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EXTRAGALACTIC ASTRONOMY WITH SIM

SIM and Essential Cosmology

[Webster's Dictionary] Essential - 1: of, relating to, or constituting essence
2 a: of the utmost importance
*   b: being a substance that is not synthesized by the body in a quantity*
sufficient for normal health and growth and that must be obtained from the diet

- ## Motion of Sun relative to GC and relative to LG

- ## Mass of Dark Matter particle (essence)

  - ### Total masses of MW and nearby galaxies

  - ### Cuspiness of galaxy centers

  - ### Minimum masses of dwarf galaxies, number of subclumps in the galaxy

- ## Form of missing baryonic matter

- ## Scale of Universe (H_o) + CMB => w – Equation of state of dark energy.

Some Basics

- ## SIM Proper Motion:
  - SIM-Lite (50 cm), 5 year: 3.8 μas/yr in 5.3(12.3) hrs. for 16th (17th) mag.
  - 1 μas/yr = 4.7 D_{Mpc} km/s
- ## SIM brightness limit = 20th mag.
  - Brightest Pop II stars (M = -4):
  - m_{TRGB} = 21 + 5 log(D_{Mpc}) = 16 + 5 log(D/100Kpc)
    - Can work on galaxies without star formation out to 300 kpc. Beyond that, need young AGB or supergiants.
  - Supergiants of M = -9.5 , are 20th mag at 8 Mpc

Fundamental Parameters of the Galaxy

- The mass distribution of the Galaxy, which is dominated by dark matter:

  - the relative contribution of the disk and halo to the gravitational potential

  - the volume mass density and surface mass density of the disk

  - the shape, mass and extent of the dark halo of the Milky Way out to 250 kpc

Taking the Measure of the MW

- **The rotation at solar circle ✈$_{LSR}$ and ω_{LSR}**
  - previously been determined by a number of methods (219 $^+/_-$ 20) (R_0 / 8) km/s.
  - These set the magnitude of the rotation curve of the Galaxy.
  - the solar distance to the center of the Milky Way, R_0
  - the LSR angular velocity around the Galactic center, ω_{LSRa}
- **Distance *and proper motions across entire Galactic disk***
  - Get full rotation curve
  - Large scale asymmetries and warps
  - Kinematic properties of different age populations
  - Cepheids and Miras
- **Other fundamental dynamical properties of the Milky Way:**
  - the pattern speed of the central bar
  - the kinematics (mean rotational velocity and velocity dispersion tensor) of the halo as a function of position

MW Galaxy tidal streams

- Tidal streams provide information on shape and mass of galaxy.

- 2 GCs (Pal 5 and NGC 5466) and several dSph have tidal tails

- Width of stream indicates rate of scattering due to interaction with subclumps.

 - Minimum mass subclumps depends on mass of dark matter
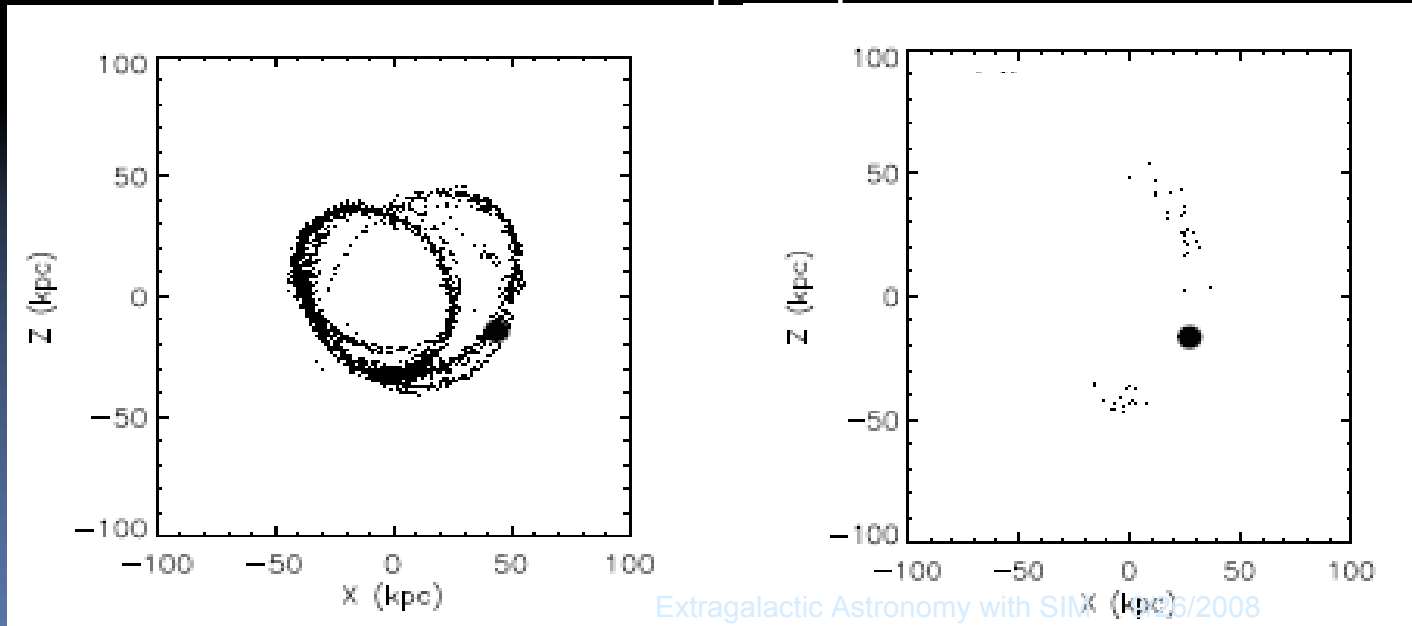
MW Clusters and Satellite Galaxies

