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A catalogue of X-ray spectra observed with the Ariel V proportional counter (Experiment C)

S. J. Bell Burnell (*) and L. Chiappetti (**)

Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, U. K.

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Summary. — The ~ 2-10 keV spectra of 73 sources, observed with MSSL's 32-channel multiwire proportional counter on Ariel V are presented. They have been produced using the spectral restoration technique of Blissett and Cruise. For 26 of these sources Ariel V spectra have not previously been published, and for these the parameters of the best-fitting single temperature Bremsstrahlung and simple power law spectra are also given. The results are compared with those obtained from other satellites; for the majority of the 26 sources these are the highest resolution spectra available.

Key words : X-ray sources — spectra — catalogue.

1. Introduction.

The Ariel V satellite was launched in October 1974 and re-entered in March 1980, having performed ~ 30000 orbits. It carried six instruments covering, between them, the energy range from ~ 2 keV to 1200 keV and including sky survey instruments, spectrometers and a rotation modulation collimator instrument. The Mullard Space Science Laboratory of University College London built and operated a 100 cm^2 area, 32 channel, multiwire proportional counter spectrometer (Experiment C) which functioned in the ~ 2-30 keV energy range with an energy resolution of ~ 18 % at 6 keV, a field of view which was $3\overset{\circ}{.}5$ FWHM, and with an offset from the spin axis which allowed the subtraction of the isotropic background count rate from the source count rate. Further details of the satellite are given by Smith and Courtier (1976), and of Experiment C by Sanford and Ives (1976).

During its life Experiment C observed and obtained spectra of ~ 100 sources, and many of these spectra have appeared in the literature (see references to table III). However, a number have not previously been published, and these are reported here. Furthermore the recent development of the spectral restoration technique by Blissett and Cruise (1979) and Kahn and Blissett (1980) provides a superior method of obtaining spectra from the observed count rates. This restoration technique has been applied to all sources observed by the spectrometer (with the exceptions noted below) and the results are reported here.

2. Spectral fitting and spectral restoration.

Conventional spectral fitting techniques involve the matching, in detector-count-rate space, of a trial spectrum to the data, the trial spectrum being adjusted until the best fit (as judged by a chi-squared test) is obtained. A disadvantage of this technique is that an *a priori* assumption about the form of the spectrum being studied is necessary; if the spectrum is not well represented by the assumed expression misleading results can be obtained. Also the correction factors needed to convert the data into an incident photon spectrum are dependent upon the spectral model. The best fit so obtained provides *an interpretation* of the data rather than an unbiased reduction.

The direct deconvolution spectral restoration technique discussed by Blissett and Cruise (1979) produces a qualitative picture of the incident spectrum free from astrophysical assumptions. It will not, of itself, give any spectral parameters, but will give an unbiased spectrum to which models may subsequently be fit. A filter must be applied to prevent high-frequency noise components dominating the solution and the degree of filtering appropriate to the signal-to-noise ratio has to be selected. Where there is a low-energy peak on a steeply falling spectrum, side lobes of the response function may cause the appearance of spurious features at high energies; this effect has been discussed by Kahn and Blissett (1980). Also the errors on adjacent points are correlated (one effect of which is to make the spectra produced by this technique look 'tidy').

3. Data analysis.

A master-list of ~ 500 sources was compiled from the 3A and 4U catalogues (Warwick *et al.*, 1981; McHardy *et al.*, 1981; Forman *et al.*, 1978), lists of transient and

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(*) Present address : Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, U.K.

(**) Present address : EXOSAT Observatory, ESOC, 5 R-Bosch-Strasse, 6100 Darmstadt, F.R.G.

other sources observed by Ariel V (Villa *et al.*, 1976; Seward *et al.*, 1976a, b; Carpenter *et al.*, 1977; Rosenberg *et al.*, 1975; White and Carpenter, 1978; Elvis *et al.*, 1975; Ricketts *et al.*, 1975; Eyles *et al.*, 1975a, b; Ives *et al.*, 1975; Maraschi *et al.*, 1976) and some MX sources. To determine the contents of the catalogue, sources were removed from this list as follows : several which are currently being studied by colleagues at MSSL were omitted; sources which were never observed by Experiment C were removed; and sources for which Experiment C spectra (restored spectra and/or spectral fits) have been previously published were set on one side. The remainder were searched for evidence of detectable X-ray emission. Those that were apparently detected were examined for confusion (a) on the basis of catalogued sources and (b) by checking that the source of the X-ray emission agreed well in position (using the technique of Davison, 1977b) with the catalogued position; those that were thus found to be confused were rejected. A few more were subsequently abandoned when they were found to be too weak or with too little exposure to allow spectral analysis.

26 sources remained and for each observation of each source the restored spectrum was obtained using the technique of Blissett and Cruise. Using conventional spectral fitting methods the best-fit single temperature thermal Bremsstrahlung spectrum (with Gaunt factor)

$$Flux = C \exp(-\sigma(E)\, N_{\mathrm{H}})\, g(T, E) \times \times (\exp(-E/kT))/E\sqrt{T} \text{ photons/cm}^2 \text{ s keV}$$

and the best-fit single power law spectrum

$$Flux = C \exp(-\sigma(E)\, N_{\mathrm{H}})\, E^{-\alpha} \text{ photons/cm}^2 \text{ s keV}$$

were also found. $\sigma(E)$ are Fireman's (1974) interstellar absorption coefficients, N_{H} the hydrogen column density, $g(T, E)$ the Gaunt factor, kT the temperature (in keV) and α the photon number spectral index. Channels below ~ 2 keV were omitted because of uncertainties in the window thickness. The same degree of filtering was applied to all sources when obtaining the restored spectrum.

The list of sources for which Experiment C spectra have been published was then examined; those sources for which *restored* spectra (i.e., obtained by the Blissett and Cruise restoration technique) have been published were discarded. Each observation of the remaining sources was checked for confusion, and if not contaminated a restored spectrum was obtained. (Again, a few sources had to be omitted at this stage because of low signal-to-noise.)

During compilation of the catalogue it was noted that although a number of weak, high galactic latitude sources from the 4U catalogue were observed by Experiment C, only those which are also in another catalogue (e.g. 3A) were detected. The « missing » sources would have been detectable at their 4U catalogued fluxes but not at their 'PST fluxes' (table 5 of Forman *et al.*, 1978).

4. The catalogue.

The catalogue contains restored spectra of all unconfused sources observed by Experiment C in spectral mode with adequate signal-to-noise except for the following :

(i) 13 sources listed in table I for which restored spectra have already been published;

(ii) 12 sources which are currently the subject of study by colleagues namely : Cygnus X-2 (Branduardi-Raymont *et al.*, 1984); 1636 − 536, 1642 − 455, 1702 − 363, 1728 − 169, 1735 − 444, 1758 − 205, 1813 − 140 and 1837 + 049 (Ercan and Cruise, 1984); and the Centaurus sources 1145 − 619, 1223 − 624 and 1258 − 613 (Gilmozzi, in preparation);

(iii) 3 sources for which spectra have been published but which by our more conservative criteria, are now found to be confused; 0535 + 262 (Maraschi *et al.*, 1976); 0535 − 668 (White and Carpenter, 1978); and 1239−599 (Huckle *et al.*, 1977);

(iv) 3 sources for which there are spectral fits (0410+102, Mitchell *et al.*, 1979; 1350 + 390, Hayes *et al.*, 1981; 1720 + 34, Hayes *et al.*, 1981) but which are too weak to allow spectral restoration.

The catalogue also contains thermal Bremsstrahlung and power law spectral fits for those sources which do not have published Experiment C spectra.

Table II lists the sources for which no previous Experiment C spectra have been published, giving the date of observation, the spectral parameters of the best fit power law and thermal Bremsstrahlung spectra, and the flux at which the source was detected on each occasion. The spectral index given is the photon number index. The errors quoted on α, kT and N_{H} are obtained from the points where vertical and horizontal bars through the best fit intersect the 90 % confidence contour. Figure 1 shows the restored spectrum of each source and the 90 % and 68 % confidence contours around the best-fit spectral parameters. Table III lists the sources for which spectral fits have been published, gives the references to the earlier work, the epoch of the observations and the source flux. (Note that in the earliest publications the errors quoted on the Ariel V spectral fits are ($\chi^2_{\mathrm{min}} + 1$) confidence limits. Later ($\chi^2_{\mathrm{min}} + 4.6$) was adopted). Figure 2 shows the restored spectra of these sources. If a source was observed more than once, where there were significant changes in the spectrum between observations several spectra are shown; otherwise a single, typical spectrum is plotted.

5. Discussion of results.

The variety of source spectra is shown by a compilation such as this in which many spectra observed with the same instrument, produced using the same algorithm, and plotted in the same way, are displayed side by side. Some spectra are smooth and featureless (e.g. 1744 − 361 in Fig. 1), others show a wealth of structure (e.g. 1538−522 in Fig. 2). Some are very steep (notably 0620 − 003 in Fig. 1) while some are almost flat (e.g. 1118 − 615 in Fig. 2). The same source can show markedly different spectra at different times (e.g. see the three spectra of 0614+091 in Fig. 2).

Large low energy cut-offs are rare. They are seen in the Seyfert galaxies NGC 3783 (1139−377) and NGC 4151 (1208 + 396), and in Centaurus A (1322 − 427). They are also found in the galactic sources 0900−403, 1538−522 (both pulsators), 1742−289, 1822−371 and 1907+097.

The use of the Blissett and Cruise technique, which does not discriminate against unknown or unexpected spectral features, shows that such features are quite common. Hitherto the use of the spectral fitting technique has tended to bias against them, so that, for example, iron line emission from the southern clusters of galaxies Sersic 40/6 (0430 − 615) and 0624 − 546, which has been reported by the NASA-Goddard group, can now also be seen in our data. The improved technique also reveals iron line emission (equivalent width 210 ± 40 eV) from X Per (0352 + 309); this has not previously been detected (White *et al.*, 1983). The Sco-type source 0614 + 091 shows evidence of line emission on some occasions, and there is tantalizing evidence of an iron line in the spectrum of 3C 273 (equivalent width 300 ± 100 eV). (Worrall *et al.* (1979) report a high resolution spectrum of this quasar which shows no evidence of spectral lines. Beltrametti and Drew (1982) suggest that hot winds ($T \gtrsim 10^8$ K) from a quasar's nucleus may be detectable in the X-ray part of its spectrum through Bremsstrahlung emission, but because 3C 273 is so luminous they do not consider it a good candidate for such emission.)

Figures 1 and 2 also suggest that many sources do not have simple, one component spectra. Examination of table II shows that only half the source spectra are well fit (i.e. between the 10 % and 90 % points of the χ^2 distribution) by either or both of the single power law or single temperature Bremsstrahlung models. Dividing the 34 entries in table II by flux into two equal groups we find that of the 17 stronger sources the spectra of only six were well fit by a simple model whereas of the 17 weaker sources, 11 were well fit by these models. Since on average the stronger sources were observed with better signal-to-noise ratio this suggests that with increasing signal-to-noise such simple models are found to be inadequate.

Any limitations of the Blissett and Cruise spectral restoration technique also become apparent through this kind of compilation (although care must be taken to distinguish between limitations inherent in the technique, instances of misapplication of the technique, and limitations of the spectrometer itself).

The spectrometer has a large field of view, so that source confusion can be a problem. We are aware of two examples in this catalogue where we suspect this to have occurred — 1728 − 337 with 1730 − 335 (where we failed in making the appropriate checks), and 1708 − 232 with weak uncatalogued sources.

Some ten or twelve of the spectra show an apparent emission feature at the high energy end of the spectrum (e.g. 0521 − 720, 1958 + 407 in Fig. 1, 0316 + 414 in Fig. 2). Kahn and Blissett (1980) note that spurious features at high energies can be produced by side lobes when there is a low energy peak on a steeply falling spectrum. However, some of the spectra which show this feature do not appear to have any low energy peak (e.g. 0521 − 720). If it were a more common feature it could be explained as a calibration problem caused by underestimation of the widths of the channels involved, but there are also high quality spectra which do not show this feature (e.g. 1617 − 155 in Fig. 2). We are therefore uncertain how to account for this feature.

In order to process the large quantity of data it was necessary to adopt a standard procedure and the application of uniform standards to all the data has produced the other limitations that we are aware of. Weak signals appear as three-sigma upper limits where more appropriate binning of the data would have produced higher significance data points (see e.g. the high temperature components in 0022 + 638 (Tycho's SN) and 0821 − 427 (Puppis A)). Also the same degree of filtering was applied to all the data, whereas ideally a level appropriate to the signal-to-noise should be selected. The most noticeable effect of this has been to smooth out sharp features like the iron absorption edges that are known to exist in the spectra of several galaxies (NGC 3783, NGC 4151 and Centaurus A). Less severe high-frequency filtering would doubtless have revealed these edges.

COMMENTS ON THE SOURCES IN FIGURE 1 AND TABLE II.

0142 + 614

The optical identification of this source is uncertain; our observed hydrogen column density of $< 5 \times 10^{21}$ cm^{-2} places a weak constraint on A_v, namely $A_v < 2$ (Gorenstein, 1975). The power law spectrum is a better fit than the thermal spectrum. In the MIT/OSO-7 catalogue (Markert *et al.*, 1979) the source has an average flux that is similar to the flux we observe, but the (4 channel) spectrum is considerably harder with $kT \sim 40$ keV and $N_H \sim 0$. White and Marshall (1983), using the HEAO 1 A2 instrument, find this source to have an even softer spectrum than we do (i.e. $kT < 3$ keV) and comment that it is like the high-state emission from a black hole. (Note that in our observation most of the data points above ~ 6 keV are 3 sigma upper limits).

