THE QUEST FOR DUAL AND BINARY AGN SYSTEMS

PROGRAM: 2018 - 2030

RSN1 (PRIMARY)

RSN4 – RSN5 (SECONDARY)

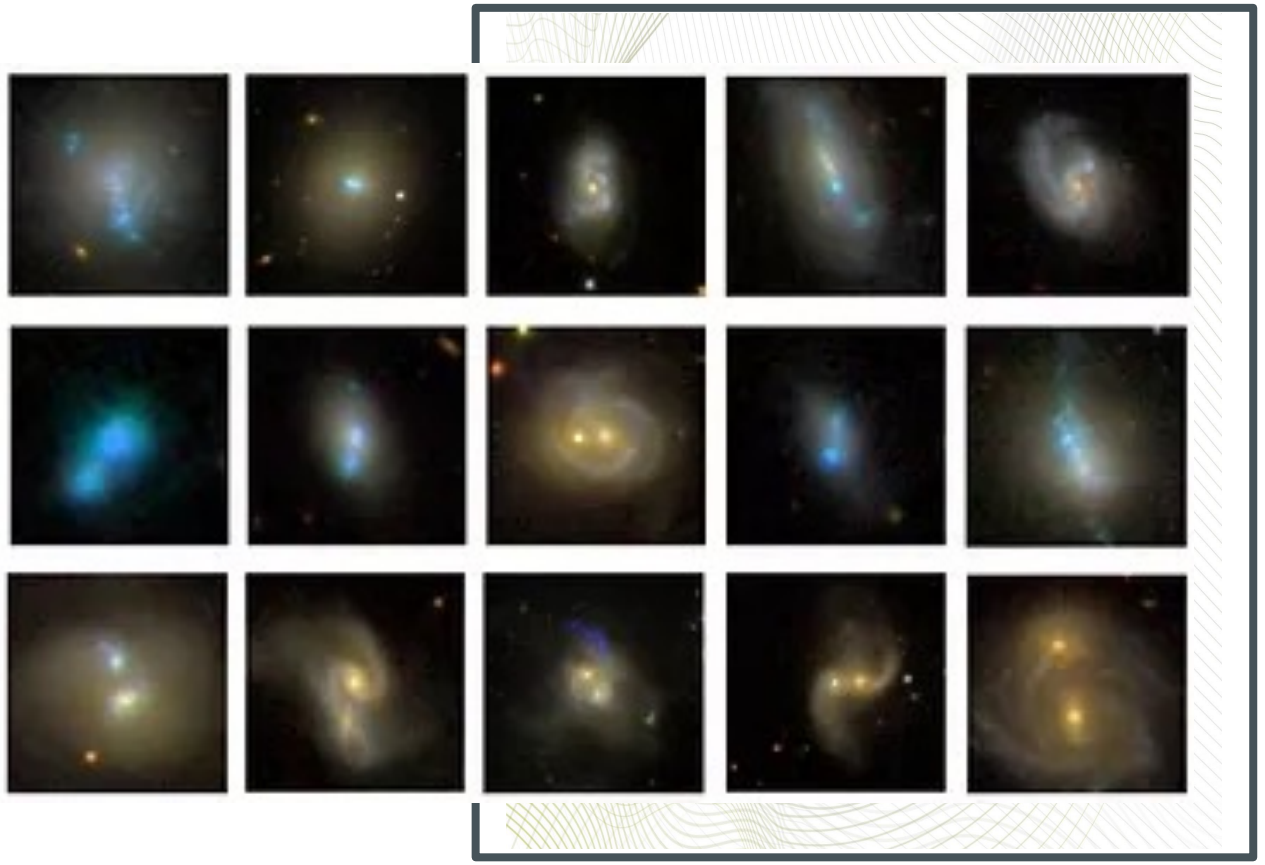
PRINCIPAL COORDINATORS:

Paola Severgnini (INAF-OABrera, Milano)

Alessandra De Rosa (INAF-IAPS, Roma)

Filippo Mannucci (INAF-Arcetri, Fienze)

Cristian Vignali (Ass. INAF-OAS Bologna)



TEAM: INAF institutes, Italian Universities and abroad Institutes

31 members: 19 INAF + 12 assoc.

2022-2024: ~ 2.4 FTE/yrs (1.9 INAF + 0.5 assoc.)

