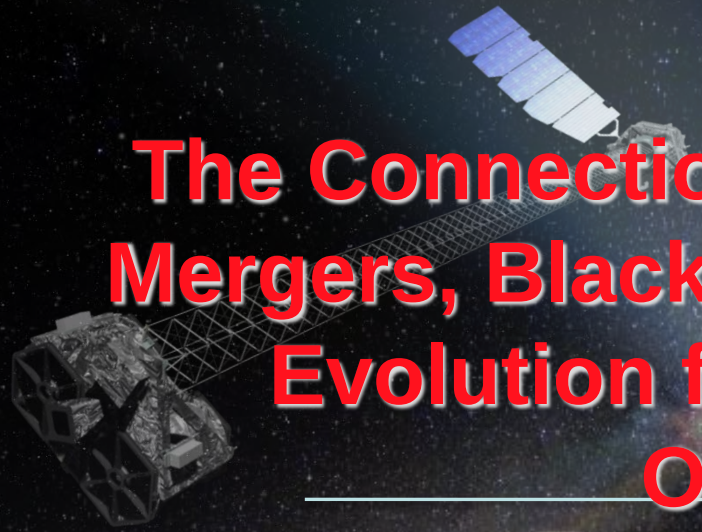


The Connection between Major Galaxy Mergers, Black Hole Growth and Galaxy Evolution from Multiwavelength Observations

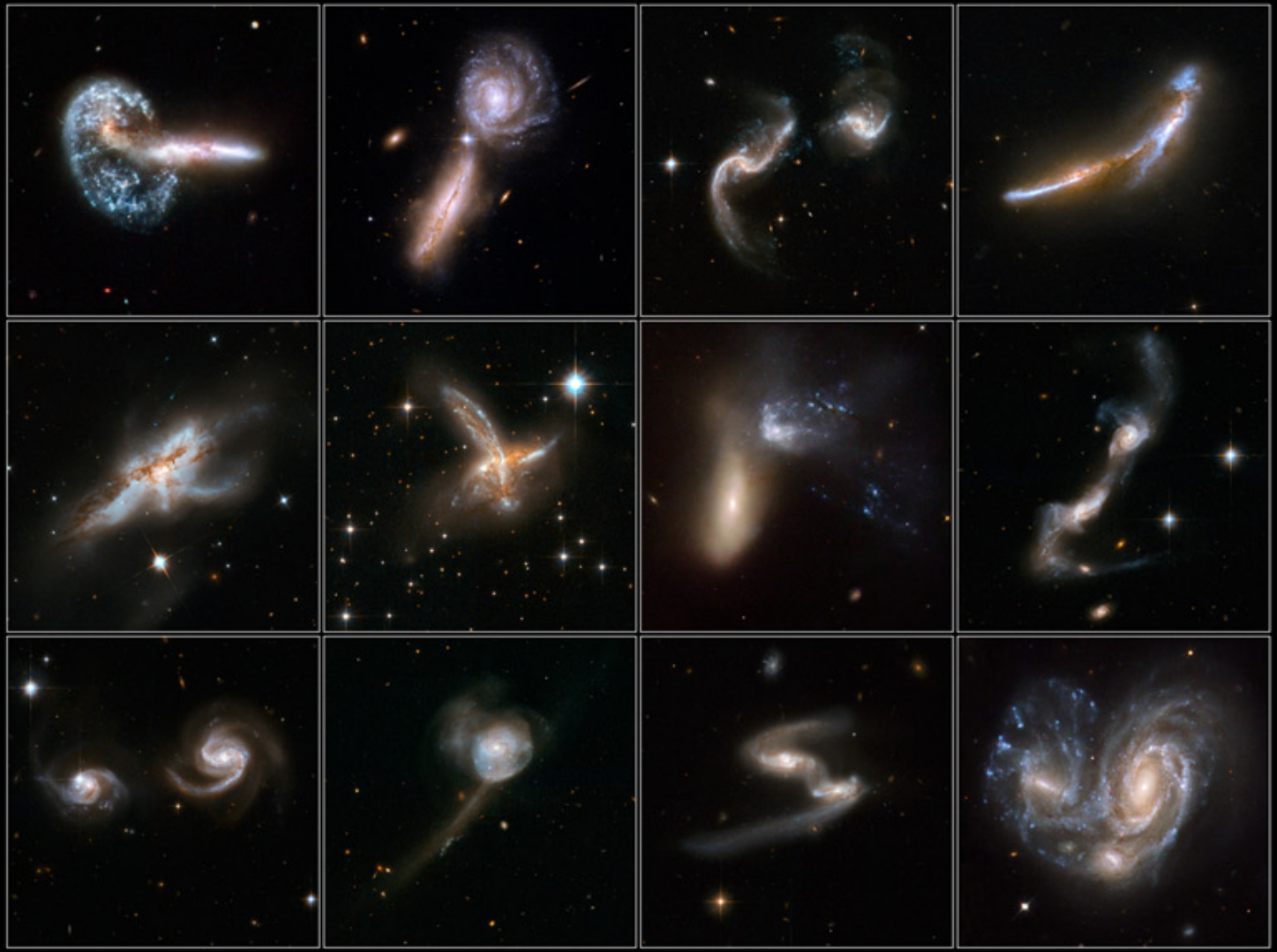
Ezequiel Treister

P. Universidad Católica

Collaborators: Franz Bauer (PUC), George Privon (PUC), Claudio Ricci (PUC), Kevin Schawinski (ETH), Mike Koss (ETH), Francisco Muller-Sanchez (Colorado), Julie Comerford (Colorado), Dave Sanders (Hawaii), Nick Scoville (Caltech), Anne Medling (Caltech), Meg Urry (Yale), Vivian U (UCR), Anne Medling (Caltech), Patricia Arevalo (UV) and others…

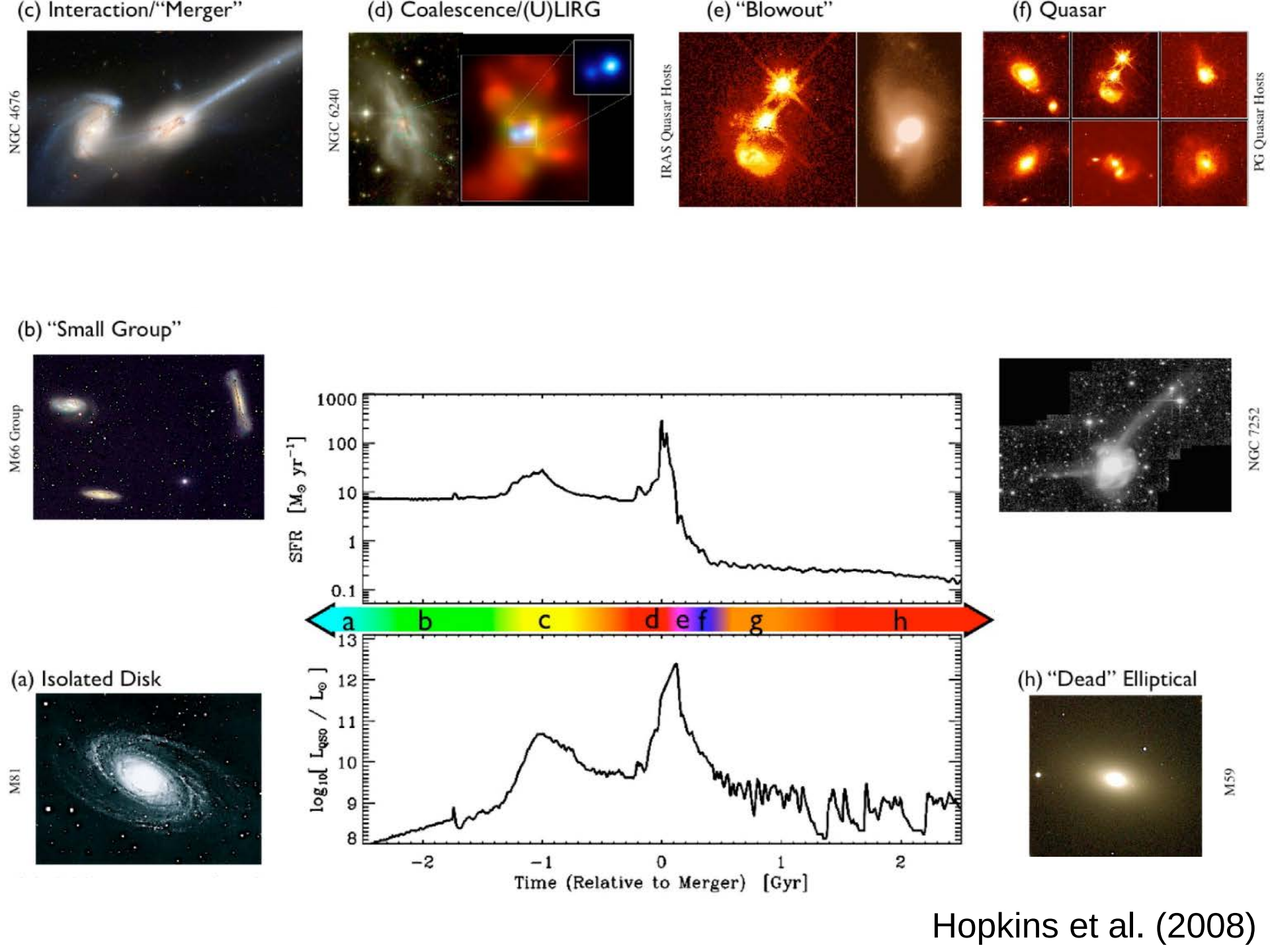
Interacting Galaxies

Hubble Space Telescope • ACS/WFC • WFPC2



NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)

STScI-PRC08-16a

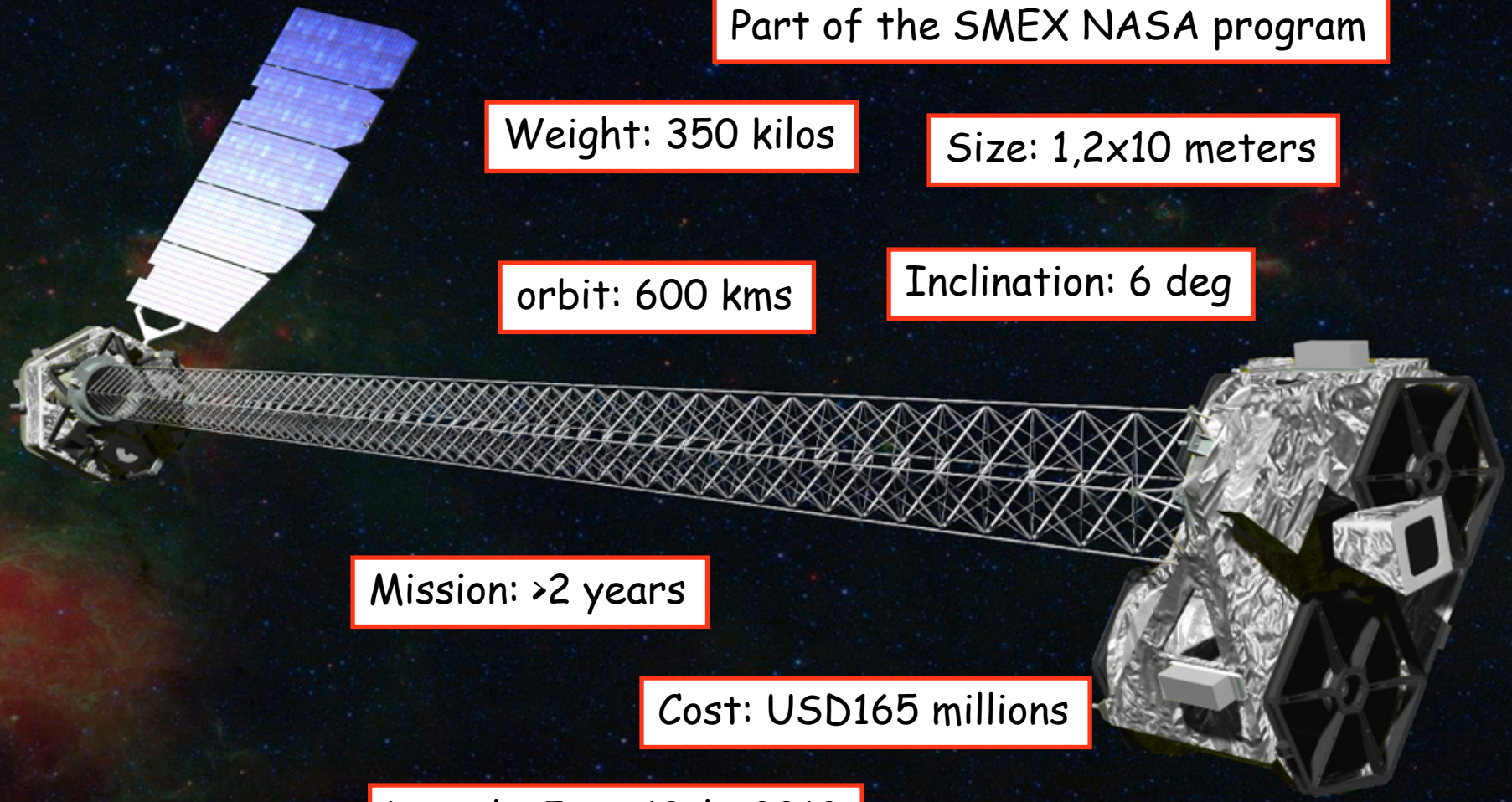


Hopkins et al. (2008)