0512 − 401

This source is in the globular cluster NGC 1851. Alcaino (1977) gives $E(B\text{-}V) = 0.1$ for this cluster, implying (Gorenstein, 1975) $N_H \sim 6.6 \times 10^{20}$ cm^{-2}, considerably below our upper limits. In the OSO-7 observation this source had an average flux close to the average of our observations. Clark, Markert and Li (1975) suggest that the source has a hard spectrum (photon number index $\alpha = 1.4$, no errors quoted) but the OSO-7 catalogue count rates (Markert *et al.*, 1979) are so loosely bound that an energy index between 0 and ~ 2.0 is allowed (photon number index ~ 1.0-3.0). An observation with the Copernicus satellite (Johnson *et al.*, 1977) was also loosely bound and was consistent with a spectrum of photon number index ~ 3 ± 2. Temperatures of 2.2 keV and 5 keV obtained with the 8 channel Monitor Proportional Counter on the Einstein Observatory have been reported by Grindlay (1981, 1982).

These broad-band spectra are mostly consistent with our results. A power law tends to be a marginally better fit to our observations than a Bremsstrahlung spectrum. There is no significant change in (continuum) spectral slope as the intensity changes between the three observations; however the shoulder at ~ 5 keV which can be seen in the figure is also visible in the spectrum from the first observation but invisible in the final one (which is of comparable statistical quality to that illustrated).

0521 − 720

The extinction to LMC X-2 is $A_v \sim 0.3$ (Bradt and McClintock, 1983) giving a column density to this source considerably below that observed here. Leong *et al.* (1971) report an energy spectral index of 0.7 ± 0.4 (photon number index 1.7 ± 0.4) or $kT = 7.5 \pm 3.3$ keV and $N_H < 3 \times 10^{22}$ cm^{-2} observed with Uhuru, and Markert and Clark (1975) report an OSO-7 spectrum which had $kT = 9.4 \pm 1.9$ keV, $N_H < 8.1 \times 10^{21}$ cm^{-2}; both these spectra are harder (but with much poorer resolution) than the one reported here. Our data are better fit by a power law spectrum. Apart from a feature in the highest energy channels which may be spurious (see the discussion at the beginning of the section) the spectrum is remarkably featureless.

0538 − 641

Cowley *et al.* (1983) have recently suggested that the compact object in LMC X-3 is a black hole. A spectrum obtained with Uhuru (Leong *et al.*, 1971) was best fit by an energy spectral index of 3.1 ± 0.8 (photon number index 4.1 ± 0.8) or $kT = 1.1 \pm 0.3$ keV and $N_H < 3 \times 10^{22}$ cm^{-2}, whereas Markert and Clark (1975) report an OSO-7 spectrum having $kT = 3.9 \pm 0.2$ keV and $N_H < 6.5 \times 10^{22}$ cm^{-2}. These are broad band spectra. A high-resolution, high quality spectrum obtained using instruments on HEAO 1 and the Einstein Observatory Solid State Spectrometer is reported by White and Marshall (1983). Between 3 and 10 keV it is slightly harder (photon number index 3.1 ± 0.2) with slightly lower column density ($(3 \pm 1) \times 10^{21}$ cm^{-2}) than the one reported here. The intensity of the source was a factor ~ 2 lower at the time of the HEAO observations. The spectrum we observe is steep, as are those of the other black hole candidates Cyg X-1 (Chiappetti *et al.*, 1981), Cir X-1 (Chiappetti and Bell Burnell, 1982) and GX 339-4 (Chiappetti, 1981). It is best fit by a thermal spectrum. There may be a shoulder in the spectrum at ~ 5 keV. Given the low extinction to the LMC there is no evidence for a soft X-ray component as has been found for Cyg X-1.

0540 − 697

LMC X-1 may also contain a black hole (see Hutchings *et al.*, 1983). Broad-band spectra of this source have been obtained by the Uhuru and OSO-7 satellites. Uhuru (Leong *et al.*, 1971) found an energy spectral index of 3.3 ± 0.7 (photon number index 4.3 ± 0.7) or

$$kT = 1.0 \pm 0.2 \text{ keV} \quad \text{and} \quad N_H < 3 \times 10^{22} \text{ cm}^{-2},$$

whereas OSO-7 (Markert and Clark, 1975) found

$$kT = 2.7 \pm 0.2 \text{ keV} \quad \text{and} \quad N_H < 1.1 \times 10^{21} \text{ cm}^{-2}.$$

White and Marshall (1983) show a high resolution spectrum obtained with HEAO's 1 and 2. Between 3 and 10 keV its best-fit spectral parameters are photon number index $= 2.8 \pm 0.2$ and hydrogen column density

$$= (9 \pm 2) \times 10^{21} \text{ cm}^{-2}.$$

This is close to, but outside, the 90 % confidence limits on the spectral parameters reported here. The source was at similar intensity levels for both observations. (Although there is not detailed agreement between the Uhuru, OSO-7 and Ariel V results for LMC's X-1, 2 and 3, the instruments on all three satellites find LMC X-2 to have a hard spectrum, with X-3 and X-1 considerably softer. No significant difference in the spectral slopes of LMC X-1 and LMC X-3 has yet been detected.) A power law is a better fit to our spectrum than an exponential. The low value of hydrogen column density is consistent with the observed extinction to this source ($A_v \sim 0.3$, Bradt and McClintock, 1983). Note that the points above 6 keV are upper limits.

0620 − 003

The strength of this transient source (Mon X-1) at peak caused the channels in the on-board pulse-height analyser to overflow. The spectra reported here were for single orbits only (i.e. ~ 100 min integrations) taken on the decline of the outburst. Spectra in this energy band at various epochs have been reported by Doxsey *et al.* (1976) (SAS-3); Matilsky *et al.* (1976) (SAS-3); Kestenbaum *et al.* (1976) (OSO-8); Citterio *et al.* (1976) (Copernicus); Carpenter *et al.* (1976) (Ariel V RMC); and Ricketts *et al.* (1975) (Ariel V SSI). Our spectra show the softening with increasing time already reported by several of these groups. The SAS-3 temperatures are 0.05 keV higher than ours and the OSO-8 temperature is at least 0.2 keV higher. The Ariel V RMC values (determined from 3 channels and up to 3 gain settings) are less precise than but are consistent with ours, as are the Copernicus values. The Ariel V SSI observations were close to the peak of the outburst when the spectrum was harder. We also find the hydrogen column density is decreasing with time, although still above the minimum expected for an $A_v = 1.2$ (i.e. $N_H = 2.6 \times 10^{21}$ cm^{-2}).

0900 − 403

Vela X-1 was observed for twelve hours on each of two consecutive days, at phase ~ 0.7-0.8. Einstein Observatory Solid State Spectrometer observations also at this phase (Kallman and White, 1982) find

$$N_H = 9.0\,(+\,0{,}7,\,-\,0.5) \times 10^{22} \text{ cm}^{-2},$$

rather less than our value, but they also found absorption edges which implied column densities about an order of magnitude greater, and noted that the column observed is very phase-dependent. Early observations with Uhuru have been reported by Forman *et al.* (1973). From the MIT/OSO-7 catalogue (Markert *et al.*, 1979) loosely constrained spectral parameters can be derived. Ulmer (1975) gives the spectrum obtained with the higher energy instrument on OSO-7. Becker *et al.* (1978) using OSO-8 found the spectrum very variable with N_H varying between 6×10^{22} cm^{-2} and 3×10^{23} cm^{-2} and photon number index between 1.05 and 1.25. They also reported an emission line at 6.8 keV. Hayakawa (1981) reports 14-channel spectra taken with the Hakucho satellite. Over the binary cycle they found no significant changes in spectral slope which had an energy (*sic*) index of ~ 1.3 or 1.4, while N_H changed from $\sim 1 \times 10^{23}$ to $\sim 3 \times 10^{23}$ cm^{-2} and was responsible for the observed changes in overall intensity. No iron emission line or absorption edge was seen. Finally, White *et al.* (1983) give a high resolution phase averaged spectrum taken when the source had smaller low energy absorption and was several times brighter than when we observed it. Their spectrum is slightly flatter than ours and shows clearly iron line emission.

The variable nature of the source makes difficult detailed comparison of results obtained at different epochs and averaged over different phase intervals. However most of these observations are consistent with our results. The source shows the hard spectrum typical of X-ray pulsators. The Fe line observed by Becker *et al.* (1978) and White *et al.* (1983) is not apparent in our spectrum, nor is there any sign of an Fe absorption edge which might become visible when the hydrogen column density reaches 10^{23} cm^{-2}. Blending of the line and edge would reduce the visibility of both. The filtering problem, discussed at the beginning of this section, may also be a significant factor.

1014 – 57

This source was reported in Seward *et al.* (1976b) but was not confirmed by the 3A catalogue (Warwick *et al.*, 1981). The flux at which we observe it is close to or below the lower flux limit of the 3A catalogue. The hard spectrum of the source is like that of the pulsating sources; it is equally well fit by power law or Bremsstrahlung spectra. There are possibly some features at ~ 6-7 keV with equivalent width 580 ± 120 eV, but better signal-to-noise is required to confirm and examine these. The column density to the source is quite low. We know of no other spectra for this source.

1042 – 595

Soft X-ray observations of the η Carinae region have been made by Bunner (1978) with OSO-8 (0.5-2 keV) and by Seward *et al.* (1979) with the Einstein satellite (1-3 keV). The Einstein Observatory resolved this low energy emission into many sources and it is not clear which of these corresponds to the high energy source, although they found the hardest spectrum source to be η Car itself with $N_{\mathrm{H}} = 2 \times 10^{21}$ cm^{-2} and $kT > 8$ keV. At higher energies there have been observations by the Ariel V SSI instrument (Seward *et al.*, 1976b and the 3A catalogue; Warwick *et al.*, 1981); Uhuru (Forman *et al.*, 1978); OSO-8 (Becker *et al.*, 1976); and this instrument. The flux of this source is not well established (2.3 ± 0.3 U cts, 4U PST flux; 3.0 ± 0.2 U cts, Ariel V SSI; 4.4 ± 0.1 U cts, OSO-8; and 5.4 ± 0.3 U cts, this observation) and may indicate high background or several sources of emission. Becker *et al.* find the spectrum to have $kT = 7.3$ $(+3.6, -2.6)$ and $N_{\mathrm{H}} = (0 - 1) \times 10^{22}$ cm^{-2} or photon number index $\alpha = 2.24$ $(+0.36, -0.39)$, and $N_{\mathrm{H}} = 1.0$ $(+1.5, -1.0) \times 10^{22}$ cm^{-2} which is less well constrained than our result, but in very good agreement with it. They also report the detection of a narrow line at 6.5 ± 0.2 keV, which is not apparent in our data.

1119 – 603

The spectrum of Cen X-3 in this energy range is very variable (see e.g. Swank *et al.*, 1976) : in addition to any changes there might be with binary phase there are marked differences between the high and low state spectra, and of course, in features like the accretion-wake dips. A_{v} to this source is ~ 4.4 (Bradt and McClintock, 1983) implying (Gorenstein, 1975) a minimum column density of ~ 10^{22} cm^{-2}. When column densities significantly less than this are found, the presence of a low energy component in the source spectrum is suspected. Column densities considerably higher than this are frequently found. The spectrum is hard, as is typical of a pulsating source.

Spectral parameters deduced from Uhuru observations have been reported by Giacconi *et al.* (1971) and Schreier *et al.* (1976). Tuohy and Cruise (1975) and Margon *et al.* (1975) discuss Copernicus observations. Hill *et al.* (1972), Bleeker *et al.* (1973) and Long *et al.* (1975) report spectra obtained during early rocket flights. Spectral parameters can also be deduced from the broad-band count rates in the MIT/OSO-7 catalogue (Markert *et al.*, 1979). Pounds *et al.* (1975) report spectra similarly deduced from the Ariel V SSI. Many high quality spectra obtained by OSO-8 at various phases (but excluding the phase of our observation) are given by Swank *et al.* (1976).

Our spectrum, which was taken between phases 0.56 and 0.63 (using the ephemeris of van der Klis *et al.*, 1980), when the source was in an intermediate state, shows the hard spectrum typical of this source. The column density is towards the lower end of, but well within the range found for Cen X-3. Note however that the spectrum is well fit by neither a single power law spectrum nor a single temperature thermal Bremsstrahlung spectrum. There is no evidence for iron-line emission.

Simultaneous observations of this source by Ariel V Experiment F at higher energies (26-1200 keV) have been reported by Evans *et al.* (1980). Combination of the two spectra shows there must be considerable steepening of the spectrum between 10 and 40 keV, as is expected for the emission from a highly magnetised neutron star (e.g. Boldt *et al.*, 1976, Pravdo and Bussard, 1981). The spectral slope observed by Ulmer (1975) ($kT = 12.8$ keV) with the 7-26 keV instrument on OSO-7 also shows this steepening. White *et al.* (1983) give a high resolution 2-40 keV spectrum which is very similar to ours (except for evidence of iron-line emission) and shows this steepening at the higher energies.

