Research
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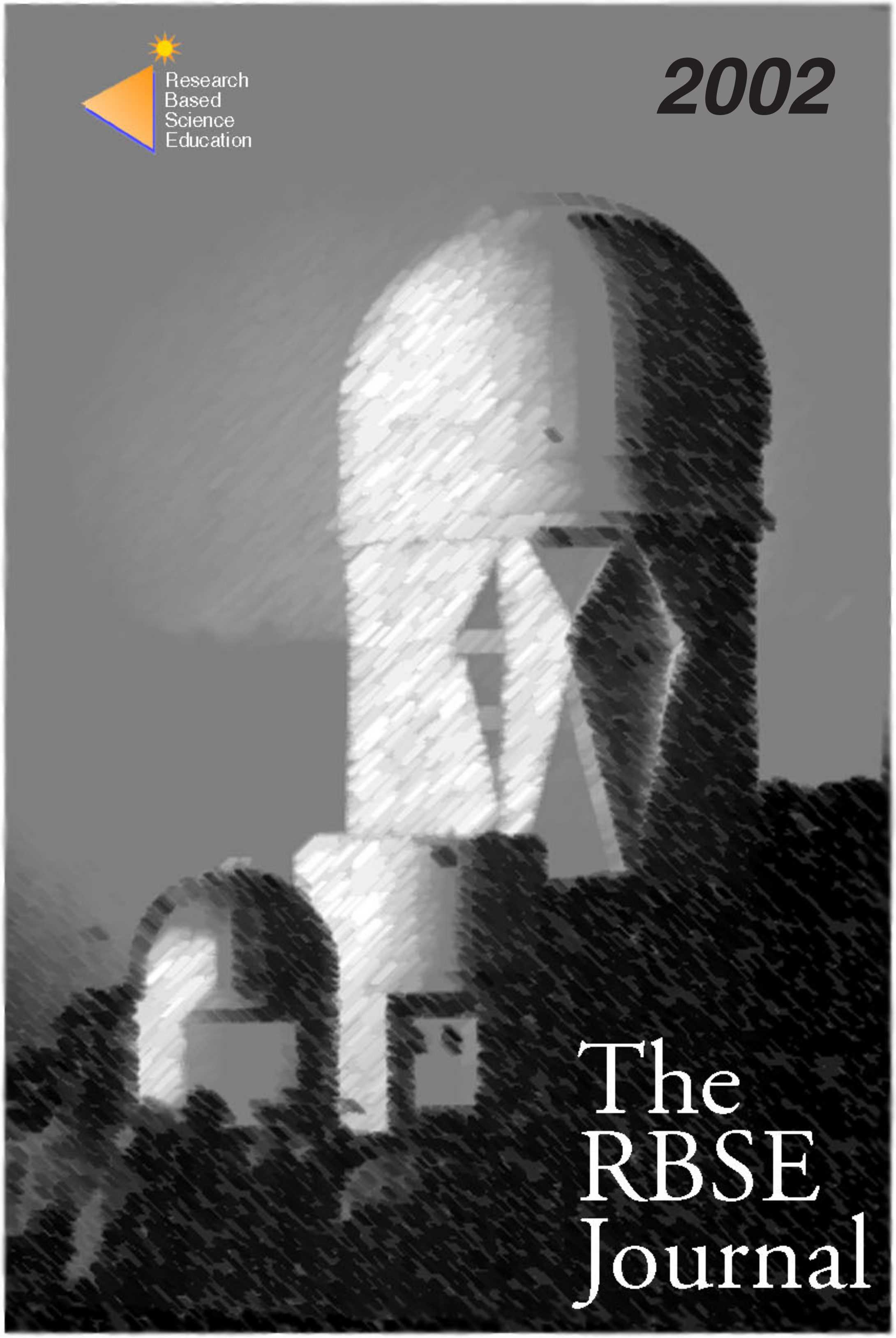
Education

2002



# The RBSE Journal

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# The RBSE Journal

## 2002

"Teacher Leaders in Research Based Science Education" (TLRBSE) is a Teacher Enhancement Program funded by the National Science Foundation. It consists of a distance learning course and a summer workshop for middle and high school teachers interested in incorporating leadership and research within their classes and school. TLRBSE brings the research experience to the classroom with materials, datasets, support and mentors during the academic year. The RBSE Journal is an annual publication intended to present the research of students participating in the TLRBSE program.