- Proper motion and velocity ellipsoid of satellite galaxies and globular clusters.

- For Mass of Galaxy out to 250 Mpc and for density, mass, and cuspiness of cores of dwarfs.
  - indicates mass of dark matter particle.

- 1% distances to clusters (2 key projects)
  - Indicates age of oldest stars
  - Set minimum age of universe.
  - How long did it take to form globulars?
  - Did globular clusters contribute to re-ionization?

Microlensing

- To measure mass of lenses requires two observables more than usual experiments.
- Usually get Einstein ring crossing time.
- SIM gets wobble of the center of light and a second viewing angle of event. For latter, need telescope at a fraction of 10AU away from Earth.
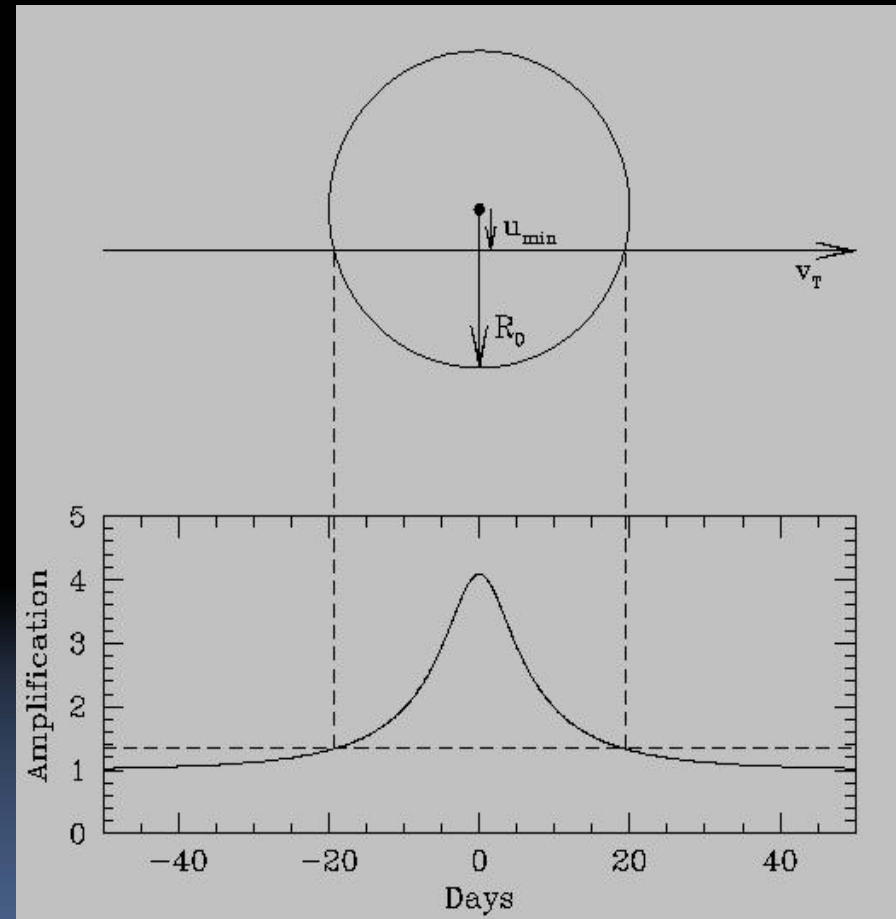
SIM Microlensing
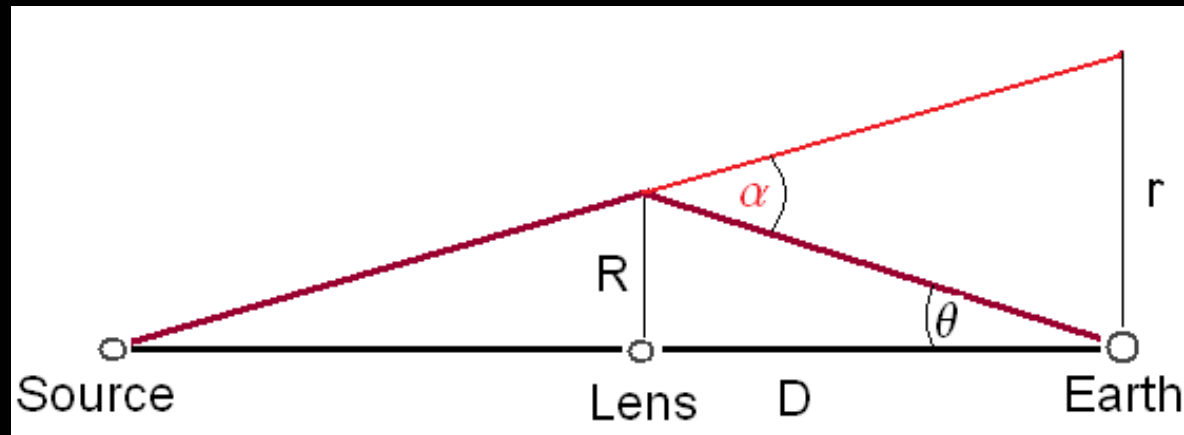
$$\square \, r = \text{♋} R = 4GM/c^2$$

