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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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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

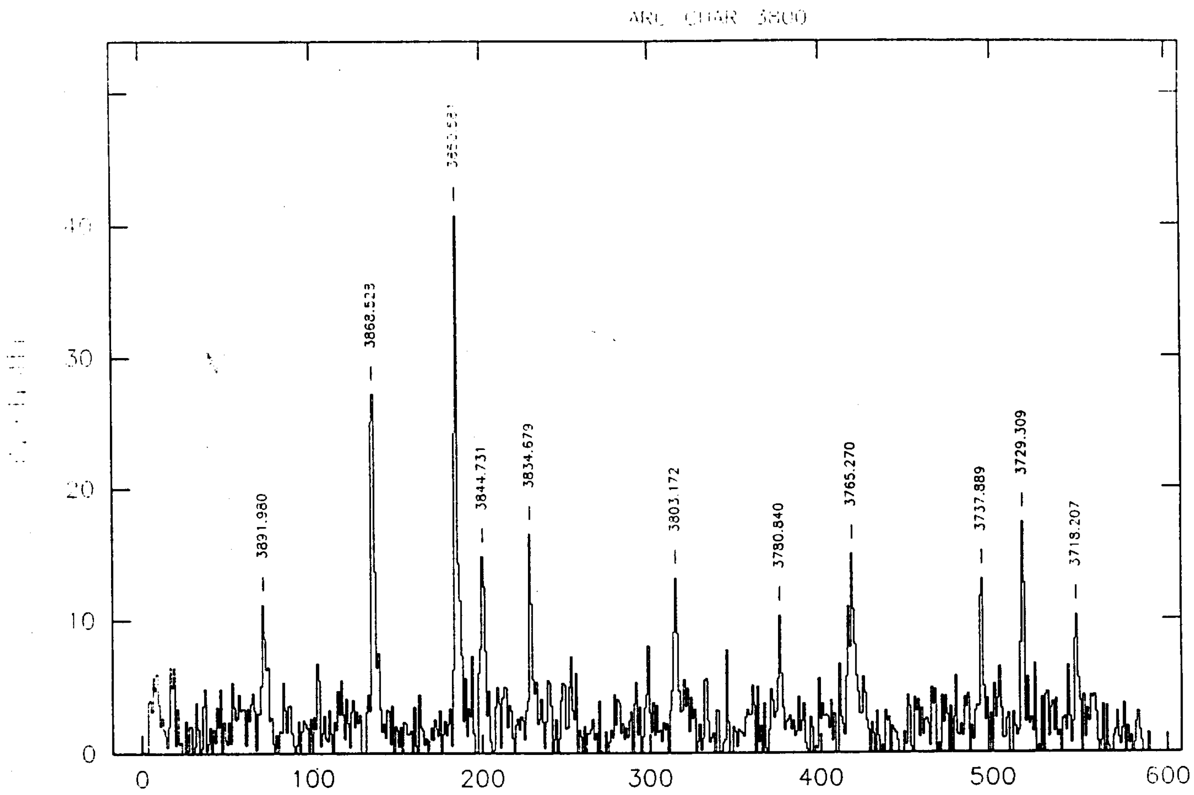
Notes to table 1 :

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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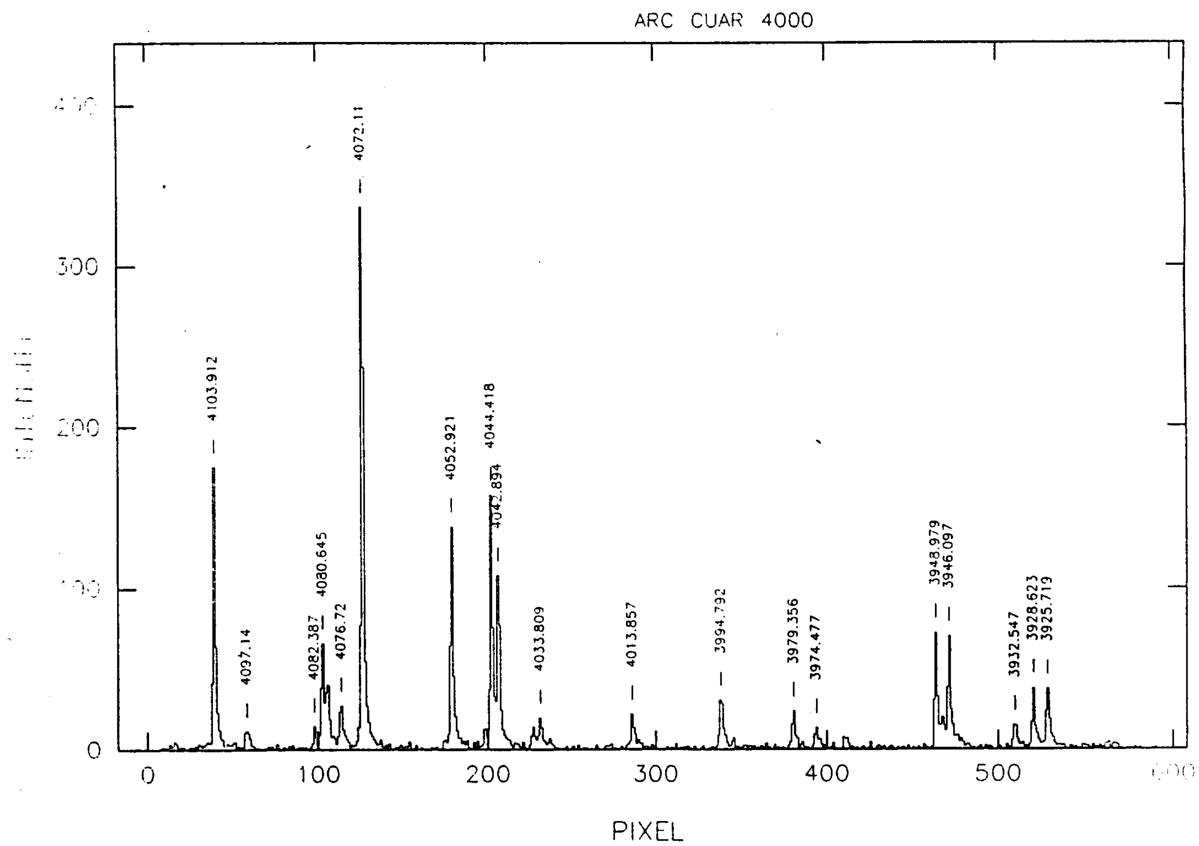