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# *Sunspot Movement According to the Initial Area*

Albert Anthony Cruz
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*Teacher: Cynthia Weehler, RBSE '00*

## *Abstract*

My interest in sunspots began with the opportunity to carryout my own research. We collaborated to develop a theory that a sunspot's speed of movement across the sun correlates with the area. I used the daily solar intensity images taken with the Kitt Peak Vacuum Telescope. I then measured the latitudes and longitude differences of the sunspots over a two-day period to calculate the distance traveled.

### *Purpose*

The intended purpose of my research is to determine whether a sunspot's area can be correlated to the distance a sunspot travels

### *Hypothesis*

I believe the area of a sunspot determines the distance a sunspot travels. I hypothesize that a sunspot of a larger area is likely to move less distance than a sunspot of less area.

### *Procedure*

The National Optical Astronomy Observatories supplied the data from the Kitt Peak Vacuum Telescope in the RBSE CD-ROM. I gathered the sunspot data by using the KPVT intensity images ranging from August 1st to December 1st.

Using the Scion Image program I measured the latitude, longitude, and area of every sunspot recorded. The longitudes and latitudes of each sunspot were taken initially and after a two-day period. This was necessary to determine the distance traveled.

Each sunspot's area was measured using the density slice option in square kilometers. The area index level of 70 on the LUT toolbar was used. The areas recorded for each sunspot was only taken initially and not at the two-day mark.

The initial and final longitude measurements were placed into this equation to account for the spherical surface of the sun's diameter at the latitude of the sunspot. The information was entered into Microsoft's Excel program to calculate the data.

Longitude difference/360

The initial longitude and final longitude equation was then combined to find the fraction of a full trip that the sunspot actually made.

(Longitude difference/360)*(2)*(3.14)*(695000)*(cosine (Latitude Mean)*((2*3.14)/360)))

The number 695000 is representative of the radius of the sun, and when calculating by radians the latitude must be multiplied by ((2*3.14)/360) this is important for the use of an excel spreadsheet.

The distances traveled by the sunspots were collected and sorted. Three groups were sorted according to the area of each sunspot.

Group1: 0.0 km2 -- 2.00*10^8 km2
Group2: 2.0*10^8 km2 -- 3.7*10^8 km2
Group3: 3.7*10^8 km2 -- 9.0*10^9 km2

The data was then graphed separately according to the area groups in chart 1. Chart 1 measures the amount of distance traveled for each sunspot recorded on the y-axis and the area of each sunspot on the x-axis. Each graphed line represents one of the sorted areas.

## Control and Error Analysis

The RBSE CD-ROM contained slight differences for all measurements when different degrees of the zoom option were used to collect data. All measurements were taken without the zoom in option, due to the fact of slight distortion of measurements.

Due to movement, a sunspot's shape changed; therefore the new location, area, and distance traveled may contain slight error in measurement. Missing data and distortion by interference lines contributed to the possibility of error.

## Conclusion

I have concluded that a sunspot's area does not appear to have any relation to the distance traveled. The graphical data shows no pattern between the two variables

