

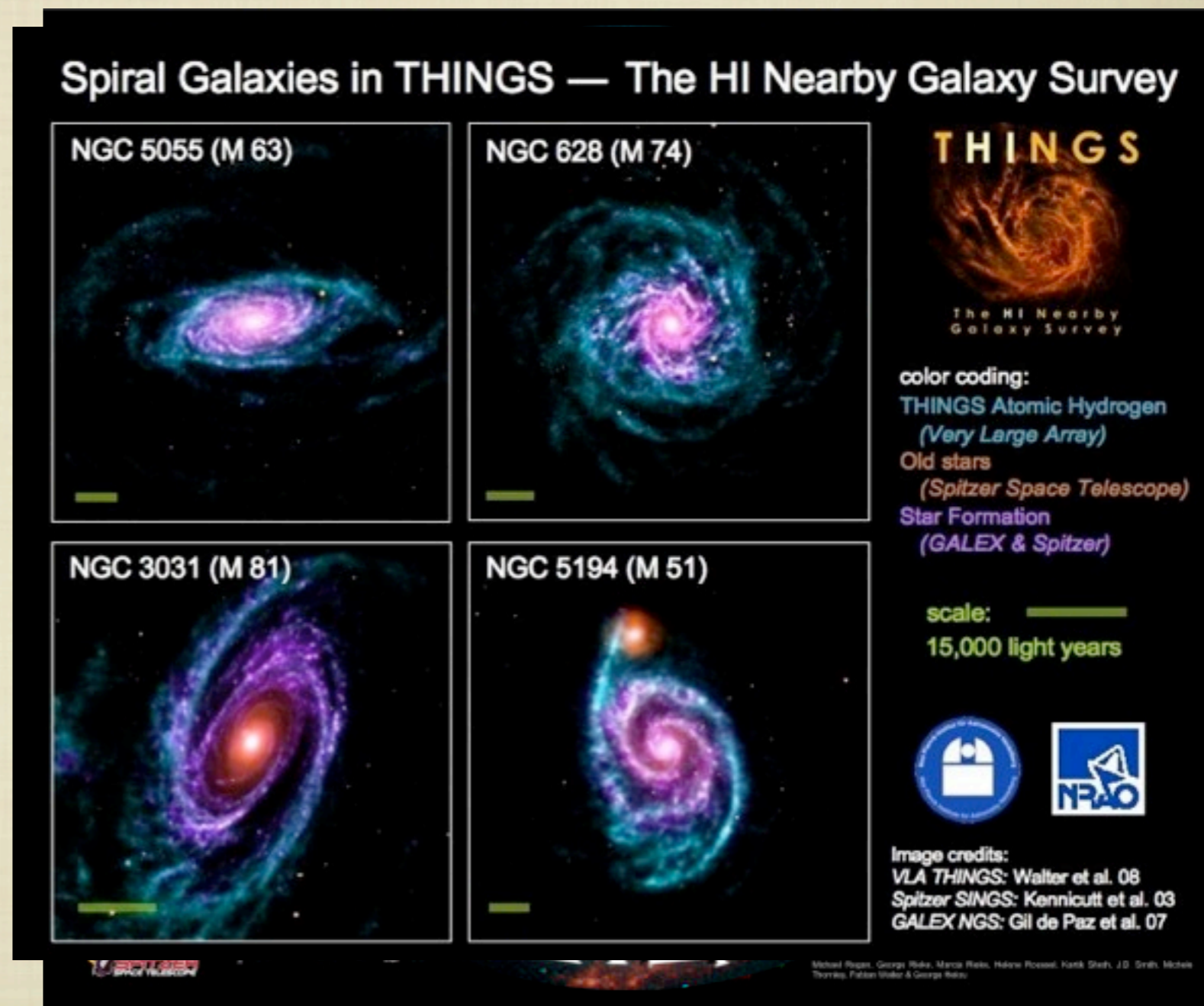
KINGFISH
SPECTROSCOPY

THE COOLING OF GAS IN GALAXIES

JD SMITH AND THE KINGFISH TEAM

WHAT?

- SURVEY OF 61 BROADLY SELECTED NEARBY GALAXIES TO ~30MPC
- PACS+SPIRE IMAGING
- PACS SPECTRO-IMAGING IN 5 KEY EMISSION LINES
- INCREDIBLY BROAD RESOLVED MULTI-WAVELENGTH COVERAGE



WHO?

- PHIL APPLETON
- LEE ARMUS
- **PEDRO BEIRÃO**
- ALBERTO BOLATTO
- BERNHARD BRANDL
- DANIELA CALZETTI
- ALISON CROCKER
- **KEVIN CROXALL**
- DANNY DALE
- BRUCE DRAINE
- CHAD ENGELBRACHT
- ARMANDO GIL DE PAZ
- KARL GORDON
- DAVID GREEN
- BRENT GROVES
- CAINA HAO
- GEORGE HELOU
- JOANNAH HINZ

- LESLIE HUNT
- BEN JOHNSON
- **ROB KENNICUTT**
- JIN KODA
- OLIVER KRAUSE
- ADAM LEROY
- ERIC MURPHY
- HANS WALTER RIX
- HELENE ROUSSEL
- MARK SAUVAGE
- EVA SCHINNERER
- J.D. SMITH
- LAURENT VIGROUX
- FABIAN WALTER
- BRAD WARREN
- CHRISTINE WILSON
- MARK WOLFIRE



- | | |
|----------|-----------|
| ■ UK | ■ SPAIN |
| ■ USA | ■ ITALY |
| ■ FRANCE | ■ GERMANY |
| ■ CANADA | ■ CHINA |

KINGFISH SCIENCE

■ **KEY SCIENCE:**

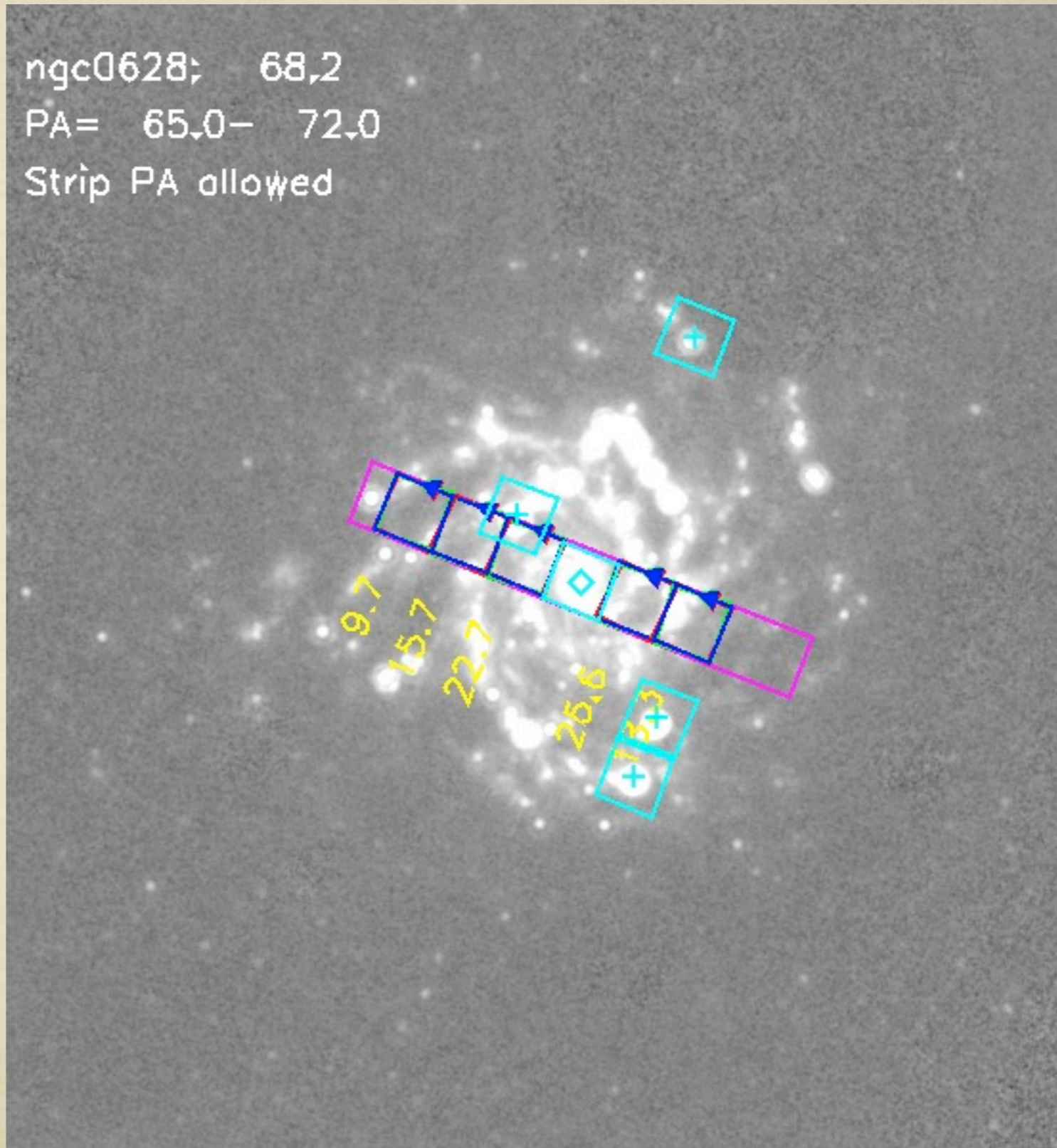
- **STAR-FORMATION RATE TRACERS**
- **STAR-FORMATION (SCHMIDT) LAW(S)**
- **GAS+DUST: COUPLED ENERGY BUDGET OF HEATING AND COOLING (SF & WEAK AGN)**
- **ISM CONDITIONS, RADIO/IR CORRELATION**
- **(TEMPERATURE INSENSITIVE) ABUNDANCES**
- **DUST MASS BUDGET (COLD DUST DISTRIBUTION?)**
- **RESOLVING OUT THE RADIO-IR CORRELATION**

