Quasar survey: data-reduction methods

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1 Preliminaries

The analyses described below require extensive use of `ciao` and `aips`, and some use of home-grown software. To run `ciao` on a HEAD machine at the CfA, simply type

```
ciao
```

and then use the various `ciao` commands as needed.

Running `aips` is a little harder, since it is set up only on the R&G group's machines. First, permit `aips` on a remote machine to display on your machine, using

```
xhost +rgalp6
```

if you are intending to run `aips` on `rgalp6`. Then login (via `ssh`) on `rgalp6` and type (for display on `cfa210`),

```
setenv DISPLAY cfa210:0.0
aips tst tv=local
```

to tell `aips` which machine to display on, and then set up `aips`. If you don't have an account on an R&G machine, contact Shoshana Rosenthal to request one.

2 Astrometry

The first step in the data-reductions involves checking the astrometry of the radio and X-ray data by finding the location of the X-ray centroid of the core, and then correcting so that it coincides with the radio centroid.

This basic astrometry is performed on the $0.5 - 7$ keV X-ray data (as extracted by Dan Schwartz, and available via the whiteboard site (`http://asc.harvard.edu/acis/jetsurvey/whiteboard.html`). The X-ray centroid can be found using `ds9` (to get a rough centroid) and then `dmstat`. I'll use, as an example, the source PKS B1202−262 (J1205−2634), for which the dataset is `acis3118_.5to7.fits`. A display (logarithmically coded) using

```
ds9 acis3118_.5to7.fits
```

suggests that the centre of the source is near $(4054, 4154)$. Since 95% of the counts in a source with a typical spectrum are contained in a region of radius 2.5 pixels on the default ACIS grid, we refine the centroid by running `dmstat` repeatedly, as

```
dmstat "acis3118_.5to7.fits[events][sky=circ(4145.9342,4042.8793,2.5)][cols sky]"
```

adjusting the centre of the circle, here $(4145.9342, 4042.8793)$, until convergence is reached. This typically takes two or three invokations of `dmstat`. The above command returns average (x, y) locations for events, as

```
sky(x, y)[pixel]
  min:        ( 4143.5102539 4040.5178223 )        @:        704
  max:        ( 4148.3671875 4045.3029785 )        @:        407
 mean:        ( 4145.934171 4042.8793332 )
sigma:        ( 0.77371562202 0.77470032281 )
  sum:        ( 3117742.4966 3040245.2585 )
 good:        ( 752 752 )
 null:        ( 0 0 )
```

where the "mean" location is the position that we are interested in. Here convergence has almost been reached, since the mean location is close to the input location. 752 good events (counts in $0.5 - 7.0$ keV) are associated with the core.

The final sky position can be converted to real coordinates using `dmcoords`, as

```
dmcoords acis3118_.5to7.fits
dmcoords>: sky 4145.9342,4042.8793
(RA,Dec):     12:05:33.320    -26:34:04.14
(RA,Dec):      181.38883      -26.56782 deg
THETA,PHI           35.9''        343.56 deg
(Logical):        4145.93       4042.88
SKY(X,Y):         4145.93       4042.88
DETX,DETY         4166.45       4075.85
CHIP ACIS-S3       290.53         73.07
TDET              4207.53       1775.07
dmcoords>: q
```

The X-ray centroid is to be compared with the radio centroid. This is probably best done using `aips`, although `dmstat` could again be used. Copy the radio image of interest (the one with the best defined radio core, which is usually the map at the highest frequency) to the `/aips/FITS` area on the R&G machine, and then use `imlod` to read it into `aips`. Find the location of the radio centroid using `imfit`, fitting a Gaussian to the brightest central part of the source.

When this is done for B1202−262, the radio centroid is found to be $(\mathrm{ra}, \mathrm{dec}) = (12^{\mathrm{h}}05^{\mathrm{m}}33\overset{\mathrm{s}}{.}209, -26^{\circ}34'04\overset{''}{.}379)$. Thus the X-ray centre is offset by $(\delta\mathrm{ra}, \delta\mathrm{dec}) = (+0\overset{\mathrm{s}}{.}111, +0\overset{''}{.}23)$, or about 1.5 arcsec. This is consistent with the expected shift in this part of the chip relative to the nominal astrometry of the sweet spot normally used.

