SOFIA Reveals [CII] Emission from Jet and Ghostly Arms in NGC 4258

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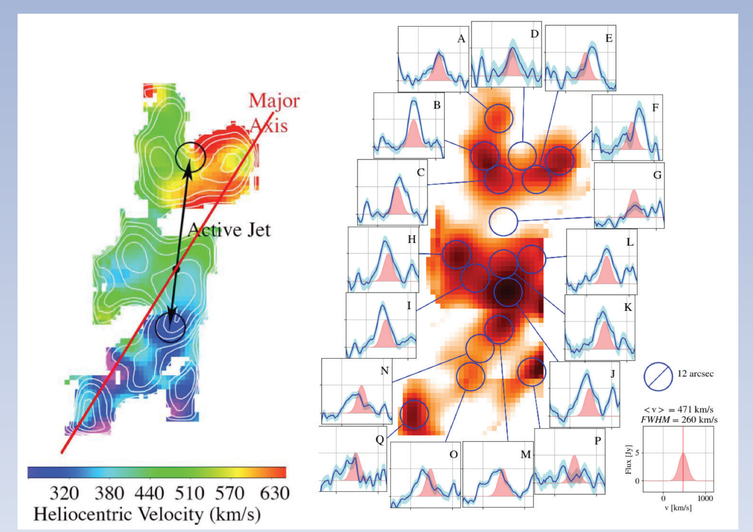
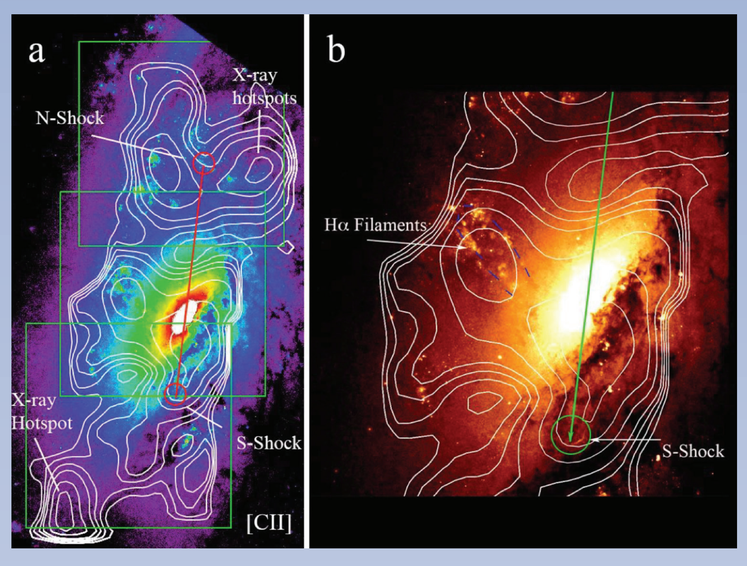
Overview

We report the first resolved detection of [CII]157.7μm emission from a jet in an active galaxy. Our SOFIA/FIFI-LS observations of the inner 5 kpc of the active galaxy NGC 4258 revealed emission associated with warm molecular hydrogen distributed along and beyond the end of the southern jet in a region known to contain shock-excited optical filaments. Emission is also associated with soft X-ray hot-spots which are the counter-parts of the ghostly radio arms of NGC 4258. The rest of the emission is associated with star formation, namely the northern arm of the galaxy and a 1 kpc long region on the minor axis of the galaxy with H-alpha filaments and young star clusters. The [CII] emission along the jet and in the hot-spots exhibit anomalous [CII]/FIR and [CII]/PAH ratios as well as large intrinsic [CII] line widths, suggesting that shocks and turbulence in the warm gas are causing the [CII] emission. We estimate that 40% of the total [CII] luminosity from the inner 5 kpc of NGC 4258 arises in shocks and turbulence (approximately 1% of the bolometric luminosity of the active nucleus). The rest is consistent with [CII] excitation associated with star formation. Such a large fraction of shock related [CII] emission has implications for interpreting [C II] luminosity of high-z galaxies, where turbulence and feedback effects from star formation and AGN probably play an important role in galaxy evolution.