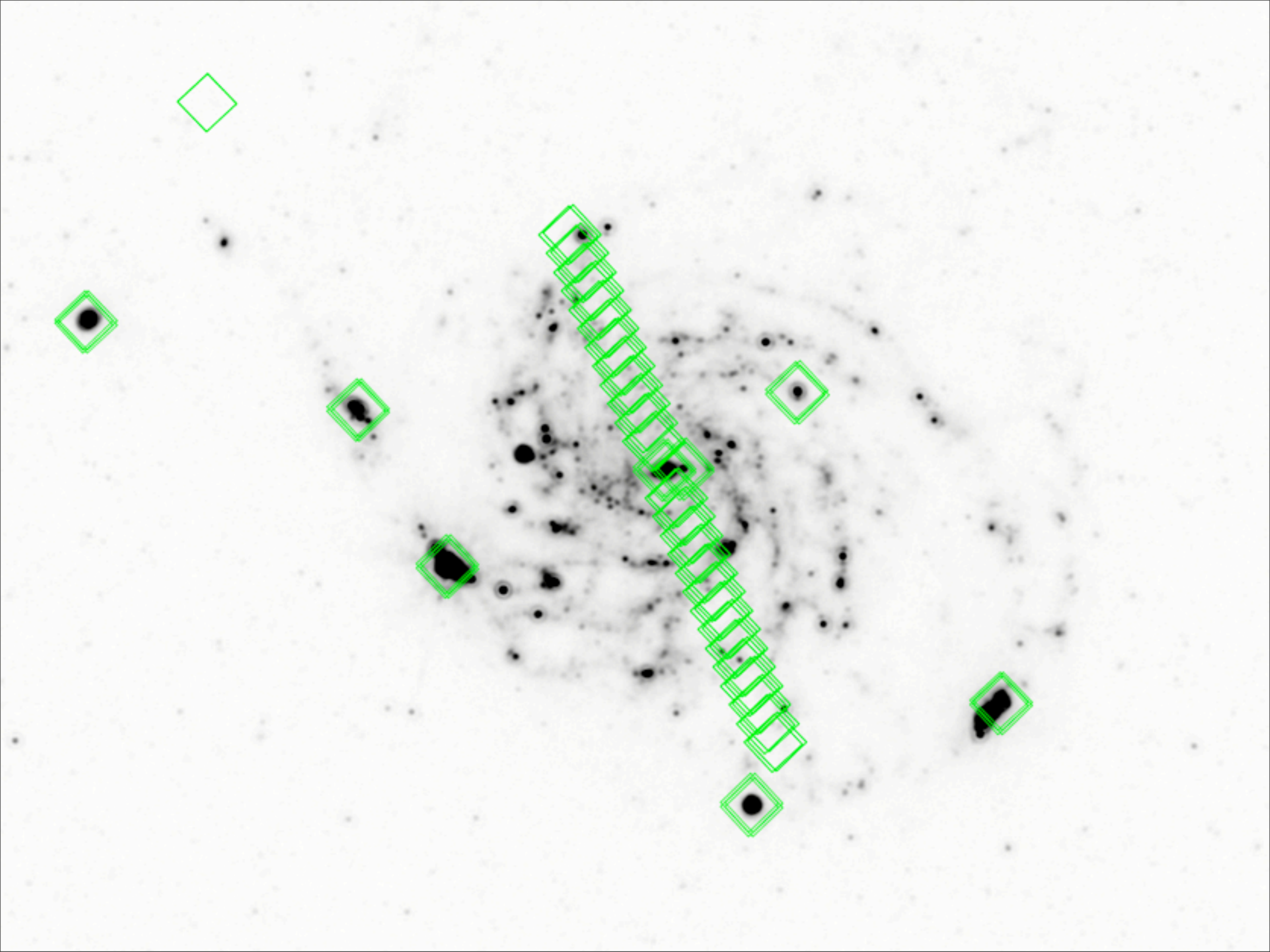
KINGFISH SO FAR

- SDP OBSERVATIONS: OF 2 GALAXIES — DEC, JAN 2009.
- TALK THIS MORNING BY D. CALZETTI
- 3 A&A SPECIAL ISSUE PAPERS:
 - **ENGELBRACHT ET AL.: SPIRE ON 13 GALAXIES**
 - **SANDSTROM ET AL.: PACS IMAGING OF NGC 1097**
 - **BEIRÃO ET AL., 2010: PACS SPECTRO-IMAGING OF NGC 1097**

KINGFISH COVERAGE

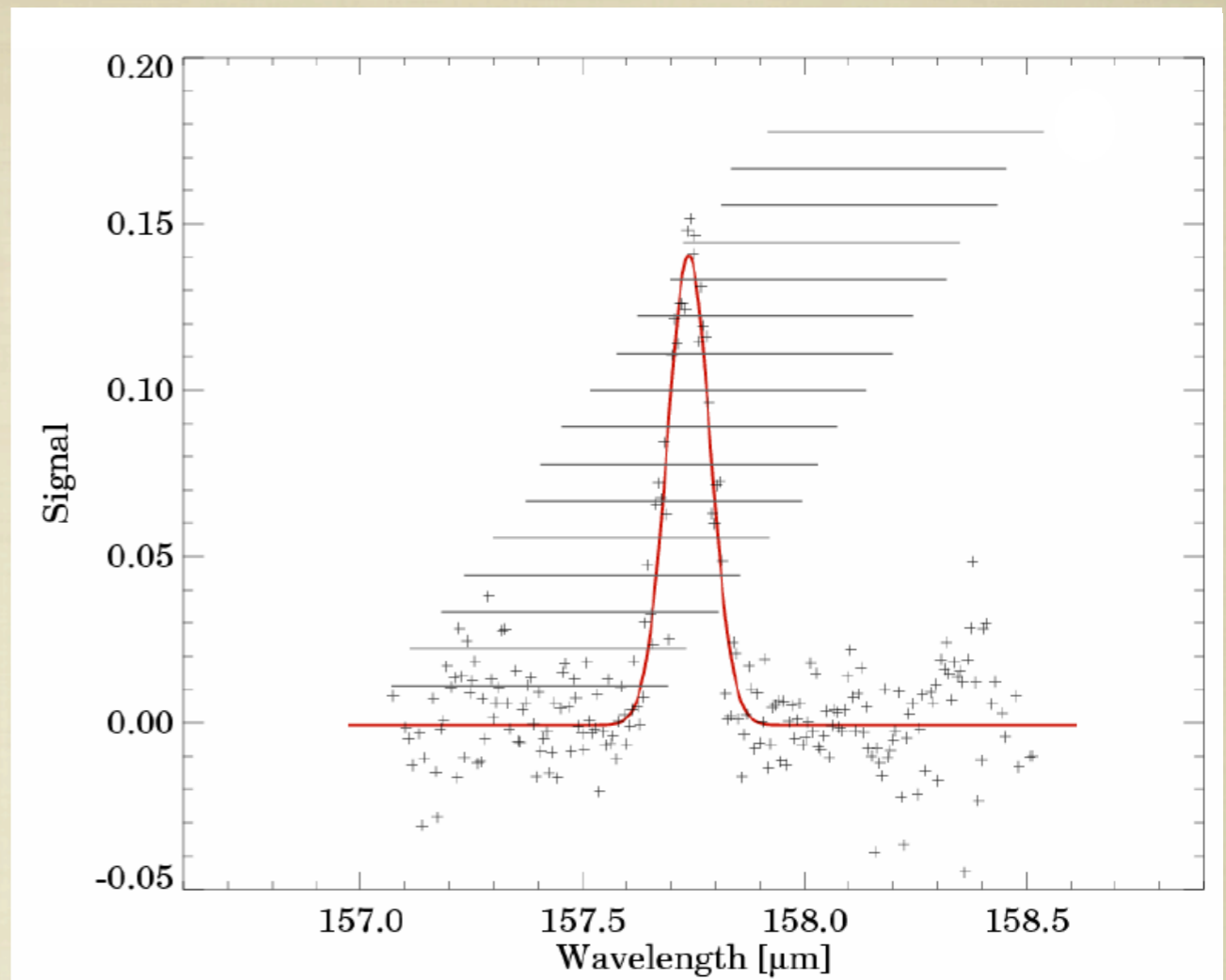
- **~50" : PACS IFU FOV**
- **ALL NUCLEI**
- **RADIAL STRIPS, MATCHED TO SINGS IRS 15–40 μ m SPECTRAL MAPS**
- **~45 EXTRANUCLEAR POSITIONS**



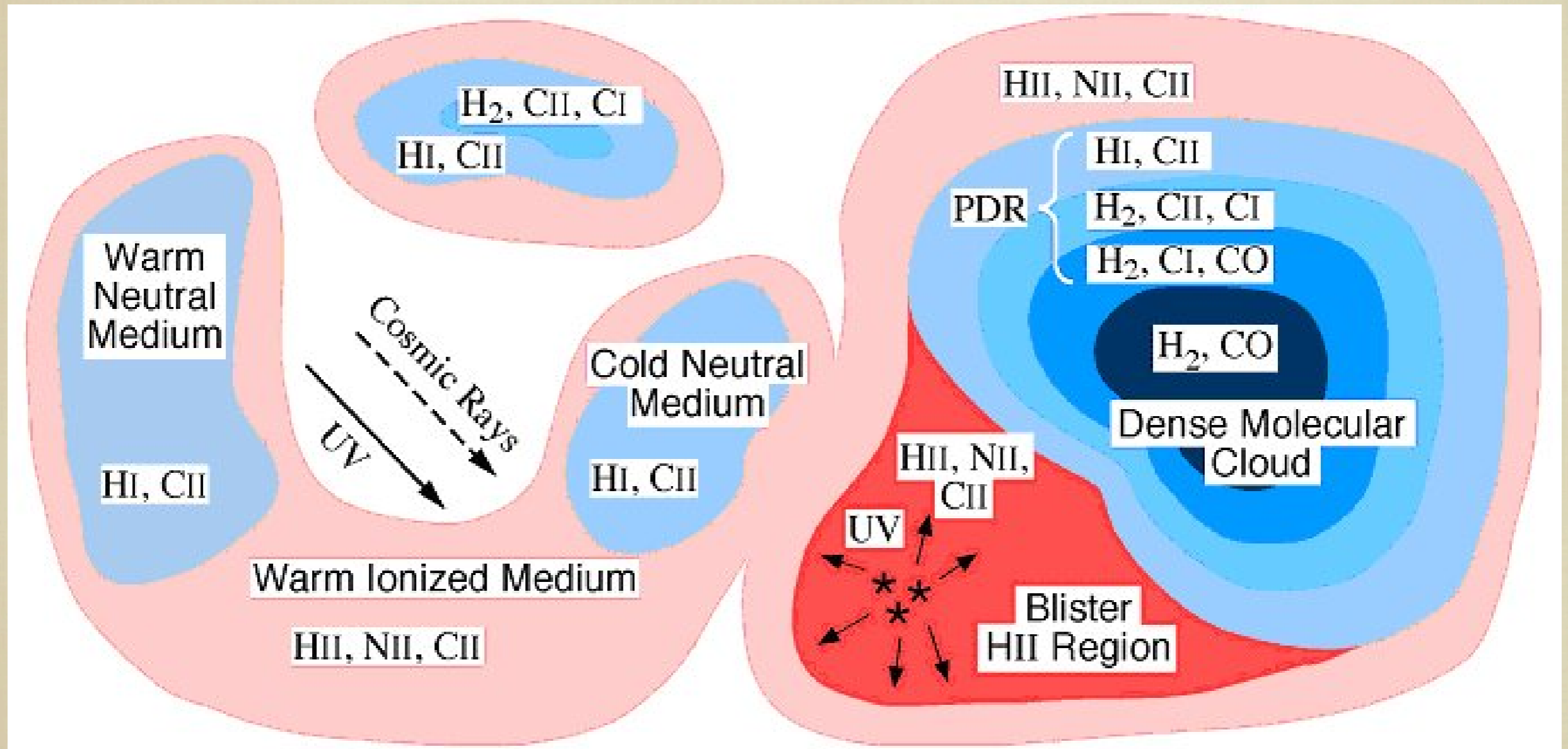


PROGRAM

- 350 HOURS OF WAVELENGTH-SWITCHED TARGETED LINE SPECTROSCOPY.
- SDP VALIDATION OF WLS VS. CHOP-NOD.
- NEW HYBRID UNCHOPPED LINE SCAN.
- SPECIAL THANKS TO **ROLAND VAVREK, PHIL APPLETON, AND THE PACS ICC.**

