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Supermassive Black Holes and the Strong Field Limit of General Relativity

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Abstract:

The energy driving a quasar or active galactic nucleus (AGN) is thought to come from the accretion of gas on to a supermassive black hole at the center of the host galaxy. Evidence for this has been hard to find, but the extremely broad iron line observed in the X-ray spectrum of one particular AGN (the Seyfert galaxy known as MCG-6-30-15) may well be the calling card of a supermassive black hole. A new model-independent approach to analyzing these intriguing X-ray emissions extracts more information about the black hole within -- including the position of the inner edge of the accretion disk and the rate at which the black hole is rotating.

Background and Research Objectives:

Supermassive black holes with accretion disks are thought to exist in the center of all galaxies. It is speculated that the active galaxies (AGN's, Quasars, Seyferts) each contain a rotating black hole, while the more quiescent galaxies, such as our own, contain a non-rotating black hole. These $\sim 10^8$ solar mass black holes may explain the immense power output from active galaxies. It was our objective to (1) provide evidence for the existence of such rotating black holes, (2) to understand better the mechanism of the power output from such AGN's, and (3) to capture the rotation of a supermassive black hole.

Importance to LANL's Science and Technology Base and National R&D Needs:

The extreme environment at the core of AGN's provide an ideal setting to test physical models and computer algorithms of relevance to LANL's programmatic directions.

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Scientific Approach and Objectives:

We undertook to model the emission from accretion flows on to supermassive black holes.

Many galaxies are now known to harbor such objects, with a mass range of 10^6 to 10^9 M. A particular class of galaxies, Seyfert objects, show X-ray emission from cold-disk accretion onto a central supermassive hole. Our work focused on the fluorescent iron Kα emission which has been observed in more than a dozen Seyferts; the evidence is that these X-ray lines arise from material in a thin disk around the hole which is illuminated by a hard X-ray source near the horizon of the hole.

Our work demonstrated several important features about the accretion flow on to supermassive black holes in Seyfert galaxies. First, we demonstrated that even with limited quality data one could place robust limits on the inner extent of the disk, despite our lack of knowledge of the disk's precise geometry and the nature of the hard X-ray source which causes the iron fluorescence. For the bright Seyfert MCG-6-30-15, we found that the disk *must* extend to within 3 Schwarzschild radii of the black hole (Bromley, Miller & Pariev 1998).

We also extended the modeling of emission from accretion disks to include the effects of turbulence in the accretion disk, an improvement in the physics that no other group has implemented. Details may be found in Pariev & Bromley (1998), and work in preparation demonstrates that with even the current level of observations (pre-Chandra X-ray Observatory) we can eliminate cold, non-turbulent disks as the source of X-ray emissions. This would be the first detection of possible internal disk structure in a relativistic system. Finally, under the guidance of George Rybicki (Harvard) we explored the effects of radiative transfer in disks that are hot enough to support ionization states of iron that can resonantly scatter the fluorescent emission.

This leads to an effect in which there is anomalous absorption in the line (Rybicki & Bromley 1998, 1999). While our results were initially treated as arcane, they preceded a recent report by Nandra et al. (astro-ph 9907193) that identifies just this effect in the Seyfert galaxy NGC~3516.

Publications

1. Rybicki, G. B., & Bromley, B. C. 1999, "Line Emission from a Relativistic Accretion Disk," submitted to the *Astrophysical Journal* (astro-ph 9711104).

2. Pariev, V. I., & Bromley, B. C. 1998, "Line emission from an Accretion Disk around a Black Hole: Effects of Disk Structure," *Astrophysical Journal*, 508, 590.

3. Bromley, B. C., Miller, W. A., & Pariev, V. I. 1998, "The inner radius of the accretion disk around a supermassive black hole," *Nature* , 391, 54.

4. Bromley, B. C., Miller, W. A., & Pariev, V. I. 1998, "Bounds on the inner radius of emission around supermassive black holes," in *Accretion Processes in Astrophysical Systems: Proceedings of the 8th Annual Astrophysics Conference in Maryland,* eds. S. Holt & T. Kallman, in press.

5. Pariev, V. I., & Bromley, B. C. 1998, "Line emission from an accretion disk around a black hole: effects of disk structure," in *Accretion Processes in Astrophysical Systems: Proceedings of the 8th Annual Astrophysics Conference in Maryland*, eds. S. Holt & T. Kallman, in press.

6. Rybicki, G. B., & Bromley, B. C. 1998, "Spectral signatures of a relativistic accretion disk," in *Accretion Processes in Astrophysical Systems: Proceedings of the 8th Annual Astrophysics Conference in Maryland,* eds. S. Holt & T. Kallman, in press.