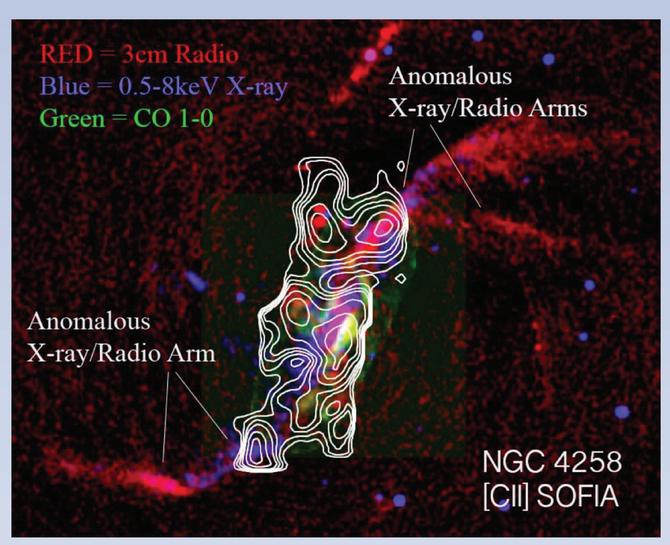


Profile of the [CII] line in different regions of the galaxy. The image shows the integrated [CII] line across the galaxy. Each region has an area corresponding to the beam of the instrument. The pink profile represents an unresolved line at the systemic velocity. Most of the lines are resolved. A clear velocity gradient is visible along the major axis and across the minor axis. The gradient along the minor axis is consistent with our Hα observations obtained at Palomar which identify a flow of gas across the minor axis.



