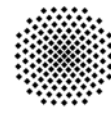
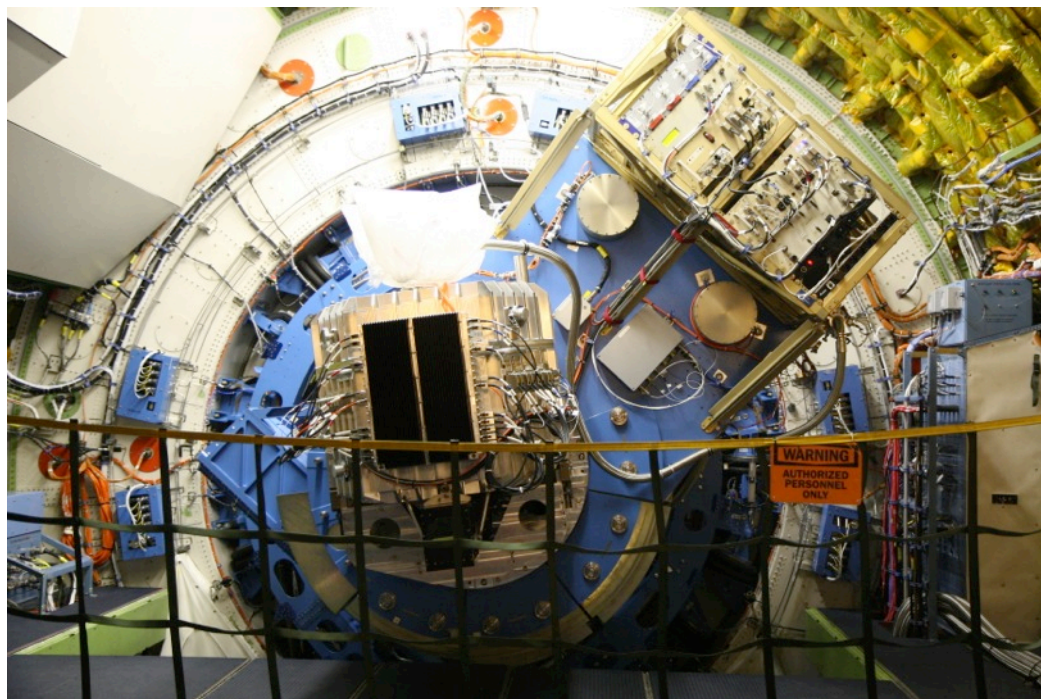




# FIFI-LS Commissioning



Gefördert durch:  
Bundesministerium  
für Wirtschaft  
und Technologie  
aufgrund eines Beschlusses  
des Deutschen Bundestages



March - April 2014



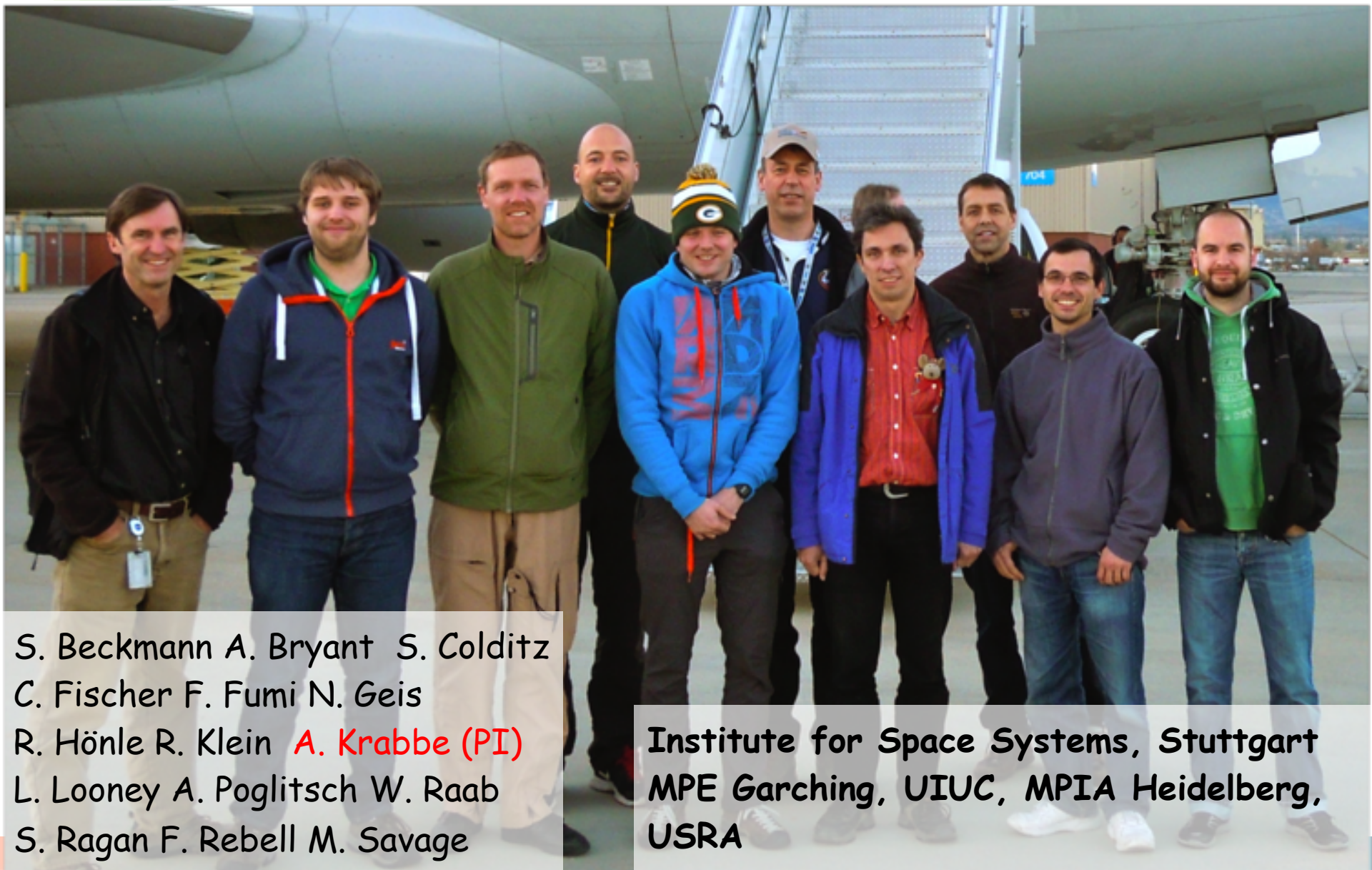
Dr. Randolf Klein  
FIFI-LS Instrument Scientist  
USRA



# The Team

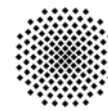


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und Technologie  
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des Deutschen Bundestages



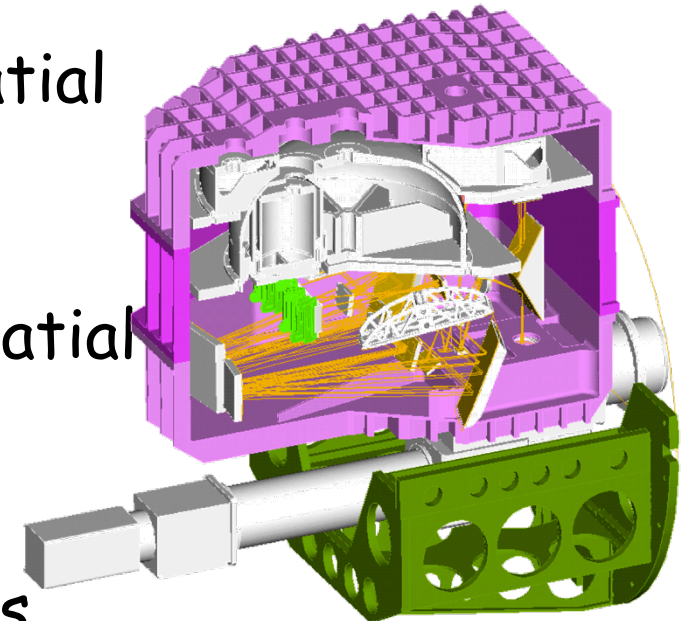
S. Beckmann A. Bryant S. Colditz  
C. Fischer F. Fumi N. Geis  
R. Hönle R. Klein **A. Krabbe (PI)**  
L. Looney A. Poglitsch W. Raab  
S. Ragan F. Rebell M. Savage

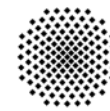
**Institute for Space Systems, Stuttgart**  
**MPE Garching, UIUC, MPIA Heidelberg,**  
**USRA**



# FIFI-LS: the Field-Imaging Far-Infrared Line Spectrometer

- Far-infrared spectrometer employing two parallel channels:
  - Blue 50-125  $\mu\text{m}$   
5x5 pixel field of view: 6" spatial pixel
  - Red 105-200  $\mu\text{m}$   
5x5 pixel field of view: 12" spatial pixel
- Imaging spectrometer concept
  - Each channel: 5x5 spatial pixels
  - 16 spectral pixels per spatial pixels
- Spectral resolution:  $R=1000-2000$

