OPTICAL IDENTIFICATION AND SPECTROSCOPY OF X-RAY SOURCES PRECISELY POSITIONED WITH A-3

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As we heard in this morning's review by Roger Doxsey and Dan Schwartz, the main purpose of the scanning modulation collimator on HEAO-1 is in the optical identification of X-ray sources by means of precise positioning. Figure 1 shows a list of those optical observers who collaborated with us in obtaining optical identifications. In particular I would like to draw your attention to the work of Phil Charles and John Thorstensen of Berkeley, who have observed on multiple occasions at Lick and at Cerro-Tololo Inter-American Observatory in Chile and have obtained several galactic counterparts. The same is true of Josh Grindlay working with Claude Canizares and Jeff McClintock of MIT, also working at the CTIO and partly at Kitt Peak. Bruce Margon of UCLA has also observed at Lick on a number of occasions in collaboration with us, Andrew Wilson, Martin Ward, and others at the Anglo-Australian telescope and also at Kitt Peak. We have collaborated with optical observers at all major telescopes in the southern hemisphere, that is telescopes in the 4 meter class, viz. those at Cerro-Telolo, the Anglo-Australian telescope, and the European Southern Observatory (also in Chile). In the northern hemisphere we collaborated with people largely at Lick, Kitt Peak, and partly at the Royan Greenwich Observatory.

Rather than try to summarize the optical identifications that we have made so far, I would rather describe a couple of the more interesting galactic identifications, 4U2129+47 and 2A0311-227. The error box for the 4U source is shown in Figure 2: the plates were taken at Lick observatory by Charles and Thorstensen. You will immediately notice that the object indicated here has an ultraviolet excess (these are the blue and ultraviolet plates). Further plates established that the indicated star is in fact variable and monitoring the source with the Lick 3 meter reflector and image tube scanner for 5 hours on September 8 last year clearly resulted in a sinusoidal type of modulation, establishing it as a binary with a 5.2 hour period (Fig. 4). Folding the photographic photometry data with this period, the same result is apparent with a peak-to-peak amplitude of just over 1 magnitude in B. A typical spectrum from the image tube scanner is shown in Figure 3. The object has a rather blue continuum with the characteristic emission lines from a galactic X-ray source; that is, helium II and the CIII/NIII blend. The optical light curve in Figure 4 is interpreted as due to the changing aspect of a late type star which is heated by the X-ray emission from the compact object, that is, the neutron star or white dwarf nearby.

The finding chart for 2A0311-227 is shown in Figure 5. The error box prefers the indicated star although we could not absolutely rule out two others. The indicated one did in fact turn out to be the counterpart. Lola Chaisson assembled the long term light curve from the Harvard plate stacks, and this is shown in Figure 6. There is clearly variability during the years plotted, with a peak at 15th magnitude and a minimum at about 17th. There was some difficulty in assembling this light curve because of proximity of the star just 18 arc sec to the west of the candidate. A spectrum of the candidate taken at the Anglo-Australian telescope late last year (78) (Fig. 7) shows that it is in fact one of the richest emission line spectra of any galactic X-ray source with the exception of AM Herculis, with which it is in fact identical. The Balmer series of hydrogen is seen very strongly in emission from Hα down to H9 and 10 with a strong Balmer continuum. There are also lines of helium I, carbon II and the usual CIII/NIII blend. What is most unusual about this spectrum is the ratio (the Balmer decrement) of Hα:Hβ:Hγ. Hα is normally 2 or 3 times as strong as Hβ. This anomaly has been explained in AM Herculis and is likewise explicable in 2A 0311-227 as due to collisional processes in a plasma with electron densities of approximately 10^{13} cm^{-3} in a region near the accretion column of a magnetic white dwarf. AM Herculis has of course been studied optically over the past two years and it has been established to be a magnetic white dwarf in a binary system.

Figure 8 shows the first extragalactic object, viz. NGC 526a which was also observed at the Anglo-Australian telescope (Fig. 9) and appears to be a Type 1 Seyfert galaxy, based on the fact that the Hα emission line has broad wings. It also has forbidden oxygen III lines and Hβ is relatively weak. Figure 10 is the spectrum of another Seyfert for which the X-ray source has been positioned by HEAO A-3. In fact, we thought it was a Seyfert nucleus in an elliptical galaxy since it has absorption lines characteristic of an elliptical but plate material from CTIO by Mark Philips has shown that it is, in fact, an SO galaxy.