To register precisely, it is useful to make a sub-gridded image from the X-ray data, using

```
dmcopy ''acis3118_.5to7.fits[bin x=4018:4274:0.50,y=3915:4171:0.5]'' ./image_.5to7_half.fits
```

copy this X-ray image to `aips`, and then do another `imfit` there. This gives a slightly different centroid location than the `dmstat` method, $(\mathrm{ra}, \mathrm{dec}) = (12^{\mathrm{h}}05^{\mathrm{m}}33\overset{\mathrm{s}}{.}321, -26^{\circ}34'04\overset{''}{.}11)$. The shift relative to the radio centroid is $(\delta\mathrm{ra}, \delta\mathrm{dec}) = (+0\overset{\mathrm{s}}{.}112, -0\overset{''}{.}27)$, so I need to offset the parameters (`crval1`, `crval2`) in the header of the X-ray image in `aips` to get a match. The existing (`crval1`, `crval2`) in the header of the X-ray map are

```
crval1 = 181.3963928  -0.000005174  degrees
crval2 = -26.5604897  -0.000000342  degrees
```

and if I change them (using `puthead`) to

```
crval1 = 181.3963928  -0.000473050  degrees
crval2 = -26.5604897  -0.000074870  degrees
```

I find that a repeat of `imfit` on the X-ray image gives identical centroid positions to the `imfit` positions for the radio core. At this point the relative astrometry of the radio and X-ray images is fixed, and since the radio frame should be good in absolute terms to better than $0\overset{''}{.}1$, the absolute locations of the cores and jet components should be well defined on both images.

$r_{\rm min}$ arcsec	$r_{\rm max}$ arcsec	$\phi_{\rm min}$ deg	$\phi_{\rm max}$ deg	$N_{\rm good}$	$N_{\rm good} - N_{\rm back}$
0.0	2.5	0.0	360.0	752	751.9 ± 27.4
2.5	7.5	0.0	360.0	88	87.5 ± 9.4
7.5	12.5	0.0	360.0	77	76.0 ± 8.8
12.5	17.5	0.0	360.0	15	13.5 ± 4.2
17.5	22.5	0.0	360.0	13	11.0 ± 4.1
22.5	27.5	0.0	360.0	8	5.5 ± 3.8
27.5	32.5	0.0	360.0	3	0.0 ± 2.4

Table 1: The radial profile of X-ray counts near B1202−262 in annuli of inner and outer radii $r_{\rm min}$ and $r_{\rm max}$, and over angular range $\phi_{\rm min}$ to $\phi_{\rm max}$. $N_{\rm good}$ is the number of "good" counts recorded by `dmstat`, and $N_{\rm good} - N_{\rm back}$ is the background-corrected number. It is clear that more than 5% of the counts lie outside the central bin, and so the source is clearly extended. Better information on the meaning of the extension requires comparison with a point spread function, as Diana does using `radial`, or could be calculated if a tabulated point spread over these annuli were available.

3 Extension and jet

The method of demonstrating, without recourse to eyeball tests, the existence of a radial extension and a jet-like structure is to look for features in simple radial profiles and azimuthal scans.

The radial profile is simplest. Construct the profile using

```
dmstat \
  "acis3118_.5to7.fits[events][sky=circle(4145.934,4042.879,2.5)][cols sky]" \
  > rad.out
dmstat \
  "acis3118_.5to7.fits[events][sky=pgrid(4145.934,4042.879,2.5:32.5:5,0:360:360)][cols sky]" \
  >> rad.out
```

which places the results from `dmstat` into file `rad.out`. Edited to their basics (which requires the removal of a lot of text), and with the background subtractions done, the results then look like Table 1, and suggest that that there is an extension of order 15 arcsec in length. At present I create this table, and the corresponding figure, by hand: a tool could be written to do the job.

Similarly, an azimuthal scan can be created using

```
dmstat \
  "acis3118_.5to7.fits[events][sky=circle(4145.934,4042.879,2.5)][cols sky]" \
  > pie.out
dmstat \
 "acis3118_.5to7.fits[events][sky=pgrid(4145.9342,4042.8793,2.5:17.5:5,0:360:30)][cols sky]" \
 >> pie.out
```

and after editing and background subtraction, a file like that in Table 2 results. This shows that the jet lies in angle near 80°. Angle is defined in the mathematical sense (anticlockwise from the negative right ascension axis) by the `ciao` data model, so this corresponds to position angle −10°, exactly as seen on Fig. 1. Interestingly, the scan also shows a fan of X-ray emission in the opposite direction to the jet. This is something that we should carefully watch in our images to see if it's a common feature, since it exists in the first two sources analysed.

4 Comparison of the radio and X-ray images

With the astrometrically-coincident images resident on disk, it is convenient to make a shifted radio map, with pixels that coincide exactly with the X-ray image. This is done using the `aips` task `hgeom` to perform the shift and regridding.

