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A spectral atlas of calibration lamps in use with the INT IDS

Atlases for the calibration arc lamps Cu-Ar, Cu-Ne, Th-Ar, Helium and bi-alkali (Al/Ca/Mg-Neon) are presented

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INTRODUCTION

We present spectral atlases for five calibration arc lamps in use on the IDS -Spectrograph: Copper-Argon, Copper-Neon, Thorium-Argon, Helium and bi-alkali (Al/Ca/Mg-Neon). The spectra presented here were obtained by JK, who spent an odd afternoon collecting some 200 arc exposures.

The first two sections describe the data and their analysis. Section three consists of a brief description of the individual spectra. The maps themselves are accompanied by a table of reference wavelengths, and a summary of the spectrograph set-up used.

The data and analysis

The spectra were recorded with the 500 and 235 camera and CCDs GEC3 and GEC4 (both blue-coated, 22 μ pixel).

One-dimensional spectra were extracted using standard FIGARO procedures. In cases where the exposure time was relatively long, it proved necessary to remove several cosmic-ray blemishes beforehand, which otherwise would have resulted in (often strong) spurious features. The spectra thus obtained were subjected to a line-finding routine in order to get an inventory of positions of emission features, which, subsequently, were identified, using an automated identification algorithm, by cross-referencing with a table of standard wavelengths. The line-finding routine searches the spectrum for local maxima of the intensity distribution and accepts the presence of a spectral feature if its intensity is above a predetermined threshold. For the latter a value was used of 4. 0 to 4. 5 times the standard deviation of the distribution of pixel intensifies taken from areas in between the emission features. Practically all features found in this way could be identified with known emission features in the spectra of the atoms or ions involved.

An effort was made to identify all features recognized by the line-search algorithm in sparsely populated areas. Thus, some line lists do include very weak lines, which nevertheless are still recorded due to the large dynamic range of the CCD detector, and are recognized by the search algorithm. One would normally not use such weak lines for calibration purposes, but they are useful in the identification process, because automated search procedures tend to be more stable when a larger number of lines are included. In areas of high line-density, the search and identification was not done exhaustively.

The maps and tables

Figures I to 8 show the arc maps. Identifications are indicated by their wavelength, and can be cross-referenced with the accompanying wavelength Tables 1 to 8. Wavelengths are given in Angstrom at standard air conditions (15 C, 76 cm Hg), in accordance with the IAU convention. The intensifies indicated in the graphs represent the number of ADUs per pixel (NOT the count rate). Therefore, a summary of the exposure times used is given in order to enable a determination of (approximate) count rates. When using the IPCS detector, care should be taken to restrict the peak rate in the lines to at most 1 Hz, by using a proper set of neutral density filters.

Notice that on the 500 camera, pixel numbers run against the wavelength for the current setting of the CCD readout. It is intended to rectify this situation and to ensure that at the telescope display the blue appears on the left-hand, and the red on the right-hand side.

The accuracy of the wavelength values is taken from the consulted literature; the last decimal given is significant. Many lines in the well-studied Argon and Neon spectra are known with an accuracy better than 0.001 Angstrom.

Blended lines (b) and weak (w) companions are indicated in the reference-line tables. Most blends in high-dispersion spectra consist of lines from the same multiples, and therefore have a well-defined (weighted) average wavelength, which is not really sensitive to the precise operating conditions of the lamp. The wavelengths of the blends in low-dispersion spectra are given by the flux- weighted average of the two principal components, as observed in the high dispersion spectra. The precise average wavelength of such blends is much more dependent on the details of the conditions in the arc lamp, in particular if the components are from different multiplets or different ionization states. Thus, care should be taken when using these blends calibrators. To give a

benchmark: when fitting a first- or second degree polynomial to identified lines (using a CCD detector), an rms error on the Position of about 0.1 Pixel can be reached. Anyway, the FIGARO ARC procedure has a facility to weed out "bad" lines.

The tables listed here are also provided in FIGARO readable format and stored in RGO's local FIGARO directory. Alternatively, they can be obtained from EJZ at RGVAD::EJZ or UK.AC.RGO.STAR::EJZ.

A short description of individual spectra

In this section, we discuss ther individual spectra, so that users can decide which lamp or lamps are best suited to their observations. Some comments only apply to CCD observations and not to IPCS ones, because of the difference in dynamic range between these detectors. In any case, the best way to judge is by actually inspecting the arc atlas.

Argon:

The spectrum of the Copper-Argon lamp presently in use with the IDS consists of the ArI and ARII spectra; Copper lines are not seen. The spectrum divides into two distinct spectral regions, as follows:

Between 3900A and 6965A the spectrum contains a large number of relatively faint lines, which can be used in both low and high dispersion work. The region 3900-5100 is particularly useful both with CCD and IPCS detectors. Between 5200A and 5500A the Argon spectrum is comparatively weak, although there are a large number of lines present, and long exposures are needed. One may be better off with the Thorium-Argon lamp for this region.

Redwards of 6965A, up to 9784A, the spectrum contains a large number of strong and very strong emission features, which give the argon arc its characteristic colour. However, in between these strong lines there are large gaps devoid of even very weak lines, particularly redwards of 7500A. There the Argon spectrum on its own is only useful for low dispersion work (150, 300 and 400 gratings); at high dispersion the Argon arc should be used in combination with another lamp (e.g. Copper-Neon).

Copper-Neon:

The Neon spectrum is dominated by very strong emission lines due to NeI in the wavelength range 5850-7440 A, which give the Neon lamp its characteristic deep-red colour. Further redwards a group of prominent features occupy the range from 7500A to 9600A, but these lines are almost an order of magnitude fainter than those in the former range. Bluewards of 5850A, the spectrum is populated by a large number of weak lines of NeI and NeII, and the copper spectrum provides the strongest features. The CuI resonance lines near 3200A are conspicuous features in IPCS spectra.

For wavelength calibrations in the red, the CuNe lamp on its own is only really useful for low-dispersion work, because the red emission lines are so spaced that at high dispersion very few lines may be present in certain wavelength intervals. At high dispersion (in the red) CuNe may be used in combination with the CuAr lamp.

In the blue, at intermediate and high dispersion, the lamp is useful, either on its own or to supplement the Argon spectrum in the region where this is a bit sparse, e.g.,. between 3000-4000A. The copper-neon spectrum is in particular suitable for high-dispersion work with the IPCS in the near UV, which requires low count rates anyway, because of the presence of the CuI resonance lines near 3200A. When using a CCD detector, considerable patience is required.

Helium:

The spectrum is that of pure HeI; the only contamination is by very weak Hydrogen; Copper lines are not seen.

Between 3800A - 5050A there are 12 well-defined lines, which are useful for calibration of very low dispersion spectra. Between 5875 and 7281 the spectrum contains 4 strong emission lines, while more redwards only a few

weak features are present. The only strong line in the far red is the intercombination line at 10830.3 A, which is just visible in CCD spectra as it is located at the red sensitivity limit.

The spectrum is useful for very low dispersion spectroscopy (e.g. Fos), or in combination with another lamp to fill gaps (e.g. Cu-Ar).

Thorium-Argon:

The Thorium spectrum is well-known for its large number of emission lines, which makes it very useful for high-dispersion work. Indeed, the ThAr lamp may be a better choice than CuAr or CuNe at several positions in the spectrum redwards of 5000A, where gaps sometimes exist between strong Argon features. The use of ThAr is not recommended for low-dispersion work, because of the severe problems which line blending would introduce. Unfortunately, with the present method of operating the ThAr lamp on the IDS, the Thorium features redwards of 7200A are exceedingly weak, and the lamp basically offers no improvement compared with Copper-Argon, unless one is using a CCD detector and prepared to heavily overexpose the very strong Argon features to bring out the weak Thorium features. This, however, is not recommended.

Bi-alkali spectrum (Al/Ca/Mg-Ne):

This lamp was originally acquired for the wavelength calibration of TAURUS data. The spectrum contains, apart from the NeI features, a large number of multiplets of CaI, MgI and AlI, which dominate the spectrum in the blue spectral range. In the far red, some of these multiplets neatly fill gaps in between the NeI lines, which would facilitate its use in high-dispersion work in several selected spectral regions. The relative strengths of the bi-alkali features in the blue make this lamp less suitable for IPCS work, the more so because no copper lines are seen. Thus, apart from its application to TAURUS calibration, this spectrum can be useful at high-dispersion work in some red wavelength intervals, and, perhaps, for high-dispersion work with the 1800 or 2400 gratings in narrow wavelength ranges in the blue.

Consulted Literature

"Tables of Spectral Lines" (1970) A.N. Zaidel', V.K. Prokof'ev, S.M. Raiskii, V.A. Slavnyi, and E.Ya. Shreider IFI/PLENUM New York-London

"Tables of Spectral Lines of Neutral and Ionized Atoms" (1968) A.R. Striganov and N.S. Sventitskii IFI/PLENUM New York-Washington

"An Atlas of the Thorium-Argon Spectrum for the ESO Echelle Spectrograph in the 3400-9000 Region" (1987) S.D'Odorico, M Ghigo and D.Ponz ESO Scientific Report No. 6

"Wavelengths and Energy levels of ArI and ArII in the region 3400-9800 A" (1973) G.Norlen Physica Scripta 8 , 249-268

Table 1 Lines observed in the Copper-Argon spectrum at high dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
3718.207	ArII	4237.420	ArII	4806.021	ArII	5421.352	ArI
3729.309	ArII	4251.185	ArI	4847.810	ArII	5439.989	ArI
3737.889	ArII	4259.362	ArI	4865.911	ArII	5442.248	ArI
3765.270	ArII	4266.286	ArI	4876.261	ArI	5443.24	ArI
3766.119	ArII	4272.169	ArI	4879.864	ArII	5451.652	ArI
3780.840	ArII	4277.528	ArII	4888.261	ArII	5454.307	ArII
3803.172	ArII	4282.898	ArII	4889.042	ArII	5457.416	ArI
3834.679	ArI	4300.101	ArI	4904.752	ArII	5467.161	ArI
3850.581	ArII	4309.239	ArII	4933.209	ArII	5473.452	ArI
3868.528	ArII	4331.200	ArII w	4956.750	ArI	5490.119	ArI
3891.980	ArII w	4333.561	ArI	4965.080	ArII	5495.874	ArI
3925.719	ArII	4335.338	ArI	4972.160	ArII	5506.113	ArI
3928.623	ArII	4345.168	ArI	5009.334	ArII	5524.957	ArI
3932.547	ArII	4348.064	ArII	5017.163	ArII	5528.93	ArI
3946.097	ArII	4352.205	ArII	5048.813	ArI	5534.45	ArI
3947.505	ArI	4362.066	ArII	5054.178	ArI	5540.90	ArI
3948.979	ArI	4367.832	ArII	5060.079	ArI	5554.050	ArII
3974.477	ArII	4370.753	ArII	5062.037	ArII	5558.702	ArI
3979.356	ArII	4375.954	ArII	5090.495	ArII	5572.541	ArI
3992.054	ArII	4379.667	ArII	5105.541	CuI	5577.685	ArII
3994.792	ArII	4385.057	ArII	5118.202	ArI	5581.871	ArI
4013.857	ArII	4400.097	ArII	5125.765	ArII	5588.720	ArI
4033.809	ArII	4400.986	ArII	5141.783	ArII	5597.476	ArI
4035.460	ArII	4420.912	ArII	5145.308	ArII	5601.122	ArI
4038.804	ArII	4426.001	ArII	5151.391	ArI	5606.733	ArI
4042.894	ArII	4430.189	ArII w	5153.235	CuI	5618.010	ArII
4044.418	ArI	4433.838	ArII	5162.285	ArI	5620.913	ArI
4045.965	ArI	4439.461	ArII w	5165.773	ArII	5623.778	ArII
4052.921	ArII	4448.879	ArII	5176.229	ArII	5625.678	ArII
4072.11	ArII b	4474.759	ArII	5177.540	ArI	5635.575	ArI b
4076.72	ArII b	4481.811	ArII	5187.746	ArI	5637.32	ArI
4079.574	ArII	4490.982	ArII	5214.774	ArI	5639.14	ArI
4080.645	ArII	4498.538	ArII	5218.202	CuI	5641.375	ArI
4082.387	ArII	4502.927	ArII	5221.271	ArI	5648.686	ArI
4097.140	ArII	4510.733	ArI	5241.091	ArI	5650.704	ArI
4103.912	ArII	4522.323	ArI	5252.788	ArI	5654.457	ArII
4112.815	ArII	4536.552	ArII	5254.465	ArI	5659.127	ArI
4128.640	ArII	4545.052	ArII	5264.782	ArII	5672.952	ArII
4131.724	ArII	4563.743	ArII w	5286.887	ArII	5681.900	ArI
4156.086	ArII	4579.350	ArII	5292.517	CuI	5689.91	ArI
4158.591	ArI	4589.899	ArII	5305.688	ArII	5691.661	ArII
4164.180	ArI	4596.097	ArI	5317.726	ArI	5700.873	ArI
4179.297	ArII	4598.763	ArII	5329.698	ArII	5712.48	ArI
4181.884	ArI	4609.567	ArII	5345.81	ArI	5738.387	ArI
4190.87	ArI b	4628.441	ArI	5347.412	ArI	5739.520	ArI
4198.317	ArI	4637.233	ArII	5358.363	ArII	5772.114	ArI
4200.675	ArI	4651.124	CuI w	5373.494	ArI	5774.009	ArI
4217.431	ArII	4657.901	ArII	5387.37	ArI	5782.130	CuI
4218.665	ArII	4702.316	ArI	5393.971	ArI	5783.536	ArI
4222.637	ArII	4726.868	ArII	5397.516	ArII	5786.555	ArII
4226.988	ArII	4732.053	ArII	5402.605	ArII	5789.474	ArI
4228.158	ArII	4735.906	ArII	5407.344	ArII	5802.080	ArI
4229.870	ArII	4764.865	ArII	5410.473	ArI	5812.760	ArII

Table 1 . The Copper-Argon spectrum at high dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
5834.263	ArI	6179.419	ArI	6664.051	ArI	7618.33	ArI
5843.778	ArII	6187.135	ArII	6666.359	ArII	7628.86	ArI
5860.310	ArI	6201.100	ArII	6677.282	ArI	7635.106	ArI
5870.454	ArII	6212.503	ArI	6684.293	ArII	7670.04	ArI
5882.624	ArI	6215.938	ArI	6698.876	ArI	7723.98	ArI b
5888.584	ArI	6230.922	ArI	6719.218	ArI	7798.55	ArI
5912.085	ArI	6239.712	ArII	6722.890	ArI	7814.33	ArI
5916.599	ArI	6243.120	ArII	6752.834	ArI	7861.91	ArI
5927.126	ArI	6248.406	ArI	6754.30	ArI	7868.195	ArI
5928.813	ArI	6278.645	ArI	6756.163	ArI w	7891.075	ArI
5940.855	ArI	6295.446	ArII	6766.612	ArI	7948.176	ArI
5942.669	ArI	6296.872	ArI	6779.933	ArI	8006.157	ArI
5949.258	ArI	6307.657	ArI	6808.531	ArII	8014.786	ArI
5964.472	ArI	6309.160	ArI	6818.291	ArI	8046.117	ArI
5968.320	ArI	6324.416	ArII	6827.249	ArI	8053.309	ArI
5971.601	ArI	6333.146	ArII	6851.884	ArI	8103.693	ArI
5981.924	ArI	6348.232	ArII	6861.269	ArII	8115.311	ArI
5985.914	ArII	6357.15	ArII b	6863.535	ArII	8264.522	ArI
5987.302	ArI	6364.894	ArI	6871.289	ArI	8384.724	ArI
5989.339	ArI	6369.575	ArI	6879.582	ArI	8408.210	ArI
5994.66	ArI	6384.717	ArI	6887.088	ArI	8424.647	ArI
5998.999	ArI	6393.797	ArII	6888.174	ArI	8521.442	ArI
6005.724	ArI	6394.729	ArII	6937.664	ArI	8605.776	ArI
6013.678	ArI	6396.610	ArII	6951.478	ArI	8620.460	ArI
6025.150	ArI	6399.207	ArII	6960.250	ArI	8667.944	ArI
6032.127	ArI	6403.013	ArII	6965.431	ArI	8678.408	ArI
6043.223	ArI	6408.904	ArII	6992.213	ArI	8736.63	ArI
6044.468	ArII	6416.307	ArI	7030.251	ArI	8761.686	ArI
6046.898	ArII	6418.370	ArII	7067.218	ArI	8771.860	ArII
6052.723	ArI	6422.897	ArII	7068.734	ArI	8784.59	ArI
6059.373	ArI	6431.555	ArI	7086.704	ArI	8799.088	ArI
6064.751	ArI	6437.600	ArII	7107.478	ArI	8840.82	ArI
6081.243	ArI	6441.900	ArII	7125.820	ArI	8849.97	ArI
6085.880	ArI	6443.860	ArII	7147.042	ArI	8874.84	ArI
6090.785	ArI	6466.553	ArI	7158.839	ArI	8905.658	ArII
6098.803	ArI	6468.048	ArII	7206.980	ArI	8931.326	ArII
6101.162	ArI	6472.429	ArII	7265.172	ArI	8962.147	ArI
6103.539	ArII	6481.145	ArII	7270.664	ArI	8986.615	ArII
6104.590	ArI	6483.083	ArII	7272.936	ArI	9008.455	ArII
6105.635	ArI	6493.969	ArI	7311.716	ArI	9017.596	ArII
6113.466	ArI	6499.106	ArI	7316.005	ArI	9057.23	ArI
6114.923	ArII	6513.846	ArI	7353.293	ArI	9073.34	ArI
6119.657	ArI	6538.112	ArI	7372.118	ArI	9075.395	ArI
6123.362	ArII	6594.66	ArI	7383.981	ArI	9122.967	ArI
6127.416	ArI	6596.114	ArI	7392.980	ArI	9194.639	ArI
6128.723	ArI	6598.678	ArI	7412.337	ArI	9198.61	ArI
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6142.05	ArI	6620.967	ArII	7435.368	ArI	9224.499	ArI
6145.441	ArI	6632.084	ArI	7471.164	ArI	9291.531	ArI
6155.239	ArI	6638.221	ArII	7484.327	ArI	9354.220	ArI
6165.123	ArI	6639.740	ArII	7500.656	ArI	9402.69	ArI
6170.174	ArI	6643.698	ArII	7503.869	ArI	9459.09	ArI
6172.278	ArII	6656.939	ArI	7510.408	ArI	9657.786	ArI
6173.096	ArI	6660.676	ArI	7514.652	ArI	9784.503	ArI

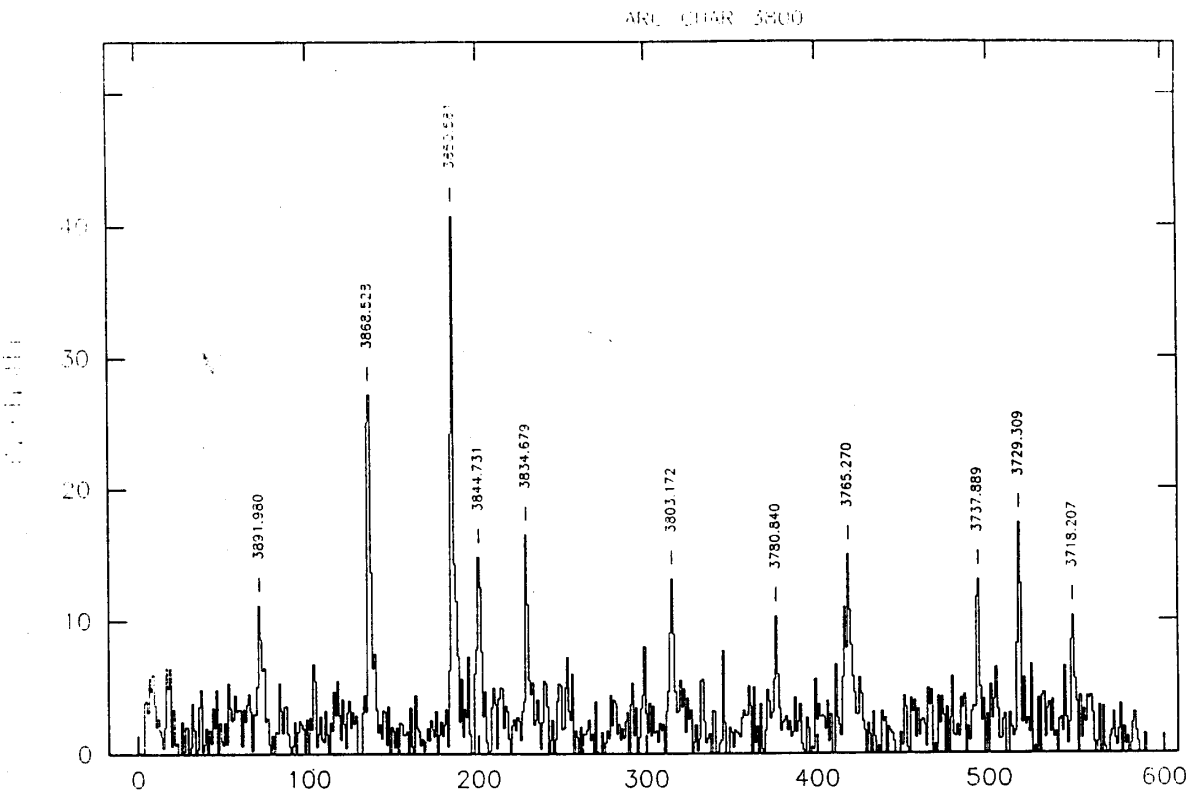
Notes to table 1 :

3891.980	weak ArII at 3891.402
4072.11	ArII, blend of 4072.005 (3) and 4072.385 (1)
4076.72	ArII, blend of 4076.628 (2) and 4076.943 (1)
4190.87	ArI, blend of 4190.714 (1) and 4191.029 (1)
4266.286	weak line of ArII at 4266.527
4331.200	weak line of ArII at 4332.030 (0.25)
4430.189	weak line of ArII at 4430.996 (0.3)
4439.461	weak line of ArII at 4439.878 (0.3) at low dispersion blended to 4439.61
4563.743	weak ArII at 4564.405
4651.124	CuI, with a weak line of ArI at 4651.388
5635.575	weak ArII at 5635.882
6357.15	ArII, blend of 6357.023 (2) 6357.678 (1)
6756.163	weak ArII at 6756.553
7723.98	ArI, blend of 7723.7611 and 7724.2072 at equal intensifies

Figure 1 The Copper-Argon spectrum between 3700 A and 9800 A at high dispersion

Notes to figure 1

Spectrum	CuAr from 3700 A to 9800 A at high dispersion	
Camera	IDS 500 mm	
Detector	GEC 3 "GEC BLUE"	
Gratings	R1200B for the region 3700 A - 5000 A	
	R1200Y for the region 5200 A - 9800 A	
Collimator	Al Wide	
Dispersion	16.5 A/mm or 2.75 pixel/A	
Exposure times	3800 - 6800	600 s
	7000 - 7400	30 s
	7600	20 s
	7750	30 s
	7900	60 s
	8050 - 8350	30 s
	8500 & 8650	60 s
	8800	600 s
	8950	300 s
	3100	30 s
	9250	60 s
	9400	120 s
	9700	30 s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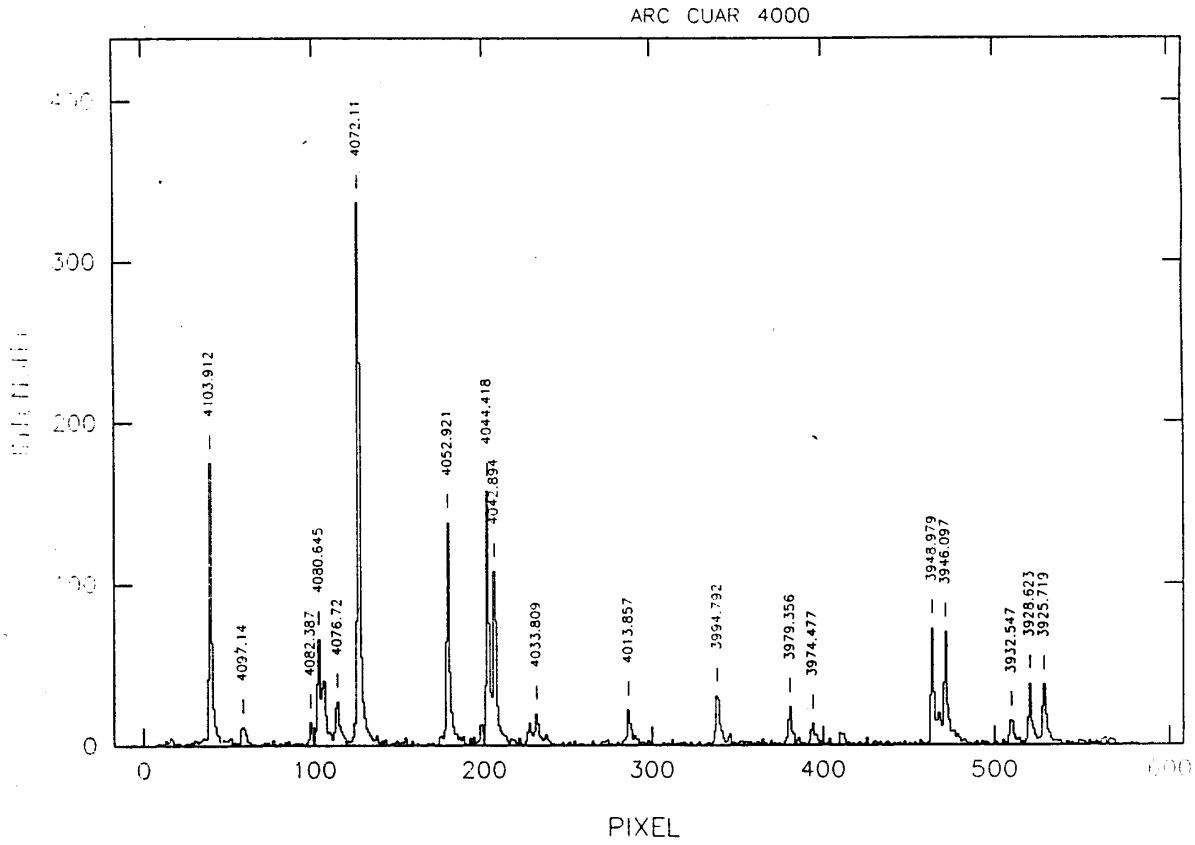
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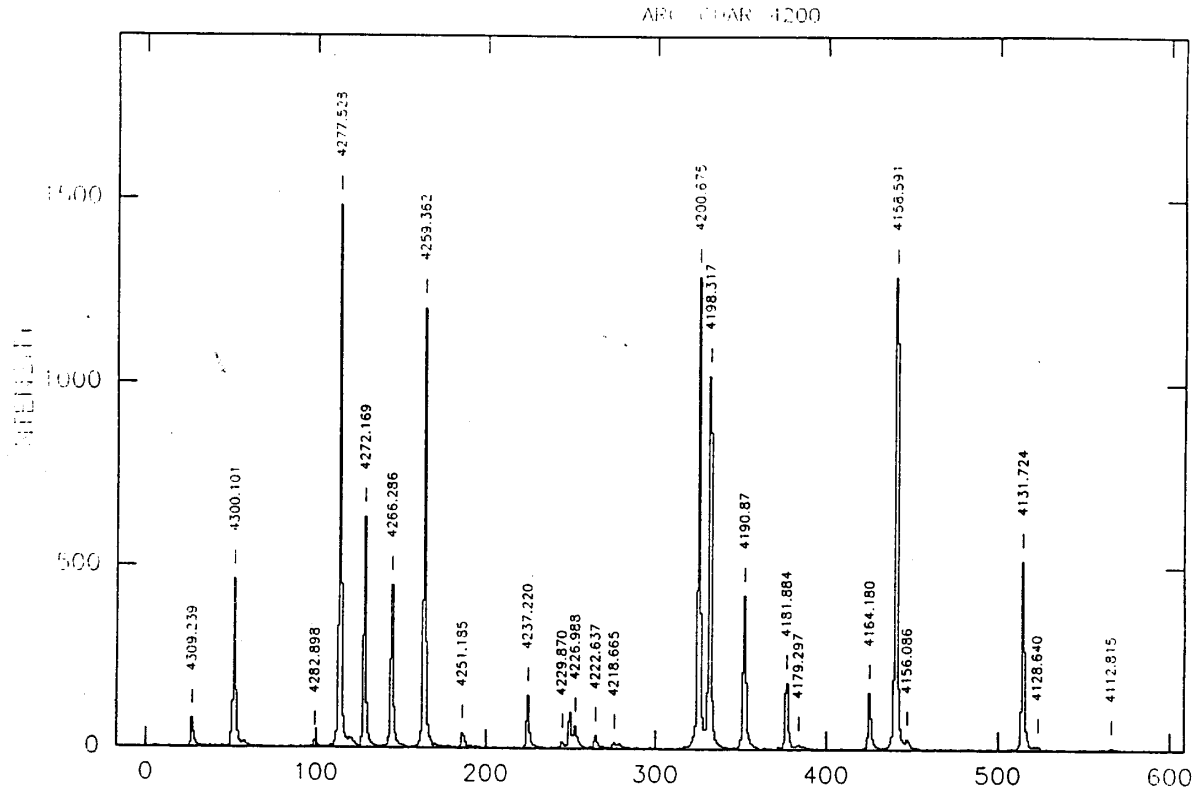
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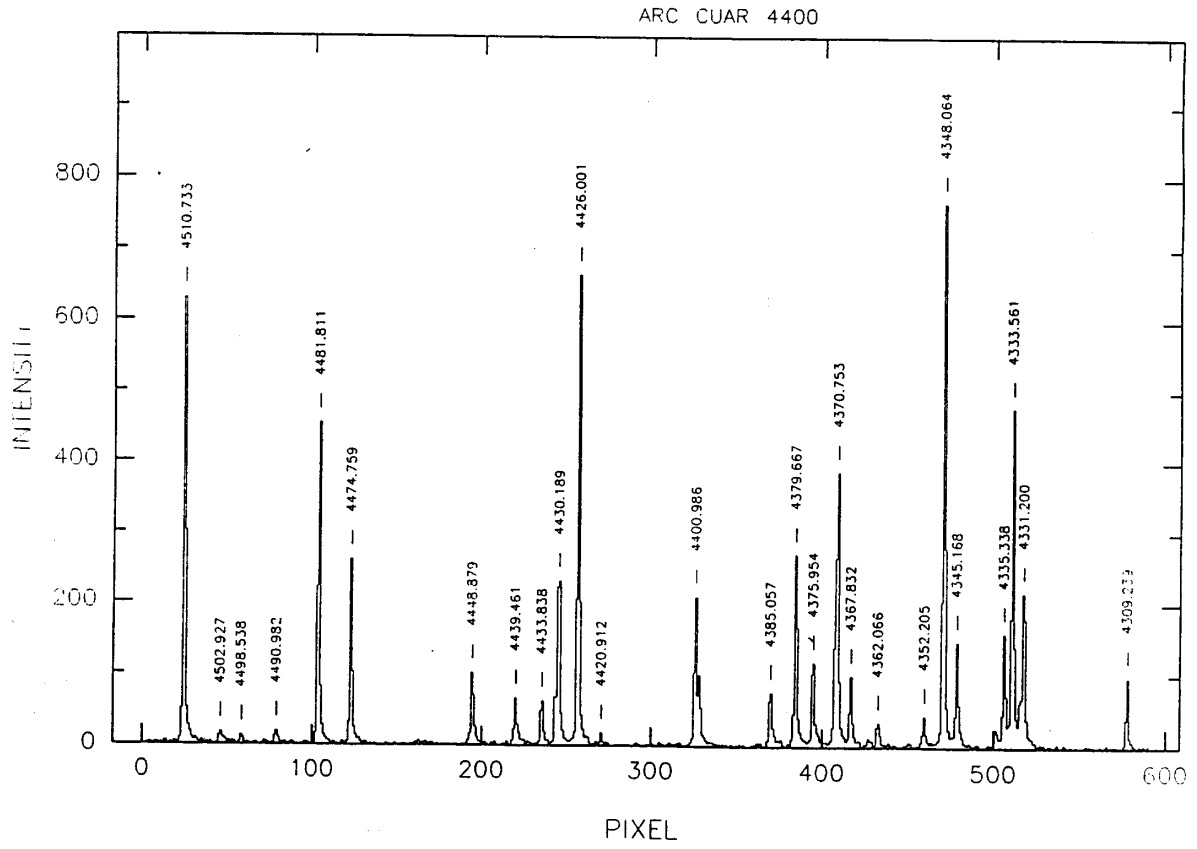
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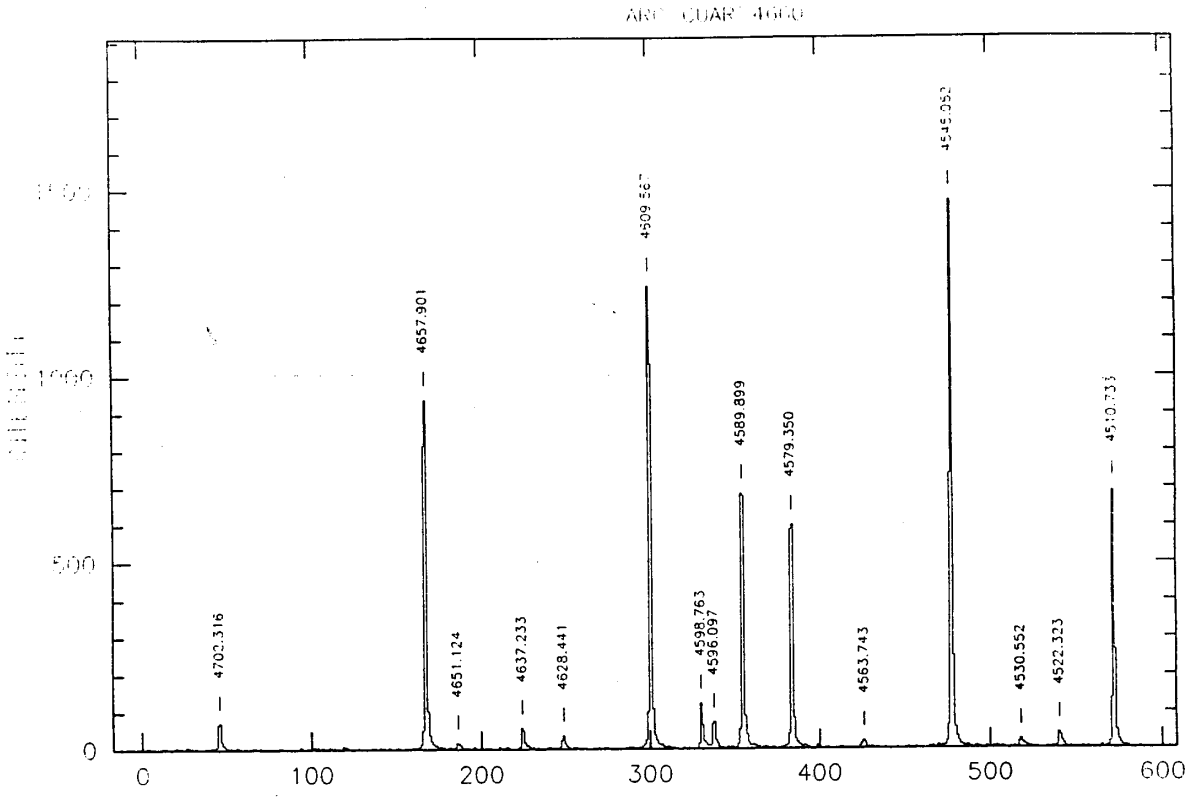
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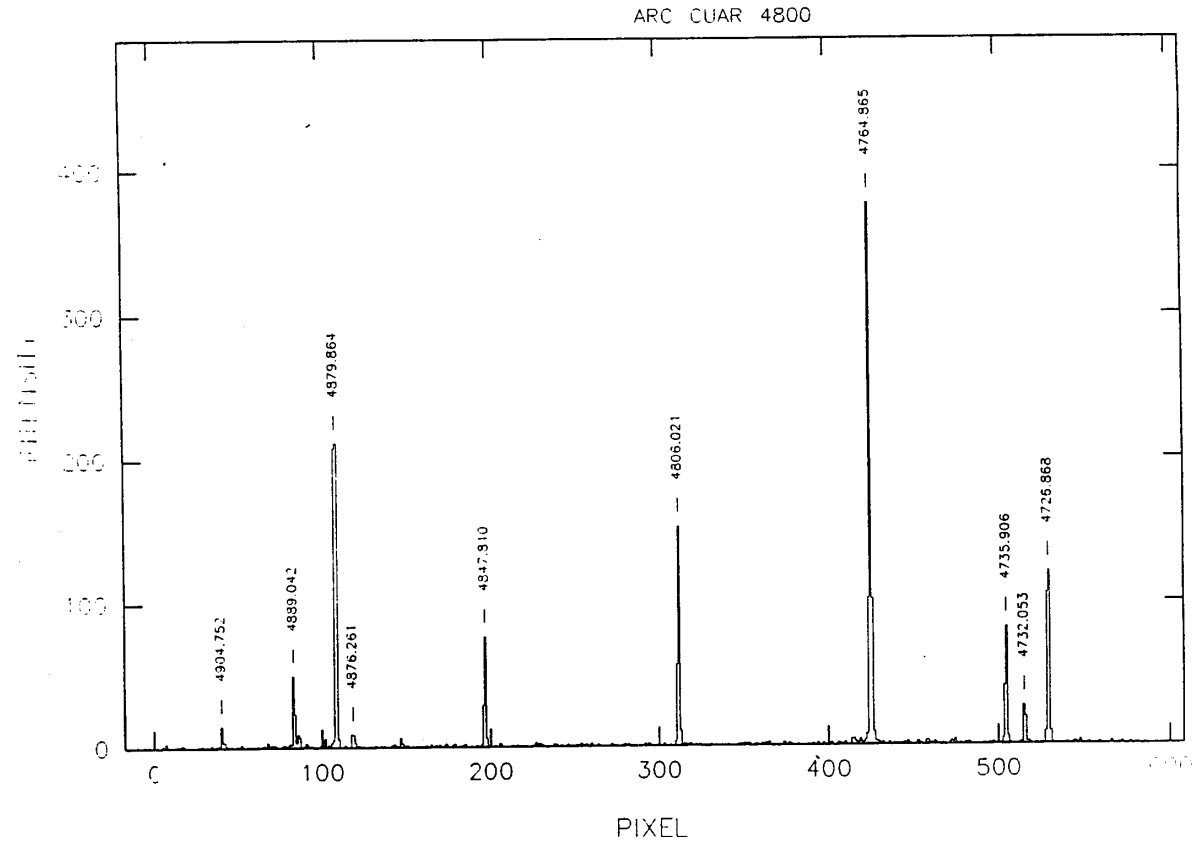
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4726.868
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400
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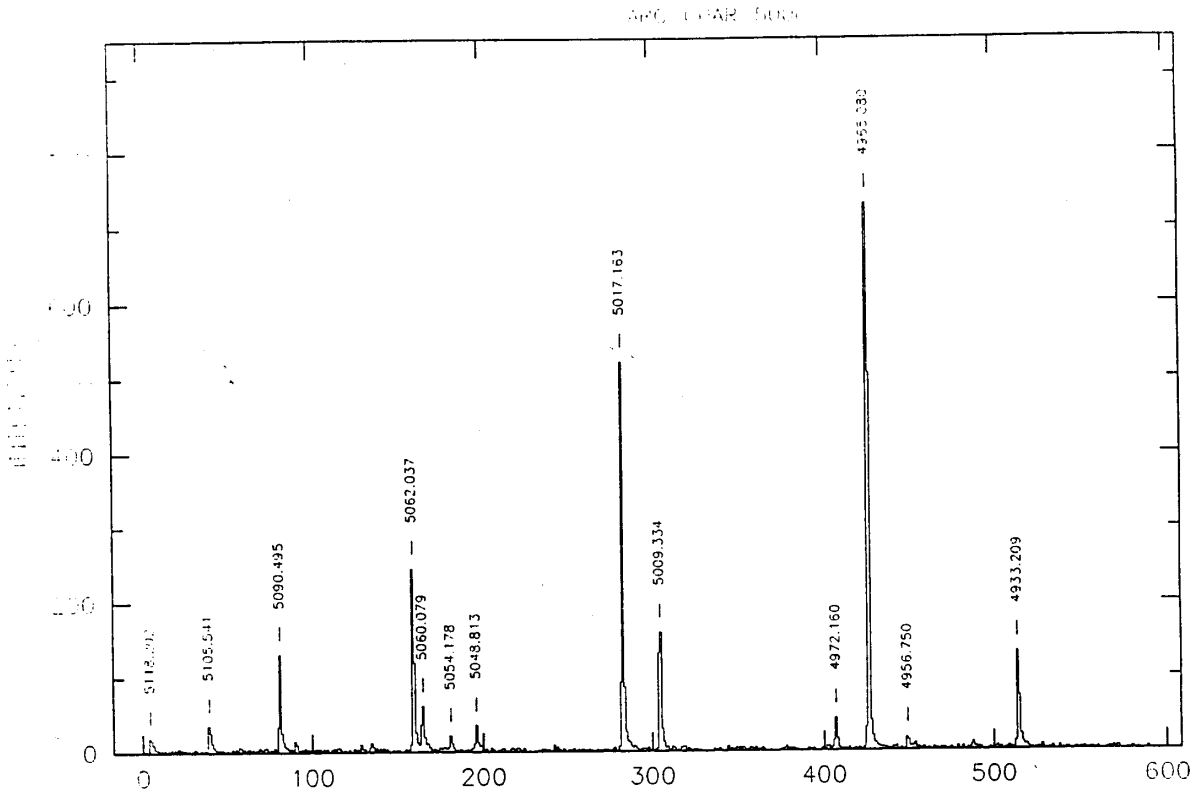
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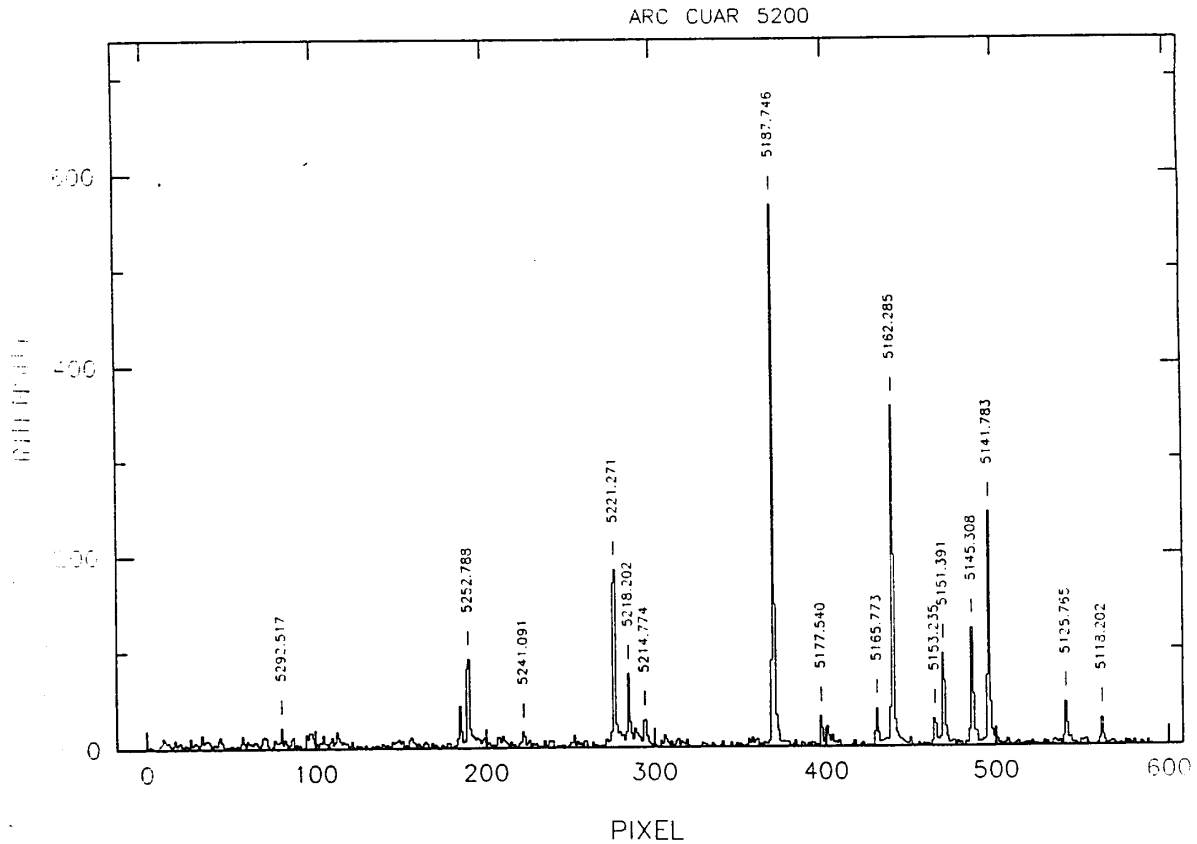
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5162.285
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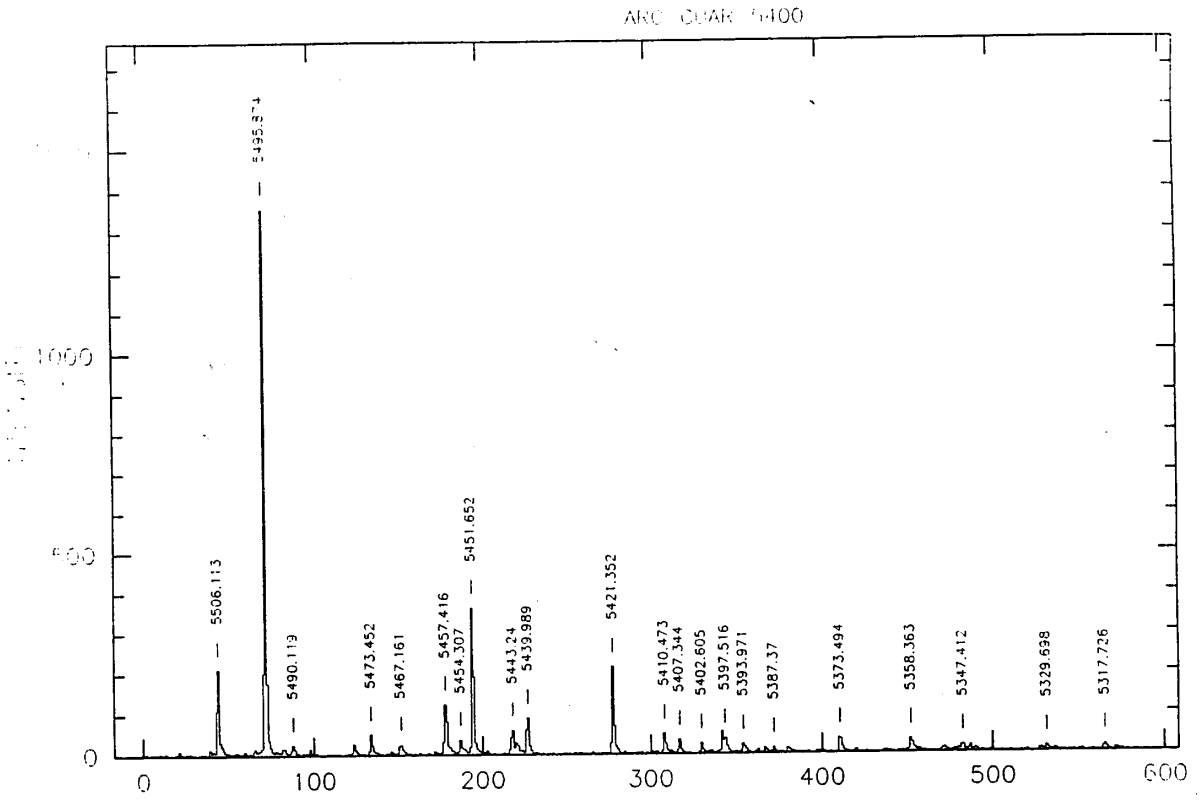
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5443.24
5439.989
5421.352
5410.473
5407.344
5402.605
5397.516
5393.971
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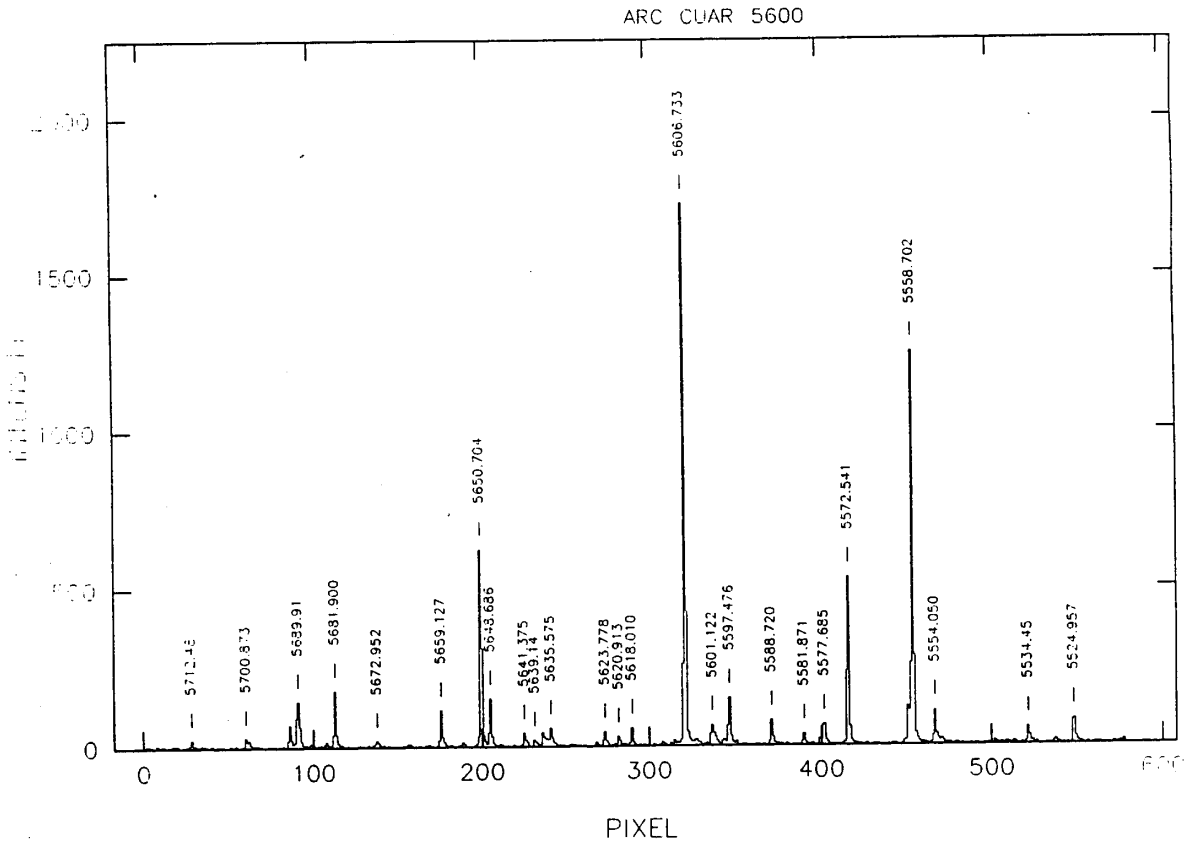
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5641.375
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5635.575
5623.778
5620.913
5618.010
5601.122
5597.476
5588.720
5581.871
5577.685
5572.541
5558.702
5554.050
5534.45
5524.957
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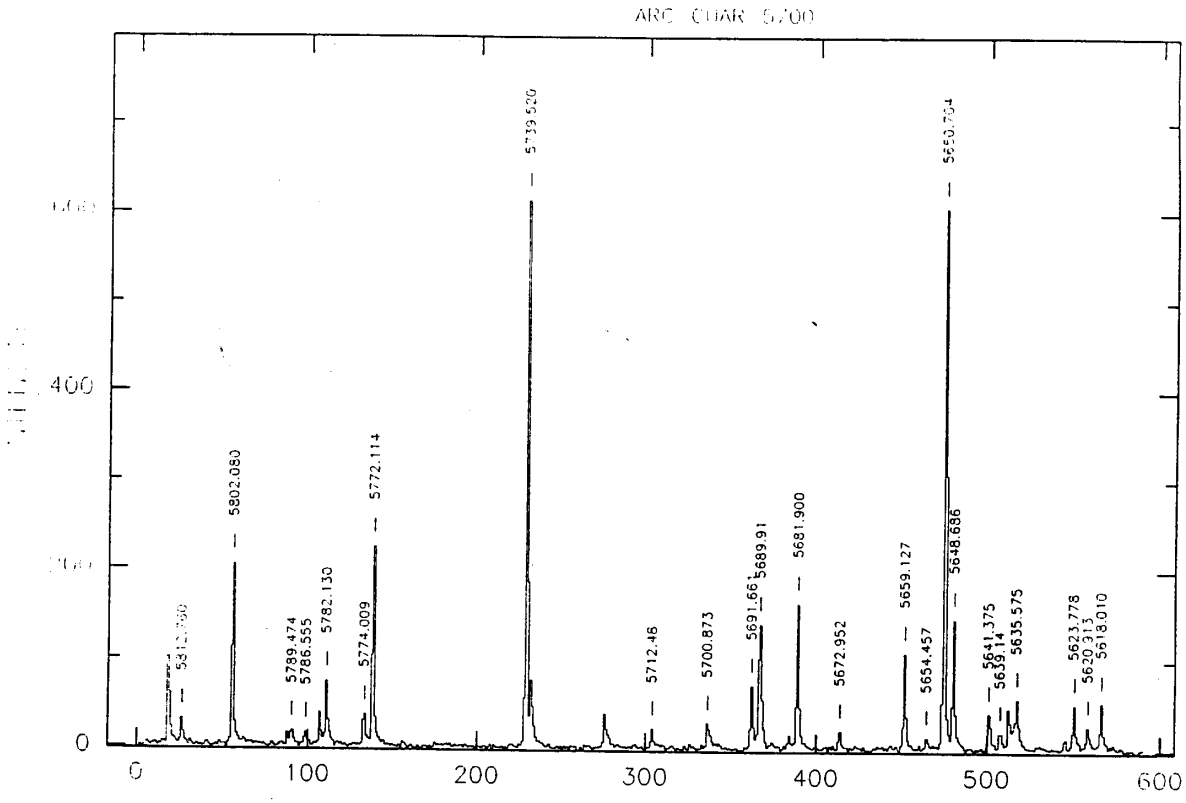
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5772.114
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5789.474
5786.555
5774.009
5712.46
5700.873
5691.66
5689.91
5681.900
5672.952
5659.127
5654.457
5648.886
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5623.778
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5618.010
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400
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500
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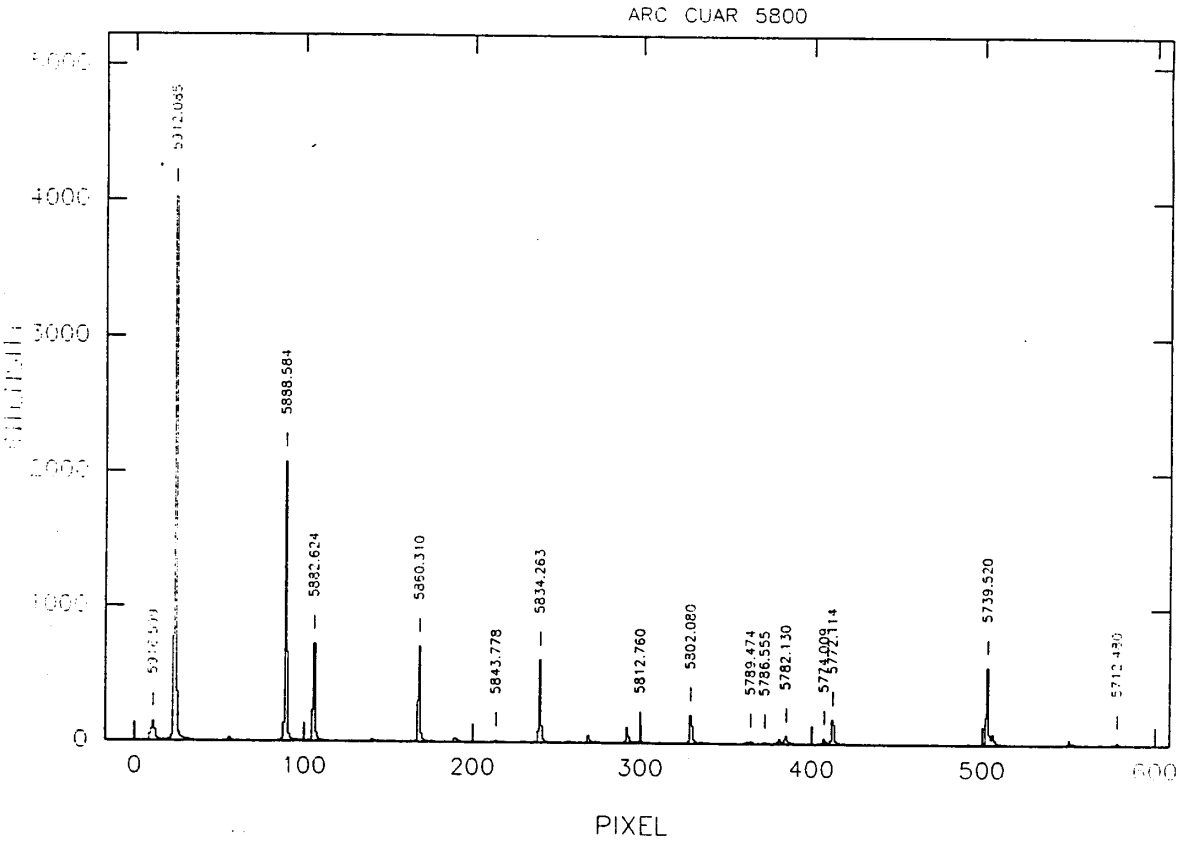
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5860.310
5834.263
5843.778
5812.760
5802.080
5789.474
5786.555
5782.130
5774.009
5772.114
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5712.430
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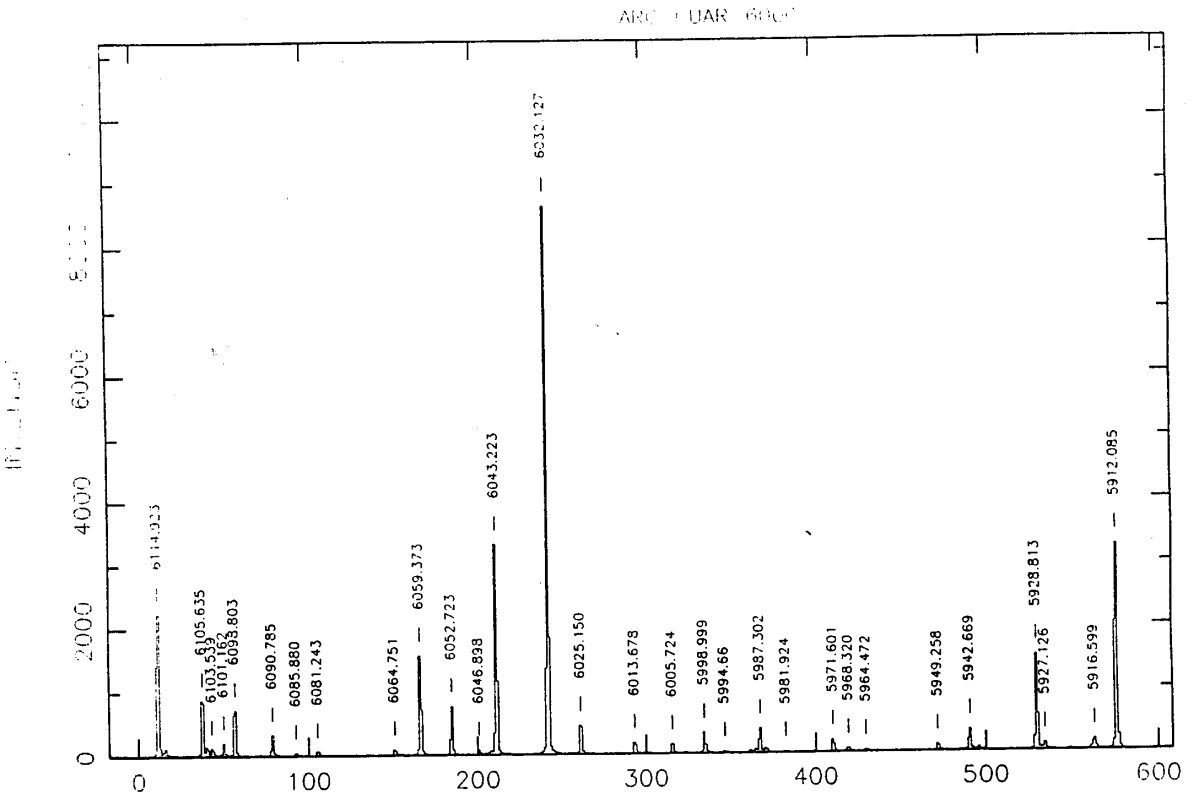
1000
2000
3000
4000
0
100
200
300
400
500
600
PIXEL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6101.182
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6059.373
6052.723
6046.898
6043.223
6025.150
6013.678
6005.724
5998.999
5994.66
5987.302
5981.924
5971.601
5968.320
5964.472
5949.258
5942.669
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6000
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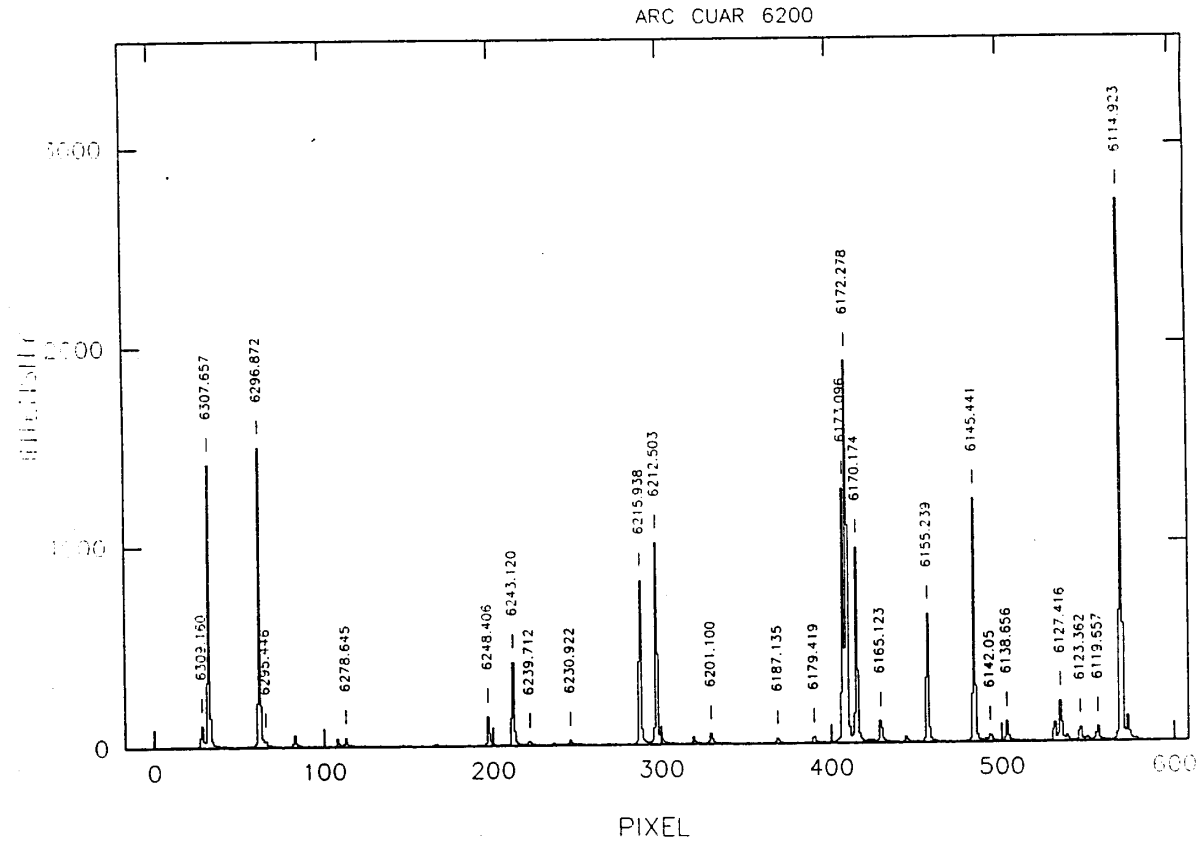
400
500
600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6303.160
6295.446
6278.645
6248.406
6243.120
6239.712
6230.922
6215.938
6212.503
6201.100
6187.135
6179.419
6172.278
6177.096
6170.174
6165.123
6155.239
6145.441
6142.05
6138.656
6127.416
6123.362
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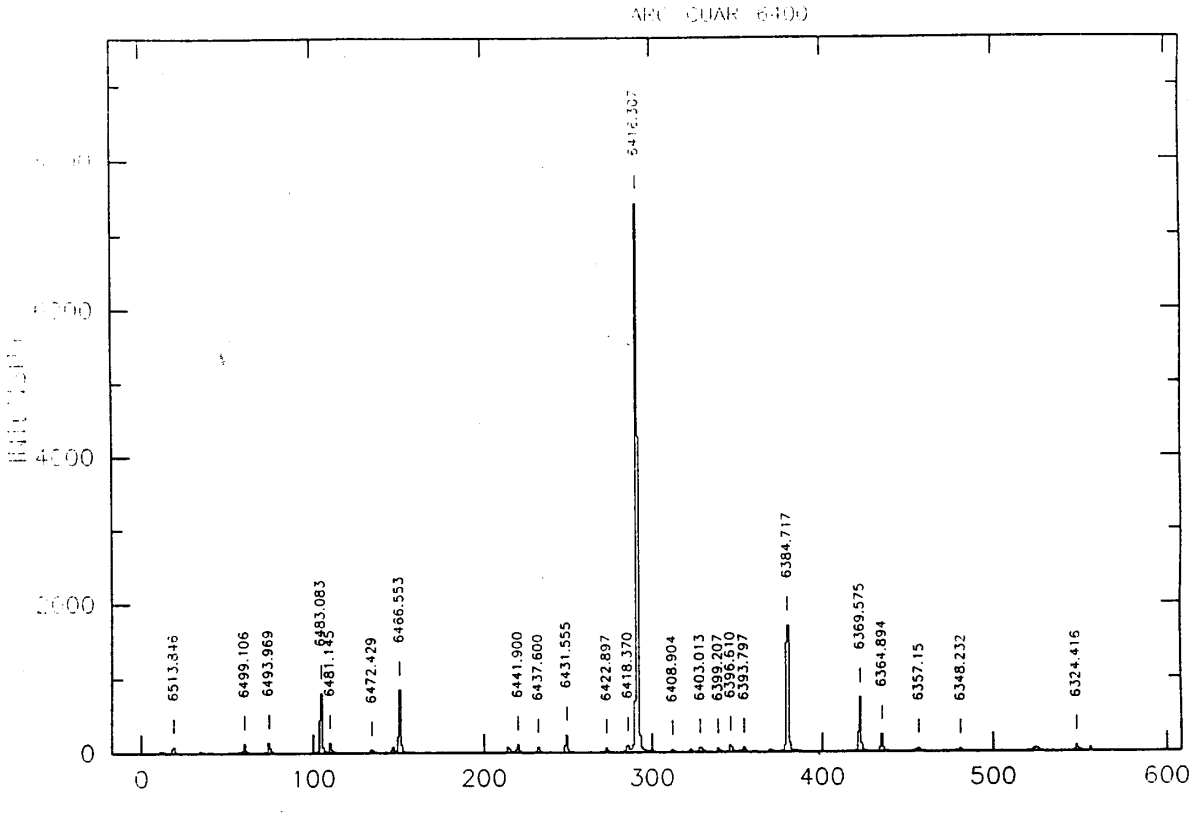
PIXEL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6483.083
6481.145
6472.429
6466.553
6441.900
6437.600
6431.555
6422.897
6418.370
6416.307
6408.904
6403.013
6399.207
6396.610
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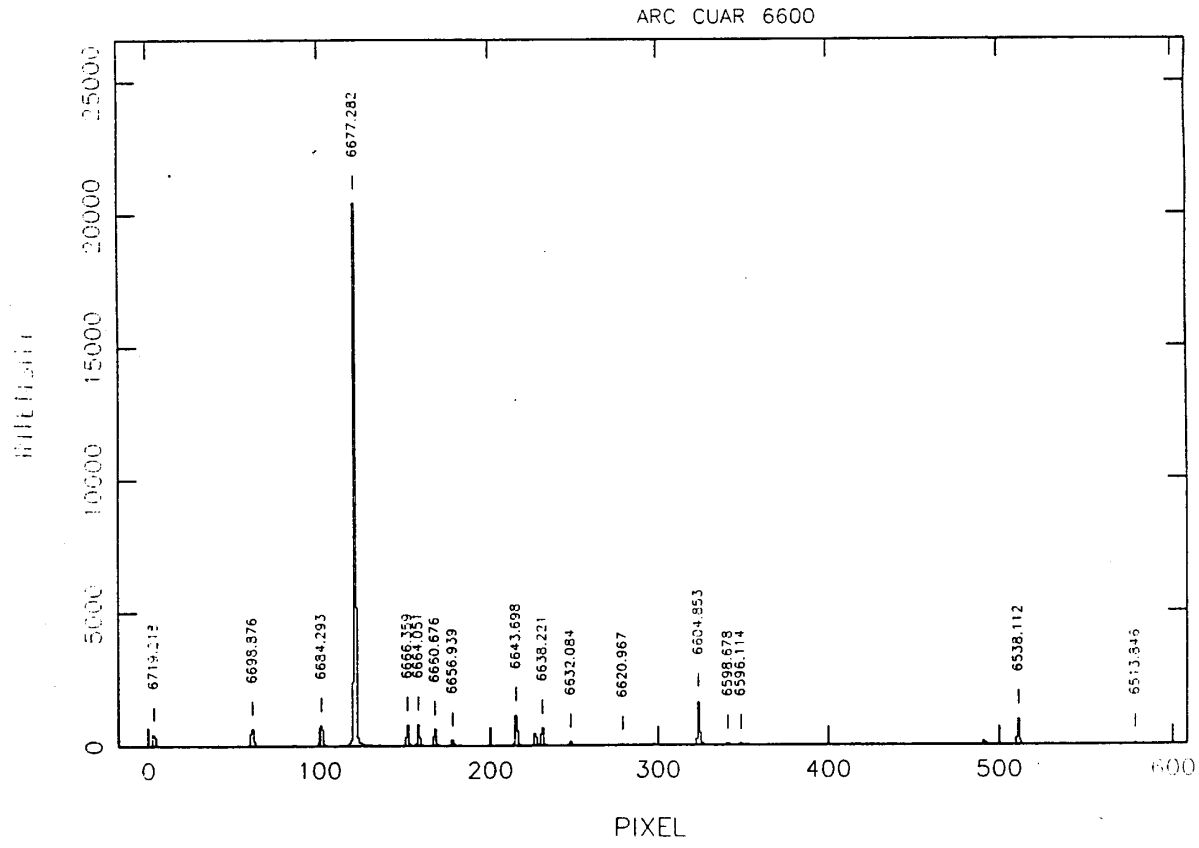
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6632.084
6620.967
6604.853
6598.678
6596.114
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500
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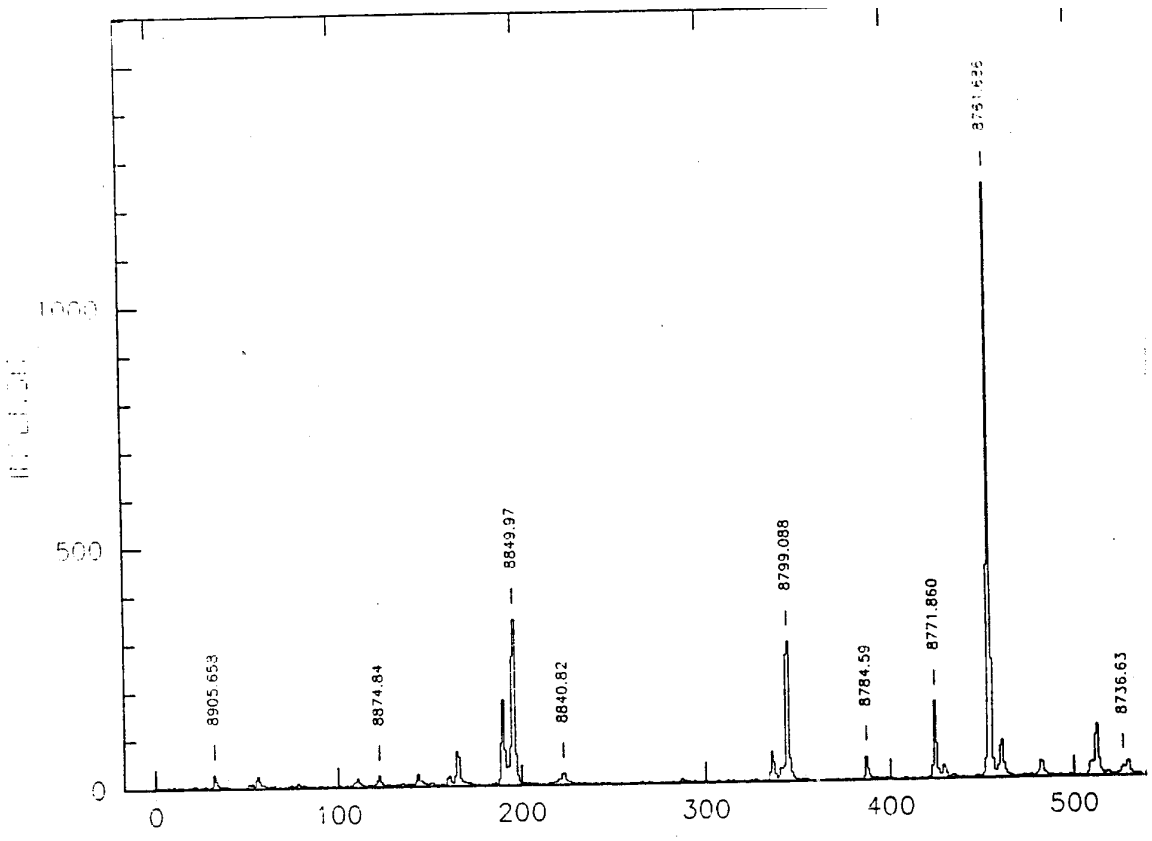
PIXEL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8771.860
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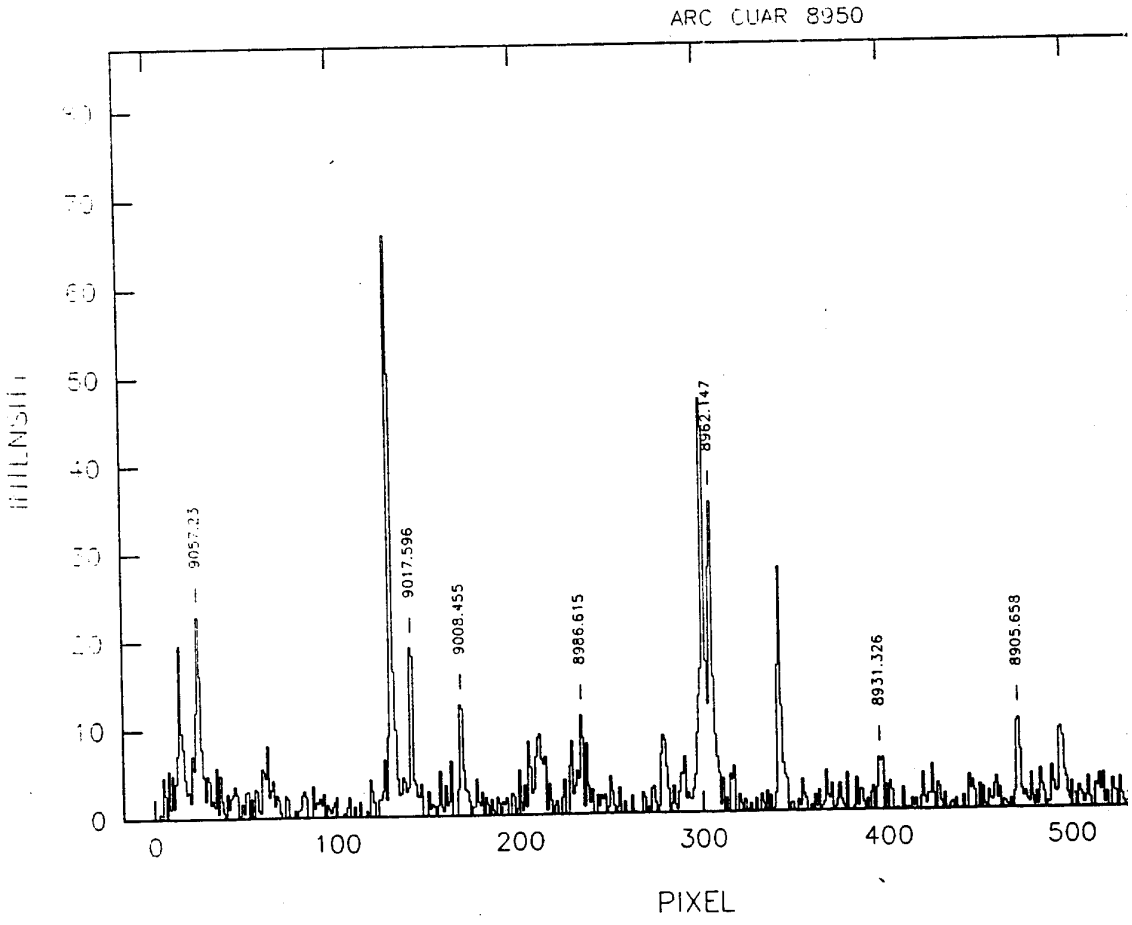
300
400
500