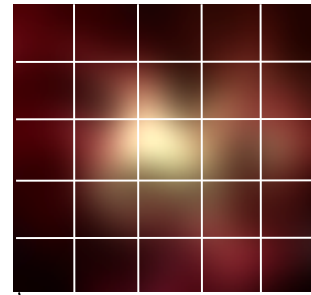




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# Integral Field Concept

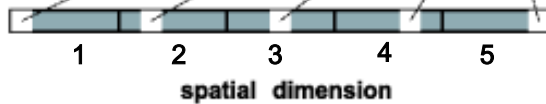
2D field of view  
becomes 1D slit



Footprint of Red and  
Blue channels are  
concentric

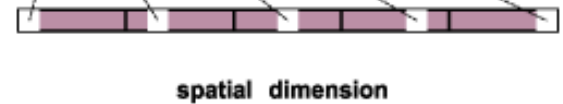
5 x 5 pixels

spectrograph  
slit



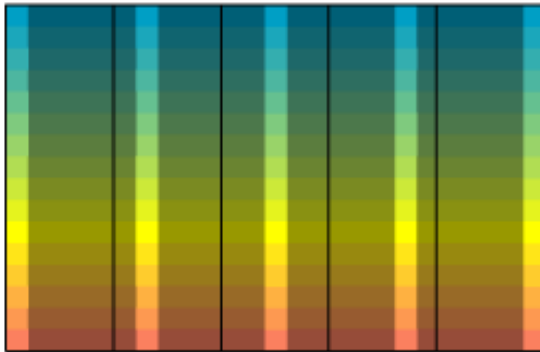
spatial dimension

spectrograph  
slit



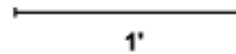
spatial dimension

spectral dimension



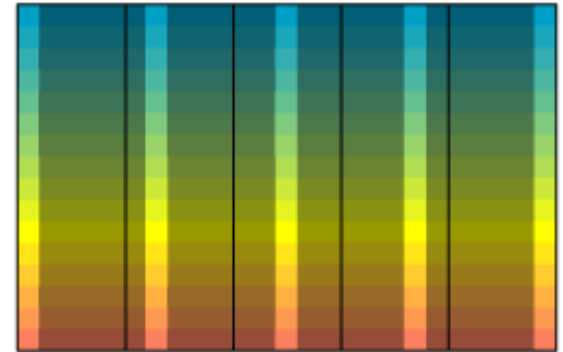
16 x 25 pixel detector array

12" x 12" (110-210 $\mu$ m) 6" x 6" (42-110 $\mu$ m)



focal plane

spectral dimension



16 x 25 pixel detector array

2D detector contains 3D data cube



## Science Case

Mapping of **FIR fine structure lines** in galactic and extra galactic sources.

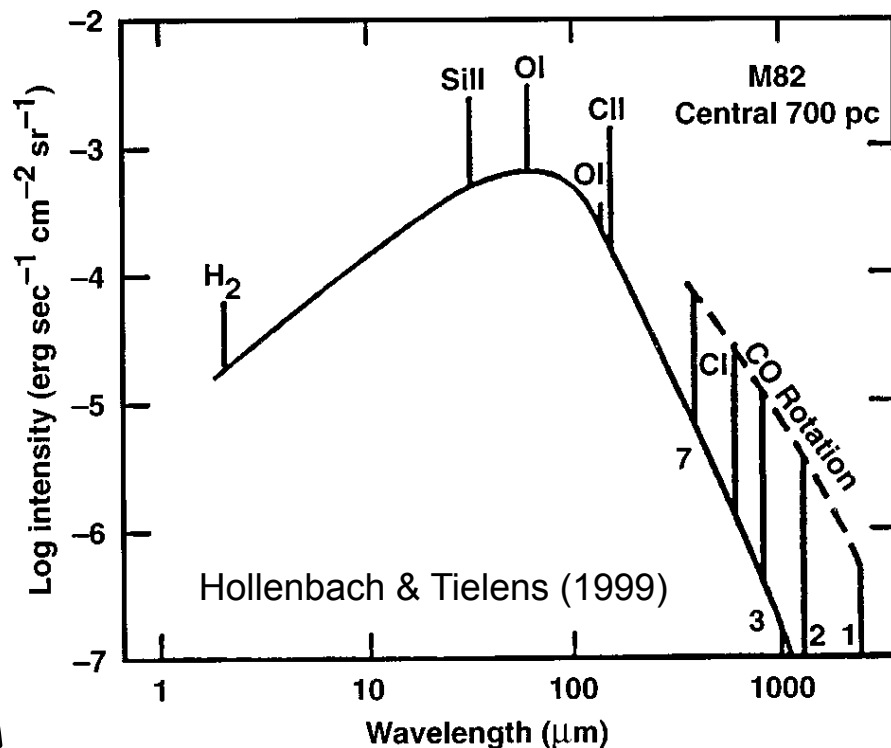
Main cooling lines of the interstellar gas in the FIFI-LS range:

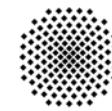
- [CII] 158 $\mu\text{m}$
- [OI] 63.18 $\mu\text{m}$ , 145.4 $\mu\text{m}$

In ionized regions:

- [OIII] 51.81 $\mu\text{m}$ , 88.36 $\mu\text{m}$

But also high-J CO lines, OH-lines etc.



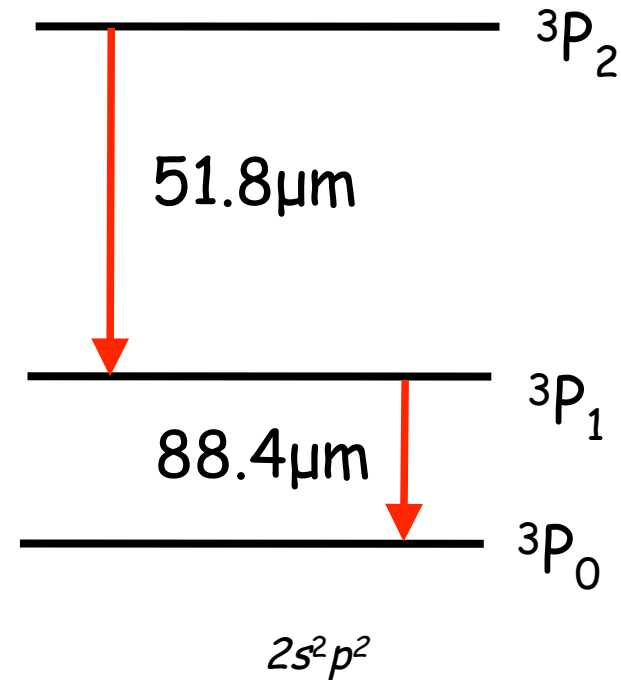


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## Fine Structure Lines

Among the brightest lines  
in the FIFI-LS range

Forbidden transitions  
between the collisionally  
excited levels within the  
ground state.



Fine-structure levels in  
the ground state of  $O^{2+}$



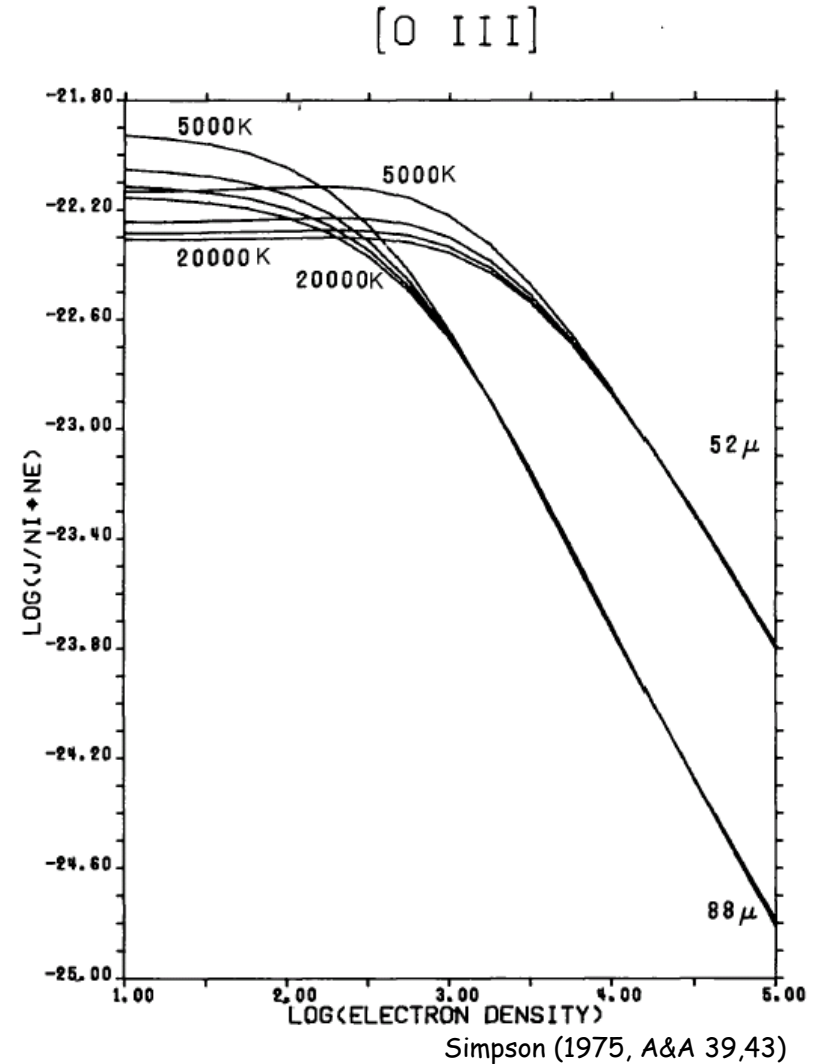
# Fine Structure Lines

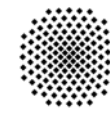
Among the brightest lines  
in the FIFI-LS range

Forbidden transitions  
between the collisionally  
excited levels within the  
ground state.