1254 – 690

The flux and spectral parameters found for this source by Uhuru (Jones, 1977) are in excellent agreement with our observations. A high resolution spectrum observed with HEAO 1 (Mason *et al.*, 1980a) has similar spectral slope, but considerably lower column density. The 2-10 keV flux found by HEAO 1 is a factor of 2-3 lower than that measured by Uhuru, Ariel V SSI (Warwick *et al.*, 1981) and this observation, although the steepening of our spectrum at > 10 keV brings the two into agreement at these energies. HEAO 1 also finds a broad emission line at 6.5 keV which is not evident in our data. The spectrum observed by Coe *et al.* (1976) with a photon number index 1.6 above 20 keV fits well on to our spectrum. Neither a single power law nor a single temperature Bremsstrahlung spectrum is a good fit to our data, presumably because of the marked change of spectral slope at ~ 10 keV. This source was observed three times during the life of Experiment C. On each occasion the spectrum was found to be the same; the flux varied between 6×10^{-2} and 10×10^{-2} photons/cm^2 s (~ 17-29 Uhuru counts).

1417 – 624

Kelley *et al.* (1981) report the detection of 17.6 s pulsations from this source and Bradt and McClintock (1983) give some information about the optical counterpart. The A_{v} they report for this source (3.0) is consistent with the hydrogen column density we find. The source strength appears very variable : during our observation it was at

3 Uhuru counts; SAS-3 saw it at about ten times this; its catalogued values are ~ 1.4 ± 0.5 Uhuru counts (3A catalogue) and 7.5 ± 0.5 Uhuru counts (4U catalogue). Using the two-channel count rates measured by SAS-3 when the source was in a high state, Apparao *et al.* (1980) find an energy spectral index of − 0.11 ± 0.04 (photon number index 0.89 ± 0.04) for N_{H} set at $5 \times 10^{22}\ \mathrm{cm}^{-2}$. This is consistent with our (low state) spectrum, and consistent with the hard spectrum expected for a pulsating source. Our spectrum is fit acceptably well by either a power law or a thermal Bremsstrahlung spectrum. It shows a prominent emission feature of equivalent width 1020 ± 250 eV which may be an iron line.

1556 − 605
Glass (1979) has observed an infrared source in the X-ray error box and Charles *et al.* (1979) have identified the optical counterpart of this galactic X-ray source. The *J-H*, *H-K* colours imply an $A_{\mathrm{v}} \sim 0$ to the infrared source, consistent with the hydrogen column density reported here for the X-ray source. Broad-band X-ray spectra reported by Markert *et al.* (1979) with energy spectral index 1.0-1.1 (photon number index 2.0-2.1) or $kT \sim 5$ keV, both with $N_{\mathrm{H}} = (0\text{-}0.5) \times 10^{22}\ \mathrm{cm}^{-2}$, are in excellent agreements with our results. The intensity at which we see the source is high (~ 46 Uhuru counts); the maximum flux quoted by Bradt and McClintock (1983) for this source is 40 μJy (~ 36 Uhuru counts) and the OSO-7, Uhuru and 3A fluxes are typically a factor of 2 or 3 lower than the value we find.

1708 − 232
Independently, this source has been identified with a cD cluster of galaxies by Wakamatsu and Malkan (1981), and by Johnston *et al.* (1981). The flux we obtain for this source (~ 9 Uhuru cts) is considerably lower than usually found for this source; if the source is correctly identified as a cluster of galaxies then it should not be variable to this extent. We suspect that contributions from other sources in the (low galactic latitude) field of view have contaminated our data. Spectral fitting to our low-quality data has not been attempted. Johnston *et al.* (1981) report a spectrum, taken with HEAO 1 A2, which is typical of a cluster, namely $kT = 8 \pm 2$ keV, with line emission at 6.7 keV and $N_{\mathrm{H}} < 2 \times 10^{22}\ \mathrm{cm}^{-2}$. This is consistent with the spectrum of Jones (1977), and with the estimated extinction (Wakamatsu and Malkan, 1981; Johnston *et al.*, 1981).

1730 − 335 (and 1728 − 337)
1730 − 335, known as the rapid burster, produces little or no steady emission but shows two modes of burst emission. The Type II or rapid bursts are believed to be the equivalent, in this source, of the steady emission. Spectra, integrated over a number of bursts, have been reported by Grindlay (1981, 1982), H. L. Marshall *et al.* (1979) and Heise *et al.* (1976). Thermal Bremsstrahlung spectra are most commonly fitted to the spectrum of this source giving temperatures between 5 and 10 keV and column densities between 3×10^{22} and $9 \times 10^{22}\ \mathrm{cm}^{-2}$ (both consistent with an $A_{\mathrm{v}} \sim 9$ to this heavily obscured globular cluster).

Comparison of our spectra of 1730 − 335 (in Fig. 1) and 1728 − 337 (in Fig. 2) indicates that independent spectra of these two sources have not been obtained. They are only ~ 0°.5 apart on the sky and we now suspect that both sources were active at the time of observation and that, in this case, our checks for confusion by neighbouring sources failed.

1744 − 361
A composite spectrum (3 channels with 3 gain settings) of this transient source is given by Carpenter *et al.* (1977). It can be fitted by power law spectra with photon number indices between 1.7 and 2.4. Our higher resolution observation, made at the same time, shows a slightly softer, featureless spectrum (the rising « tail » at high energies is upper limits only), which is well fit by neither a single power law nor a single temperature Bremsstrahlung spectrum. The optical counterpart has not been identified; the column density we observe suggests the obscuration to this source could be as large as $A_{\mathrm{v}} \sim 10$ or 20, although a sizeable fraction of this may be within the source itself.

1746 − 370
Although the identification of this source with the globular cluster NGC 6441 has been secure for some time, no moderate or high resolution X-ray spectra of this source have been published. The MIT/OSO-7 catalogue (Markert *et al.*, 1979) reports a 3-channel spectrum having photon number index between 1.0 and 2.2 and

$$N_{\mathrm{H}} < 5 \times 10^{22}\ \mathrm{cm}^{-2}$$

or kT between 4 and 50 keV and $N_{\mathrm{H}} < 4 \times 10^{22}\ \mathrm{cm}^{-2}$. Jones (1977) uses the 7 energy channels of Uhuru to produce the loosely constrained spectral parameters of photon number index between 1.5 and 4.2, N_{H} between 1.5×10^{22} and $2 \times 10^{23}\ \mathrm{cm}^{-2}$, or kT between 2 and 10 keV, N_{H} up to $9 \times 10^{22}\ \mathrm{cm}^{-2}$. These spectra are consistent with ours, although the flux was noticeably higher when Ariel V observed the source. Grindlay (1981, 1982) using the 8 channel Monitor Proportional Counter on the Einstein Observatory gives temperatures of 6 and 9 keV.

A thermal Bremsstrahlung spectrum is a better fit to our data than a power law, although neither is a good fit. There are slight indications of features in the spectrum — for example it is not as « clean » as the spectra (of comparable statistical quality) of the preceding and following sources in this catalogue. The extinction to this globular cluster ($A_{\mathrm{v}} = 1.4$) is consistent with a low column density, but Grindlay (1981, 1982) finds evidence for a low energy component in the spectrum of this source, which, if present, would complicate the determination of N_{H}.

1820 − 303
1820 − 303 is in the globular cluster NGC 6624. It is a source of X-ray bursts and the « steady » source is known to be variable in both intensity and spectrum, but because of infrequent observation with a variety of instruments on different satellites the nature of the variability is ill-understood. The extinction to this source is $A_{\mathrm{v}} = 0.8$, implying a minimum hydrogen column density of

$$1.7 \times 10^{21}\ \mathrm{cm}^{-2}\,.$$

Canizares and Neighbours (1975) report a four-channel OSO-7 spectrum of this source, Fay *et al.* (1977) give a six-channel spectrum observed by the Copernicus satellite (when the source was at an intensity of only 40 Uhuru counts) and Jones (1977) a seven-channel spectrum obtained with Uhuru. Monitor Proportional Counter spectra (eight channels) have been obtained by Grindlay (1981, 1982), one of which suggests the presence of low energy emission.

Clear evidence for spectral variability was first reported by Parsignault and Grindlay (1978) who with the 15 channel instrument on ANS made several observations of the source in 1975 and 1976 — each an integration over a period of several days. In early 1975 the source was observed at ~ 210 Uhuru counts; the spectrum was well fit by an exponential model having $kT = 4.27 \pm 0.36$ keV (without Gaunt factor) and

$$N_{\mathrm{H}} = 1.8(+1.9, -0.8) \times 10^{21}\ \mathrm{cm}^{-2}$$

with evidence at the three-sigma level for iron line emission. Six months later the average intensity was ~ 50 Uhuru counts, the spectrum was equally well fit by power law or exponential models (the kT in this case being 15 ± 7 keV, $N_{\mathrm{H}} < 1.3 \times 10^{22}\ \mathrm{cm}^{-2}$) but there was no clear evidence of an iron line. In the month before our observation ANS observed the source again and found the mean intensity to be ~ 215 Uhuru counts, found that the spectrum was badly fit both by power law and exponential models (the best-fit parameters being energy spectral index $= 1.89 \pm 0.08$ with $N_{\mathrm{H}} = 9.3(+1.6, -3.0) \times 10^{21}\ \mathrm{cm}^{-2}$ or $kT = 6.91 \pm 0.89$ keV with $N_{\mathrm{H}} < 3 \times 10^{21}\ \mathrm{cm}^{-2}$) and again found no evidence for iron-line emission. Finally, Hayakawa (1981) reports an observation of the source for nine days in August 1979 when it again was in a high state (260 Uhuru counts). Four detectors on Hakucho covered the energy range 0.3-10 keV, although most of the channels were below 3 keV. He reports an (average) spectrum having $kT = 7.5(+4.5, -2.3)$ keV and

$$N_{\mathrm{H}} = (1.2 \pm 0.3) \times 10^{21}\ \mathrm{cm}^{-2} \quad \text{or} \quad \alpha = 2.1 \pm 0.3$$

(presumably photon number index) and

$$N_{\mathrm{H}} = (2.1 \pm 0.7) \times 10^{21}\ \mathrm{cm}^{-2}.$$

There is no indication given of the quality of either fit.

With Ariel V Experiment C there was sufficient signal-to-noise to obtain high quality spectra with integration times of ~ 100 min (one satellite orbit). Nine such spectra on three consecutive days were obtained and details of two, representative, spectra are given in table II. We find that although the thermal Bremsstrahlung spectrum is usually a slightly better fit to our data, frequently neither the Bremsstrahlung nor the power law models are good fits. We see no evidence for the iron line that Parsignault and Grindlay found in their first observation of the source. Our best fit spectral parameters are similar to those found by ANS. We also find evidence for a correlation between intensity and kT similar to that reported by Mason *et al.* (1976) for sources like Sco X-1, and by Branduardi *et al.* (1980) for Cyg X-2. This correlation is based on nine data points only; using the t-distribution it was significant at between the 99 and 99.8 % confidence level. We note that Sco X-1 and similar sources show these correlated fluctuations on timescales of hours. For Cyg X-2 the variation was observed within a 24-hour period, but observations taken on longer time-scales did not show the correlation. The data reported here cover a 48-hour interval so the correlation in this case appears to operate on a slightly longer time-scale. It is unlikely that observations integrated over several days or longer would show this effect, however.

1822−371

Although an Ariel V Experiment C spectrum of this source has been published (Charles *et al.*, 1980) it is included here because further discussion of the observations is necessary. The source was observed twice, in May 1977 and May 1978; the results previously reported are based on part of the 1978 observations.

Contrary to the work of Charles *et al.* we find in the data the 5.57 hour period discovered by White *et al.* (1981). The periodicity is most noticeable in the 1977 data but can also be seen in the second observation. Folding the data at the period given by White *et al.* produces a light curve qualitatively similar to theirs, with the minimum occurring at the correct phase; there is evidence for the double minimum in the 1978 light curve. The percentage modulation is approximately half that observed by White *et al.*, however, and the overall flux of the source is lower, too.

Reanalysis of the spectral mode data used by Charles *et al.* shows the spectrum to be hard; below 2.5 keV there are only upper limits to the flux detected. We confirm that, as found previously, the black body is the only simple spectral model that is a good fit. However the size of the emission region deduced from the intensity and the black body temperature has $50\ \mathrm{m} < r < 1\ \mathrm{km}$ for a source distance between 600 pc (Mason *et al.*, 1980b). and 10 kpc (White *et al.*, 1981). This would be acceptable only if the compact object was a highly magnetised neutron star. As shown by Fabian *et al.* (1982) the spectrum of this source is complex and cannot be adequately modelled by simple spectra; the good fit to the Ariel V data obtained with the single-temperature black body model is probably fortuitous. White *et al.* note that spectra obtained a year apart are very similar, and this is also the case with the Ariel V spectra. However we note that spectra taken ten days apart have markedly different intensities and low energy cut offs.

1907 + 097.

Marshall and Ricketts (1980) found an 8.38 day period in the X-ray emission from this source. Our observations, made at phase 0.4, show the source to have a hard spectrum, considerable low energy cut-off (as would be expected for the extinction of $A_{\mathrm{v}} \sim 8$ found by Schwartz *et al.*, 1980) and perhaps a suggestion of iron line emission. It is similar to the spectra of many pulsating sources (cf. 0900-403 in Fig. 1 or 1538-522 in Fig. 2) (¹). Schwartz *et al.* (1972) report a spectrum of this source (their source 1) which is of lower resolution (15 channels) than ours, but is remarkably similar in shape. They find a source intensity about twice the value we find. A three-channel spectrum from the HEAO 1 modulation collimator reported by Schwartz *et al.* (1980), and a four channel spectrum taken during November 1974 by the Ariel V SSI (Marshall and Ricketts, 1980) are consistent with our results. However, the spectrum deduced from SSI observations when the source flared to ~ 20 times its normal value in January 1980 is very much softer. White and Marshall (1983), using the HEAO 1 A2 instrument, report that the spectral hardness of this source resembles that of a black hole candidate in a low state, or an X-ray pulsator.