Main Scientific Goals

- ✓ **At what stage in the merger sequence is black hole growth triggered?**
- ✓ **How is this black hole growth triggered?**
- ✓ **How does black hole growth affect galaxy evolution?**

NuSTAR



Part of the SMEX NASA program

Weight: 350 kilos

Size: 1,2x10 meters

orbit: 600 kms

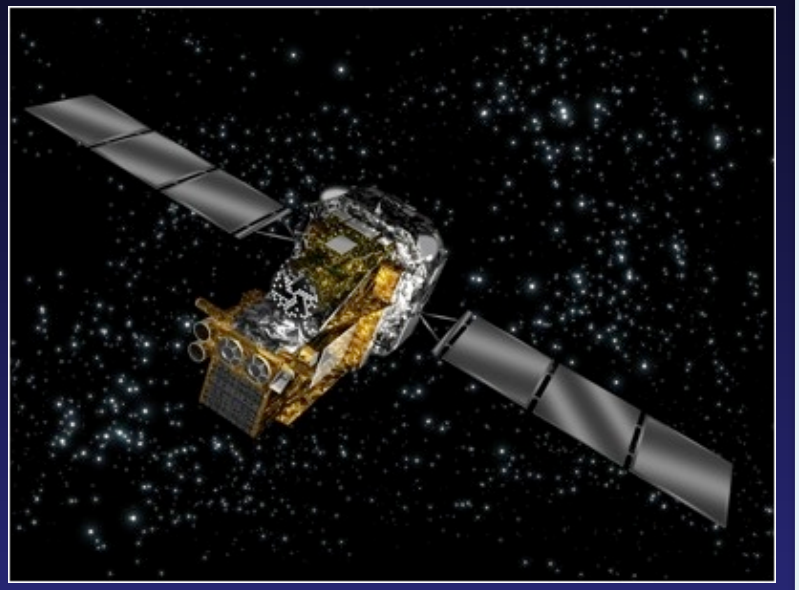
Inclination: 6 deg

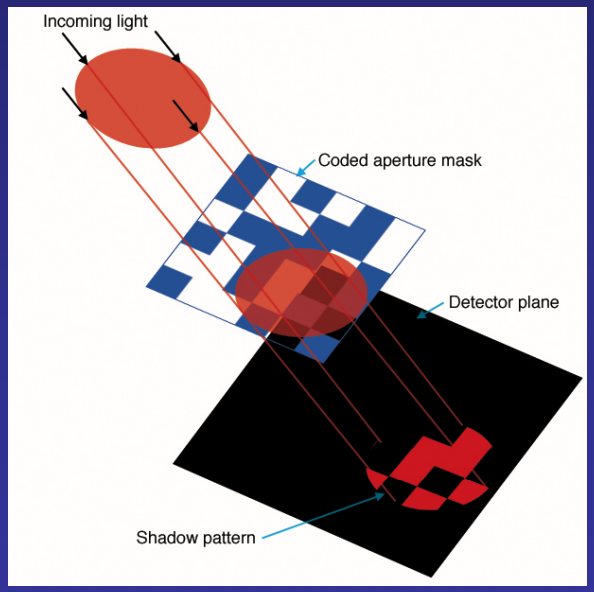
Mission: >2 years

Cost: USD165 millions

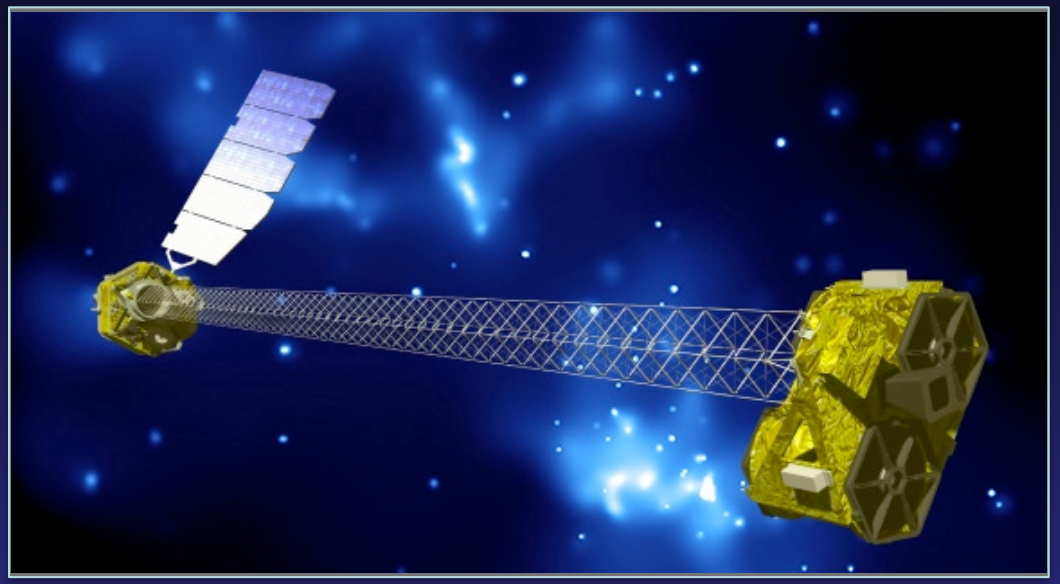
Launch: June 13th, 2012

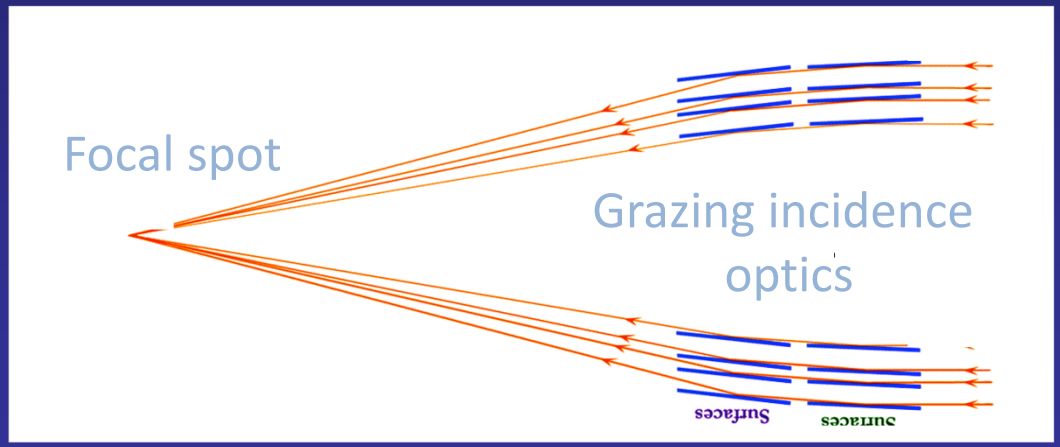
INTEGRAL, Swift BAT



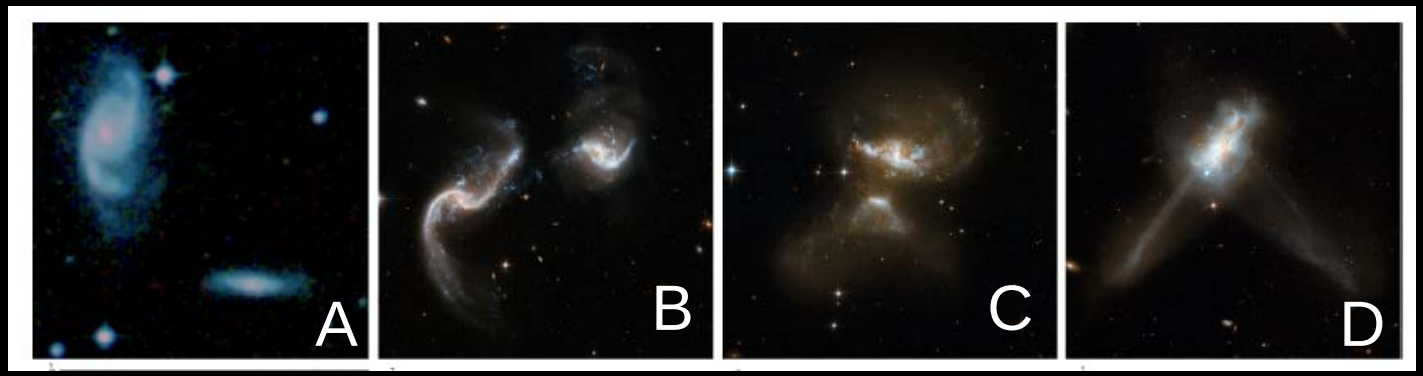


NuSTAR





Complete Sample of nearby (U)LIRGs



Nearby (U)LIRGs spanning the merger sequence following the Stierwalt et al. 2013 morphological classification.

NuSTAR Cycle 1 GO Program
200 ksec, 12 targets

- Have existing Chandra Observations
- <120 Mpc away
- log L_{FIR}>11.3 L_o

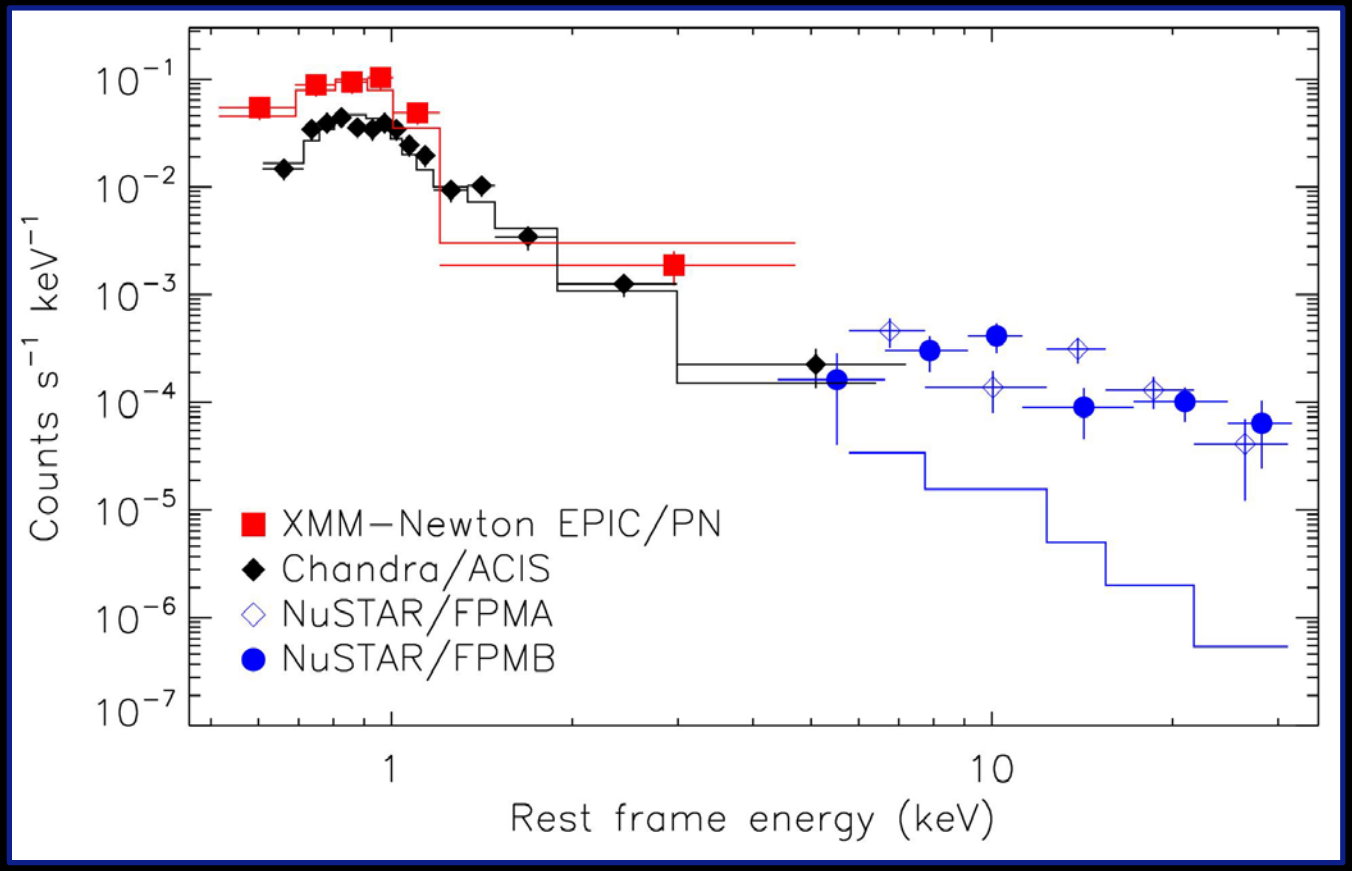
Name	log L_{IR} (erg/s)	Merger Stage
MCG+08-18-013	11.34	A
NGC3110	11.37	A
Arp256	11.48	B
ESO440-IG058_N	11.43	B
ESO440-IG058_S	11.43	B
NGC6286_N	11.37	B
NGC6286_S	11.37	B
MCG+12-02-001	11.50	C
NGC4922	11.38	C
IRASF18293-3413	11.88	C
NGC0034	11.49	D
IRASF17138-1017	11.49	D

Complete Sample of nearby (U)LIRGs

NGC6286 (stage B)

Complete Sample of nearby (U)LIRGs

NGC6286 (stage B)



Ricci et al., 2016

New heavily-obscured AGN confirmed by NuSTAR observations.