ARC CUAR 8950
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9008.455
8986.615
8962.747
8931.326
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30
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60
70
0
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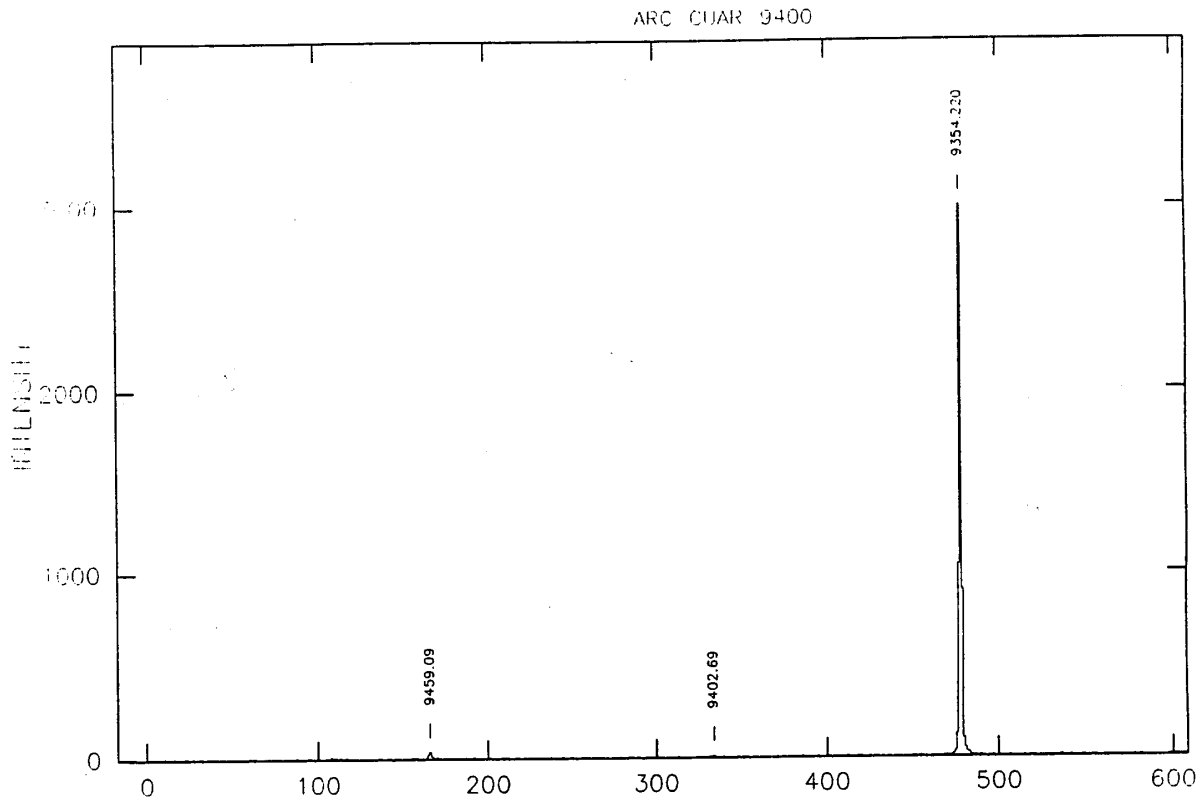
300
400
500
PIXEL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300
400
500
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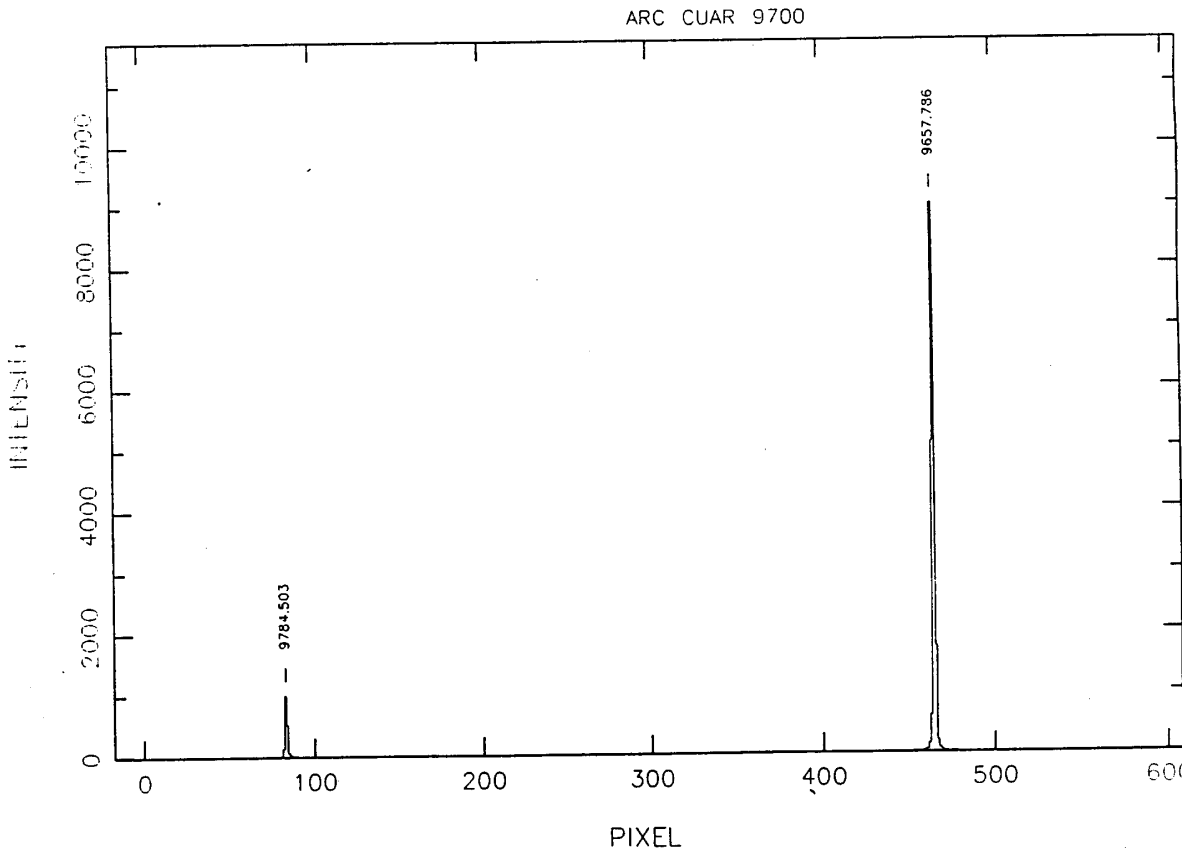
ARC CUAR 9700
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6000
4000
2000
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200
300
400
500
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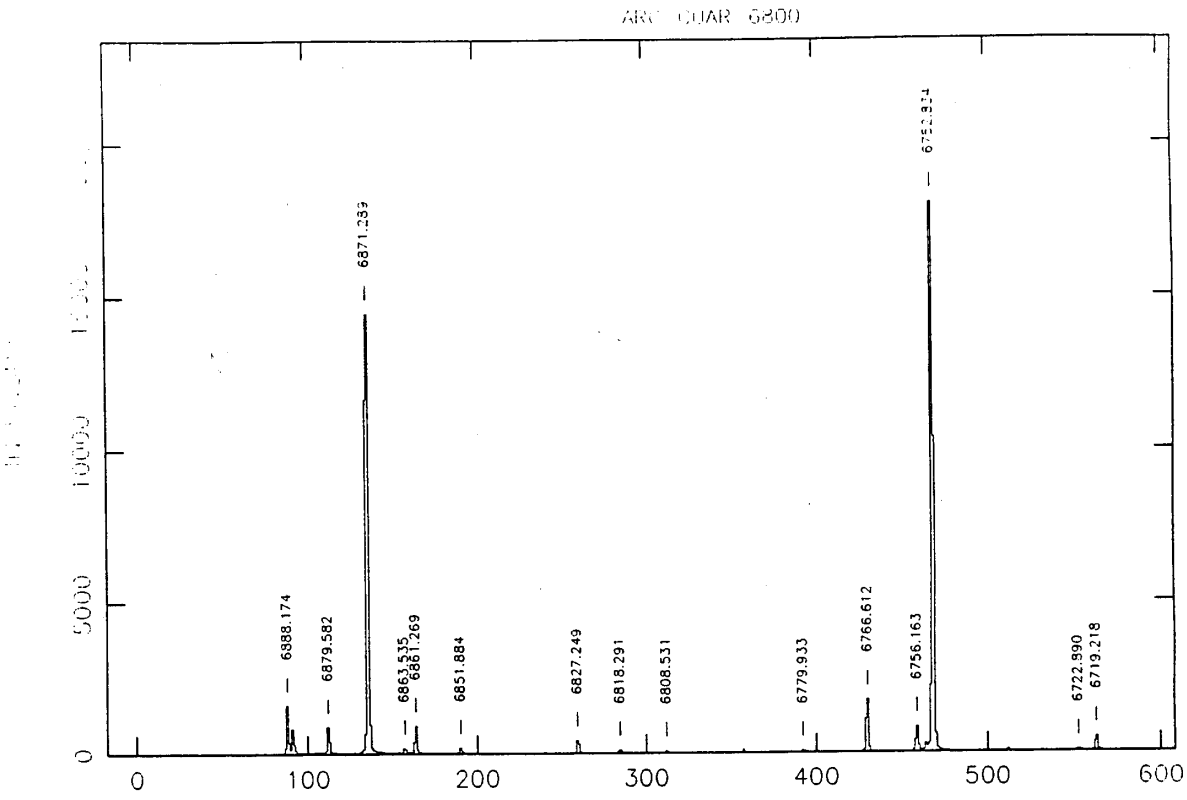
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6861.269
6851.884
6827.249
6818.291
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6766.612
6756.163
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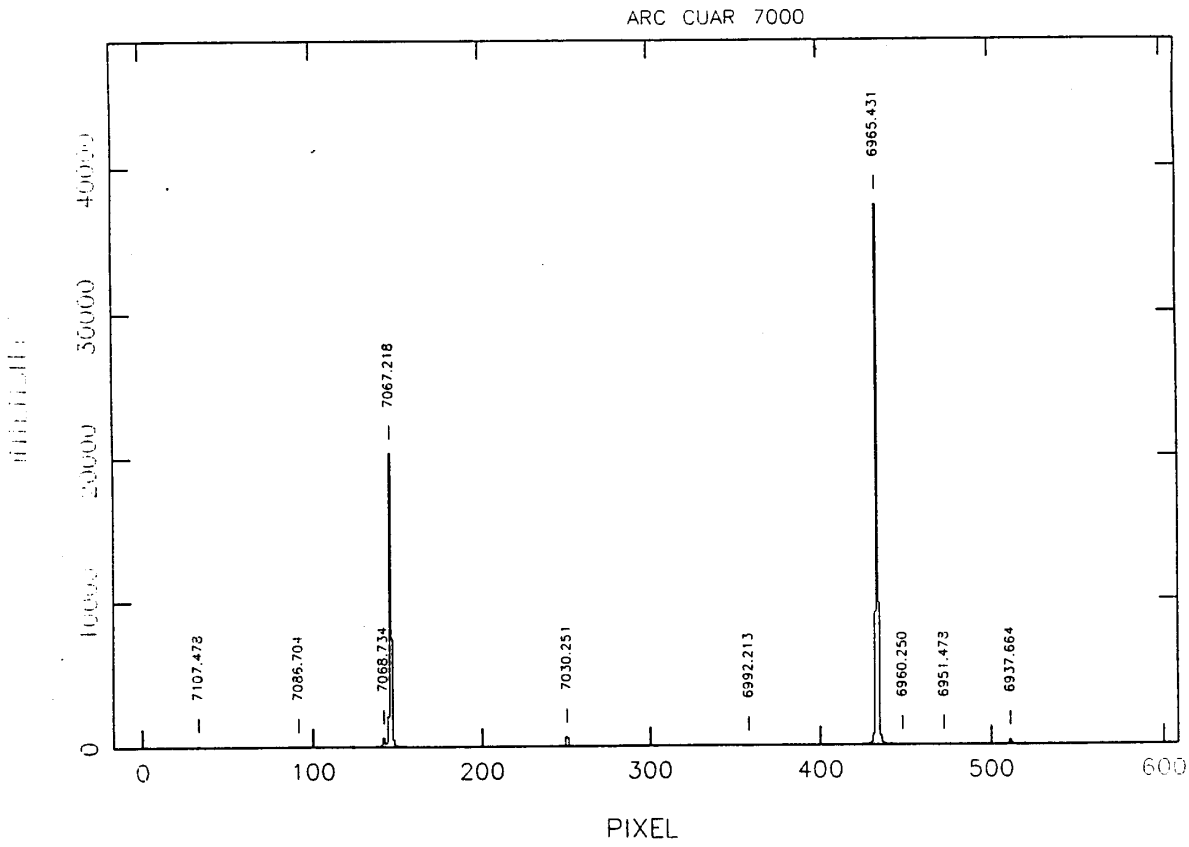
500
600


ARC CUAR 7000
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7088.734
7067.218
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6960.250
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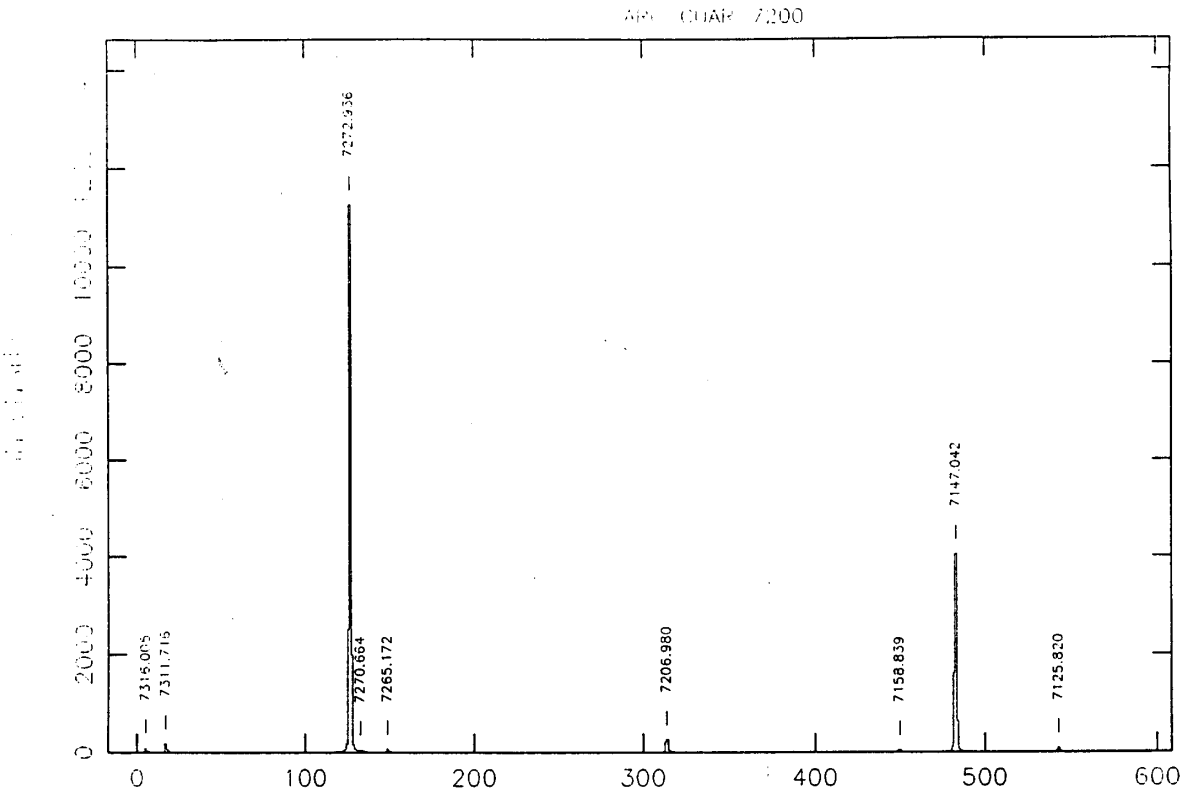
500
600
PIXEL


ARC CUAR 7200
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7270.664
7265.172
7206.980
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7147.042
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8000
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300
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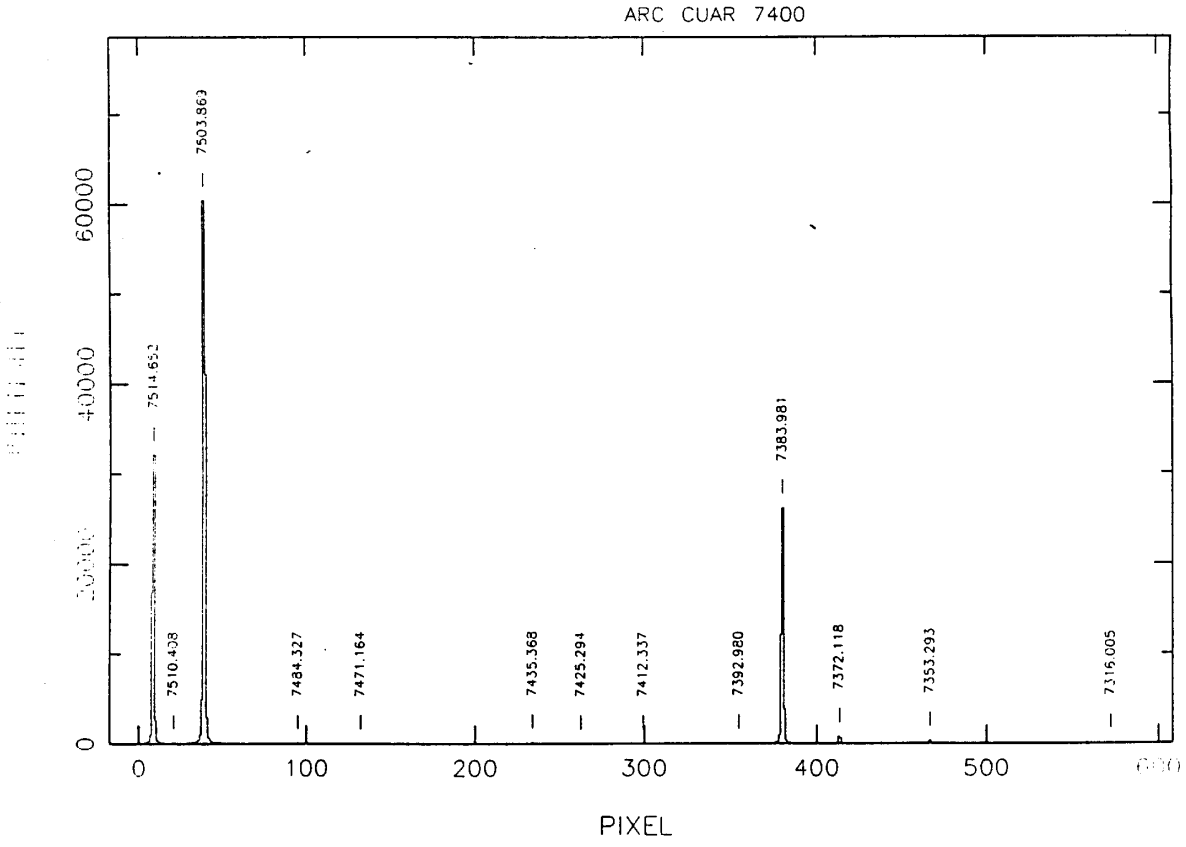
500
600


ARC CUAR 7400
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7510.438
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7435.368
7425.294
7412.337
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400
500
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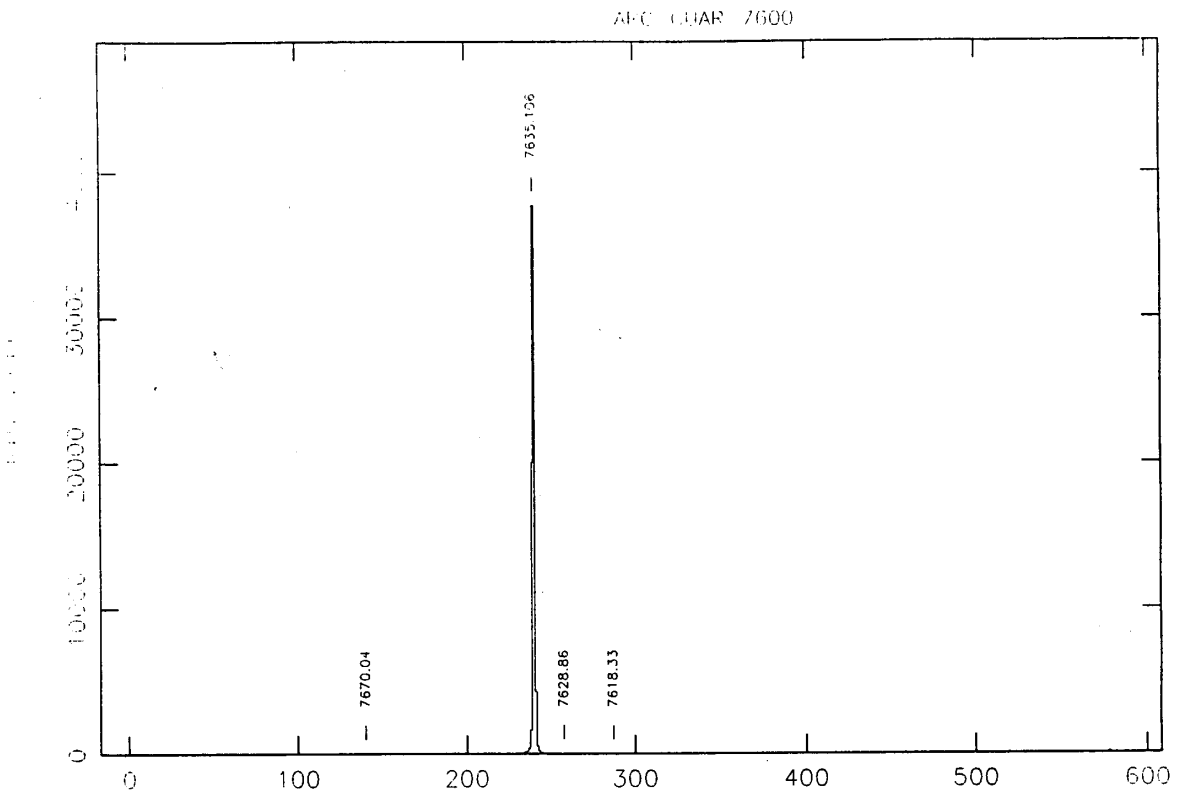
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400
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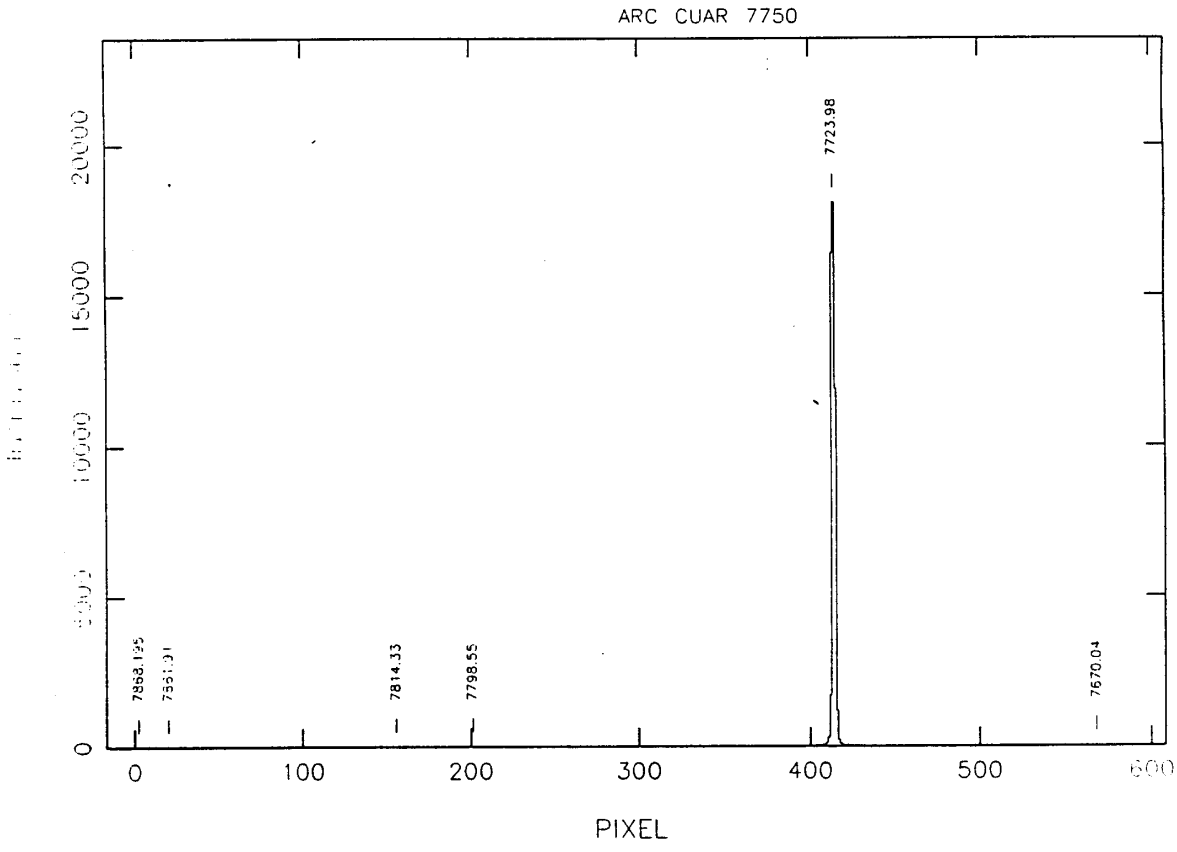
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7814.33
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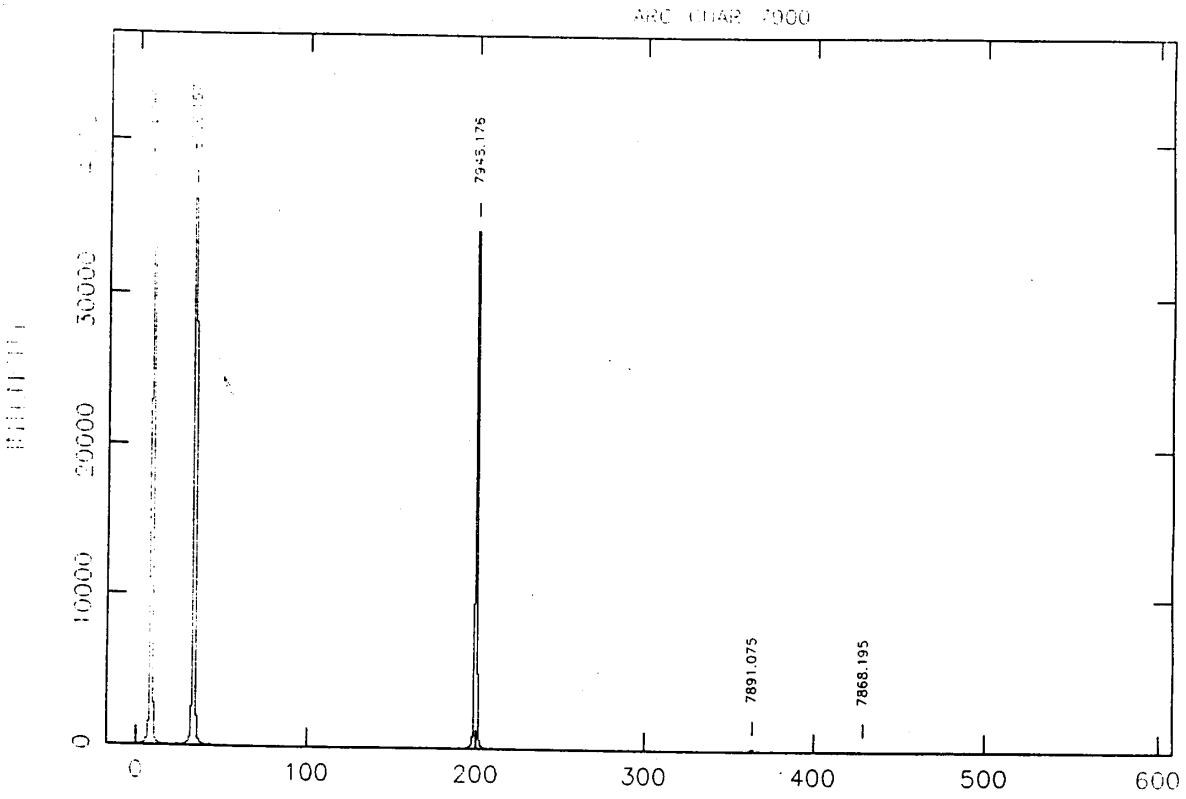
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30000
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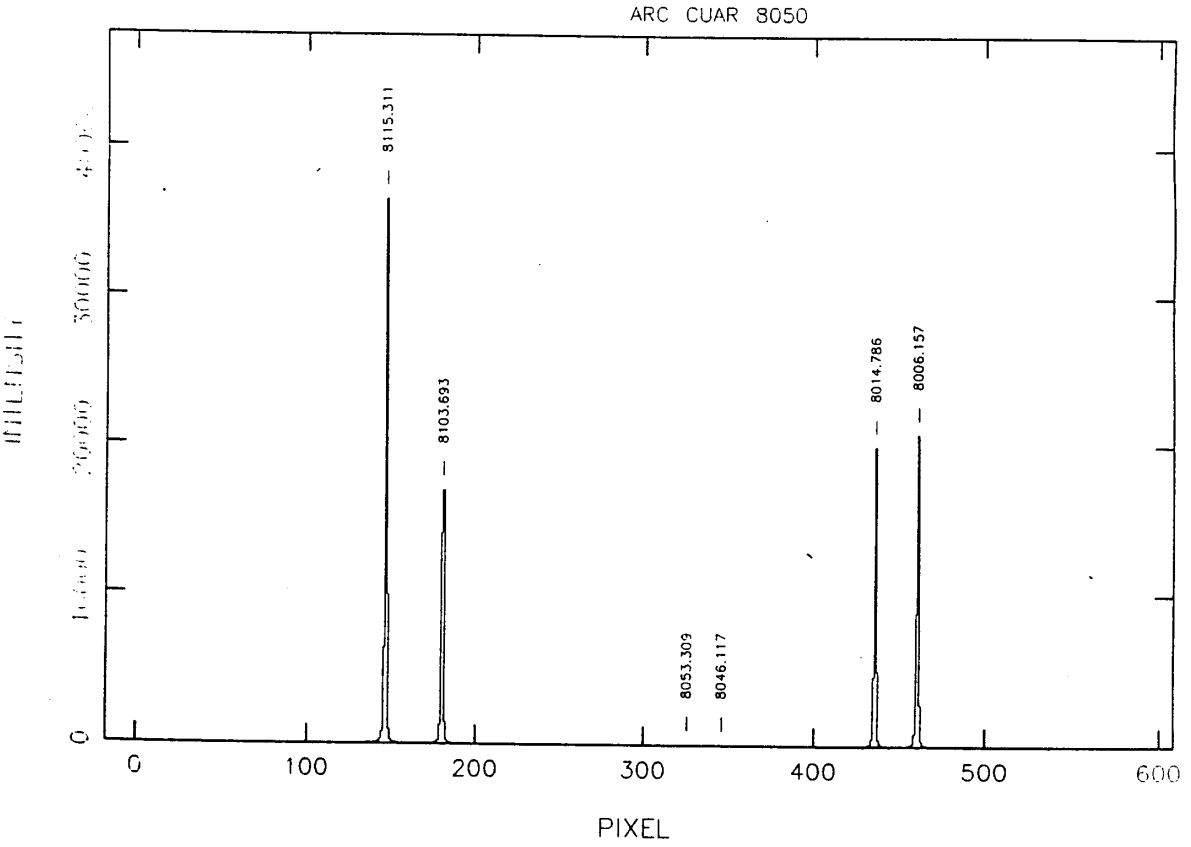
100
200
300
400
500
600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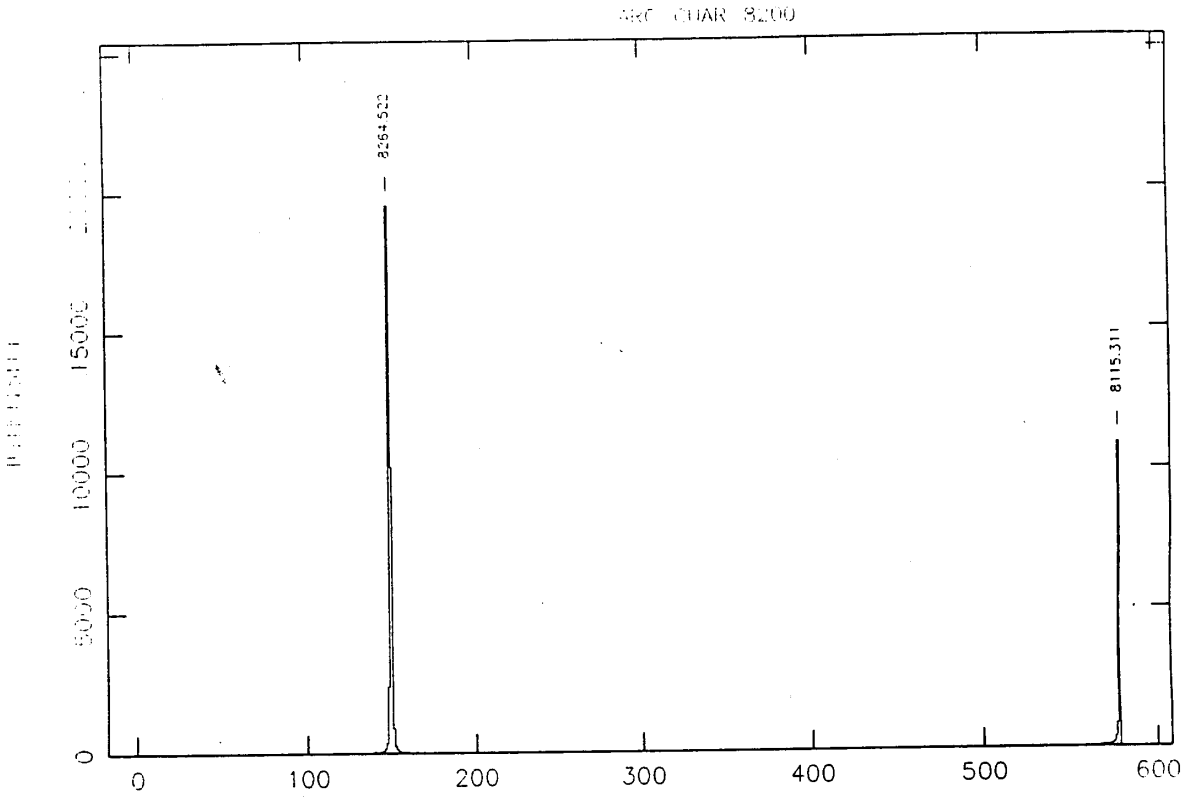
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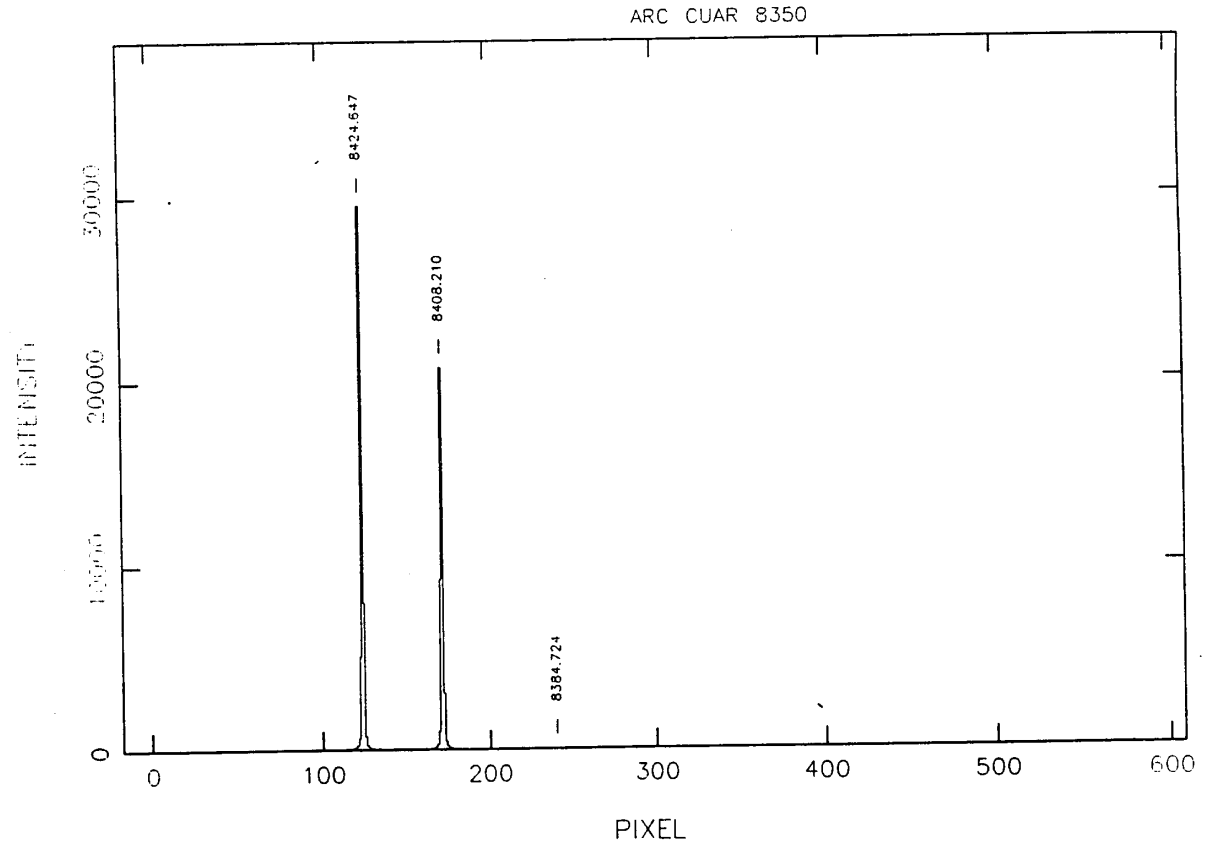
300
400
500
600