INAF	
OABrera - Milano	IAPS - Roma
P. Severgnini	A. De Rosa
V. Braito	R. Serafinelli (AdR)
A. Caccianiga	
R. Della Ceca	OA-Arcetri - Firenze
I. Del Vecchio	F. Mannucci
M. Landoni	F. Belfiore
A. Moretti	G. Cresci
P. Saracco	E. Nardini
	E. Pancino
OAS - Bologna	OA-Abruzzo - Teramo
F. Cusano	G. Di Rico
M. Dadina	E. Portaluri

Assoc.	
Uni. Bologna	Un. Bicocca Milano
C. Vignali	M. Colpi
	M. Bonetti (AdR)
Uni. Roma 3	M. Dotti
S. Bianchi	A. Sesana
Uni. Oslo	Uni. Firenze
C. Cicone	A. Marconi
	G. Tozzi
ESA/ESAC	
L. Ballo	Uni. Trento
	A. Perego
GSSI	
J. Harns	

TEAM WITH HIGH LEVEL OF EXPERTISE:

- ✓ **Observational:** reduction, analysis and interpretation of MW data
- ✓ **Theorical:** dynamic and kinematic properties of SMBH in binary / dual systems
- ✓ **Instrumental:** development of new instrumentation

❖ Training of Master and Bachelor students

Additionally, many external international collaborators (MPIA, MPIFR, Georgia Inst. of Technology, Columbia Univ., Jive, IAA-CSIC, UCLA e Keck obs.)

SCIENTIFIC CASE: DUAL/BINARY AGN

THEORETICAL PREDICTIONS:

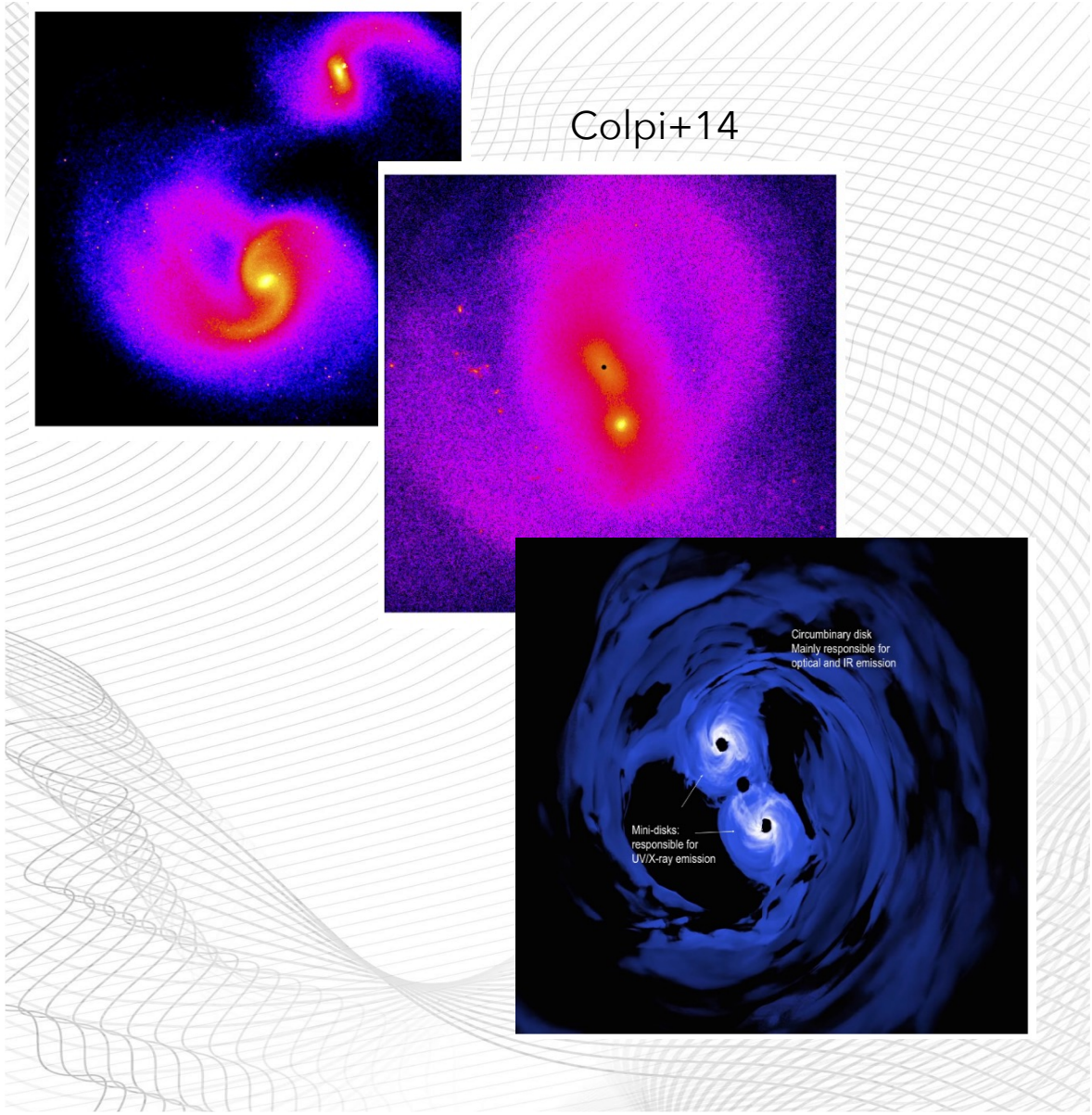
Galaxy interactions trigger AGN
in advanced-stage merger
(Van Wassenhove+12, Blecha+13, Capelo+15)

