Pressure Ionization Instability: Connection between Seyferts and GBHCs

Sergei Nayakshin

Department of Physics, the University of Arizona, Tucson, AZ, 85721

Abstract. Spectrum of Seyfert 1 Galaxies (S1G hereafter) is very similar to that of several Galactic Black Hole Candidates (GBHCs) in their hard state, suggestive that both classes of objects have similar physical processes. However, recent work has shown that reprocessing features make the patchy corona-disk model (PCD model: the best current explanation of S1G spectrum) problematic for GBHCs. To address the similarities and differences in spectrum of Seyferts and GBHCs, we consider the structure of the ionized X-ray skin near an active magnetic flare. We show that the X-ray skin is subject to a thermal instability, similar in nature to the well known ionization instability of quasar emission line regions. Due to the much higher ionizing X-ray flux in GBHCs, the only stable solution for the upper layer of the accretion disk is that in which it is highly ionized and is at the Compton temperature (∼few keV). We show that this accounts for the difference in spectrum of GBHCs and S1G. In addition, same instability, applied to S1G, leads to the X-ray skin temperature $T \sim 1 - 3 \times 10^5$ Kelvin, which then may explain the observed spectral shape of BBB.

1. Introduction

The X-ray spectra of S1G and GBHCs indicate that the reflection and reprocessing of incident X-rays into lower frequency radiation is an ubiquitous and important process (Pounds et al. 1990, Nandra & Pounds 1994; Zdziarski et al. 1996). It is generally believed that the universality of the X-ray spectral index in S1G ($\Gamma \simeq 1.9$) may be attributed to the fact that the reprocessing of X-rays within the disk-corona of the two-phase model leads to an electron cooling rate that is roughly proportional to the heating rate inside the active regions (AR) where the X-ray continuum originates (Haardt & Maraschi 1991, 1993; Haardt, Maraschi & Ghisellini 1994; Svensson 1996). Although the X-ray spectra of GBHCs are similar to that of Seyfert galaxies, they are considerably harder (most have an intrinsic power-law index of $\Gamma \sim 1.5 - 1.7$), and the reprocessing features are less prominent (Zdziarski et al. 1996). Dove et al. (1997) recently showed that a Rossi X-ray observation of Cygnus X-1 shows no significant evidence of reflection features. The relatively hard power law and the weak reprocessing/reflection features led Dove et al. (1997, 1998), Gierlinski et al. (1997) and Poutanen, Krolik & Ryde (1997) to conclude that the PCD model does not apply to Cygnus X-1. This conclusion is sensitive to the assumption
Figure 1. The geometry of the active region (AR, the X-ray source) and the transition layer. Magnetic fields, confining AR and supplying it with energy are not shown. Transition region is defined as the upper layer of the disk with Thomson depth of ∼ few, where the incident X-ray flux $F_x$ is substantially larger than the intrinsic disk flux $F_d$.

that the accretion disk is relatively cold, such that ∼ 90% of the reprocessed coronal radiation is re-emitted by the disk as thermal radiation (with a temperature ∼ 150 eV). To test validity of this assumption, we extend earlier work of Nayakshin & Melia (1997), who investigated the X-ray reflection process in AGNs assuming that the ARs are magnetic flares above the disk, on the case of GBHCs.

2. Thermal Instability of the Transition Region

The relevant geometry is shown in Figure (1). Since the flux of the ionizing radiation from the active region is rapidly declining with distance away from the flare, only the gas near the active regions (with a radial size ∼ a few times the size of the active region) may be highly ionized. To distinguish these important X-ray illuminated regions from the “average” X-ray skin of the accretion disk (i.e., far enough from active magnetic flares), we will refer to these as transition layers (or regions). We will only consider the structure of the cold disk in the transition layer and only solve the radiation transfer problem for these regions as well, because this is where most reprocessed coronal radiation will take place.