ARC CUAR 8350
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INTENSITY
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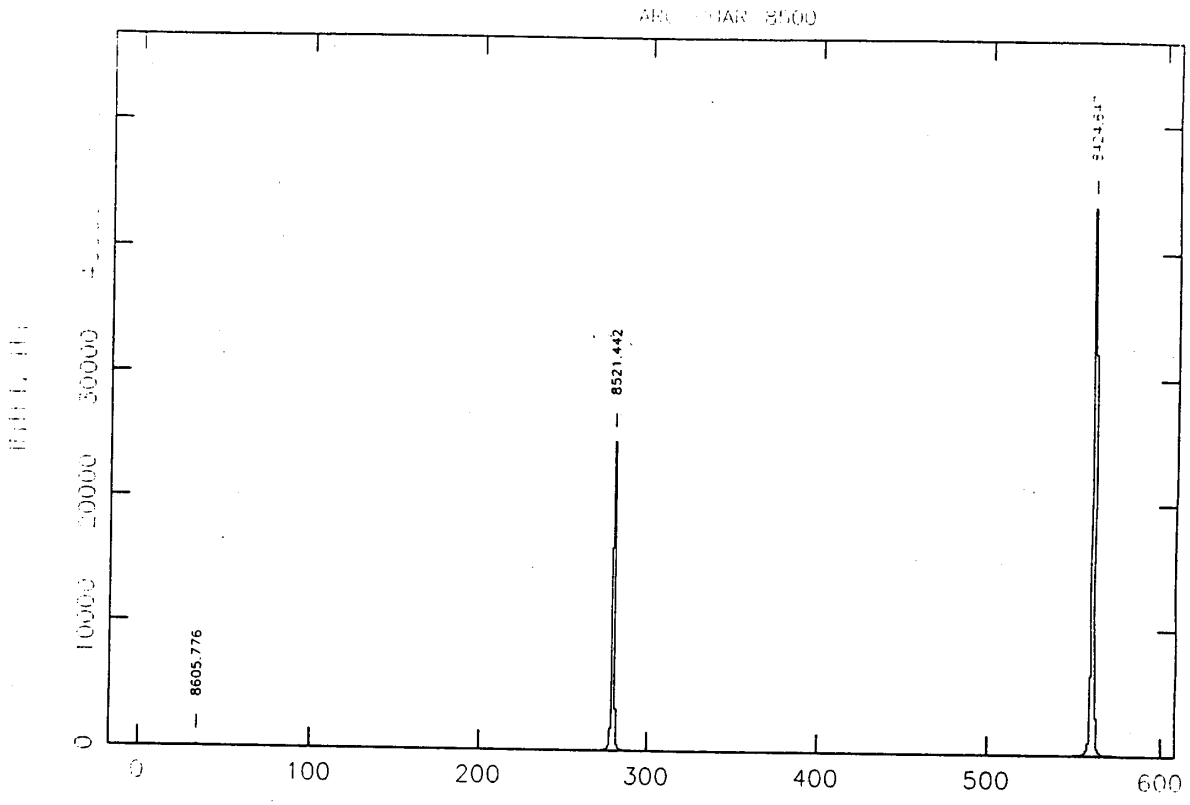
PIXEL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500
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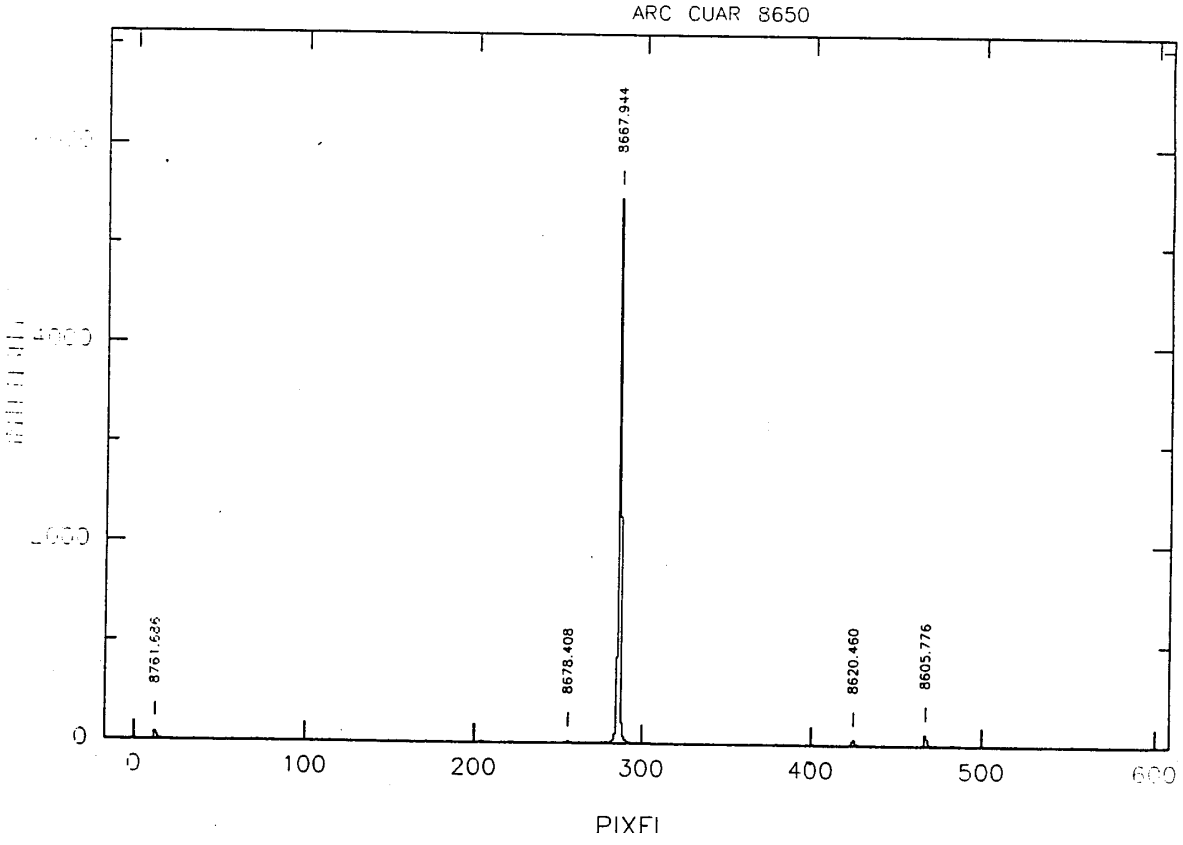
ARC CUAR 8650
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8761.636
8678.408
8620.460
8605.776
0
100
200
300
400
500
600
PIXFI

Table 2 Copper-Argon at low dispersion (400 l/mm gratings)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
3729.309	ArII	4348.064	ArII	4904.752	ArII	5495.874	ArI
3737.889	ArII	4352.205	ArII	4933.209	ArII	5506.113	ArI
3765.55	ArII b	4362.066	ArII	4965.080	ArII	5524.957	ArI
3803.172	ArII	4367.832	ArII	4972.160	ArII	5528.93	ArI
3834.679	ArI	4370.753	ArII	5009.334	ArII	5534.45	ArI
3850.581	ArII	4375.954	ArII	5017.163	ArII	5540.90	ArI
3868.528	ArII	4379.667	ArII	5048.813	ArI	5554.050	ArII
3891.980	ArII	4385.057	ArII	5054.178	ArI	5558.702	ArI
3925.719	ArII	4400.76	ArII b	5062.037	ArII	5572.541	ArI
3928.623	ArII	4426.001	ArII	5090.495	ArII	5577.685	ArII
3932.547	ArII	4430.189	ArII	5105.541	CuI	5581.871	ArI
3946.097	ArII	4433.838	ArII	5118.202	ArI	5588.720	ArI
3948.979	ArI	4439.61	ArII b	5125.765	ArII	5597.476	ArI
3979.356	ArII	4448.879	ArII	5141.783	ArII	5601.122	ArI
3994.792	ArII	4474.759	ArII	5145.308	ArII	5606.733	ArI
4013.857	ArII	4481.811	ArII	5151.391	ArI	5618.010	ArII
4034.63	ArII b	4490.982	ArII	5162.285	ArI	5623.778	ArII
4044.418	ArI	4498.538	ArII	5165.773	ArII	5641.375	ArI
4052.921	ArII	4502.927	ArII	5177.540	ArI	5650.704	ArI w
4072.11	ArII b	4510.733	ArI	5187.746	ArI	5659.127	ArI
4079.574	ArII	4522.323	ArI	5214.77	ArI	5681.900	ArI
4103.912	ArII	4530.552	ArII	5218.202	CuI	5689.91	ArI w
4131.724	ArII	4545.052	ArII	5221.271	ArI	5700.873	ArI
4158.591	ArI	4563.743	ArII	5252.788	ArI	5739.520	ArI
4164.180	ArI	4579.350	ArII	5264.782	ArII	5772.114	ArI
4181.884	ArI	4589.899	ArII	5286.887	ArII	5782.130	CuI w
4190.37	ArI b	4596.097	ArI	5292.517	CuI	5786.555	ArII
4198.317	ArI	4598.763	ArII	5305.688	ArII	5789.474	ArI
4200.675	ArI	4609.567	ArII	5347.412	ArI	5802.080	ArI
4218.25	ArII b	4628.441	ArI	5358.363	ArII	5834.263	ArI
4222.637	ArII	4637.233	ArII	5373.494	ArI	5860.310	ArI
4227.77	ArII b	4657.901	ArII	5393.560	ArII	5882.624	ArI
4237.220	ArII	4702.316	ArI	5397.516	ArII	5888.584	ArI
4251.185	ArI	4721.591	ArII	5402.605	ArII	5912.085	ArI
4259.362	ArI	4726.868	ArII	5407.344	ArII	5916.599	ArI
4266.41	Ar b	4732.053	ArII	5410.473	ArI	5928.813	ArI
4272.169	ArI	4735.906	ArII	5421.352	ArI	5942.669	ArI
4277.528	ArII	4764.865	ArII	5439.989	ArI	5949.258	ArI
4282.898	ArII	4806.021	ArII	5443.24	ArI	5964.472	ArI
4300.101	ArI w	4847.810	ArII	5451.652	ArI	5968.320	ArI
4309.239	ArII	4865.911	ArII	5457.416	ArI	5971.601	ArI
4331.200	ArII w	4876.261	ArI	5467.161	ArI	5987.302	ArI
4333.561	ArI	4879.864	ArII	5473.452	ArI	5998.999	ArI
4345.168	ArI	4889.042	ArII	5490.119	ArI	6005.724	ArI

Table 2: Copper-Argon at low dispersion (400 l/mm gratings; continued)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
6013.678	ArI	6278.645	ArI	6719.218	ArI	7392.980	ArI
6025.150	ArI	6296.872	ArI	6722.890	ArI	7435.368	ArI
6032.127	ArI	6307.657	ArI	6752.834	ArI	7503.869	ArI
6043.223	ArI	6324.416	ArII	6756.163	ArI	7514.652	ArI
6052.723	ArI	6333.146	ArII	6766.612	ArI	7635.106	ArI
6059.373	ArI	6357.15	ArII b	6779.933	ArI	7723.98	ArI b
6064.751	ArI	6364.894	ArI	6818.291	ArI	7851.075	ArI
6081.243	ArI	6369.575	ArI	6827.249	ArI	7948.176	ArI
6085.880	ArI	6384.717	ArI	6861.269	ArII	8006.157	ArI
6090.785	ArI	6403.013	ArII	6871.289	ArI	8014.786	ArI
6098.803	ArI	6416.307	ArI	6879.582	ArI	8053.309	ArI
6105.635	ArI	6431.555	ArI	6887.81	ArI b	8103.693	ArI
6114.923	ArII	6442.75	ArII b	6937.664	ArI	8115.311	ArI
6119.657	ArI	6466.553	ArI	6951.478	ArI	8264.522	ArI
6123.362	ArII	6483.083	ArII	6965.431	ArI	8384.724	ArI
6127.84	ArI b	6493.969	ArI	7030.251	ArI	8392.28	ArI
6138.656	ArII	6499.106	ArI	7067.218	ArI	8408.210	ArI
6142.05	ArI	6538.112	ArI	7086.704	ArI	8424.647	ArI
6145.441	ArI	6595.114	ArI	7107.478	ArI	8521.442	ArI
6155.239	ArI	6604.853	ArI	7125.820	ArI	8605.776	ArI
6165.123	ArI	6632.084	ArI	7147.042	ArI	8620.460	ArI
6170.174	ArI	6638.70	ArII b	7158.839	ArI	8667.944	ArI
6172.60	Ar b	6643.698	ArII	7206.980	ArI	8761.686	ArI
6179.419	ArI	6656.939	ArI	7265.172	ArI	9122.967	ArI
6187.135	ArII	6660.676	ArI	7272.936	ArI	9194.639	ArI
6201.100	ArII	6664.051	ArI	7311.716	ArI	9224.499	ArI
6212.503	ArI	6666.359	ArII	7316.005	ArI	9291.531	ArI
6215.938	ArI	6677.282	ArI	7353.293	ArI	9354.220	ArI
6243.120	ArII	6684.293	ArII	7372.118	ArI	9657.786	ArI
6248.406	ArI	6698.876	ArI	7383.981	ArI	9784.503	ArI

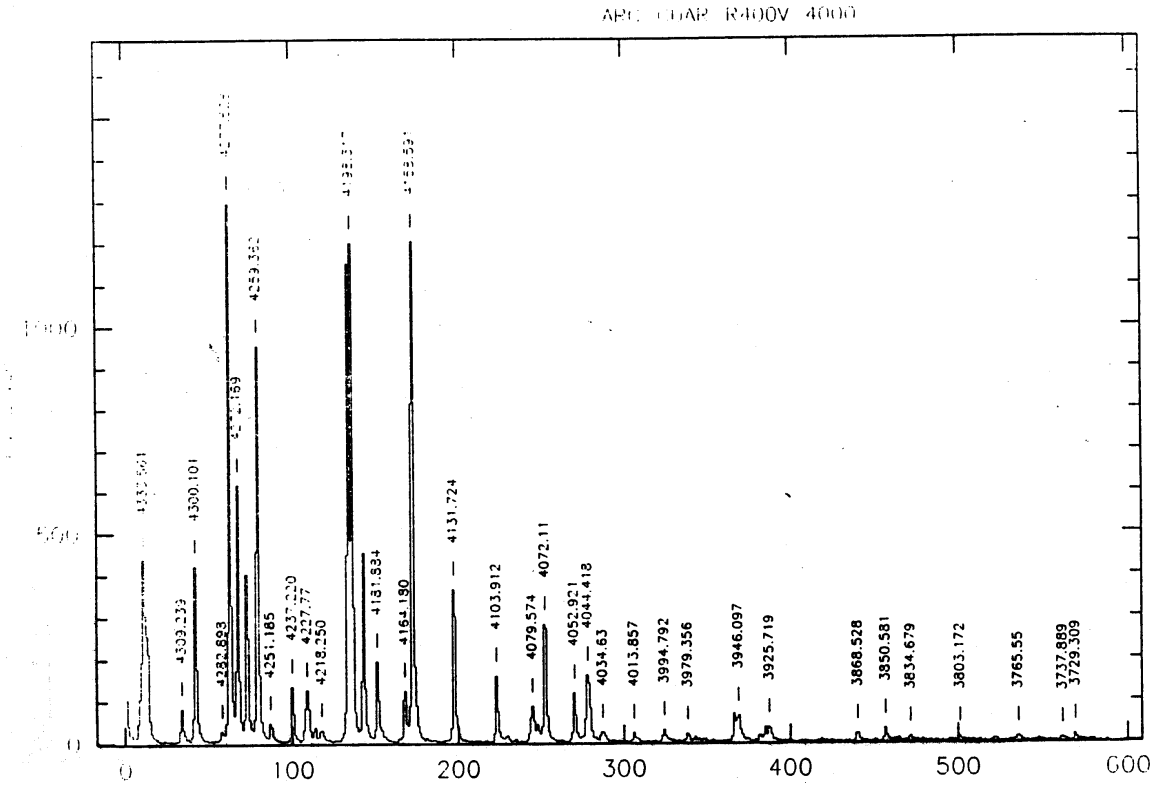
Notes to table 2

Line	
3765.55	ArII, blend of 3765.270 (2) and 3766.119 (1)
4034.63	ArII, blend of 4033.8093 (1) and 4035.4600 (1)
4072.11	ArII, blend of 4072.005 (3) and 4072.385 (1)
4190.87	ArI, blend of 4190.714 and 4191.029
4218.25	ArII, blend of 4218.665 (2) and 4217.431 (1)
4227.77	ArII, blend of 4226.988 (1) and 4228.158 (2)
4266.41	Ar, blend of ArI 4266.286 (1) and ArII 4266.527 (1)
4300.101	ArI, weak ArII at 4300.650
4333.561	ArI, weak ArI at 4335.338
4400.76	ArII, blend of 4400.0968 (1) and 4400.9863 (3)
4439.61	ArII, blend of 4439.461 (7) and 4439.878 (4)
5650.704	ArI, weak ArI at 5648.6863
5689.91	ArI, weak ArI at 5691.6612
5782.130	CuI, weak ArI at 5783.536
6127.84	ArI, blend of 6121.416 (2) and 6128.723 (1)
6172.60	Ar, blend of ArII 6172.278 (3) and ArI 6173.096 (2)
6357.15	ArII, blend of 6357.023 and 6357.678
6442.75	ArII, blend of 6441.8994 (2) and 6443.8598 (1)
6638.70	ArII, blend of 6638.221 (2) and 6639.740 (1)
6887.81	ArI, blend of 6888.174 (2) and 6887.088 (1)
7723.98	ArI, blend of 7723.7611 and 7724.2072 at equal intensifies

Figure 2: The Copper-Argon spectrum at low dispersion (400 l/mm gratings)

Notes to figure 2

Spectrum	Copper-Argon (Cu-Ar) from 3700 to 9800 Angstrom	
Camera	IDS 500 mm	
Detector	GEC 3 "GEC BLUE"	
Gratings	R400V for the region 4000 A - 6000 A	
	R400R for the region 6000 A - 9500 A	
Collimator	Al Wide	
Dispersion	49 A/mm or 0.927 pixel/A	
Exposure times	4000 - 6500 Angstrom	600 seconds
	7000	30 seconds
	7500	20 seconds
	8000 & 9500	30 seconds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4079.574
4072.11
4052.921
4044.418
4034.63
4013.857
3994.792
3979.356
3946.097
3925.719
3868.528
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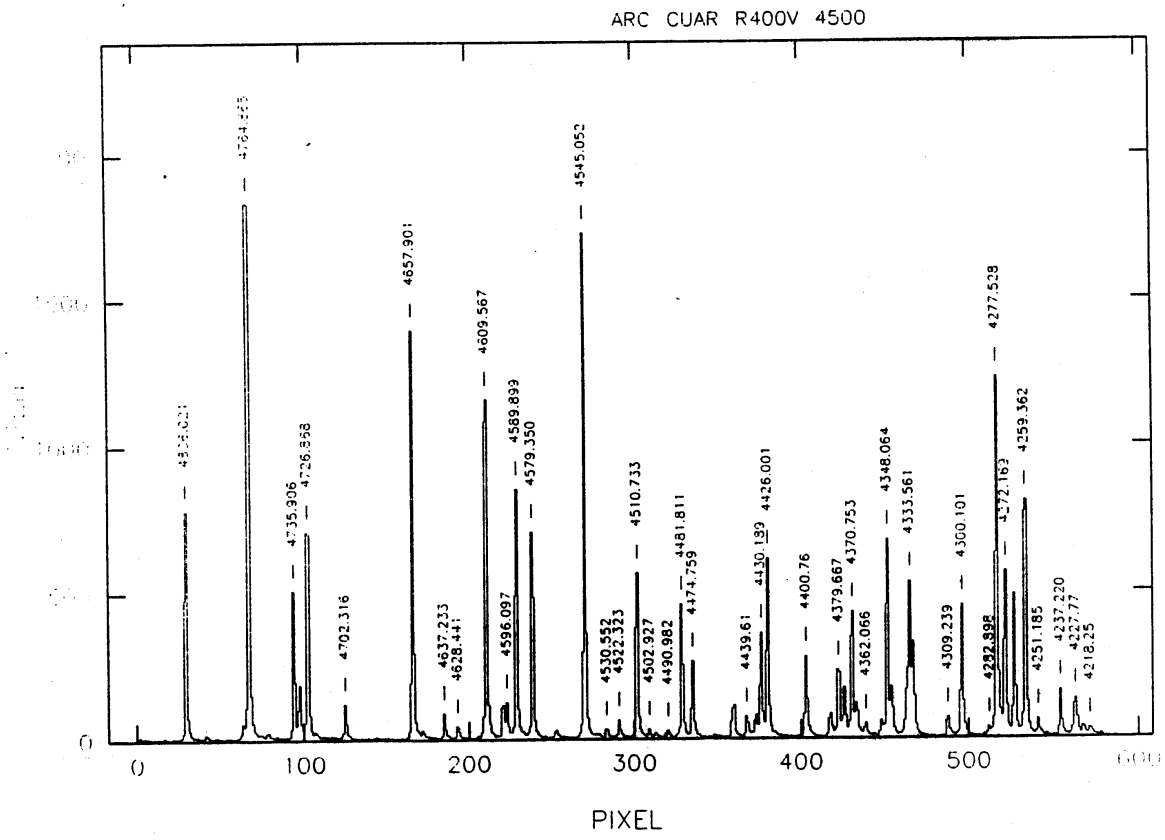
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4333.561
4300.101
4277.528
4259.362
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4237.220
4227.77
4218.25
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4726.568
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4439.61
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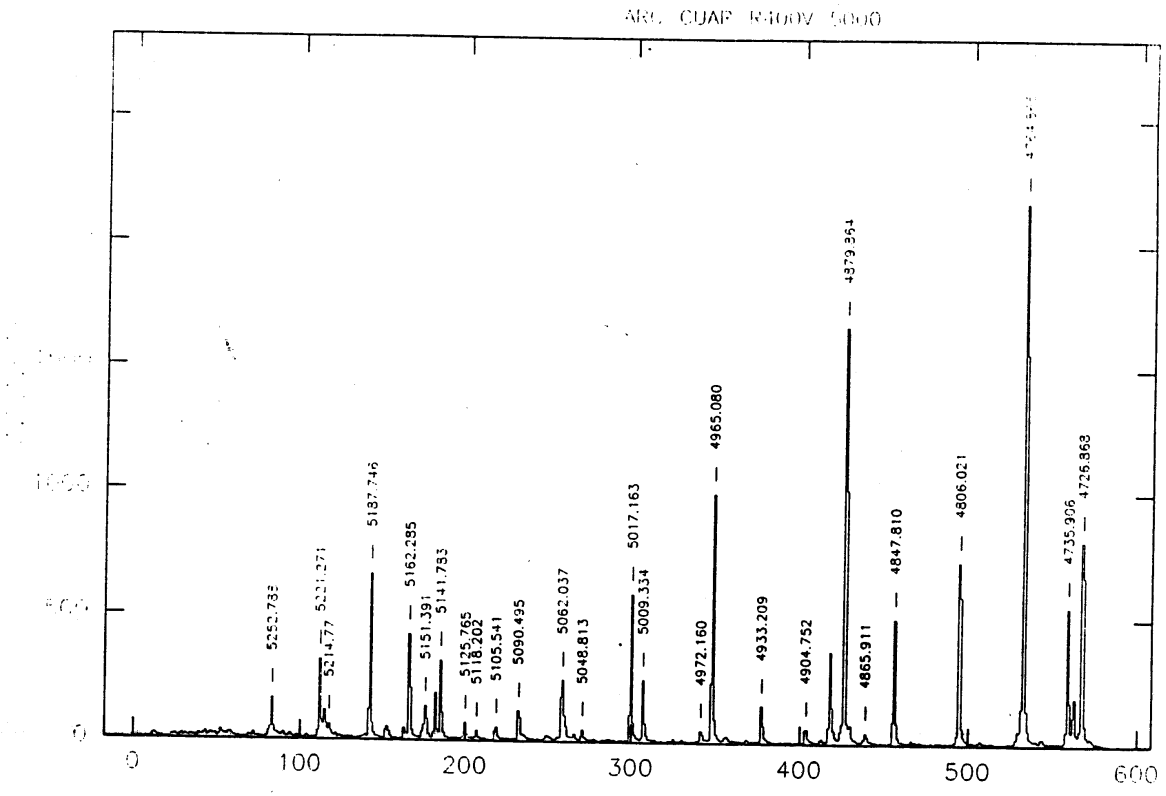
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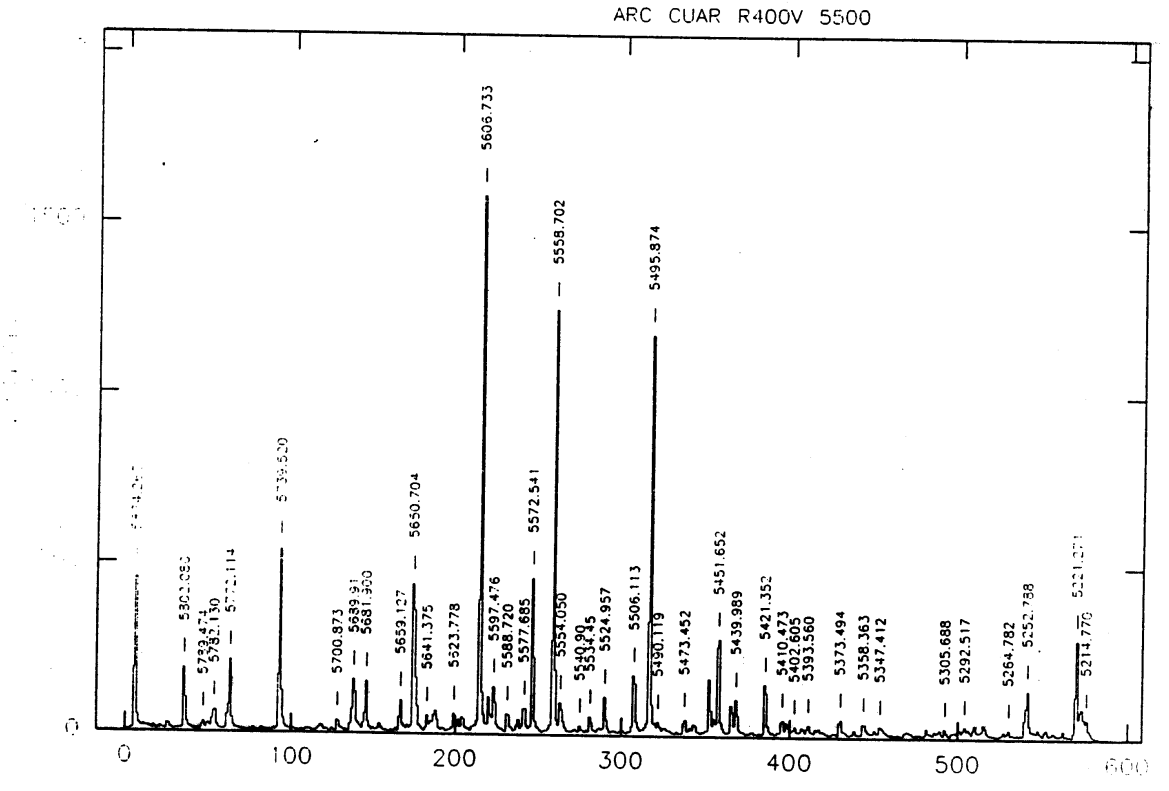
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5534.95
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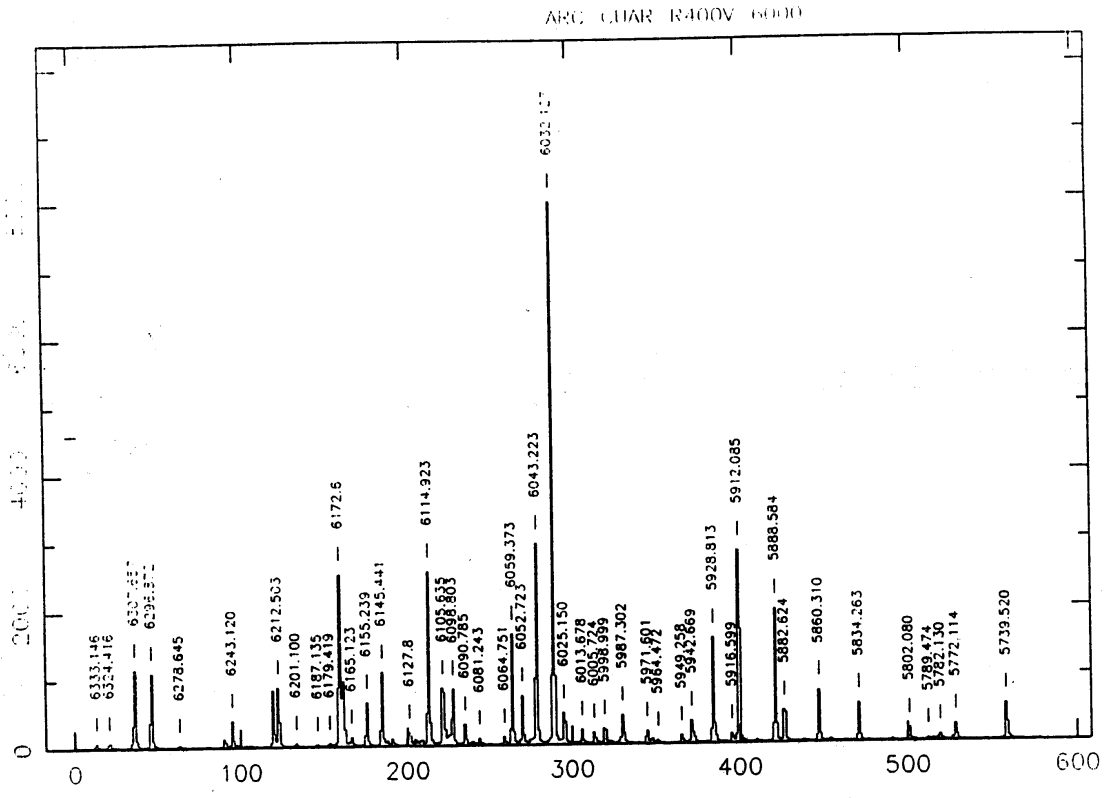
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6172.6
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6032.127
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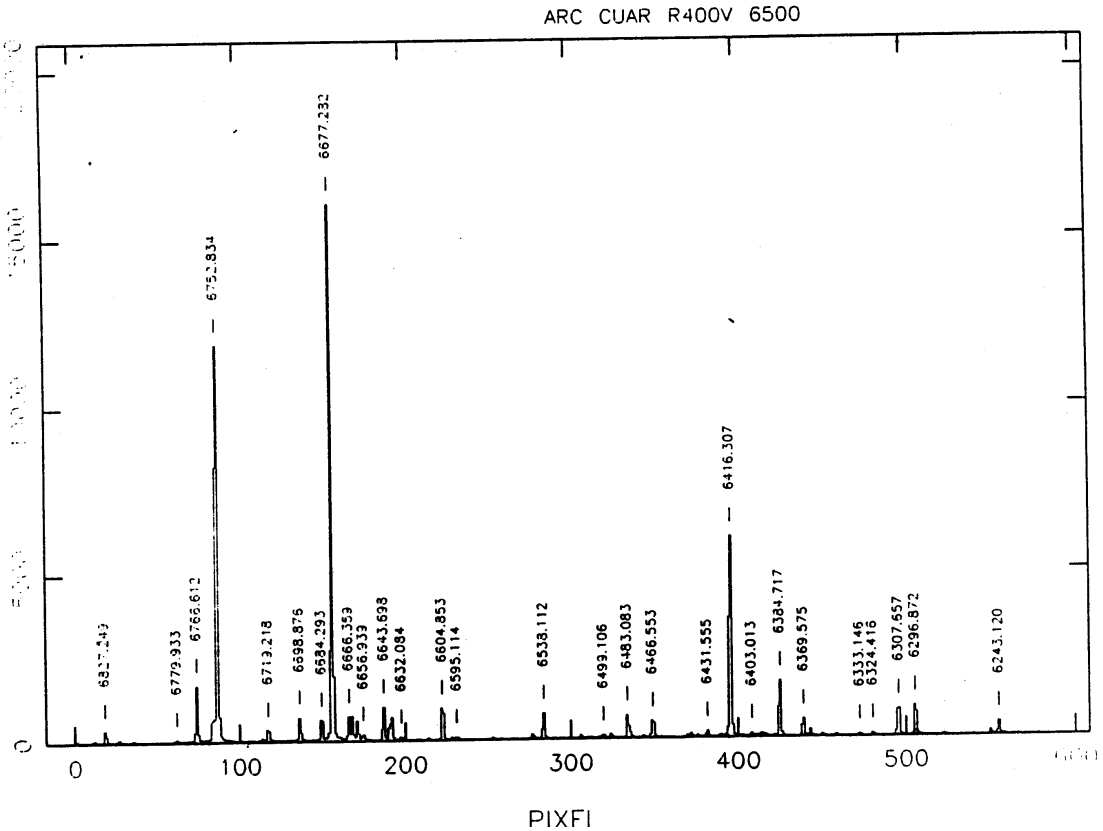
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6684.293
6666.359
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6643.698
6632.084
6604.853
6595.114
6538.112
6493.106
6483.083
6466.553
6431.555
6416.307
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6384.717
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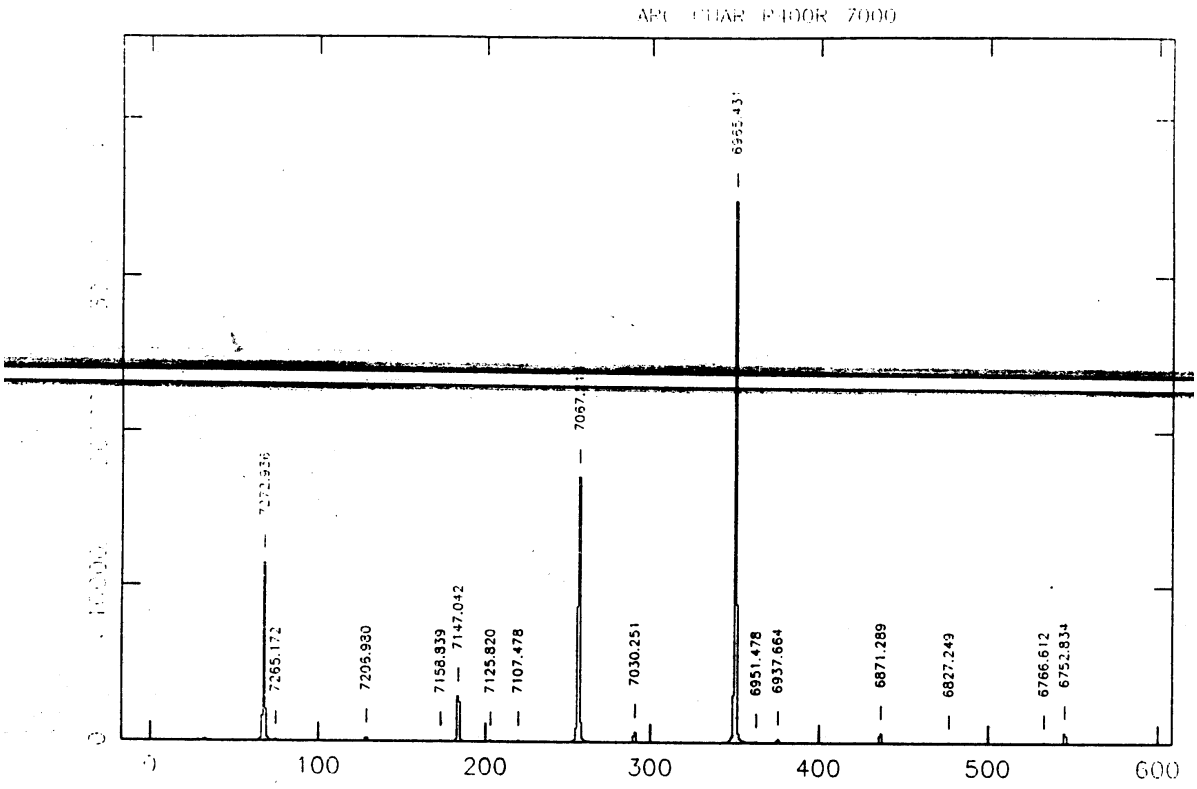
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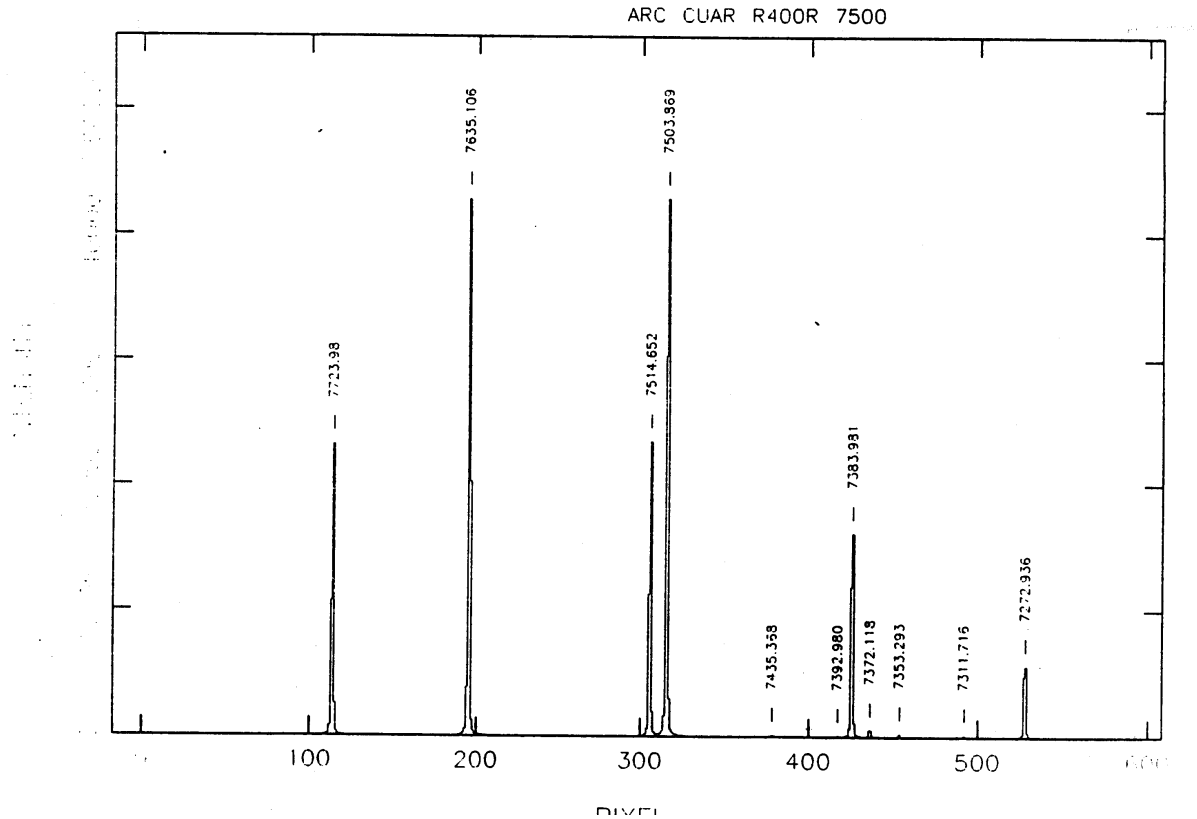
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400
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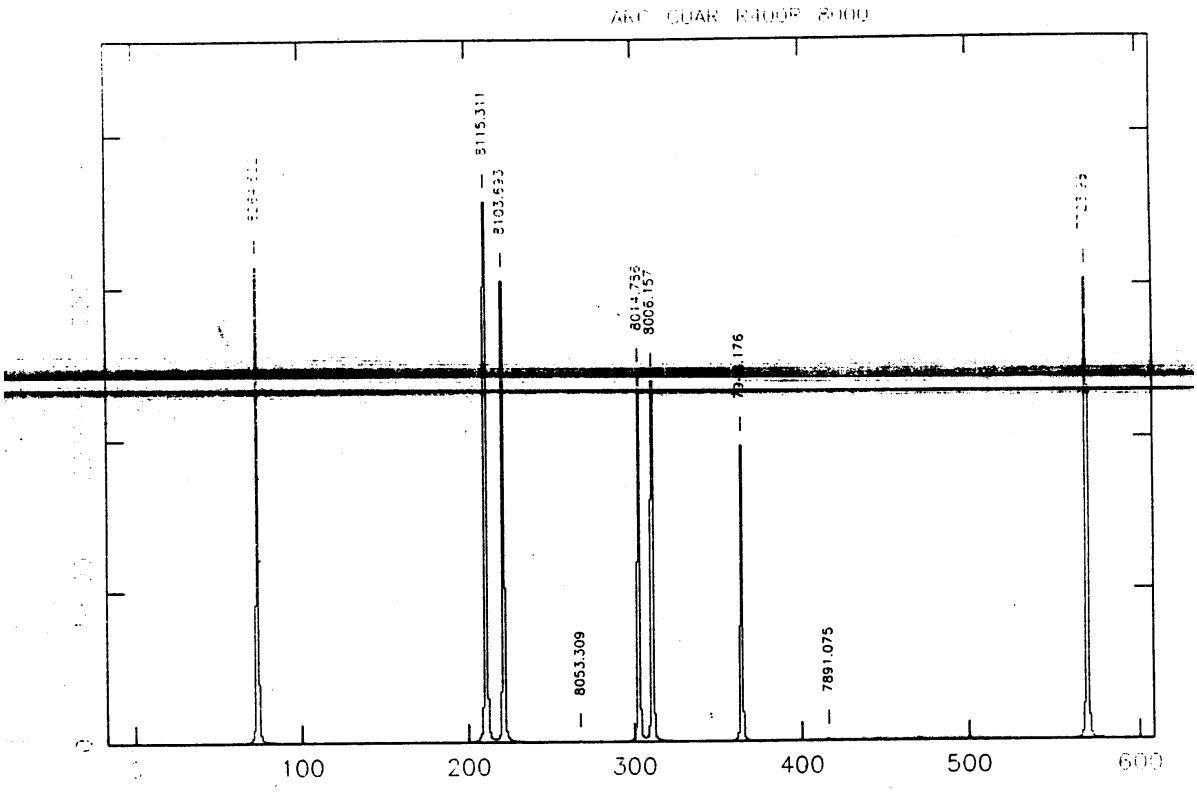
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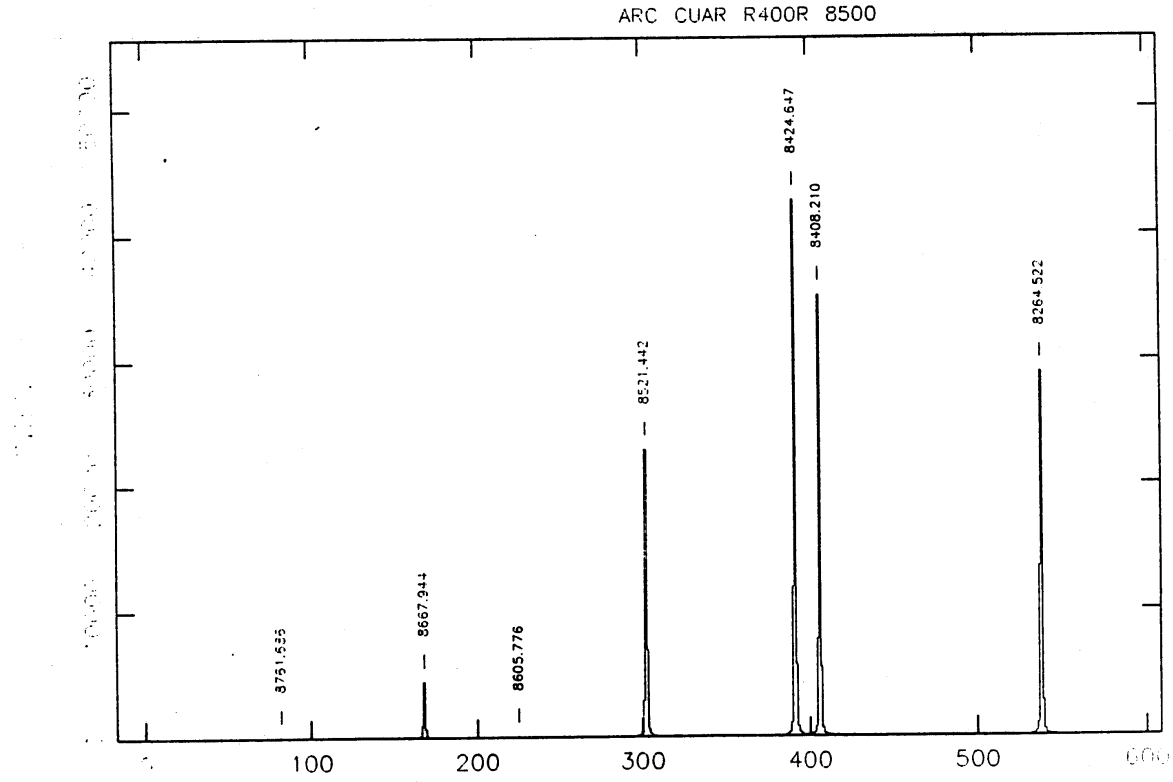
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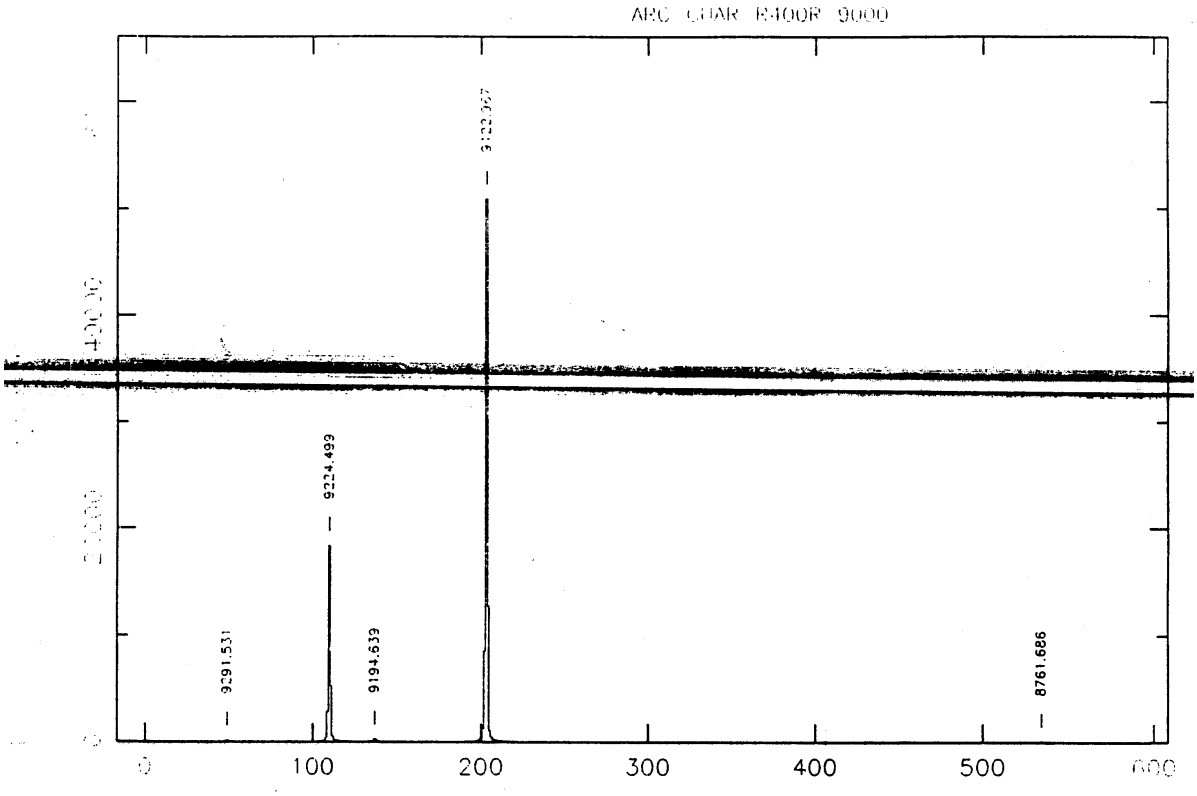
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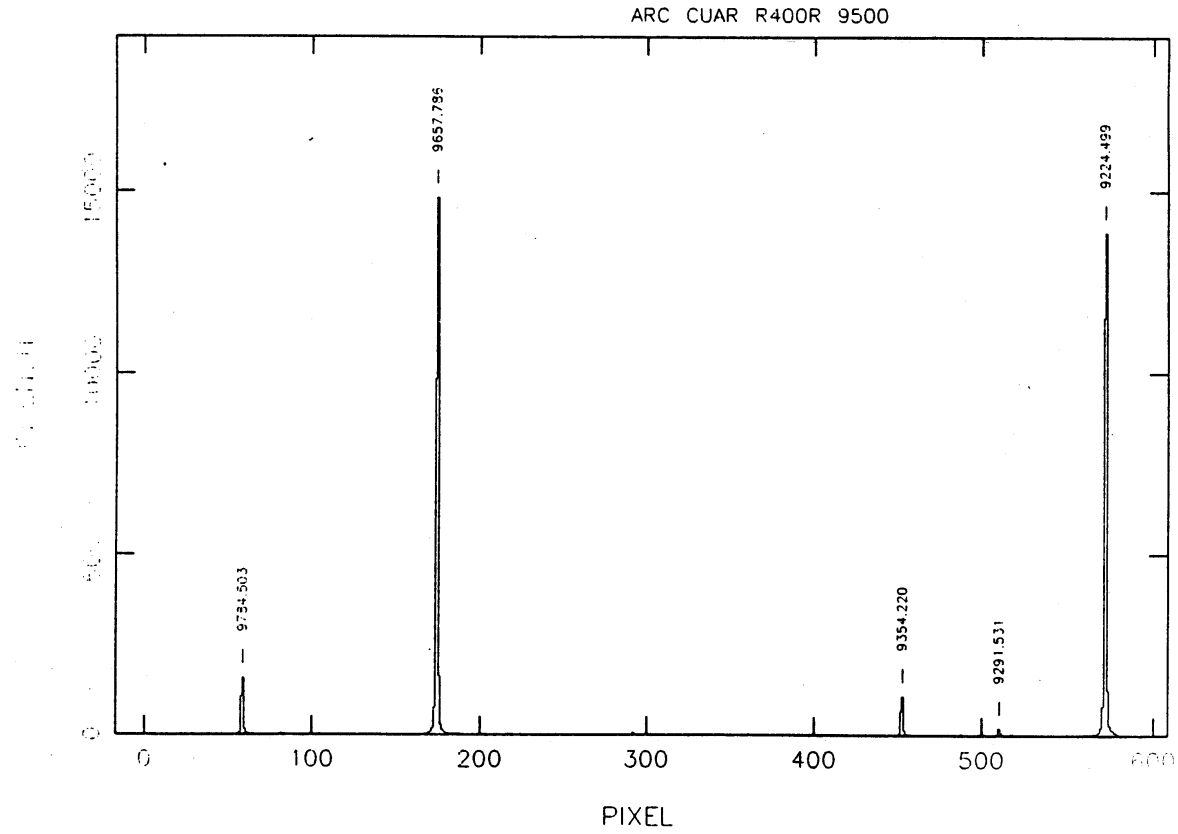
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0
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200
300
400
500
PIXEL

Table 3 : Lines observed in low dispersion CuAr spectra (150 l/mm grating)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
3947.53	Ar b	4965.08	ArII	6025.150	ArI	7372.118	ArI
4043.90	Ar b	5009.334	ArII	6032.127	ArI	7383.981	ArI
4072.11	ArII	5017.163	ArII	6043.223	ArI	7435.368	ArI
4103.912	ArII	5062.037	ArII	6052.723	ArI	7471.164	ArI
4131.724	ArII	5090.495	ArII	6059.373	ArI	7503.869	ArI
4158.591	ArI	5141.783	ArII	6098.803	ArI	7514.652	ArI
4181.884	ArI	5162.285	ArI	6105.635	ArI	7635.106	ArI
4190.87	Ar b	5187.746	ArI	6114.923	ArII	7723.98	Ar b
4199.63	ArI b	5221.07	ArI w	6145.441	ArI	7891.075	ArI
4259.362	ArI	5253.13	ArI b	6155.239	ArI	7948.176	ArI
4277.528	ArII	5373.494	ArI	6172.03	Ar b	8006.157	ArI
4300.101	ArI	5421.352	ArI	6214.02	ArI b	8014.786	ArI
4331.31	ArI b	5451.652	ArI w	6243.120	ArII	8053.309	ArI
4348.064	ArII	5495.874	ArI	6296.872	ArI	8103.693	ArI
4370.753	ArII	5506.113	ArI	6307.657	ArI	8115.311	ArI
4427.05	ArII	5524.957	ArI	6369.575	ArI	8264.523	ArI
4474.759	ArII	5558.702	ArI	6384.717	ArI	8408.210	ArI
4481.811	ArII	5572.541	ArI	6416.307	ArI	8424.648	ArI
4510.733	ArI	5606.733	ArI	6677.282	ArI	8521.442	ArI
4545.052	ArII	5650.704	ArI	6684.293	ArII	8605.776	ArI
4579.350	ArII	5681.900	ArI	6752.834	ArI	8667.944	ArI
4589.899	ArII	5689.910	ArI	6871.289	ArI	8761.686	ArI
4609.567	ArII	5739.520	ArI	6937.664	ArI	8849.970	ArI
4657.901	ArII	5772.114	ArI	6965.430	ArI	9075.395	ArI
4702.316	ArI	5802.080	ArI	7030.252	ArI	9122.967	ArI
4726.868	ArII	5834.263	ArI	7067.218	ArI	9194.639	ArI
4735.906	ArII	5860.310	ArI	7107.478	ArI	9224.499	ArI
4764.865	ArII	5882.624	ArI	7125.820	ArI	9291.531	ArI
4806.021	ArII	5888.584	ArI	7147.042	ArI	9354.220	ArI
4847.810	ArII	5912.085	ArI	7206.980	ArI	9657.786	ArI
4879.864	ArII	5928.813	ArI	7272.936	ArI	9784.503	ArI
4889.042	ArII	5987.302	ArI	7311.716	ArI		
4933.209	ArII	5998.999	ArI	7353.293	ArI		

