

UCLES Thorium-Argon Atlas with the MITLL CCD

Stuart Ryder, AAO

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With the advent of larger-format array detectors at the AAO (e.g., the MIT/LL 4K×2K CCDs), the process of arc line identification and spectrograph setup has in some ways become more complicated than before, owing to the bewildering number of arc lines and spectral orders captured in one image. Although a variety of arc line atlases are available for the ThAr lamp (e.g., D'Odorico et al. 1987, Bessell and Pettini 1991, Meurer et al. 1991, and Lipman et al. 1993), most of them are out of print, every arc lamp produces slightly different line ratios, and even the line ratios from any given lamp will change with time. This atlas (and its on-line counterpart) is not intended to replace these useful references, but rather to serve as a complement, particularly when using UCLES with the MITLL CCDs.

The data was obtained on 1999 October 22, using the MITLL2 CCD. This detector suffered a catastrophic failure in January 2000, but was re-born as the MITLL2A detector in March 2000, by switching to the opposite readout amplifier. The only significant difference between MITLL2 and MITLL2A images is that they are reversed laterally relative to one another. The detector was binned ×2 in the spatial direction, and 2 settings of the 31.6 grooves mm⁻¹ grating were used: one centred on 3946.0 Å covering 3522–4653 Å (orders 160–123), and the other on 6182.6 Å covering 4824–9386 Å (orders 61–117). Note that the detector was not centred on the peak of any one order, but since the extent of each order recorded in one MITLL CCD image extends way beyond the free spectral range, there is still almost complete wavelength coverage throughout. The exposure time in the blue was 10 seconds, and 2 seconds in the red (which unavoidably results in some extremely saturated lines beyond 7000 Å). The line identification and fitting was carried out using **ecidentify** within IRAF, relying mainly on the line identifications in Lipman et al. (1993) and the IRAF line list in `linelists$thar.dat`. Generally a 4th order fit in x should be sufficient to remove any trend in the residuals with pixel number, and a 5th order fit in y should remove any trend with order number.

A list of the orders identified in each image, together with the wavelength ranges covered by the detector (which is generally much greater than the FSR

listed in Appendix A.2 of the UCLES manual), is given in Tables 1 and 2, after which plots are presented with most of the prominent lines marked. The images in Figures 1 and 2 show the raw XMEM display for the MITLL2A detector (MITLL3 images have the same orientation), which has wavelength increasing (order number decreasing) going from left to right, and redder wavelengths at the bottom of each order. Note that this is the **reverse of the Tek CCD orientation**, and when the files are saved in FITS format, they will then be reversed about the x-axis. Thus, *it is not necessary to flip MITLL CCD images prior to reduction* (as is usually done with Tek CCD images) if you wish to have wavelength increasing with pixel number along each order.

References

- Bessell, M. S., & Pettini, M. 1991, *UCLES Spectrum of the Thorium-Argon Hollow-Cathode Lamp. I. 79 grooves mm⁻¹ echelle grating and IPCS detector*, AAO User Manual 28.1 (Sydney: AAO).
- D'Odorico, S., Ghigo, M., & Ponz, D. 1987, *An Atlas of the Thorium-Argon Spectrum for the ESO Echelle Spectrograph in the 3400–9000 Å region*, ESO Scientific Report No. 6 (Garching: ESO).
- Lipman, K., Pettini, M., Wall, M., & Walton, N. 1993, *UES Spectrum of Thorium-Argon Hollow-Cathode Lamp*, ING La Palma Technical Note No. 91 (Cambridge: RGO).
- Meurer, G. R., Pettini, M., & Stathakis, R. A. 1991, *UCLES Spectrum of the Thorium-Argon Hollow-Cathode Lamp. II. 31.6 grooves mm⁻¹ echelle grating and Thomson CCD*, AAO User Manual 34.1 (Sydney: AAO).

Order	λ range (Å)	Order	λ range (Å)
61	9241–9386	90	6268–6365
62	9092–9234	91	6200–6297
63	8948–9088	92	6132–6229
64	8809–8945	93	6067–6162
65	8673–8808	94	6002–6097
66	8542–8674	95	5939–6031
67	8415–8545	96	5877–5969
68	8291–8421	97	5817–5909
69	8171–8298	98	5758–5848
70	8055–8180	99	5700–5790
71	7942–8067	100	5643–5730
72	7832–7954	101	5587–5674
73	7725–7845	102	5532–5619
74	7621–7741	103	5479–5564
75	7519–7636	104	5426–5511
76	7421–7538	105	5375–5460
77	7324–7439	106	5324–5406
78	7231–7343	107	5274–5356
79	7139–7251	108	5226–5308
80	7050–7160	109	5178–5260
81	6963–7073	110	5131–5211
82	6879–6986	111	5084–5164
83	6796–6903	112	5039–5119
84	6715–6820	113	4995–5072
85	6636–6741	114	4951–5028
86	6559–6661	115	4908–4985
87	6484–6586	116	4866–4943
88	6411–6511	117	4824–4899
89	6339–6439		

Table 1: List of order numbers captured by the red wavelength setting, and the respective wavelength ranges shown in the plots.

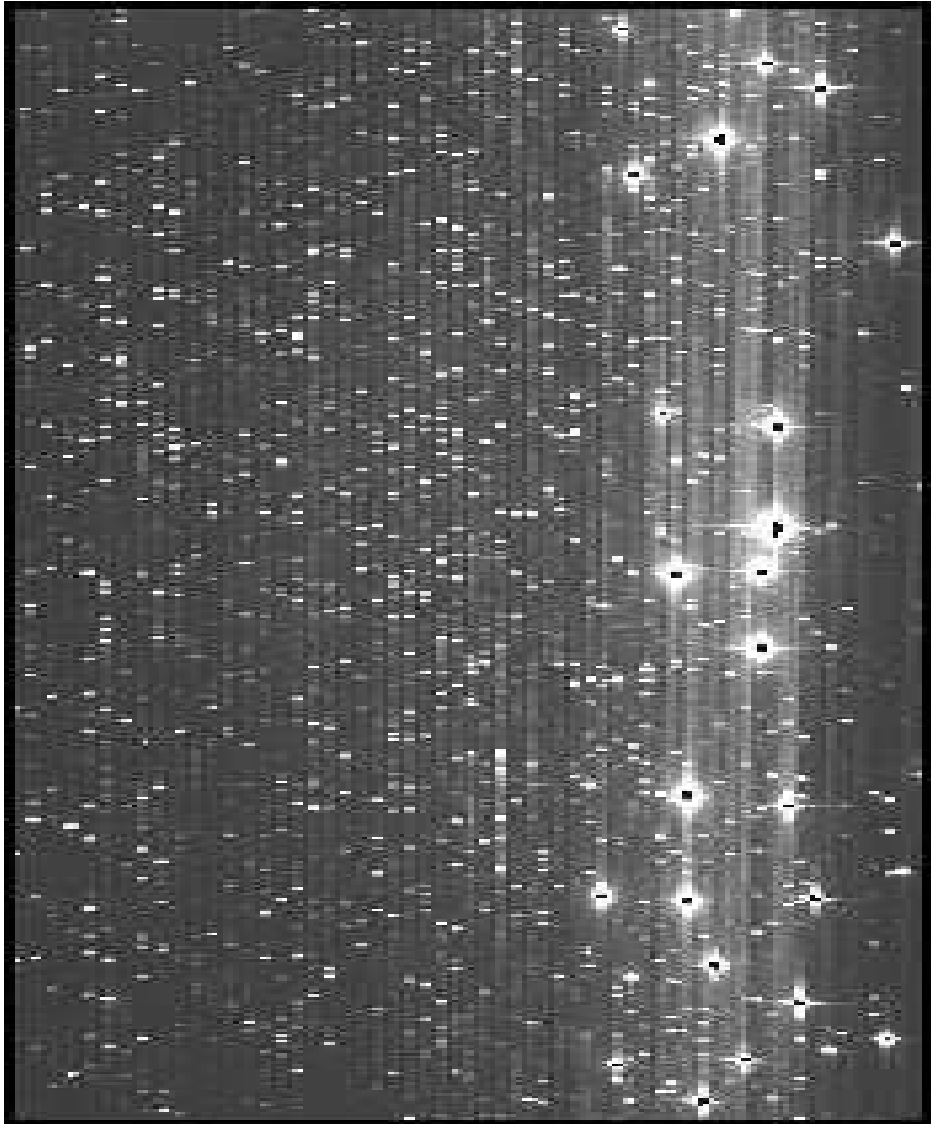
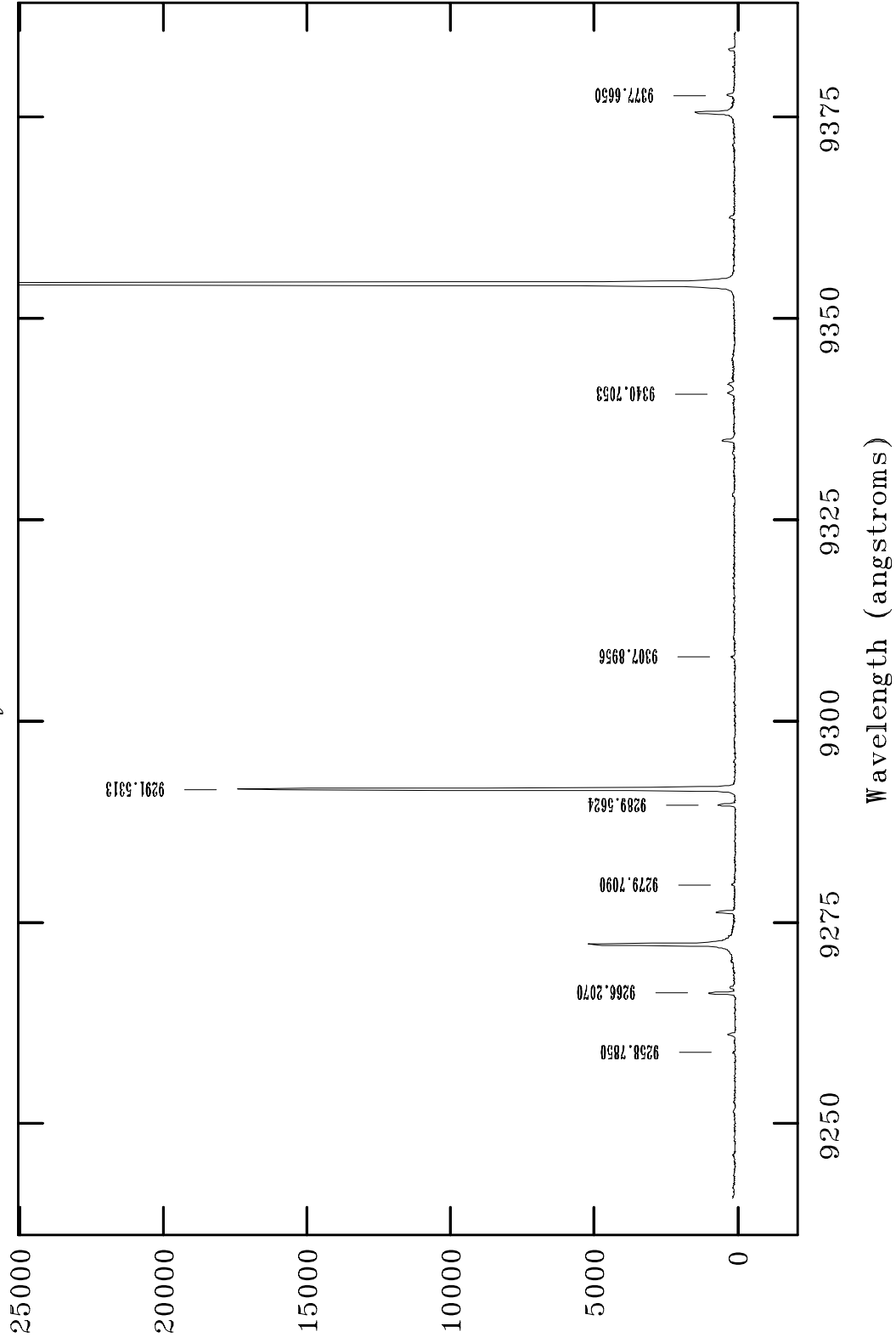
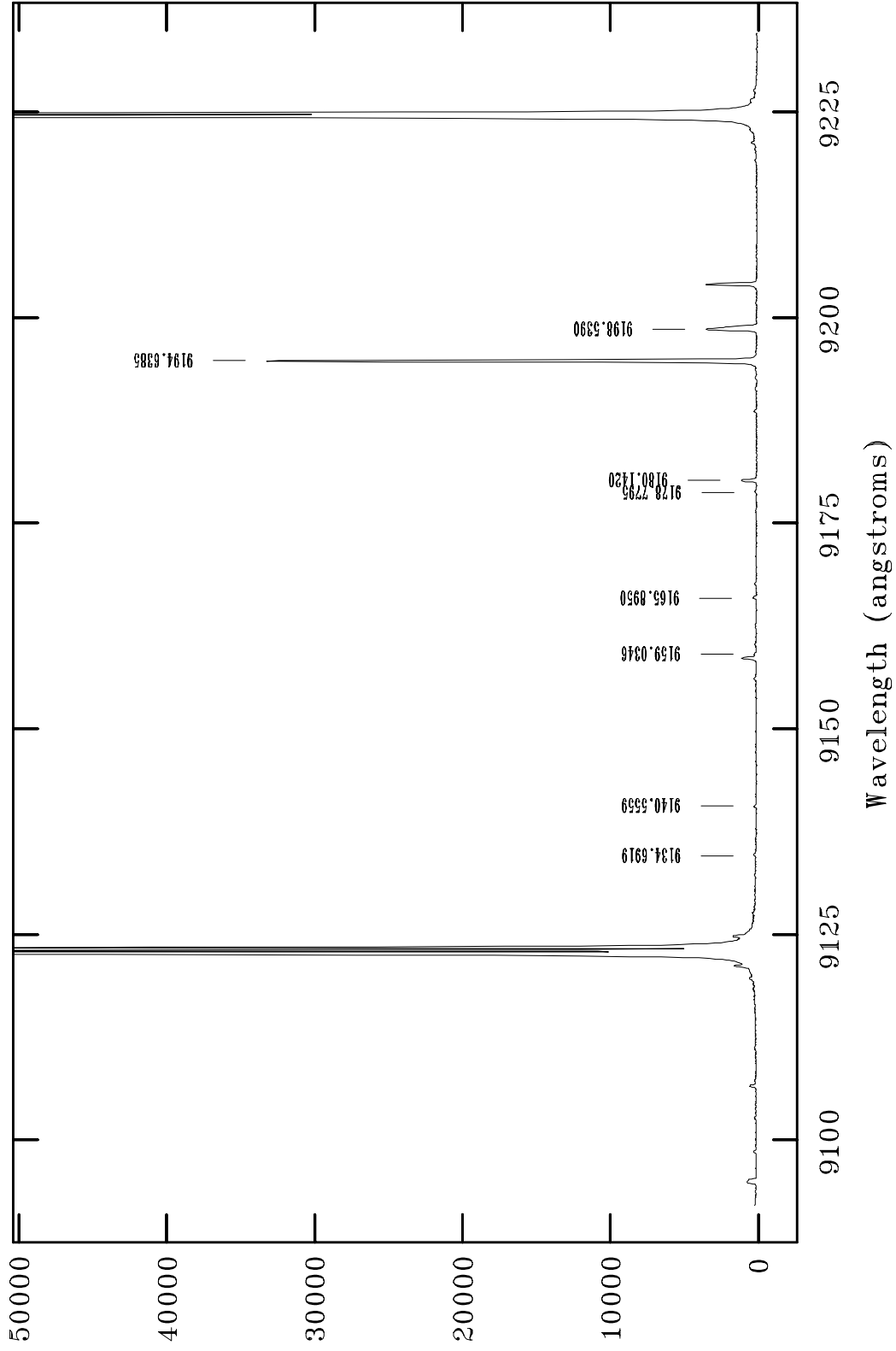


Figure 1: Raw XMEM display (stretched by a factor of 2 in the x direction) when the grating is set to 6182.6 \AA . The leftmost order which does not run off the edge of this image is order 117 the rightmost complete order is 61. The most heavily saturated line is at 8115 \AA in order 70.