Measure $\square$ by apparent motion of source through transit and measure r by study of differences in lensing event at SIM compared with event at Earth.

# Microlensing and Cosmology

- **What is the form of the missing normal matter?**
  - Less than half of baryonic matter is accounted for
 - Blackholes, neutron stars, brown dwarfs, hydrogen/helium planets, snowballs

Proper Motion of Galaxies

- Proper motions of ~27 galaxies from SIM.
- Only 27 galaxies have stars with V < 20th mag
- Measure 5-20 stars per galaxy.
- Low mass galaxies have σ_v < 30 km/s, high mass ones have well defined rotational motions.
- Obtain ~10 – 20 km/s absolute proper motions.
- Use Least Action Method (Peebles 1989) to solve for orbits. Find orbits in which mutual gravitational attractions map from homogeneous (no peculiar velocities) to present spatial distribution in 13.7 Gyr. χ^2 on final 3d-velocity provides goodness of fit.
- Obtain total mass, total M/L ratio, constraints on hot dark matter density, and history of group formation.
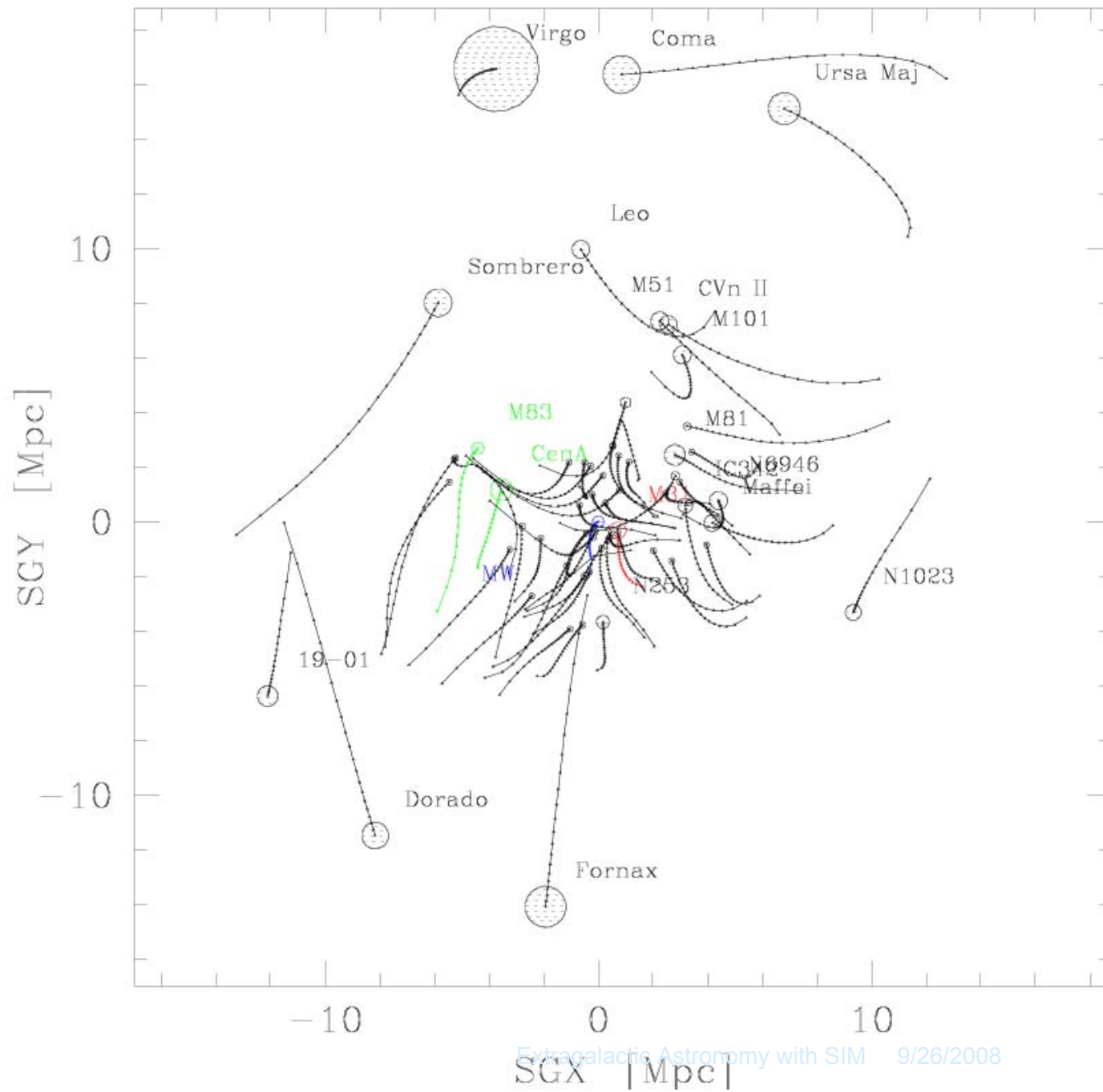
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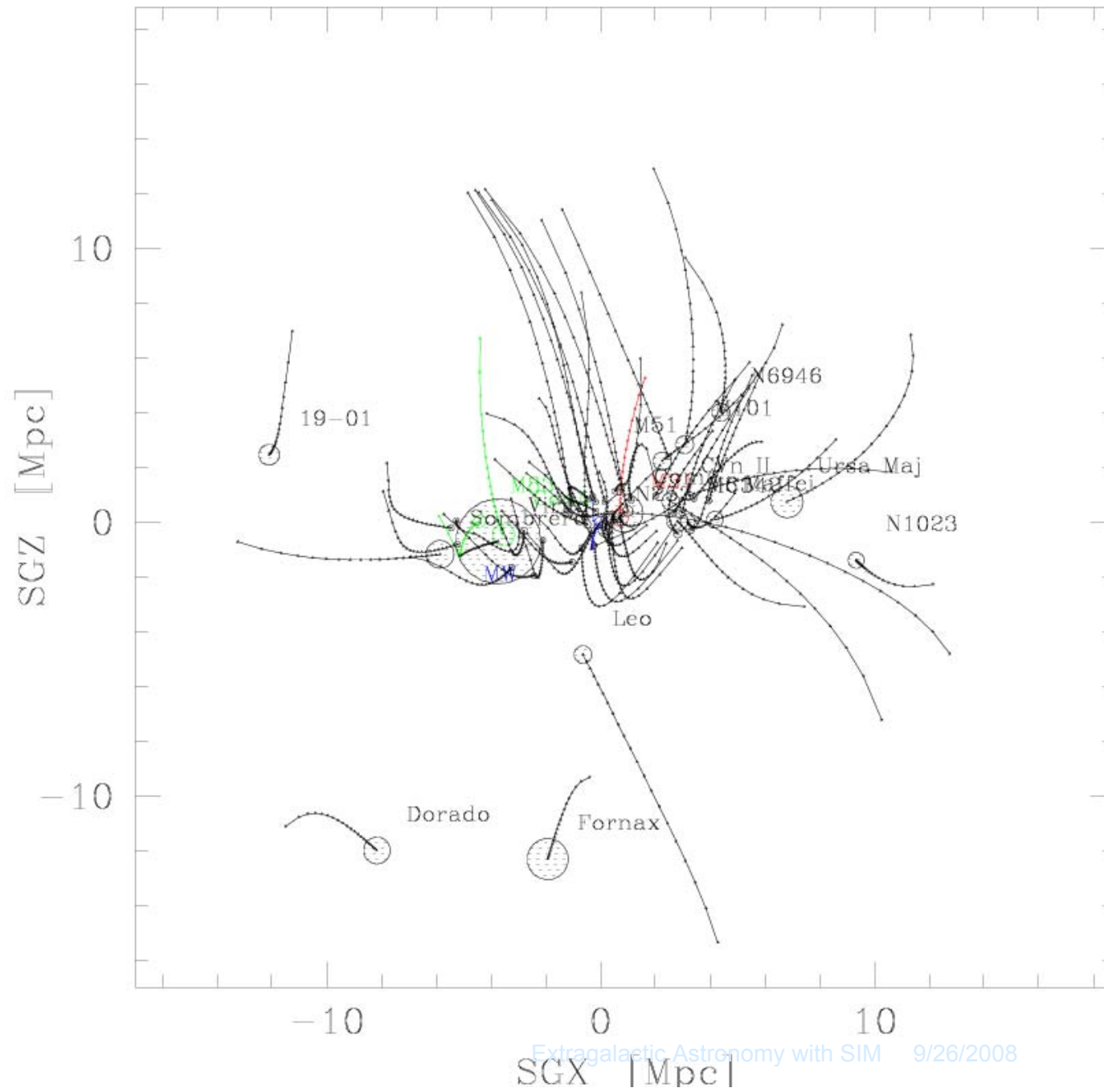
QSO/AGN