N_H~$6x10^{23}$-$1.3x10^{24}$ cm^{-2}

L_X(10-50keV)~10^{42} erg/s

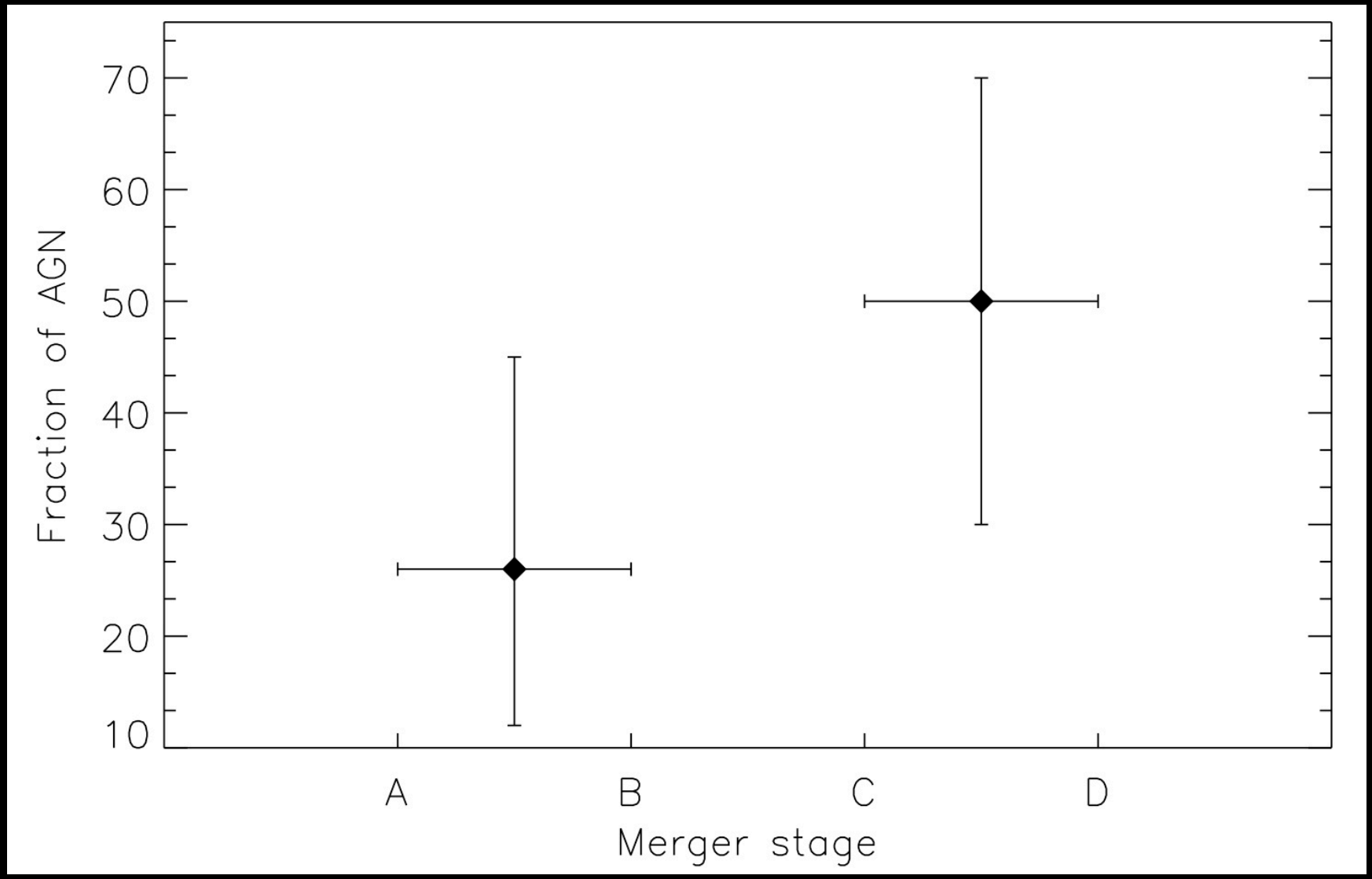
Complete Sample of nearby (U)LIRGs

Summary

Merger Stage	Number of sources	Detections	Heavily Obscured
Stage A	2	0 (0%)	0 (0%)
Stage B	5	1 (20%)	1 (100%)
Stage C	3	3 (100%)	3 (100%)
Stage D	2	1 (50%)	1 (100%)

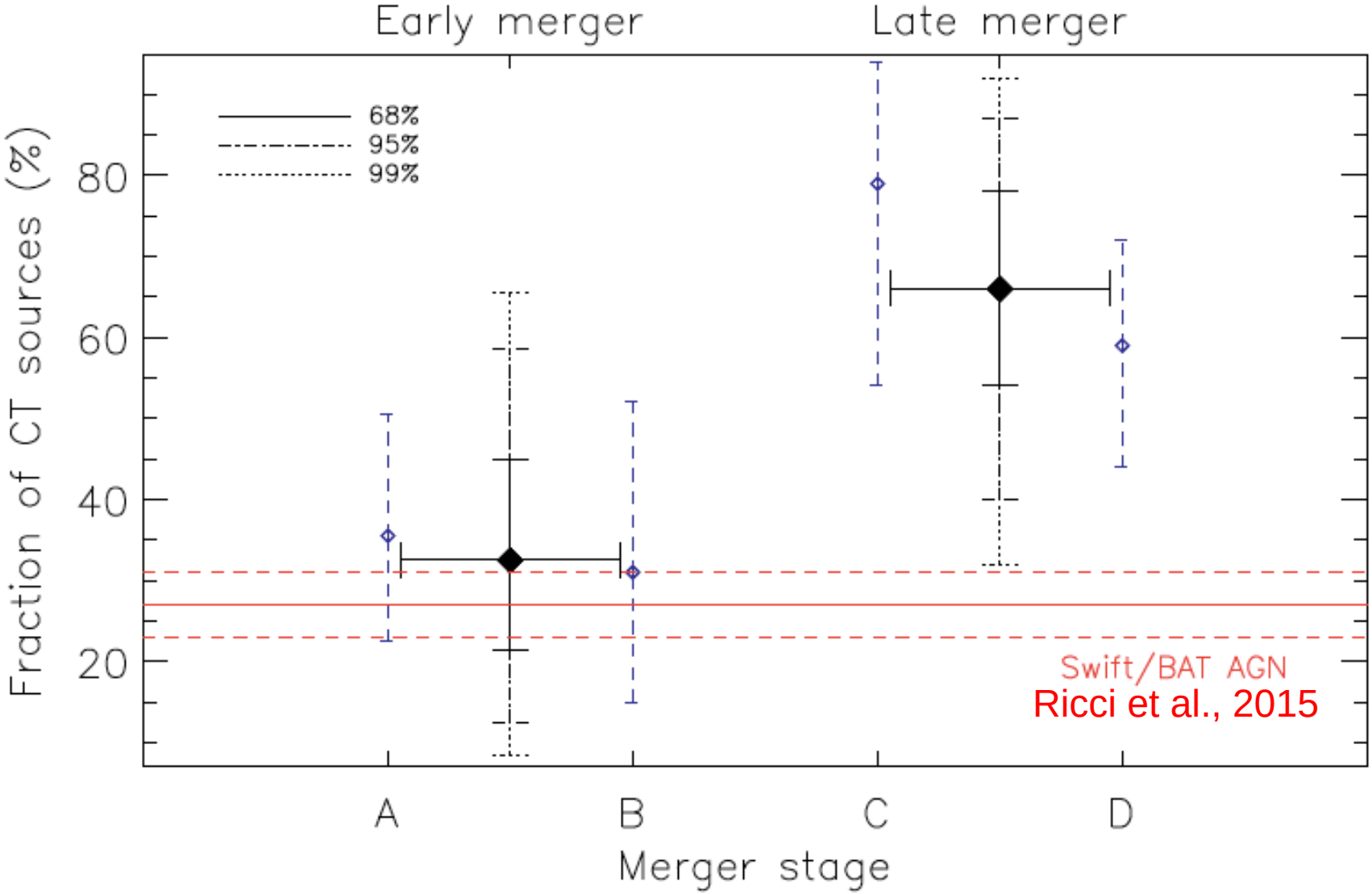
Ricci et al., submitted

AGN Fraction Versus Merger Stage



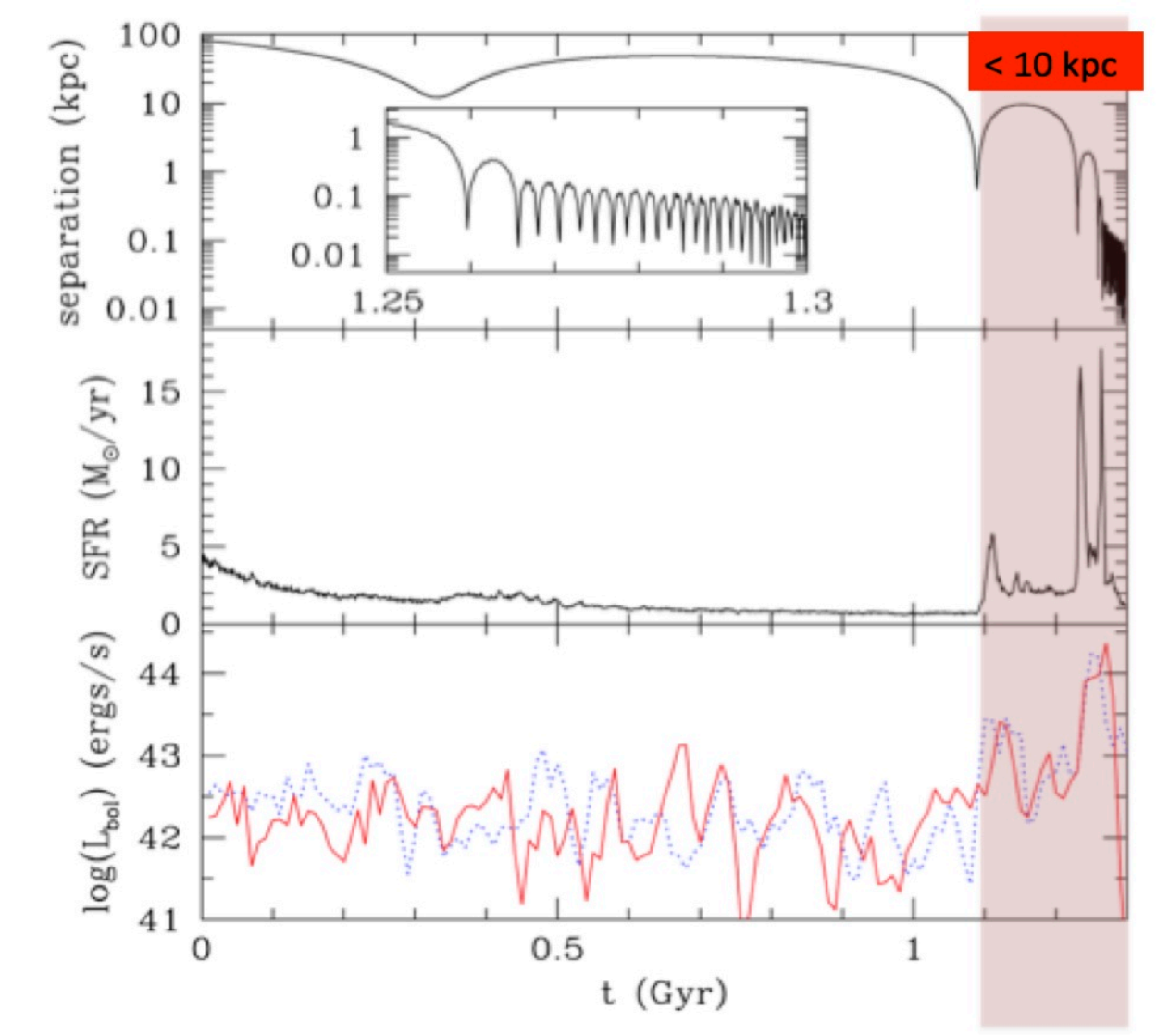
Ricci et al., submitted

Compton Thick AGN Fraction



Ricci et al., submitted

The Dual AGN Phase



Van Wassenhove et al. (2012)

Multiwavelength Observations of Dual AGN

MODA

Tracing the structure and kinematics of the gas in all its phases (atomic, ionized, molecular) in confirmed nearby dual AGN.

