The Close AGN Reference Survey (CARS)

Discovery of a global [C II] 158 μm line excess in AGN HE 1353−1917

I. Smirnova-Pinchukova[1], B. Husemann[1], G. Busch[2], P. Appleton[3], M. Bethermin[4], F. Combes[5], S. Croom[6], T. A. Davis[7], C. Fischer[8], M. Gaspari[9,⋆], B. Groves[10], R. Klein[11], C. P. O'Dea[12,13], M. Pérez-Torres[14,15], J. Scharwächter[16], M. Singha[12], G. R. Tremblay[17], and T. Urrutia[18]

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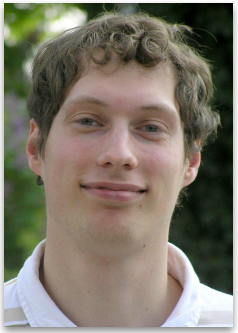
ABSTRACT

The [C II]λ158 μm line is one of the strongest far-infrared (FIR) lines and an important coolant in the interstellar medium of galaxies that is accessible out to high redshifts. The excitation of [C II] is complex and can best be studied in detail at low redshifts. Here we report the discovery of the highest global [C II] excess with respect to the FIR luminosity in the nearby AGN host galaxy HE 1353−1917. This galaxy is exceptional among a sample of five targets because the AGN ionization cone and radio jet directly intercept the cold galactic disk. As a consequence, a massive multiphase gas outflow on kiloparsec scales is embedded in an extended narrow-line region. Because HE 1353−1917 is distinguished by these special properties from our four bright AGN, we propose that a global [C II] excess in AGN host galaxies could be a direct signature of a multiphase AGN-driven outflow with a high mass-loading factor.

Key words. galaxies: Seyfert – galaxies: star formation – ISM: jets and outflows – infrared: ISM

Irina (me)



Dr. Bernd Husemann

Irina Smirnova-Pinchukova:

PhD student @ MPIA in Heidelberg, Germany

Close AGN Reference Survey (CARS) member

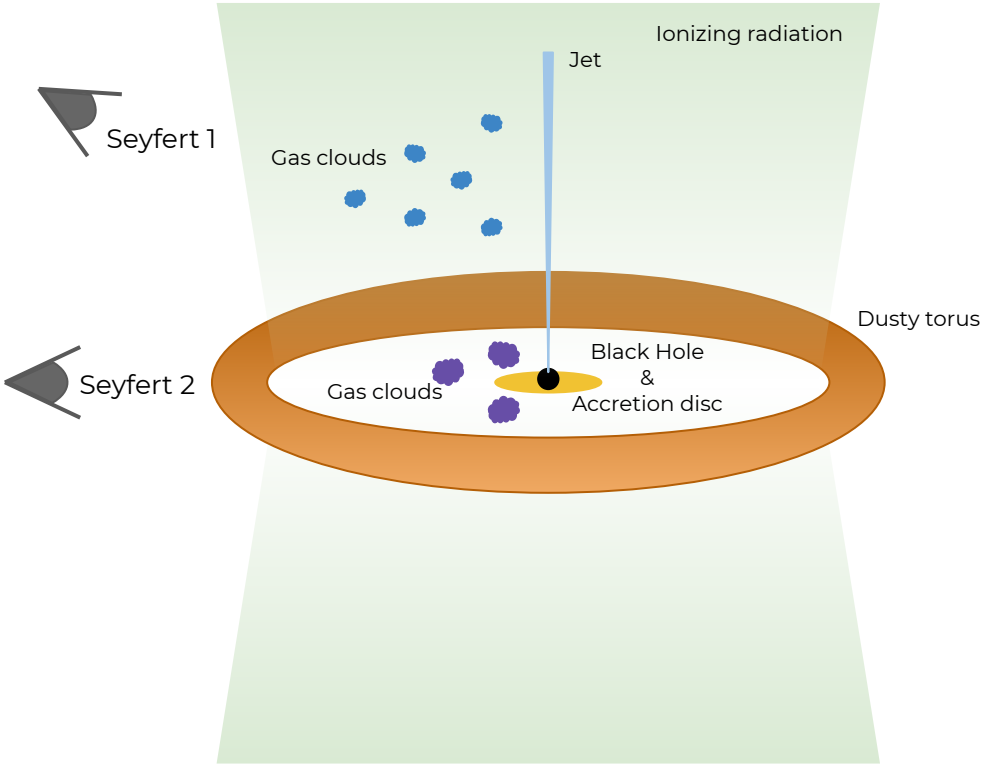
July 2017 -> SOFIA flight from Christchurch

CLOSE AGN REFERENCE SURVEY

1.2 document map

1. Formal
2. Introduction
3. First result
4. Main result
5. FIFI-LS data
6. MUSE synergy
7. Explanation
8. Other cases
9. Reduction
10. Further investigation
11. Summary
12. Other plans

2.1 unified model



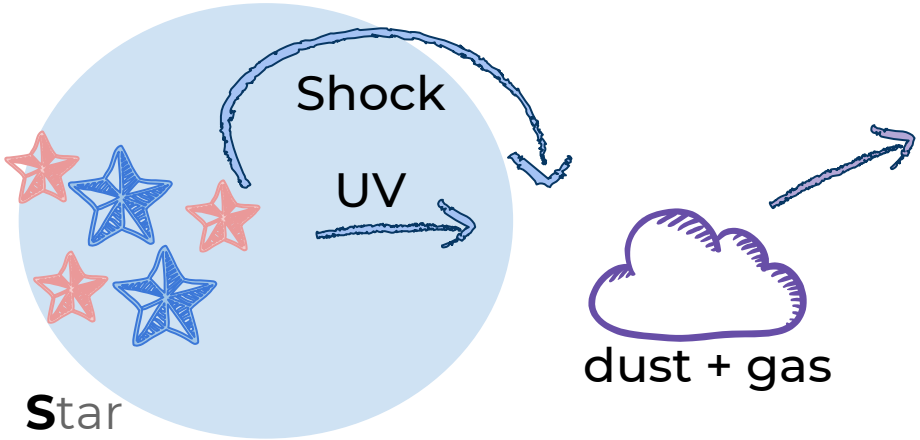
Active **G**alactic **N**uclei are accreting SuperMassive Black Holes

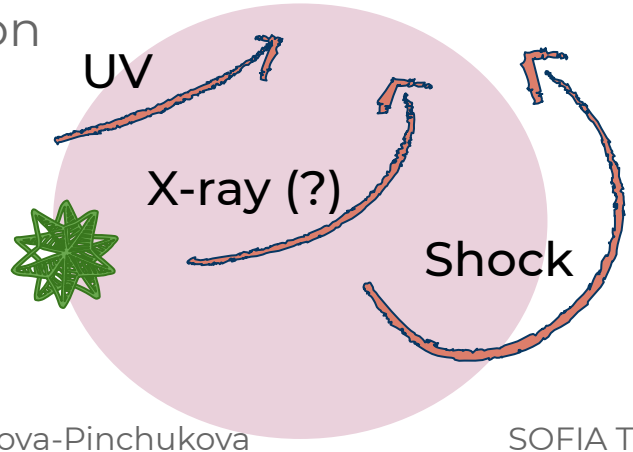
Seyfert type 1 or 2 depends on the viewing angle

In Seyfert 1 AGN SMBH vicinity is unobscured

In Seyfert 2 AGN SMBH vicinity is obscured by the dusty torus

2.2 [CII] emission line





[CII] 158μm line -

one of the brightest in the **F**ar **I**nfra**R**ed

The [CII] line is an effective cooler of the ISM

but it is not sensitive to the heating mechanism

The usual mechanism in normal galaxies is connected to star formation

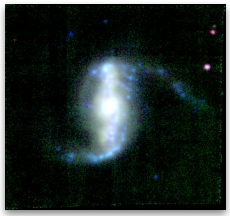
But what is the effect of AGN?

