Science with the Hubble Space Telescope – II
Space Telescope Science Institute, 1996
P. Benvenuti, F. D. Macchetto, & E. J. Schreier, eds.

Modeling of the Blue Bump Emission in High Redshift Quasars.

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Abstract. High luminosity and high redshift combine in quasars to give conditions that allow studies of the intergalactic medium, as well as the emission mechanism in quasars. High luminosity makes quasars bright enough to study in detail at $z = 3$. High redshift also brings the EUV part of the emitted spectrum into observable wavelengths, and it is in the EUV where the power output of quasars peaks, and where the photoionizing continuum is produced.

We present results of the modeling of the spectrum of the high redshift (z=2.72), high luminosity ($L \sim 5\times10^{48}$ ergs s^{-1}) quasar, HS1700+6416 (Reimers et al. 1989), observed with HST FOS (Reimers at al 1992) and GHRS (Reimers 1995). We analyzed the HST spectra together with optical spectrophotometry and identified absorption systems towards the quasar. We corrected the spectra for the intervening Lyman limit absorbers and defined the intrinsic optical-UV continuum. The continuum extends down to 310Å. We included the X-ray spectrum from the ROSAT PSPC observation (Reimers et al. 1995) from 0.37 keV to ∼10 keV in the rest frame. The X-ray energy index for the best fit power law model is equal to 1.24. It is steep, but not unusual for radio-quiet quasars at this redshift (Bechtold et al 1994). The observed α_{ox}=1.69 is consistent with the prediction given by the relation between α_{ox} and optical luminosity for radio-quiet quasars (Bechtold et al 1994).

We fit the HS1700+6416 spectral energy distribution with several theoretical models including accretion disk models and free-free optically thin emission. None of the applied models can fit the UV continuum of HS1700+6416.

1. Spectral Energy Distribution of HS1700+6416

IRAS

IRAS observations were taken between January and November 1983. The satellite scanned HS1700+6416 several times during this period. Addscan analysis revealed a detection at 60 μm (Tanner et al. 1995).

HST FOS We have extracted data for HS1700+6416 from the HST Archive. We recalibrated the FOS data using the CALFOS in STSDAS and the latest calibration files provided by the STScI. We corrected the spectra for interstellar reddening assuming E(B-V)=0.051, which corresponds to a Galactic column density of N_H=2.46$\times10^{20}$cm^{-2}.

There are seven optically thin Lyman limit systems present in the FOS spectra. We have corrected the spectrum for those systems using the optical depth and redshifts given by Vogel & Reimers (1995). The continuum was found using FINDSL, the iterative fitting procedure described in Aldcroft (1993).

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Optical

The optical spectrum of HS1700+6416 was taken on July 4, 1995, using the FLWO Tillinghast 1.5-meter telescope with the FAST spectrograph (exposure time of 900 seconds). The spectrum has been corrected for the interstellar reddening with E(B-V)=0.051.

X-ray Data

ROSAT PSPC pointed towards HS1700+6416 twice in 1992 and 1993 (Reimers et al. 1995). We have extracted both data sets from the ROSAT archive and fitted them with a single power-law model, assuming only Galactic absorption (N_H=2.46×10^{20}cm^{-1}). We found an energy index of the best fit power law model (χ^2=32 for 42 dof) equal to α_E=1.24$\pm$0.06.

Table 1. Lyman Limit Systems[a]

Redshift	τ
2.433	0.31575
2.315	0.4460
2.1678	0.4460
1.8465	0.3542
1.725	0.70687
1.1572	0.4460
0.8642	0.1410

[a] Vogel & Reimers, 1995

Table 2. DATA

Instrument	Observed Band	Rest Frame	Date	Ref
IRAS	100–12 μm	26.8–3.2 μm	Jan-Nov 1983	Neugebauer et al. 1984
FLWO	7540-3650 Å	2027-981 Å	July 1995	This Work
HST FOS	3240-1140 Å	871-306 Å	G270H: Dec 13/14 1991 G190H Dec 13/14 1991 G130H Feb 13/14 1992	Reimers et al. 1992
ROSAT PSPC	0.1-2.5 keV	0.37-9.3 keV	Nov 13/14 1992 July 21/22 1993	Reimers et al. 1995

2. Modelling the Spectral Energy Distribution of HS1700+6416

• **Accretion disks.**

We considered the standard α-disk models in both Schwarzschild and Kerr geometries (as in Laor & Netzer 1990, Sun & Malkan 1989). We include the modification due to electron scattering and Comptonization of soft photons in the disk atmosphere again for both Schwarzschild (Czerny & Elvis 1987, Maraschi & Molendi 1990) and Kerr geometries (Siemiginowska et al 1995). The detailed description of the applied model can be found in Siemiginowska et al. (1995).