$r_{\rm min}$ arcsec	$r_{\rm max}$ arcsec	$\phi_{\rm min}$ deg	$\phi_{\rm max}$ deg	$N_{\rm good}$	$N_{\rm good} - N_{\rm back}$
0.0	2.5	0.0	360.0	752	751.9 ± 27.4
2.5	7.5	0.0	30.0	2	2.0 ± 1.4
2.5	7.5	30.0	60.0	6	6.0 ± 2.4
2.5	7.5	60.0	90.0	42	42.0 ± 6.5
2.5	7.5	90.0	120.0	12	12.0 ± 3.5
2.5	7.5	120.0	150.0	1	1.0 ± 1.0
2.5	7.5	150.0	180.0	3	3.0 ± 1.7
2.5	7.5	180.0	210.0	3	3.0 ± 1.7
2.5	7.5	210.0	240.0	4	4.0 ± 2.0
2.5	7.5	240.0	270.0	6	6.0 ± 2.4
2.5	7.5	270.0	300.0	4	4.0 ± 2.0
2.5	7.5	300.0	330.0	4	4.0 ± 2.0
2.5	7.5	330.0	360.0	1	1.0 ± 1.0
7.5	12.5	0.0	30.0	4	3.9 ± 2.0
7.5	12.5	30.0	60.0	5	4.9 ± 2.2
7.5	12.5	60.0	90.0	60	59.9 ± 7.7
7.5	12.5	90.0	120.0	3	2.9 ± 1.7
7.5	12.5	120.0	150.0	0	-0.1 ± 1.0
7.5	12.5	150.0	180.0	2	1.9 ± 1.4
7.5	12.5	180.0	210.0	1	0.9 ± 1.0
7.5	12.5	210.0	240.0	0	-0.1 ± 1.0
7.5	12.5	240.0	270.0	1	0.9 ± 1.0
7.5	12.5	270.0	300.0	0	-0.1 ± 1.0
7.5	12.5	300.0	330.0	0	-0.1 ± 1.0
7.5	12.5	330.0	360.0	1	0.9 ± 1.0
12.5	17.5	0.0	30.0	0	-0.1 ± 1.0
12.5	17.5	30.0	60.0	1	0.9 ± 1.0
12.5	17.5	60.0	90.0	3	2.9 ± 1.7
12.5	17.5	90.0	120.0	3	2.9 ± 1.7
12.5	17.5	120.0	150.0	1	0.9 ± 1.0
12.5	17.5	150.0	180.0	0	-0.1 ± 1.0
12.5	17.5	180.0	210.0	1	0.9 ± 1.0
12.5	17.5	210.0	240.0	3	2.9 ± 1.7
12.5	17.5	240.0	270.0	0	-0.1 ± 1.0
12.5	17.5	270.0	300.0	1	0.9 ± 1.0
12.5	17.5	300.0	330.0	2	1.9 ± 1.4
12.5	17.5	330.0	360.0	0	-0.1 ± 1.0

Table 2: The azimuthal distribution of X-ray counts near B1202−262. It is clear that there is a sudden rise in the counts at angles $\phi \sim 80^\circ$ in the annuli from $2.5 - 17.5$ arcsec from the core. This is the jet. It also appears that there is a fan-like emission opposite to the jet and more diffuse, spanning $\sim 90^\circ$ in the $2.5 - 7.5$ arcsec ring. This is also seen in J0922−3959, which suggests a theme to check in the survey.

Shifting the radio image is far better than shifting the X-ray image, since it avoids the problem of creating pixels with fractional counts.

A good black-and-white overlay of the radio and X-ray images can now be produced using `kntr`. I choose to plot radio contours at -1, 1, 2, 4, 8, 16, 32, 64, 128, 256, and 512×0.001 Jy on a grey-scale representation of the X-ray image, with the grey scale running from 0 (white) to 4 counts (black). The resulting plot (Fig. 1) is written to the `/tmp` directory of `rgalp6` using `lwpla` (with text forced to be in the Times Roman font, and default `functype`), and then copied to the working area on `cfa210` using `sftp`.

This is a suitable point to create radio and X-ray images with exactly the same angular resolution, so that the relative brightness profiles along the jet can be created. Taking a look at the radio and X-ray data, I see that the highest angular resolution image is the VLA C-band image, for which the restoring clean beam is an ellipse with FWHM sizes 1.19×0.31 arcsec in position angle $-30^\circ\!.98$ (from the `aips` header). This is first shifted to the same pixel grid as the X-ray image (as was done earlier with the X-band data, using `hgeom`). I then convolve this to a 1.2 arcsec circular beam, using `convl` (with `bmaj`, `bmin`, and `bpa` set, but allowing `convl` to calculate `factor` to keep the flux density scale in units of mJy/beam).