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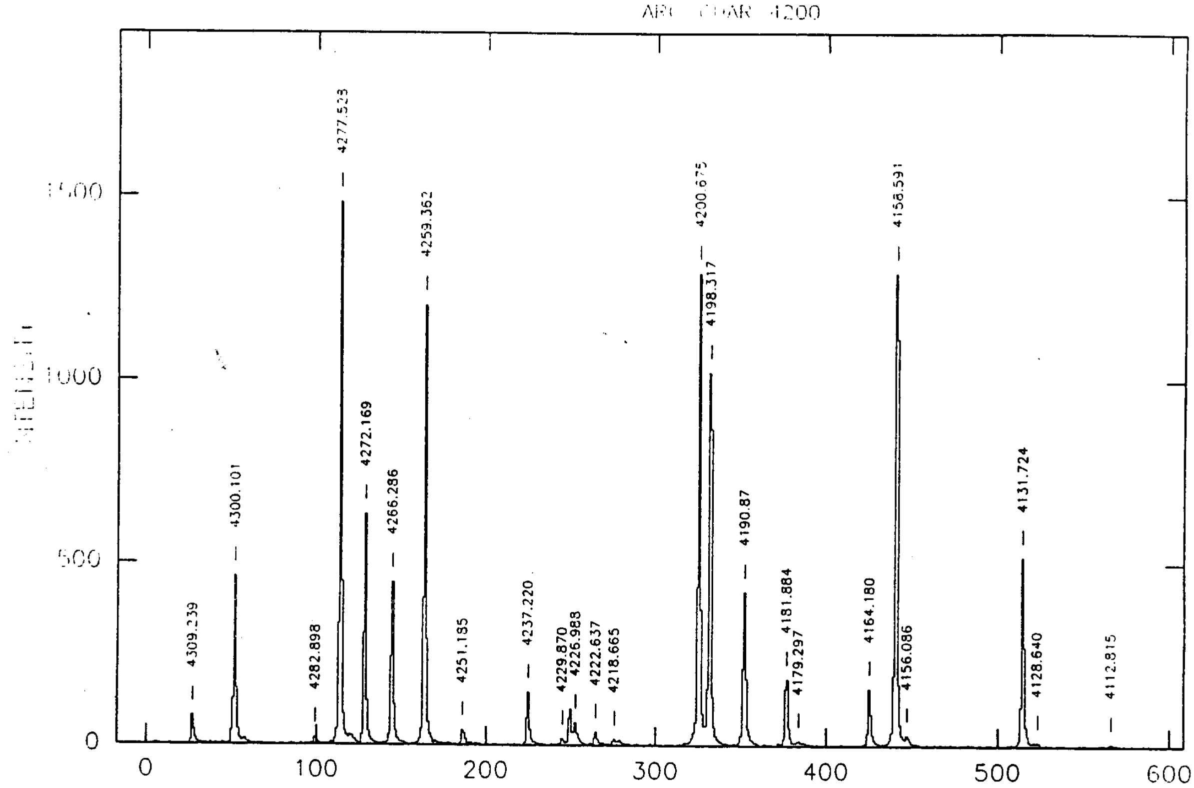
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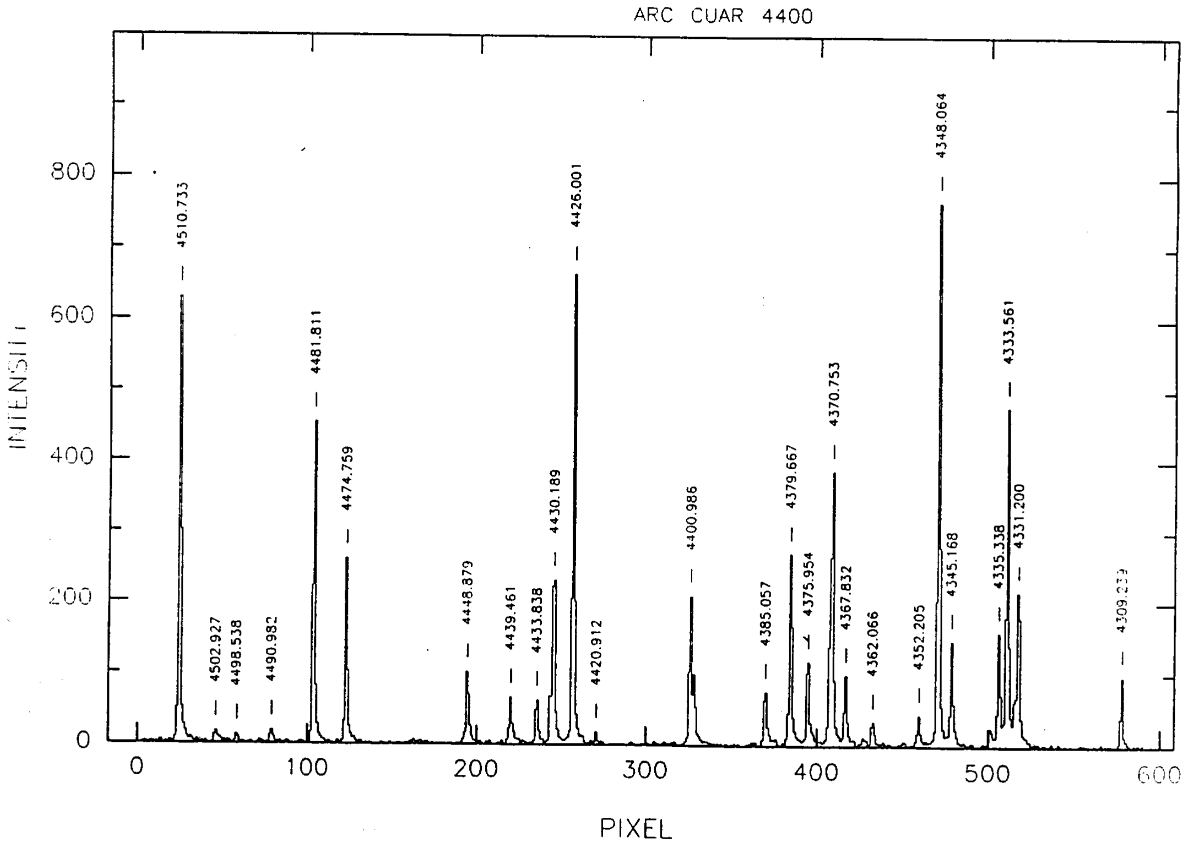
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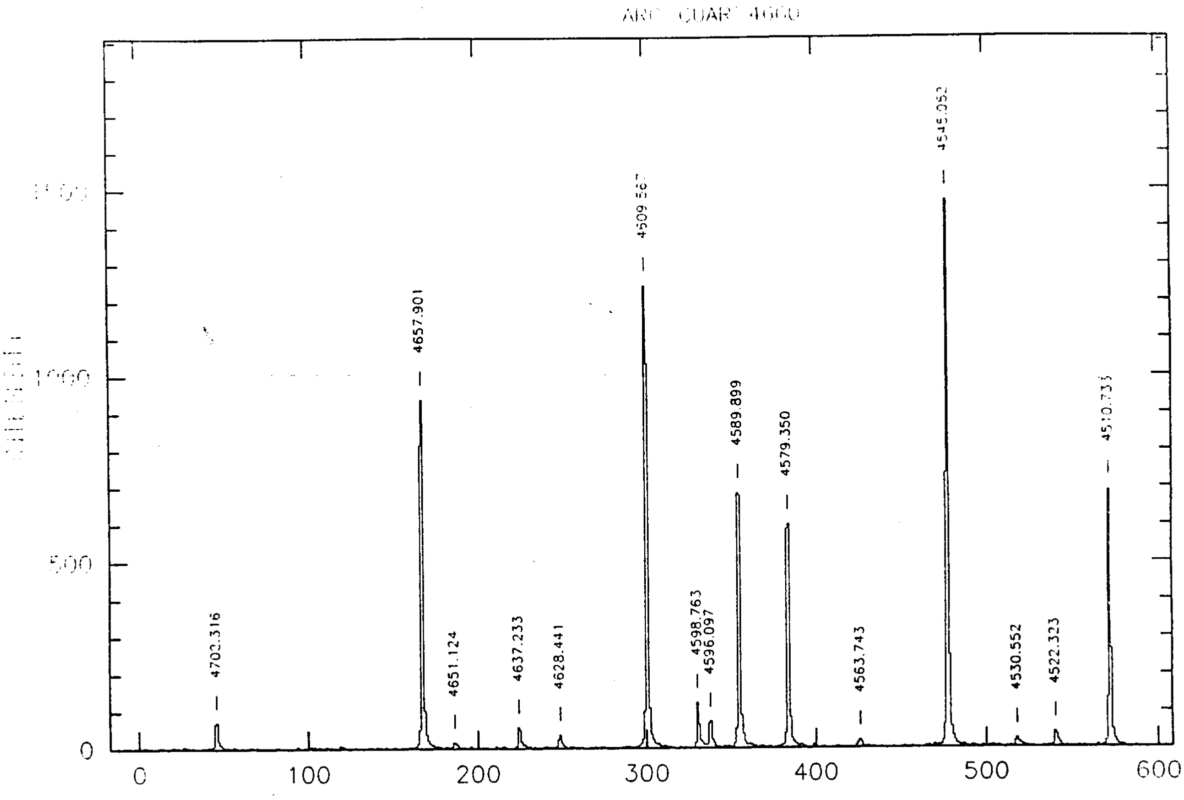

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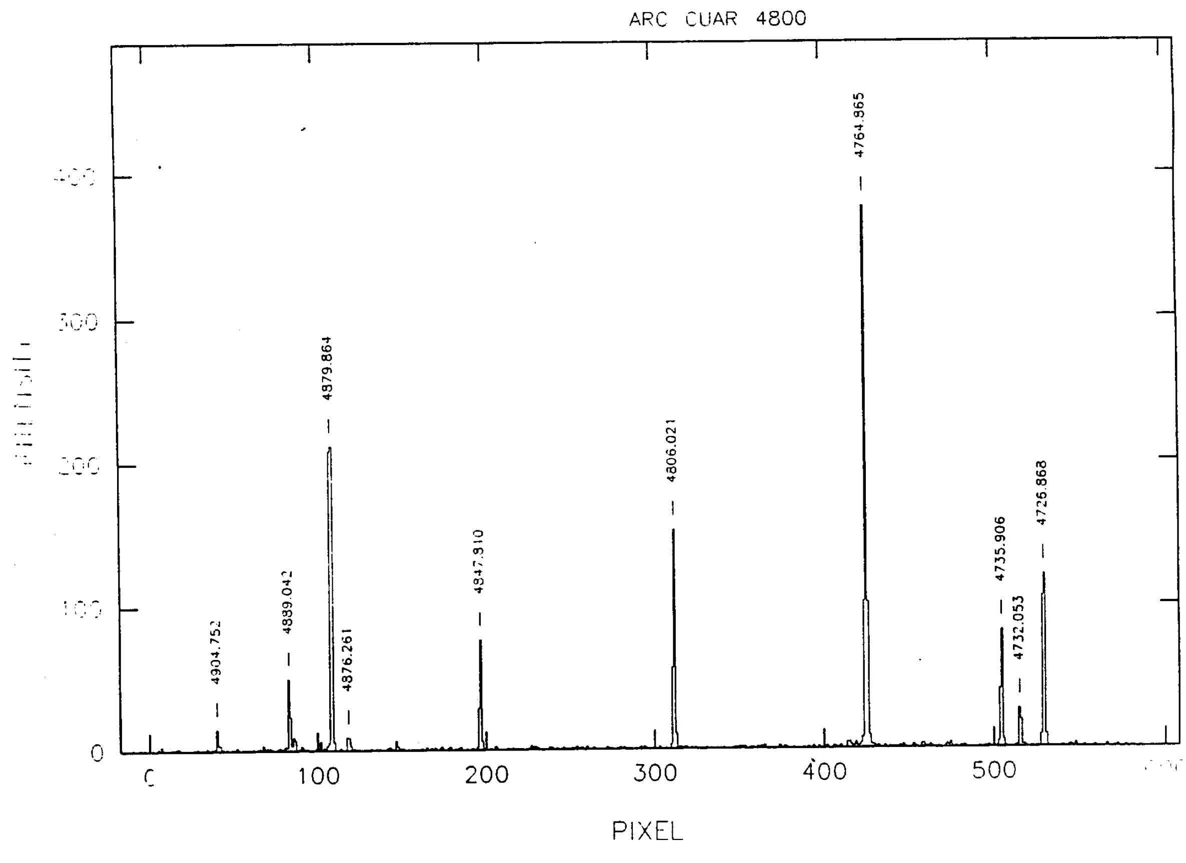

