Inspiraling, Binary, and Recoiling Black Holes in Nearby Galaxies

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Method and science goals

Make a high-resolution 8.6 GHz VLBA search for off-nuclear and binary SMBHs in a complete sample of $\sim 10^3$ nearby ($D_A < 200$ Mpc) massive galaxy bulges to:

1. discover off-nuclear inspiraling SMBHs predicted by the “merger tree” theory for massive galaxy evolution
2. resolve “stalled” binary SMBHs in tight ($d \sim 10$ pc) orbits
3. discover off-nuclear recoiling SMBHs kicked out by the strong anisotropic gravitational radiation sought by LISA and NANOgrav
4. discover currently active nearby SMBHs (no dust bias)
**Nearby galaxy sample**

2MASS $K_{20fe} < 12.25$
NVSS $S_{1.4} > 100$ mJy
$\delta \geq -40^\circ$, $|b| \geq 5^\circ$

$N = 923$ galaxies

$<D_A> \sim 200$ Mpc so
1 mas $\sim 1$ pc

$<L_{1.4}> \sim 10^{24}$ W Hz$^{-1}$

> 90% are radio-loud AGN

$\delta \geq -40^\circ$, $|b| \geq 5^\circ$
Automated Dynamic Scheduling

Scheduling BC196 segments

This service is for generating segments of BC196 schedules and for confirming of cancelling schedules VLBA experiment BC196.
Detailed instruction how to make a schedule file are available here.
Note: this resource is for authorized users only!

**Action: create a schedule**

- Format: YYYY.MM.DD_hh:mm
- Start UTC date: 2011.01.21_16:30
- Stop UTC date: 2011.01.22_03:00
- Segment code: D
- Password: ********

**Submit**

**Action: confirm the schedule**

Enter here the full path name of the schedule file
Password: ********
Automated Analysis

- Fringe-fitting: dedicated AIPS-independent software \texttt{PIMA}. Results are exported to
  1. Astrometry software VTD/post-Solve for source position estimation;
  2. Program \texttt{flux_est} for coarse flux density estimation;
  3. DIFMAP for imaging.

- Quality control and interactive astrometric analysis. Second run of refringing outliers.

- Coarse flux density estimation.

- Global astrometric analysis using all astro/geo VLBI data since 1980 through present.

- Update of the project web page.

Typical cost for a $6^h$ segment: $20^h$ CPU time and $0.5^h$ human time.
Fig. 3.—
Top: Example of BC 191 X-band CLEAN images for three objects of different parsec-scale morphology. The image of 1801+007 was reconstructed from two scans observed within two separate segments from August 3 and 21, 2010. Dynamic range of the image is greater than 100:1.

Bottom: Correlated flux density versus projected spacings corresponding to the images shown on top.

Fig. 4.— SDSS image of a promising candidate for an offset black hole in the highest cluster galaxy Zw 8193 (J1717+4226) with VLBA-2MASS offset of 2.4′′. The radio source lies north of the SDSS and 2MASS position.

\[ 5\sigma \sim 6 \text{ mJy in 8 min} \]
\[ \Delta \alpha, \Delta \delta \sim 1-3 \text{ mas} \]
\[ \Theta \sim \text{mas} \]
\[ \text{DR} \sim 100:1 \]
First results