For the X-ray data this is not so easy, since the PRF isn't exactly Gaussian, and its width depends on the distribution of photon energies. The procedure I used was, therefore, to experiment with values of `bmaj` and `bmin` (with `bpa` set to zero) until `imfit` fitted the FWHM of the core of the source to be 1.2 arcsec. This required `bmaj` = `bmin` = 0.80 arcsec. At the same time, I set `factor` = 1 to conserve the number of counts on the frame.

The resulting convolved, same-resolution, C-band and X-ray images are shown in Fig. 2. The similarity of the jets is striking, though significant differences can be seen: the radio jet appears more curved since a small-scale jet extends all the way to the radio core, while the X-ray jet only appears after a small gap, and then seems to be straight until it terminates in a bright spot. In fact, Fig. 1 suggests that there are a few counts associated with the jet after this hot-spot, when the jet turns abruptly to the NE.

A good radio to X-ray brightness profile can now be obtained by taking the values of points on the ridge-line of the jets in Fig. 2 (it is crucial that the angular resolutions of the maps are the same, which is why this cannot be done earlier). These values are given in Table 3. Since the pixels on the image are 0.246 arcsec on a side, and the beam has a FWHM of 1.2 arcsec, I don't record the values every pixel on the ridge-line, but only every other pixel. This still allows a substantial oversampling.

The error calculation is simple for the radio data (the errors are uniform on a synthesis map, if we ignore systematic errors associated with the image reconstruction), and are therefore the noise on the map. This is 0.5 mJy. For the X-ray data, the number of counts that contribute to any one value given is $28\times$ the value, and therefore the Poisson errors can be estimated as $\sqrt{S_{\rm X}/28}$. The background is much less than 0.1 scaled counts in the X-ray data, and entirely negligible in the radio data.

Interestingly enough, in the flux density/flux plane, the track of the jet as we move out from the core appears to describe a loop. The radio and X-ray surface brightnesses also appear to show different behaviours with distance from the core of the source.

5 Spectroscopy

To perform spectroscopy on the data, I first extract from designated regions using `psextract` and then fit using `sherpa`.

For the core, I define the region file `core.reg` as

```
# Region file format: CIAO version 1.0
+circle(4145.934,4042.879,2.5)
```

and a corresponding background region nearby, `sky.reg`,

```
# Region file format: CIAO version 1.0
+annulus(4145.934,4042.879,15.0,25.0)
```

from which I will perform the extraction using `psextract`. In addition, we need to define a region for the jet. I feel it's important to have something which comes into contact with the core, and since we're dealing with a bent object, it's