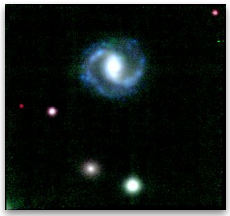
2.3 the observed sample

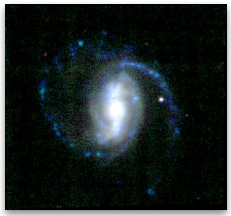
SOFIA Proposal 04_0056

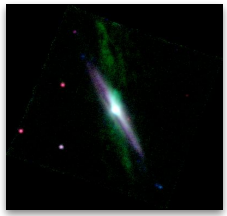
How accurate is [CII] tracing star formation in nearby luminous AGN?

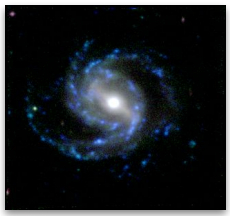
Principal Investigator: Dr. Bernd Husemann


HE 0433-1028


HE 1029-1831


HE 1108-2813


HE 1353-1917


HE 2211-3903

5 AGN Seyfert 1 hosts

SOFIA/FIFI-LS observations

MUSE cubes available

Close AGN Reference Survey
www.cars-survey.org

3.1 spatial analysis: first result

The Astrophysical Journal Letters, 866:L9 (6pp), 2018 October 10 https://doi.org/10.3847/2041-8213/aae25d

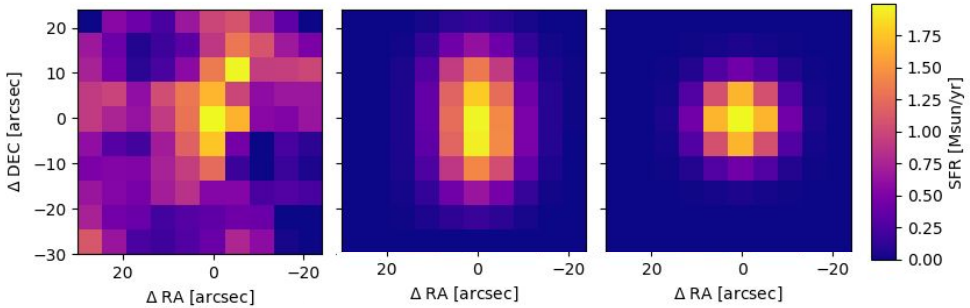
The Close AGN Reference Survey (CARS): SOFIA Detects Spatially Resolved [C II] Emission in the Luminous AGN HE 0433-1028*

G. Busch[1], B. Husemann[2], I. Smirnova-Pinchukova[2], A. Eckart[1,3], S. A. Baum[4,5], F. Combes[6], S. M. Croom[7], T. A. Davis[8], N. Fazeli[1], C. Fischer[9], M. Gaspari[10,20], R. Klein[11], M. Krumpe[12], R. McElroy[2], C. P. O'Dea[13,14], M. A. Perez-Torres[15,16], M. C. Powell[17], Á. Sánchez-Monge[1], J. Scharwächter[18], G. R. Tremblay[19], and T. Urrutia[12]
[1] I. Physikalisches Institut der Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany; busch@ph1.uni-koeln.de