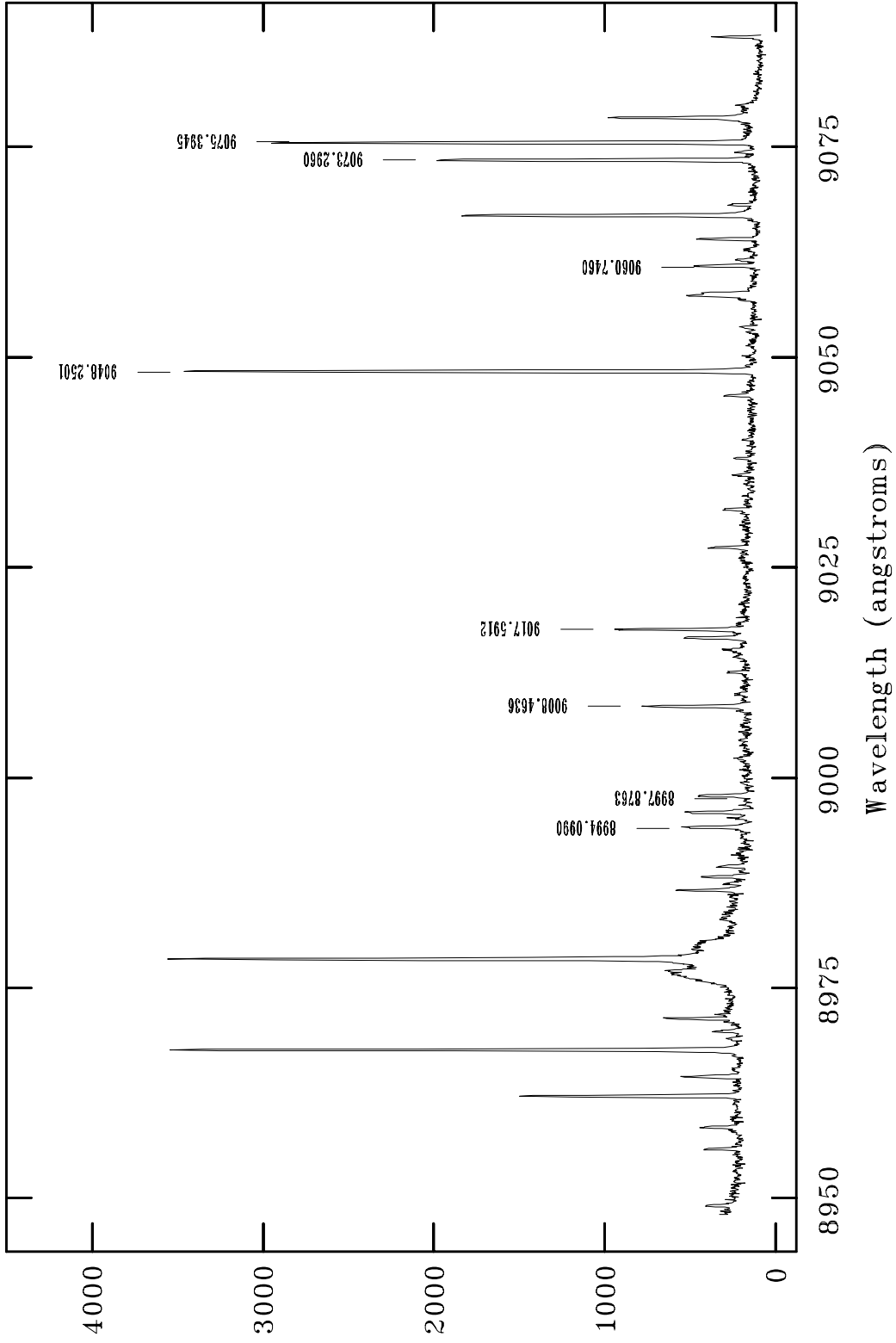
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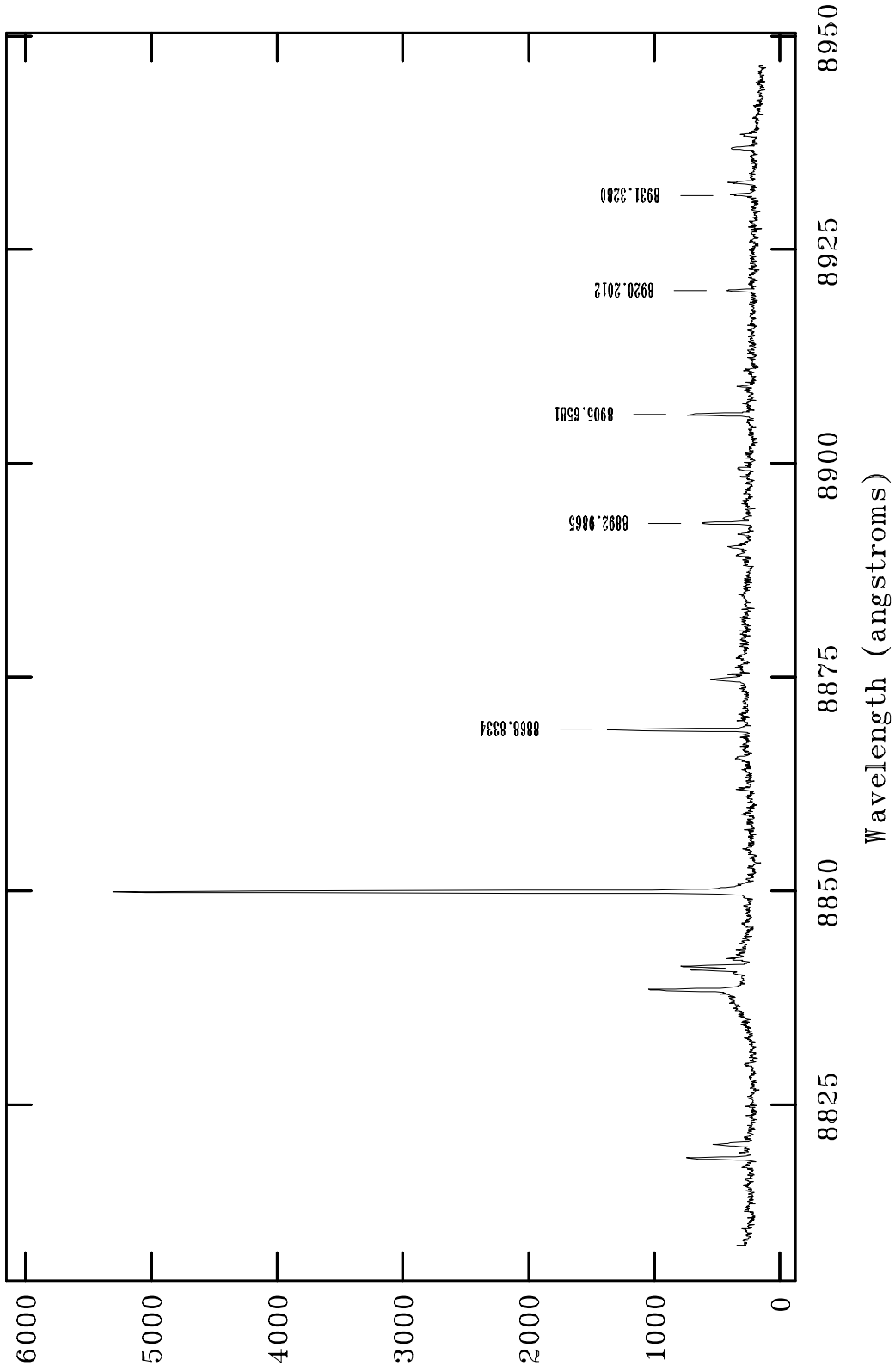
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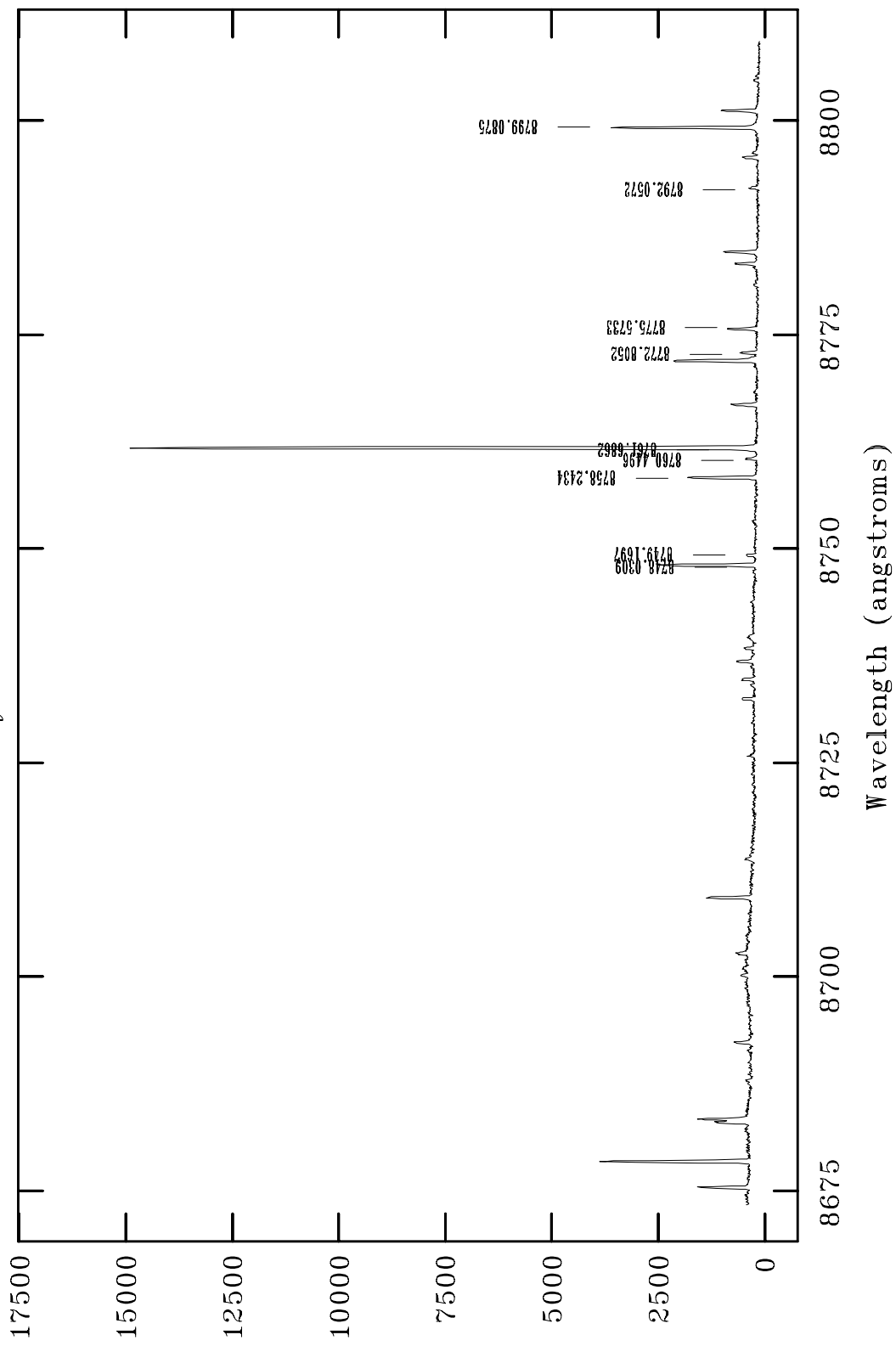
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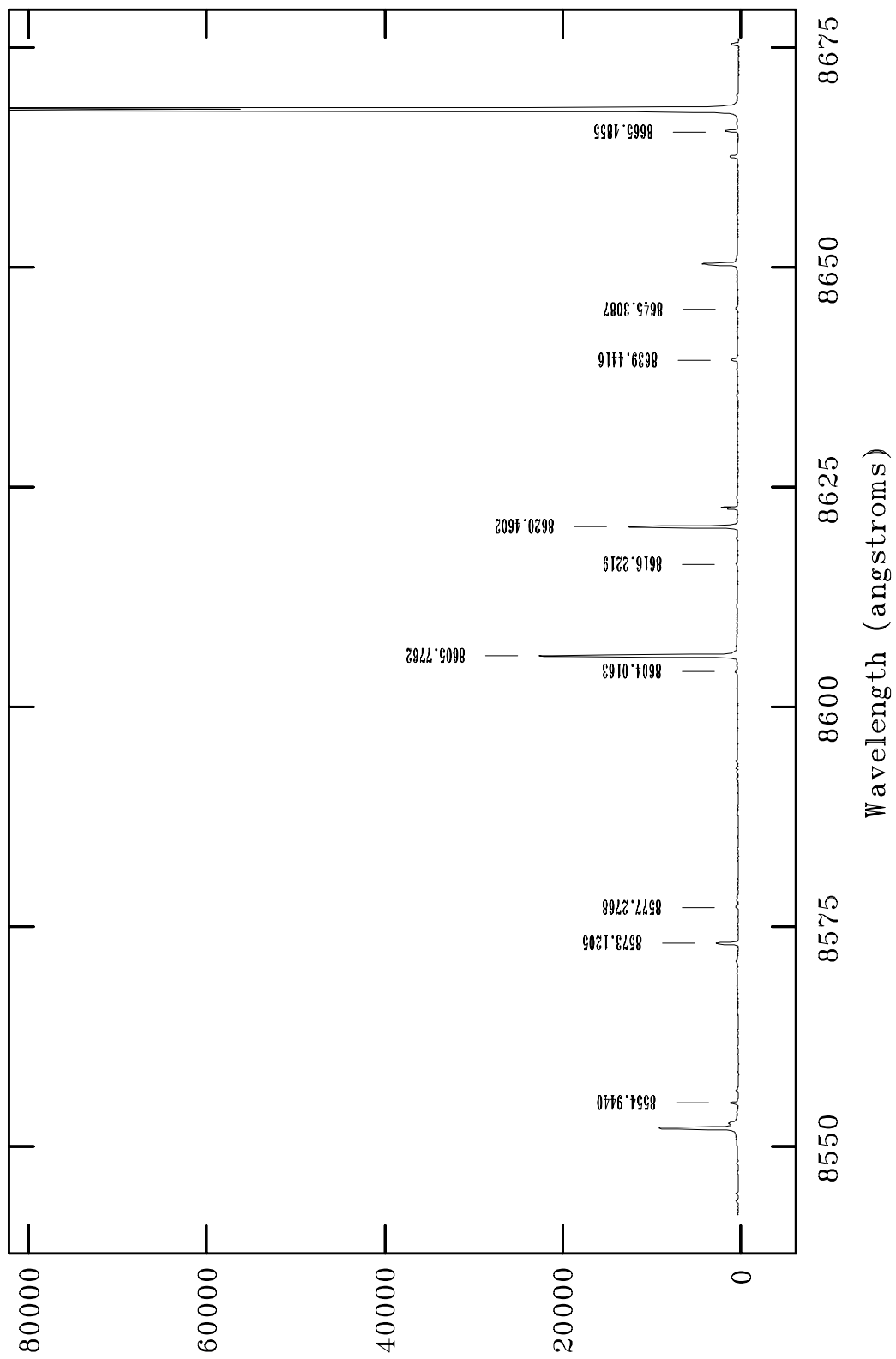
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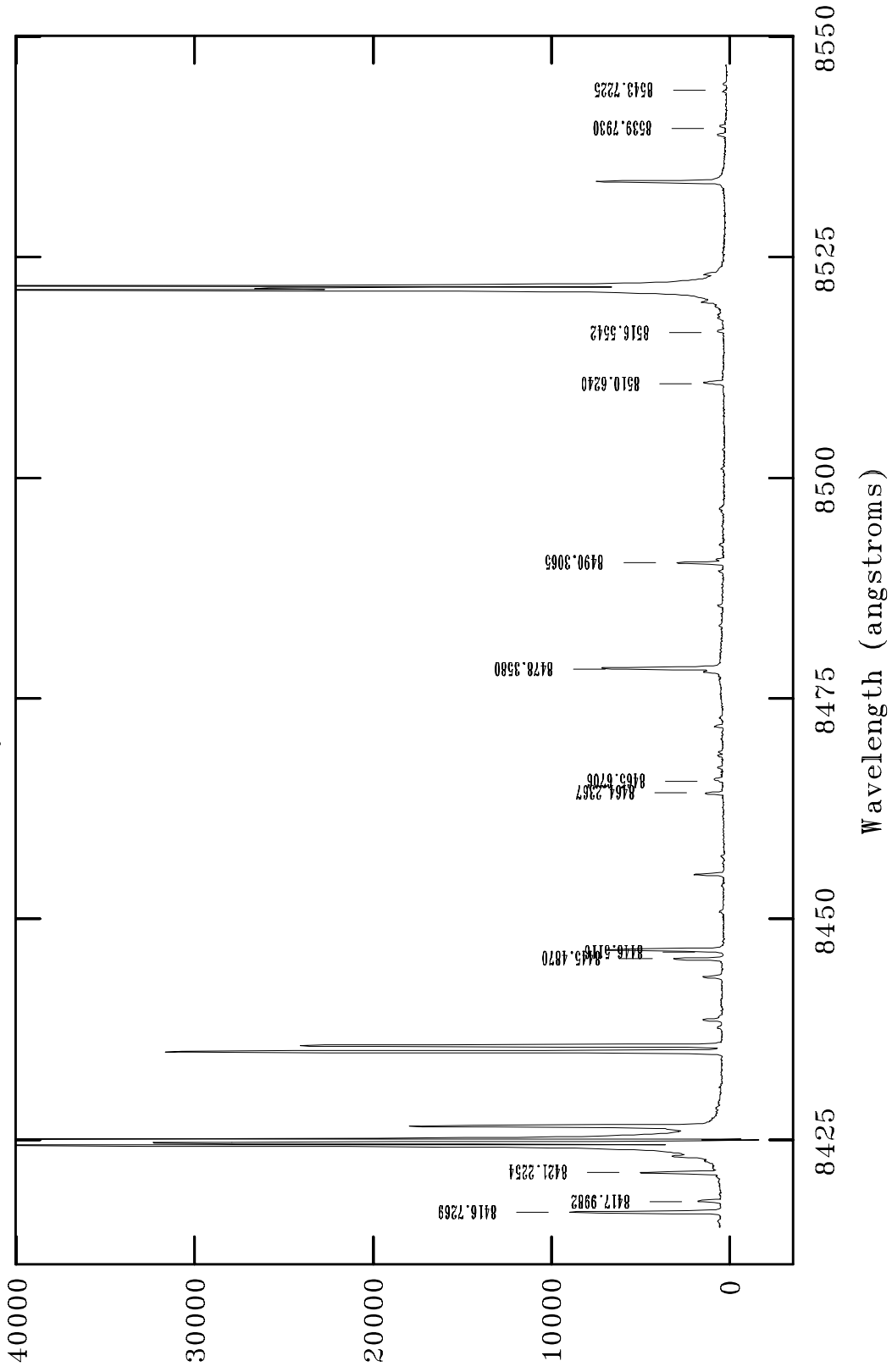
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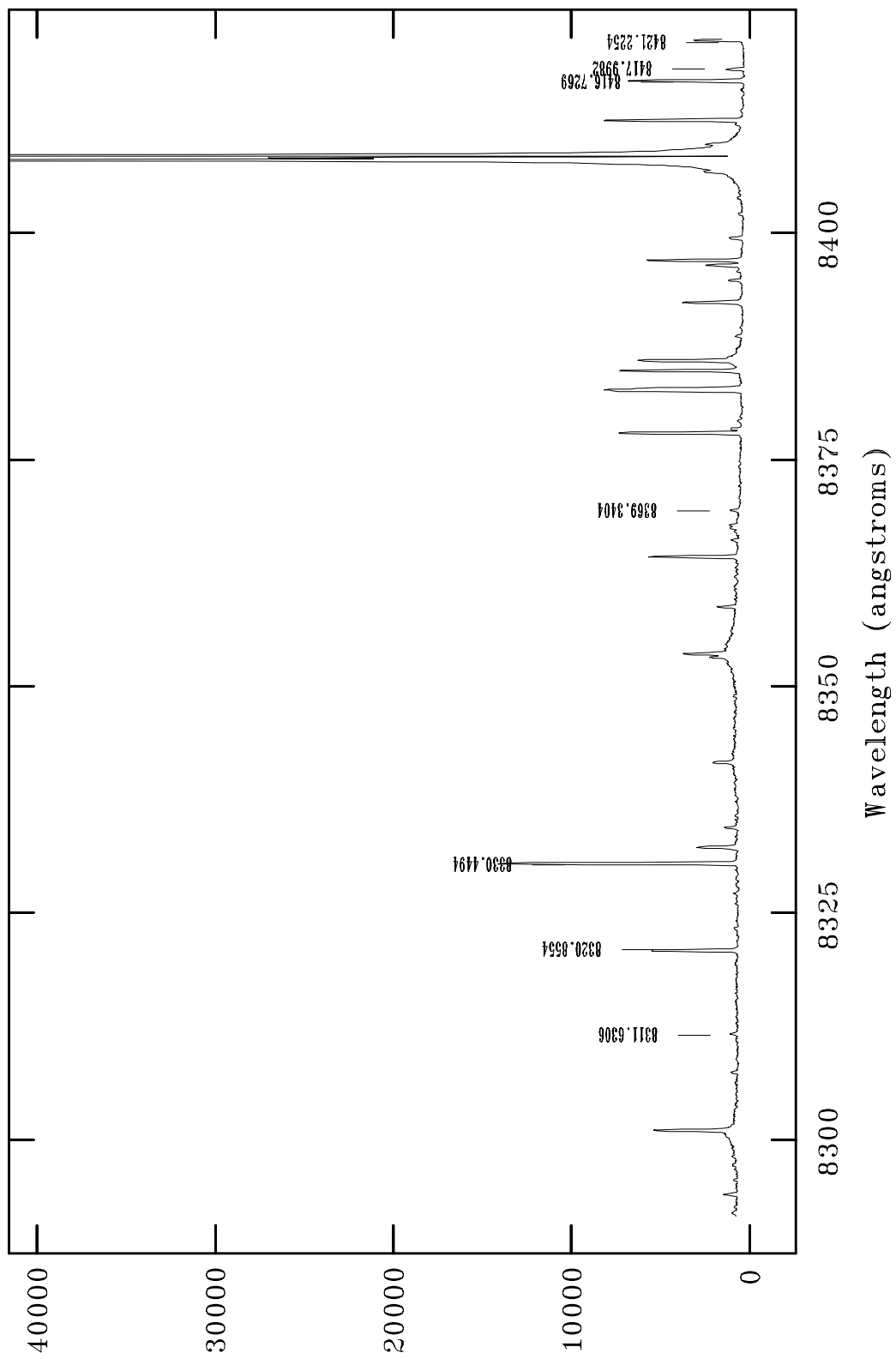
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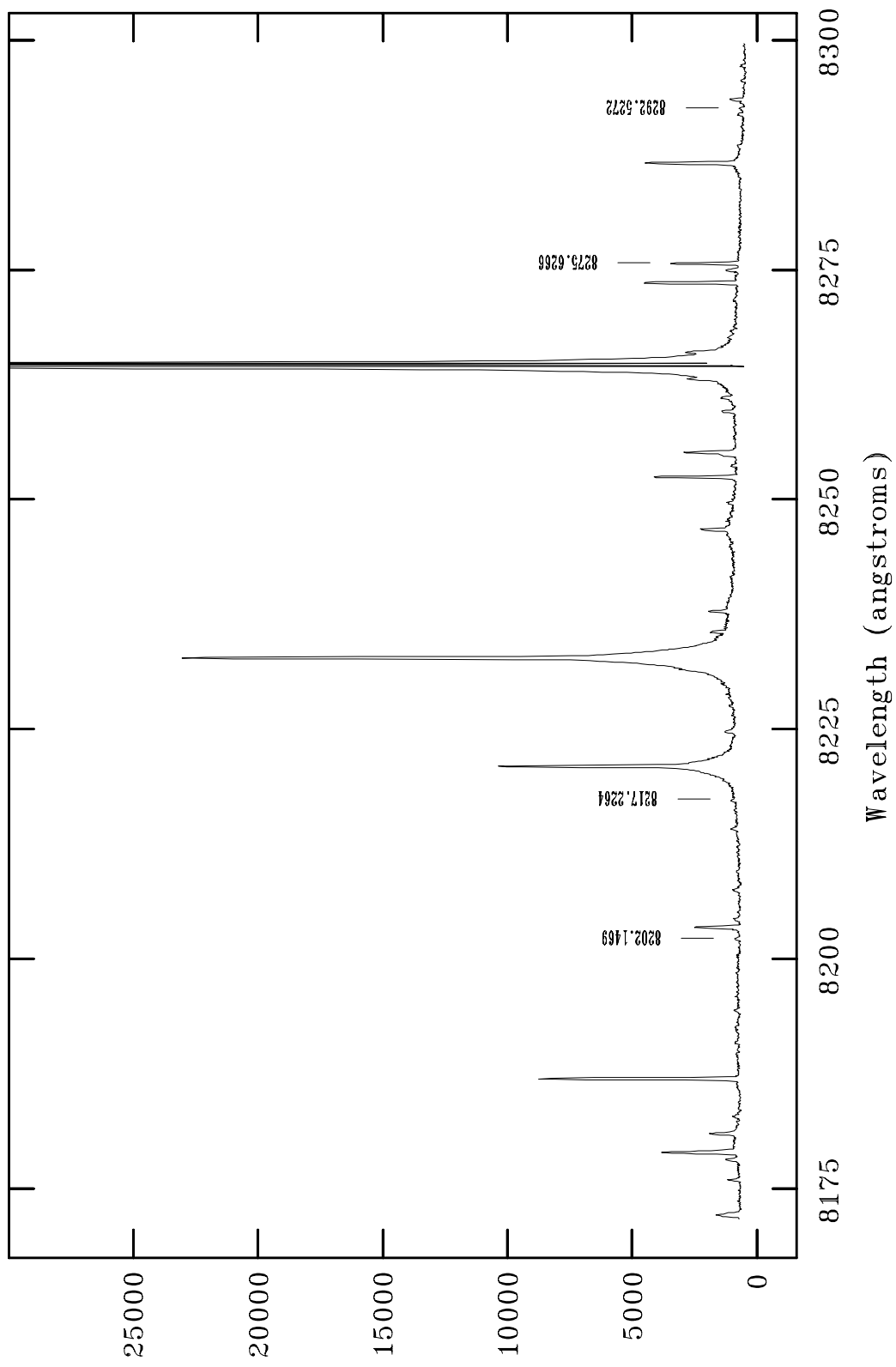
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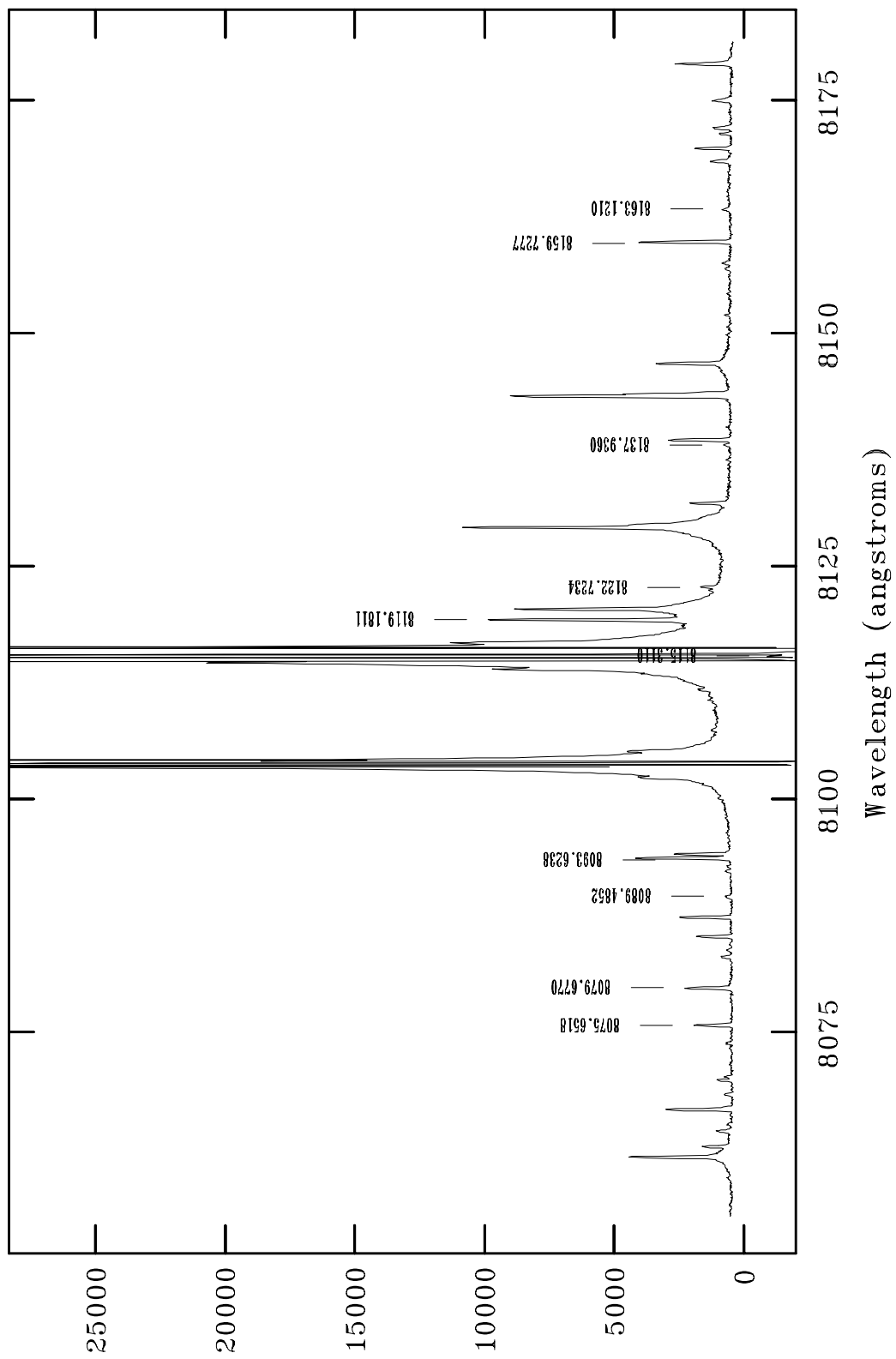
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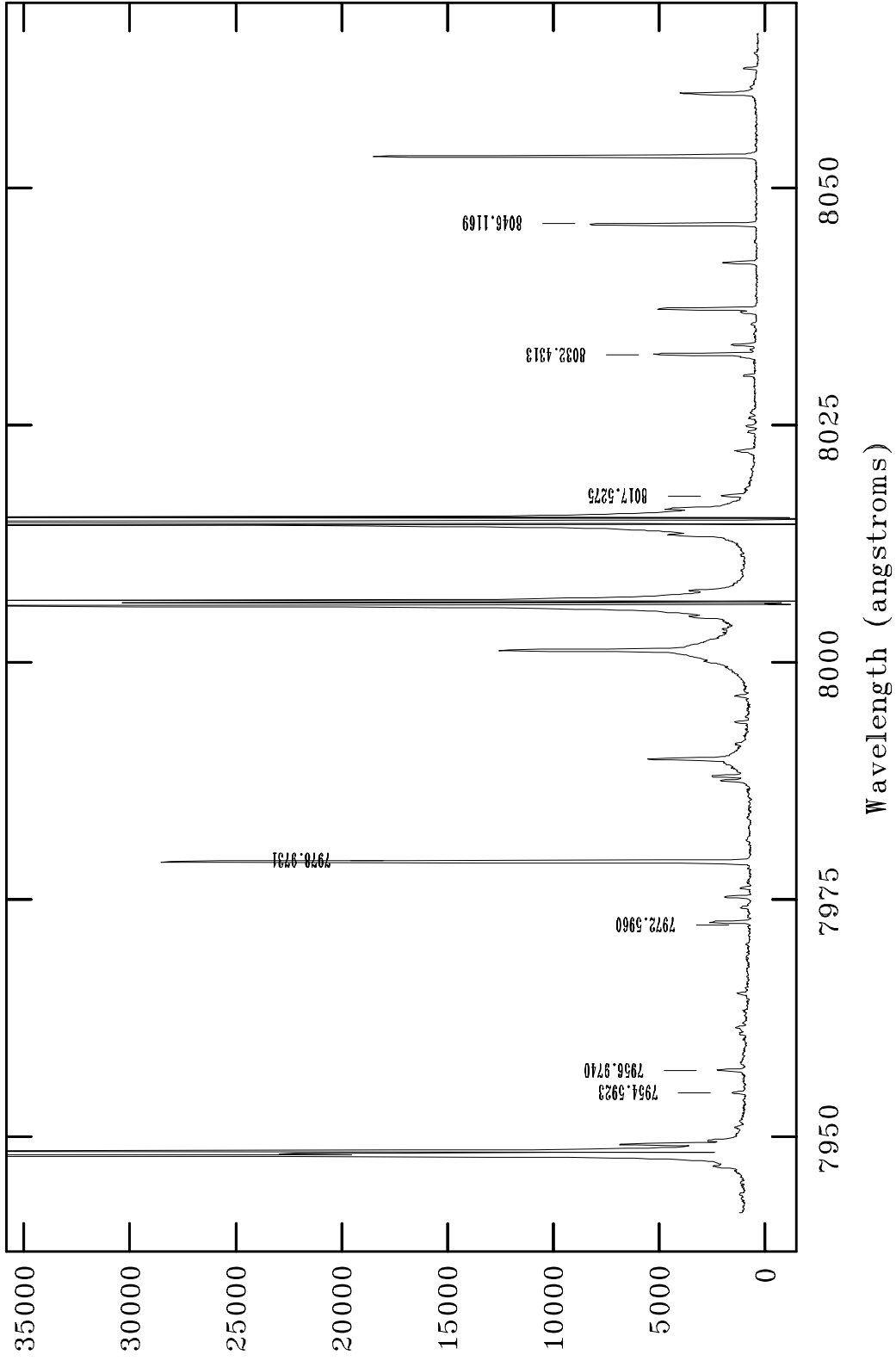
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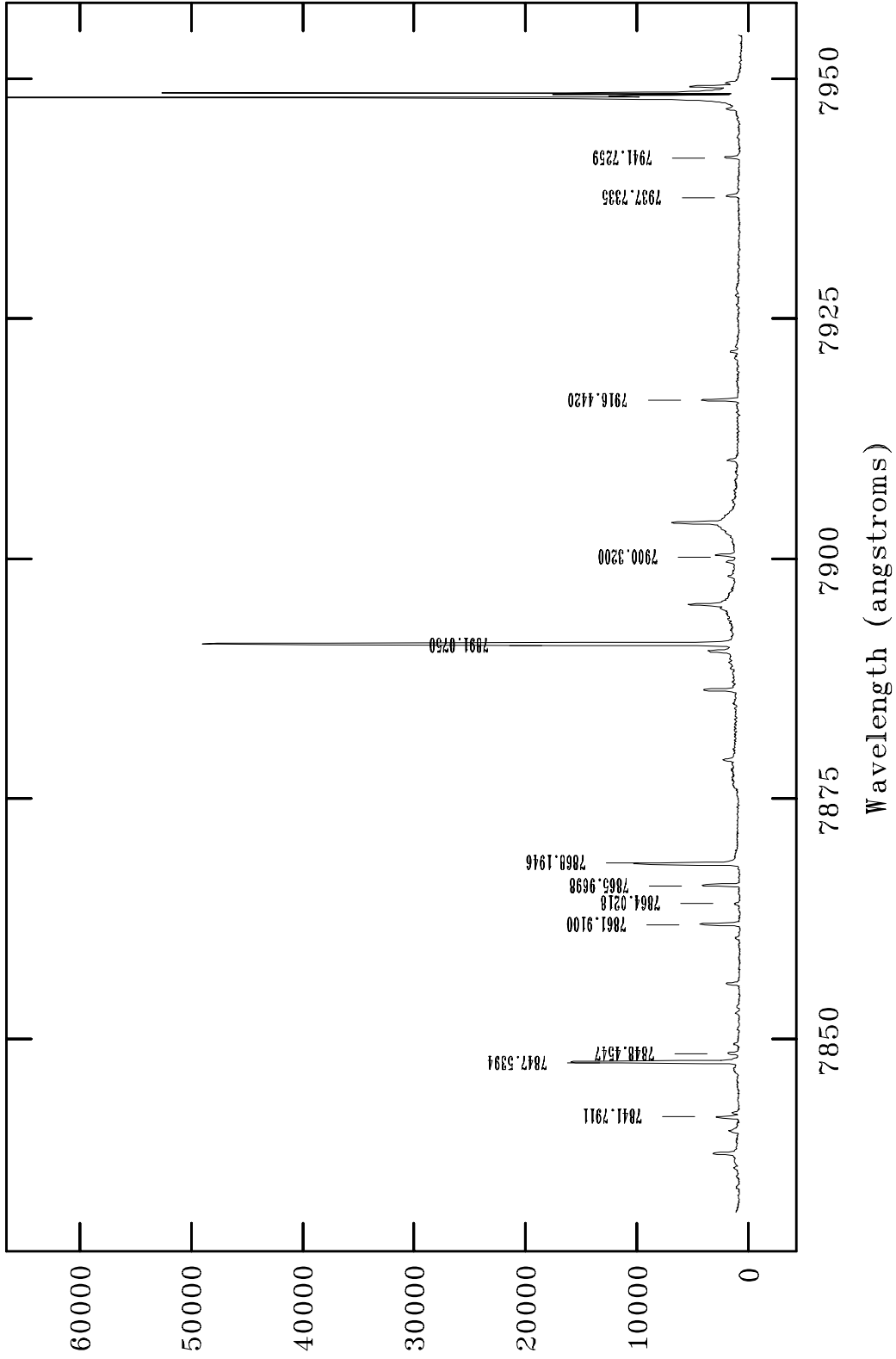
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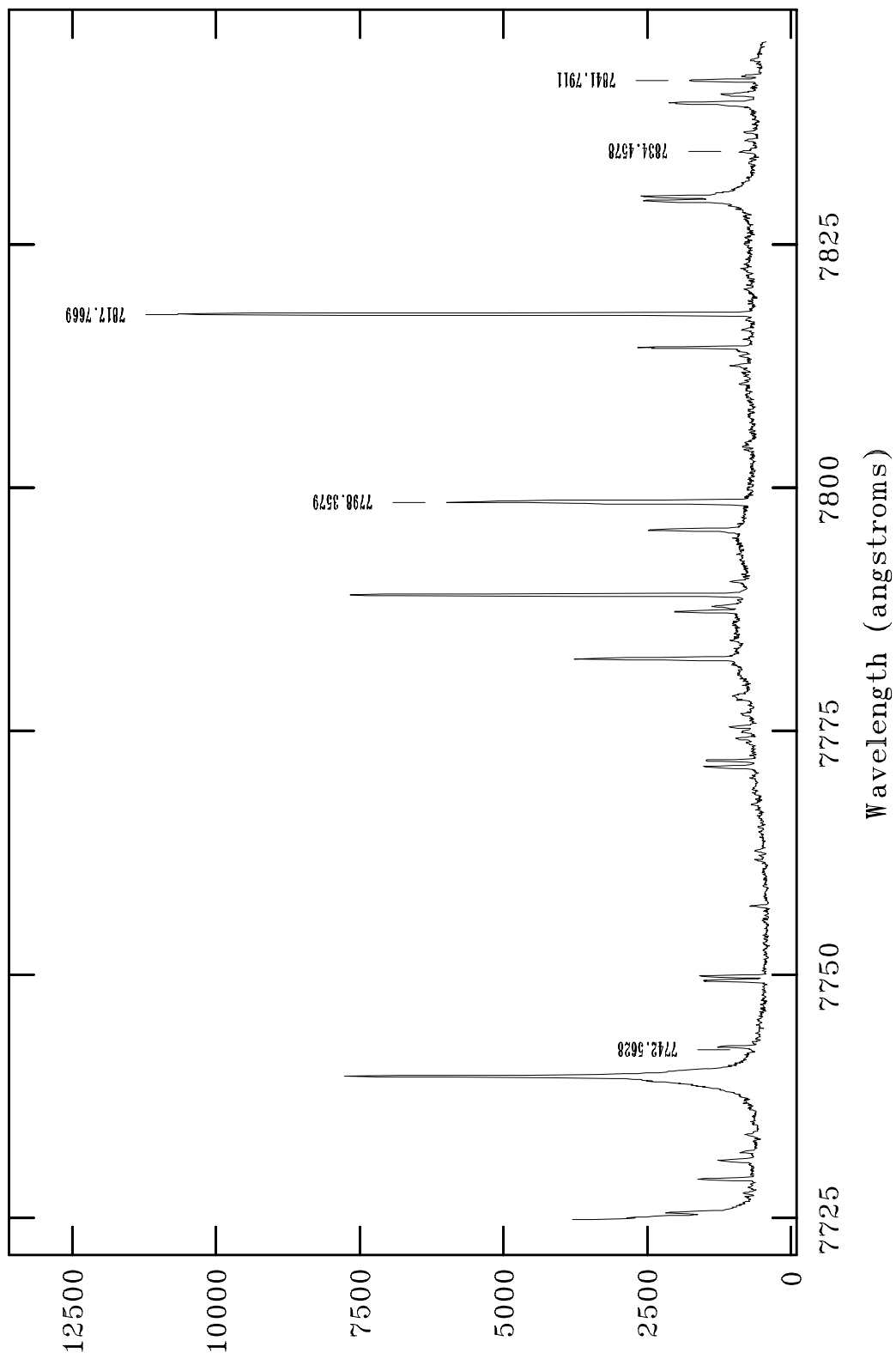
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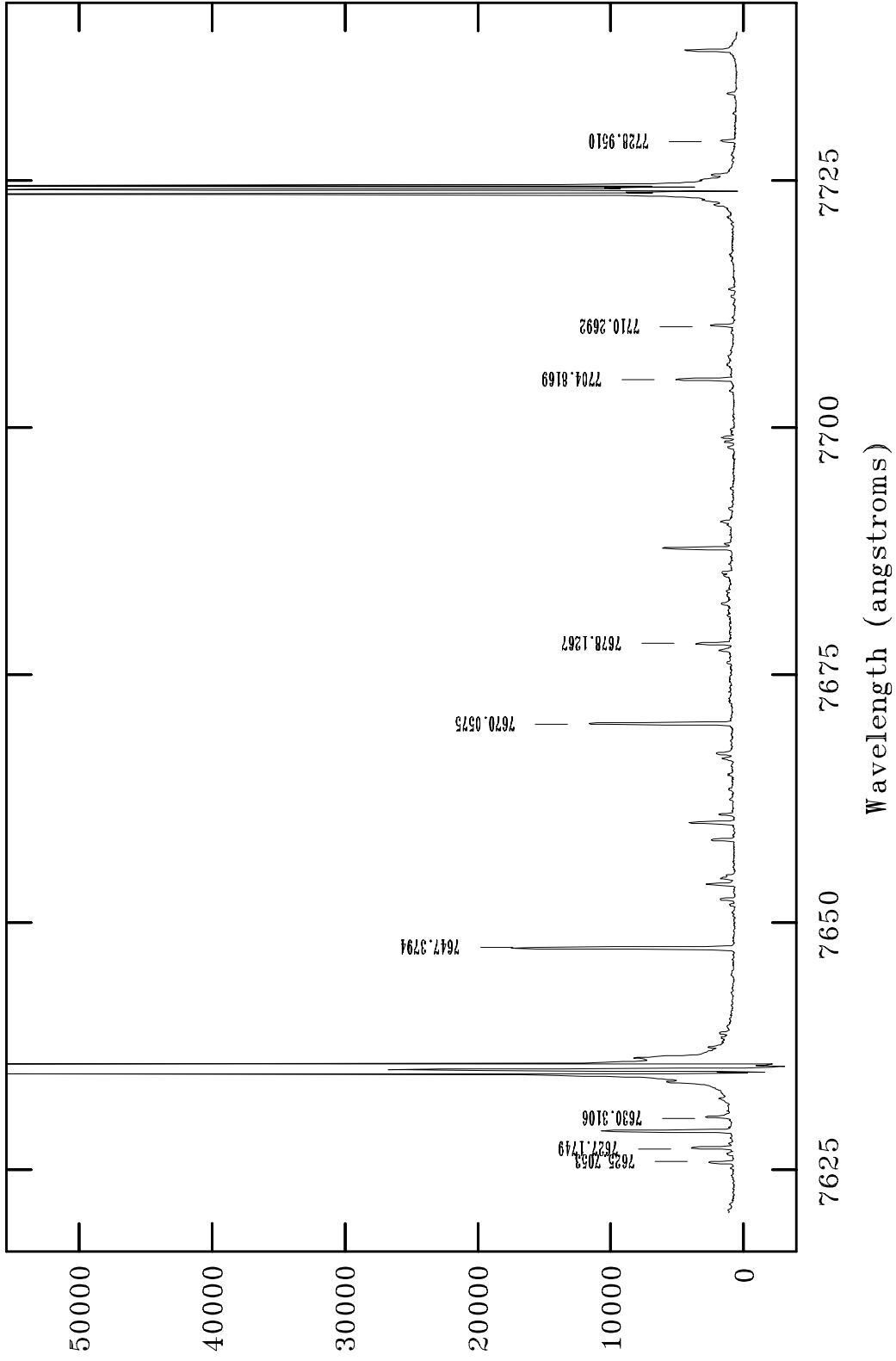
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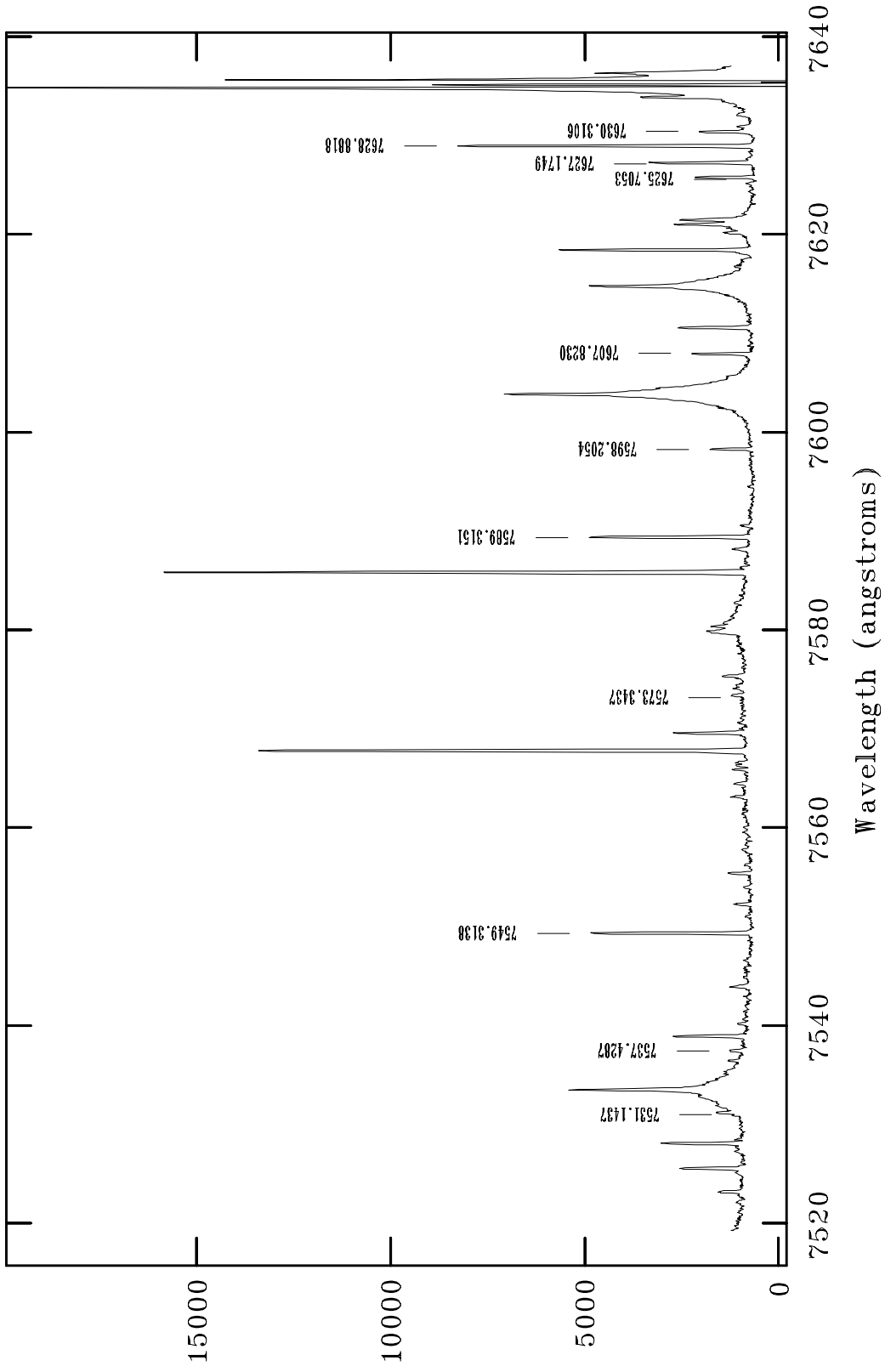
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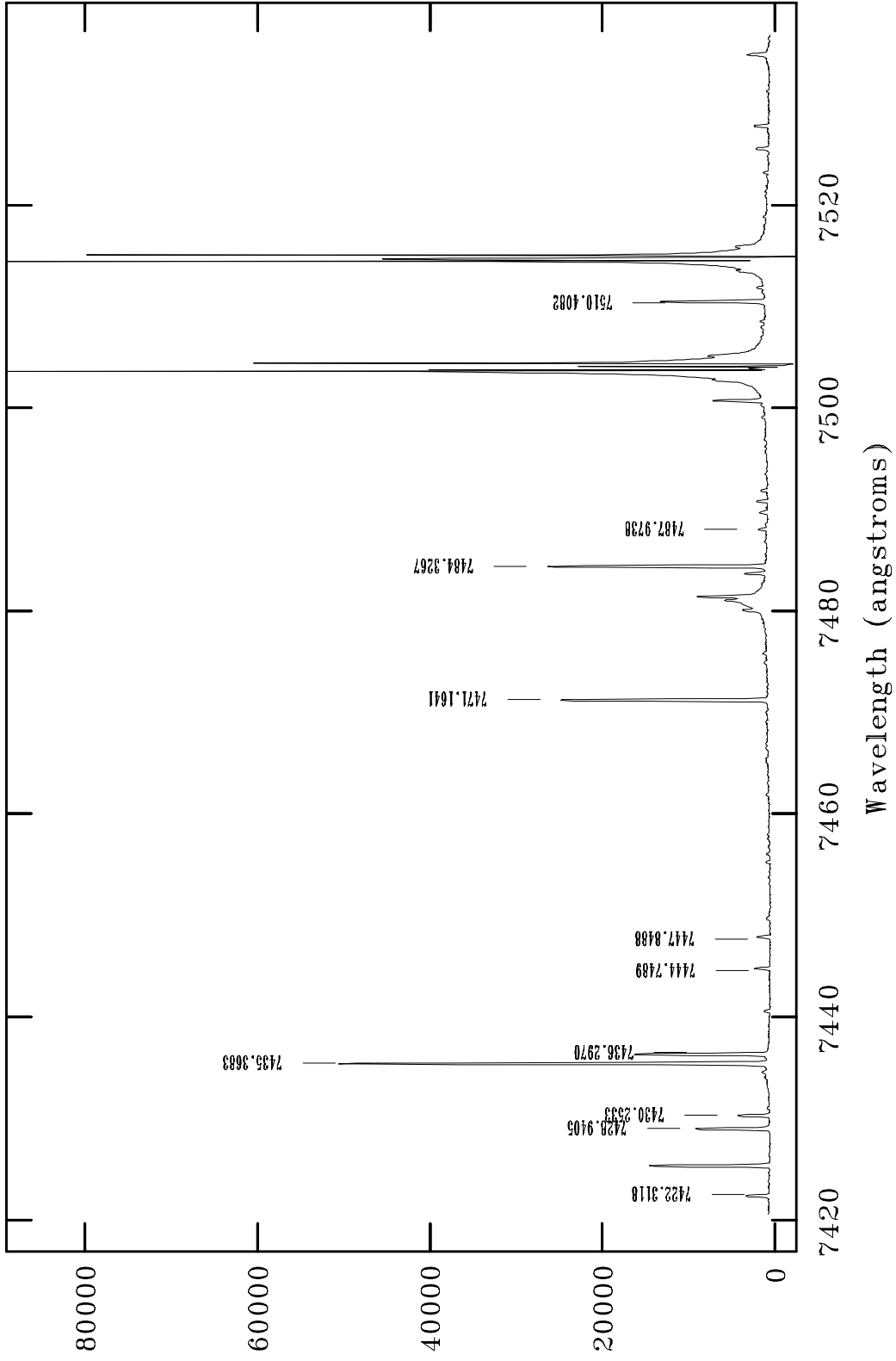
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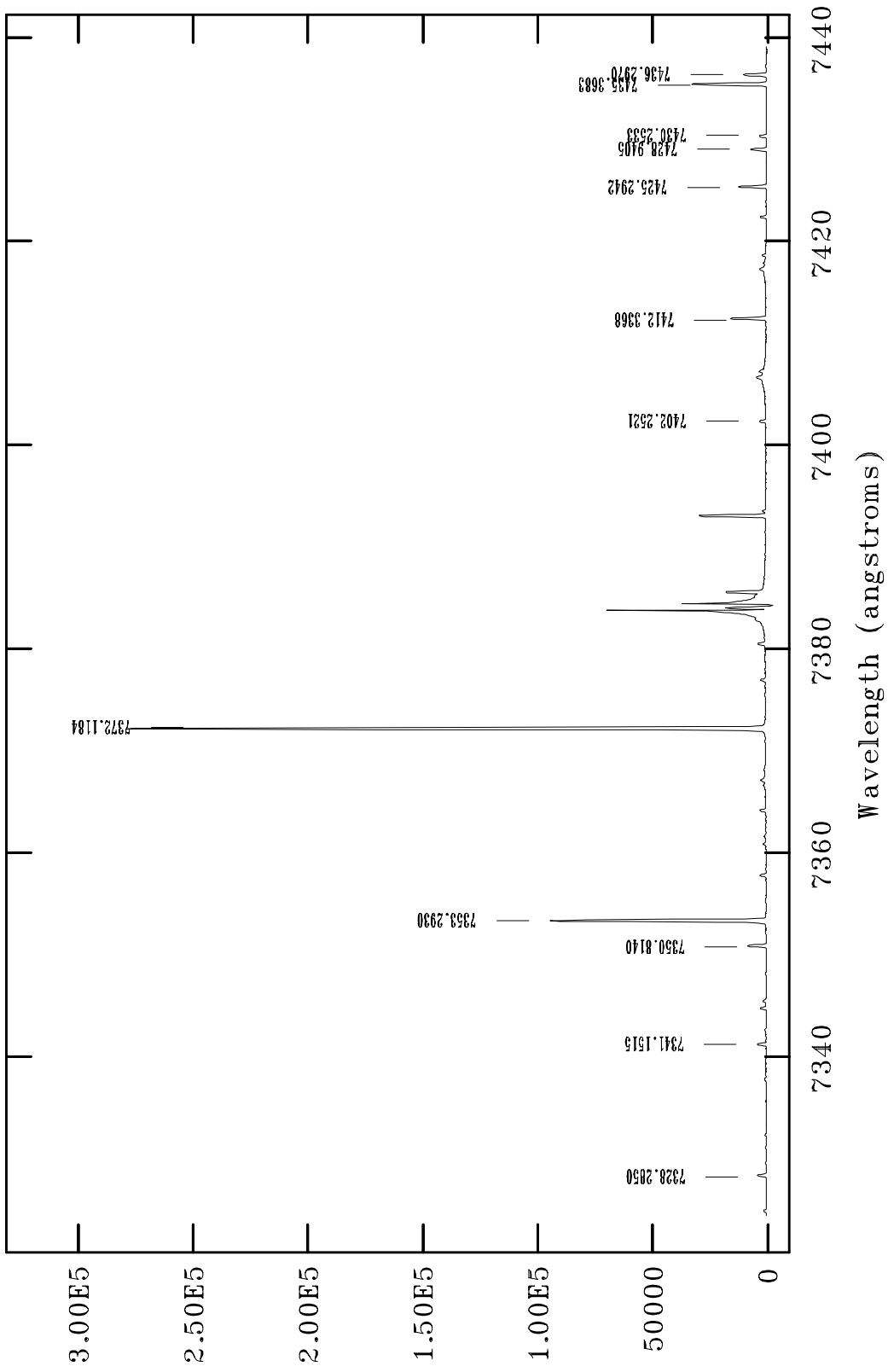
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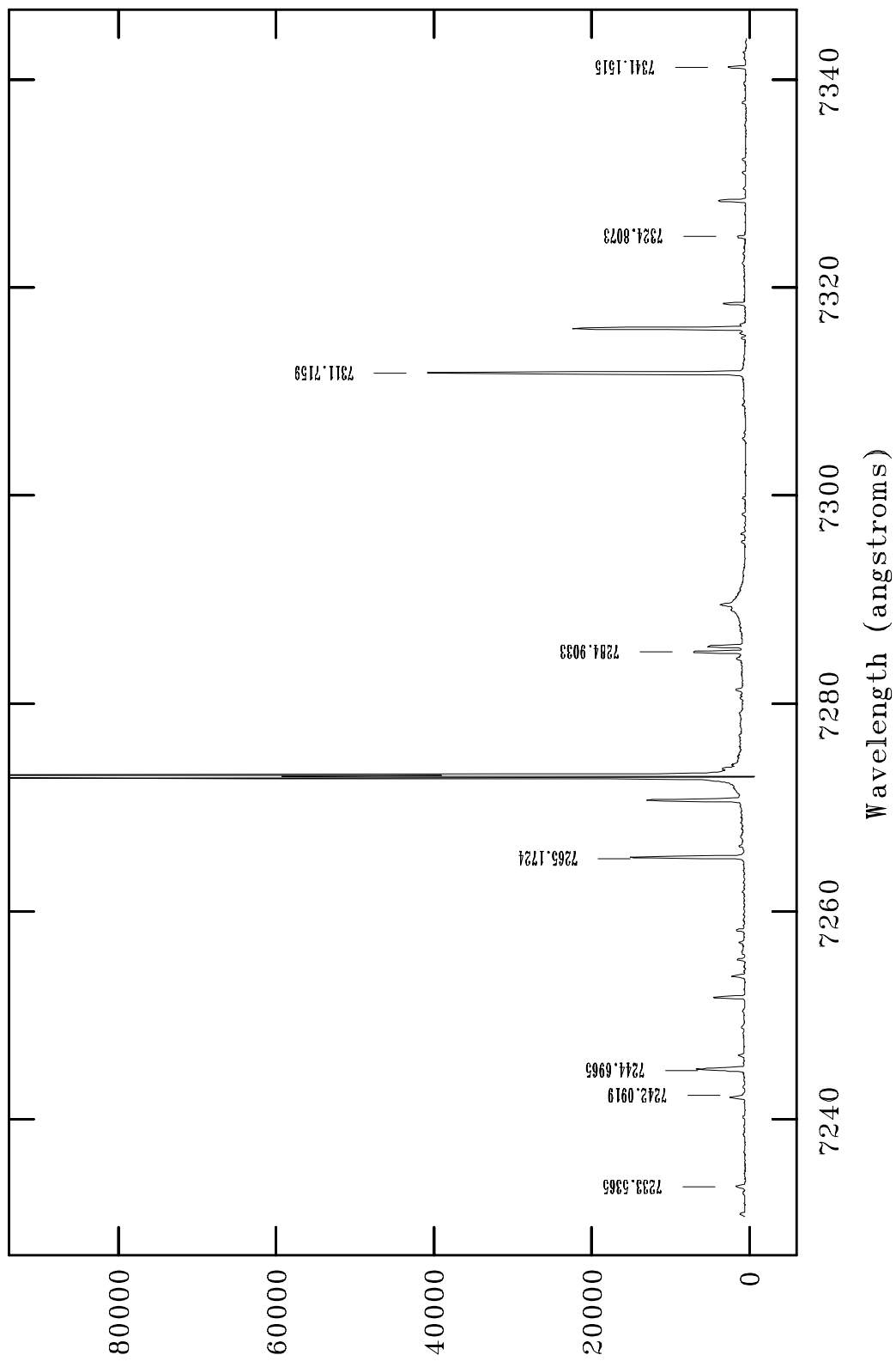
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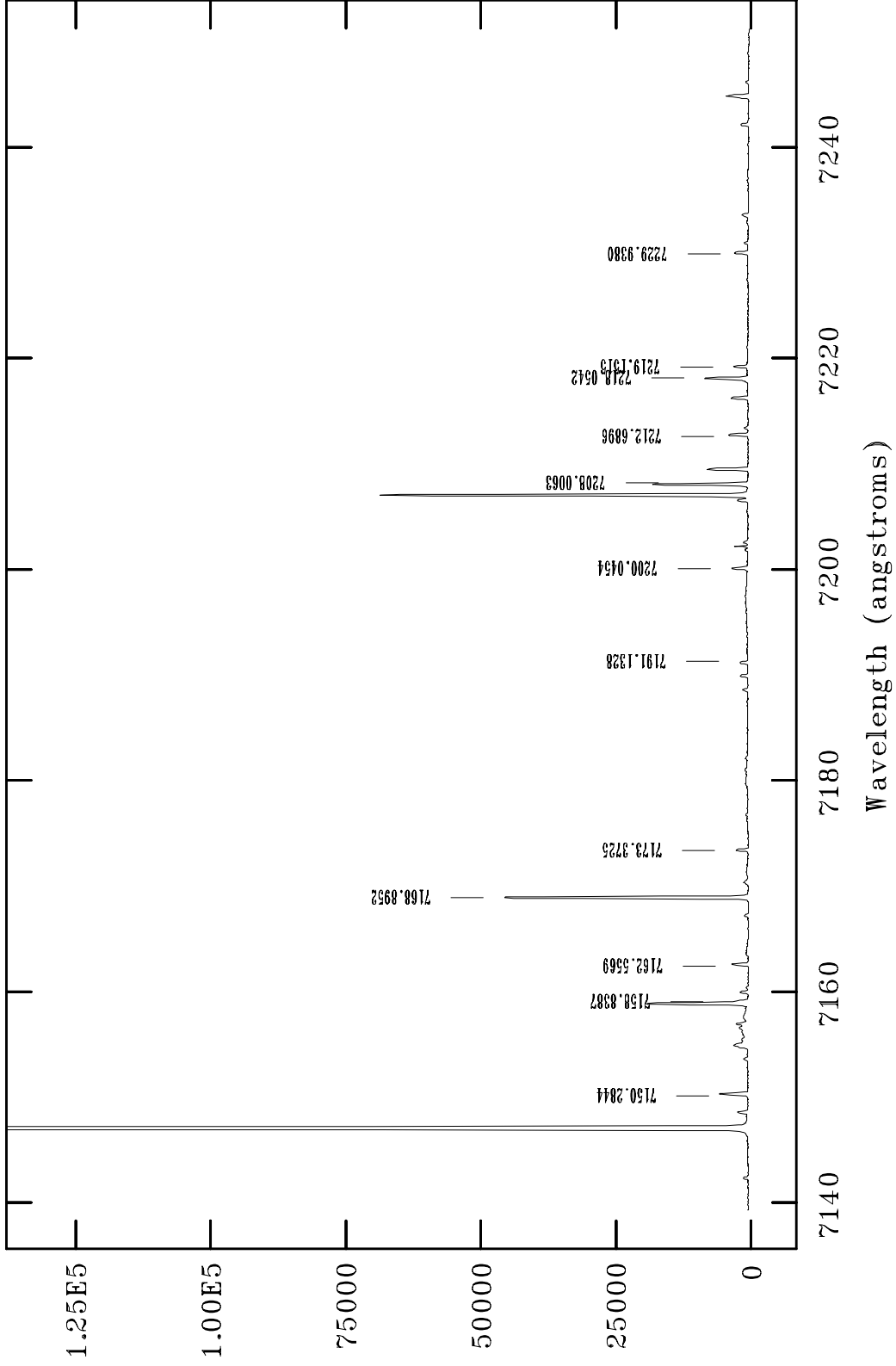
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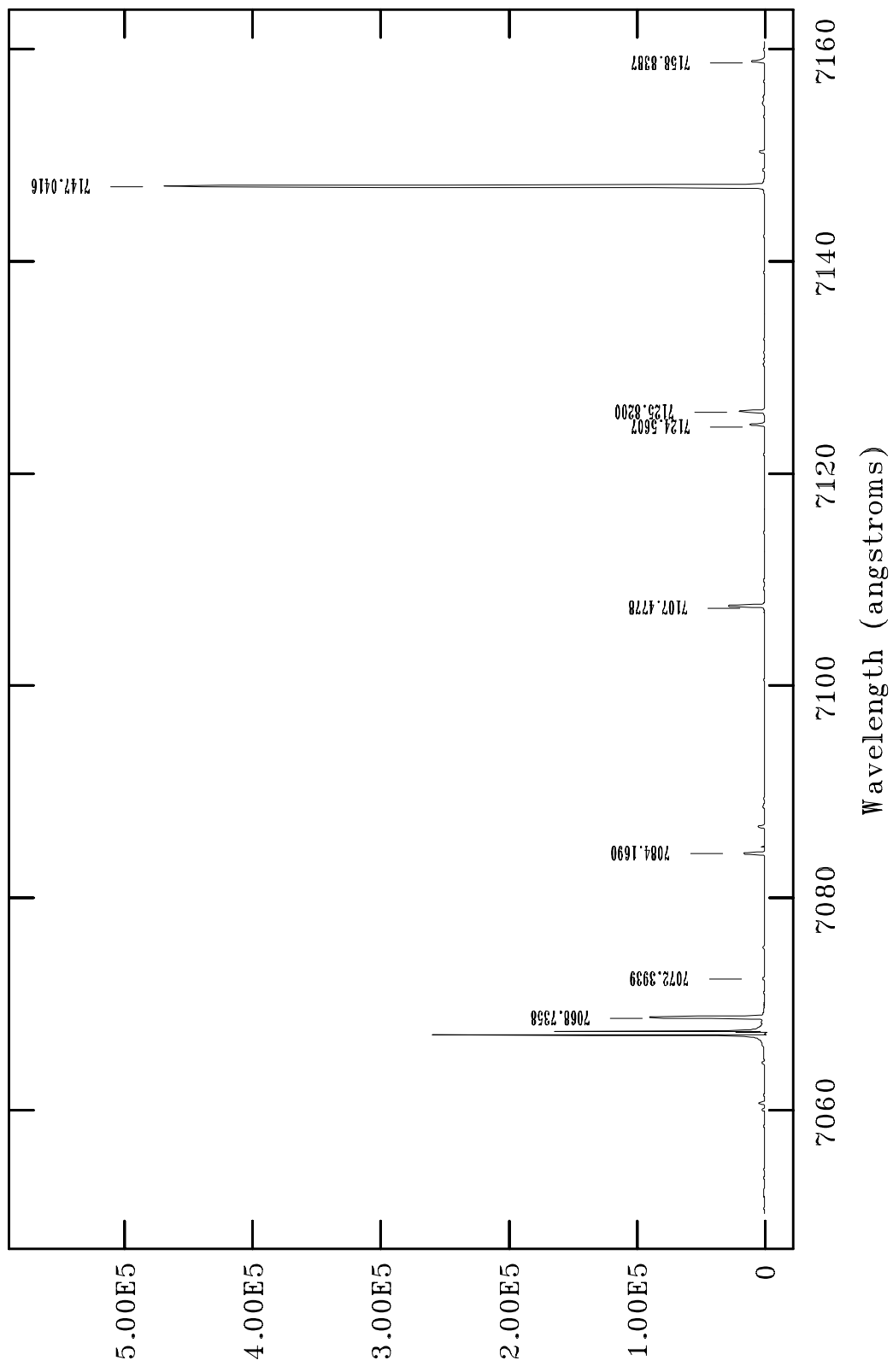
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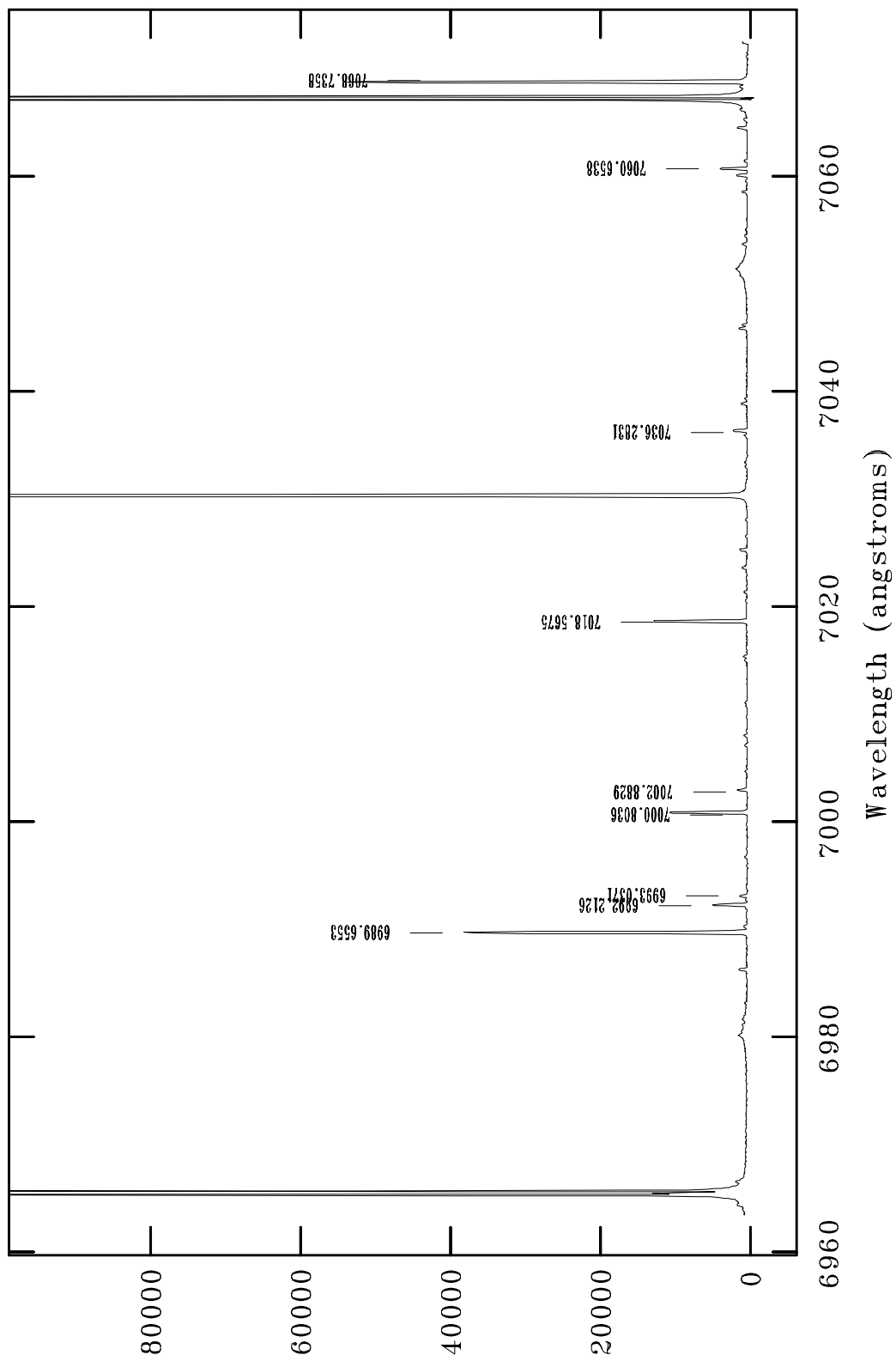
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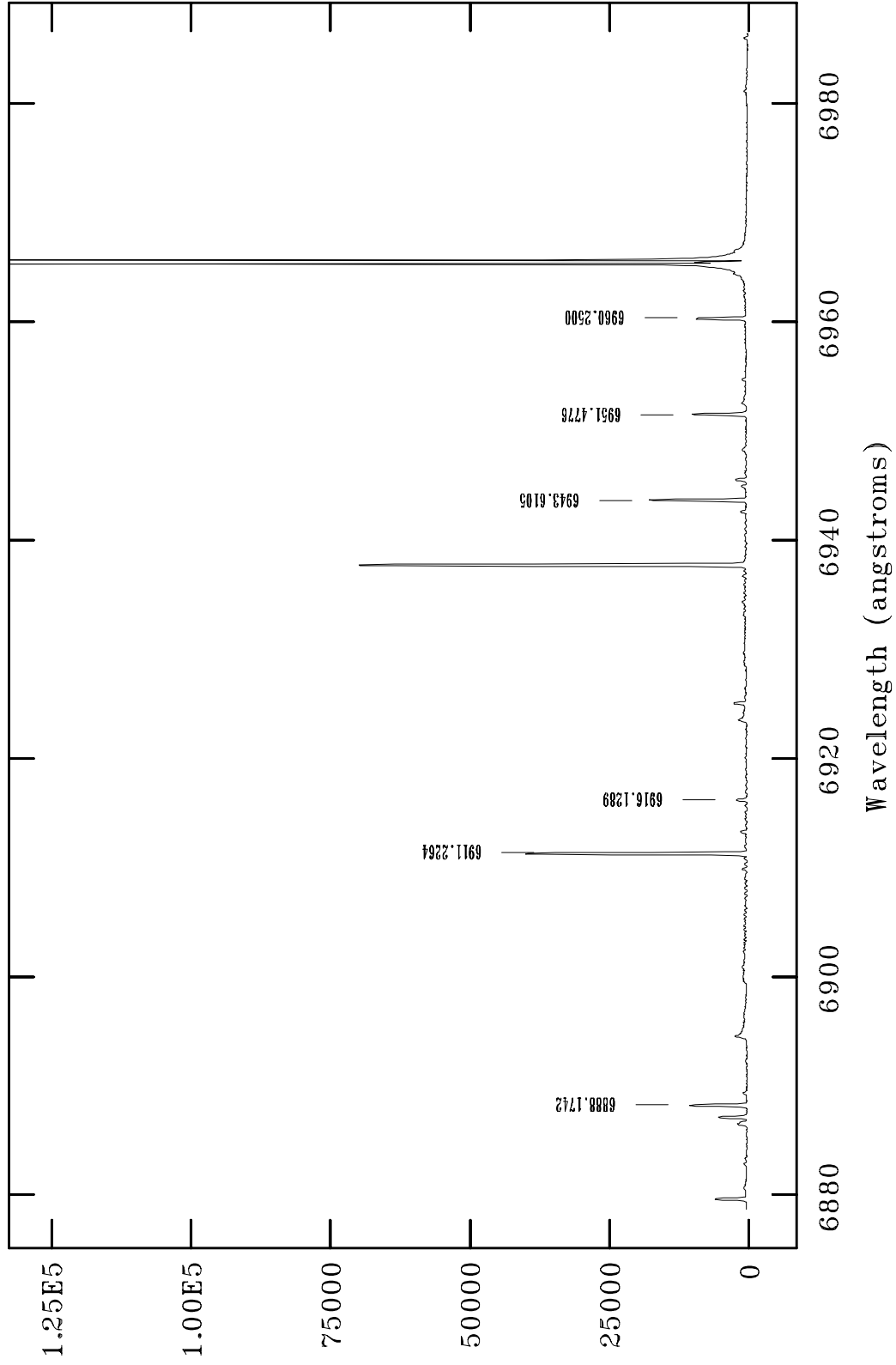
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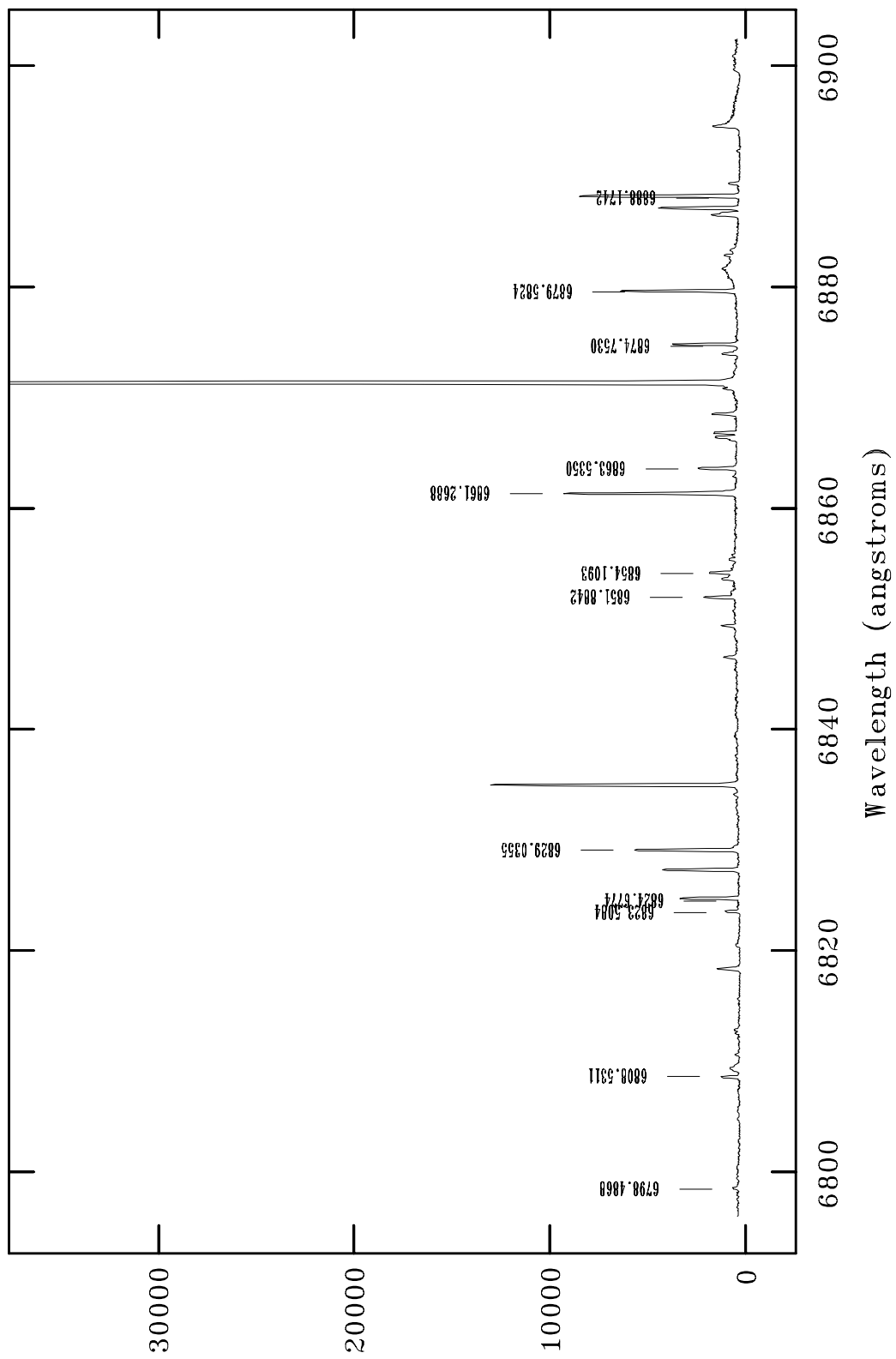
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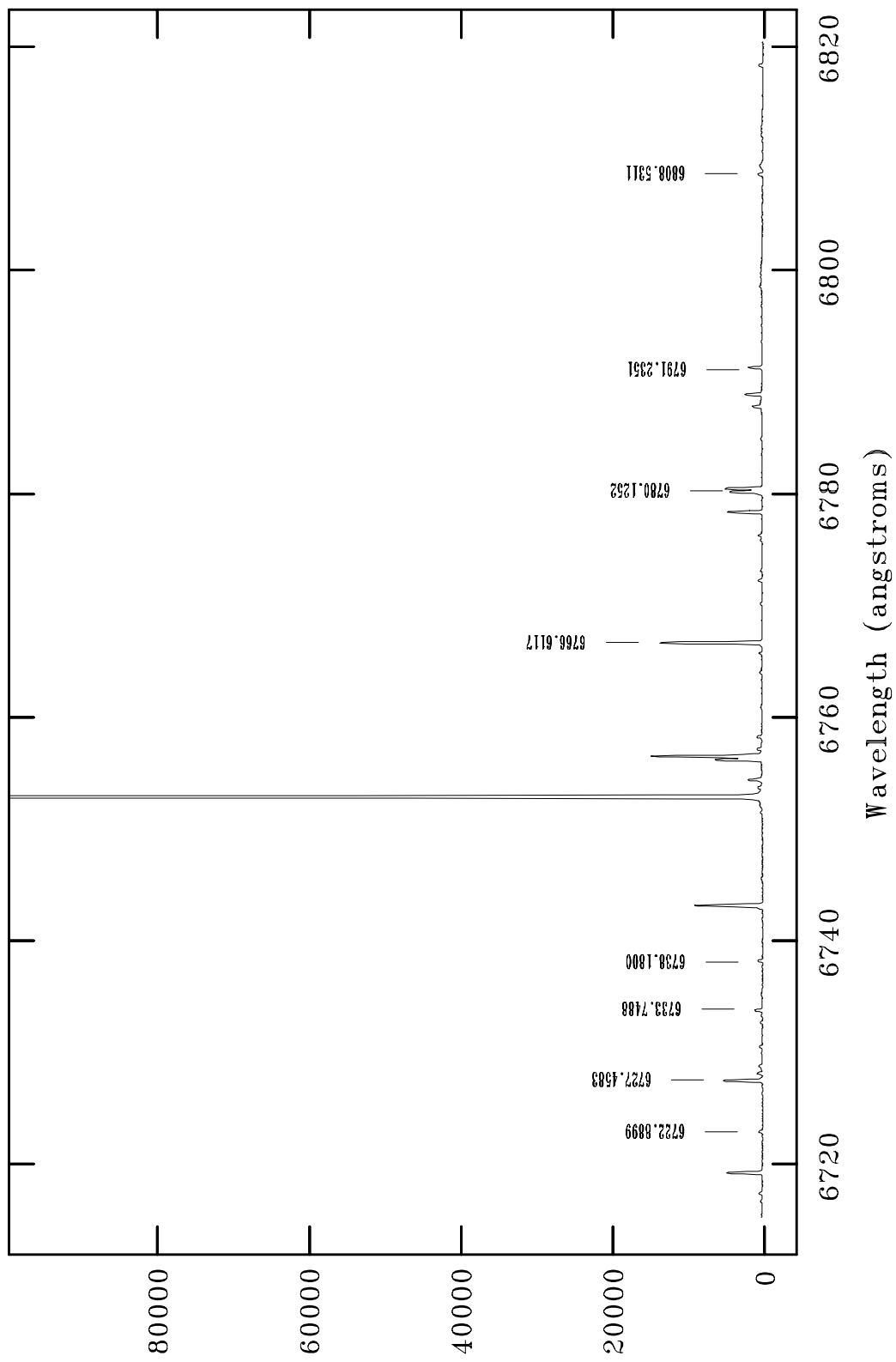
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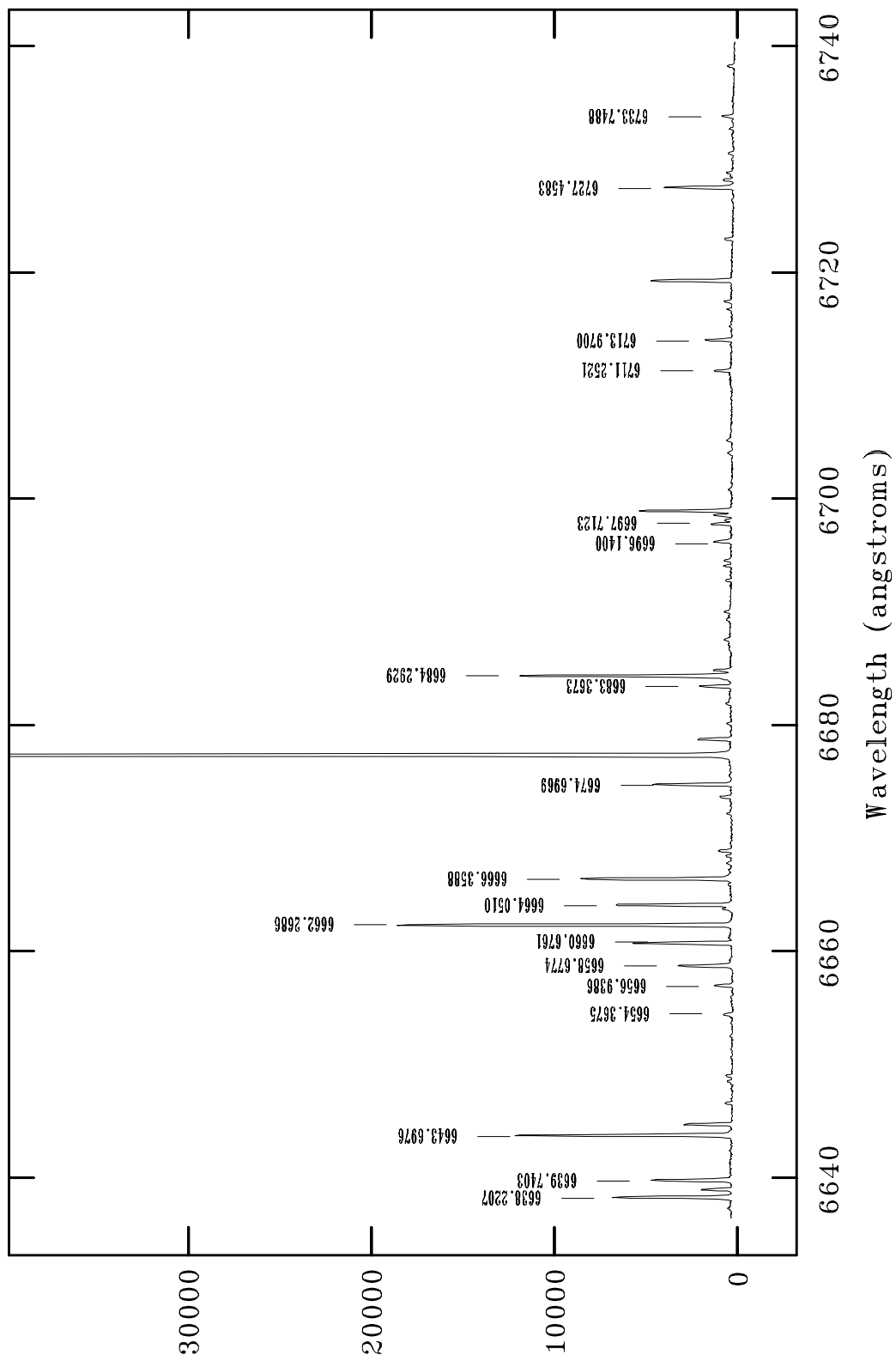
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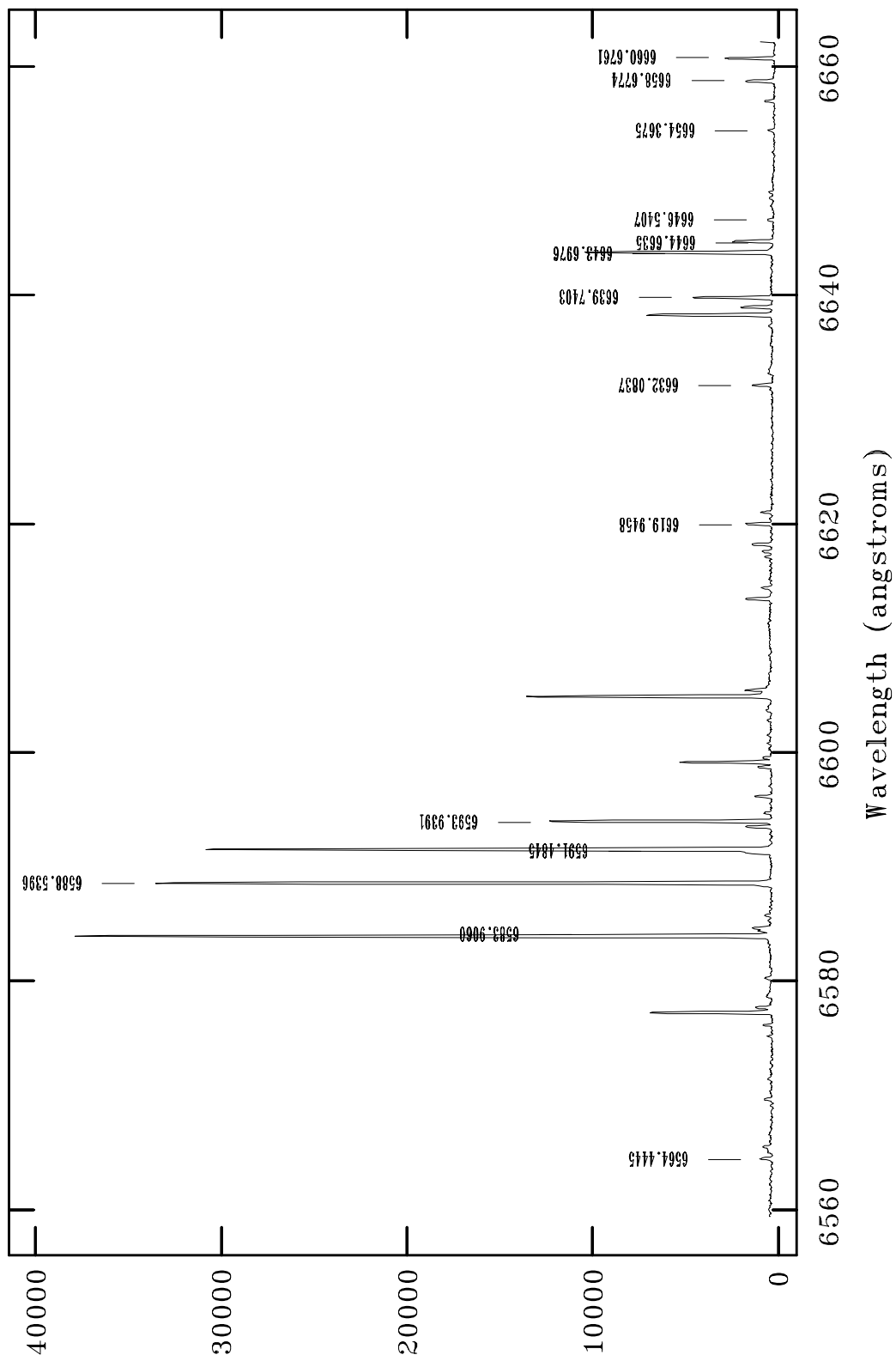
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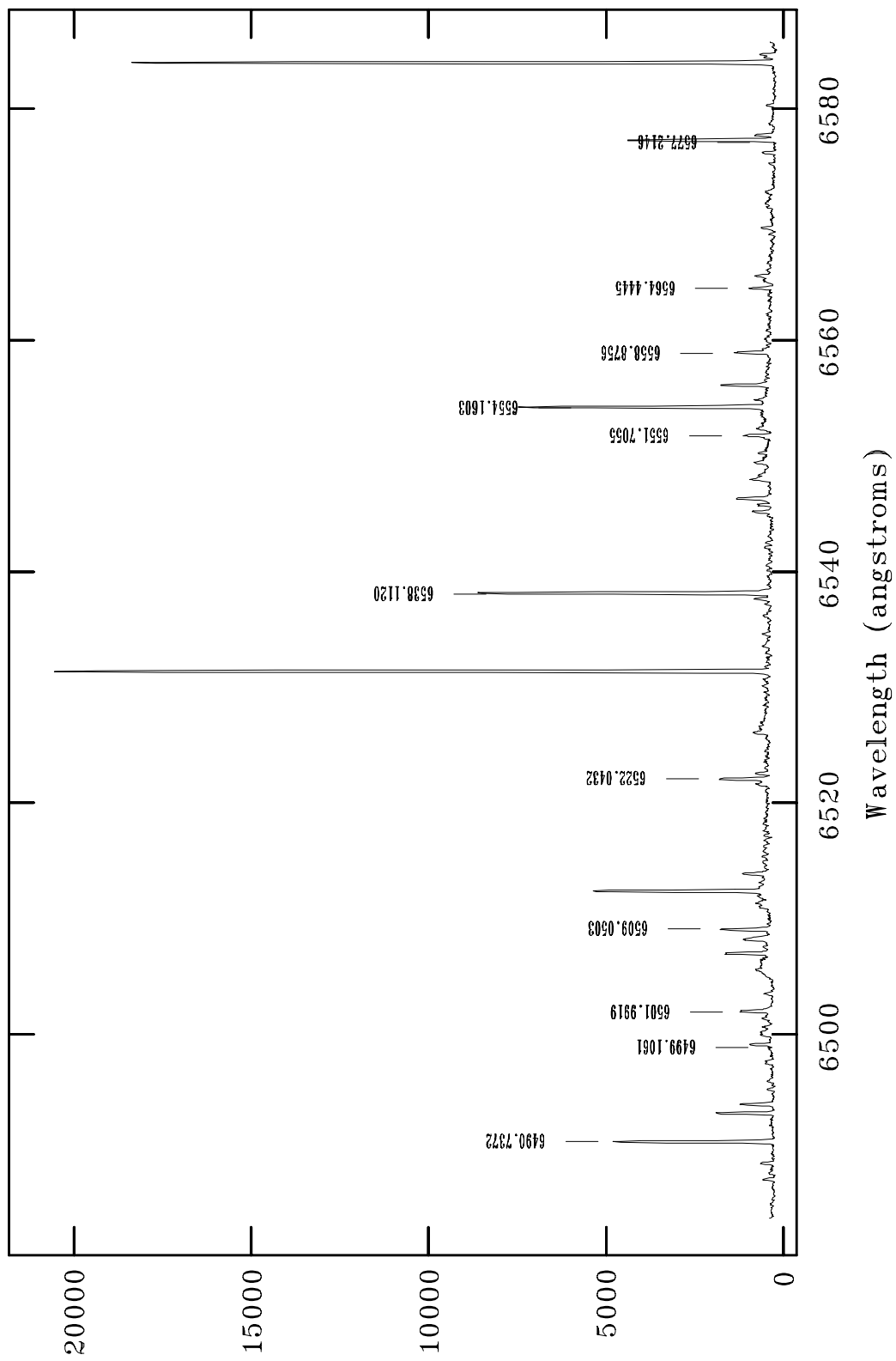
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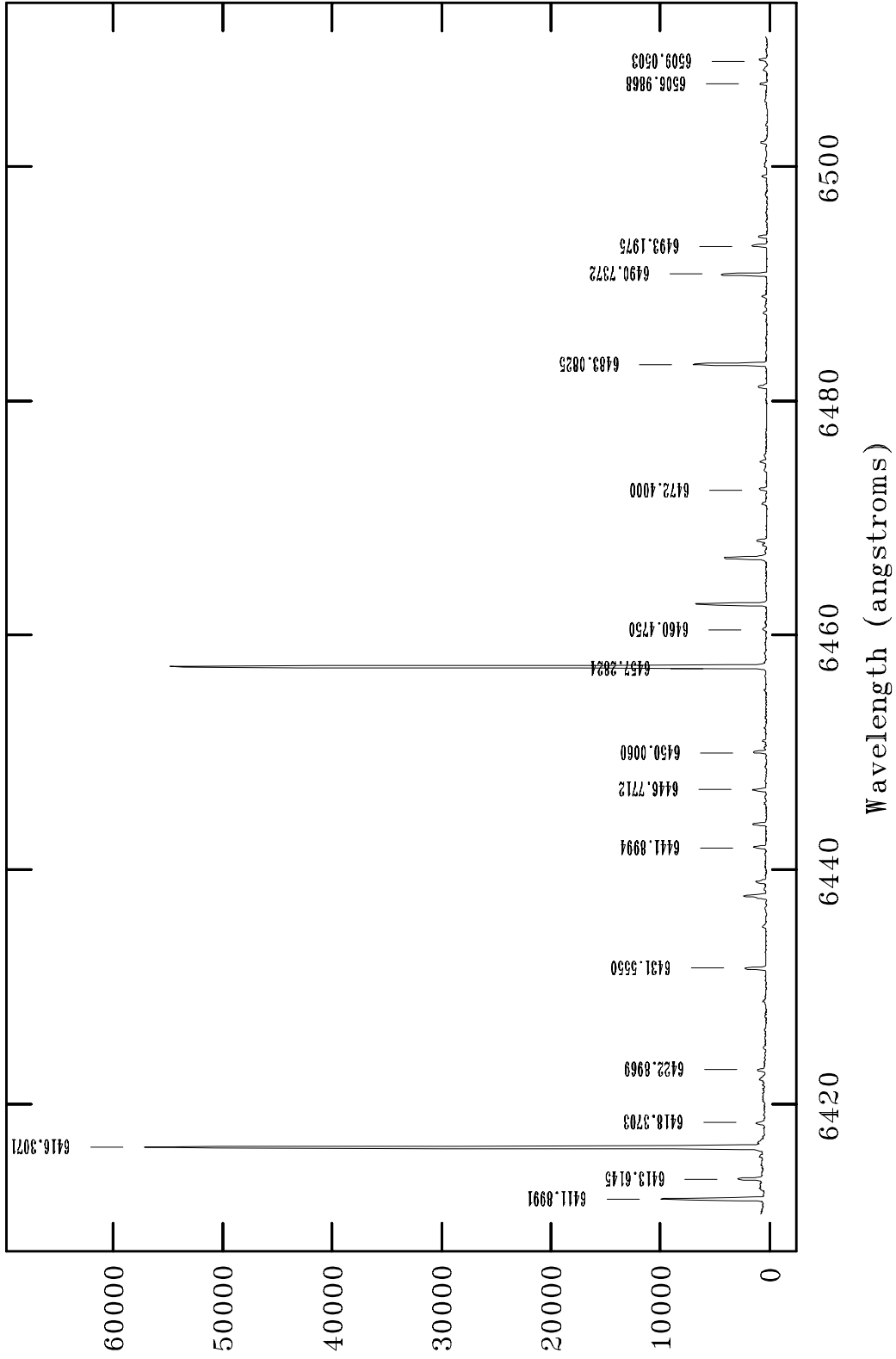
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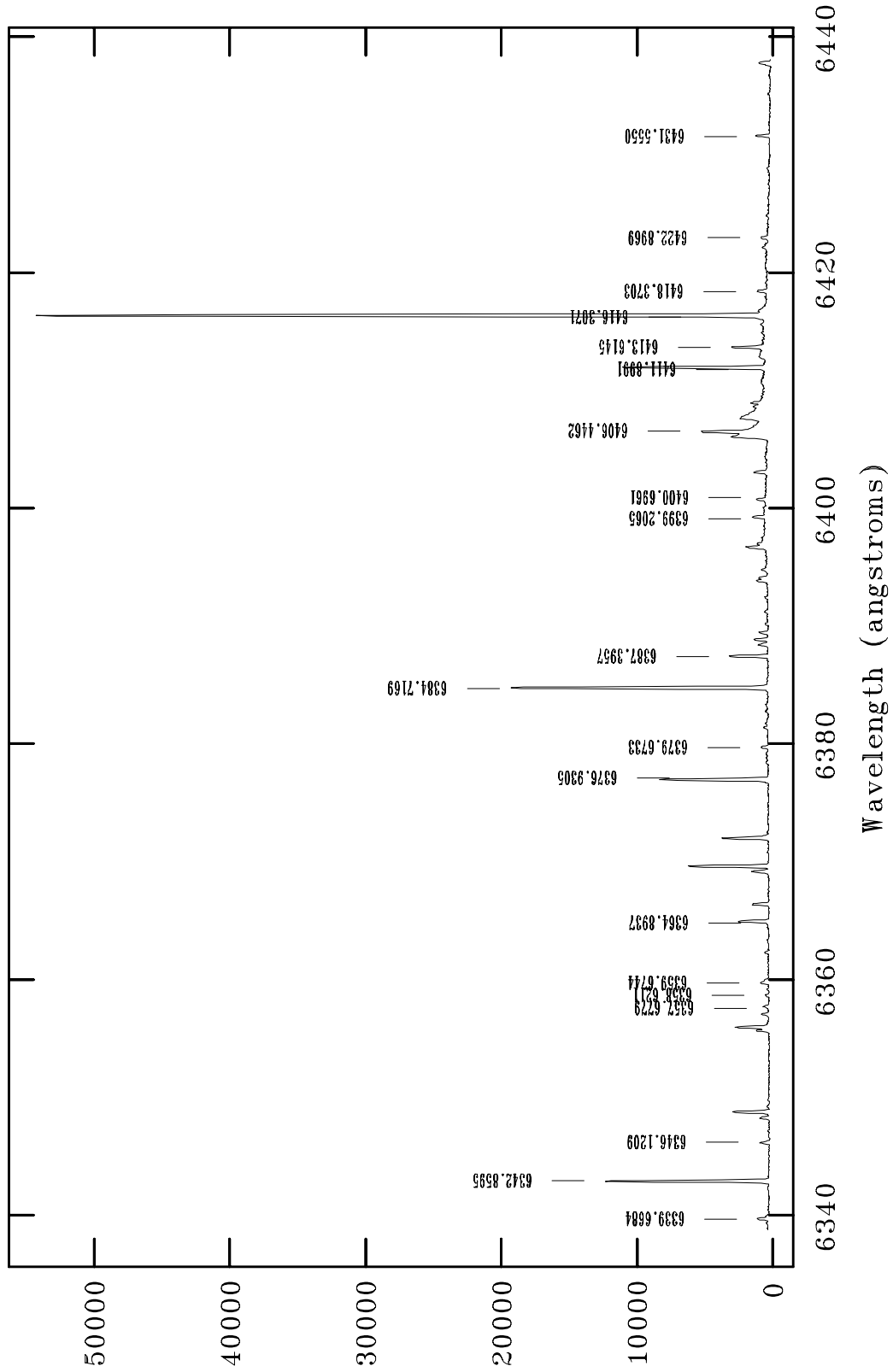
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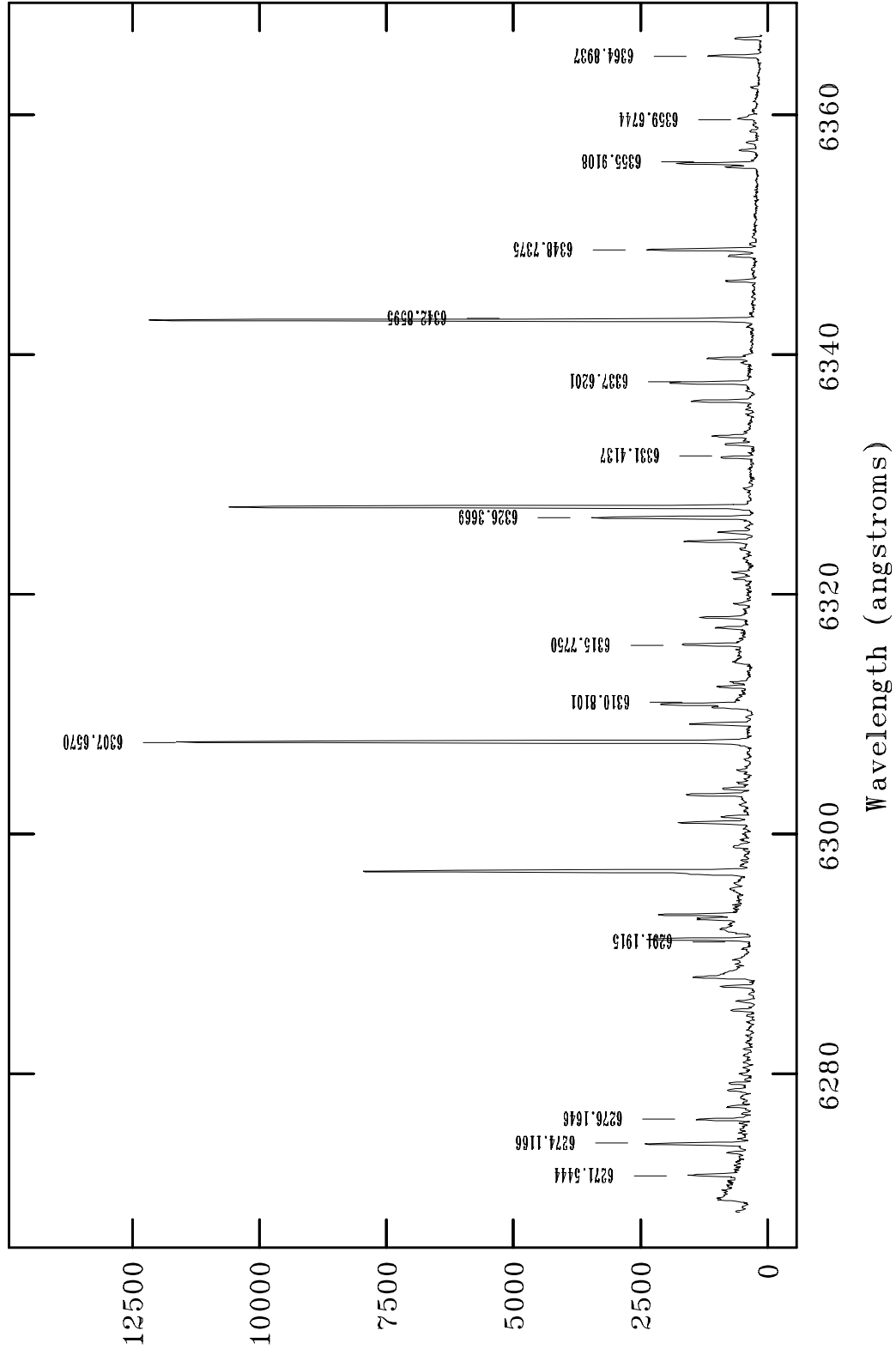
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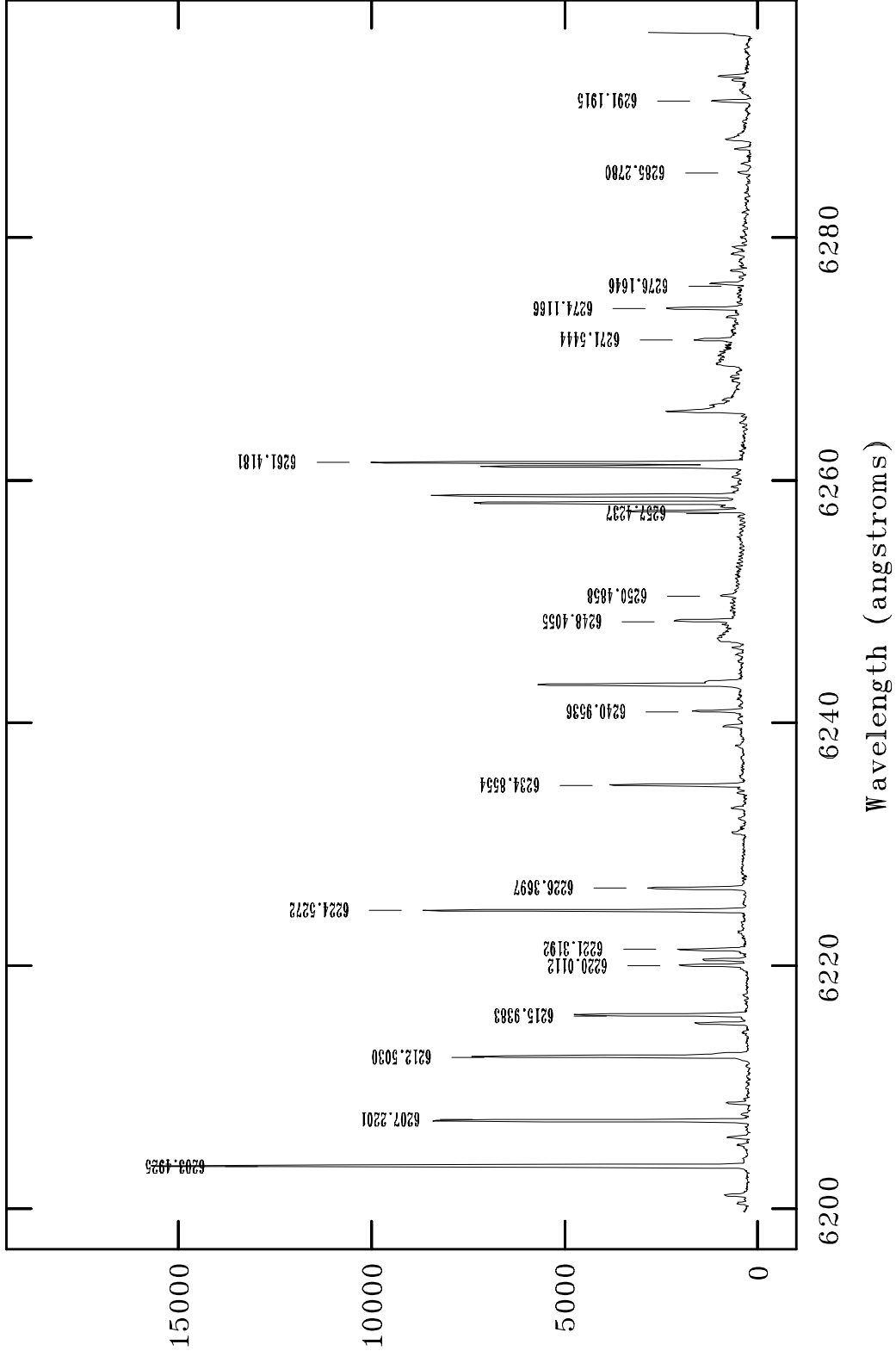
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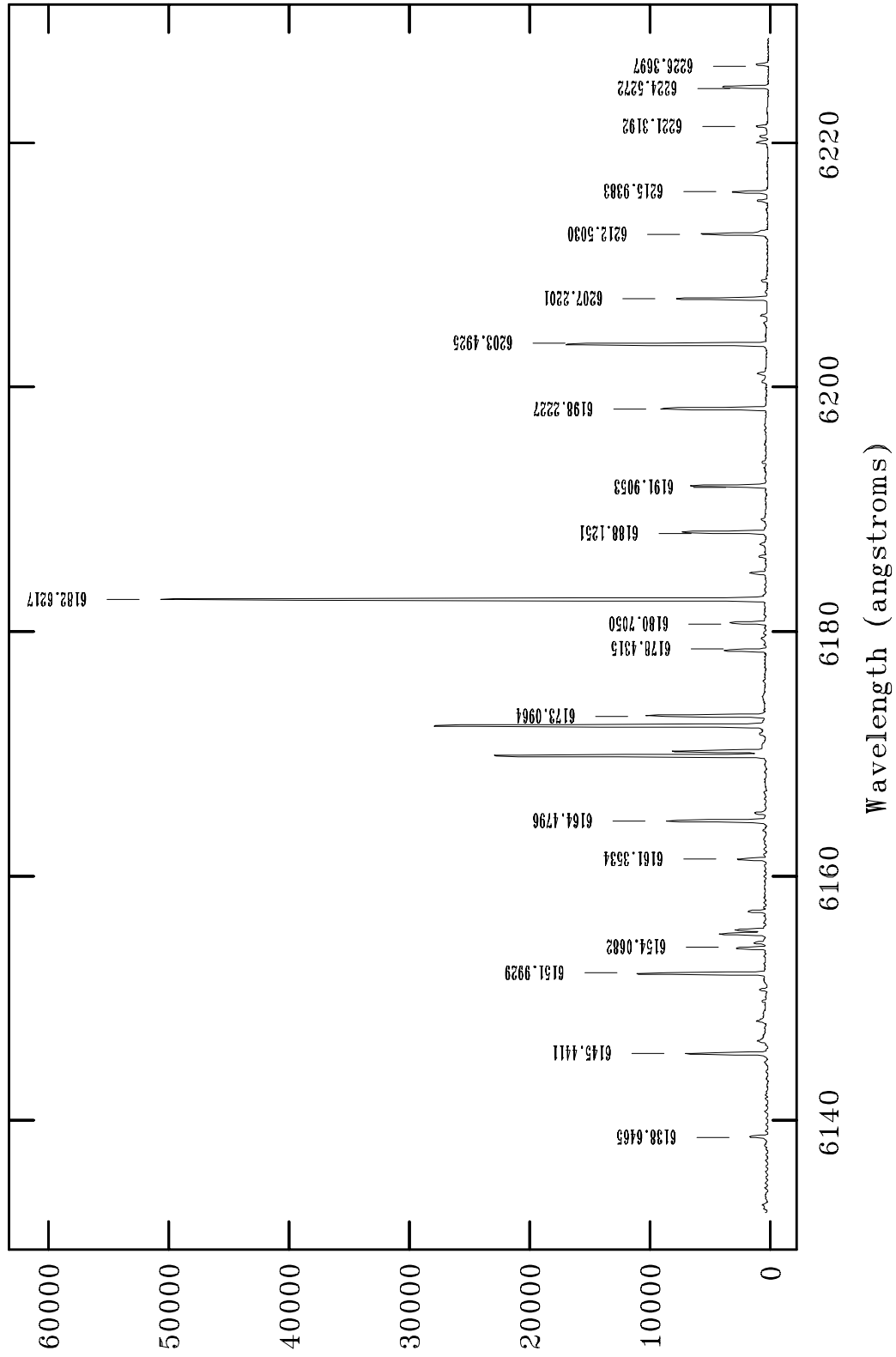
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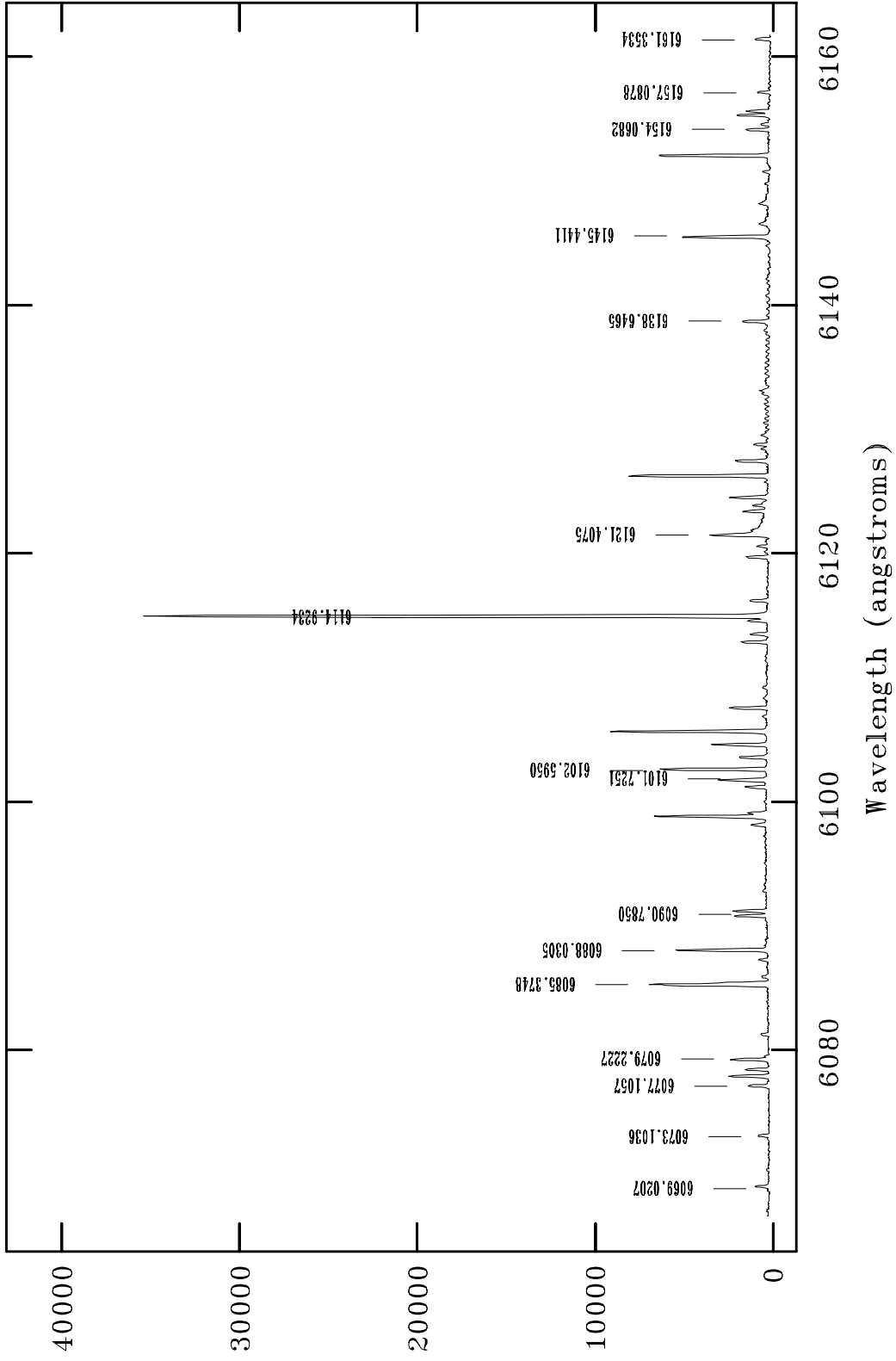
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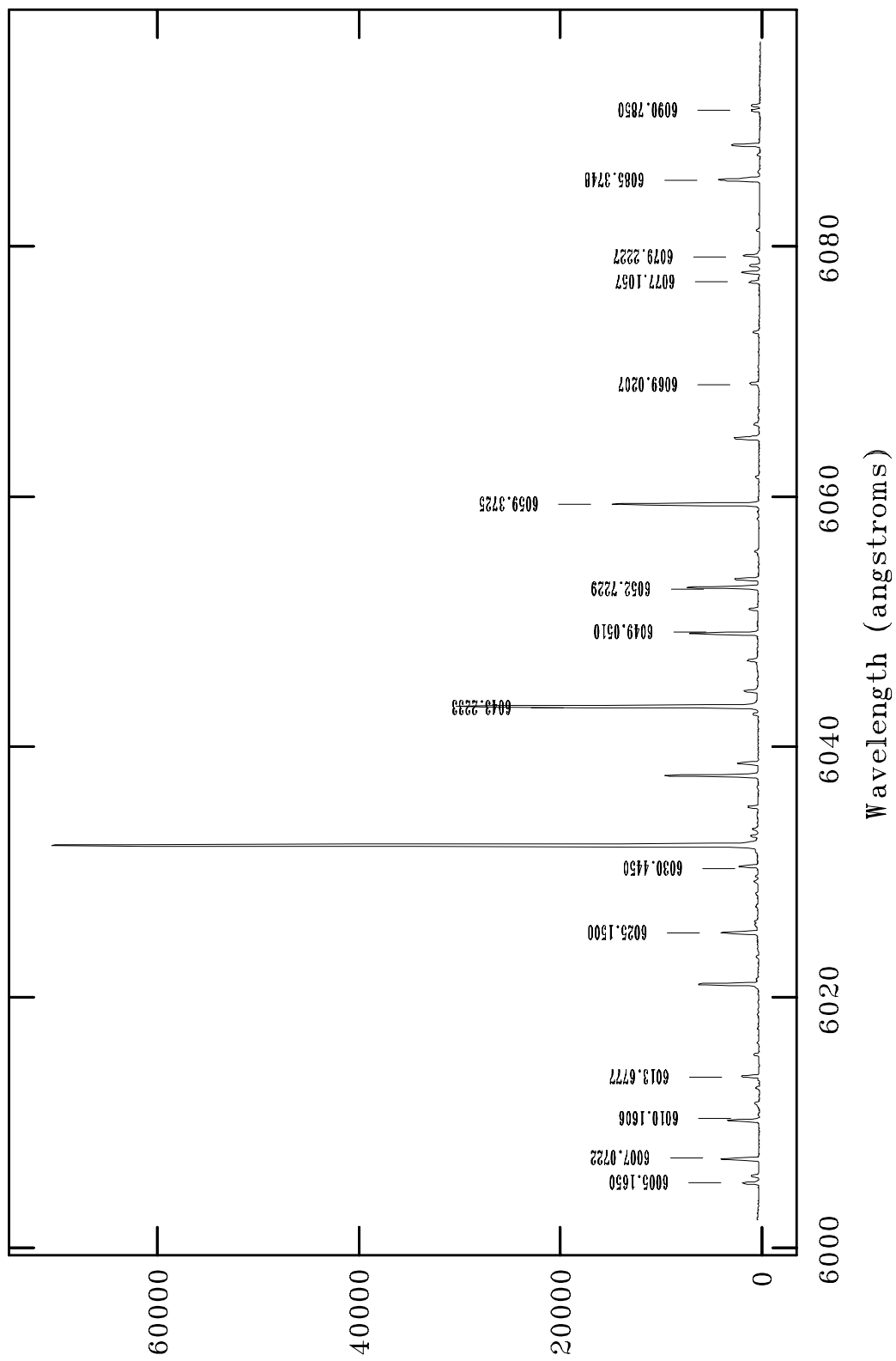
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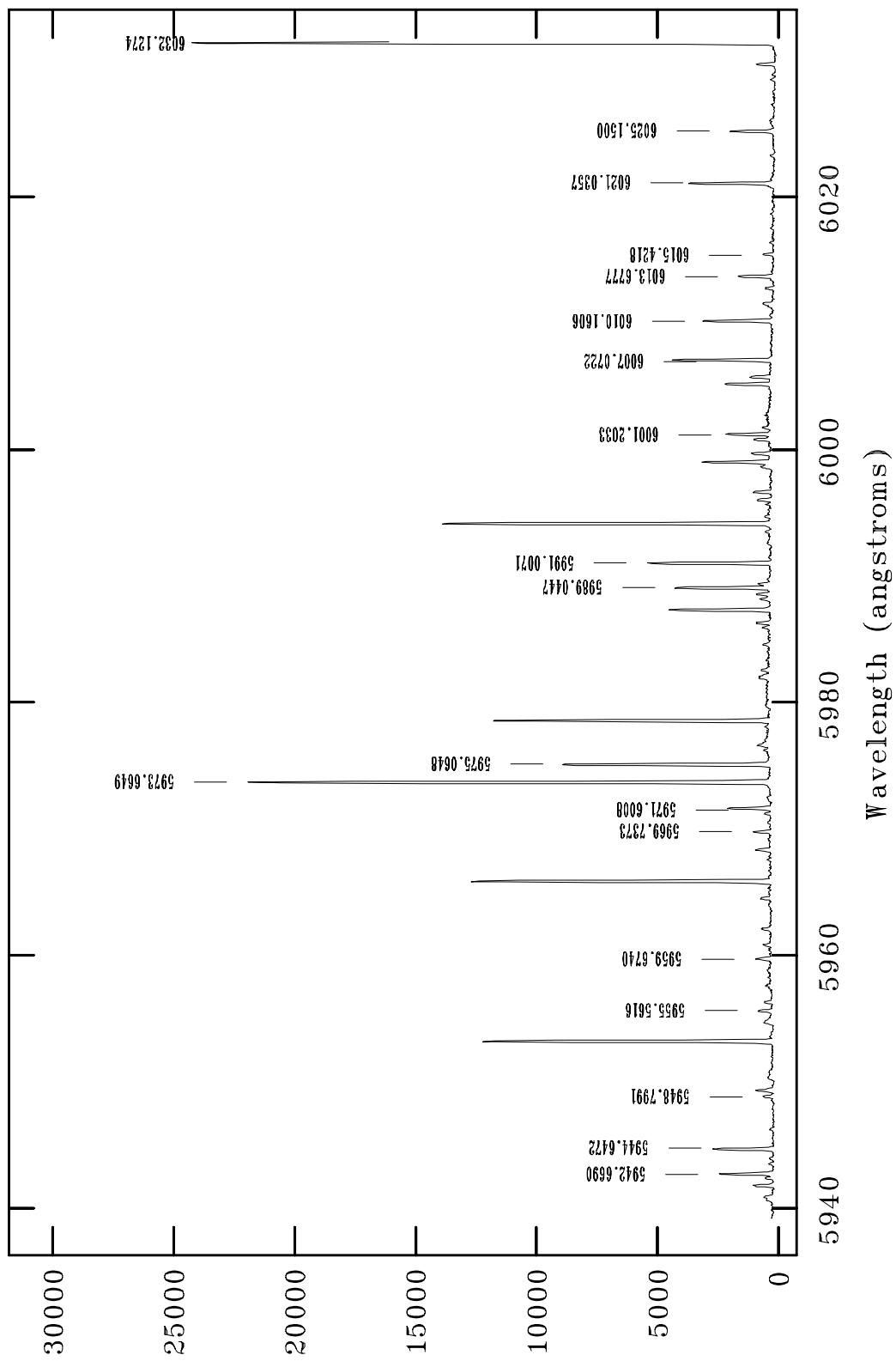
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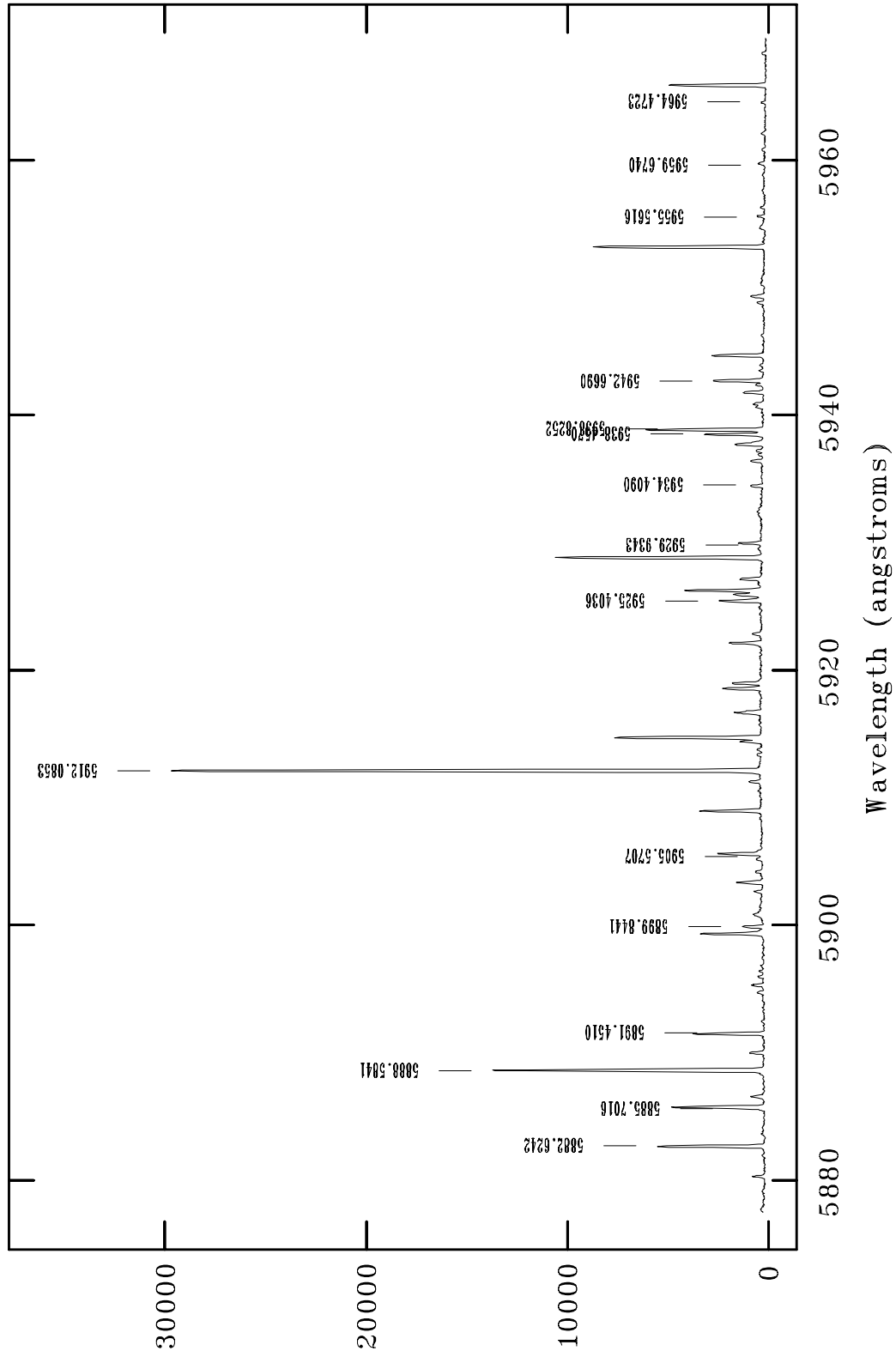
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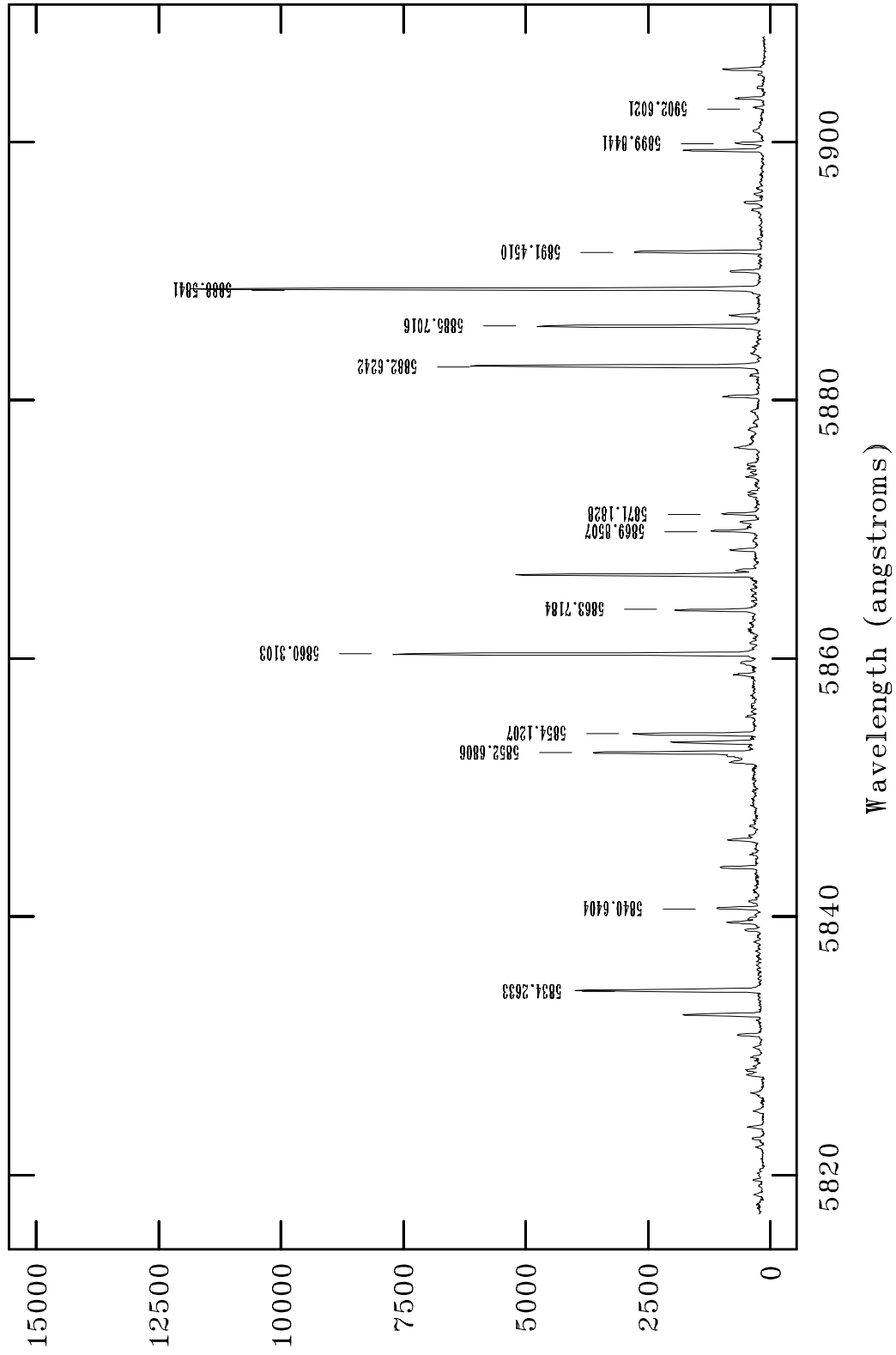
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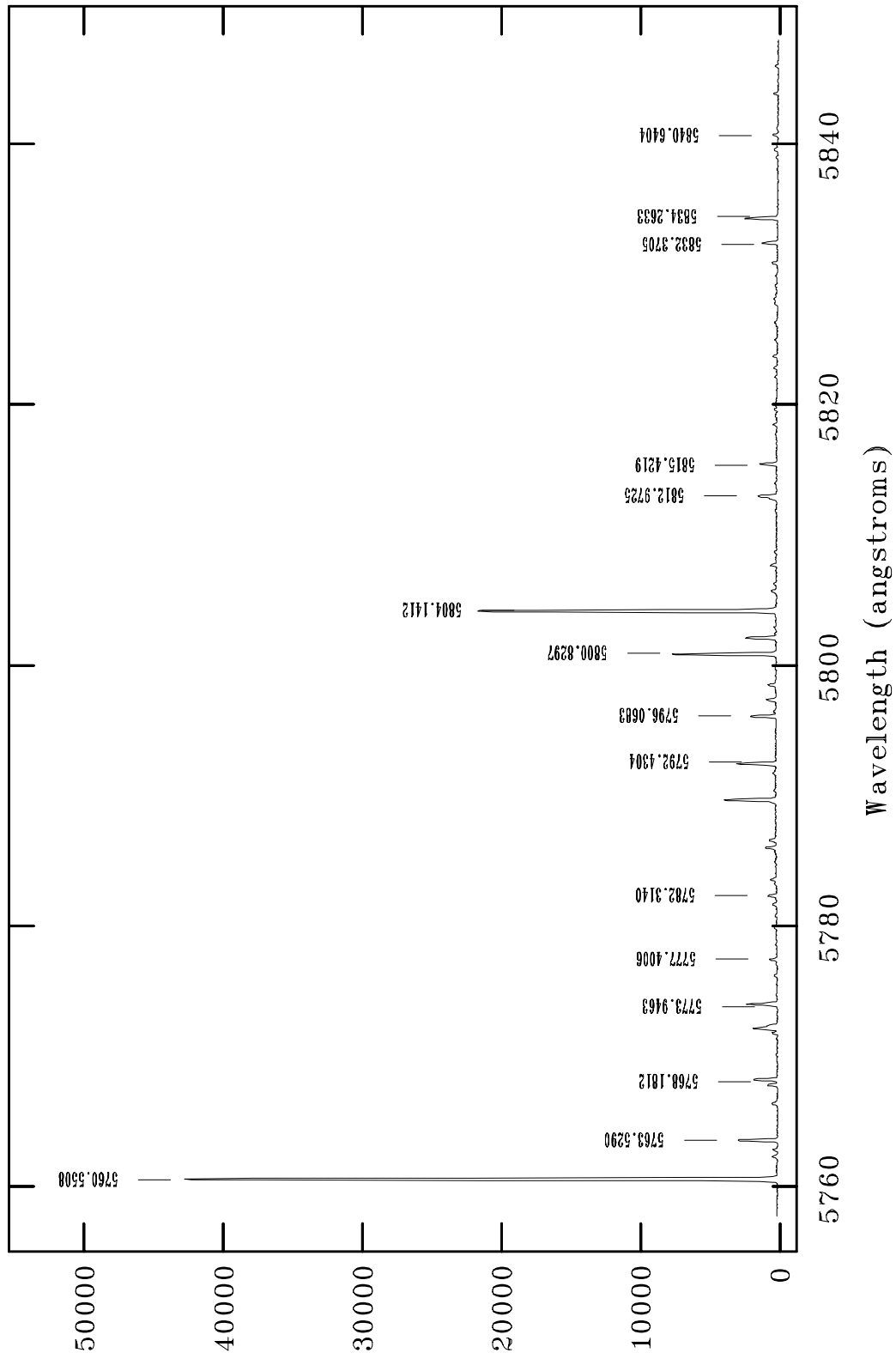
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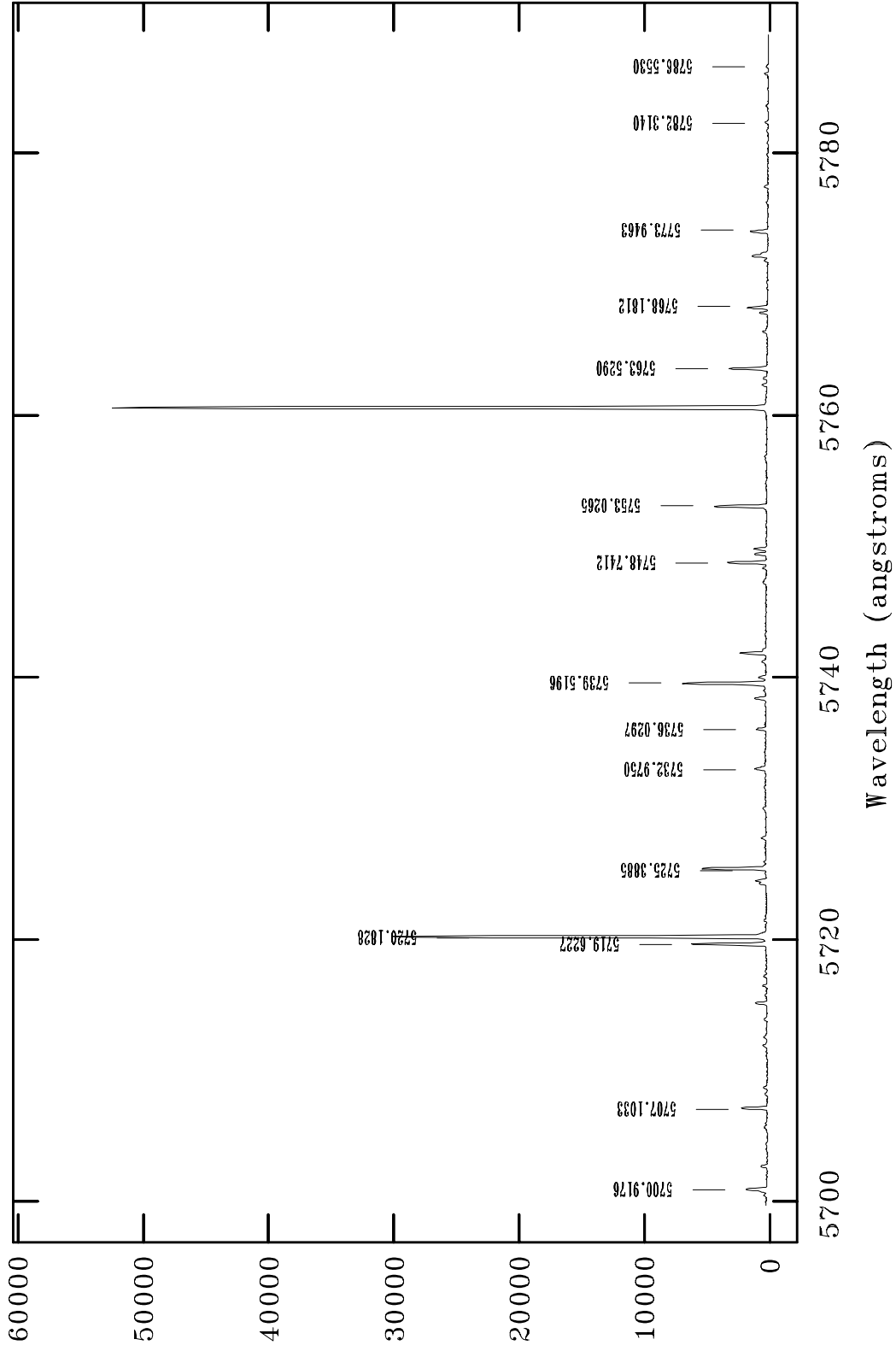
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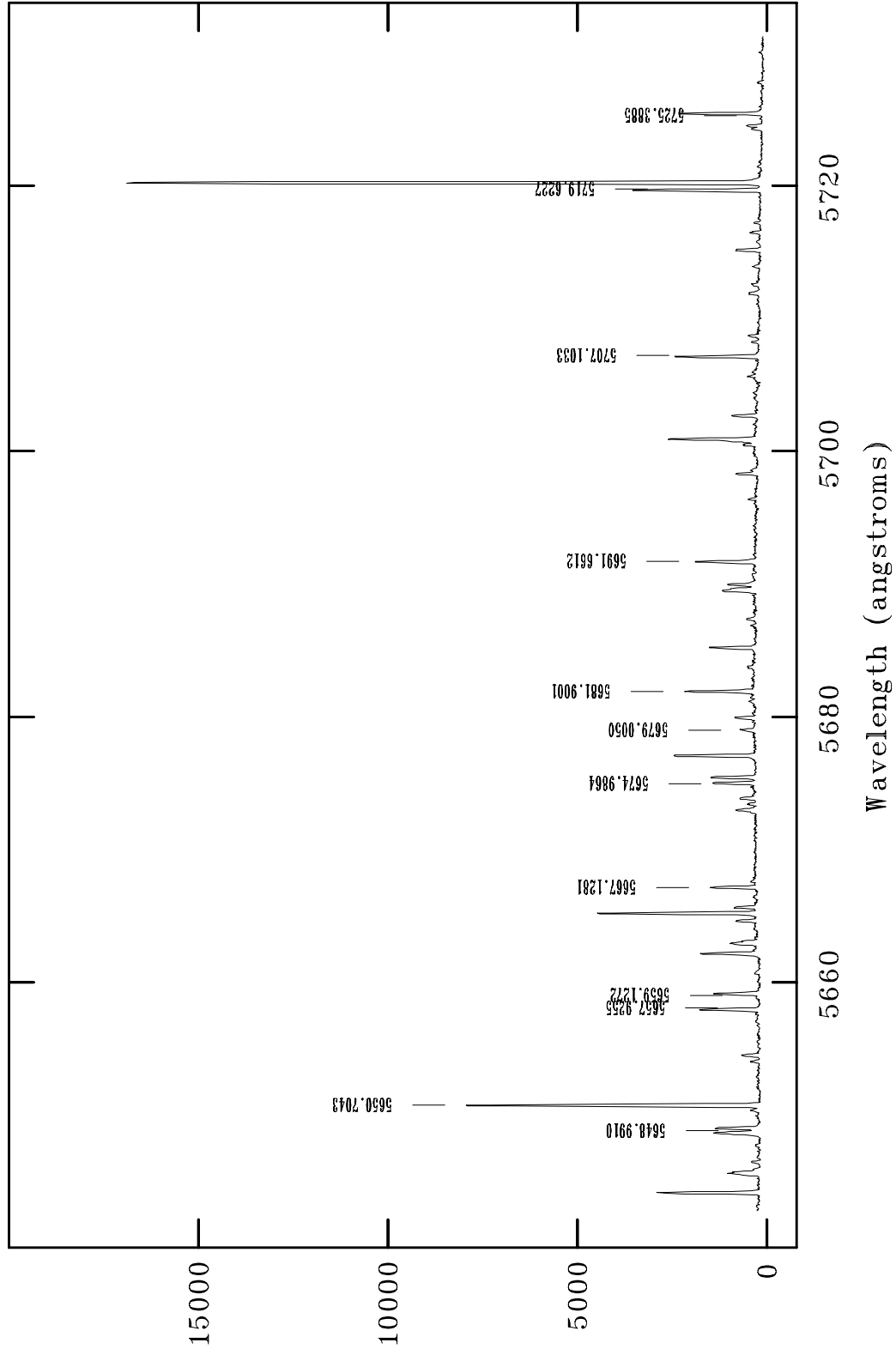
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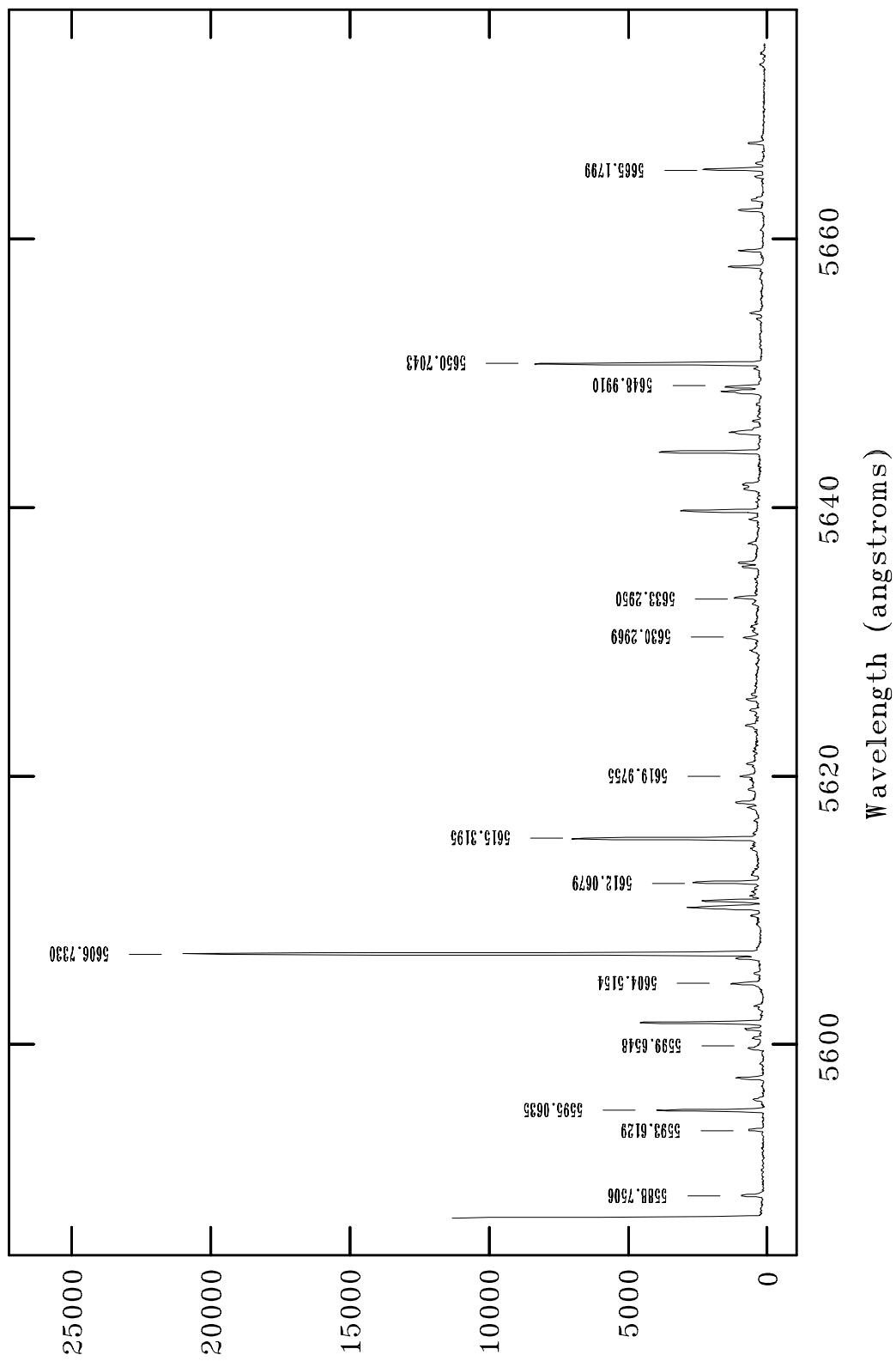
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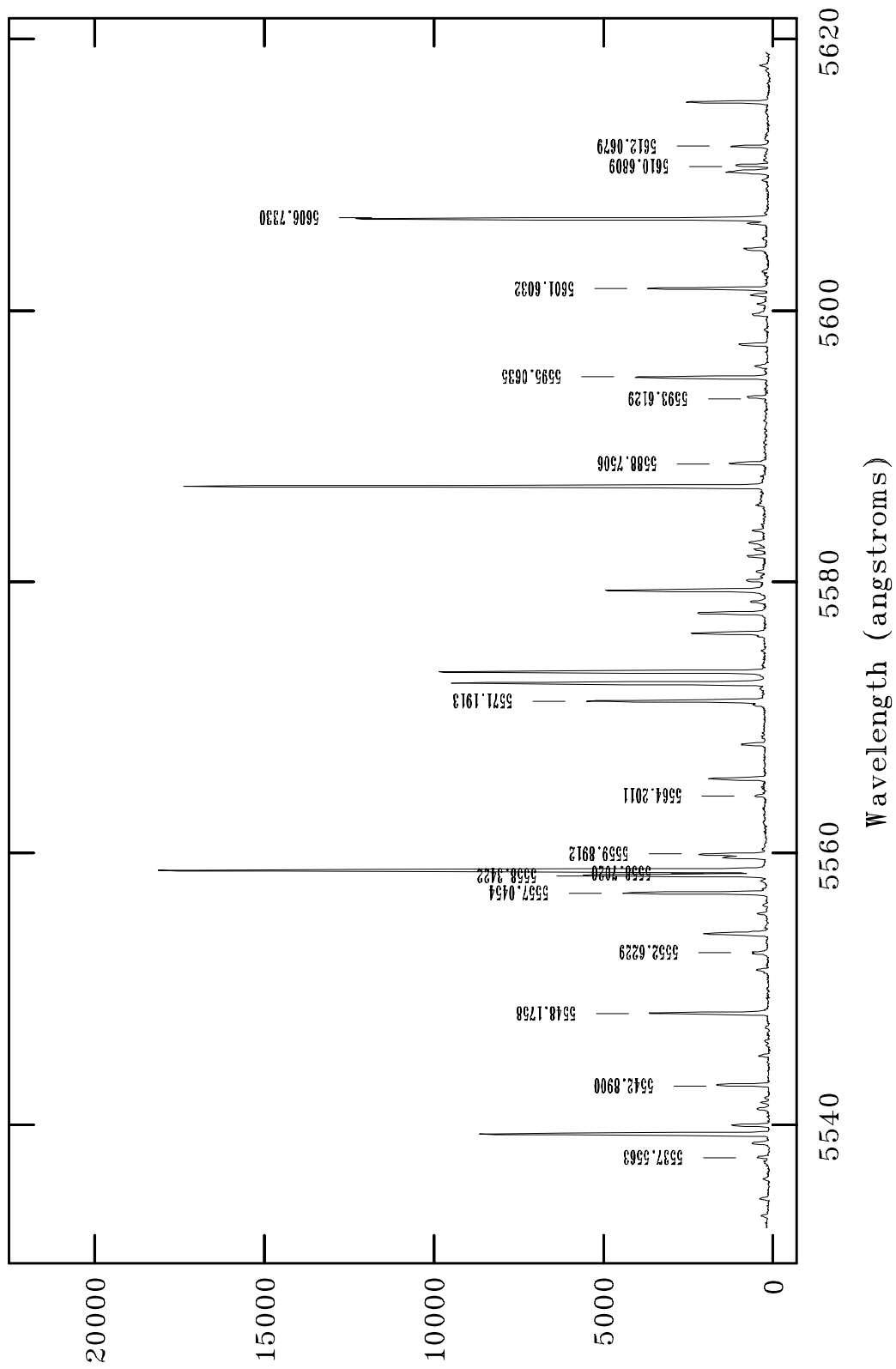
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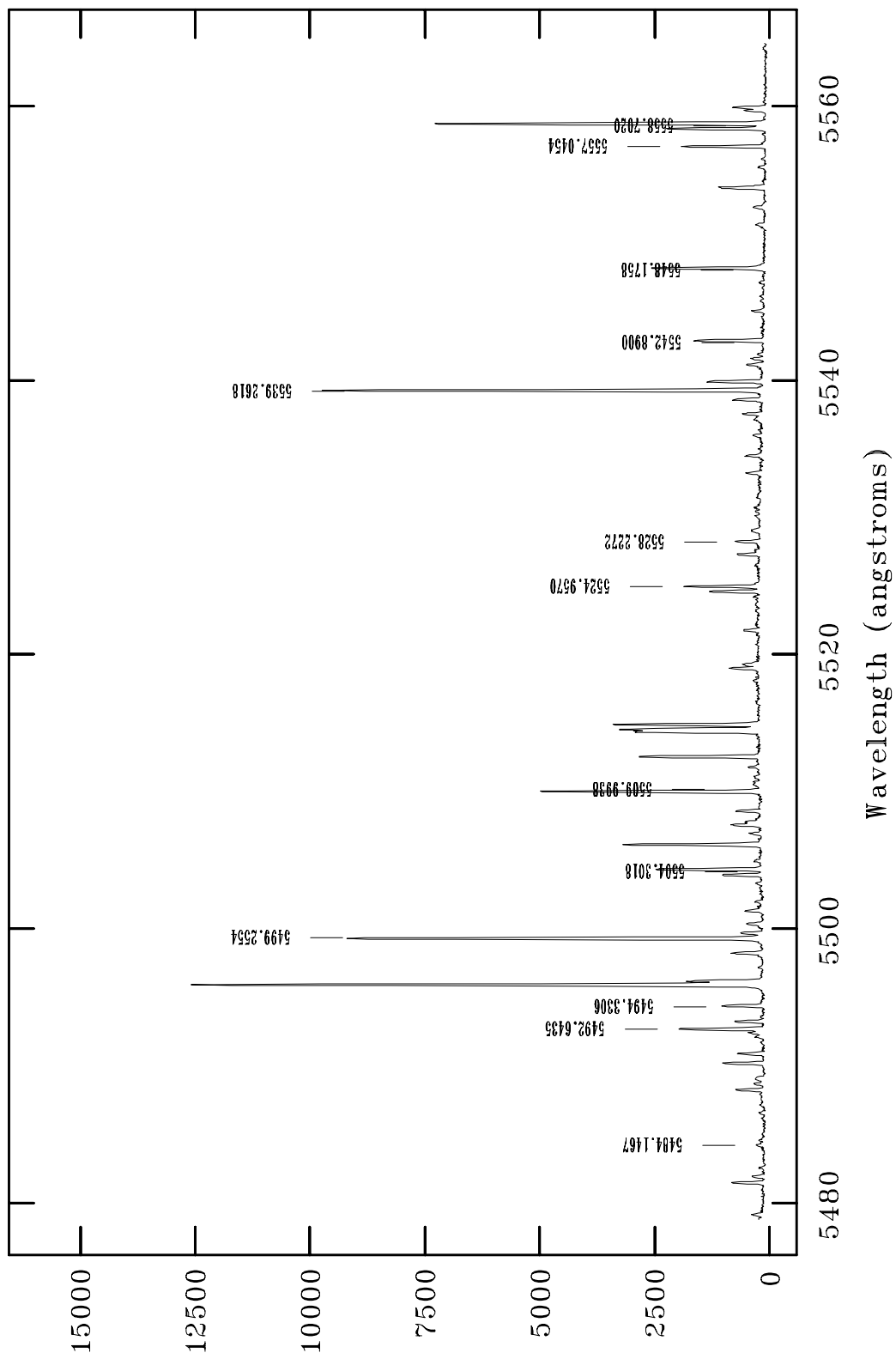
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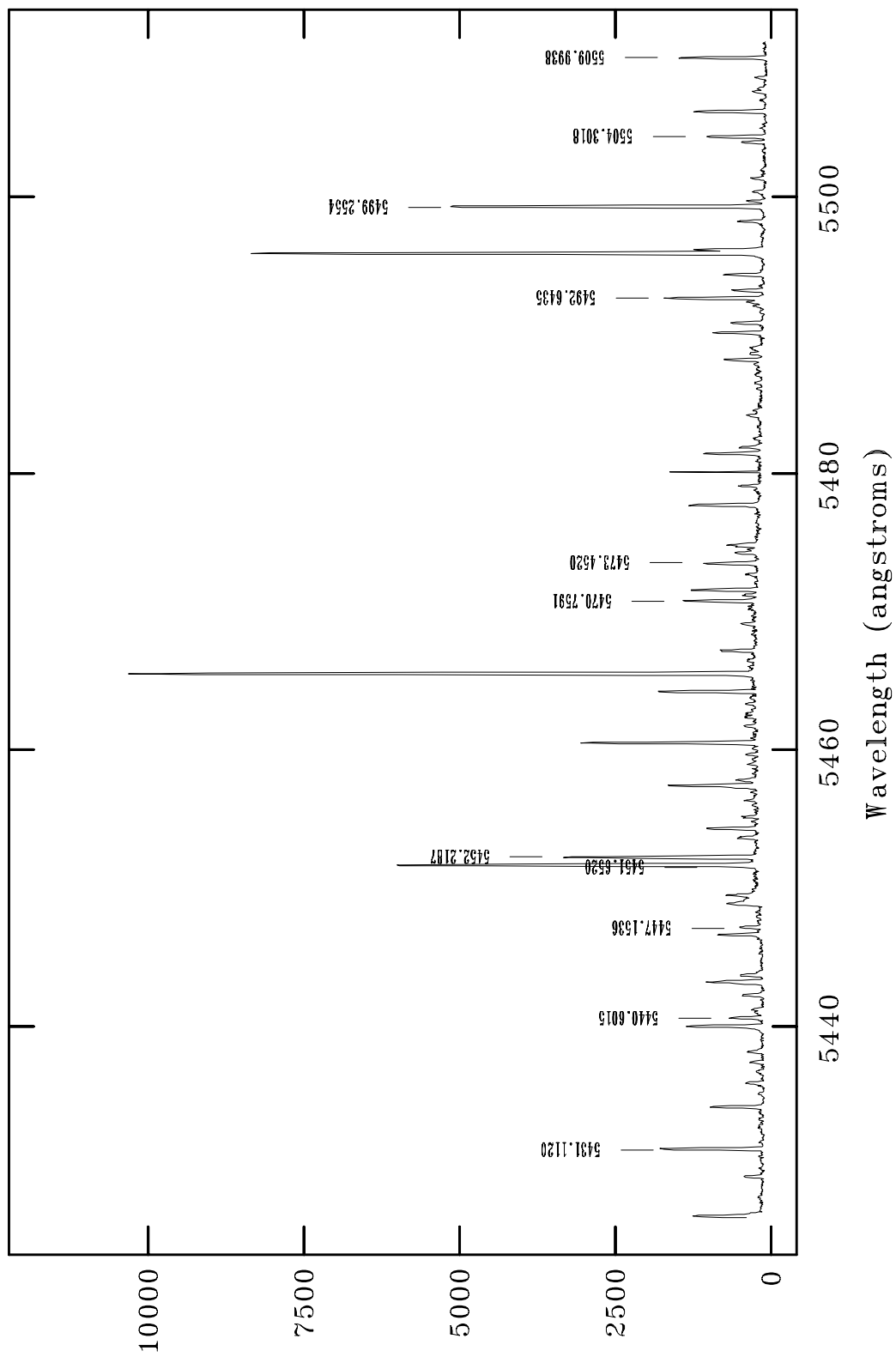
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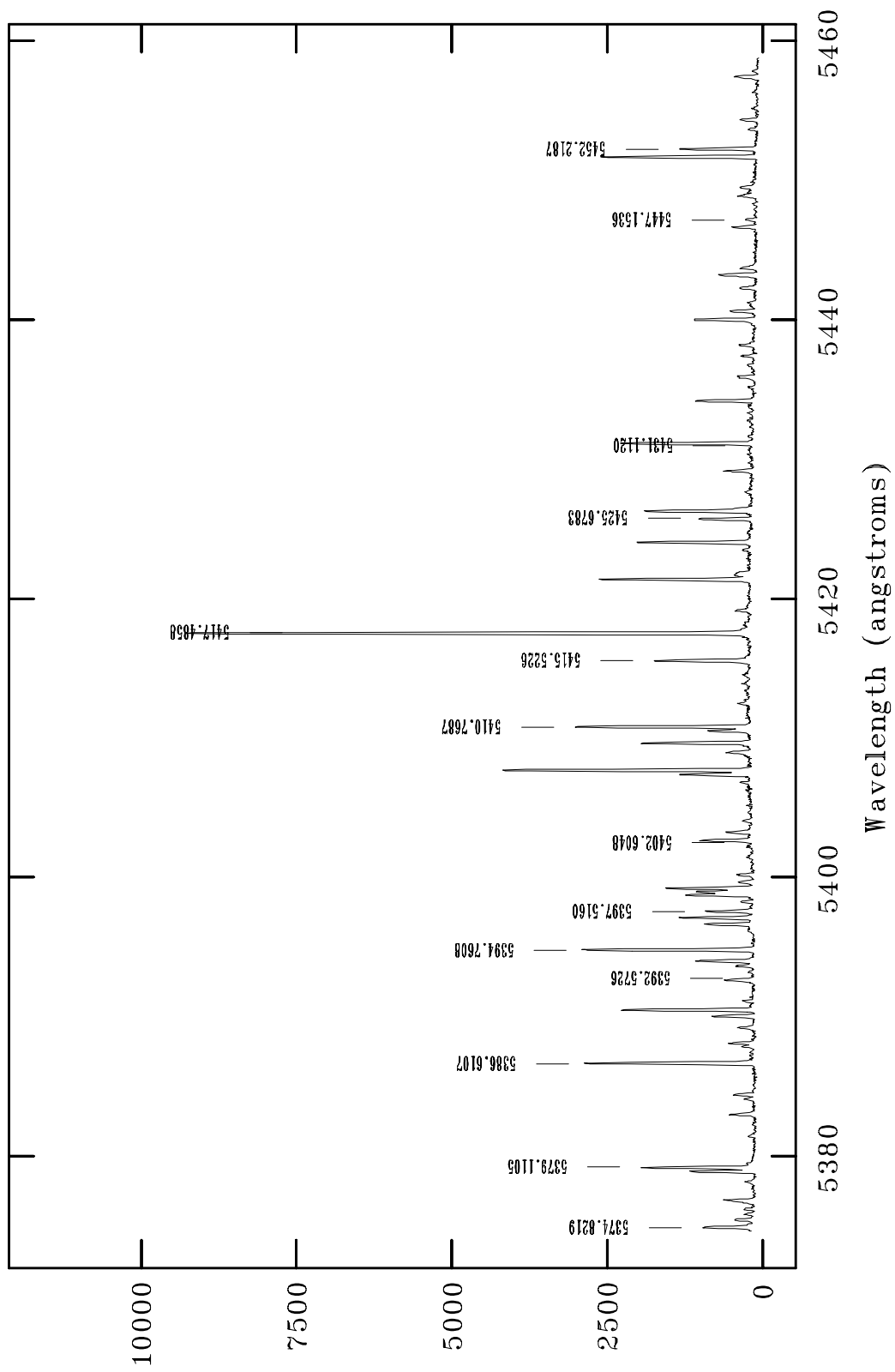
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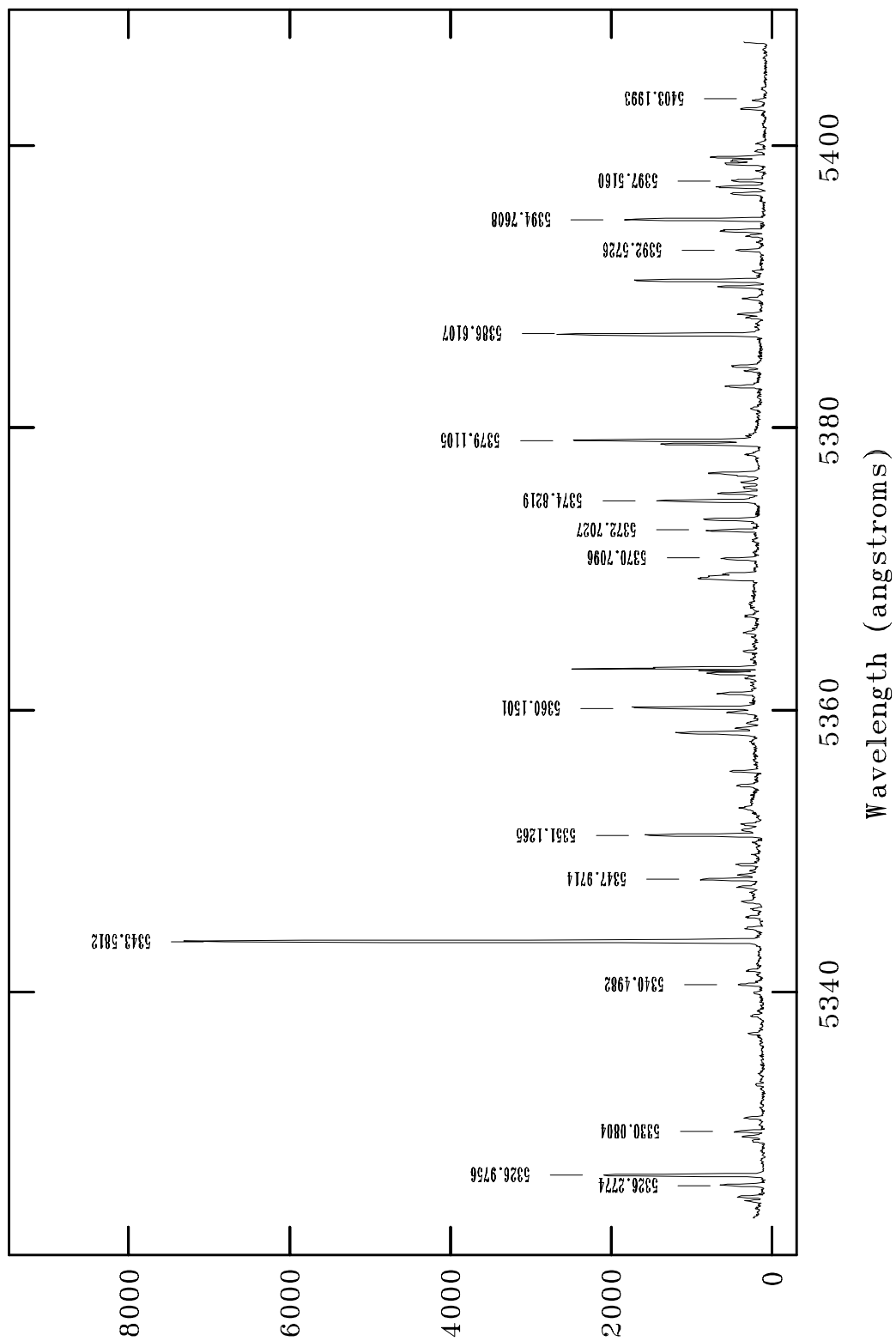
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ecidentify 22oct0043.ec: ThAr