Dual AGN ($M_{BH}>10^5\ M_{sun}$):
sep.: several kpc down to sub-kpc
(early and late stage of galaxy merger)

Binary AGN: gravitational bounded SMBHs
(pc/sub-pc sep., post-merged galaxy)

Coalescence: the two SMBHs merge producing a single black hole

De Rosa+19, NewAR, 8601525



SCIENTIFIC CASE: DUAL/BINARY AGN

THEORETICAL PREDICTIONS:

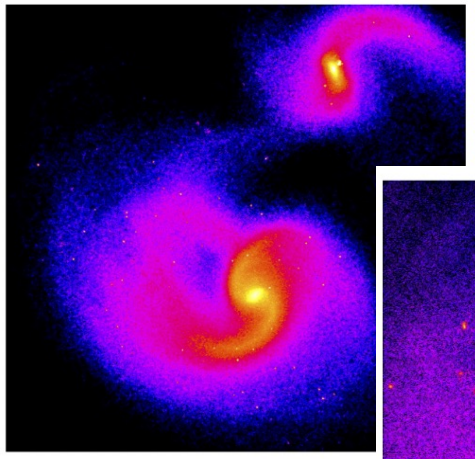
Galaxy interactions trigger AGN
in advanced-stage merger
(Van Wassenhove+12, Blecha+13, Capelo+15)

Dual AGN ($M_{BH}>10^5\ M_{sun}$):
sep.: several kpc down to sub-kpc
(early and late stage of galaxy merger)

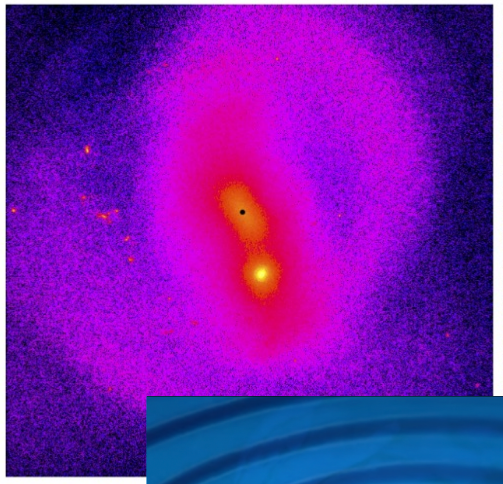
Binary AGN: gravitational bounded SMBHs
(pc/sub-pc sep., post-merged galaxy)

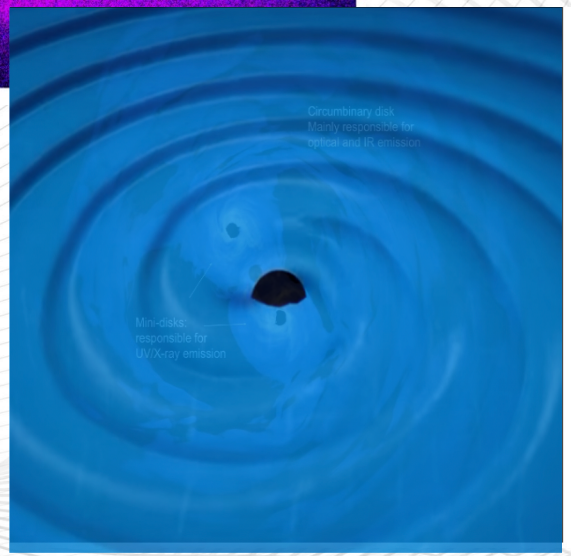
Coalescence: the two SMBHs merge producing a single black hole

Emission of GW in the low-frequency ranges
(PTA, LISA, LGWA)