Dr. Gerold Busch

FIFI-LS data MUSE prior point source

HE0433-1028

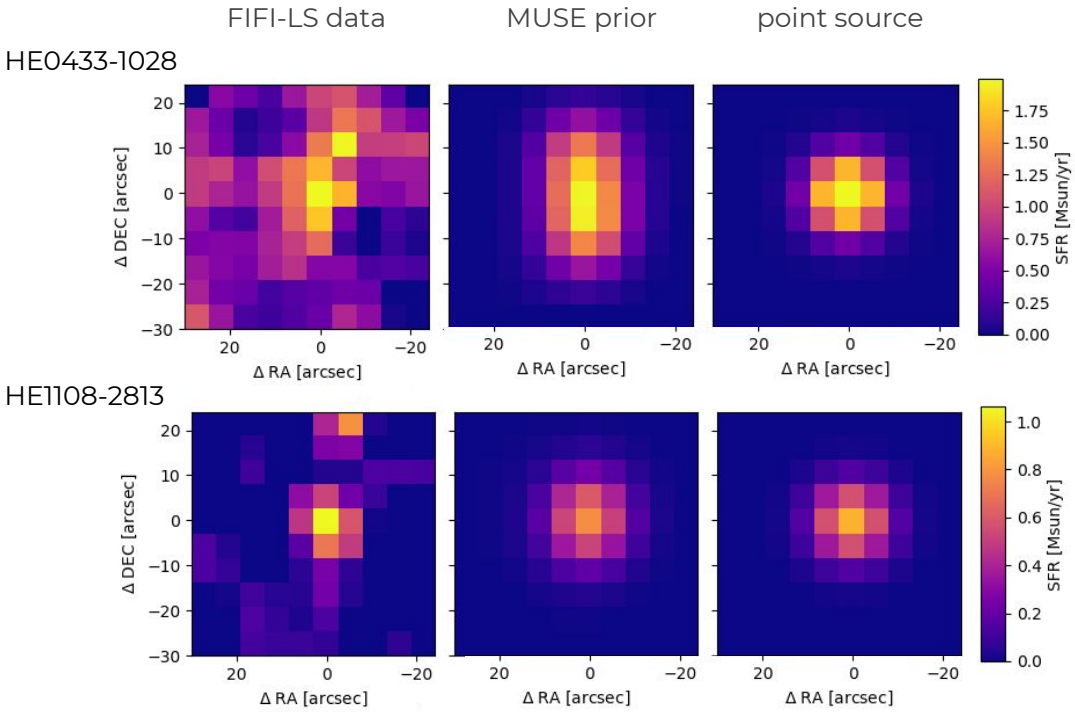


HE 0433-1028 is a strongly barred galaxy

MUSE Hα is used as a prior for star formation map

Point source is used to model AGN impact on the [CII] map

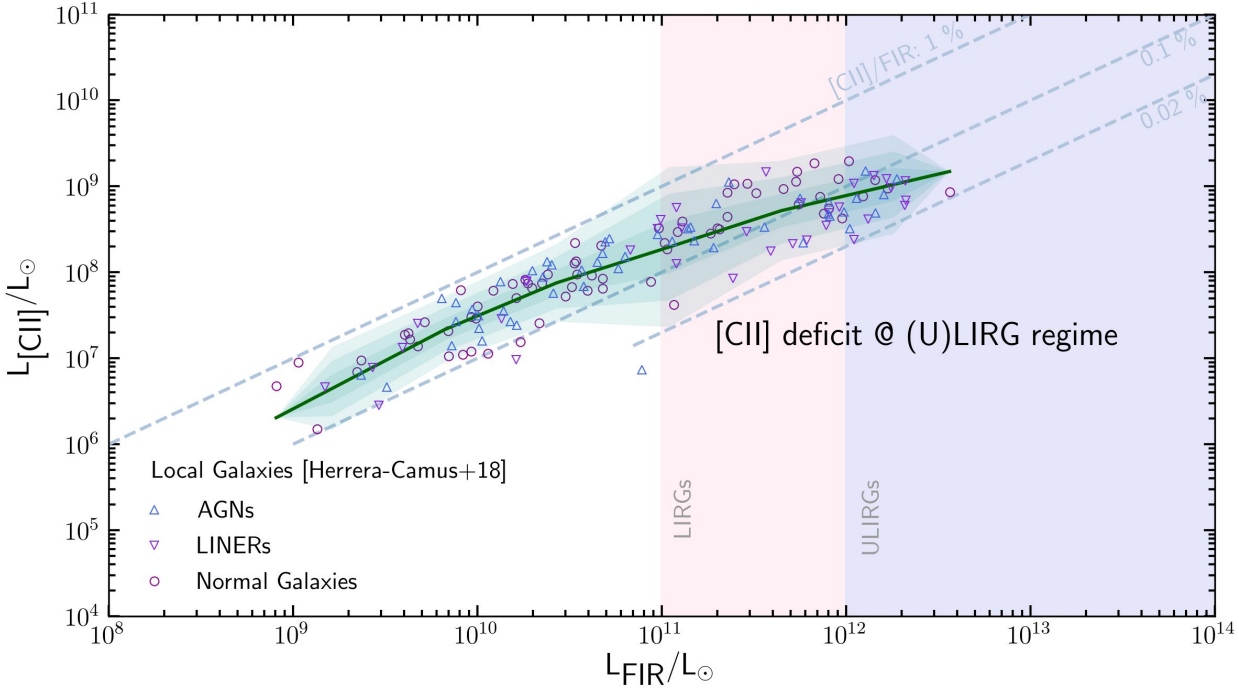
3.2 spatial analysis: complications



…but this approach was not suitable for all the observed galaxies

Other galaxies have very little difference between the MUSE prediction of the star formation map and the point source

4.1 total luminosity: literature background



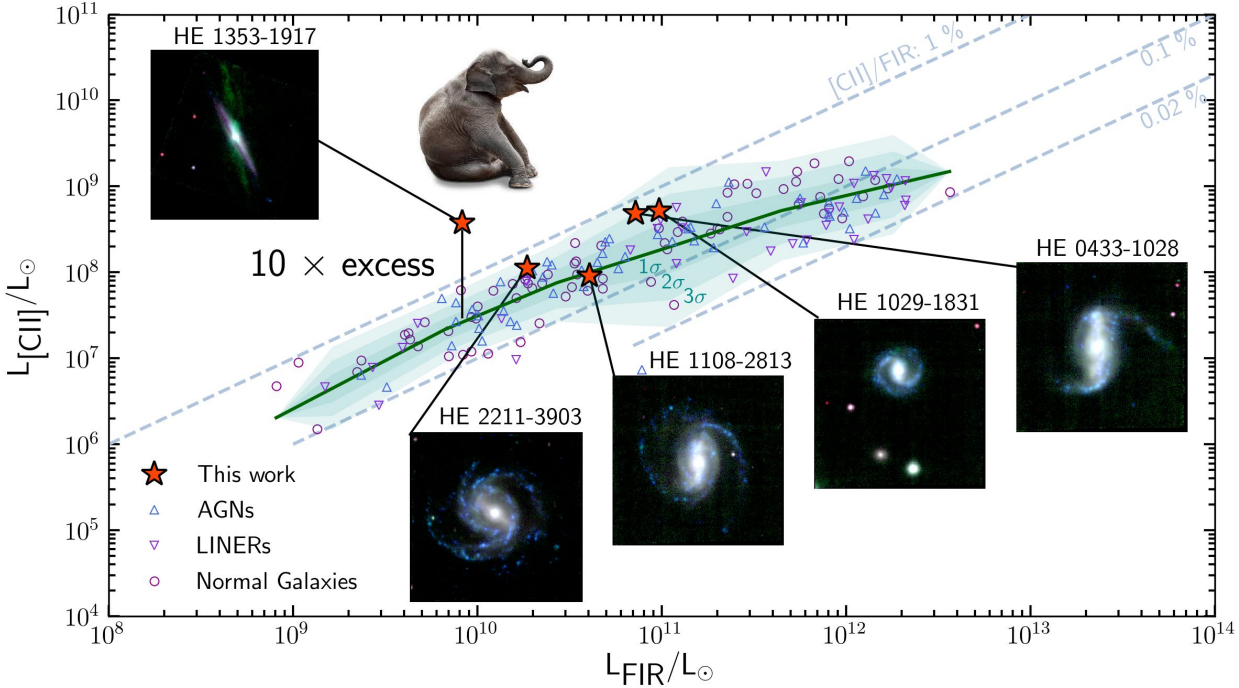
[CII] and FIR are correlated because both of them are tracing star formation

There is no significant difference between normal and AGN galaxies

The trend flattens out at the (Ultra)Luminous InfraRed regime

The reasons of [CII] deficit are still not well understood

4.2 total luminosity: elephant in the room



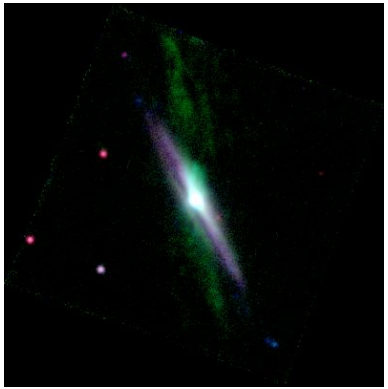
Four galaxies observed with FIFI-LS follow the relation

...but the fifth one is a strong outlier

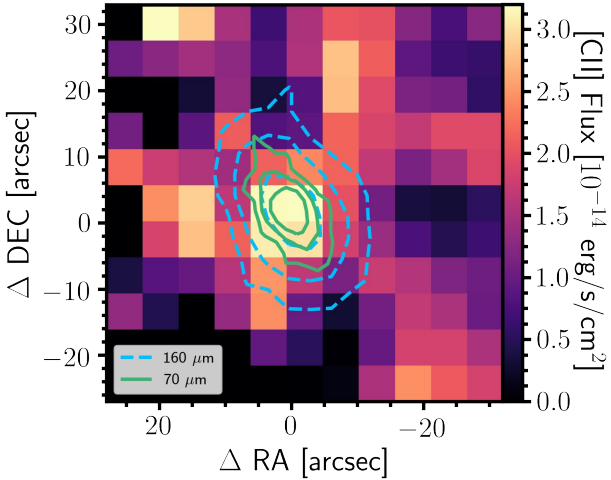
Why is it so?

5.1 spatial hint

MUSE i band [OIII] Hα



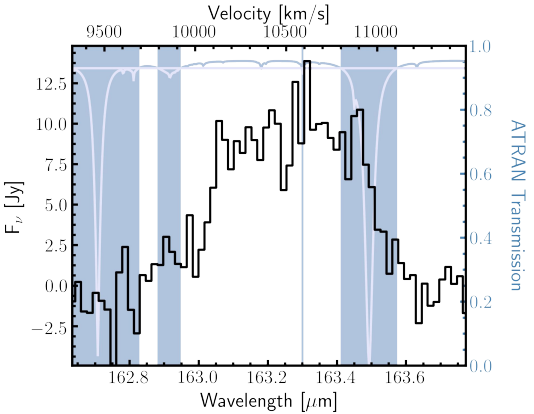
FIFI-LS/SOFIA & PACS/*Herschel*



FIFI-LS [CII] map shows that the excess comes from the central part of the galaxy rather than from the star-forming disc

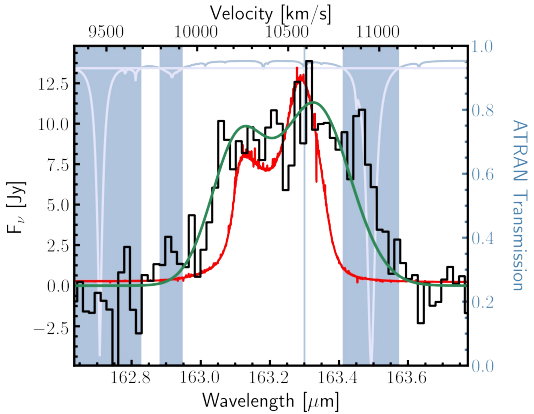
Is AGN responsible for the excess?