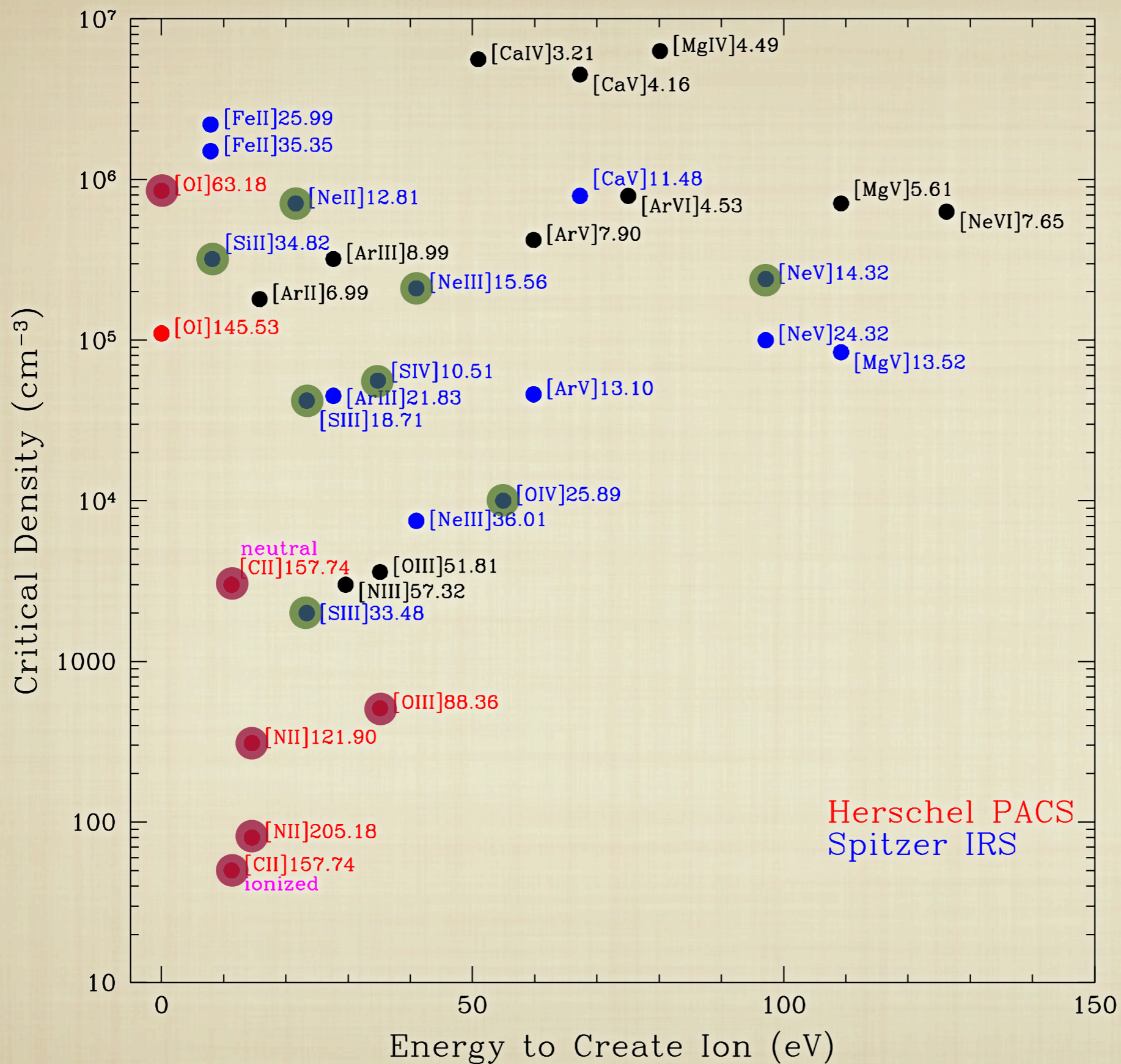


PHASES OF THE ISM



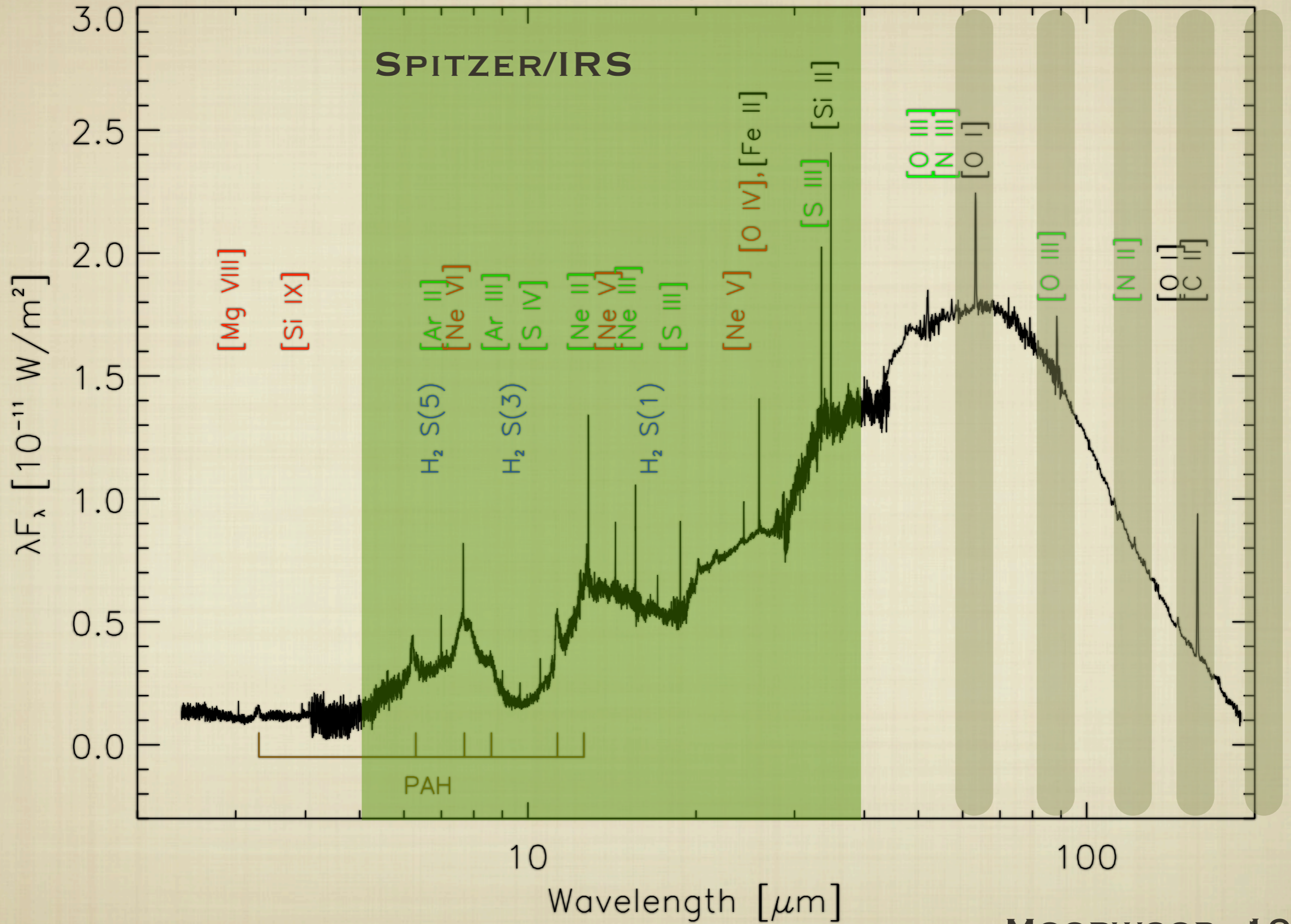
COURTESY CRAIG KULESA

INFRARED LINES: A ROADMAP



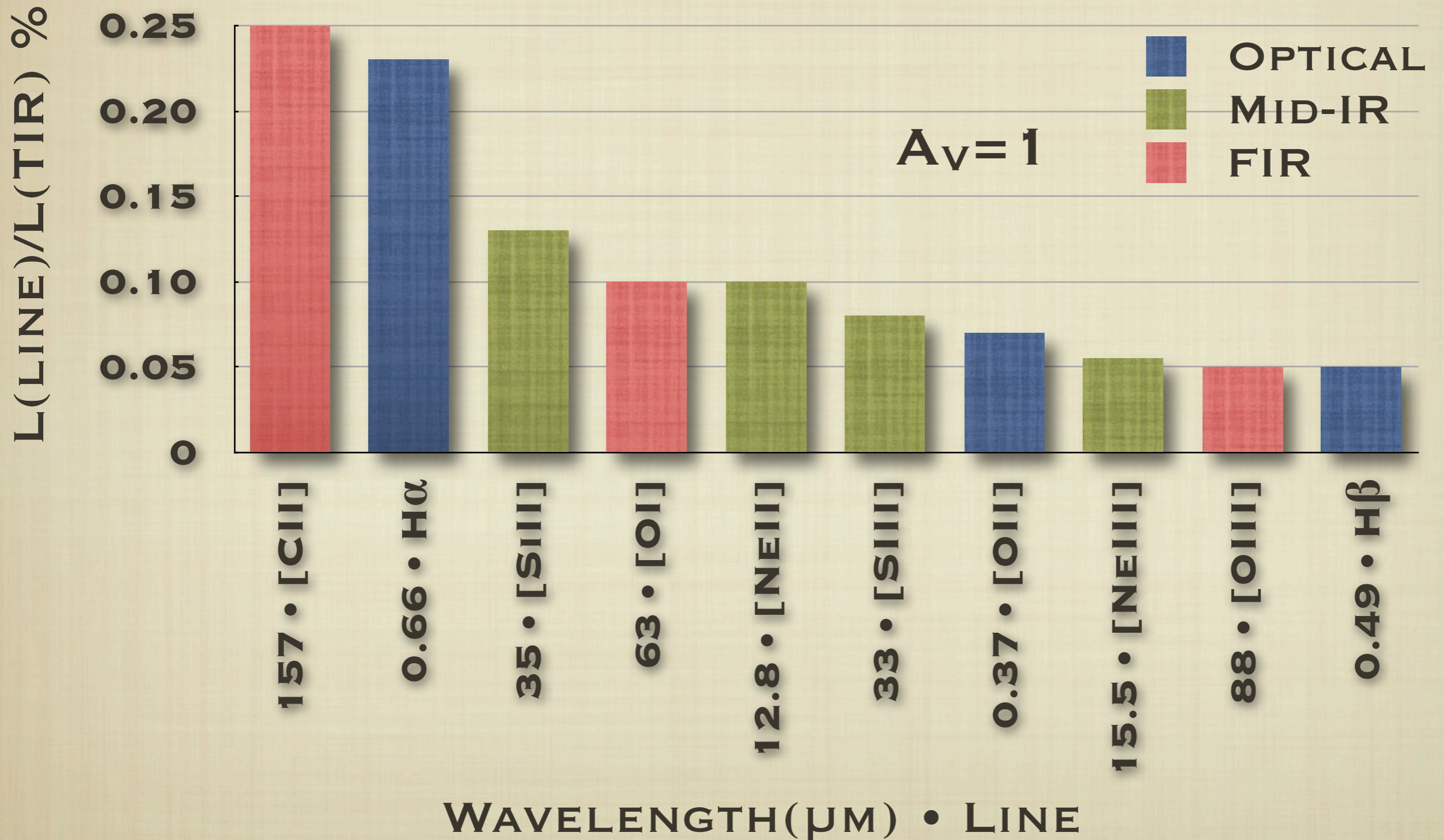
Herschel PACS
Spitzer IRS

Circinus Galaxy SWS + LWS



MOORWOOD, 1996

THE TOP 10 MOST LUMINOUS (OBSERVED) EMISSION LINES OF STAR-FORMING GALAXIES