(¹) *Note added in proof :* Tanaka *et al.* report (IAU Circular 3882) the detection of a ~ 438 s pulsation.

1907 + 074

This source (which is also known as 4U 1909 + 07 or A 1908 + 07) has no identified optical counterpart, nor has any spectrum been published. Our observations show it to have a hard spectrum with iron line emission (equivalent width 660 ± 220 eV).

1909 + 048

We observed SS 433 when it was in a high intensity state and find it has a hard spectrum with iron line emission (equivalent width 940 ± 250 eV). Seaquist *et al.* (1982) using six channels of the Monitor Proportional Counter on the Einstein Observatory report that the spectrum hardens as the source intensity increases. Ariel VI (Ricketts *et al.*, 1981) observed the source in a high intensity state; they also see iron line emission with equivalent widths from 600 ± 100 to 900 ± 200 eV, and find spectral indices which range in value from comparable to ours to noticeably softer. F. E. Marshall *et al.* (1979) report a HEAO A2 spectrum, made when the source was at a lower intensity, and find a softer spectrum than ours (but again with line emission, which had equivalent width 575 ± 320 eV). The column densities determined by the Ariel VI and HEAO 1 A2 instruments are comparable with ours and consistent with the minimum A_v to this source of 4.6 (Bradt and McClintock, 1983).

1936 − 68

This uncatalogued source in the Pavo region was first discovered by Mitchell *et al.* (1979) and a position for it is given in that paper. It lies outside the area covered by the Einstein Observatory deep survey (Griffiths *et al.*, 1983). The source was not found in the HEAO 1 A2 survey, probably because its flux is close to, or slightly below, the survey threshold (Piccinotti *et al.*, 1982). It is not found either in the HEAO 1 A2 soft X-ray catalogue (Nugent *et al.*, 1983), suggesting it does not have a significant low energy (< 3 keV) component in its spectrum. The spectrum we observe is moderately hard, with evidence of iron line emission (equivalent width 500 ± 250 eV).

1958 + 407

Observations of the spectrum of Cygnus A in this energy range have been reported by Longair and Willmore (1974) (Copernicus satellite) and Brinkman *et al.* (1977) (ANS). There is uncertainty about both the flux and the extent of the source at these energies (see the discussions in Fabbiano *et al.*, 1979, and Kafatos, 1978). The three-channel spectrum obtained by Longair and Willmore is consistent with our results, as is the 1-8 keV spectrum reported by Brinkman *et al.* The spectrum deduced from the count rates in four channels on OSO-7 (Markert *et al.*, 1979) is much softer, however. It is unlikely that the iron line which is clearly visible in our spectrum (with equivalent width 700 ± 100 eV) would have been detected by any of these instruments. There are, however, unpublished reports of the detection by OSO-8 of iron line emission from Cygnus A (see Kafatos, 1978, and Culhane, 1978).

2008 − 568

McHardy (1978) suggests that this source is a cluster of galaxies. Our spectrum is of limited statistical quality, but we know of no other for this source. The spectrum is equally well fit by a power law or a thermal Bremsstrahlung model and is somewhat harder than one expects for a cluster of galaxies (see e.g. Mitchell *et al.*, 1979).

2127 + 119

This source is in the globular cluster NGC 7078. It is known to be variable (see e.g. Bradt and McClintock, 1983) but there have been few spectral observations of it. Grindlay (1981, 1982) has observed it with the Monitor Proportional Counter on the Einstein Observatory and reports temperatures of 5 and 8 keV respectively (the former at least, and possibly both, being determined without the Gaunt factor). Our data, taken when the source was at very low intensity, are equally well fit by power law or thermal Bremsstrahlung models, and the temperature determined in the latter case is consistent with Grindlay's results.

2129 + 470

Using the ephemeris of McClintock *et al.* (1981) (which extrapolates to our epoch with an uncertainty of ~ 10 % of one period) our data were divided into three phase bins. The spectra for the three phase bins are quite different. Line emission (probably iron) is seen with an equivalent width of 1500 ± 400 eV, but only in the first spectrum, and there appears also to be variation in the low energy emission during the cycle. The total flux and the iron line emission peak together (as in Cygnus X-3) but this maximum flux is at a phase of 0.0-0.3. At phases 0.3-0.7 where maximum flux might be expected the flux is slightly lower, and the final bin (phases 0.7-0.0) has the lowest flux.

McClintock *et al.* (1982) observed this source with the IPC and MPC on the Einstein Observatory. The seven-channel MPC spectrum, averaged over a whole binary cycle, has a photon number index of 1.90 ± 0.03 and a column density of $< 10^{22}$ cm^{-2}, which is consistent with our result. They also report that the shapes of the X-ray light curves are independent of energy (over the range 1-7 keV). At first sight this appears to be in conflict with our results which show considerable spectral change with binary phase. However, considering suitably broad bands we find that the ratios of the 5-10 keV flux to the 2-5 keV flux for our three phase bins are 0.66 ± 0.09 (phase 0.0-0.3), 0.56 ± 0.06 (phase 0.3-0.7) and 0.43 ± 0.11 (phase 0.7-0.0), which are the same to within three standard deviations.

The fluxes at which we detect the source are similar to those measured by HEAO 1 (Thorstensen *et al.*, 1979) and by the Einstein Observatory (McClintock *et al.*, 1982). They are towards the lower end of the range reported in the 3A catalogue (Warwick *et al.*, 1981) and considerably below the 4U fluxes (Forman *et al.*, 1978).

6. Conclusions.

The 2-10 keV spectra of 73 sources obtained using the Blissett and Cruise spectral restoration technique are reported. The technique is superior to the spectral fitting technique in that it allows changes in spectral slope, emission and absorption features to show more clearly. For example, iron line emission, not previously noticed in our data, is now seen in the spectra of X Per and possibly also in 3C 273. For 26 of the sources (including : the black hole candidates LMC X-1 and LMC X-3; SS 433; Cyg A; five globular clusters; one or possibly two clusters of galaxies; three X-ray pulsators; two transient sources; 2129 + 470 and several other stellar systems) no Ariel V spectrum has previously been published. These results are discussed and compared with spectra obtained with other instruments.

In many cases the Ariel V spectra are the highest resolution spectra available (and in several cases they are the only spectra available).

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TABLE I. — *Sources for which restored spectra have already been published.*

Source names		References
0026+593		Chiappetti and Bell Burnell (1983)
0531+219	Crab	Blissett and Cruise (1979)
0656-072		Chiappetti and Bell Burnell (1983)
1246-588		Chiappetti and Bell Burnell (1983)
1415+253	NGC 5548	Hayes et al. (1980b)
1439-61	MSH 14-63	Chiappetti and Bell Burnell (1983)
1510-590	MSH 15-52	Chiappetti and Bell Burnell (1982)
1516-569	Cir X-1	Chiappetti and Bell Burnell (1982)
1659-487	GX 339-4	Chiappetti (1981)
1833-078		Chiappetti and Bell Burnell (1983)
1956+35	Cyg X-1	Chiappetti et al. (1981)
2030+407	Cyg X-3	Blissett et al. (1981)
2321+585	Cas A	Blissett and Cruise (1979)

TABLE II. — *Sources for which Ariel V spectra have not previously been published.*

Source name	Epoch of obs.	Spectral index or kT (keV)	Column density NH (10^{22}cm^{-2})	χ^2	DoF	2-10 keV flux 10^{-2} ph/cm^{2}s	flux error	Equiv Uhuru Counts
0142+614	1975 July 8-10	2.3 (+ 0.2 ,- 0.2)	0.0 (+0.6 ,)	15.9	17	2.5	0.1	6
2S,3A,4U		4.5 (+ 1.7 ,- 0.7)	0.0 (+0.5 ,)	26.4				
unident.								
0512-401	1976 Aug 23-24,27	2.1 (+ 0.4 ,- 0.4)	0.0 (+1.2 ,)	14.3	8	0.8	0.1	2
2S,3A,4U		7.0 (+ 7.0 ,- 2.0)	0.0 (+1.0 ,)	17.7				
NGC 1851								
	*1978 July 25-26	1.9 (+ 0.1 ,- 0.2)	0.0 (+0.8 ,)	16.5	18	3.5	0.1	10
		9.0 (+ 4.0 ,- 1.8)	0.0 (+0.5 ,)	19.1				
	1978 Aug 1-2	2.2 (+ 0.1 ,- 0.2)	1.0 (+0.7 ,-0.4)	11.0	18	4.3	0.1	12
		7.5 (+ 1.3 ,- 1.3)	0.0 (+0.4 ,)	8.8				
0521-720	1975 Nov 4	2.65(+ 0.10,- 0.13)	3.0 (+0.7 ,-0.5)	14.8	22	5.5	0.1	15
3A,4U		5.0 (+ 0.6 ,- 0.5)	0.8 (+0.6 ,-0.4)	11.6				
LMC X-2								
0538-641	1977 Aug 7-8	3.8 (+ 0.2 ,- 0.2)	3.5 (+0.8 ,-1.0)	15.8	8	6.2	0.2	14
3A,4U		2.5 (+ 0.3 ,- 0.3)	0.0 (+0.8 ,)	12.6				
LMC X-3								
0540-697	1977 June 29,	3.1 (+ 0.2 ,- 0.2)	0.0 (+0.5 ,)	11.8	12	7.8	0.2	17
3A,4U	July 7	2.25(+ 0.25,- 0.25)	0.0 (+0.4 ,)	25.1				
LMC X-1								
0620-003	1975 Aug 21	6.85(+ 0.01,- 0.10)	10.1 (+0.1 ,-0.1)	331.0	26	11400.	54.	22473
2S,3A		1.24(+ 0.01,- 0.01)	1.60(+0.10,-0.05)	85.9				
Nova Mon								
	*1975 Oct 12	7.00(+ 0.02,- 0.06)	7.80(+0.25,-0.08)	72.3	22	4434.	37.	8247
		1.09(+ 0.01,- 0.01)	0.50(+0.12,-0.12)	56.1				
0900-403	1974 Dec 12	1.3 (+ 0.7 ,- 0.5)	13.0 (+0.8 ,-1.3)	59.0	27	8.5	0.1	35
3A,4U		24.0 (,- 1.2)	18.0 (+0.5 ,-2.3)	104.7				
Vela X-1								
	*1974 Dec 13	1.65(+ 0.10,- 0.06)	16.0 (+1.3 ,-1.8)	17.1	21	6.3	0.1	26
		28.0 (,- 4.0)	14.0 (+2.0 ,-1.1)	15.7				
1014-57	1977 Sep 1-2,3-4	1.50(+ 0.25,- 0.30)	0.5 (+1.8 ,)	15.1	13	0.9	0.1	3
A		22.0 (,-11.0)	0.5 (+2.0 ,)	15.2				
Unident.								
1042-595	1977 Sep 11,12,	2.25(+ 0.20,- 0.30)	0.2 (+1.0 ,)	12.4	14	2.0	0.1	5
3A,4U	16,17	5.0 (+ 2.9 ,- 1.0)	0.0 (+0.8 ,)	15.4				
η Carinae								
1119-603	1977 Sep 19	1.55(+ 0.70,- 0.80)	4.0 (+0.5 ,-0.6)	51.0	27	27.3	0.8	97
3A,4U		26.0 (,- 5.0)	4.5 (+1.0 ,-1.4)	45.9				
Cen X-3								
1254-690	1976 Jan 29,30	2.80(+ 0.07,- 0.06)	4.4 (+0.3 ,-0.4)	49.9	15	8.0	0.1	23
2S,3A,4U		5.0 (+ 0.4 ,- 0.2)	1.6 (+0.4 ,-0.2)	50.0				
"Star 30"								
1417-624	1977 May 13,14,15	1.0 (+ 1.0 ,- 0.5)	0.0 (+3.0 ,)	5.5	3	0.9	0.1	3
2S,3A,4U		19.0 (,-14.0)	0.0 (+7.8 ,)	6.2				
"Star 7"								
1556-605	1977 May 7,9,11	2.1 (+ 0.1 ,- 0.2)	0.0 (+0.8 ,)	14.4	12	16.2	0.6	46
2S,3A,4U		6.0 (+ 1.8 ,- 1.4)	0.0 (+0.5 ,)	16.8				
"Star 43"								
1708-232	1976 Apr 14	No spectral fitting attempted				2.6	0.4	9
3A,4U								
cD clust								
1730-335	1977 Apr 19,20,21	2.1 (+ 0.3 ,- 0.3)	5.0 (+2.8 ,-2.5)	6.1	16	17.9	0.9	57
2S,MXB		9.0 (+ 6.0 ,- 3.0)	4.0 (+3.0 ,-3.0)	5.5				
glob cl.								
1744-361	1976 Mar 2-7	2.90(+ 0.02,- 0.06)	5.5 (+0.5 ,-0.2)	44.9	26	40.4	0.4	118
A		6.1 (+ 0.2 ,- 0.2)	1.3 (+0.4 ,-0.2)	39.9				
unident.								
1746-370	1978 Apr 18-22	2.15(+ 0.07,- 0.07)	1.6 (+0.4 ,-0.4)	58.1	24	16.4	0.3	47
2S,3A,4U		9.0 (+ 0.7 ,- 1.2)	0.2 (+0.4 ,)	35.7				
NGC 6441								
1820-303	*1976 Apr 18	2.40(+ 0.07,- 0.10)	3.2 (+0.4 ,-0.3)	12.3	25	48.3	1.5	142
2S,3A,4U		6.5 (+ 0.7 ,- 0.6)	1.6 (+0.4 ,-0.3)	14.6				
NGC 6624								
	1976 Apr 19	1.57(+ 0.02,- 0.02)	0.5 (+0.1 ,-0.1)	63.2	25	77.6	1.0	235
		21.0 (+ 1.8 ,- 1.5)	0.3 (+0.1 ,-0.1)	58.1				

TABLE II *(continued)*.