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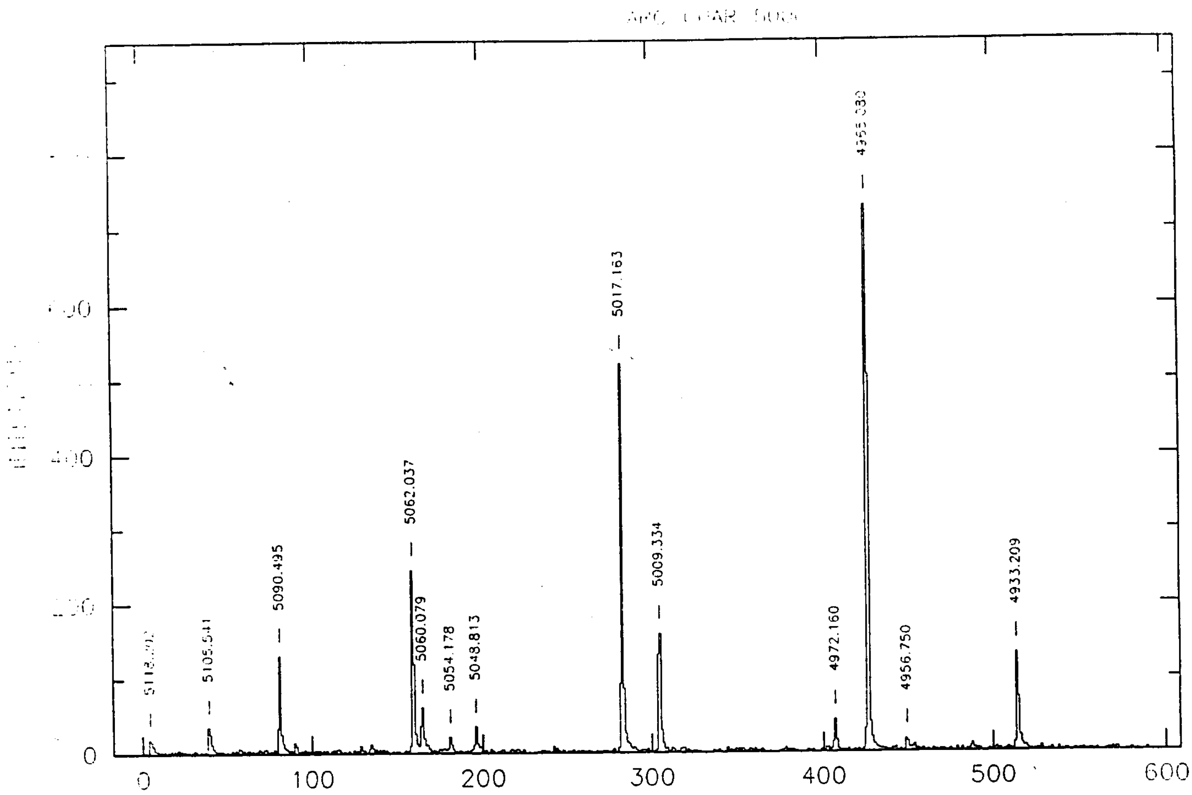

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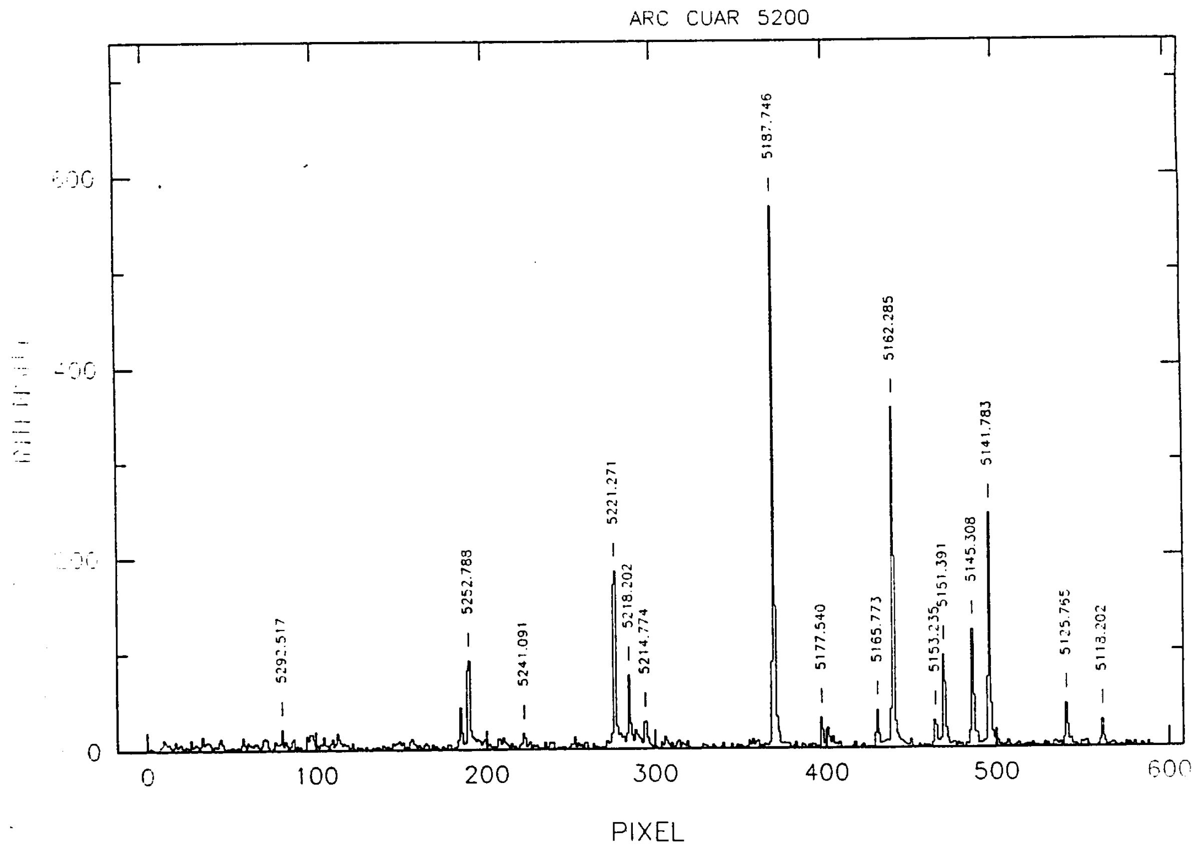

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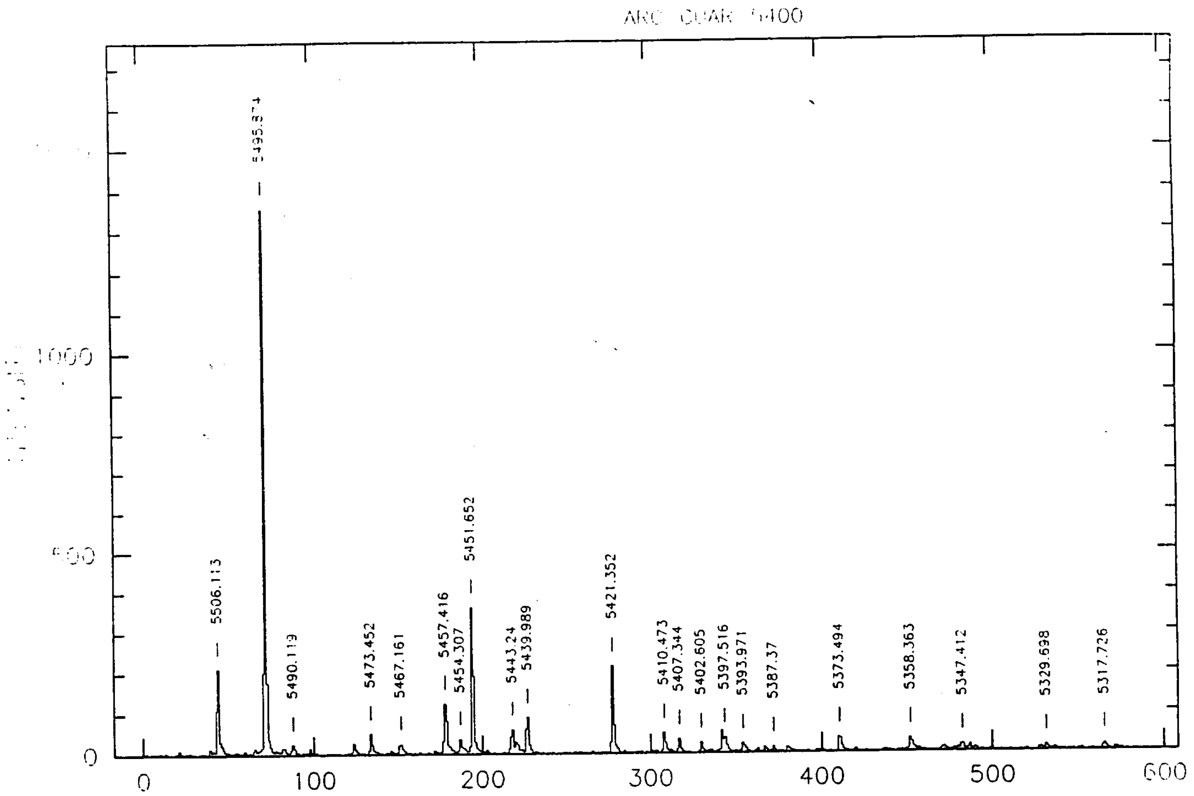
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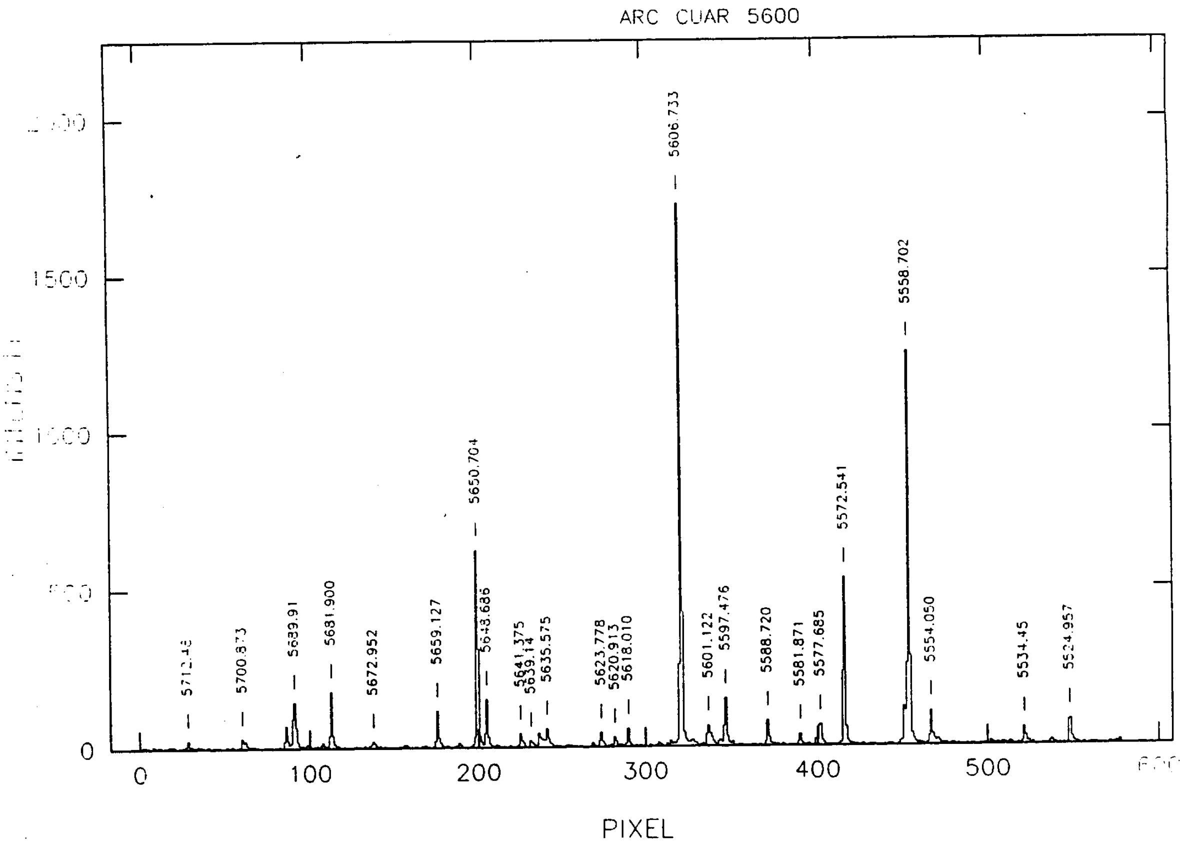