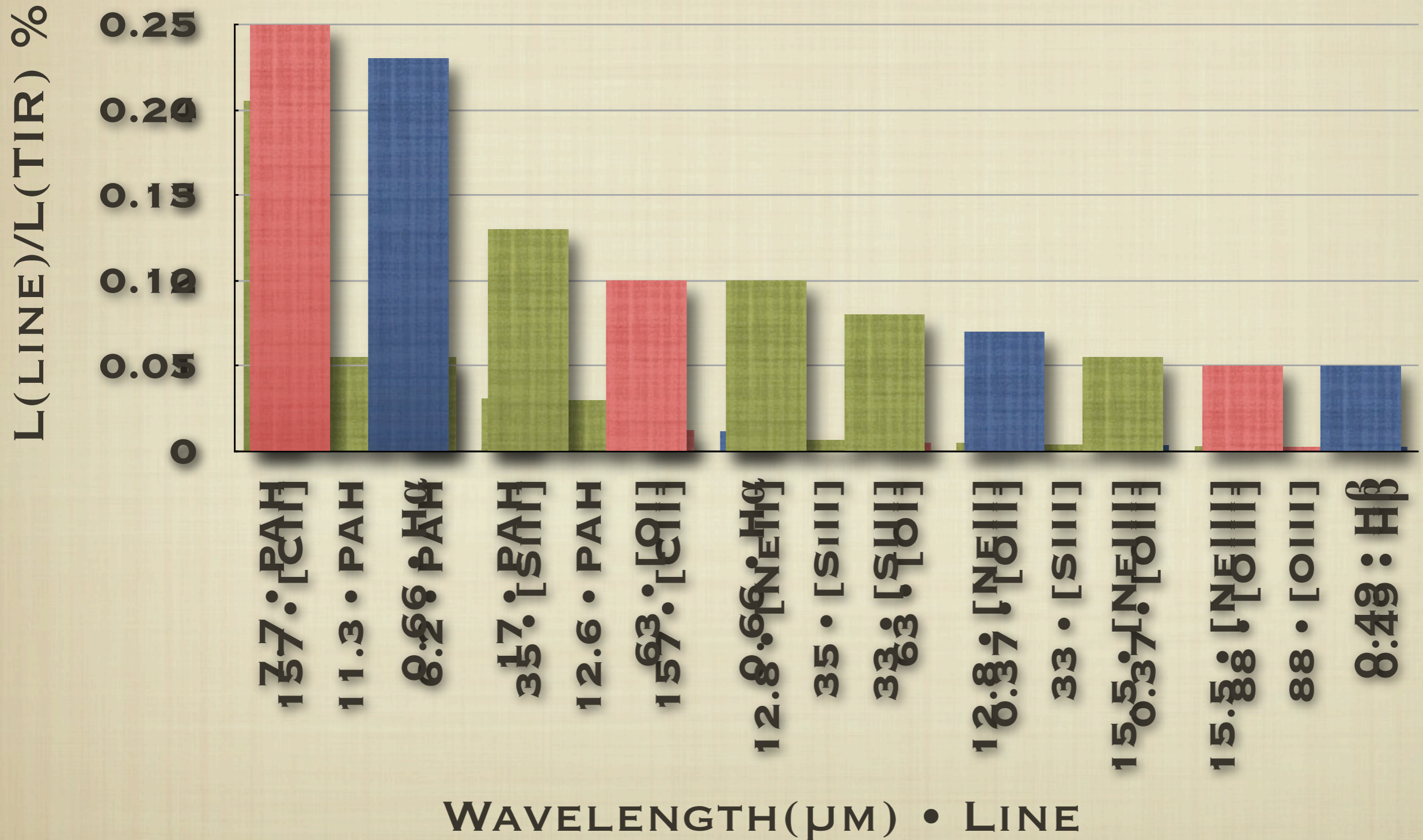


OUR OBSERVATIONS

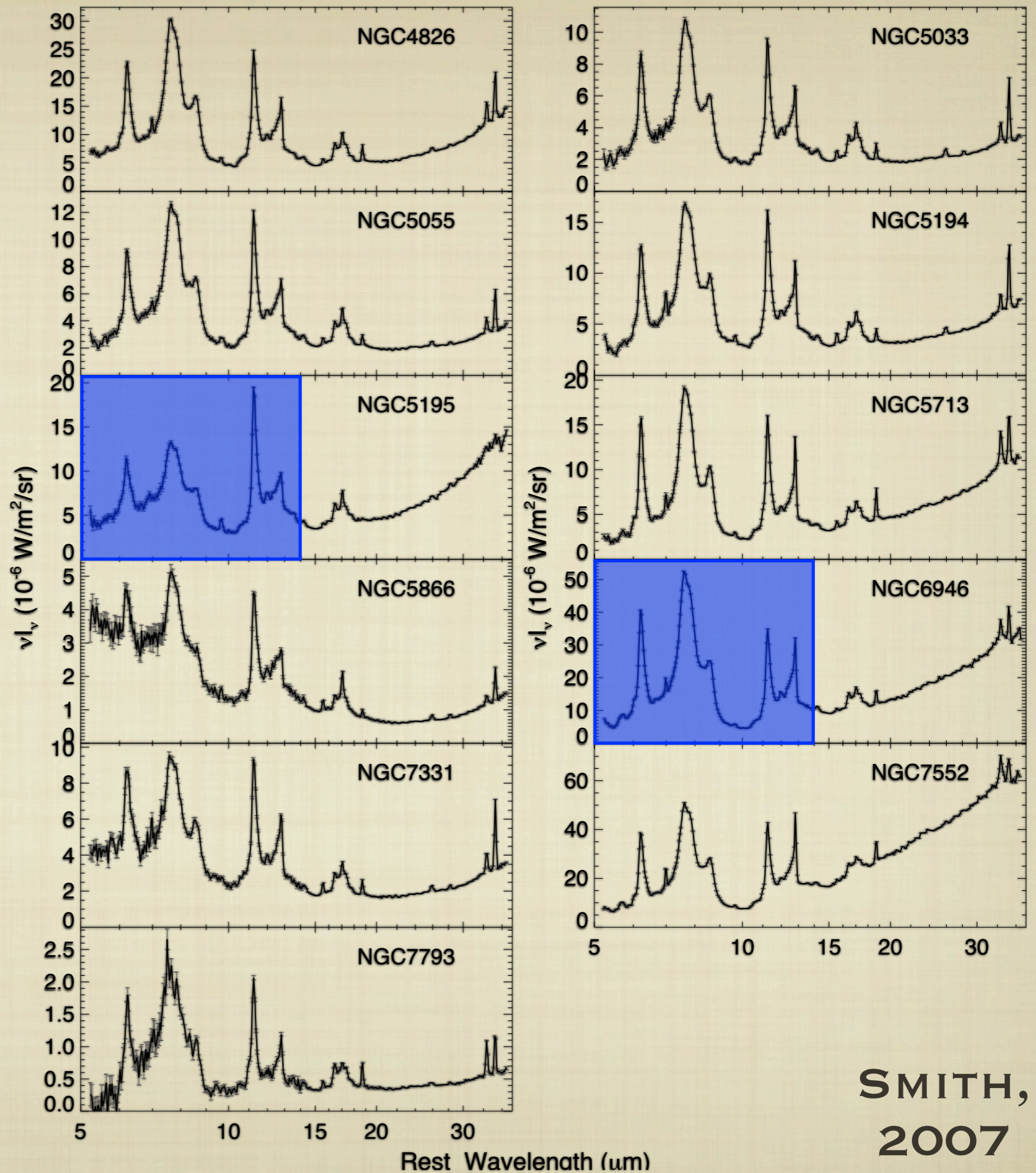
LINE	LINE/FIR	PREDOMINANT EMISSION
[CII] 158μM	0.3%	IONIZED, NEUTRAL GAS
[OI] 63μM	0.2%	NEUTRAL AND SHOCKED GAS
[OIII] 88μM	0.1%	HII REGIONS
[NII] 122μM	0.03%	IONIZED GAS
[NII] 205μM	<0.02% †	IONIZED GAS

