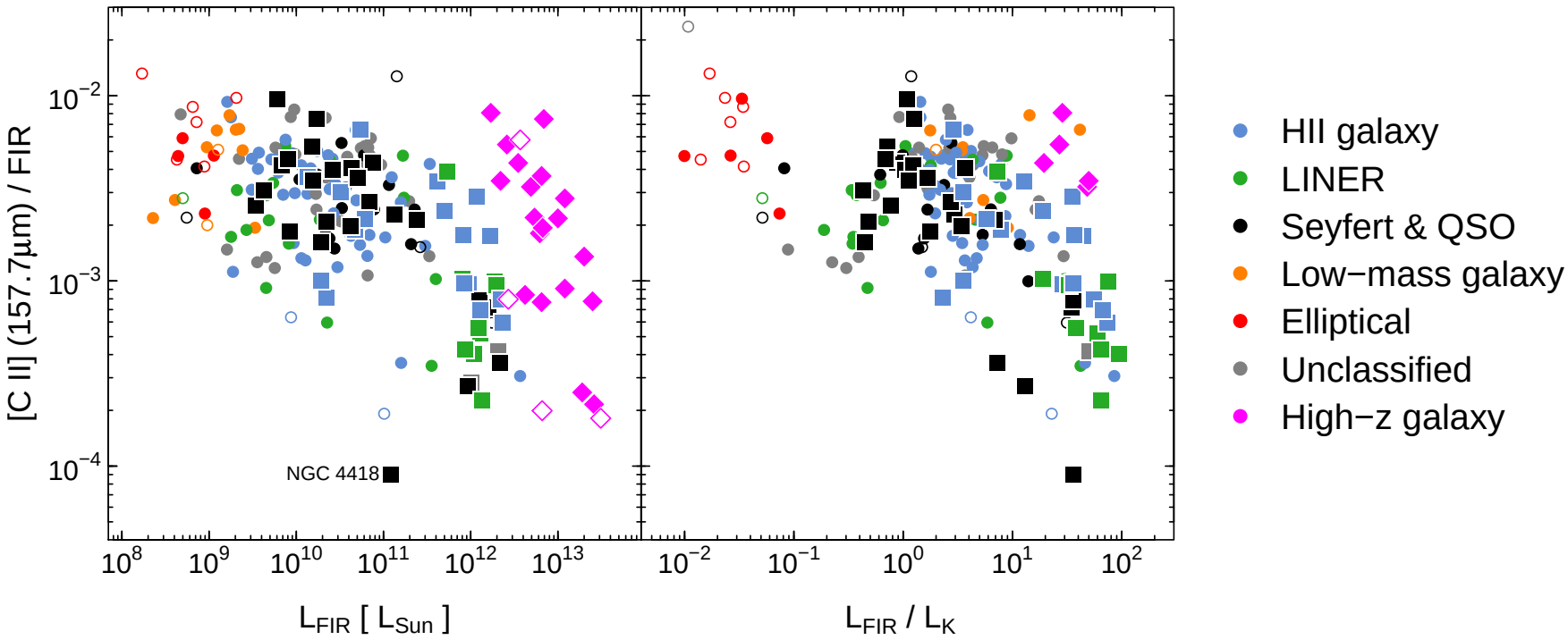
[Hailey-Dunsheath et al. 2010, ApJ 714: L162]

[Maiolino et al. 2009, A&A 500: L1]

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

The [CII] line deficit vs. sSFR $\propto L_{FIR}/L_K$



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[Malhotra et al. 2001, ApJ 561: 766]

[Ivison et al. 2010, A&A 518: L35]

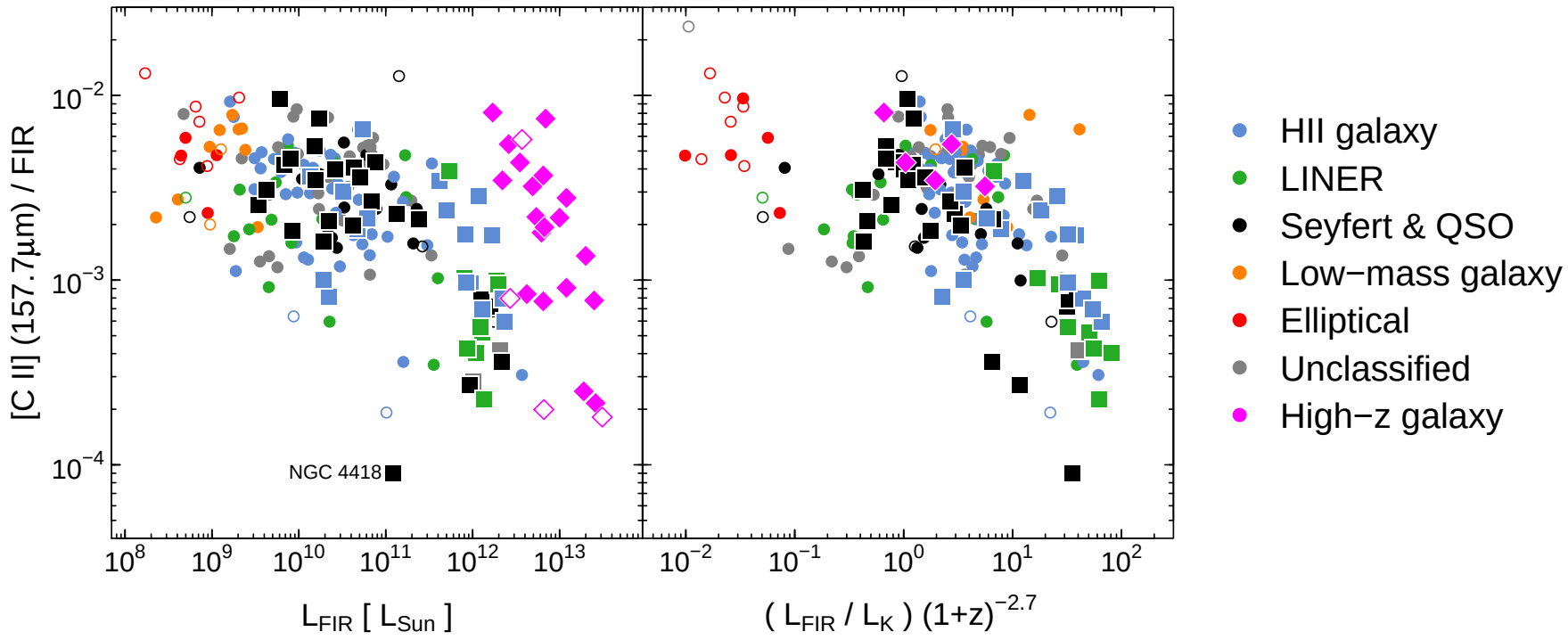
[Stacey et al. 2010, ApJ 724: 957]

[Hailey-Dunsheath et al. 2010, ApJ 714: L162]

[Maiolino et al. 2009, A&A 500: L1]

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

The [CII] line deficit vs. sSFR excess $\propto L_{FIR}/L_K \times (1+z)^{-2.7}$



[Graciá-Carpio et al. 2011, ApJ 728: L7]

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[Ivison et al. 2010, A&A 518: L35]

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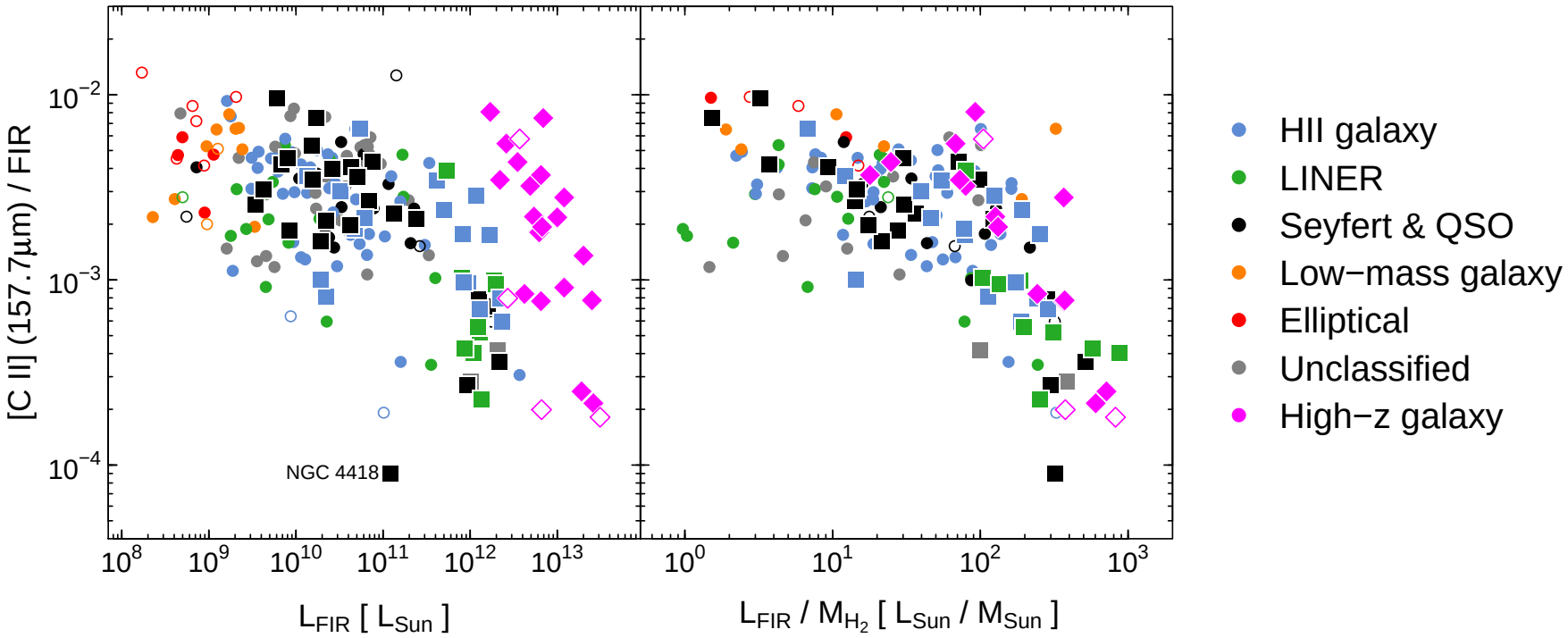
The [CII] line deficit vs. SFE $\propto L_{FIR}/M_{H_2}$



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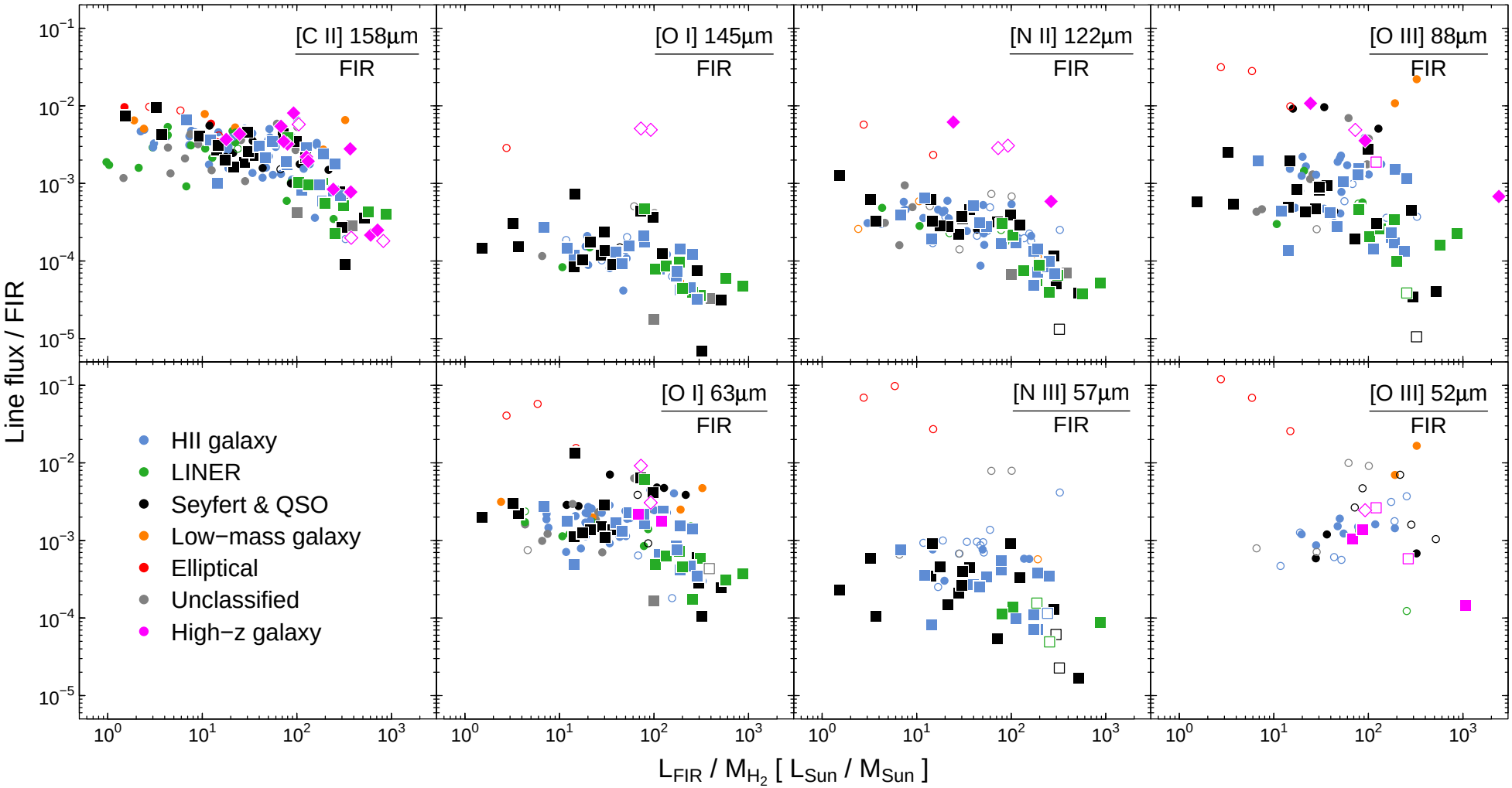
A general far-infrared line deficit