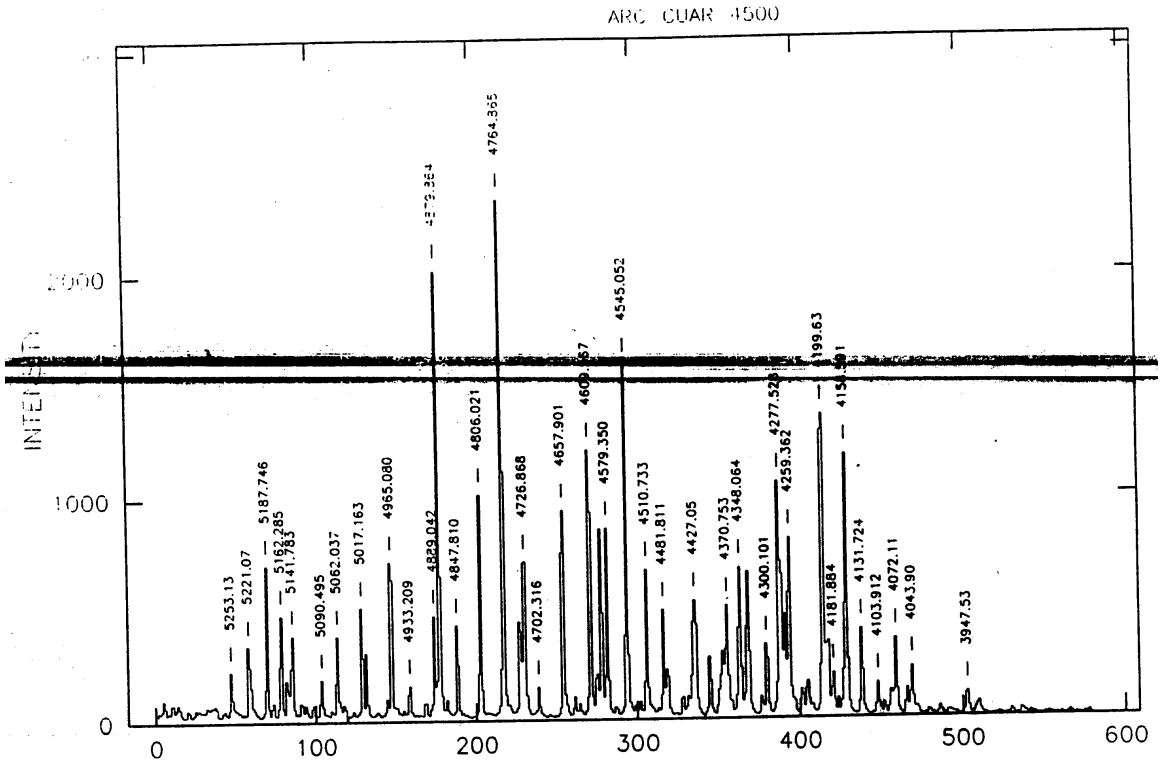
Notes to Table 3

Line	
3947.53	Ar, blend of 3946.097 ArII and 3948.979 ArI
4043.90	Ar, blend of 4042.894 ArII and 4044.418 ArI
4072.11	ArII, blend of 4072.005 and 4072.385
4190.87	ArI, bland of 4190.714 and 4191.029
4199.63	ArI, blend of 4200.675 and 4198.317
4333.31	Ar, blend of ArII 4331.200 and ArI 4333.561 and 4335.338
4427.05	ArII, blend of 4426.001 and 4430.189
5221.07	ArI, weak CuI at 5218.202
5253.13	ArI, blend of ArI 5252.788 and 5254.465
5451.652	ArI, weak ArI at 5457.416
6172.03	Ar, blend of ArI 6170.174, ArII 6172.278 and ArI 6173.096
6214.02	ArI, blend of 6212.503 and 6215.938
7723.98	ArI, blend of 7723.761 and 7724.207

Figure 3: The Copper-Argon spectrum at low dispersion (150 l/mm gratings)

Notes to figure 3

Spectrum	CuAr at low dispersion	
Camera	IDS 500 mm	
Detector	GEC 3 "GEC BLUE"	
Grating	R150V	
Collimator	Al Wide	
Dispersion	131 A/mm or 0.347 pixel/A	
Exposure times	4500 & 5500 Angstrom	600 seconds
	6500	30 seconds
	7500	20 seconds
	8500 & 9500	30 seconds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5090.495
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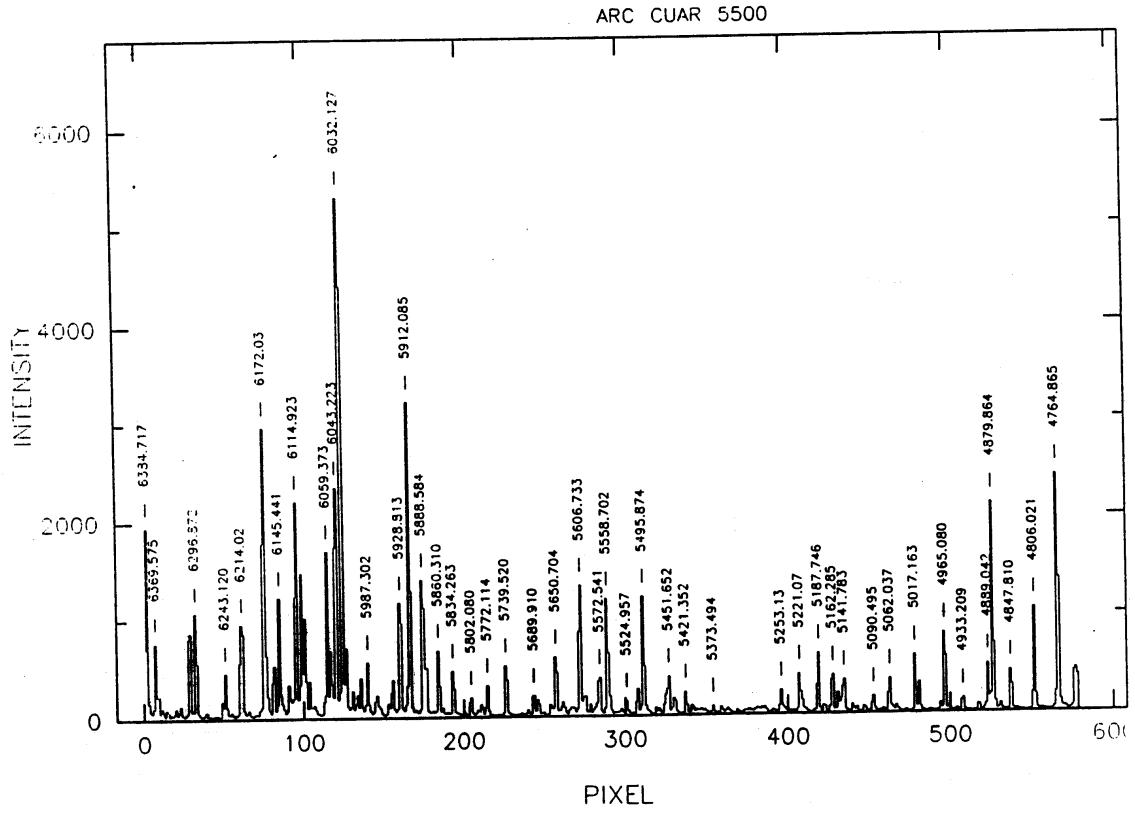
3947.53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6145.441
6114.923
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6043.223
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5860.310
5834.263
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5772.114
5739.520
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5650.704
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5558.702
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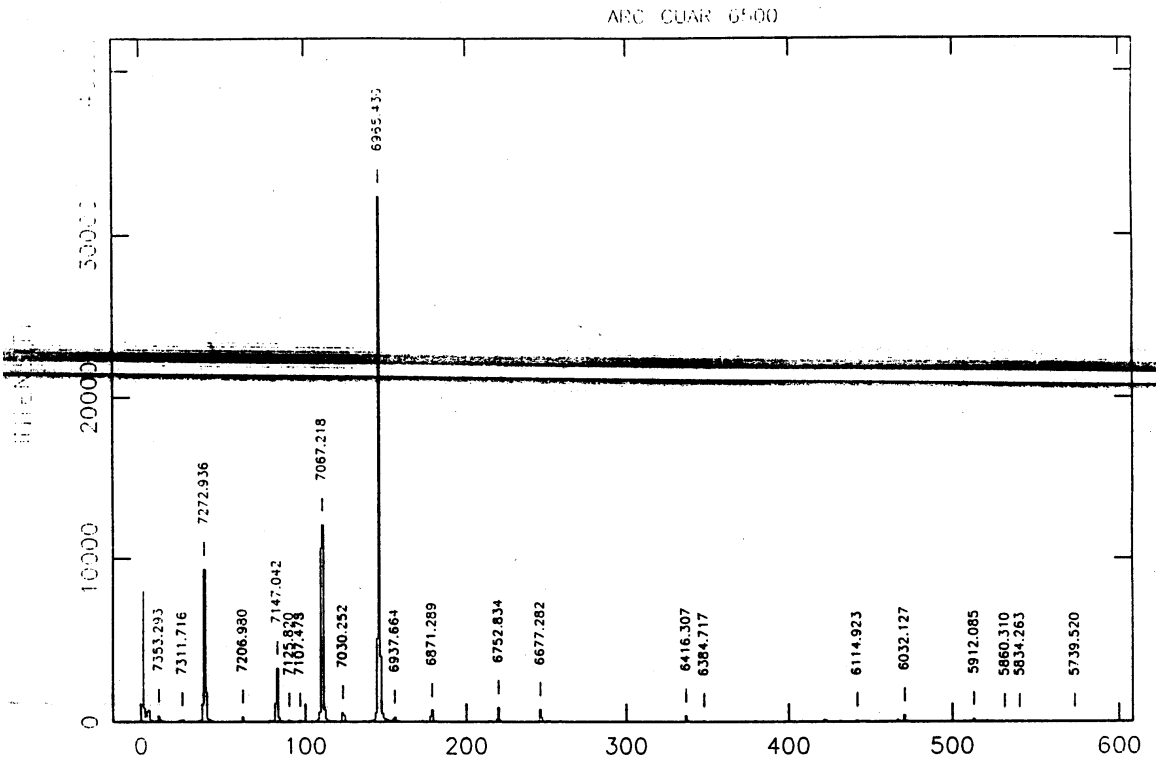
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6416.307
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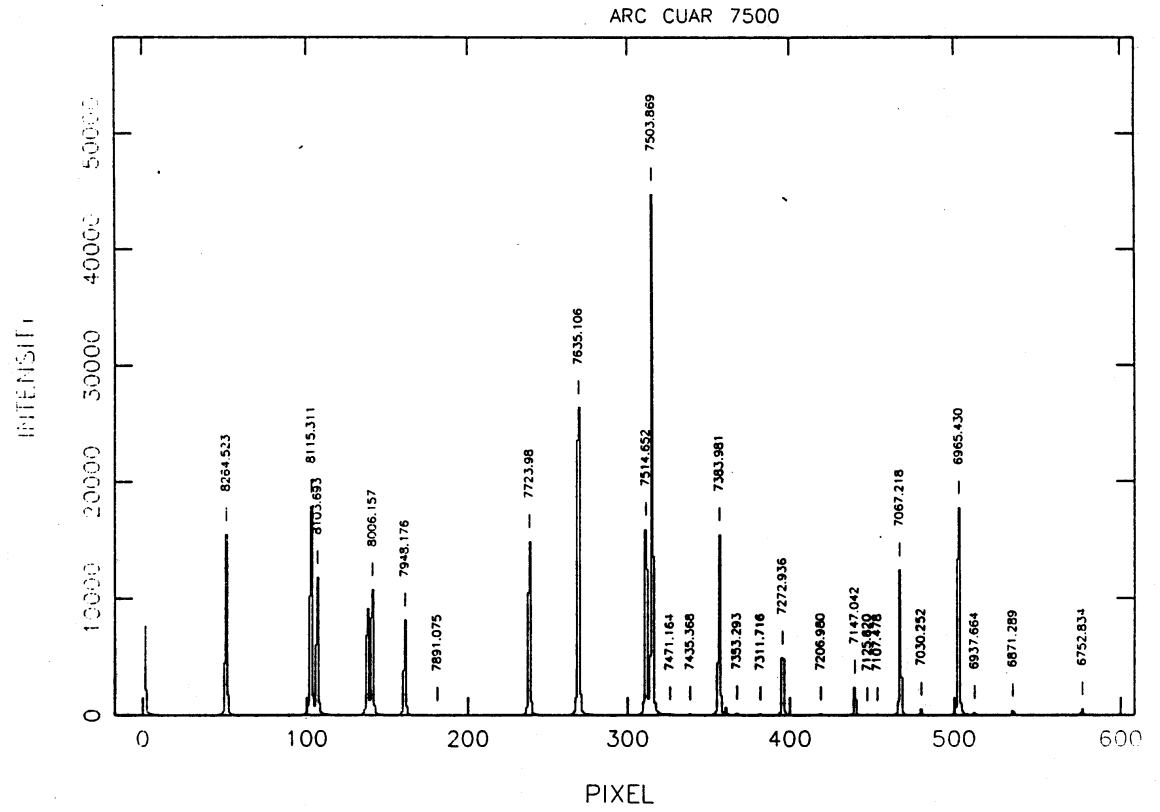
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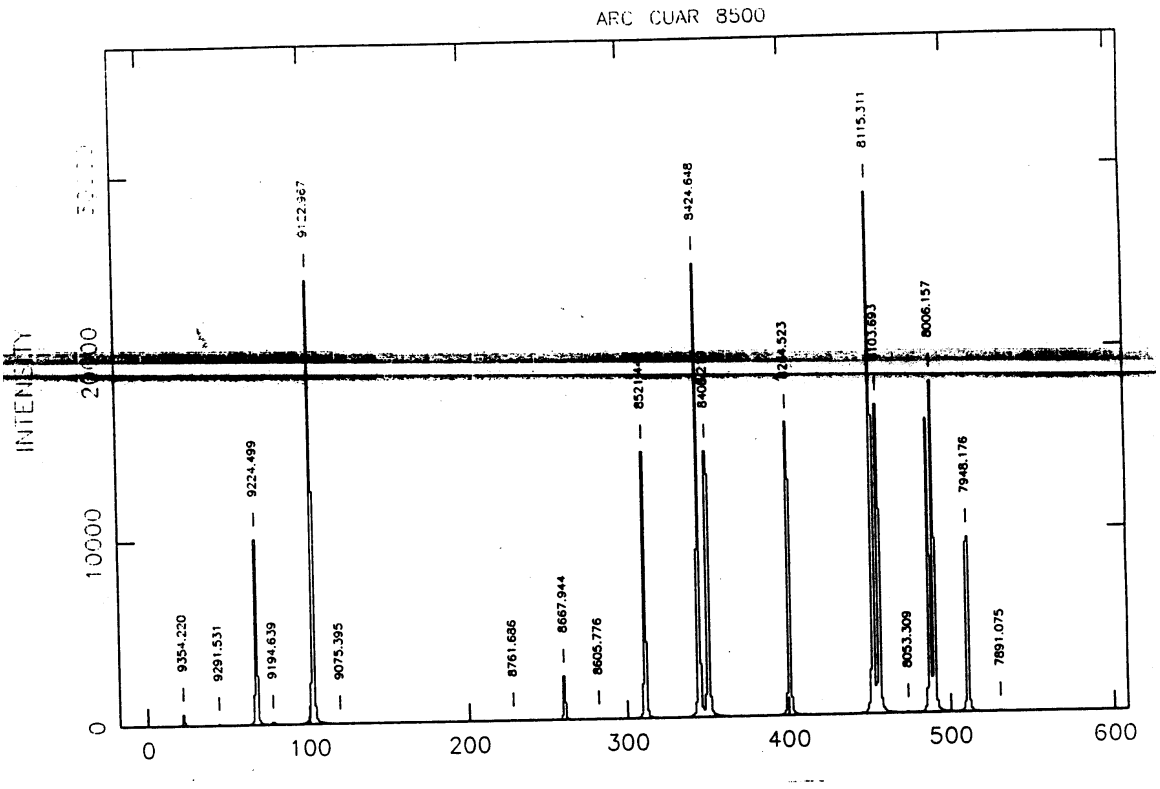
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8424.648
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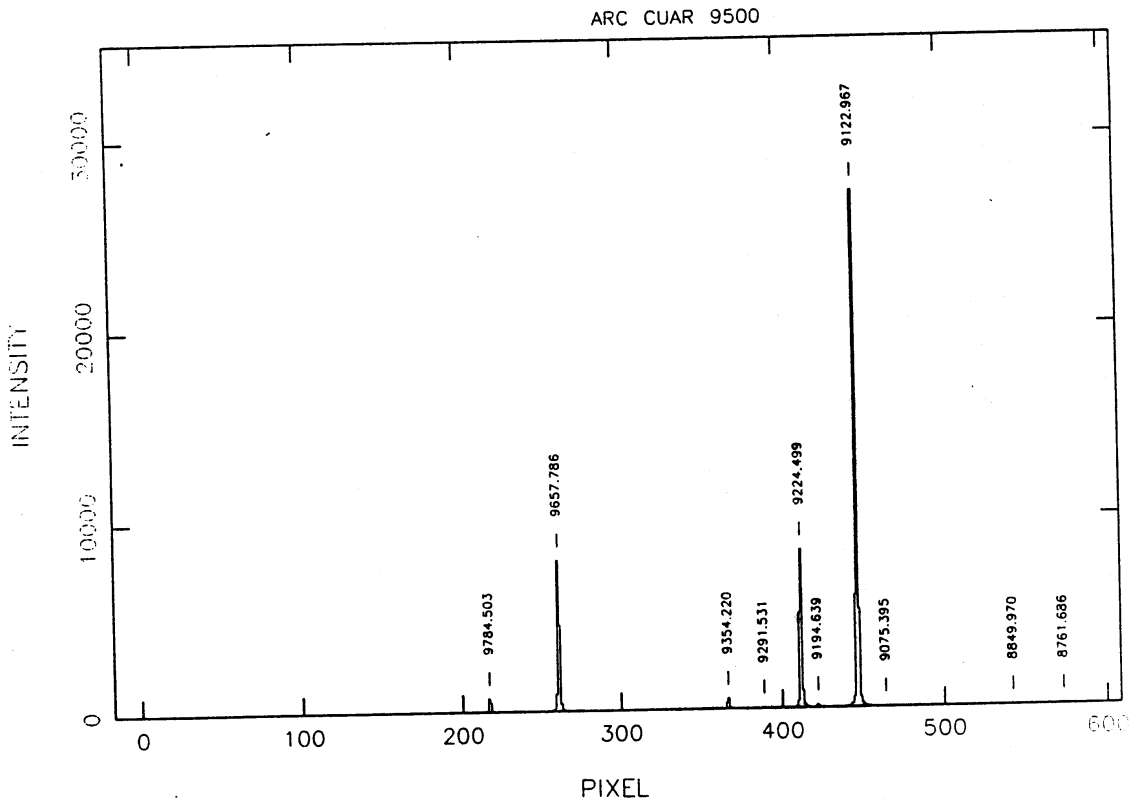
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8849.970
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Table 4 : The Copper-Neon spectrum at high dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Sy
3247.540	CuI	4837.312	NeI	5782.13	CuI	8082.458	Ne
3273.962	CuI	4884.915	NeI	5804.449	NeI	8092.63	Cu
3279.82	CuI	4909.726	CuI	5811.42	NeI	8095.55	Cu
3323.75	NeII	4957.033	NeI	5820.155	NeI	8118.550	Ne
3334.87	NeII	5005.160	NeI	5828.91	NeI	8128.93	Ne
3337.84	CuI	5016.61	CuI	5852.488	NeI	8136.406	Ne
3369.87	NeI b	5031.3484	NeI	5881.895	NeI	8235.30	Cu
3378.28	NeI	5037.7505	NeI	5902.464	NeI	8248.70	Ne
3417.904	NeI	5074.200	NeI	5944.834	NeI	8259.380	Ne
3447.703	NeI	5080.383	NeI	5965.474	NeI	8266.076	Ne
3454.195	NeI	5105.541	CuI	5975.534	NeI w	8277.60	Cu
3466.579	NeI	5113.675	NeI	6029.997	NeI	8300.326	Ne
3472.571	NeI	5116.503	NeI	6074.338	NeI	8365.75	Ne
3501.217	NeI	5122.30	NeI b	6096.163	NeI	8377.607	Ne
3520.472	NeI	5144.97	NeI b	6128.451	NeI	8418.427	Ne
3530.39	CuI	5153.235	CuI	6143.063	NeI	8463.37	Ne
3568.53	NeI	5158.89	NeI	6163.594	NeI	8484.45	Ne
3593.56	NeI b	5188.612	NeI	6217.281	NeI	8495.36	Ne
3600.169	NeI	5193.18	NeI	6266.495	NeI	8503.46	Cu
3664.11	NeII	5203.895	NeI	6304.789	NeI	8544.70	Ne
3694.20	NeII	5208.863	NeI	6334.428	NeI	8571.360	Ne
3709.64	NeII	5218.202	CuI	6382.991	NeI	8582.91	Ne
3713.08	NeII	5222.351	NeI	6402.247	NeI	8591.259	Ne
3727.08	NeII	5234.028	NeI	6506.528	NeI	8634.648	Ne
3766.29	NeII	5274.04	NeI	6532.882	NeI	8647.05	Ne
3777.13	NeII	5280.09	NeI	6598.953	NeI	8654.383	Ne
3829.77	NeII	5292.52	CuI	6652.09	NeI	8679.491	Ne
4022.66	CuI	5298.190	NeI	6678.277	NeI	8681.920	Ne
4062.84	CuI w	5304.756	NeI	6717.043	NeI	8704.15	Ne
4174.37	NeI	5326.396	NeI	6929.468	NeI	8771.70	Ne
4219.76	NeII	5330.778	NeI	7024.051	NeI	8780.622	Ne
4231.60	NeII	5341.091	NeI	7032.413	NeI	8783.755	Ne
4275.11	NeI b	5343.284	NeI	7059.109	NeI	8853.867	Ne
4290.40	NeII	5349.21	NeI	7173.939	NeI	8865.67	Ne
4379.50	NeII	5352.67	CuI	7245.167	NeI	8919.50	Ne
4391.94	NeII	5355.30	NeI b	7438.899	NeI	8988.58	Ne
4397.94	NeII	5360.012	NeI	7472.43	NeI	9148.68	Ne
4409.30	NeII	5372.31	NeI	7488.872	NeI	9201.76	Ne
4413.20	NeII	5374.975	NeI	7535.775	NeI	9220.05	Ne
4428.54	NeII	5400.562	NeI	7544.046	NeI	9221.59	Ne
4430.90	NeII	5412.66	NeI	7562.01	CuII	9226.67	Ne
4480.36	CuI	5418.56	NeI	7579.02	CuII	9275.53	Ne
4509.39	CuI	5433.65	NeI	7652.36	CuII	9300.85	Ne
4530.82	CuI	5494.41	NeI	7724.63	NeI	9310.58	Ne
4537.704	NeI b	5562.769	NeI w	7726.64	CuII	9313.98	Ne
4651.130	CuI	5652.57	NeI	7825.66	CuII	9326.52	Ne
4656.3923	NeI	5656.659	NeI	7839.08	NeI	9373.28	Ne
4704.395	NeI	5662.547	NeI	7895.83	CuII	9425.38	Ne
4715.344	NeI	5689.817	NeI	7902.57	CuII	9459.21	Ne
4724.48	NeI b	5700.24	CuI	7927.11	NeI	9486.680	Ne
4752.7313	NeI	5719.225	NeI	7933.13	CuI	9534.17	Ne
4818.40	NeI b	5748.298	NeI	7937.01	NeI	9547.40	Ne
4821.924	NeI	5760.59	NeI	7943.180	NeI	9665.424	Ne
4827.34	NeI w	5764.418	NeI	7972.01	CuII		

Notes to Table 4

Line	
3369.87	NeI, blend of 3369.908 (7) and 3369.809 (5)
3593.56	NeI, blend of 3593.526 (2) and 3593.640 (1)
3600.169	NeI, possibly contaminated with CuI 3599.13
4062.84	CuI, blend of 4062.70 (2.0) and 4063.29 (.6)
4275.11	NeI, blend of 4275.56 (7) and 4274.66 (5)
4537.704	NeI, blend of 4537.751 (1.0) and 4537.683 (0.3)
4704.395	NeI, blended with 4704.60 CuI
4724.48	NeI, blend of 4725.25 (1) and 4723.84 (1)
4818.40	NeI, blend of 4818.79 (1) and 4817.64 (2)
4827.34	weak NeI at 4827.56
5122.30	NeI, blend of 5122.26 (1) and 5122.34 (1)
5144.97	NeI, blend of 5144.94 (1) and 5145.01 (1)
5193.18	NeI, blend of 5193.13 (1) and 5193.22 (1)
5355.30	NeI, blend of 5355.18 (1) and 5355.42 (1)
5562.769	weak NeI at 5562.44
5975.534	weak NeI at 5974.63
8266.076	weak NeI at 8267.11
8377.607	weak NeI at 8376.41
8865.67	NeI, blend of 8865.759 (4) and 8865.33

Figure 4: The Copper-Neon spectrum at high dispersion

Notes to figure 4

Spectrum	CuNe from 3200 to 9600 Angstrom at high dispersion	
Camera	IDS 235 mm	
Detector	GEC 4 "GEC BLUE" ; pixel size : 22 mu	
Gratings	R1200B for the region 3200 A - 4600 A	
	R1200Y for the region 4600 A - 9600 A	
Collimator	Al UV	
Dispersion	34 A/m or 1.34 pixel/A	
Exposure times	3200 - 5200 Angstrom	600 s
	5400 & 5600	300 s
	5800	15 s
	6000	10 s
	6200 & 6400	20 s
	6600 - 7400	30 s
	7600	20 s
	7800 & 8000	60 s
	8200 - 8600	20 s
	8800	30 s
	9000	120 s
	9200	300 s
	9400 & 9600	600 s

Table 5: The Copper Neon spectrum at low dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symb
3247.540	CuI	5330.778	NeI	6382.991	NeI	8300.326	NeI
3273.962	CuI	5341.091	NeI	6402.247	NeI	8377.607	NeI
3447.703	NeI	5400.5619	NeI	6506.528	NeI	8418.427	NeI
3520.472	NeI	5748.299	NeI	6532.882	NeI	8495.360	NeI
3713.08	NeII	5764.418	NeI	6598.953	NeI	8591.258	NeI
3777.13	NeII	5852.4878	NeI	6678.277	NeI	8634.648	NeI
4022.66	NeI	5881.8950	NeI	6717.043	NeI	8654.383	NeI
4275.11	NeI b	5944.834	NeI	6929.468	NeI	8853.866	NeI
4530.82	CuI	5975.534	NeI w	7032.413	NeI	8865.670	NeI b
4651.13	CuI	6030.000	NeI	7173.939	NeI	8919.500	NeI
4704.395	NeI w	6074.338	NeI	7245.167	NeI	9148.680	NeI
4884.915	NeI	6096.163	NeI	7438.899	NeI	9300.850	NeI
5037.7505	NeI	6143.063	NeI	7488.872	NeI	9326.520	NeI
5080.383	NeI	6163.594	NeI	7535.775	NeI	9425.380	NeI
5105.541	CuI	6217.281	NeI	7943.180	NeI	9665.424	NeI
5116.503	NeI	6266.495	NeI	8082.458	NeI		
5153.235	CuI	6304.789	NeI	8136.406	NeI		
5218.202	CuI	6334.428	NeI	8266.08	NeI b		

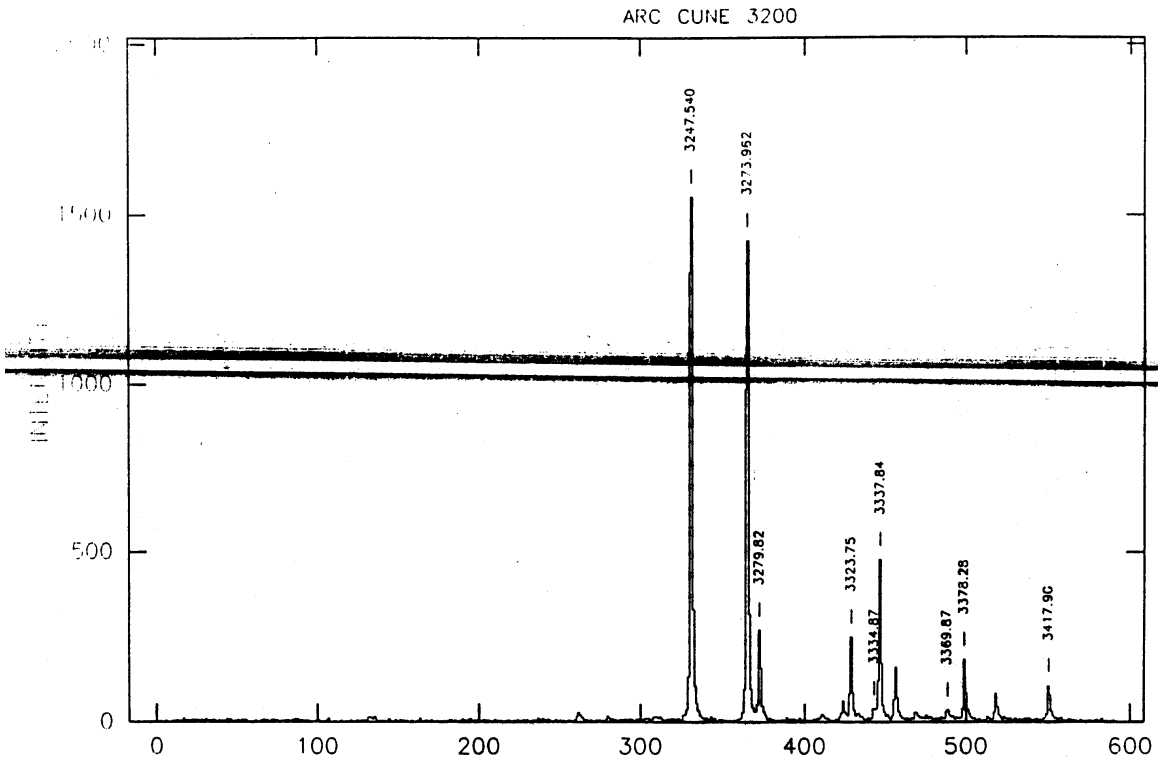
Notes to Table 5

Line	
4275.11	NeI, blend of 4274.66 and 4275.56
4704.395	NeI, weak CuI at 4704.60
5975.534	NeI, weak NeI at 5974.63
8266.08	NeI, blend at 8259.38
8865.67	NeI, blend of 8865.33 and 8865.76