Lastly, I am going to talk about Parkes 2155-304. Figure 11 shows the only A3 error box inside the NRL error box which Herb Friedman mentioned this morning. We asked Hjellming and others at the Very Large Array to obtain an improved position for the radio source which was initially catalogued approximately 30 arc sec north of the stellar object shown here. The refined position from the VLA shows the radio source to be coincident with this 14th magnitude optical object to within approximately 3 arc sec. We also collaborated with Santiago Tapia of the University of Arizona on this object to show that the object is polarized; polarization, in fact, varying as a function of time from about 7 percent in the blue in October 1978 down to about 3 percent in December (Fig. 11). Tapia also obtained a red plate of the object which shows diffuse emission, which you can just see on either side of this optical object (Fig. 11, right), but this diffuse image is not visible on the UK Schmidt blue plate (left). This diffuse emission on the red plate ia apparent when you compare it with the diffraction spikes which are barely visible on the two stars at the lower right. The long term light curve of this object, again assembled by Lola Chaisson, shows variability which is characteristic of BL Lac objects. The problem with BL Lac objects, however, is that it is very difficult to observe spectroscopic optical features. Figure 13 is a spectrum obtained on the 3.9 m AAT with integration time of about half an hour and showed nothing in the way of either emission or absorption features. Phil Charles may, however, have been more successful. He claims to have seen forbidden oxygen III in this spectrum, at a red shift of about .17. If the red shift is confirmed, this makes it one of the most luminous X-ray sources yet observed at approximately 10^{47} ergs/sec. The overall spectrum is shown on the final slide (Fig. 14) from the radio through to the X-ray region. Most of the data points were taken around November-December last year, with HEAO-A-2 data from November 1977. It is tempting to fit the overall spectrum with one smooth curve but until we get more data filling in the emission regions it is difficult to establish an overall mechanism.

OBSERVER	INSTITUTE	OBSERVATORY
P.A. Charles J. Thorstensen	University of California, Berkeley	Lick, CTIO
D. Crampton	Dominion Astrophysical Observatory	DAO
M. Davis J. Huchra	Center for Astrophysics	SAO (Mt. Hopkins)
J. Grindlay C. Canizares J. McClintock	Center for Astrophysics M.I.T.	CTIO, KPNO, McGraw Hill
A. Longmore D. Malin	Royal Observatory, Edinburgh	UK Schmidt (Australia)
W. Liller	Center for Astrophysics	CTIO
B. Margon	University of California, Los Angeles	Lick
S. Mayo J. Whelan B.A. Cooke I. McHardy	Institute of Astronomy University of Leicester	AAT, RGO
P. Murdin	Anglo-Australian Observatory	AAT
S. Tapia	University of Arizona	Steward Observatory
R.M. Thomas J. Greenhill D. Watts	University of Tasmania	AAT
J. van Paradijs	MIT, University of Amsterdam	ESO
M. Ward J.C. Blades A.S. Wilson	Institute of Astronomy Anglo-Australian Observatory University of Maryland	AAT, Mt. Stromlo KPNO