Source name	Epoch of obs.	Spectral index or kT (keV)	Column density NH (10^{22}cm^{-2})	χ^2	DoF	2-10 keV flux 10^{-2} pb/cm^{2}s	flux error	Equiv. Uhuru Counts
1822-371	1978 May 9,10,	1.4 (+ 0.2 ,- 0.2)	6.0 (+3.0 ,-3.0)	27.9	10	3.3	0.2	13
3A,4U	11,12	18.0 (,- 5.0)	8.0 (+5.0 ,-2.5)	28.7				
V691 CrA		2.5 (+ 0.3 ,- 0.3)	0.0 (+2.3 ,)	15.9	(blackbody fit)			
1907+097	*1975 June 6	1.10(+ 0.15,- 0.10)	2.0 (+1.1 ,-1.1)	24.7	24	4.4	0.1	16
3A,4U		23.0 (,- 4.5)	5.0 (+1.2 ,-1.5)	37.2				
OB? star		2.3 (+ 0.2 ,- 0.2)	0.0 (+0.5 ,)	40.2	(blackbody fit)			
	1975 June 7	1.5 (+ 0.2 ,- 0.2)	5.0 (+3.0 ,-2.0)	12.7	13	3.2	0.2	12
		22.0 (,- 7.0)	6.0 (+3.1 ,-2.4)	13.2				
		2,6 (+ 0.2 ,- 0.3)	0.0 (+1.5 ,)	16.8	(blackbody fit)			
1907+074	1977 Mar 25,26,27	1.60(+ 0.15,- 0.15)	3.0 (+1.5 ,-1.2)	40.6	21	2.9	0.1	10
3A,4U		20.0 (,- 6.0)	3.0 (+1.5 ,-1.3)	37.2				
unident.								
1909+048	1976 Oct 19,20	1.50(+ 0.27,- 0.28)	0.0 (+1.6 ,)	15.7	14	2.4	0.1	8
3A,4U		20.0 (,- 8.5)	0.0 (+2.2 ,)	16.0				
SS 433								
1936-68	1976 May 22-25	1.4 (+ 0.2 ,- 0.4)	0.0 (+1.3 ,)	21.9	13	0.40	0.03	1
unident.		23.0 (,- 6.0)	0.0 (+1.7 ,)	28.4				
1958+407	1975 May 15-17	1.6 (+ 0.3 ,- 0.3)	0.0 (+0.9 ,)	28.2	17	1.5	0.1	4
3A,4U		18.0 (,- 9.0)	0.0 (+0.8 ,)	30.0				
Cyg A								
2008-568	1976 May 19-22	1.5 (+ 0.6 ,- 0.8)	1.0 (+4.0 ,)	5.9	6	1.1	0.1	3
3A		20.0 (,-14.0)	1.0 (+4.0 ,)	6.4				
cl gals?								
2127+119	1976 June 18,20,	2.5 (+ 0.7 ,- 0.9)	0.0 (+3.0 ,)	4.7	3	0.8	0.1	2
2S,3A,4U	21,23,24	5.0 (+16.0 ,- 2.4)	0.0 (+2.0 ,)	5.6				
NGC 7078								
2129+470	1975 June 13-16							
3A,4U	* (i) phase 0.0-0.3	1.75(+ 0.40,- 0.40)	2.0 (+2.0 ,-2.0)	25.2	13	1.4	0.1	5
V1727Cyg		18.0 (,-10.0)	1.0 (+2.5 ,)	20.6				
	* (ii) phase 0.3-0.7	1.8 (+ 0.3 ,- 0.4)	0.0 (+1.8 ,)	25.0	10	1.2	0.1	4
		10.0 (+ 8.0 ,- 4.5)	0.0 (+1.7 ,)	24.8				
	*(iii) phase 0.7-0.0	2.25(,- 1.00)	3.0 (+4.0 ,-3.0)	1.6	4	0.8	0.1	2
		14.0 (,-10.0)	1.0 (+4.5 ,)	1.6				

* For sources observed more than once this indicates which spectrum is displayed in Figure 1.

References for table III.

1 Davison, Culhane & Mitchell 1976
2 Hayes et al. 1981
3 Hayes, Culhane & Bell Burnell 1980a
4 Coe et al. 1981
5 Davison 1977a
6 Stark 1979
7 Mitchell et al. 1979
8 Mitchell, Ives & Culhane 1977
9 Mitchell et al. 1976
10 Sanford & Ives 1976
11 White et al. 1976
12 Sanford 1977
13 Mason et al. 1976
14 Parkes et al. 1977
15 Berthelsdorf & Culhane 1979
16 Zarnecki 1979
17 Zarnecki et al. 1978
18 Mason & Culhane 1978
19 Ives & Sanford 1976
20 Maraschi et al. 1976
21 Ives, Sanford & Bell Burnell 1975
22 Barr et al. 1977
23 Ives, Sanford & Penston 1976
24 Culhane 1978
25 Davison 1978
26 Bell Burnell & Culhane 1979
27 Mitchell & Culhane 1977
28 Stark, Bell Burnell & Culhane 1978
29 Stark, Davison & Culhane 1976
30 Zarnecki & Bibbo 1979
31 Davison 1977b
32 Lamb & Sanford 1979
33 Greenhill et al. 1979
34 Snijders et al. 1979
35 Parmar, Sanford & Fabian 1980
36 Davison & Fabian 1977
37 Branduardi et al. 1976
38 Charles, Thorstensen & Barr 1980
39 Barr et al. 1980

TABLE III. — *Sources for which Ariel V Expt. C spectra have been published.*

Source name(s)		Epoch of this spectrum	Ariel V Expt C spectral fits (references*)	2-10 keV flux 10^{-2} ph/cm^{2}s	
				flux	error
0022+638 3A,4U	Tycho	1975 Apr 1-10	1	8.64	0.07
0039-795 3U?	ESO 012-G21	1976 Aug 13-17	2,3	0.28	0.04
0115-737 3A,4U	SMC X-1	1975 Nov 12	4, 5	8.48	0.14
0121-353 3A,4U	NGC 526a	1976 July 26-30	2, 6	0.53	0.04
0256+129 3A,4U	Abell 401	1975 July 18-21	7, 8	0.95	0.04
0316+414 3A,4U	Perseus cl.	1975 Sep 6-7	8, 9, 10	16.0	0.2
0316-442 3A	4U0321-45	1976 July 30-Aug 4	7	0.46	0.06
0342-536 3A,4U	CA0340-536	1976 Aug 5-8	7	0.81	0.05
0352+309 2S,3A,4U	X Per	1975 Sep 2-5	11	5.45	0.07
0430-615 3A,4U	Ser 40/6	1976 Aug 17-22	7,12	0.72	0.04
0446+449 H,3A,4U	3C 129	1975 Apr 10-11	7	1.46	0.06
0557-383 3A,4U	Seyfert	1978 Aug 5-9	2	1.72	0.03
0614+091 2S,3A,4U	V1055 Ori	(i)1975 Apr 30-May 1	13	14.2	0.2
		(ii)1975 Aug 18-19		8.8	0.2
		(iii)1975 Sep 25-27		19.8	0.2
0614+224 3A,4U	IC 443	1975 Sep 21-25	14	1.45	0.07
0624-546 3A,4U	cl. of gals?	1976 Aug 27-Sep 1	15, 7	0.90	0.03
0821-427 3A,4U	Puppis A	1975 Oct 25-26	16, 17	6.12	0.15
0833-450 3A,4U	Vela PSR	1975 Oct 27	18	3.69	0.24
1036-272 3A,4U	Abell 1060	1975 Dec 12-16	7,8,19	0.98	0.06
1118-615 A	Cen X-mas	1974 Dec 25	20,21	26.0	0.2
1139-377 3A,4U	NGC 3783	1978 Nov 6-17	2	0.46	0.03
1141+198 3A,4U	Abell 1367	1976 Dec 9-14	7,8	0.75	0.05
1208+396 3A,4U	NGC 4151	(i)1974 Nov 26-28	2, 6, 22, 23	2.04	0.05
		(ii)1976 Jan 7-9		2.02	0.05
		(iii)1976 Dec 23-26		0.56	0.03
1226+023 3A,4U	3C 273	1974 Dec 4-6	24	0.80	0.05
1228+125 3A,4U	Virgo cl.	1974 Nov 30-Dec 2	25, 10	0.91	0.08
1237-049 H,3A,4U	NGC 4593	1975 Dec 25-30	2, 26, 7	0.35	0.03
1246-411 3A,4U	Cen cl.	1978 Dec 7-10,23-28 and 1979 Jan 23-24	27, 8, 10	3.00	0.07
1249-289 3A,4U	EX Hydrae	1975 Dec 22-24	6, 28	1.48	0.08
1257+282 3A,4U	Coma cl.	1976 Nov 17-30	7, 8, 10	5.98	0.03
1322-427 3A,4U	Cen A	(i)1975 Jan 17-18	6, 29	8.52	0.09
		(ii)1976 Jan 19-23		7.04	0.06
		(iii)1978 Dec 18-21		3.87	0.05
1345+269 3A,4U	Abell 1795	1977 Jan 12-15	7	1.23	0.06
1348+700 3A	Mk 279 or MCG 12-13-24	1976 Dec 30 - 1977 Jan 3	2, 6, 28	0.21	0.02
1411-028 3A,4U	NGC 5506	1976 Jan 12-14	2, 6, 28	0.28	0.03
1458-41 4U	SN 1006	1976 Jan 17-19	30	0.46	0.05
1524-617 A,2S,3A	TrA X-1	1975 Feb 7-8	20	67.9	0.9
1538-522 2S,3A,4U	QV Nor	1976 Sep 7-8	31	3.9	0.1
1558+276 3A,4U	Abell 2124	1977 Jan 31-Feb 1	7	0.65	0.06
1617-155 3A,4U	Sco X-1	1975 Mar 4	32, 33	3519.	10.
1653+398 3A,4U	Mk 501	1975 Mar 15-17	6,34	0.36	0.03
1656+354 3A,4U	Her X-1	(i)1977 Feb 2-3	35, 36	0.93	0.05
		(ii)1977 Feb 5		18.8	0.8
1709+787 3A,4U	Abell 2256	1975 Mar 17-19	7, 8	0.85	0.03
1728-337 2S,3A,4U	glob. cl.?	1978 Apr 18 (but see also discussion of 1730-335 in section V)	11	14.9	1.3
1742-289 A	K3V star	1975 Feb 23	37	284.	2.
1822-371 3A,4U		See table 2 and figure 2	38	See table 2	
1847+78 4U	3C 390.3	1976 Oct 29-Nov 2	2, 6, 39	0.13	0.02
1916-79 4U	unidentified	1976 May 25-27	6, 28	0.31	0.03
1955-68 4U	Pavo cl.	1976 May 27-29	7	0.62	0.04
2041-107 3A	Mk 509	1976 May 11-13	2, 6	0.63	0.07

(*) The references are listed under table II.