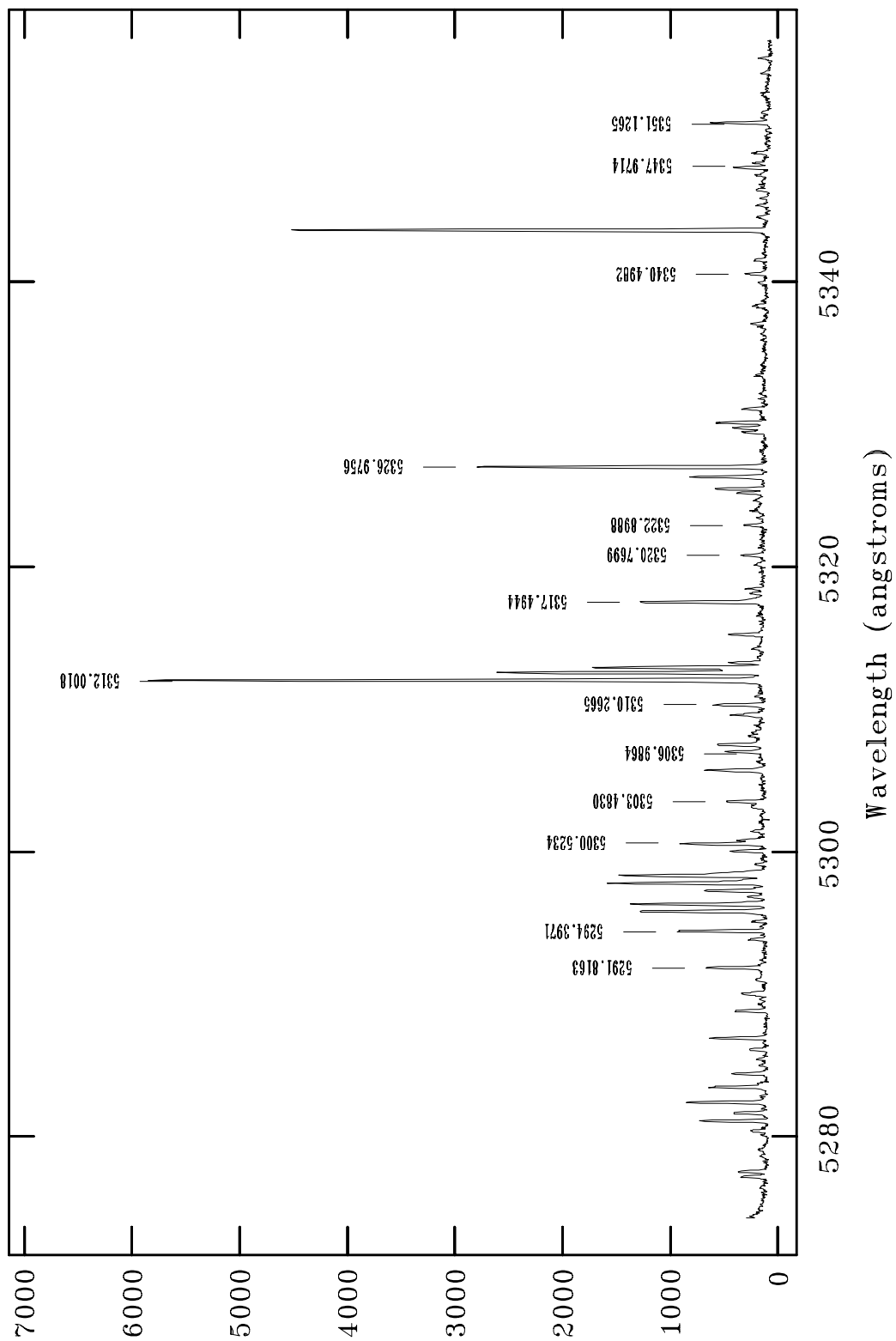
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:11:54 24-Nov-1999
Aperture 45, Image line 45, Order 105
ecidentify 22oct0043.ec: ThAr