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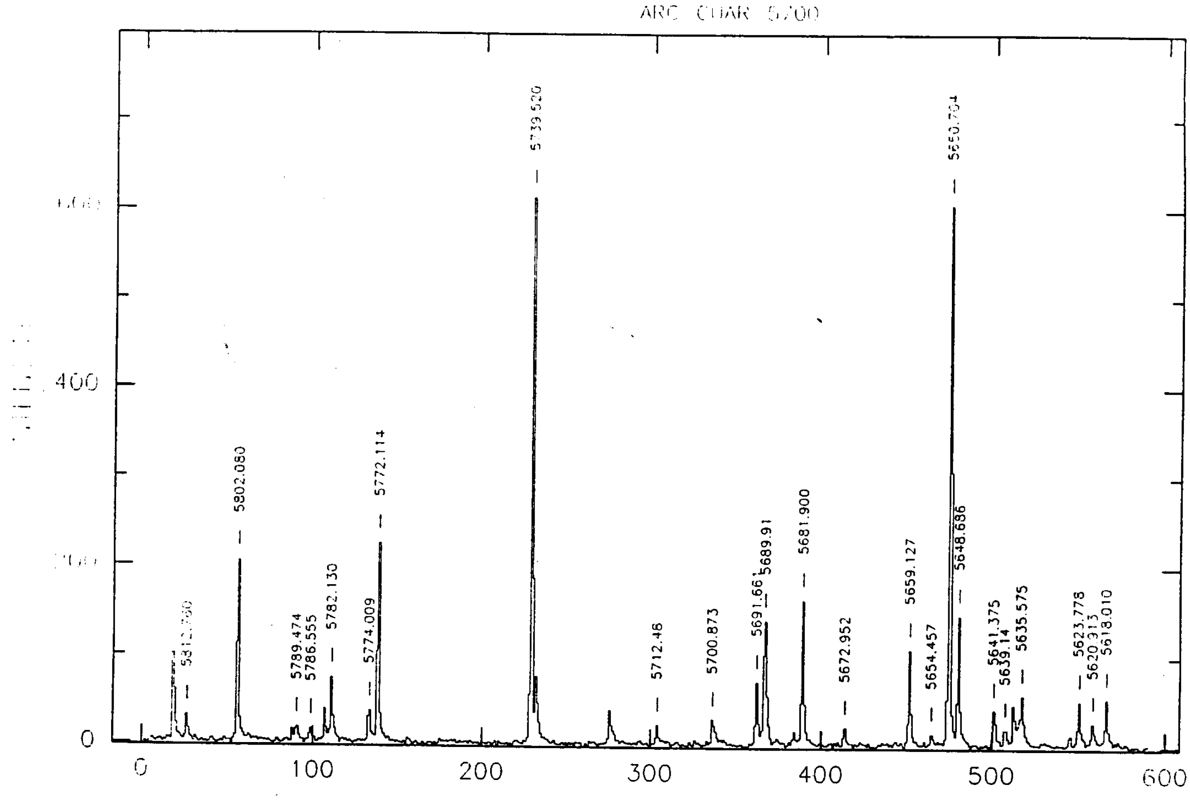
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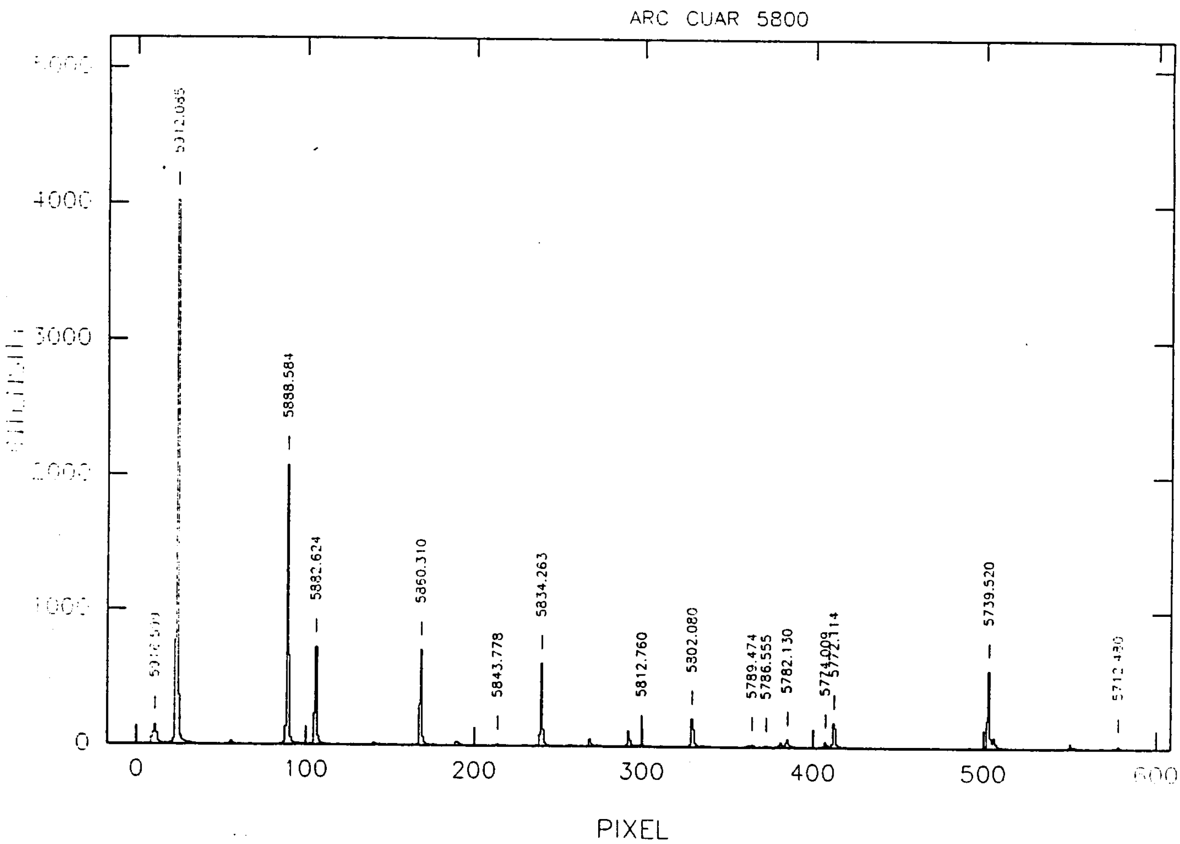
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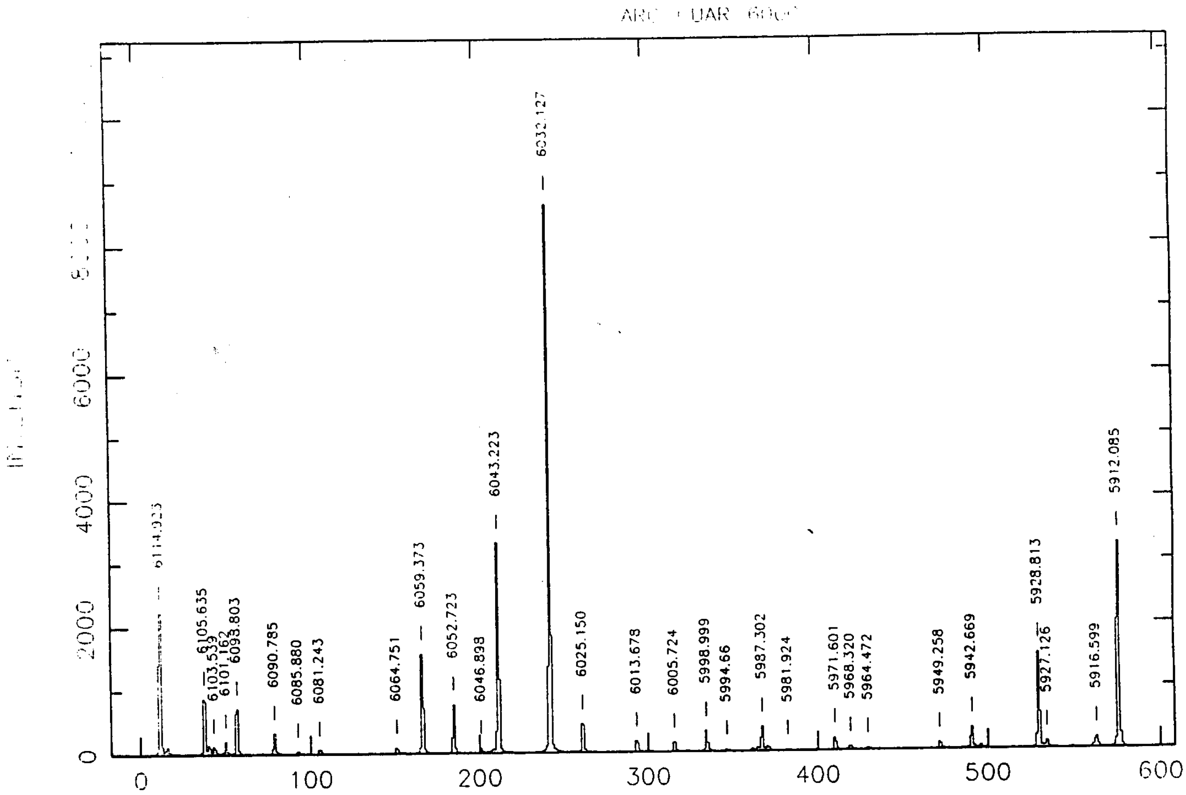
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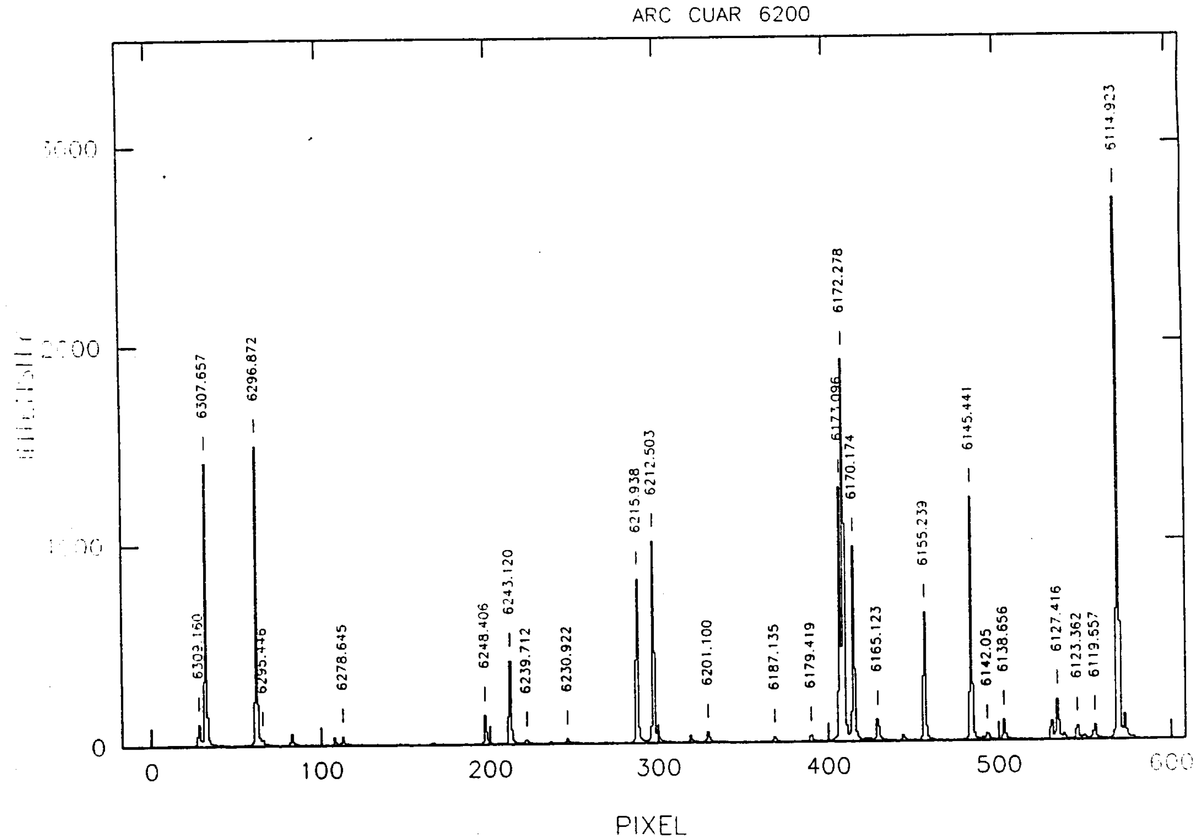
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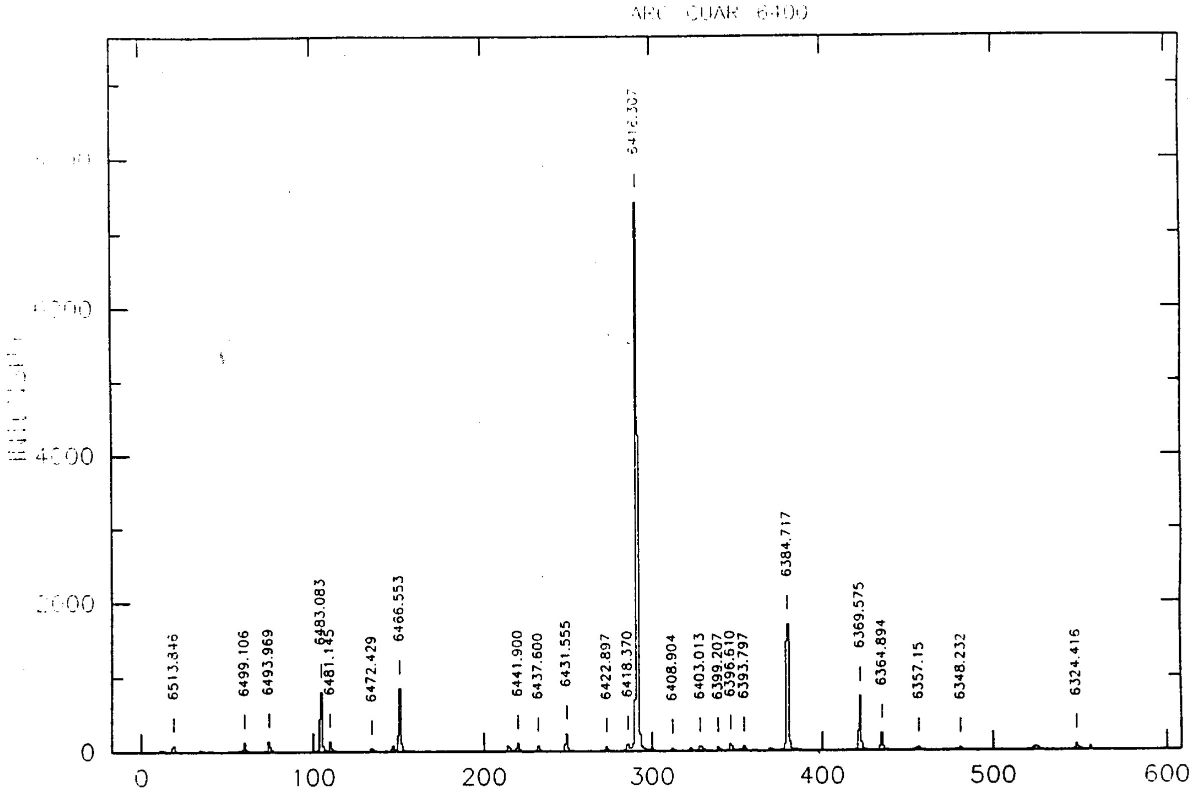