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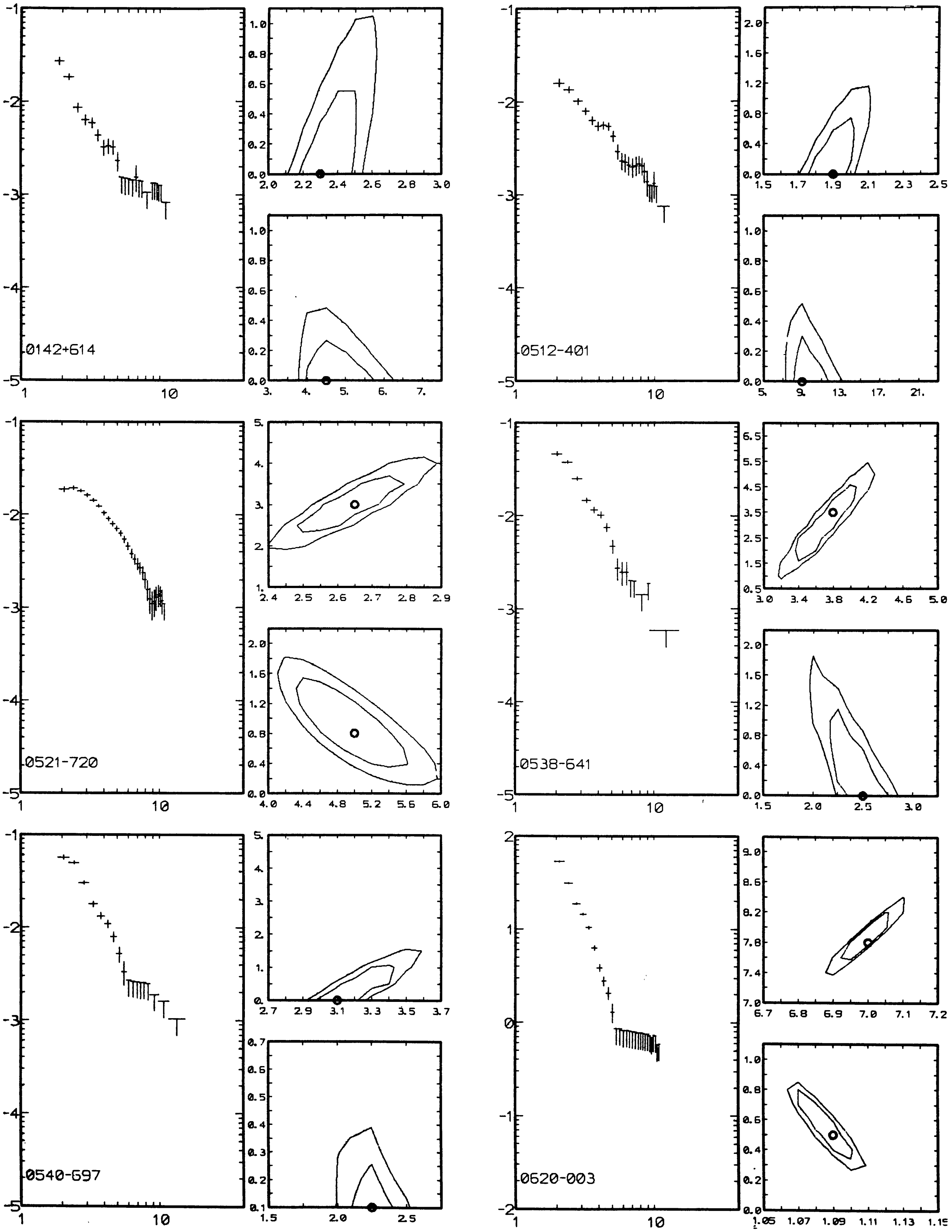

FIGURE 1. — The spectra of those sources for which no Experiment C spectra have been published. The restored spectra (left-hand panel) are in units of log photons cm^{-2} s^{-1} keV^{-1} *versus* energy in keV. The upper limits (plotted as « T » shapes) are at the 3 sigma level. The confidence contour plots are for the power law (top right panel) and thermal Bremsstrahlung + Gaunt (bottom right panel) fits. The y-scale is hydrogen column density in units of 10^{22} cm^{-2}, the x-scale respectively photon number index and kT (keV). The best fit is indicated by the circlet and the confidence contours are plotted at the 68 % ($\chi^2_{\min}$ + 2.3) and 90 % ($\chi^2_{\min}$ + 4.6) confidence levels.

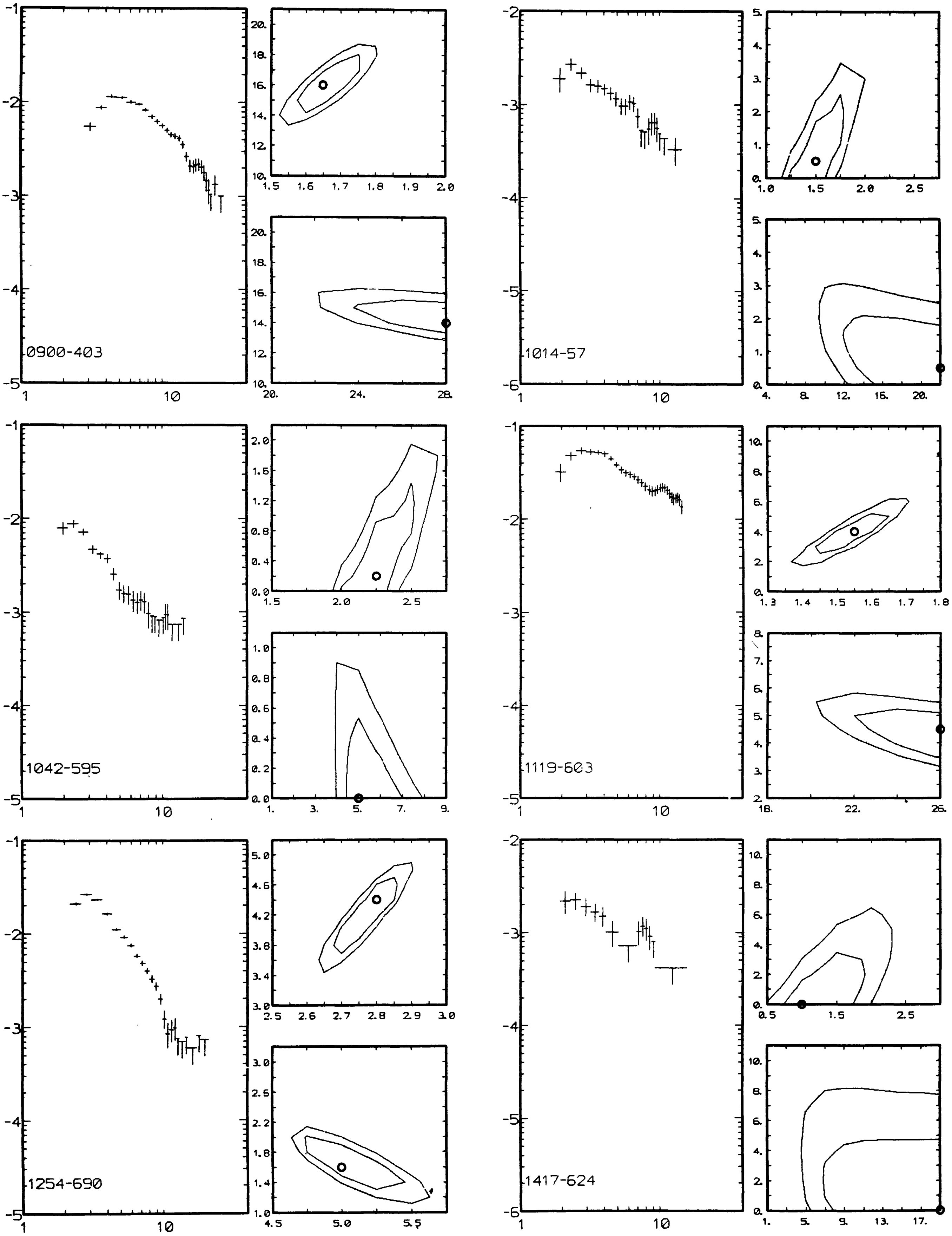

FIGURE 1 *(continued)*.

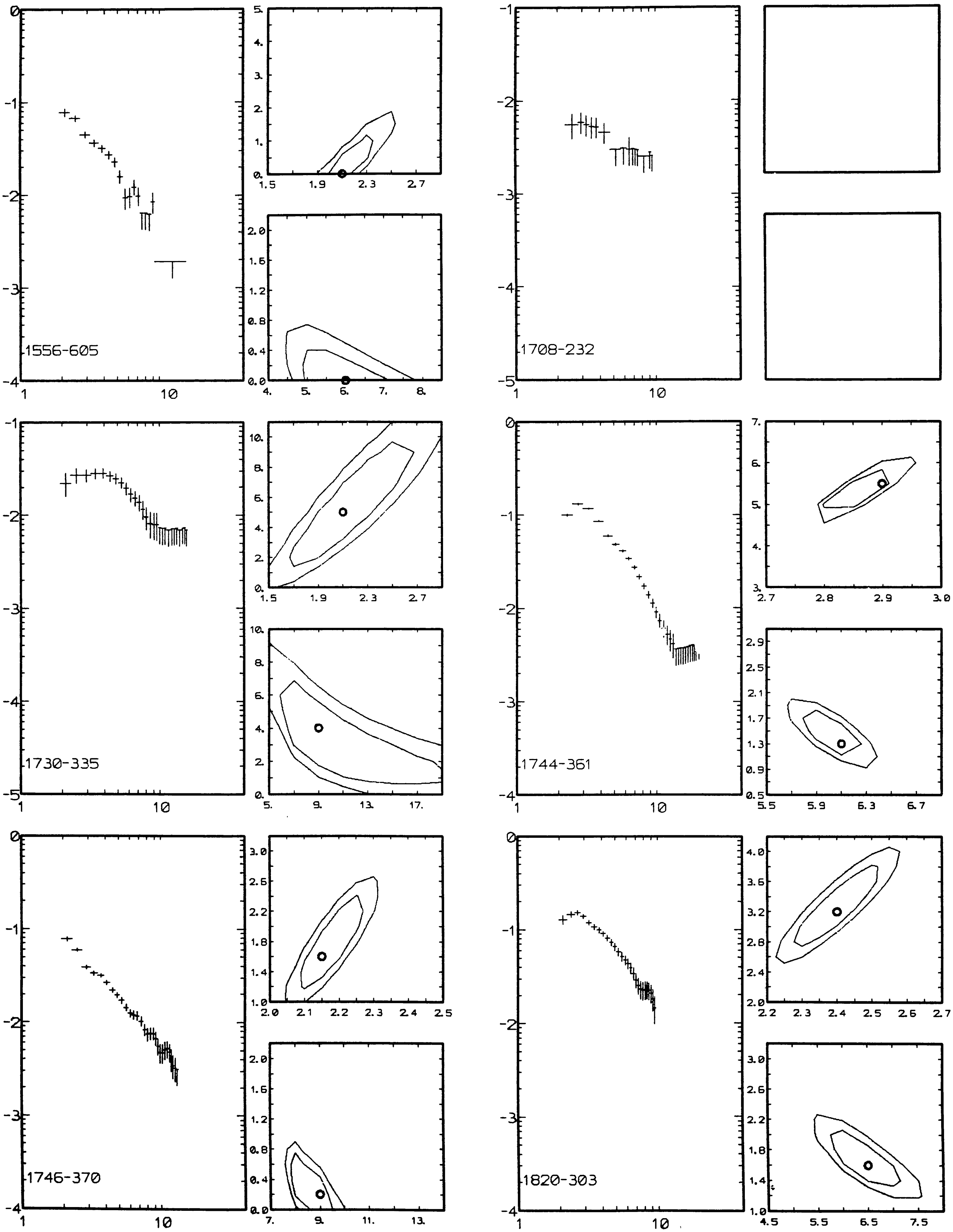

FIGURE 1 *(continued)*.

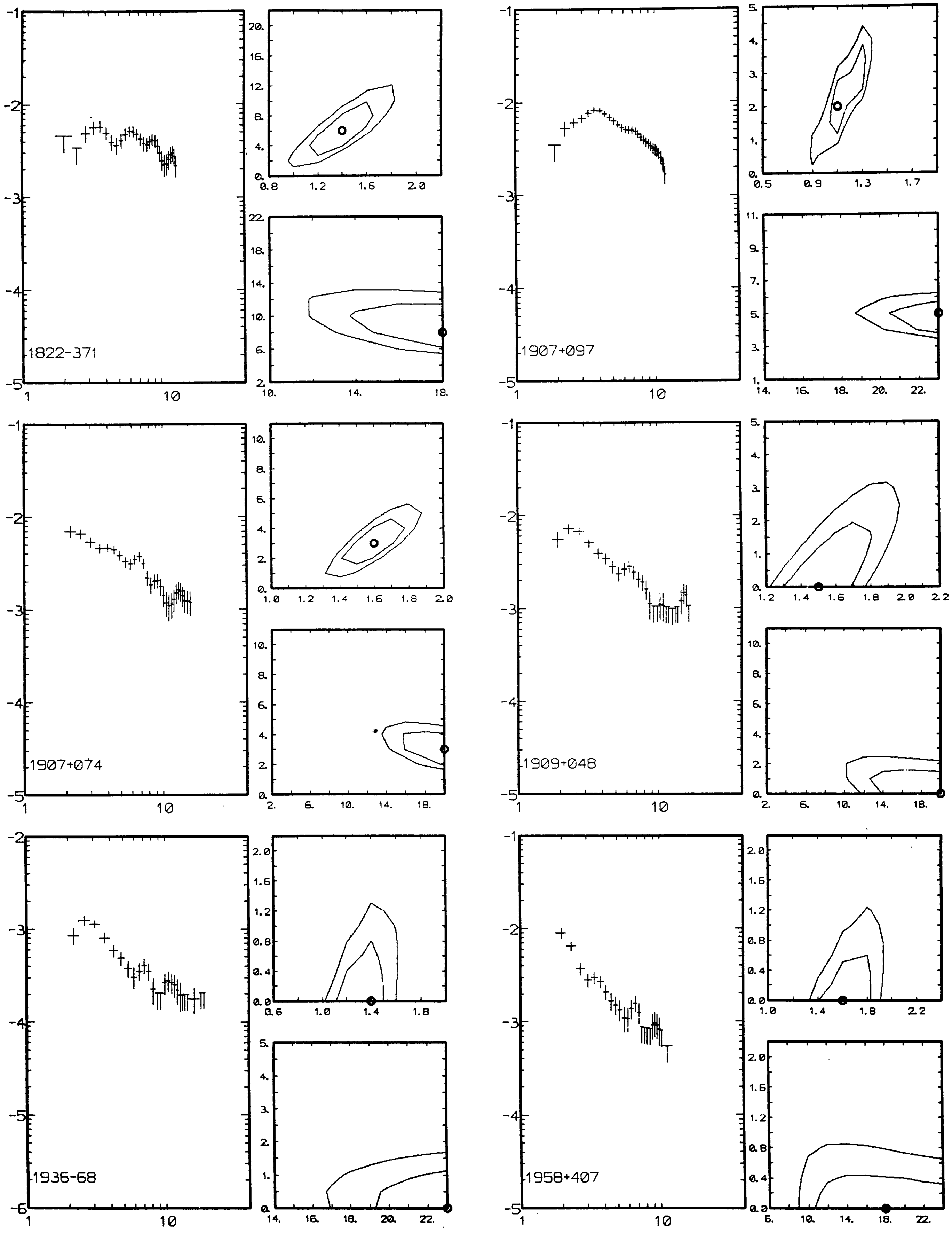

FIGURE 1 *(continued)*.