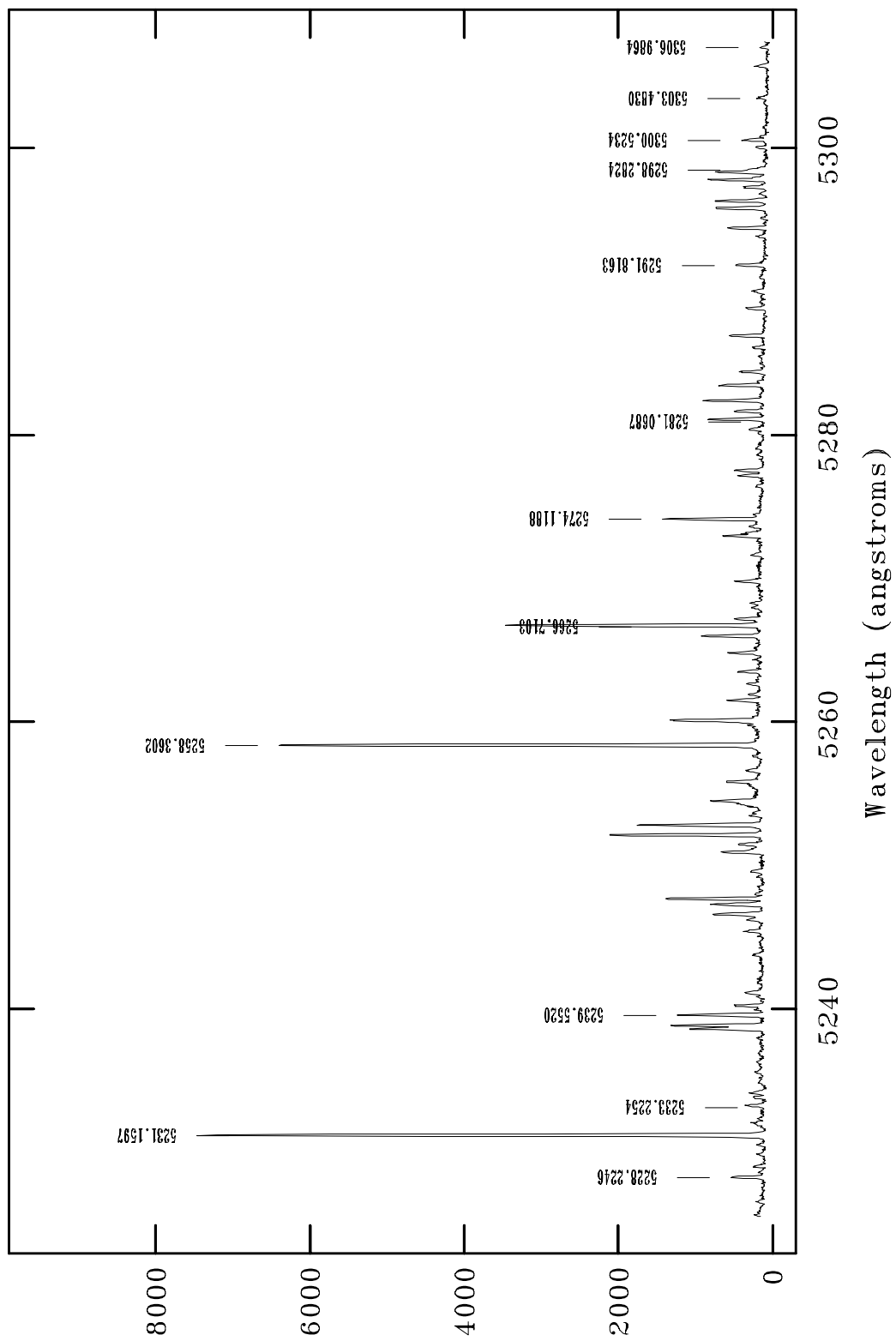
NOAO/IRAF V2.11.2EXPORT sdr@aaoepp2 Wed 11:12:17 24-Nov-1999
Aperture 46, Image line 46, Order 106
ecidentify 22oct0043.ec: ThAr