Figure 1

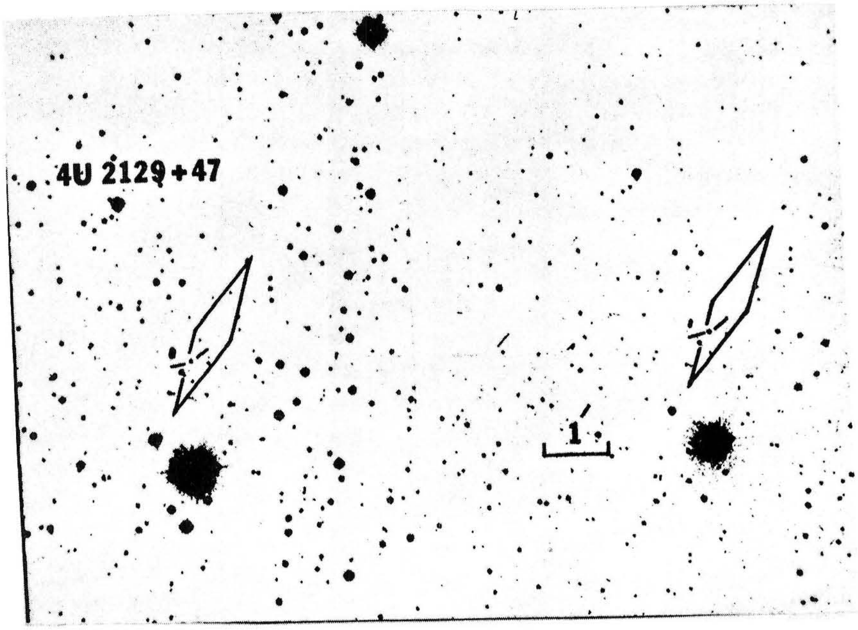


Figure 2

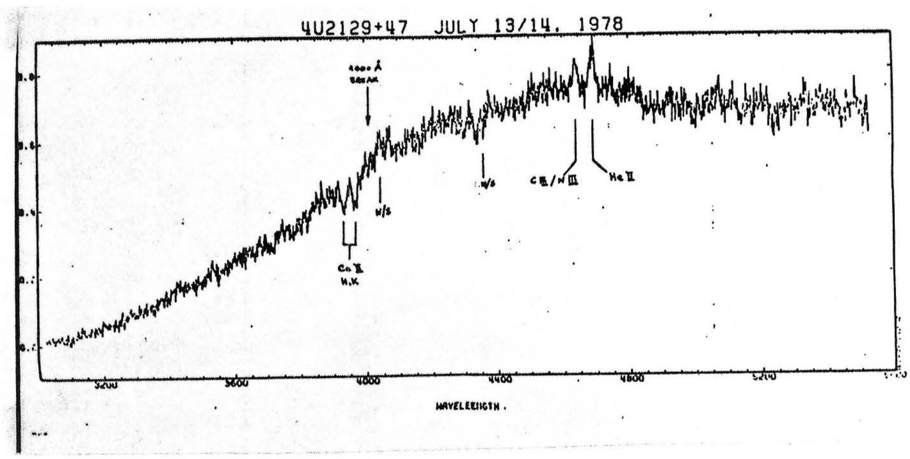


Figure 3

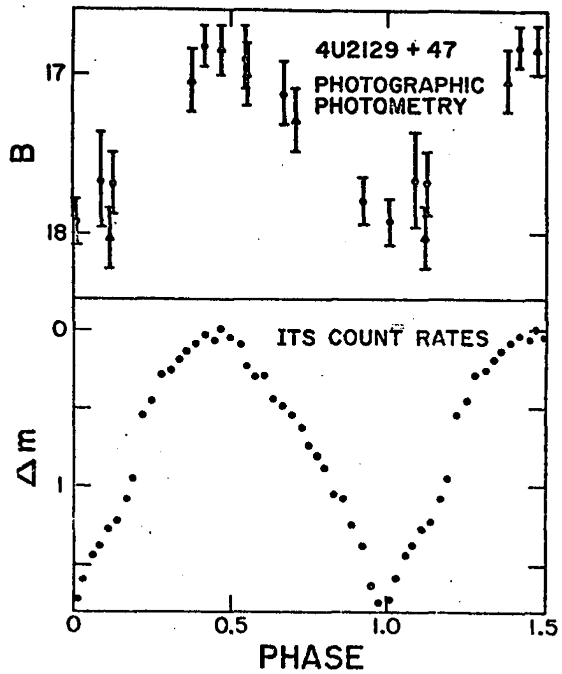


Figure 4

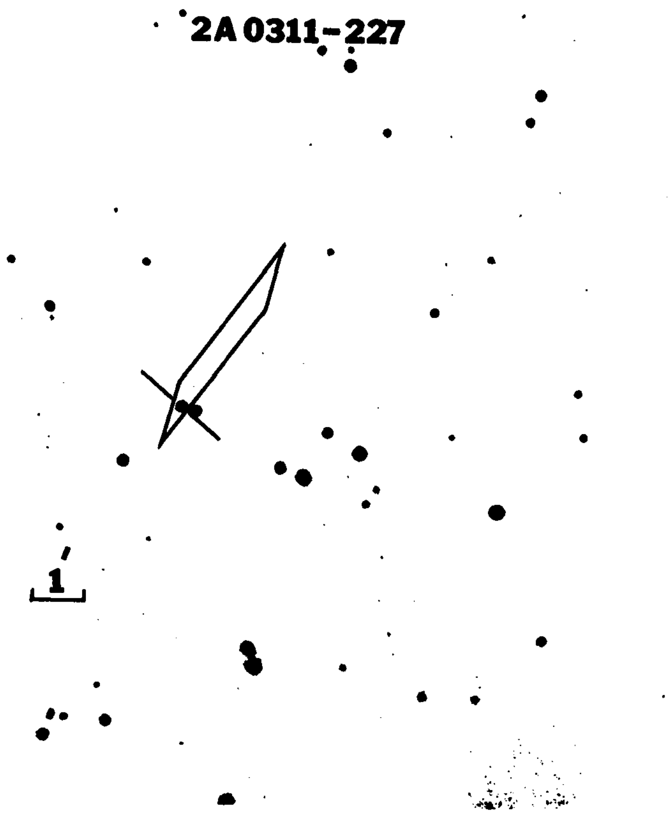


