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THE X-RAY SPECTRUM OF QSO 0241+622

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ABSTRACT

We present the X-ray spectrum of QSO 0241+622 in the range 2-50 keV measured with the Goddard Space Flight Center proportional counters on OSO-8. The best power law fit has a photon spectral index and 90% errors $\Gamma = 1.93\ (+0.5, -0.3)$ and low energy absorption consistent with reported gas column densities, but a thermal bremsstrahlung form with temperature 13.1 keV cannot be excluded. No indication of spectral variability is found in three observations of the source with HEAO-A2[2], although we observe a possible 15-30% intensity change over a period of 6 months. The quasar is similar to 3C 273 in the proportion of energy emitted in various bands, excluding the radio, if reported radiation above 50 keV from its direction is indeed associated with QSO 0241+622. We make comparisons between the two quasars in a discussion of possible energy generation scenarios. Implications concerning quasar contributions to the diffuse background are discussed.

Subject headings: quasars - X-rays: sources - X-rays: spectra

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I. INTRODUCTION

With the advent of the HEAO-2 X-ray telescope and its imaging detectors, it has been established that quasars typically emit $\sim 10^{44} - 10^{47}$ erg s^{-1} of X-rays in the 0.5 - 4.5 keV band (Tananbaum et al. 1979). Previous to this, non-imaging proportional counters with a few hundred square centimeters of area have had the capability of measuring the three or four brightest to higher X-ray energies and of investigating spectral and temporal characteristics. A recent review of such observations is given by Bradt (1979). The first report of X-ray emission from the direction of a quasar was of that from 3C 273 (Bowyer et al. 1970). Confirmation of the identification subsequently followed (Bradt et al. 1979). A spectral measurement in the 2-50 keV range from the A2 experiment on HEAO-1 (Worrall et al. 1979) found the data to fit a power law of photon number index, Γ, $\sim$ 1.51 between 2 and 10 keV with a slight flattening 10-30 keV. A 90% confidence upper limit of 33 eV was placed on the equivalent width of any iron fluorescence line.

In this paper we present a spectral measurement of the third-to-be-discovered X-ray quasar, QSO 0241+622 (Apparao et al. 1978). In this case, the quasar was only discovered after the SAS-3 measurement of the position of a UHURU X-ray source which had attained significance when it was found to be the only X-ray emitter in a $\sim$ 4 square degree field from which COS-B detected localized γ-ray emission (Hermsen et al. 1977). It is significant as being the only quasar other than 3C 273 for which measurements currently exist over such an extensive energy band.

II. X-RAY OBSERVATIONS

A. Spectral

The spectral parameters are determined from an observation with the A detector of the Goddard Space Flight Center X-ray spectroscopy experiment on

OSO-8 between Feb. 15 and 25, 1978. The detector is a xenon multiwire proportional counter which has a 5^{0} circular field of view and which rotates about a point on its circumference which is aligned along the satellite spin axis. A portion of the traced area which is uncontaminated by the source can be used for subtraction of diffuse sky and internal detector counts. For an experiment description see Serlemitsos et al. (1976). Figure 1 shows the counting rate per pulse height analyzer channel together with the implied incident spectrum after folding through the detector response, assuming a simple power law form with low energy absorption. The 90% error contour for photon spectral index, Γ, and hydrogen column density, N_H, is also given. Our value for N_H agrees well with that of 8.9 10^{21} atoms cm^{-2} found from 21 cm radio measurements (see Margon and Kwitter 1978). Since fits with much smaller absorption than this can be excluded, our data restrict Γ to 1.93 (+0.5, -0.3) with 90% confidence. The fit to this simple power law form with the parameter values shown in the figure is acceptable, but only at an 8% confidence level. However, no significant improvement is achieved by the inclusion of iron line emission or from using a thermal bremsstrahlung form. The latter increases χ^2 by 3 for the same number of degrees of freedom, with a best-fit temperature of 13.1 keV.

In addition to the OSO-8 observation, the A2 detectors on HEAO-1 scanned the source for three periods of $\sim$ 5 days separated by $\sim$ 6 months (see Table 1). For a description of the A2 experiment see Rothschild et al. (1979). In the scanning mode, the spin axis of the satellite tracks the sun, thereby moving by approximately one degree each day, and the detectors at 90^{0} to this scan great circles on the sky once every $\sim$ 30 minutes. A portion of the scan close to but not including the source is used for subtraction of diffuse sky and internal detector counts. Through the satellite mission, larger portions of the time were spent in a pointing mode, rendering chronologically decreasing statistics for the three scanning mode observations of the quasar, and consequently producing increasing errors on the best fit parameter values. Figure 2 shows the 90%

error contour for N_H and Γ for the OSO-8 observation along with those for the first two HEAO-A2 measurements. The intensities of the source for the various observations will be discussed in section IIB, but here we conclude that there is no evidence from our data for spectral variability.

We must consider the possibility of our data being contaminated by a second weak X-ray source. About $1\overset{\circ}{.}3$ from the quasar there is a variable radio source associated with an OB star, which was discovered by Gregory and Taylor (1978) during outburst on Aug. 26, 1977. The A1 detectors on HEAO-1 trace identical great sky circles to ours, 180^0 out of phase. For the observing period immediately prior to the radio source outburst they recorded X-ray emission consistent with its location at $\sim$ 15% the intensity of the quasar (Share et al. 1979). However, an upper limit of about one half this intensity was measured by SAS-3 in Dec. 1977 (Apparao et al. 1978). Our HEAO-A2 and OSO-8 observations are all well fit by the collimator response to a single point source at the quasar position. However, for a location so close to the quasar we cannot rule out emission at a level $\lesssim$20% of the quasar intensity. Our spectrum cannot exclude emission from such a source but, since the HEAO A1 and SAS 3 values suggest variability and since all our spectral measurements indicate constancy in Γ, we feel that the radio source has negligible influence on our derived spectrum. This is especially true for our most accurate determination in Feb. 1978 when the radio source was not in outburst (Gregory et al. 1979).

The situation regarding spectral information from previous measurements can be seen in Figure 3. The dashed line is an extrapolation of the OSO-8 X-ray spectrum. It is drawn simply to aid the eye in relating the positions of the other data. The only experiment to have obtained a spectrum in our energy range is that on OSO 7 (Maraschi et al. 1978). The indication is of a somewhat harder slope, but from the limited statistics of these data one cannot rule out our fit. Ariel 5 found evidence for a hard tail from this region (Coe, Quenby and Engel 1978). However, considering the 8^0 field of view of the scintillator used in the experiment one must seriously question the association of this feature with the quasar. There is similar doubt as to the association of the 100 MeV COS B γ-ray emission. Figure 3 also shows the high energy γ-ray upper limit of Helmken and Weekes (1979). Rough observation dates are shown for all the data, and one must consider possible variability at any or all of the energy regimes when interpreting these measurements.