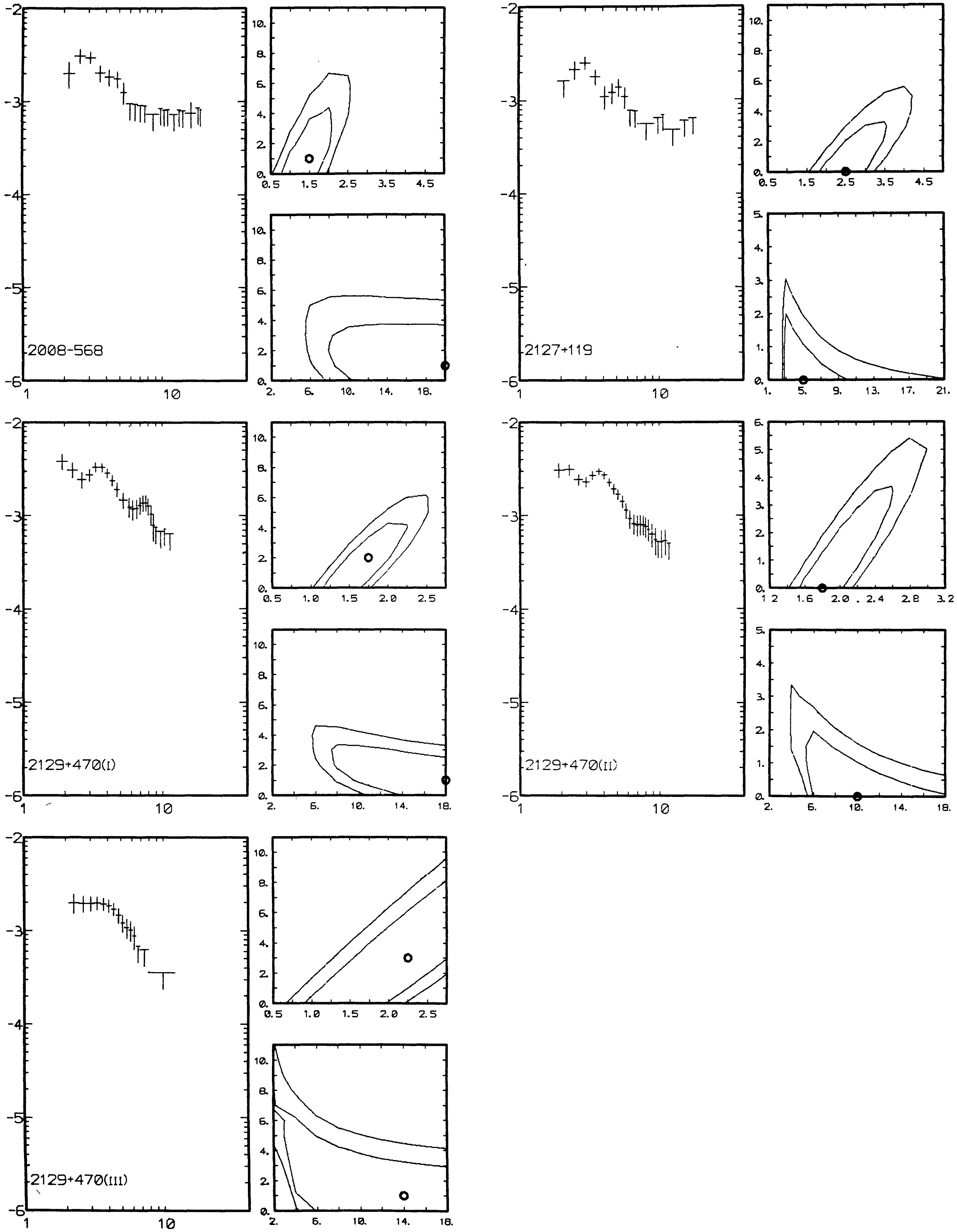

FIGURE 1 *(continued)*.

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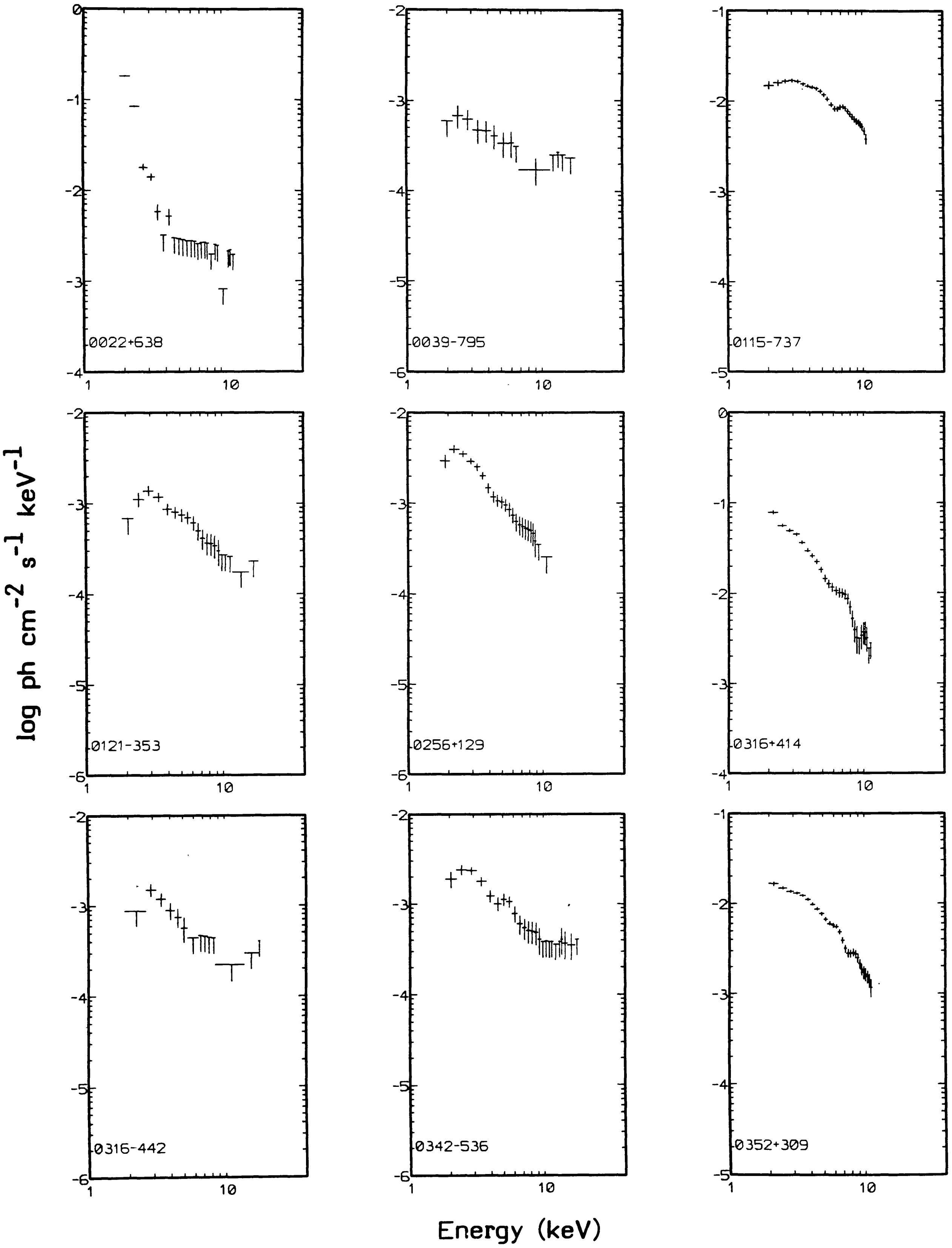

FIGURE 2. — Restored spectra of those X-ray sources for which spectral fits have been published. The upper limits (plotted as « T » shapes) are at the 3 sigma level.

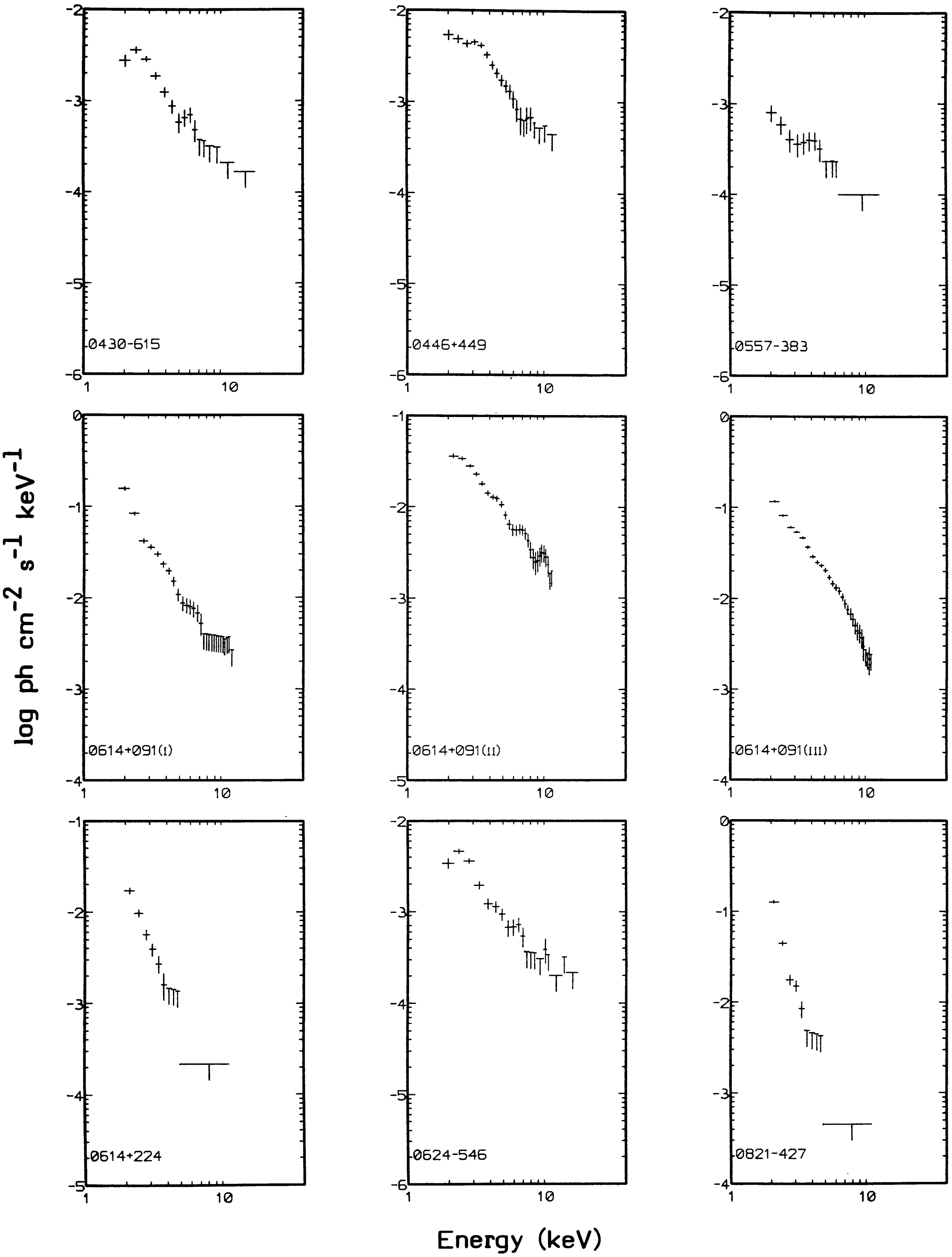

FIGURE 2 *(continued)*.