Main instruments: ALMA, VLT MUSE, SINFONI and VISIR, Keck/OSIRIS
Supporting observations with XMM, Chandra and NuSTAR

Sample: 17 confirmed (X-rays) dual AGN at $z<0.1$

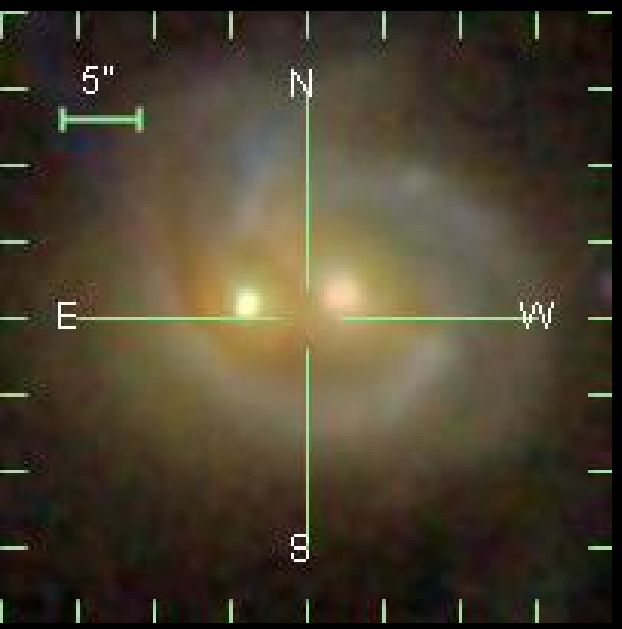
More info: http://moda.astro.puc.cl

Multiwavelength Observations of Dual AGN

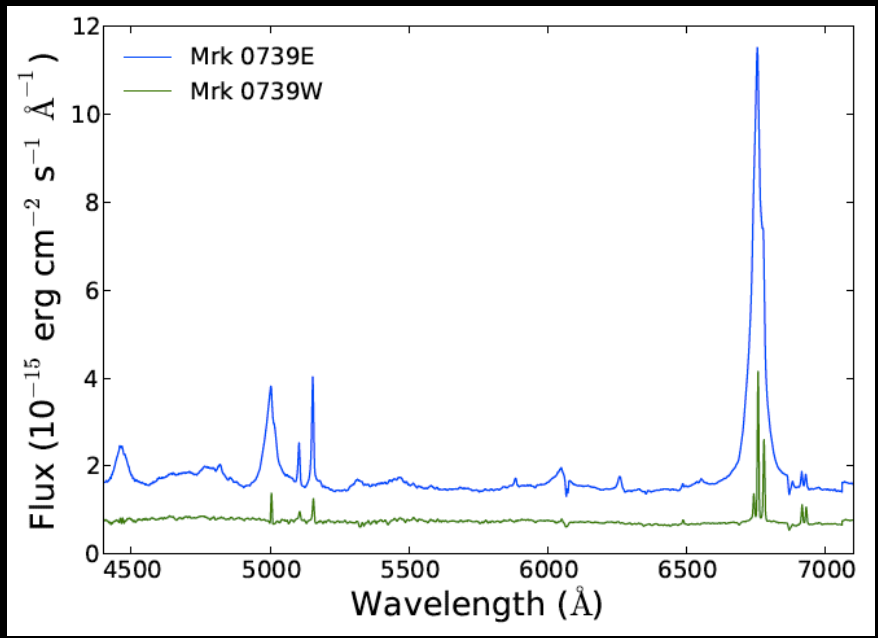
MODA

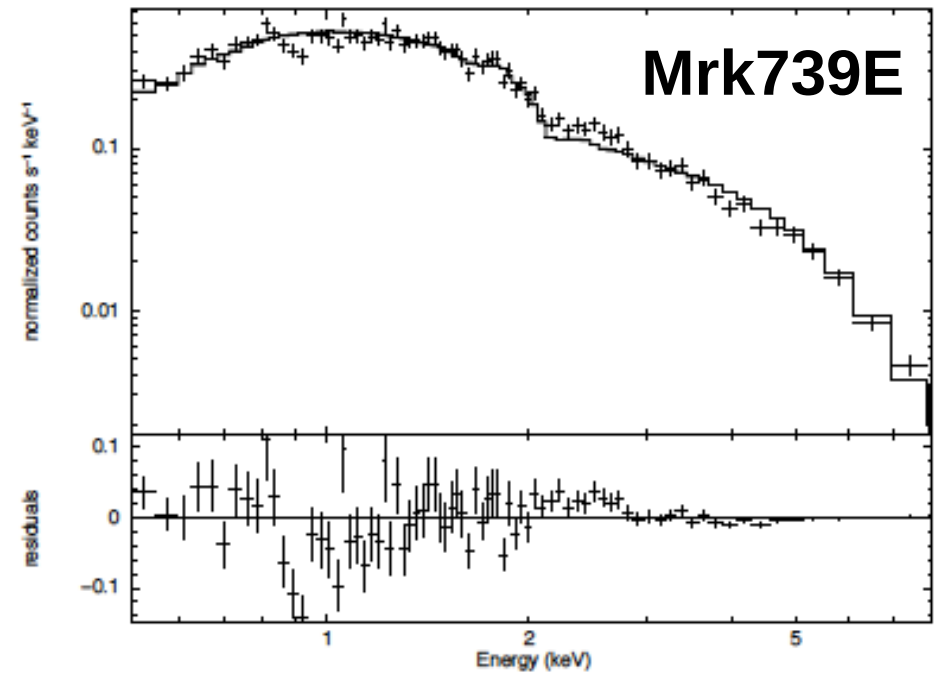
Results for the 3 dual (sep <10 kpc) AGN confirmed by Chandra observations: Mrk739, Mrk463, NGC6240

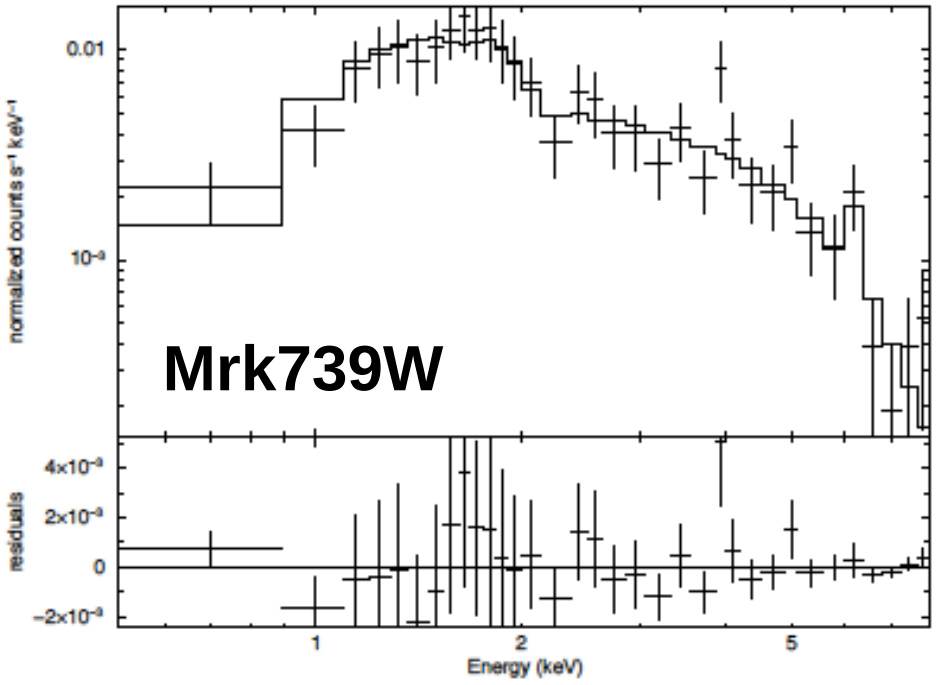
	Mrk739	**Mrk463**	**NGC6240**
Distance (Mpc)	130	220	103
Separation (kpc)	3.4	3.8	1.0
Log L_{FIR} (L_o)	10.6	11.1	11.5
Nuclear Obscuration	1 obscured, 1 unobscured	2 heavily obscured	2 heavily obscured