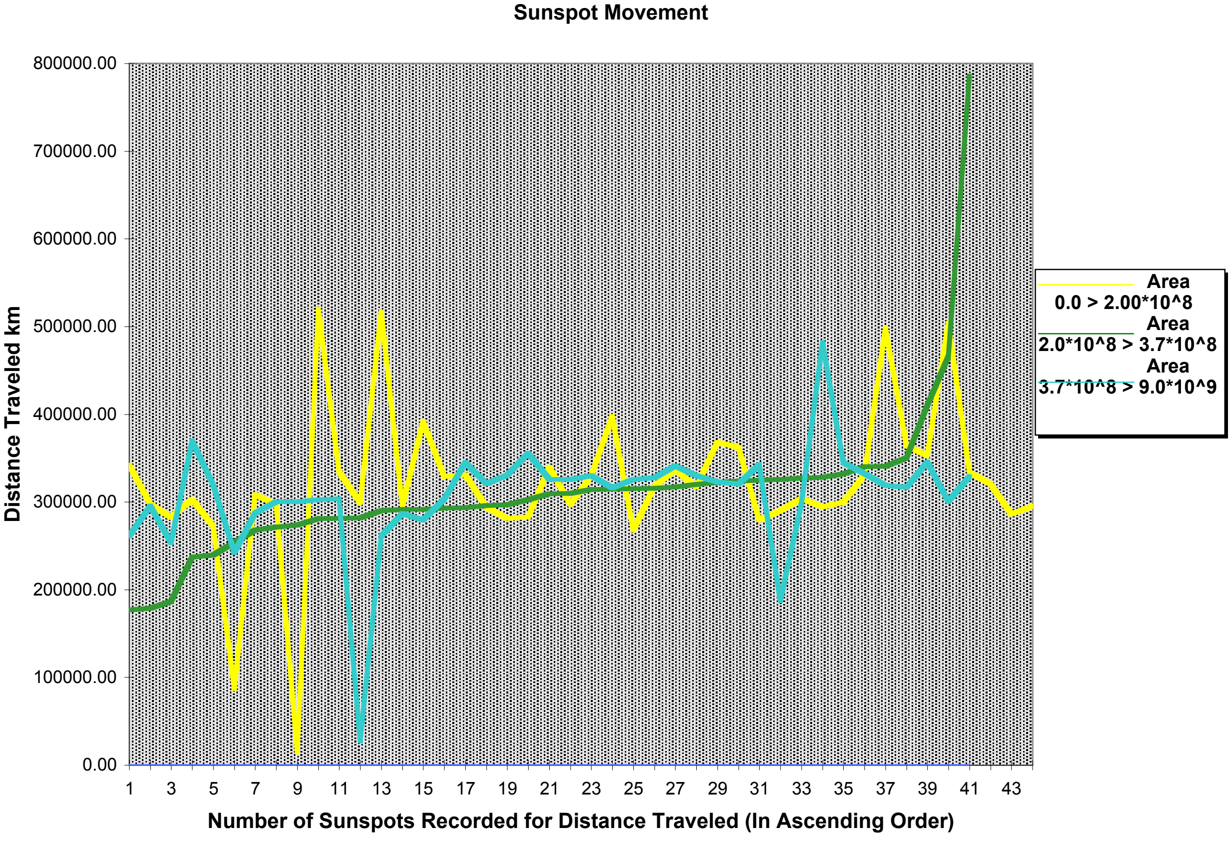
## Extension

I have justified my conclusion on limited data and would care to acquire more data to confirm my research. There is not a conclusive reason why sunspots of all sizes move in a natural or consistent pattern, which has raised more questions to be investigated.

## References

RBSE CD-ROM v6.5
Solar Telescope National Optical Astronomy Observatory (NOAO)
Dr. Rector, Travis and Dr. Kendall, Larrs--Research-Based Science Education NOAO
Mrs. Weehler, Research Inspiration