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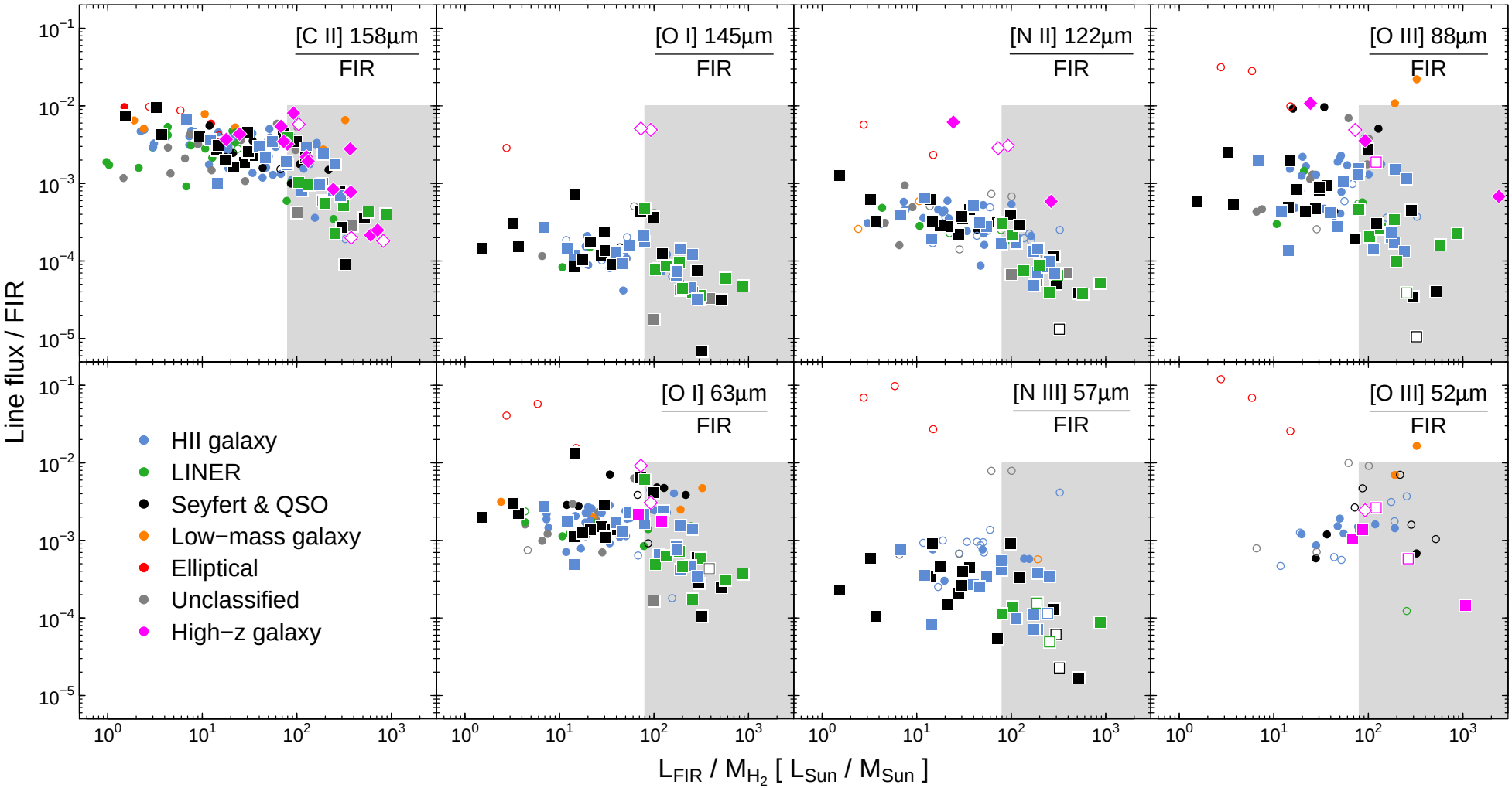
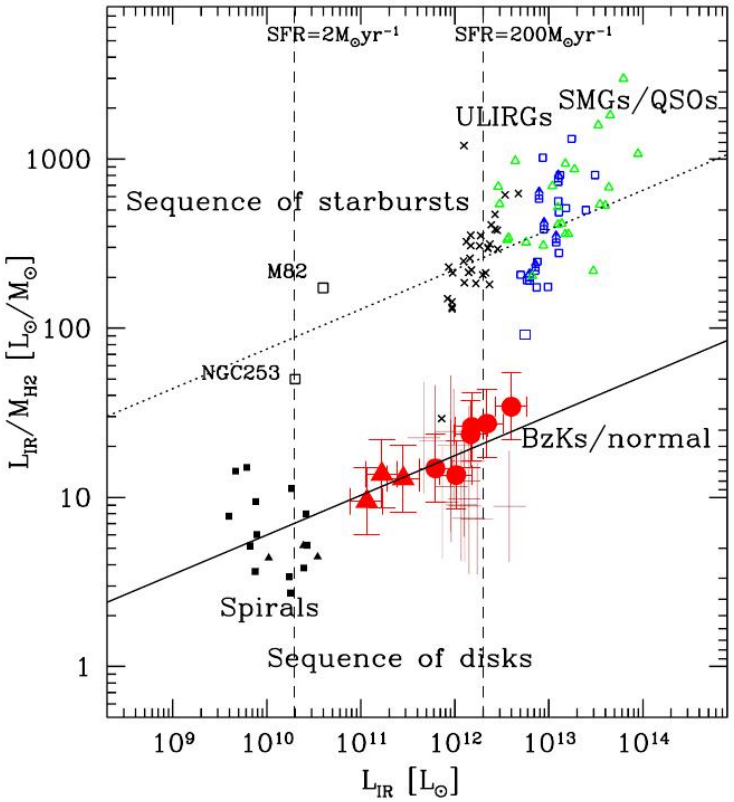


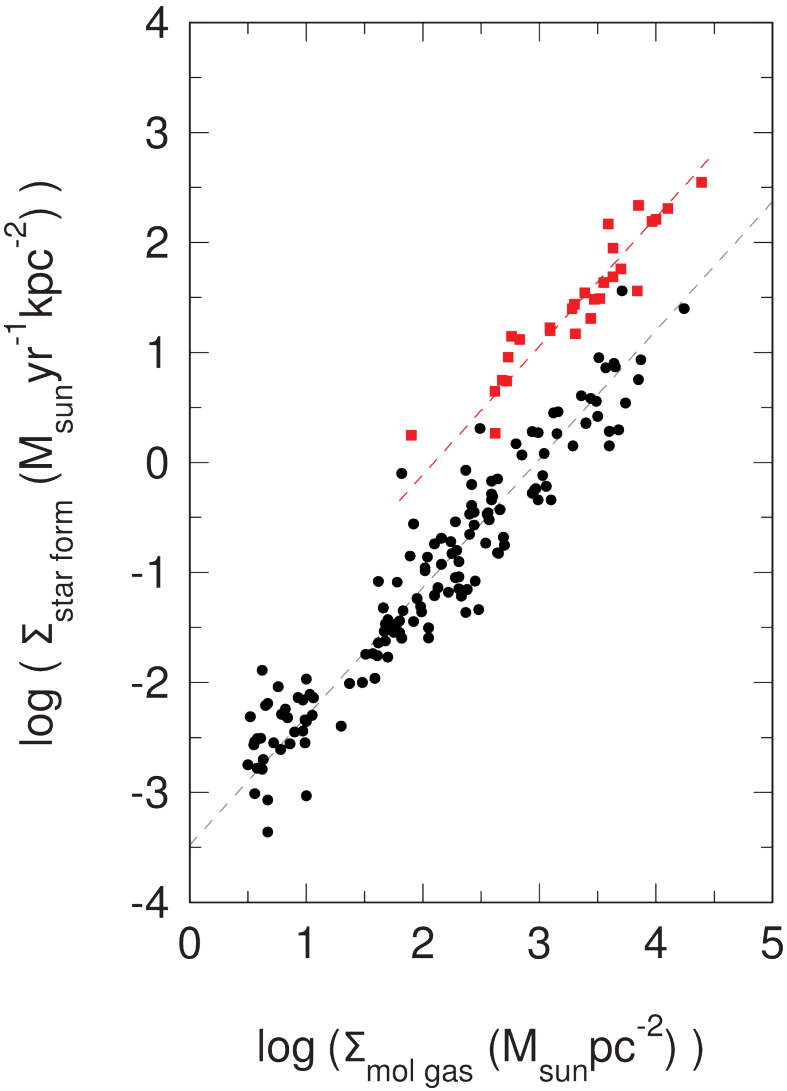
[Graciá-Carpio et al. 2011, ApJ 728: L7]

Two modes of star formation

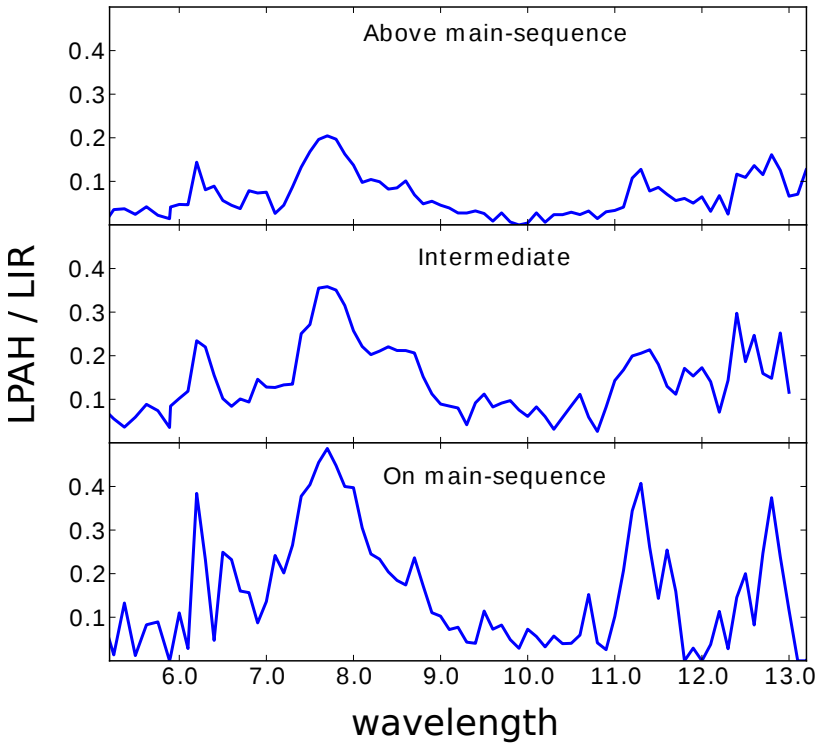


[Genzel et al. 2010, MNRAS 407: 2091]

[Daddi et al. 2010, ApJ 714: L118]

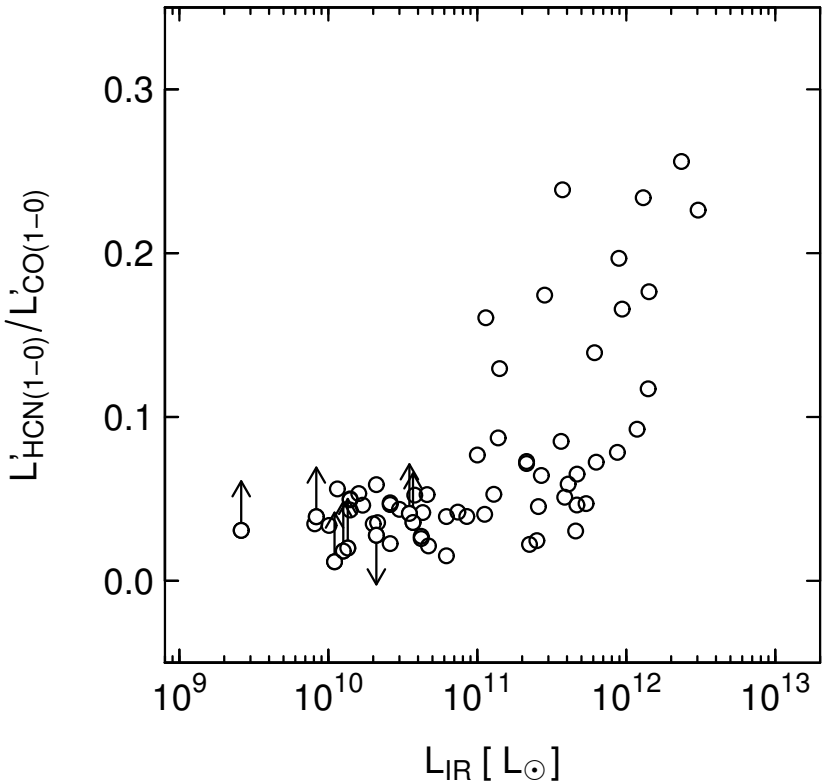


More evidence for different ISM properties



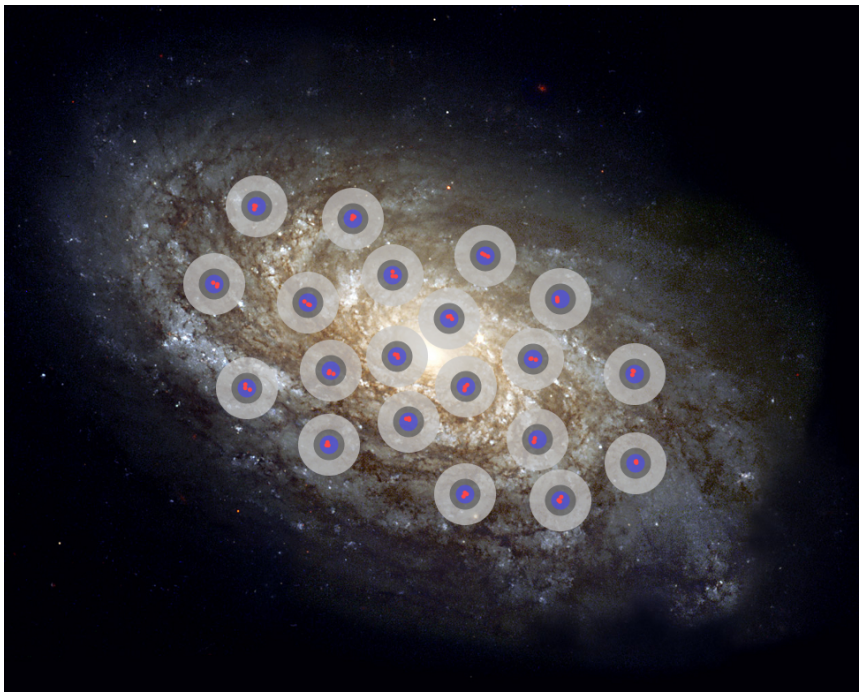
[Nordon et al. 2011, astro-ph/1106.1186]