Mrk 739

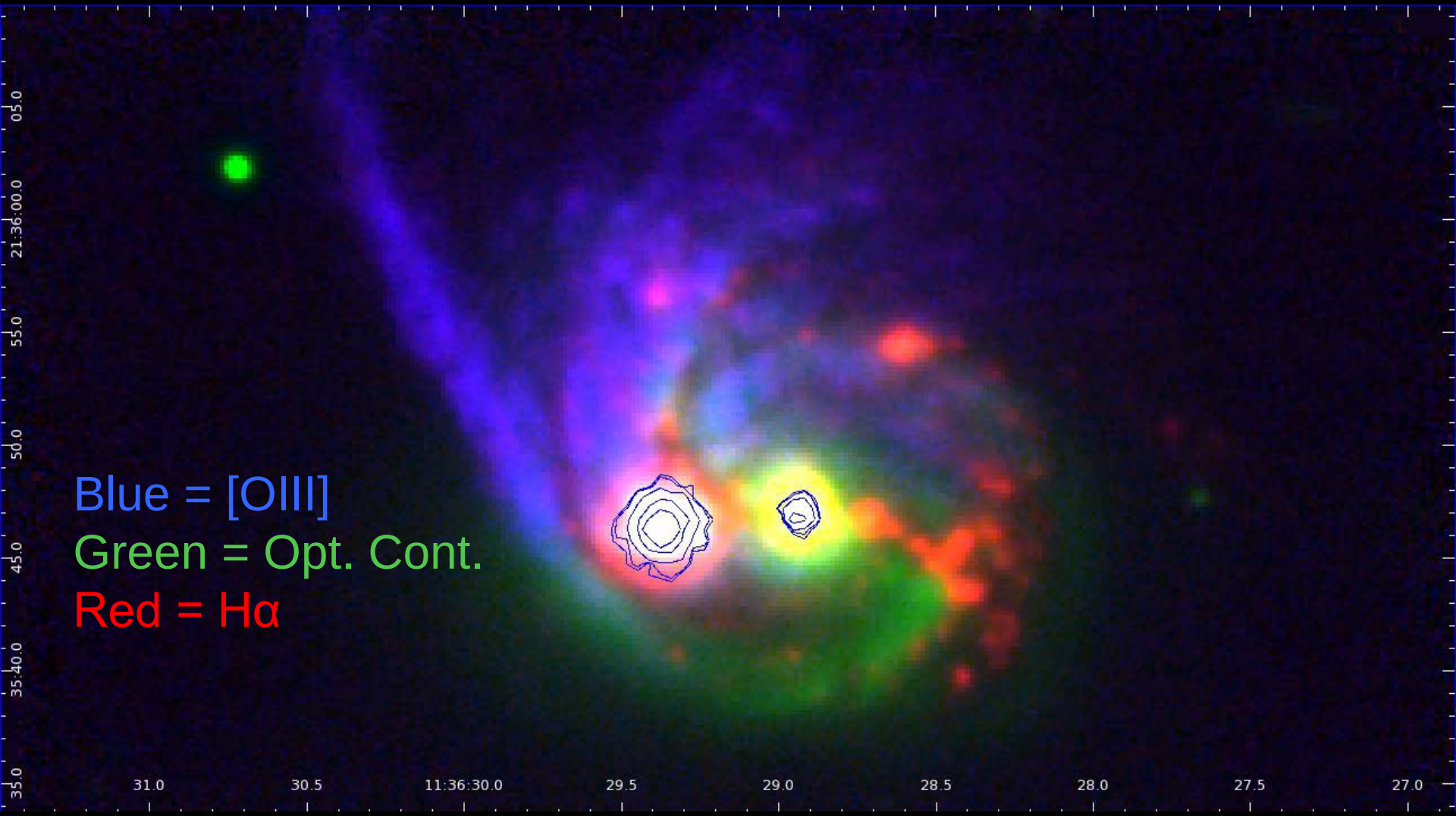






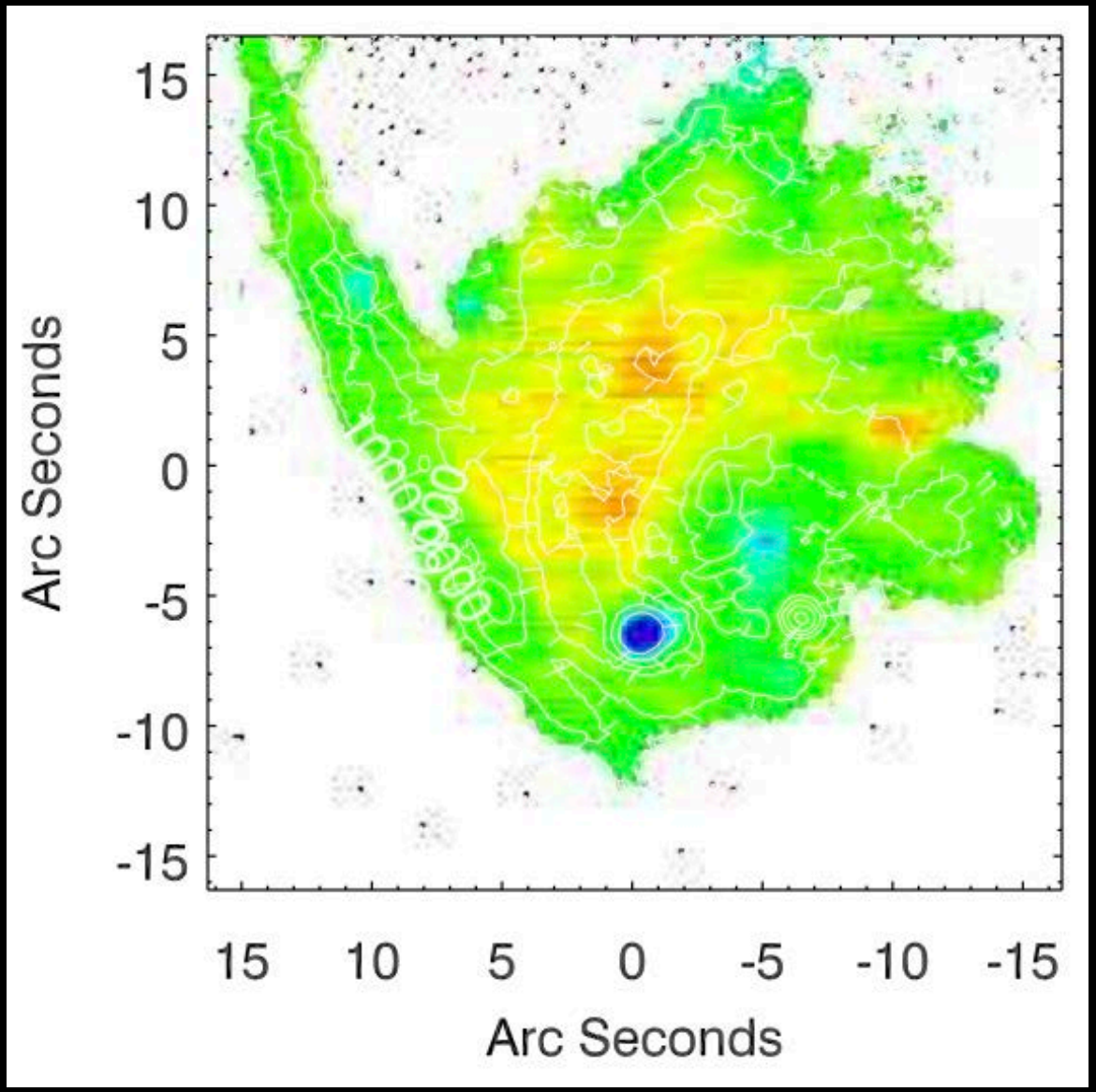
Koss et al. 2011

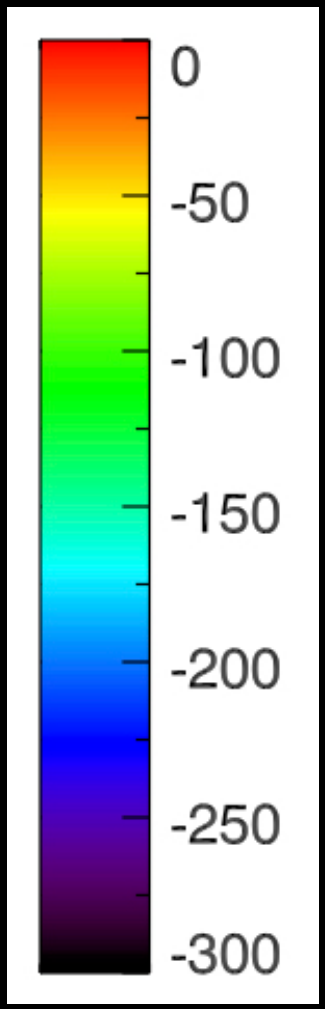
Mrk 739 MUSE Image



Treister et al., in prep.

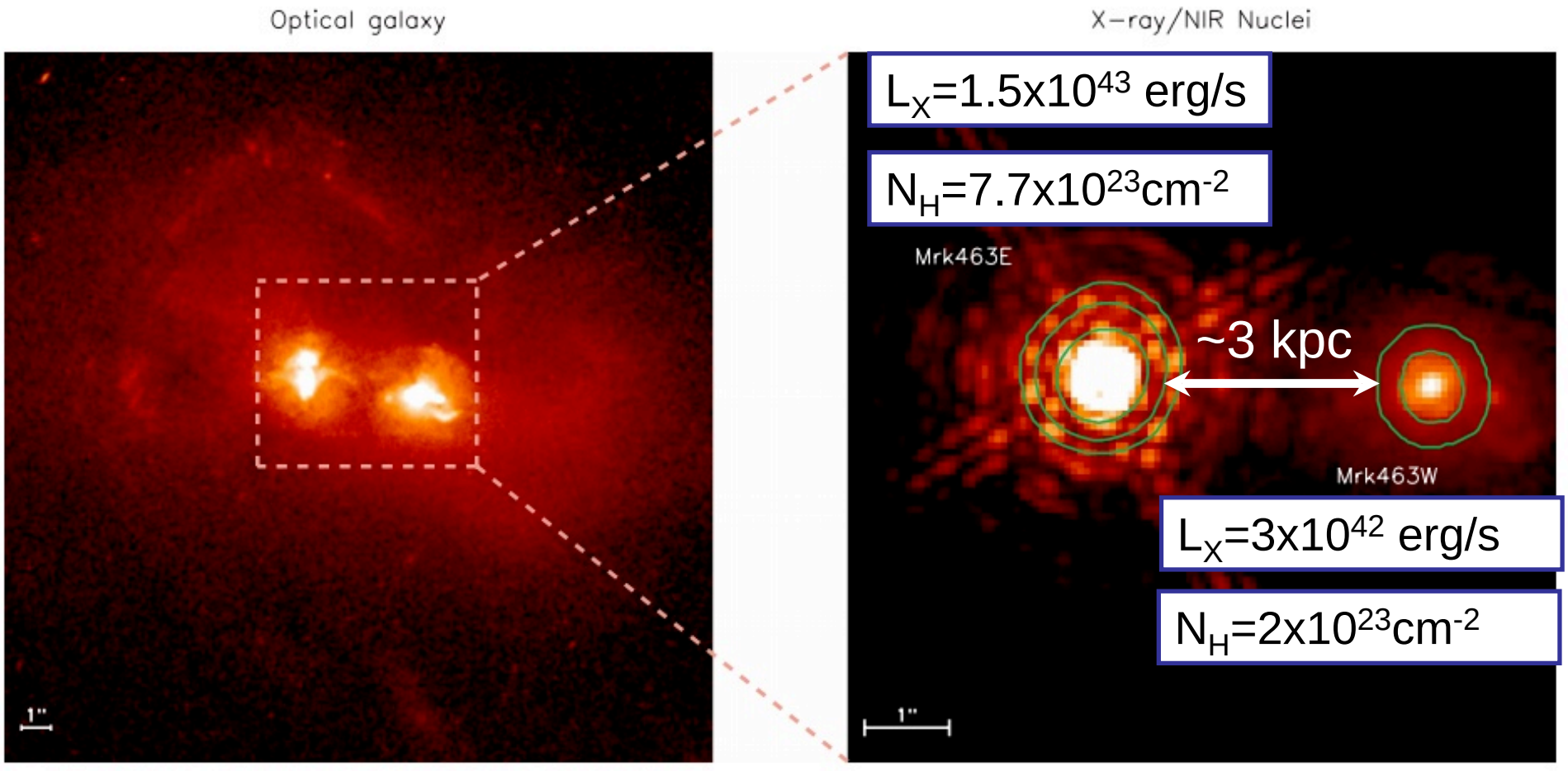
Mrk 739 [OIII] Velocity Profile





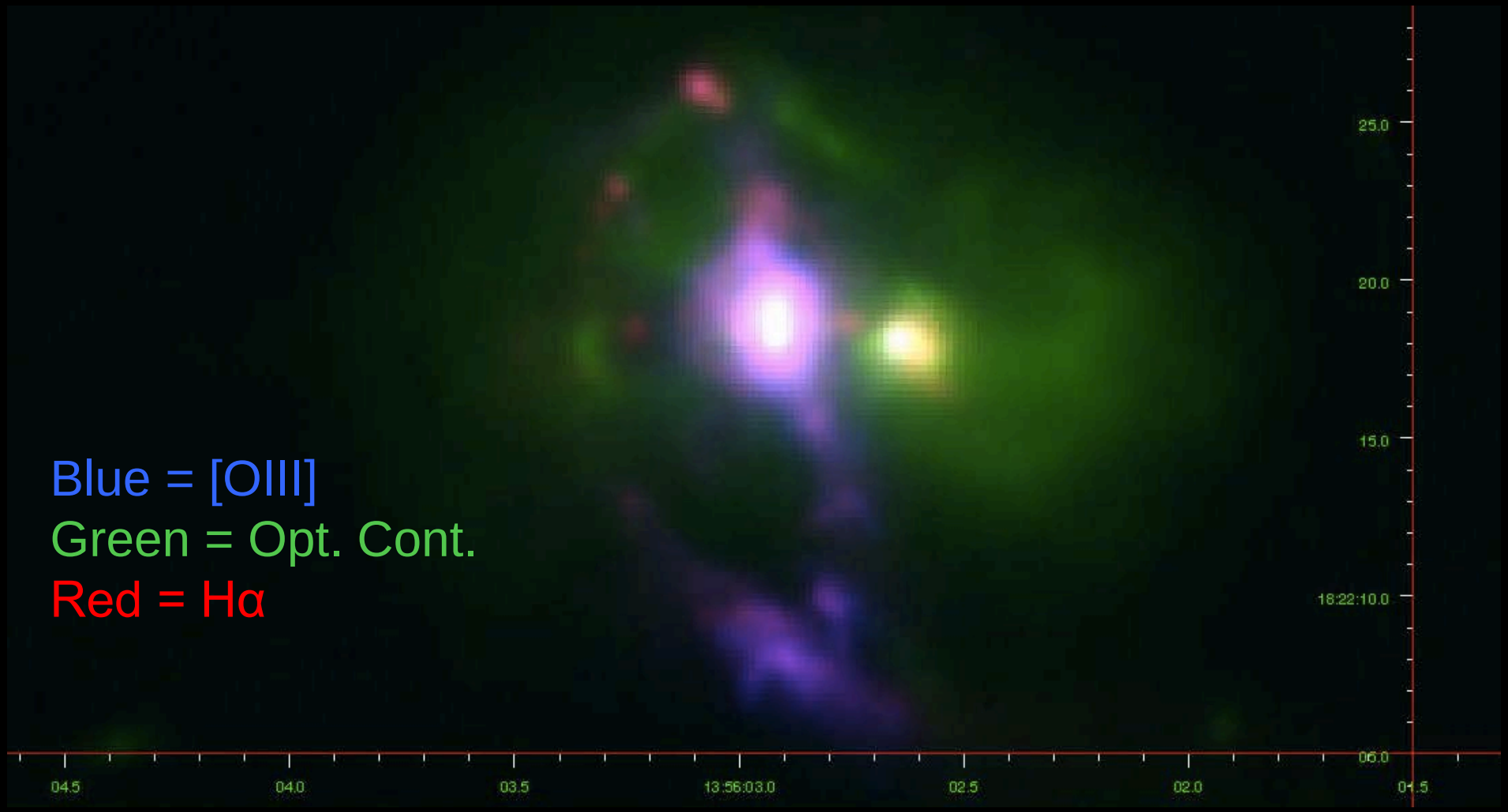
Treister et al., in prep.

