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THE BIG BLUE BUMP AND SOFT X-RAY EXCESS OF INDIVIDUAL QUASARS

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RESUMEN

Para una muestra de 11 cuásares, encontramos que el exceso de rayos-X suaves *no* es una prolongación de la Gran Joroba Azul. Aún más, adoptando un continuo ionizante teórico que es absorbido por una cantidad dada de polvo intrínseco, podemos reconciliar un continuo universal con el quiebre UV observado en cada cuásar, así como con el problema de suavidad en cuásares.

ABSTRACT

For a sample of 11 quasars, we find that the soft X-ray excess component is not prolongation of the Big Blue Bump. Furthermore, adopting a theoretical continuum that is absorbed by the appropriate amount of intrinsic dust, we are able to reconcile a universal theoretical continuum with the observed *UV break* in each quasar and the *softness problem*.

Key Words: dust, extinction — galaxies: ISM — quasars: general — ultraviolet: galaxies — X-rays: galaxies

1. INTRODUCTION

The optical-UV spectral feature in quasars commonly referred as the *Big Blue Bump* (BBB) is generally believed to be the thermal manifestation of an accretion disk. However, state-of-art models do not reproduce well the *UV break* observed near 1100 Å. In addition, models that roughly reproduce the shape of the observed BBB present the so-called *softness problem* as pointed out by Binette et al. (2008, hereafter B08). No disk model can solve both problems simultaneously. In the X-ray domain, the spectra of quasars are frequently fit with a simple power law. However, there are quasars that show additional components such as intrinsic absorption or a soft excess (Mathur et al. 1994). An observational gap exists between the EUV and the X-rays (the gray zone in Figure 1 of B08) where the Milky Way absorbs all photons. Thus the SED behavior within this gap is not known. The usual way of connecting the ionizing continua of these two domains is to use a simple extrapolation of the far-UV power law into the soft X-rays. In this work, we explore the following questions: (1) is the Soft X-ray Excess a simple prolongation of the BBB? (2) is it possible to reconcile the *UV break* with a theoretical universal SED? and finally, (3) does this universal SED resolve the *softness problem*?

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2. MATCHING THE UV AND THE X-RAY COMPONENTS

In order to answer these questions and to derive useful constraints on BBB models, we analyzed the individual UV and X-ray spectra of 11 quasars for which high-quality spectral datasets exist in both the *HST-FOS* (kindly lent us by Telfer; Telfer et al. 2002) and *Chandra-ACIS* (obtained from the archives) presented in Figure 1. Labels are related to the quasars names as follow: (a) PKS 1127-14, (b) PKS 0405-123, (c) 3C 351, (d) 3C 334 (e) B2 0827+24, (f) PKS 1354+19, (g) 3C 454.3, (h) OI 363, (i) PKS 1136-13, (j) PG 1634+706, (k) PG 1115+080. This sample of eleven quasars have the following characteristics (see Haro-Corzo et al. 2007, hereafter H07): a redshift between 0.3 and 1.8, a sufficiently wide spectral coverage shortward and longward of 1100 Å, and an an absence of any deep absorption trough. We fit each observed domain (UV and X-rays) separately. The best-fits in the UV are based on two different hypotheses concerning the environment of each quasar (see below). Finally, we combine the best-fits from both domains into a single SED in $\nu F\nu$ ($\propto \nu^{\beta}$, where $\beta = +\alpha + 1$) and attempt to extrapolate the fits towards the EUV gap, as shown in Figure 1.