† BEYOND ISO'S COVERAGE, BASED ON LOW-DENSITY LIMIT RATIO

PAH POWER

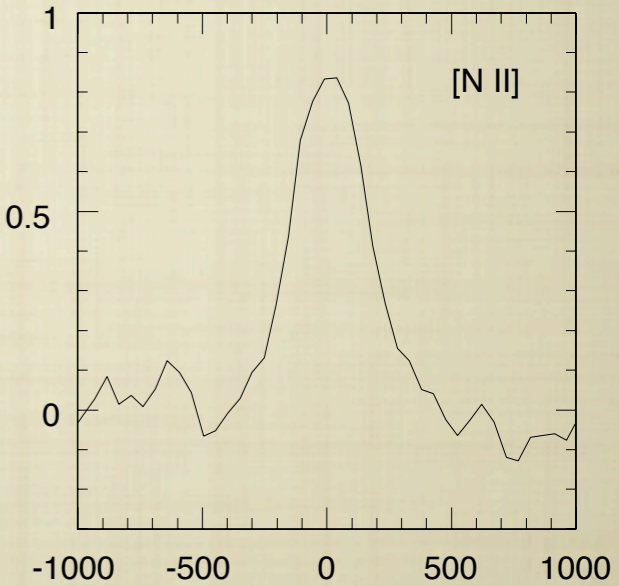
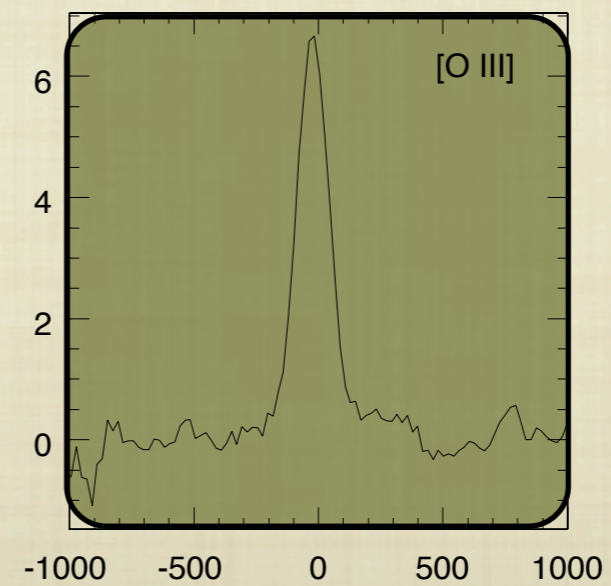
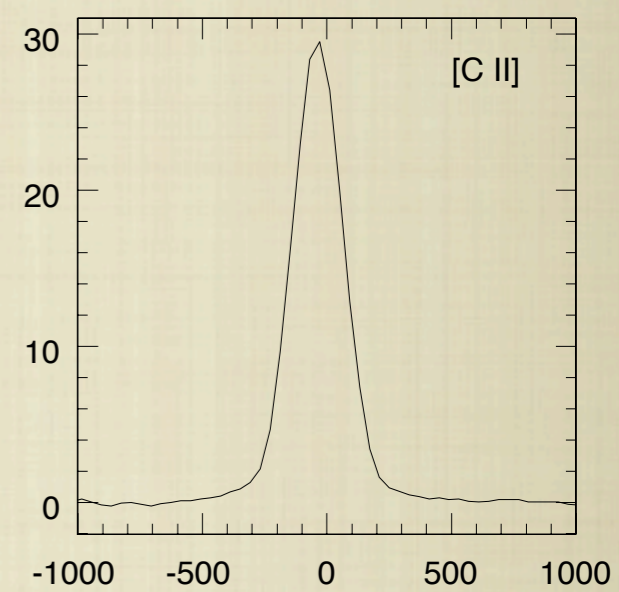
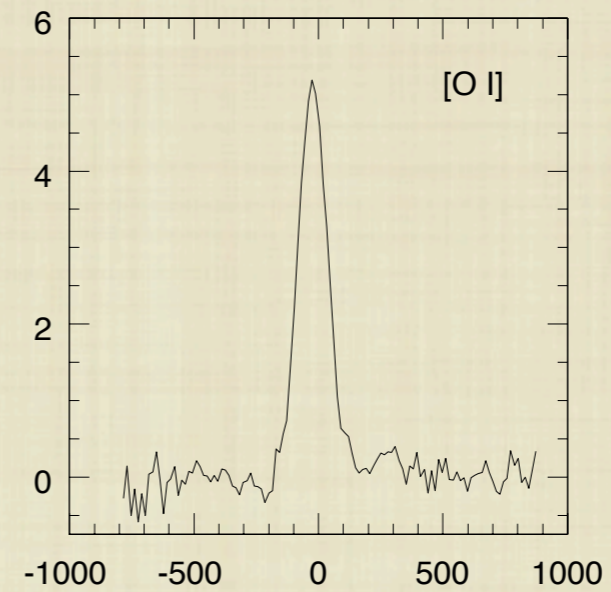
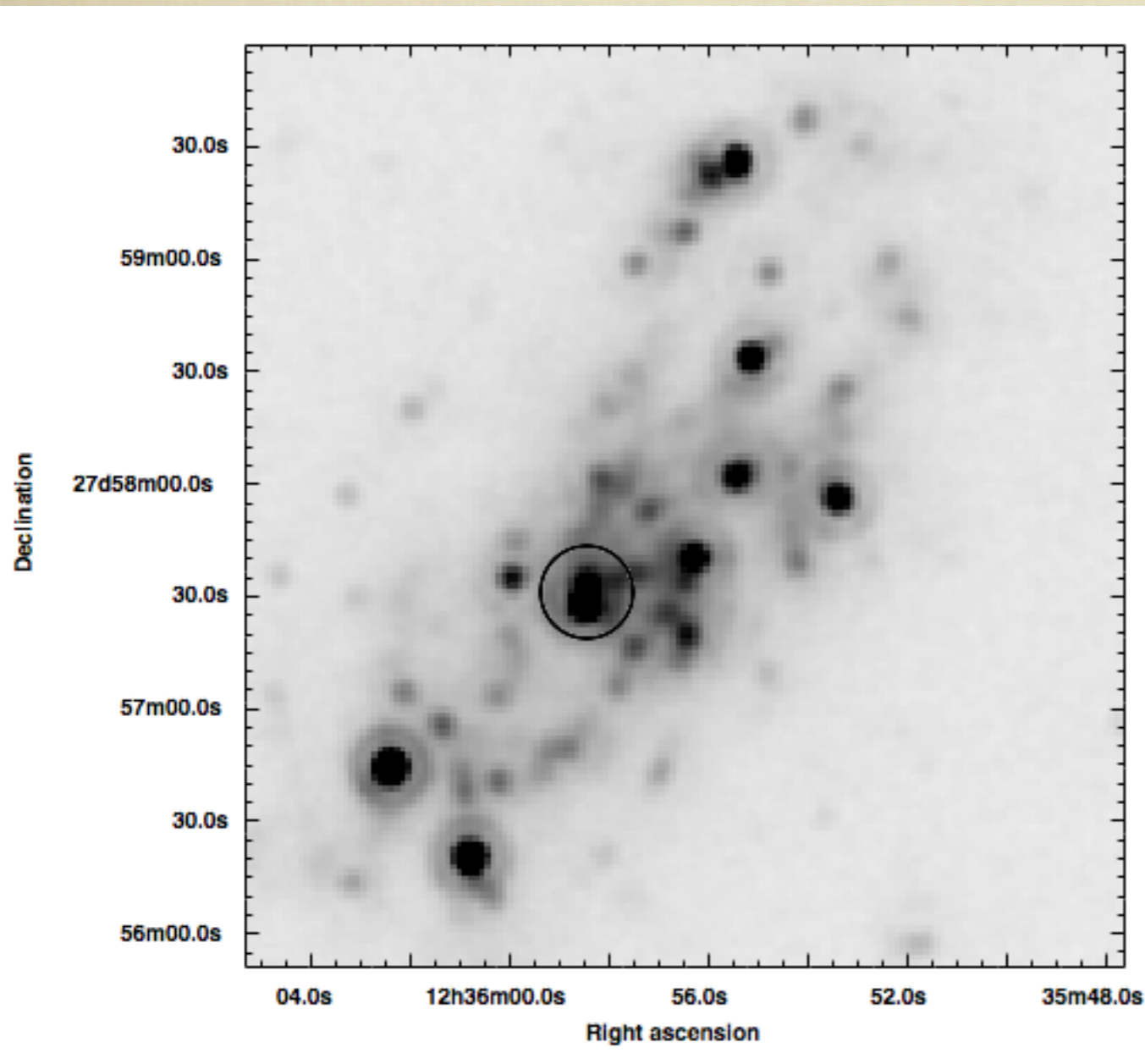


RESOLVED PAH EMISSION



SMITH,
2007

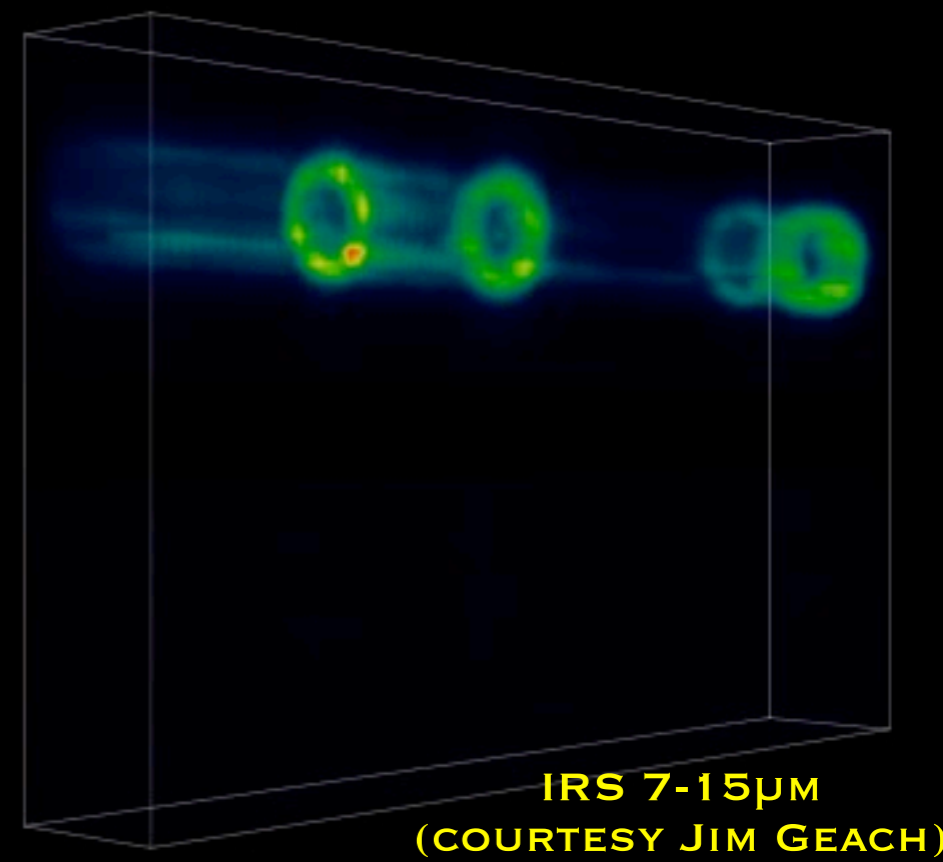
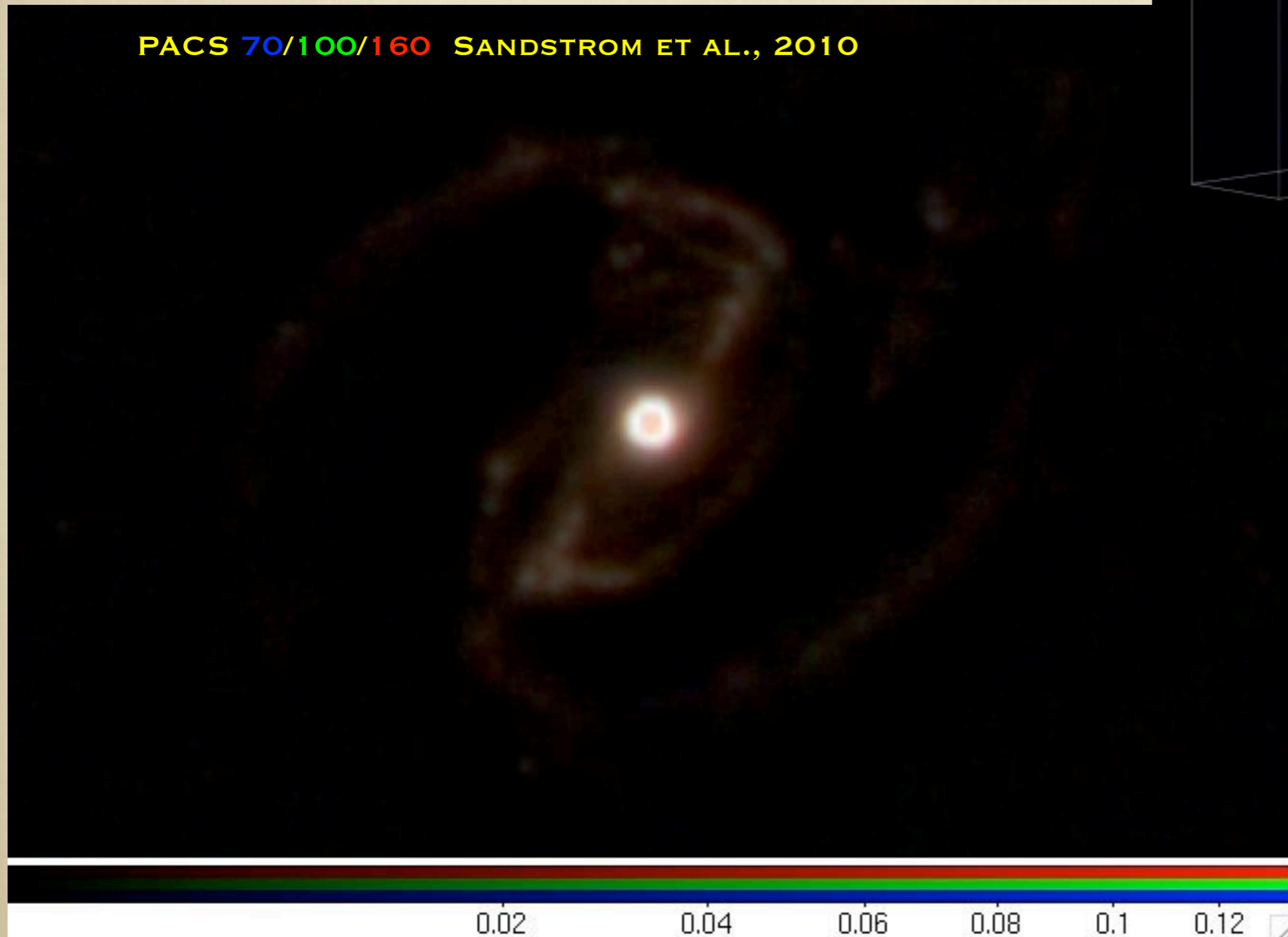
NGC 4559



VELOCITY (KM/S)