[Elbaz et al. 2011, astro-ph/1105.2537]



[Gao & Solomon 2004, ApJ 606: 271]

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



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

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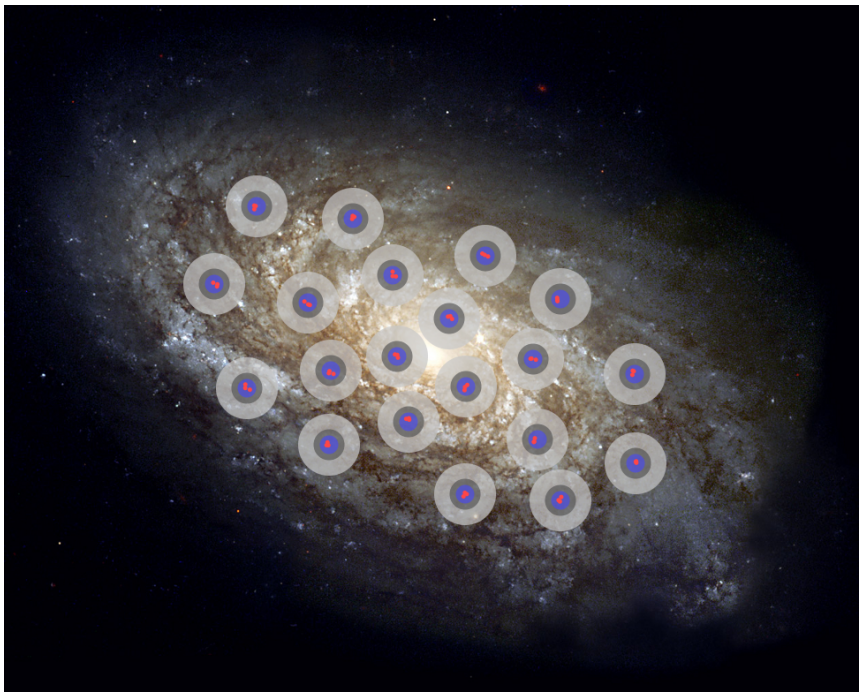

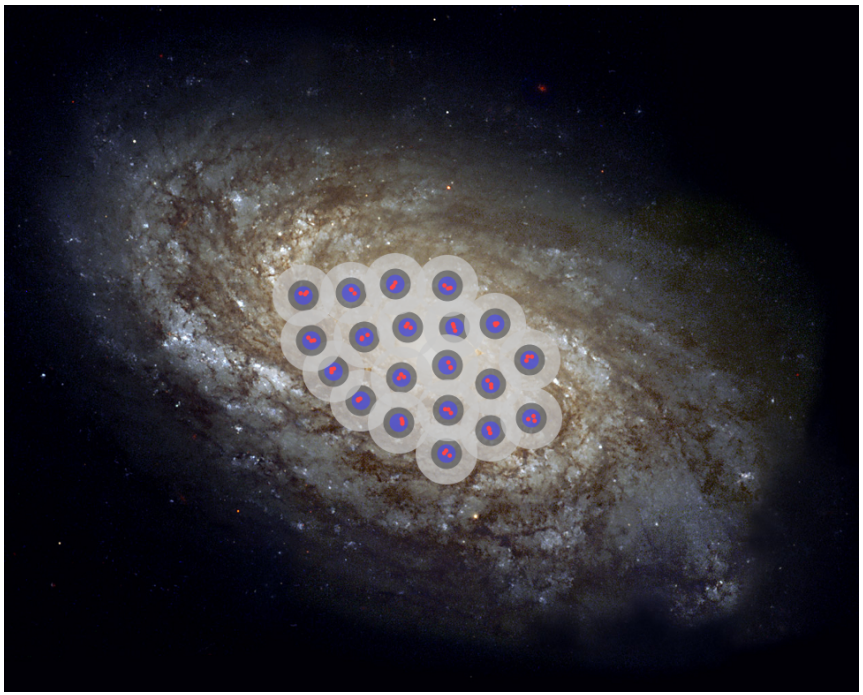

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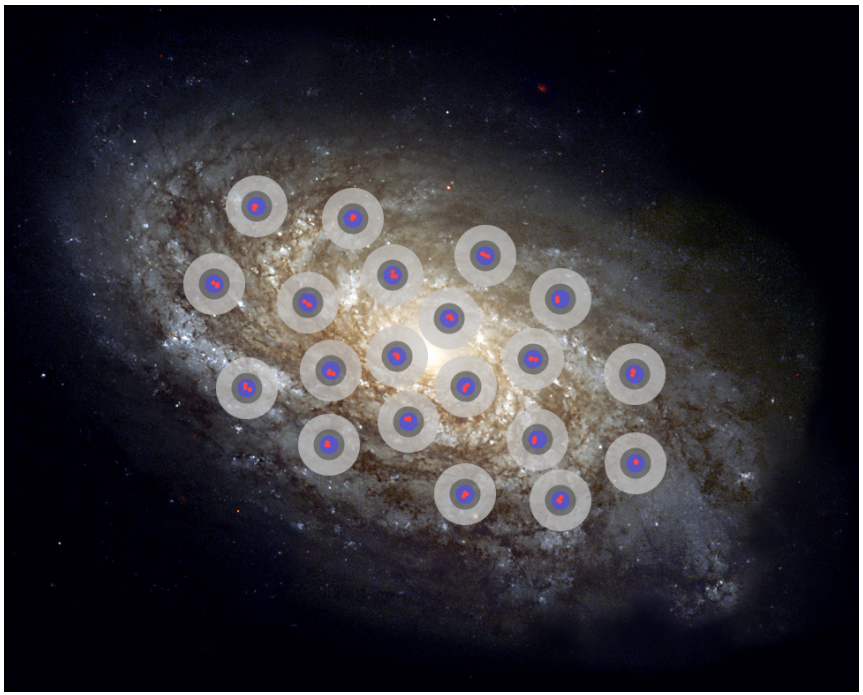
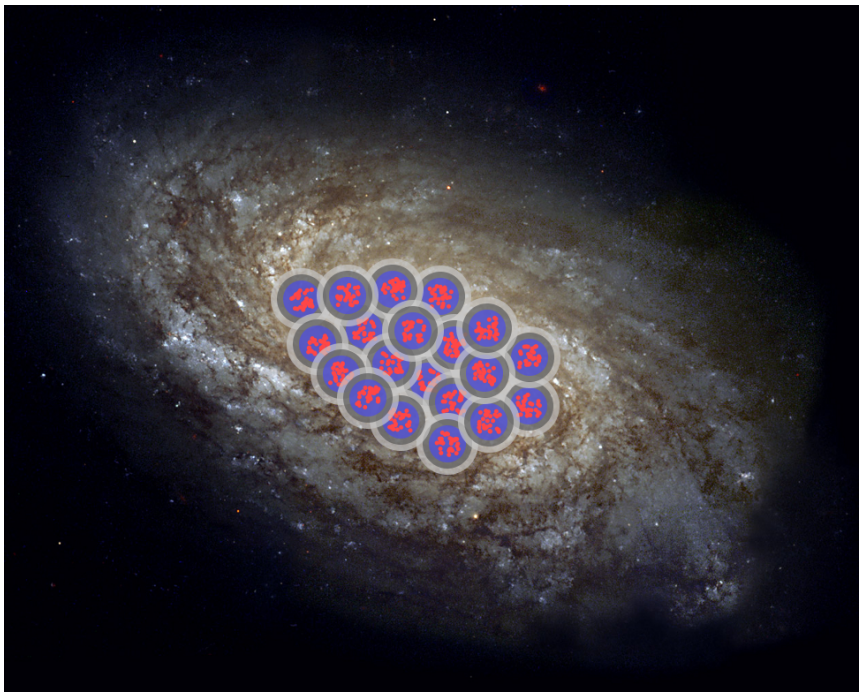
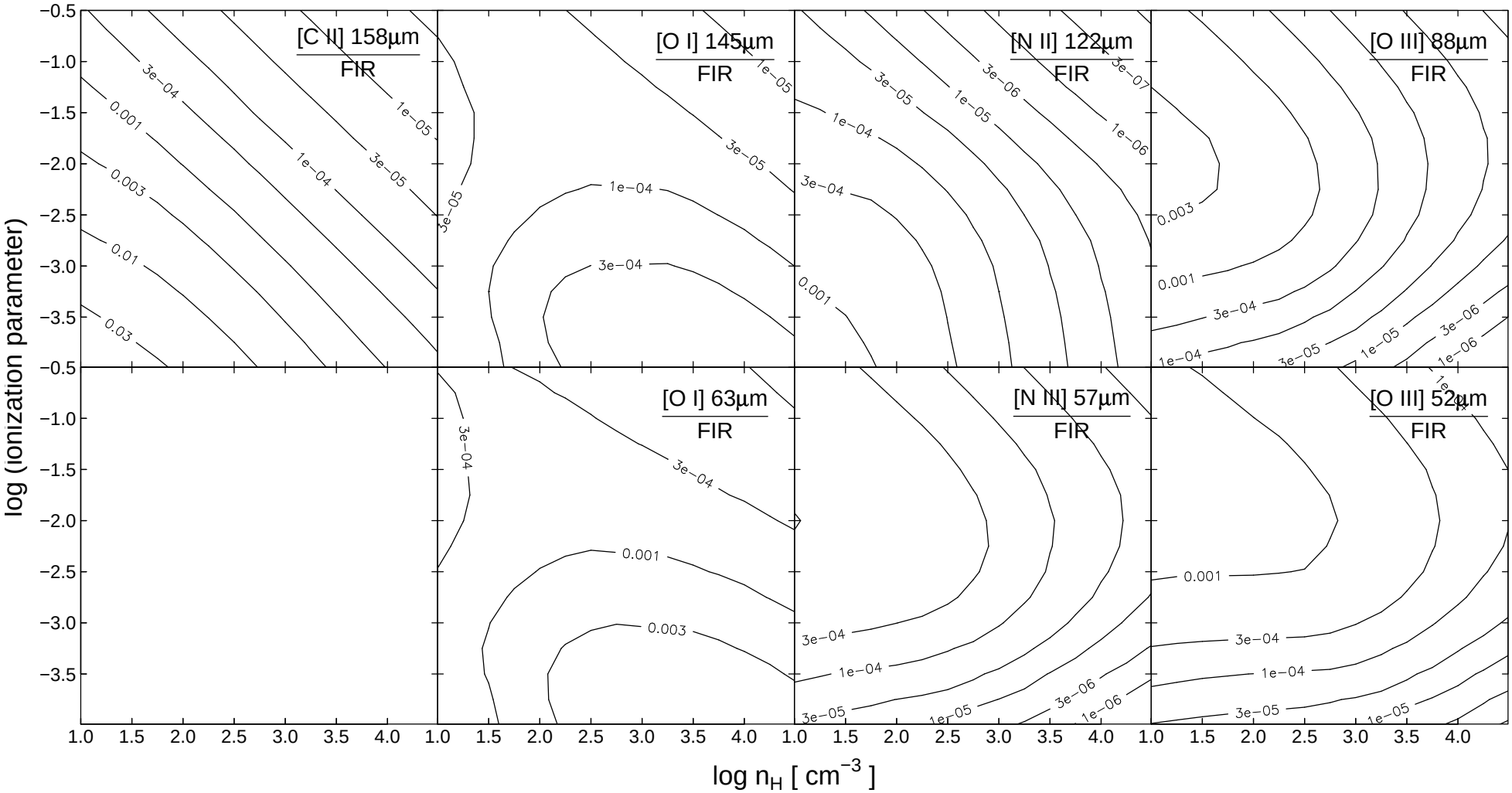