5.2 spectral hint



Data

Mask



Fit

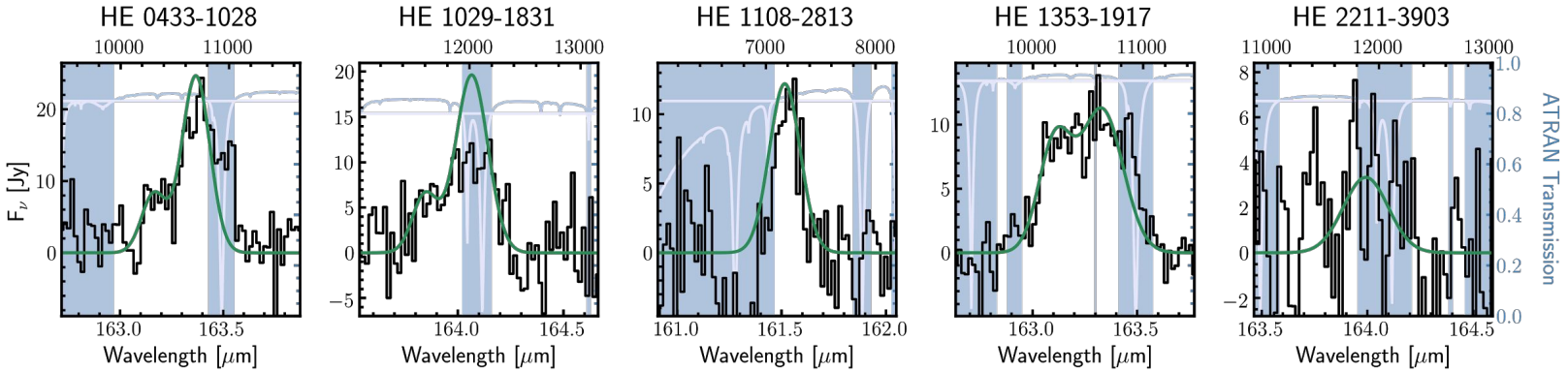
MUSE Hα

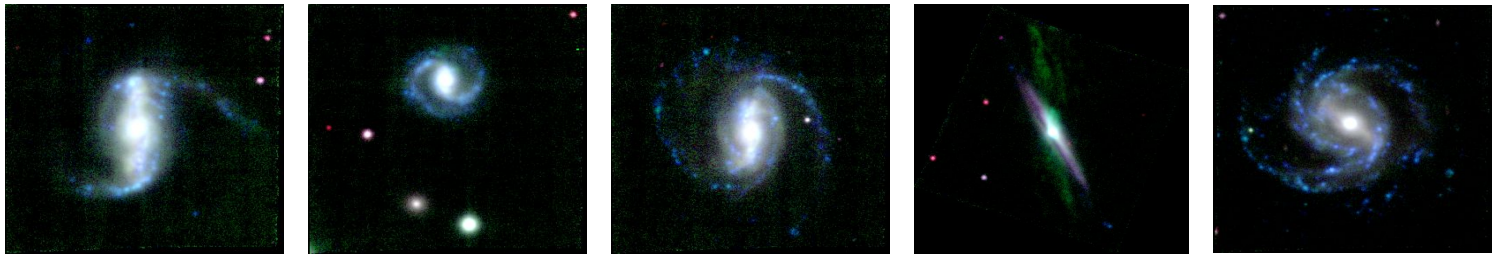
FIFI-LS [CII] line profile shows double-peaked feature as well as Hα profile

Why is the line so broad?

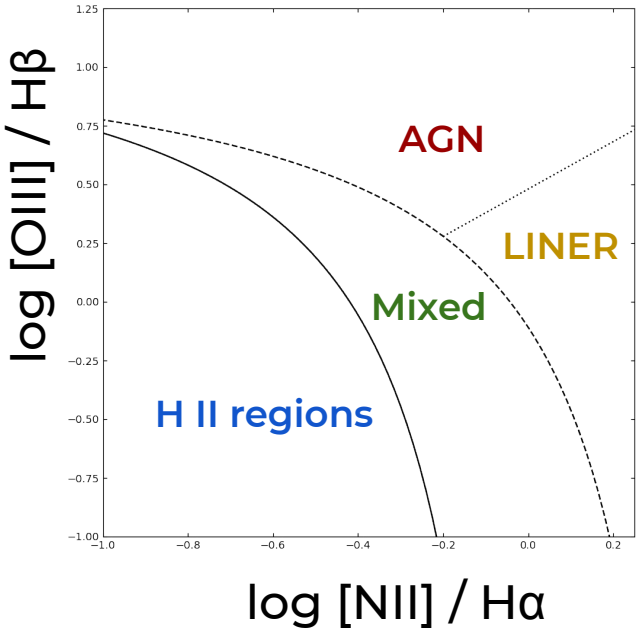
760 ± 60 km/s

5.3 spectral hint





6.1 synergy with MUSE



BPT diagram is an emission line diagnostic diagram proposed by [Baldwin, Phillips & Terlevich 1981]

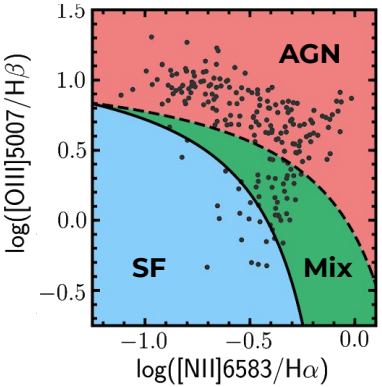
The demarcation lines:

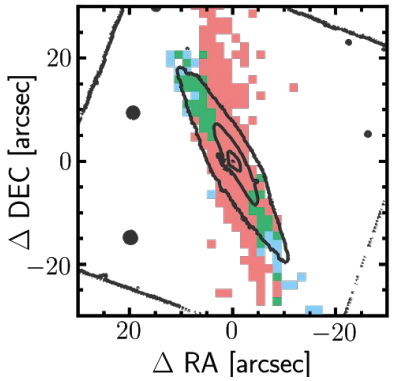
—— [Kauffmann et al. 2003]

– – – [Kewley et al. 2001]

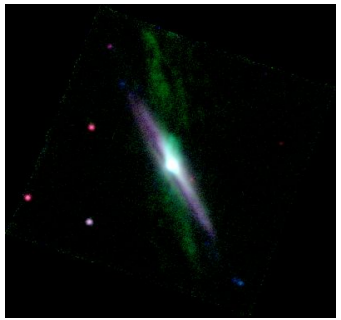
····· [Cid Fernandes et al. 2010]