2.1. *The UV SED in the Dust-free Case*

We assume in this case that the environment is dust-free, i.e., the observed UV spectra only need to be corrected for Galactic dust and intergalactic Lyα absorption. The UV continuum best-fits using broken powerlaws as templates are shown in Figure 1

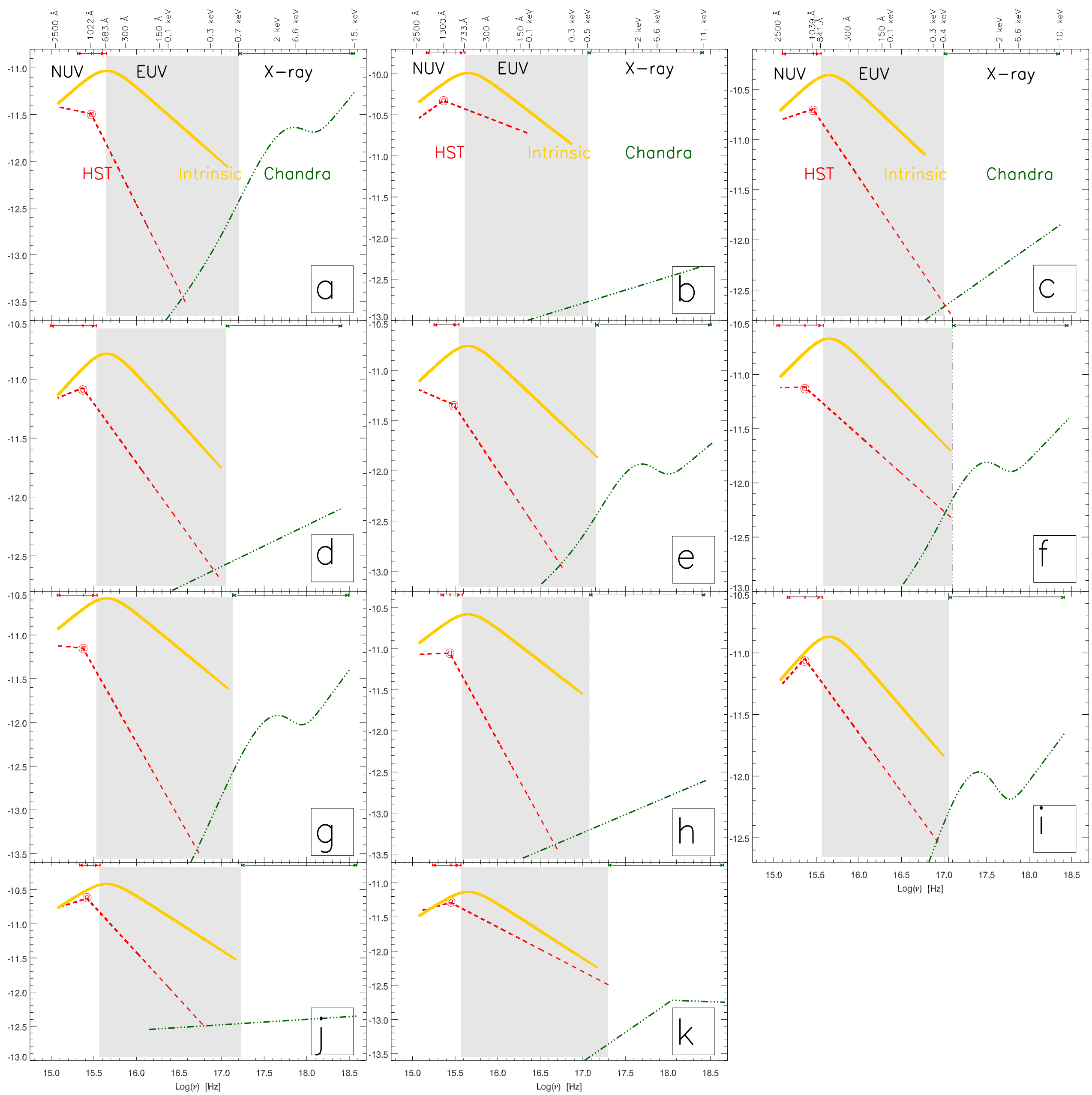

Fig. 1. Best-fit models in $\nu F\nu \, vs \, \nu$ of the UV and X-ray domains for each quasar. To avoid cluttering, the data are not superimposed (but see H07). In the UV domain, the models are based on two different hypotheses concerning the environment of individual quasars: the dust-free case (dashed lines, see § 2.1) or the dust-absorbed case, by amorphous carbon and nanodiamond grains (thick solid lines, see § 2.2). The X-ray continuum for each quasar is represented by a dot-dashed line. The symbol "@" denotes the *UV break* position. The gray shaded area represents the domain where there is no data. Black arrows at the top of each panel indicate the wavelength coverage of the original data.