The compactness parameter of the active region, $l$, is defined as

$$l \equiv \frac{F_x \sigma_T \Delta R}{m_e c^3},$$

(1)

and is expected to be larger than or of order of unity (e.g., Poutanen & Svensson 1996, Poutanen, Svensson & Stern 1997, Chapter 2 in Nayakshin 1998b). Here, $F_x$ is the X-ray illuminating flux from the flare, $\sigma_T$ is the Thomson cross section, and $\Delta R$ is the size of the active region $\Delta R$, which is thought to be of the order of the accretion disk height scale $H$ (e.g., Galeev et al. 1979). Inverting this definition, one gets an estimate for $F_x$ for a given compactness parameter. Due to space limitations, we just mention that one can show that (1) during the flare, the ionizing X-ray flux $F_x$ substantially exceeds the disk thermal flux $F_{disk}$ in parameter space appropriate for both S1Gs and GBHCs; (2) the X-radiation
ram pressure, $F_x/c$ is much larger than the gas pressure in the disk atmosphere (Nayakshin 1998b, Nayakshin & Dove 1998, paper I & II hereafter). Under these conditions, the ionizing radiation ram pressure compresses the disk atmosphere (in the transition layer only, of course) so that the gas pressure there matches the ram pressure, i.e., $P \lesssim F_x/c$.

Thermal instability was discovered by Field (1965) for a general physical system. He introduced the “cooling function” $\Lambda_{\text{net}}$, defined as difference between cooling and heating rates per unit volume, divided by the gas density $n$ squared. Energy equilibria correspond to $\Lambda_{\text{net}} = 0$. He argued that a physical system is usually in pressure equilibrium with its surroundings. Thus, any perturbation of the temperature $T$ and the density $n$ of the system should occur at a constant pressure. The system is unstable when

$$\left(\frac{\partial \Lambda_{\text{net}}}{\partial T}\right)_P < 0,$$

since then an increase in the temperature leads to heating increasing faster than cooling, and thus the temperature continues to increase. Similarly, perturbation to a lower $T$ will cause the cooling to exceed heating, and $T$ will continue to decrease.

In ionization balance studies, it turns out convenient to define two parameters. The first one is the “density ionization parameter” $\xi$, equal to (Krolik, McKee & Tarter 1981) $\xi = 4\pi F_x/n$. The second one is the “pressure ionization parameter”, defined as $\Xi = F_x/(2cnkT) \equiv P_{\text{rad}}/P$, where $P$ is the gas pressure. This definition of $\Xi$ is the one used in the ionization code XSTAR (see below), and is different by factor 2.3 from the original definition of Krolik et al. (1981), who used the hydrogen density instead of the electron density. In papers I & II, we showed that Fields instability criterion is equivalent to the following condition (see also Krolik et al. 1981):

$$\left(\frac{d\Xi}{dT}\right)_{\Lambda_{\text{net}} = 0} < 0$$

We now apply the X-ray ionization code XSTAR, written by T. Kallman and J. Krolik, to the problem of the the transition layer. A truly self-consistent treatment would involve solving radiation transfer in the optically thick transition layer, and, in addition, finding the distribution of the gas density in the transition layer that would satisfy pressure balance. Since radiation force acting on the gas depends on the opacity of the gas, this is a difficult non-linear problem. We defer such a detailed study to future work, and simply solve (using XSTAR) the local energy and ionization balance for an optically thin layer of gas in the transition region. We assume that the ionizing spectrum consists of the incident X-ray power law with the energy spectral index typical of GBHCs in the hard state, i.e., $\Gamma = 1.5 - 1.75$, exponentially cutoff at 100 keV, and the blackbody spectrum at temperature $T_{\text{min}}$ with flux equal to the X-ray flux. We include the former component to mimic the spectrum reflected from the cold disk below the transition layer (usually as much as 80 – 90 % of the reflected flux comes out as the cold black body emission, see §3).

When applying the code, one should be aware that it is not possible for the transition region to have temperature lower than the effective temperature of
Figure 2. Gas temperature versus pressure ionization parameter $\Xi$ for GBHCs. Values of the parameters are: $\Gamma = 1.5, 1.75, 1.75, 1.7$ and $kT_{\text{min}} = 200, 100, 200, 400$ eV, corresponding to the fine solid, thick solid, dotted and dash-dotted curves, respectively. The ionization equilibrium is unstable when the curve has a negative slope. Note that there exist no solution for $T$ below $T_{\text{min}}$.