Colpi+14

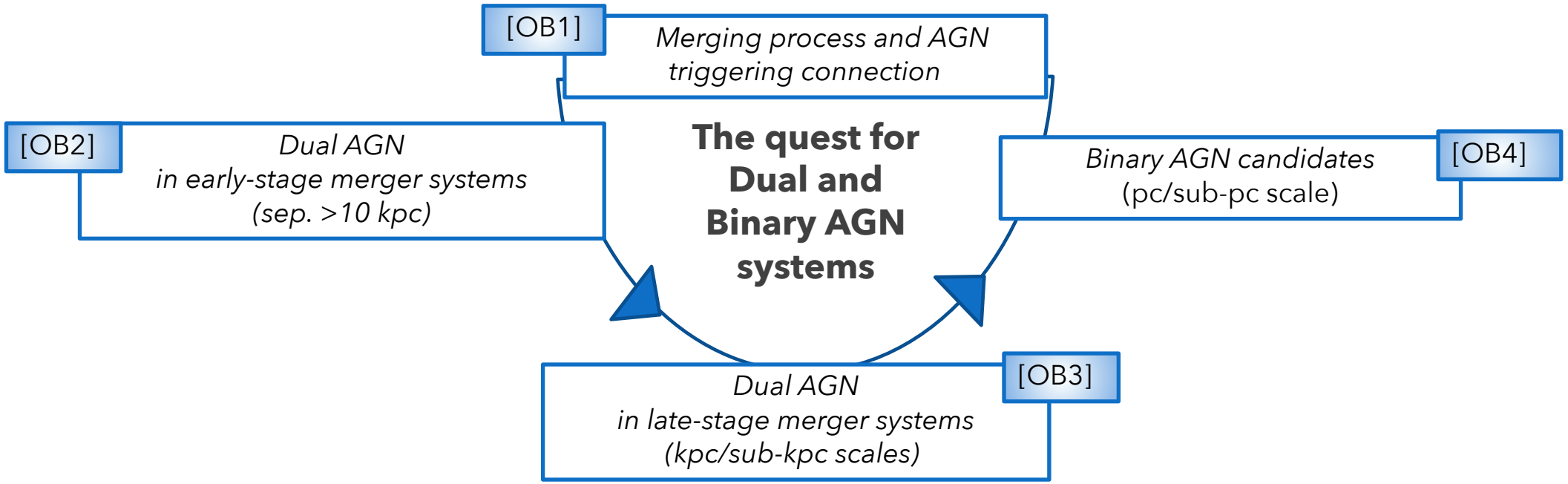




De Rosa+19, NewAR, 8601525

OUR PROGRAM – OBJECTIVES [OB]

AIM: Testing theorical predictions regarding the incidence, properties and evolution of dual/binary AGN in interacting galaxies

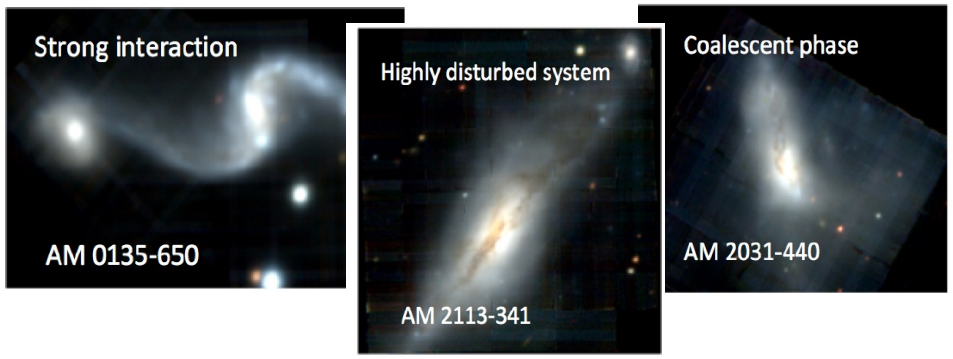


DATA & PLANNINGS [OB1]

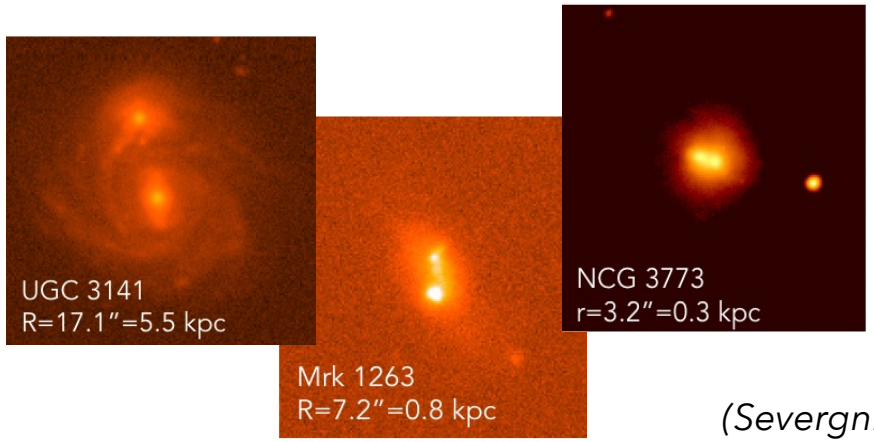
Merging process and AGN triggering connection

[Coord.: De Rosa, Severgnini, Vignali]

SAMPLES: optically selected interacting systems (from 100 kpc down to sub-kpc scales)



SOSIMPLE
~150 src
(Davison+21)



Mezcua et al (2014)
sample: ~52 src

(Severgnini et al. in prep.)