B. Variability

Figure 4 summarizes the recorded intensity from these and previous observations. The errors reflect counting rate statistics only and the conversion to 2-10 keV intensities from the work of other authors has been made assuming our best fit OSO-8 spectral parameters. In an intensity comparison between different experiments this assumption is only one of several possible systematic errors. For OSO-8 and HEAO-A2 we estimate a more appropriate error to be 30% for each data point and application of such a correction to all of the measurements in Figure 4 gives consistency to a constant flux at a 5% confidence level. When comparing measurements made with the same detector counting statistics are the dominant consideration. The HEAO-A2 data therefore provide the best indication of variability of $\sim$ 30% over a timescale of 6 months. Since we feel that the variable radio source in the region causes at the most a 15% contamination (see Section IIA), we conclude that there is evidence for some small X-ray variability of the quasar over timescales of months. This would be consistent with the variability time found for 3C 273 (White and Ricketts 1979; Bradt et al. 1979; Worrall et al. 1979). Our results for daily variability for each of our observations are consistent with the 10% upper limit found by Share et al. (1979).

III. THE COMPOSITE SPECTRUM

Figure 5 shows the composite differential energy spectrum of QSO 0241+622. Unfortunately not all the observations were made simultaneously. Approximate dates for each are given.

The quasar classification of the source resulted from the optical observations of Apparao et al. (1978). Subsequent more detailed measurements by Margon and Kwitter (1978) yielded a redshift of 0.0438. An early discovery of the quasar was prohibited by its large galactic extinction, estimated at $A_V \simeq 4.6$ mag. by these authors using five separate methods. An argument that A_V has been overestimated is, however, presented by Ford (1978), who has observed nebulosity around the quasar of an extent and distribution suggestive of an associated spiral galaxy. These values for the redshift and extinction would combine to give the galaxy an excessively high luminosity. Although other observations suggest that galaxy and quasar associations may not be uncommon among low redshift quasars (Hawkins 1978), until further evidence places the galaxy at the quasar's redshift we choose to adopt the value of A_V given by Margon and Kwitter (1978). Their flux values so corrected are plotted.

Optical variability is reported by Abati (1979) from examination of 8 years of Asiago plates. Intensity changes over timescales of months indicate a source size $\lesssim$ 0.05pc.

The infrared spectrum was determined by Soifer, Neugebauer and Matthews (1979) who are also in agreement with the value for A_V given above. These authors draw attention to the consistency of the spectral index with the average from a sample of 8 other low redshift quasars studied by Neugebauer et al. (1979). In particular, apart from being about a factor of 5 less luminous, its similarity to 3C 273 is quite remarkable.

The radio emission of QSO 0241+622 was first measured by Apparao et al. (1978) and subsequently spatially resolved by Tzanetakis et al. (1978). It exhibits an extended component of energy index $\alpha = 0.7$ which contributes negligibly above 3 10^9 Hz. (The energy index is defined $f_\nu \propto \nu^{-\alpha}$, related to the photon spectral index by $\Gamma = \alpha + 1$). The compact component of size < .3 arc sec ($\sim$ 400 pc for $H_0 = 50$ km s^{-1} Mpc^{-1}) rises with energy and is shown in Figure 5. Feldman (1980) has measured variability at 10^{10} Hz which indicates a size $\lesssim$ 0.1 pc.

The OSO 8 and Ariel 5 X-ray and the COS B γ-ray measurements are included in Figure 5 although the possibility that the last two are not associated with the source has already been mentioned. The γ-ray association is particularly in doubt. Since the direction lies in the galactic plane it is no coincidence that there have been several other suggested associations. These include the HII region W3 (Strong 1977), the variable radio star GT 0236+610 (Gregory and Taylor 1978) and the diffuse nebula IC 1805 (Montmerle 1979). In support of the quasar association is the fact that γ-rays have been seen from the directions of both these bright X-ray quasars. Table 2 shows the implied luminosities for QSO 0241+622 and 3C 273 in the γ-ray band together with the radio, optical and X-ray. One notices that, excluding the radio range in which QSO 0241+622 is underluminous, the emission in the other regimes are in rough proportion. Furthermore the degrees of variability for each are very similar. To be more particular, for 3C 273 the X-ray and radio variability and VLBI measurements agree at a size $\lesssim$ .7 pc. Variability sizes for QSO 0241+622 are a little smaller but this might also be consistent with its 4-10 times lower luminosity.

Figure 6 shows for comparison a composite spectrum of 3C 273. There is a large library of observations of this well-studied quasar and those on the figure are representative rather than comprehensive. Without attributing much importance to variability, which has been generally found to be a factor of a few at most for these data, we can make some qualitative statements about these composite spectra:

1. Both quasars have similar infrared spectra which become flat in the optical range.

2. For both quasars an extrapolation from the optical must cut off steeply and then show spectral hardening before connecting with the X-ray band.

3. 3C 273 exhibits a sharp or gradual spectral break between the X-ray and γ-ray bands. Accommodation of the Ariel 5 X-ray measurements requires a hardening and subsequent break in the same region for QSO 0241+622 (we would

assume that the rather extreme feature suggested in Figure 5 is due to variability).

4. Both quasars require spectral hardening between 10^8 and 10^{12} eV (a high energy upper limit for 3C 273 not shown in Figure 6 is given by Weekes (1978)).

IV. SCENARIOS FOR THE ENERGY GENERATION

Despite the two obvious problems, i.e. the uncertainty that the data in all the wavebands emanate from the quasar and the non-simultaneity of the measurements, we will attempt to briefly discuss the observations in light of current scenarios regarding energy production in quasars. We will make a comparison with 3C 273 because this is the only other quasar seen over the same large energy range. Indeed, since the similarity between the proportion of energy emitted in each band for each quasar has been used to some extent to justify the association of the high energy emission with the objects, we are obliged to consider similar energy mechanisms.

Jones (1979) has used the theory of Jones and Hardee (1979) to show that 3C 273 is well fit by a synchrotron self-Compton model. The radio, X-ray and γ-ray emission are accounted for. Since the radio emission observed for QSO 0241+622 is not strong enough for it to give a good fit to the model (at other frequencies this quasar appears to be just a slightly less luminous 3C 273), we must postulate the existence of a synchrotron component which has become optically thick by frequencies $\lesssim$ 20 GHz. This leads to the prediction of an angular source size which is smaller than for 3C 273.