6.2 synergy with MUSE





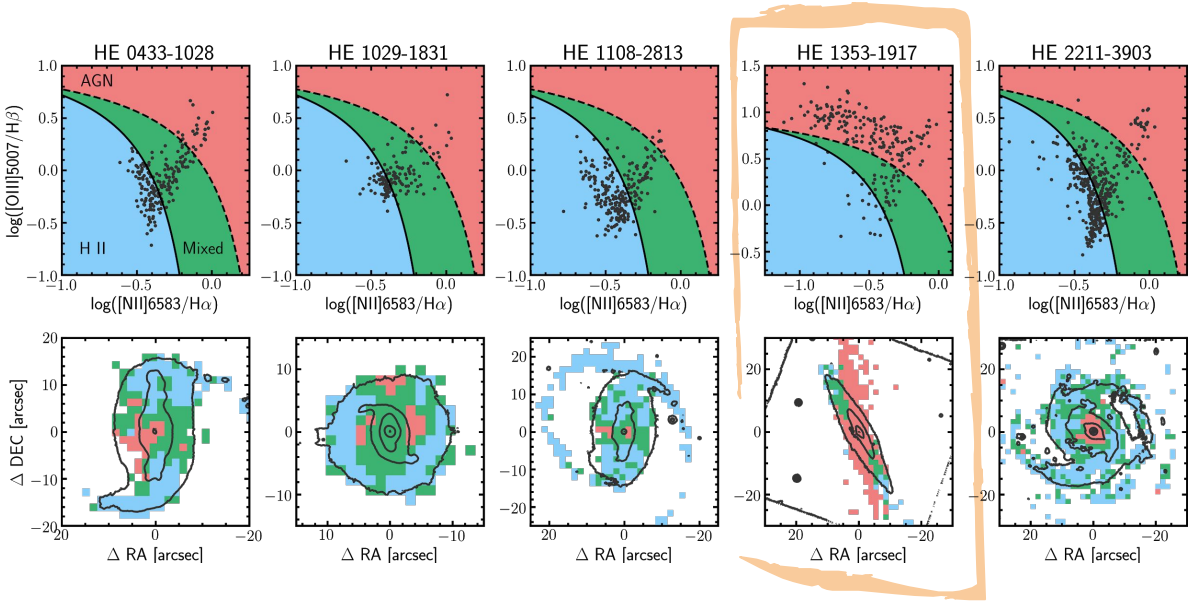
MUSE i band [OIII] Hα



BPT analysis helps to understand which spatial regions are ionized due to star formation or AGN

In HE 1353-1917 75% of Hα flux comes from AGN ionized regions

6.3 synergy with MUSE



The other 4 face-on galaxies in the sample are mostly star-forming

Is it a coincidence or edge-on apparent morphology makes the difference?

7.1 multiwavelength analysis

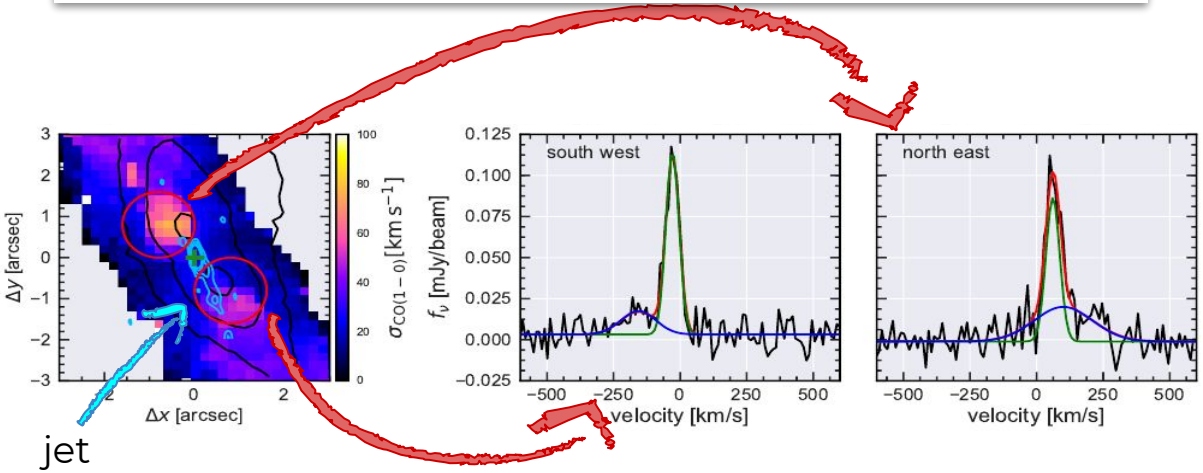
A&A 627, A53 (2019)
https://doi.org/10.1051/0004-6361/201935283

Astronomy & Astrophysics

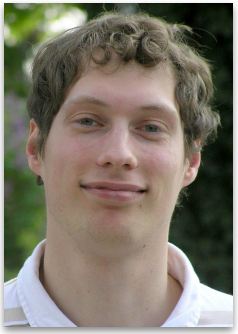
The Close AGN Reference Survey (CARS)

A massive multi-phase outflow impacting the edge-on galaxy HE 1353−1917

B. Husemann[1], J. Scharwächter[2], T. A. Davis[3], M. Pérez-Torres[4,5], I. Smirnova-Pinchukova[1], G. R. Tremblay[6], M. Krumpe[7], F. Combes[8], S. A. Baum[9,10], G. Busch[11], T. Connor[12], S. M. Croom[13], M. Gaspari[14,⋆], R. P. Kraft[6], C. P. O'Dea[9,10], M. Powell[15], M. Singha[9], and T. Urrutia[7]



jet

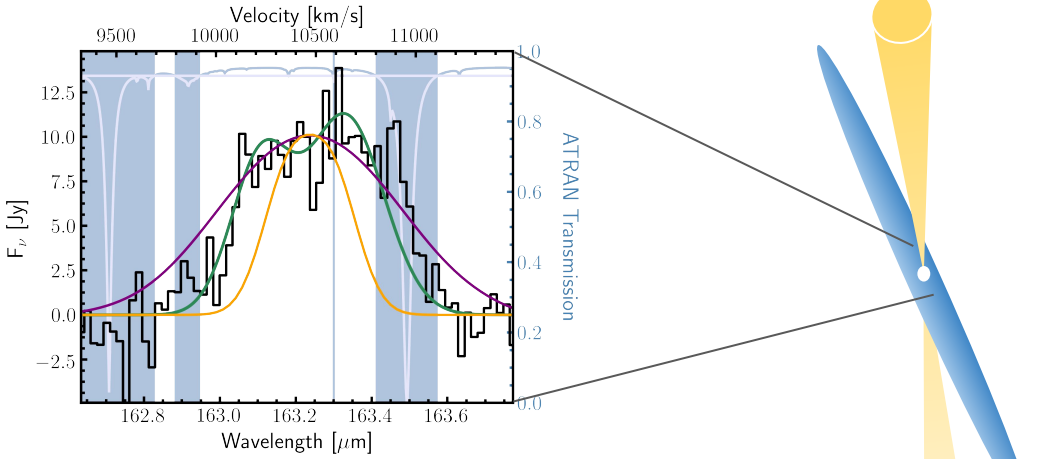


Dr. Bernd Husemann

The detailed multiwavelength analysis revealed the massive multi-phase outflow

The jet goes through the galactic disc

7.2 explanation: broad line



Data Outflow CO (1-0)

Mask Outflow [OIII]