An underlying power law with α=0.58, normalized at the IR data point, has been added to the accretion disk emission.

• **Thermal bremsstrahlung**

We also considered (free-free) from a single temperature optically thin cloud (as in Barvainis 1993).

Table 3. MODELS

Model	M_8	$\dot{M}$ [$M_\odot yr^{-1}$]	$\cos\theta$	L/L_{Edd}	T [K]
Blackbody (S)	2.8	120	1.0	15.6	
Modified Blackbody (S)	20	100	1.0	1.8	
Blackbody (K)	100	21.2	0.5	0.3	
Modified Blackbody (K)	100	56.5	0.5; 0.75	0.8	
Opt. Thin Free-Free					6×10^5

S – Schwarzschild, K – Kerr geometry.

3. Results

• The UV continuum of HS1700+6416 flattens (in $\log \nu L_\nu$) towards high frequencies which may indicate the presence of a luminosity peak. The continuum should turn-over at higher frequencies, since the X-ray luminosity is more than 2 orders of magnitude lower than the extrapolated UV continuum would predict.

• $\alpha_{ox} = \log(F_{2keV}/F_{3000\mathring{A}})/2.685$ is equal to 1.69. This is consistent with the prediction given by the relation between α_{ox} and optical luminosity for radio-quiet quasars (Bechtold et al. 1994).

• Modified blackbody emission from an accretion disk in the Schwarzschild geometry does the best at fitting the observed far UV continuum. However, it does not fit the long wavelength part of the spectrum. It also requires a high accretion rate, slightly above the Eddington value.

• Local blackbody emission from an accretion disk in the Kerr geometry can describe the optical data, but its continuum drops sharply below the HST observed spectra in the far-UV region.

• Optically thin free-free emission does not have the correct shape in the optical-UV band.

4. Conclusions

• The entire broad-band SED of quasars should be used to model their continua.

• The far-UV spectral region observed with HST gives powerful constraints on the models.

• None of the applied models can fit the far UV continuum of HS1700+6416.

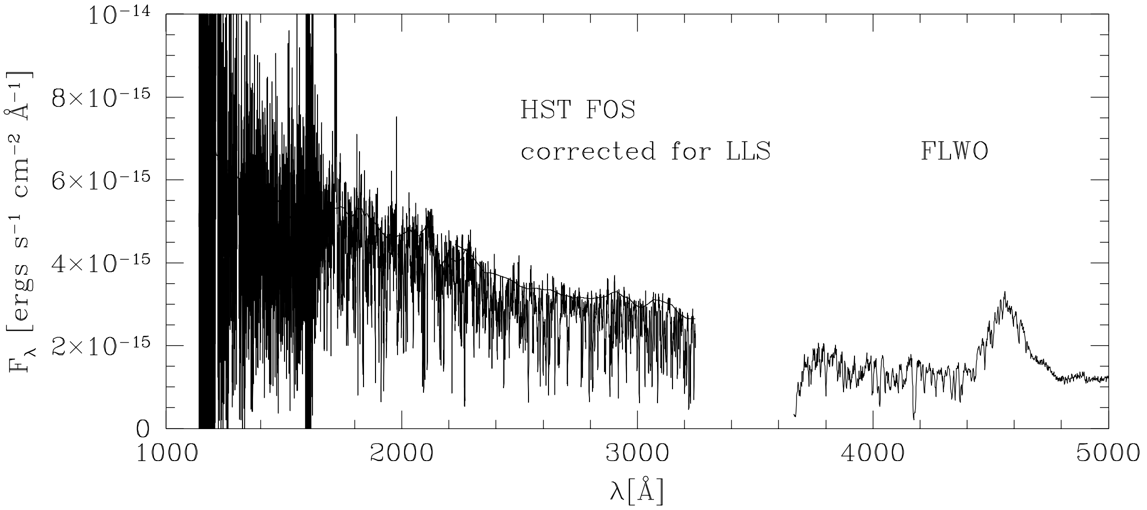

Figure 1. Spectral energy distribution of HS 1700+641, corrected for the absorption due to the Lyman limit systems. Solid line represents a continuum fit. The data are also corrected for the interstellar reddening.

Acknowledgments. Support for this work was provided by NASA through grants number AR-5294.01-93A and AR-05785.01-94A from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc. under NASA contract NAS5-26555.