The details of an X-ray origin from Comptonized lower energy photons have been considered by Katz (1976) and Eardley et al. (1978). The latter consider the problem in the context of accretion discs around non-rotating massive black holes, where Comptonization will take place in the hot inner disc region of size r_i which is probably only $\sim$ 20 Schwarzchild radii. For a black hole of mass M this is $\sim 2\ 10^{-12}$ M pc. Shapiro, Lightman and Eardley (1976) consider in detail the case of an inner disc characterized by two temperatures: that of the electrons is $T_e \sim 10^9$ K, and the ion temperature is $T_i \sim 10^{12}$ K. An outer cool disc region may be the supply of lower energy photons. The optical variability results of Abati (1979) for QSO 0241+622 suggest this outer disc to be of size $r_o \lesssim 5\ 10^{-2}$ pc and therefore assuming $r_o > 10\ r_i$ we can restrict the possible black hole mass to $\lesssim 2\ 10^9\ M_o$. It is interesting to note that de Bruyn (1979) has presented evidence that the compact optical component of Seyfert I galaxies may be of thermal origin and of this outer cool disc size scale.

The Comptonization models do not account for radiation higher than that at X-ray energies without invoking a further mechanism. Theory which has certain testable predictions when future instruments are able to make more sensitive measurements above $\sim$ 100 keV has been proposed by Leiter and Kafatos (1979). These authors suggest that plasma blobs, falling into the ergosphere of a massive rotating Kerr black hole, facilitate fluctuating high energy X-ray and γ-ray emission via Penrose photoproduction. Photons of $\sim$ 50 keV, which could be produced in the disc by the Comptonization mechanism already discussed and which are moving inwards to the black hole, are blueshifted and energized by the Compton process on the electrons in the ergosphere and ejected as low energy γ-rays with a predicted cut-off at $\sim$ 2 MeV. Penrose pair production can make electrons and positrons of maximum energy $\sim$ 2 GeV. These can convert to γ-rays in the vicinity of the accretion disc and also constitute a particle supply for synchrotron radio emission. A different magnetic field strength, accretion rate or orientation of the Kerr black hole spin axis relative to the observer may be causing the difference between QSO 0241+622 and 3C 273 in their radio emission. There are not yet enough data for either quasar to confirm the existence of the two spectral breaks at the specified energies, which are predicted to be universal and distinguishable.

McBreen (1979) shows that for 3C 273 the upper limit to the X-ray size from variability is sufficiently large to satisfy the necessary lower size limit for the γ-rays to be produced in the same region without being absorbed by pair production. For QSO 0241+62 we find a size > 0.03 pc. Since r_o is $\lesssim$ 0.05 pc, the electrons and positrons must reach the outer disc or beyond before converting to γ-rays. Finally, we note that Penrose photoproduction beams into a 40^{0} angle about the rotating black hole's equator. Therefore for certain quasars the emission above $\sim$ 50 keV would not be expected to be seen. This is possibly why the third brightest X-ray quasar, MR 2251-178, has not yet been reported as a γ-ray emitter.

V. QUASARS AND THE X-RAY BACKGROUND

The energy band in which statistically good measurements of the X-ray background have been made is that between 3 and 50 keV. Here the spectrum exhibits a steepening, predominantly at $\sim$ 40 keV, such that it is well characterized by a thermal bremsstrahlung analytical form of this temperature (Marshall et al. 1980). If one assumes that quasars evolve in their X-ray properties in a like manner to their other characteristics, as is supported now by the Einstein Observatory measurements (Tananbaum et al. 1979), the dominant contribution to the background should be coming from objects at redshifts $z \gtrsim 1$. Assuming the X-ray spectral shape does not evolve, this implies that a nearby quasar should have some steepening in the spectrum at an energy $\gtrsim$ 80 keV. Data in this energy range are presently scarce and await more sensitive instruments. Measurements do however exist for 3C 273, which show a gradual steepening above $\sim$ 30 keV (Primini et al. 1979). Although the spectrum for 3C 273 also steepens below 6 keV, the $\Gamma \simeq 1.4$ power law observed between 6 and 30 keV is consistent with the gaunt factor dominated part of a thermal bremsstrahlung form of characteristic temperature $\gtrsim$ 80 keV (Worrall et al. 1979). In contrast, we have found the spectrum of QSO 0241+622 to be inconsistent with $\Gamma \simeq$ 1.4 and if it were redshifted to $z \simeq 1$ it would retain its Crab-like power law form which cannot be reconciled with the diffuse background. Indeed, when the data > 6 keV are modelled to a thermal bremsstrahlung spectrum of temperature 80 keV, the fit is unacceptable, having a probability of < 0.1%.

From a sample of two quasars, it is obviously not possible to say which, if either, might be typical of the class in general. The fact that QSO 0241+622 can be considered radio-quiet, a characteristic of $\sim$ 90% of optically selected quasars (see e.g. Sramek and Weedman (1978)), may support its claim. Other active galaxy classes, although not providing substantial diffuse background contributions, have average spectra worthy of comparison because similar radiation mechanisms may be at work. A sample of Seyfert I galaxies, for example, was found by Mushotzky et al. (1979) to have a mean index of $\Gamma \sim 1.65$ with a 1σ dispersion of 0.1. A rather smaller sample of BL Lac objects suggest the class may be characterized in the 1-50 keV range by variable low energy components ($\Gamma \gtrsim 2$) with hard variable higher energy tails ($\Gamma \simeq 1$) (see e.g. Worrall et al. 1980). Neither class have spectra consistent with the diffuse background. The quasars QSO 0241+622 and 3C 273 do not show the characteristics of BL Lac spectra. Their mean power law index is however consistent with that for Seyfert galaxies although the large scatter suggests quasars to be a less uniform class.

VI. SUMMARY

We have presented a spectrum for QSO 0241+622 in the 2-50 keV band. Our statistics are almost comparable with those previously reported for the brightest X-ray quasar 3C 273 (Worrall et al. 1979) and therefore we extend to two the sample of quasars for which we have a good knowledge of the spectral shape in this energy range. Whereas 3C 273 was found to be fairly hard and, if redshifted to a distance where the contribution of quasars to the diffuse background would be a maximum, would exhibit a shape not too dissimilar to that of the background, QSO 0241+622 is softer and more Crab-like in its slope. Such a spectrum from one of the more populous type of radio-quiet quasar is not compatible with that of the diffuse X-ray emission.