- Optical structures of QSOs: Is the red emission aligned with the blue emission?

- We plan to use quasars/AGN to tie stellar reference frame to the universal inertial frame. But, how stable are their photocenters? Can these be used for defining precision reference frame?

- Search for binary supermassive blackholes. In late phase of galaxy merger, BH pair spiral in and attain high enough velocities to measure a proper motion.
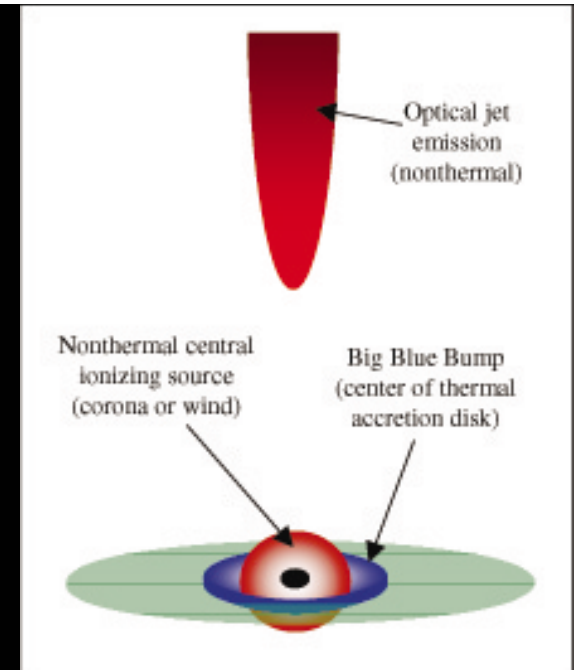
Conclusion

- We have tried the same old, same old way of imaging and spectroscopy for decades now. It has not answered the essential questions in cosmology.

- It is time for a change. It is time to try a new way. The way forward is clear. It is time for precision astrometry to faint levels.

- It is time for SIM!