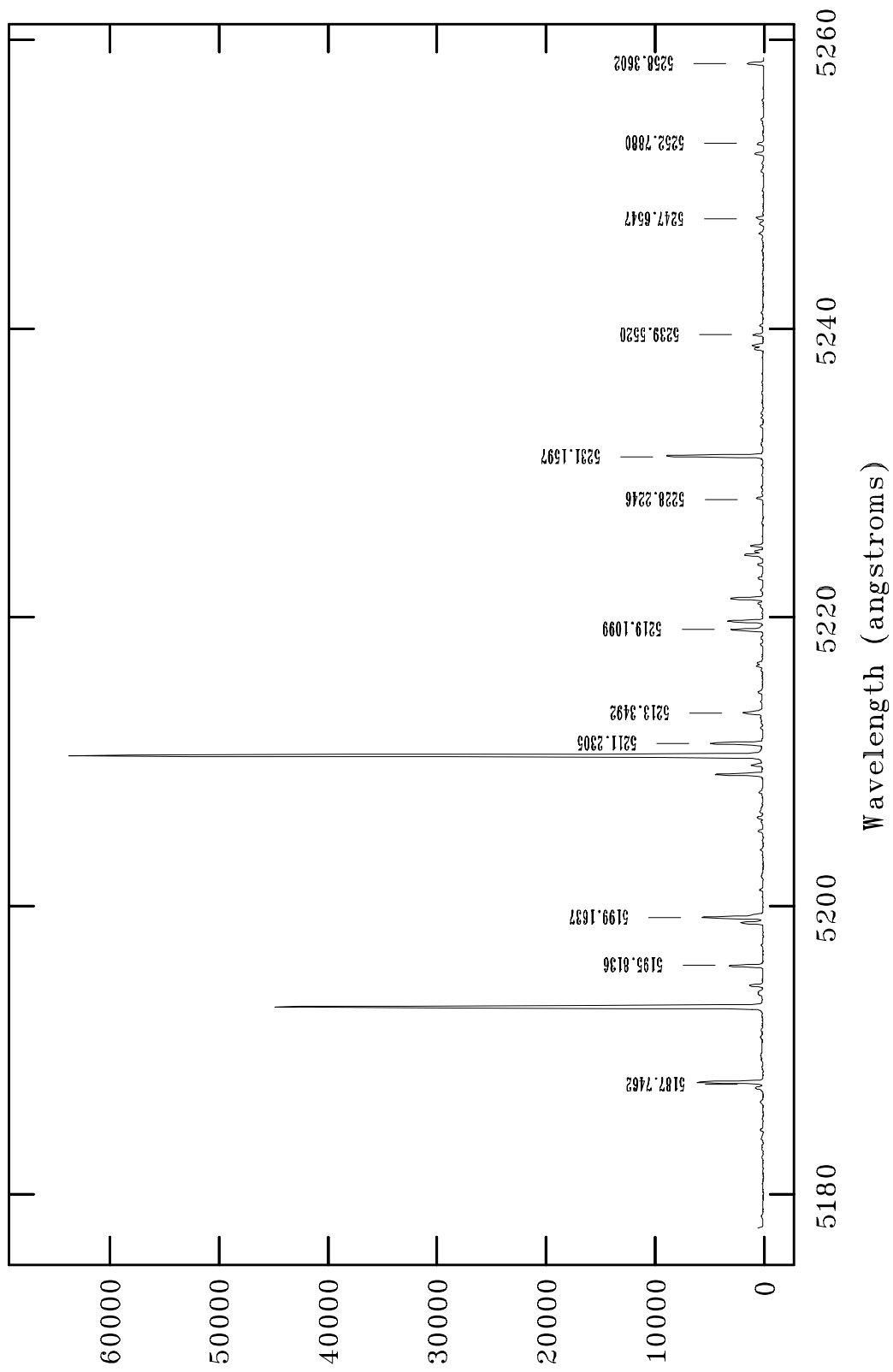
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:12:44 24-Nov-1999
Aperture 47, Image line 47, Order 107
ecidentify 22oct0043.ec: ThAr



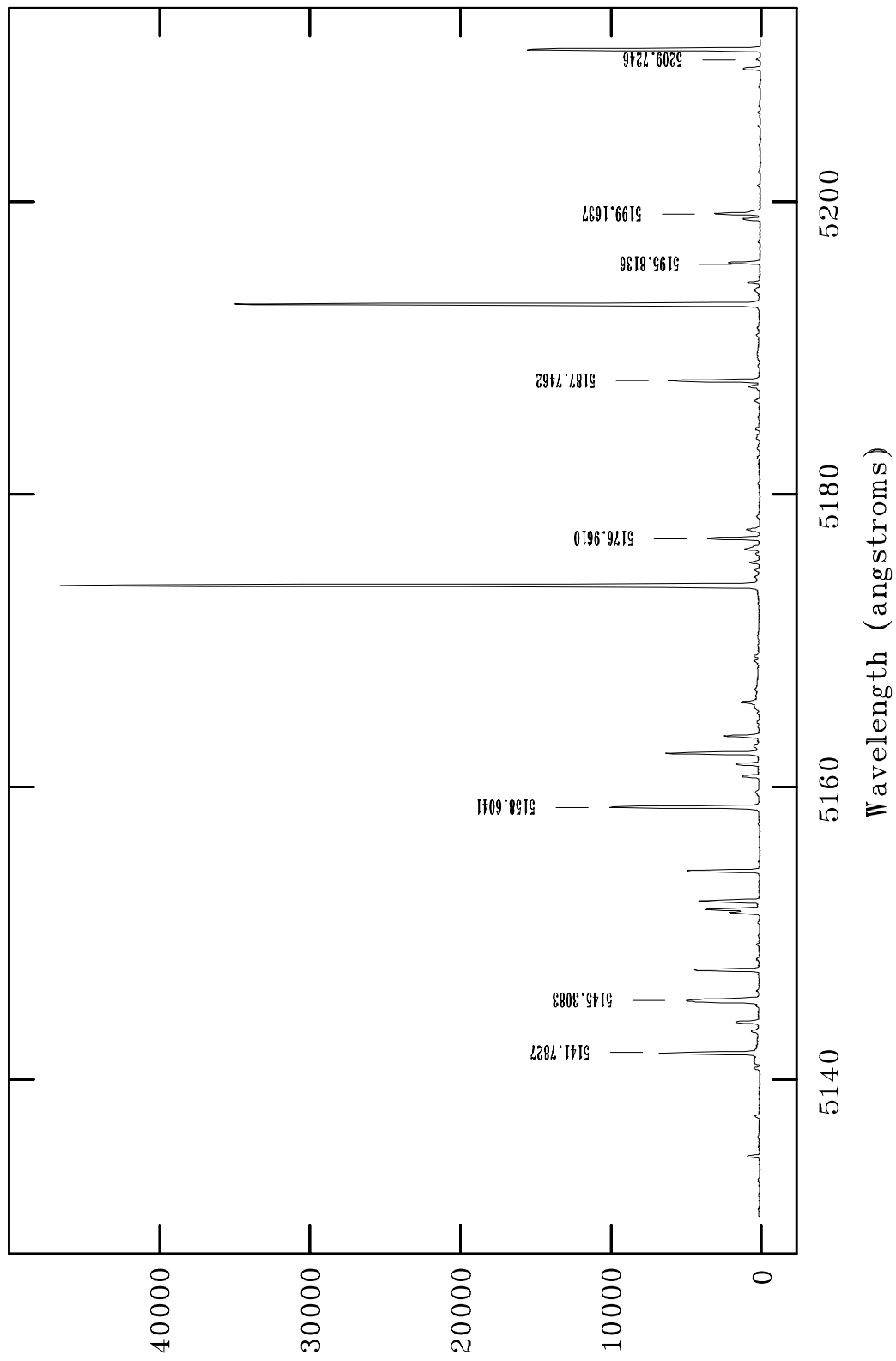
NOAO/IRAF V2.11.2EXPORT sdr@aoepp2 Wed 11:13:11 24-Nov-1999
Aperture 48, Image line 48, Order 108
ecidentify 22oct0043.ec: ThAr



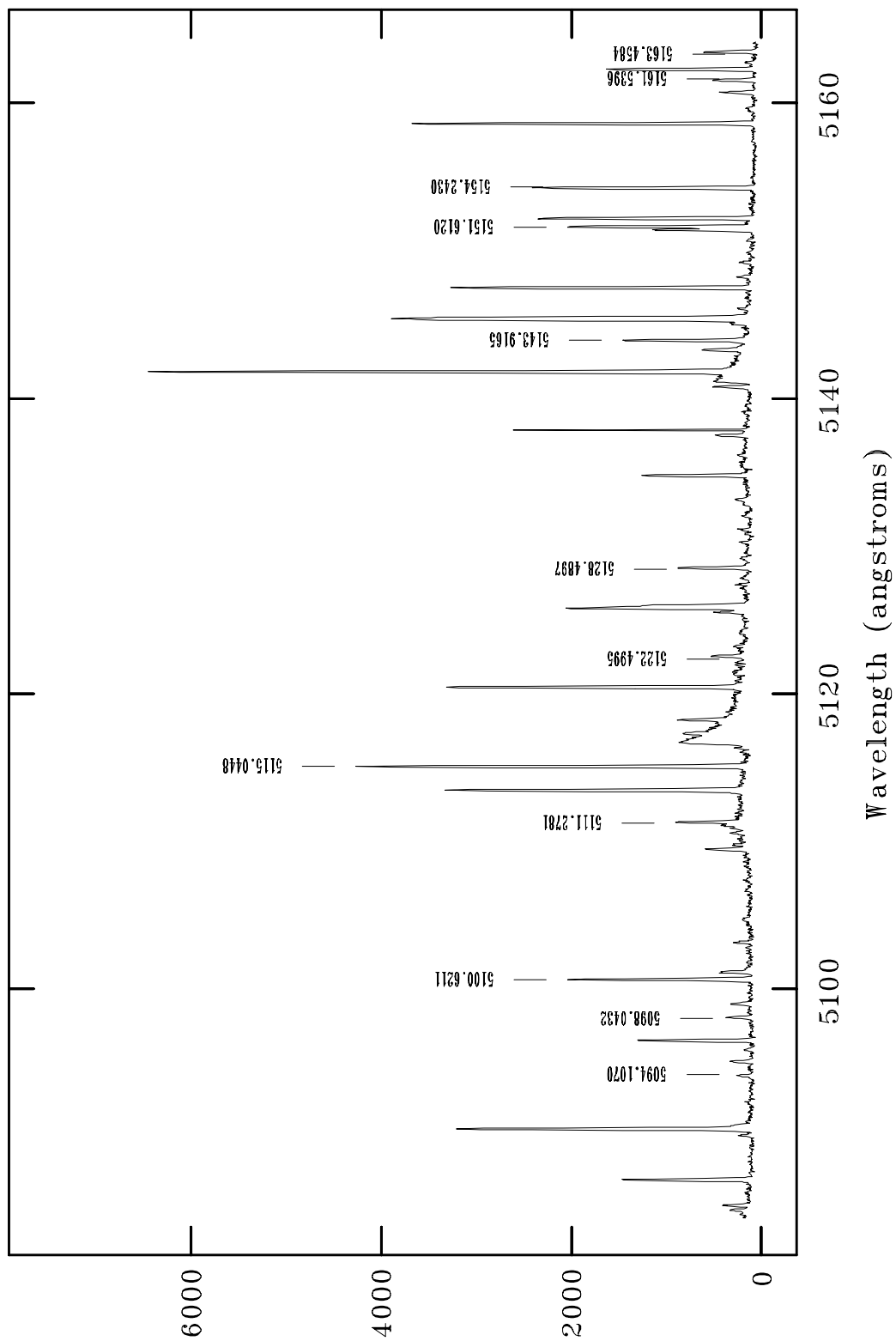
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:13:42 24-Nov-1999
Aperture 49, Image line 49, Order 109
ecidentify 22oct0043.ec: ThAr



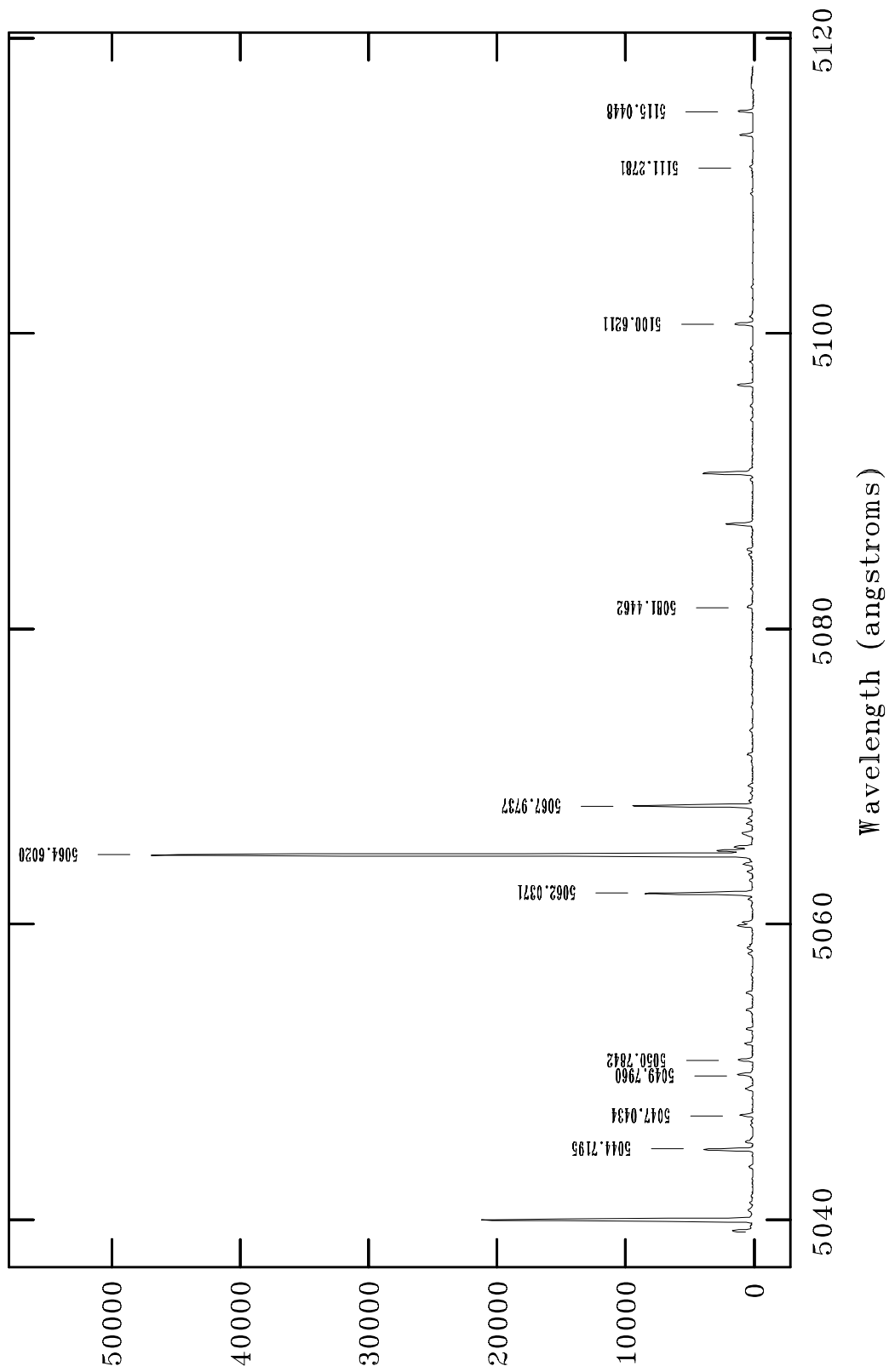
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:14:10 24-Nov-1999
Aperture 50, Image line 50, Order 110
ecidentify 22oct0043.ec: ThAr



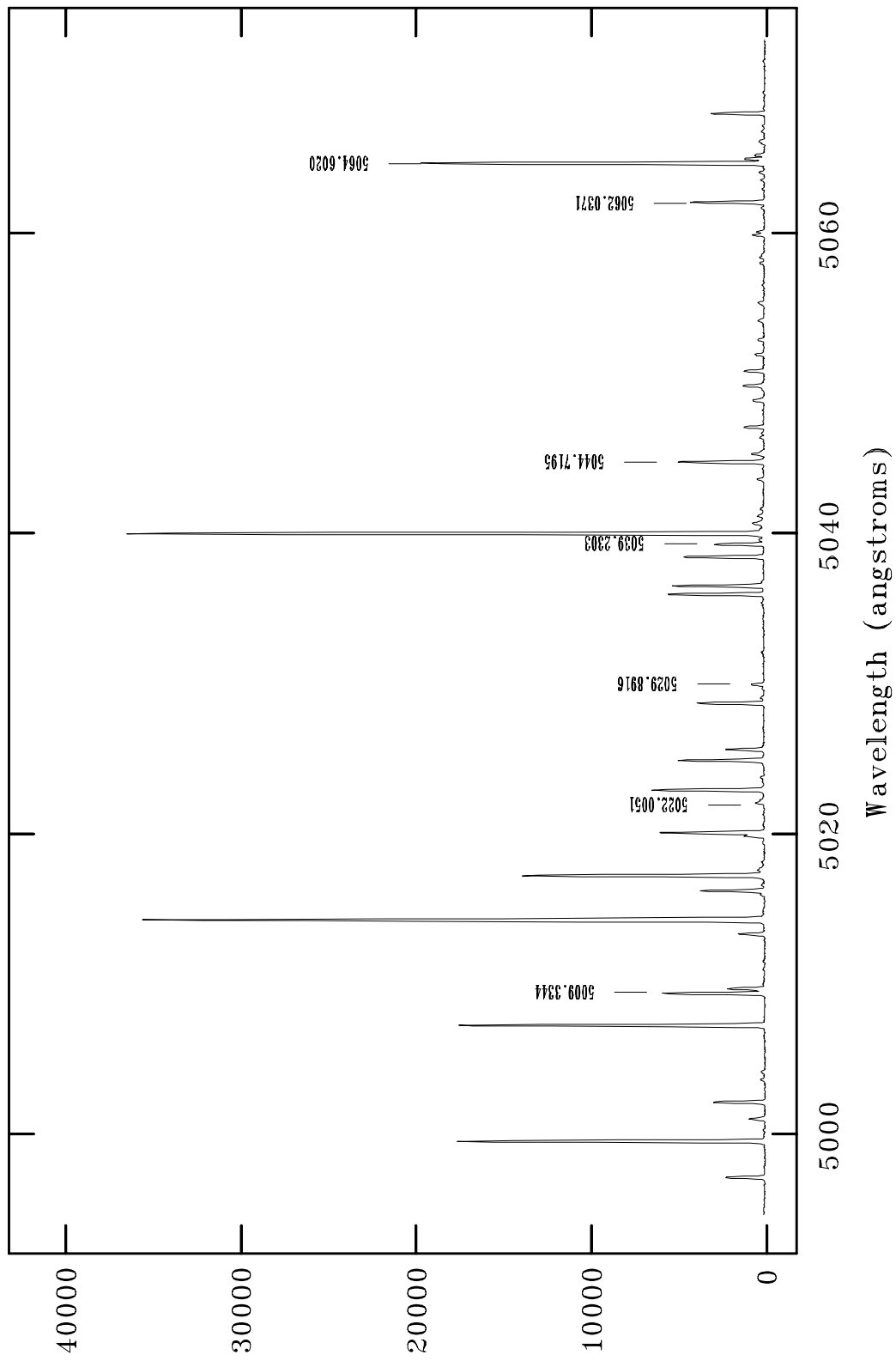
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:14:36 24-Nov-1999
Aperture 51, Image line 51, Order 111
ecidentify 22oct0043.ec: ThAr



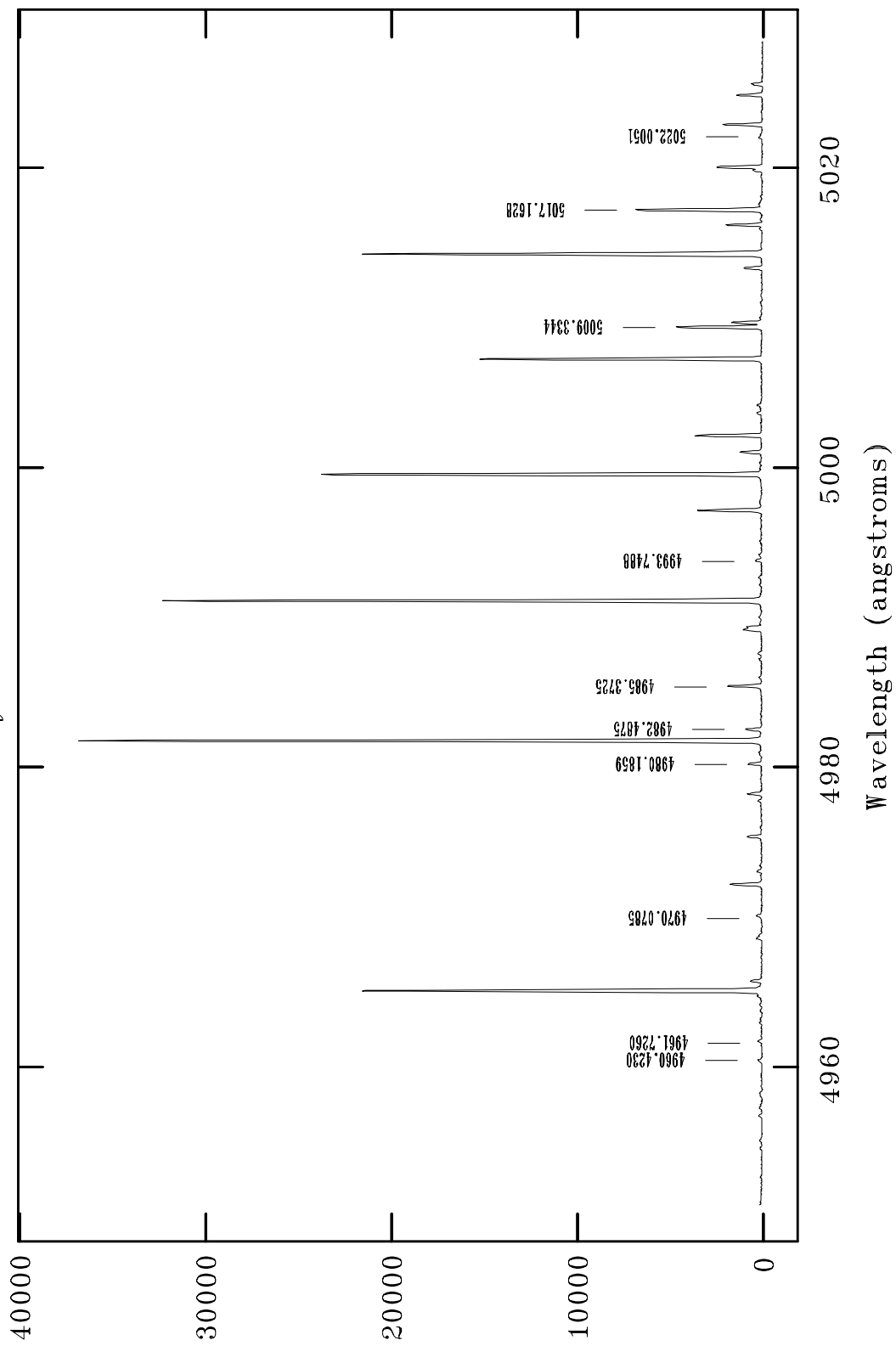
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:15:06 24-Nov-1999
Aperture 52, Image line 52, Order 112
ecidentify 22oct0043.ec: ThAr



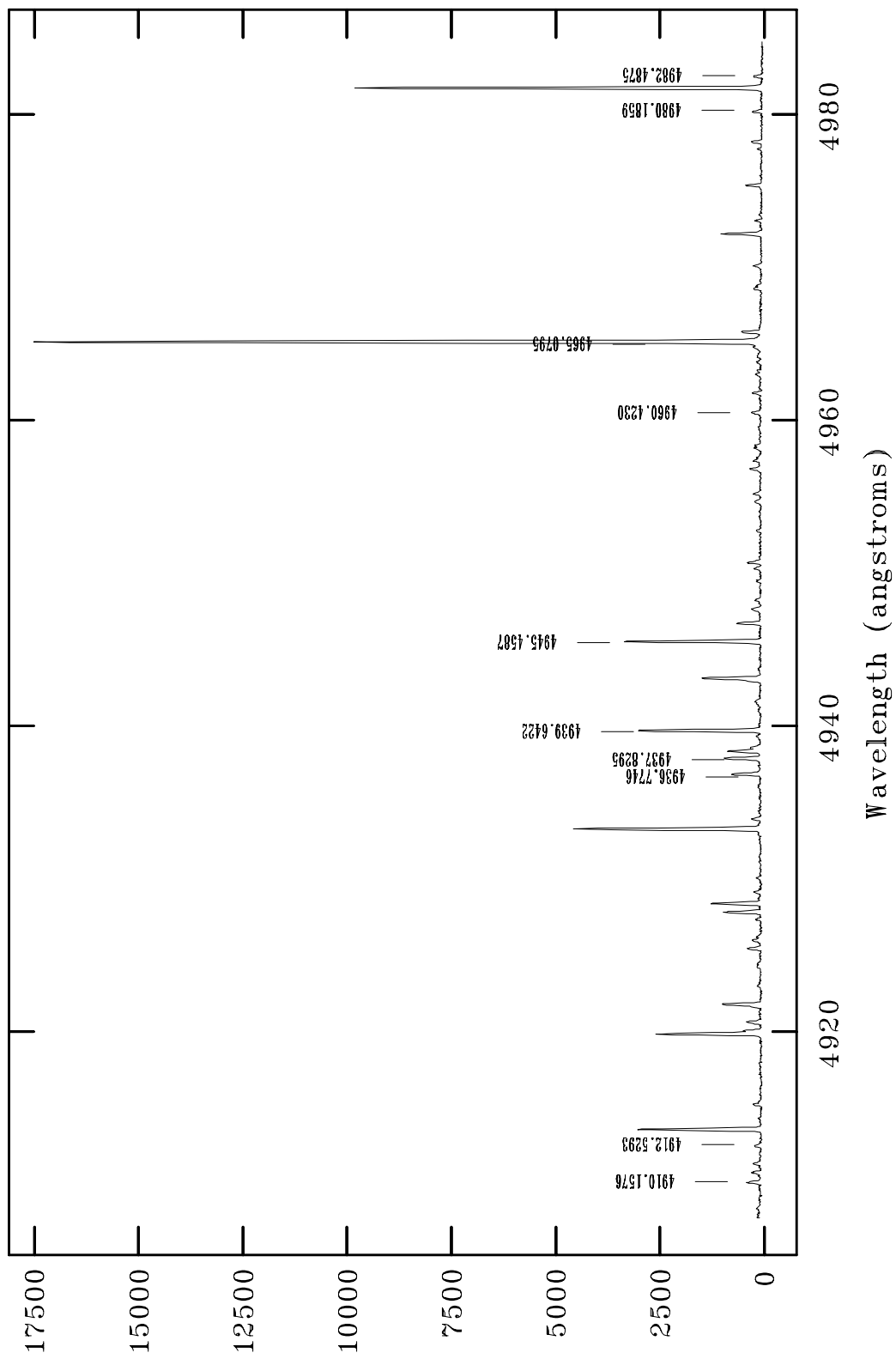
NOAO/IRAF V2.11.2EXPORT sdr@aaoepp2 Wed 11:15:34 24-Nov-1999
Aperture 53, Image line 53, Order 113
ecidentify 22oct0043.ec: ThAr



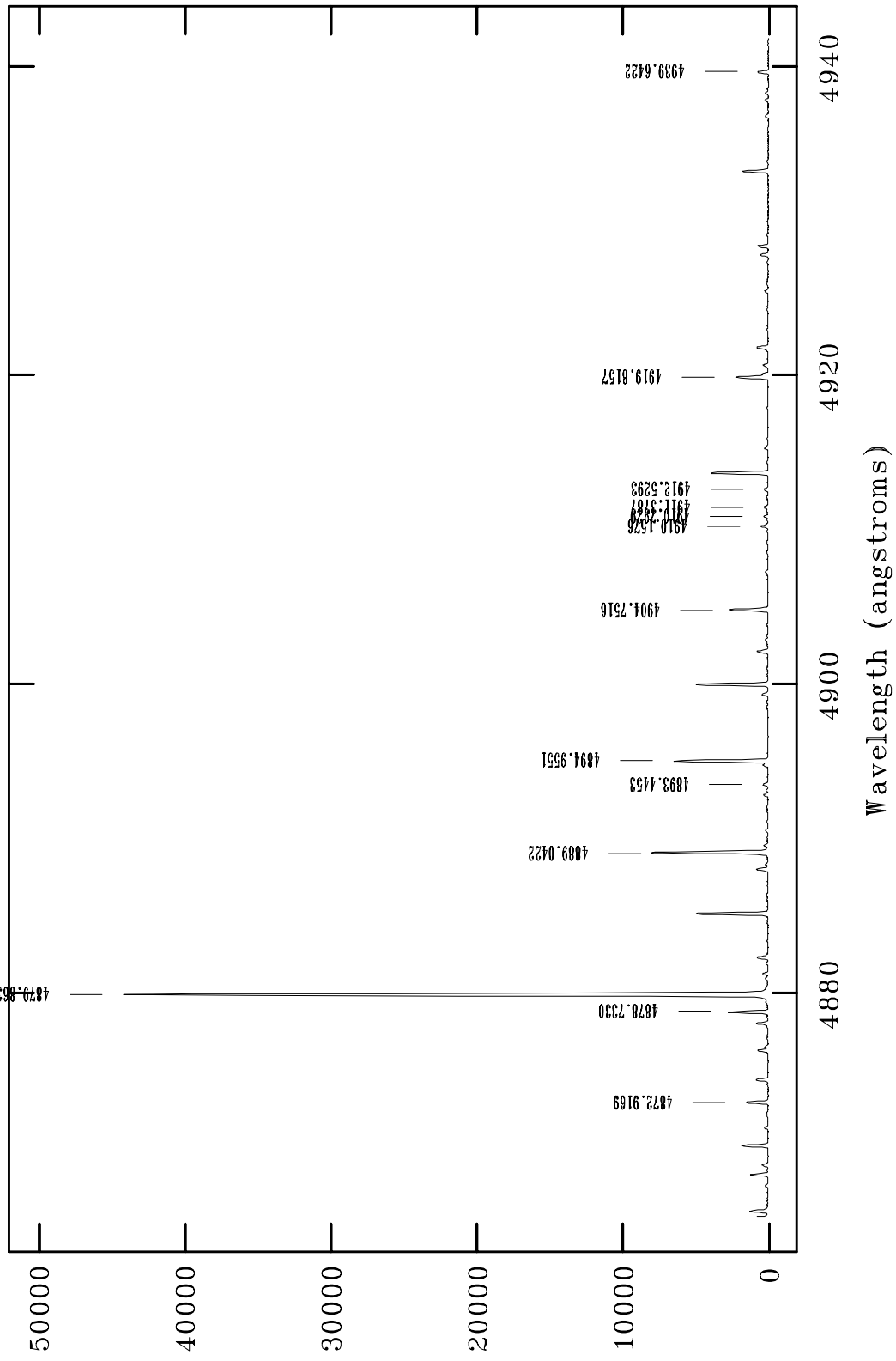
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:15:59 24-Nov-1999
Aperture 54, Image line 54, Order 114
ecidentify 22oct0043.ec: ThAr



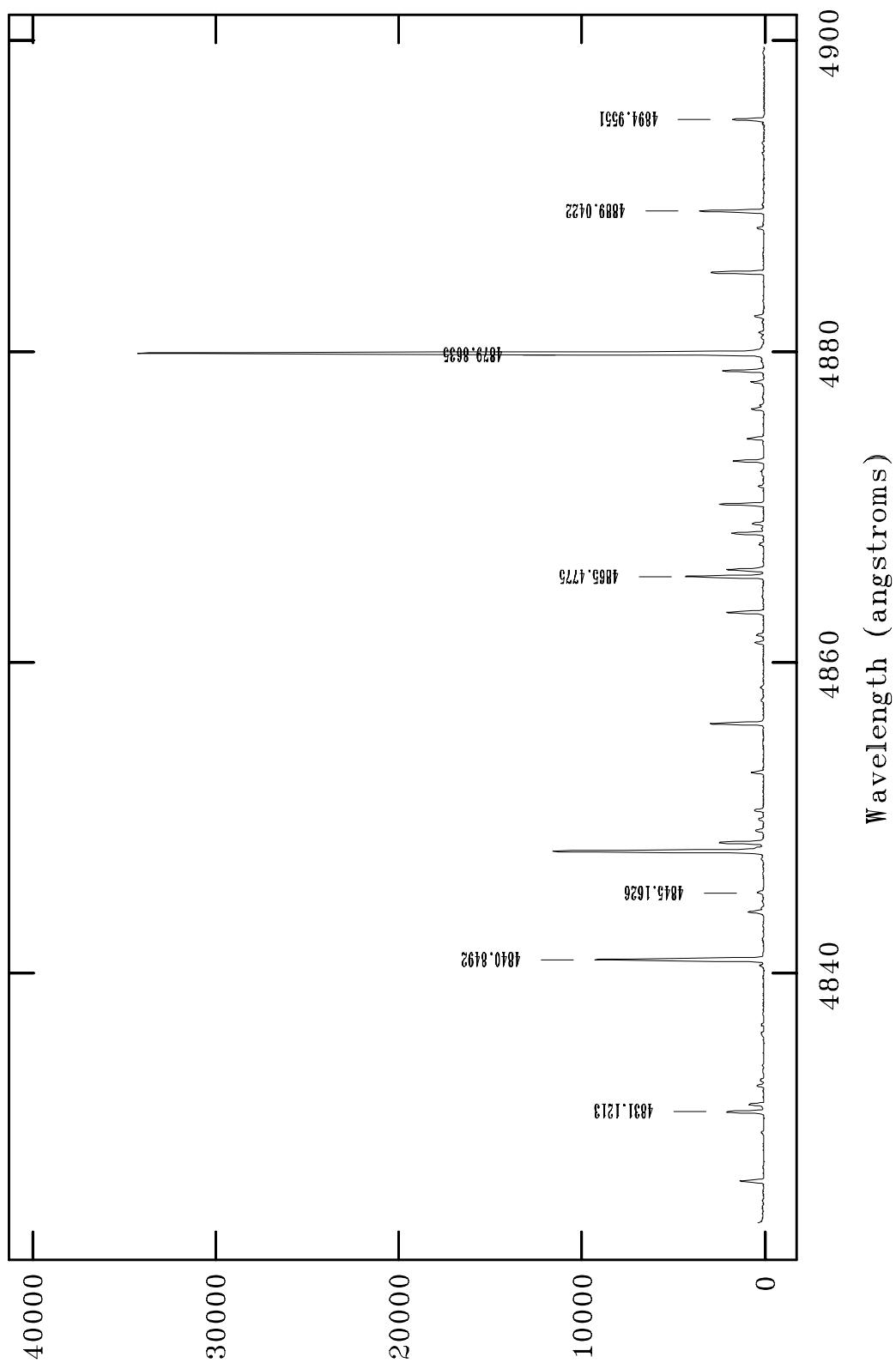
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 11:16:22 24-Nov-1999
Aperture 55, Image line 55, Order 115
ecidentify 22oct0043.ec: ThAr



NOAO/IRAF V2.11.2EXPORT sdr@aaoepp2 Wed 11:16:51 24-Nov-1999
Aperture 56, Image line 56, Order 116
ecidentify 22oct0043.ec: ThAr



NOAO/IRAF V2.11.2EXPORT sdr@aaoepp2 Wed 11:17:21 24-Nov-1999
Aperture 57, Image line 57, Order 117
ecidentify 22oct0043.ec: ThAr



Order	λ range (Å)	Order	λ range (Å)
123	4581–4653	142	3969–4031
124	4544–4616	143	3941–4003
125	4508–4578	144	3914–3976
126	4472–4542	145	3887–3949
127	4437–4507	146	3861–3921
128	4402–4472	147	3834–3894
129	4368–4438	148	3808–3868
130	4335–4402	149	3783–3843
131	4302–4369	150	3758–3818
132	4269–4336	151	3733–3793
133	4237–4304	152	3708–3768
134	4206–4273	153	3684–3741
135	4175–4240	154	3660–3717
136	4144–4209	155	3636–3693
137	4114–4179	156	3613–3670
138	4084–4149	157	3590–3647
139	4055–4120	158	3567–3624
140	4026–4088	159	3544–3599
141	3997–4059	160	3522–3577

Table 2: List of order numbers captured by the blue wavelength setting, and the respective wavelength ranges shown in the plots.

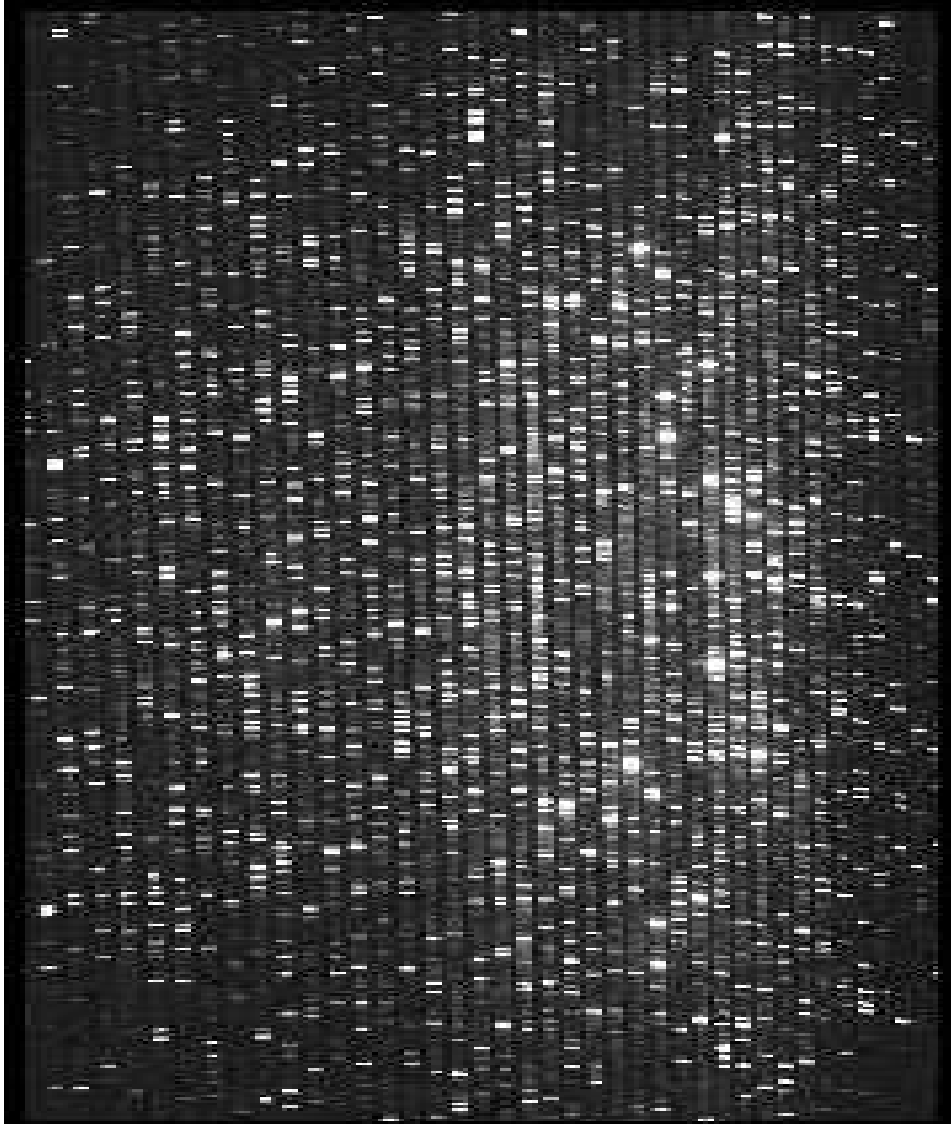
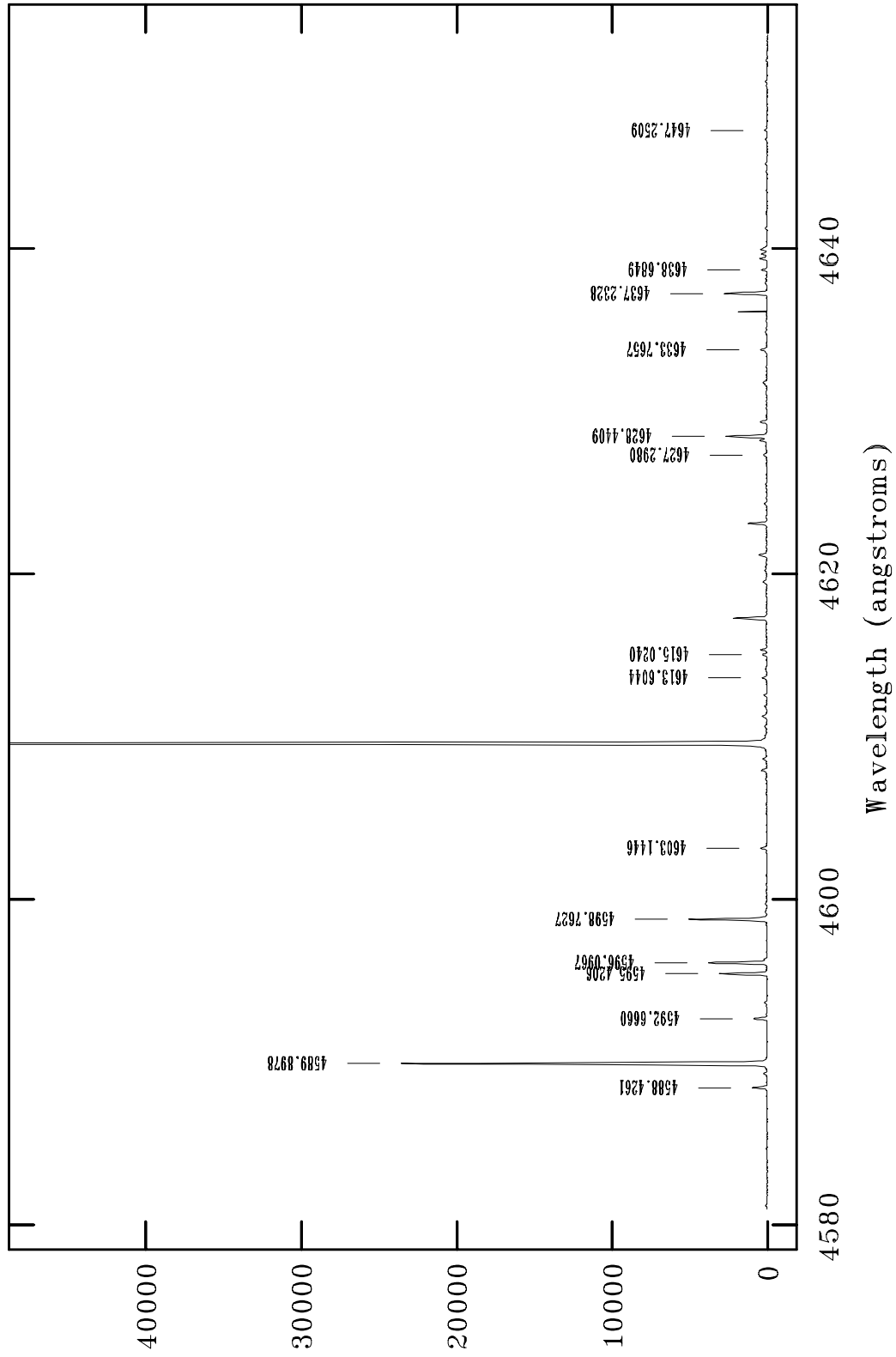
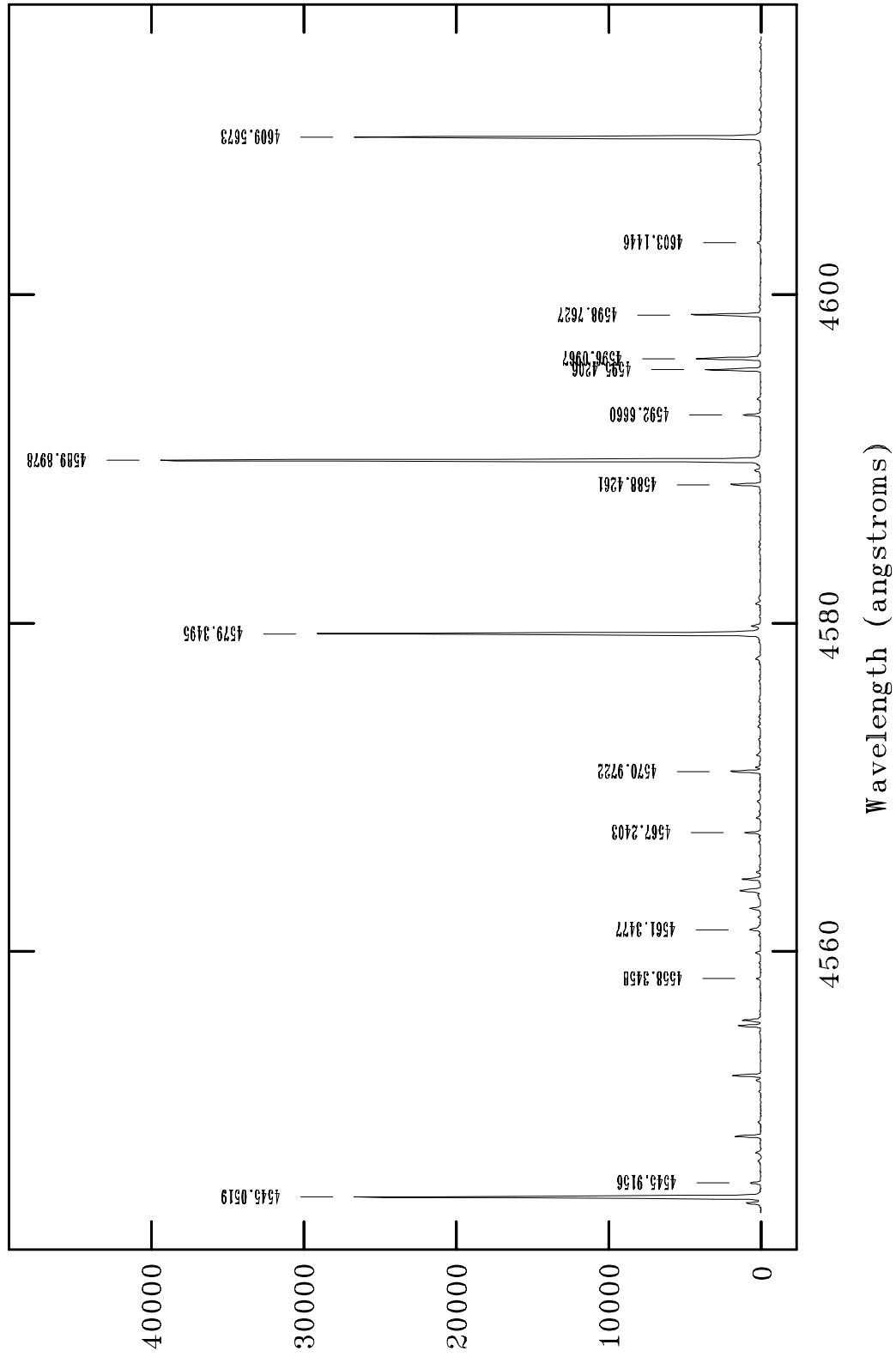


Figure 2: Raw XMEM display (stretched by a factor of 2 in the x direction) when the grating is set to 3946.0 Å. The leftmost order which does not run off the edge of this image is order 160; the rightmost complete order is 123.