GOALS:

(1) estimate the fraction of single and dual AGN in mergers vs. the relative separation (Severgnini et al. in prep.)
(2) comparison with samples of non-interacting gal.
(3) comparison with AGN triggering models

ARCHIVAL DATA: SDSS, HST, MUSE, XMM and Chandra

DEDICATED OBSERVATIONS (INAF-PI):

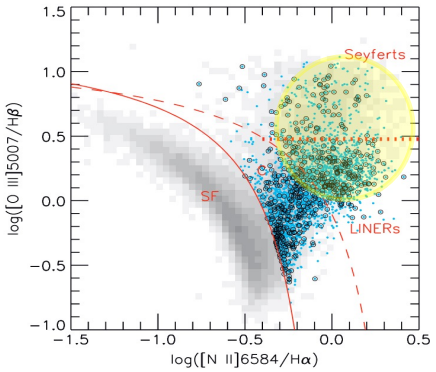
Facility	Instrum.	Time	type	Status
SWIFT	**XRT**	**300 ks**	**X-ray imaging/spectroscopy**	**on-going**
CHANDRA		**180 ks**	**X-ray imaging/spectroscopy**	**on-going**
ESO/VLT	**FORS2**	**14h**	**High S/N, narrow-slit spectroscopy**	**executed**
LBT	MODS	14 h	High S/N, narrow-slit spectroscopy	submitted
CHANDRA		50 ks	X-ray imaging/spectroscopy	submitted

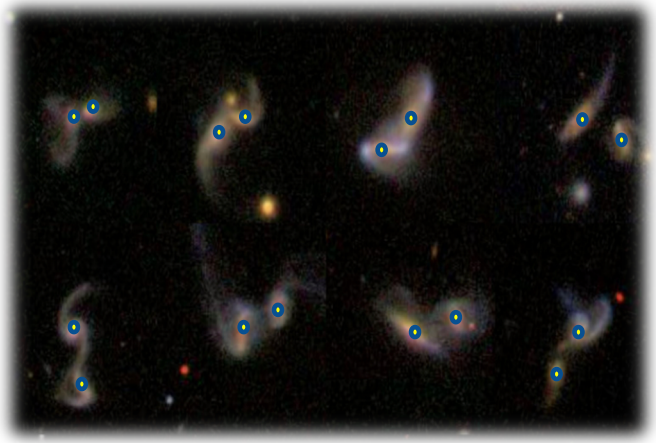
DATA, PLANNINGS & EARLY RESULTS [OB2]

Dual AGN in early-stage merger systems (sep.>10 kpc)

[Coord.: De Rosa, Severgnini, Vignali]

SAMPLE: SDSS spectroscopically selected dual AGN with sep>10 kpc (Liu+11, Whang+09, Smith+10)





ARCHIVAL DATA: XMM and Chandra ~ 100 sources

DEDICATED OBSERVATIONS (INAF-PI):

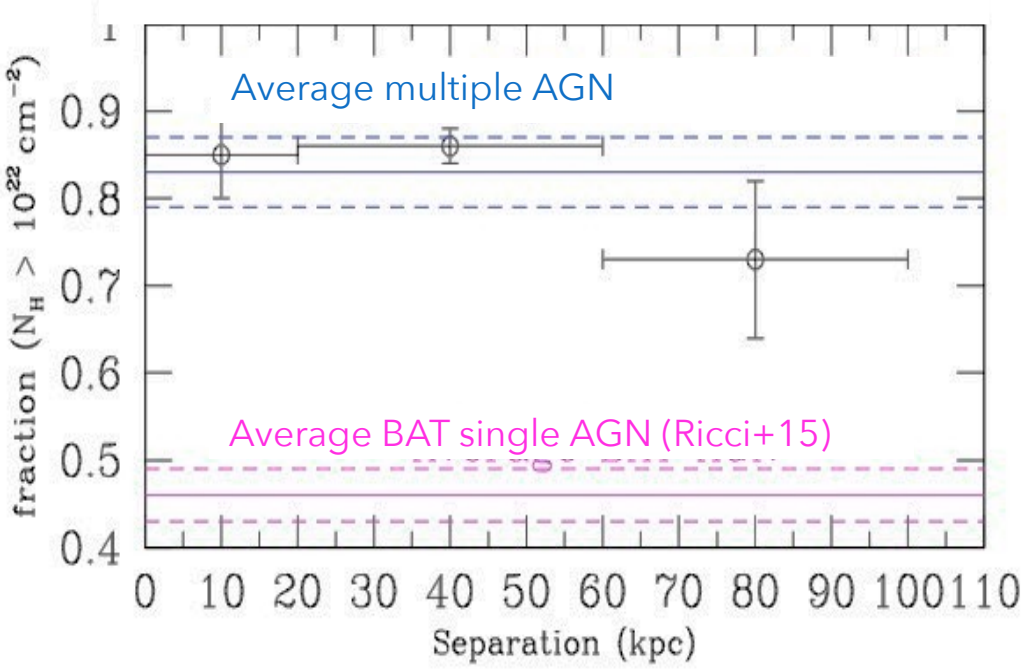
300 ks of XMM observation (on-going) De Rosa et al. in prep.