Mrk 463



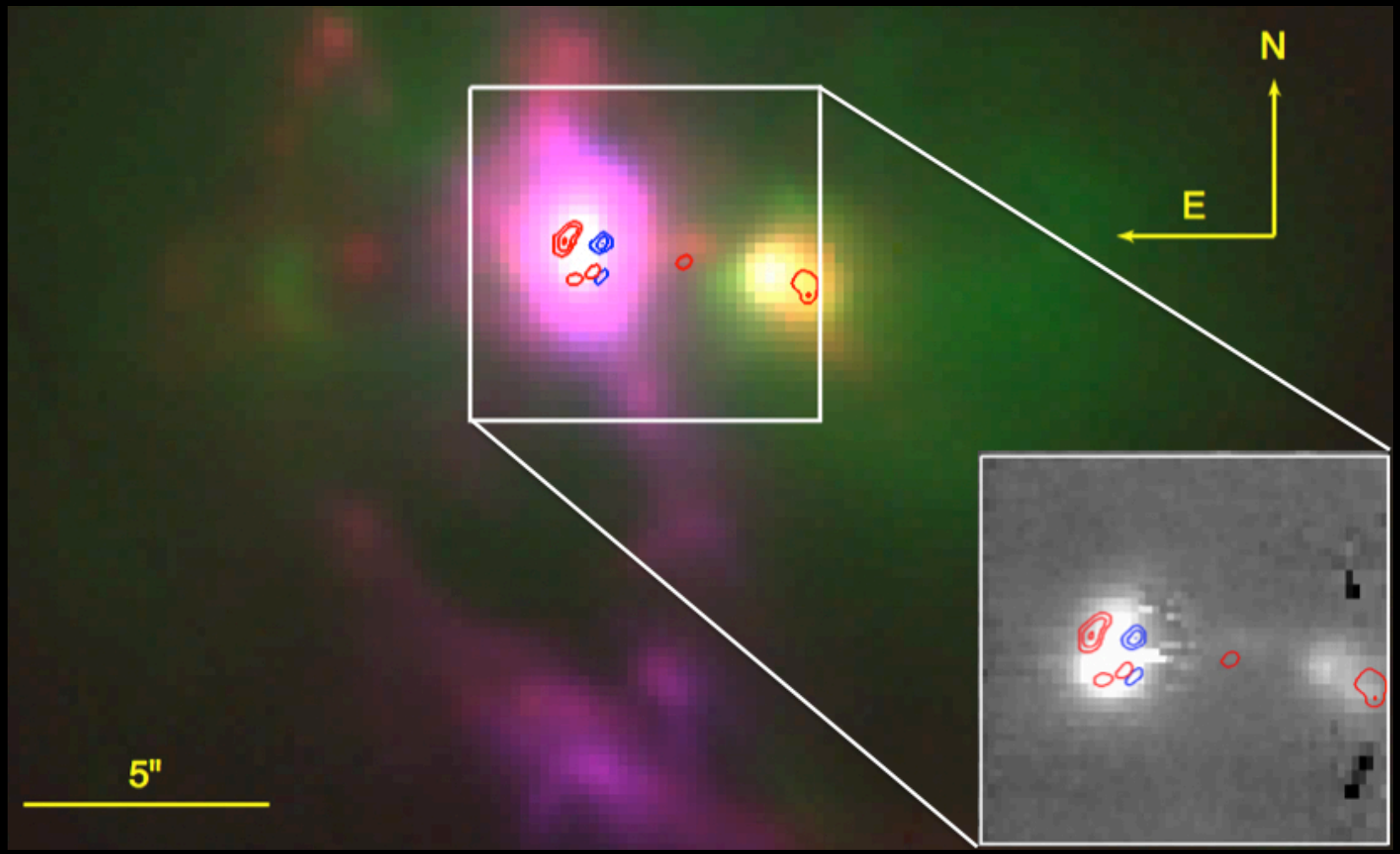
Bianchi et al., 2008

Mrk 463 MUSE Image



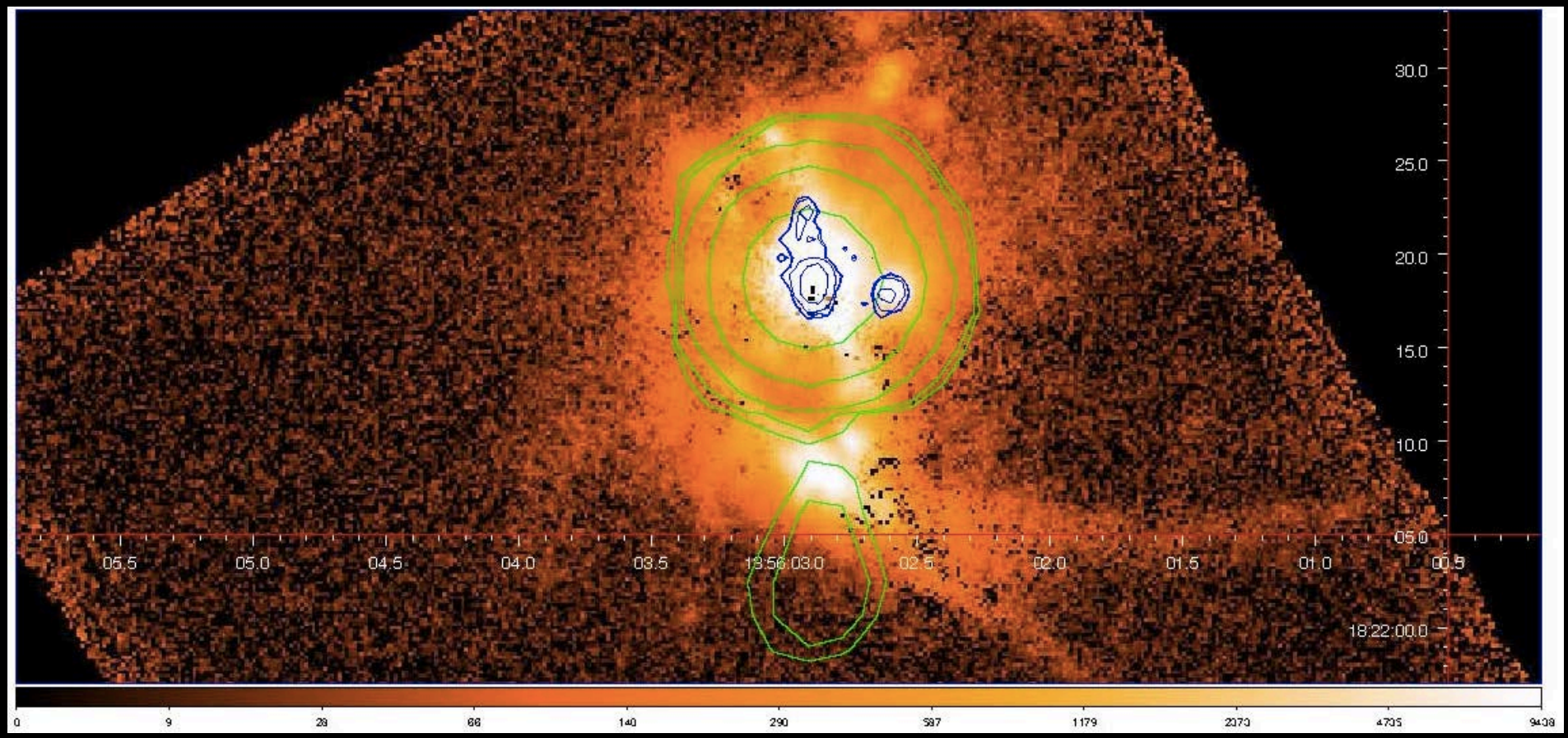
Treister et al., in prep.

Mrk 463 MUSE+SINFONI+ALMA



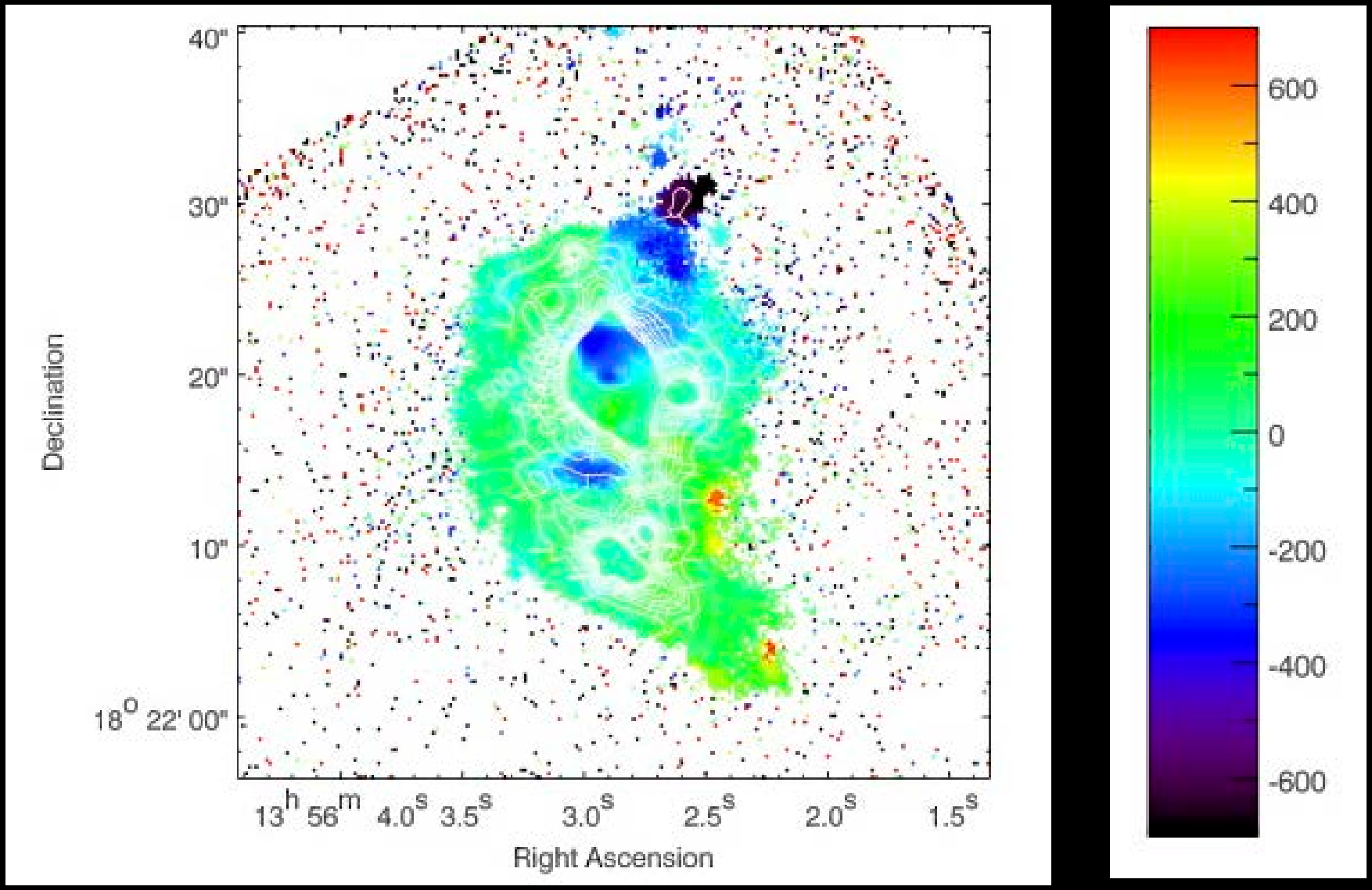
Treister et al., in prep.