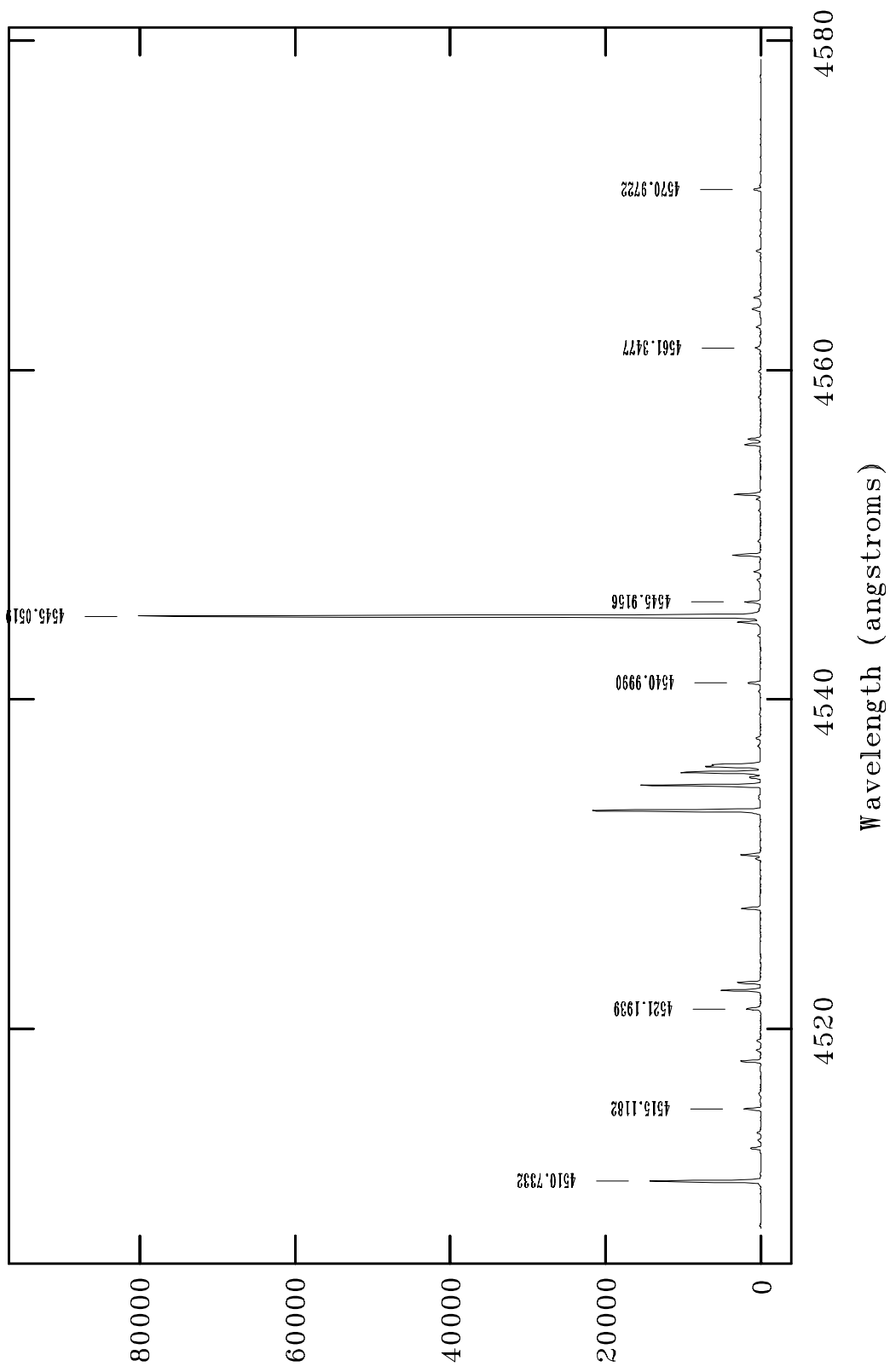
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:14:48 24-Nov-1999
Aperture 1, Image line 1, Order 123
ecidentify 22oct0055.ec: ThAr



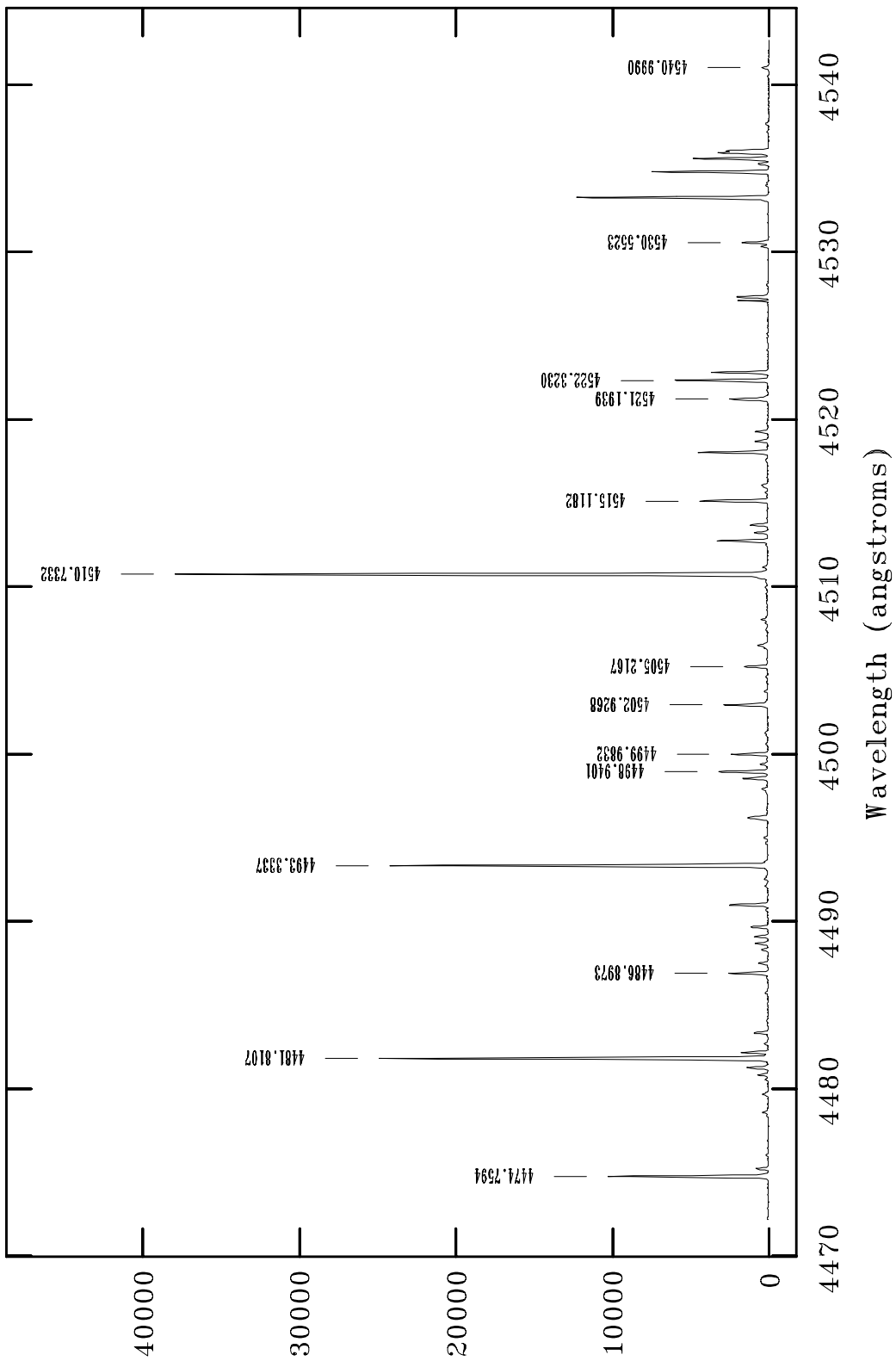
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:15:55 24-Nov-1999
Aperture 2, Image line 2, Order 124
ecidentify 22oct0055.ec: ThAr



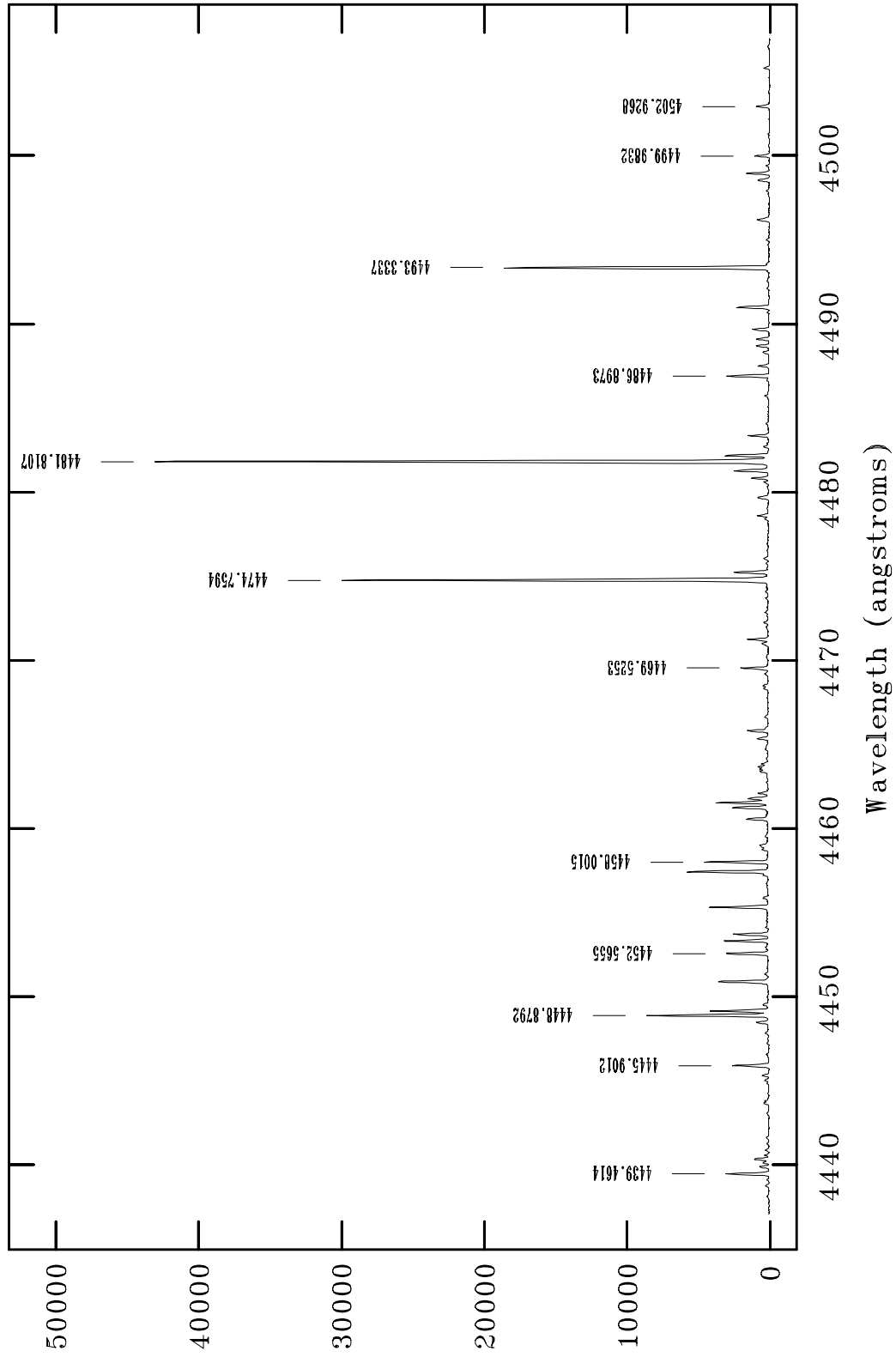
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:16:35 24-Nov-1999
Aperture 3, Image line 3, Order 125
ecidentify 22oct0055.ec: ThAr



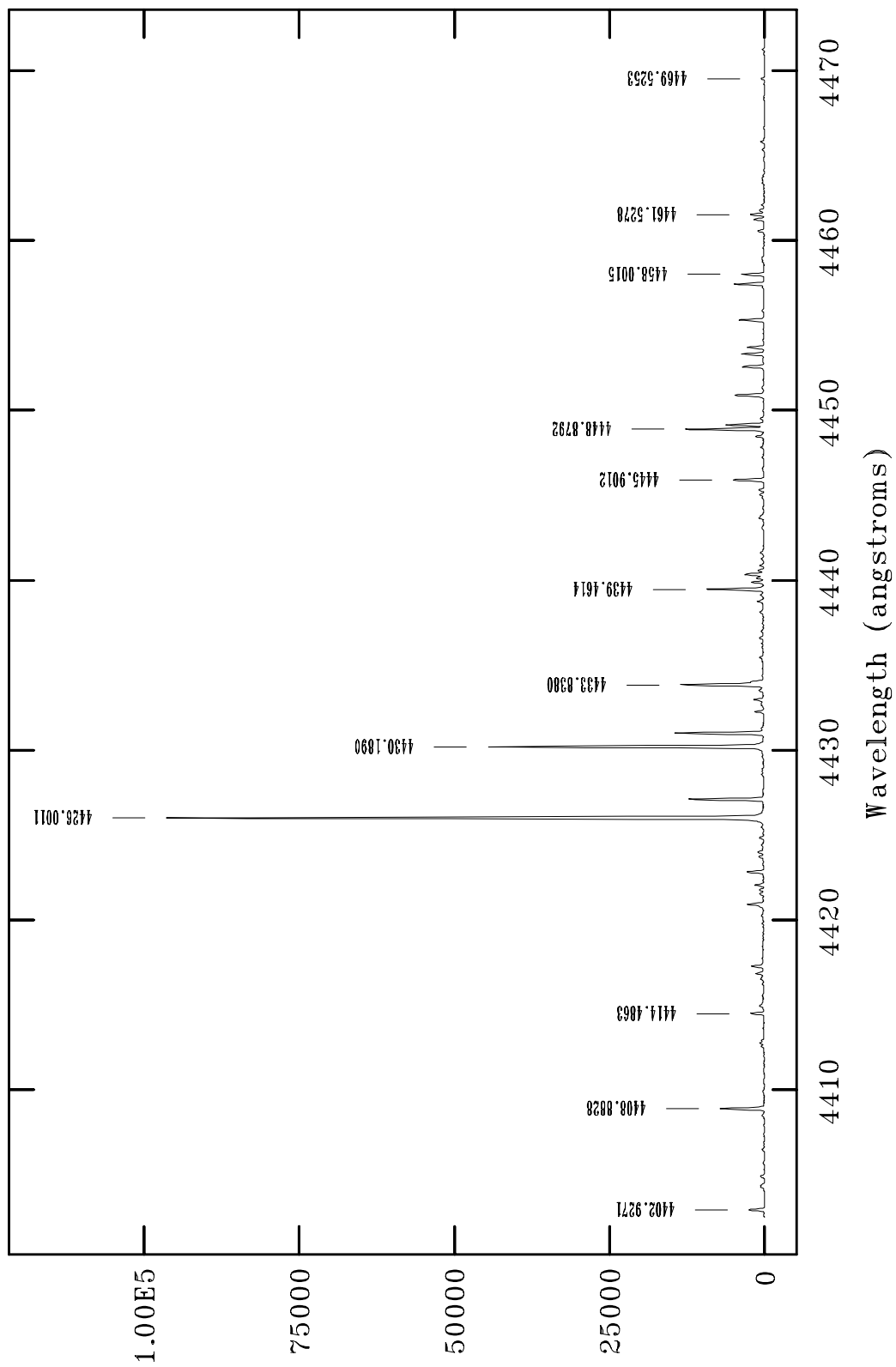
NOAO/IRAF V2.11.2EXPORT sdr@aaopepp2 Wed 15:17:05 24-Nov-1999
Aperture 4, Image line 4, Order 126
ecidentify 22oct0055.ec: ThAr



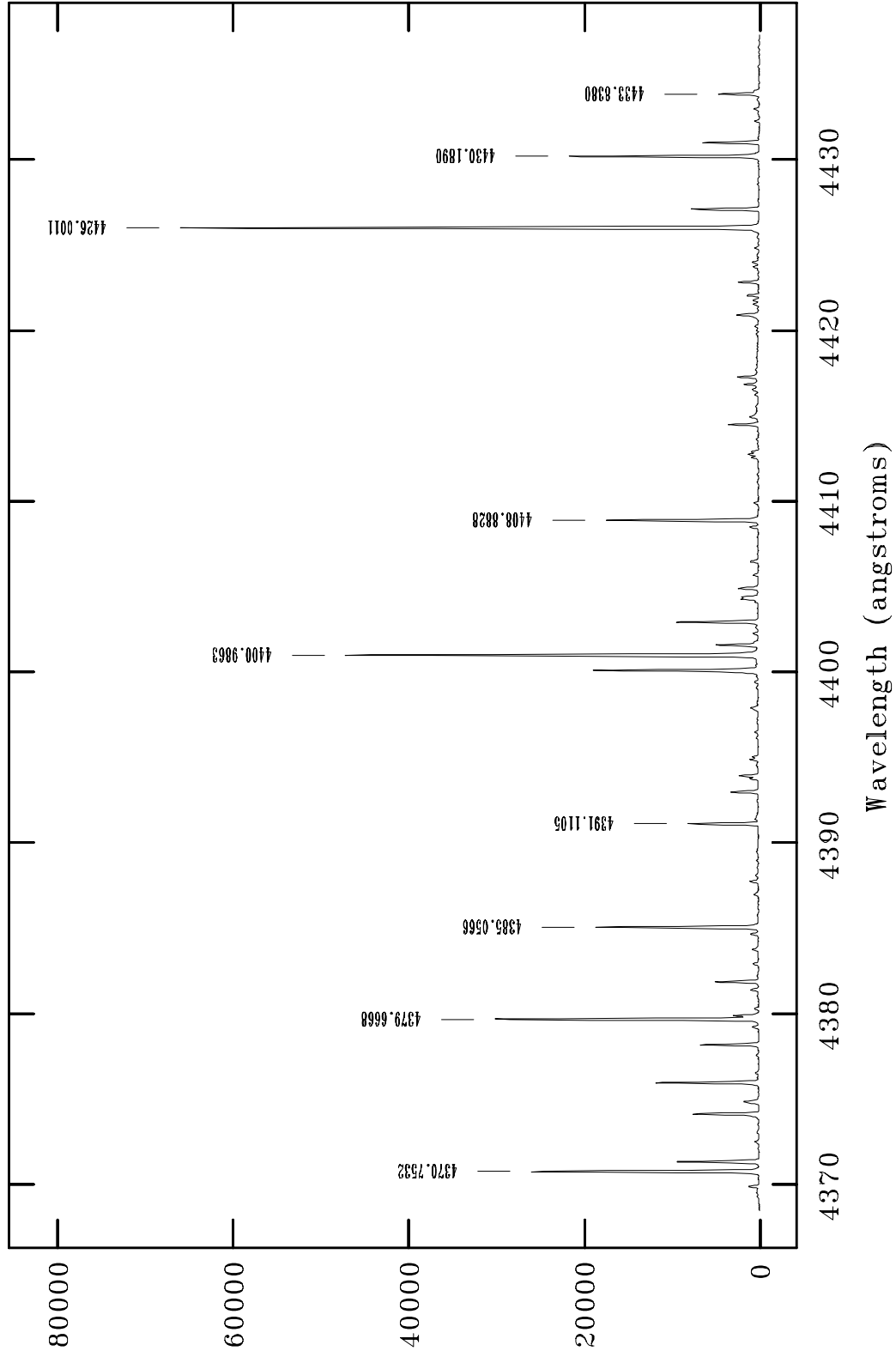
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:17:36 24-Nov-1999
Aperture 5, Image line 5, Order 127
ecidentify 22oct0055.ec: ThAr



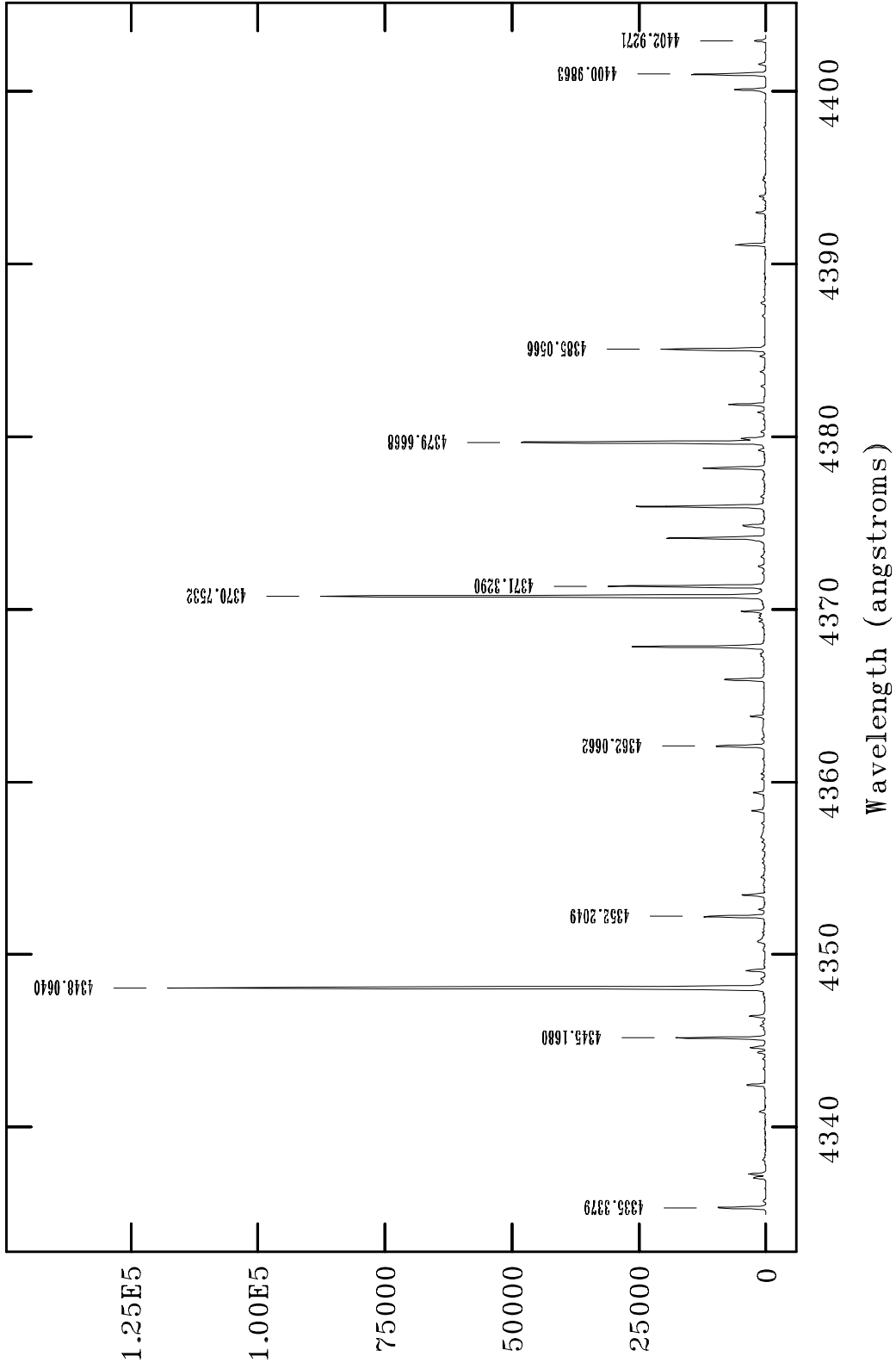
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:18:13 24-Nov-1999
Aperture 6, Image line 6, Order 128
identify 22oct0055.ec: ThAr



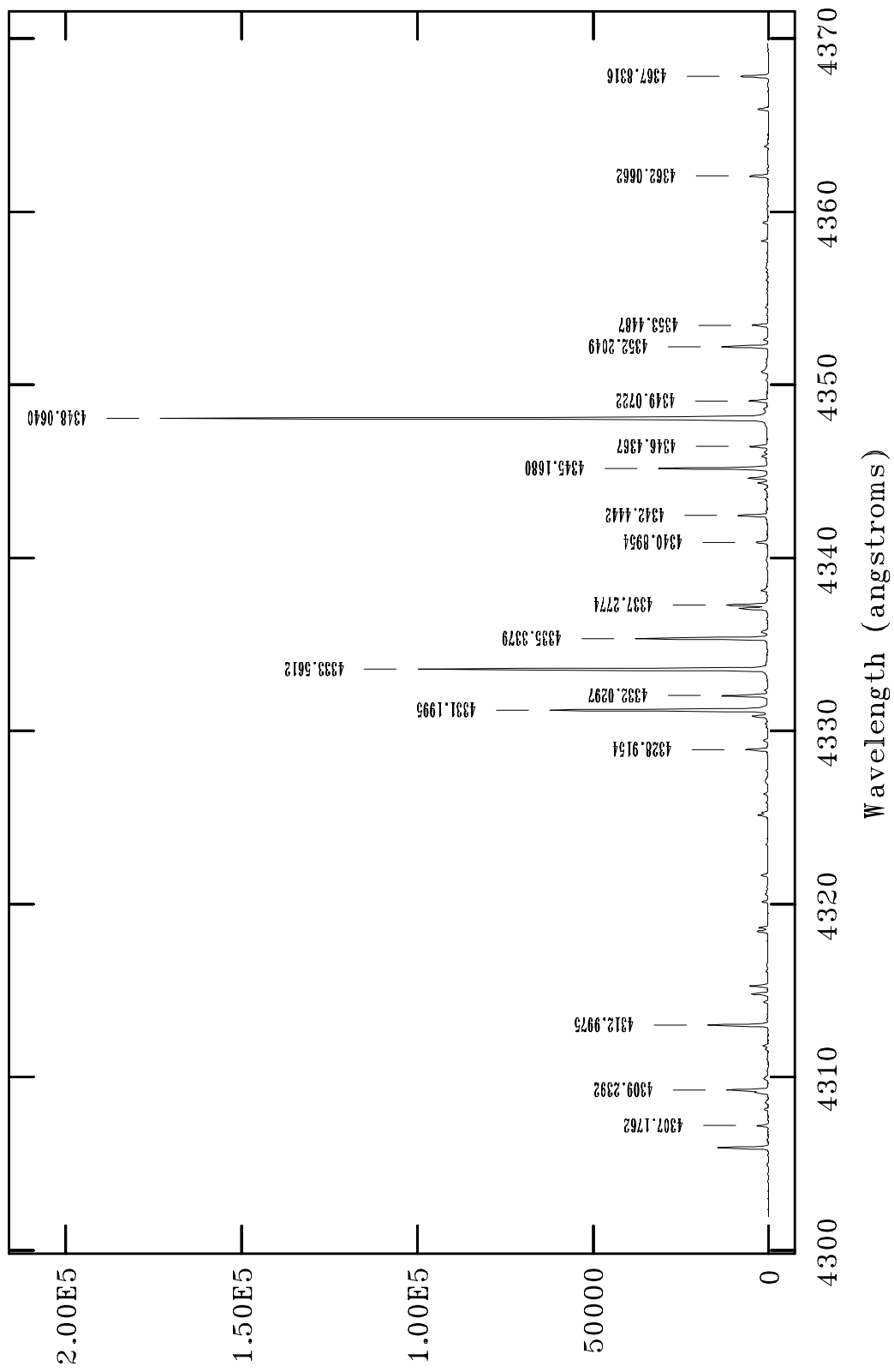
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:18:37 24-Nov-1999
Aperture 7, Image line 7, Order 129
ecidentify 22oct0055.ec: ThAr



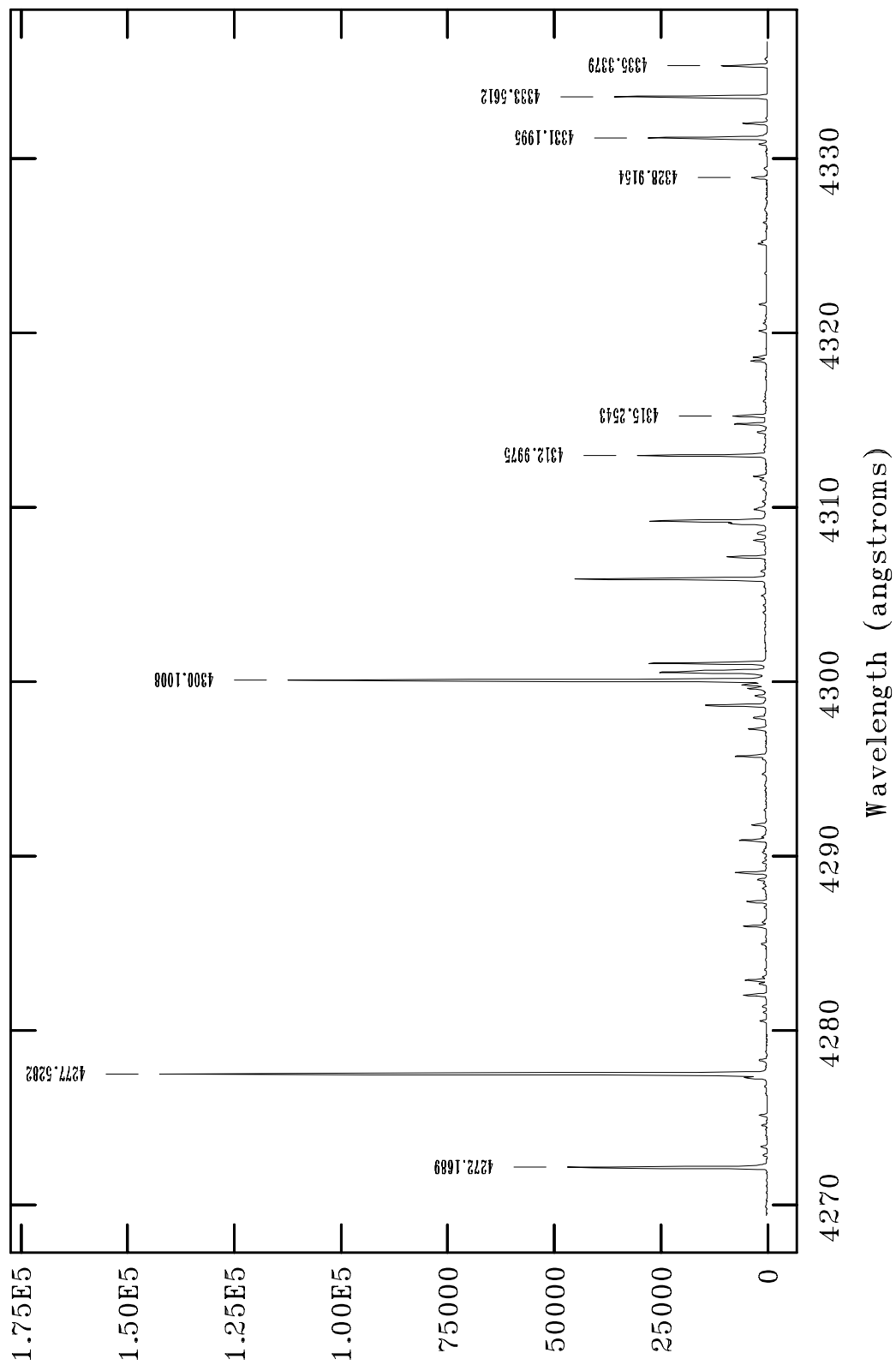
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:19:08 24-Nov-1999
Aperture 8, Image line 8, Order 130
ecidntify 22oct0055.ec: ThAr



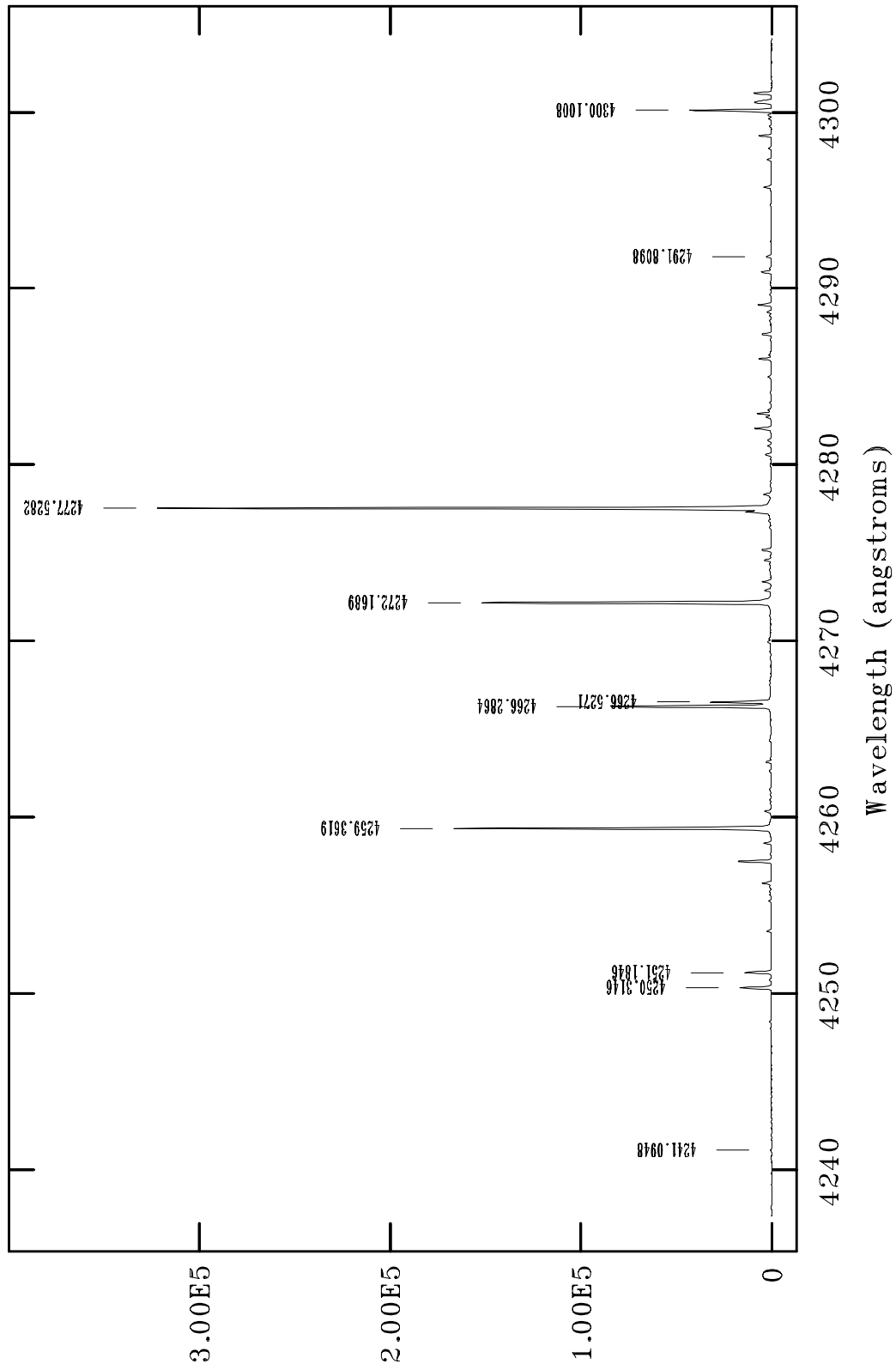
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:19:39 24-Nov-1999
Aperture 9, Image line 9, Order 131
ecidentify 22oct0055.ec: ThAr



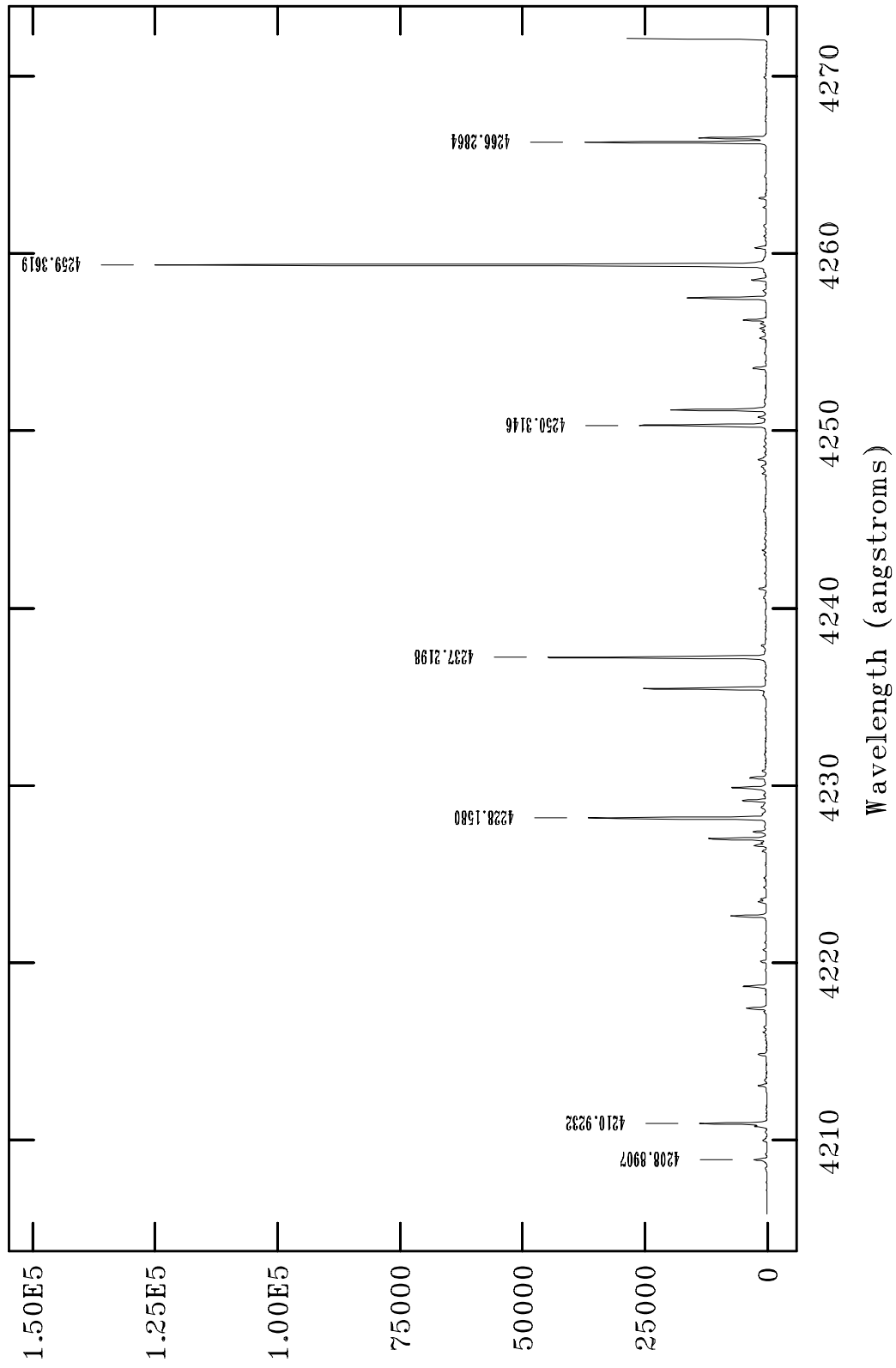
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:20:11 24-Nov-1999
Aperture 10, Image line 10, Order 132
ecidentify 22oct0055.ec: ThAr



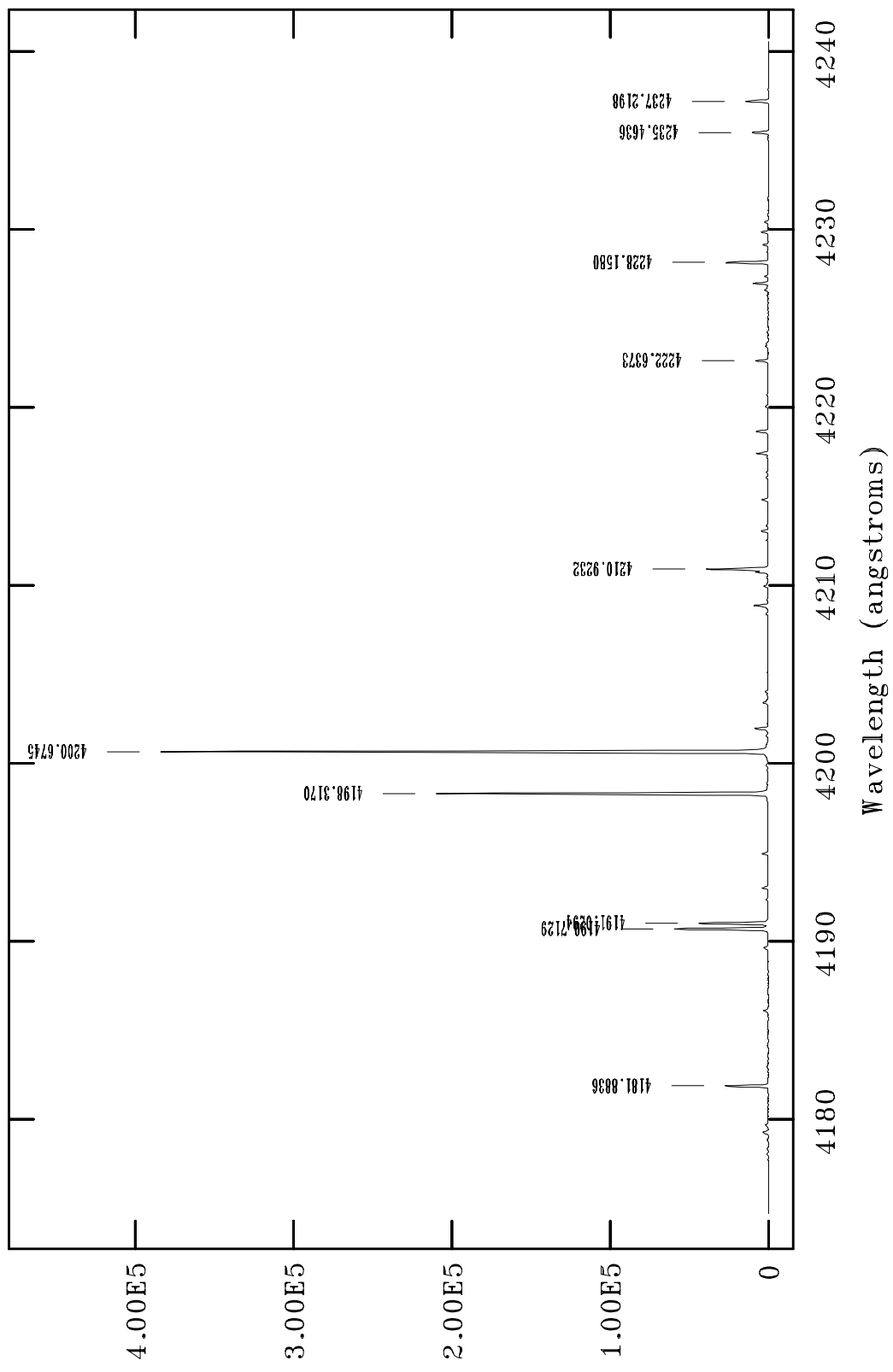
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:20:52 24-Nov-1999
Aperture 11, Image line 11, Order 133
ecidentify 22oct0055.ec: ThAr