GOALS:

(1) AGN physical properties (L, N_H, etc) -> (De Rosa et al in prep.)
(2) comparison with isolated AGN;
(3) comparison with closer systems [OB3]

(De Rosa+15, De Rosa+18, Guainazzi+21)

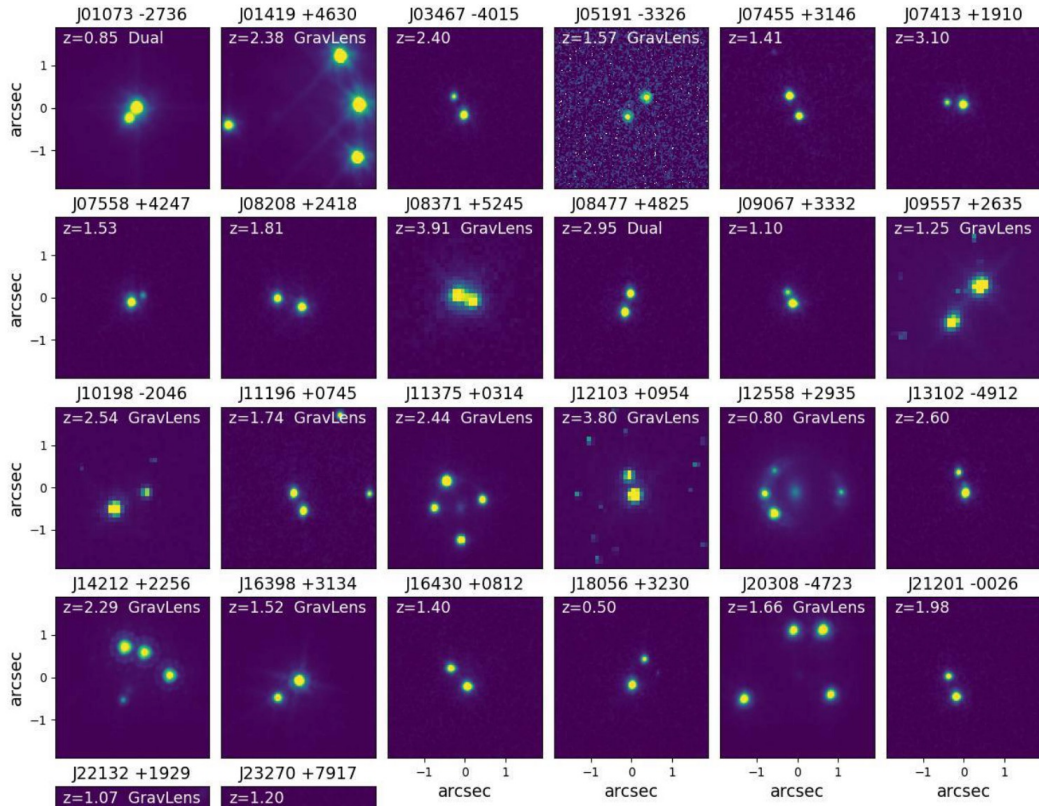
Multiple AGN exhibit larger nuclear obscuration with respect to single AGN

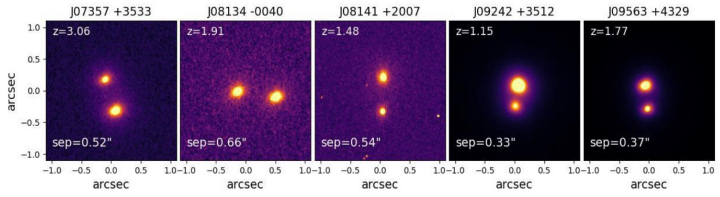


DATA, PLANNINGS & EARLY REASULTS [OB3]

Dual AGN in late-stage merger systems (kpc and sub-kpc scales)
[Coord.: Mannucci]

Archival HST images





AO-assisted LBT images (K-band).

SAMPLE1:

GMP sample (EDR3)
Gaia Multi Peak method

Gaia PSF~0.11″

G-band selection
~ 260 systems of multiple compact objects
ang. sep <1″
z>0.3
(Mannucci+22, Nat. Astron. in press)

DEDICATED OBSERVATIONS (INAF-PI):

Facility	Instrum.	Time	type	Status
Keck	OSIRIS	8h	AO spatially resolved spectroscopy	executed
LBT	LUCI	5h	AO near-IR imaging	executed
TNG	DOLORES	9h	integrated spectra	accepted
ESO/VLT	MUSE	4h	AO spatially resolved spectroscopy	accepted
ESO/VLT	ERIS	80h	AO spatially resolved spectroscopy - GTO	accepted
ESO/NTT	EFOSC2	19h	integrated spectra	accepted
ESO/NTT	SOFI	11h	integrated multi-band photometry	accepted
NOT	AFOSC	60h	integrated spectra	accepted
CHANDRA		90 ks	high-resolution X-ray imaging	submitted
HST	WFC3	146 obj	multi-band high-res. imaging, SNAP	submitted
ESO/VLT	MUSE	22h	AO spatially resolved spectroscopy	submitted
ALMA		21h	High-resolution 870 micron obs.	submitted

GOALS:

