Tracking the Moving Optical Photocenters of Active Galaxies: Binary Black Holes, Accretion Disks, and Relativistic Jets

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A. Wehrle/ 10th SIM Sci.Team Mtg.
Understanding the fundamental AGN power source

- Accretion onto massive black holes fuels the energetic AGN phenomena-- but how does it work?
  - How are galaxy mergers related to the AGN phenomenon?
  - Are binary black holes (resulting from mergers?) common?
  - What are the sizes and geometric relations between the components of the 'core' region: jets, accretion disk, hot corona?
  - How much do viewing direction and observational selections affect the picture?
Three AGN questions which SIM will address:

1. Does the most compact non-thermal optical emission from an AGN come from an accretion disk or from a relativistic jet?

2. Do the cores of galaxies harbor binary supermassive black holes remaining from galaxy mergers?

3. Does the separation of the radio core and optical photocenter of the quasars used for the reference frame tie change on the timescales of their photometric variability, or is the separation stable?
Key Project Strategy

The AGN/Reference Frame SIM Key Projects have 3% of SIM observing time

- Monthly observations should yield results within the first year of operation
- Observe several target-rich ‘permatiles’, not a statistical sample
- Validate use of AGNs as reference frame objects
SIM will make 3 kinds of AGN measurements

- Relative astrometry between quasars and reference stars or other quasars
  - Differential wide-angle observing at levels of ~ few μas (depending on magnitude)
  - select permatiles that contain both “interesting” and potentially “stable” AGN, then measure the changes
- Global astrometry: motion of quasars relative to global reference frame
  - Frame accuracy is ~ 4 μas
  - Detect quasar motions at about this level
  - Statistical properties of ~50 quasars as part of the grid
- Astrometric shifts as a function of wavelength
  - Directly provide structure information on scales of 10s of μas
Sample permatile for relative astrometry

- Select tile centers for objects of interest
- Virgo permatile contains:
  - M87
  - 3C 273
  - Two ICRF quasars
  - 6 - 8 grid stars

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Representative quasar spectrum

- SIM observes in the optical band
- Strongly 'concave' spectrum indicates transition between components

Estimating the emission region size

- Accretion disks are small
  - $\sim 160\, \mu\text{m}$ at $15\, \text{Mpc} - M31$
  - $\sim 2\, \mu\text{m}$ at $3C345 - z = 0.6$
- Hot corona region is also small
  - $\sim 70\, R_\odot$ corresponds to $\sim 1\, \mu\text{m}$ at $z = 0.6$
- Implication: AGN nuclei are indeed compact enough to get fringes on with SIM
- News: Optical flare within the jet of M87 outshine the nucleus! Observed with HST; timescale ~ 4 weeks. Variability size scale corresponds to $30\, \mu\text{m}$ (Pereira et al. 2003 ApJ Letters)
- Implication: Shockvelocities in jet may be bright and compact enough to observe with SIM

Reference Frame Tie - two requirements

1. SIM needs a non-rotating frame (for Galactic structure studies)
   - We don't know to select radio-loud quasars
   - Maybe radio-quiet quasars are more suitable?
2. Need to reference to the ICRF
   - Internationally recognized
   - Need radio and optically bright quasars to tie SIM to the ICRF

Could pick two different quasar samples:
- radio-loud
- radio-quiet
- not yet a solved problem

3C345
Overview of Preparatory Science Work 2004-2006

1. Quasar Radio Stability
   Measure separations of radio quasar groups within 15" perimeters (4
   perimeters, at least 20 quasars per year)
2. Target Choice and Development of Observing Strategy
   Investigate how quasar group, number of radio stars, brightness of
   target, effects of brightness varying during measurements, "crowded
   and complex field" simulations
3. Optical Monitoring of Photometric Variability
   Compact radio quasars vary 1 to 5 magnitude on timescales of
   months/years. Monitor selected target candidates at ground-based
   optical observatories to get good historical database.
4. Keck Interferometry
   Note that Ke and VLBT groups detected their first AGNs in 2003; we
   anticipate that quasar detection (15th magnitude and fainter) should be
   possible in 2005

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Accomplishments this year (1 of 2)

> Conducted first set of VLBA phase referencing
   experiments on selected AGN to see if the cores are
   moving with respect to nearby ICRF sources (joint
   proposal with Johnston, Fey et al. group)
   • 2 experiments, data analysis in progress
> Began to evaluate historical optical variability of ICRF
   and astrophysically interesting AGN to establish timescale
   and magnitude of variability
> Analysis of microvariability results in literature
> Overview of active optical monitoring programs for possible
   collaboration
> Advertised for postdoc

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Accomplishments this year (2 of 2)

> Using SIMsim, verified that predicted ~14μas differential
   wide angle performance of SIM can be achieved on
   targets of 15th magnitude with a single look
> Produced samples of potential targets: radio-loud and
   radio-quiet quasars matched in redshift and (probably) in
   black hole mass
> Published papers describing Key Project and technique of
   using differential-colors to determine location of optical
   non-thermal jet emission
   > Webster et al. 2002 SPIE

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Next Year’s Work

> Analyze VLBA data; propose and conduct additional experiments to
   address question of relative stability of radio photometers within
   selected perimeters
> Quantify how brightness and structure in optical quasars will affect
   SIM measurements (“crowded and complex field”) for single model
   structures
> Work on AGN target choices, also exploring which radio stars should
   be included for reference frame tie (coordinating with Johnston et al.
> Analyze performance of SIM using differential color phase
> Use PTF to develop team expertise in ground-based optical
   interferometers
> Our postdoc will start in early 2004 (top candidate identified and
   contacted)

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We have started the long-term monitoring of potential SIM targets to quantify the motion of radio photocenters.

We have characterized optical monitoring and analysis programs.

Our collaboration with Ken Johnston's Key Project team is underway.

Our top postdoc candidate has been contacted.

The addition of a postdoc to devote concentrated attention to the Key Project and the allocated funding to support the involvement of the co-investigators enable our Key Project to get up and running.

Summary