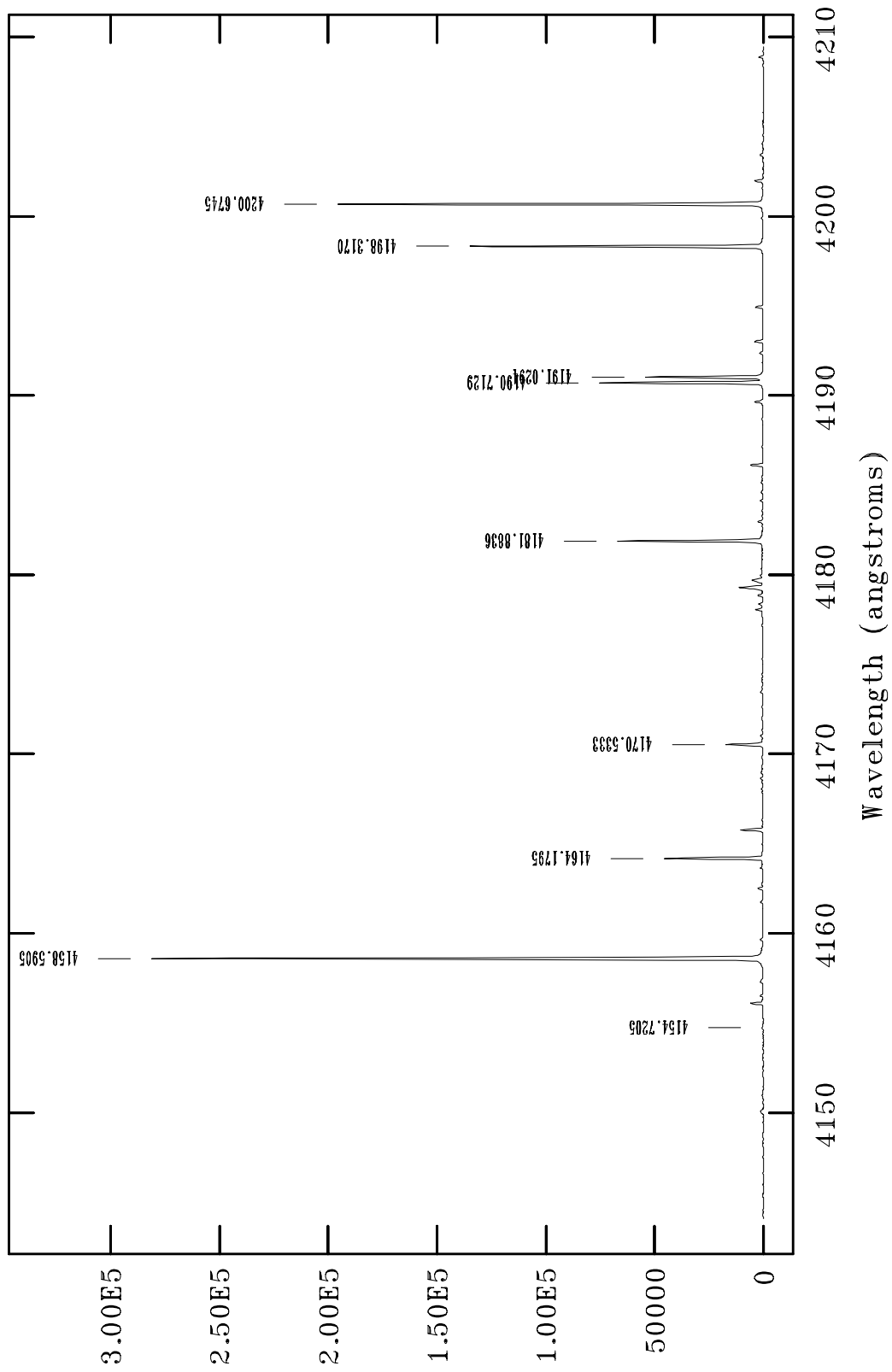
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:21:20 24-Nov-1999
Aperture 12, Image line 12, Order 134
ecidentify 22oct0055.ec: ThAr



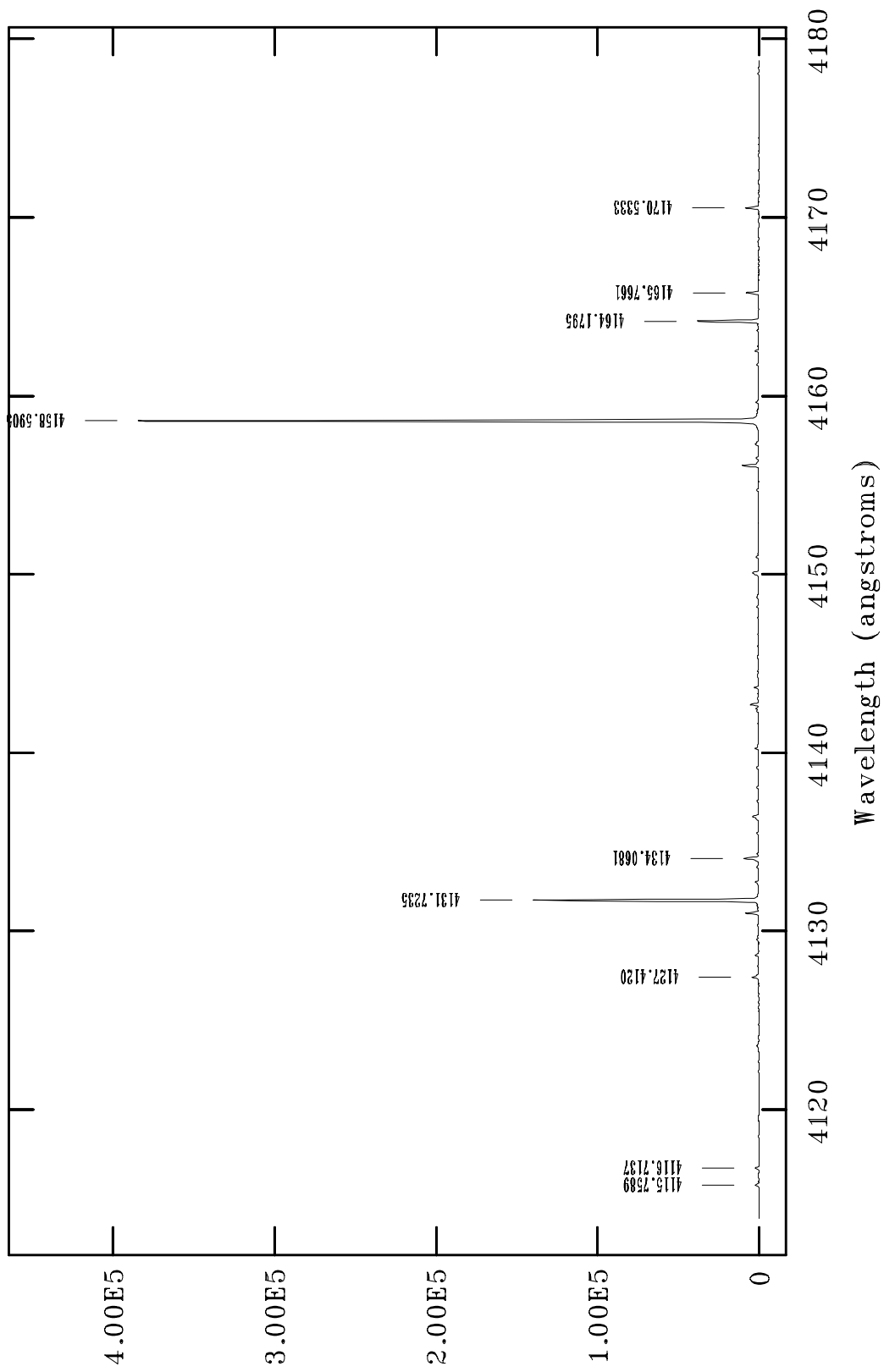
NOAO/IRAF V2.11.2EXPORT sdr@aaopepp2 Wed 15:21:48 24-Nov-1999
Aperture 13, Image line 13, Order 135
identify 22oct0055.ec: ThAr



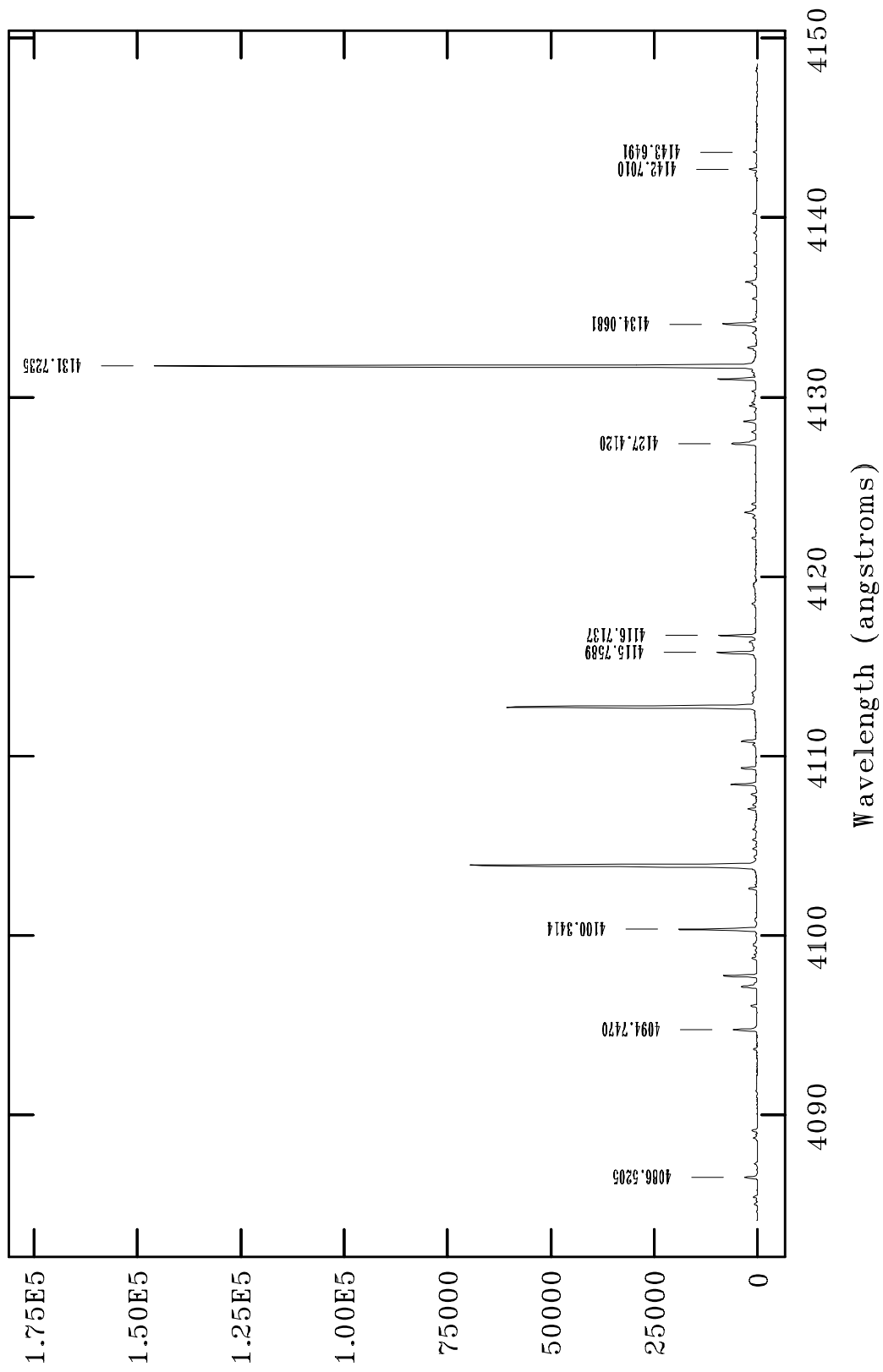
NOAO/IRAF V2.11.2EXPORT sdr@aaopepp2 Wed 15:22:14 24-Nov-1999
Aperture 14, Image line 14, Order 136
ecidentify 22oct0055.ec: ThAr



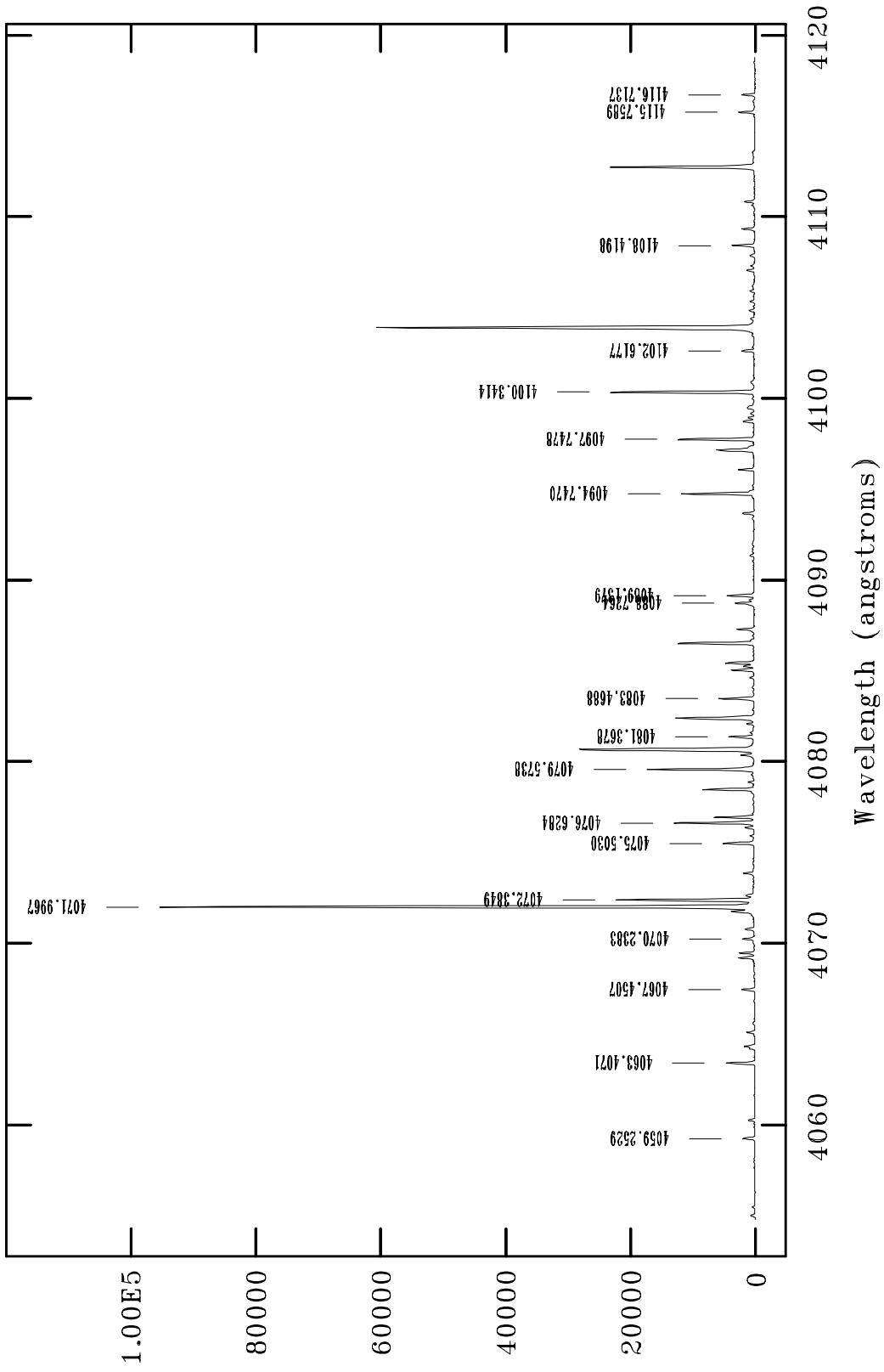
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:22:47 24-Nov-1999
Aperture 15, Image line 15, Order 137
ecidentify 22oct0055.ec: ThAr



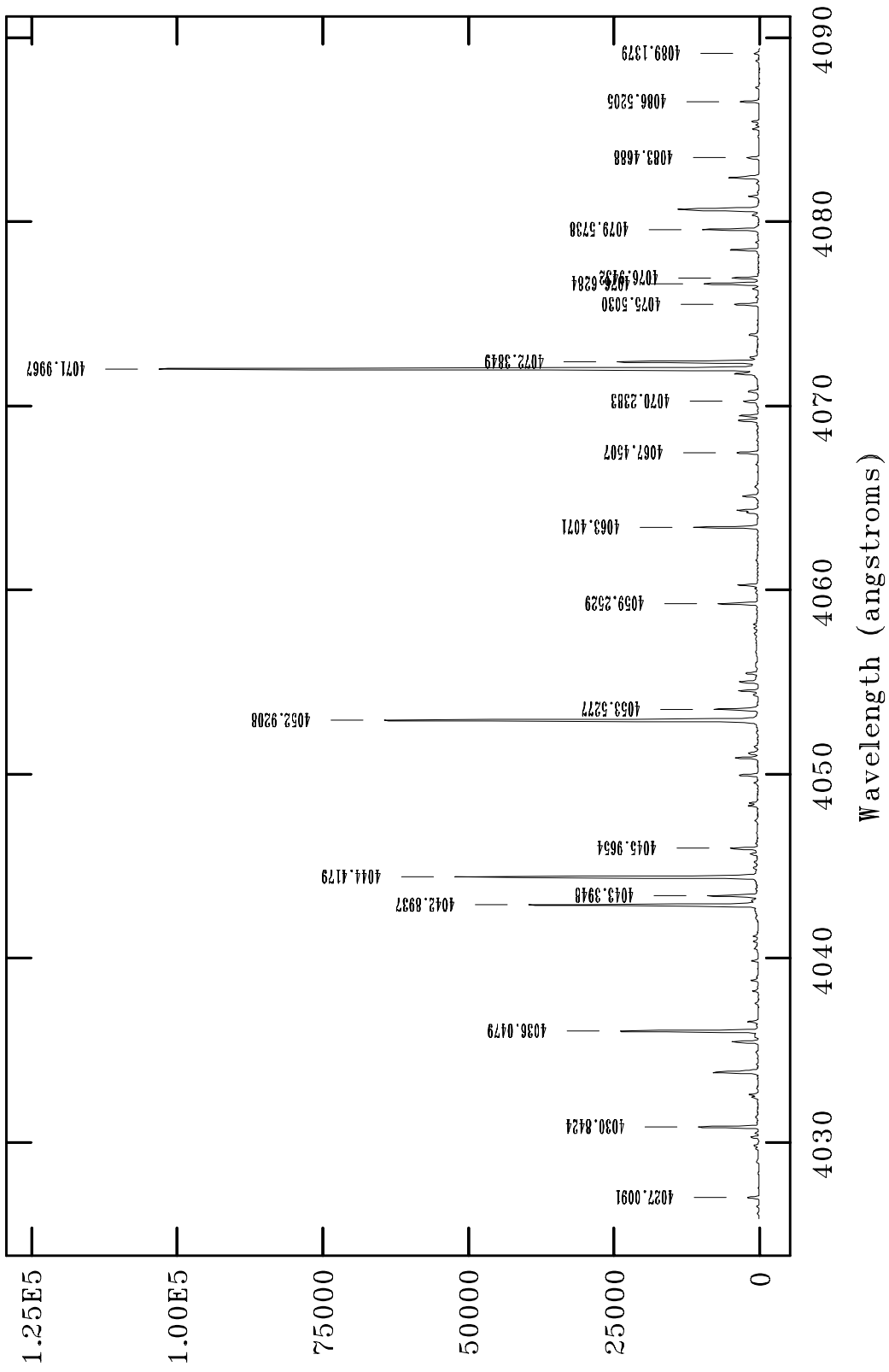
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:23:13 24-Nov-1999
Aperture 16, Image line 16, Order 138
ecidentify 22oct0055.ec: ThAr



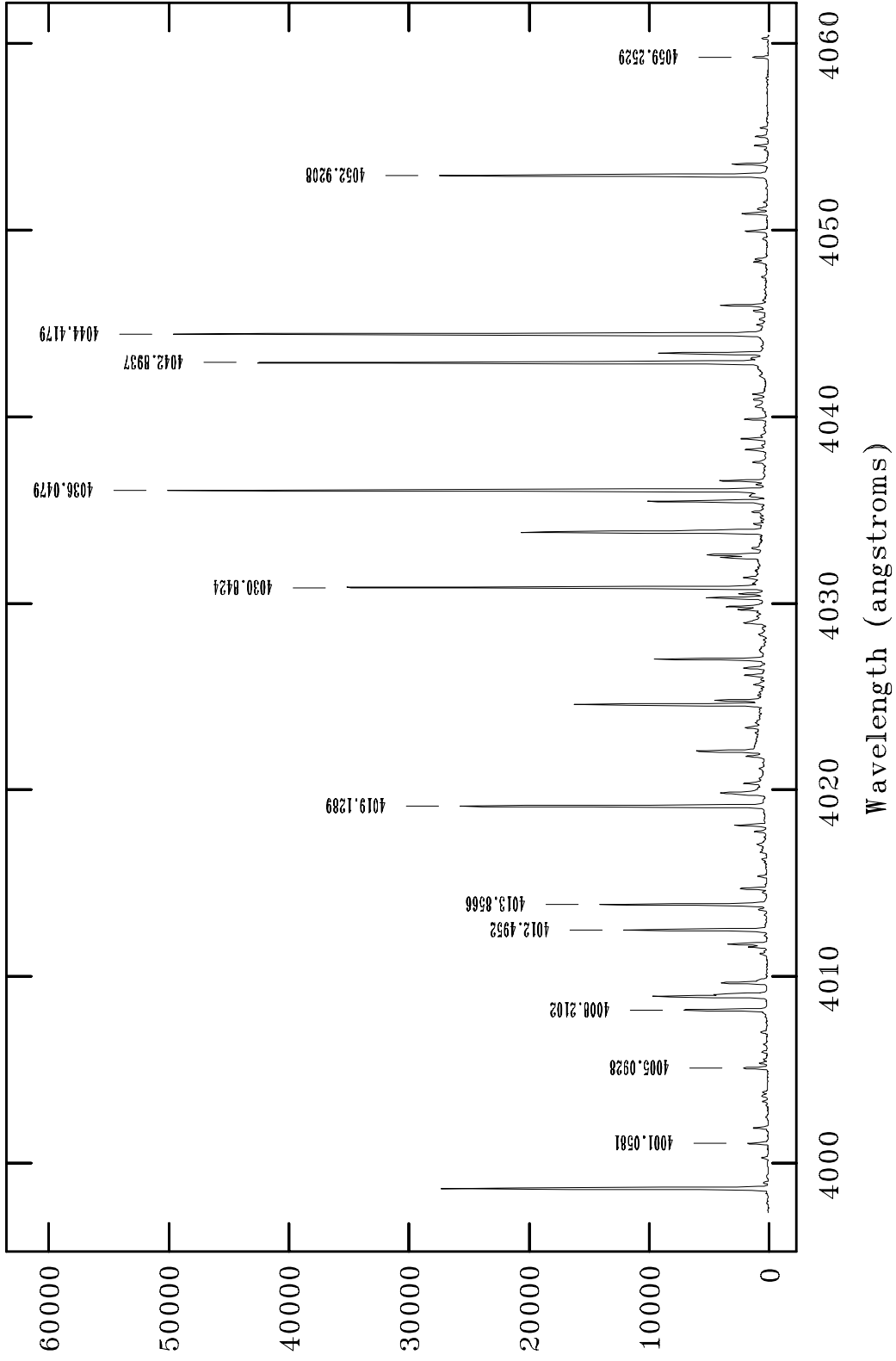
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:23:39 24-Nov-1999
Aperture 17, Image line 17, Order 139
ecidentify 22oct0055.ec: ThAr



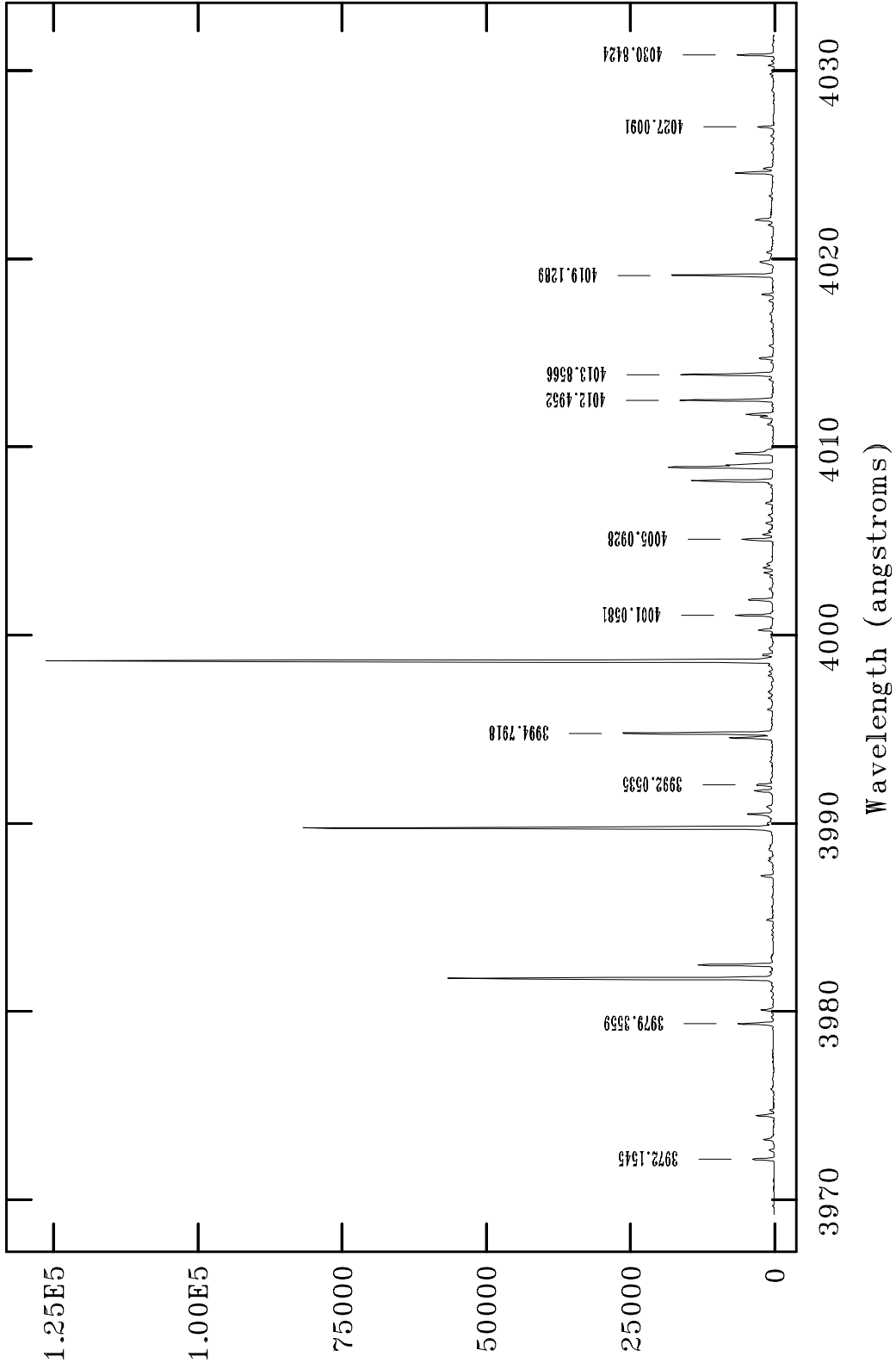
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:24:07 24-Nov-1999
Aperture 18, Image line 18, Order 140
identify 22oct0055.ec: ThAr



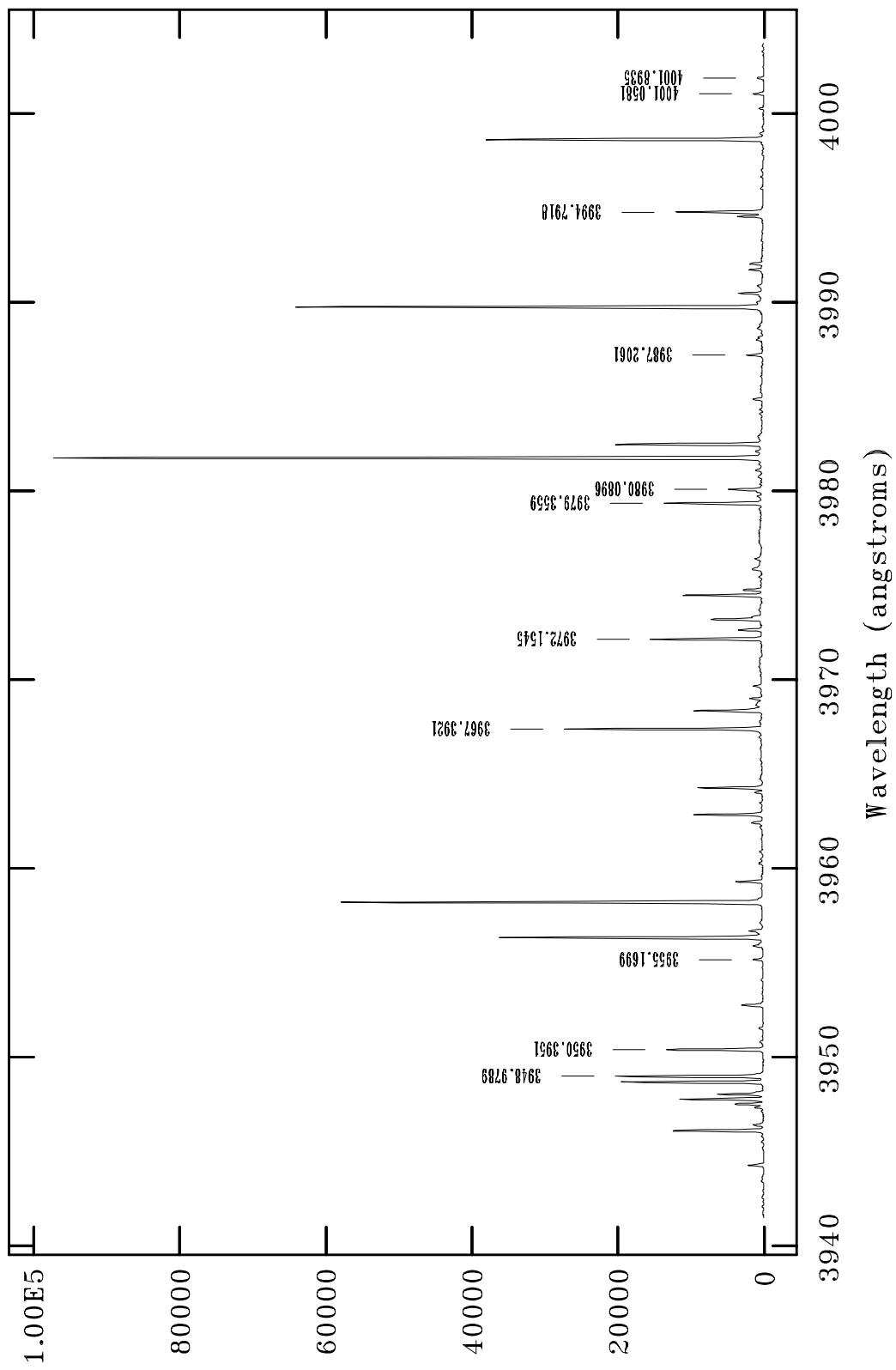
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:24:33 24-Nov-1999
Aperture 19, Image line 19, Order 141
ecidentify 22oct0055.ec: ThAr



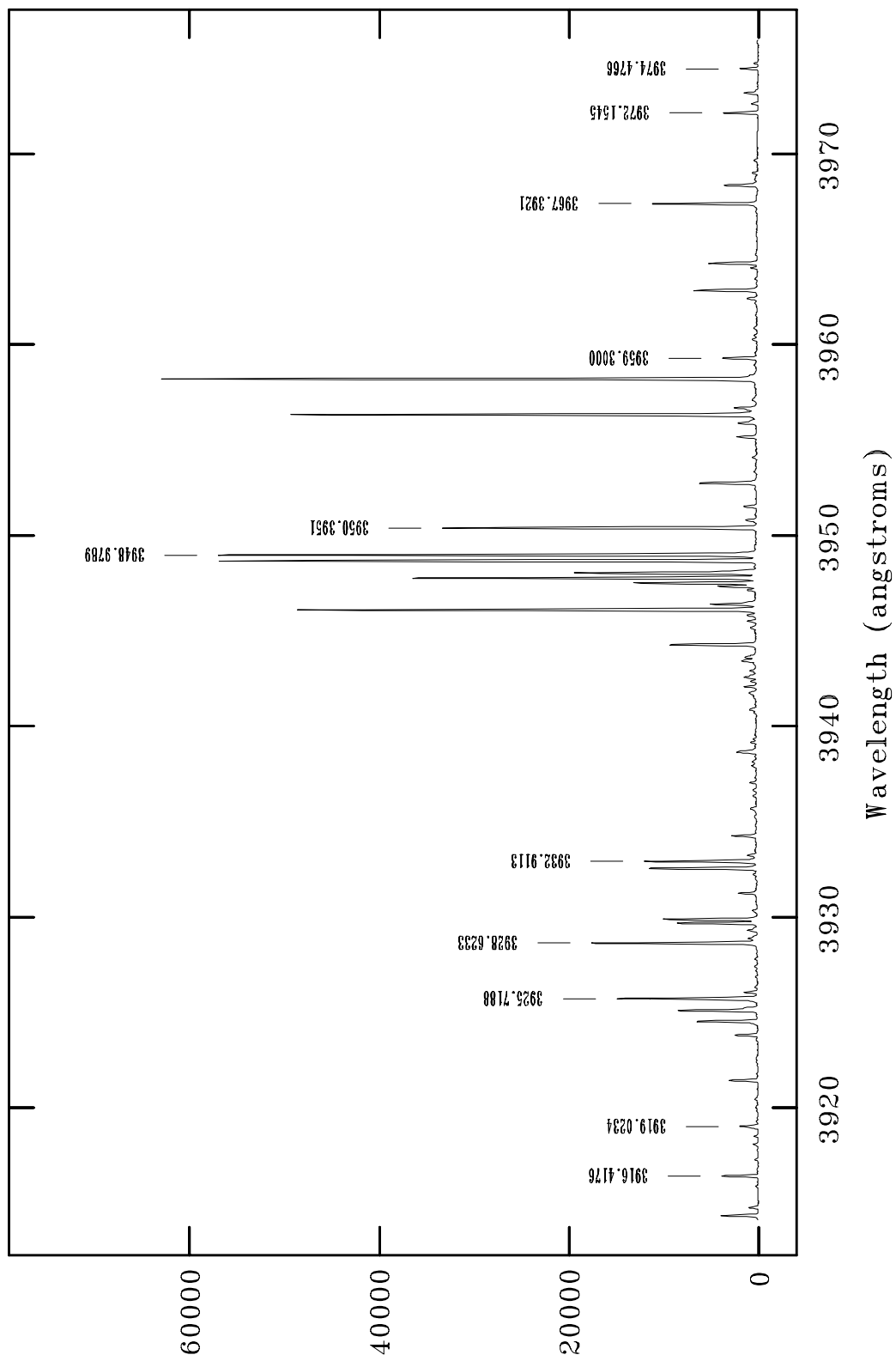
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:25:58 24-Nov-1999
Aperture 20, Image line 20, Order 142
ecidentify 22oct0055.ec: ThAr



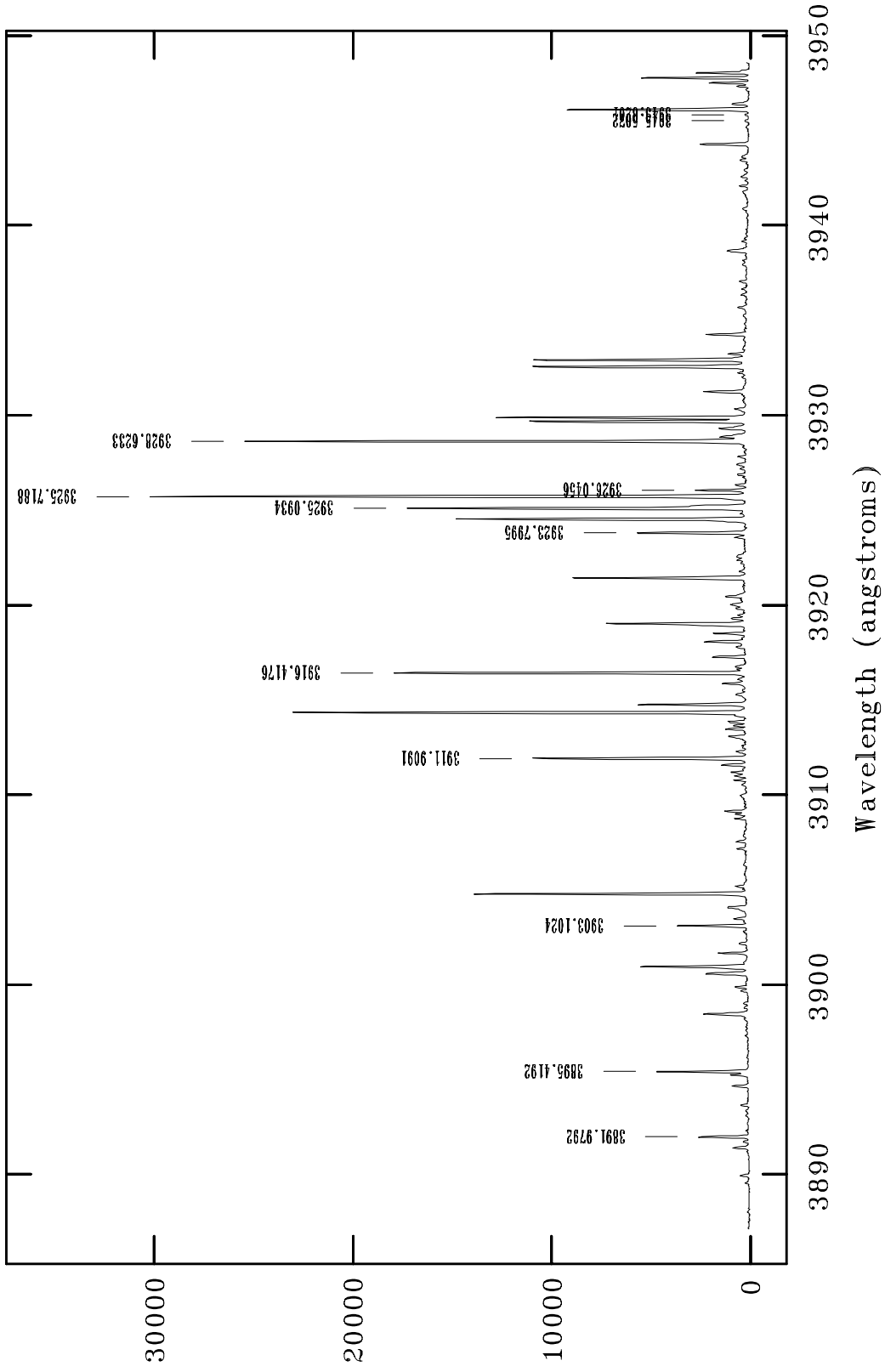
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:26:32 24-Nov-1999
Aperture 21, Image line 21, Order 143
ecidentify 22oct0055.ec: ThAr



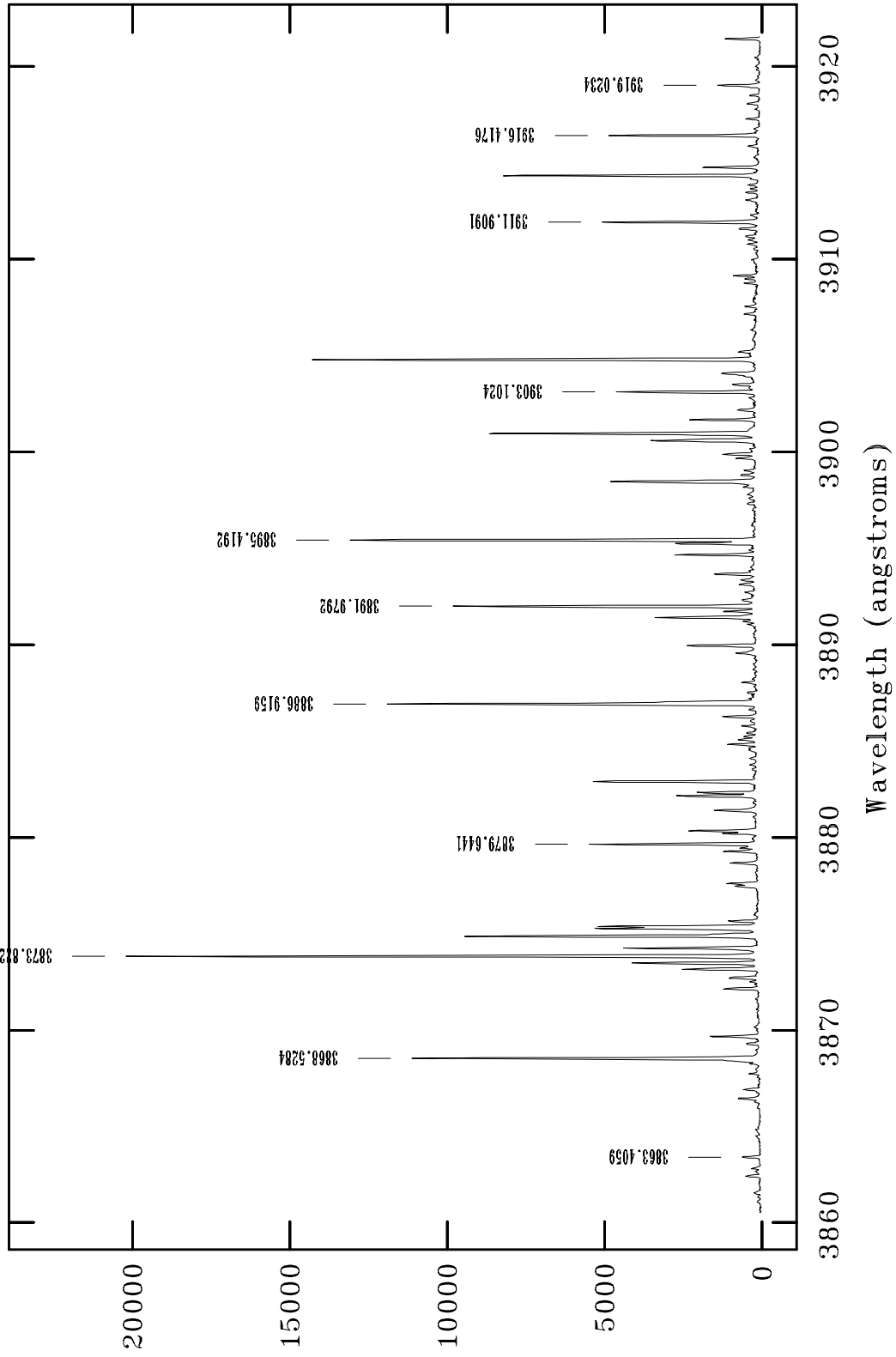
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 15:26:58 24-Nov-1999
Aperture 22, Image line 22, Order 144
ecidentify 22oct0055.ec: ThAr



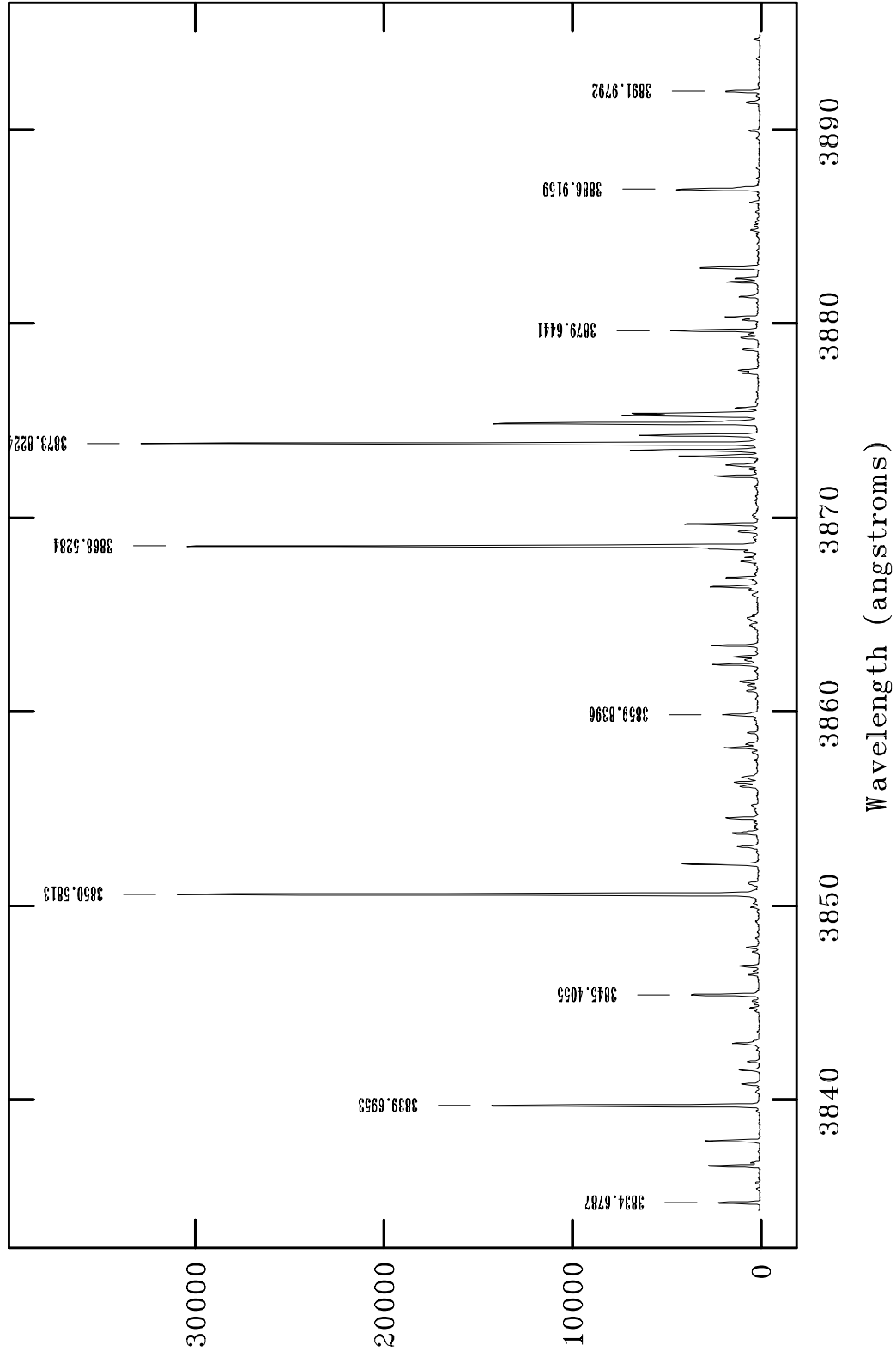
NOAO/IRAF V2.11.2EXPORT sdr@aaoepp2 Wed 15:27:30 24-Nov-1999
Aperture 23, Image line 23, Order 145
ecidentify 22oct0055.ec: ThAr