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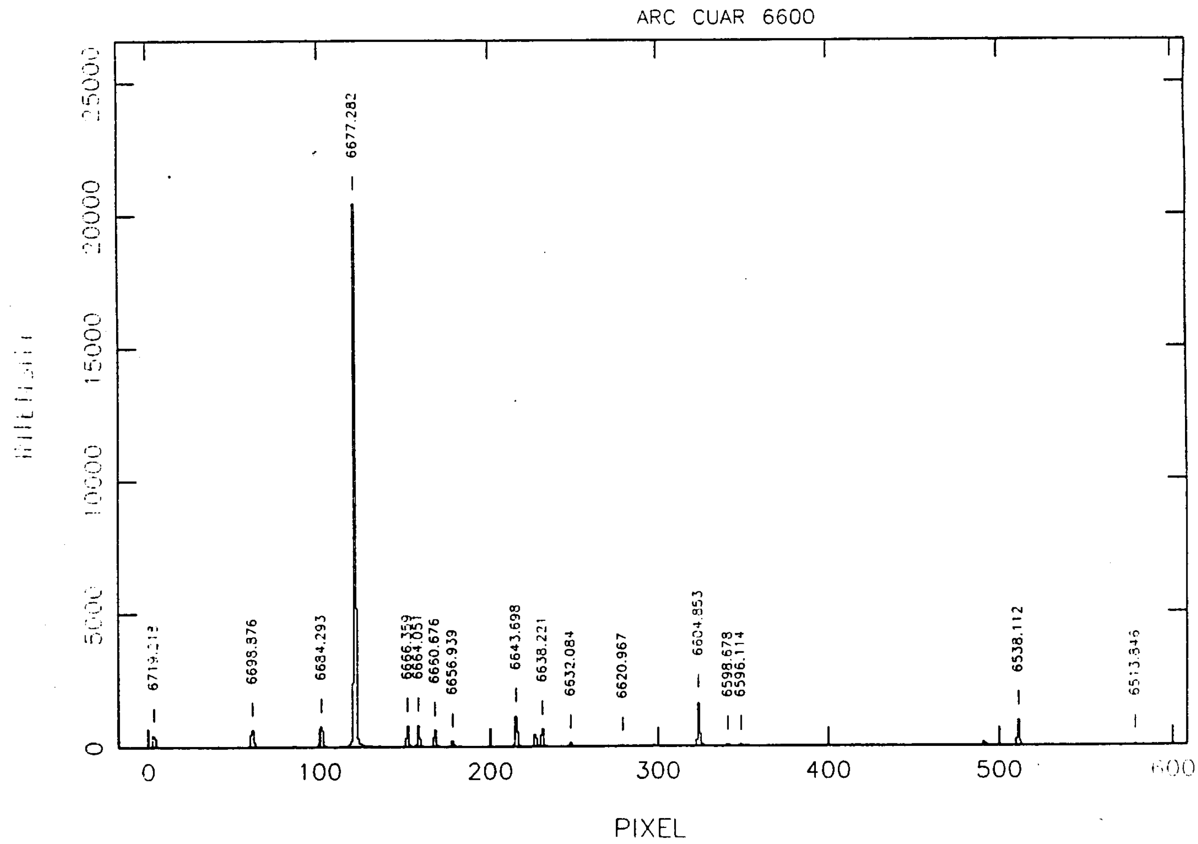
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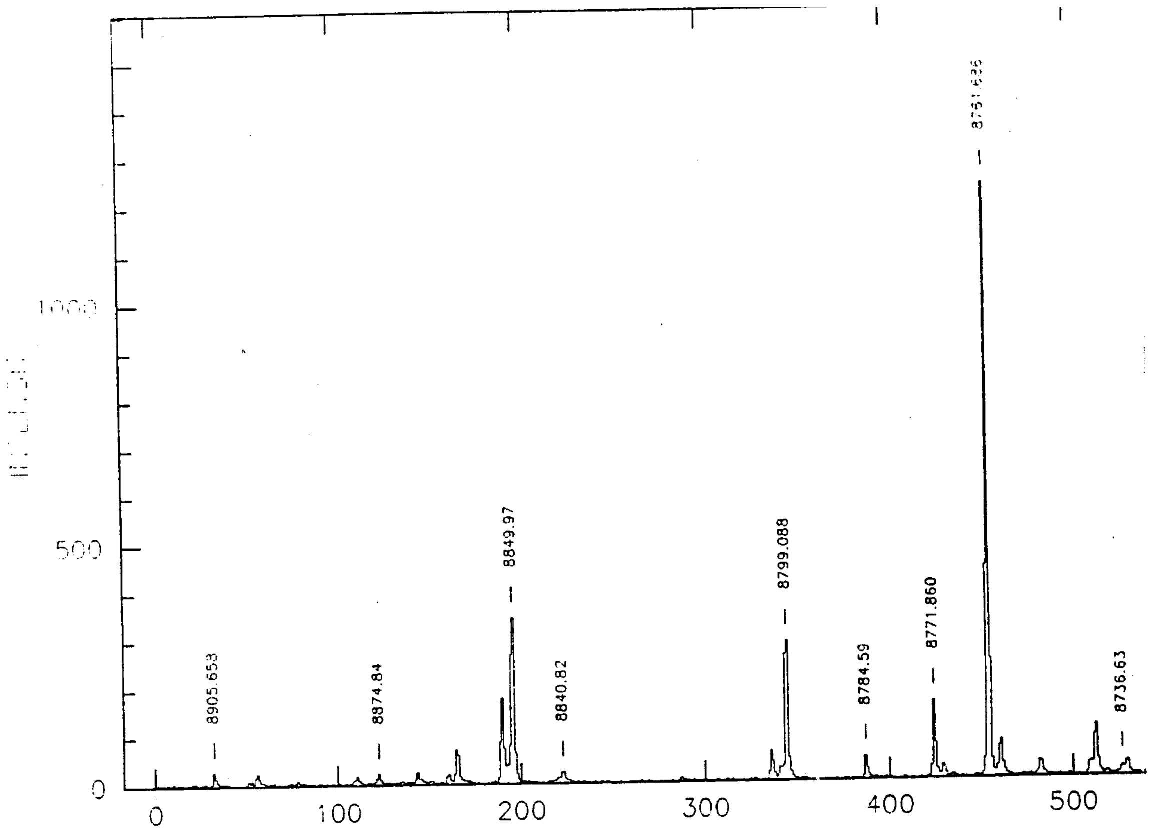

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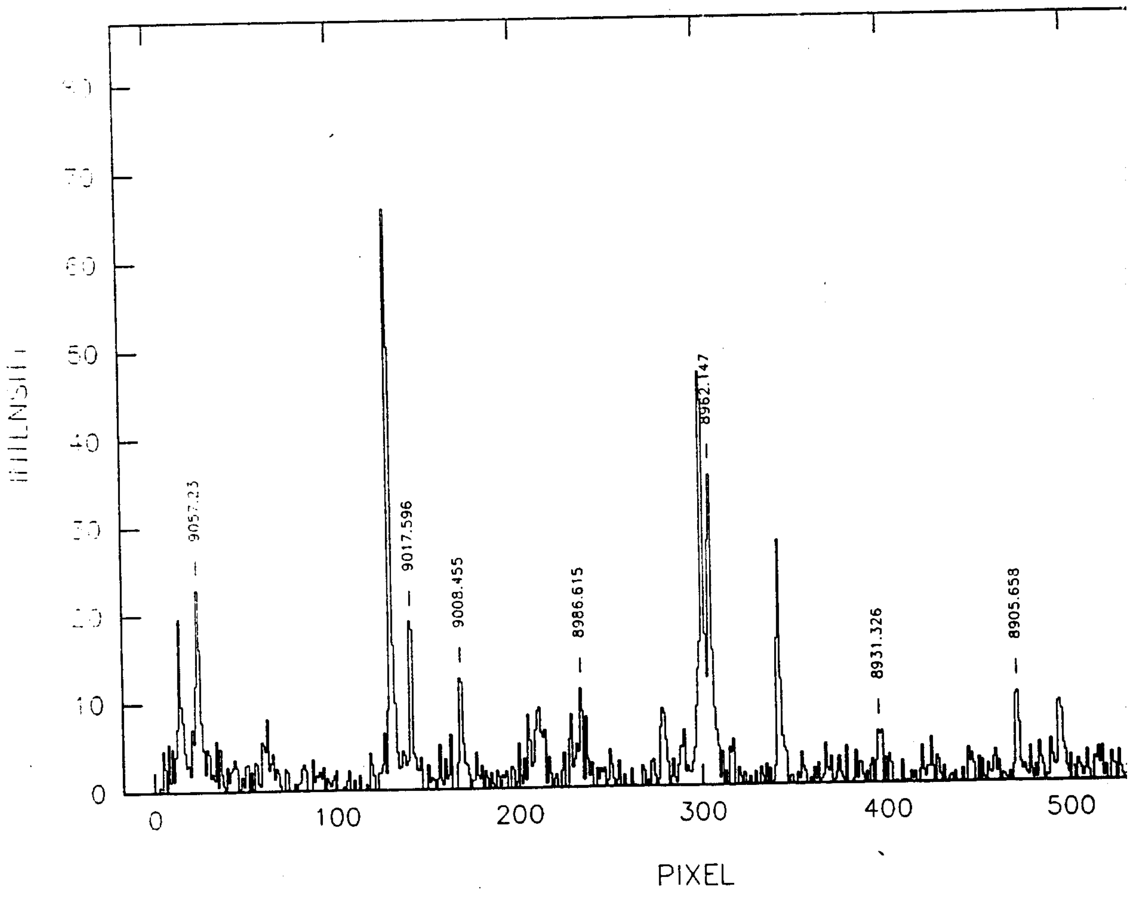

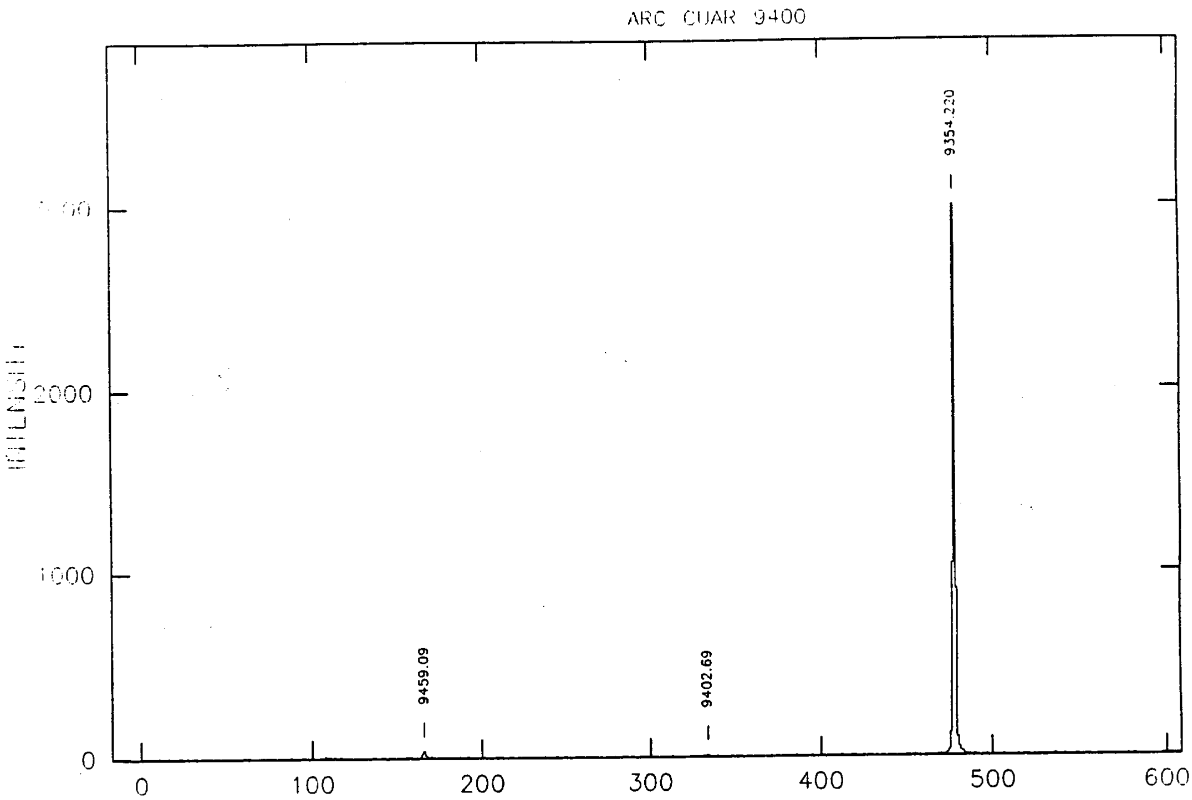
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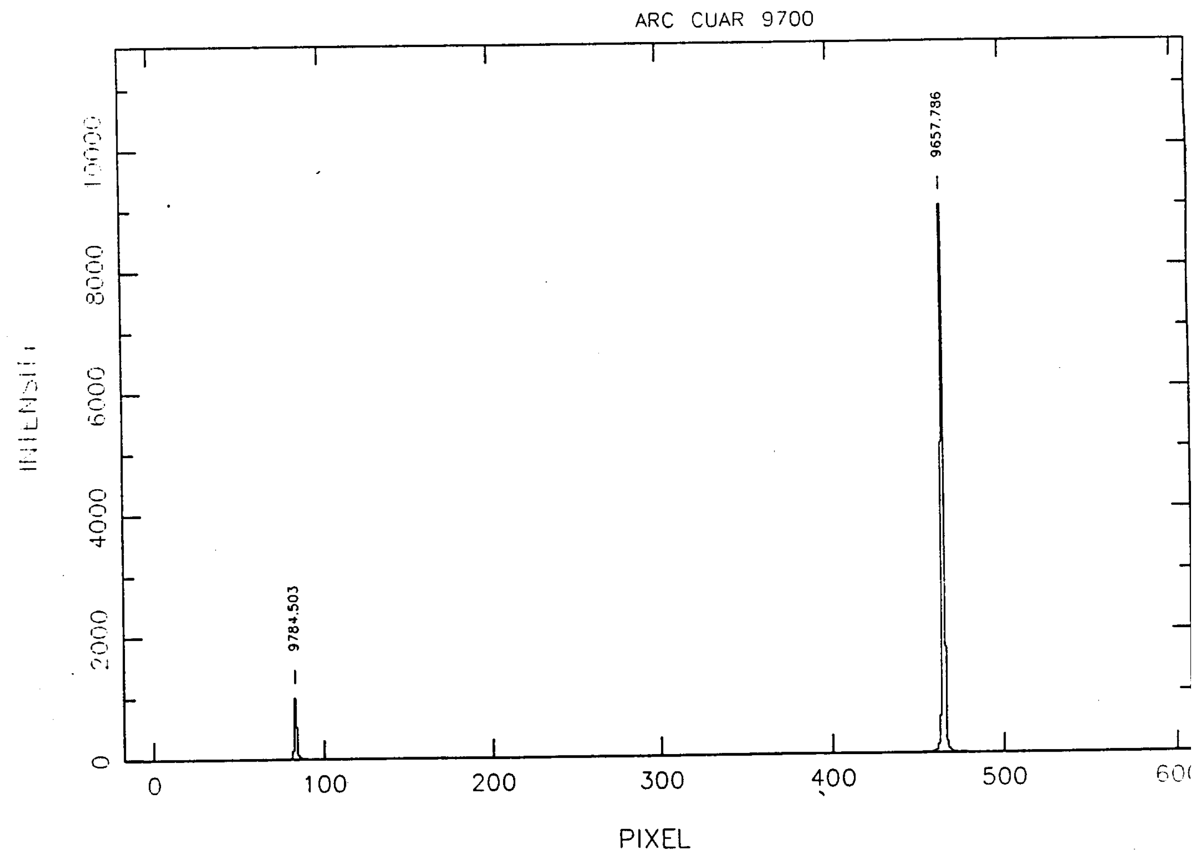