$L_{FIR}/M_{H_2} \simeq 1\text{–}100\, L_\odot\, M_\odot^{-1}$



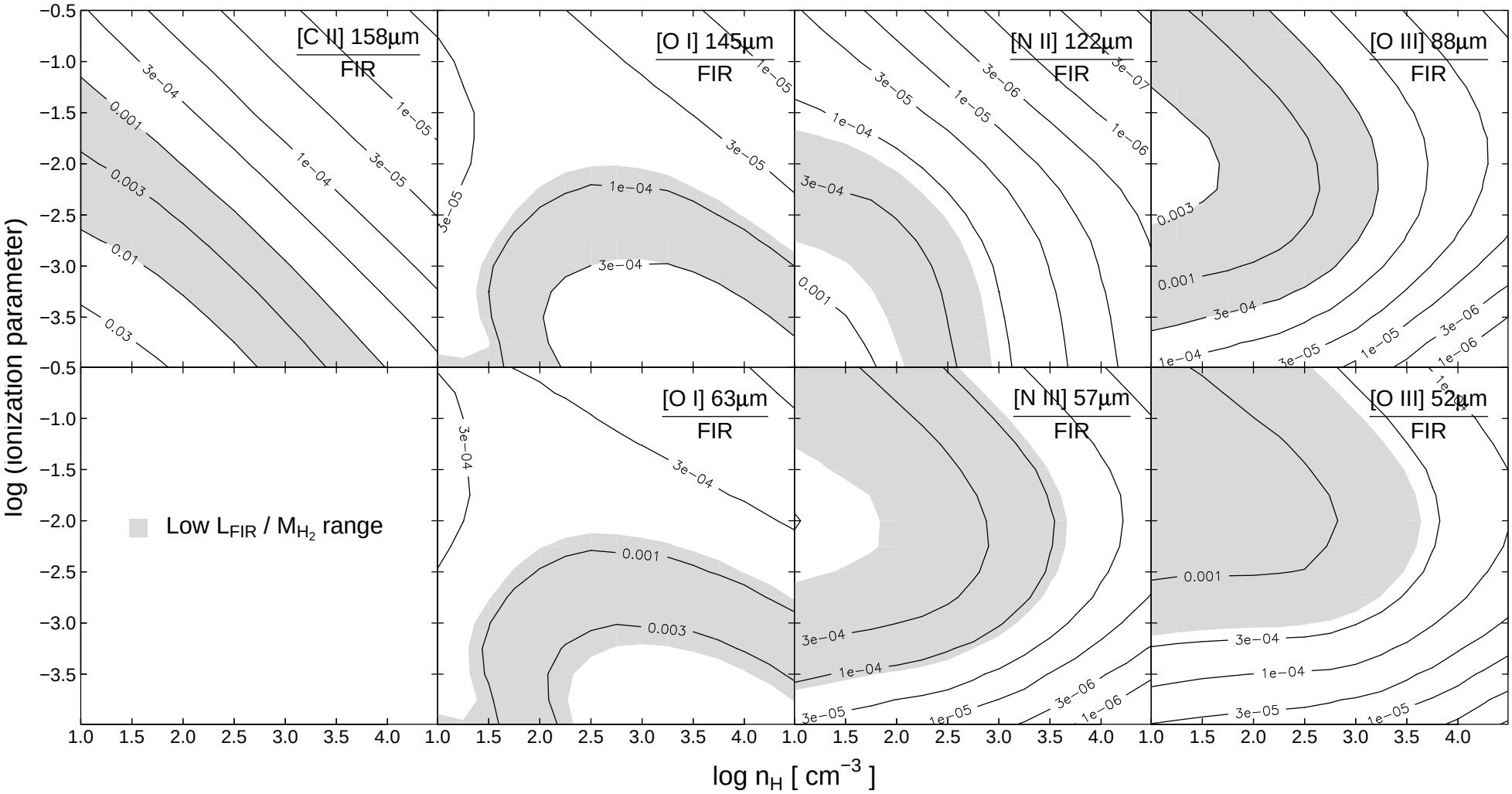
$L_{FIR}/M_{H_2} \simeq 100\text{–}1000\, L_\odot\, M_\odot^{-1}$