Chart1



## Group 1

| | Lat 1 | Lat 2 | **Lat Mean** | Long 1 | Long 2 | **Long Diff** | **Area** |
|---|---|---|---|---|---|---|---|
| 10 | -13.3 | -13.8 | **-13.6** | 26.7 | -2.3 | **29.0** | 2030000.00 |
| 9 | -22.0 | -23.4 | **-22.7** | -5.6 | 21.0 | **26.6** | 13300000.00 |
| 7 | -17.8 | -18.6 | **-18.2** | -1.4 | 23.1 | **24.5** | 25300000.00 |
| 5 | -13.3 | -13.5 | **-13.4** | -2.4 | 23.3 | **25.7** | 27500000.00 |
| 11 | -9.8 | -10.7 | **-10.3** | -27.3 | -4.5 | **22.8** | 30400000.00 |
| 26 | 10.0 | 10.9 | **10.5** | 31.7 | 24.4 | **7.3** | 36000000.00 |
| 101 | -9.6 | -9.6 | **-9.6** | -7.4 | 18.4 | **25.8** | 36400000.00 |
| 8 | -22.1 | -22.4 | **-22.3** | -3.4 | 23.1 | **26.5** | 36500000.00 |
| 27 | 21.7 | 19.9 | **20.8** | -57.3 | -56.0 | **1.3** | 37800000.00 |
| 17 | 16.7 | 15.4 | **16.1** | -51.2 | -6.6 | **44.6** | 40000000.00 |
| 90 | -5.7 | -5.5 | **-5.6** | 11.8 | 39.5 | **27.7** | 46000000.00 |
| 86 | -8.6 | -7.2 | **-7.9** | -36.8 | -11.9 | **24.9** | 47000000.00 |
| 21 | -9.9 | -10.9 | **-10.4** | -13.4 | 29.9 | **43.3** | 49100000.00 |
| 113 | 12.3 | 13.0 | **12.7** | 15.1 | 40.0 | **24.9** | 49900000.00 |
| 20 | -9.2 | -8.6 | **-8.9** | -9.5 | 23.2 | **32.7** | 51200000.00 |
| 34 | 12.7 | 12.6 | **12.7** | -54.9 | -27.1 | **27.8** | 57300000.00 |
| 1 | 13.4 | 12.7 | **13.1** | -29.7 | -1.7 | **28.0** | 61600000.00 |
| 87 | -7.2 | -5.9 | **-6.6** | -39.4 | -15.0 | **24.4** | 67100000.00 |
| 12 | -14.5 | -15.5 | **-15.0** | -38.0 | -14.0 | **24.0** | 67600000.00 |
| 48 | -28.0 | -27.8 | **-27.9** | -30.7 | -4.3 | **26.4** | 68300000.00 |
| 122 | -7.1 | -5.8 | **-6.5** | -15.8 | 12.4 | **28.2** | 70600000.00 |
| 88 | -9.7 | -7.7 | **-8.7** | -38.8 | -14.0 | **24.8** | 71300000.00 |
| 89 | 25.3 | 24.8 | **25.1** | 28.6 | 58.6 | **30.0** | 77600000.00 |
| 66 | -3.1 | -1.4 | **-2.3** | -29.5 | 3.3 | **32.8** | 78700000.00 |
| 30 | -34.1 | -31.6 | **-32.9** | -32.1 | -5.8 | **26.3** | 79200000.00 |
| 112 | 12.6 | 13.6 | **13.1** | 16.7 | 43.6 | **26.9** | 83900000.00 |
| 49 | 10.0 | 10.5 | **10.3** | -47.5 | -19.3 | **28.2** | 84600000.00 |
| 93 | -20.0 | -19.9 | **-20.0** | -10.7 | 17.1 | **27.8** | 85300000.00 |
| 65 | 14.1 | 17.0 | **15.6** | -45.7 | -14.2 | **31.5** | 86800000.00 |
| 67 | -2.5 | -2.3 | **-2.4** | -34.3 | -4.4 | **29.9** | 100000000.00 |
| 111 | 27.0 | 27.4 | **27.2** | -9.2 | 16.7 | **25.9** | 110000000.00 |
| 54 | -14.5 | -15.9 | **-15.2** | -12.5 | 12.3 | **24.8** | 110000000.00 |
| 81 | -18.0 | -18.8 | **-18.4** | -30.1 | -3.7 | **26.4** | 115000000.00 |
| 40 | 18.3 | 18.9 | **18.6** | -10.6 | 15.0 | **25.6** | 116000000.00 |
| 80 | -18.4 | -17.7 | **-18.1** | -27.3 | -1.3 | **26.0** | 123000000.00 |
| 108 | 14.7 | 14.8 | **14.8** | -54.4 | -26.2 | **28.2** | 127000000.00 |
| 18 | -15.2 | -15.7 | **-15.5** | 3.7 | 46.3 | **42.6** | 127000000.00 |
| 3 | 12.3 | 13.4 | **12.9** | 46.3 | 77.1 | **30.8** | 128000000.00 |
| 28 | 28.1 | 25.0 | **26.6** | -77.9 | -45.4 | **32.5** | 132000000.00 |
| 16 | 15.6 | 14.1 | **14.9** | -46.1 | -3.1 | **43.0** | 133000000.00 |
| 78 | -9.5 | -9.1 | **-9.3** | 7.8 | 35.7 | **27.9** | 137000000.00 |
| 105 | 17.7 | -18.2 | **-0.3** | -29.5 | -3.1 | **26.4** | 138000000.00 |
| 23 | 24.6 | 24.9 | **24.8** | -41.7 | -15.7 | **26.0** | 147000000.00 |
| 60 | 14.0 | 14.0 | **14.0** | 24.9 | 50.0 | **25.1** | 147000000.00 |