Fit

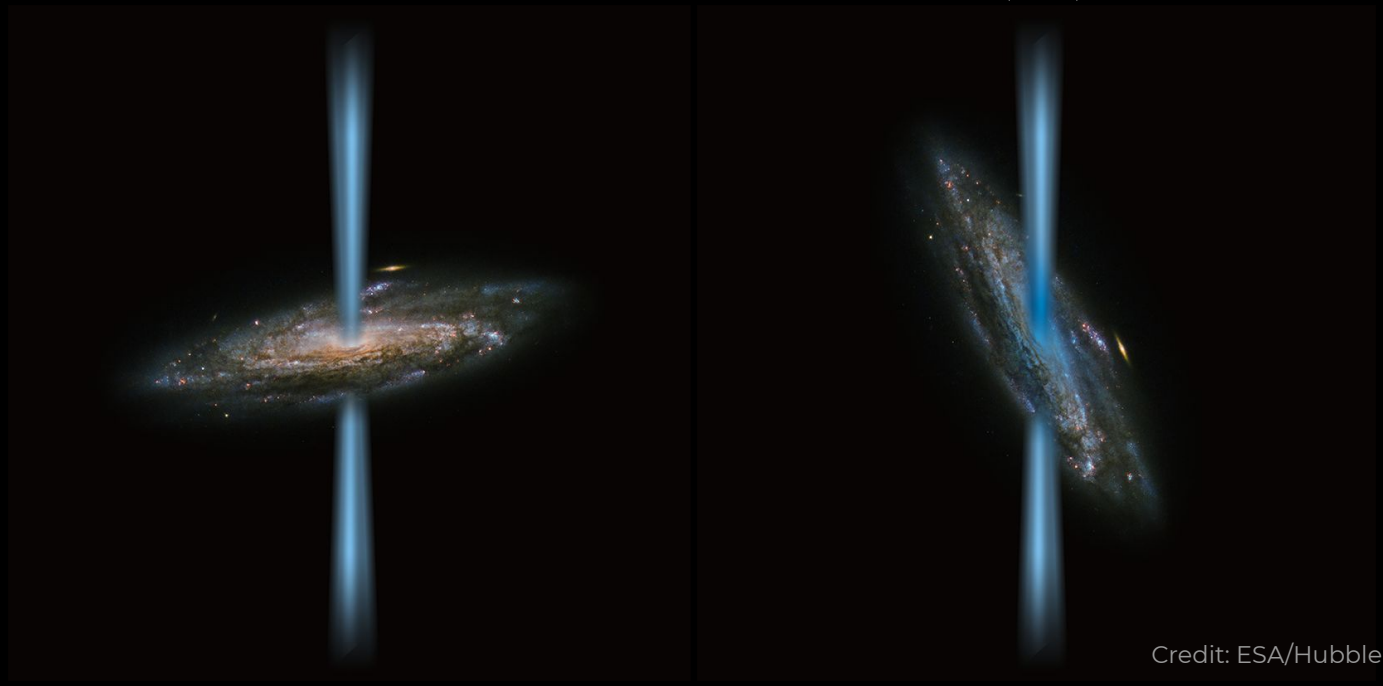
The [CII] line profile is broad because it also comes from the multi-phase outflow

[CII] emission in HE 1353-1917 is connected to the shocks in the outflow

7.3 explanation: the reasons

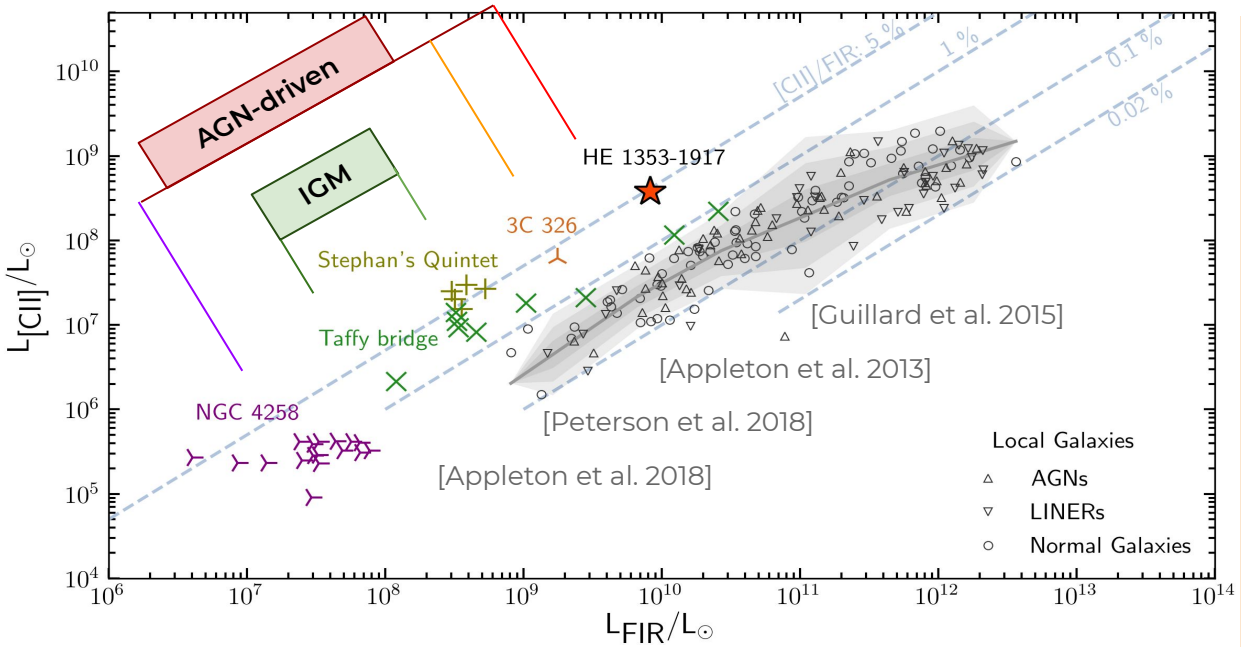
typical Seyfert 1

observed Seyfert 1



Credit: ESA/Hubble & NASA/SOFIA/L. Proudfit

8.1 other cases: local galaxies



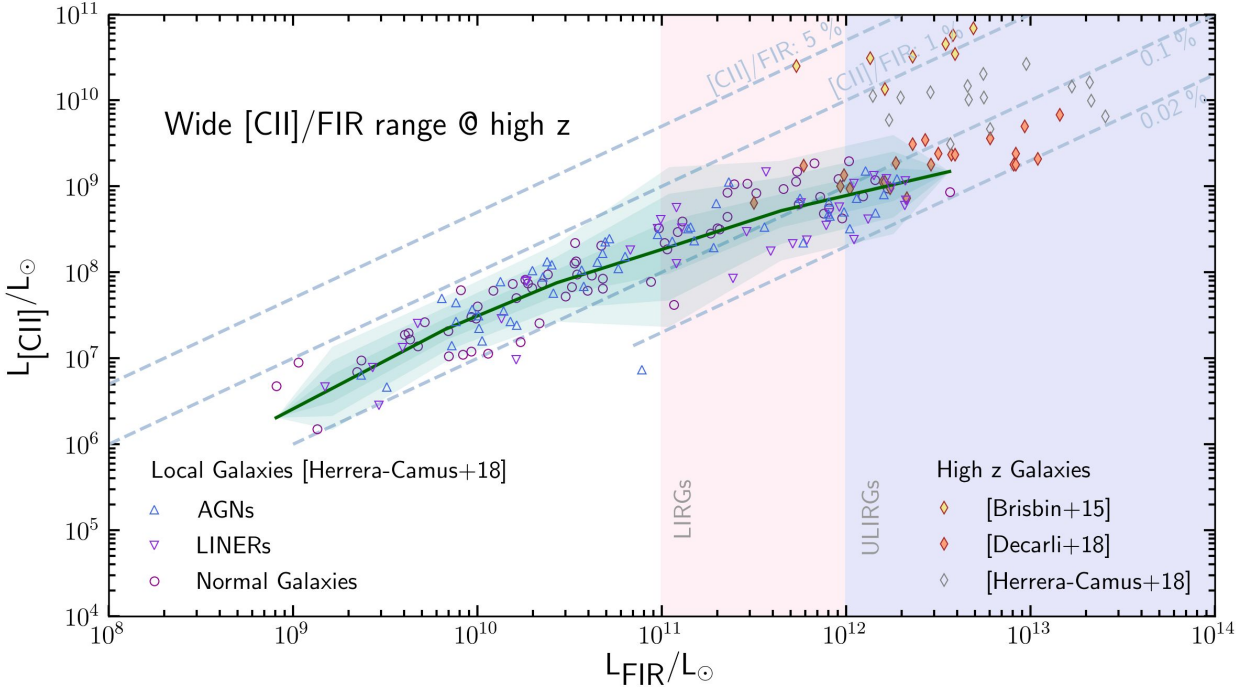
HE 1353-1917 has global [CII] line excess with [CII]/FIR ~ 4%

3C 326 is a radio galaxy with global [CII] line enhancement

NGC 4258 shows [CII] enhancement in local regions, connected to the AGN-driven jet