Figure 5 : Copper-Neon spectrum at low dispersion

Notes to figure 5

Spectrum	CuNe at low dispersion	
Camera	IDS 500 mm	
Detector	GEC 4 "GEC BLUE" ; 22 mu pixel	
Gratings	R150V	
Collimator	Al UV	
Dispersion	131 A/mm or 0.347 pixel/A	
Exposure times	4500	600 s
	5500	10 s
	6500	5 s
	7500	5 s
	8500	120 s
	9500	300 s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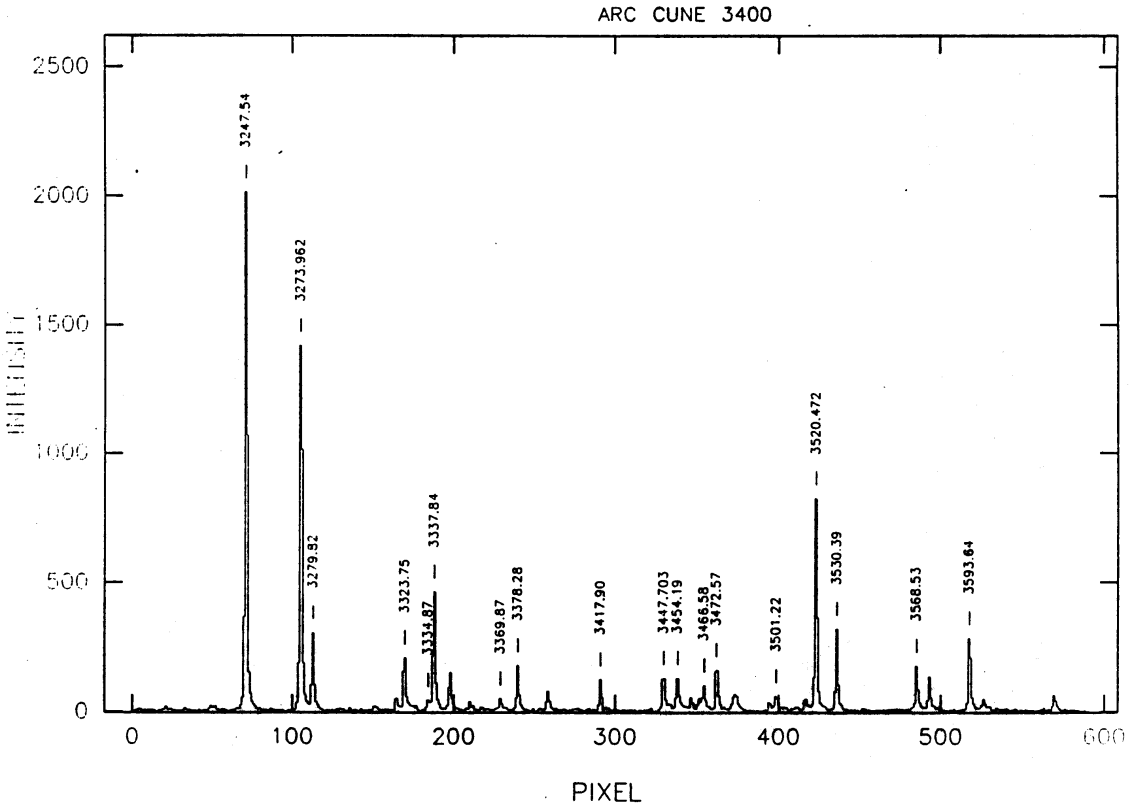
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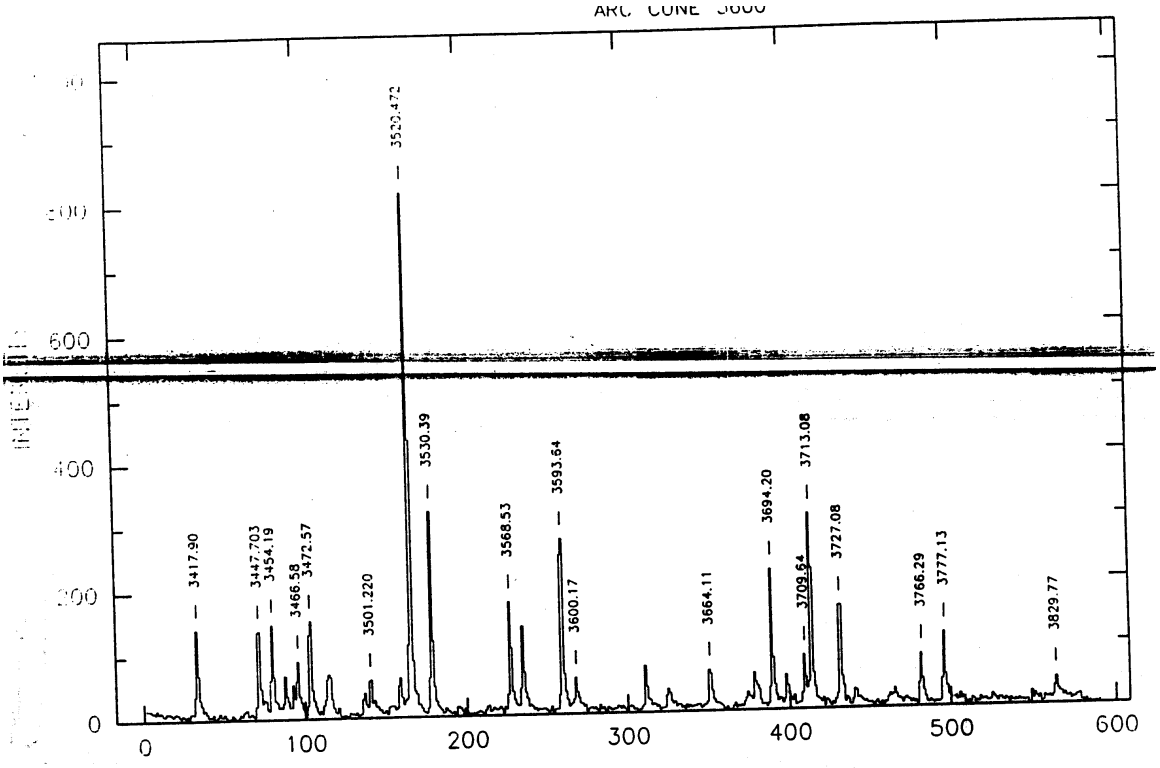
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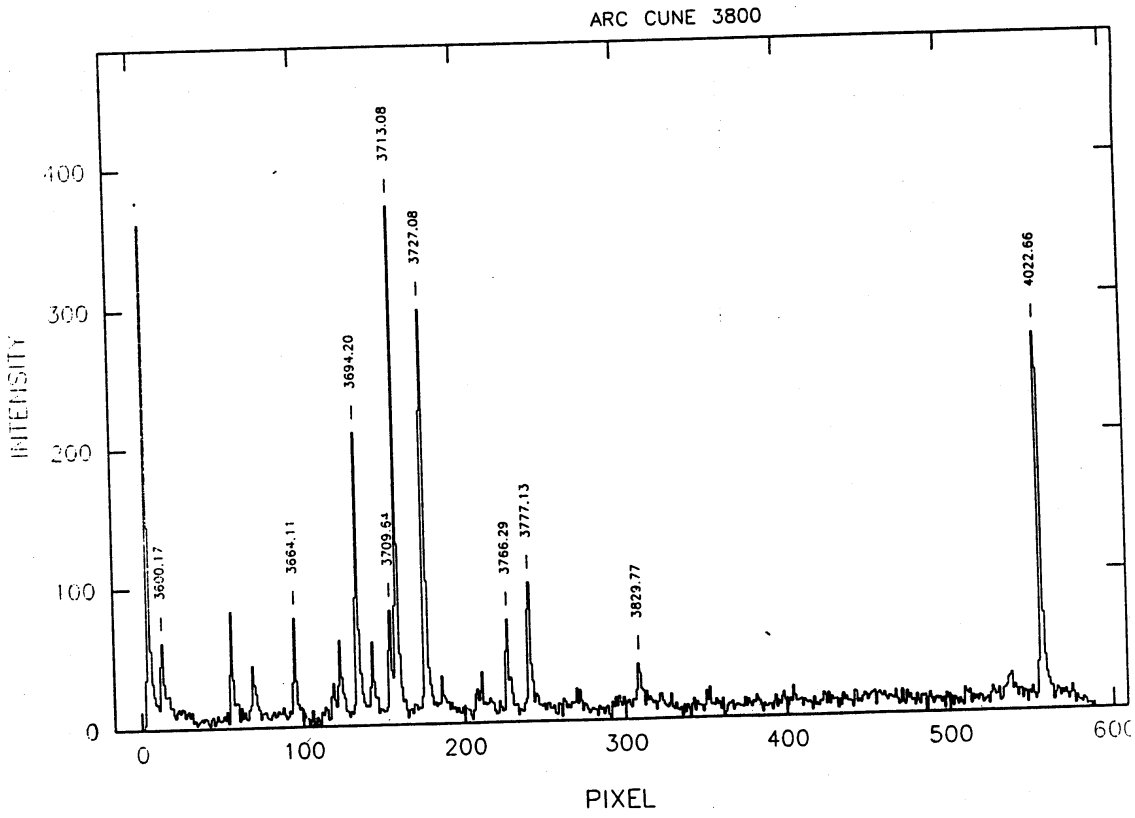
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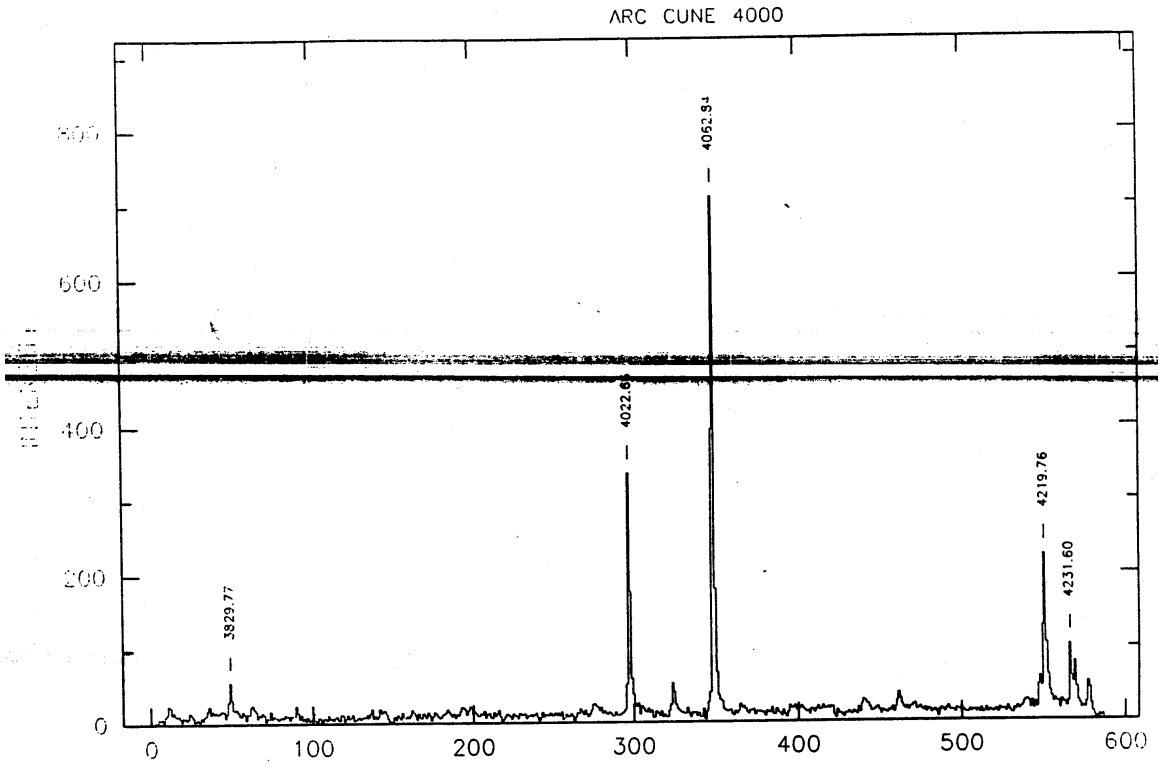
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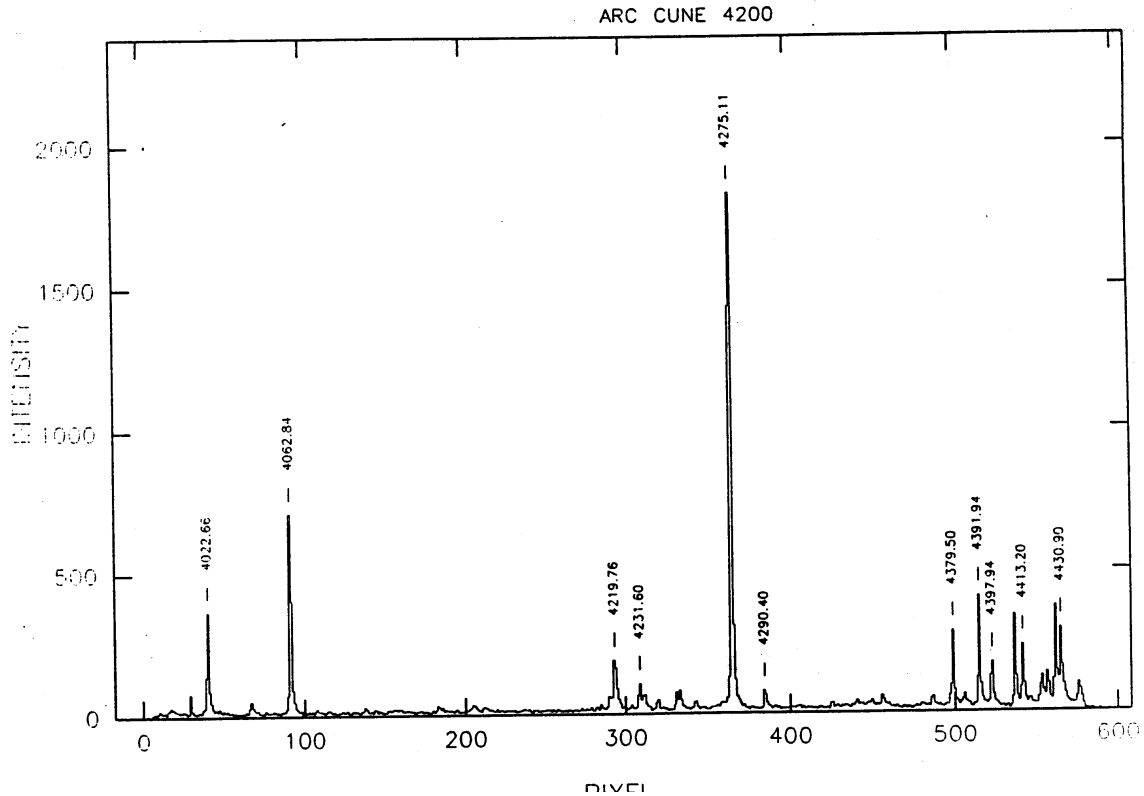
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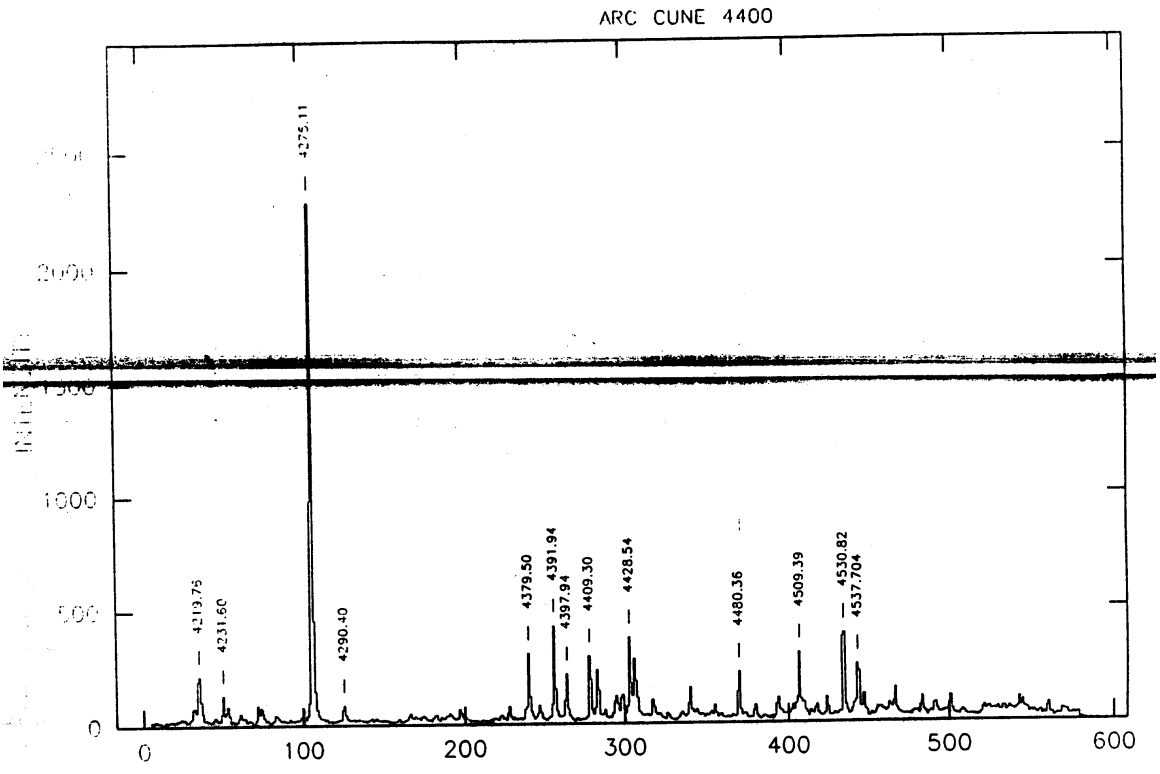
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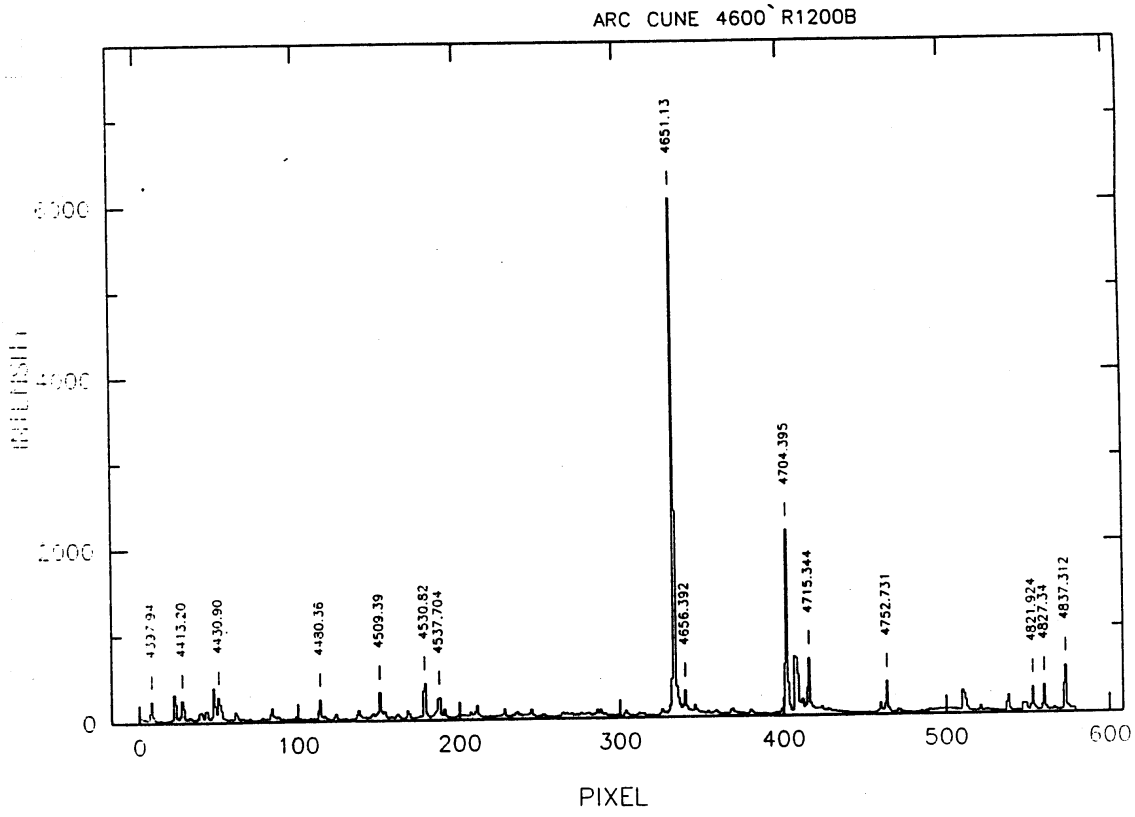
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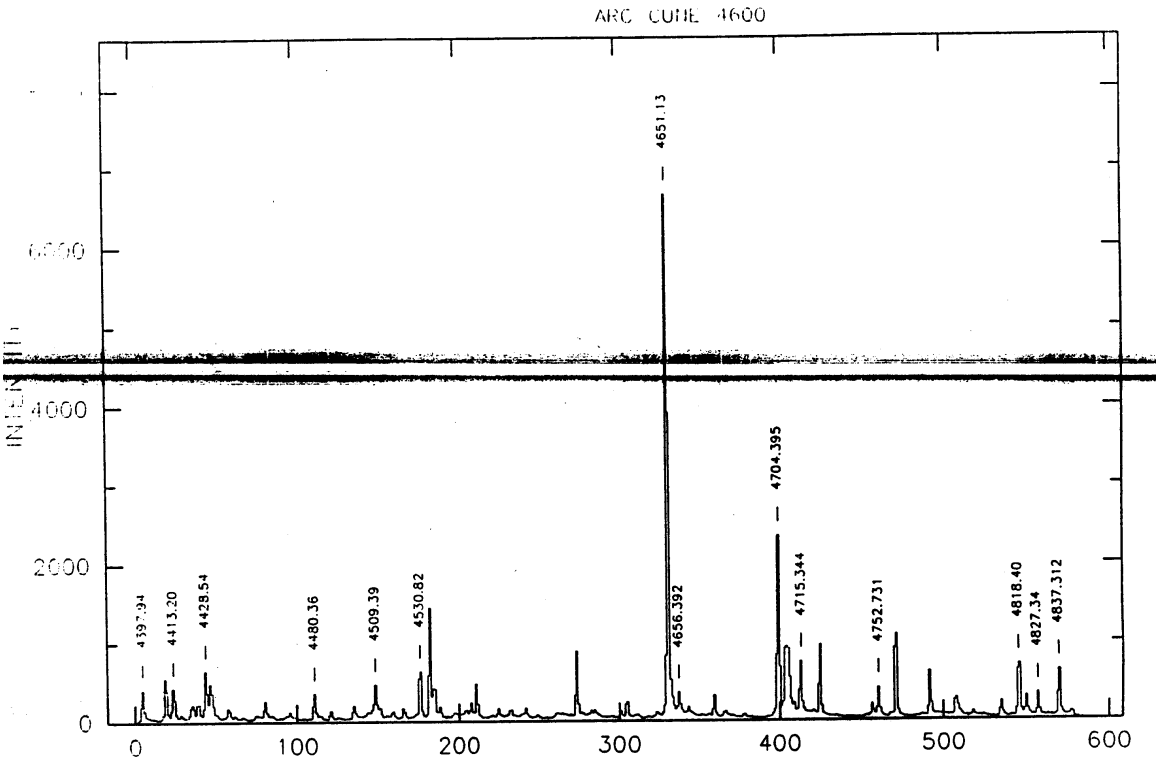
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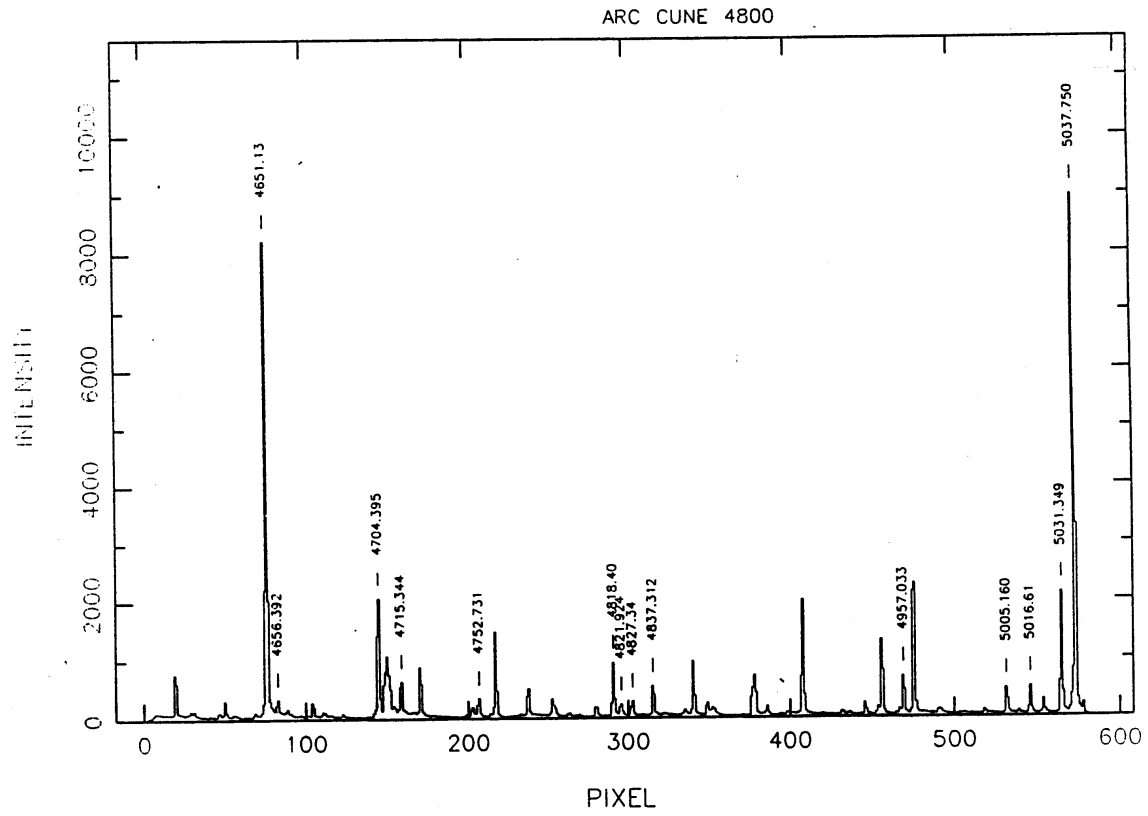
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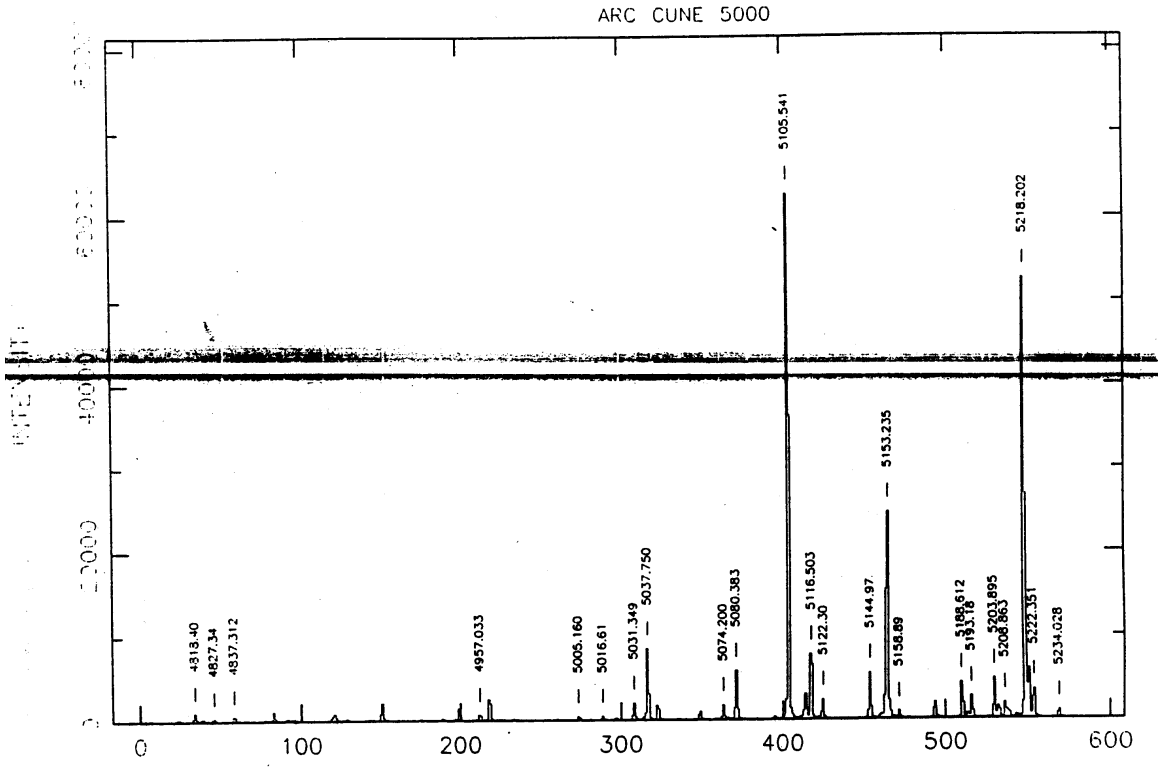
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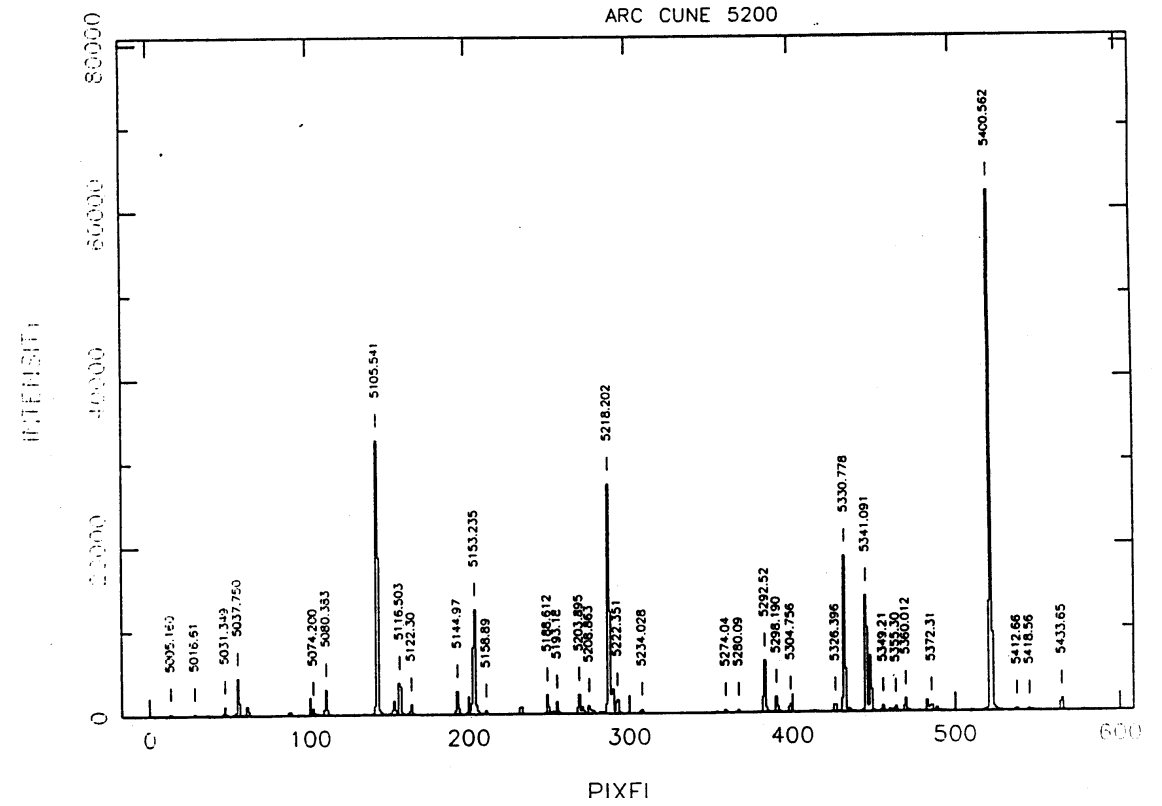
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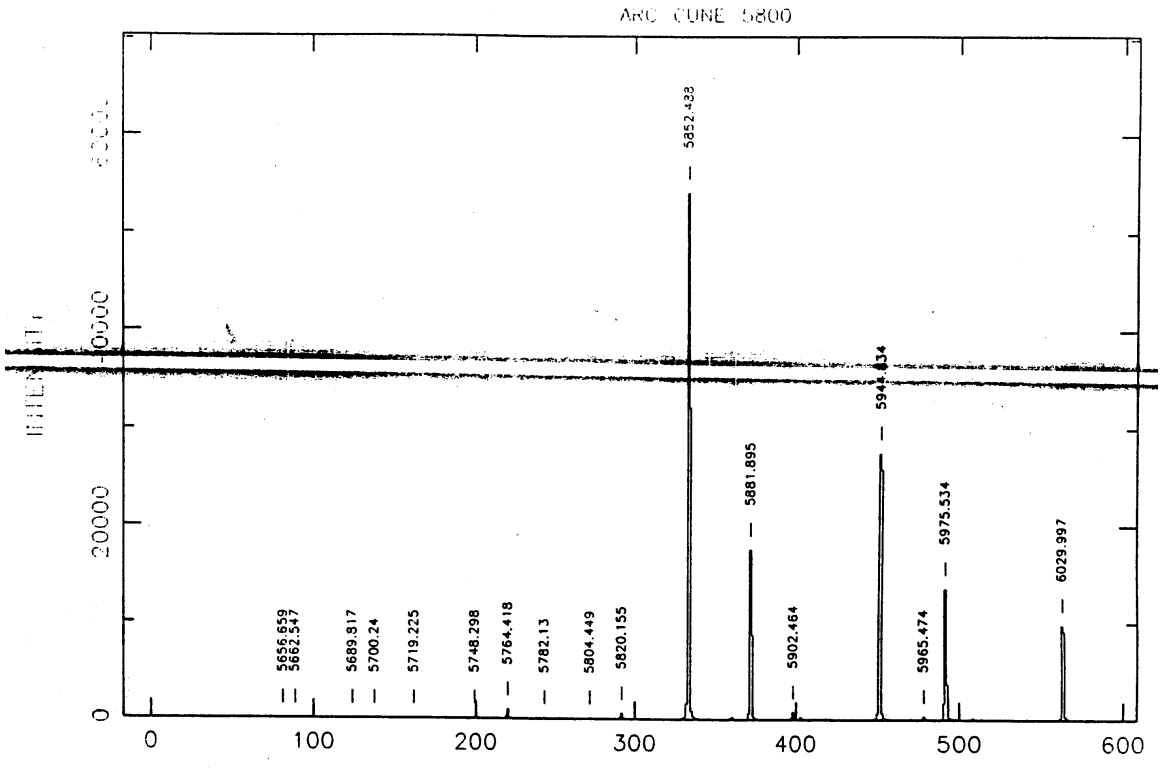
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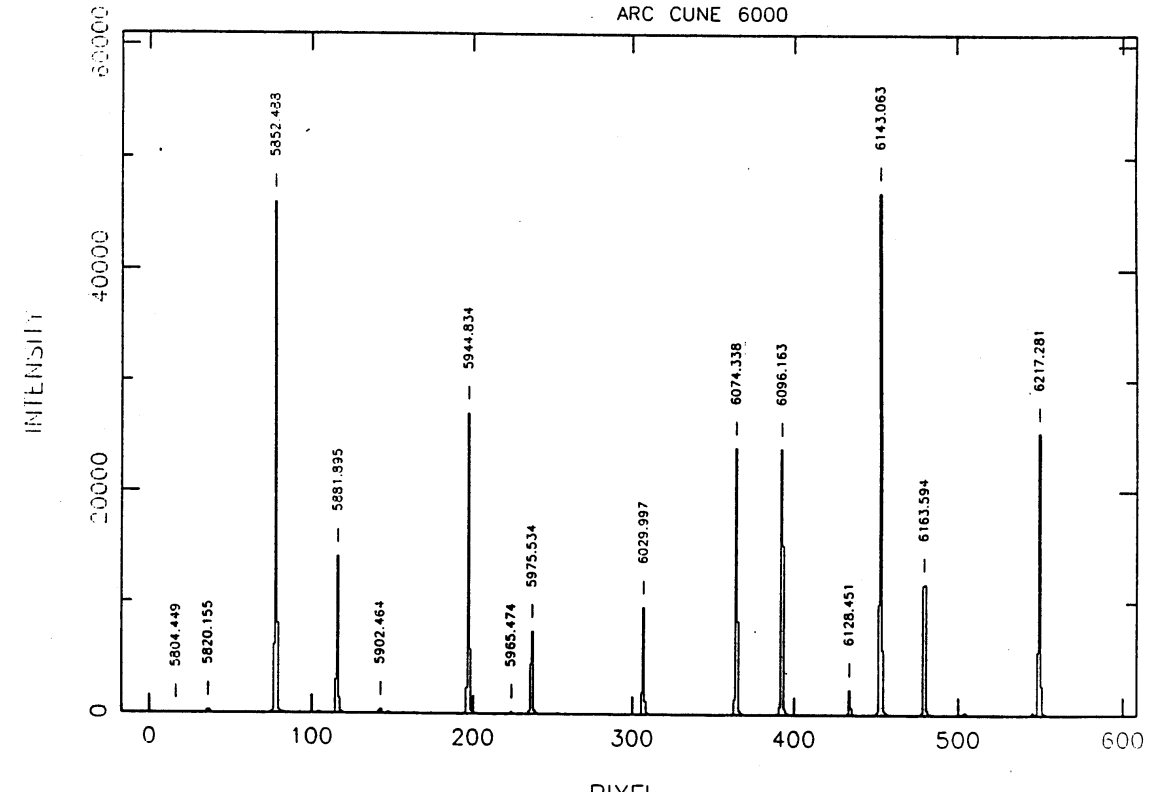
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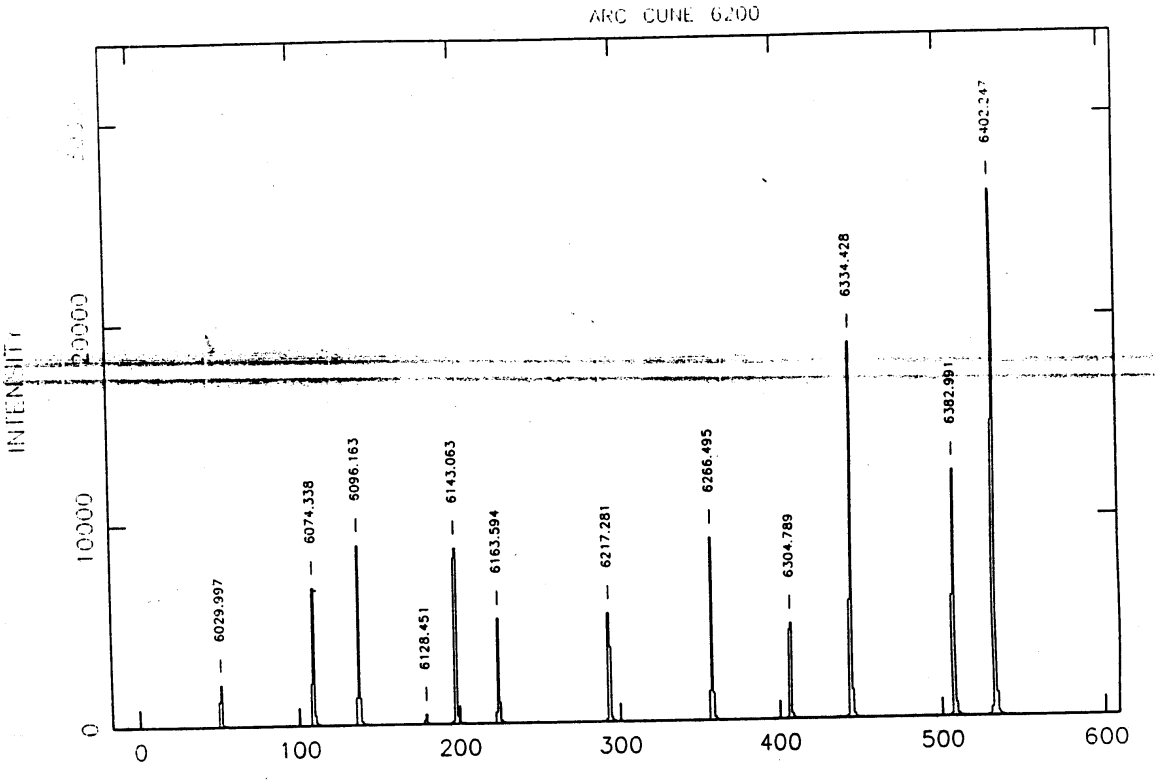
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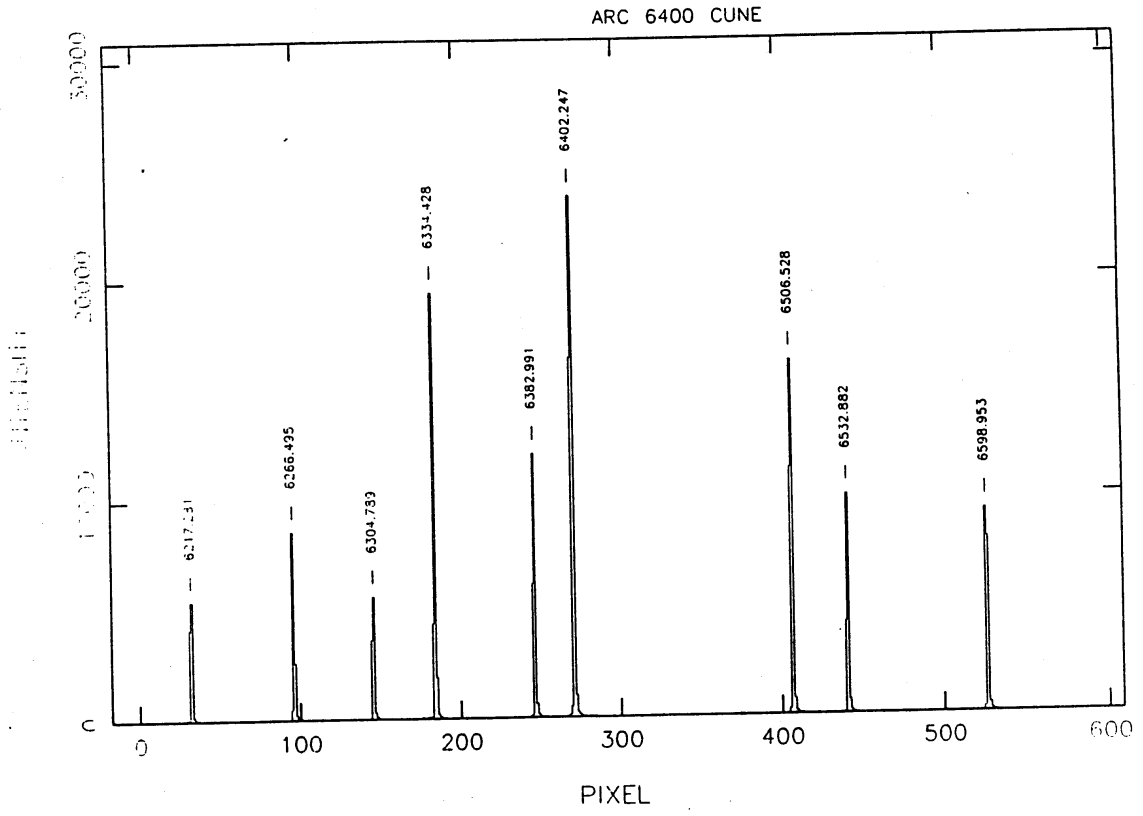
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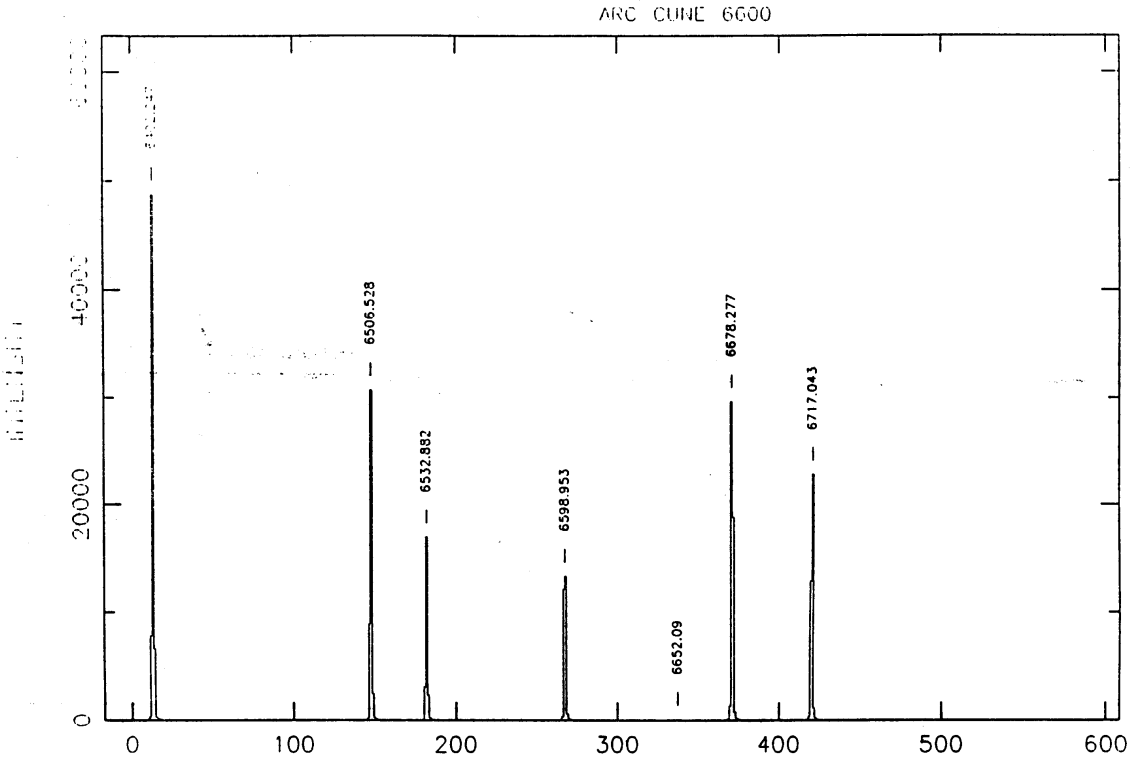
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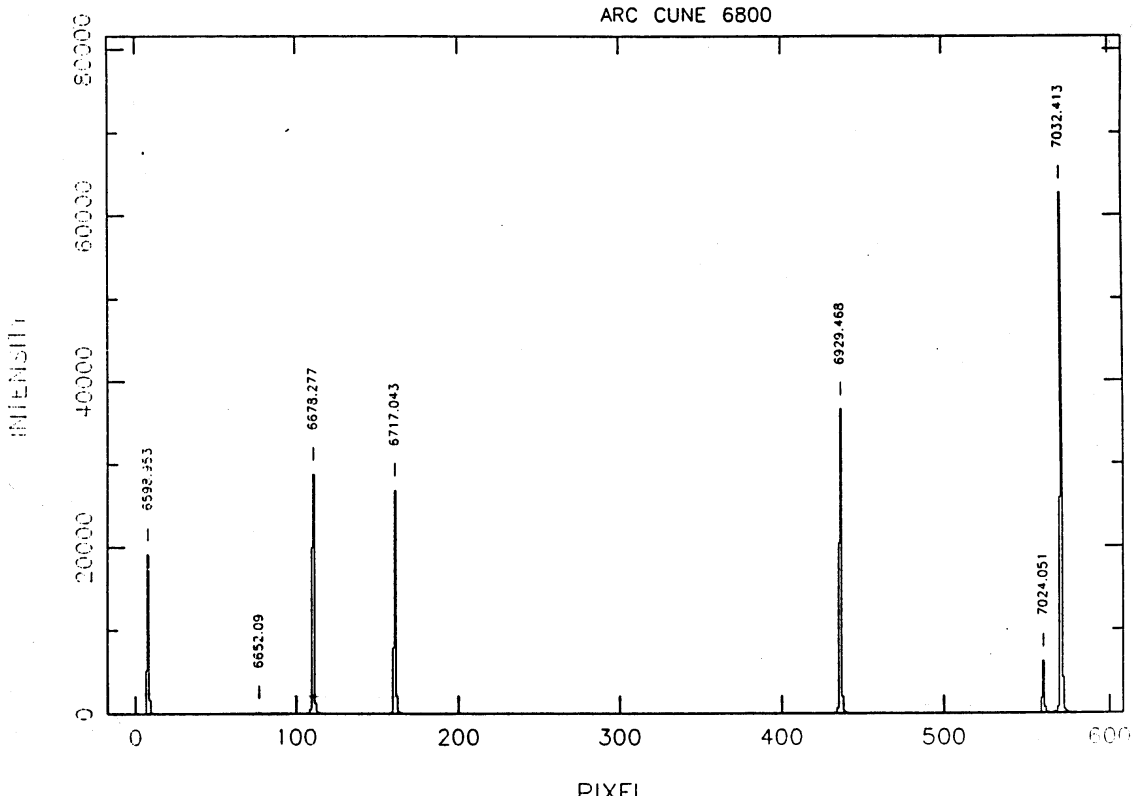
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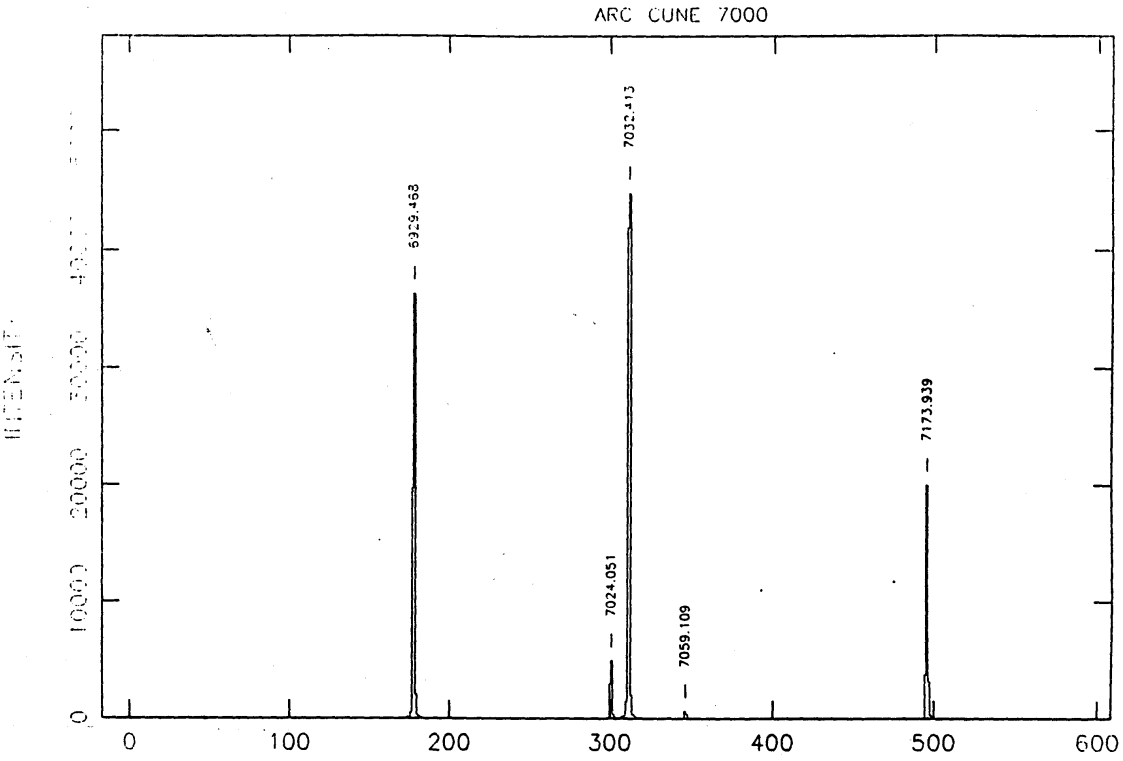
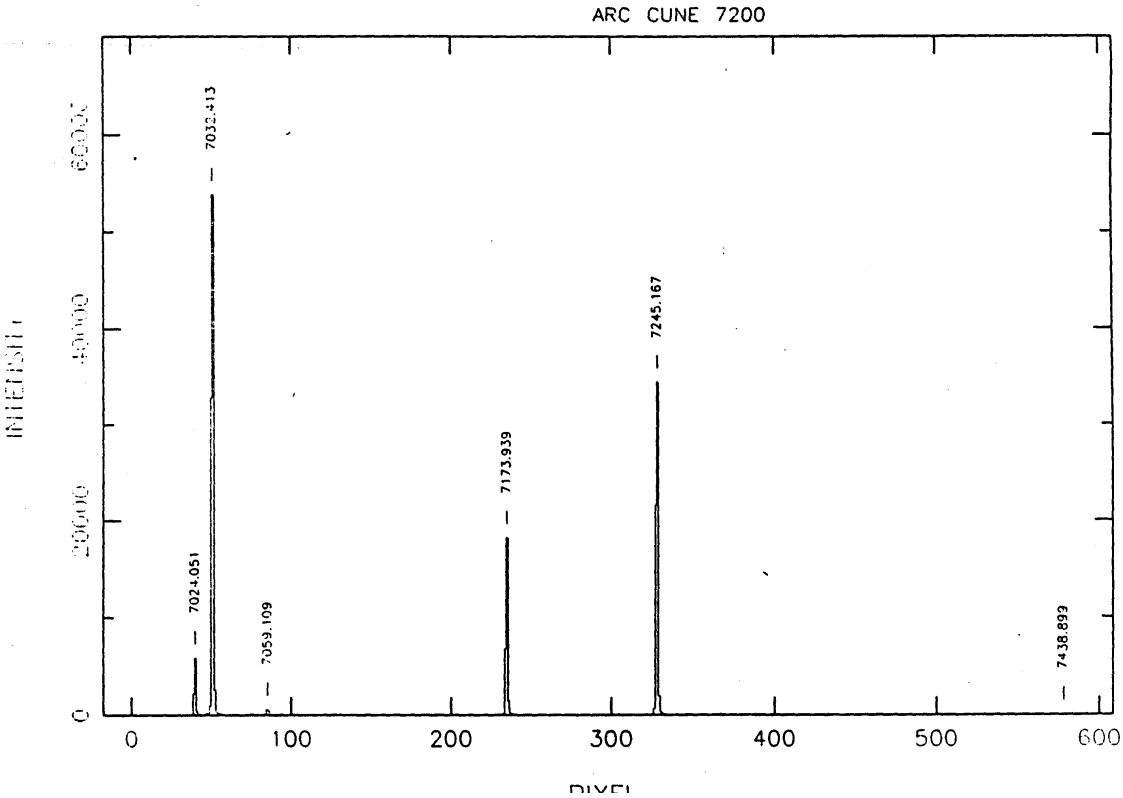

ARC CUNE 7000
6329.468
7032.413
7024.051
7059.109
7173.939
0
100
200
300
400
500
600


ARC CUNE 7200
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7024.051
7059.109
7173.939
7245.167
7438.893
0
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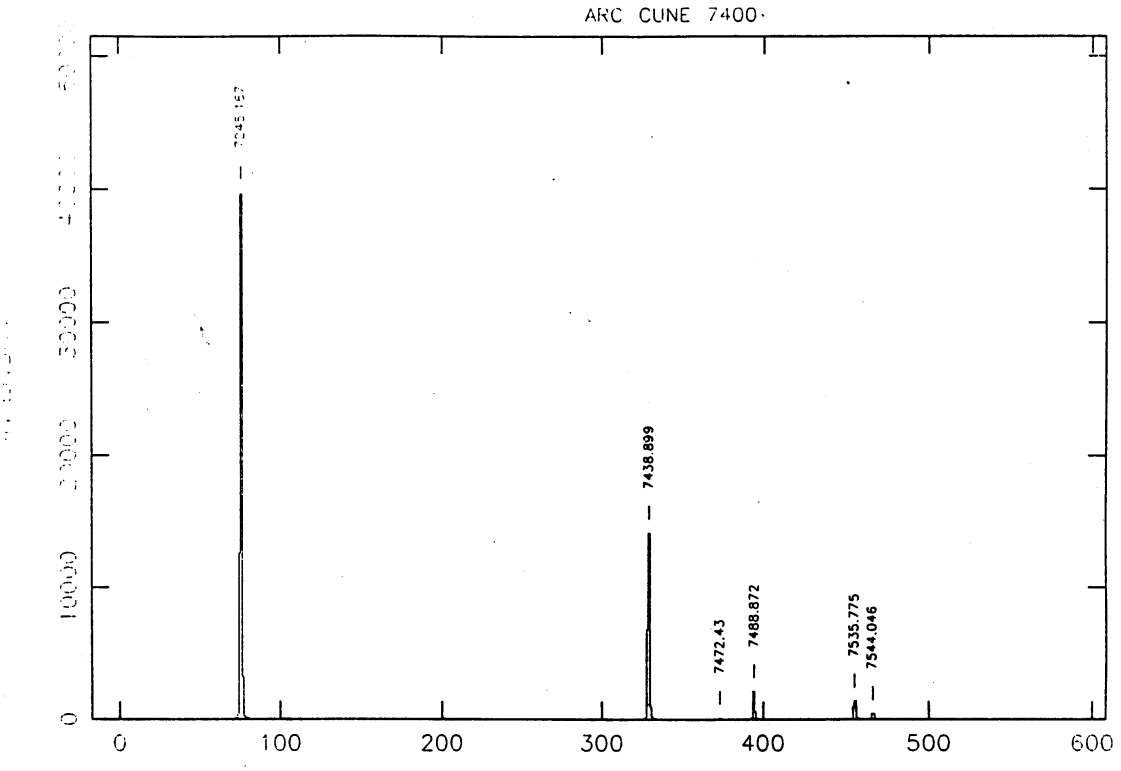
200
300
400
500
600


ARC CUNE 7400
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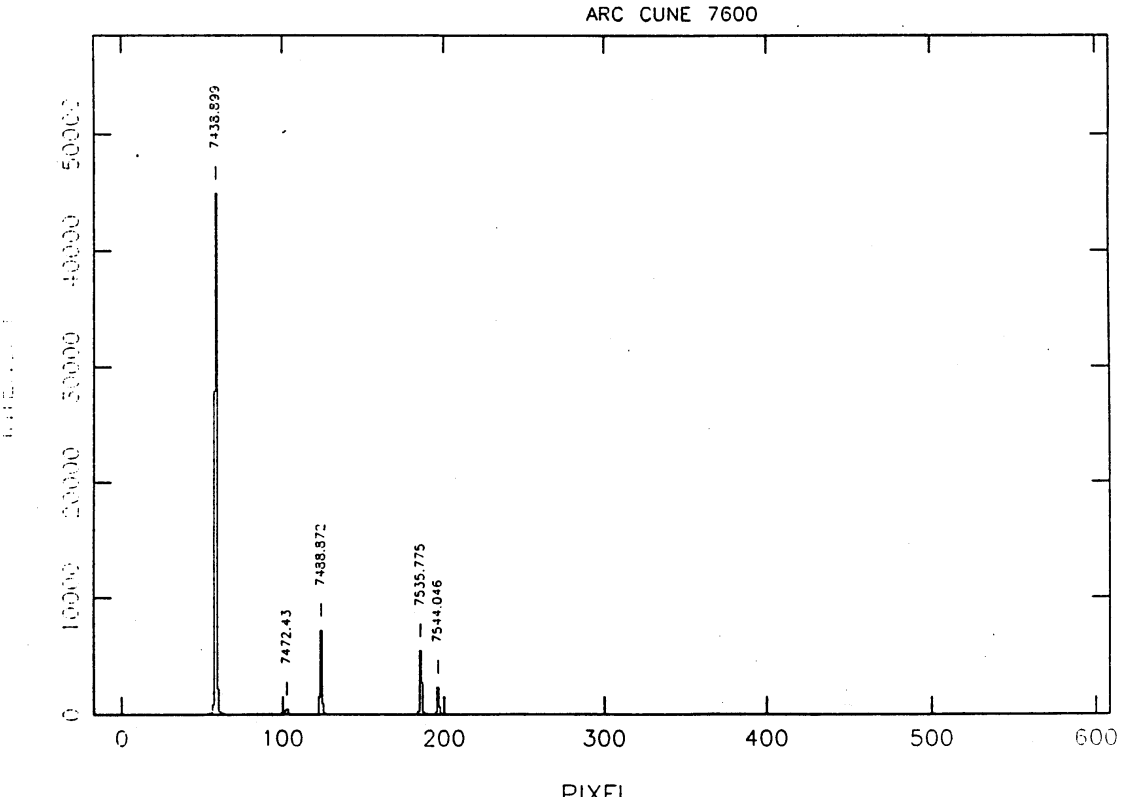
7472.43
7488.872
7535.775
7544.046
0
100
200
300
400
500
600


ARC CUNE 7600
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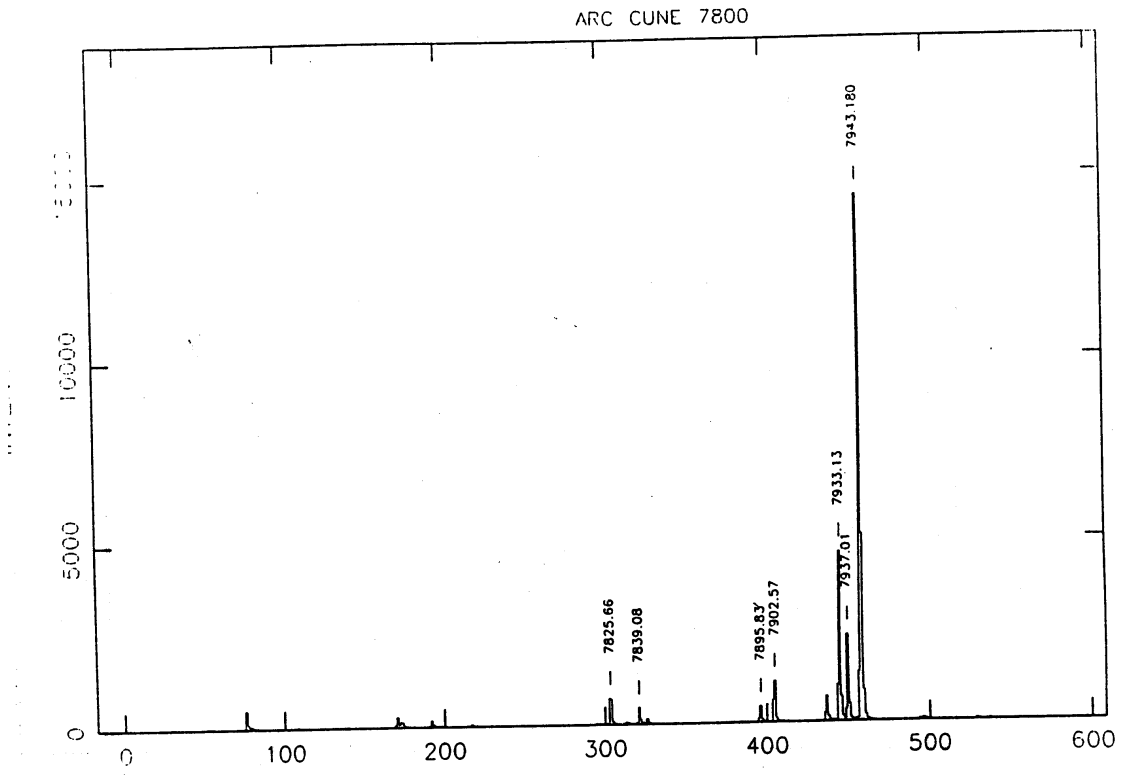
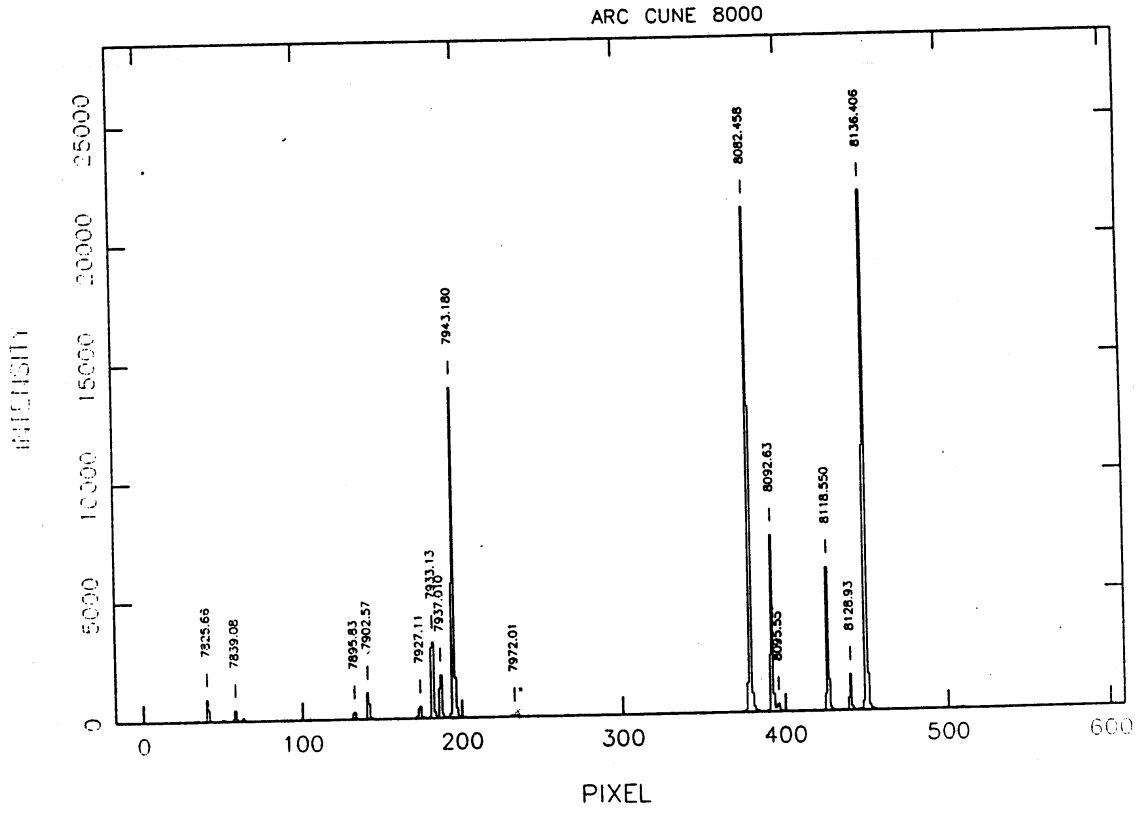
7472.43
7488.872
7535.775
7544.046
0
100
200
300
400
500
600
PIXEL


ARC CUNE 7800
7825.66
7839.08
7895.83
7902.57
7933.13
7937.01
7943.180
0
5000
10000
100
200
300
400
500
600


ARC CUNE 8000
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7839.08
7895.83
7902.57
7927.11
7933.13
7937.010
7943.180
7972.01
8082.458
8092.63
8095.55
8118.550
8128.93
8136.406
0
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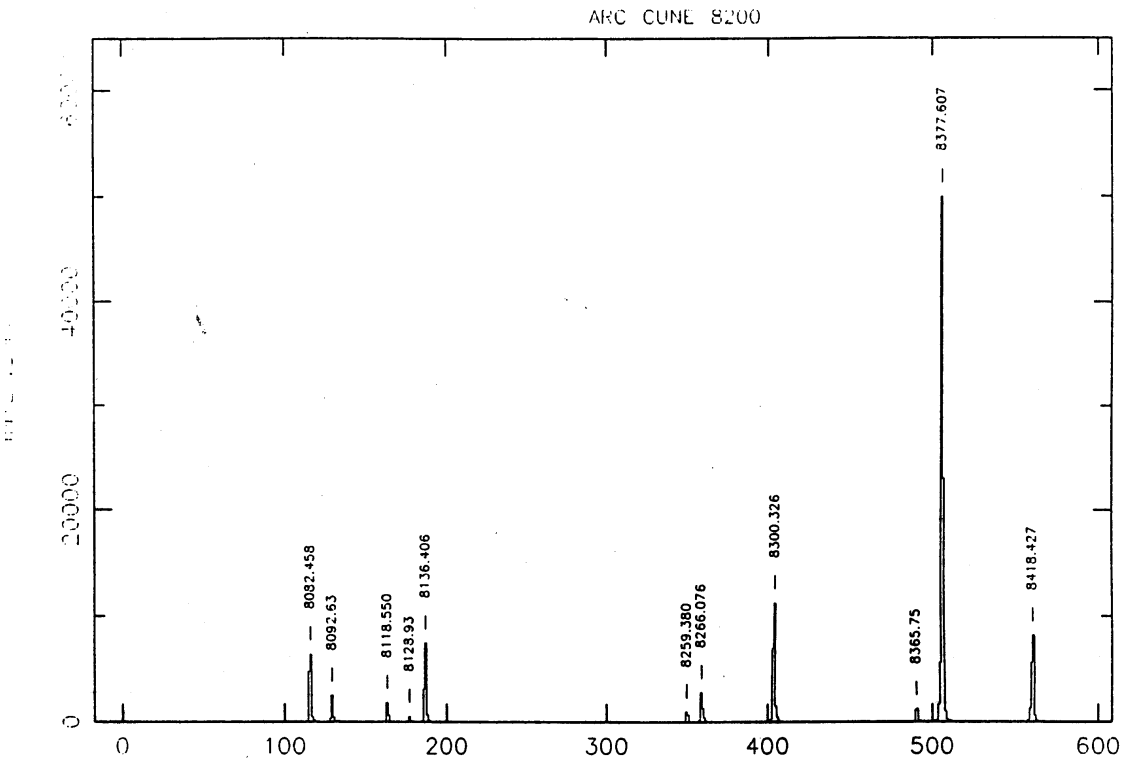
10000
15000
20000
25000
100
200
300
400
500
600
PIXEL


ARC CUNE 8200
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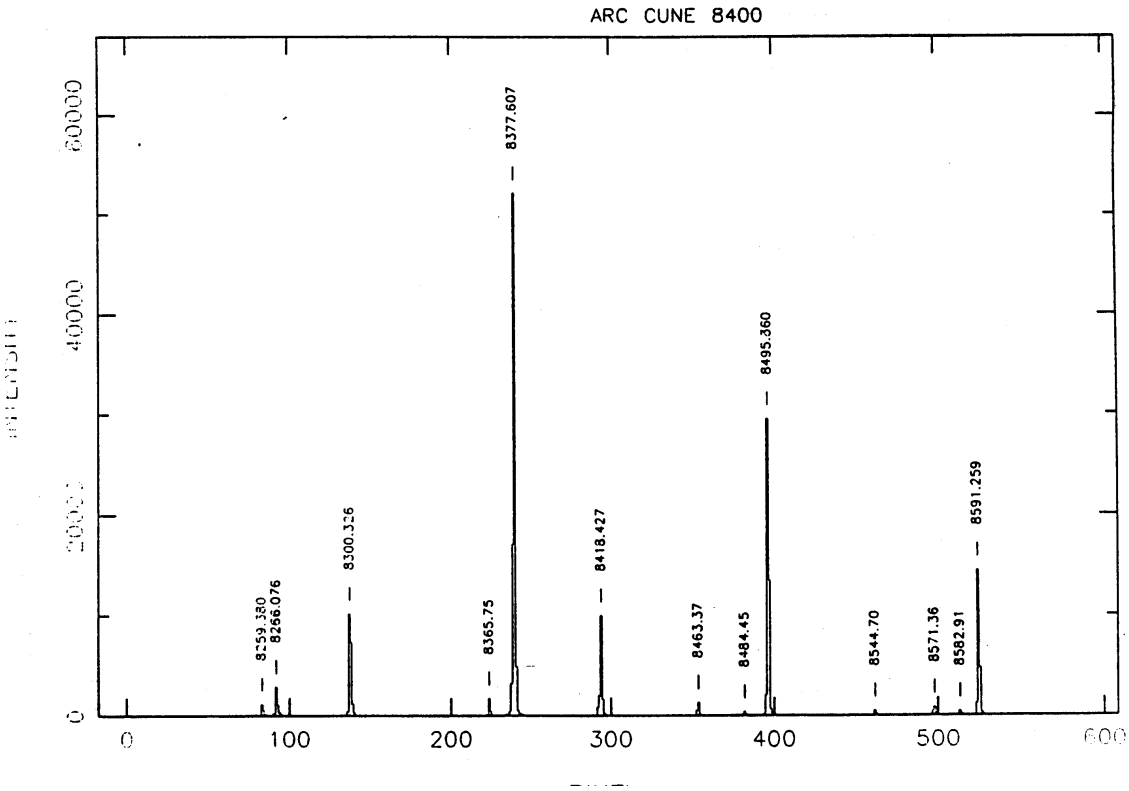
20000
8082.458
8092.63
8118.550
8128.93
8136.406
8259.380
8266.076
8300.326
8365.75
8377.607
8418.427
0
100
200
300
400
500
600


ARC CUNE 8400
0
40000
60000
8259.380
8266.076
8300.326
8365.75
8377.607
8418.427
8463.37
8484.45
8495.360
8544.70
8571.36
8582.91
8591.259
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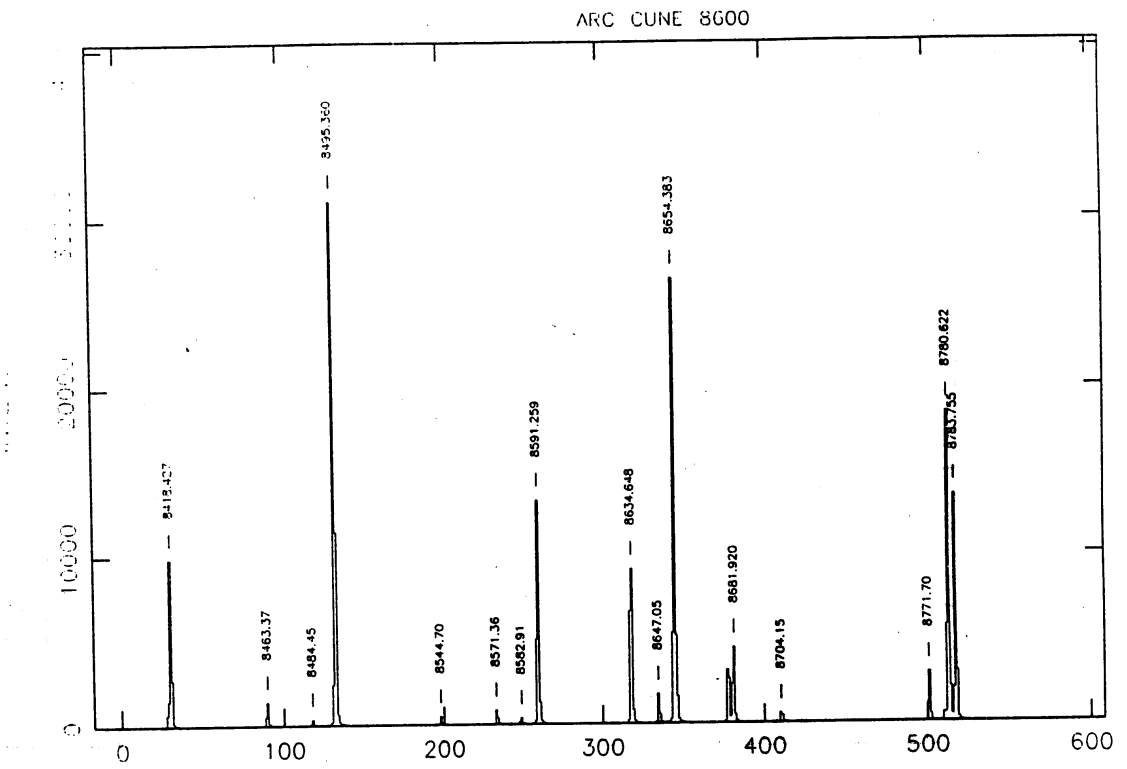
200
300
400
500
600


ARC CUNE 8600
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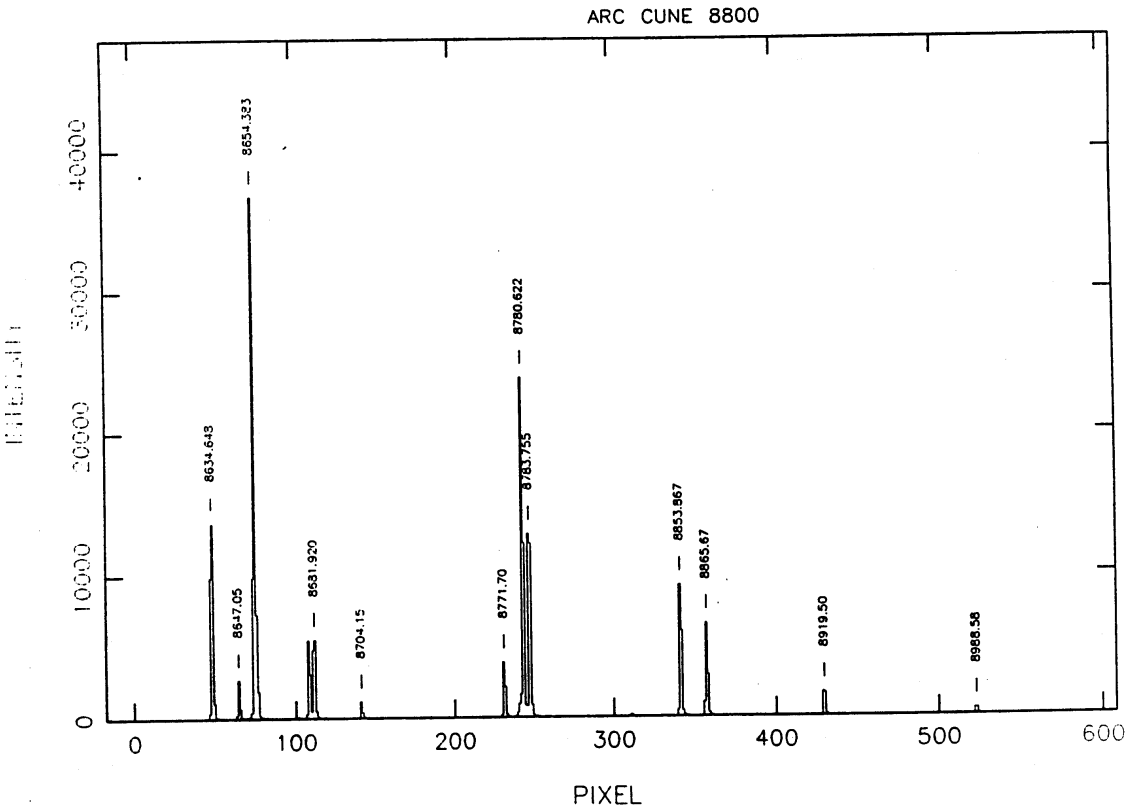
8654.383
8591.259
8634.648
8780.622
8783.755
8418.427
8463.37
8484.45
8544.70
8571.36
8582.91
8647.05
8681.920
8704.15
8771.70
0
10000
0
100
200
300
400
500
600