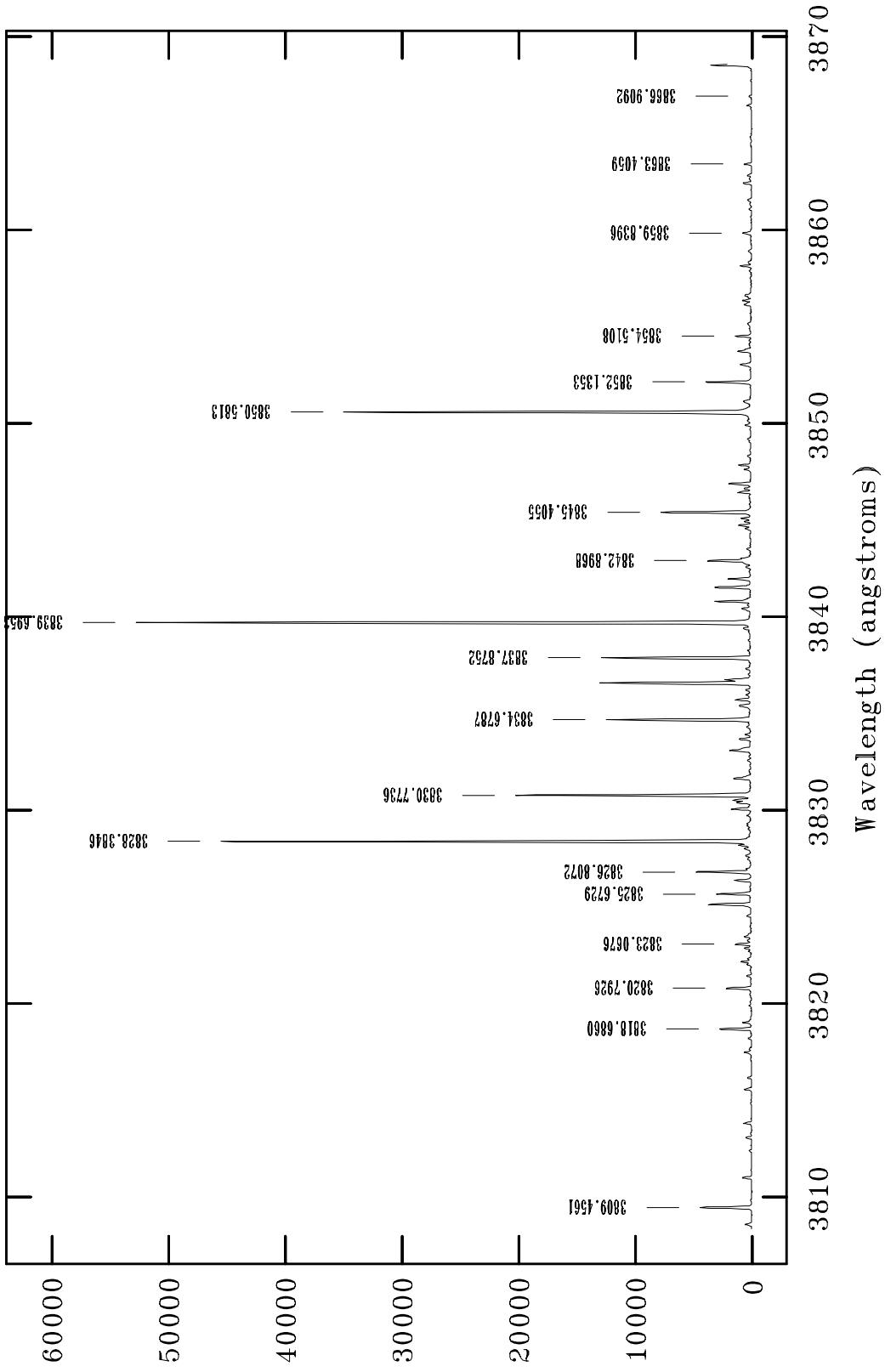
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:21:08 24-Nov-1999
Aperture 24, Image line 24, Order 146
ecidentify 22oct0055.ec: ThAr



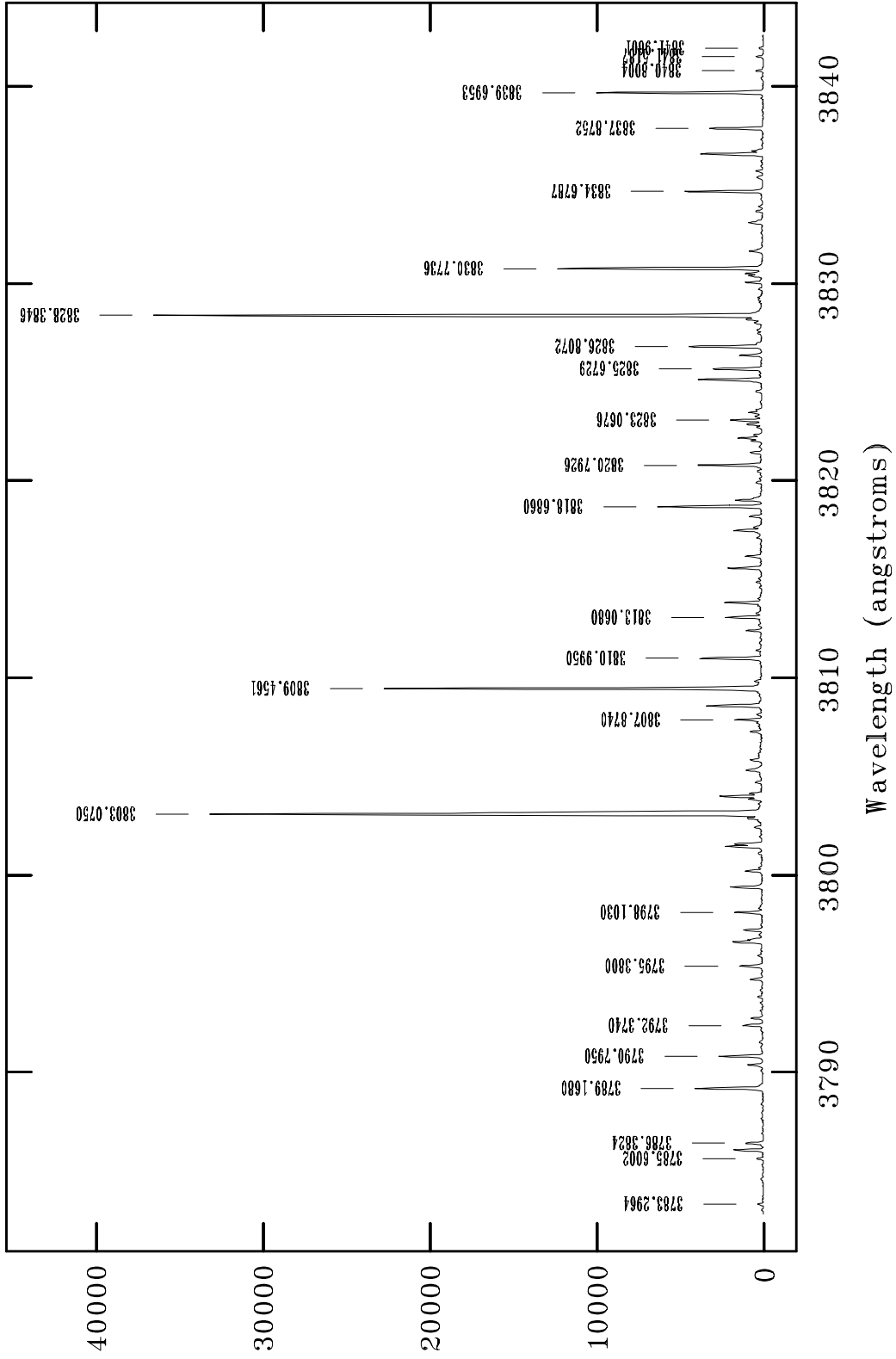
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:21:33 24-Nov-1999
Aperture 25, Image line 25, Order 147
ecidentify 22oct0055.ec: ThAr



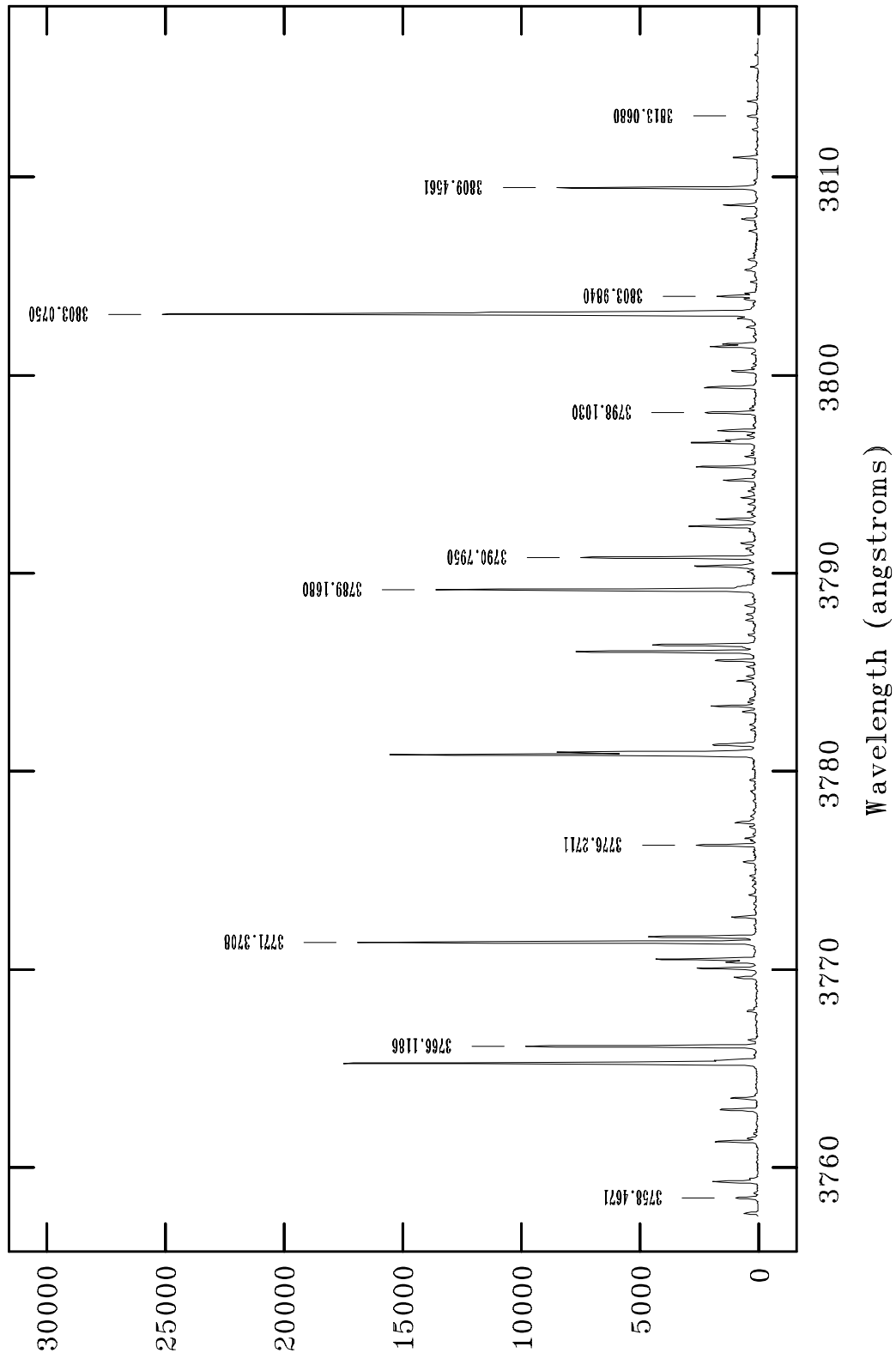
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:21:59 24-Nov-1999
Aperture 26, Image line 26, Order 148
identify 22oct0055.ec: ThAr



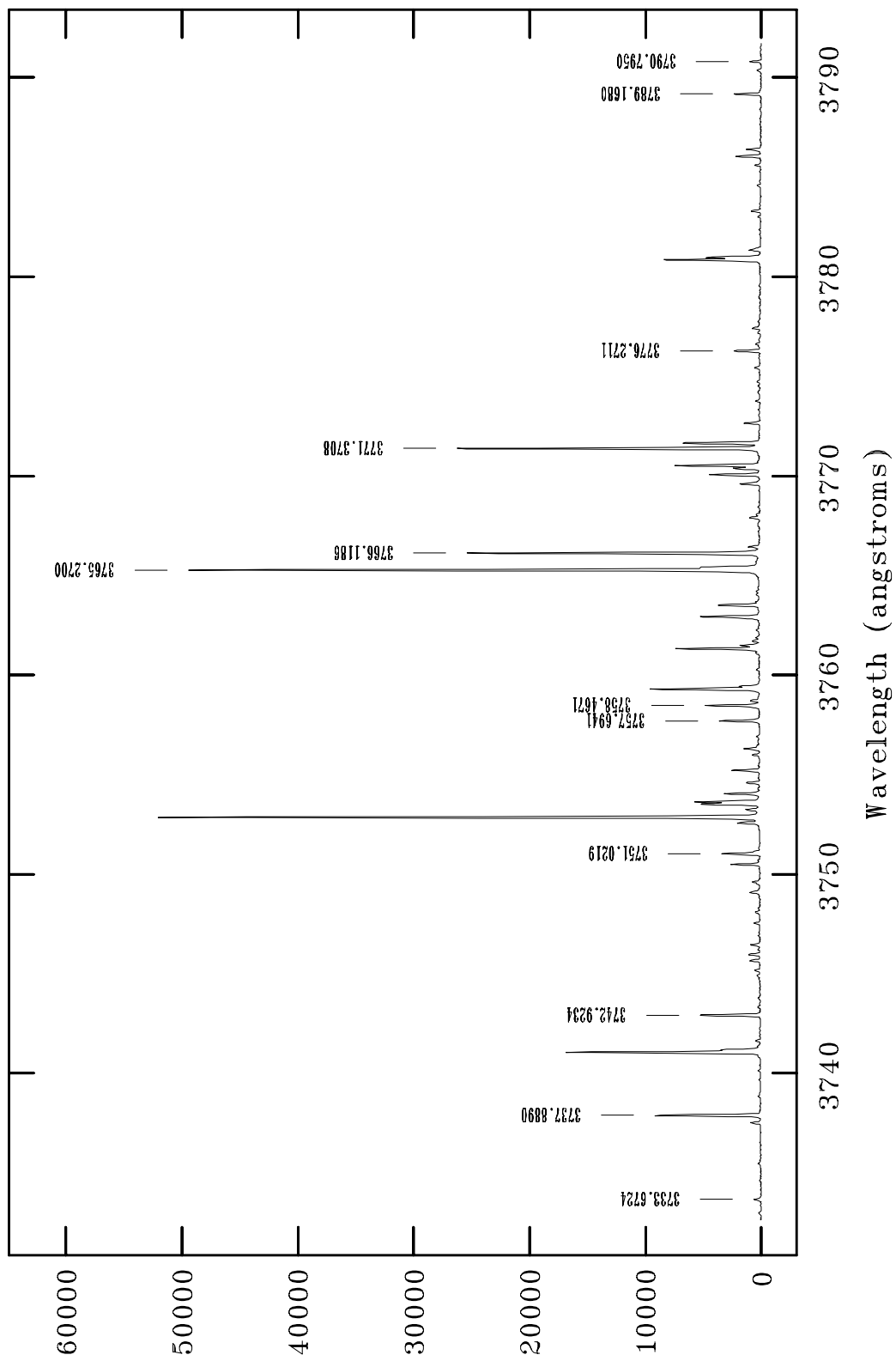
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:22:23 24-Nov-1999
Aperture 27, Image line 27, Order 149
identify 22oct0055.ec: ThAr



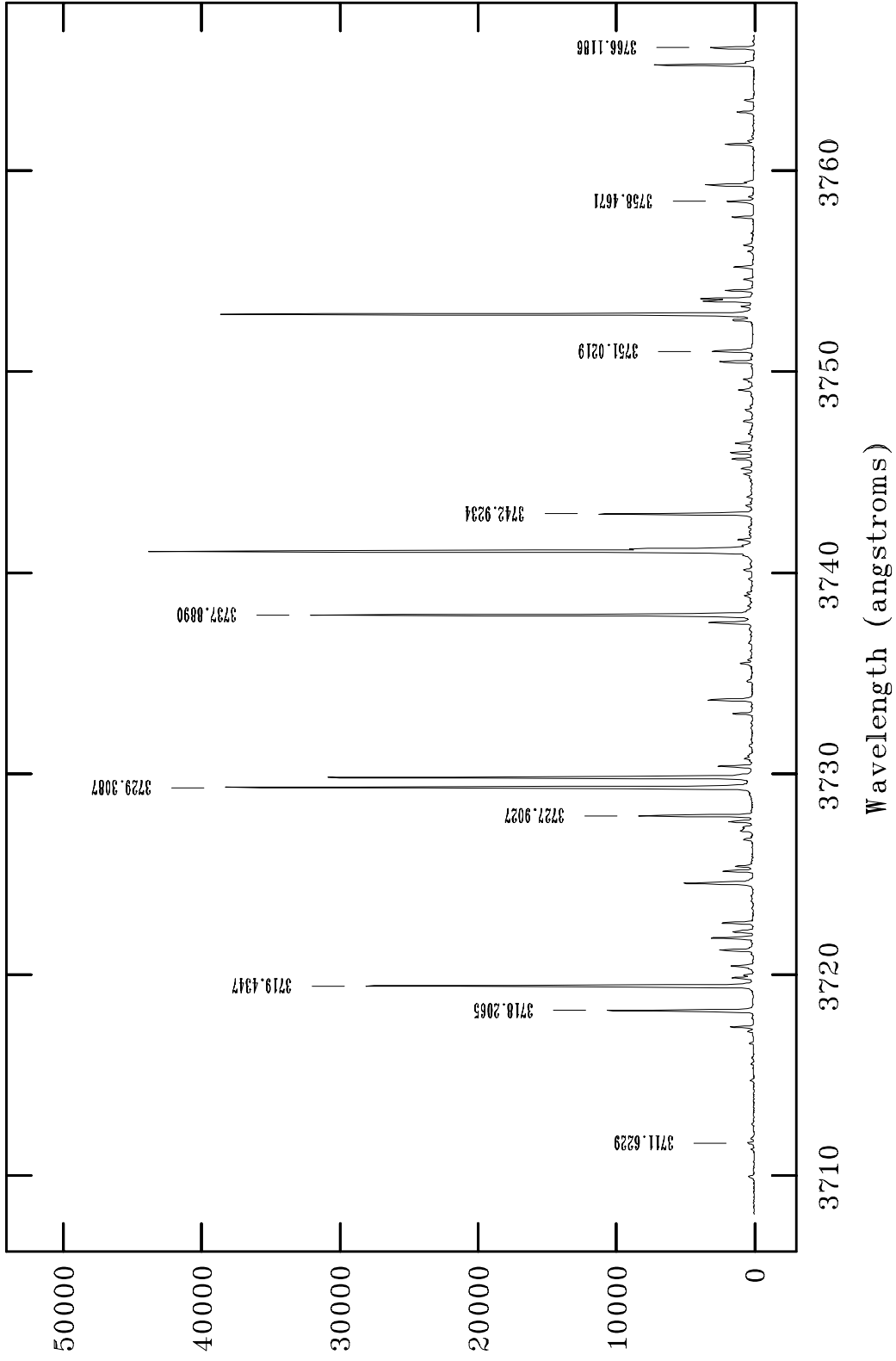
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:22:48 24-Nov-1999
Aperture 28, Image line 28, Order 150
ecidentify 22oct0055.ec: ThAr



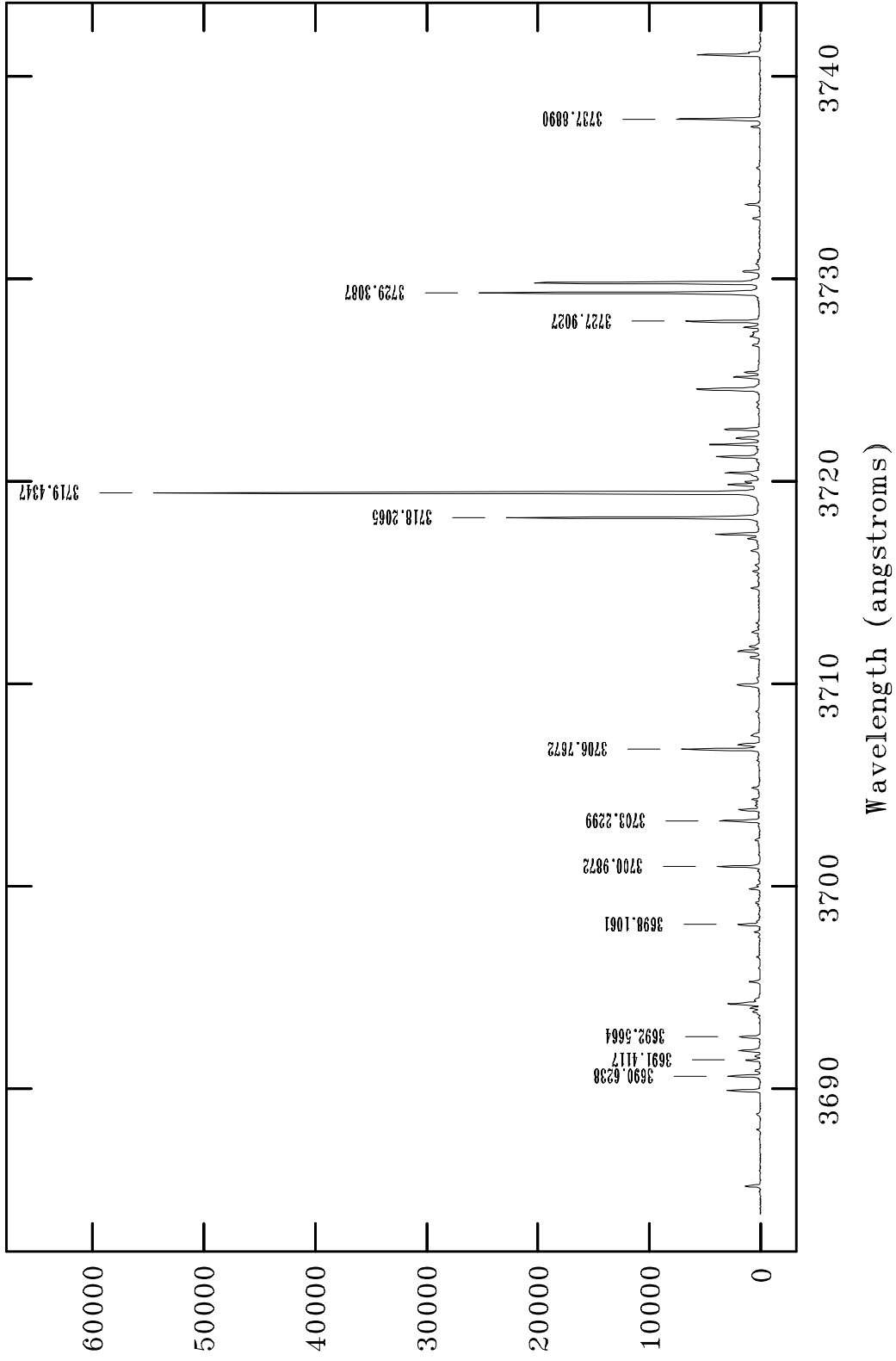
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:23:11 24-Nov-1999
Aperture 29, Image line 29, Order 151
ecidentify 22oct0055.ec: ThAr



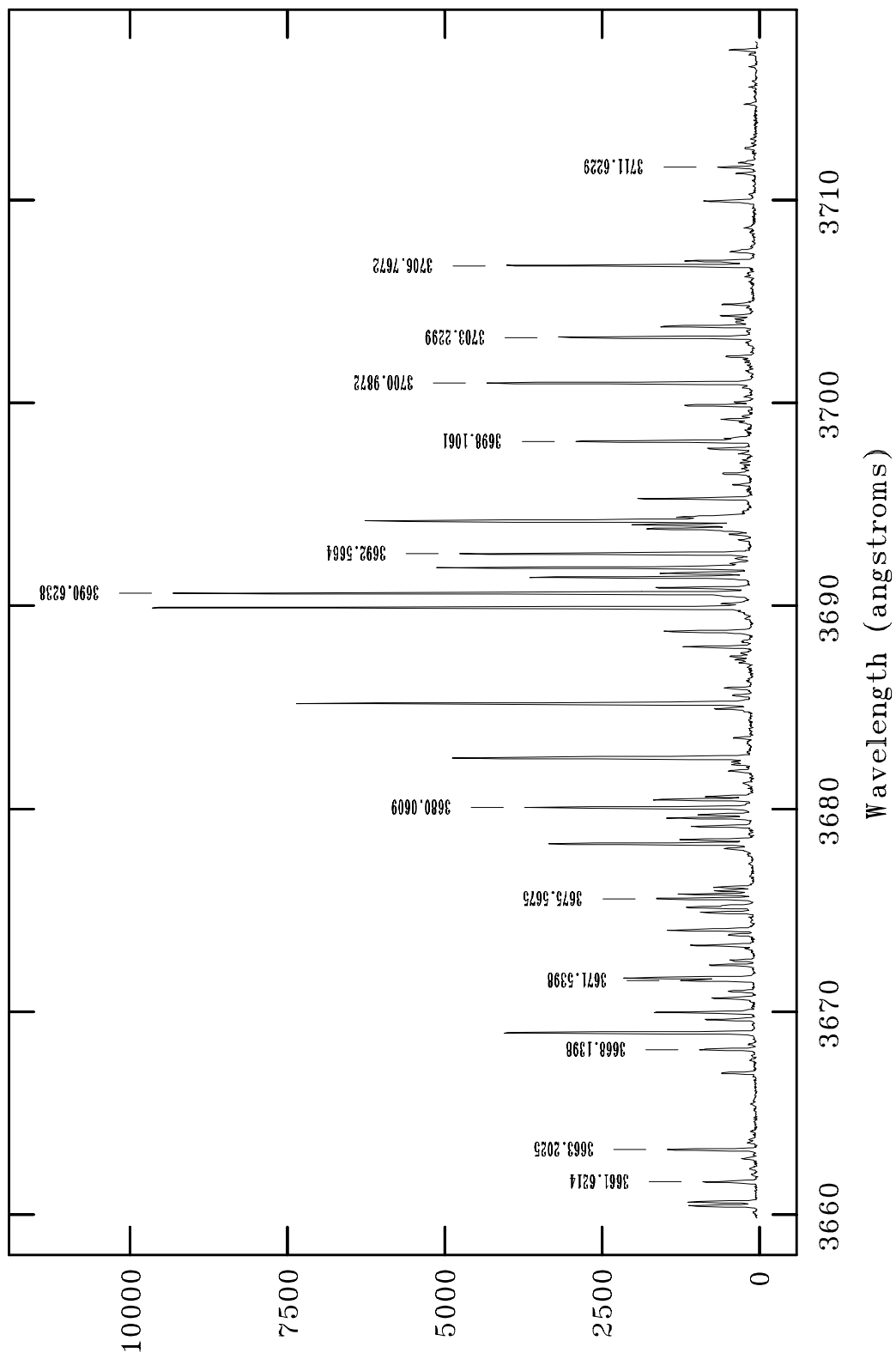
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:23:35 24-Nov-1999
Aperture 30, Image line 30, Order 152
ecidentify 22oct0055.ec: ThAr



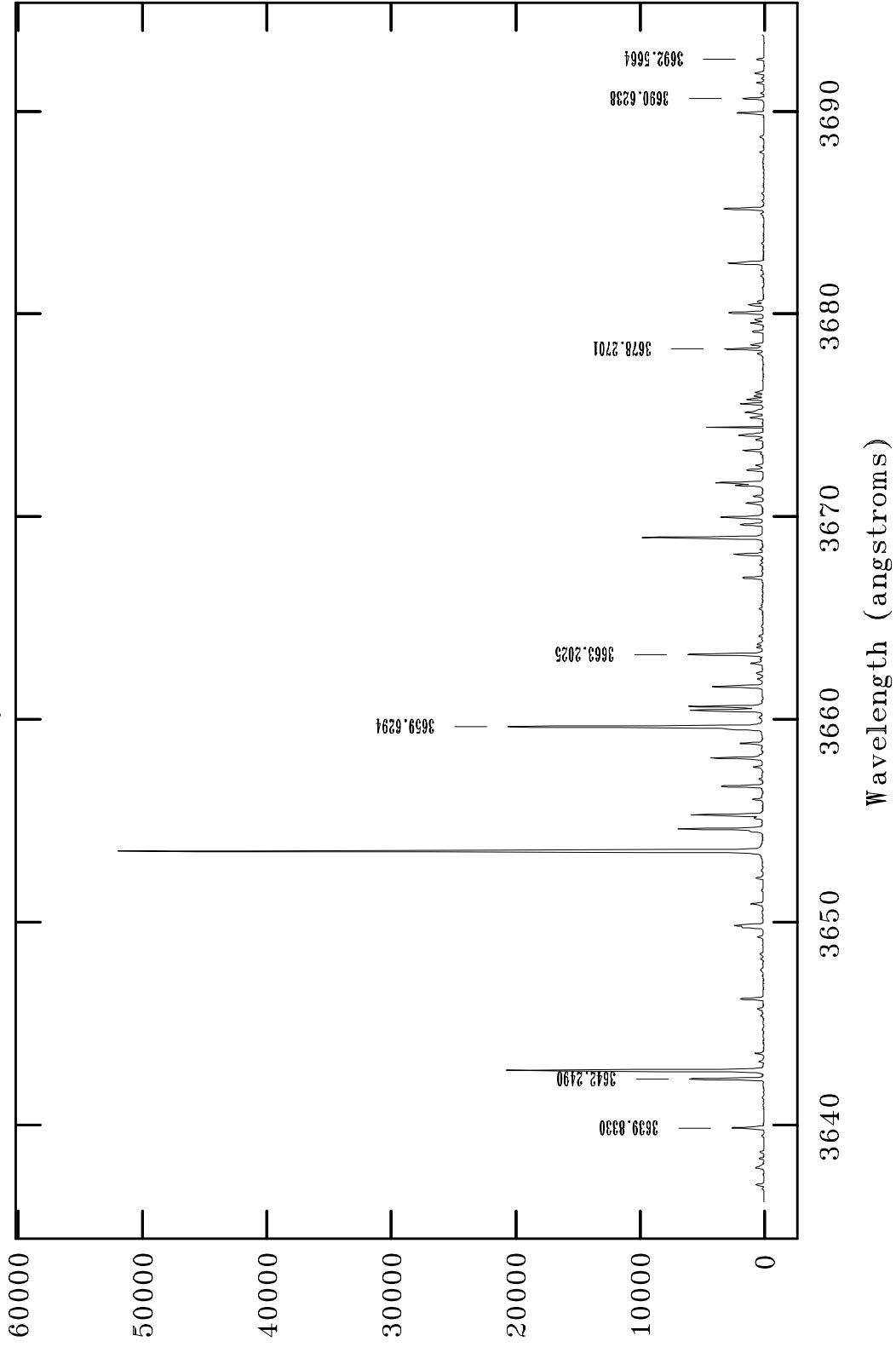
NOAO/IRAF V2.11.2EXPORT sdr@aaopepp2 Wed 17:23:59 24-Nov-1999
Aperture 31, Image line 31, Order 153
ecidentify 22oct0055.ec: ThAr



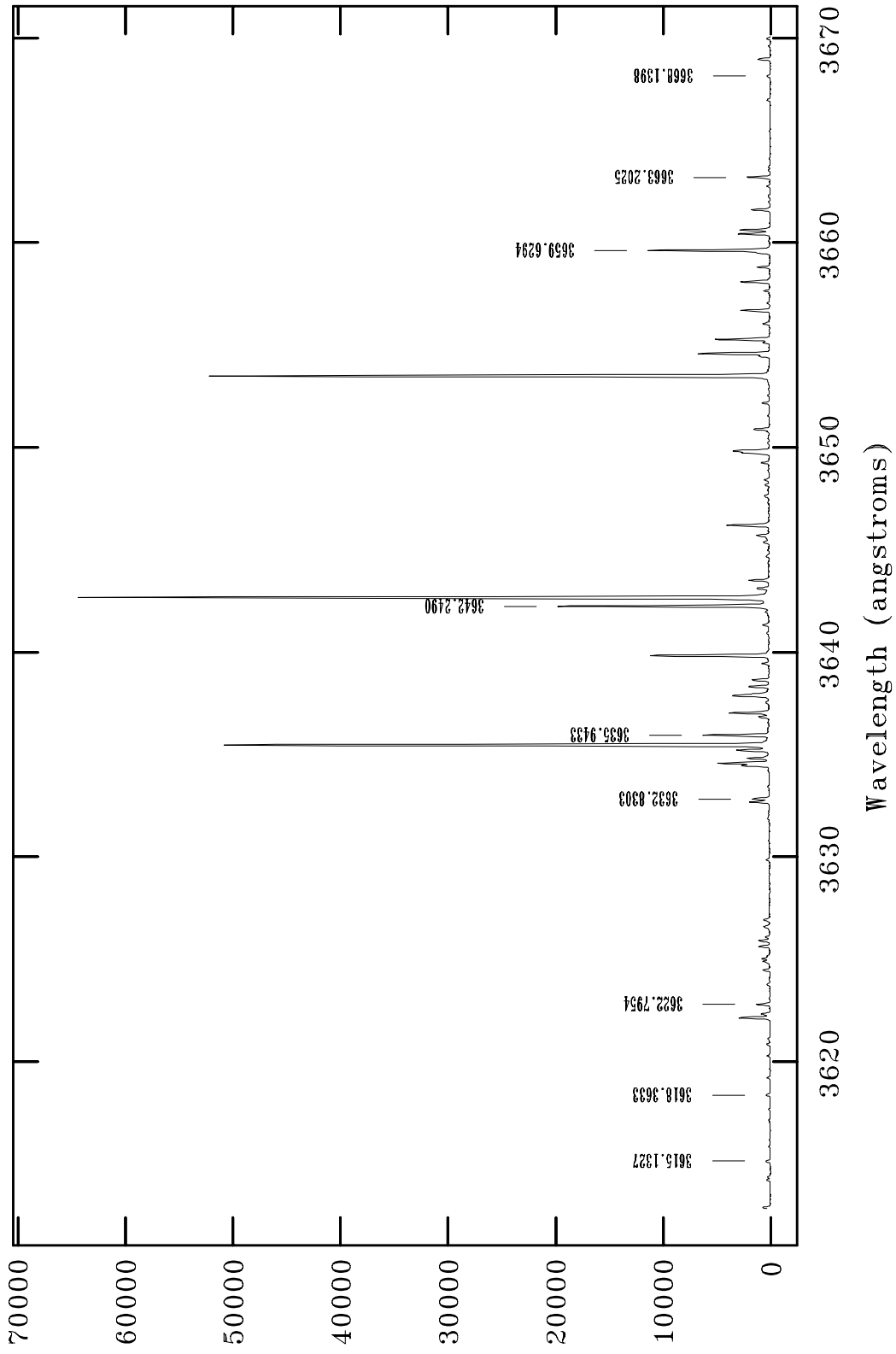
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:24:23 24-Nov-1999
Aperture 32, Image line 32, Order 154
ecidentify 22oct0055.ec: ThAr



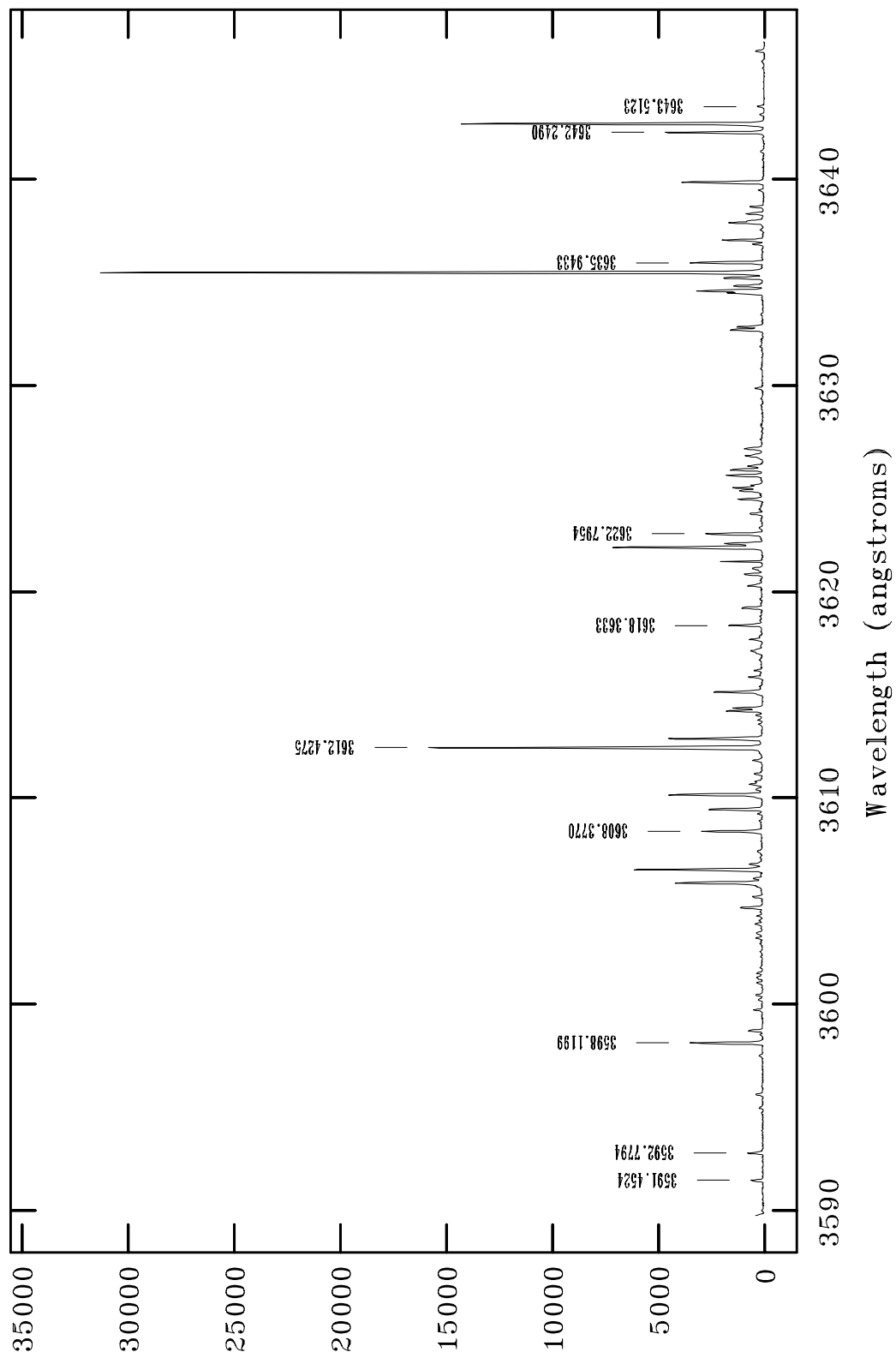
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:24:47 24-Nov-1999
Aperture 33, Image line 33, Order 155
ecidentify 22oct0055.ec: ThAr



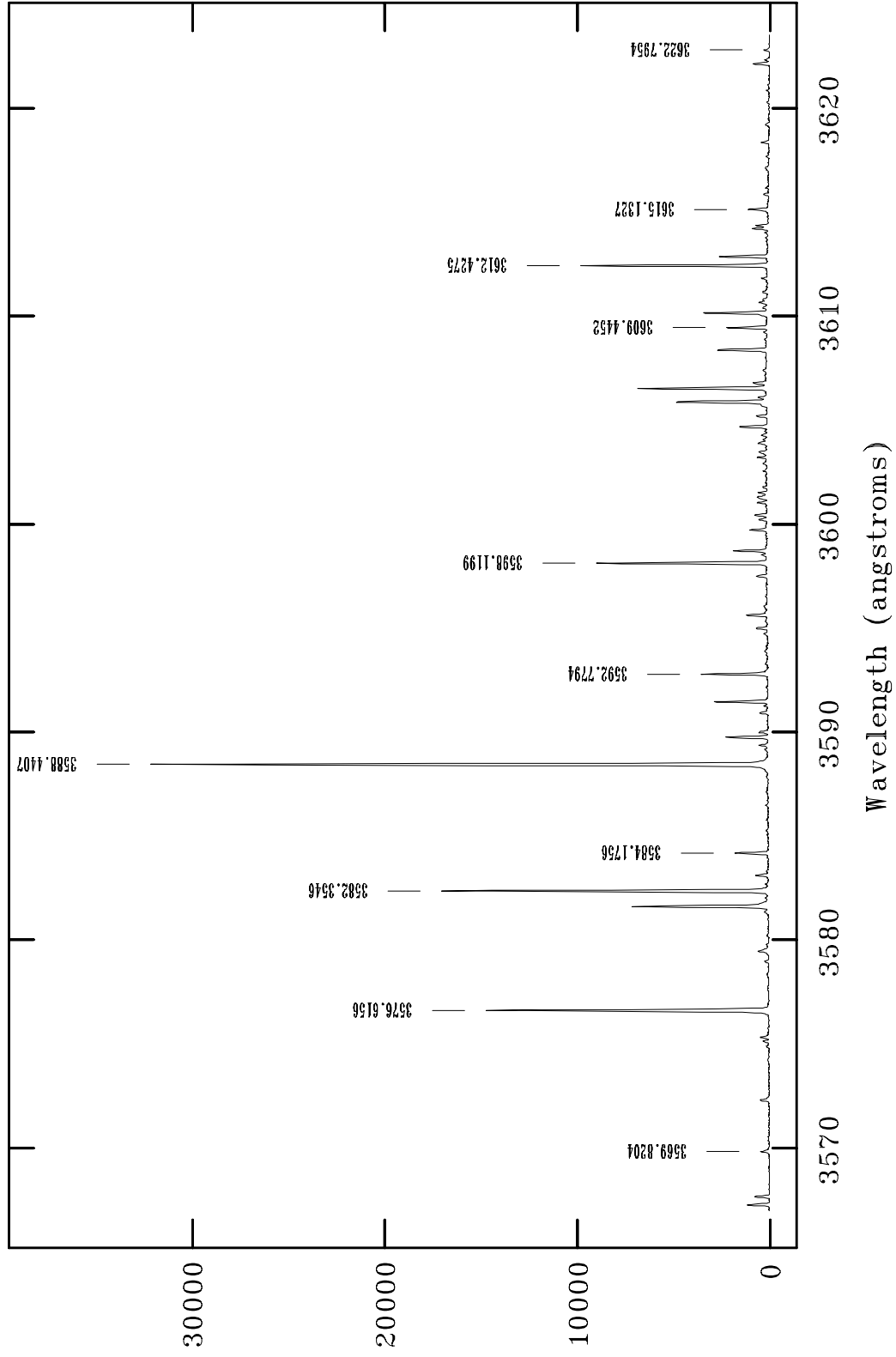
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:25:15 24-Nov-1999
Aperture 34, Image line 34, Order 156
ecidentify 22oct0055.ec: ThAr



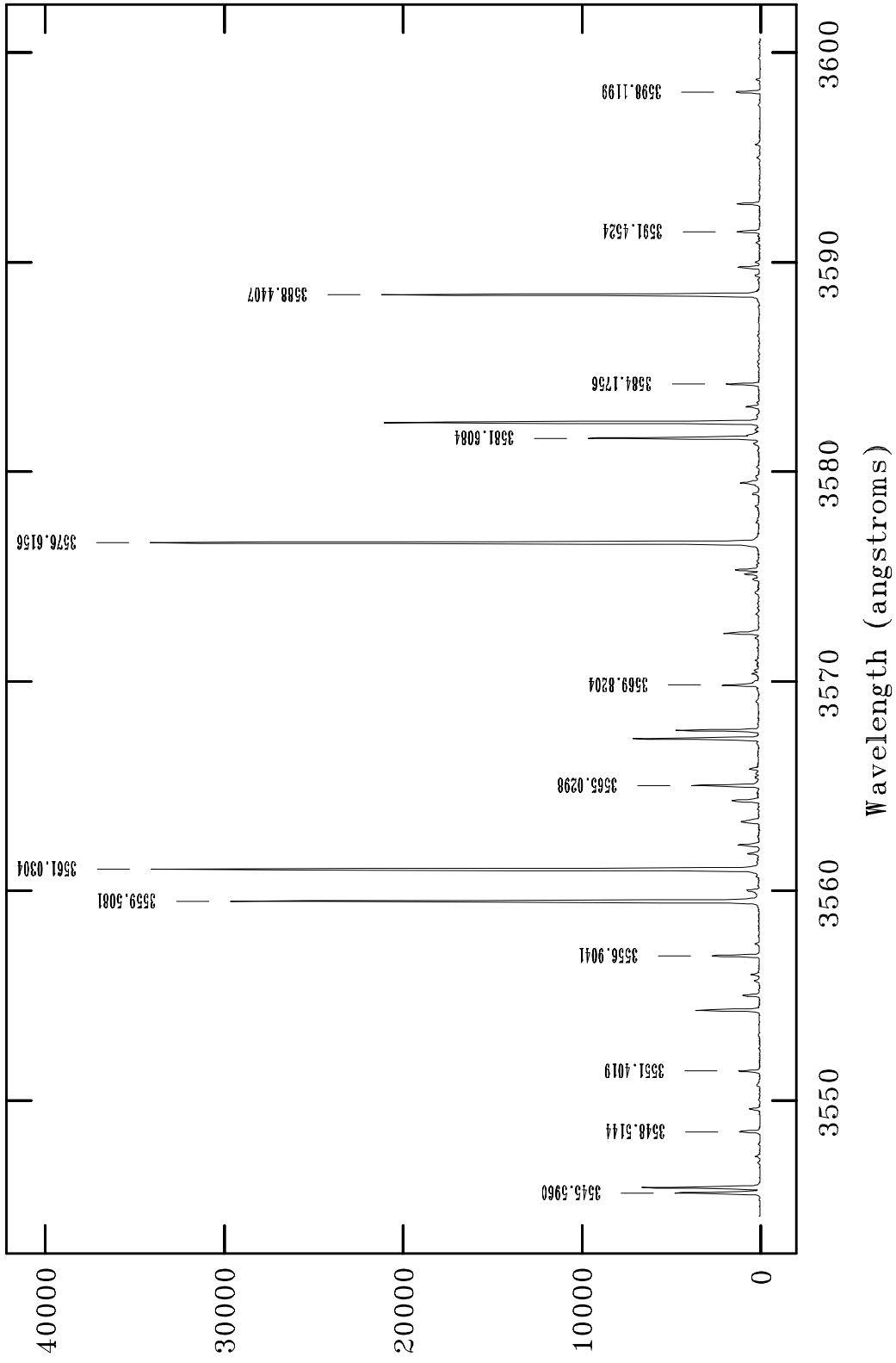
NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:25:39 24-Nov-1999
Aperture 35, Image line 35, Order 157
ecidentify 22oct0055.ec: ThAr



NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:26:05 24-Nov-1999
Aperture 36, Image line 36, Order 158
ecidentify 22oct0055.ec: ThAr



NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:27:45 24-Nov-1999
Aperture 37, Image line 37, Order 159
ecidentify 22oct0055.ec: ThAr



NOAO/IRAF V2.11.2EXPORT sdr@aaopp2 Wed 17:28:08 24-Nov-1999
Aperture 38, Image line 38, Order 160
ecidentify 22oct0055.ec: ThAr