Cloudy models



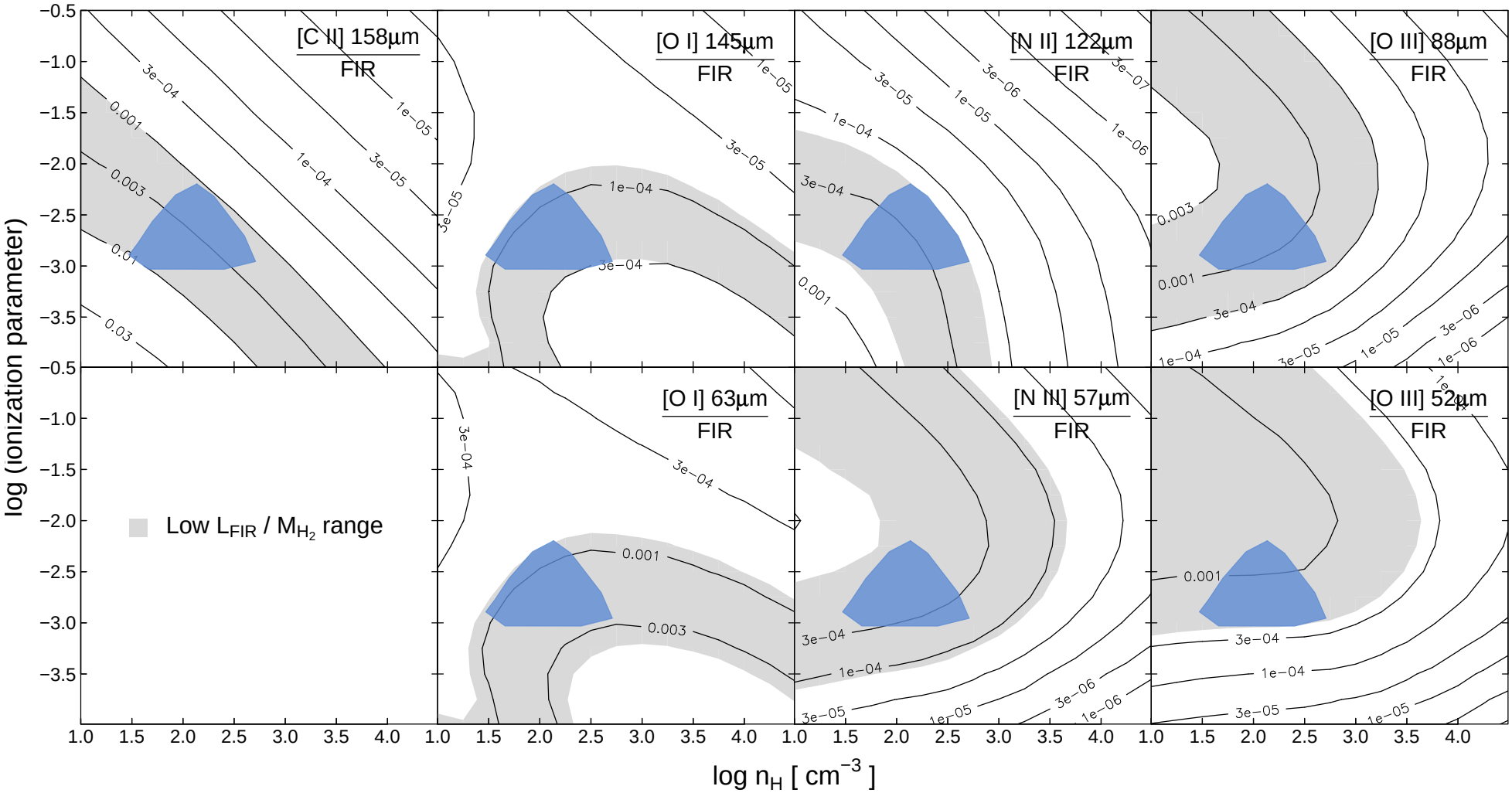
$T_* = 36000\,K$, $A_V = 100\,mag$

Cloudy models

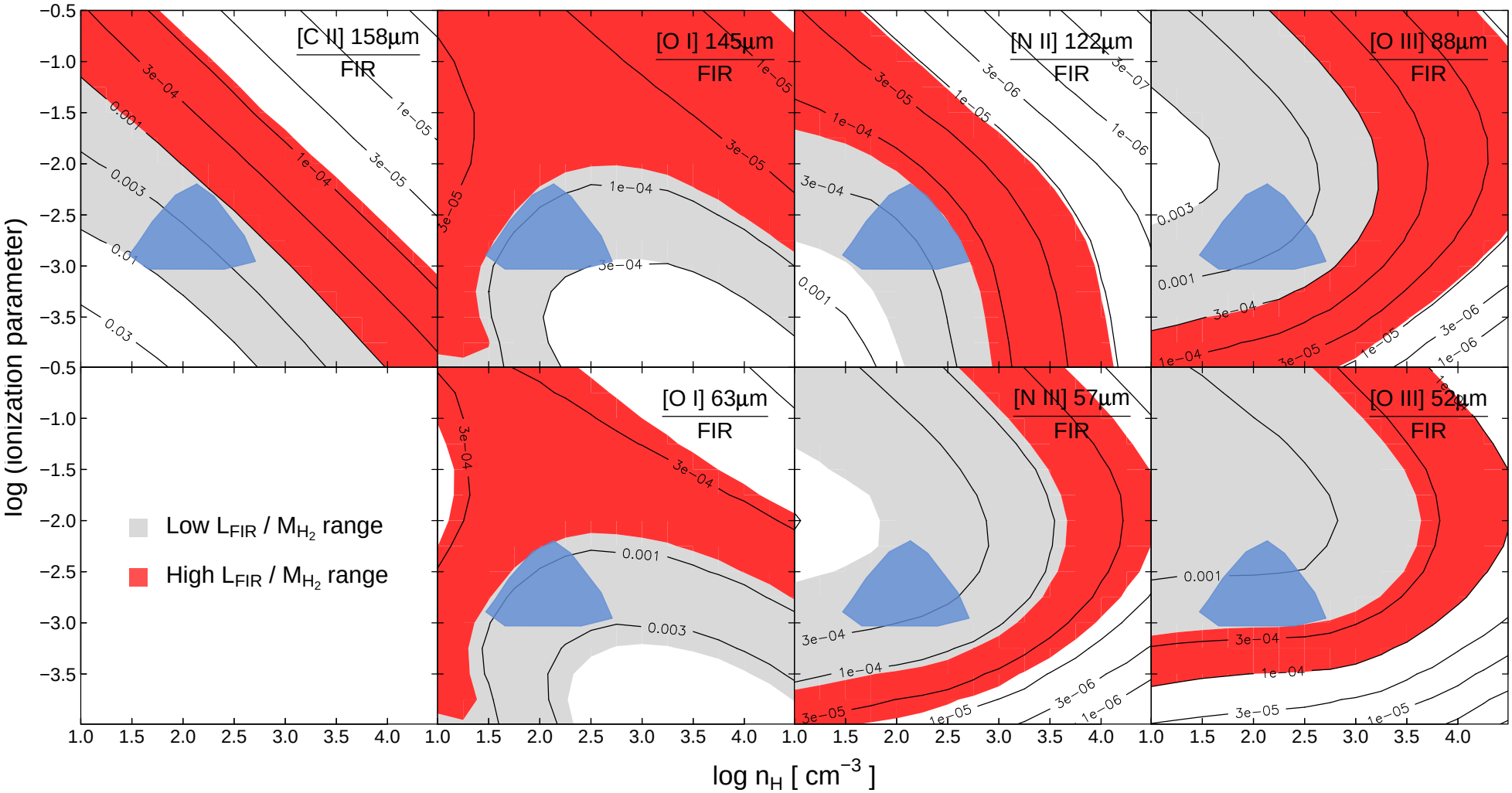


$T_* = 36000\,K$, $A_V = 100\,mag$

Cloudy models

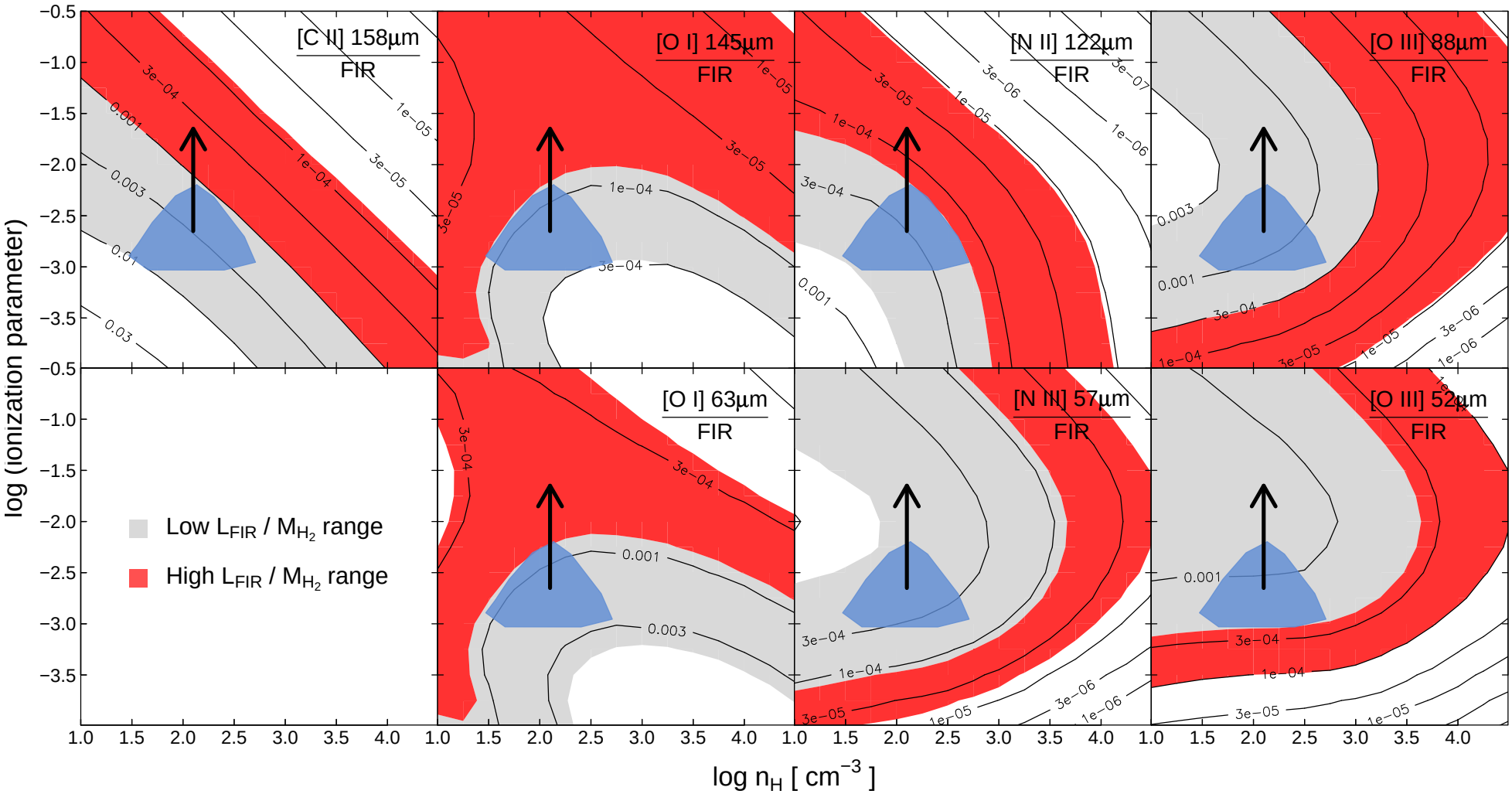


Cloudy models



$T_* = 36000\,K$, $A_V = 100\,mag$

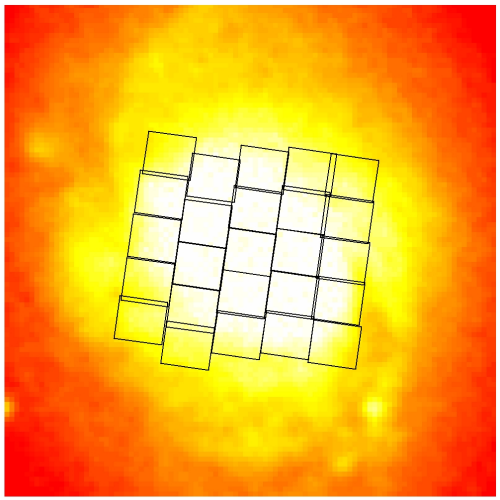
Cloudy models

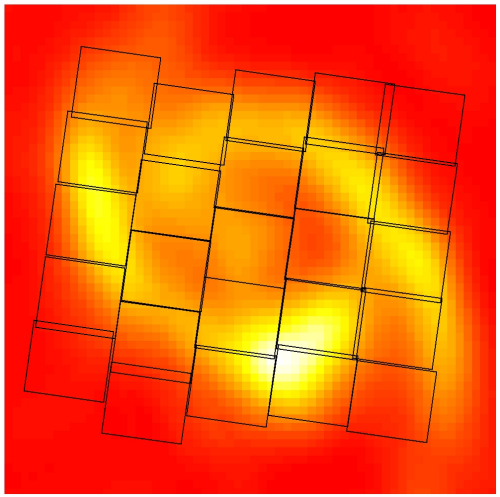


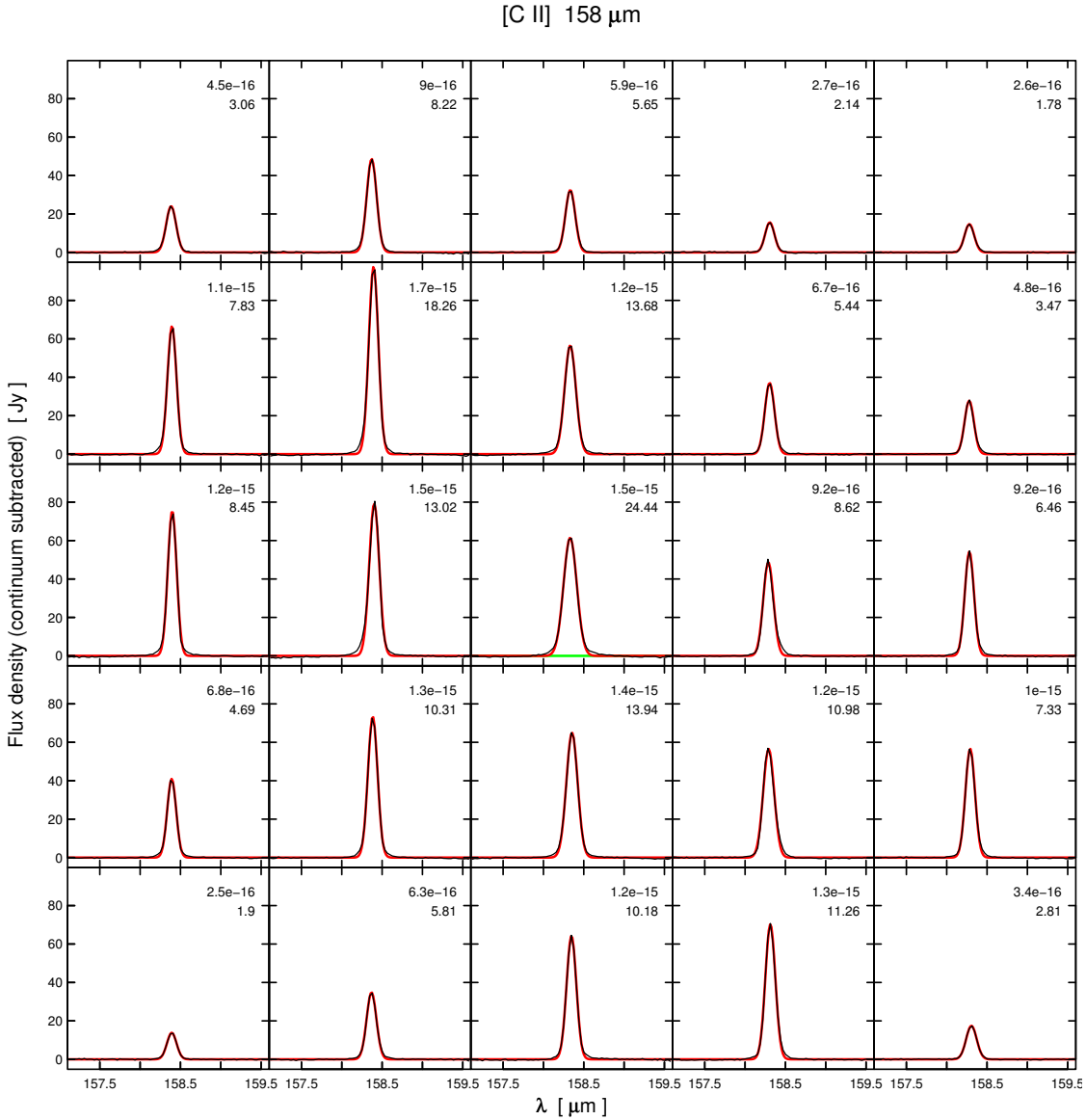
$T_* = 36000\,K$, $A_V = 100\,mag$

Spatially resolved properties (work in progress)

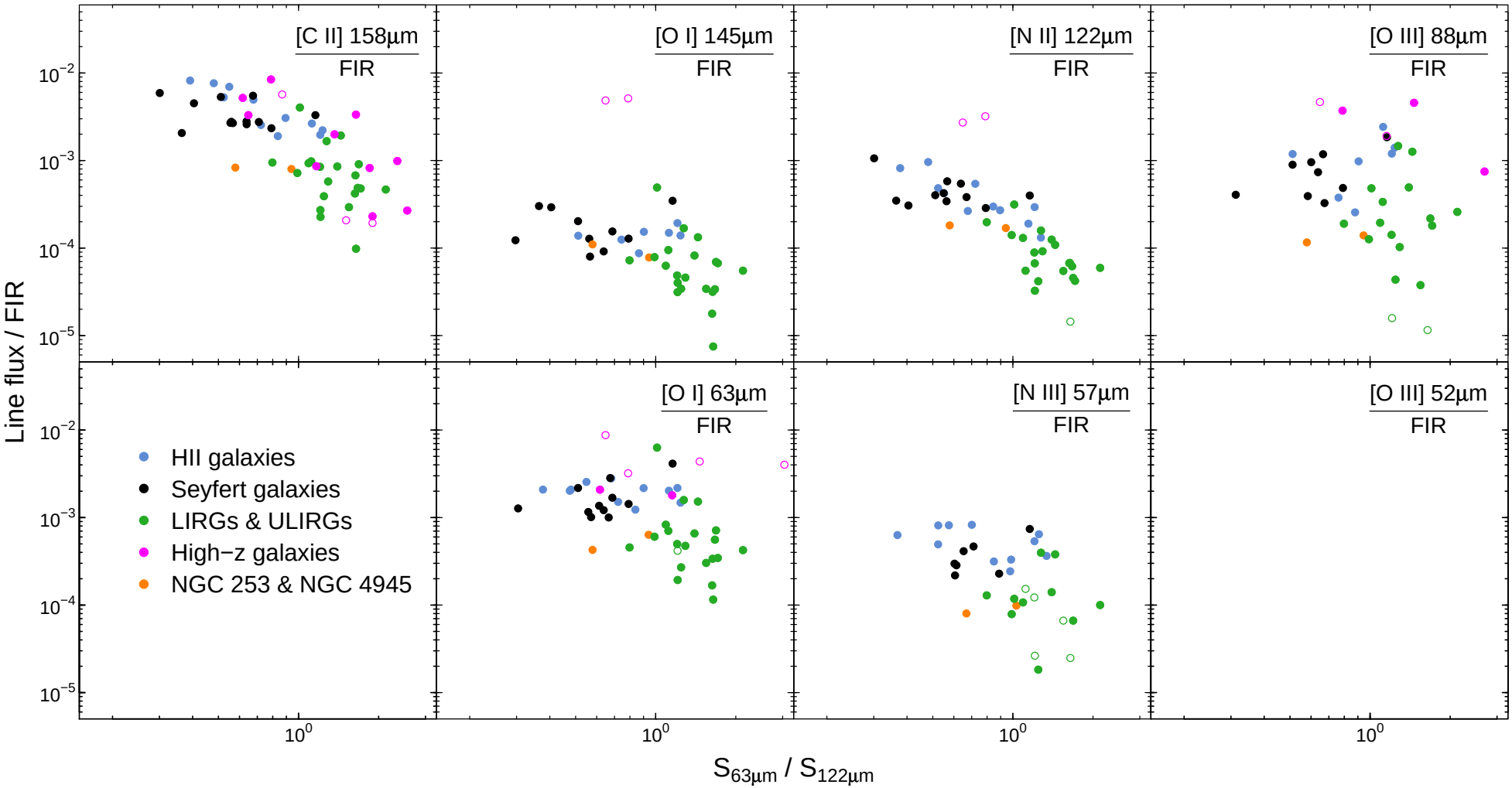
NGC 1068 line and continuum maps





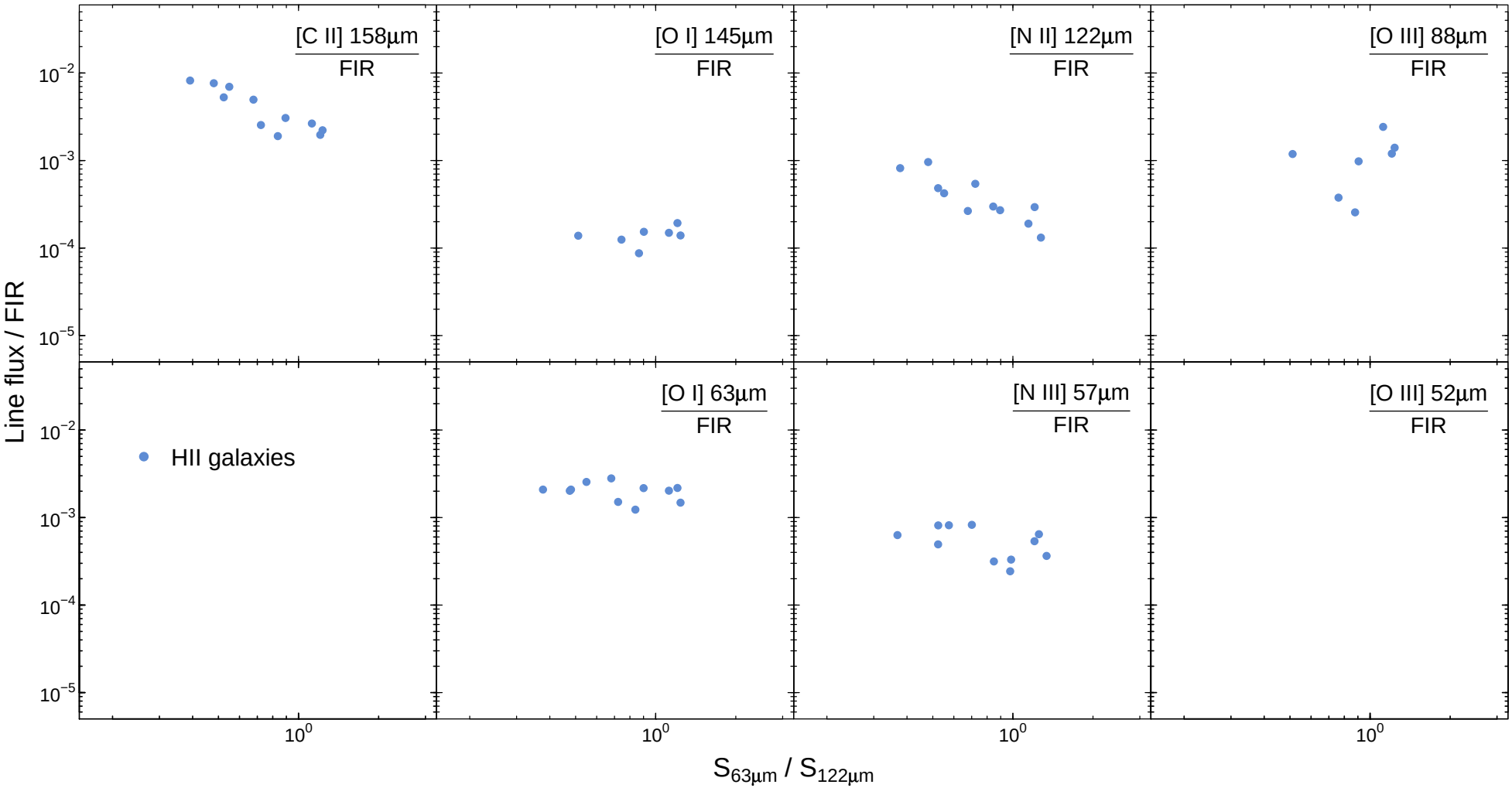


Spatially resolved information



[Graciá-Carpio et al. in preparation]

Spatially resolved information



[Graciá-Carpio et al. in preparation]