Mrk 463 [OIII] Emission



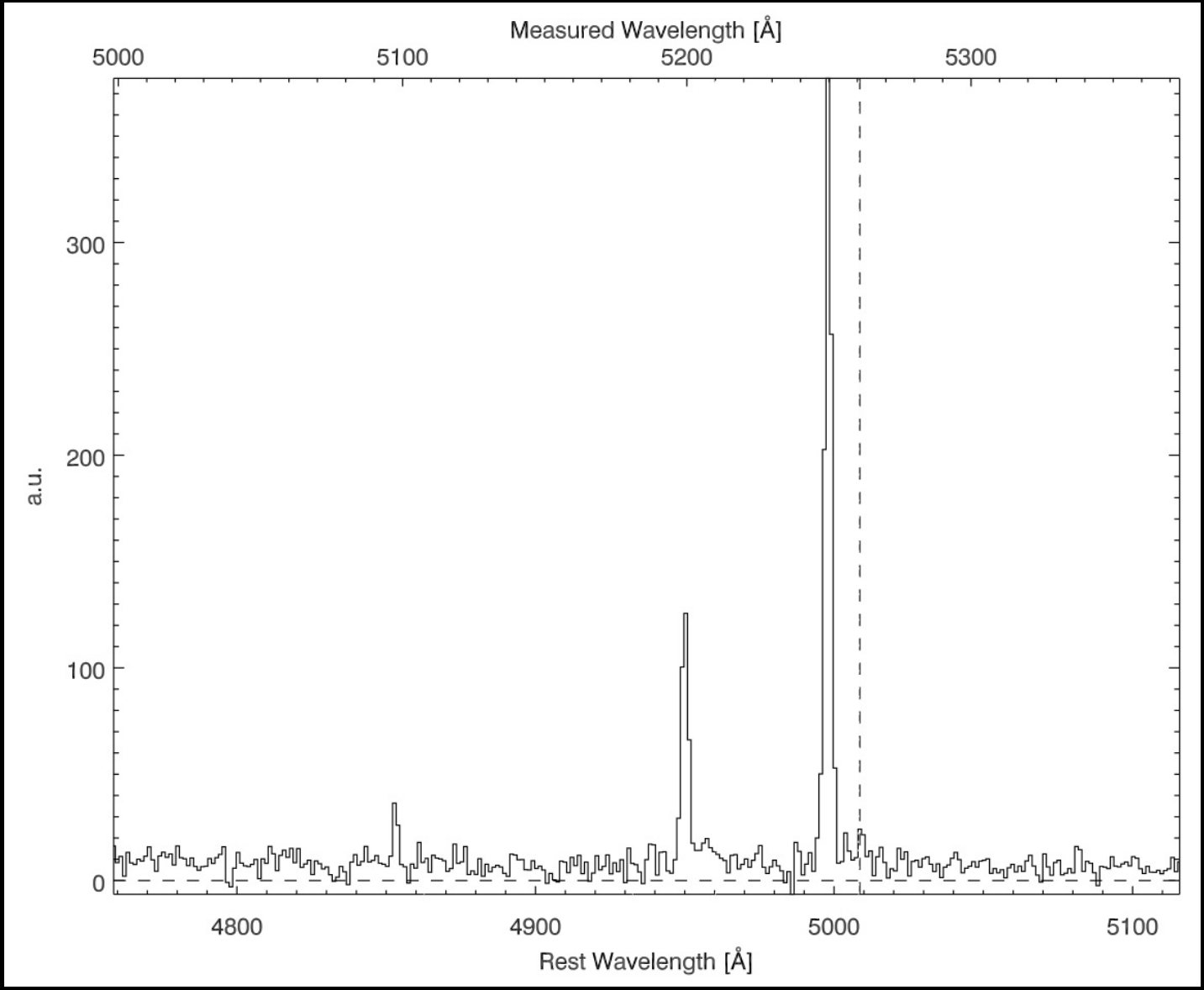
Treister et al., in prep.

Mrk 463 Velocity Profile



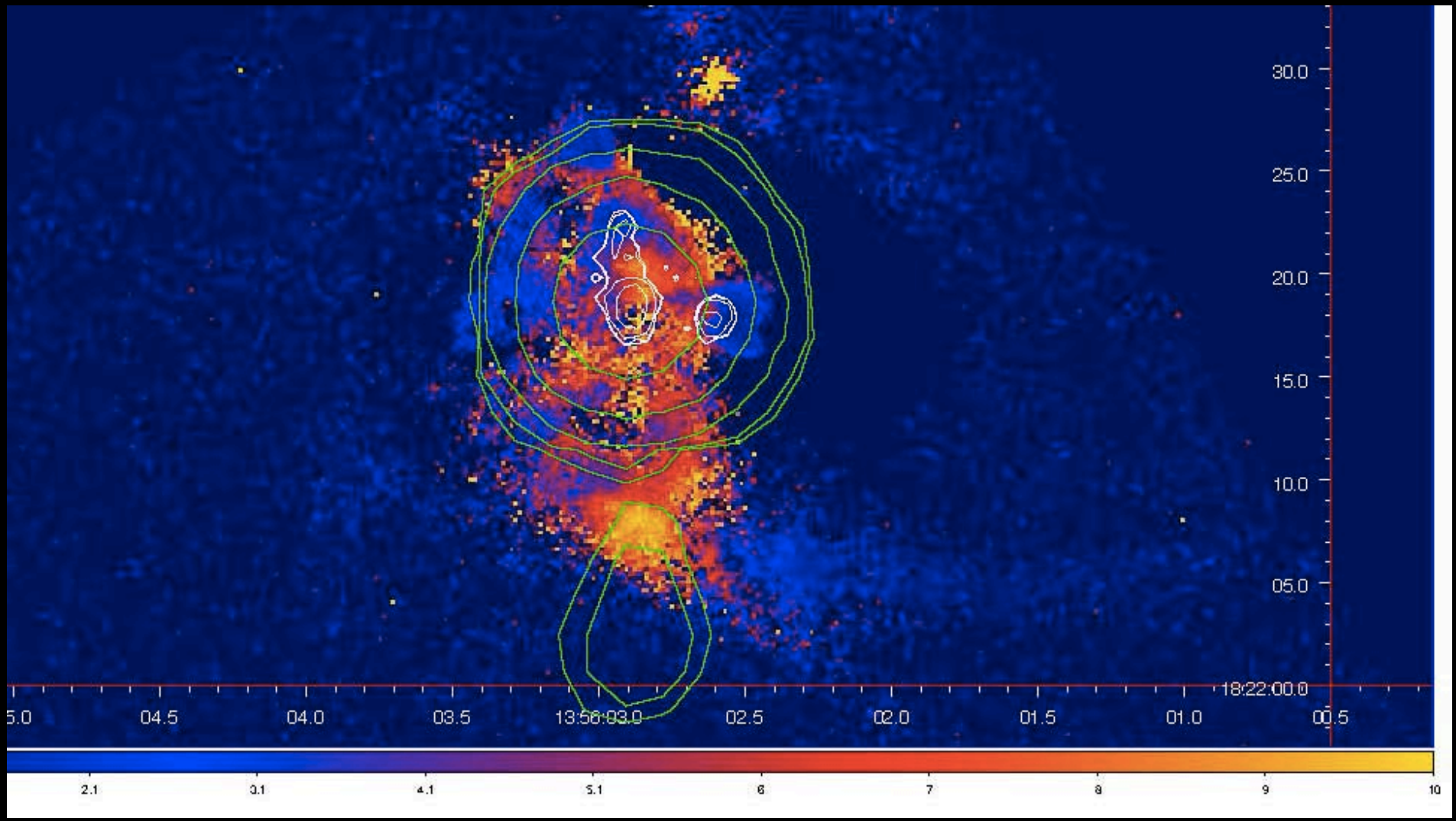
Treister et al., in prep.

Mrk 463 Outflow



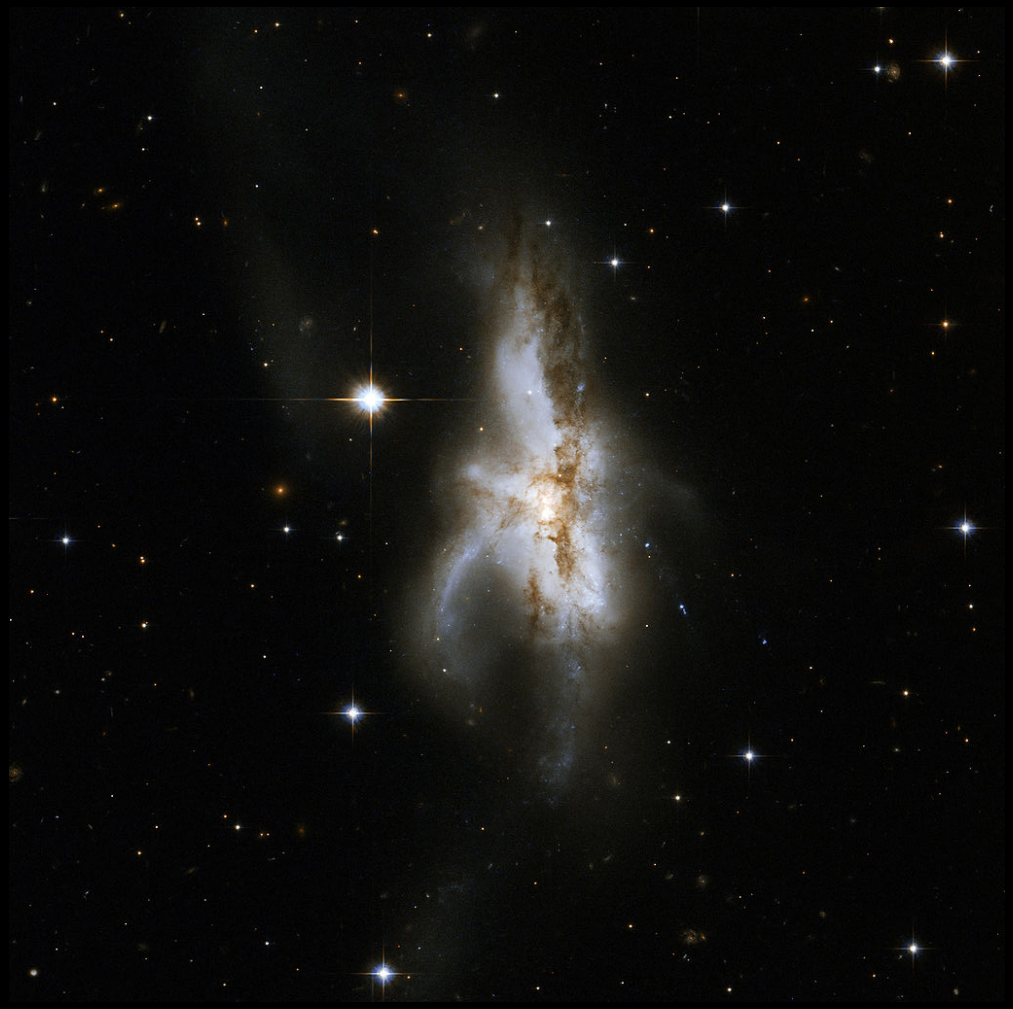
Treister et al., in prep.

Mrk 463 [OIII] to Hβ



Treister et al., in prep.

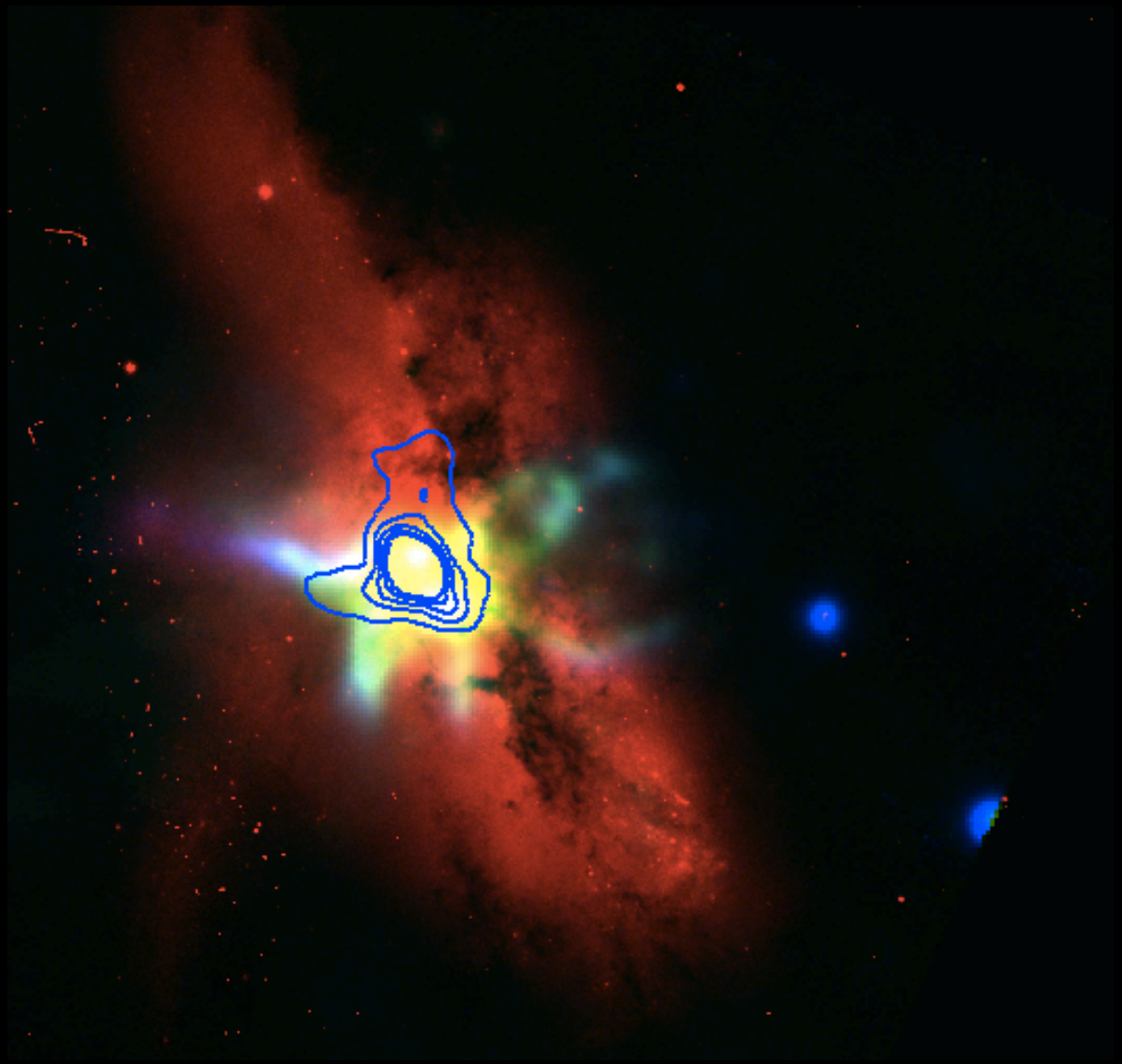
NGC6240



- $L_{IR}=8.5x10^{11}L_o$
- SFR≤150 $M_o yr^{-1}$
- Dual AGN
- Southern SMBH $M\approx10^9 M_o$

