# Molecular Gas in the Nuclear Regions of Nearby Dual AGN

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#### (c) Interaction/"Merger"



#### (d) Coalescence/(U)LIRG



#### (e) "Blowout"



#### (f) Quasar



#### (b) "Small Group"



NGC 7252

# **SMBH Growth and SF Simulations**



Van Wassenhove et al. (2012)



Blecha et al. (2011)

# **SMBH Growth and SF Simulations**



Blecha et al. (2018)

#### **Compton Thick AGN Fraction**



Ricci et al. (2017)

### **AO Observations of Swift-BAT AGN**

![](_page_5_Picture_1.jpeg)

Koss et al. (2018)

### **AO Observations of Swift-BAT AGN**

![](_page_6_Figure_1.jpeg)

Koss et al. (2018)

# The Importance of Dual AGN

![](_page_7_Picture_1.jpeg)

# 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 information: http://moda.astro.puc.cl

#### Mrk 463

Optical galaxy

X-ray/NIR Nuclei

![](_page_9_Figure_3.jpeg)

Bianchi et al., 2008

### Mrk 463 MUSE Image

![](_page_10_Figure_1.jpeg)

Treister et al., 2018

# Mrk 463 [OIII] to Hβ

![](_page_11_Figure_1.jpeg)

Treister et al., 2018

### Mrk 463 [OIII] Velocity Diagram

![](_page_12_Figure_1.jpeg)

Treister et al., 2018

## Mrk 463 ALMA CO(2-1) Velocity Map

![](_page_13_Figure_1.jpeg)

# NGC6240

![](_page_14_Picture_1.jpeg)

- $L_{IR} = 8.5 \times 10^{11} L_{o}$
- SFR≤150 M<sub>o</sub>yr<sup>-1</sup>
- Dual AGN
- Each SMBH M≈8x10<sup>8</sup>M<sub>o</sub> (Medling+2015)

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

#### ALMA Cycle 4 Observations of NGC6240

![](_page_15_Picture_1.jpeg)

Blue = F450W HST Green = F814W HST Red = ALMA CO(2-1) 2" Band 6 CO(2-1) ~0.03" res (15pc) ~5 hrs integration

Ν

# IRAM PdBI CO(2-1) Map

![](_page_16_Figure_1.jpeg)

Tacconi et al. 1999

### ALMA Cycle 4 Observations of NGC6240

![](_page_17_Picture_1.jpeg)

### NGC6240 CO(2-1) Moment 0 Map

![](_page_18_Figure_1.jpeg)

 $1.2 \times 10^{10} M_{o}$  in mol. gas in central region. **BH** Sphere of influence ~220pc (15 res elements) Southern nucleus: 1.5x10<sup>9</sup>M<sub>o</sub> Northern nucleus: 6.6x10<sup>8</sup>M<sub>o</sub>

## Continuum

NGC6240 235 GHz Continuum

![](_page_19_Figure_2.jpeg)

Detected continuum emission around nuclei.

Southern nucleus:  $1.5 \times 10^9 M_o$  (~half unresolved)

Northern nucleus: 8.5x10<sup>8</sup>M<sub>o</sub>

## NGC6240 CO(2-1) Velocity Map

![](_page_20_Figure_1.jpeg)

Velocity gradient between the nuclei ~500km/s outflow, ~ $10^9M_o$  of mol. gas Rotation in southern nucleus, gradient in northern one.

![](_page_20_Figure_3.jpeg)

#### **High Velocity Structure**

![](_page_21_Figure_1.jpeg)

>500km/s structure

 $\sim 10^9 M_o$  of mol. gas

Appears connected with the Northern nucleus

# **Southern SMBH Mass**

![](_page_22_Figure_1.jpeg)

Enclosed mass in southern ~30pc >2x10<sup>8</sup>M<sub>o</sub>

Broadly consistent with previous measurement by Medling et al. 2015: ~8.8x10<sup>8</sup>M<sub>o</sub>

## **M-Sigma Relation**

![](_page_23_Figure_1.jpeg)

Medling et al. (2015)

### **M-Sigma Relation**

![](_page_24_Figure_1.jpeg)

System still has  $\sim 10^{10} M_0$  in the central region available for both star formation and SMBH growth

Medling et al. (2015)

# Conclusions

Significant (heavily obscured) SMBH associated with major galaxy mergers, in particular near coalescence.

The dual AGN phase can be very important to establish the SMBH galaxy evolution connection.

Mrk 463 shows potential molecular inflows of ~100  $M_0$ /yr, comparable to the observed ionized outflows and SFR. Evidence for AGN-driven outflows reaching scales of 10s kpc.

High resolution (15pc) ALMA CO(2-1) observations show filamentary clumpy structure between the two nuclei, with  $\sim 10^{10}M_0$  in molecular gas.

While currently above the M-sigma relation, enough mol. gas to reach the correlation.