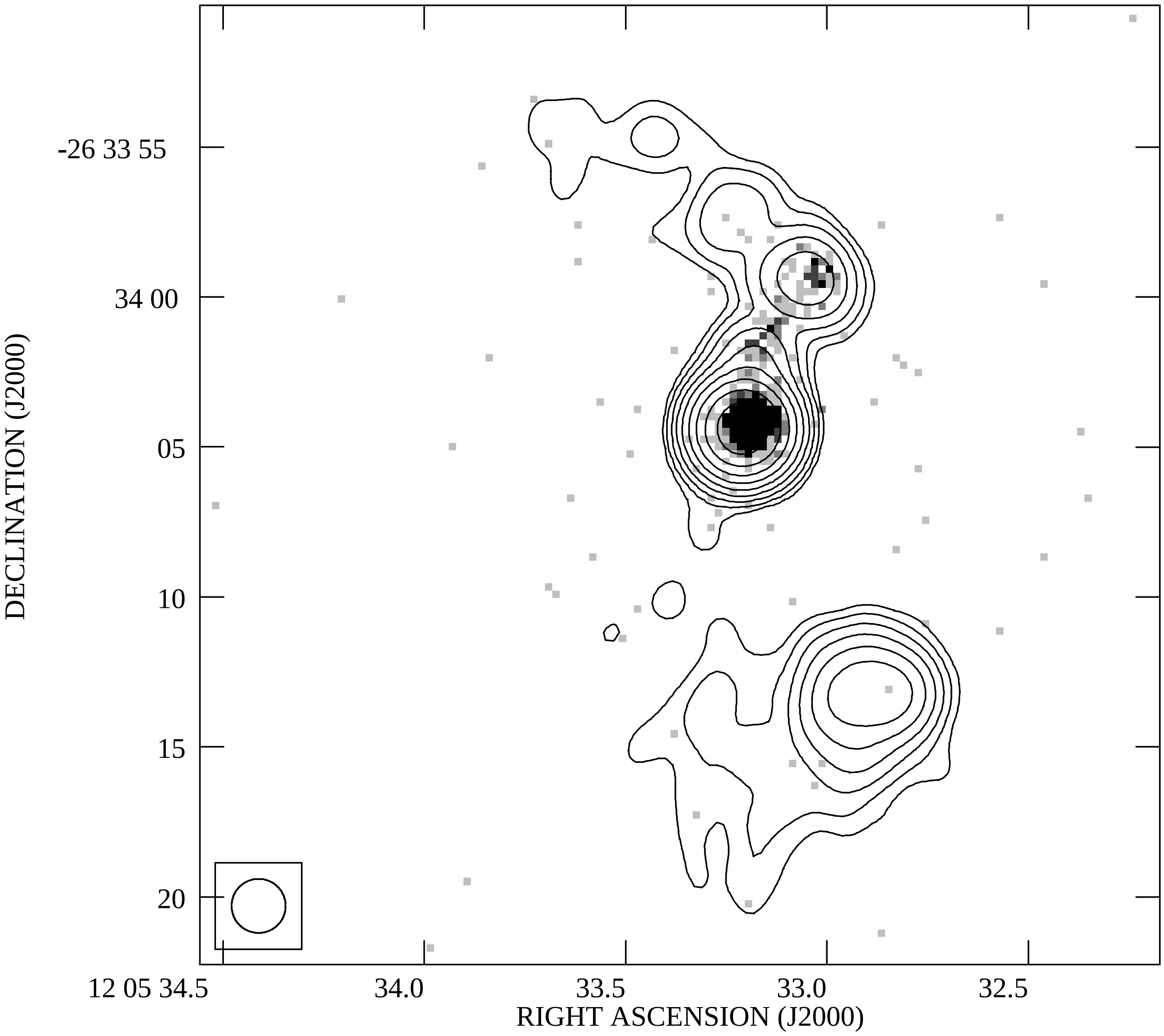
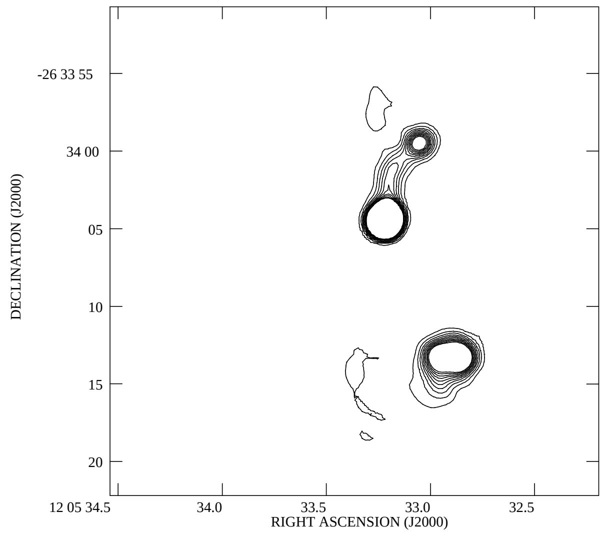


Figure 1: An overlay of X-band radio flux density (contours) on X-ray counts (grey scale) for B1202−262. The radio contours are at −1, 1, 2, 4, 8 ... ×1 mJy per beam. The grey scale runs from 0 (white) to 4 (black) counts per 0.25 arcsec square pixel. A close correspondence between the radio and X-ray structures of the source is clear, although there are small differences in detail.



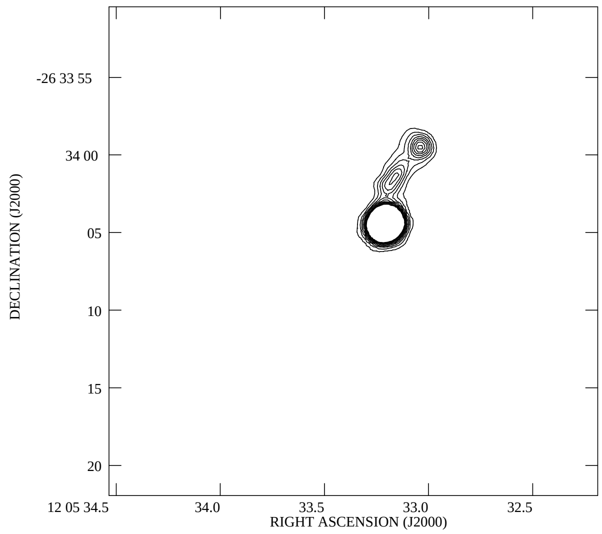


Figure 2: The C-band image of B1202−262 (left) and X-ray image (right) convolved to the same 1.2 arcsec FWHM Gaussian beam. Contours are drawn at units of $-1,\ 1,\ 2\ldots 10\times 3$ mJy/beam and 0.2 counts/pixel. The strong similarities of the jets are apparent, though significant differences are apparent on the small scale.