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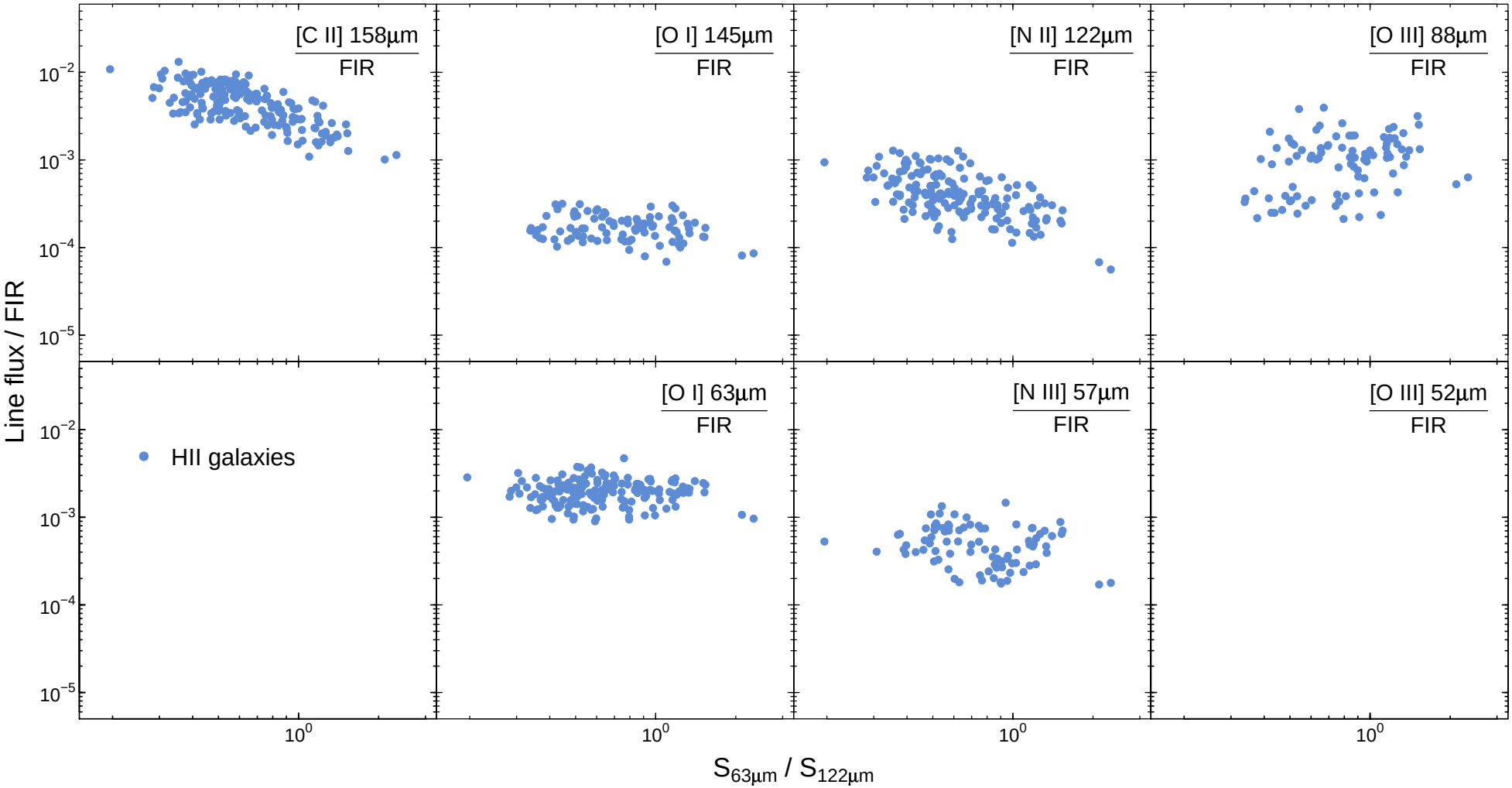
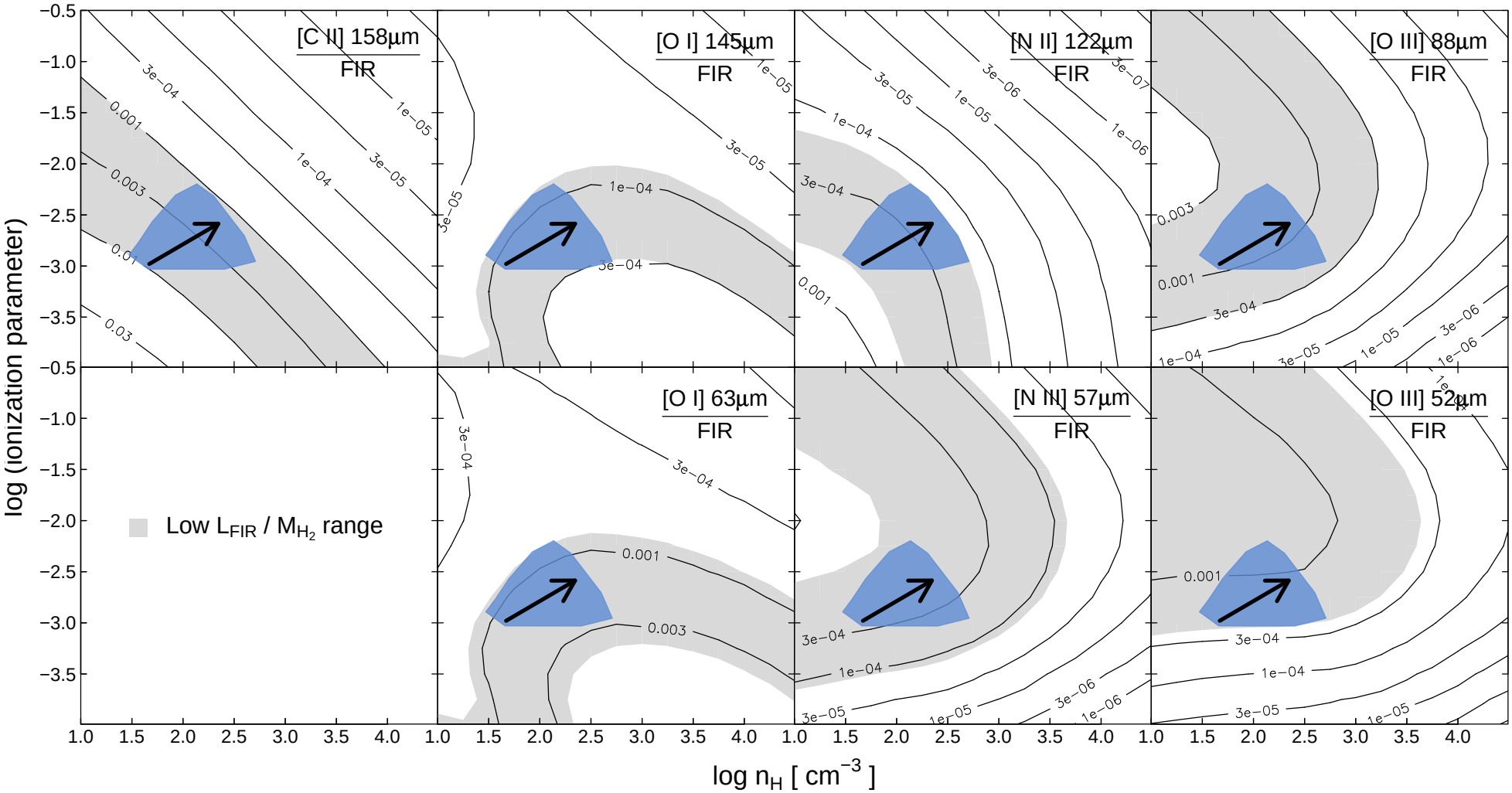


[Graciá-Carpio et al. in preparation]

Cloudy models



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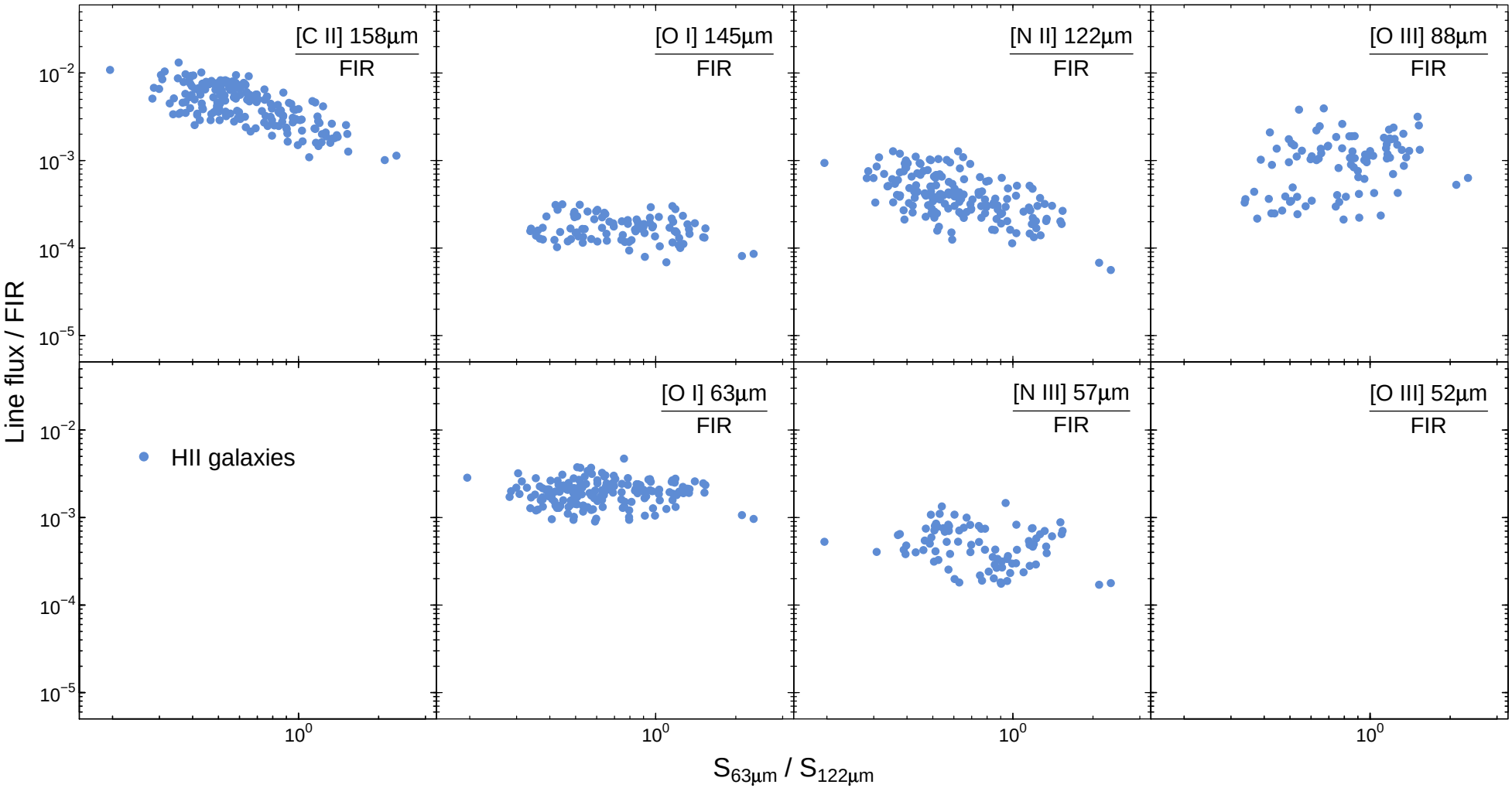

[Graciá-Carpio et al. in preparation]

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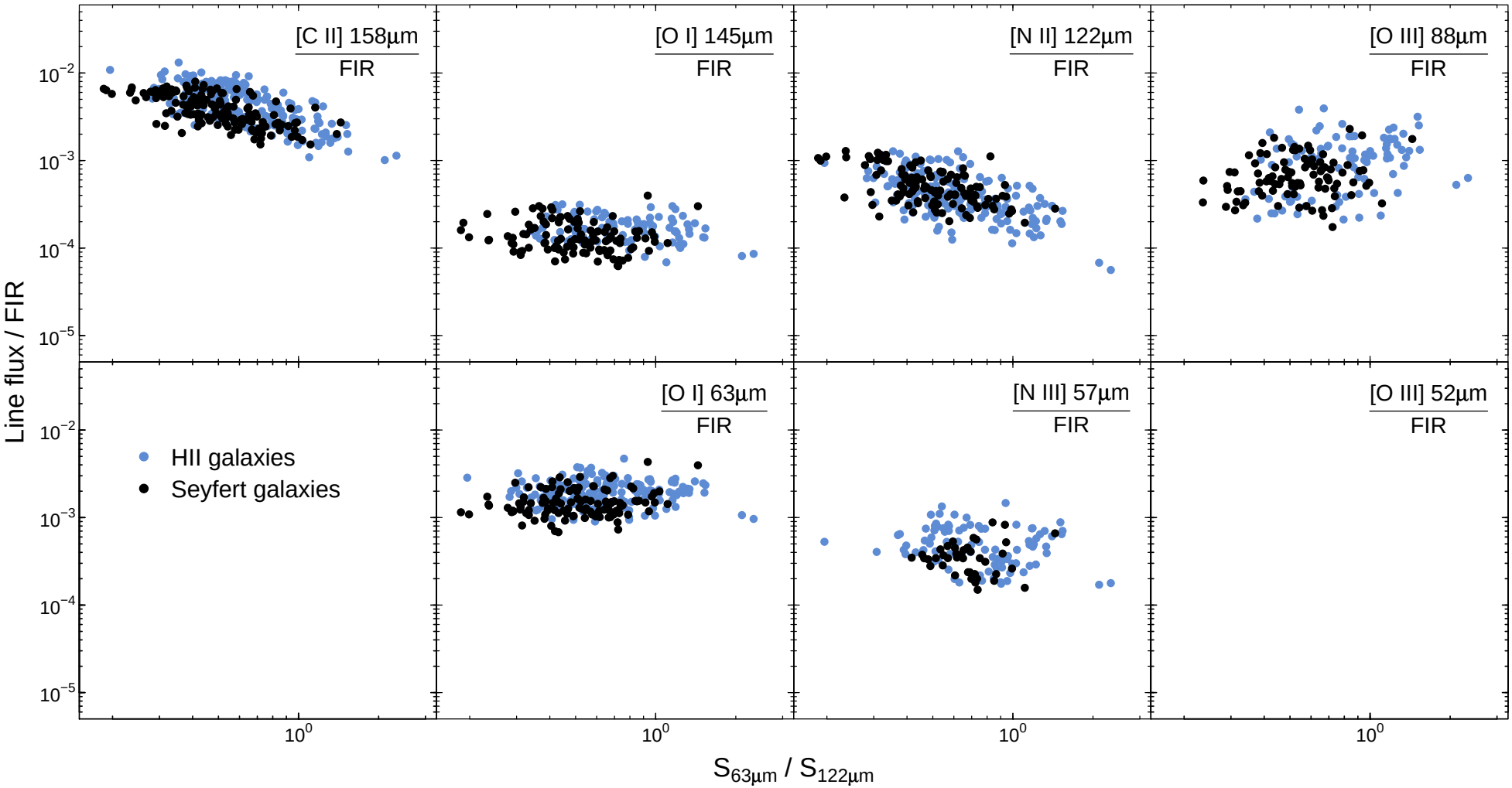