Radiation above 50 keV has been reported from the direction of QSO 0241+622. An argument that such emission truly emanates from the quasar is supported by the consequent similarity to 3C 273 in its proportion of energy emitted in various bands. The radio range is an exception. Here QSO 0241+622 is underluminous.

Production of the X-rays by synchrotron self-Compton emission (Jones and Hardee 1979 and references therein) or Comptonization of lower energy photons (Katz 1976; Eardley et al. 1978) seem reasonable scenarios. For the latter, models such as accretion discs around massive black holes give natural sources for such photons of energies between the visible light and X-ray range. Cooler outer disc regions may then be producing thermal optical radiation. Indeed perhaps thermal rather than non-thermal production is more appropriate for radiation in visible light in view of results for Seyfert 1 galaxies found by de Bruyn (1979). Unfortunately the accretion disc models tend to have enough free parameters to fit virtually any X-ray spectral form and the composite spectrum does not presently provide strong constraints. To obtain radiation at energies above $\sim$ 100 keV a mechanism such as that of Penrose photoproduction as proposed by Leiter and Kafatos (1979) may be appropriate. This also has the advantage of producing electrons of $\sim$ GeV energies which could power a radio synchrotron source. The mechanism makes predictions for the energy range above $\sim$ 100 keV. In particular, two distinctive spectral breaks at $\sim$ 2 MeV and $\sim$ 2 GeV are expected and the radiation should be emitted in bursts possibly lasting over timescales of days. More measurements particularly above 50 keV are required to test these predictions. Observations taken simultaneously in different wavebands will eliminate possible misinterpretation of the composite spectra of such sources caused by flux variability.

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TABLE 1: OBSERVATION TIMES

DATE	DETECTOR	MODE
Aug 21-26, 1977	HEAO A2	Scan
Feb 16-24, 1978	OSO 8 'A' Detector	Point
Feb 17-23, 1978	HEAO A2	Scan
Aug 21-26, 1978	HEAO A2	Scan

TABLE 2: LUMINOSITIES OF QSO 0241+622 and 3C 273
IN DIFFERENT ENERGY BANDS (see also Bradt 1979)

	QSO 0241+622	3C 273
z	0.0438	0.158
L_r (1-22) 10^9 Hz	7.1 10^{41} (1) var. (∿2 over mths.)(2)	6.8 10^{44} (3) var. (∿3 over mths.)(4)
L_o (5-7) 10^{14} Hz	1.3 10^{45} (5) var. (∿1.7 over mths.)(6)	5.7 10^{45} (7) var. (∿1.5 over mths.)(4)
L_x (2-10) keV (4.8-24) 10^{17} Hz	(2.6-10.1) 10^{44} (8) var. over mths.	(2.2-11.8) 10^{45} (9) var. over mths.
L_γ (50-500) MeV (1.2-12) 10^{23} Hz	4.2 10^{45} (10) Assume α = 1.0	3.2 10^{46} (11)

[1] Tzanetakis et al. (1978); Apparao et al. (1978)

[2] Feldman (1980)

[3] Rudnick et al. (1978); Jones and Hardee (1979)

[4] see Bradt (1979)

[5] Margon and Kwitter (1978)

[6] Abati (1979)

[7] de Bruyn and Sargent (1978)

[8] Maraschi et al. (1978); Apparao et al. (1978); Forman et al. (1978); this paper

[9] White and Ricketts (1979); Worrall et al. (1979)

[10] Hermsen et al. (1977)

[11] Swanenburg et al. (1978)

FIGURE CAPTIONS

Figure 1 - The OSO 8 X-ray spectrum of QSO 0241+622. The count rates and best fit for a model of a simple power law with low energy absorption are given together with the implied incident photon spectrum after folding through the detector response. The error contour for N_H and Γ is for 90% confidence. Require $N_H \gtrsim 5\ 10^{-21}$ (see text).

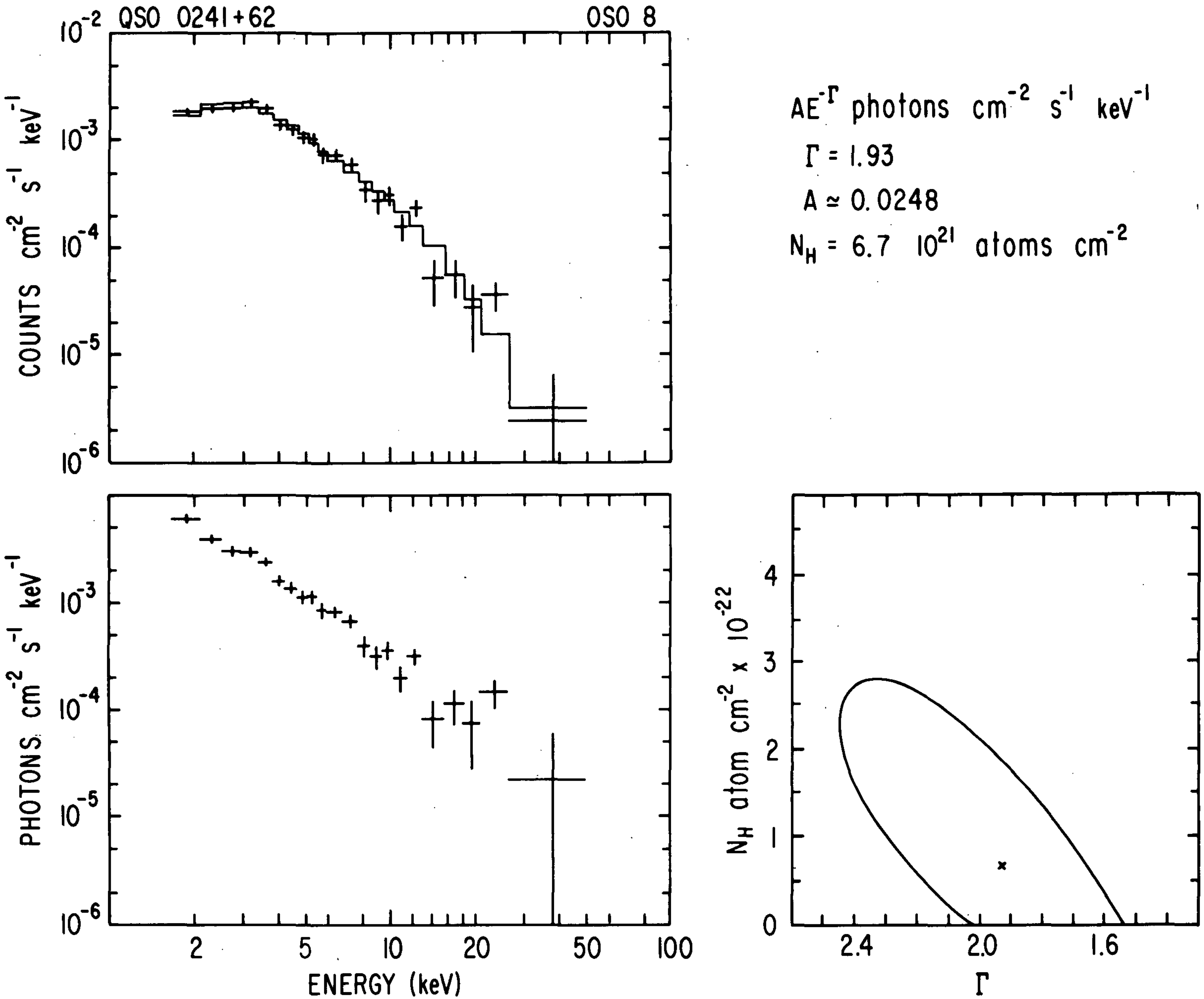
Figure 2 - The 90% error contour for N_H and Γ for the OSO 8 measurement compared with those for the first two HEAO A2 scanning observations. The latter chronologically degrade in statistics due to the increased time spent pointing at other sky regions.