x (pixels)	y (pixels)	$S_{\rm R}$ (mJy)	$S_{\rm X}$ (scaled counts)	$S_{\rm X}/S_{\rm R}$ (scaled counts/mJy)	feature
256	257	426.7 ± 0.5	26.5 ± 1.0	0.062 ± 0.002	core
256	259	284.4 ± 0.5	11.6 ± 0.6	0.041 ± 0.002	
256	261	93.3 ± 0.5	2.35 ± 0.29	0.025 ± 0.003	core/inner radio jet
257	263	27.9 ± 0.5	0.79 ± 0.17	0.028 ± 0.006	
257	265	18.5 ± 0.5	1.01 ± 0.19	0.055 ± 0.010	X-ray jet start
257	267	17.8 ± 0.5	1.16 ± 0.20	0.065 ± 0.011	
258	269	16.8 ± 0.5	1.06 ± 0.19	0.063 ± 0.011	
259	271	16.2 ± 0.5	0.78 ± 0.17	0.048 ± 0.011	
260	273	13.4 ± 0.5	0.54 ± 0.14	0.040 ± 0.010	X-ray jet fading
262	275	16.8 ± 0.5	0.49 ± 0.13	0.029 ± 0.008	
264	277	38.2 ± 0.5	1.22 ± 0.21	0.032 ± 0.006	
265	278	40.0 ± 0.5	1.24 ± 0.21	0.031 ± 0.005	radio/X-ray knot at bend
263	279	20.5 ± 0.5	0.50 ± 0.13	0.024 ± 0.006	
261	280	4.7 ± 0.5	0.16 ± 0.08	0.034 ± 0.017	
259	281	1.6 ± 0.5	0.12 ± 0.07	0.075 ± 0.050	
257	282	2.1 ± 0.5	0.11 ± 0.06	0.052 ± 0.031	
255	285	3.9 ± 0.5	0.03 ± 0.03	0.008 ± 0.008	jet fade-out

Table 3: Radio and X-ray brightnesses measured down the ridge-line of the jet. $S_{\rm R}$ is the radio flux density of this part of the jet, in mJy/beam, while $S_{\rm X}$ is the $0.5-7.0$ keV flux.

a little difficult to define a suitable structure (probably a polygon approximating the radio contours would be good). Adequate at this stage, however, is a set of circles: one which is tangent to the core, one with lies at the northern tip of the jet, and one which fills in the middle. The region file, `jet.reg`, is then

```
# Region file format: CIAO version 1.0
+circle(4150.0,4053.0,2.5)
+circle(4146.5,4048.0,2.5)
+circle(4148.25,4050.5,2.5)
```

The spectrum cannot be extracted from the $0.5 - 7.0$ keV dataset, since this would put an artificial edge into the spectrum at the low end, and since the `psextract` task needs to see the aspect data to get a proper weighting over the telescope responses. I therefore downloaded the full dataset (using `Chaser`). Before doing extractions, go to the directory holding the primary data, and

```
punlearn ardlib.par
acis_set_ardlib
```

to set up the `ardlib`. The `ardlib.par` file is unique to each dataset and must be deleted before any other dataset is studied.

Now, set up parameters for `psextract`, and for the core

```
plist psextract
```

shows the parameters as

```
    events = primary/acisf03118N001_evt2.fits[sky=region(red/core.reg)]
  bgevents = primary/acisf03118N001_evt2.fits[sky=region(red/sky.reg)]
      root = core
      aoff = secondary/acisf03118_000N001_aoff1.fits
    bgaoff = secondary/acisf03118_000N001_aoff1.fits
    (ptype = pi)
    (gtype = NUM_CTS)
    (gspec = 25)
  (verbose = 0)
     (mode = ql)
```

and `psextract` creates the necessary files, `core.arf`, `core.asphist`, `core.pi`, `core.rmf`, `core.soff`, `core_bg.arf`, `core_bg.pi`, `core_bg.rmf`, and `core_bg_grp.pi`.

Similarly, a spectrum for the jet can be extracted.