## Group 2

| | Lat 1 | Lat 2 | **Lat Mean** | Long 1 | Long 2 | **Long Diff** | **Area** |
|---|---|---|---|---|---|---|---|
| 85 | -12.9 | -91.2 | **-52.1** | 5.7 | 29.4 | **23.7** | 246000000.00 |
| 125 | -8.8 | -9.0 | **-8.9** | -26.1 | -11.2 | **14.9** | 366000000.00 |
| 126 | -7.1 | -7.2 | **-7.2** | -19.7 | -4.2 | **15.5** | 260000000.00 |
| 25 | -30.9 | -31.9 | **-31.4** | -7.1 | 15.8 | **22.9** | 196000000.00 |
| 71 | -9.1 | -8.6 | **-8.9** | 41.7 | 61.7 | **20.0** | 278000000.00 |
| 24 | -29.0 | -29.5 | **-29.3** | 0.5 | 24.5 | **24.0** | 265000000.00 |
| 68 | -10.7 | -10.9 | **-10.8** | -57.2 | -34.7 | **22.5** | 367000000.00 |
| 13 | -15.9 | -16.6 | **-16.3** | -44.3 | -21.0 | **23.3** | 217000000.00 |
| 33 | -25.8 | -25.4 | **-25.6** | -40.0 | -15.0 | **25.0** | 243000000.00 |
| 107 | -20.4 | -21.4 | **-20.9** | -39.6 | -14.8 | **24.8** | 359000000.00 |
| 42 | 29.9 | 30.2 | **30.1** | 32.4 | 59.2 | **26.8** | 369000000.00 |
| 84 | 8.4 | 8.8 | **8.6** | 48.3 | 71.8 | **23.5** | 223000000.00 |
| 103 | 26.9 | 26.9 | **26.9** | -62.7 | -35.9 | **26.8** | 344000000.00 |
| 116 | 16.9 | 16.9 | **16.9** | -12.1 | 13.0 | **25.1** | 161000000.00 |
| 121 | 24.3 | 24.5 | **24.4** | -18.9 | 7.5 | **26.4** | 178000000.00 |
| 106 | -19.3 | -19.5 | **-19.4** | -35.4 | -9.8 | **25.6** | 187000000.00 |
| 41 | 26.6 | 26.9 | **26.8** | 41.1 | 68.2 | **27.1** | 227000000.00 |
| 53 | -16.7 | -16.0 | **-16.4** | -9.6 | 15.8 | **25.4** | 174000000.00 |
| 47 | -16.1 | -16.3 | **-16.2** | 18.4 | 43.9 | **25.5** | 164000000.00 |
| 74 | -7.8 | -7.9 | **-7.9** | -20.7 | 4.5 | **25.2** | 368000000.00 |
| 37 | 14.8 | 16.8 | **15.8** | -60.9 | -34.4 | **26.5** | 263000000.00 |
| 91 | -18.8 | -18.9 | **-18.9** | -10.9 | 16.1 | **27.0** | 356000000.00 |
| 46 | 15.2 | -15.7 | **-0.3** | 15.5 | 41.4 | **25.9** | 199000000.00 |
| 62 | 13.3 | 14.4 | **13.9** | -52.5 | -25.8 | **26.7** | 158000000.00 |
| 72 | 16.3 | 16.6 | **16.5** | -9.2 | 17.9 | **27.1** | 224000000.00 |
| 44 | 12.9 | 13.3 | **13.1** | 21.6 | 48.3 | **26.7** | 359000000.00 |
| 63 | 12.3 | 13.1 | **12.7** | -52.8 | -26.0 | **26.8** | 205000000.00 |
| 45 | -5.4 | -5.7 | **-5.6** | -8.5 | 18.0 | **26.5** | 151000000.00 |
| 114 | 8.9 | 9.1 | **9.0** | 32.8 | 59.7 | **26.9** | 218000000.00 |
| 99 | -12.9 | -12.8 | **-12.9** | 17.8 | 45.2 | **27.4** | 336000000.00 |
| 100 | -8.8 | -8.9 | **-8.9** | 30.3 | 57.4 | **27.1** | 371000000.00 |
| 36 | 15.8 | 17.0 | **16.4** | -59.6 | -31.6 | **28.0** | 152000000.00 |
| 52 | -14.9 | -14.6 | **-14.8** | -7.2 | 20.7 | **27.9** | 288000000.00 |
| 56 | -10.4 | -9.9 | **-10.2** | -70.3 | -42.8 | **27.5** | 209000000.00 |
| 32 | -5.4 | -5.2 | **-5.3** | -15.0 | 12.5 | **27.5** | 297000000.00 |
| 14 | 14.3 | 13.9 | **14.1** | -41.6 | -70.5 | **28.9** | 297000000.00 |
| 50 | 21.9 | 22.3 | **22.1** | -82.8 | -52.5 | **30.3** | 288000000.00 |
| 29 | 30.7 | 26.7 | **28.7** | -82.8 | -49.9 | **32.9** | 192000000.00 |
| 124 | -9.7 | -9.4 | **-9.6** | -24.3 | 10.0 | **34.3** | 299000000.00 |
| 19 | -15.6 | -15.6 | **-15.6** | -0.9 | 39.0 | **39.9** | 155000000.00 |
| 76 | -10.3 | -9.9 | **-10.1** | -19.9 | 45.9 | **65.8** | 162000000.00 |