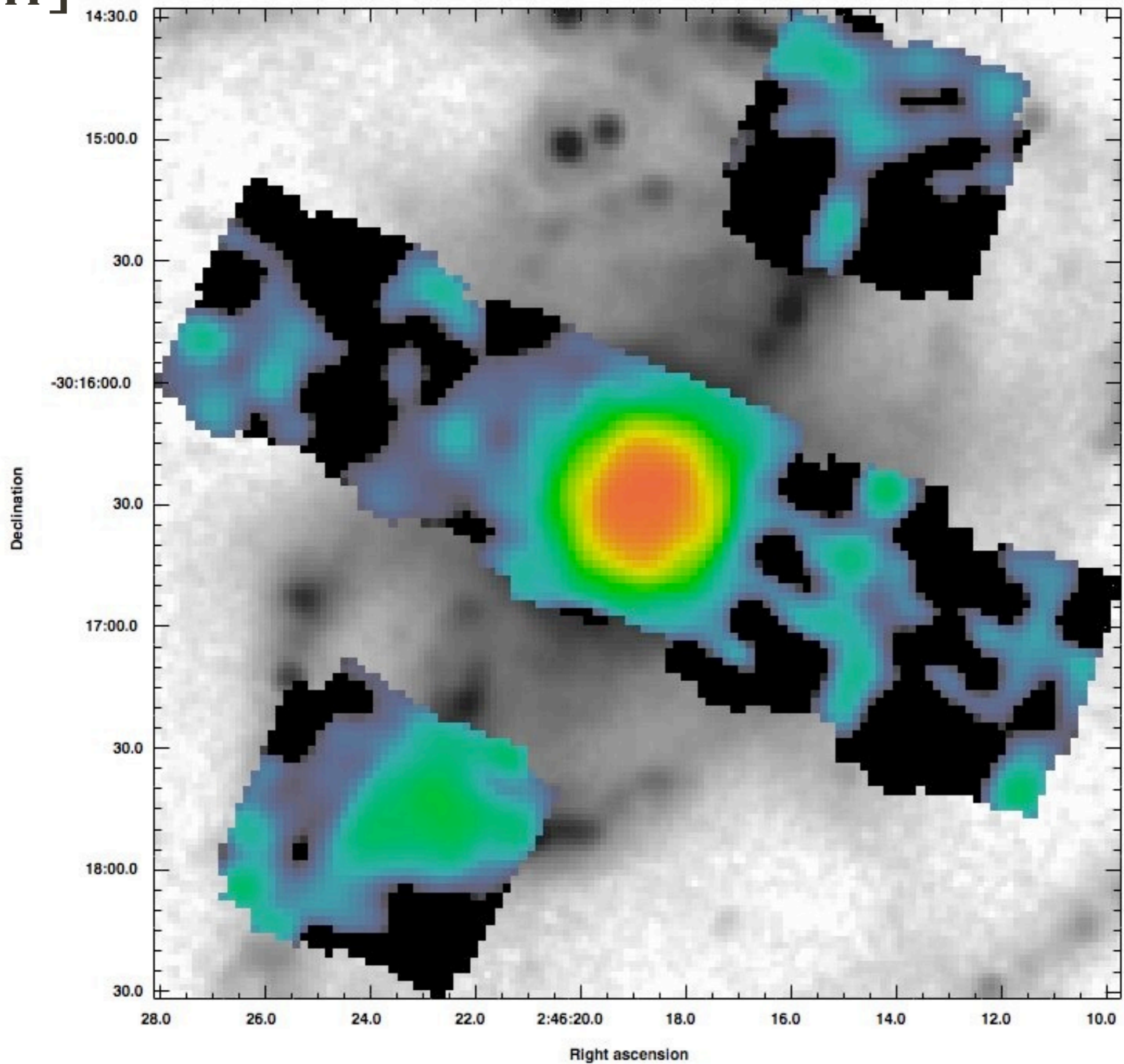
NGC 1097

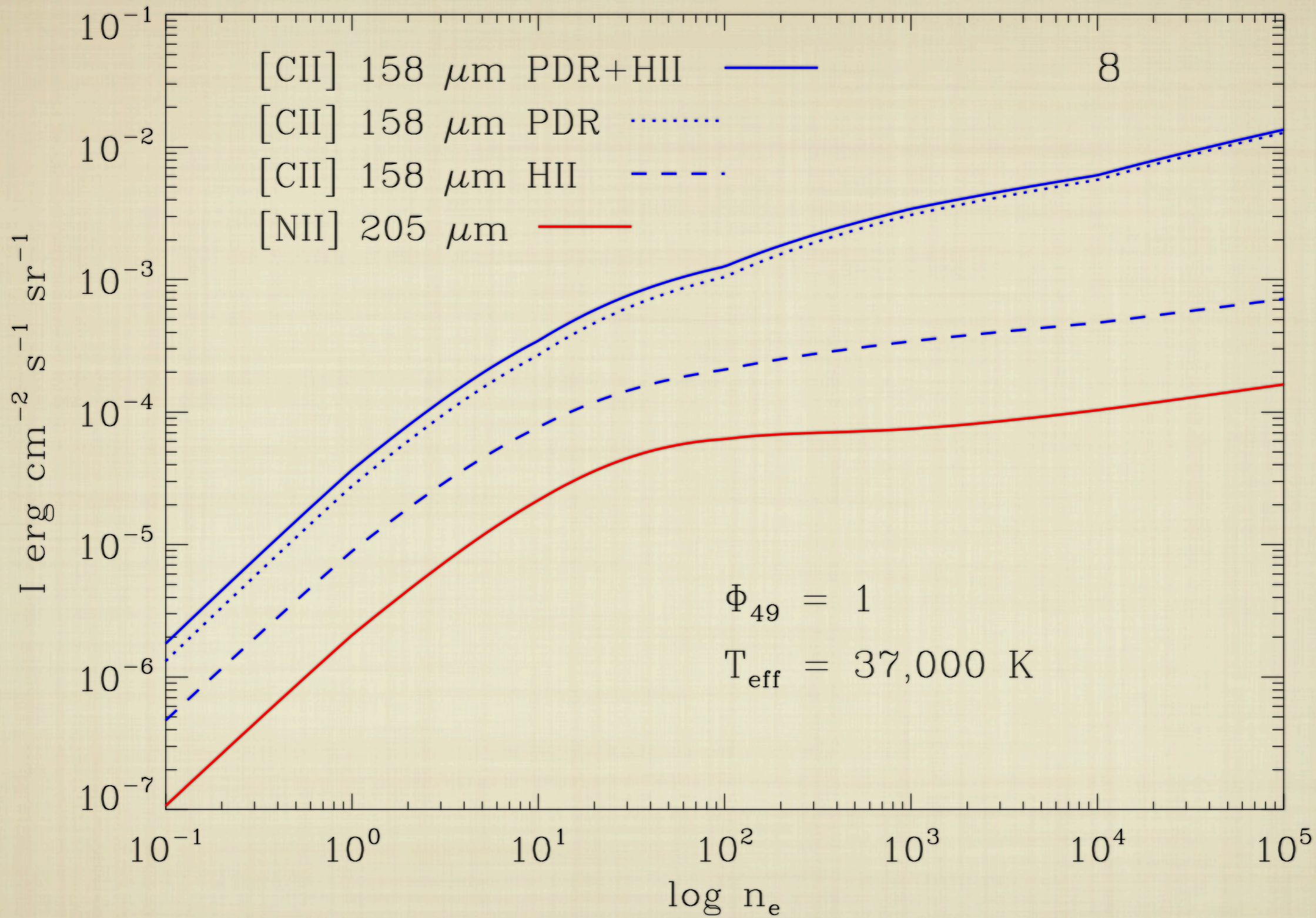
PACS 70/100/160 SANDSTROM ET AL., 2010



IRS 7-15 μm
(COURTESY JIM GEACH)

[CII]

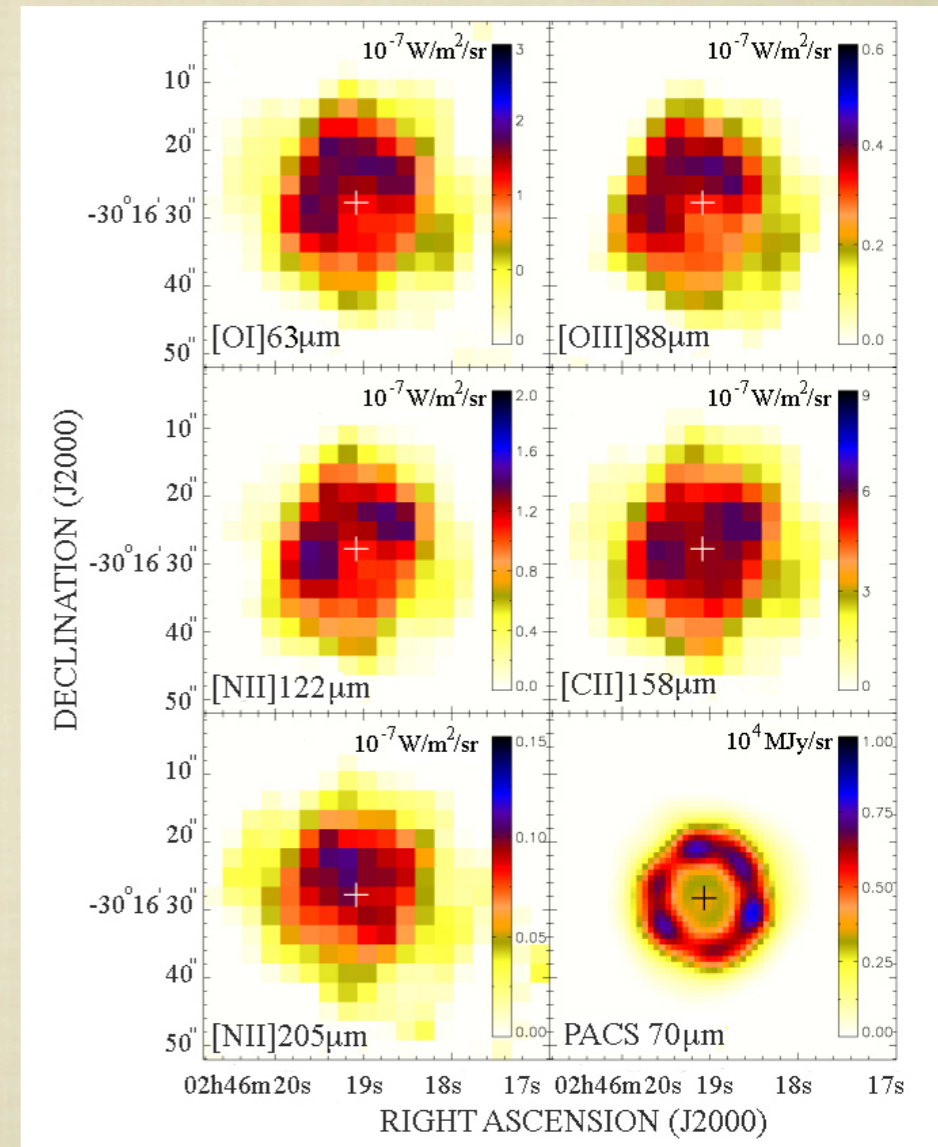
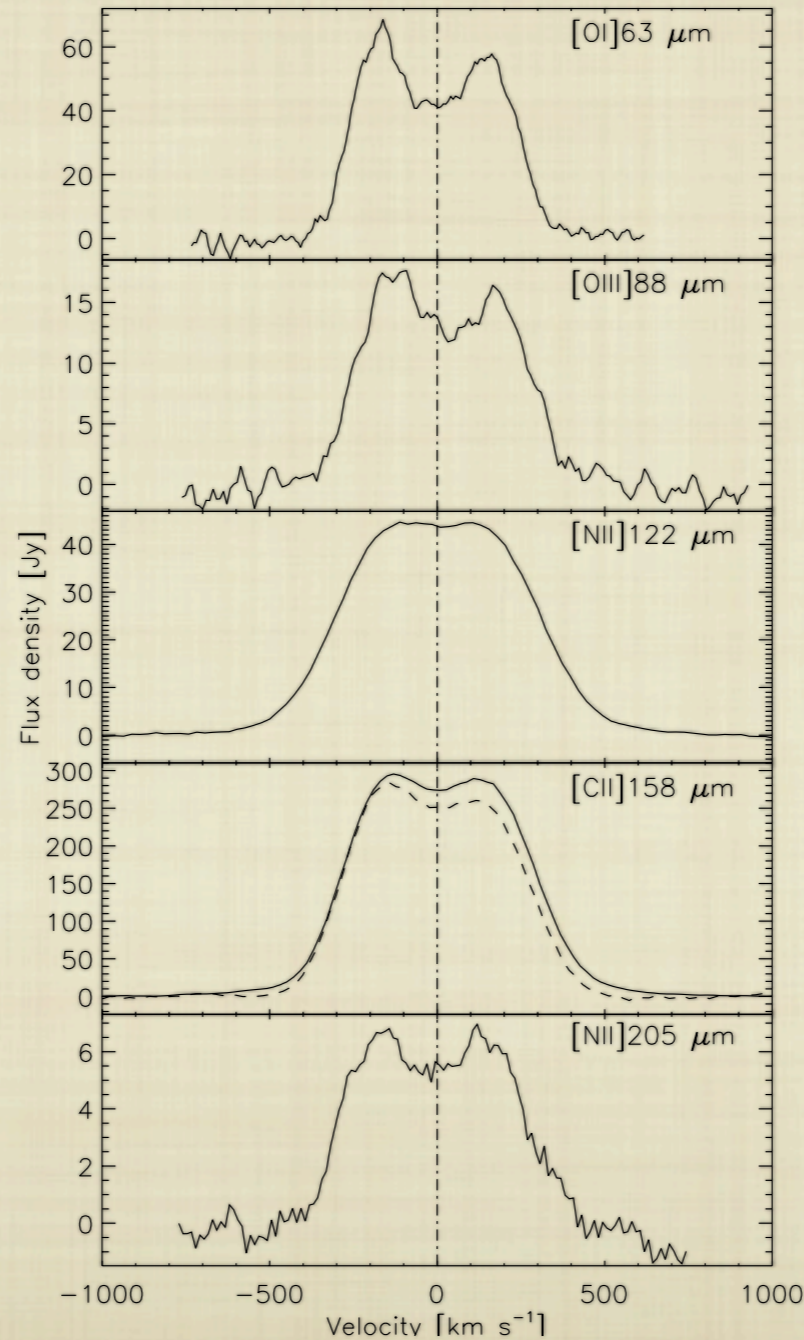