The spectra are analysed with `sherpa` which I use with a script, as

```
sherpa fit_core_1 >& fit_core_1.out
```

where the script is

```
#
# fit_core_1   Sherpa fit to core spectrum: absorbed power-law
#
# Turn off prompting
#
paramprompt off
#
# Read PI data (has pointer to RMF and ARF files in it)
#
data 1 ../red/core.pi
#
```

```
# Notice only the sensible energy range
#
ignore all
notice 1 energy 0.5:7.0
ignore bad
#
# Subtract background from data
#
subtract
#
# Define absorbed thermal model for halo
#
xswabs[galabs]
galabs.nH=0.0710
freeze galabs.nh
#
xszwabs[agnabs]
agnabs.nH       = 0.235
agnabs.redshift = 0.789
thaw   agnabs.nH
freeze agnabs.redshift
#
xszpowerlw[agnpower]
agnpower.phoindx  = 1.483
agnpower.redshift = 0.789
agnpower.norm     = 4.33e-04
thaw   agnpower.phoindx
freeze agnpower.redshift
thaw   agnpower.norm
#
# Assign model to data.
#
source 1 = galabs * agnabs * agnpower
#
# Show data
#
plotx 1 energy
lplot 1 data 1
d 1 xlabel blue
d 1 ylabel blue
redraw
#
show
#
# Simple fit
#
method powell
show powell
fit 1
#
# Look at goodness of fit, and errors
#
```

```
goodness
uncertainty.sigma=1
uncertainty
#
# Make a plot of the results, with plot output to file
#
plotx 1 energy
lplot 2 fit 1 residuals 1
#
d 1 location 0.15 0.90 0.35 0.90
d 2 location 0.15 0.90 0.10 0.35
#
title "J1205-2634 core"
#
d 1 xlabel
d 1 tickvals x off
d 1 limits x  0.0 8.0
d 1 ylabel black
#
d 2 limits x  0.0 8.0
d 2 xlabel black
d 2 ylabel black
#
redraw
print postfile fit_core_1a.ps
#
# Check uncertainty regions: detailed calculations
#
covariance
#
region-projection.arange =  1
show region-projection
region-projection agnabs.nH agnpower.phoindx
title "J1205-2634 core parameters"
d 1 xlabel black
d 1 xlabel "\rm Intrinsic absorbing column, N_H (10^{22} cm^{-2})"
d 1 ylabel black
d 1 ylabel "\rm Photon index, \Gamma"
redraw
print postfile fit_core_1b.ps
#
# End
#
exit
#
```

This script makes use of the redshift of the object (from NED), $z = 0.789$, and the absorbing column in our galaxy, $N_{\rm H} = 7.11 \times 10^{20}$ cm^{-2} (from colden), and fits the spectrum as an absorbed power law in the energy range 0.5-7.0 keV.

The output shows a good fit to an absorbed power-law, with the best-fit model having an intrinsic (quasar-related) column $N_{\rm H} = (2.3 \pm 0.5) \times 10^{21}$ cm^{-2}, a photon index $\Gamma = 1.48 \pm 0.04$, and a normalization $(4.33 \pm 0.02) \times 10^{-4}$. The fit has $\chi^2 = 22.4$ with 25 degrees of freedom (from 28 datapoints), so that there is a 61% probability of having got a

