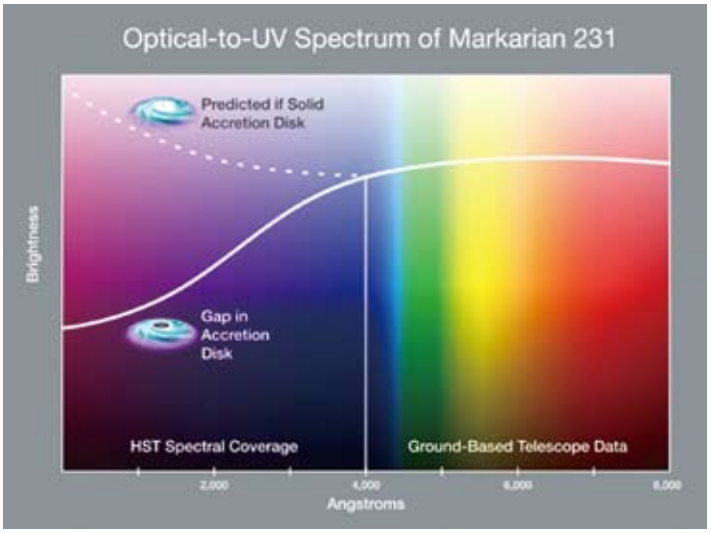
Hidden Pairs of Supermassive Black Holes

LU Youjun and YAN Changshuo from the National Astronomical Observatories, Chinese Academy of Sciences (NAOC) and their collaborators have found a supermassive binary black hole hiding at the center of Markarian 231, the nearest galaxy to Earth that hosts a Quasar.

Search for binary black holes is of great importance not only for understanding the formation and evolution of galaxies but also for investigating gravitational wave radiation and testing the gravity theory. Observations show that most galaxies, if not all, host supermassive black holes in their centers. In the standard galaxy formation model, a big galaxy is assembled through merger and collision of two small galaxies. The two central supermassive black holes orbit around each other as a result of the merger and generate tremendous amount of gravitational wave radiation at the end of the orbiting. In the mean time, the merger can cause the gas in the two small galaxies—if gas is rich—to sink into the center of the merged galaxy which triggers a brilliant Quasar there. Astrophysicists expect the existence of binary black holes in many of those brilliant Quasars. However, the evidence is ambiguous and uncertain.

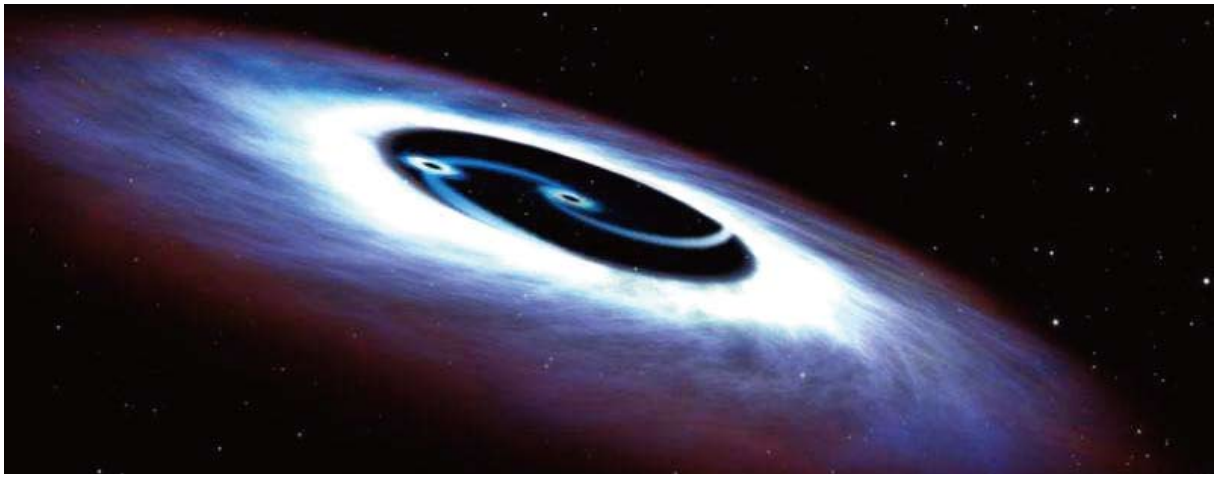


An illustration of the optical-to-ultraviolet continuum spectrum of Markarian 231 and the model. Credit: NASA, ESA, and P. Jeffries (STScI).

Image of Markarian 231 by the Hubble space telescope. Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA) - ESA/Hubble Collaboration, and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University).

Researchers from NAOC, the University of Oklahoma, and the Kavli Institute for Astronomy and Astrophysics at Peking University jointly investigated the optical-ultraviolet continuum spectrum from the core of Markarian 231, which was obtained by the Hubble Space telescope and some ground based optical telescope such as Keck. They found that the "surprising and extreme feature", a deficit, in the optical to ultraviolet continuum of Markarian 231, can be best explained by a model involved a supermassive binary black hole.

If only one black hole were present at the center of the quasar, the whole accretion disk made of surrounding hot gas would glow in ultraviolet rays. Instead, the ultraviolet glow of the gaseous disk abruptly drops off toward the center. This provides observational evidence that the disk has a big donut hole encircling the central black hole. The best explanation for the observational data, based on dynamical models, is that the center of the disk is carved out by the action of two black holes orbiting each other. The central black hole is estimated to be 150 million times the mass of our sun, and the companion weighs in at 4 million



An artist illustration picture of the binary black hole system. Credit: NASA, ESA, and G. Bacon.

solar masses. The second, smaller black hole orbits in the inner edge of the accretion disk, and has its own mini-disk with an ultraviolet glow. The dynamic duo completes an orbit around each other every 1.2 years. The binary black holes are predicted to spiral together and collide within a few hundred thousand years.

"We are extremely excited about this finding because it not only shows the existence of a close binary black hole in Mrk 231, but also paves the way to systematically search binary black holes via the nature of their ultraviolet light emission," LU Youjun said.

"The structure of our universe, such as those of giant galaxies and of galaxies clusters, grows by merging smaller systems into larger ones, and binary black holes are natural consequences of these mergers of galaxies," explained co-investigator DAI Xinyu, who is from the University of Oklahoma.

The lower-mass black hole is the remnant of a smaller galaxy that merged with Markarian 231, located only about 600 million light-years away from the earth. Evidence of a recent merger comes from the host galaxy's asymmetry, and the long tidal tails of young blue stars. The result of the merger has been to make Markarian 231 an energetic starburst galaxy with a star formation rate 100 times greater than that of our Milky Way galaxy. The in-falling gas fuels the black holes' "engine", triggering outflows and gas turbulence that incites a firestorm of star birth.

Their finding was published in the *Astrophysical Journal*.