The X-radiation, i.e., $T_{\text{min}} = (F_x/\sigma)^{1/4}$. The reason why simulations may give temperatures lower than $T_{\text{min}}$ is that in this parameter range XSTAR neglects certain de-excitation processes, which leads to an overestimate of the cooling rate for $T \sim T_{\text{min}}$ (Życki et al. 1994; see their section 2.3). In the spirit of one zone approximation for the transition layer, we use an average X-ray flux $\langle F_x \rangle$ as seen by the transition region, which we parameterize as $\langle F_x \rangle = 0.1F_x/q_1$, where $q_1 = q/10$, and $q$ is a dimensionless number of order 10 (see figure 1; $F_x$ is the X-ray flux at the active region). Nayakshin (1998b) shows that

$$T_{\text{min}} \approx 5.0 \times 10^6 l^{1/4} q_1^{-1/4} \left( \frac{\dot{m}}{0.05} \right)^{-1/20} \alpha^{1/40} M_1^{-9/40} [1 - f]^{-1/40}$$

(4)

where $l \gg 0.01$ is the compactness parameter, $\dot{m}$ is the dimensionless accretion rate, $M_1 \equiv M/10 M_\odot$, $f$ is the fraction of power supplied from the disk to corona (see Nayakshin 1998a) and $\alpha$ is the viscosity parameter.

Figure 2 shows results of our calculations for several different X-ray ionizing spectra. A stable solution for the transition layer structure will have a positive slope of the curve, and also satisfy the pressure equilibrium condition. As discussed earlier, $P \leq F_x/c$ (i.e., $\Xi \geq 1$). In addition, if the gas is completely ionized, the absorption opacity is negligible compared to the Thomson opacity. Because all the incident X-ray flux is eventually reflected, the net flux is zero, and so the net radiation force is zero. In that case $P$ adjusts to the value appropriate for the accretion disk atmosphere in the absence of the ionizing flux (see also Sincell & Krolik 1996), i.e., $\Xi \gg 1$. Thus, the upper branch of the ionization equilibrium curve, where the transition layer is at the Compton equilibrium temperature, is stable, because the ionization curve has a positive slope and the large values of $\Xi$ are physically allowed.
In addition to the Compton equilibrium state, there is a smaller stable region for temperatures in the range between 100 and 200 eV. The presence of this region is explained by a decrease in heating, rather than an increase in cooling (cf. equation \( \text{and recall } \Lambda_{\text{net}} = \text{cooling} - \text{heating} \). The X-ray heating decreases in the temperature range 100 – 200 eV with increasing \( T \) because of consequent destruction (ionization) of ions with ionization energy close to \( kT \). This is highly unlikely that the transition region will stabilize at the temperature 100 – 200 eV, because the effective temperature \( T_{\text{min}} \) is at or above this temperature range. Further, Nayakshin (1998b) considered the effects of the radiation pressure in the transition layer more accurately by computing the gas cross sections to the incident and reprocessed fluxes. He shows that the stable state with \( kT \sim 100 – 200 \) eV is forbidden on the grounds of the pressure equilibrium.

Rounding this discussion up, we believe that the only stable configuration available for the transition layer of GBHCs in the hard state is the one at the local Compton temperature. Future work should concentrate on finding not only the exact value of \( \tau_x \), but the exact distribution of gas temperature, density and ionization state in the atmosphere of the accretion disk as well. For now, however, we will treat \( \tau_x \) as a free parameter and numerically investigate the ramifications of the transition layer on the spectrum of escaping radiation and the physical properties of the corona.

3. “Three-Phase” Model for GBHCs

To explore how the structure of the ionized transition region affects the X-ray spectrum from magnetic flares, we computed the X-ray spectrum from a magnetic flare above the transition layer with a range of \( \tau_{\text{trans}} \). The gas in the active region is heated uniformly throughout the region and is cooled by the Compton interactions with radiation re-entering the active region from below. Even though the geometry of the AR is probably closer to a sphere or a hemisphere than a slab, we shall adopt the latter for numerical convenience, neglecting the boundary effects. Experience has shown that spectra produced by Comptonization in different geometries are usually qualitatively similar (i.e., a power-law plus an exponential roll-over), and it is actually the fraction of soft photons entering the corona that accounts for most of the differences in the various models, because it is this fraction that affects the AR energy balance. To crudely take geometry into account, we permit only a part of the reprocessed radiation to re-enter the corona, and fix this fraction at 0.5 (cf. Poutanen & Svensson 1996). The Thomson optical depth of the corona is fixed at \( \tau_c = 0.7 \). We employ the Eddington (two-stream) approximation for the radiative transfer in both the AR and the transition layer.