Figure 5

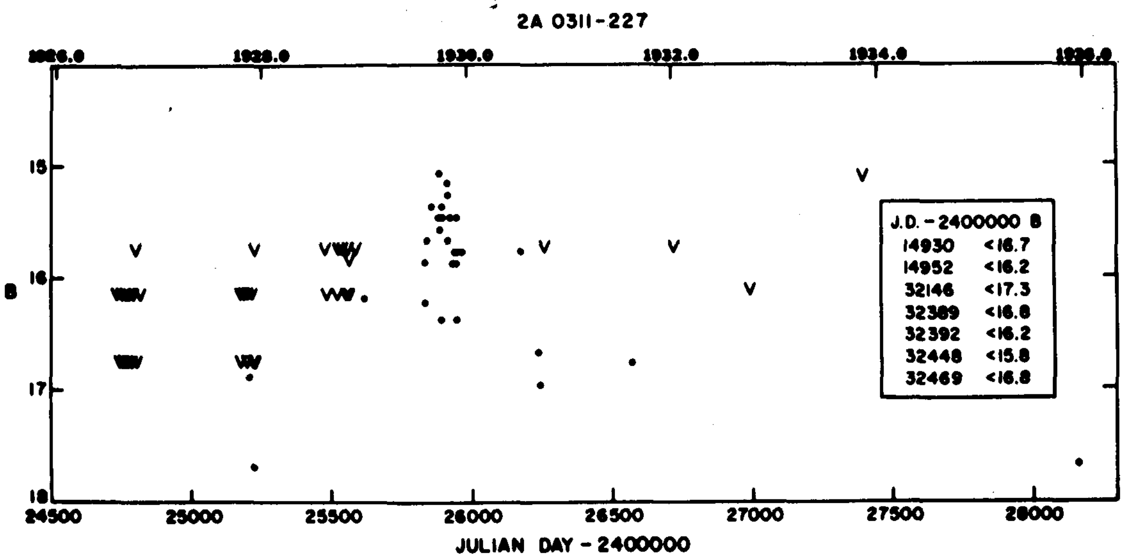


Figure 6

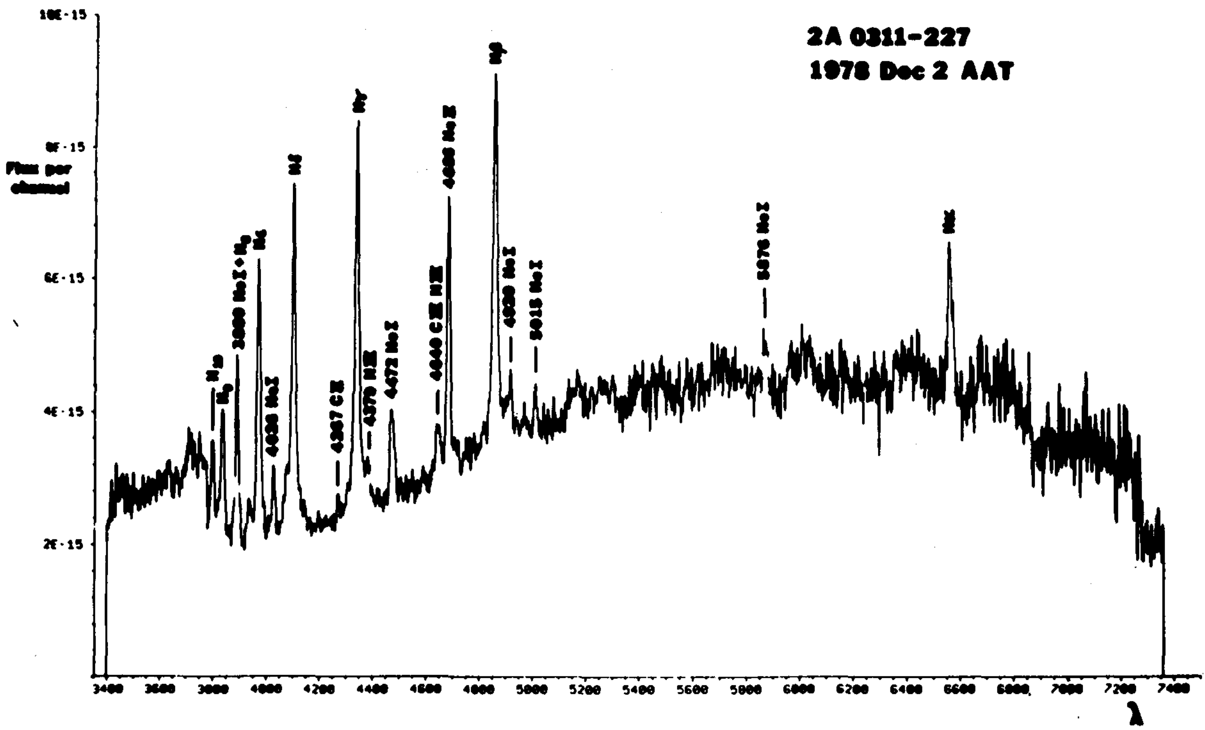


Figure 7

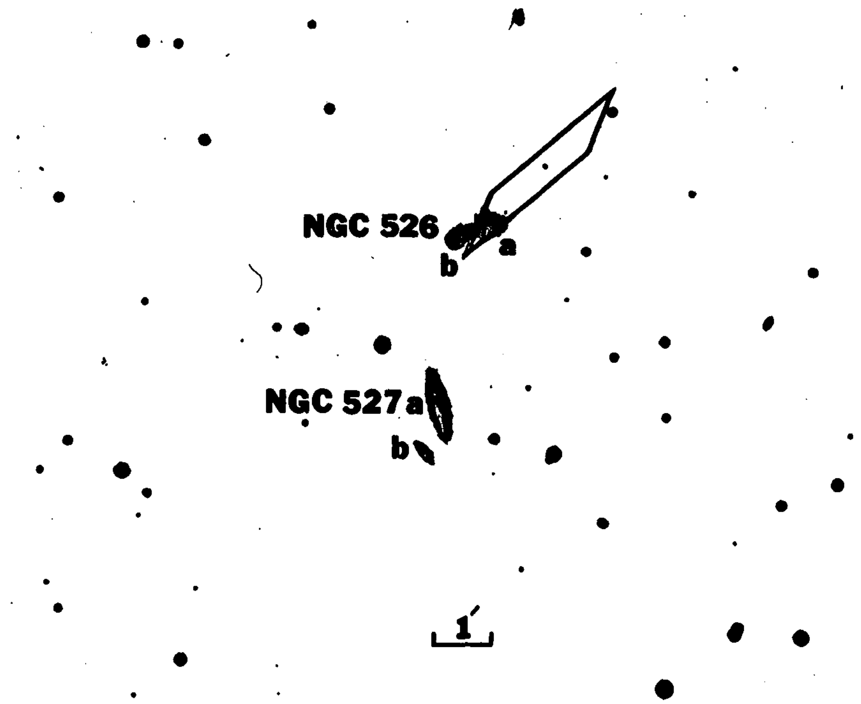


Figure 8