## Diagnostic lines/ratios:

- Density indicator for dense gas
- Thermometer for diffuse gas





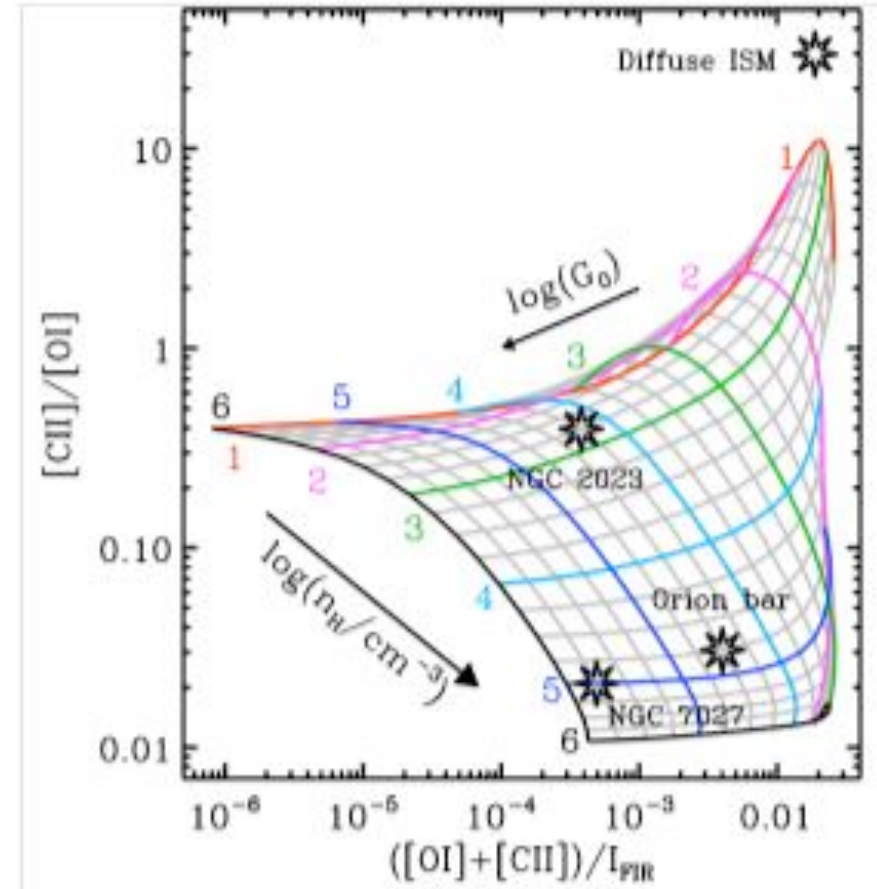
# Fine Structure Lines

Among the brightest lines in the FIFI-LS range

Forbidden transitions between the collisionally excited levels within the ground state.

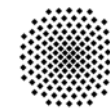
## Diagnostic lines/ratios:

- Density indicator for dense gas
- Thermometer for diffuse gas
- Radiation field
- Abundances



Kaufman et al. 1999





## Commissioning Flights

March 4 -13:

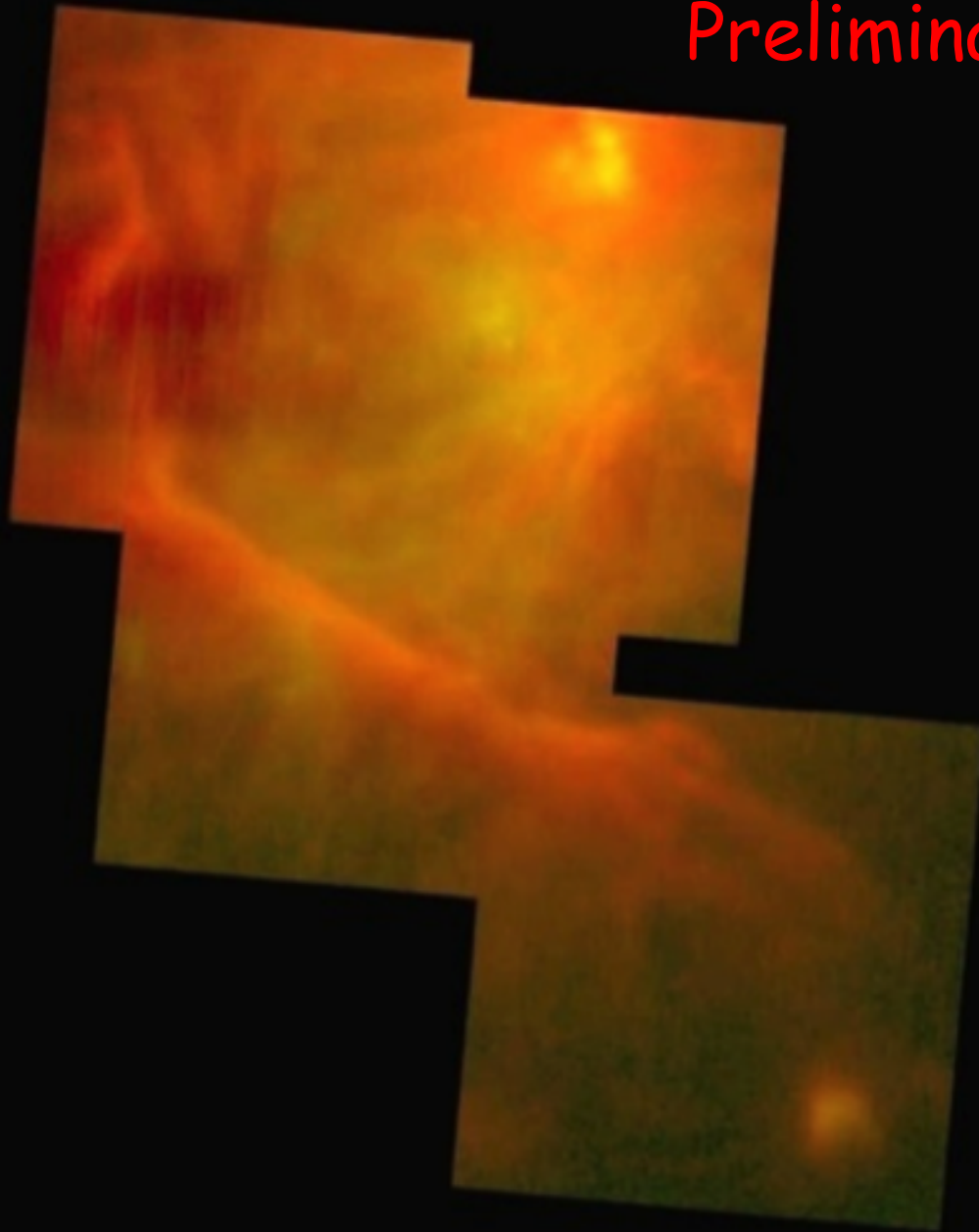
- 1<sup>st</sup> installation of FIFI-LS in SOFIA
- 2 nights of Line Ops (testing from the ground)
- 3 flights: commissioning

Data analysis and resulting bug fixes

April 14-26:

- 2<sup>nd</sup> Installation
- 1 night of Line Ops
- 5 flights: commissioning and science

# Preliminary Results: M42



mid-infrared (SOFIA)