The disk below the flare is broken into two regions: (i) the completely ionized transition region, situated on the top of (ii) the cold accretion disk, which emits blackbody radiation at a specified temperature. We model the transition layer as being one dimensional. The X-radiation enters the transition region through its top. In this region, the only process taken into account is the Compton scattering. After being down-scattered, the X-radiation is “incident” on the cold accretion disk from the bottom of the transition layer. The incident
Figure 3. (a) Resulting spectrum from the patchy corona disk model as a function of the Thomson optical depth $\tau_{\text{trans}}$ of the transition layer. Notice that higher values of $\tau_{\text{trans}}$ lead to harder spectrum with the disk blackbody component getting progressively smaller. (b) Decomposition of the total spectrum on its constituents. See text for details.

spectrum is reflected in the standard manner (Magdziarz & Zdziarski 1995). The total radiation spectrum re-entering the transition layer from below is the sum of the reflection component and the blackbody component due to the disk thermal emission, which is normalized such that the incident flux from the transition region is equal to the sum of the fluxes from the reflection component and the blackbody. The optically thick cold disk is held at a temperature $T_{bb} = 2.4 \times 10^6$ Kelvin.

The observed spectrum consists of the direct component, emerging through the top of the AR, and a fraction of the reflected radiation that emerges from the transition layer and does not pass through the corona on its way to us (see Fig. 1). This fraction is chosen to be 0.5 as well. Physically, it accounts for the fact that, as viewed by an observer, a part of the transition region itself is blocked by the active region. The overall setup of the active region - disk connection is very similar to the one used by Poutanen & Svensson (1996), except for the addition of transition layer on the top of the cold disk.

Figure (3a) shows the “observed” spectrum for several values of $\tau_{\text{trans}}$: 0, 0.6, 2.5, and 10. It can be seen that the spectrum hardens as $\tau_{\text{trans}}$ increases and the fraction of energy in reprocessed (soft) component below $\sim 2$ keV decreases, which can be understood by noting that a larger fraction of the photons from the AR is reflected before they have a chance to penetrate into the cold disk where the blackbody component is created. In Figure (3b) we show the components that contribute to the overall spectrum for $\tau_{\text{trans}} = 3$. The solid, dashed and dotted curves show the total spectrum, the AR intrinsic spectrum and the reprocessed spectrum (emerging from the top of the transition layer). Notice that the reprocessed component has about equal amount of power below and above 2 keV, whereas the usual division of power in the reflected spectrum (from a neutral reflector) is 80 – 90 in the soft and 20 – 10 % in the hard components, correspondingly (e.g., Magdziarz & Zdziarski 1995). This is the most profound
difference between our calculations and those of previous workers, who assumed that the disk boundary is infinitely sharp, so that there is no transition layer between the AR and the cold disk.

Gierlinski et al. (1997) have attempted to fit broad-band spectrum of Cyg X-1 with active regions above a cold accretion disk, and showed that the most difficult issue for the two-phase model is the too small observed amount of the reprocessed soft X-radiation. For example, Zheng et al. (1997) shows that Cyg X-1 luminosity in the hard state below 1.3 keV is about $5 \times 10^{36}$ erg/s, whereas the luminosity above 1.3 keV is $\sim 3 - 4 \times 10^{37}$ erg/s. This is impossible in the context of the simple PCD model, since about half of the X-radiation impinge on the cold disk and get reprocessed into the blackbody radiation. Accordingly, the minimum luminosity in soft X-rays below 1.3 keV should be about that of the hard component. However, we find that, with the advent of the transition layer, the combined power below 2 keV accounts for only 25% of the total for $\tau_{\text{trans}} = 3$. Further, notice that the spectra are correspondingly harder in X-rays, which explains why GBHCs spectra are harder than those of typical SIG. In paper I we address the other reprocessing features (e.g., the iron line and anisotropy break) and show that the theory predictions are consistent with Cyg X-1 spectrum. In paper II, we apply the non-linear Monte-Carlo routine (for details of the routine and geometry, see Dove, Wilms, & Begelman 1997), and demonstrate that our results obtained with the simpler Eddington approximation code hold true.