[Graciá-Carpio et al. in preparation]

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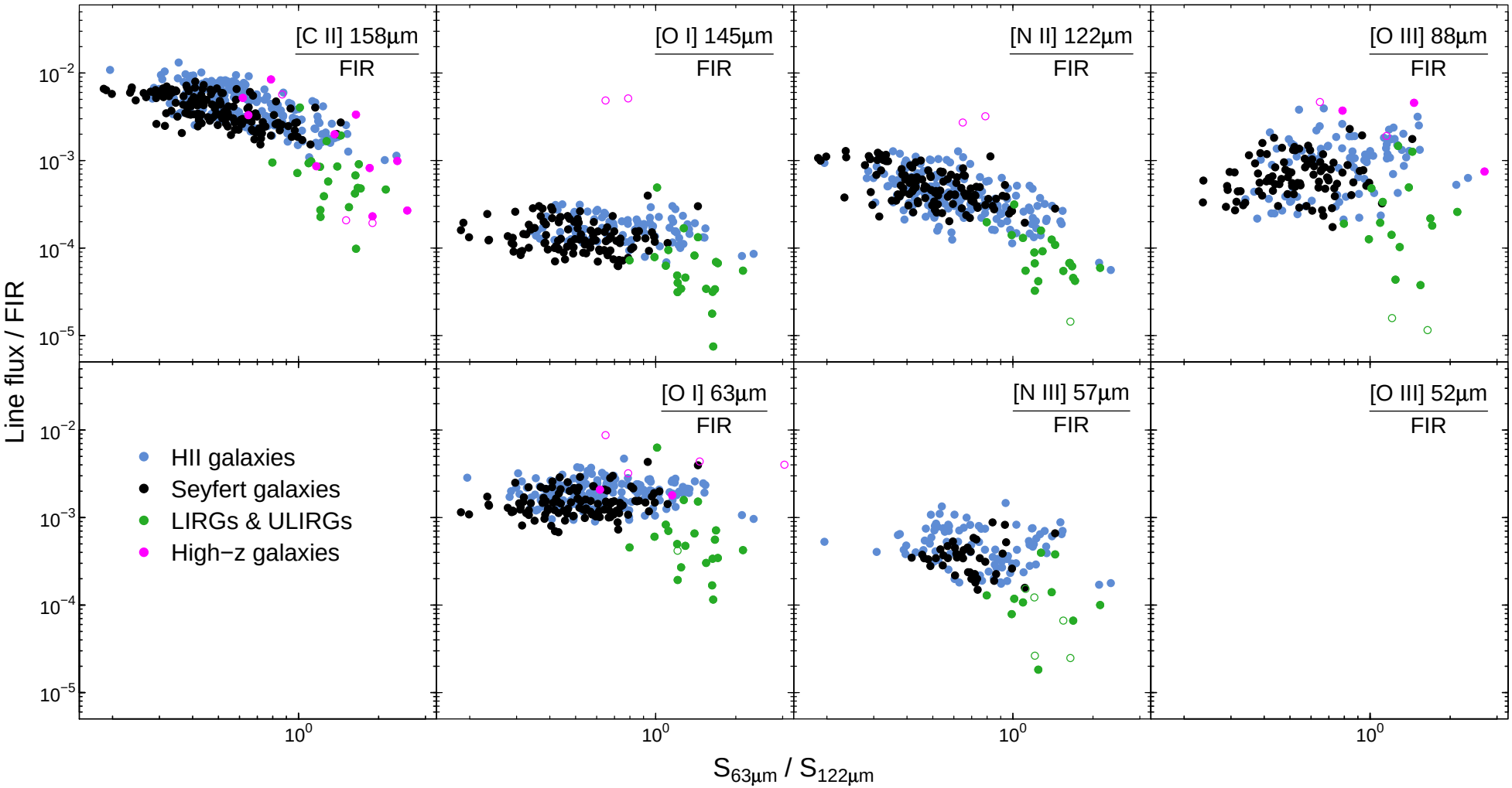

[Graciá-Carpio et al. in preparation]

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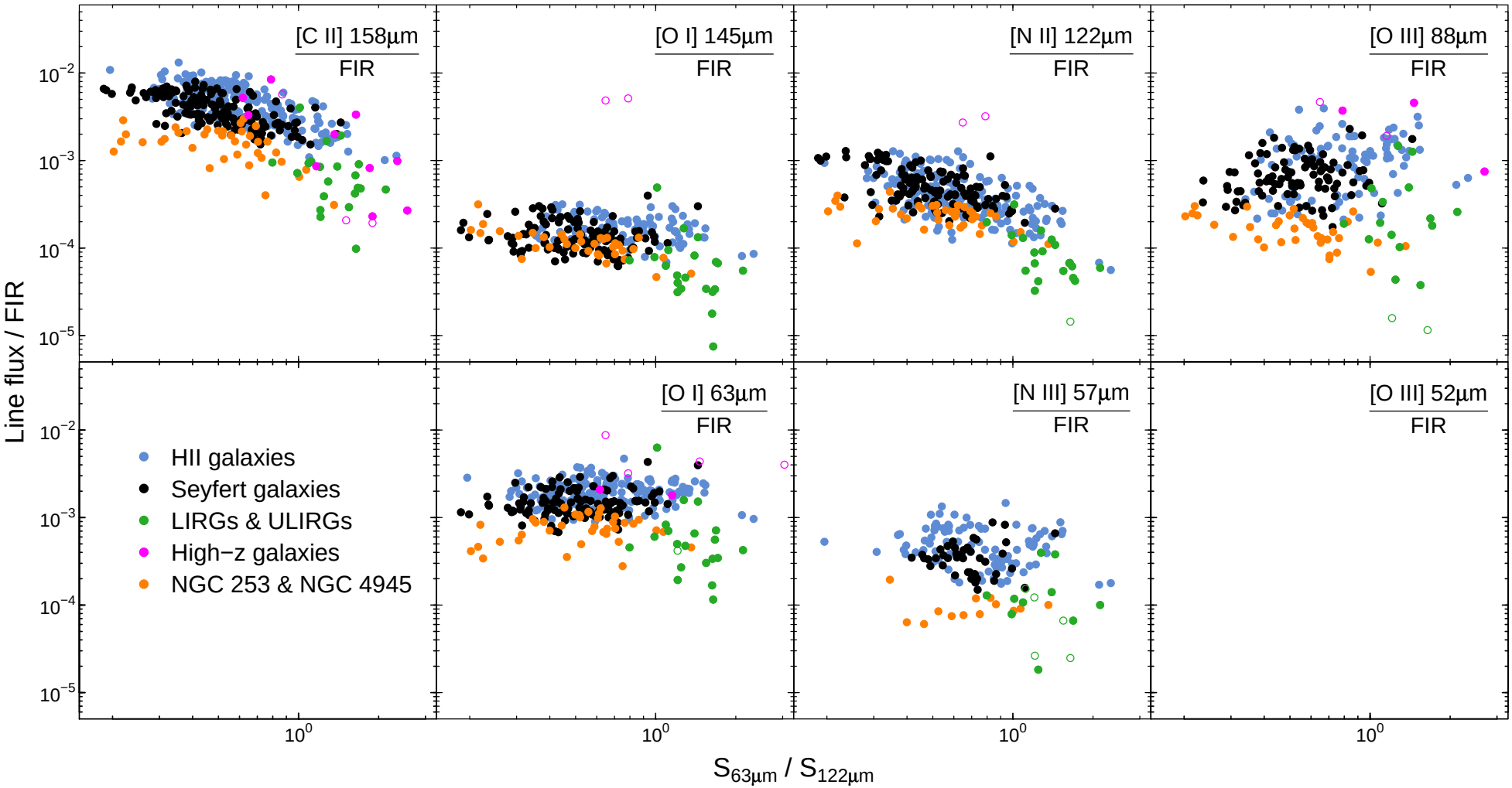
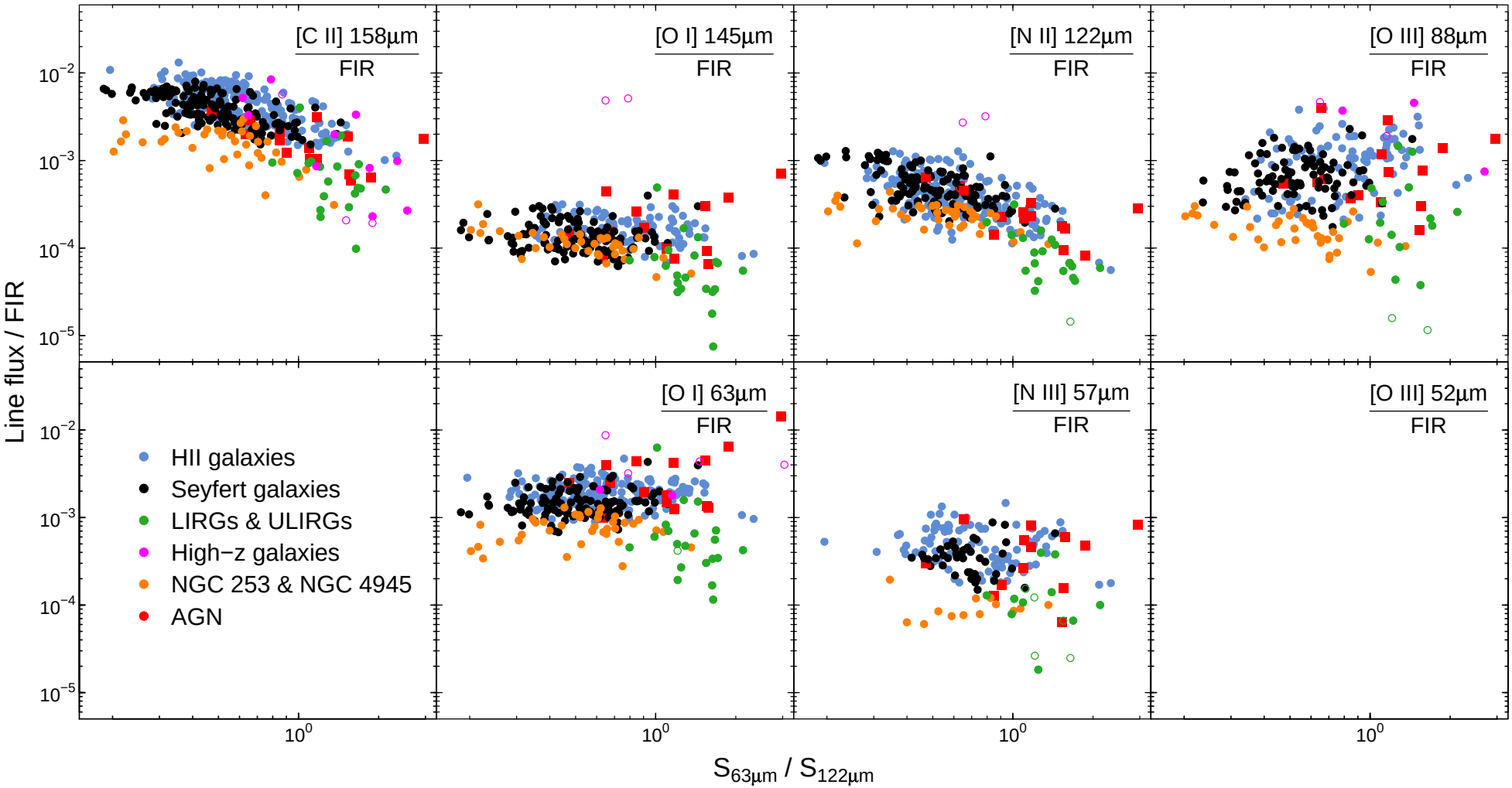


[Graciá-Carpio et al. in preparation]

Effect of AGN



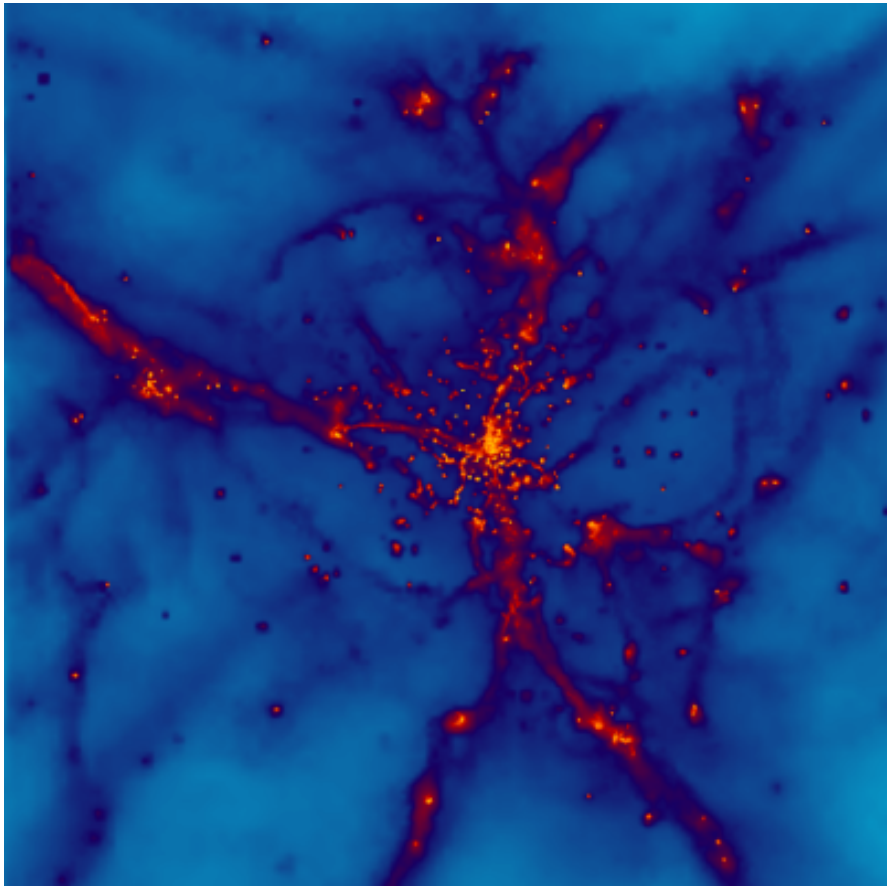
[Graciá-Carpio et al. in preparation]