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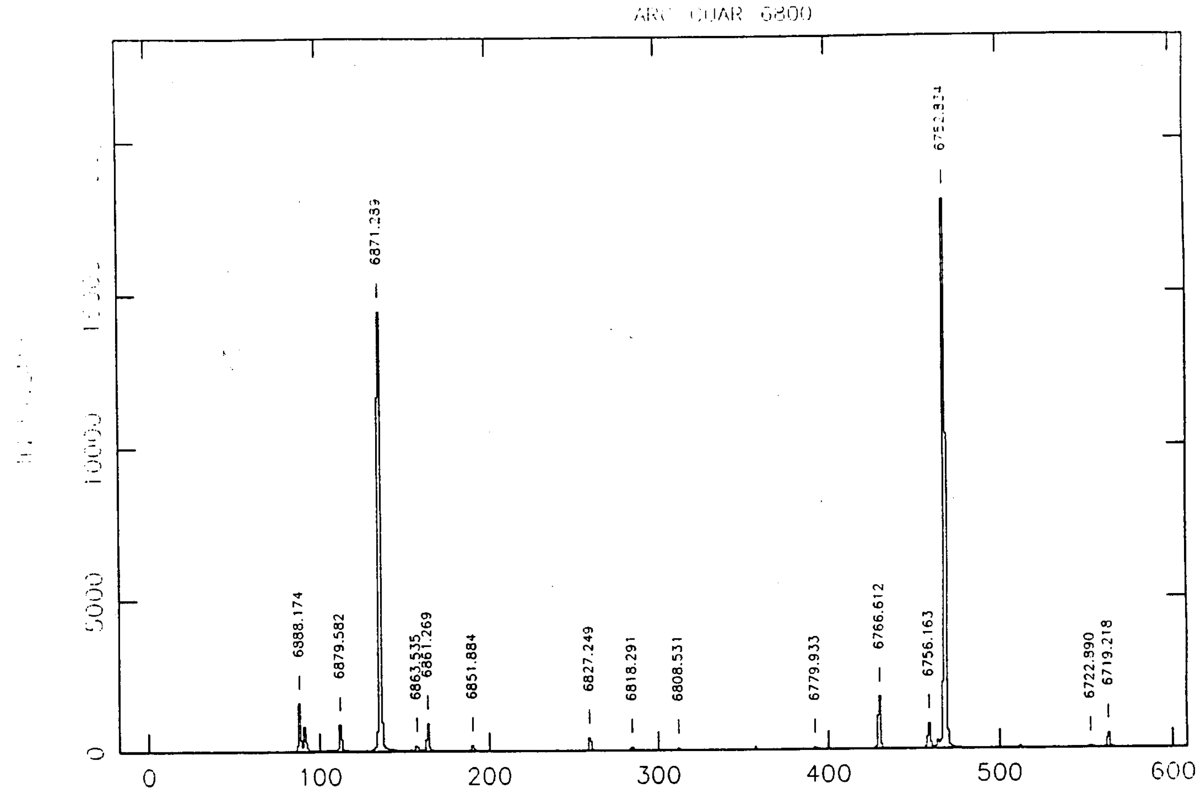
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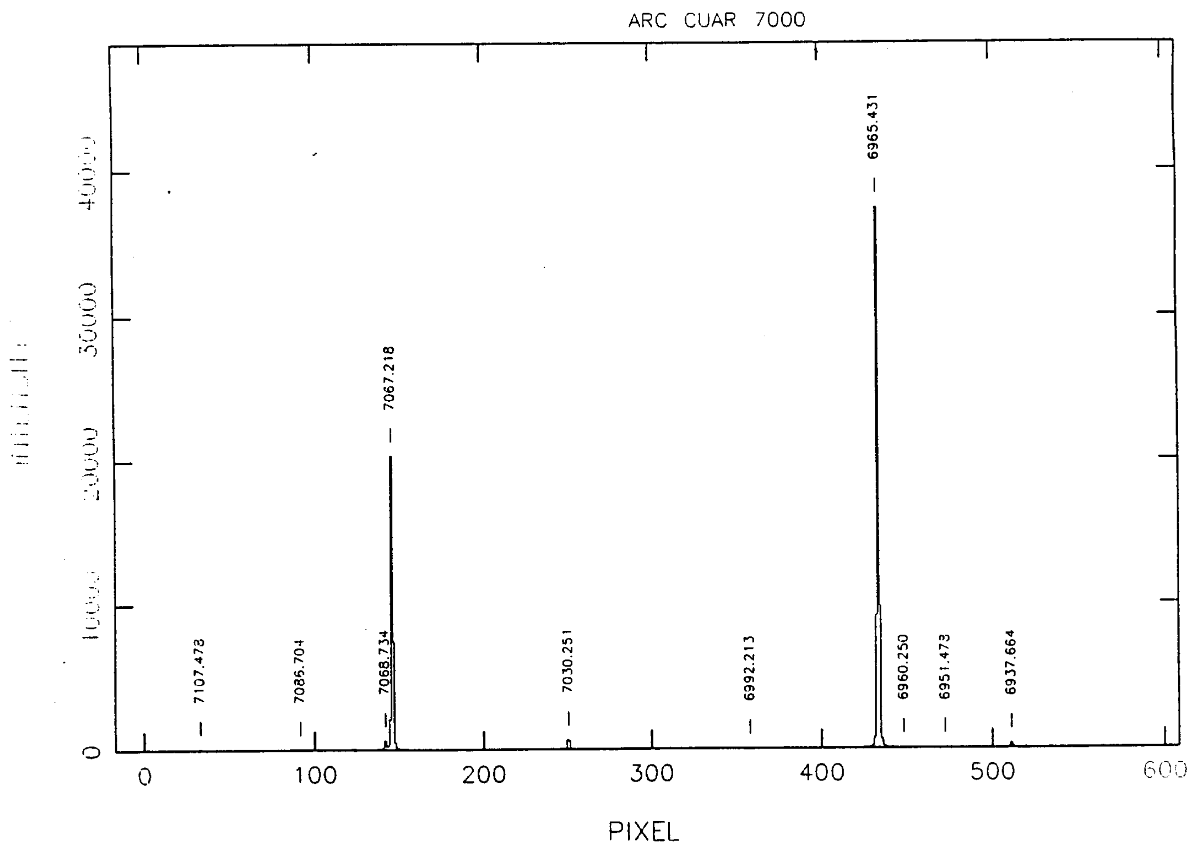
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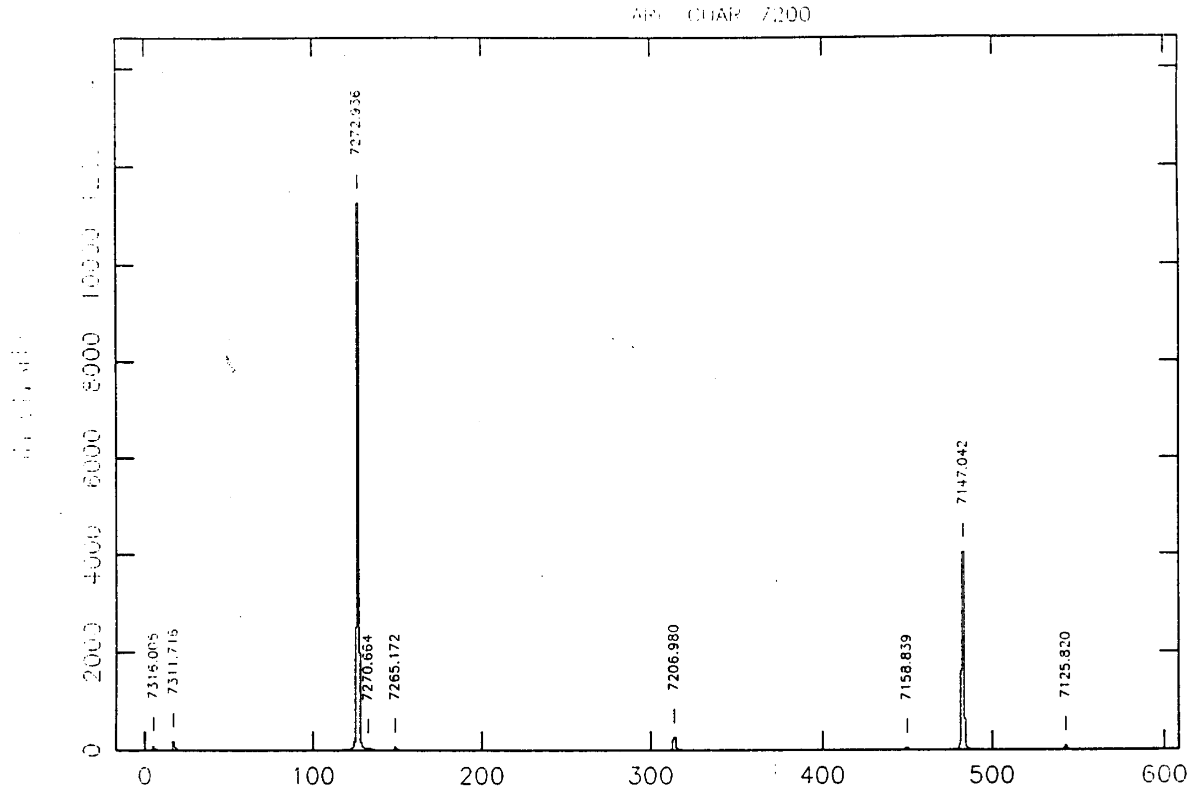
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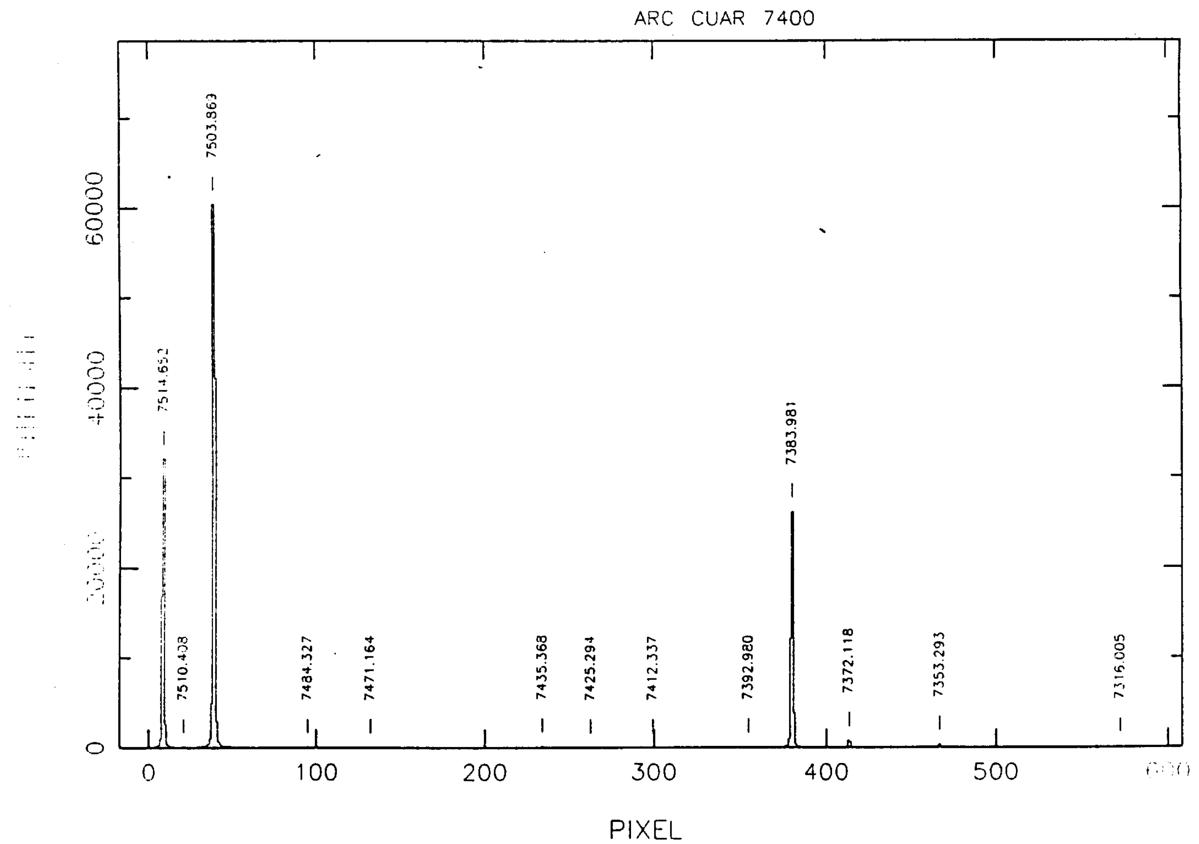