4. The Pressure Ionization Instability for AGN

We now discuss the thermal instability of the surface layer for AGN. The most important distinction from the GBHC case is the much higher mass of the AGN, and thus the ionizing X-ray flux is smaller by $\sim 7$ orders of magnitude (since $F_{\text{x}} \propto L/R^2 \propto \dot{m}L_{\text{Edd}}/R^2 \propto \dot{m}M^{-1}$). The minimum X-ray skin temperature is again approximated by setting the blackbody flux equal to the incident flux. The gas pressure dominated solution gives (paper I)

$$T_{\text{min}} \simeq 1.5 \times 10^5 l^{1/4} \alpha^{1/40} M_8^{-9/40} \left( \frac{\dot{m}}{0.005} \right)^{-1/20} (1 - f)^{-1/40} \left( \frac{q}{10} \right)^{-1/4},$$

(5)

whereas the radiation-dominated one yields

$$T_{\text{min}} \simeq 1.24 \times 10^5 l^{1/4} M_8^{-1/4} \left( \frac{\dot{m}}{0.005} \right)^{-1/4} (1 - f)^{-1/4} \left( \frac{q}{10} \right)^{-1/4}$$

(6)

These estimates show our main point right away: the lower X-ray flux density in AGN may allow the transition layer to saturate at either the cold equilibrium state or the "island" state with $T \sim 100 - 200$ eV, whereas that was not possible for GBHCs. To investigate this idea, we ran XSTAR as described in §2, but for parameters appropriate for an AGN transition layer. The X-rays illuminating the transition region are assumed to mimic the typical Seyfert hard spectra, i.e., a power-law with photon index $\Gamma = 1.9$ and the exponential roll-over at $100 - 200$ keV range. We also add the reflected blackbody component as described in §3.
We show results of two such simulations in Figure (4). The solid curve corresponds to $T_{\text{min}} = 6$ eV and the rollover energy of 100 keV, while for the dotted curve $T_{\text{min}} = 12$ eV and the rollover energy of 200 keV. As explained earlier, XSTAR produces inaccurate results below $T \sim T_{\text{min}}$, so that these regions of the ionization equilibrium curve should be disregarded. Notice that the “cold” equilibrium branch, i.e., the region with $T \sim 10^5$ K is broader in terms of $\Xi$ than the island state. Further, preliminary more detailed pressure equilibrium considerations (paper I) show that the island state is unlikely to satisfy the pressure equilibrium, so that the two truly stable solutions for the transition layer in AGN are the cold stable state with $kT \sim 10 – 30$ eV and the hot Compton equilibrium state, which we already discussed for GBHCs in §3.

In addition, the Rosseland mean optical depth to the UV emission is of order 1 to few for the temperature range $kT \sim 10 – 30$ eV (paper I). As one can check using Field (1965) stability criterion, the transition layer radiating via blackbody or modified emission is thermally stable. This consideration adds weight to our optically thin calculations in that the cold state of the transition layer in AGN disks should be unquestionably stable.

It is interesting to note that the reflection component and the fluorescent iron line that are always present in the spectra of radio-quiet Seyfert Galaxies (e.g., Gondek et al. 1996, Zdziarski et al. 1996, George & Fabian 1991) can be best fitted with a neutral or weakly ionized reflector. From work of Matt, Fabian & Ross (1993, 1996) and Zycki et al. (1994), it is known that the ionization parameter $\xi \gtrsim 100$ is required to fit S1G data. The cold stable solution found here corresponds to $\xi$ ranging from few tens to $\sim 200$ (paper I), thus being consistent with observations of X-ray reflection and iron lines in Seyferts.

5. The Origin of the Big Blue Bump (BBB) in Seyferts

In recent years, there has been considerable progress in observations of the BBB (e.g., Walter & Fink 1993; Walter et al. 1994; Zhou et al. 1997). It was found that the observed spectral shape of the bump component in Seyfert 1’s
hardly varies, even though the luminosity $L$ (of the bump) ranges over 6 orders of magnitude from source to source. This fact is uneasy to understand from the point of view of any disk emission mechanism (see, e.g., Nayakshin 1998b, Chapter 5 & references there).