## Group 3

| | Lat 1 | Lat 2 | **Lat Mean** | Long 1 | Long 2 | **Long Diff** | **Area** |
|---|---|---|---|---|---|---|---|
| 120 | 24.2 | 24.8 | **24.5** | 13.3 | 15.8 | **2.5** | 470000000.00 |
| 123 | -8.4 | -8.3 | **-8.4** | -17.1 | -1.5 | **15.6** | 773000000.00 |
| 4 | 14.3 | 12.0 | **13.2** | 52.7 | 73.2 | **20.5** | 444000000.00 |
| 70 | -7.9 | -8.2 | **-8.1** | 46.3 | 67.4 | **21.1** | 394000000.00 |
| 57 | 11.5 | 10.0 | **10.8** | -3.4 | -25.3 | **21.9** | 384000000.00 |
| 69 | -11.5 | -12.0 | **-11.8** | 43.1 | 65.1 | **22.0** | 490000000.00 |
| 117 | -16.3 | -16.2 | **-16.3** | -62.8 | -38.8 | **24.0** | 520000000.00 |
| 22 | 23.7 | 23.7 | **23.7** | -35.9 | -10.1 | **25.8** | 504000000.00 |
| 6 | -16.2 | -17.0 | **-16.6** | -1.6 | 23.1 | **24.7** | 446000000.00 |
| 2 | 19.7 | 19.9 | **19.8** | -17.7 | 8.2 | **25.9** | 384000000.00 |
| 59 | 15.7 | 16.0 | **15.9** | -3.1 | 22.4 | **25.5** | 773000000.00 |
| 35 | 15.7 | 15.9 | **15.8** | -57.9 | -32.2 | **25.7** | 451000000.00 |
| 115 | 25.1 | 25.8 | **25.5** | -57.0 | -29.6 | **27.4** | 449000000.00 |
| 118 | 23.8 | 24.0 | **23.9** | 11.2 | 38.3 | **27.1** | 2430000000.00 |
| 38 | 14.2 | 15.5 | **14.9** | -66.3 | -40.5 | **25.8** | 455000000.00 |
| 77 | 32.4 | 32.6 | **32.5** | 41.4 | 71.0 | **29.6** | 521000000.00 |
| 83 | 7.8 | 8.5 | **8.2** | 41.4 | 66.7 | **25.3** | 461000000.00 |
| 102 | 9.6 | 9.1 | **9.4** | -21.1 | 5.3 | **26.4** | 630000000.00 |
| 119 | 13.0 | 13.1 | **13.1** | -51.5 | -24.7 | **26.8** | 1040000000.00 |
| 75 | -4.8 | -4.5 | **-4.7** | -43.6 | -17.2 | **26.4** | 1030000000.00 |
| 39 | 7.9 | 8.6 | **8.3** | -57.2 | -30.6 | **26.6** | 411000000.00 |
| 61 | 14.0 | 15.5 | **14.8** | -42.8 | -15.5 | **27.3** | 752000000.00 |
| 55 | -13.7 | -13.5 | **-13.6** | -64.4 | -37.2 | **27.2** | 544000000.00 |
| 98 | -7.0 | -6.9 | **-7.0** | 3.5 | 30.3 | **26.8** | 705000000.00 |