ARC CUNE 8800
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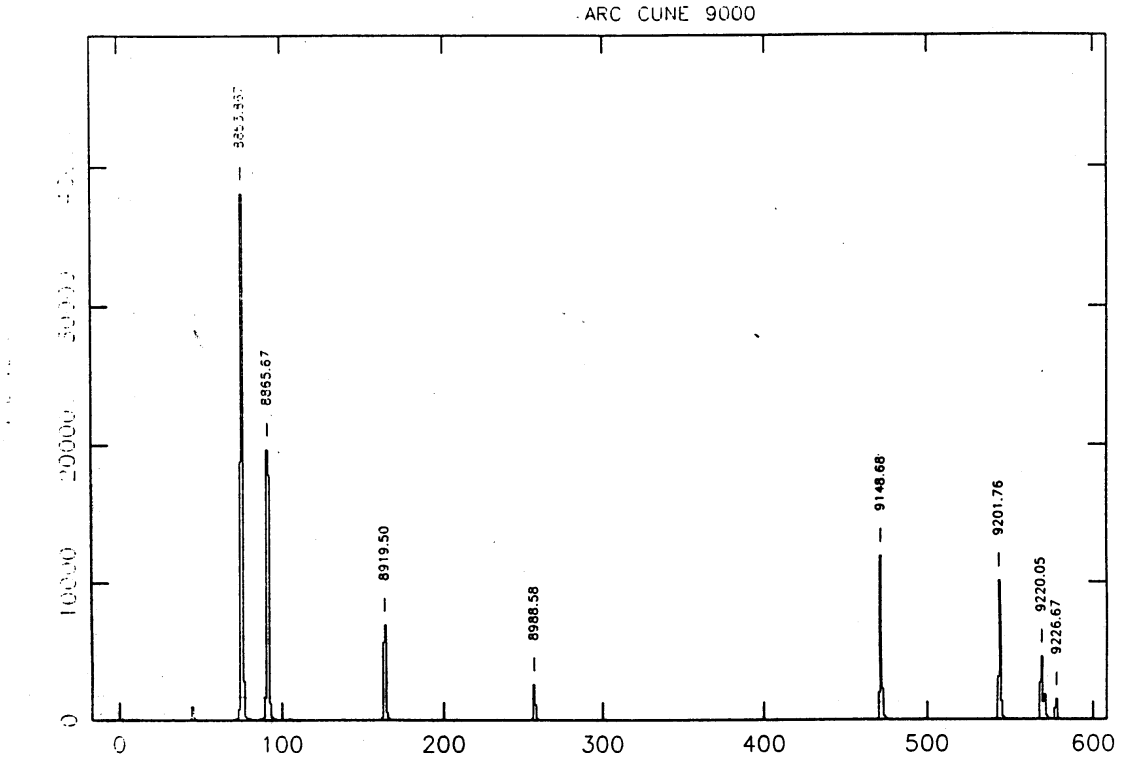
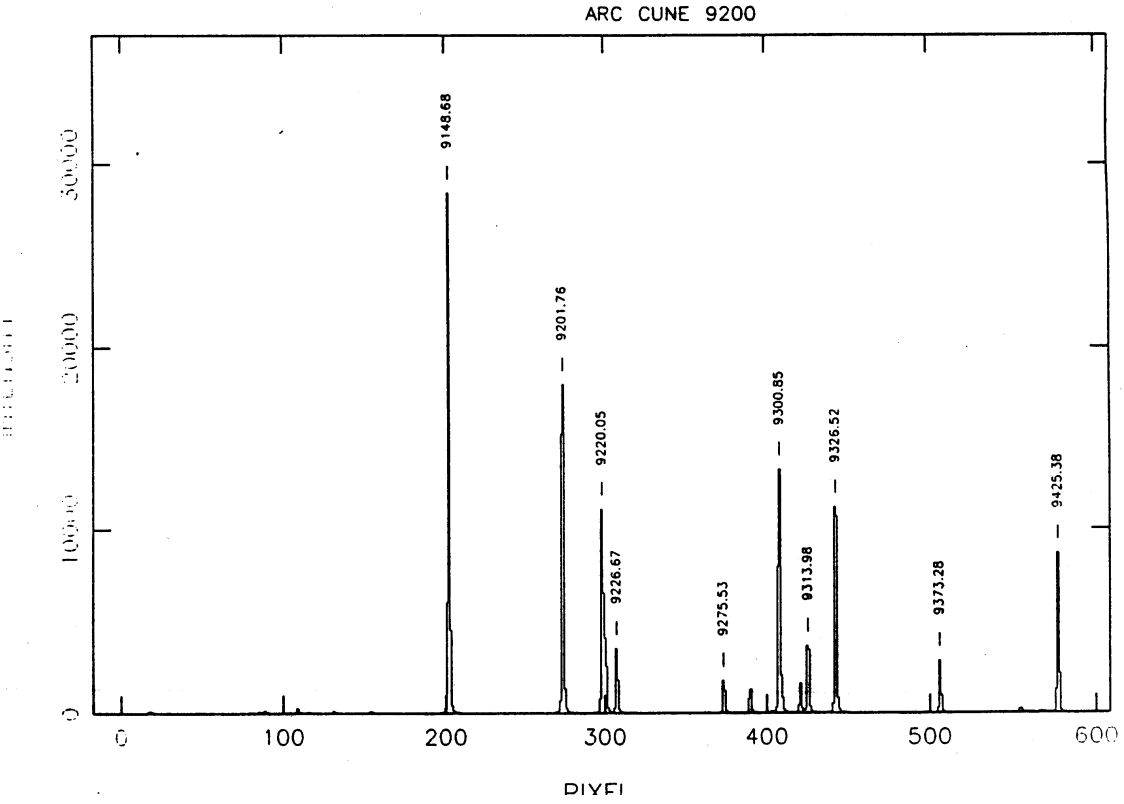
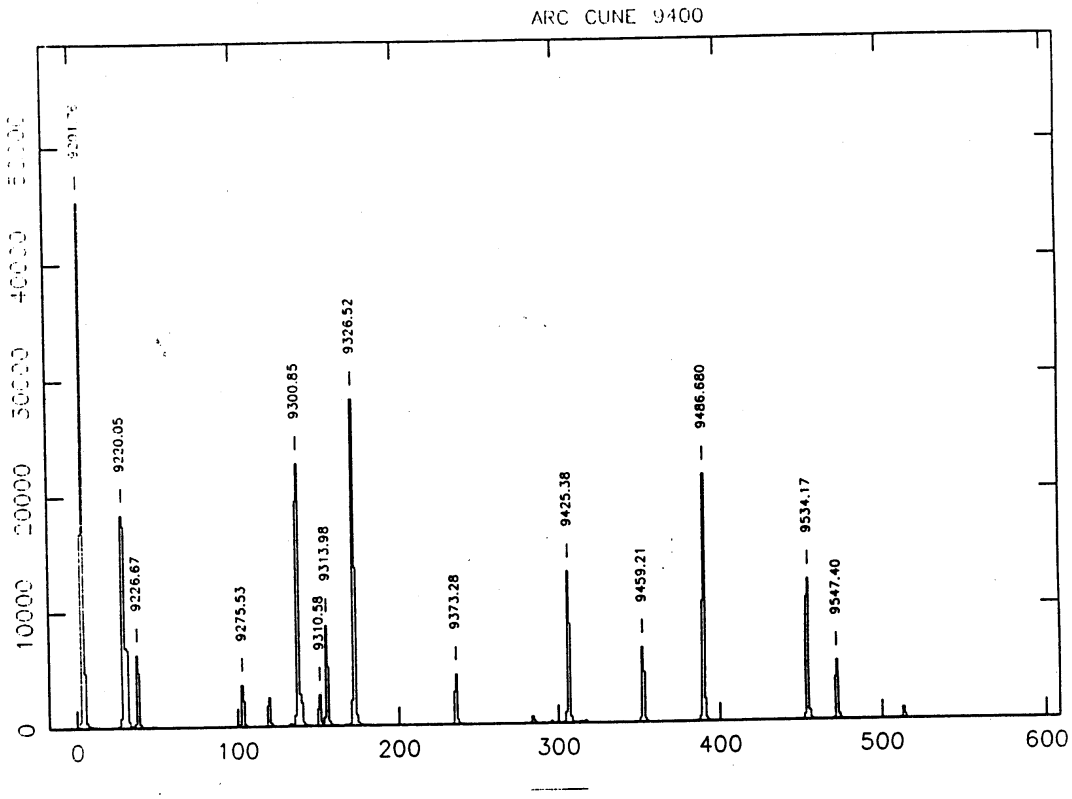
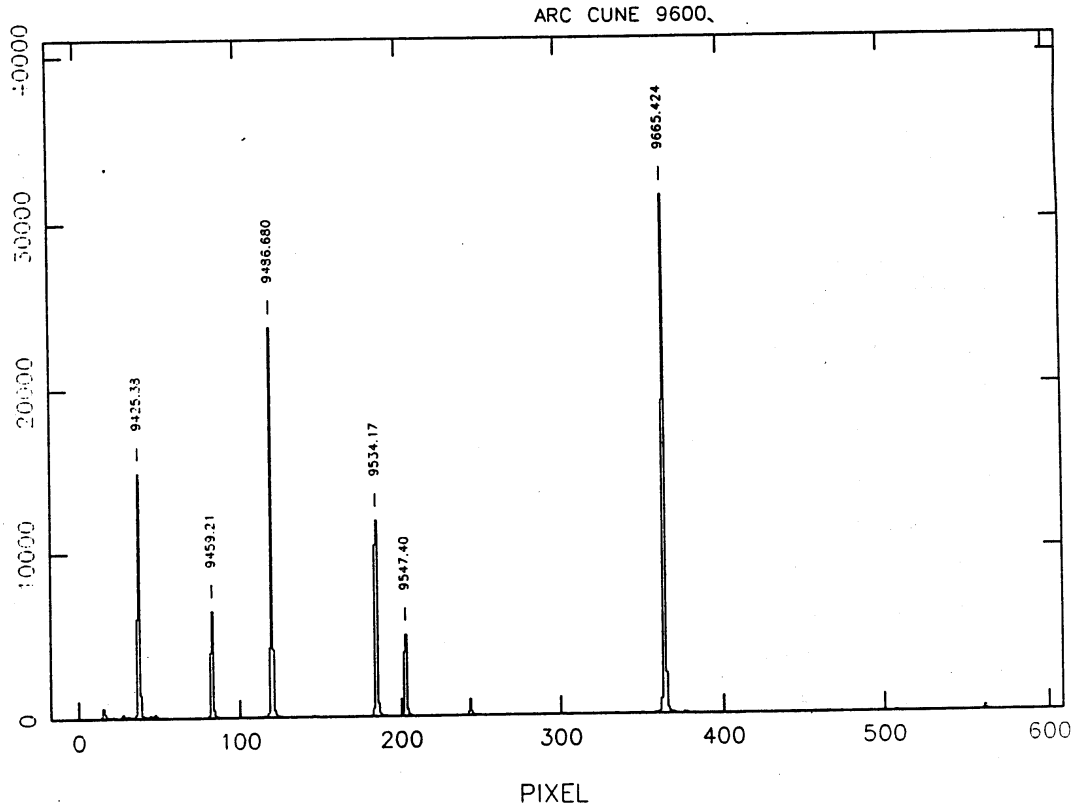
8634.648
8780.622
8783.755
8853.867
8865.67
8631.920
8647.05
8704.15
8771.70
8919.50
8988.58
0
10000
20000
30000
40000
0
100
200
300
400
500
600
PIXEL


ARC CUNE 9000
8865.67
8919.50
8988.58
9148.68
9201.76
9220.05
9226.67
0
100
200
300
400
500
600


ARC CUNE 9200
9148.68
9201.76
9220.05
9226.67
9275.53
9300.85
9313.98
9326.52
9373.28
9425.38
0
100
200
300
400
500
600
DIXEL


ARC CUNE 9400
9220.05
9226.67
9275.53
9300.85
9310.58
9313.98
9326.52
9373.28
9425.38
9459.21
9486.680
9534.17
9547.40
0
10000
20000
30000
40000
0
100
200
300
400
500
600


ARC CUNE 9600
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9459.21
9486.680
9534.17
9547.40
9665.424
0
10000
20000
30000
40000
0
100
200
300
400
500
600
PIXEL

Table 5: The Copper Neon spectrum at low dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
3247.540	CuI	5330.778	NeI	6382.991	NeI	8300.326	NeI
3273.962	CuI	5341.091	NeI	6402.247	NeI	8377.607	NeI
3447.703	NeI	5400.5619	NeI	6506.528	NeI	8418.427	NeI
3520.472	NeI	5748.299	NeI	6532.882	NeI	8495.360	NeI
3713.08	NeII	5764.418	NeI	6598.953	NeI	8591.258	NeI
3777.13	NeII	5852.4878	NeI	6678.277	NeI	8634.648	NeI
4022.66	NeI	5881.8950	NeI	6717.043	NeI	8654.383	NeI
4275.11	NeI b	5944.834	NeI	6929.468	NeI	8853.866	NeI
4530.82	CuI	5975.534	NeI w	7032.413	NeI	8865.670	NeI b
4651.13	CuI	6030.000	NeI	7173.939	NeI	8919.500	NeI
4704.395	NeI w	6074.338	NeI	7245.167	NeI	9148.680	NeI
4884.915	NeI	6096.163	NeI	7438.899	NeI	9300.850	NeI
5037.7505	NeI	6143.063	NeI	7488.872	NeI	9326.520	NeI
5080.383	NeI	6163.594	NeI	7535.775	NeI	9425.380	NeI
5105.541	CuI	6217.281	NeI	7943.180	NeI	9665.424	NeI
5116.503	NeI	6266.495	NeI	8082.458	NeI		
5153.235	CuI	6304.789	NeI	8136.406	NeI		
5218.202	CuI	6334.428	NeI	8266.08	NeI b		

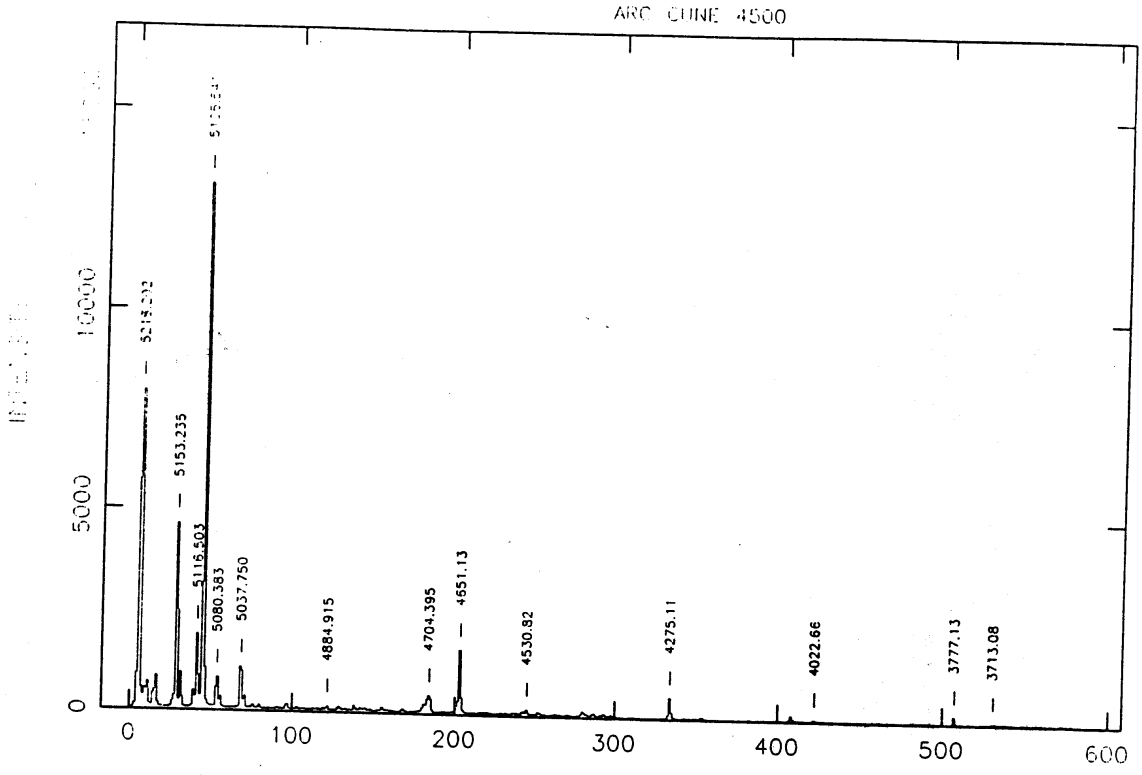
Notes to Table 5

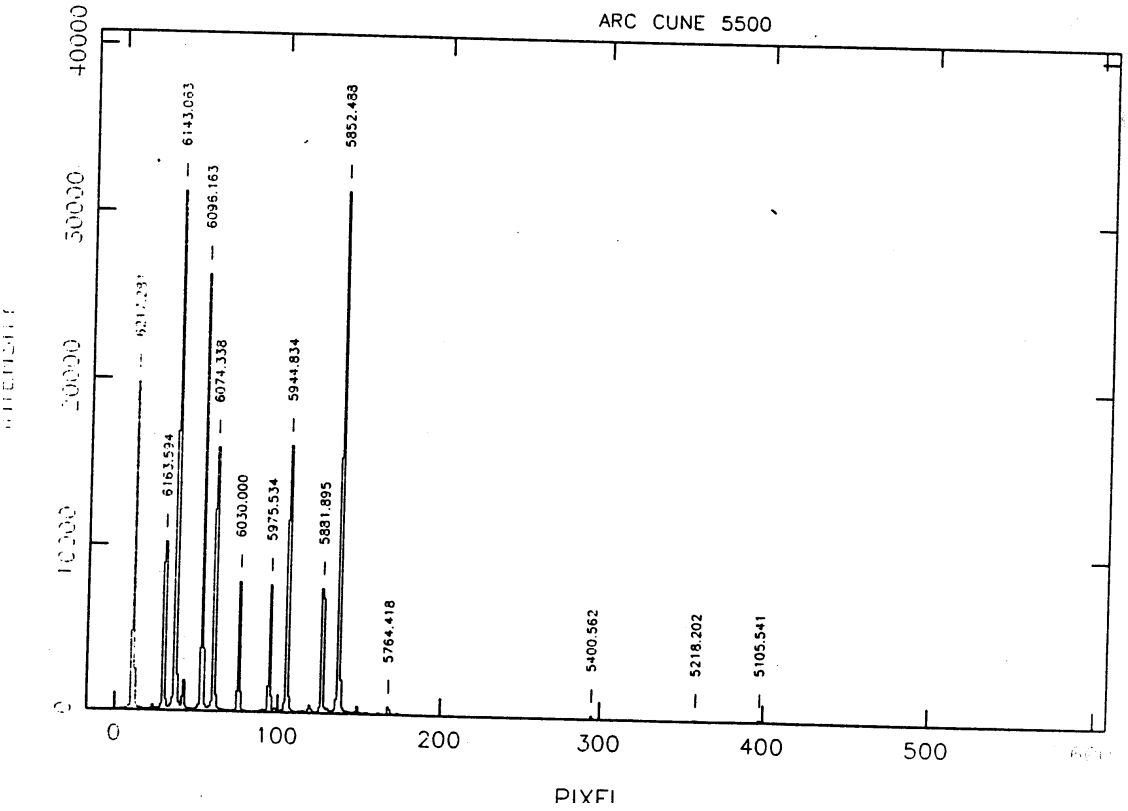
Line	
4275.11	NeI, blend of 4274.66 and 4275.56
4704.395	NeI, weak CuI at 4704.60
5975.534	NeI, weak NeI at 5974.63
8266.08	NeI, blend at 8259.38
8865.67	NeI, blend of 8865.33 and 8865.76

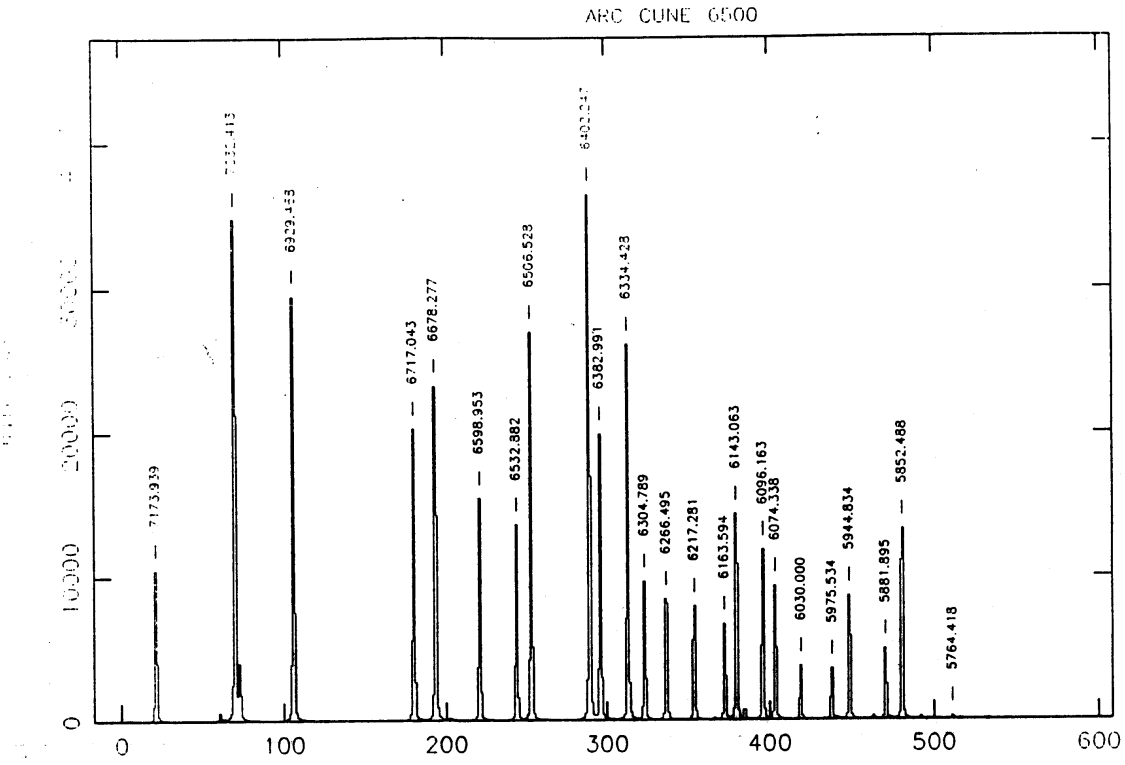
Figure 5 : Copper-Neon spectrum at low dispersion

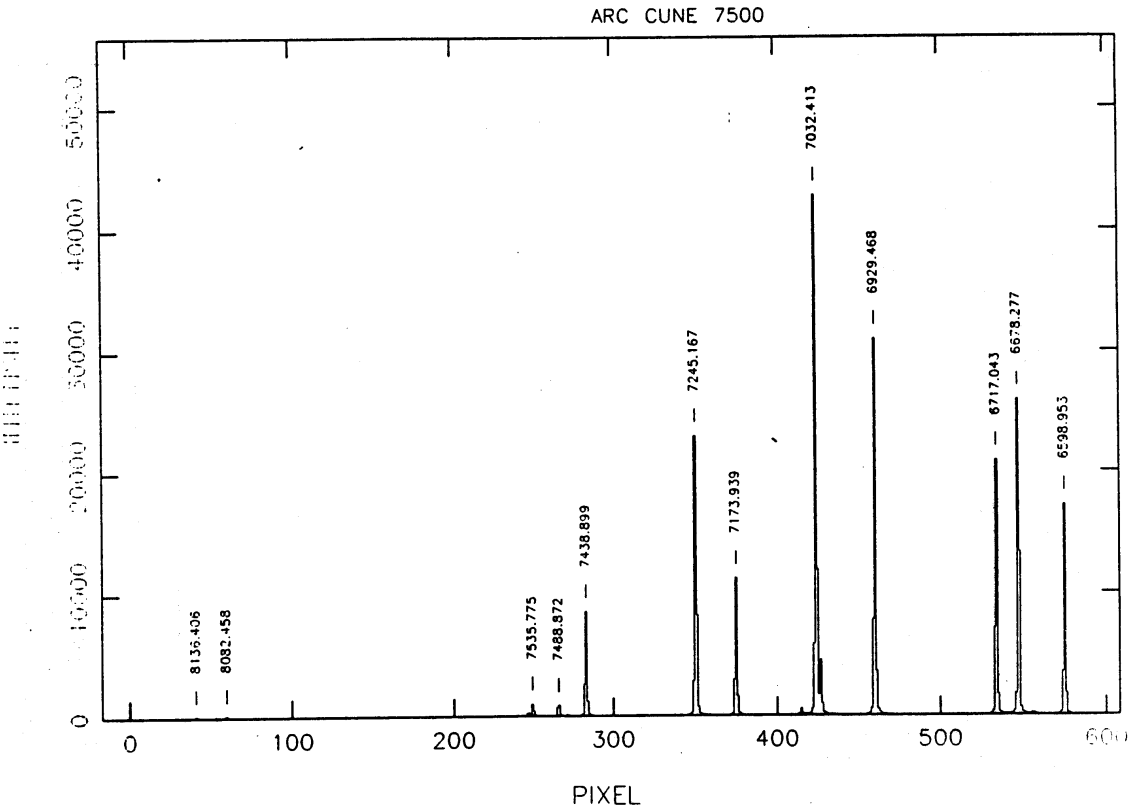
Notes to figure 5

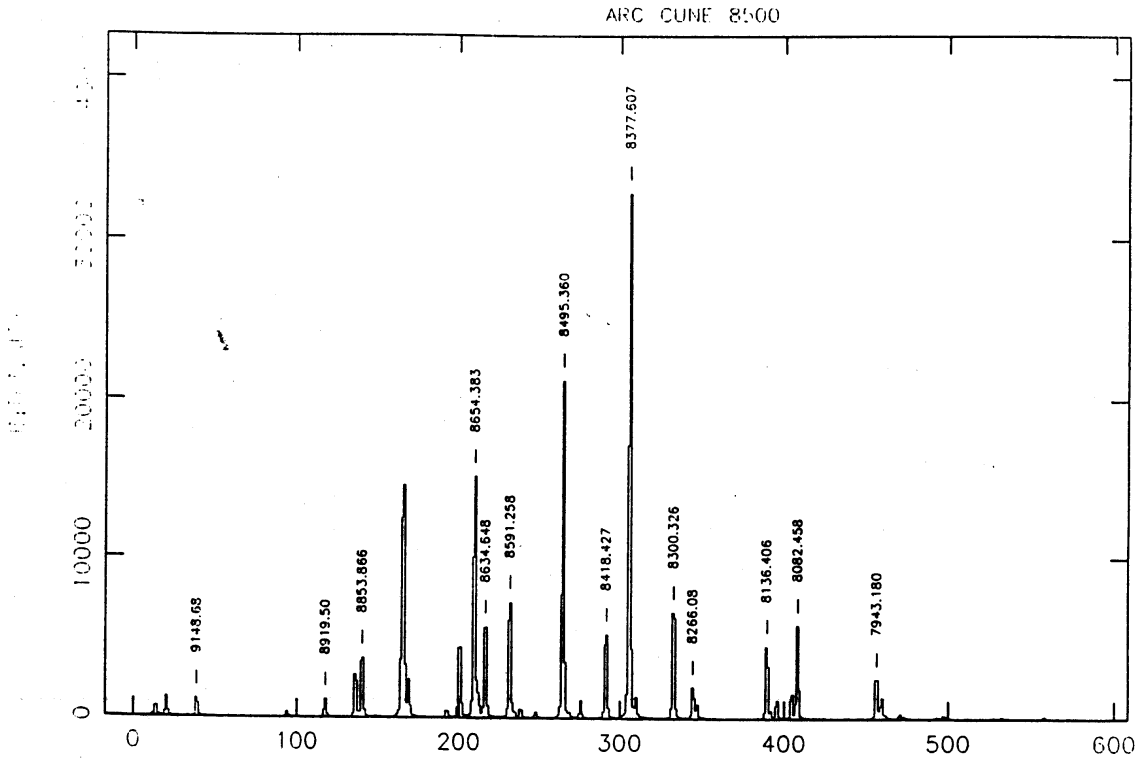
Spectrum	CuNe at low dispersion	
Camera	IDS 500 mm	
Detector	GEC 4 "GEC BLUE" ; 22 mu pixel	
Gratings	R150V	
Collimator	Al UV	
Dispersion	131 A/mm or 0.347 pixel/A	
Exposure times	4500	600 s
	5500	10 s
	6500	5 s
	7500	5 s
	8500	120 s
	9500	300 s


ARC CUNE 4500
5218.202
5153.235
5116.503
5080.383
5037.750
4884.915
4704.395
4651.13
4530.82
4275.11
4022.66
3777.13
3713.08
0
5000
10000
0
100
200
300
400
500
600


ARC CUNE 5500
6143.063
6096.163
6074.338
5944.834
5852.488
6163.594
6030.000
5975.534
5881.895
5764.418
5400.562
5218.202
5105.541
0
100000
200000
300000
400000
0
100
200
300
400
500
PIXEL


ARC CUNE 6500
7173.939
6929.468
6717.043
6678.277
6598.953
6532.882
6506.523
6382.991
6334.423
6304.789
6266.495
6217.281
6163.594
6143.063
6096.163
6074.338
6030.000
5975.534
5944.834
5881.895
5852.488
5764.418
0
10000
0
100
200
300
400
500
600


ARC CUNE 7500
8136.406
8082.458
7535.775
7488.872
7438.899
7245.167
7173.939
7032.413
6929.468
6717.043
6678.277
6598.953
0
10000
20000
30000
40000
0
100
200
300
400
500
PIXEL


ARC CUNE 8500
9148.68
8919.50
8853.866
8654.383
8634.648
8591.258
8495.360
8418.427
8377.607
8300.326
8266.08
8136.406
8082.458
7943.180
0
10000
0
100
200
300
400
500
600

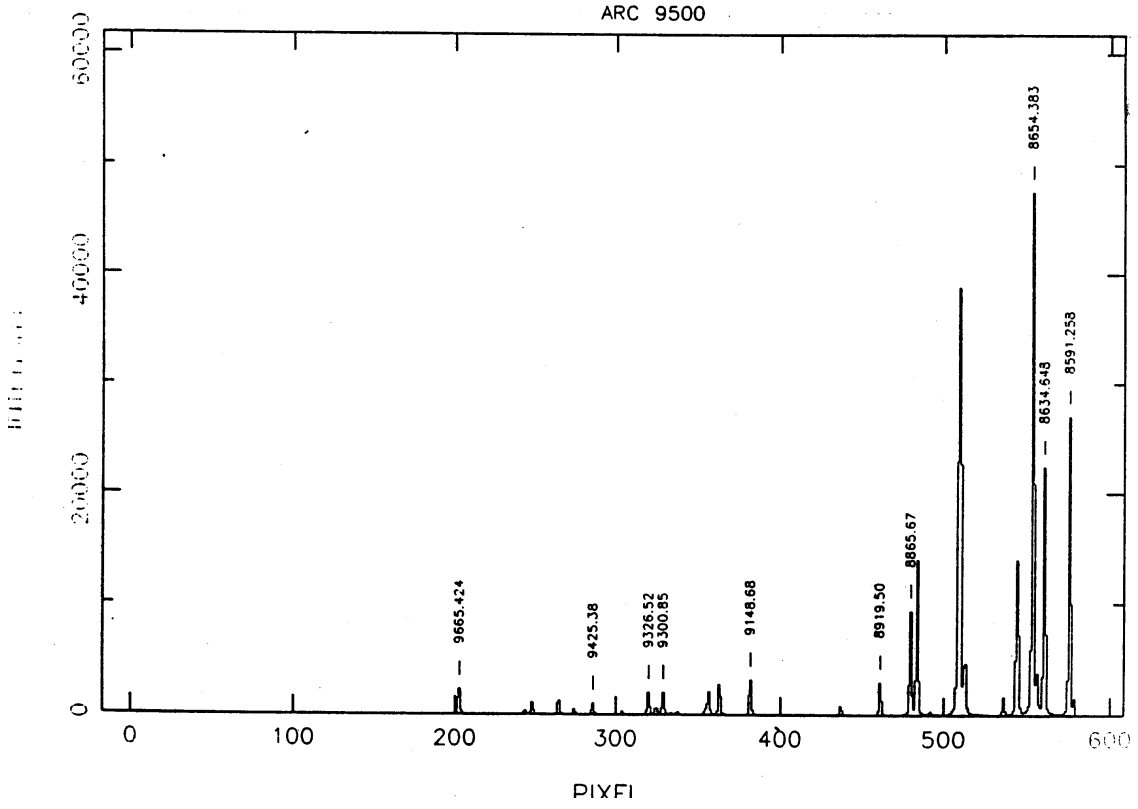

ARC 9500
9665.424
9425.38
9326.52
9300.85
9148.68
8919.50
8865.67
8654.383
8634.648
8591.258
0
20000
40000
60000
0
100
200
300
400
500
600
PIXEL

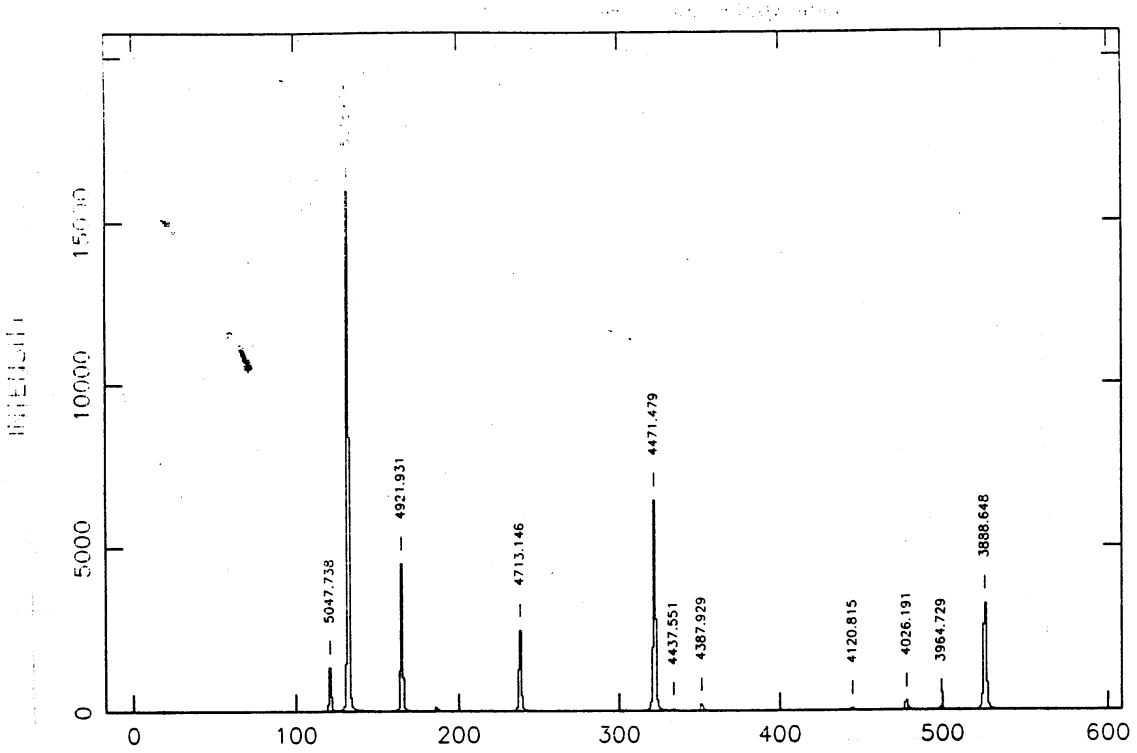
Table 6 : The Helium spectrum

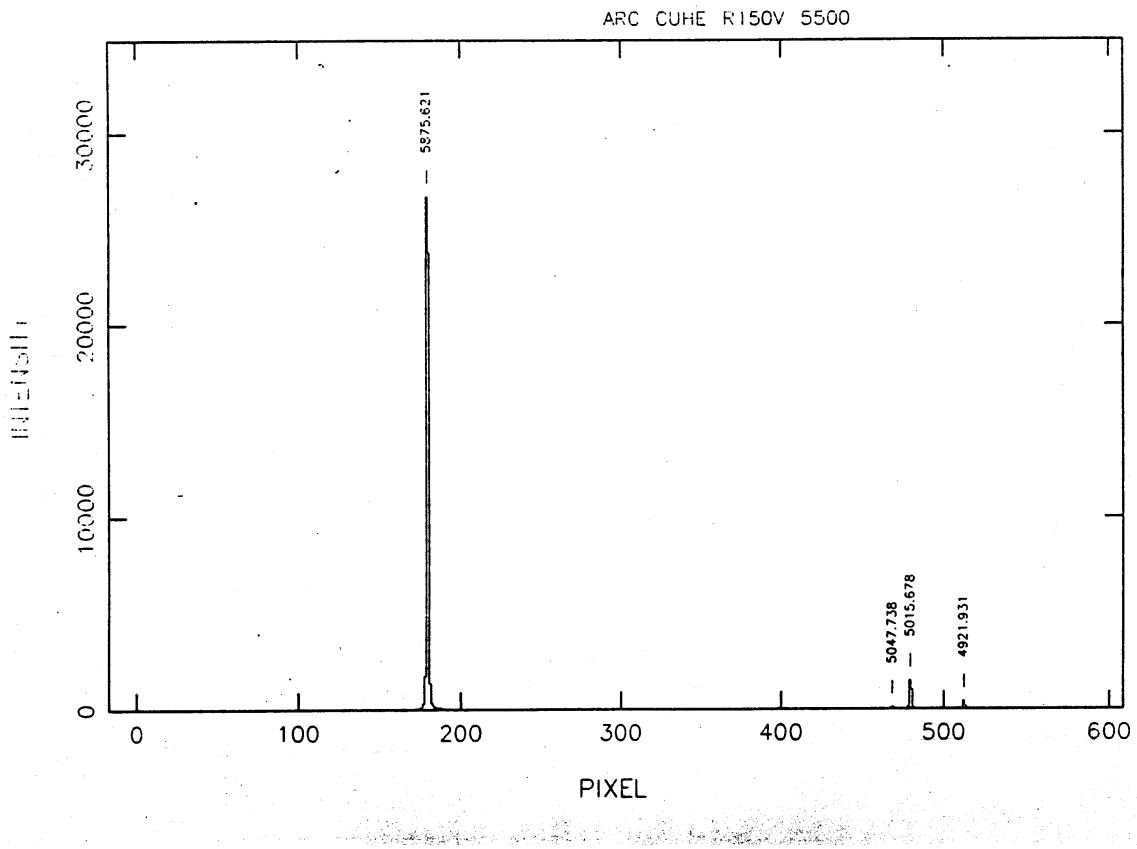
Line	Symbol	Line	Symbol	Line	Symbol
3819.607	HeI	4437.551	HeI	6678.151	HeI
3888.648	HeI	4471.479	HeI	7065.190	HeI
3964.729	HeI	4713.146	HeI	7261.349	HeI
4026.191	HeI	4921.931	HeI	9463.610	HeI
4120.815	HeI	5015.678	HeI	9603.420	HeI
4143.761	HeI	5047.738	HeI	10829.340	HeI
4387.929	HeI	5875.621	HeI		

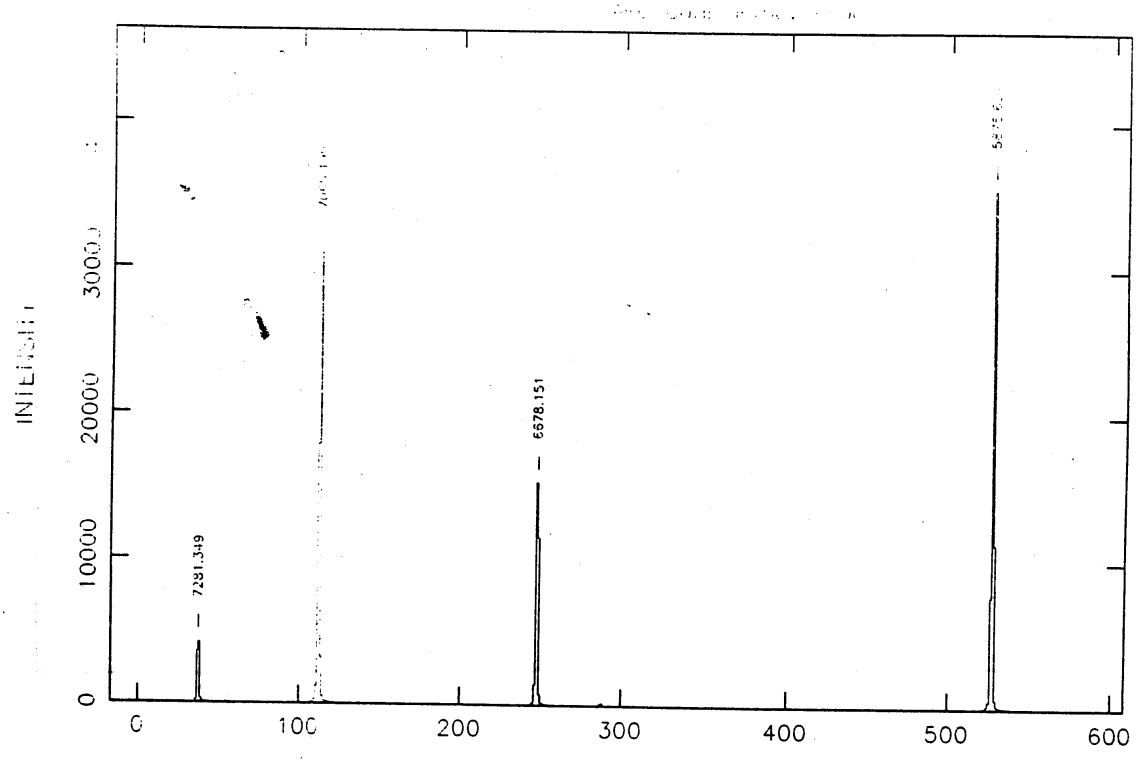
Figure 6 : The Helium spectrum

Notes to figure 6

Spectrum	CuHe at low dispersion	
Camera	IDS 500 mm	
Detector	GEC 3 "GEC BLUE"	
Grating	R150V	
Collimator	Al Wide	
Dispersion	131 A/mm or 0.347 pixel/A	
Exposure times	4500	300 s
	5500 - 7500	30 s


0
5000
10000
5047.738
4921.931
4713.146
4471.479
4437.551
4387.929
4120.815
4026.191
3964.729
3888.648
0
100
200
300
400
500
600


ARC CUHE R150V 5500
0
10000
20000
30000
5875.621
5047.738
5015.678
4921.931
0
100
200
300
400
500
600
PIXEL


INTENSITY
30000
20000
10000
0
7281.349
6678.151
0
100
200
300
400
500
600

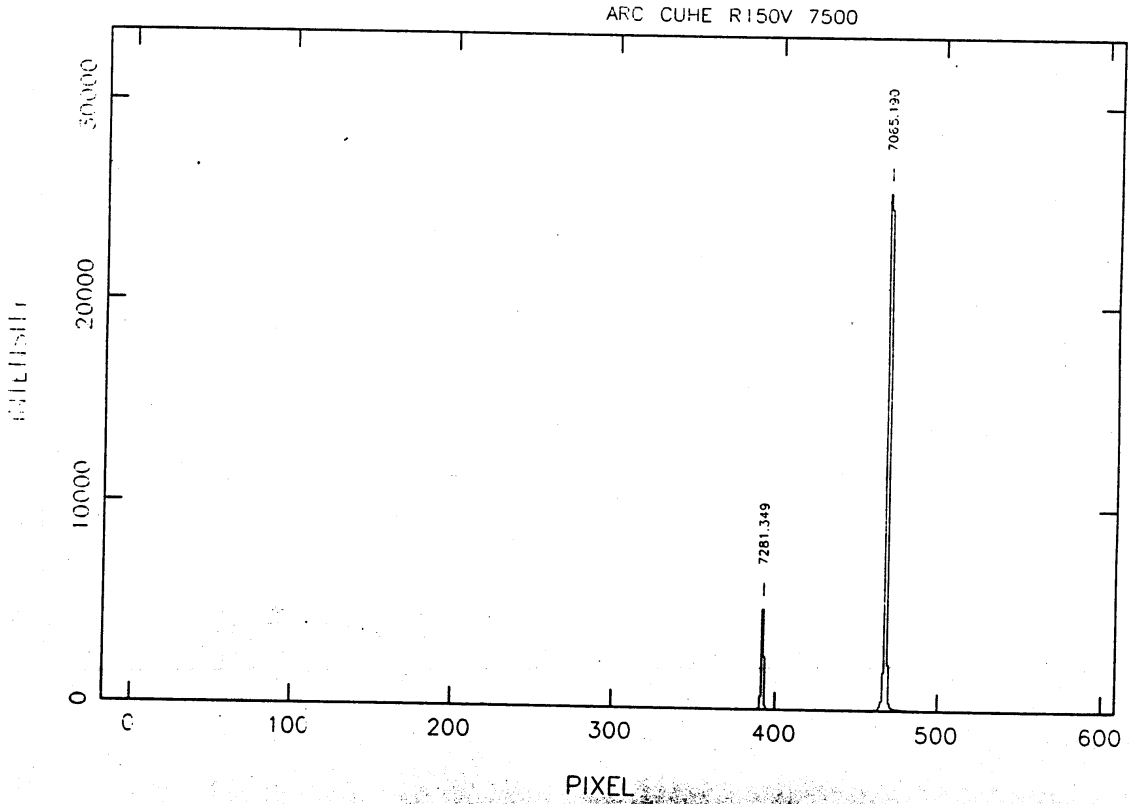

ARC CUHE R150V 7500
INTENSITY
30000
20000
10000
0
7065.190
7281.349
0
100
200
300
400
500
600
PIXEL

Table 7: The Thorium-Argon spectrum at high dispersion

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
3925.719	ArII	4259.362	ArI	4598.763	ArII	5050.784	ThI
3928.623	ArII	4266.286	ArI	4609.567	ArII	5054.178	ArI
3932.547	ArII	4272.169	ArI	4628.441	ArI	5060.079	ArI
3946.097	ArII	4277.528	ArII	4637.233	ArII	5062.037	ArII
3947.505	ArI	4282.041	ThI	4657.901	ArII	5064.80	ThI b
3948.979	ArI	4282.898	ArII	4673.660	ThI	5067.973	ThI
3967.392	ThI	4300.101	ArI	4686.194	ThI	5090.495	ArII
3979.356	ArII	4309.239	ArII	4695.038	ThI	5096.484	ThI
3994.792	ArII	4312.997	ThI	4702.316	ArI	5100.621	ThI
4012.495	ThI	4331.200	ArII	4703.989	ThI	5115.043	ThI
4013.857	ArII	4333.561	ArI	4723.438	ThI	5118.202	ArI
4019.129	ThII	4335.338	ArI	4726.868	ArII	5125.765	ArII w
4030.842	ThI	4337.277	ThI	4732.053	ArII	5141.783	ArII
4033.809	ArII	4345.168	ArI	4735.906	ArII	5145.308	ArII
4036.048	ThI	4348.064	ArII	4740.529	ThI	5151.391	ArI
4042.894	ArII	4352.205	ArII	4764.865	ArII	5154.243	ThI
4044.418	ArI	4362.066	ArII	4778.294	ThI	5158.604	ThI
4045.965	ArI	4367.832	ArII	4789.386	ThI	5162.285	ArI
4052.921	ArII	4370.753	ArII	4806.021	ArII	5163.458	ThI
4072.11	ArII	4374.124	ThI	4808.133	ThI	5165.773	ArII
4076.72	ArII	4375.954	ArII	4822.854	ThI	5176.229	ArII w
4079.574	ArII	4378.176	ThI	4831.121	ThI	5176.961	ThI
4080.645	ArII	4379.667	ArII	4840.843	ThI	5187.746	ArI
4082.387	ArII	4381.860	ThII	4847.810	ArII	5195.813	ThI
4094.747	ThI	4385.057	ArII	4863.172	ThI	5199.163	ThI
4097.14	ArII	4391.110	ThII	4865.477	ThI	5211.230	ThI
4100.341	ThI	4400.097	ArII	4872.917	ThI	5213.349	ThI
4103.912	ArII	4400.986	ArII	4876.261	ArI	5216.597	ThII
4112.815	ArII	4408.883	ThI	4878.733	ThI	5219.108	ThI
4131.724	ArII	4420.912	ArII	4879.864	ArII	5221.271	ArI
4156.086	ArII	4426.001	ArII	4888.261	ArII	5231.159	ThI
4158.591	ArI	4430.189	ArII	4889.042	ArII	5238.813	ThI
4164.180	ArI	4430.996	ArII	4894.955	ThI	5241.091	ArI
4179.297	ArII	4433.838	ArII	4904.752	ArII	5247.654	ThII
4181.884	ArI	4439.461	ArII	4919.815	ThI	5252.788	ArI
4190.87	ArI b	4448.879	ArII	4933.209	ArII	5254.465	ArI
4198.317	ArI	4474.759	ArII	4939.642	ThI	5258.360	ThI
4200.675	ArI	4481.811	ArII	4943.064	ThI	5264.782	ArII
4210.923	ThI	4490.982	ArII	4945.458	ThI	5266.710	ThI
4217.431	ArII	4493.333	ThI	4965.080	ArII	5296.227	ThI
4218.665	ArII	4502.927	ArII	4972.160	ArII	5297.92	ThI b
4222.637	ArII	4510.733	ArI	4985.372	ThI	5312.18	ThI b
4226.988	ArII	4515.118	ThI	5002.097	ThI	5317.494	ThI
4228.158	ArII	4522.323	ArI	5009.334	ArII	5326.975	ThI
4229.870	ArII	4530.552	ArII	5017.163	ArII	5343.581	ThI
4235.463	ThI	4545.052	ArII	5028.655	ThI	5358.363	ArII
4237.220	ArII	4563.743	ArII	5039.230	ThI	5373.494	ArI
4250.314	ThI	4579.350	ArII	5044.719	ThI	5379.110	ThI
4251.185	ArI	4589.899	ArII	5047.043	ThI	5386.610	ThI
4257.496	ThI	4595.77	ThI b	5048.813	ThI	5390.440	ThI

Table 7: The Thorium-Argon spectrum at high dispersion (continued)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
5393.971	ArI	5610.231	ThI	5860.310	ArI	6090.785	ArI
5394.760	ThI	5612.068	ThI	5863.718	ThI	6098.803	ArI
5397.516	ArII	5615.319	ThI	5882.624	ArI	6101.162	ArI
5398.701	ThI	5618.010	ArII	5885.701	ThI	6104.590	ArI
5402.605	ArII	5623.778	ArII	5888.584	ArI	6105.635	ArI
5407.51	ArII	5625.678	ArII	5891.451	ThI	6112.837	ThII
5410.60	ArI b	5635.575	ArI w	5905.570	ThI	6114.923	ArII
5415.491	ThI	5637.32	ArI	5908.935	ThI	6119.657	ArI
5417.485	ThI	5639.746	ThI b	5912.085	ArI	6123.362	ArII
5421.352	ArI	5641.375	ArI	5914.671	ThI	6124.480	ThI
5431.112	ThI	5645.668	ThI	5916.599	ArI	6127.416	ArI
5439.989	ArI	5648.686	ArI	5926.236	ThI	6128.723	ArI
5442.248	ArI	5650.704	ArI	5927.126	ArI	6138.656	ArII
5443.118	ThI	5654.457	ArII	5928.813	ArI	6145.441	ArI
5451.652	ArI	5659.127	ArI	5938.825	ThI	6151.993	ThI
3454.307	ArII	5665.180	ThI	5940.855	ArI	6155.35	ThI b
5457.416	ArI	5672.952	ArII	5942.669	ArI	6164.479	ThI b
5464.205	ThI	5677.053	ThI	5944.647	ThI	6170.00	ThI b
5473.452	ArI	5681.900	ArI	5949.258	ArI	6172.278	ArII
5492.643	ThI	5689.91	ArI	5968.320	ArI	6173.096	ArI
5495.874	ArI	5691.661	ArII	5971.601	ArI	6178.431	ThI
5499.255	ThI	5700.917	ThII w	5973.664	ThI	6182.621	ThI
5504.301	ThI	5707.103	ThII	5975.064	ThI	6188.125	ThI
5506.113	ArI	5712.48	ArI	5986.266	ThI	6191.905	ThI
5509.993	ThI	5720.183	ThI	5987.302	ArI	6198.222	ThI
5514.673	ThI	5725.388	ThI	5989.044	ThI	6201.100	ArII
5524.957	ArI	5738.387	ArI	5991.007	ThI	6203.492	ThI
5534.45	ArI	5739.520	ArI	5994.128	ThI	6207.220	ThI
5539.262	ThI	5741.829	ThI	5998.999	ArI	6212.503	ArI
5542.890	ThI	5748.741	ThI	6001.165	ThI	6215.938	ArI
5548.175	ThI	5749.388	ThII	6005.165	ThI	6224.527	ThI
5551.372	ThII	5753.026	ThI	6007.072	ThI	6226.369	ThI
5554.050	ArII	5760.550	ThI	6010.166	ThI	6234.855	ThI
5557.045	ThI	5763.529	ThI	6013.678	ArI	6243.120	ArII
5558.702	ArI	5768.181	ThI	6021.035	ThI	6248.406	ArI
5559.891	ThI	5772.114	ArI	6025.150	ArI	6257.423	ThI
5571.191	ThI	5773.946	ThI	6030.445	ThI	6261.418	ThI
5572.541	ArI	5783.536	ArI	6032.127	ArI	6274.164	ThI
5573.353	ThI	5789.56	ThI b	6037.697	ThI	6293.242	ThI
5576.204	ThI	5792.430	ThI	6043.223	ArI	6295.446	ArII
5577.685	ArII	5796.068	ThI	6044.432	ThII	6296.872	ArI
5579.358	ThI	5798.478	ThI	6046.898	ArII	6307.657	ArI
5581.871	ArI	5800.829	ThI	6049.051	ThI	6309.160	ArI
5587.026	ThI	5802.080	ArI	6052.723	ArI	6324.416	ArII
5588.720	ArI	5804.141	ThI	6059.373	ArI	6327.277	ThI
5595.063	ThI	5812.84	Ar b	6064.751	ArI	6337.620	ThI
5597.476	ArI	5834.263	ArI	6073.103	ThII	6339.668	ThI
5601.603	ThI	5843.778	ArII	6081.243	ArI	6342.859	ThI
5604.515	ThI	5852.680	ThI	6085.374	ThI w	6348.737	ThI
5606.733	ArI	5853.471	ThI	6088.030	ThI	6355.910	ThI

Table 7: The Thorium-Argon spectrum at high dispersion (continued)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
6364.894	ArI	6619.946	ThII	6965.431	ArI	8046.117	ArI
6369.575	ArI	6632.084	ArI	6989.655	ThI	8053.309	ArI
6371.943	ThI	6638.221	ArII	6992.213	ArI	8103.693	ArI
6376.930	ThI	6639.740	ArII	7018.567	ThI	8115.311	ArI
6384.717	ArI	6643.698	ArII	7030.251	ArI	8264.522	ArI
6387.395	ThI	6644.663	ThI	7067.218	ArI	8384.724	ArI
6393.797	ArII	6656.939	ArI	7068.734	ArI	8408.210	ArI
6396.610	ArII	6658.677	ThI	7084.169	ThI	8416.727	ThI
6399.207	ArII	6660.676	ArI	7086.704	ArI	8424.647	ArI
6403.013	ArII	6662.268	ThI	7107.478	ArI	8521.442	ArI
6406.446	ThI	6664.051	ArI	7124.560	ThI	8554.944	ThI
6408.904	ArII	6666.359	ArII	7125.820	ArI	8605.776	ArI
6411.899	ThI	6674.697	ThI	7147.042	ArI	8620.460	ArI
6413.614	ThI	6677.282	ArI	7158.839	ArI	8667.944	ArI
6416.307	ArI	6678.706	ThI	7168.895	ThI	8678.408	ArI
6418.370	ArII	6683.367	ThI	7206.980	ArI	8736.63	ArI
6422.897	ArII	6684.293	ArII	7265.172	ArI	8748.031	ThI
6431.555	ArI	6698.876	ArI	7270.664	ArI	8758.287	ThI
6437.600	ArII w	6713.970	ThI	7272.936	ArI	8761.686	ArI
6439.070	ThI	6719.218	ArI	7284.903	ThI	8771.860	ArII
6441.900	ArII	6727.458	ThI	7311.716	ArI	8784.59	ArI
6443.860	ArII	6752.834	ArI	7316.005	ArI	8799.088	ArI
6457.282	ThI	6754.30	ArI	7353.293	ArI	8840.82	ArI
6462.595	ThI	6756.31	ThI b	7372.118	ArI	8849.97	ArI
6466.553	ArI	6766.612	ArI	7383.981	ArI	8851.791	ThI
6468.048	ArII	6778.312	ThI	7392.980	ArI	8868.833	ThI
6481.145	ArII	6780.125	ThI	7412.337	ArI	8874.84	ArI
6483.083	ArII	6788.840	ThI	7425.294	ArI	8905.658	ArII
6490.737	ThI	6791.235	ThI	7435.368	ArI	8931.326	ArII
6493.197	ThI	6818.291	ArI	7471.164	ArI	8962.147	ArI
6493.969	ArI	6824.677	ThI	7484.327	ArI	8967.640	ThI
6499.106	ArI	6827.249	ArI	7500.656	ArI	8986.615	ArII
6506.986	ThI	6829.035	ThI	7503.869	ArI	9008.455	ArII
6512.364	ThI	6834.924	ThI	7510.408	ArI	9017.596	ArII
6513.846	ArI	6851.884	ArI	7514.652	ArI	9048.250	ThI
6522.043	ThI	6861.269	ArII	7618.33	ArI	9057.23	ArI
6531.341	ThI	6163.535	ArII	7628.86	ArI	9073.34	ArI
6538.112	ArI	6866.366	ThI	7635.106	ArI	9075.395	ArI
6554.160	ThI	6868.450	ThI	7670.04	ArI	9122.967	ArI
6558.875	ThI	6871.289	ArI	7723.98	ArI b	9194.639	ArI
6577.214	ThI	6874.753	ThI	7798.55	ArI	9198.61	ArI
6583.906	ThI	6879.582	ArI	7814.33	ArI	9219.003	ArII
6588.539	ThI	6887.088	ArI	7861.91	ArI	9224.499	ArI
6591.484	ThI	6888.174	ArI	7868.195	ArI	9291.531	ArI
6593.939	ThI	6911.226	ThI	7891.075	ArI	9354.220	ArI
6596.114	ArI	6937.664	ArI	7948.176	ArI	9402.69	ArI
6598.678	ArI	6943.60	ThI	7978.917	ArI	9459.09	ArI
6604.853	ArI	6951.478	ArI	8006.157	ArI	9657.786	ArI
6613.374	ThI	6960.250	ArI	8014.786	ArI	9784.503	ArI