In Stephan's Quintet and Taffy bridge the excess comes from the shocked intergalactic regions

8.2 other cases: high-z galaxies

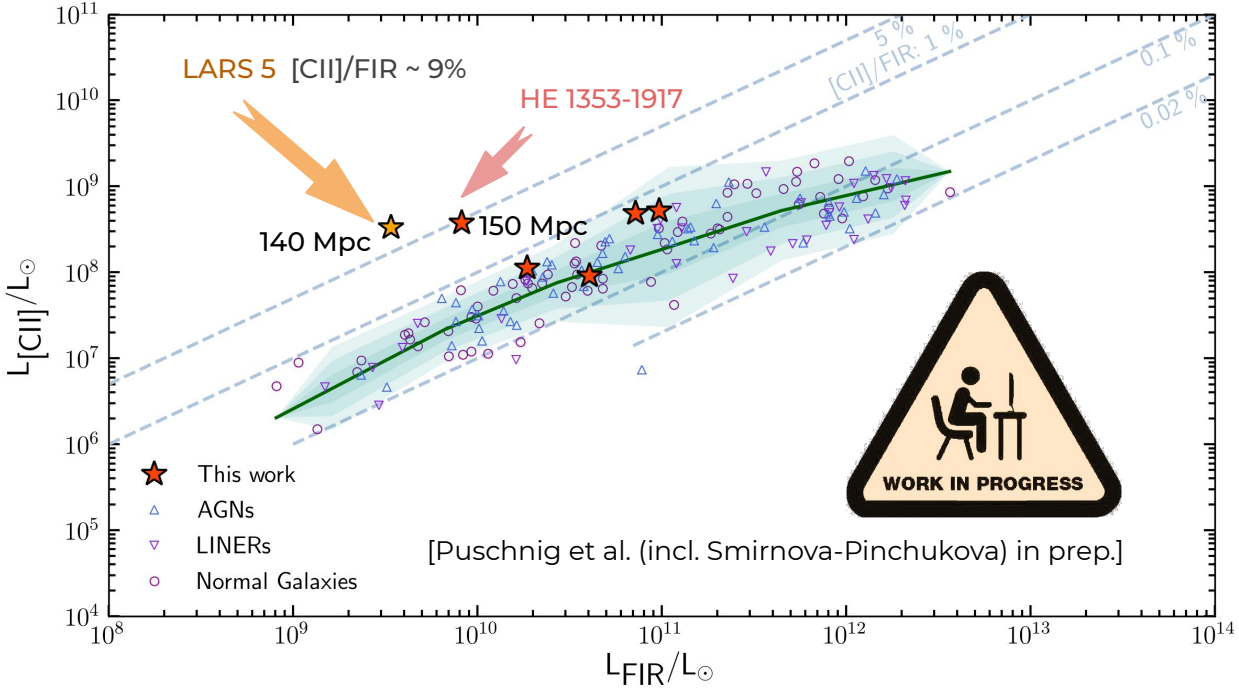


What is the nature of the wide [CII]/FIR range for the high-z galaxies?

Shocked intergalactic media?

AGN-driven outflows?

8.3 other cases: another FIFI-LS discovery



LARS 5 - a galaxy with strong wings induced by the star formation

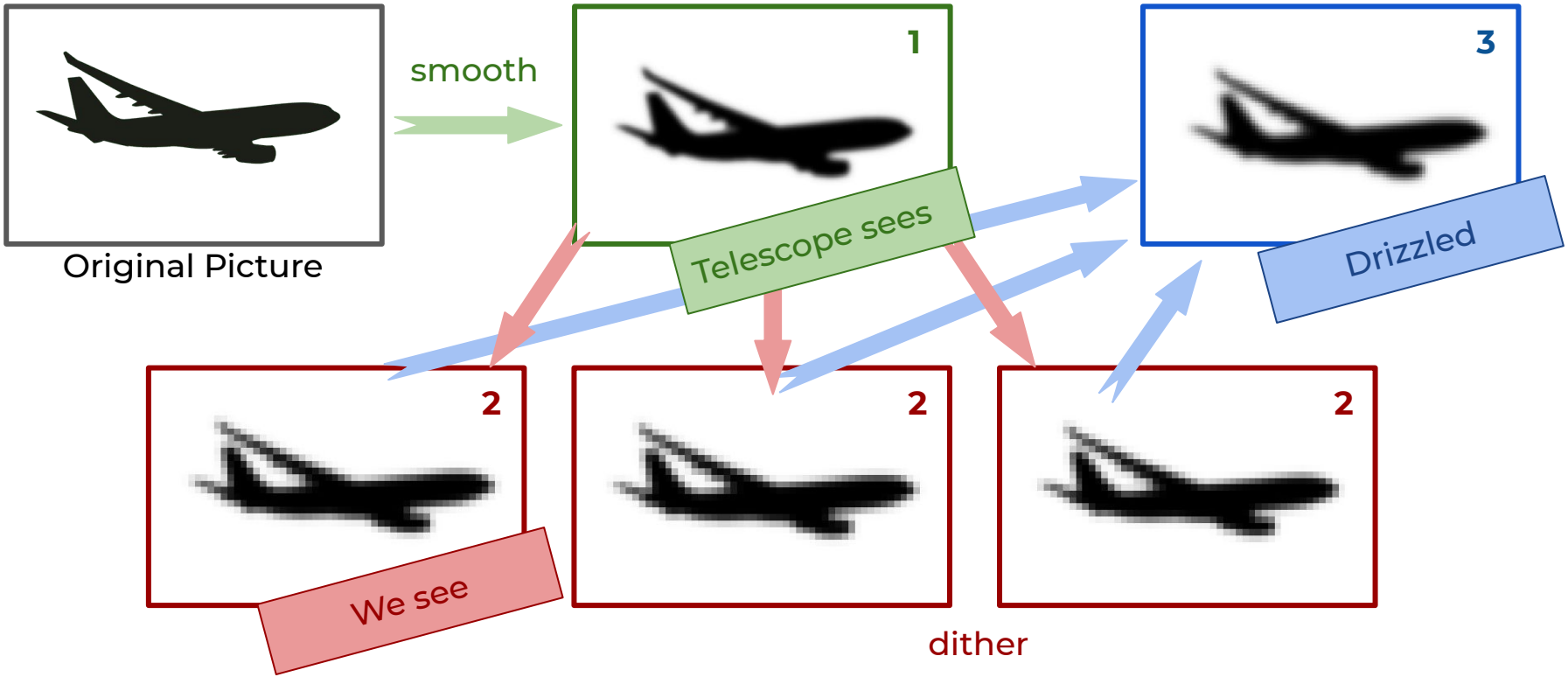
[CII]/FIR ~ 9%!!! Even more than 4% in HE 1353-1917

More surprises from the most distant galaxies observed with SOFIA

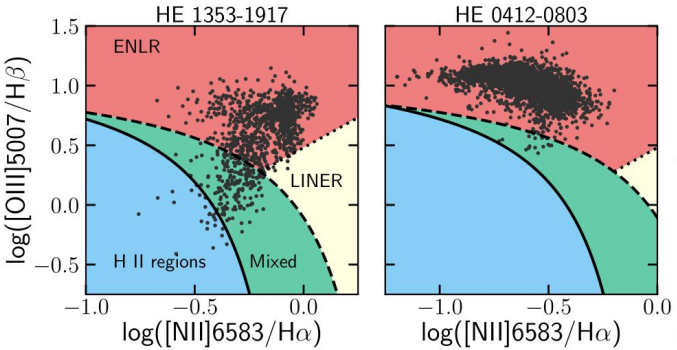
The key is in data reduction

9. reduction tricks

[Fruchter & Hook 1997]



