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# Radio and X-ray emission in AGN

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# Black holes are everywhere!



- ALL galaxies host a super-massive black hole. They are "active" only for short periods of time
- The black hole appears to regulate the evolution of its host galaxy
- The Milky Way itself hosts an extraordinarily dim, super-massive black hole at its center: Sagittarius A\*

### In the local Universe

Luminous AGN : ~ 1% of all galaxies

Low Luminosity AGN : ~ 40% of all galaxies

Dormant BH: 60% of all galaxies

Ho (2008) – "Nuclear Activity in Nearby Galaxies"

# Ingredients for standard bright AGN



To explain emission across such a vast range of energy, one needs a combination of:

- Accretion disk (multiple black-bodies) + hot corona of electrons (comptonization)
- Relativistic particle acceleration (jets) in 10% of AGN
- Dust (at 50K), heated by the radiation from the accretion disc

#### How does this picture change for 40% of AGN?



# Jets and accretion regimes in XRBs



Unification in XRBs is about different accretion regimes





Sikora, Stawarz, Lasota, 2007

# Jet-disk coupling in AGN



Körding, Falcke, & Markoff (2002); see also Fender, Gallo, & Jonker (2003) Low-state (ADAF+jet):

- Sgr A\*
- Nearby Giant Ellipticals
- LINERs
- FRI sources
- LLAGN
- BL Lacs
- Some LL Seyferts
- XBONGs

# The X-ray versus Radio



# The X-ray versus Radio



#### Radio Loud RL:

- ✓ Flat power-law slope
- ✓ Weak reprocessing features
- ✓ Different geometry and/or accretion efficiency
- ✓ Jet and beaming effects contaminate/ dilute the accretion component

1 mas

0 -1

✓ Ionized reflection



# Jet-disk coupling in AGN: radio vs X-rays



→ X-ray flux due to Comptonization emission indicates that the radio jet is launched by the hot electrons in the accretion flow in all spectral states of Cyg X-1

# Jet-disk coupling in XRBs



### **Black hole unification**



### Jet-disk coupling in LLAGN



Origin of radio emission in LLAGN Possible physical mechanisms in Radio-Quiet:

✓ Synchrotron emission from a jet:

✓ Relativistic? Sub-relativistic? Weak jet? Outflow?

✓ Free-free emission from a molecular torus or corona?

✓ ADAF? CDAF? RIAF? ...



### Kilo-pc scale Jets in local RQ AGN



- I I I I







# ....at low luminosities





VLBI Survey of 23 Seyfert nuclei

- 6 and 20 cm survey •
- 90 microJy/beam •
- Linear scales 0.05 pc @10 Mpc •







PLot file version 2 created 27-JAN-2011 14:54:16 BOTH: NGC4477 IPOL 4990.490 MHZ NGC4477.IIM006.1







Giroletti&Panessa 2009, Bontempi et al. 2012, Panessa&Giroletti 2013 MNRAS/arXiv:1304.0794

### Are sub-pc radio cores ubiquitous

#### At 20 cm (1.4 GHz):

- NVSS : 26/28 (93%)
- VLA : 18/28 (64%)
- VLBI : 12/21 (57%)

#### At 6 cm (5 GHz): • VLA : 23/28 (82%) • VLBI : 13/21 (62%)



• Lower detection rate with respect to VLA

• RQ nuclei are less ubiquitous at VLBI spatial scale resolution

Water maser detection rate of <u>26%</u> → compared to 7% of maser surveys (Braatz et al. 1997)

#### Radio versus X-rays correlation



Panessa & Giroletti 2013 MNRAS/<u>arXiv:1304.0794</u>

### Resolved radio emission at sub-pc scales





# NGC 5273: a LLAGN with no jet



#### Resolved radio emission or variable radio source?

Giroletti & Panessa 2009, ApJL



# ....at high luminosities

### Hard X-ray selected INTEGRAL AGN Complete sample





Unbiased view!!

#### Hard X-ray selected sample of luminous AGN:

- -> INTEGRAL 20-100 keV (Malizia et al 2009)
- -> 2-10 keV X-ray data (Malizia et al. + literature)
- -> NVSS radio data (Maiorano et al. in prep)

# Scaling Relations: L<sub>radio</sub> versus L<sub>X-ray</sub>



\*RL In agreement with the EFFICIENT BRANCH law of 1.4\*

#### Fundamental plane for BH activity



-> Large scatter, INTEGRAL AGN sample the high Eddington accretion regime
→ more radio with respect to that expected from the Fundamental Plane

### **INTEGRAL AGN 22 GHz water maser survey**



✓ Water maser emission traces a disk, a jet or outflow

#### Tarchi et al 2011



The discovery of a water mega-maser in IGR J16385-2057:

- it is a NLSy1 (masers are tipically found in obscured AGN)
- it resides in an elliptical galaxy (masers are rare in ellipticals)

Water maser detection rate in the INTEGRAL sample of 17%--> Castangia et al. in preparation

Thank you!