Figure 3 - Photon measurements from the direction of QSO 0241+622 for energies above 2 keV. The dashed line is an extrapolation of the best fit X-ray power law spectrum.

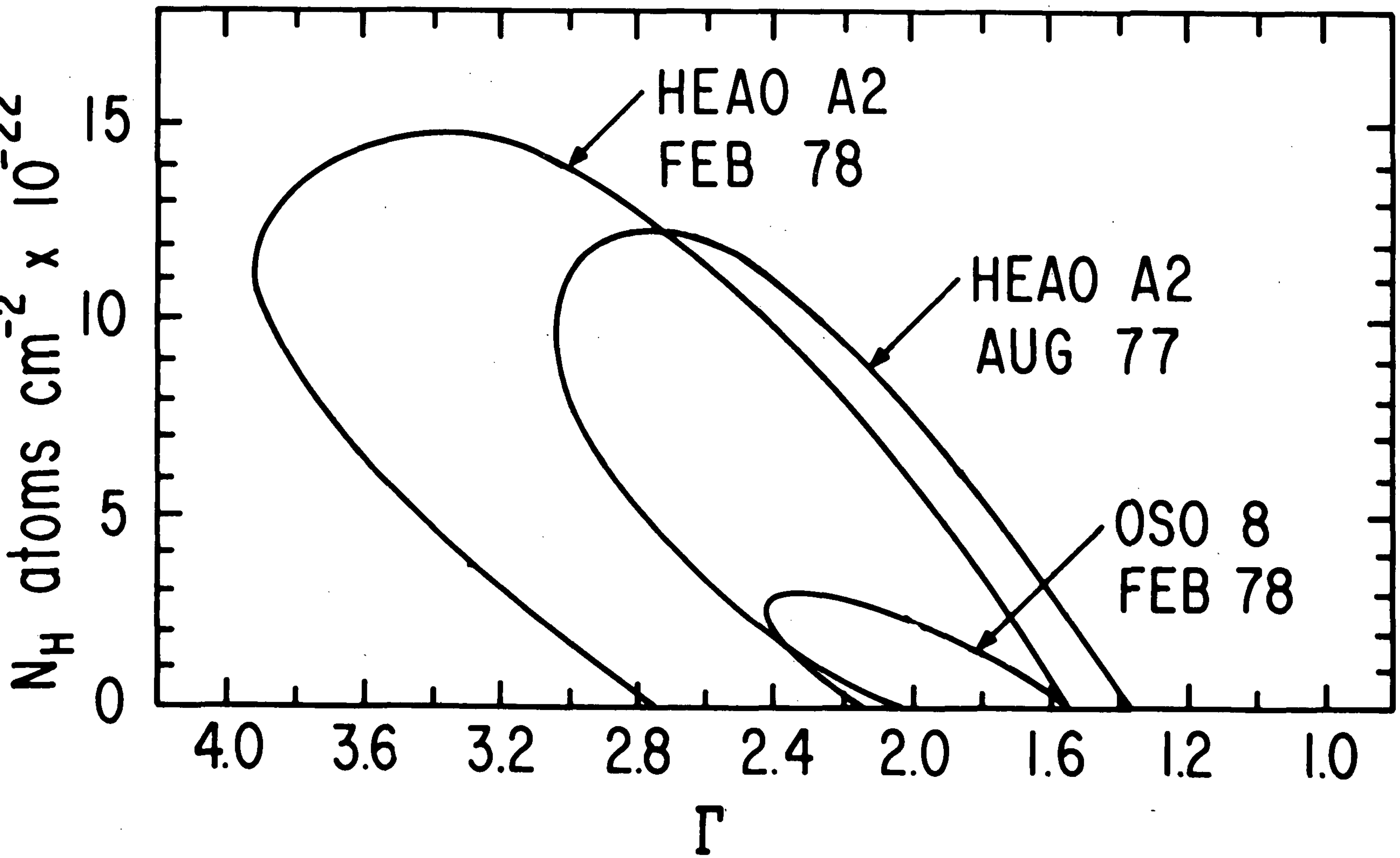
Figure 4 - 2-10 keV flux measurements of QSO 0241+622 from various satellite experiments. Errors are one sigma statistical only. Conversions from count rates to energy flux have assumed an invarient spectral form of that determined here and additional systematic errors probably of at least 30% should be included when comparing the intensities found using different instruments. The three HEAO A2 measurements weakly indicate variability (see text). The Uhuru, OSO 7 and SAS 3 count rates are taken from Forman et al. (1978), Maraschi et al. (1978) and Apparao et al. (1978) respectively.