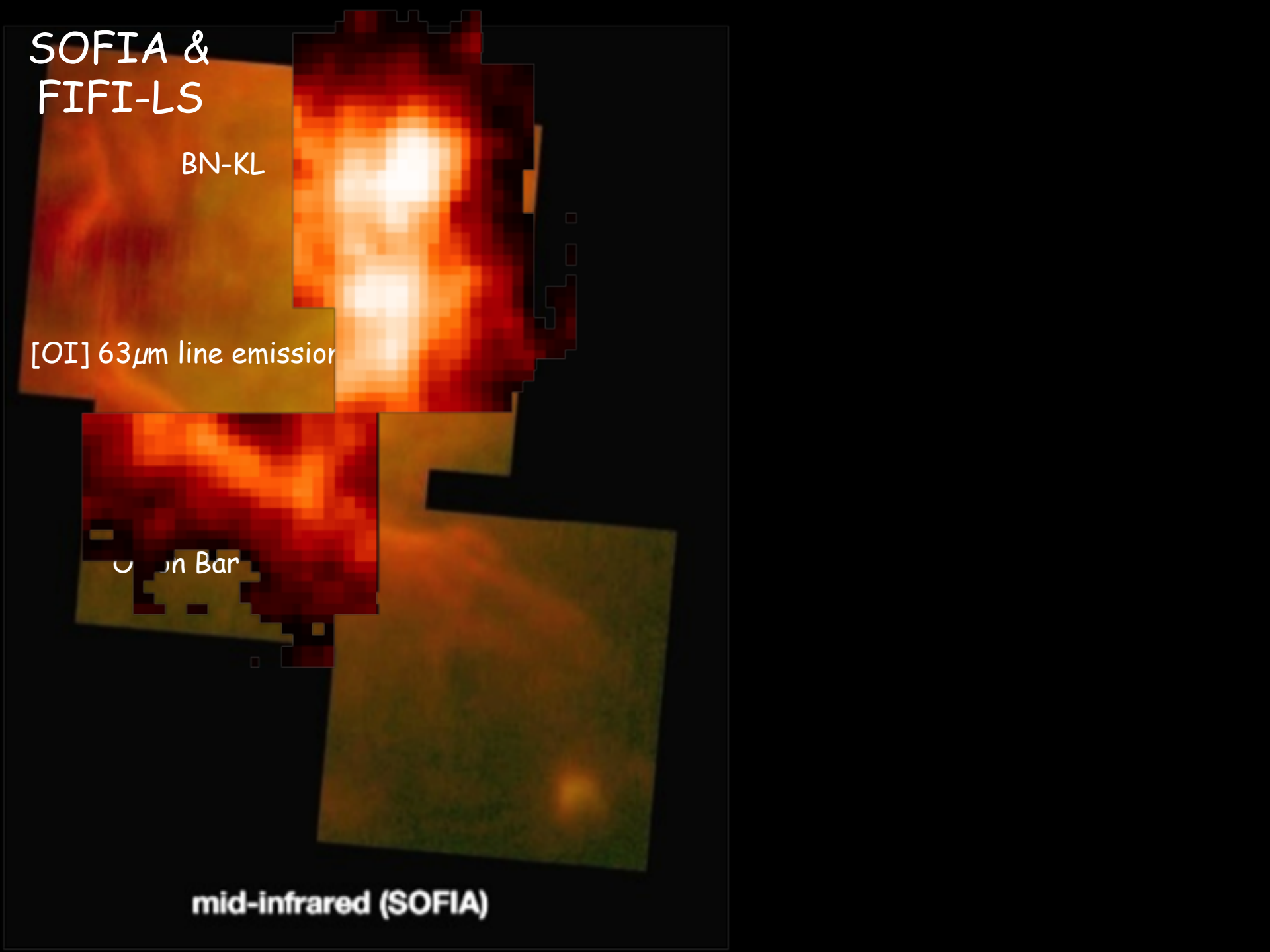
# SOFIA & FIFI-LS

BN-KL

[OI] 63 $\mu$ m line emission

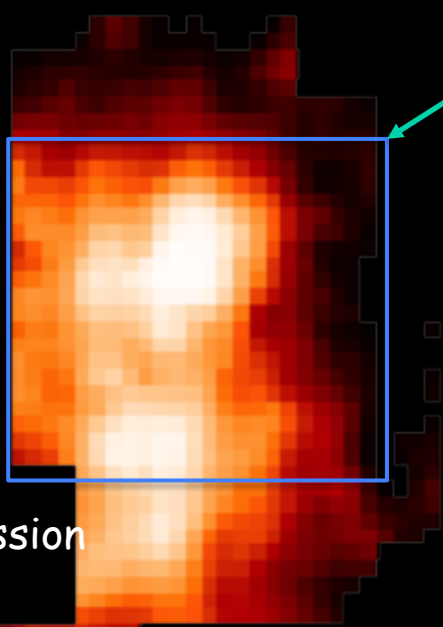
Union Bar

mid-infrared (SOFIA)



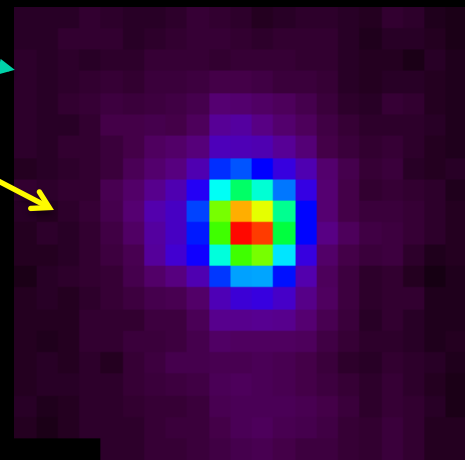
# SOFIA & FIFI-LS

BN-KL

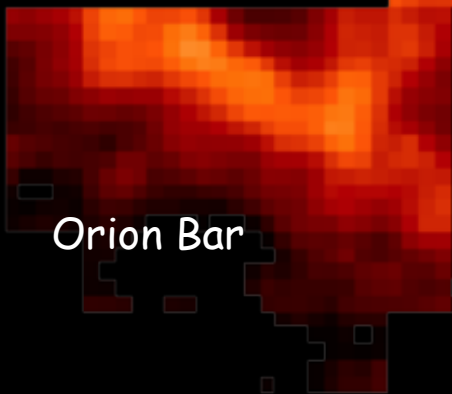


BN-KL Position

Continuum@ 63  $\mu\text{m}$



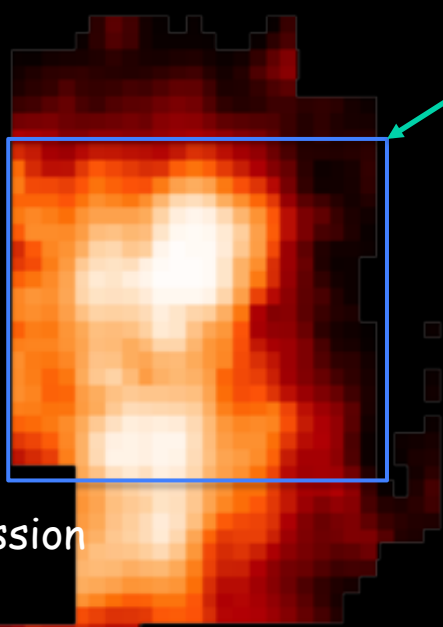
[OI] 63  $\mu\text{m}$  line emission



Orion Bar

# SOFIA & FIFI-LS

BN-KL



BN-KL Position

Continuum@ 63  $\mu\text{m}$

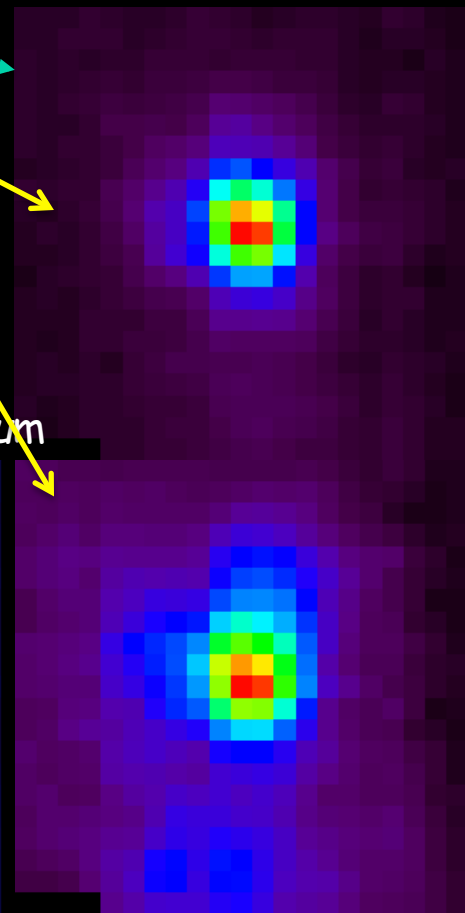
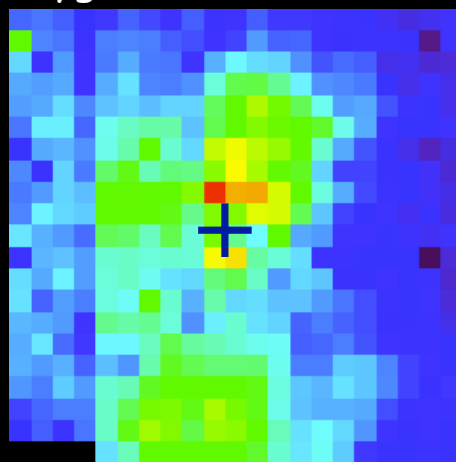
Continuum and oxygen emission @ 63  $\mu\text{m}$