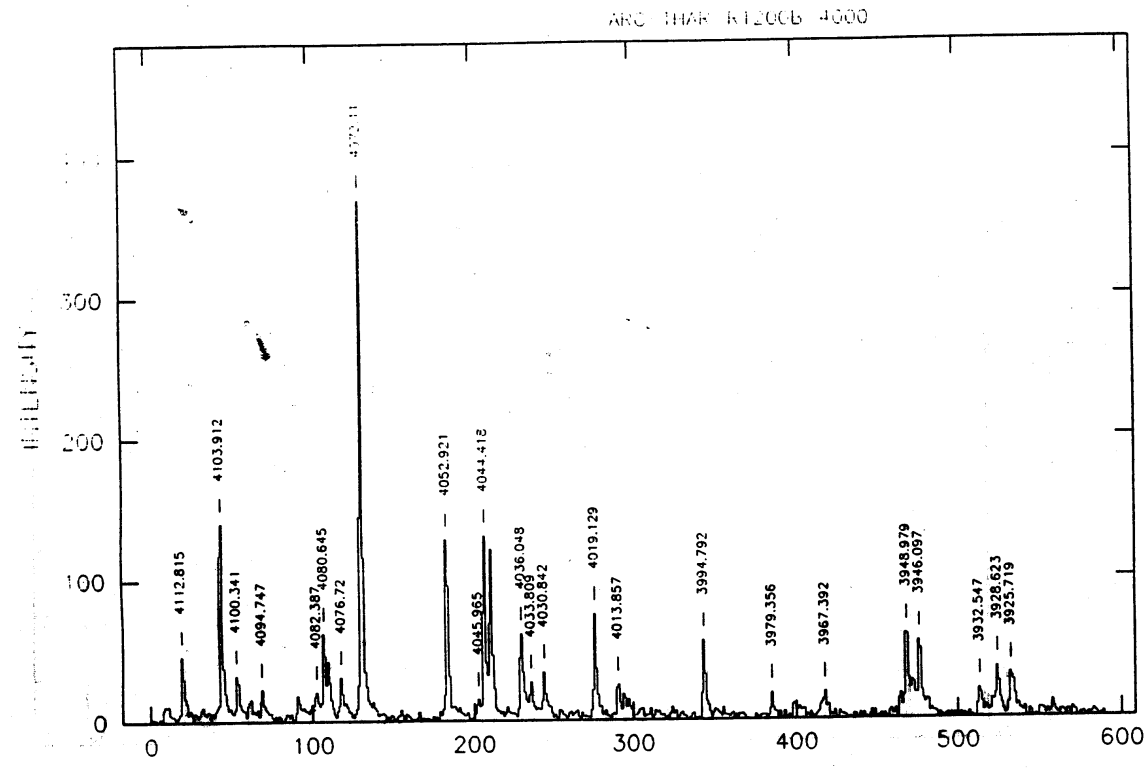
Notes to table 7

Line	Symbol	
4072.11	ArII	blend of 4072.005 (3) and 4072.385 (1)
4076.72	ArII	blend of 4076.628 (2) and 4076.943 (1)
4190.87	ArI	blend of 4190.714 (1) and 4191.029 (1)
4595.77	ThI+ArI	blend of ThI 4595.420 and ArI 4596.097
5064.80	ThI	blend 5064.602 and 5064.945
5125.765	ArII	weak ThI at 5125.950
5176.229	ArII	weak ArI at 5177.540
5297.92	ThI	blend of 5297.743 (2) and 5298.282 (1)
5312.18	ThI	blend of 5312.002 (1) and 5312.528 (0.5)
5407.51	ArII+ThI	ArII 5407.344 and ThI 5407.653
5410.60	ArI+ThI	ArI 5410.473 and ThI 5410.768
5635.575	ArI	weak ArII at 5635.882
5639.746	ThI	blended with ArI 5639.140
5700.917	ThII	weak ArI at 5700.873
5789.56	ThI	blend of ThI 5789.645 & ArI 5789.474 & ArII 5789.555
5812.84	Ar	blend of ArII 5812.84 & ArI 5812.760 & ThI 5812.972
6085.374	ThI	weak ArI at 6085.880
6155.35	ThI+ArI	ThI 6155.581 & ArI 6155.239
6164.479	ThI	weak ArI at 6165.123
6170.00	ThI+ArI	ThI 6169.822 and ArI 6170.174
6437.600	ArII	weak ThI at 6437.761
6756.31	ThI+ArI	ThI 6756.453 and ArI 6756.163
7723.98	ArI	blend of 7723.7611 and 7724.2072 at equal intensifies

Figure 7 : Thorium-Argon spectrum between 3900 and 7200

Notes to figure 7

Spectrum	ThAr from 3900 A to 7300 A at high dispersion	
Camera	IDS 500mm	
Detector	GEC 3 "GEC BLUE"	
Gratings	R1200Y for the region 3900 A - 5200 A	
	R1200V for the region 5200 A - 7300 A	
Collimator	Al Wide	
Dispersion	16.5 A/mm or 2.75 pixel/A	
Exposure times	4000 - 6800 A	600 s
	7000 & 7200 A	60 s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4030.842
4019.129
4013.857
3994.792
3979.356
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3925.719
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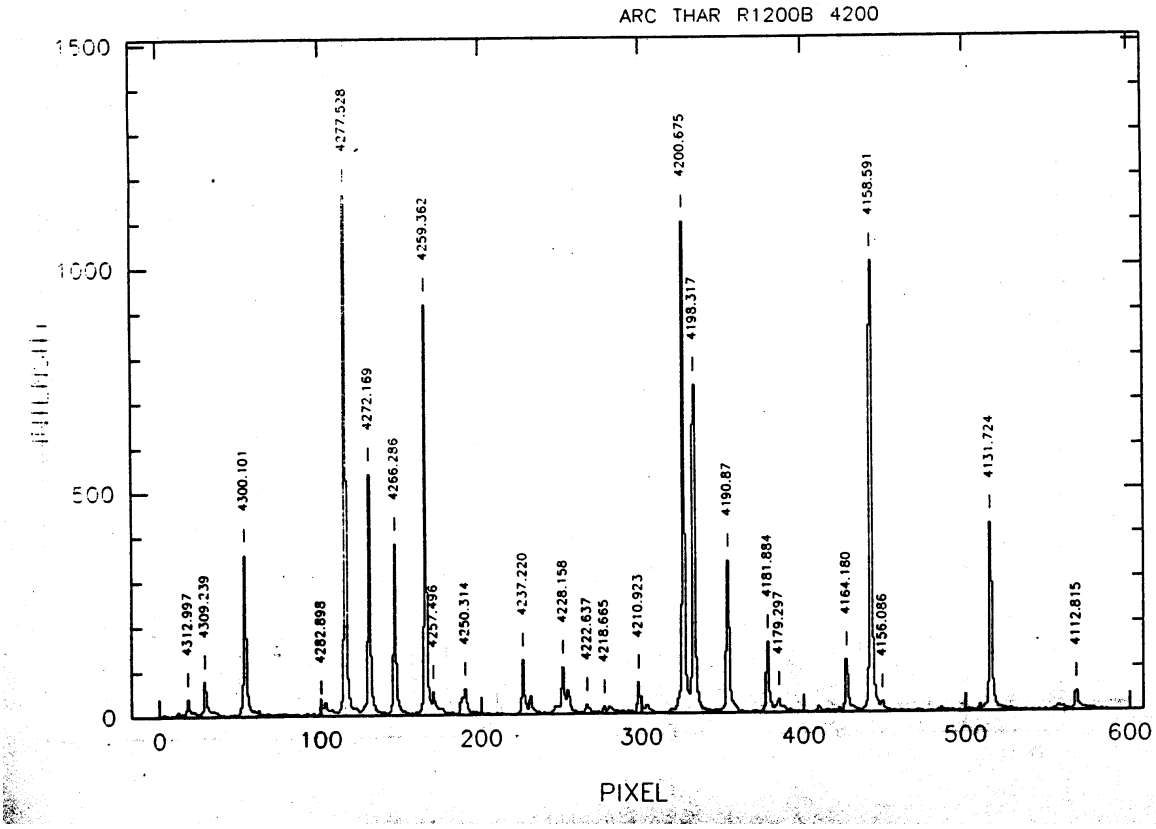
200
300
400
500
600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4259.362
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4250.314
4237.220
4228.158
4222.637
4218.665
4210.923
4200.675
4198.317
4190.87
4181.884
4179.297
4164.180
4158.591
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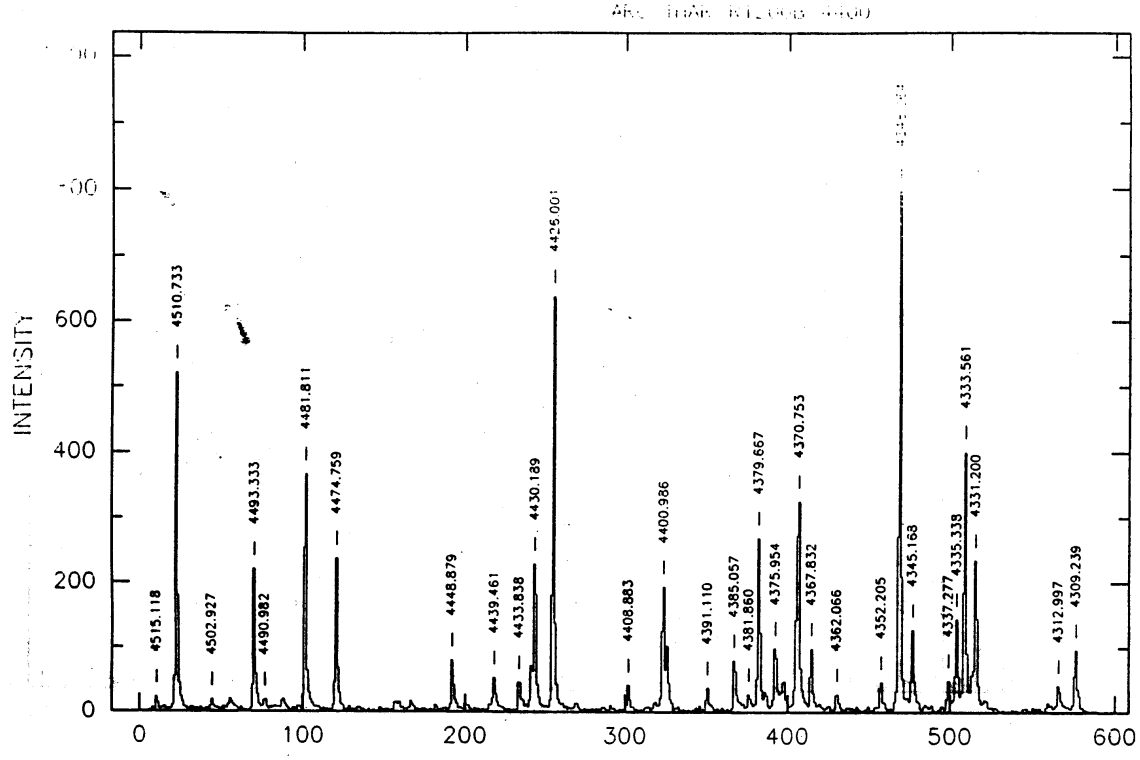
500
600
PIXEL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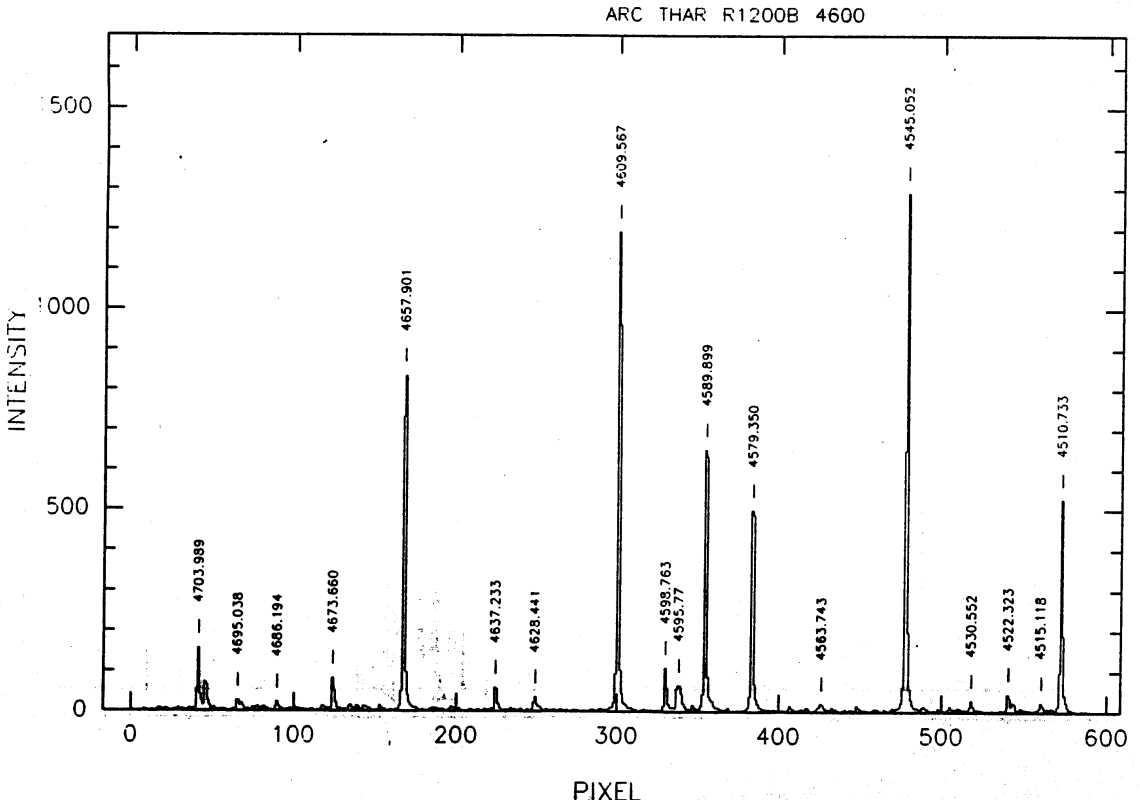
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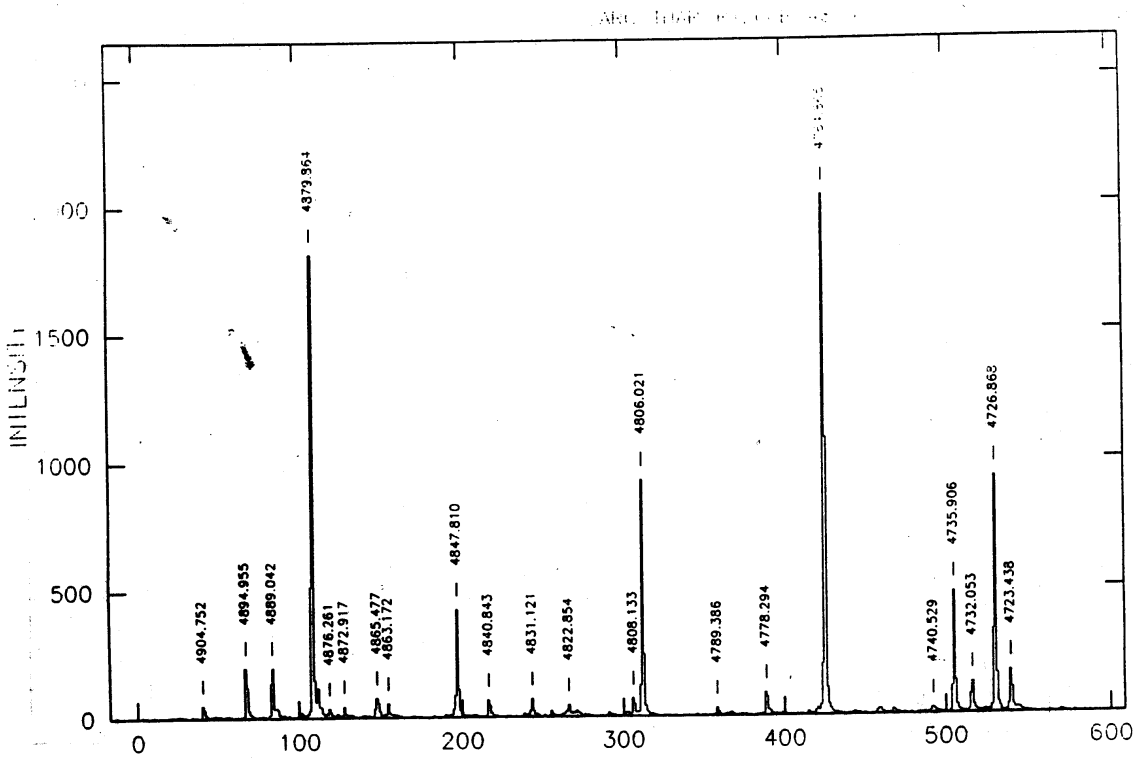
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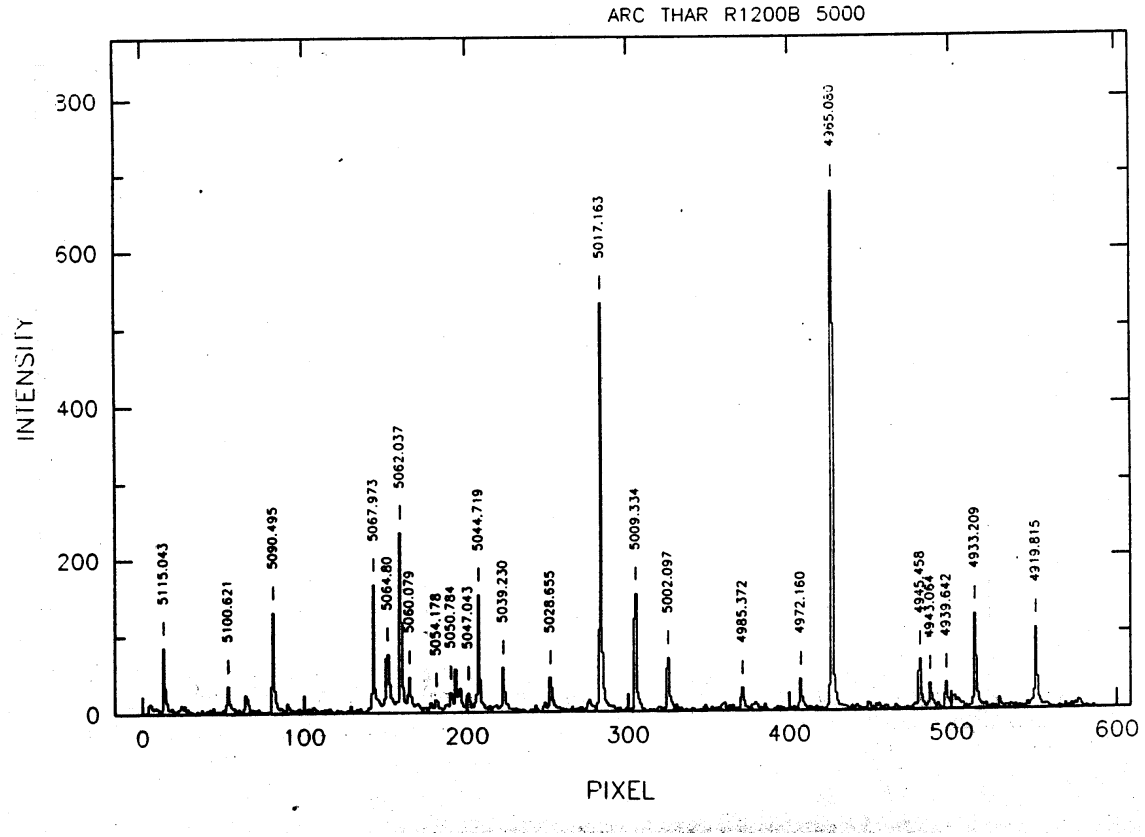
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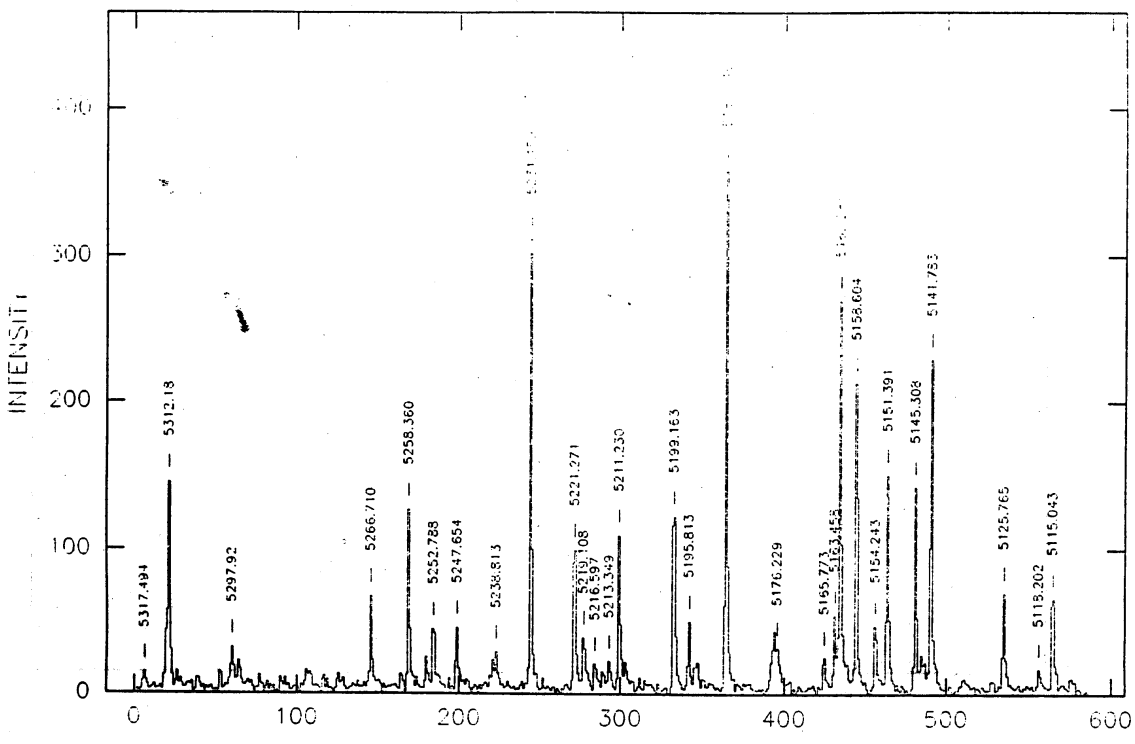
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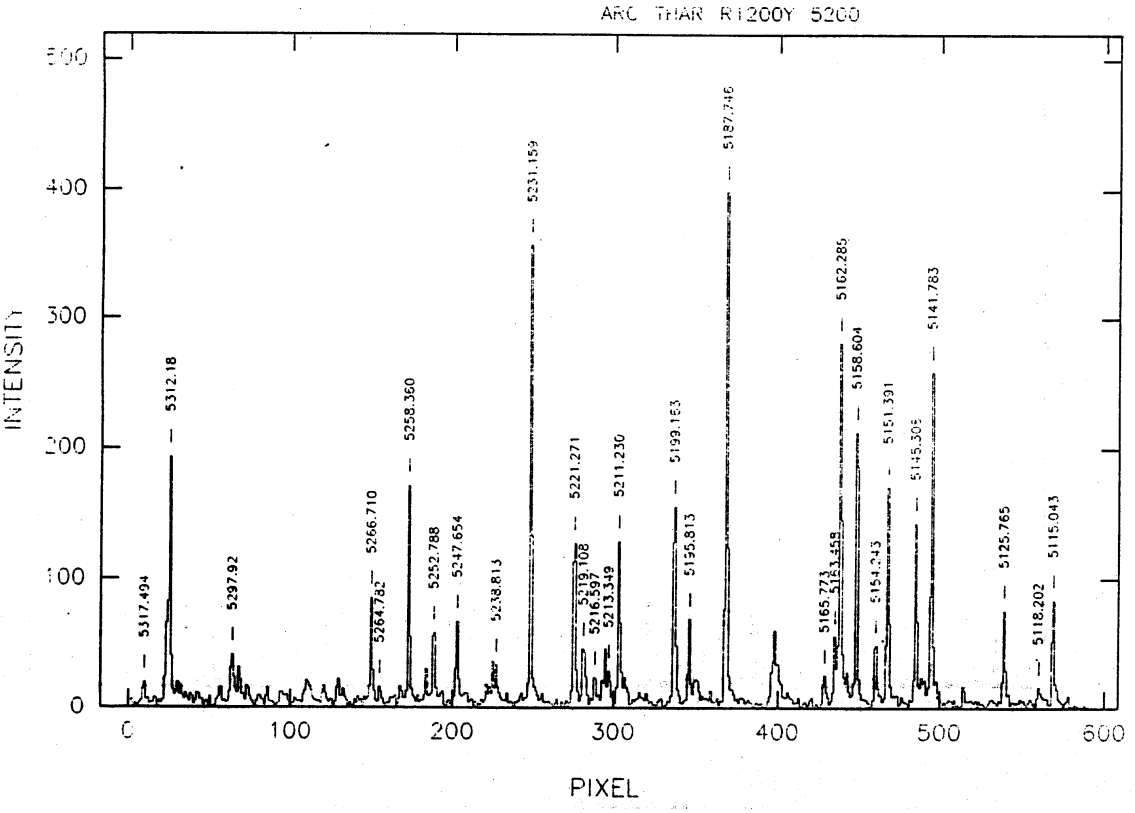
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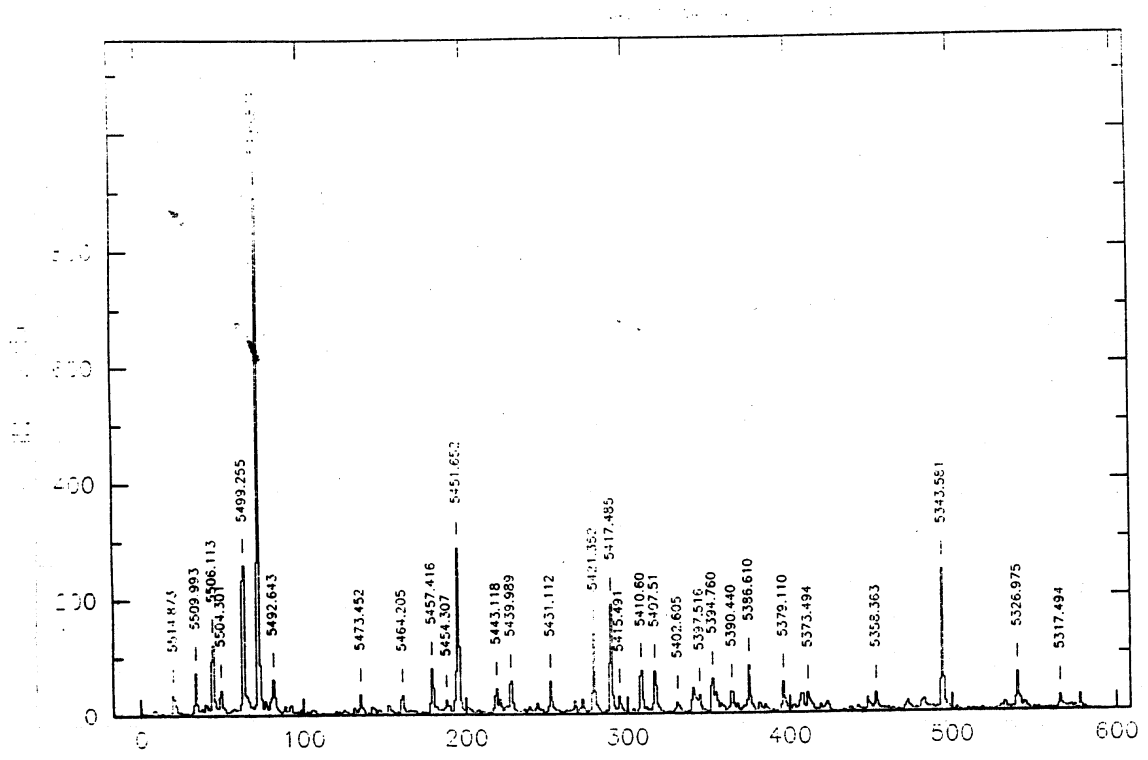
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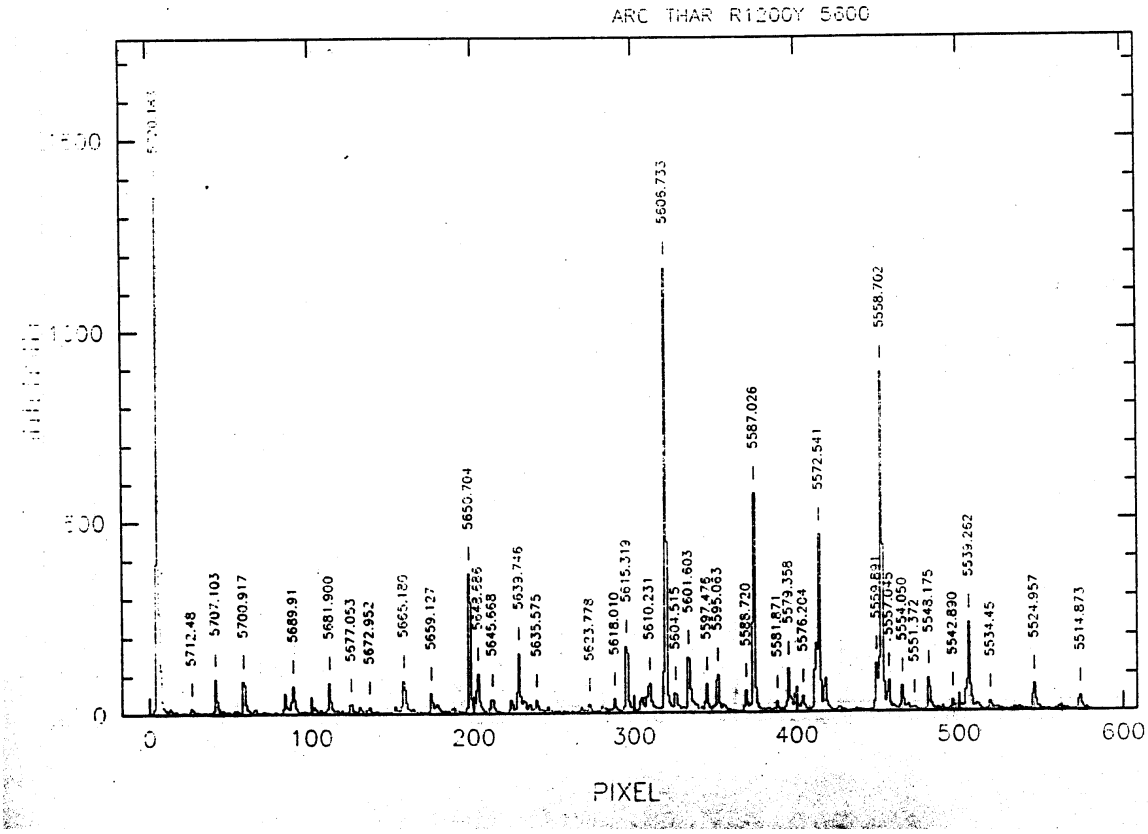
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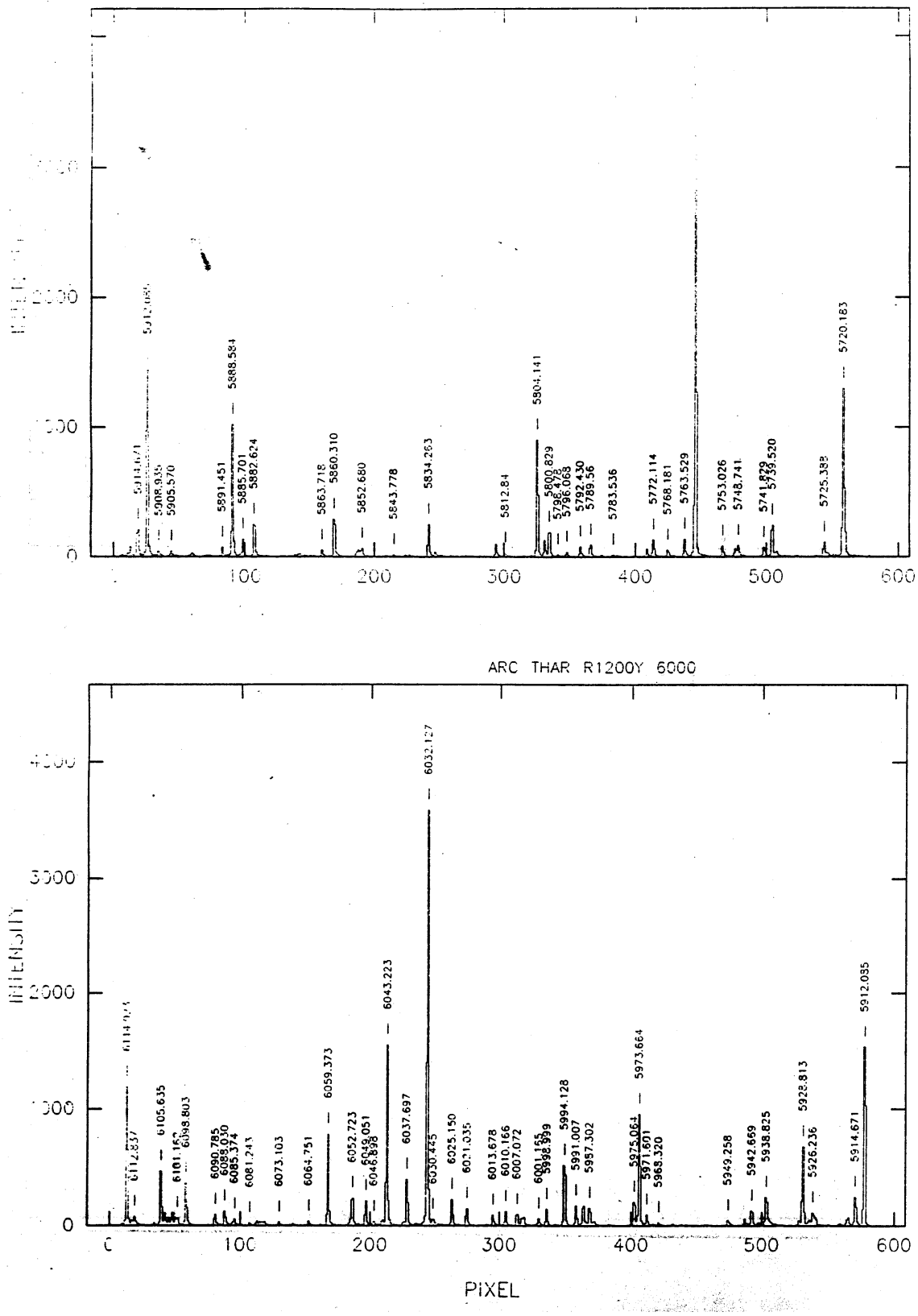
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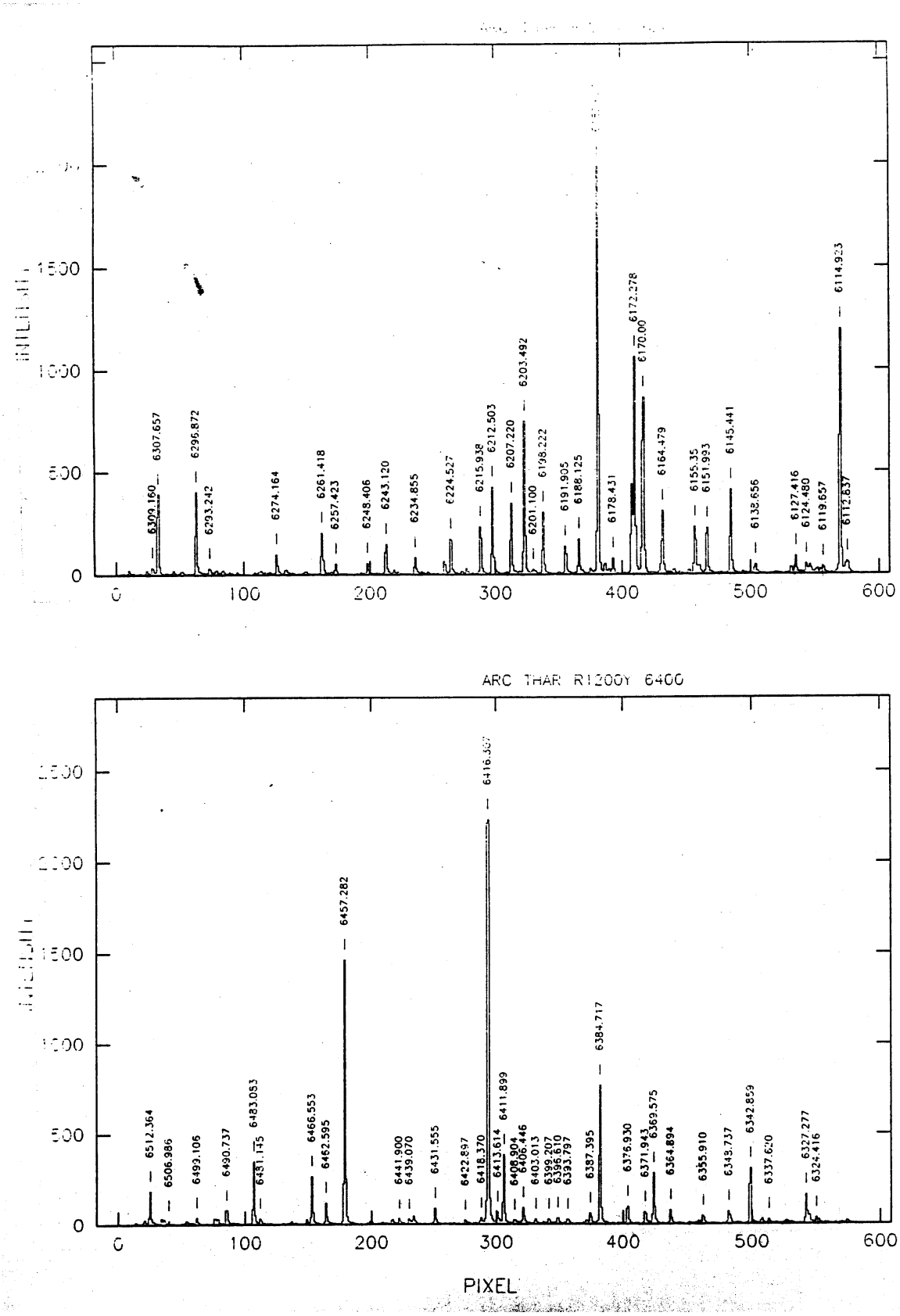
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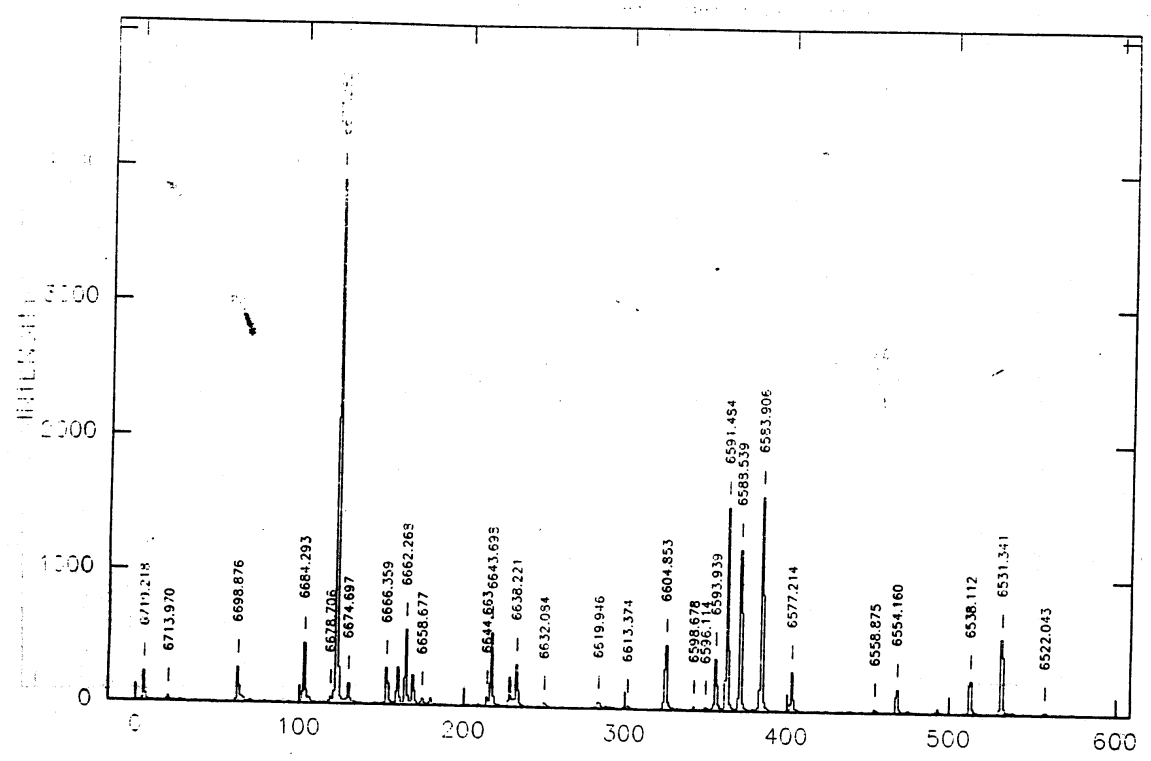
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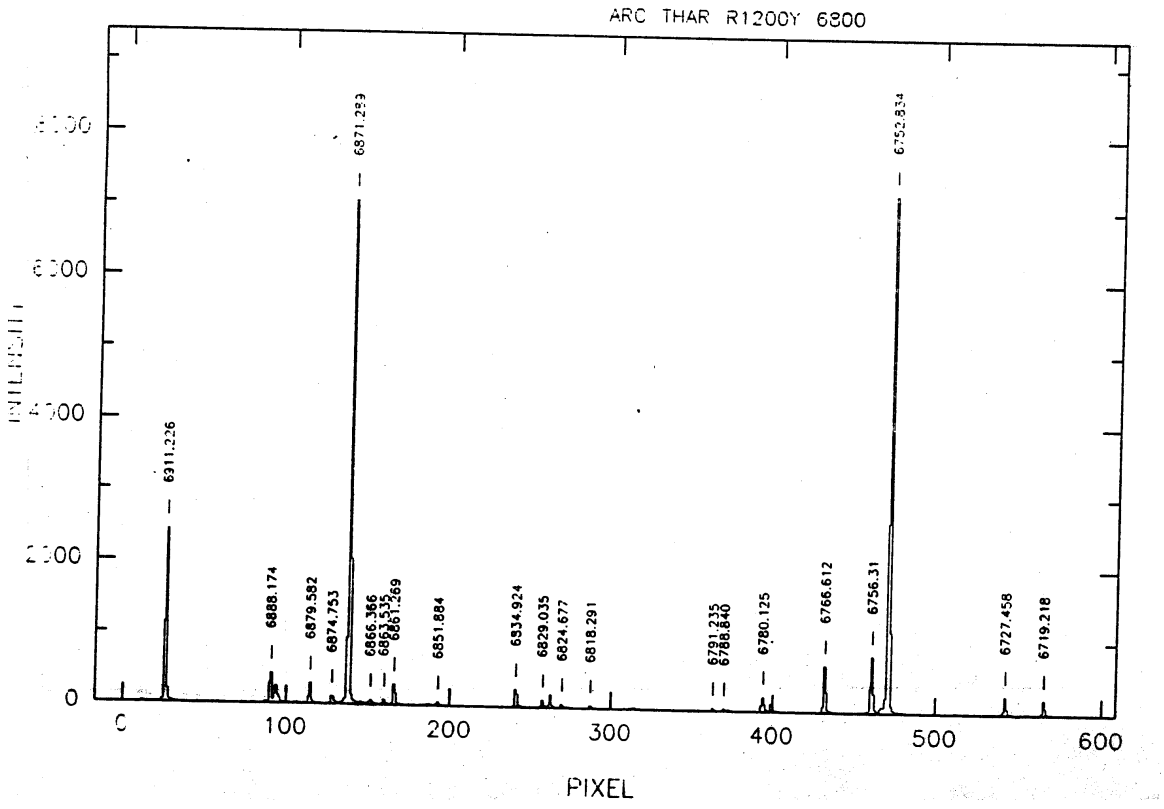
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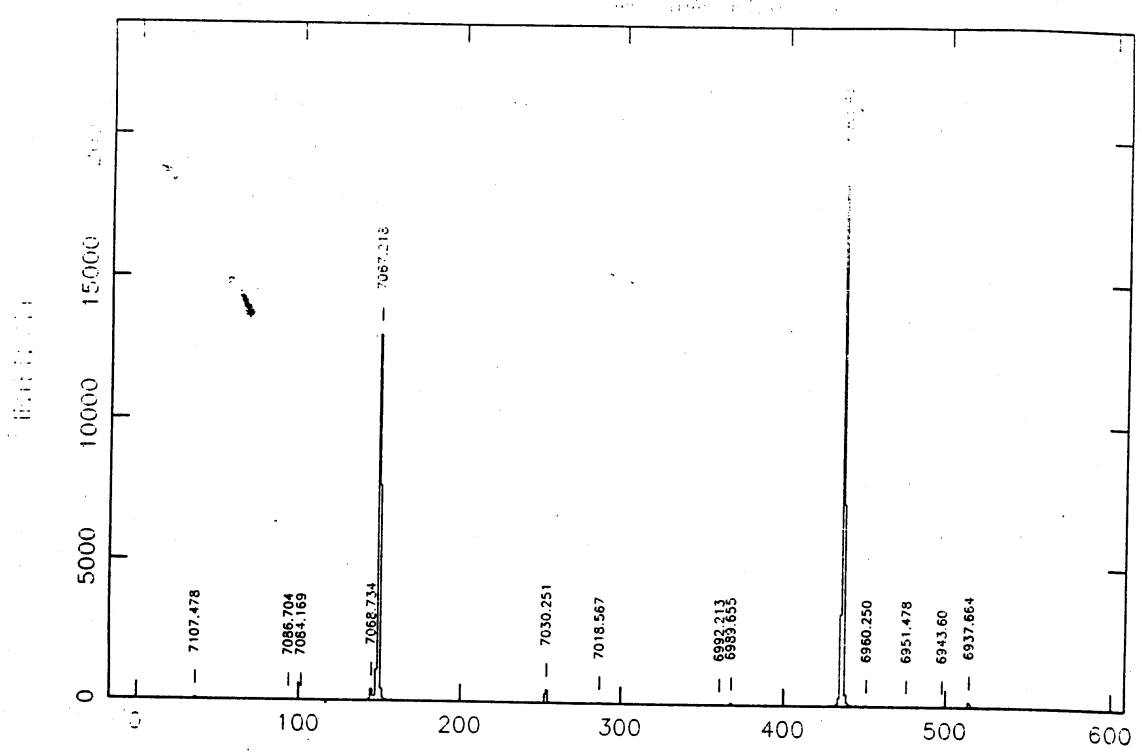
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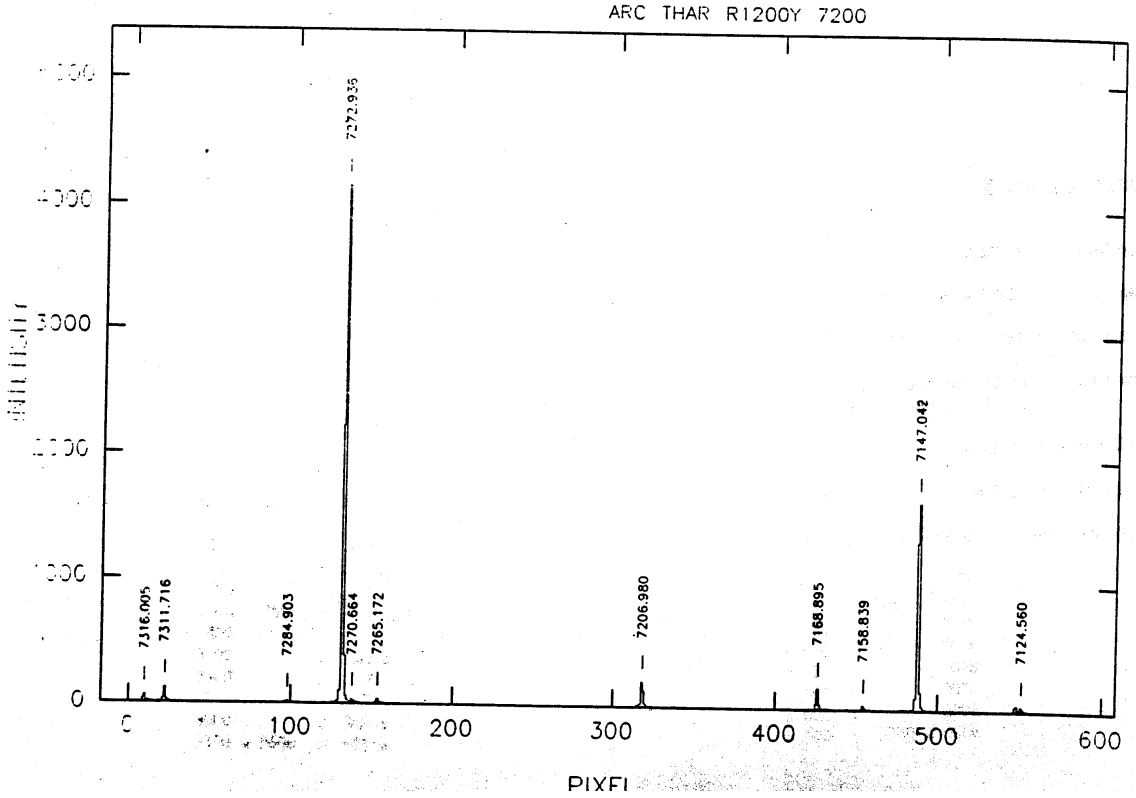
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7147.042
7124.560
0
100
200
300
400
500
600

Table 8 : arc-line table "Al/Ca/Mg Neon" (continued)

Line	Symbol	Line	Symbol	Line	Symbol	Line	Symbol
6030.000	NeI	6532.882	NeI	7943.180	NeI	8783.755	NeI
6074.338	NeI	6598.953	NeI	8082.458	NeI	8806.757	MgI
6096.163	NeI	6652.09	NeI	8118.550	NeI	8830.91	NeI
6118.027	NeI	6666.897	NeI	8128.93	NeI	8853.867	NeI
6122.219	CaI	6678.277	NeI	8136.406	NeI	8865.67	NeI b
6128.460	NeI	6707.807	LiI	8248.70	NeI	8919.50	NeI
6143.063	NeI	6717.043	NeI	8259.380	NeI	8988.58	NeI
6163.594	NeI	6929.468	NeI	8266.076	NeI w	9148.68	NeI
6174.883	NeI	7024.051	NeI	8300.326	NeI	9201.76	NeI
6182.146	NeI	7032.413	NeI	8365.75	NeI	9220.05	NeI
6205.778	NeI	7051.294	NeI	8377.607	NeI w	9221.59	NeI
6213.876	NeI	7059.109	NeI	8418.427	NeI	9226.67	NeI
6217.281	NeI	7148.147	CaI	8463.37	NeI	9275.53	NeI
6258.796	NeI	7173.939	NeI	8484.45	NeI	9287.42	A1II
6266.495	NeI	7245.167	NeI	8495.360	NeI	9300.85	NeI
6293.745	NeI	7438.899	NeI	8544.70	NeI	9310.58	NeI
6304.789	NeI	7472.43	NeI	8571.36	NeI	9313.98	NeI
6313.692	NeI	7488.872	NeI	8582.91	NeI	9326.52	NeI
6328.165	NeI	7535.775	NeI	8591.259	NeI	9373.28	NeI
6334.428	NeI	7544.046	NeI	8634.648	NeI	9425.38	NeI
6382.991	NeI	7665.99	KI	8647.05	NeI	9459.21	NeI
6402.247	NeI	7698.959	KI	8654.383	NeI	9486.680	NeI
6439.073	CaI	7724.63	NeI	8679.491	NeI	9534.17	NeI
6444.712	NeI	7833.06	NeI	8681.920	NeI	9547.40	NeI
6462.566	CaI	7839.08	NeI	8704.15	NeI	9665.424	NeI
6493.780	CaI	7927.11	NeI	8771.70	NeI		
6506.528	NeI	7937.01	NeI	8780.622	NeI NeI		

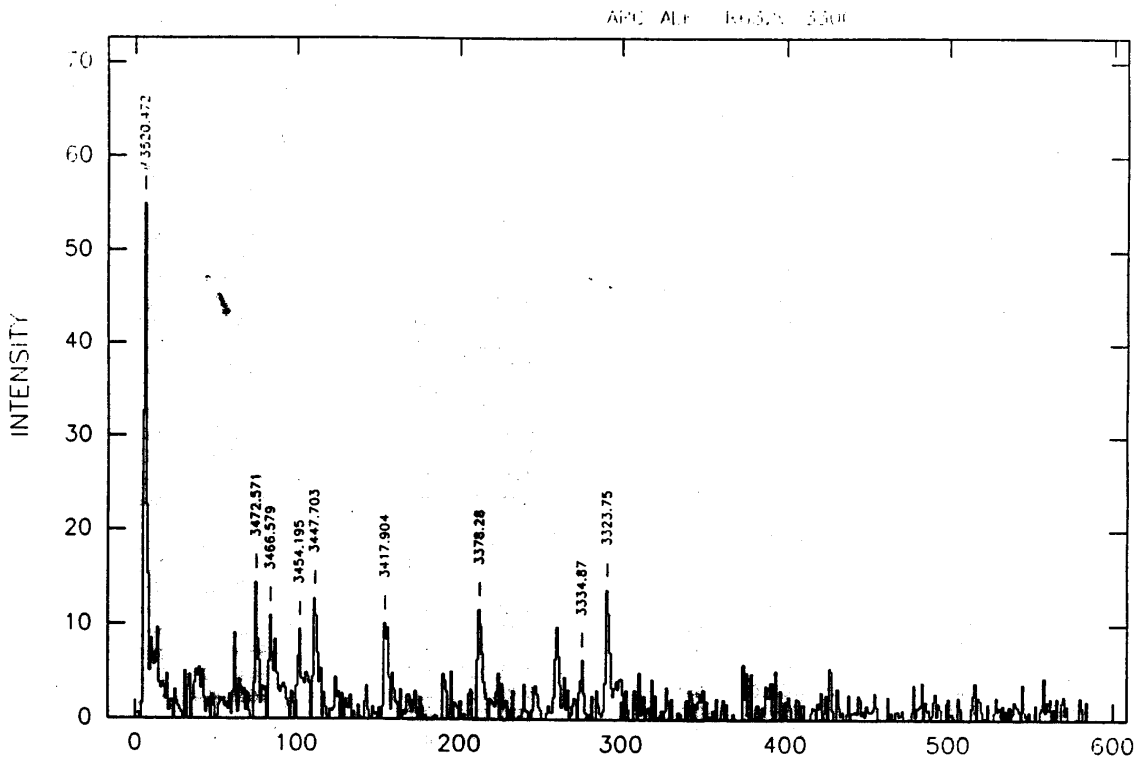
Notes to Table 8 (continued)

Line	
7665.99	KI resonance line + 2nd order AlI 3832.536
7698.959	KI resonance line
8266.076	weak NeI at 8627.11
8377.607	weak NeI at 8376.41
8865.67	NeI, blend of 8865.759 (4) and 8865.33 (1)

Figure 8 : Bi-alkali spectra (Al/Ca/Mg.Ne)