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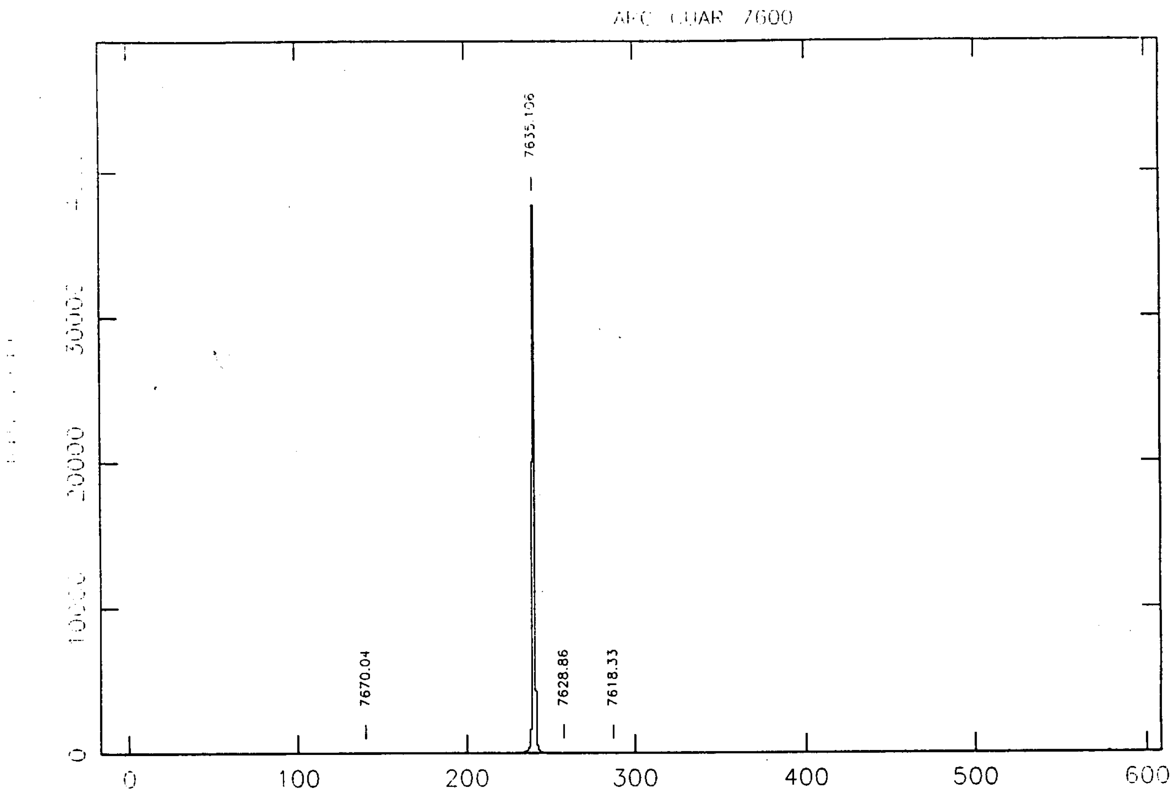
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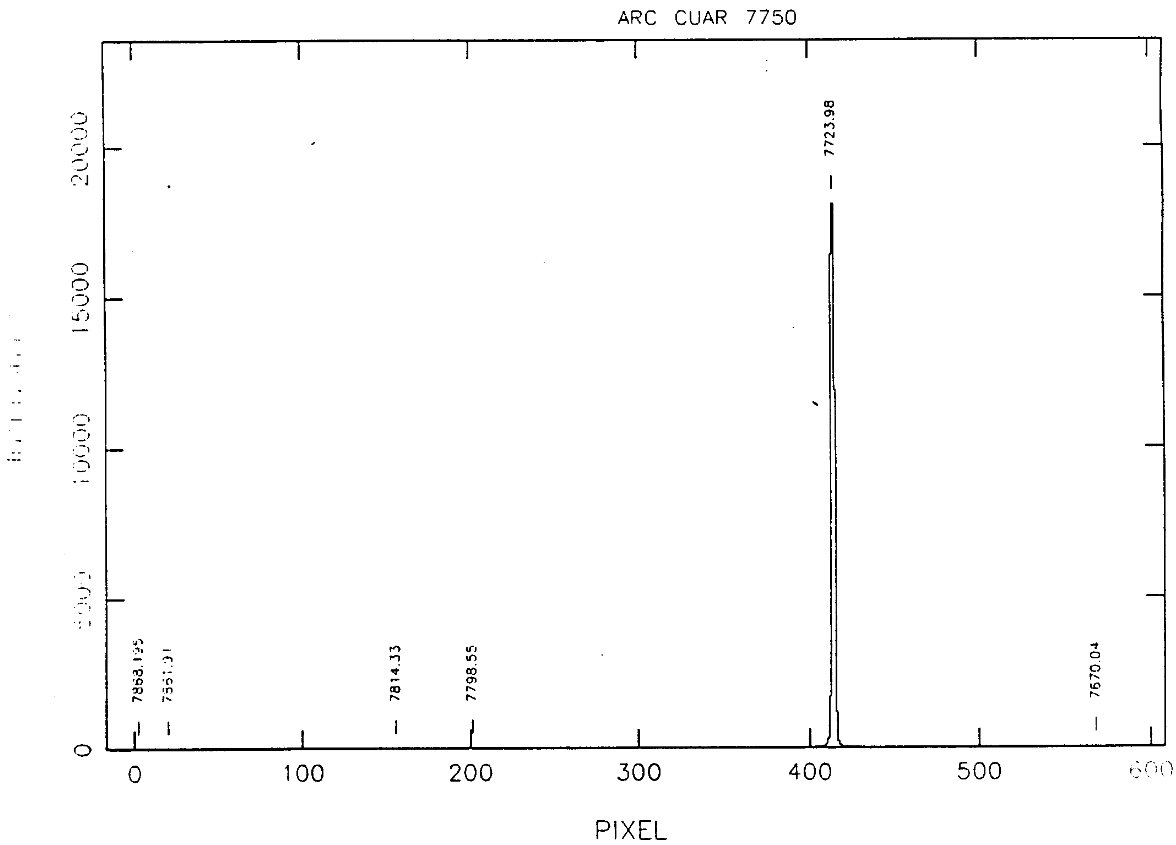
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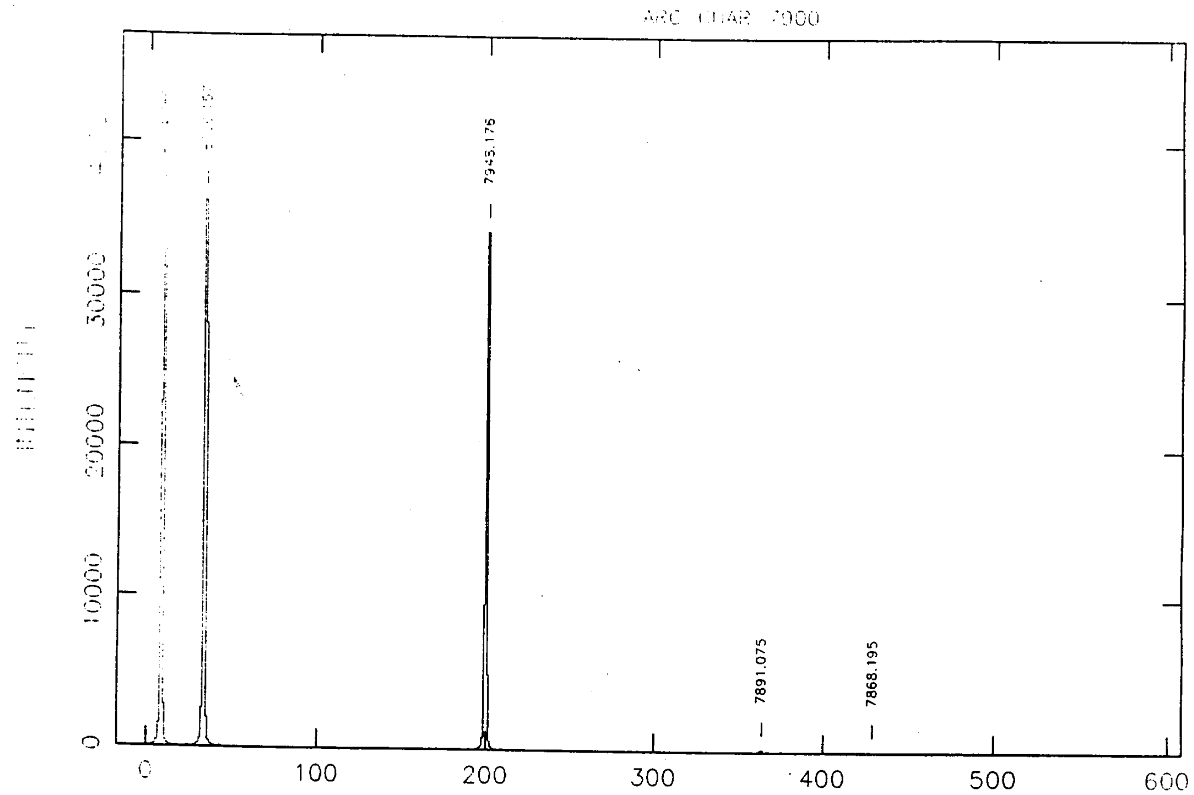
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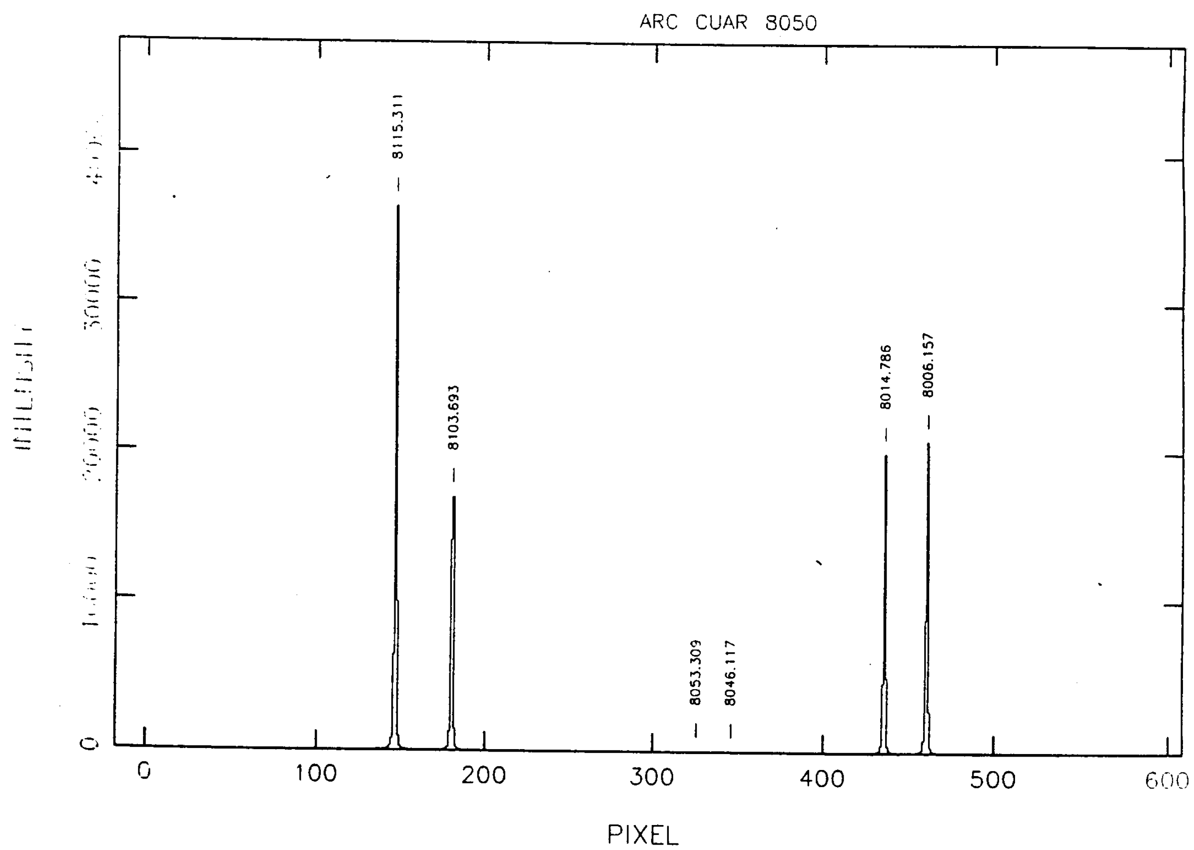