| 79 | -18.4 | -17.4 | **-17.9** | -23.9 | 4.3 | **28.2** | 612000000.00 |
| 104 | -18.4 | -18.2 | **-18.3** | -26.6 | 1.7 | **28.3** | 598000000.00 |
| 73 | -7.4 | -7.5 | **-7.5** | -10.3 | 16.8 | **27.1** | 646000000.00 |
| 92 | -20.0 | 20.2 | **0.1** | -12.6 | 14.4 | **27.0** | 656000000.00 |
| 64 | 8.2 | 10.1 | **9.2** | -59.0 | -31.5 | **27.5** | 6060000000.00 |
| 95 | -8.6 | -8.5 | **-8.6** | -48.9 | -21.4 | **27.5** | 700000000.00 |
| 58 | 12.9 | 12.5 | **12.7** | -4.5 | 23.4 | **27.9** | 616000000.00 |
| 82 | 5.3 | 5.9 | **5.6** | -8.5 | 18.9 | **27.4** | 557000000.00 |
| 110 | 23.1 | 23.1 | **23.1** | -74.1 | -44.3 | **29.8** | 1000000000.00 |
| 51 | -13.5 | -12.9 | **-13.2** | -6.3 | 22.6 | **28.9** | 684000000.00 |
| 97 | 12.9 | 13.3 | **13.1** | -51.8 | -22.8 | **29.0** | 764000000.00 |
| 31 | -6.1 | -5.9 | **-6.0** | -10.1 | 18.5 | **28.6** | 530000000.00 |
| 109 | 16.1 | 16.0 | **16.1** | -33.5 | -3.9 | **29.6** | 794000000.00 |
| 96 | 5.4 | 5.4 | **5.4** | -47.0 | -18.4 | **28.6** | 1350000000.00 |
| 94 | -6.4 | -6.3 | **-6.4** | -41.0 | -11.5 | **29.5** | 584000000.00 |
| 43 | 11.2 | 11.7 | **11.5** | 27.9 | 59.0 | **31.1** | 405000000.00 |
| 15 | 21.1 | 21.9 | **21.5** | -58.4 | -15.7 | **42.7** | 773000000.00 |

# *The Number of Sunspots vs. Birth Rates*

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## *Abstract*

Sunspots are spots ranging 60,000 square miles to spots the size of the Earth. The are magnetic fields that are beneith the surface of the sun. They are cooler than the actual surface of the sun and they apear darker because of this. The spots are always present on the sun. But at times the spots, or magnetic fields are larger than other spots. It is said that every 11 years the sunspots go through a cycle. The cycle moves through times where the solar flares, sunspots, and solar ejections go from a high rate to a low rate.