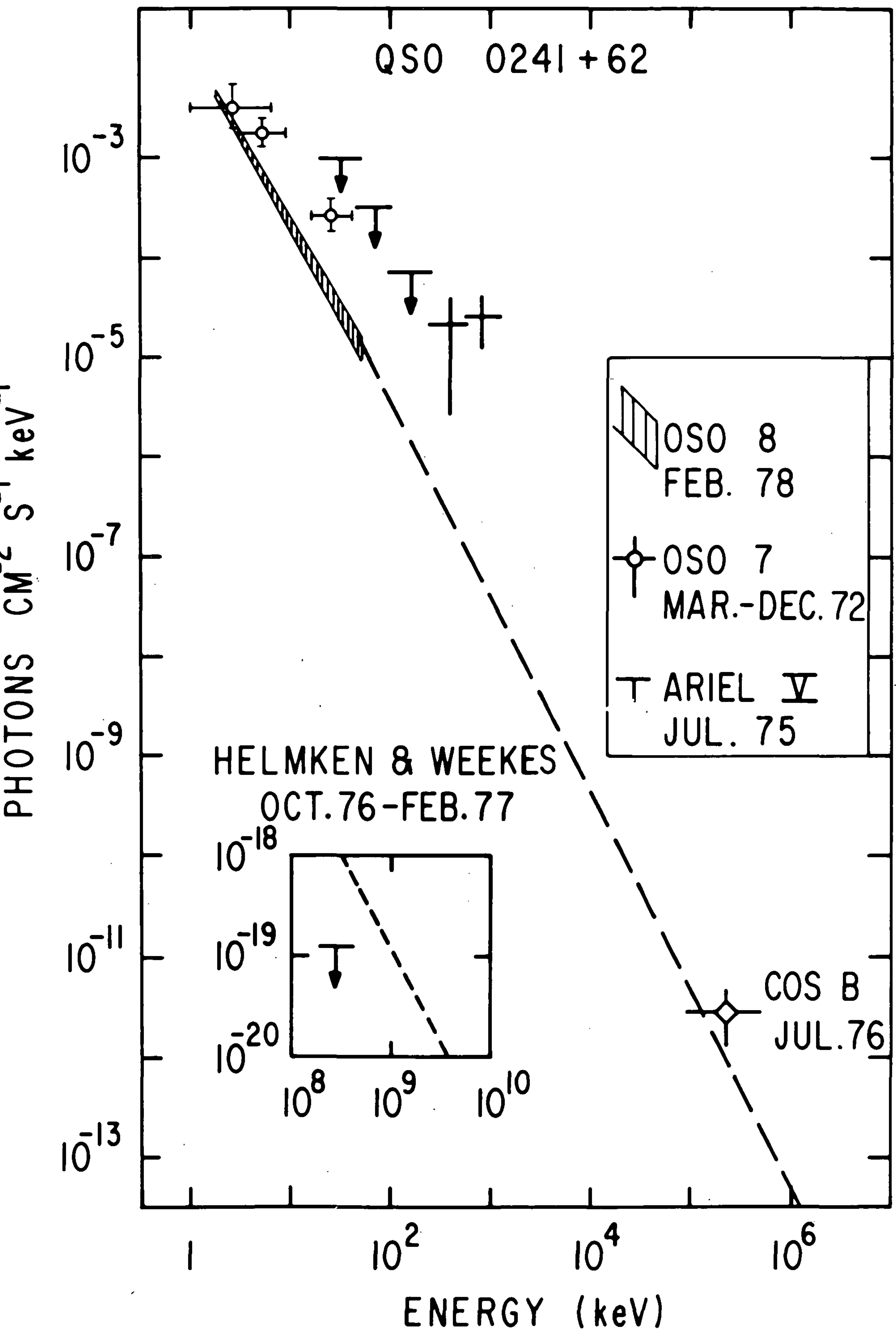
Figure 5 - A composite of reported measurements from the direction of QSO 0241+622.

Figure 6 - A composite spectrum for 3C 273 from a representative sample of reported measurements.