We believe that our theory of the ionization pressure instability may offer a plausible explanation for the BBB emission. As our ionization equilibria calculations show, there is no stable solution for the transition region in the temperature range $\sim 3 \times 10^5 \lesssim T \lesssim 10^7$ Kelvin. Furthermore, temperatures below the effective temperature of the X-ray radiation are also forbidden. If PCD model is correct at all, $l \gg 0.01$. Preliminary estimates (Nayakshin 1998b) show that $l \sim 0.1$ is required to explain soft X-ray part of Cyg X-1 spectrum. Since we believe it is the same physics of the PCD model that explains both GBHCs and Seyferts, $l \sim 0.1$ yields $T_{\text{min}} \sim 10^5$ K (see equations 5 & 6) for AGN. Thus, the only low temperature solution permitted by the stability analysis for AGN with $M \sim 10^8 M_\odot$ is the one with temperature $1 \sim 3 \times 10^5$ Kelvin. From our calculations, we also found that the Rosseland mean optical depth to the UV emission is of order 1 to few in the cold stable state. The radiation spectrum produced by the transition layer will therefore be either a blackbody spectrum, or a modified blackbody (with recombination lines as well, of course). Since a moderately optically thick emission spectrum saturates at photon energy of $\sim 2 - 4 \times kT$, $T \sim 2 \times 10^5$ provides an excellent match to the observed roll-over energies of $\sim 40 - 80$ eV (e.g., Walter et al. 1994).

The most attractive feature of this suggestion is that the temperature of the BBB is fixed by atomic physics, in particular by the fact that many atomic species have ionization potential close to 1 Rydberg $\simeq 1.5 \times 10^5$ K, which may explain the fact that the BBB shape changes so little from source to source. The stable temperature range is independent of the number of magnetic flares, and so it is independent of the X-ray luminosity of the source, as found by Walter & Fink (1993) and Walter et al. (1994). Further, supplemented by our theory of the division of power between the corona and the disk, the pressure ionization instability can explain disappearance of the bump for AGN more luminous than typical S1G, e.g., quasars from Zheng et al. (1997) and Laor et al. (1997) samples (see Nayakshin 1998a and paper I).

6. Discussion

By considering the irradiated X-ray skin close to an active magnetic flare above a cold accretion disk, we have shown that the skin equilibrium is in general unstable. Two stable states (one cold and one hot) exist. For the case of GBHCs, we showed that the low temperature equilibrium state is forbidden due to a high value of the ionizing flux. Thus, the X-ray irradiated skin of GBHCs must be in the hot equilibrium configuration, where the gas is at the local Compton temperature ($kT \sim$ few keV). In an attempt to determine the effects of this skin on the spectrum from a magnetic flare, we modeled the ionization structure of the disk by assuming a completely ionized layer with Thomson optical depth of $\sim$ few to be situated on the top of the cold disk (cf. Fig. 1).

We found that the transition layer alters the reflected spectrum significantly, and that it leads to GBHCs spectra being harder than Seyfert 1 spectra for same
parameters of magnetic flares. We also found that the highly ionized transition layer can account for the disappearance/weakening of the reprocessing features, such as iron line. We thus conclude that spectrum of GBHCs in their hard state is consistent with PCD model when one takes into account the pressure ionization instability discussed here.

Applying our results to AGN case, we found that, due to a substantially lower ionizing flux as compared to GBHCs case, there exists a stable solution for the transition layer in the temperature range $T \sim 1 - 3 \times 10^5$ K. Thus, the reprocessed features are expected to be characteristic of cold, almost neutral reflector, being consistent with observations of AGN (e.g., Zdziarski et al. 1996). The narrow range in the temperature of the transition region in S1G may explain the observed roll-over energies in the BBB spectrum.