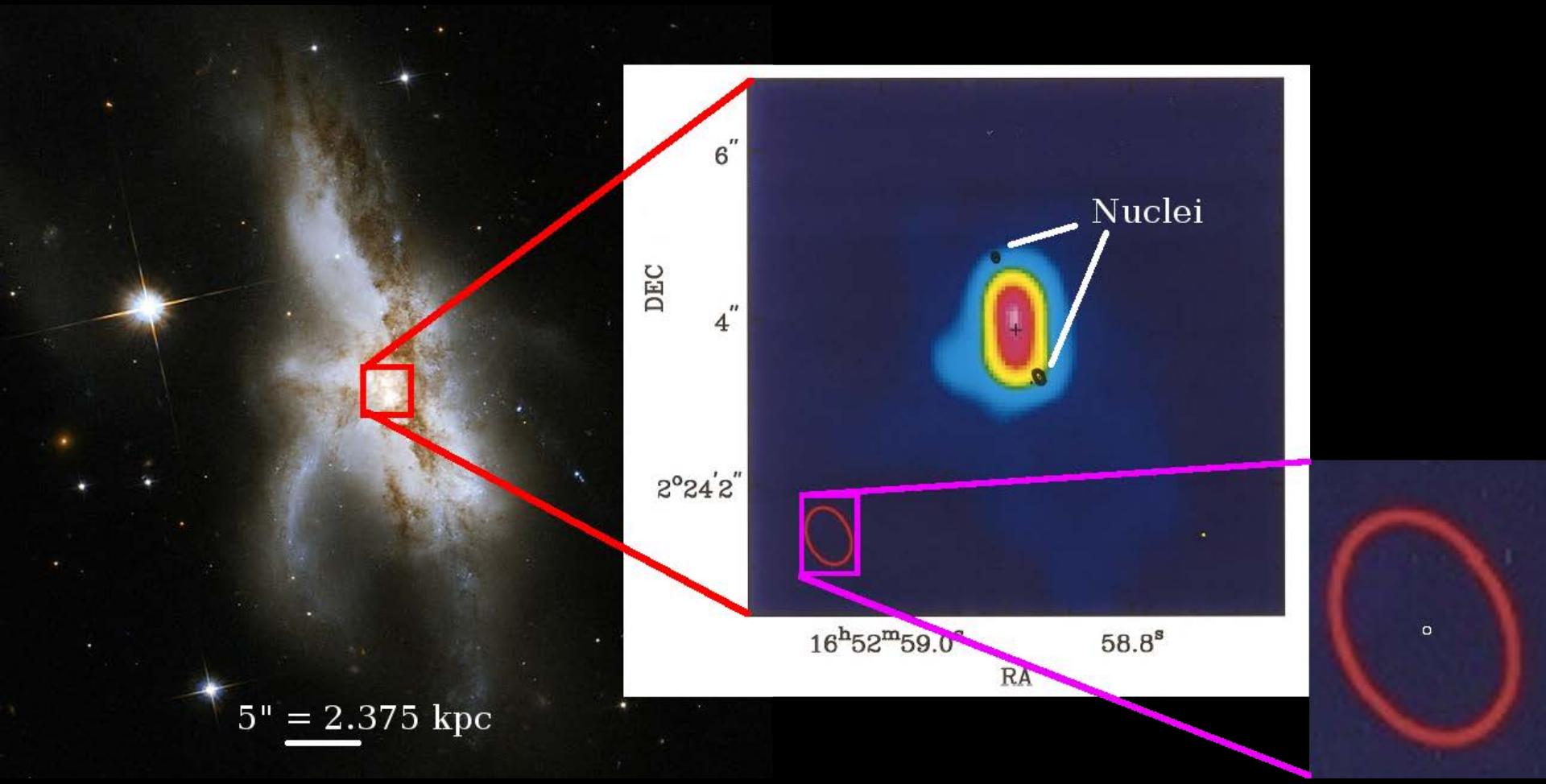
(Heckman+1987, Komossa+2003, Armus+2009, Medling+2011, Feruglio+2013ab)

Hα, [OIII] and CO Emission in NGC6240

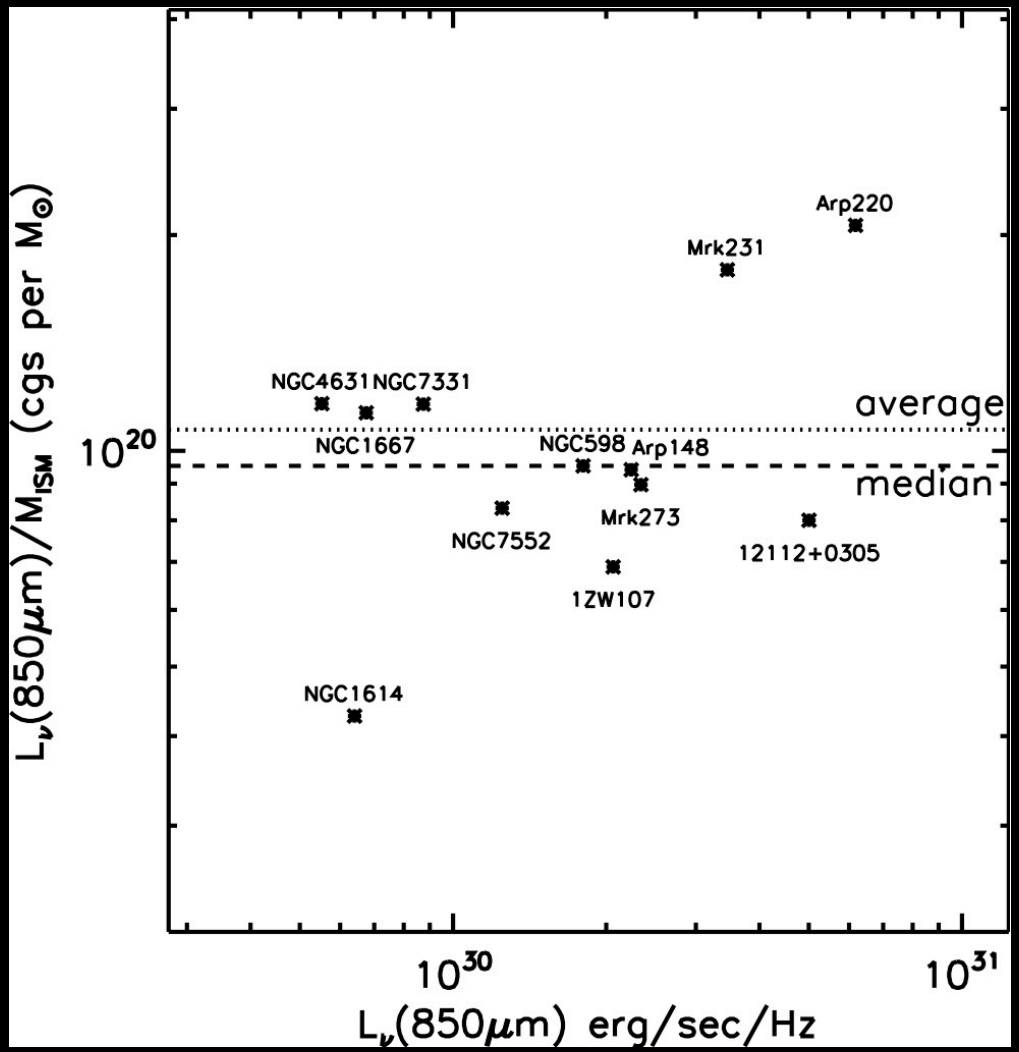


Privon et al., in prep.

ALMA Cycle 4 Observations of NGC6240



Measuring ISM Mass



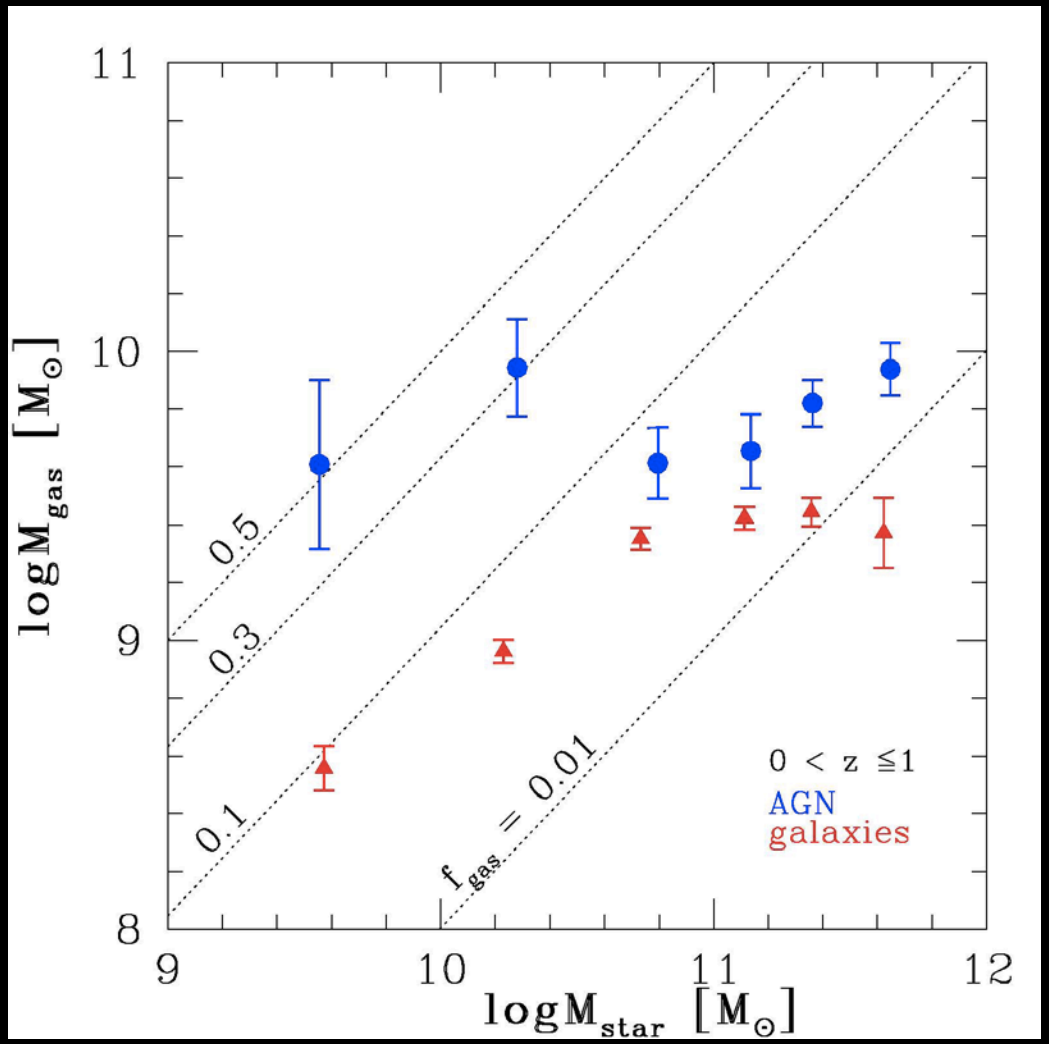
Good correlation between 850 um emission and ISM mass.

Can be used to measure mass directly from continuum measurements

~minutes per galaxy for ALMA

Scoville et al. (2012)

ISM Mass in AGN Host Galaxies



AGN appear to have higher gas masses than normal galaxies at the same stellar mass

We are extending this to z~3 AGN in the COSMOS field.

Ongoing ALMA cycle 4 program, ~8 hours in band 6.

Vito et al. (2014)

Summary

NuSTAR observations of volume limited sample of ULIRGs indicate higher AGN fraction when the two galaxies are near coalescence (stage C).

Also indication of more obscured system in these last interaction stages.

Optical and near-IR IFU studies of dual AGN show evidence of outflows and potentially feedback effects. These are the sources in which the SMBH-galaxy co-evolution takes place

Several ongoing ALMA projects aim to study the properties of the molecular gas and dust in AGN