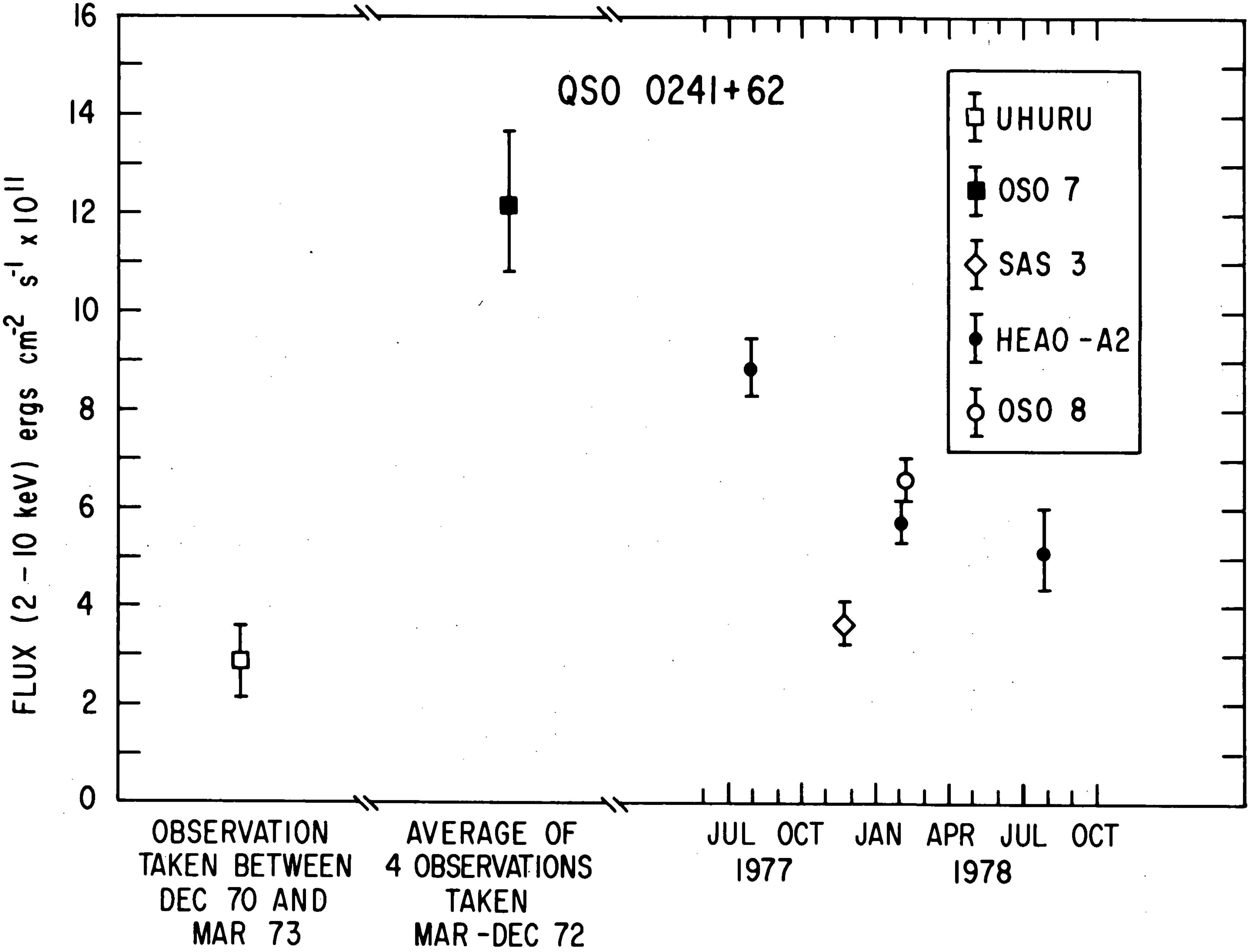


QSO 0241+62
OSO 8
COUNTS cm^-2 s^-1 keV^-1
PHOTONS cm^-2 s^-1 keV^-1
ENERGY (keV)
AE^-Γ photons cm^-2 s^-1 keV^-1
Γ = 1.93
A ≃ 0.0248
N_H = 6.7 10^21 atoms cm^-2
N_H atom cm^-2 x 10^-22
Γ

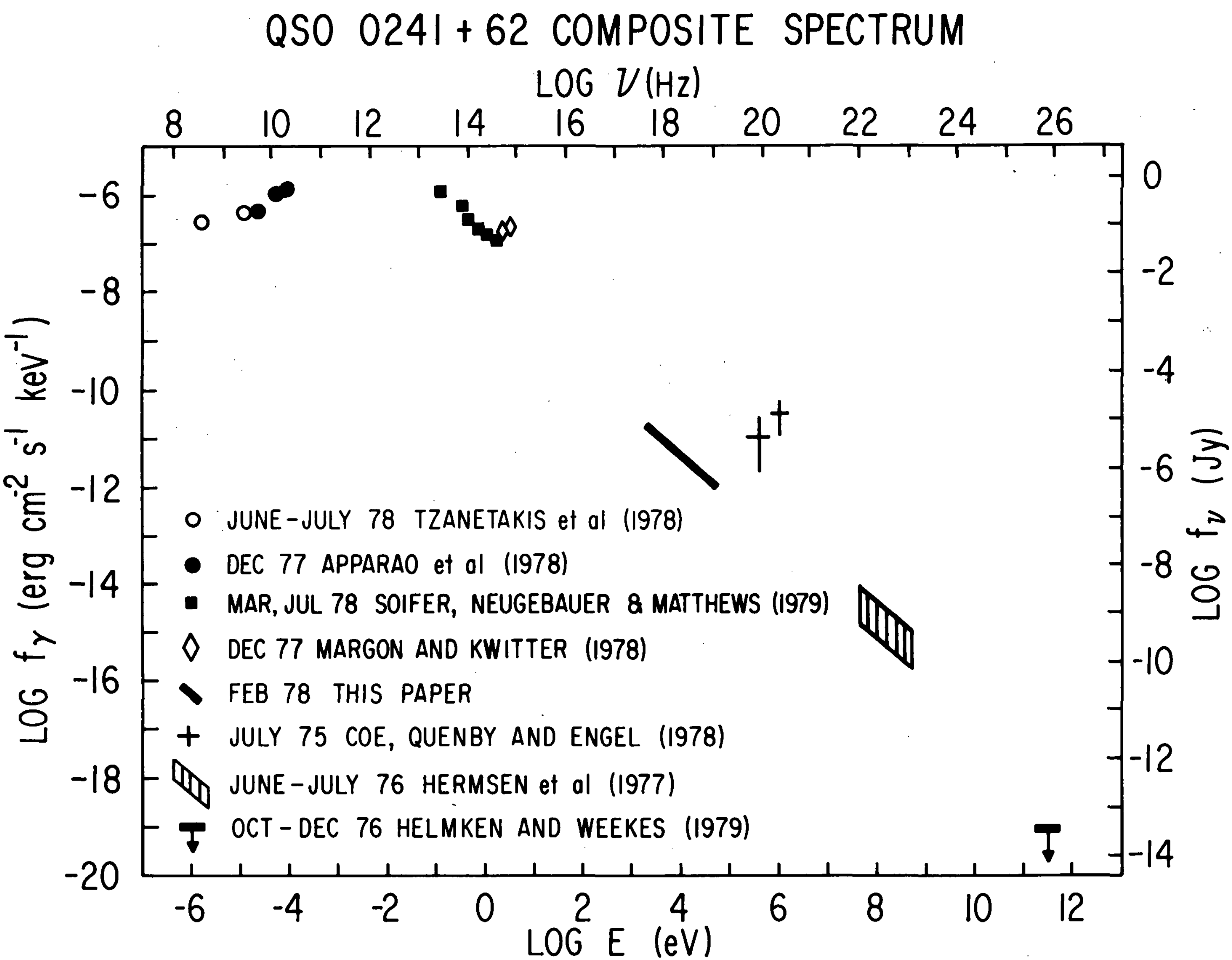

HEAO A2
FEB 78
HEAO A2
AUG 77
OSO 8
FEB 78
N_H atoms cm^{-2} x 10^{-22}
15
10
5
0
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
1.0
Γ