An unexpected Herschel contribution to galaxy evolution

Three “dark” ingredients in galaxy evolution models

Three “dark” ingredients in galaxy evolution models

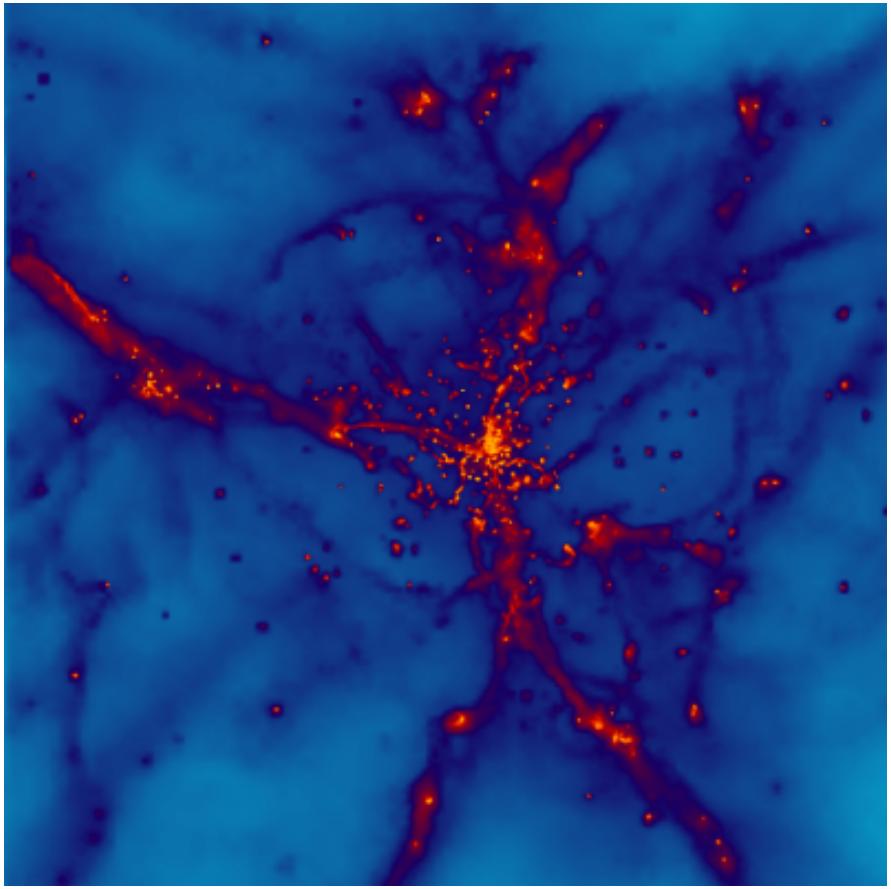
- Dark matter
- Dark energy



[Schaye et al. 2010, MNRAS 402: 1536]

Three “dark” ingredients in galaxy evolution models

- Dark matter
- Dark energy
- Dark molecular outflows



[Schaye et al. 2010, MNRAS 402: 1536]

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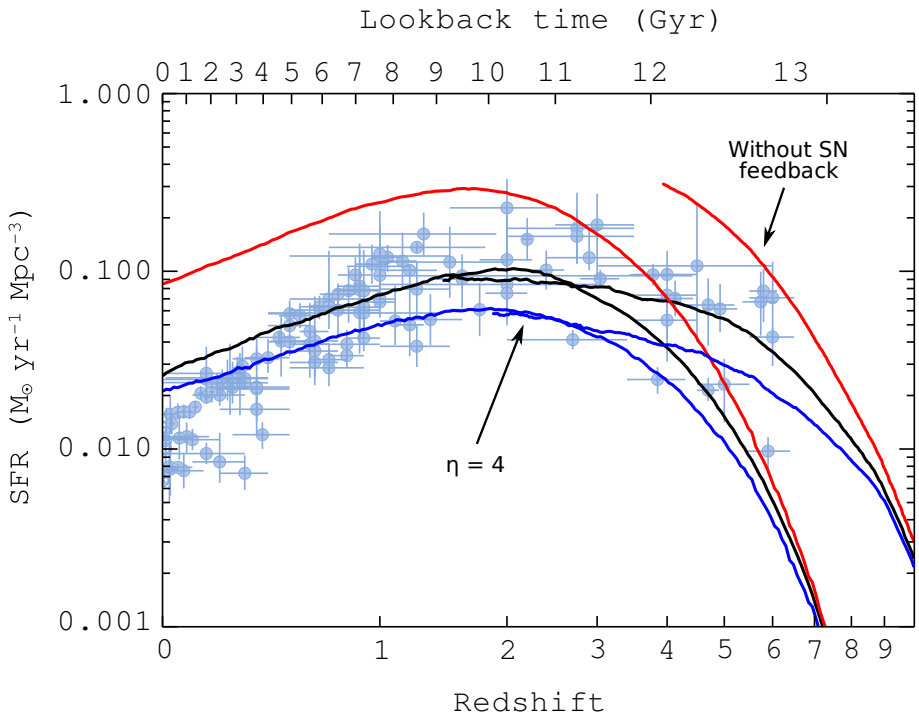
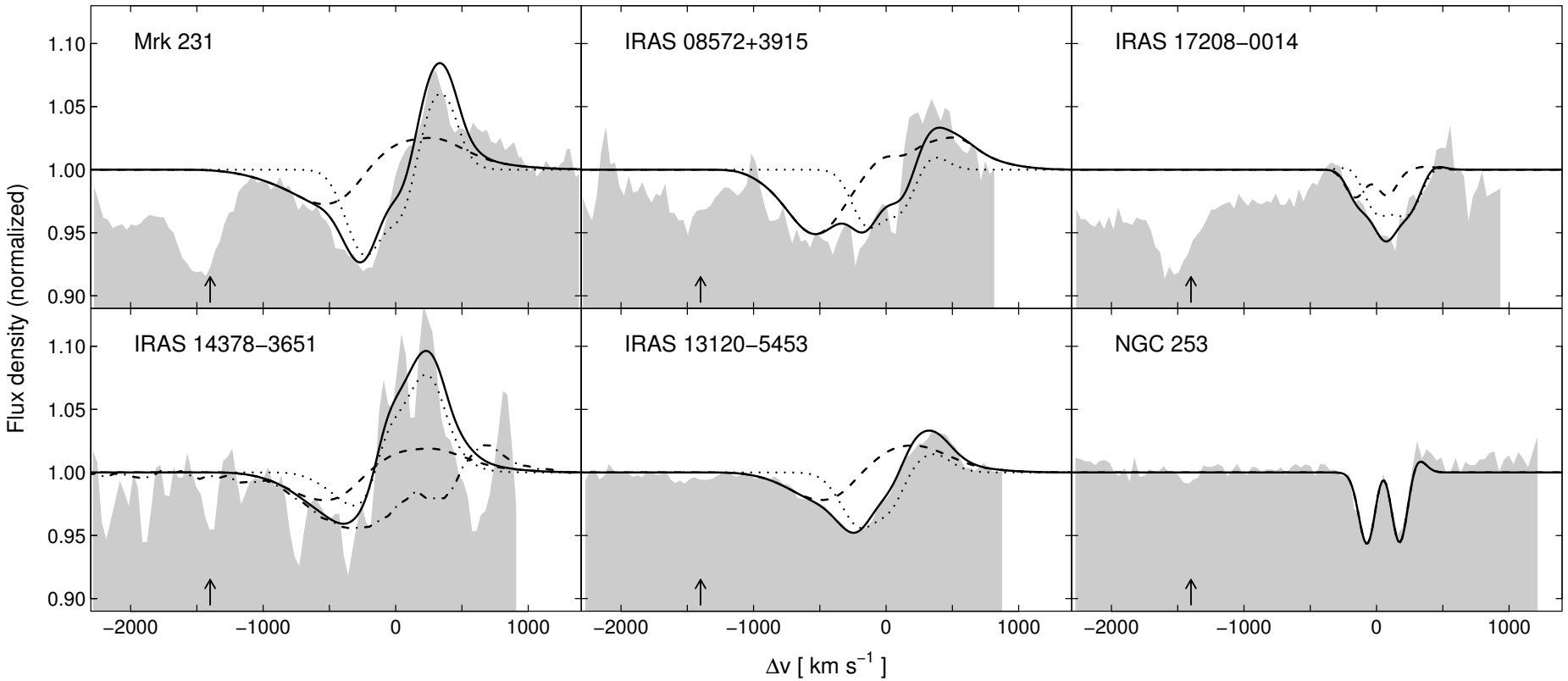


[Schaye et al. 2010, MNRAS 402: 1536]

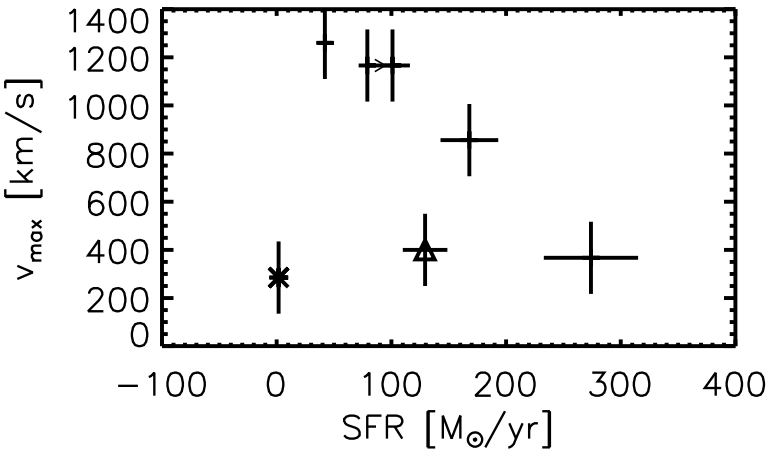
Molecular outflows

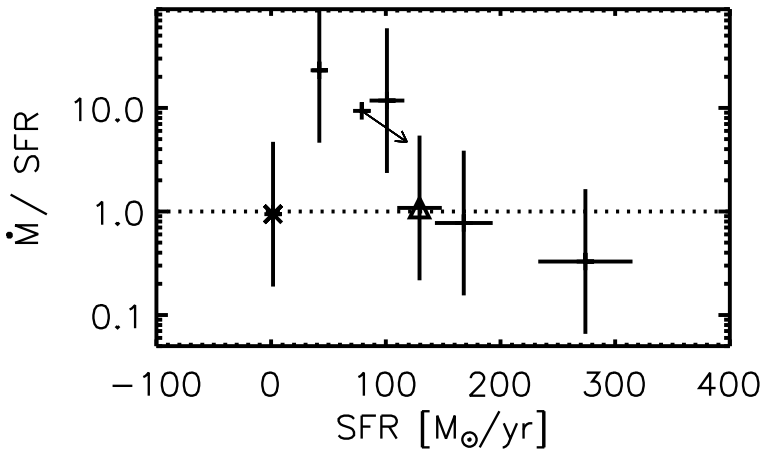


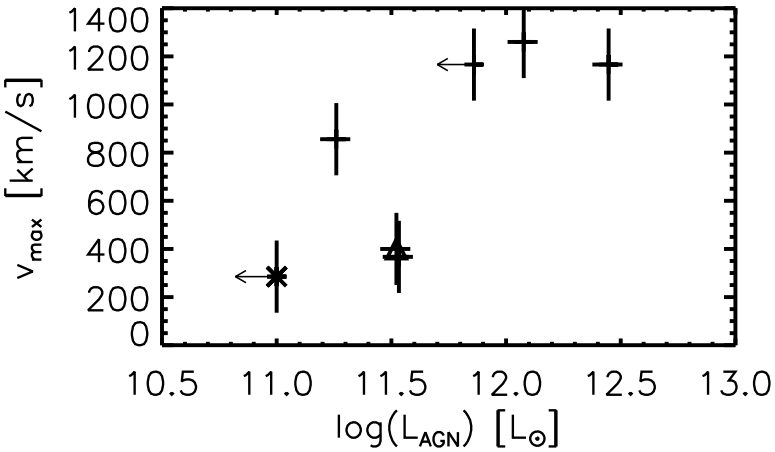
Mass outflow rate $\sim$ 90–1200 $M_\odot$ yr^{-1}

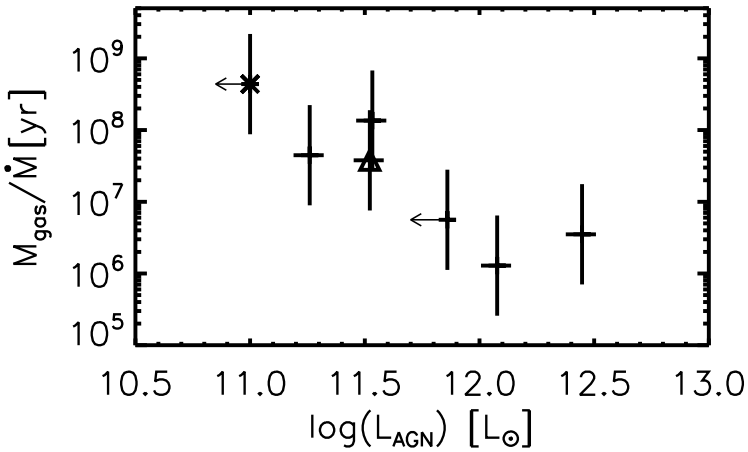
[Sturm et al. 2011, ApJ 733: L16]

Molecular outflows









[Sturm et al. 2011, ApJ 733: L16]

Conclusions

- L_{FIR}/M_{H_2} is a good proxy for the relative brightness of the far-infrared fine structure lines.
- We find line deficits in all the fine structure lines, regardless of their origin in the ionized or neutral phase of the ISM.
- The L_{FIR}/M_{H_2} threshold is similar to the limit that separates between the two modes of star formation recently found in galaxies.
- High ionization parameters can explain the line deficits in the [C II], [O I] and [N II] lines. Further modeling is needed to explain the [N III] and [O III] lines.
- We find molecular outflows in most of the ULIRGs we have observed. In some cases, these molecular outflows can expell the full molecular gas content of the galaxy in a time scale of a few Myr.