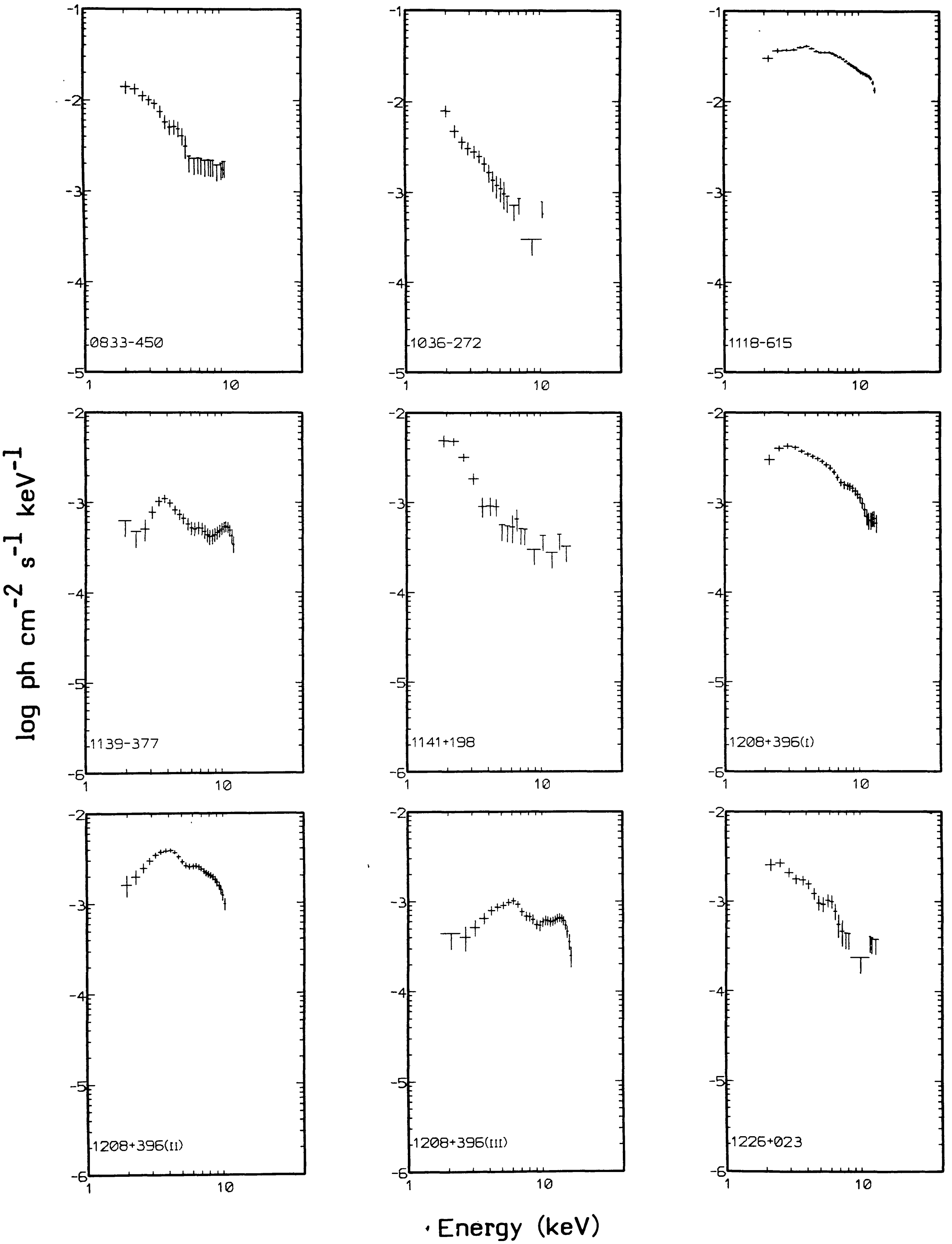

FIGURE 2 *(continued)*.

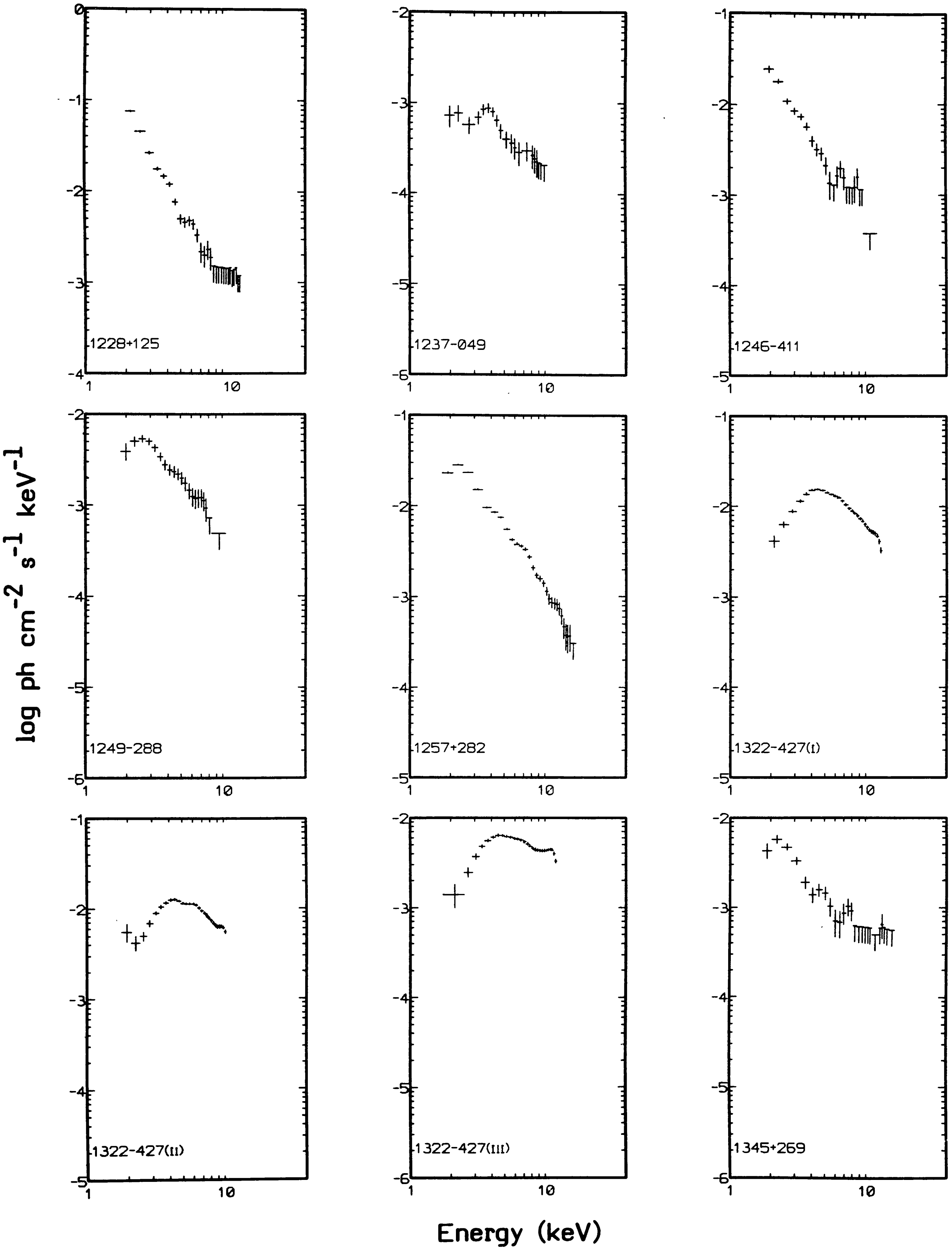

FIGURE 2 *(continued)*.

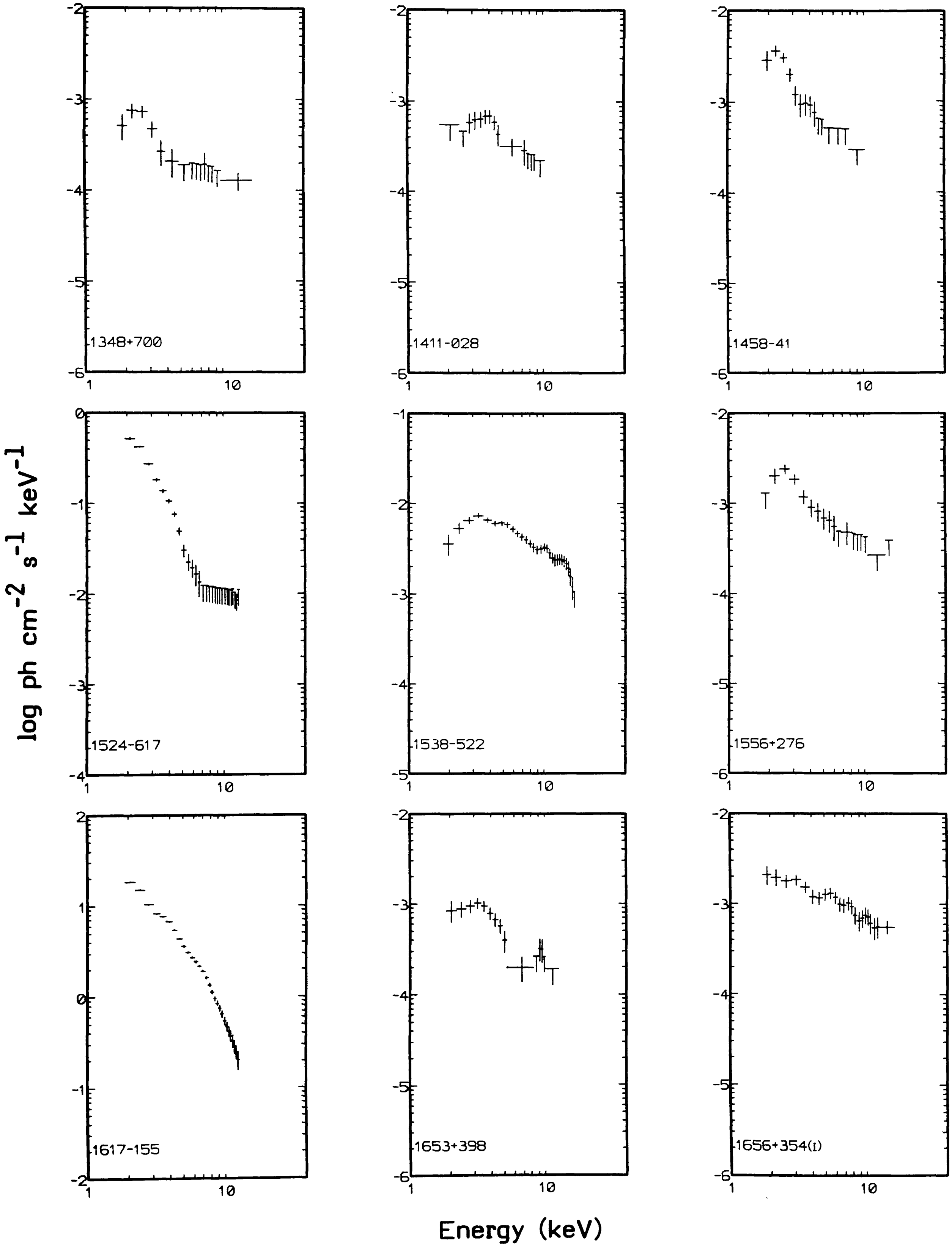

FIGURE 2 *(continued)*.

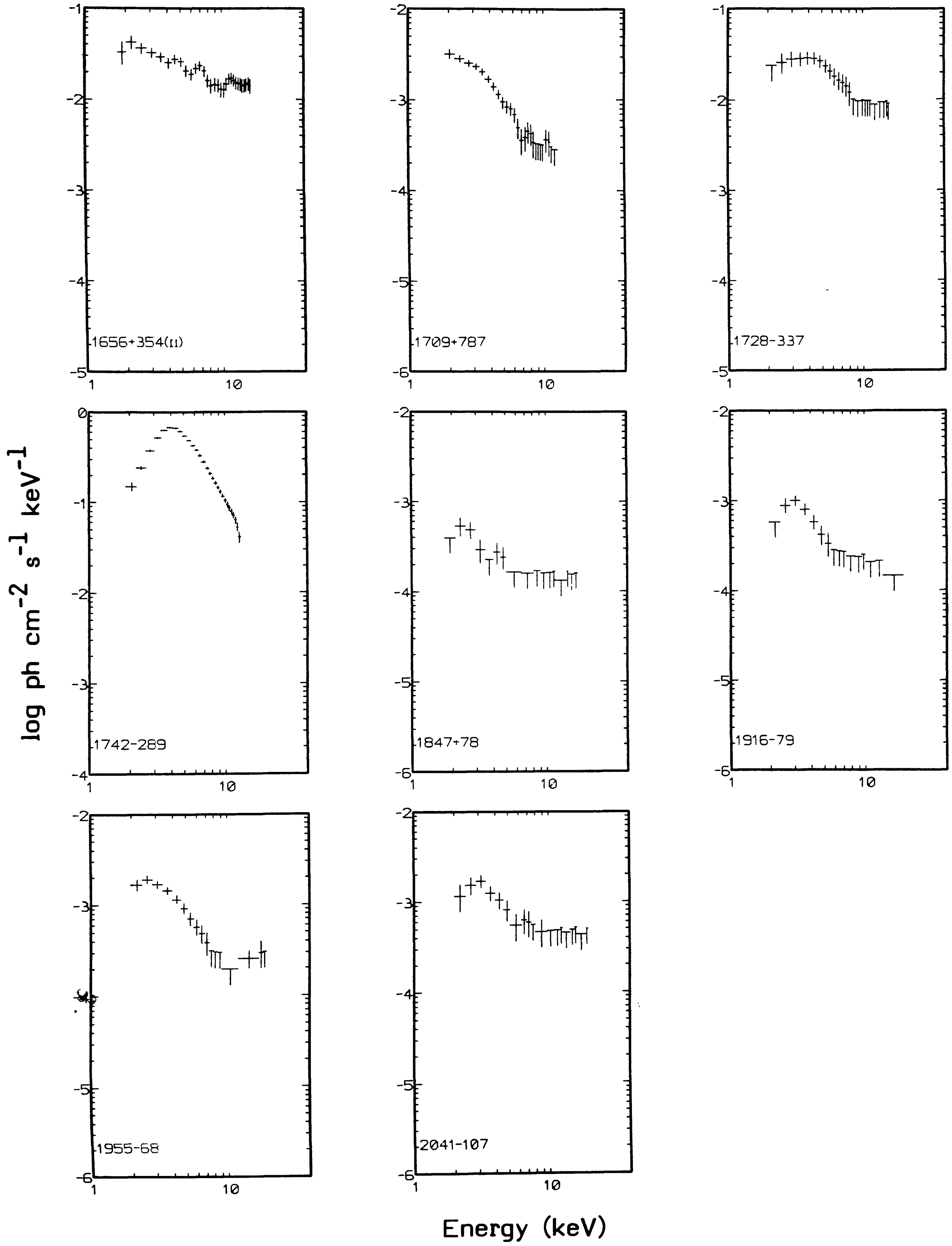

FIGURE 2 *(continued)*.