Oxygen emission @ 63  $\mu\text{m}$

[OI] 63  $\mu\text{m}$  line emission

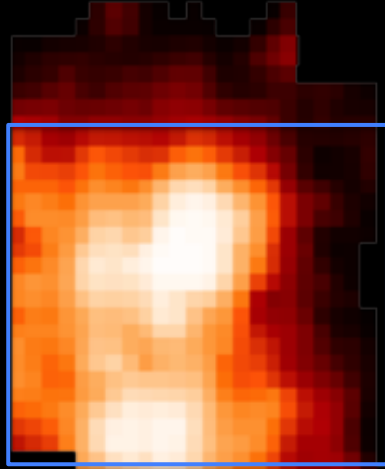


Orion Bar



# SOFIA & FIFI-LS

BN-KL

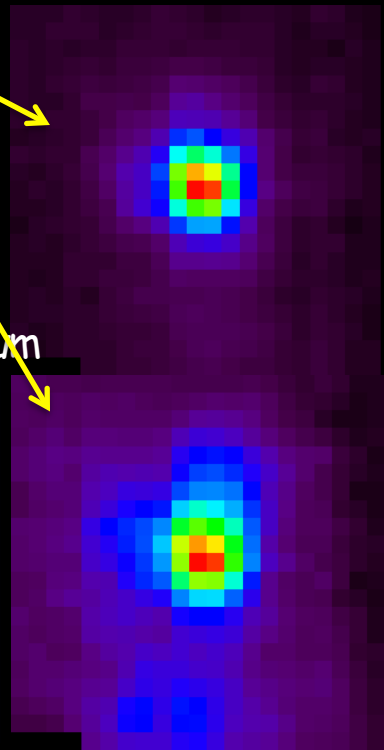


BN-KL Position

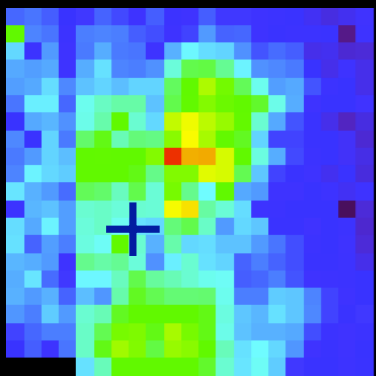
Continuum@ 63  $\mu\text{m}$

Continuum and oxygen emission @ 63  $\mu\text{m}$

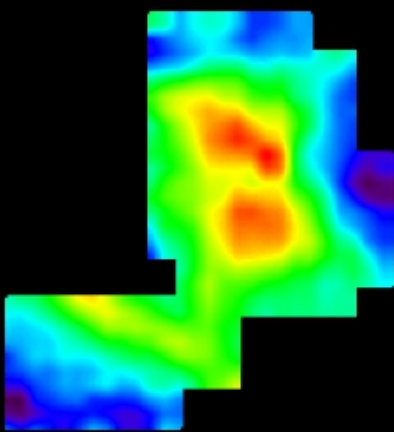
Oxygen emission @ 63  $\mu\text{m}$



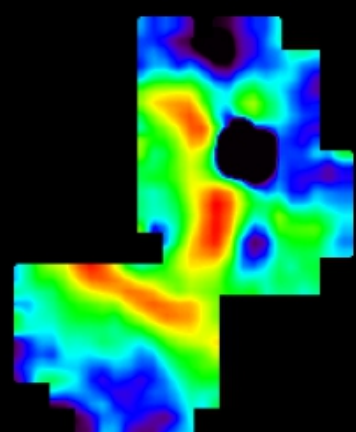
[OI] 63  $\mu\text{m}$  line emission



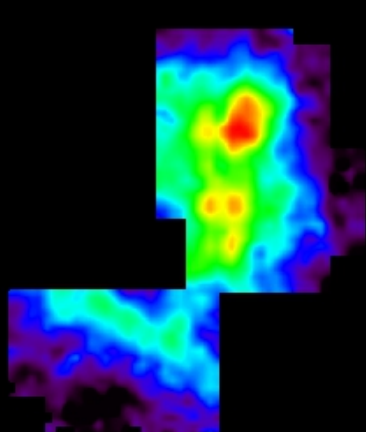
Orion Bar



[CII] @ 157  $\mu\text{m}$



[OI] @ 145  $\mu\text{m}$

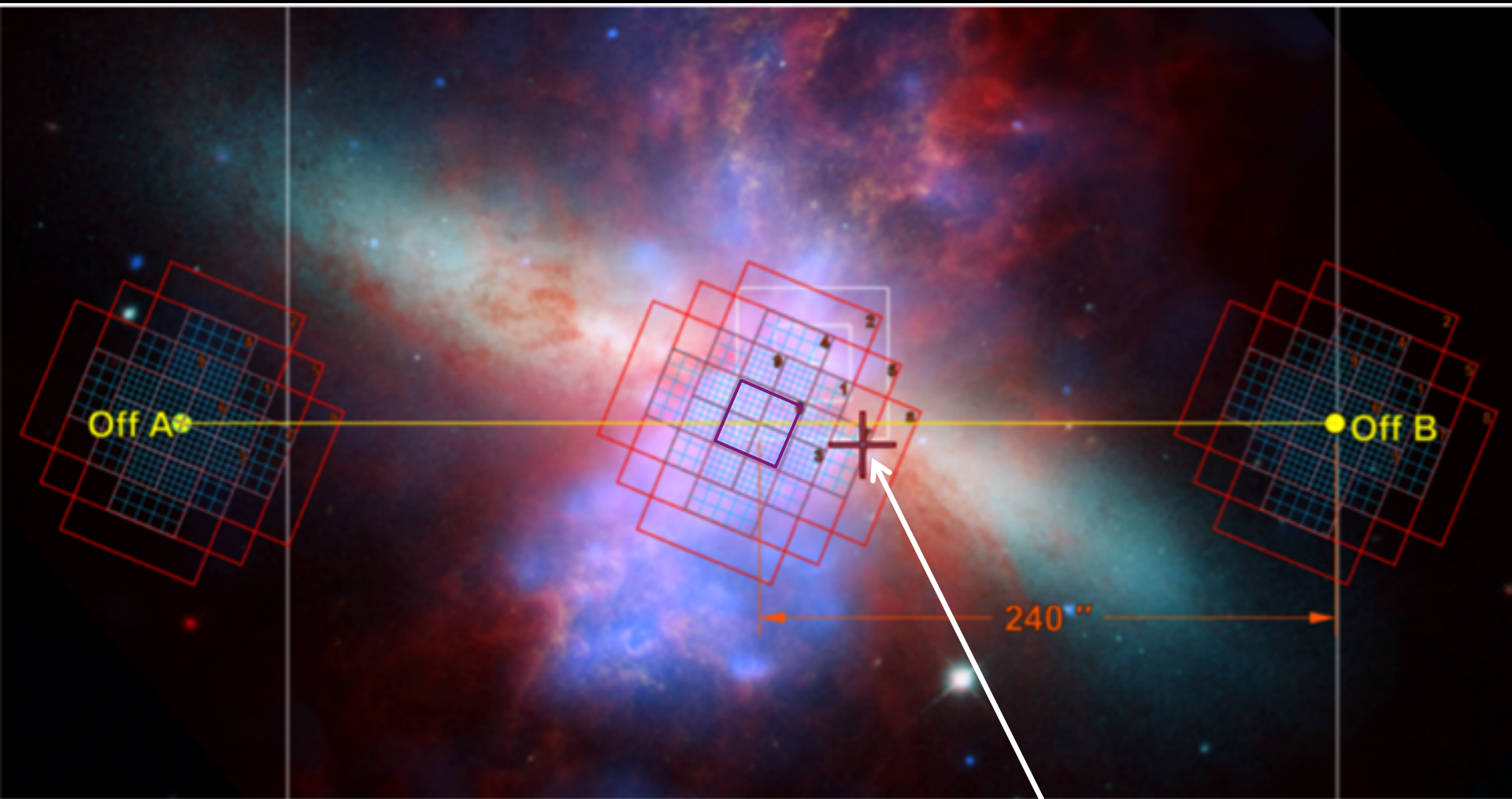


[OI] @ 63  $\mu\text{m}$

SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Oxygen

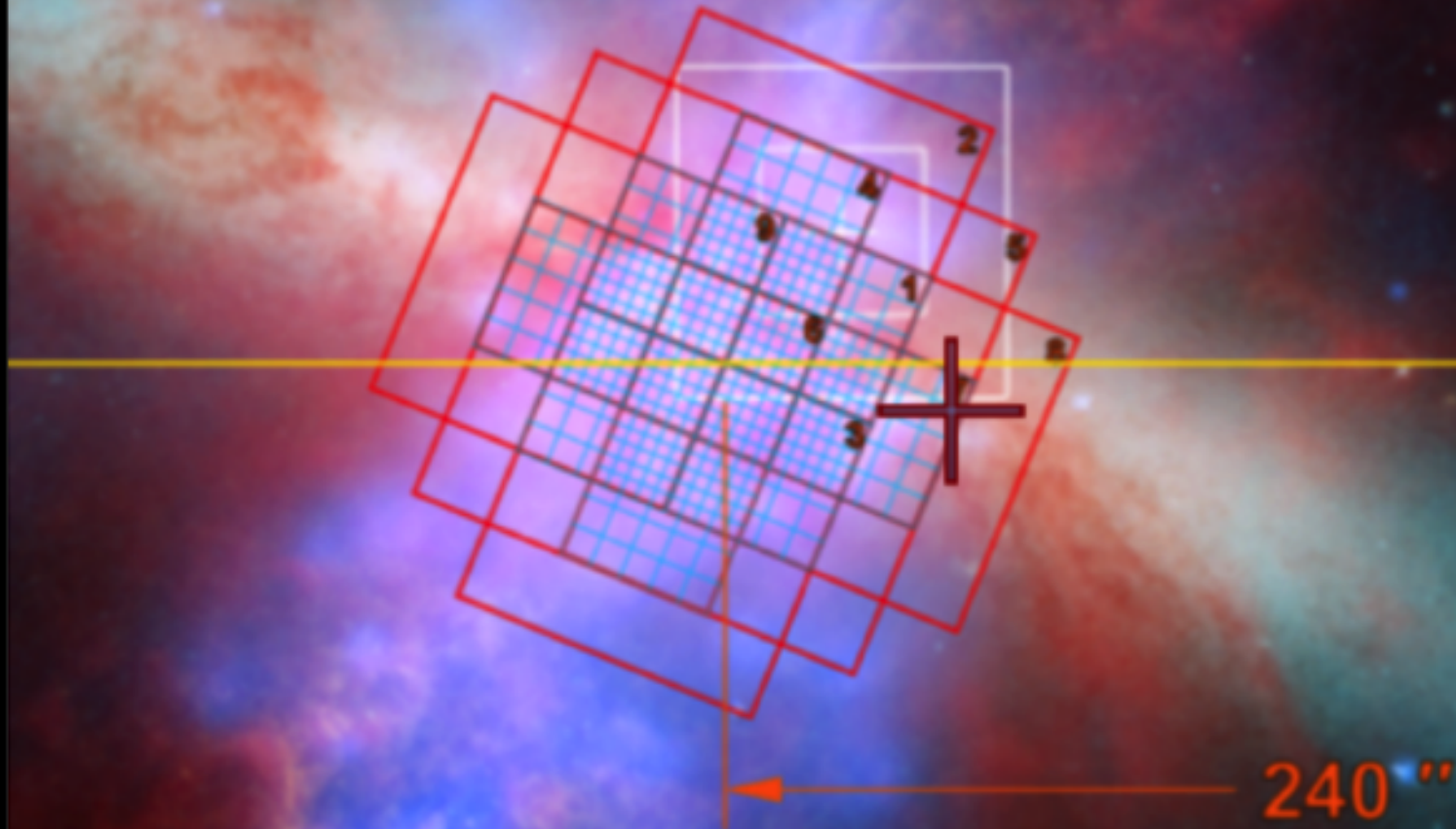


Location of SN, but a detection  
was not to be expected.

SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Carbon



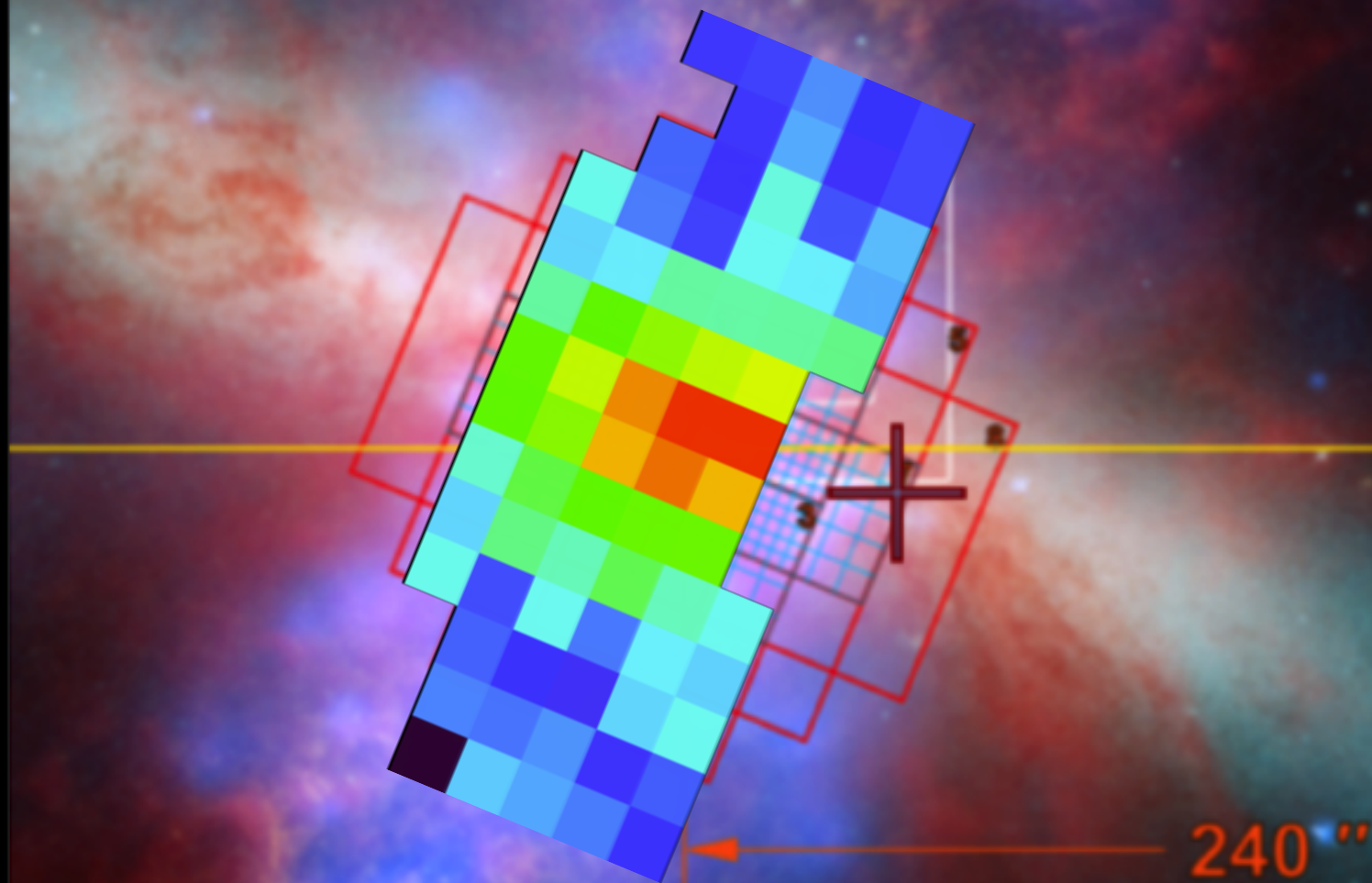
Background image: HST, Spitzer & Chandra



SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Carbon



Ionized Carbon @ 157  $\mu\text{m}$

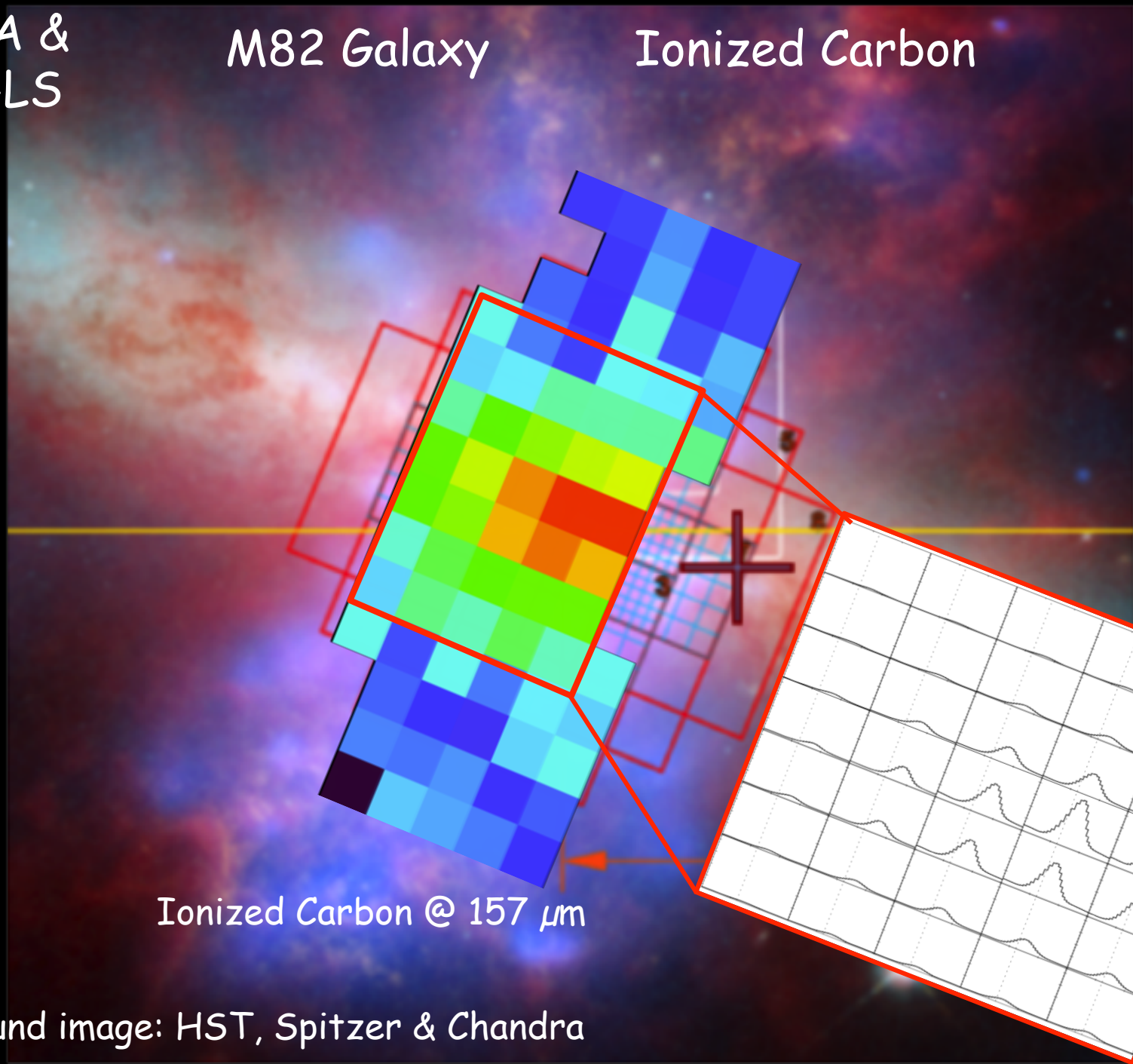
240''