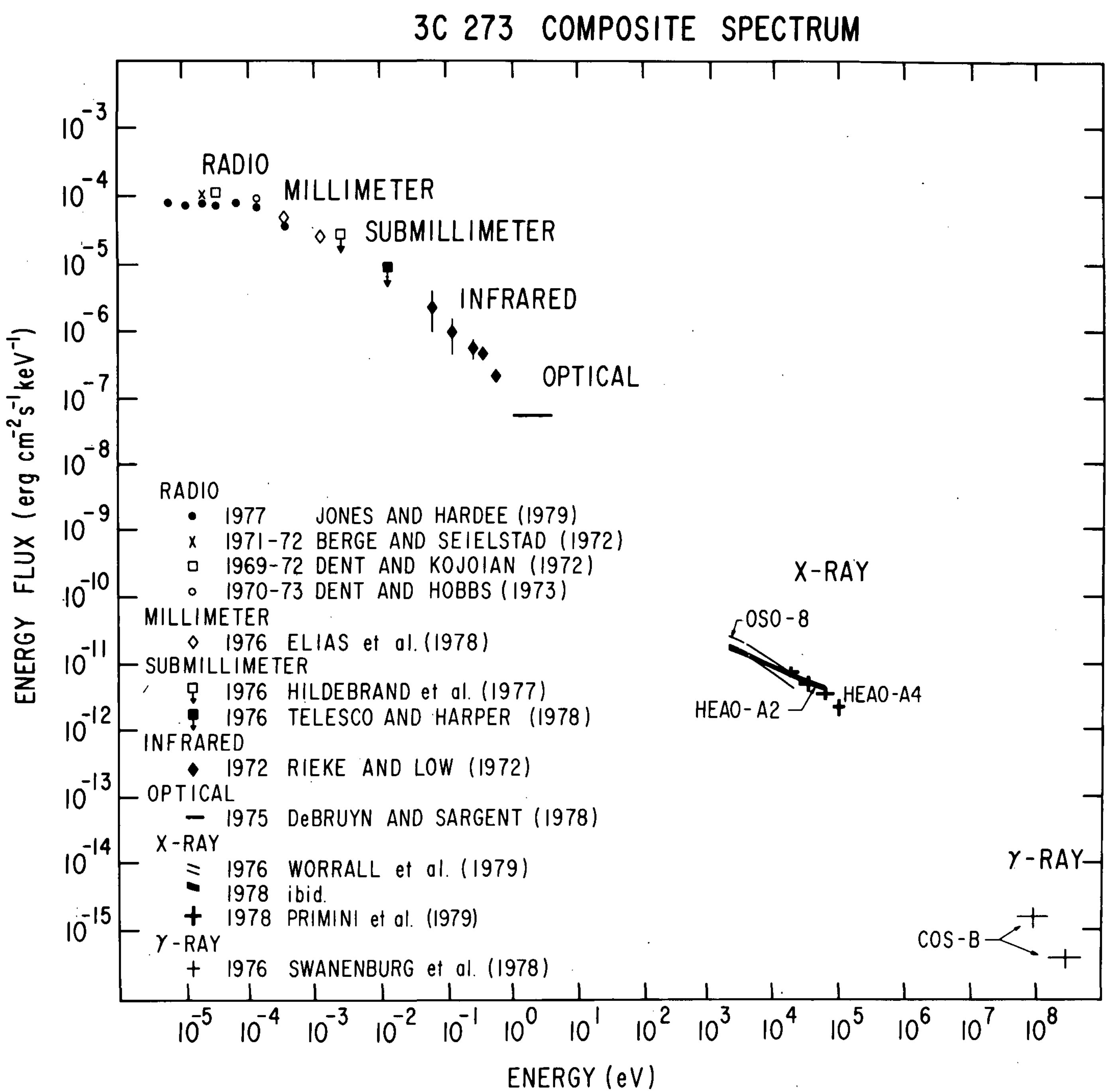


QSO 0241+62
PHOTONS CM^-2 S^-1 keV^-1
10^-3
10^-5
10^-7
10^-9
10^-11
10^-13
OSO 8
FEB. 78
OSO 7
MAR.-DEC. 72
ARIEL V
JUL. 75
HELMKEN & WEEKES
OCT. 76-FEB. 77
10^-18
10^-19
10^-20
10^8
10^9
10^10
COS B
JUL. 76
1
10^2
10^4
10^6
ENERGY (keV)



QSO 0241+62
UHURU
OSO 7
SAS 3
HEAO -A2
OSO 8
FLUX (2 – 10 keV) ergs cm^{-2} s^{-1} x 10^{11}
0
2
4
6
8
10
12
14
16
OBSERVATION TAKEN BETWEEN DEC 70 AND MAR 73
AVERAGE OF 4 OBSERVATIONS TAKEN MAR-DEC 72
JUL OCT 1977
JAN APR JUL OCT 1978


QSO 0241 + 62 COMPOSITE SPECTRUM
LOG ν (Hz)
8
10
12
14
16
18
20
22
24
26
LOG f_γ (erg cm^-2 s^-1 keV^-1)
-6
-8
-10
-12
-14
-16
-18
-20
LOG f_ν (Jy)
0
-2
-4
-6
-8
-10
-12
-14
LOG E (eV)
-6
-4
-2
0
2
4
6
8
10
12
JUNE-JULY 78 TZANETAKIS et al (1978)
DEC 77 APPARAO et al (1978)
MAR, JUL 78 SOIFER, NEUGEBAUER & MATTHEWS (1979)
DEC 77 MARGON AND KWITTER (1978)
FEB 78 THIS PAPER
JULY 75 COE, QUENBY AND ENGEL (1978)
JUNE-JULY 76 HERMSEN et al (1977)
OCT-DEC 76 HELMKEN AND WEEKES (1979)



3C 273 COMPOSITE SPECTRUM
RADIO
MILLIMETER
SUBMILLIMETER
INFRARED
OPTICAL
X-RAY
OSO-8
HEAO-A2
HEAO-A4
γ-RAY
COS-B
RADIO
1977 JONES AND HARDEE (1979)
1971-72 BERGE AND SEIELSTAD (1972)
1969-72 DENT AND KOJOIAN (1972)
1970-73 DENT AND HOBBS (1973)
MILLIMETER
1976 ELIAS et al. (1978)
SUBMILLIMETER
1976 HILDEBRAND et al. (1977)
1976 TELESCO AND HARPER (1978)
INFRARED
1972 RIEKE AND LOW (1972)
OPTICAL
1975 DeBRUYN AND SARGENT (1978)
X-RAY
1976 WORRALL et al. (1979)
1978 ibid.
1978 PRIMINI et al. (1979)
γ-RAY
1976 SWANENBURG et al. (1978)
ENERGY FLUX (erg cm⁻²s⁻¹keV⁻¹)
ENERGY (eV)

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16. Abstract

We present the X-ray spectrum of QSO 0241+622 in the range 2-50 keV measured with the Goddard Space Flight Center proportional counters on OSO-8. The best power law fit has a photon spectral index and 90% errors $\Gamma = 1.93$ (+0.5, -0.3) and low energy absorption consistent with reported gas column densities, but a thermal bremsstrahlung form with temperature 13.1 keV cannot be excluded. No indication of spectral variability is found in three observations of the source with HEAO-A2, although we observe a possible 15-30% intensity change over a period of 6 months. The quasar is similar to 3C 273 in the proportion of energy emitted in various bands, excluding the radio, if reported radiation above 50 keV from its direction is indeed associated with QSO 0241+622. We make comparisons between the two quasars in a discussion of possible energy generation scenarios. Implications concerning quasar contributions to the diffuse background are discussed.

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