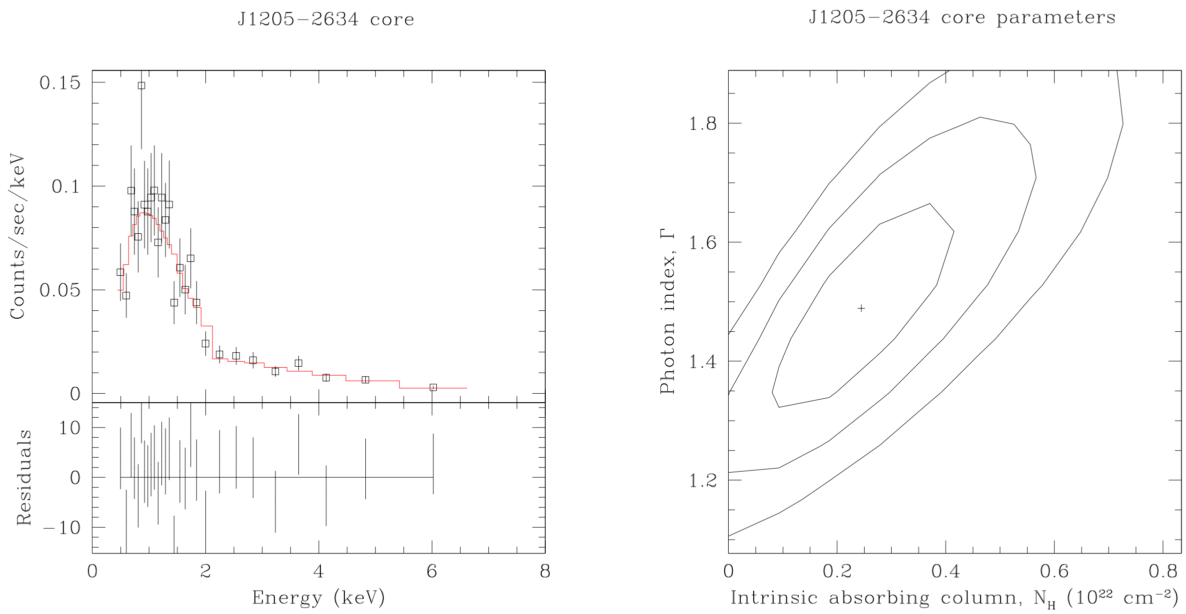


Figure 3: The spectrum of the core of B1202−262 and the 1, 2, 3σ uncertainty contours for fitted parameters. The spectrum is a good fit to a simple power law, absorbed by the Galactic column, although the best fit includes some intrinsic column at the redshift of the quasar. This best-fit spectrum is shown on the left, and the permitted range of intrinsic column and power-law index, Γ, is shown on the right.

better fit by chance. The fit, and the confidence regions for $N_{\rm H}$ and Γ, are shown in Fig. 3.

A similar script for the jet, where I had to use `gspec` $= 15$, or only 15 counts per bin, to get a sensible number of bins, found a good fit ($\chi^2 = 2.6$ with 5 degrees of freedom from 8 data-points) with an intrinsic $N_{\rm H} = 1.3^{+1.4}_{-1.0} \times 10^{21}$ cm^{-2}, a photon index $\Gamma_{\rm jet} = 1.35^{+0.11}_{-0.09}$, and a normalization $(5.5 \pm 0.7) \times 10^{-5}$. This is shown in Fig. 4.

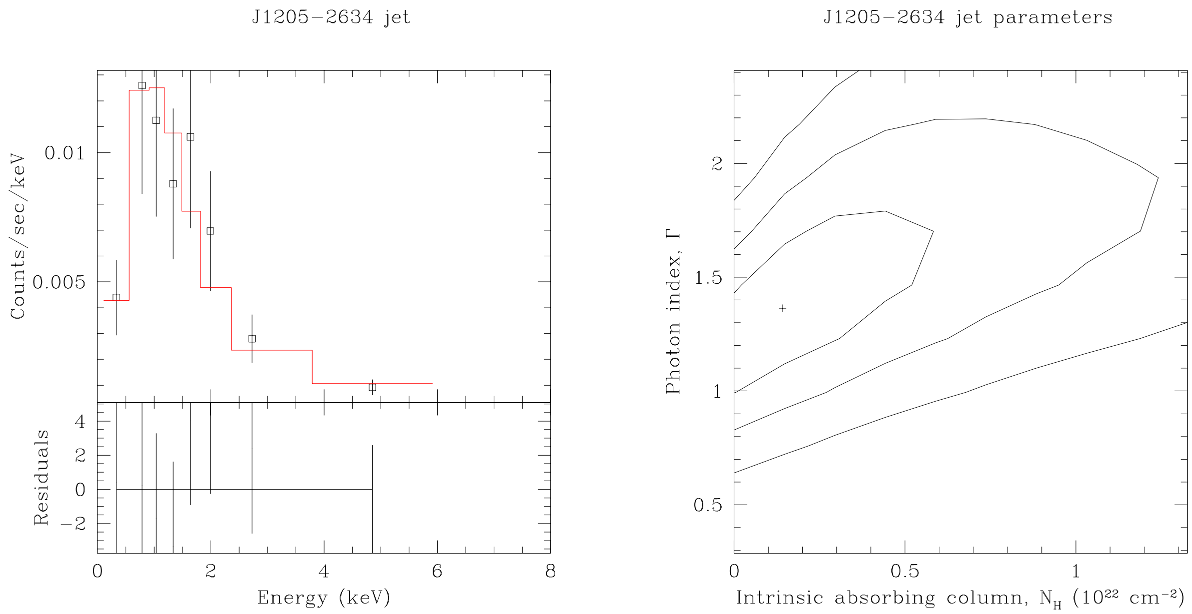


Figure 4: The spectrum of the jet of B1202−262 and the 1, 2, 3σ uncertainty contours for fitted parameters. The spectrum is a good fit to a simple power law, absorbed by the Galactic column, although the best fit includes some intrinsic column at the redshift of the quasar. This best-fit spectrum is shown on the left, and the permitted range of intrinsic column and power-law index, Γ, is shown on the right.