*Black Holes from Stars to Galaxies – Across the Range of Masses*
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# Observational manifestations of accretion onto isolated black holes of different masses

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**Abstract.** The process of accretion onto the isolated black holes under the various conditions of the ISM and its observational manifestations are discussed. For the majority of the Galaxy volume the accretion rate is as low as $10^{-6}$–$10^{-9}$ of Eddington one, and the accretion is spherically-symmetric. Such objects manifest itself as a weak optical and x-ray sources with featureless spectra and the significant variability of the emission.

For the BH located inside the dense molecular cloud the regime of accretion depends on its mass and velocity. A massive (100–1000$M_\odot$) BH born in the cloud or having low relative velocity, may manifest itself as a ultra-luminous x-ray source (ULX).

**Keywords.** Accretion – black hole physics – ISM: clouds – ISM: general

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For the majority of Galaxy, filled with hot and warm ionized hydrogen, the regime of accretion onto the stellar mass isolated black holes is spherical, as the captured specific angular momentum is much smaller than one on the last stable orbit. The accretion rate is also small, $\dot{m}\dot{M}/\dot{M}_{edd} \sim 10^{-10}$–$10^{-5}$ for the velocity of 50–100 km/s (Shvartsman 1971, Ipser & Price 1982). So, the emission of the accretion flow is dominated by the non-thermal synchrotron component due to accelerated particles(Beskin & Karpov 2005). The total luminosity of such object is then $L = 9.6 \cdot 10^{33} M_{10}^3 n_1^2 (V^2 + c_s^2)_{16}^{-3} \sim 10^{29} - 10^{34}$ erg/s.

For typical interstellar medium parameters, a $10 M_\odot$ black hole at 100 pc distance will be a 16–$25^{\mathrm{m}}$ optical source coinciding with the highly variable bright X-ray counterpart and a very faint gamma-ray one. The hard emission consists of a distinct flares (Beskin & Karpov 2005; see Fig. 1) carrying the information on a structure of space-time near the horizon. Such black hole mimics the optical appearance of known classes of objects with featureless optical spectra, such as DC-dwarfs and blazars (see the sample spectrum in Fig. 2).

The intermediate mass black holes (IMBH, 100–1000$M_\odot$) may form as a result of the collapse of first massive stars or due to the mergers of the stars in the centers of globular clusters, and is assumed to populate the halo of the galaxies. They may be observable while crossing the galactic plane. Typical velocities for them are 50–100 km/s, the accretion rate is again $\dot{m} \sim 10^{-10}$–$10^{-6}$, and the luminosity is $10^{30}$–$10^{35}$ erg/s. Such objects appear as a strong IR sources coincided with optical and UV/X-ray counterparts. The example of computed spectrum for such object is shown in Fig. 2.

The accreting stellar mass black hole may be located in a dense molecular cloud (Mapelli *et al.* 2006). The time scale of the cloud crossing is about $10^5$–$10^6$ years for the velocity of 50–100 km/s. The black hole moving slower ionizes and heats the cloud before it may start to accrete it, and falls in the class of low-density accretion models. The fast-moving black hole also ionizes the cloud while flying through it, as the Strömgren radius is always larger than the Bondi one. The ionization time scale is 10–100 years – this is

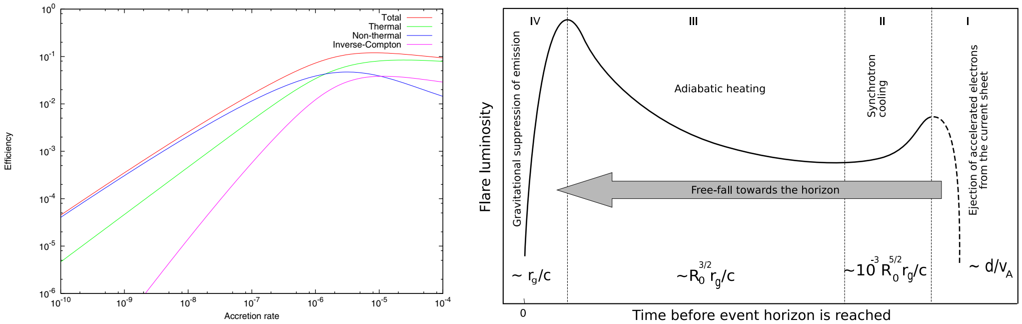

**Figure 1.** Left panel: efficiencies of the synchrotron emission of thermal and non-thermal electron components of the accretion flow. Right panel: internal structure of a flare as a reflection of the electron cloud evolution. The prevailing physical mechanisms defining the observed emission are denoted and typical durations of the stages are shown.

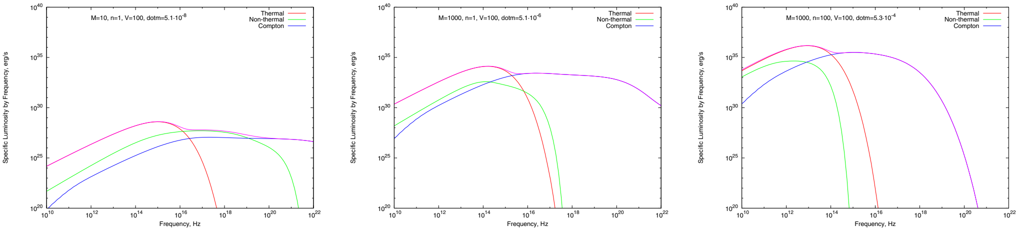

**Figure 2.** Spectra of accreting isolated black holes. The left panel corresponds to the stellar-mass black hole in low-density ISM, the middle – to the IMBH in ISM, and the right one – to the IMBH in dense molecular cloud.

the "active phase" of the black hole inside the dense molecular cloud accretion. After this time the luminosity drops down several orders of magnitude. During the "active phase" the accretion rate is high, so the inverse Compton emission is important. Strong gamma-ray counterpart appears along with the radio, infrared, optical and X-ray one. The luminosity is of order $10^{34}$–$10^{36}$ erg/s, and the sample spectrum is shown in Fig. 2.

In the rare case of IMBH born in the cloud or having low relative velocity (less than 10 km/s), it may appear as ULX, with luminosity $L \sim 10^{39}$–$10^{40}$ erg/s for either spherical or disk regime of accretion.

In the case of the accretion disk formation (due to the large gradients of density and velocity in molecular clouds) the picture basically remains the same. The difference is in the spectral shape – the X-ray part becomes larger while the optical and IR fainter.

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