(dashed lines). The UV spectra are all characterized by a sharp *UV break* between 988 Å and 1303 Å. The break position is marked by the symbol "@" in Figure 1. The steepening in the SED shortward of the *UV break* varies from object to object. In the case of the X-ray domain, the best-fits (dot-dashed line) were corrected for Galactic absorption. We obtained a marked improvement in the statistics of the X-ray models, however, after considering an *intrinsic cold*[3] absorption component[4] in 7 quasars (for the remaining 4 quasars, only an upper limit was derived). A fit improvement was also present in 5 quasars after adding a soft X-ray excess component. As can be observed in Figure 1, for 9 out of 11 quasars, the far-UV best-fit powerlaw either does not connect with the X-ray SED or result in an inflection in the SED. We conclude that the soft X-ray component is not a simple prolongation of the BBB component, but must have a different origin.

2.2. *The UV SED in the Dust Case*

The paradigm behind this section is that a universal intrinsic SED exists in most AGN, but it is absorbed by different amounts of intrinsic dust. As before, Galactic and extragalactic absorption was considered in our data analysis. The hypothesis behind the proposed test are the following:

• **Intrinsic Universal SED**: We have been exploring intrinsic SEDs (see H07) that can produce a much higher number of hard ionizing photons (in the extreme-UV) than provided by the broken powerlaw observed (see § 2.1). This new intrinsic SED (solid lines in Figure 1) could in principle help resolve the *softness problem* because it resembles the very hard SEDs used in theoretical studies of the BLR emission lines (plotted in Figures 8 and 9 of H07). We define our universal SED as a power law with a near-UV spectral index in $\nu F\nu$ of $\beta_{NUV} = 0.8$, multiplied by a rollover function defined in H07, in order that our SED remains consistent with the observed X-ray flux. This means that our spectral index in the *extreme* UV becomes $\beta_{FUV} = -0.8$.

• **Intrinsic Dust Screen**: Based on previous works (H07, see also Figure 4 of B08), successful dust models rely on a grain composition made of two types: nanodiamonds and amorphous carbon. Hence two extinction curves are needed. While both are responsible of absorbing a significant amount of UV photons, only nanodiamonds can account for the sharp UV break.

We can successfully reproduce the observed spectra (F_{obs}) of the 11 quasars by attenuating our universal SED (F_{int}) by two transmissions curves, i.e., $F_{obs}=F_{int}\times\exp(-N_H\,\sigma_{ND})\times\exp(-N_H\,\sigma_{AC})$, where N_H is a free parameter, that controls the amount of dust required to reproduce the spectral index observed. Interestingly, we have found that the column densities of the dust screen are consistent with those inferred from the X-ray best-fits (see H07). For all quasars, we find that our extrapolation of the intrinsic SED lies above the observed X-ray flux. This is shown in Figure 1. This implies that the "true" universal SED should be characterized by a sharper turn-over or one that occurs at much higher energies than assumed here. Maybe accretion disk models might be more suitable than our assumed ad hoc universal SED given that they are meaningful and likely to provide the required photons and luminosity expected by the photoionization models.

3. DISCUSSION

We found that it is possible to account for the presence of a sharp UV break and to resolve the *softness problem* by having just a universal intrinsic SED attenuated by dust. This universal SED can also be made compatible with those required by photoionization calculations of the BLR.

For almost all of the 11 quasars (with or without dust absorption), the soft X-ray component must be different from the BBB, given that an extrapolation of the BBB powerlaw results in a sharp SED inflection in the EUV at the junction point with the X-ray best-fit models.

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[3]Except for 3C 351, where an ionized absorber was modeled with the PHASE code (Krongold et al. 2003).

[4]The presence of intrinsic absorption allows some room for the possible presence of extinction in the UV, as explored below in § 2.2.