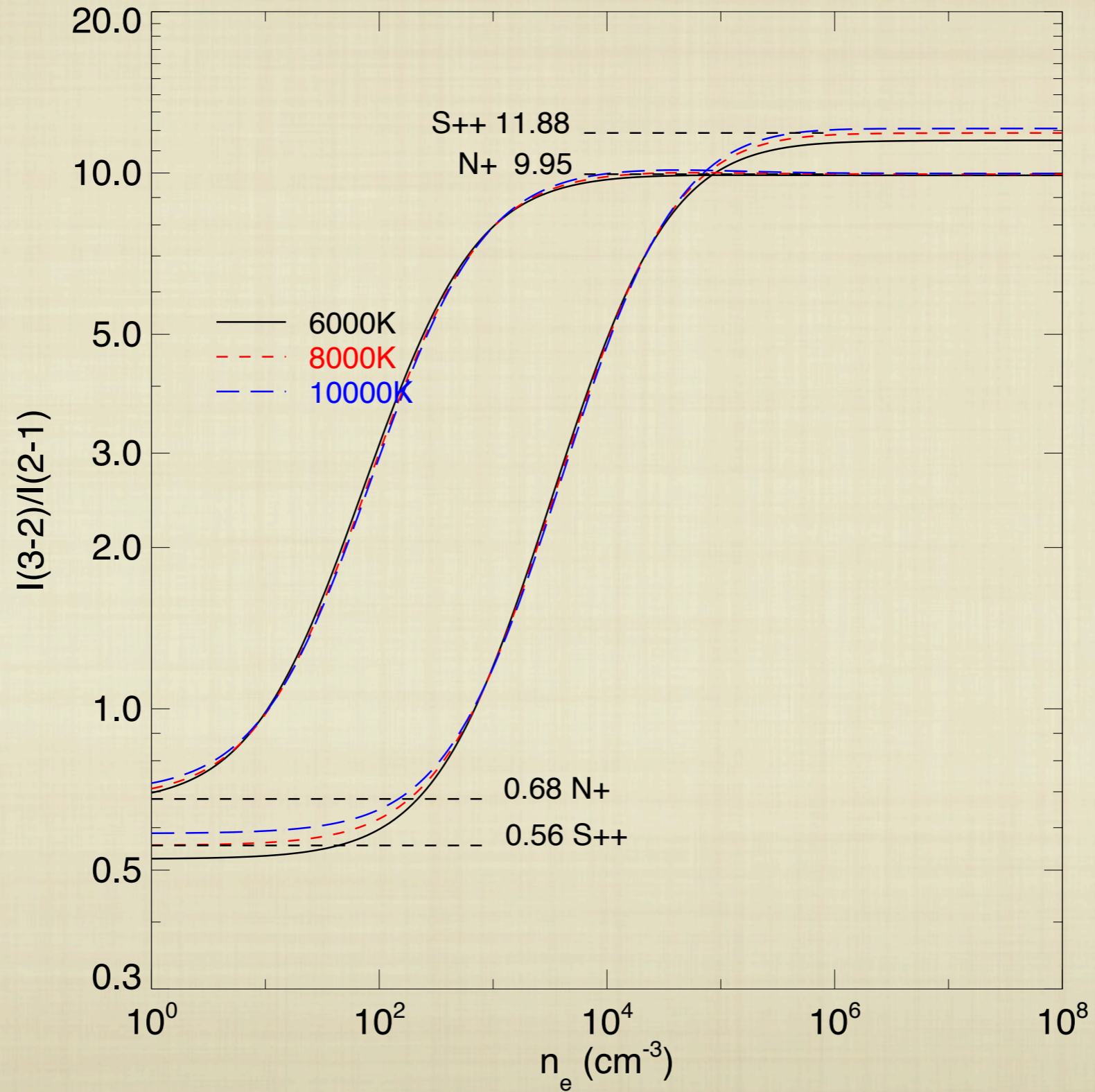
WOLFIRE, ET AL., IN PREP

NGC 1097's RING

- LINE IMAGING IN ALL 5 TARGET LINES
- RING FULLY RESOLVED AT SHORTEST WAVELENGTHS
- CONSIDERABLE VARIATIONS IN LINE RATIO
- DOUBLE PEAKED EMISSION

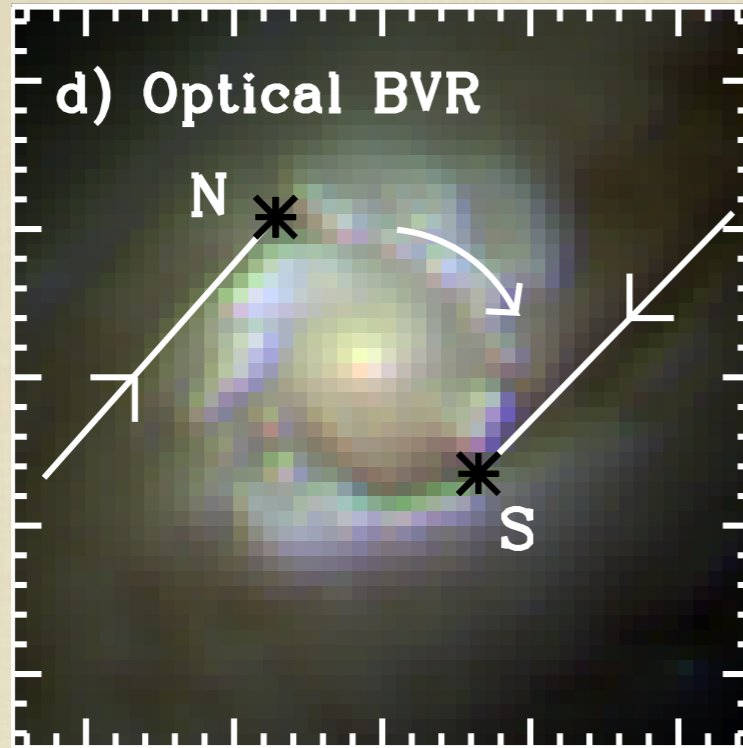


DIAGNOSTICS

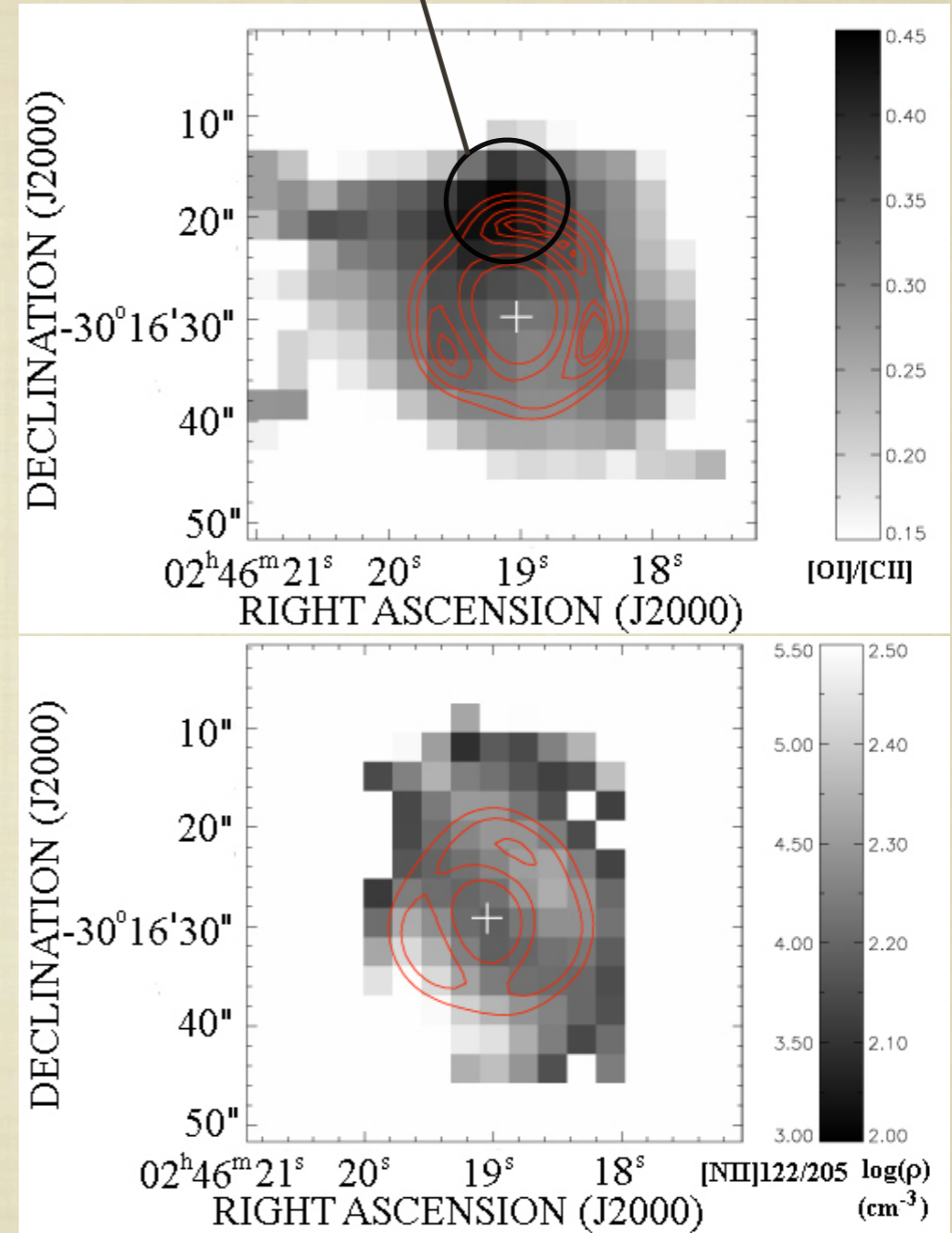


PEAK $[O I]/[C II]=\sim 0.5 \Rightarrow G_0 \sim 200-300$
(MEIJERINK PDR MODELS)