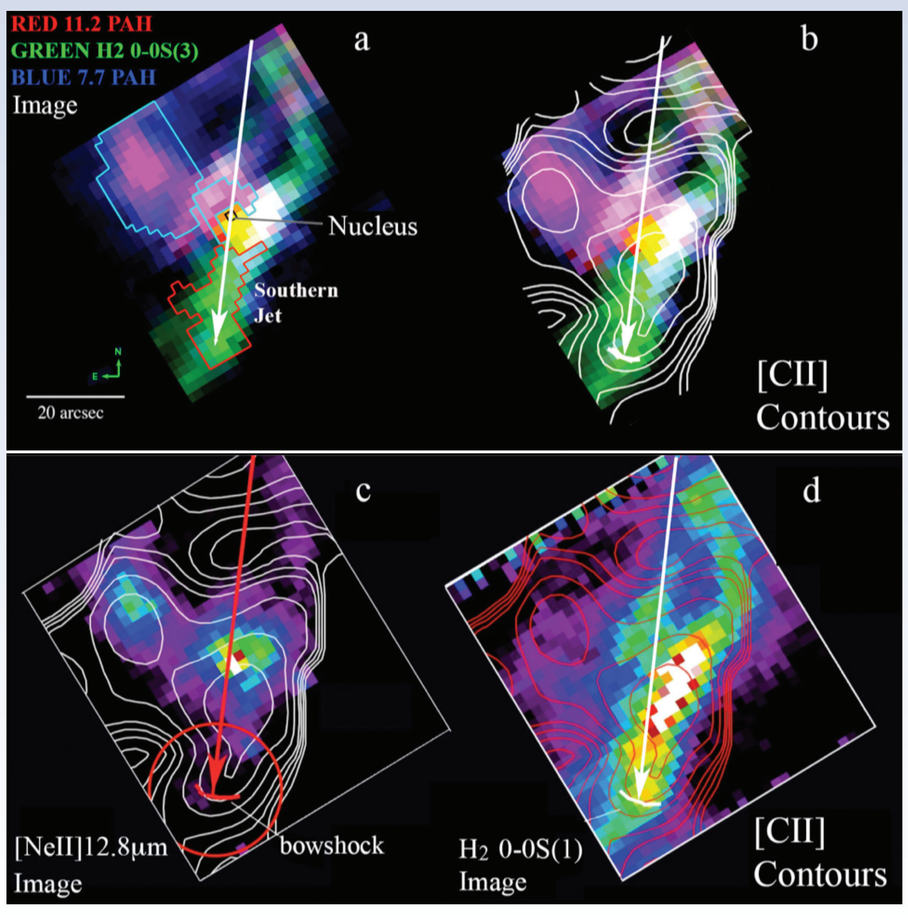
Comparison with Optical

Integrated [CII] emission contours over an HST image of NGC 4258. On the right: the central region with Hα filaments and the Southern jet have bright [CII] emission.



Ghostly Arms in Radio/X-ray

Ghostly arms detected in the X-ray and radio emit also in [CII]. In particular, the two hot spots are clearly detected in [CII].



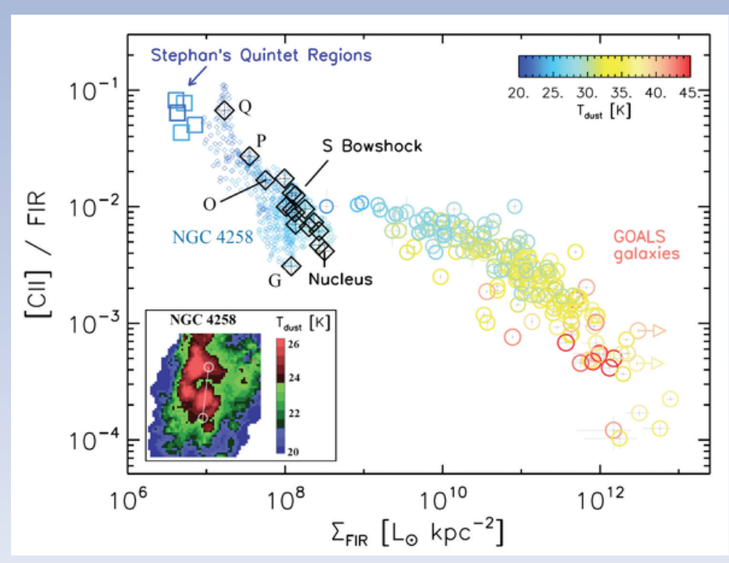
Emission along Minor Axis and Jet

[CII] emission across the minor axis correlates well with the PAH emission while, along the jet, it correlates with H_2 emission.

In the region of the bowshock, the absence of [NeII] emission shows that free electrons are not responsible for the [CII] emission.

The [CII] emission is due to shock.

Excess wrt FIR



A comparison of the [CII] and FIR emission in NGC 4258 shows that most of the regions are compatible with star formation in a locus around the faint end of the GOALS relationship. Some of the regions (hot spots and bowshock) have an excess of [CII] emission with respect to their FIR emission.

Conclusions

The [CII] emission corresponds to shock-excited H2 emission along the southern jet of NGC 4258. This is the first resolved detection of [CII] emission along an AGN jet.

[CII] emission is detected also on the bright X-ray/radio spots along the ghostly arms where [CII]/FIR and [CII]/PAH ratios are anomalously high.

[CII] is emitted along the minor axis filament on a region with gas flow, Hα star forming regions, and PAH emission.

[CII] velocity filed is highly disturbed with the highest velocity dispersion in the southern bow-shock due to turbulence and shock.

Up to 40% of the total [CII] emission is due to shocks and turbulence. [CII] dissipates ~1% of the total power emitted by the AGN. This should be taken into account when interpreting [CII] as a proxy for star formation in distant galaxies. Ratios of [CII]/FIR > 3% indicate contribution of shock and turbulence to the total [CII] emission.

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