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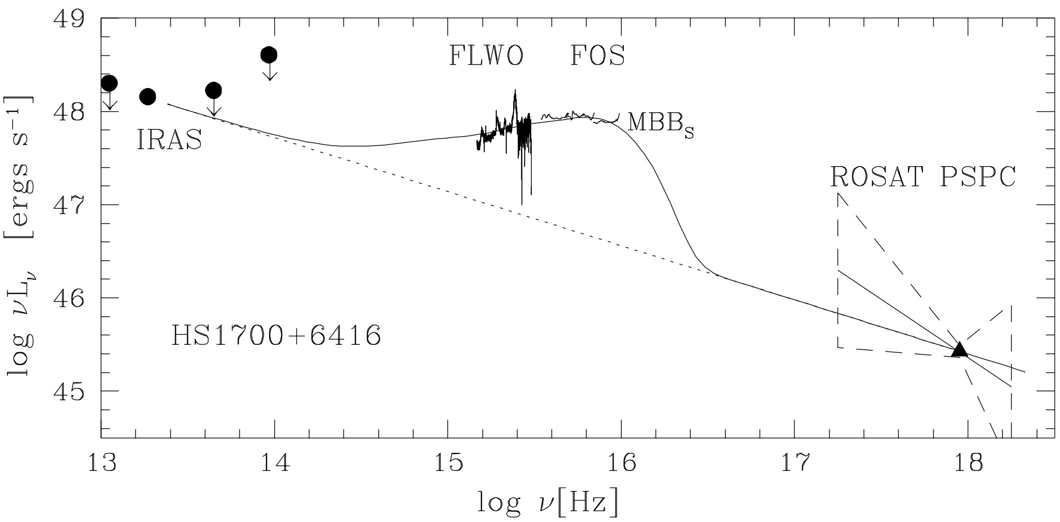

Figure 2. SED from IR to X-rays in the rest frame (H_0=50 km s^{-1}Mpc^{-1}, q$_0$=0) for HS1700+6416. IRAS 3σ upper limits are indicated with the arrows. ROSAT PSPC best fit power law is plotted with the solid line and 1σ error on the power law fit is indicated with the dashed lines. We plot the modified blackbody emission from an accretion disk (Schwarzschild geometry) plus the underlying power law (α=0.58) from IR to X-ray band.

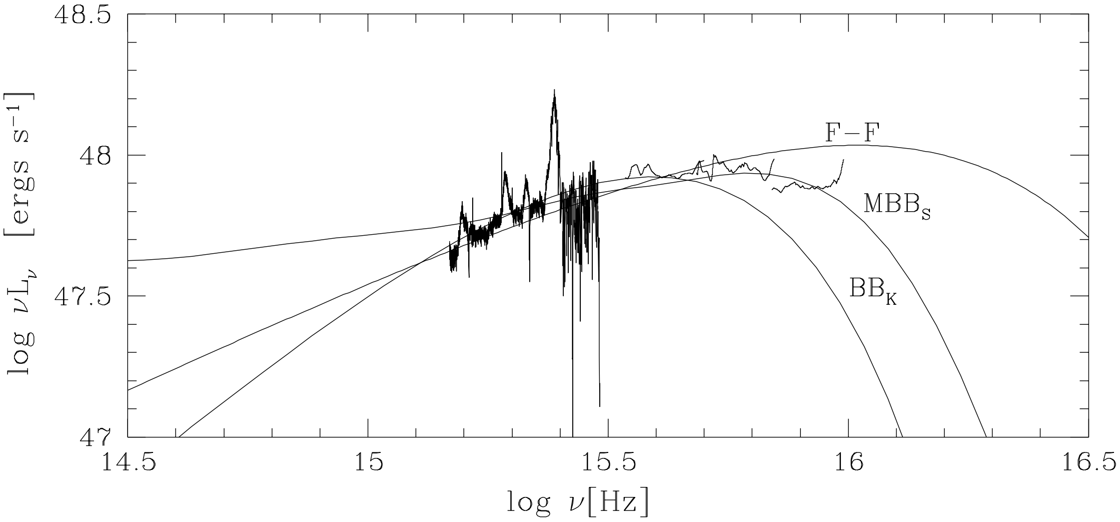

Figure 3. Spectral energy distribution in the UV for HS1700+6416. Models indicated in the plot: F-F - optically thin free-free emission; MBB$_S$ - modified blackbody emission from an accretion disk in the Schwarzschild geometry: BB$_K$ - local blackbody emission from an accretion disk in the Kerr geometry.