

Black-Hole Galactic Nuclei: A High Energy Perspective

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Abstract

The gravitational radiation signals to be anticipated from events involving black hole galactic nuclei depend on the spin of the underlying object. To obtain evidence about the spin of Seyfert AGN black holes, we can rely on future ultra-high resolution spectral/spatial X-ray studies of iron K line fluorescence from the innermost regions of accreting matter. Normal galaxies present more of a challenge. To account for the highest energy cosmic rays we propose that ultra-relativistic particle acceleration can occur near the event horizons of spun-up supermassive black holes at the non-active nuclei of giant elliptical galaxies. This conjecture about the black hole spin associated with such nuclei is subject to verification via the characteristic TeV curvature radiation expected to be detected with upcoming gamma-ray observatories.

1. X-rays

Supermassive black holes are present at the center of every nearby galaxy [1]. Those that are Seyferts are expected to exhibit nuclear X-ray spectra that directly reflect the geometry associated with the underlying black hole. It has already been established from ASCA data that the iron K X-ray line broadening observed from several Seyfert AGNs is largely due to accretion disk fluorescence undergoing gravitational redshift induced by galactic nuclei of black hole mass up to $\sim 10^8 M_{\odot}$ (see [2] and references therein). However, it may often be necessary to localize this emission to within a radius of $\sim 6GM/c^2$ in order to unambiguously distinguish a Kerr hole from a Schwarzschild object [3]. For most of the AGNs within $\sim 10^2$ Mpc considered by Nandra *et al* [2] the 10^{-7} arc-second resolution to be provided by the Micro Arc-second X-ray Imaging Mission (MAXIM) envisaged by White [4] should be sufficient for this purpose. However, as inferred from X-ray upper limits obtained with the Chandra Observatory [5], the largest black holes ($>10^8 M_{\odot}$) generally reside in non-active galaxies; their lack of compact core X-ray emission then precludes spectral line-shape determination of spin, as contrasted with what is expected to be feasible for active (Seyfert) galaxies. Yet, some knowledge of this fundamental parameter could be crucial for the proper interpretation of gravitational radiation associated with events in such normal massive galaxies, be they remote or their local counterparts.

2. Cosmic Rays and Gamma-Rays

The highest energy hadronic cosmic rays ($\geq 10^2$ EeV), having survived the drag induced by the pervasive thermal relic microwave radiation field, must come from sources within 10^2 Mpc [6]. Although there is a paucity of quasars in this region of the universe, the number of luminous ($M_B < -21$) elliptical galaxies harboring core MDOs (Massive Dark Objects $\geq 10^9 M_\bullet$) within this present-epoch volume [1,7,8] is now known to be comparable to the number of Seyfert AGN with black hole cores of 10^6 – $10^8 M_\bullet$ [9]. These MDOs are the quasar remnant black holes ('dead quasars') expected in the present epoch [10], sufficiently massive to preclude the tidal disruption of any infalling star, normal as well as compact [11]. Guided by the membrane paradigm [12], as applied to those that involve accreting spun-up black holes, we [13-15] consider them as potential generators of extremely relativistic UHECRs (ultra-high-energy cosmic rays). Necessarily dark in low energy photons (radio to x-ray), these MDO compact dynamos should yield significant gamma ray emission of TeV curvature radiation characteristic of the acceleration of UHECRs by such spun-up black-hole based quasar remnants, and thereby be directly observable out to $\sim 10^2$ Mpc [14-17]. Therefore, to obtain direct evidence that an MDO in the otherwise dark nucleus of a giant elliptical galaxy is a spun-up black hole we should examine it for TeV gamma-ray curvature radiation characteristic of the putative compact dynamo production of the highest energy cosmic rays ($\geq 10^2$ EeV). It has been suggested [18] that the enhanced cosmic ray flux at ~ 1 EeV from the general direction of our own galactic center could be due to a compact dynamo associated with the Sgr A* black hole ($\sim 2.5 \times 10^6 M_\bullet$) and that the characteristic curvature radiation expected in this case at ~ 0.1 TeV should be observable with the GLAST space gamma-ray mission [19] as well as with the CANGAROO [20] and HESS [21] ground-based gamma-ray imaging atmospheric Cherenkov telescopes.

3. Outlook

X-ray and gamma-ray observations of nearby supermassive black-hole galactic nuclei could help significantly in providing the basic knowledge of spin needed to properly investigate and interpret the characteristic gravitational radiation generated in some of the major events of such objects throughout their history. Events of particular interest could signal interactions like those involving plunging stars and the coalescence of supermassive black holes in galactic mergers, where the effects of spin-orbit coupling come into play [22].

The highest energy cosmic rays may well originate in dark galactic nuclei harboring the most massive black holes. Detection of concomitant TeV curvature gamma radiation would then be indicative of cosmic ray acceleration driven by a spinning black hole in an otherwise non-active nucleus. The proposed gamma-ray observations of such apparently normal galactic nuclei complements the anticipated ultra-high resolution spectral/spatial studies of present-epoch AGN X-ray emission from close to the associated black hole event horizon for active nuclei. Taken together, these two avenues of investigation have the potential of distinguishing the geometry (Kerr vs Schwarzschild) underlying these two fundamentally different black-hole based objects.

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