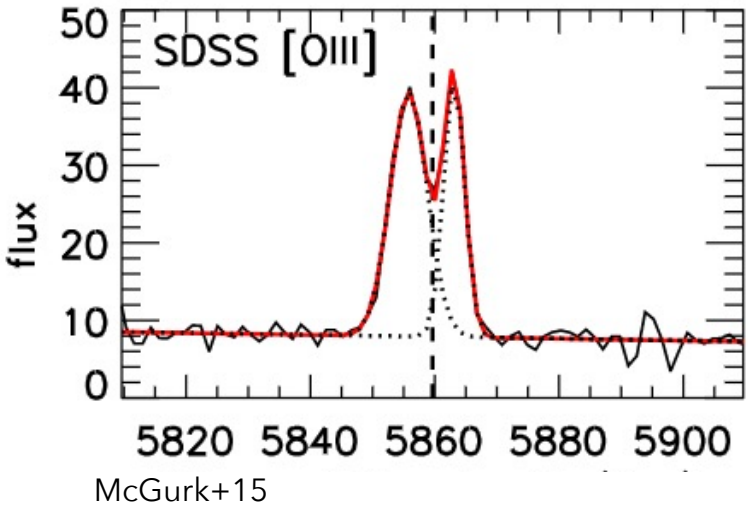
(1) physical properties
(2) large and reliable samples of dual AGN with kpc/sub-kpc sep.
(3) test of model predictions

DATA, PLANNINGS & EARLY RESULTS [OB3]

Dual AGN in late-stage merger systems (kpc and sub-kpc scales)
[Coord.: Severgnini]

SAMPLE2:

SDSS dual-peaked Narrow Line AGN
(Wang+09, Smith+10, Liu+10, Ge+12)
More obscured dual AGN candidates

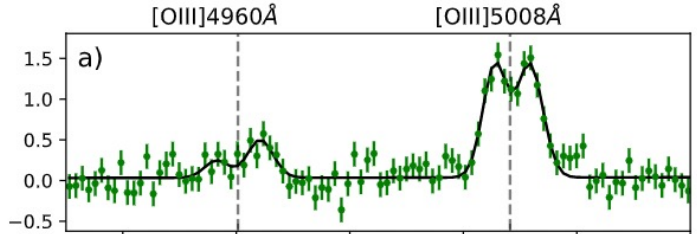


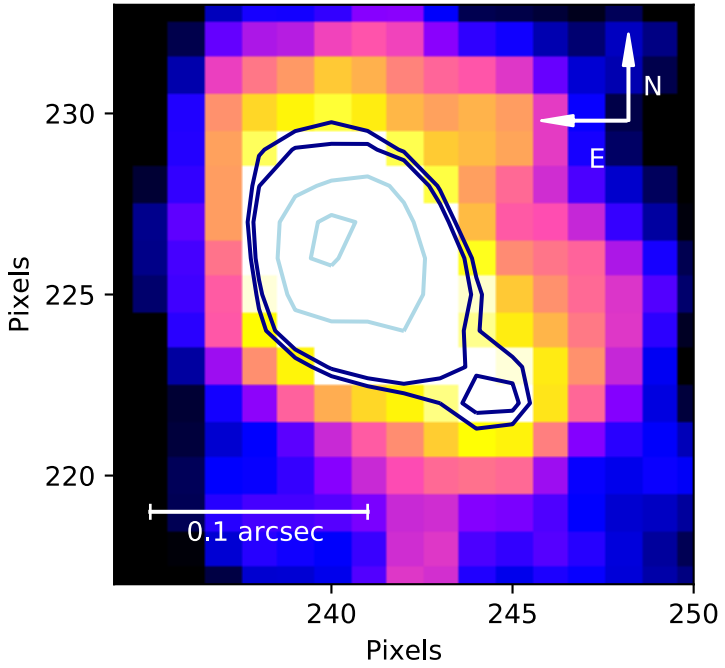
McGurk+15

DEDICATED OBSEVATIONS:

LBT-LUCI AO NIR images (on-going progr.)

SDSSJ1431+4358 (z=0.09): double-peaked NL AGN





AO-assisted LBT-LUCI observ. (K-band) unveils the presence of a sub-kpc dual AGN (0.5 kpc sep.) hosted in an heavily obscured system.

(Severgnini+21)

DATA, PLANNINGS & EARLY RESULTS [OB4]

The quest of Binary AGN candidates (pc/sub-pc scale)

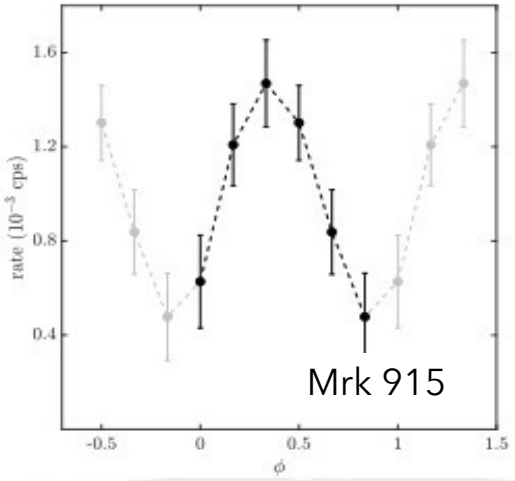
[Coord.: De Rosa, Severgnini, Vignali]

INDIRECT METHOD:

- Periodic modulation in the optical, UV and X-ray light curves (d'Ascoli+18);
- Double-peaked broad emission lines in the X-ray and optical spectra (Popovic+21).