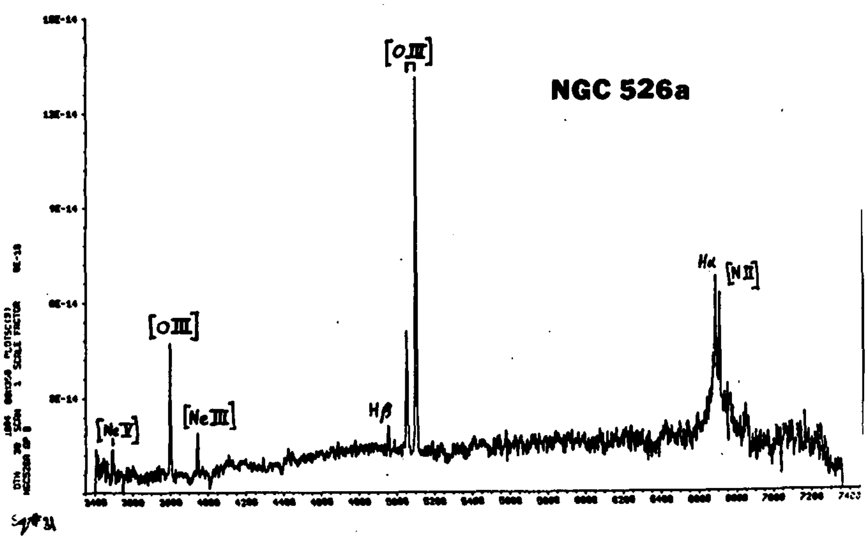


Figure 9

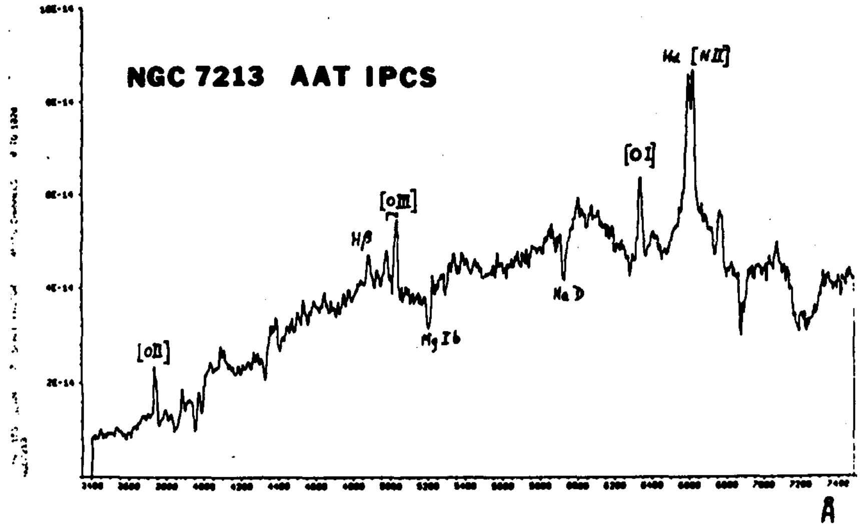


Figure 10

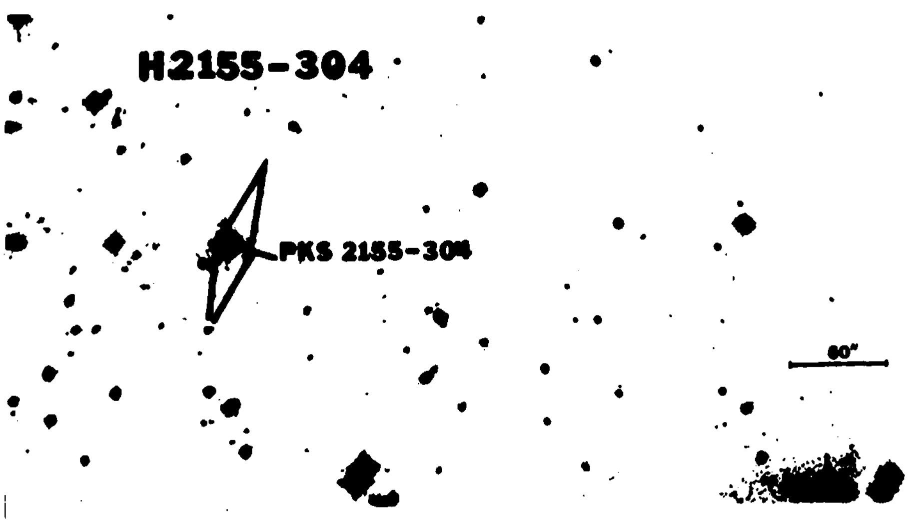


Figure 11

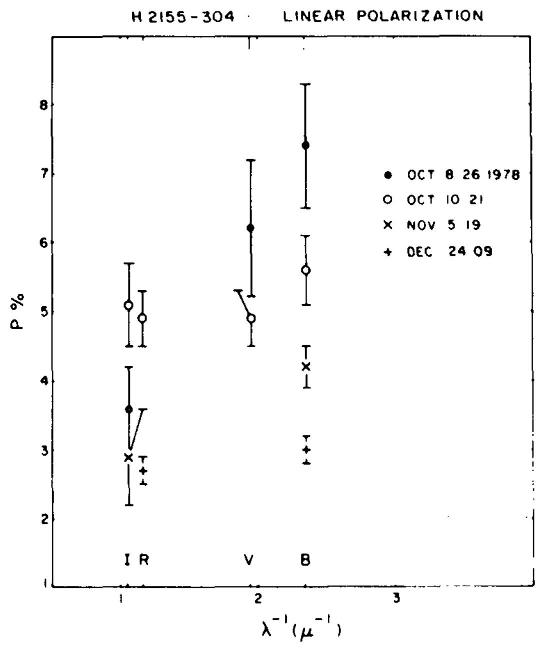


Figure 12