Notes to figure 8

Spectrum	Al/Ca/Mg-Ne	
Camera	IDS 500 mm	
Detector	GEC 3 "GEC BLUE"	
Gratings	R632V for the region 3300 A - 5400 A	
	R600R for the region 5700 A - 9600 A	
Collimator	Al Wide	
Dispersion	32 A/mm or 1.45 pixel/A	
Exposure times	3300 - 5100 A	600 s
	5400 A	300 s
	5700 A	30 s
	6000 - 7500 A	20 s
	7800 A	300 s
	8100 A	600 s
	8400 A	30 s
	8700 A	120 s
	9000 A	300 s
	9300 & 9600 A	600 s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70
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200
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400
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3454.195
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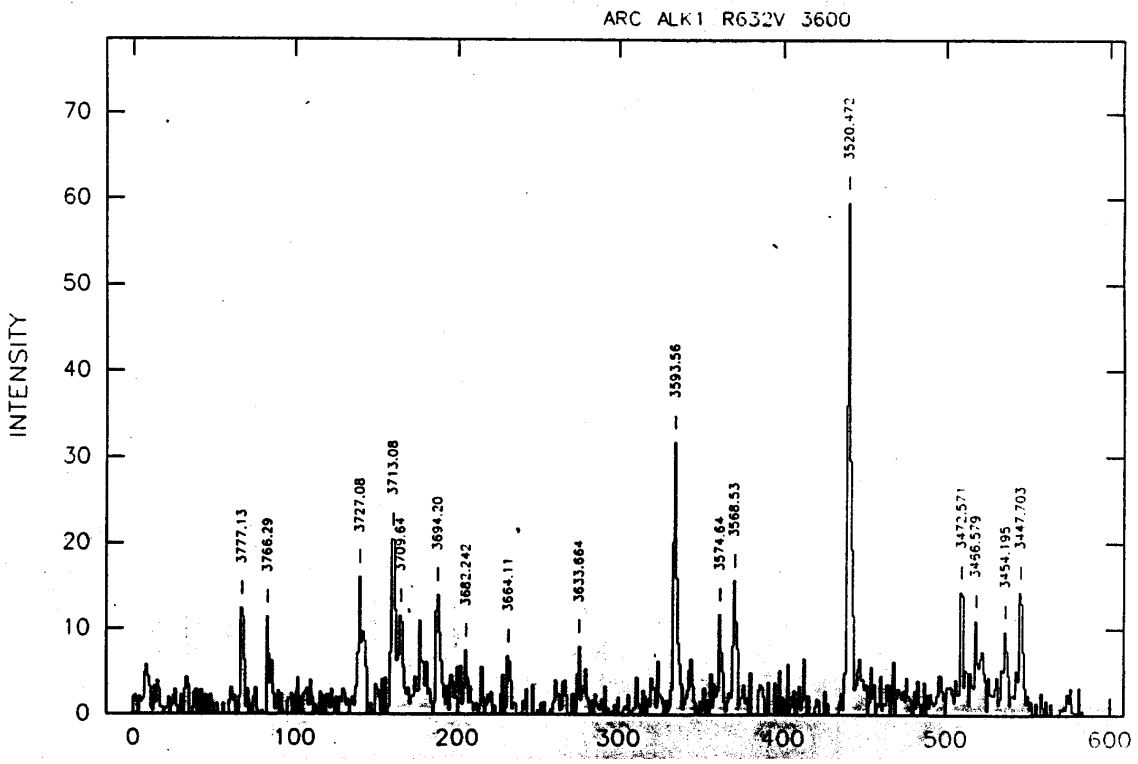
3334.87
3323.75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600
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3766.29
3727.08
3713.08
3709.64
3694.20
3682.242
3664.11
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3574.64
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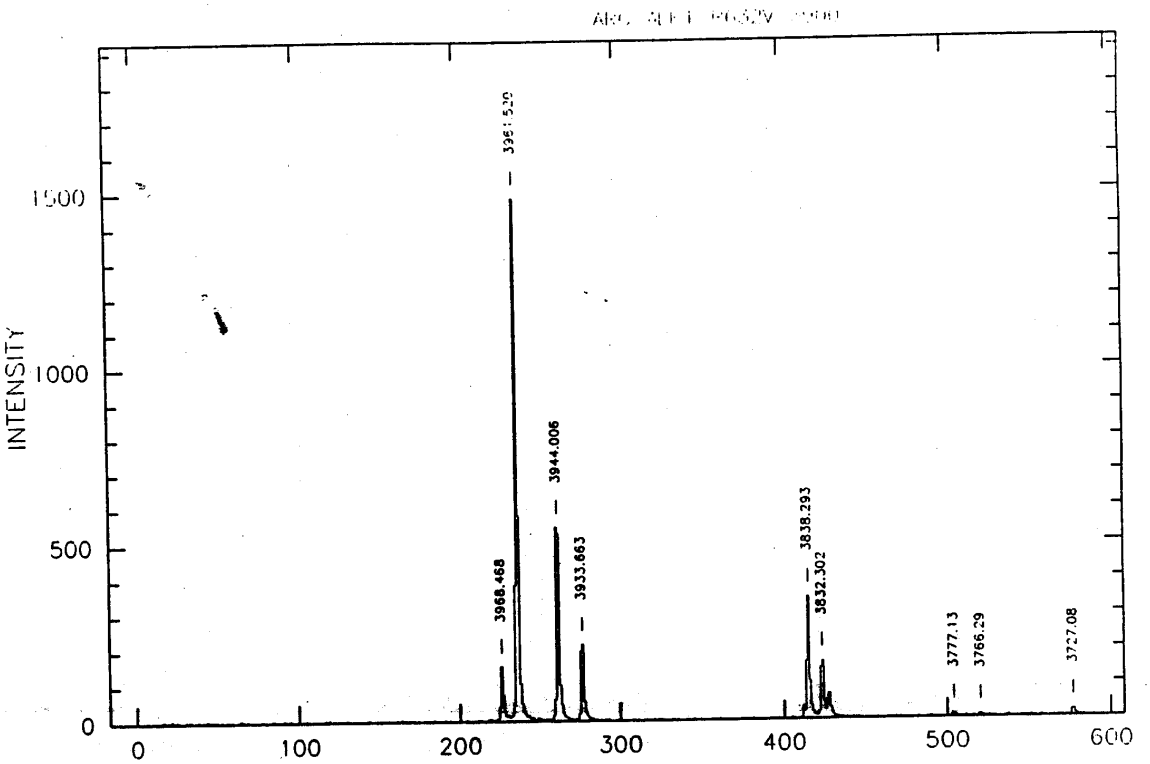
3447.703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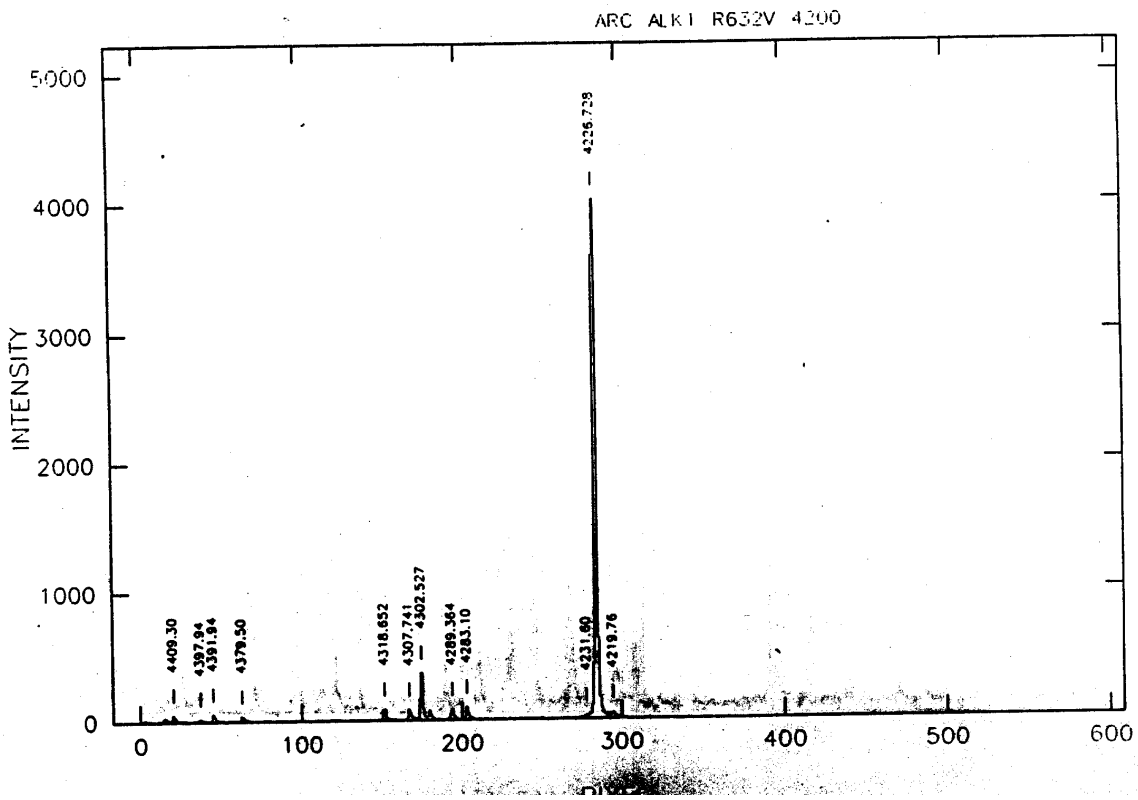
3832.302
3777.13
3766.29
3727.08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500
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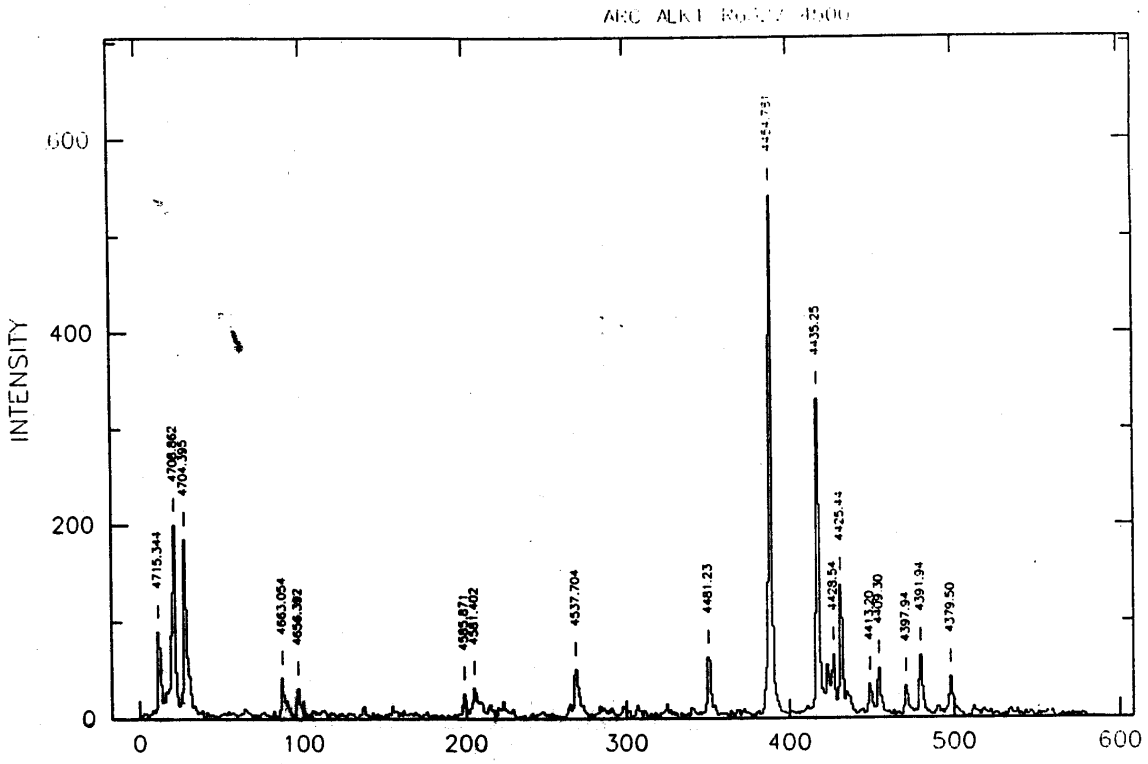
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500
600
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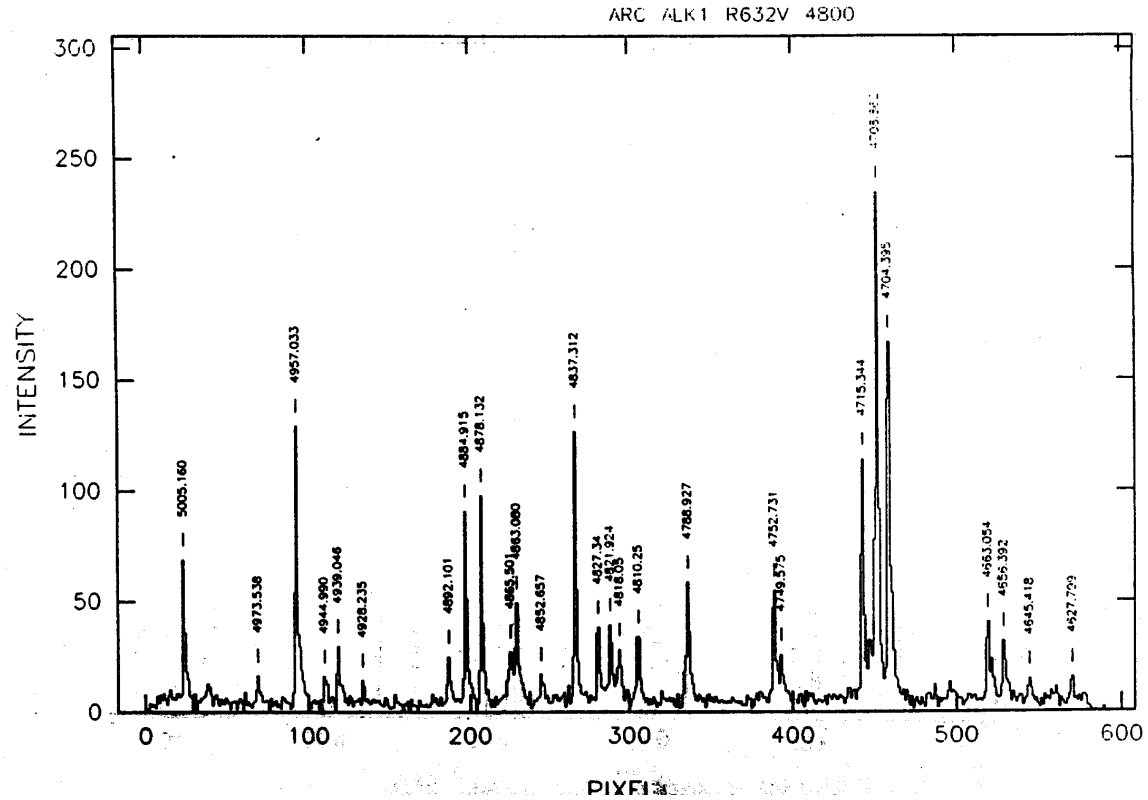
4379.50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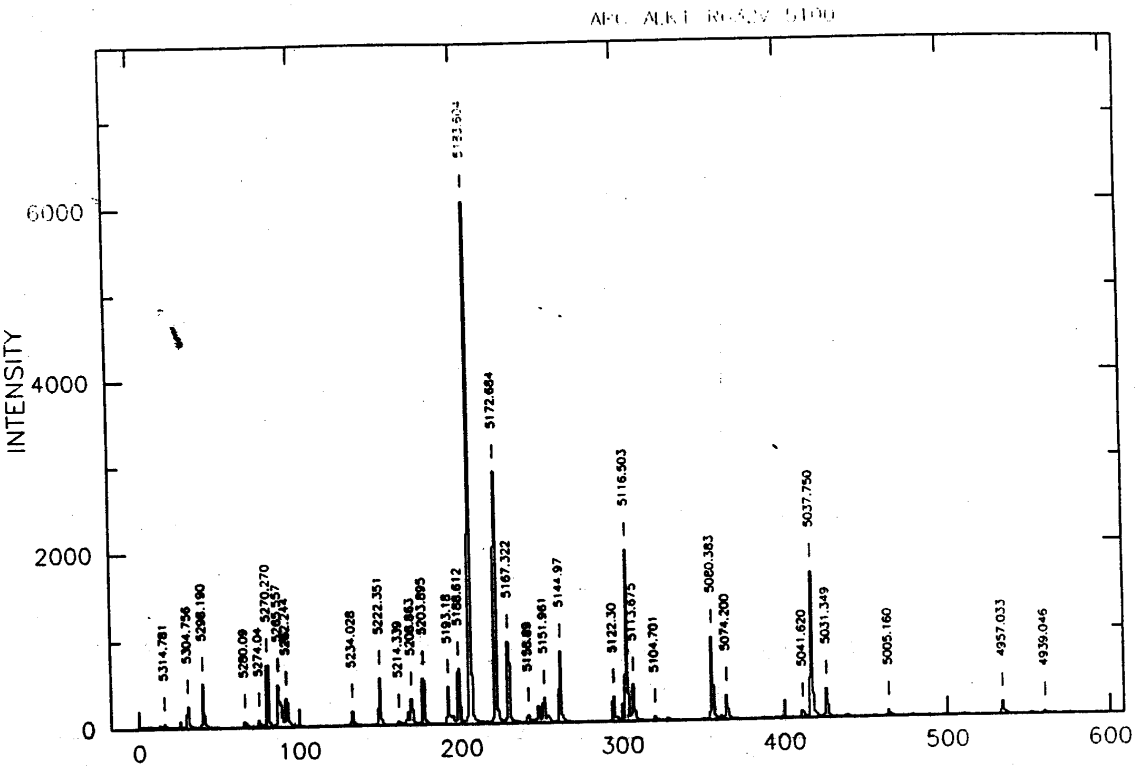
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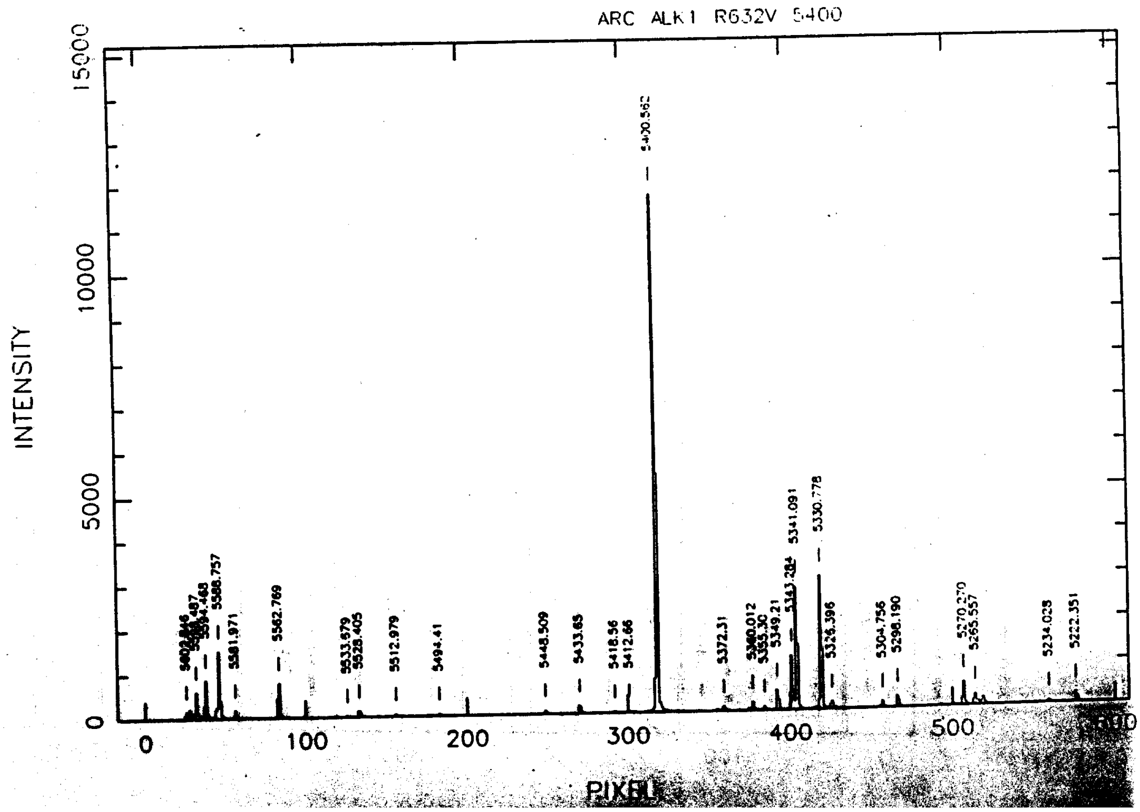
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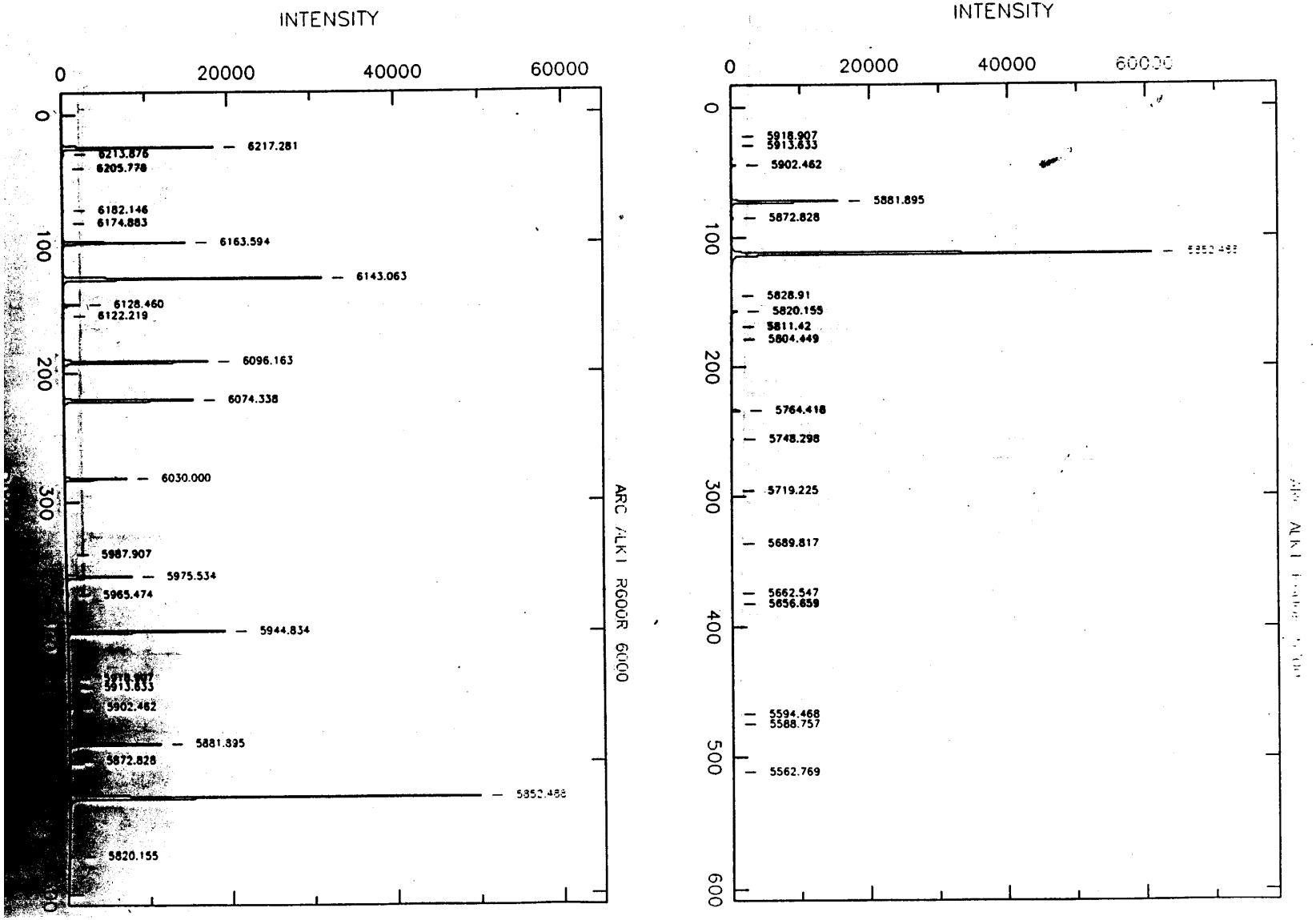
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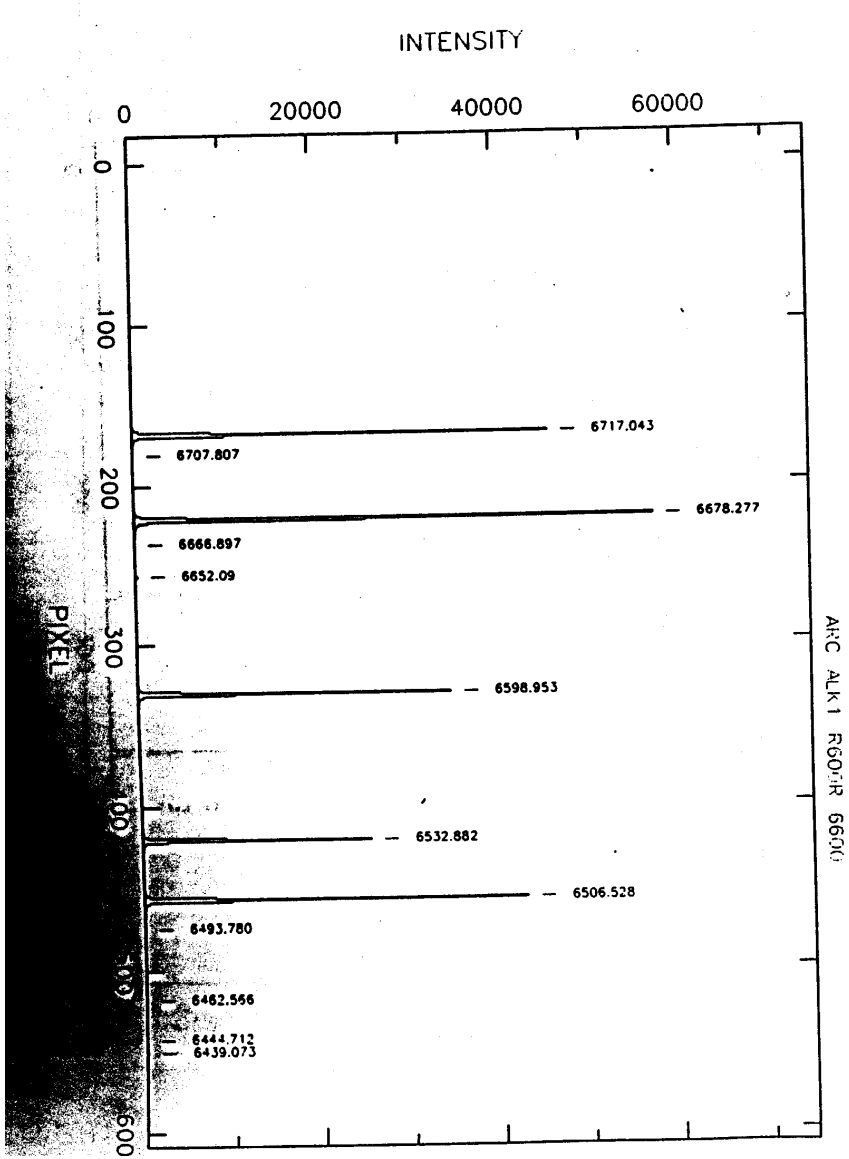
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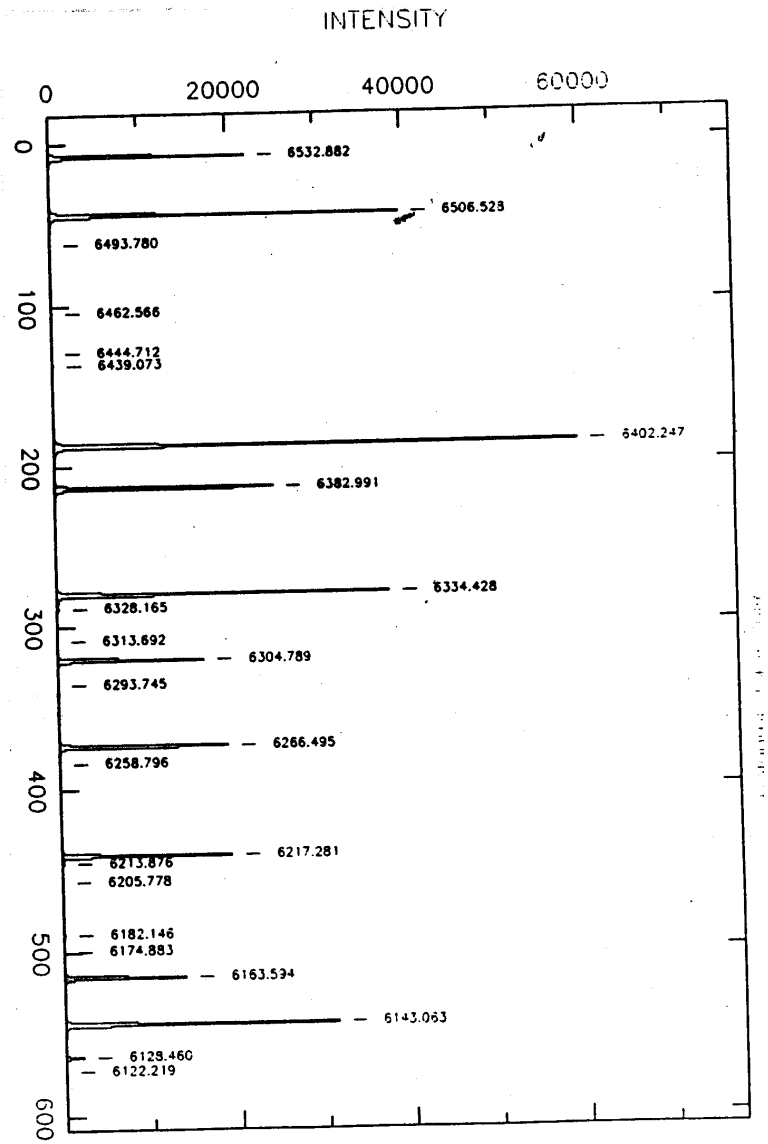
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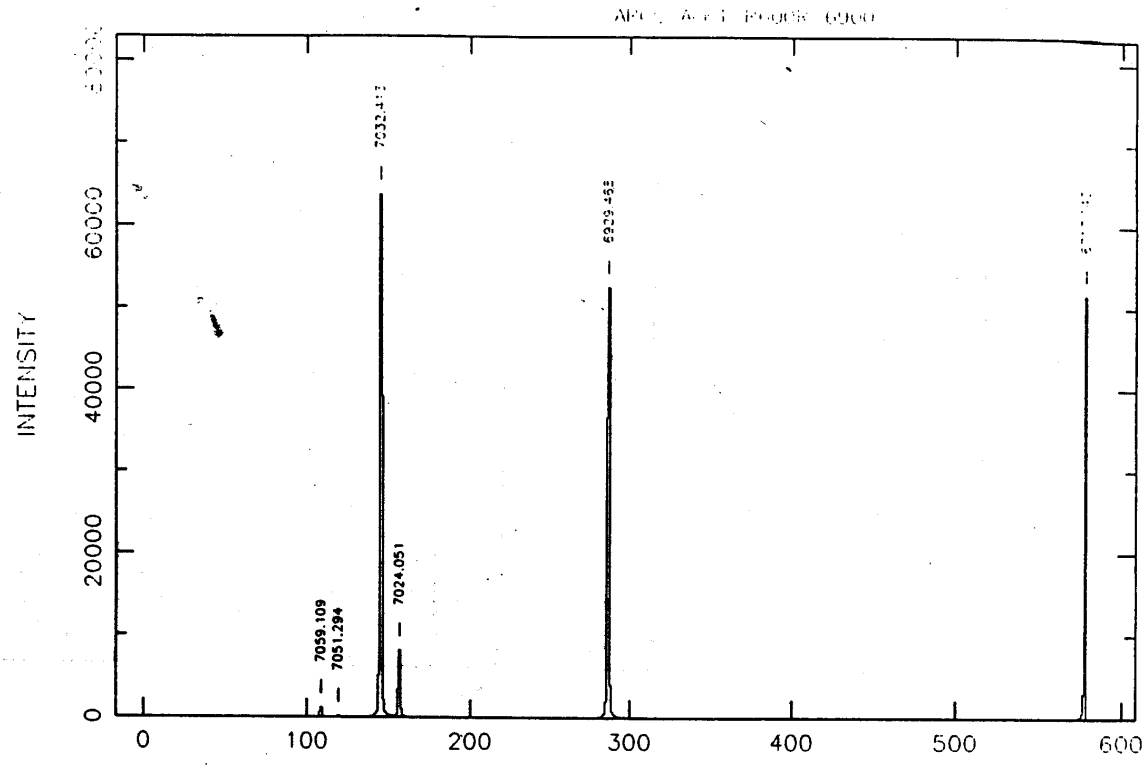
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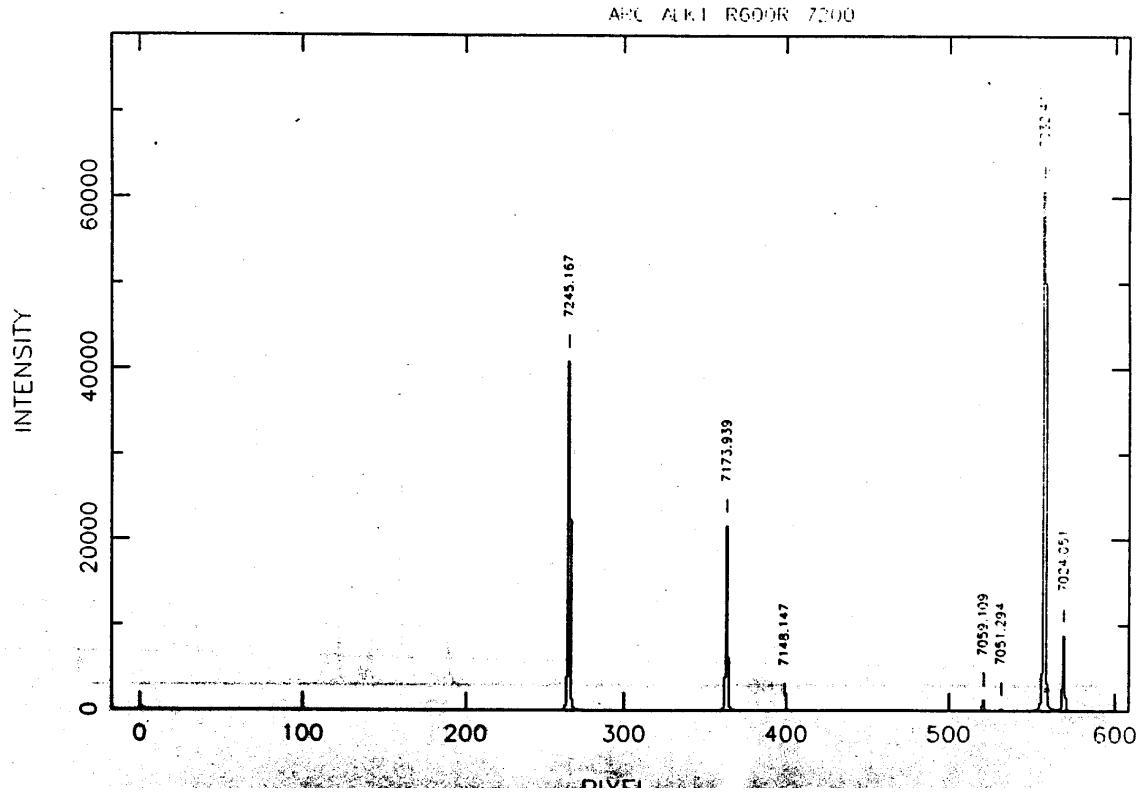
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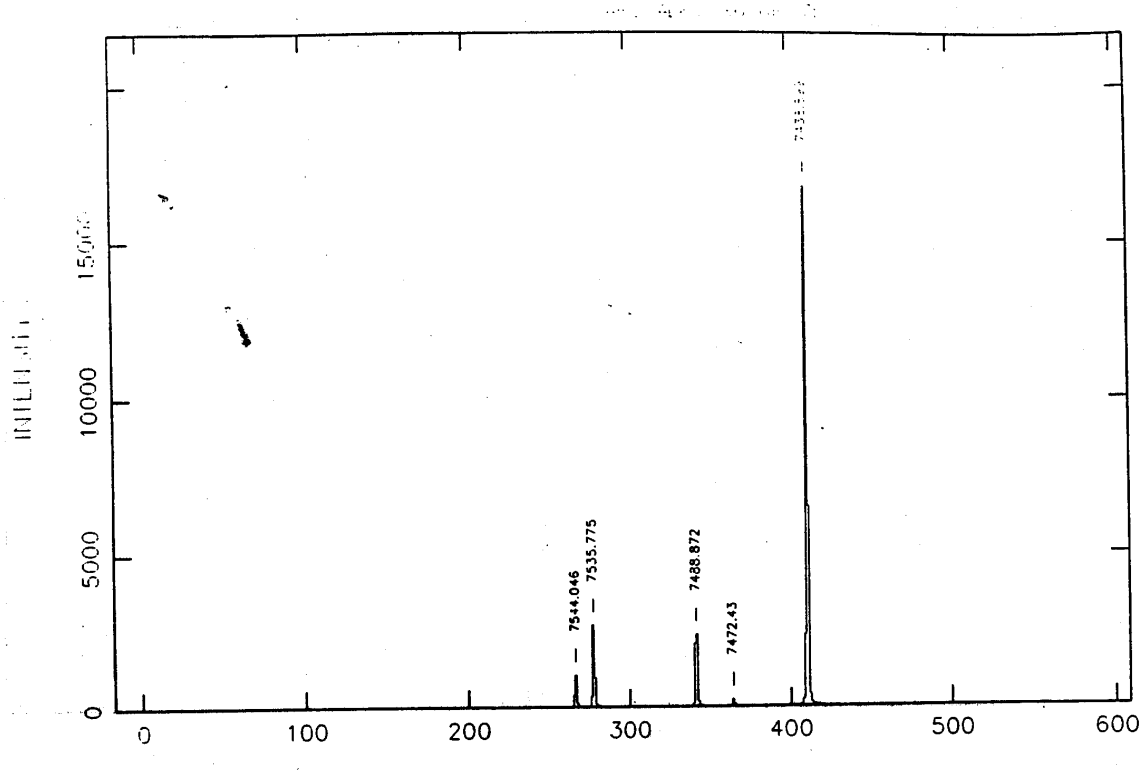
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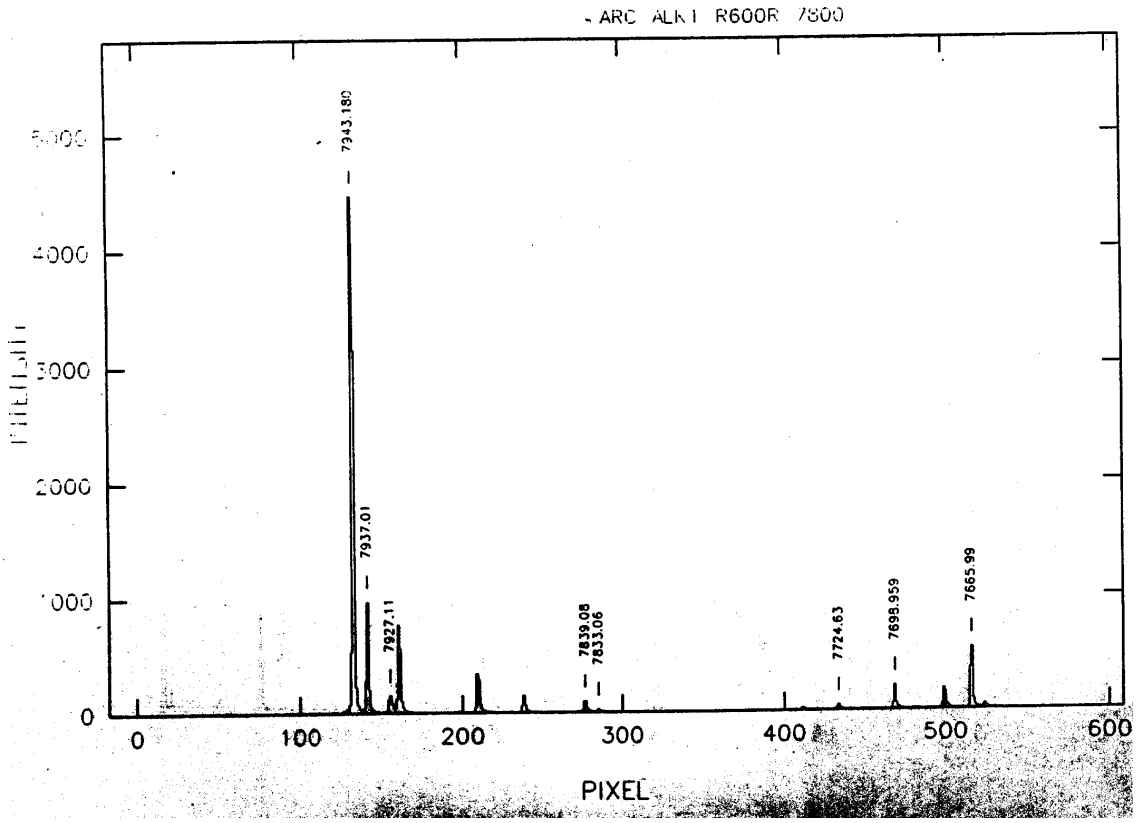
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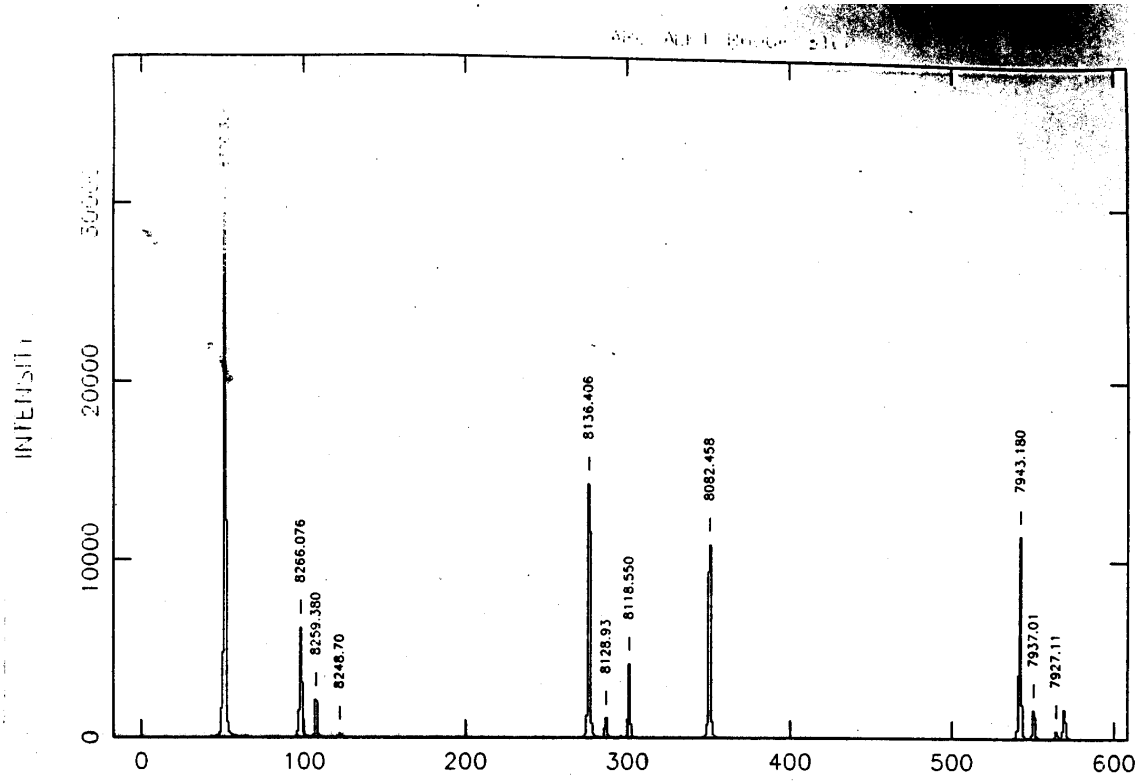
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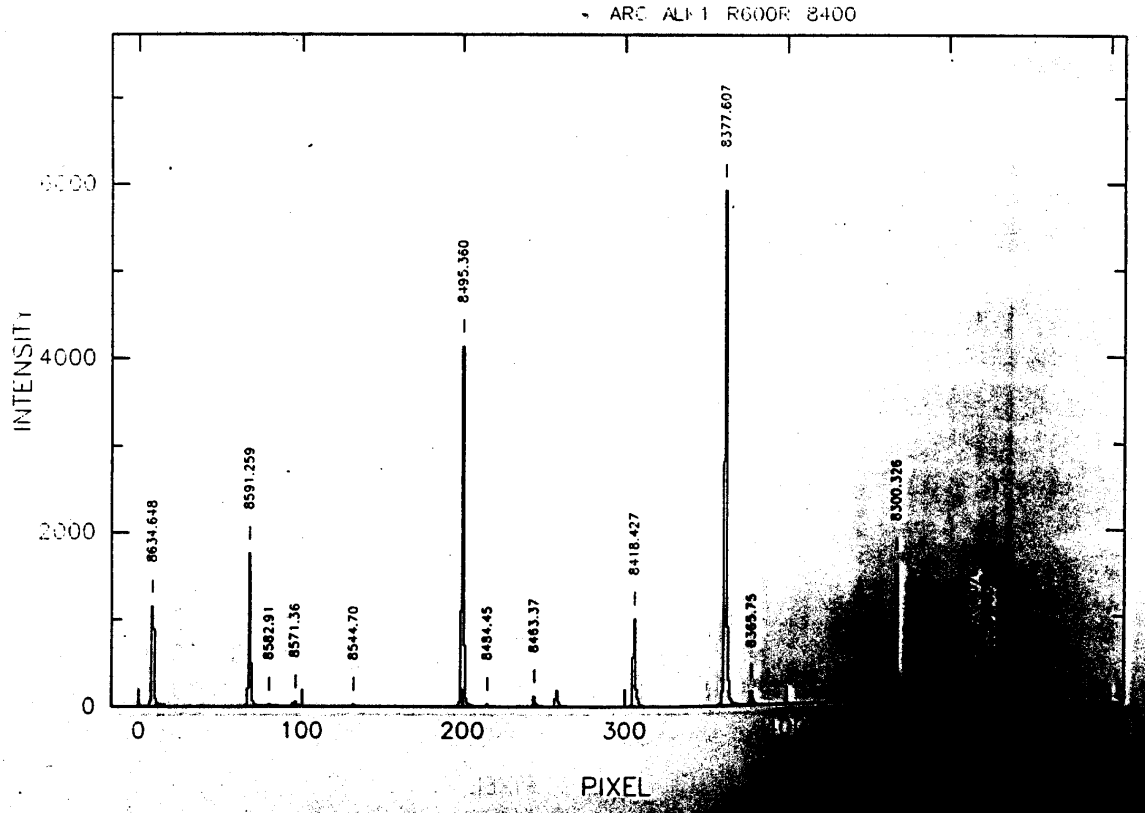
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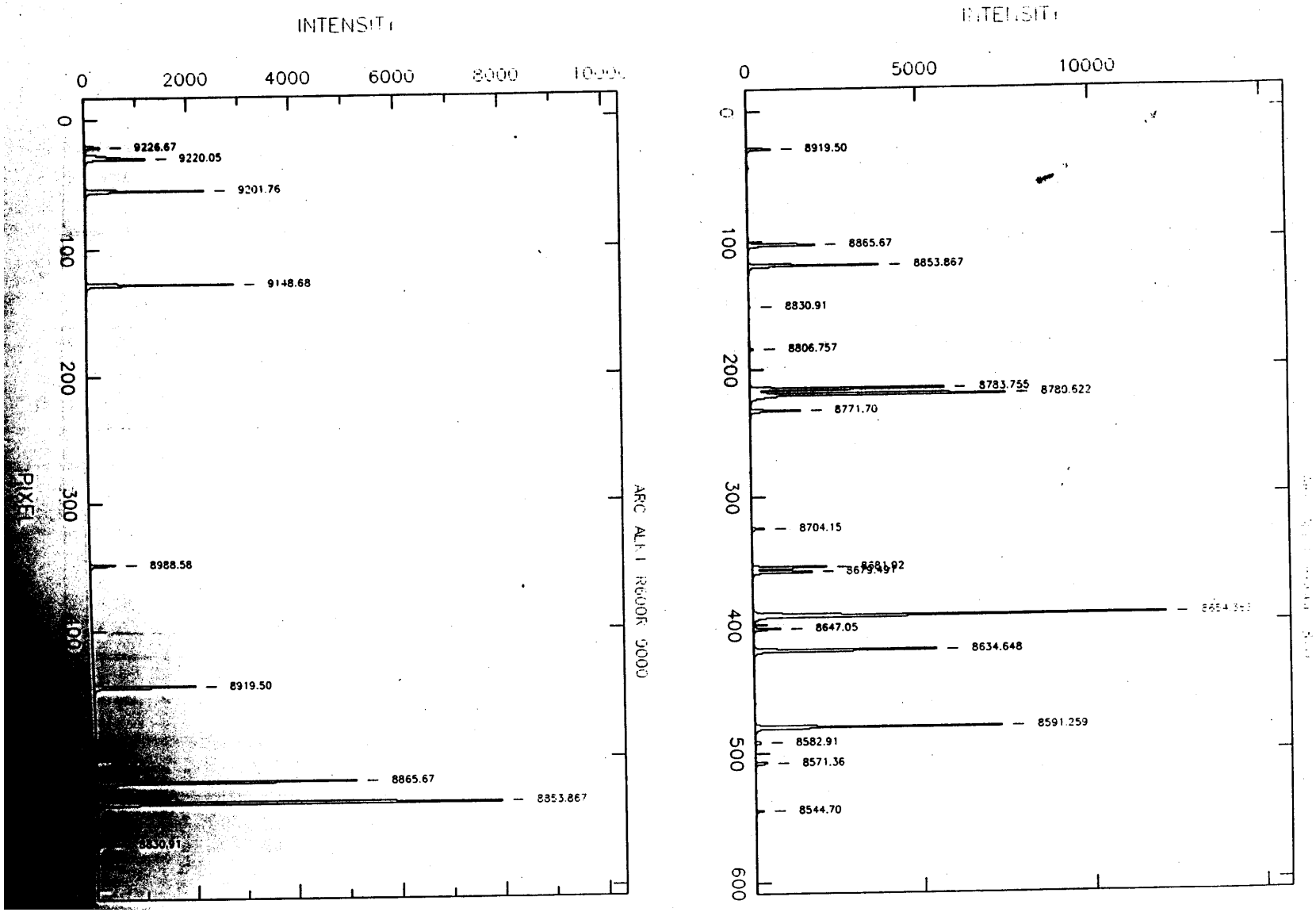
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INTENSITY
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10000
0
100
200
300
400
500
600
8919.50
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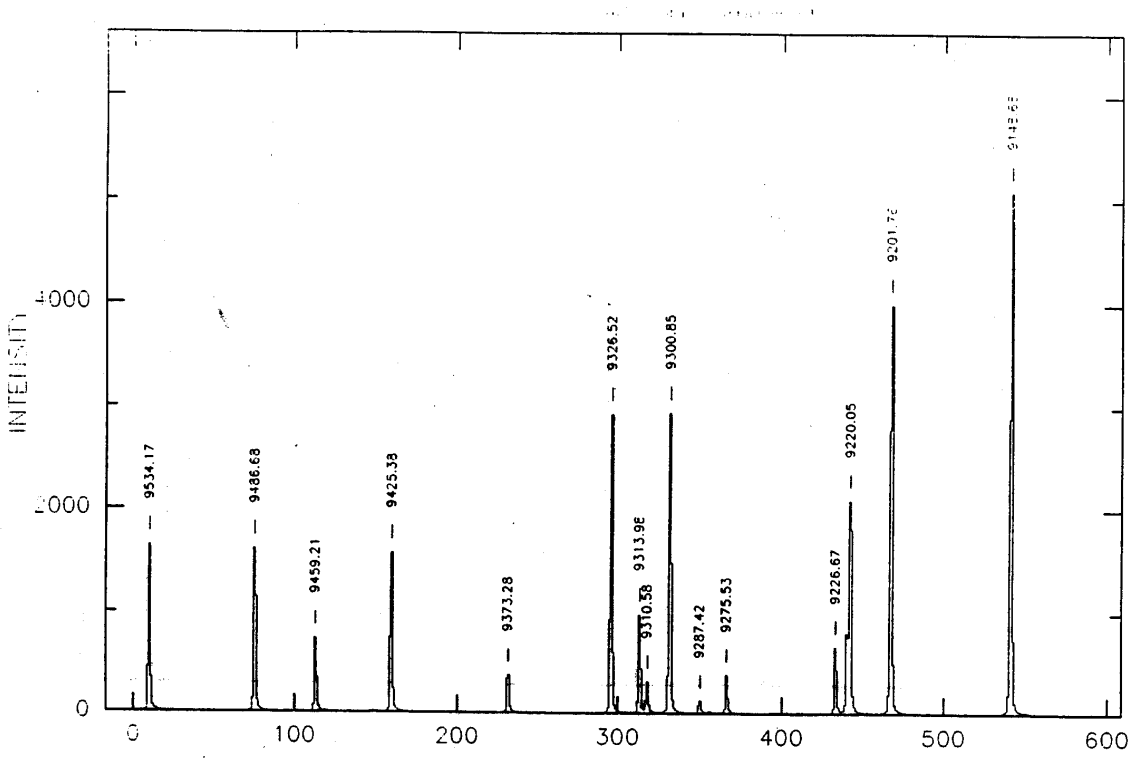
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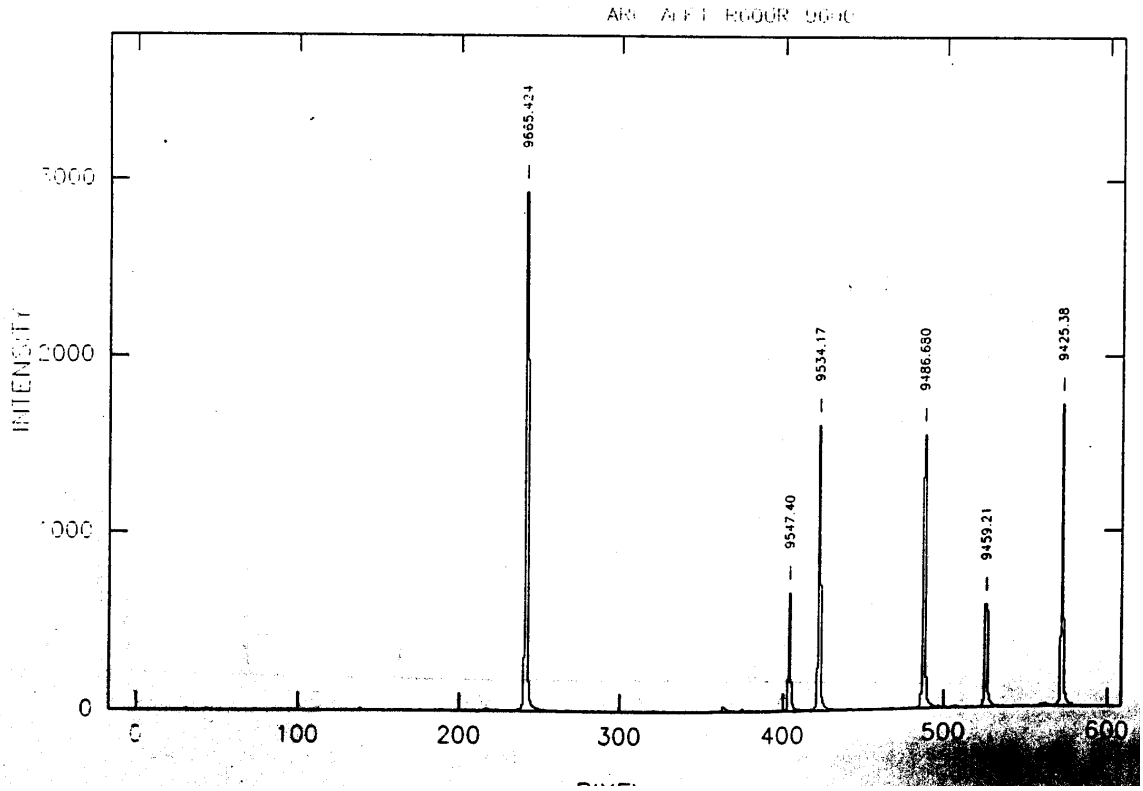
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