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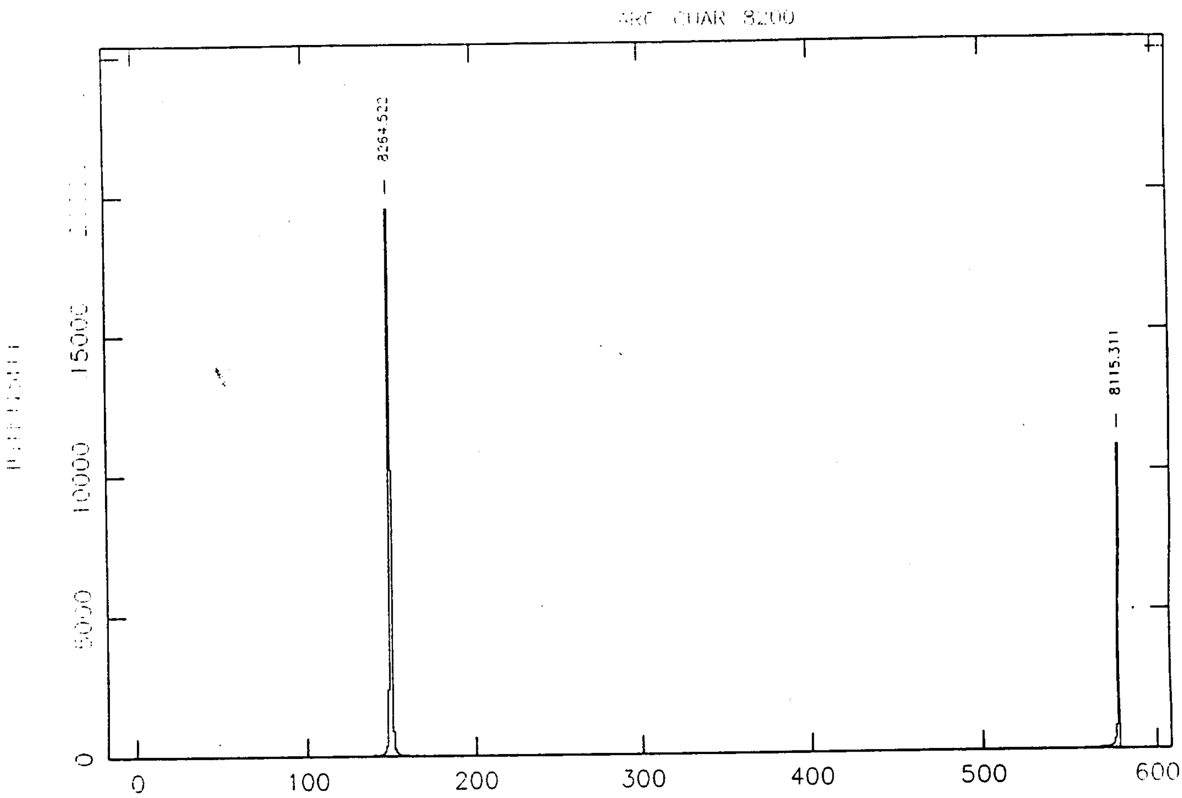
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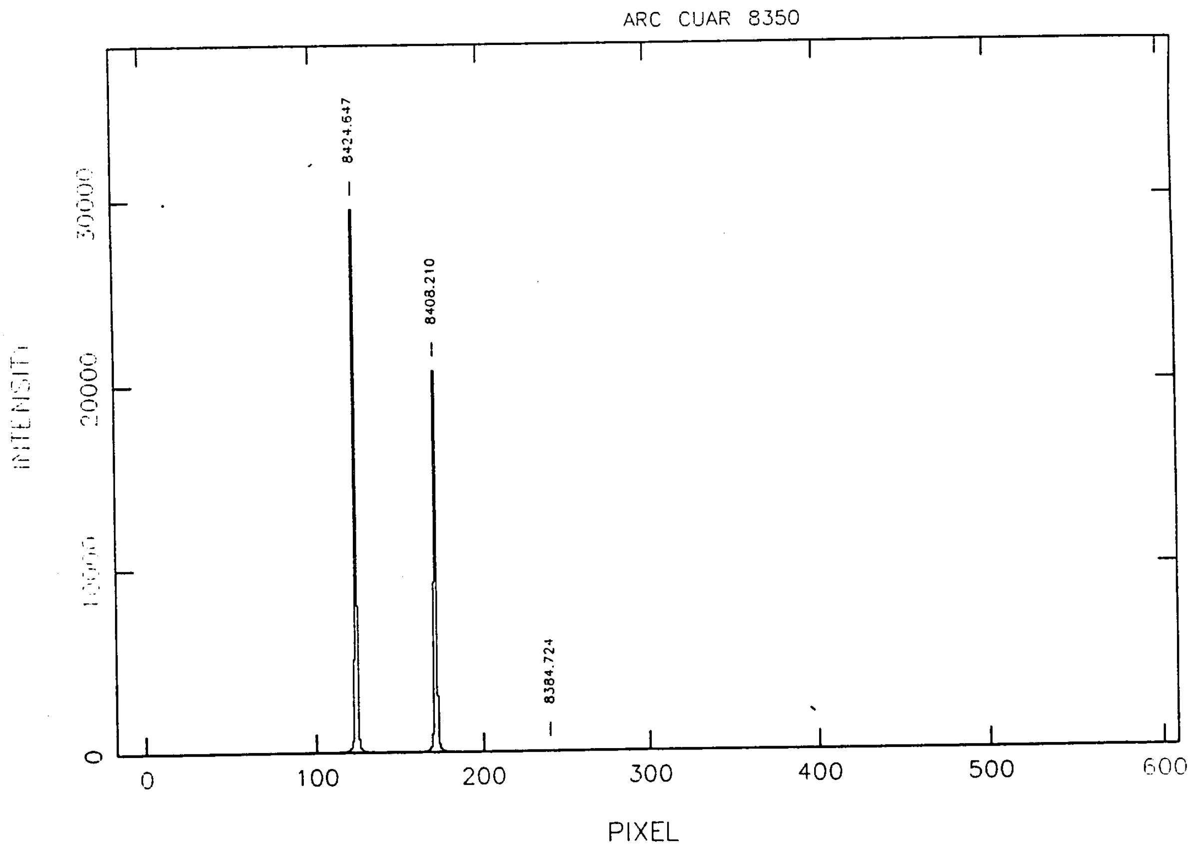
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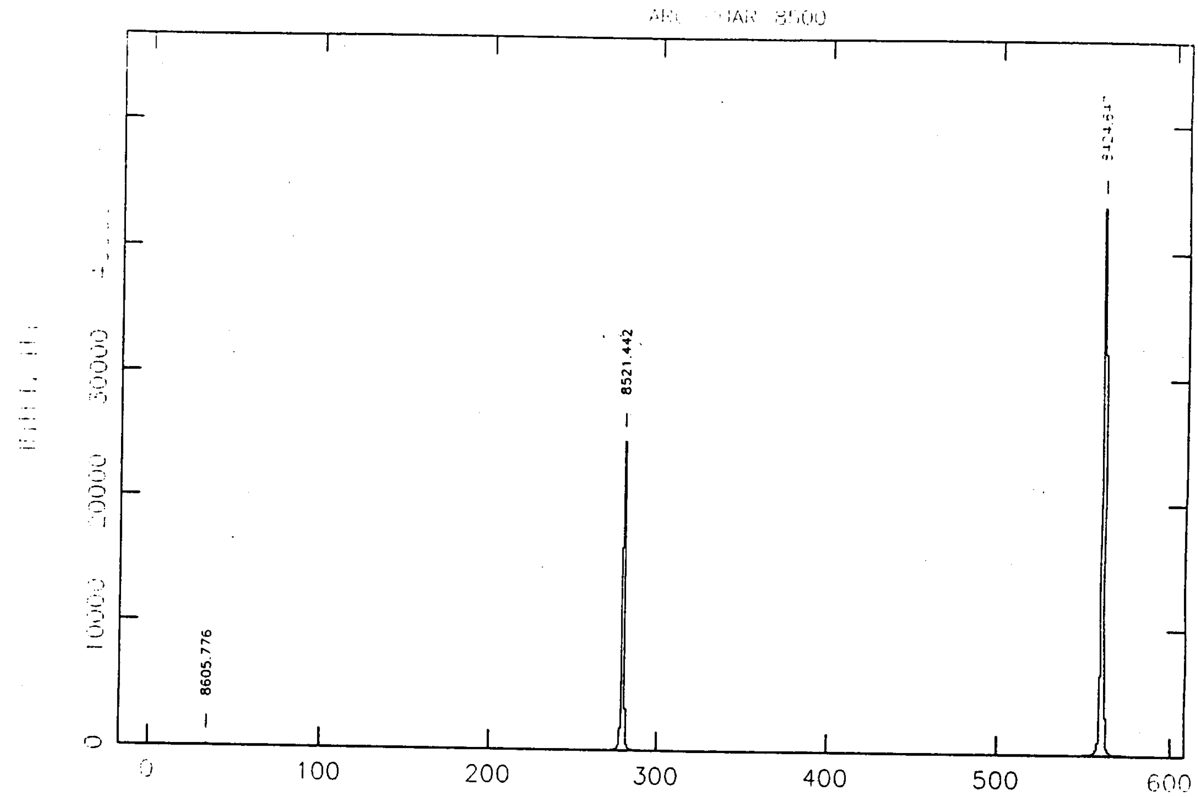
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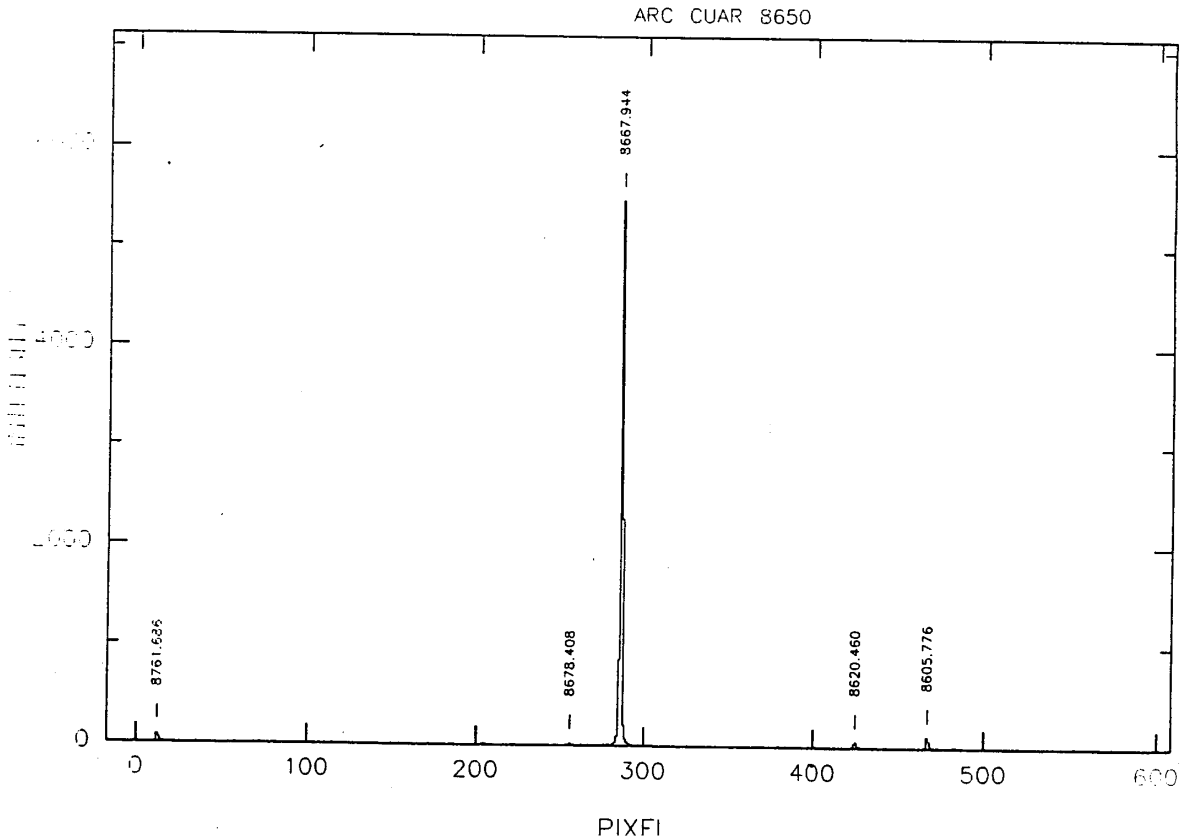
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