Commenting on the distinction of our work on the ionization structure of the disk from extensive previous studies of this issue (e.g., Zycki et al. 1994, Ross, Fabian & Brandt 1996 and references there), we note that the difference is caused by two factors: (1) previous workers assumed that the corona is uniform and covers the whole disk, whereas here we test the case of strongly localized emission from magnetic flares, and (2), more importantly, previous studies fixed the X-ray skin gas density at the disk mid-plane value, which, we note, have little to do with the disk atmosphere density. The usual statement that the density of radiation-dominated disks is approximately constant is only correct as long as one stays deep inside the disk, far from the surface (see, e.g., §2a and Fig. 11 of Shakura & Sunyaev 1973). Further, the pressure ionization instability is not apparent in studies where the gas density is fixed to a constant value, regardless of its value. As shown by Field (1965), the thermal instability for the case with $n = \text{const}$ is always weaker than it is for the case of a system in pressure equilibrium (and it actually disappears in the given situation), which is apparently the reason why this instability was not recognized before.

Thus, as far as we can see, observations of the hard state of the GBHCs do not rule out magnetic flares as the source of X-rays, and instead support this theory. We preliminary estimate that the observed X-ray spectrum of Cyg X-1 can be explained by the transition optical depth of $\sim 3$, which is physically plausible, and that, apart from the self-consistent difference in the structure of the transition layer, same parameters for magnetic flares might be used in both AGN and GBHCs to explain their spectra.

Acknowledgments. The author is very thankful to the workshop organizers for the travel support, and to F. Melia for support and useful discussions in an early stage of this work.

References

Dove, J. B., Wilms, J., & Begelman, M. C., 1997, ApJ, 487, 747
Dove, J. B., Wilms, J., Nowak, M. A., Vaughan, M. A., & Begelman, M. C., 1998, MNRAS, in press
Field, G.B. 1965, ApJ, 142, 531
Galeev, A. A., Rosner, R., & Vaiana, G. S., 1979, ApJ, 229, 318
George, I.M., & Fabian, A.C. 1991, MNRAS, 249, 352
Gierlinski, M. et al. 1997, MNRAS, 288, 958
Gondek, D., et al. 1996, MNRAS, 82, 646
Haardt F., & Maraschi, L., 1991, ApJ, 380, L51
Haardt F. & Maraschi L., 1993, ApJ, 413, 507
Haardt F., Maraschi, L., & Ghisellini, G. 1994, ApJ, 432, L95
Krolik, J.H., McKee, C.F., & Tarter, C.B. 1981, ApJ, 249, 422
Laor, A., et al. 1997, ApJ, 477, 93
Magdziarz, P. & Zdziarski, A.A. 1995, MNRAS, 273, 837
Matt, G., Fabian, A.C., & Ross, R. R. 1993, MNRAS, 262, 179
Matt, G., Fabian, A.C., & Ross, R. R. 1996, MNRAS, 278, 1111
Nandra, K., & Pounds, K. A., 1994, MNRAS, 268, 405
Nayakshin, S. & Melia, F. 1997, ApJ, 484, L103
Nayakshin, S. 1998a, these proceedings.
Nayakshin, S. 1998b, PhD thesis, The University of Arizona, astro-ph/9811061.
Nayakshin, S. & Dove, J. B., 1998, submitted to ApJ, astro-ph/9811059.
Pounds, K.A., et al. 1990, Nature, 344, 132
Poutanen, J. & Svensson, R. 1996, ApJ, 470, 249
Poutanen, J, Krolik, J.H, & Ryde, F. 1997, in the Proceedingsof the 4th Compton Symposium, astro-ph/9707244
Ross, R.R., Fabian, A.C., Brandt, W.N. 1996, MNRAS, 278, 1082
Shakura, N.I., & Sunyaev, R. A. 1973, ApJ, 24, 337
Sincell, M.W. & Krolik, J.H. 1997, ApJ, 476, 605S
Svensson, R. 1996, ApJ Supplement, 120, 475
Walter, R., & Fink, H.H. 1993, A&A, 274, 105
Walter, R., et al. 1994, A&A, 285, 119
Zdziarski, A.A., Gierlinski, M., Gondek, D., & Magdziarz, P. 1996, A&A Suppl., 120, 553
Zheng, W. et al. 1997, ApJ, 475, 469
Zhou, Y., et al. 1997, ApJ, 475, L9
Życki, P.T. et. al. 1994, ApJ, 437, 597