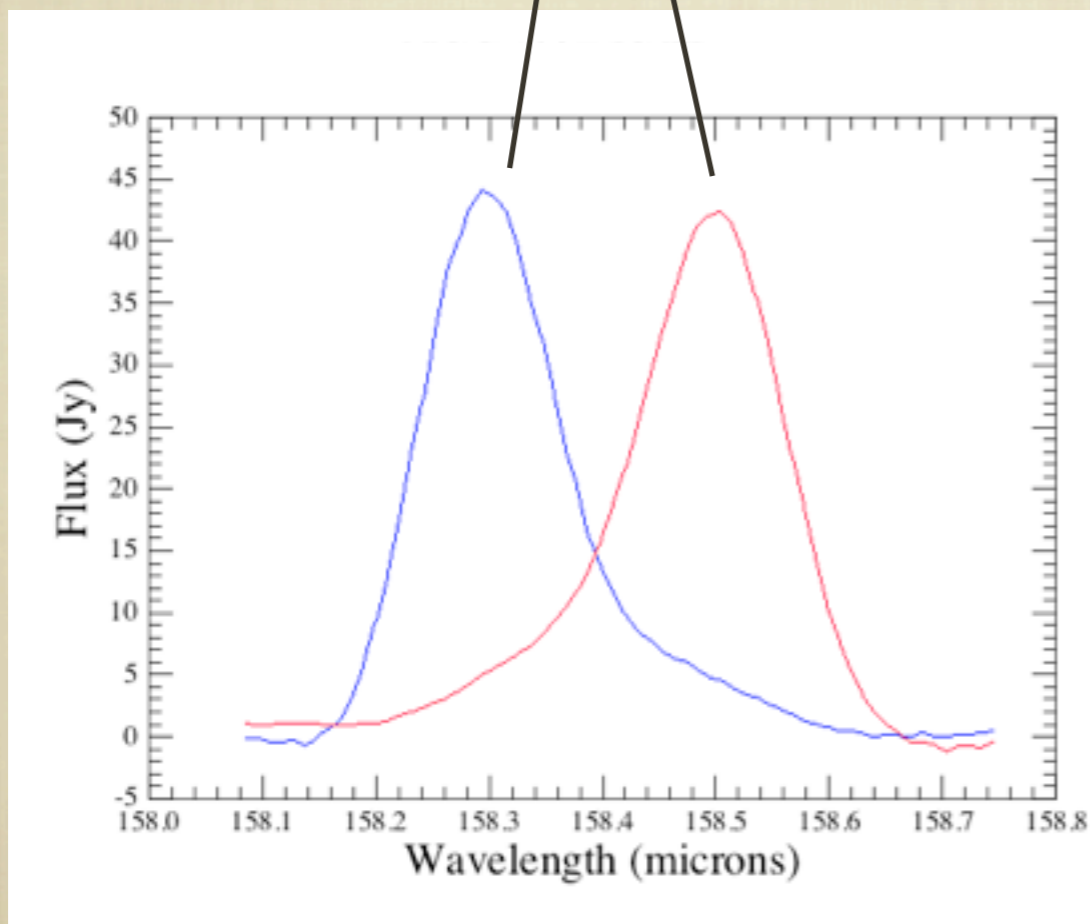
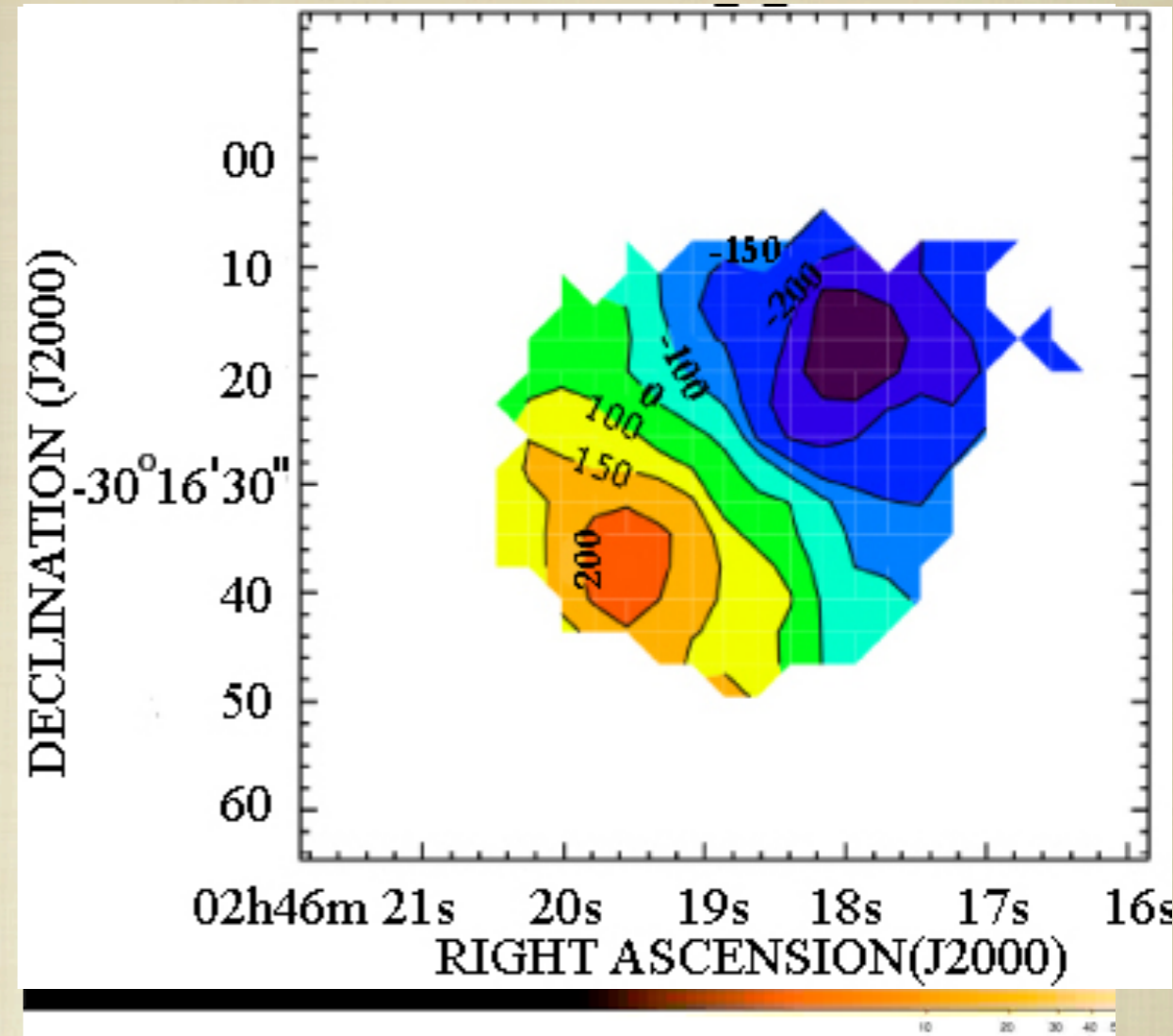
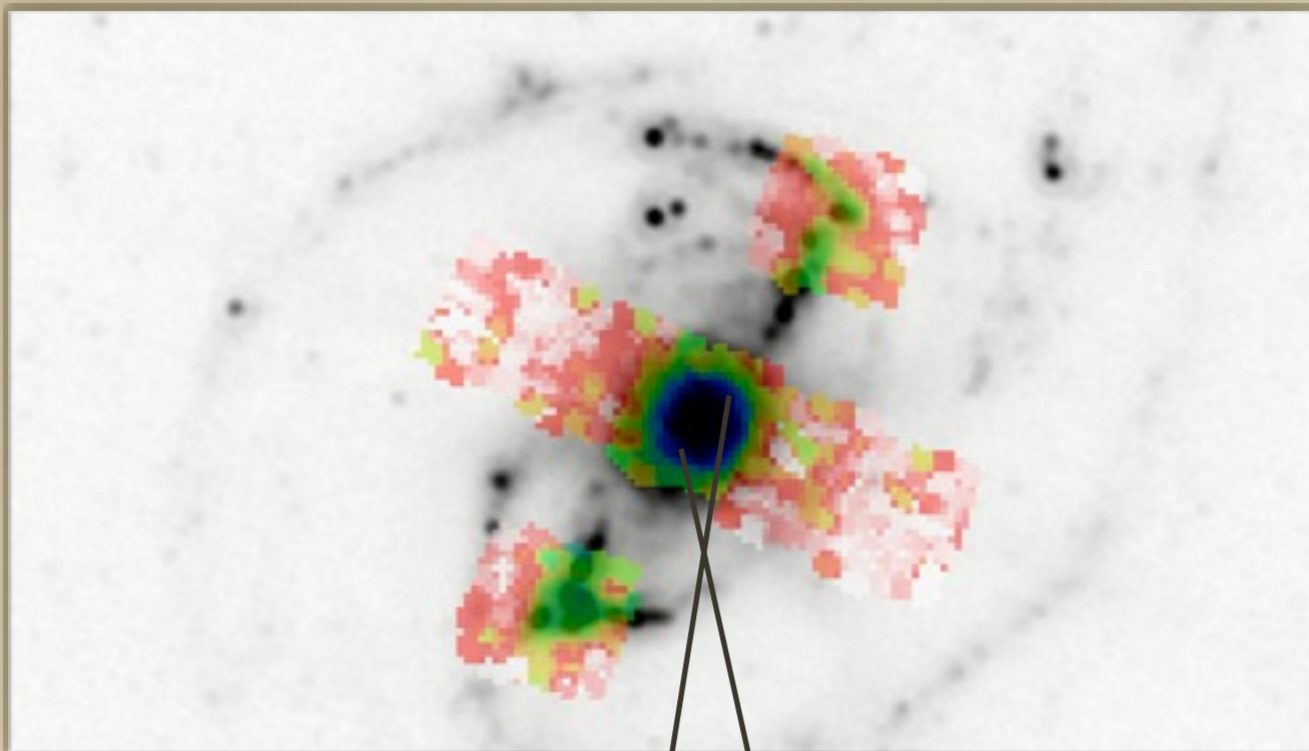
NGC 1097



- INNER STAR-FORMING RING AROUND A SEYFERT 1 NUCLEUS.



BEIRÃO ET AL., 2010



NGC 1097

- WAVELENGTH SWITCHING SDP DATA
- [C II] @ 158 MICRON

CONCLUSIONS

- EXCEPTIONAL PERFORMANCE OF PACS SPECTROMETER.
- FULL GAS COOLING VS. DUST HEATING CENSUS, MAPPED ON SUB-KPC SCALES.
- RESOLVING SUB-KPC SCALE LINE EMISSION. STAR-FORMING RINGS: EVIDENCE FOR FUELING.
- KINEMATICS OF THE LOW DENSITY NEUTRAL AND IONIZED MEDIUM.