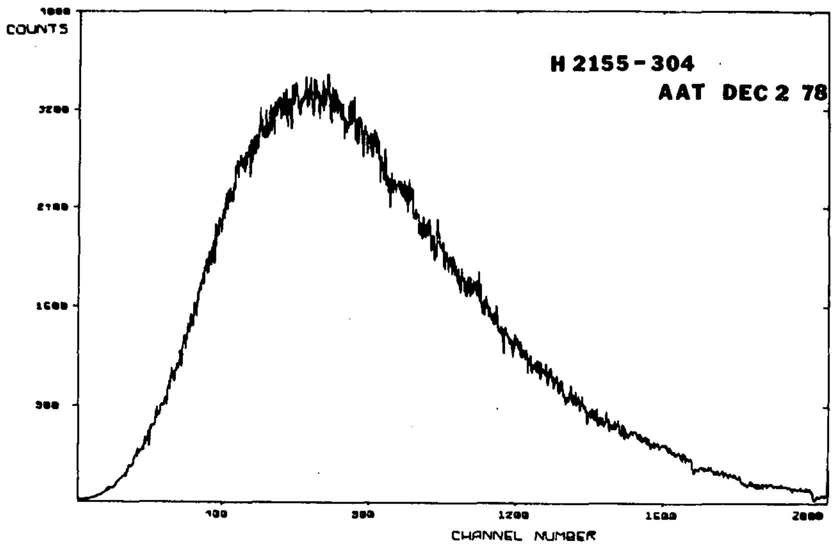
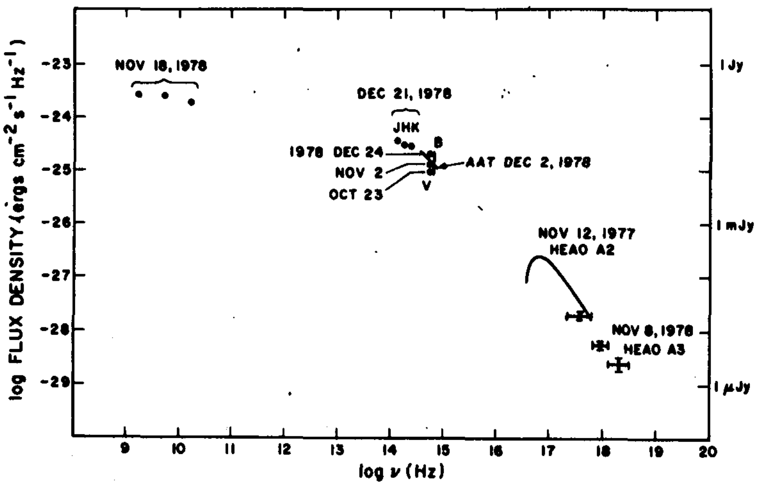


Figure 13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DEC 21, 1978
JHK
B
1978 DEC 24
NOV 2
OCT 23
V
AAT DEC 2, 1978
NOV 12, 1977
HEAO A2
NOV 8, 1978
HEAO A3
1 Jy
1 mJy
1 μJy
-23
-24
-25
-26
-27
-28
-29
log FLUX DENSITY (ergs cm^{-2} s^{-1} Hz^{-1})
9
10
11
12
13
14
15
16
17
18
19
20
log ν (Hz)

Figure 14