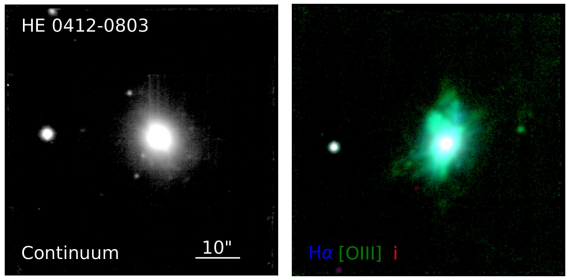
10.1 further investigation



German SOFIA Cycle 7 Proposal Review Summary

Proposal ID: 07_0117
Proposal Title: What causes [CII] line excess in AGN host galaxies?
Principal Investigator: Ms. Irina Smirnova-Pinchukova

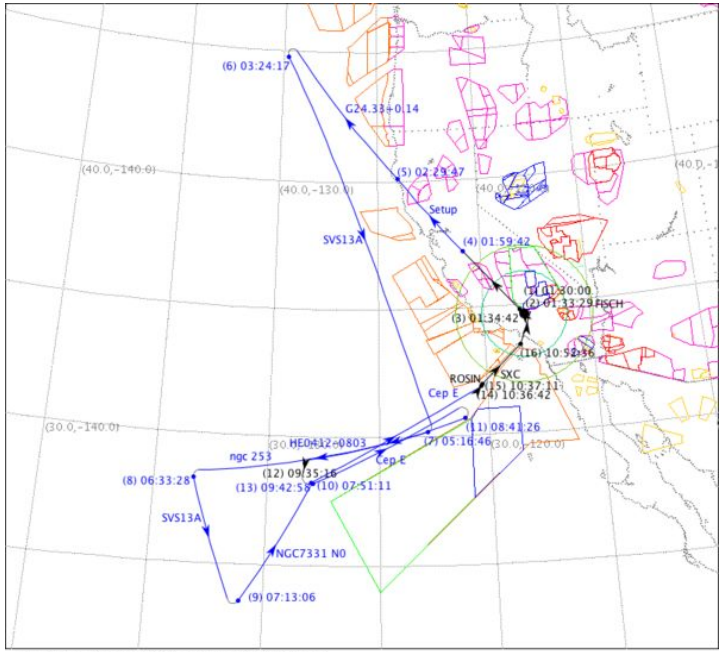
Grade: 3.0
Category: "Do If Time"



HE 0412-0803 is an elliptical galaxy with no star formation but lots of AGN ionized gas

It is a good candidate to check AGN-driven mechanisms of [CII] excitation

10.2 further investigation



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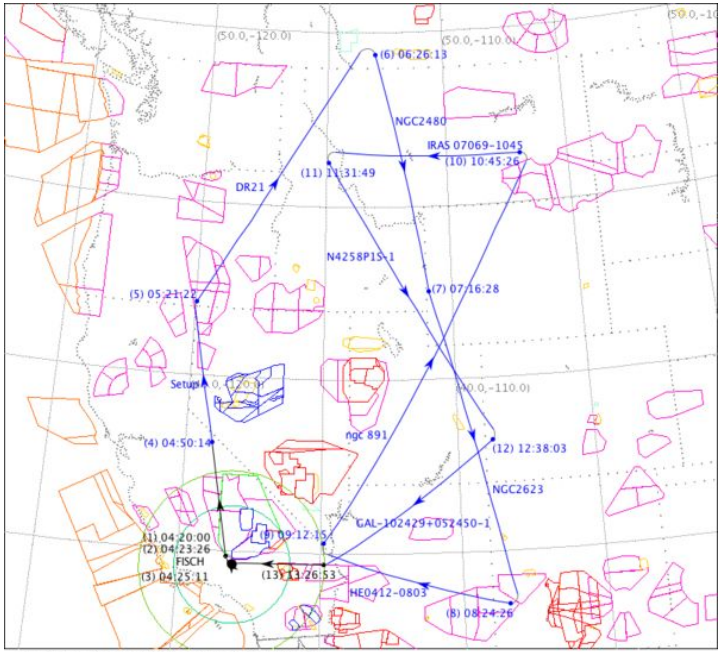
Est. Landing Time: 2019-Nov-02 11:05 UTC
Flight Duration: 09:35
Sunset: 00:58:42 Sunset Az: 253 Sunrise: 14:13:39 Sunrise Az: 107 UTC
Weather Forecast: 0000 Thu Oct 17 2019 - 0600 Sun Oct 20 2019 UTC
Forecast Timestamp: 0406 Thu Oct 17 2019 PT
Flight Plan Comment: HARVEY
enters OCEANIC
Saved: 2019-Oct-17 18:13 UTC User: kbower



Flight Plan Filename: 201910_FI_HOGAN_MOPS.fp
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Flight Duration: 09:36
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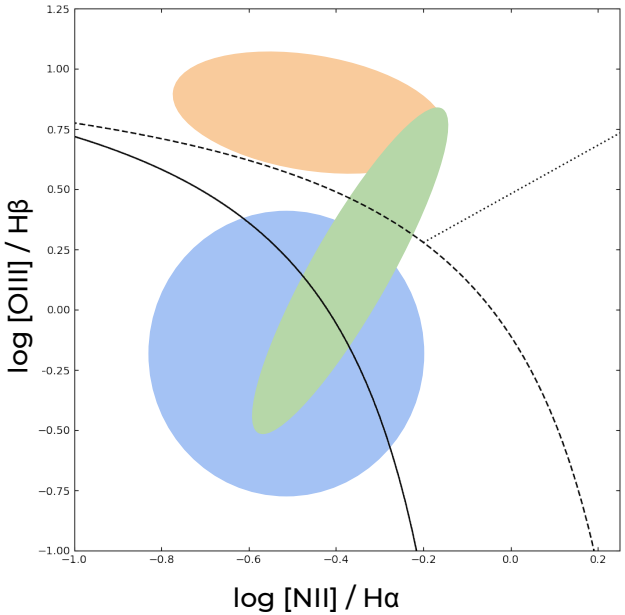
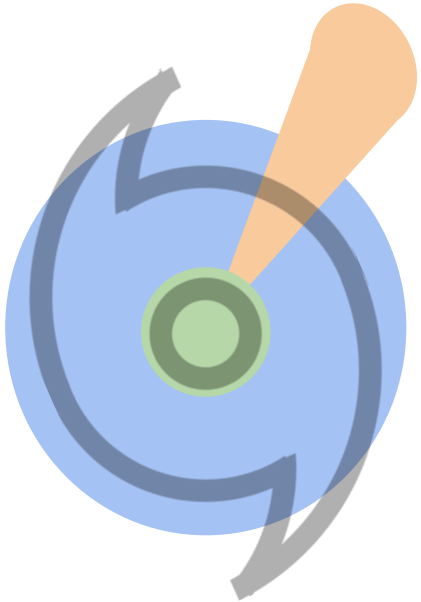
Weather Forecast: 0000 Thu Oct 17 2019 - 0600 Sun Oct 20 2019 UTC
Forecast Timestamp: 0406 Thu Oct 17 2019 PT
Flight Plan Comment: HOGAN (lowest value contingent "orange" flight)
near dawn landing - triggers TOL040
Saved: 2019-Oct-17 18:13 UTC User: kbower

11. summary

- ➔ [CII] is an important ISM tracer
- ➔ HE 1353-1917 is a unique AGN host galaxy with the global [CII] line excess
- ➔ Global [CII] line excess might be an indicator for massive multi-phase outflows in AGN
- ➔ My personal webpage: **http://SPIrina.gitlab.io/**

12. other plans





BPT morphology:

A new concept of shapes on the BPT diagram

Will help to calculate the star formation rate of AGN galaxies in a more precise way