TARGETS: Two of the most promising binary AGN (Severgnini+18, Serafinelli+20, Severgnini+22 in press)

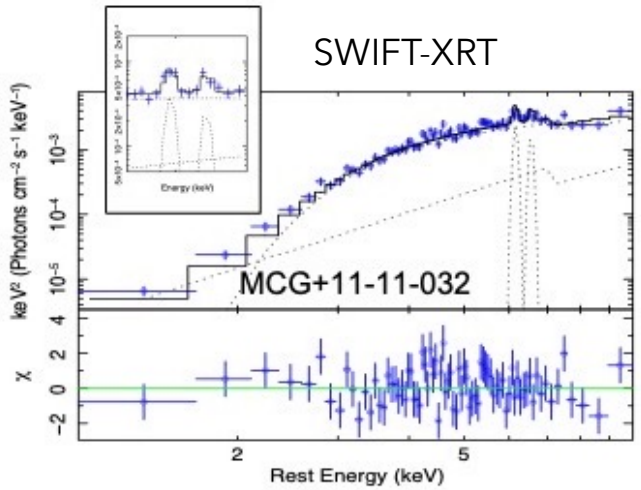
105-Months Swift-BAT Survey (Oh et al.2018)



P_0~35 months, *sep~5x10^{-3} pc*

T_{coal}~1.5 Myr

SWIFT-XRT



Δv~0.06c -> P_0~25 months,

sep~7x10^{-3} pc, T_{coal}~3x10^4 yr

DEDICATED OBSERVATIONS GMP SAMPLE (INAF-PI):

Facility	Instrum.	Time	type	Status
SWIFT	XRT	150 ks	X-ray monitoring	on-going
Loiano	BFOSC	40h	Optical (phot.+spect) monitoring for 2 sources	on-going

EXPECTED ACHIVEMENTS:

(1) Binary AGN properties
(2) comparison with theoretical predictions
(3) comparison with PTA results

SYNERGIES WITH FUTURE FACILITIES

Building up the science case for planned and concept facilities

BINARY AGN M_{BH}~10^5-10^6 M_{sun}

lisa

Scheda-INAF: Valiante

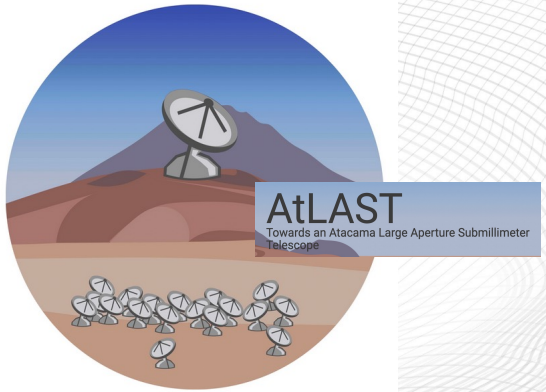
LGWA LUNAR GRAVITATIONAL WAVE ANTENNA

Scheda-INAF: Harms (LGWA-PI)

SoXS

Scheda-INAF: Campana

Dual AGN – galaxy co-evolution up to high z



Scheda-INAF: Poppi
PI: Cicone

Dual AGN M_{BH}~10^5-10^6 M_{sun}
Sub-arsec separations

NASA Orbiting Configurable Artificial Star (ORCAS)

ORCAS4LBT

Scheda-INAF: Di Rico

MAORY

PI: Ciliegi

ERIS

Scheda-INAF: Ricciardi

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

SUMMARY

- ***11 papers published since 2018 led by INAF or assoc. + 8 external collaborators***
  Exhaustive publication list of all the team (including observational and theoretical results):
  https://ui.adsabs.harvard.edu/public-libraries/oLNfNJnlSHyRpbVdSaXpkw
- Great interest from the international scientific community!
  15 accepted proposals since 2021 (all led by INAF or assoc.) + 10 nights of GTO with ERIS
  - ~250 hrs (ground based telescopes)
  - ~850 ks (satellites)
- ***6 proposal submitted in 2022***

CRITICAL ISSUE

- The only AdR position (ASI funds) fully dedicated to the project ended in Aug. 2021
- TD FTE =0
- ***No funds are currently available for this program***

FUNDING OPPORTUNITIES

INAF- Large Grant

2 Postdoc positions fully dedicated to the program (pending, PI Severgnini)
Timing and fast publication of the results are fundamental in this competitive field to ensure a leading role to INAF

Thank you!