Background image: HST, Spitzer & Chandra

SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Carbon



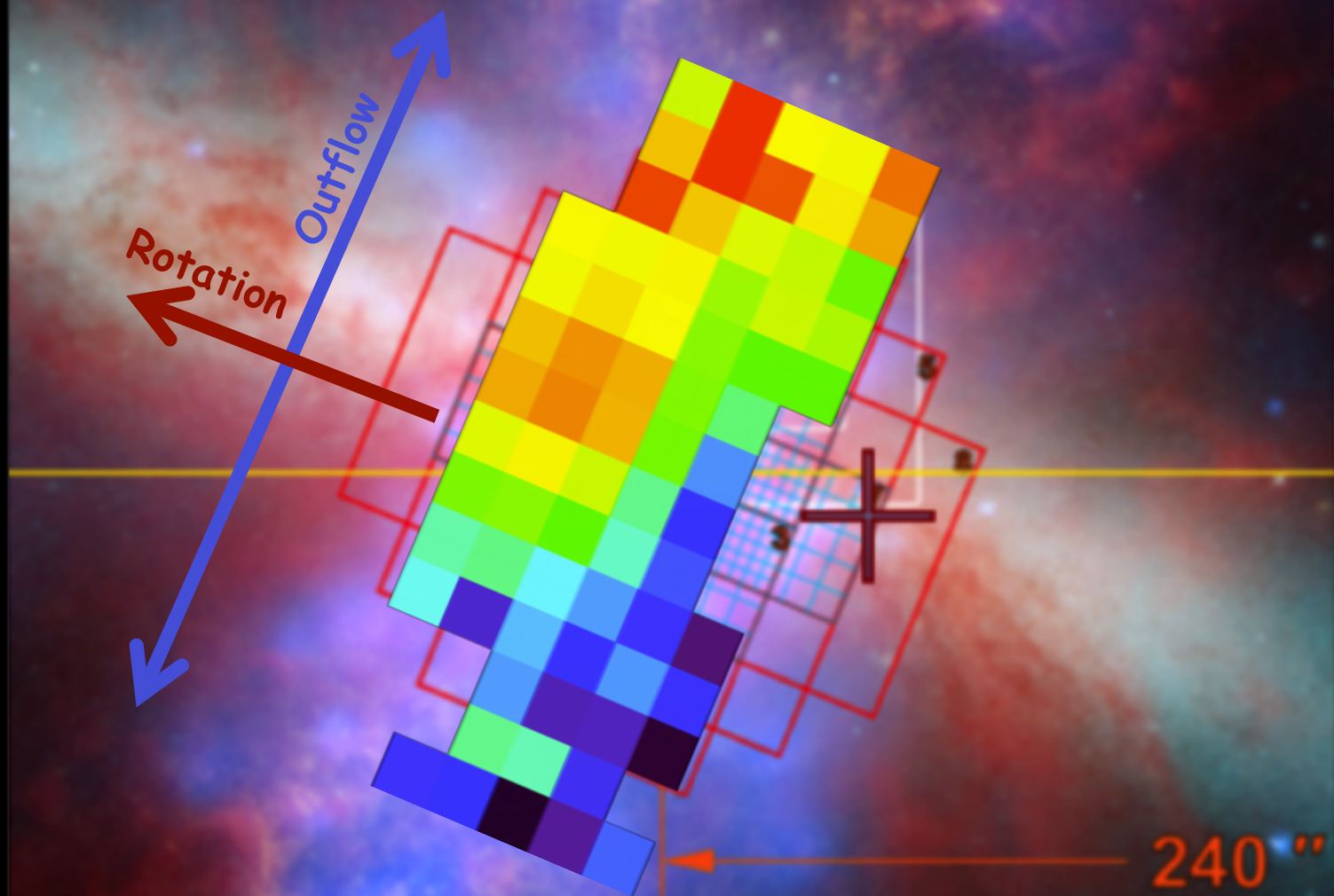
Ionized Carbon @ 157  $\mu\text{m}$

Background image: HST, Spitzer & Chandra

SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Carbon



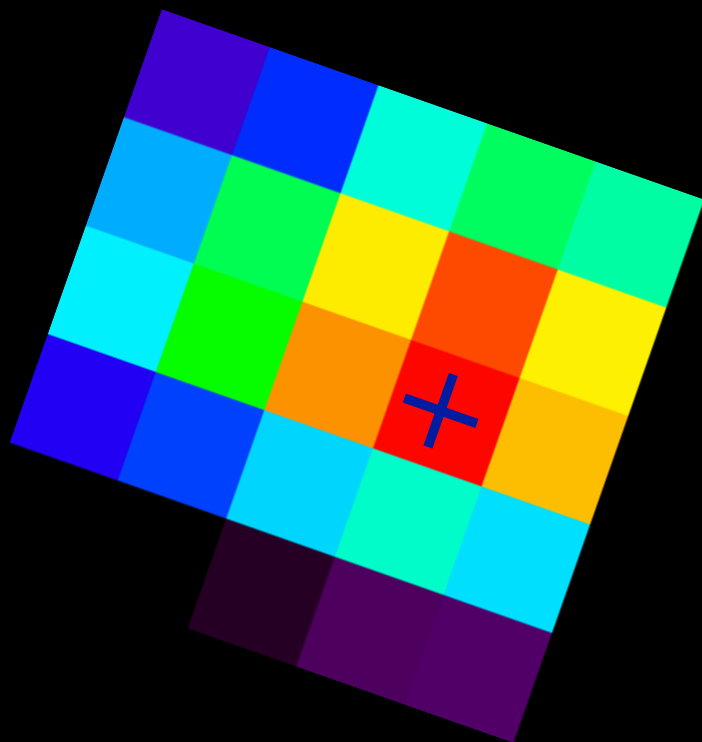
Velocity of ionized Carbon @ 157  $\mu\text{m}$   
from -130 km/s to +130 km/s

Background image: HST, Spitzer & Chandra

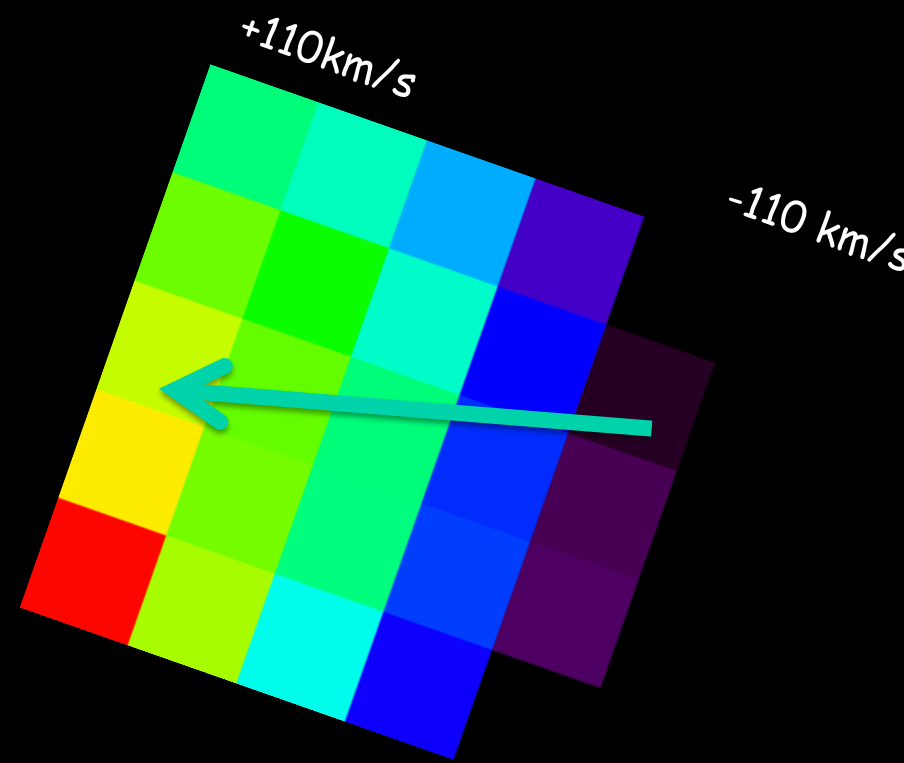
SOFIA &  
FIFI-LS

M82 Galaxy

Ionized Oxygen

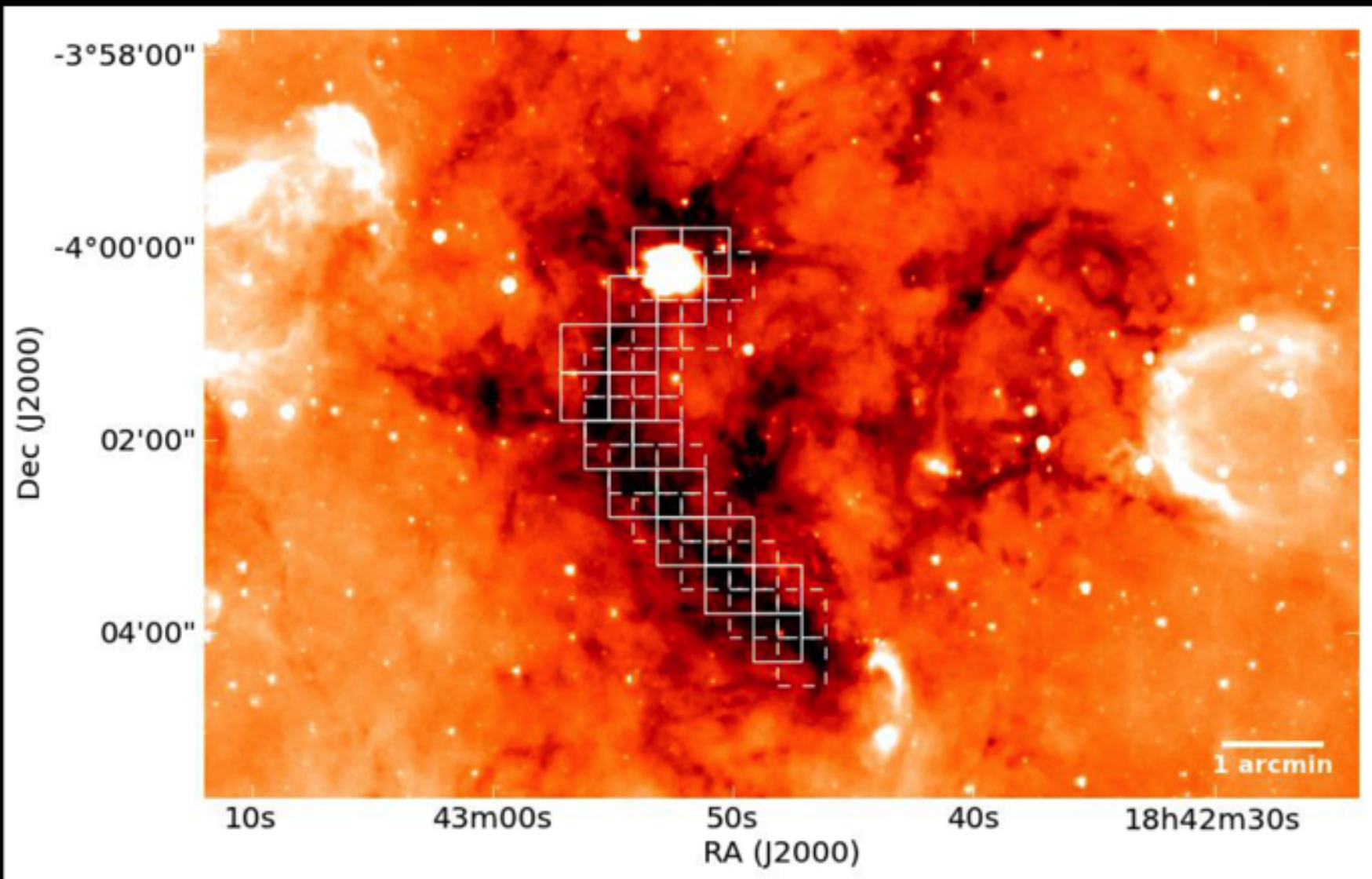


[OIII] 52 $\mu$ m line emission

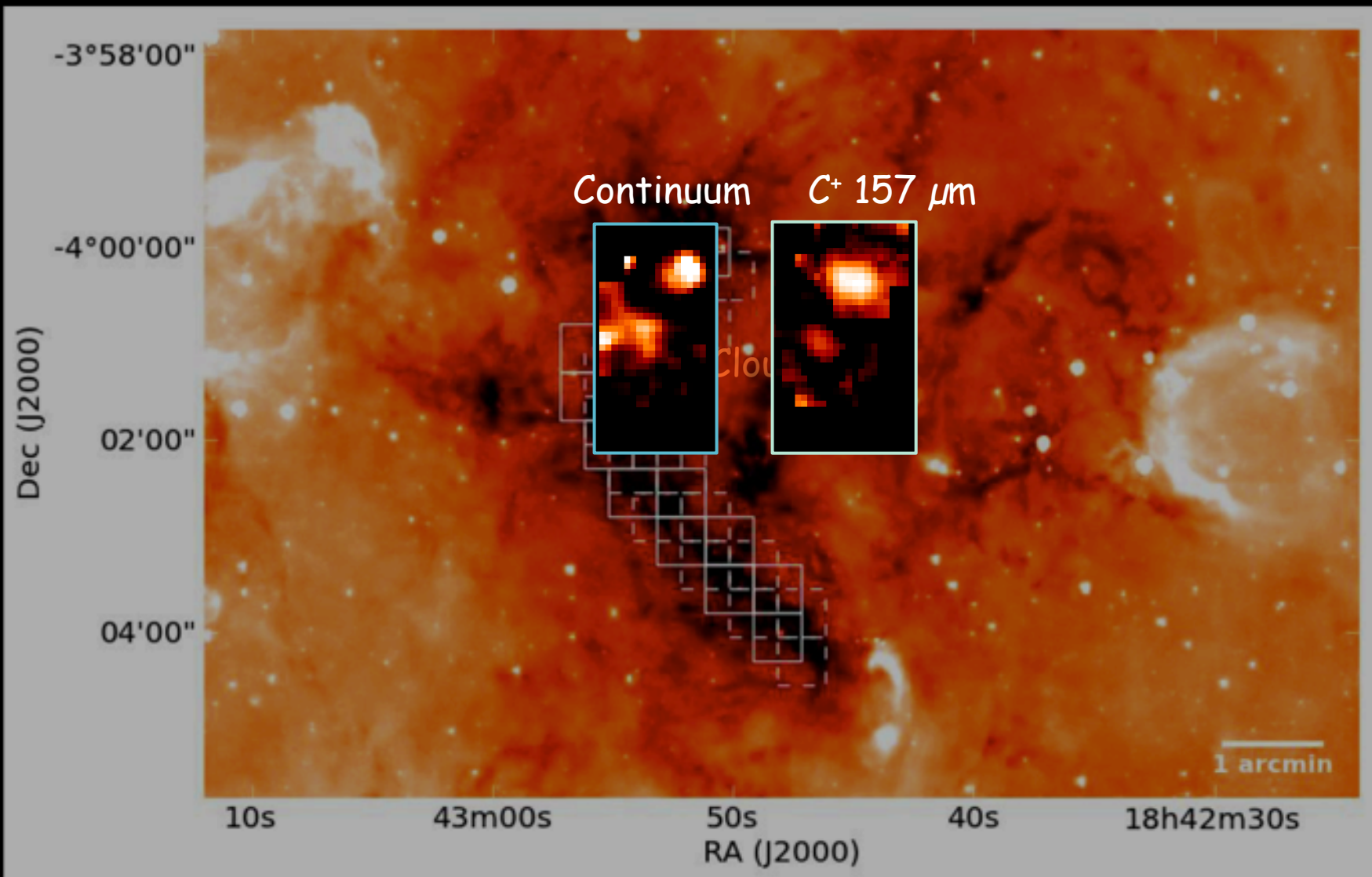


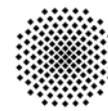
[OIII] 52 $\mu$ m rotation speed

# Dark Cloud G28.34



# Dark Cloud G28.34





## Cycle 3

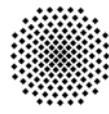
FIFI-LS is offered as PI-instrument, but can be proposed for like a facility instrument, i.e.

- No need to contact the instrument team.
- Fully supported in proposal tools with AOTs/AORs.

but

- Data reduction by FIFI-LS team, co-authors publications.





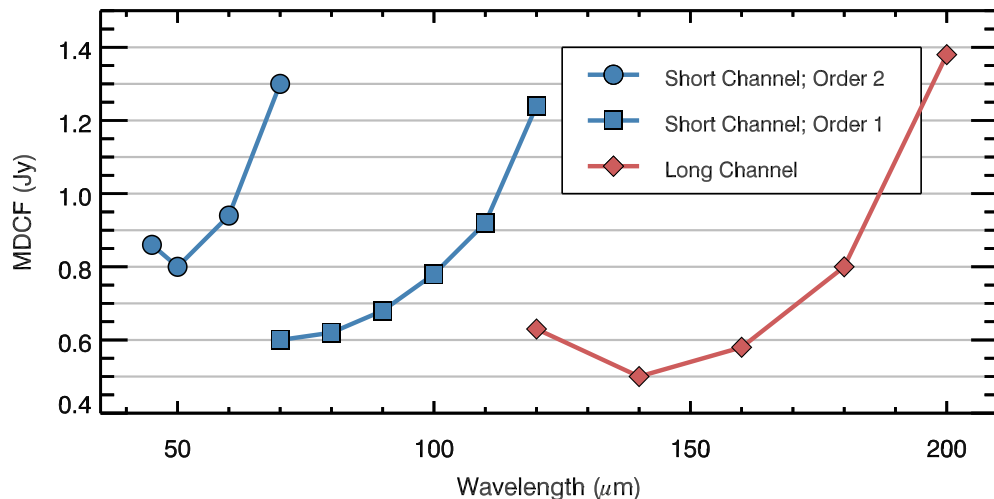
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des Deutschen Bundestages

# Performance

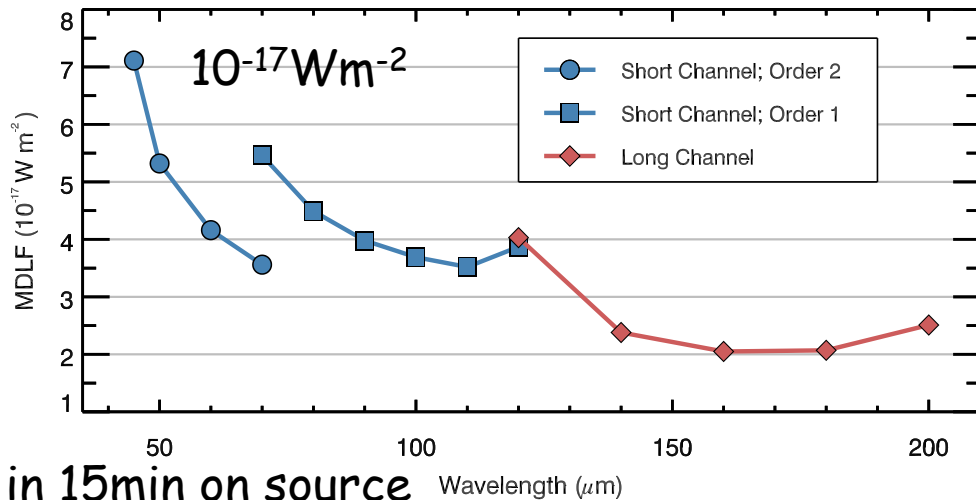
The commissioning data is still being analyzed to update the pre-commissioning values.

The main calibration uncertainty is the atmospheric absorption.

Minimum Detectable Continuum Flux



Minimum Detectable Line Flux



4 $\sigma$  in 15min on source





## FIFI-LS and PACS

FIFI-LS and the PACS spectrometer (was on Herschel) are sister instruments sharing many design features.

- Same detector, same IFU
- Similar optical layout

Herschel's cold telescope in space allowed highly sensitive observations

BUT

FIFI-LS

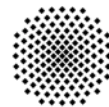
- Two gratings
- 6" and 12" pixels
- Fast mapping of two lines

PACS-S

- One grating
- 9.7" pixels
- Single line, slower telescope



## Summary



### FIFI-LS

- is SOFIA's FIR (50-200 $\mu$ m) imaging spectrometer.
- allows to efficiently map two spectral lines simultaneously.
- probes the state of the ISM with FIR lines.
- successfully completed its first two commissioning/science flight series.
- is offered in the Cycle 3 Call for Proposals.

<http://www.sofia.usra.edu>

**Come to the SOFIA booth!**

**Write some proposals!**