The births in the United States also change dramaticaly everyday, and there is not a day when not one person is born. Therefore there is a number of sunspots and a number of birth rates every day. By comparing the births with the sunspots you can tell if there are any correlations.

## *Purpose*

The original purpose is to determine if sunspots have any influence on the births in the area that we live. We determined this by collecting data from the Scion Image program and also from a nearby hospital. By comparing the two years of data, we will determine if the amount of sunspots has to do with birth rates.

## *Hypothesis*

The sunspots, in our opinions, will not have any coinicdence with the birth rates. We at first believed that it would, but then decided we thought that it would not.

## *Procedure*

We acquired information from a nearby hospital and we also recorded sunspot data. We recorded this information for a period of 2 years. After averaging together the number of sunspots per month and averaging the number of birth rates per month.

## *Analysis*

After looking at our total sunspot data and our total two-year birth listings, we saw that there was not a relationship between the total number of sunspots and birth rates. There was no pattern to the total combined area of sunspots compared with the number of hospital births. The data that was gathered was almost in complete support of our hypothesis. Unfortunately only two years of information was provided from our local hospital.

## *Conclusions*

Considering there was not that much data provided from our hospital. Also some of the sunspot data that we found was incomplete and not accurate. There were many dates that we could not find the correct counts for. For the over all project, it was a success in letting us know that there was no comparison.

Sunspots vs Birth Rates

|  |  |  | Sunspot # |  | Birth # |
|---|---|---|---|---|---|
| Year | Month |  | 62 |  | 40 |
| 1999 | Jan |  | 66.3 |  | 39 |
|  | Feb |  | 68.8 |  | 43 |
|  | Mar |  | 63.7 |  | 28 |
|  | Apr |  | 106.4 |  | 41 |
|  | May |  | 137.6 |  | 34 |
|  | Jun |  | 113.5 |  | 44 |
|  | Jul |  | 93.8 |  | 39 |
|  | Aug |  | 71.4 |  | 50 |
|  | Sep |  | 116.7 |  | 43 |
|  | Oct |  | 133.2 |  | 42 |
|  | Nov |  | 84.6 |  | 40 |
|  | Dec | Average Sunspot # | 93.16 | Average Birth # | 40.25 |
|  |  |  | 90.1 |  | 35 |
| 2000 | Jan |  | 112.9 |  | 49 |
|  | Feb |  | 138.5 |  | 40 |
|  | Mar |  | 125.5 |  | 41 |
|  | Apr |  | 121.6 |  | 46 |
|  | May |  | 124.9 |  | 46 |
|  | Jun |  | 169.1 |  | 35 |
|  | Jul |  | 130.5 |  | 47 |
|  | Aug |  | 109.9 |  | 48 |
|  | Sep |  | 99.4 |  | 42 |
|  | Oct |  | 106.8 |  | 40 |
|  | Nov |  | 104.3 |  | 53 |
|  | Dec | Average Sunspot # | 119.46 | Average Birth # | 43.3 |

# *Comparing Sunspot Data to Tornadoes*

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*Teacher: Carl Katsu, RBSE '01*

## *Abstract*

We tried to find out whether or not sunspots affect the number of tornadoes produced in North America. We counted the number of tornadoes from January, 1999, through December, 2000. Then we looked up tornado statistics for those days and found the locations of them and how many occurred.

The results were somewhat inconclusive due to the fact that we could not obtain all the data we needed nor have much time to complete our analysis. From the results that we acquired, we established that the number of sunspots do not affect the number of tornadoes in North America. These results are useful for knowledge that sunspots do not affect tornado patterns and occurrences.

## *Purpose*

We are trying to find out if sunspots have any effect on tornadoes. The way we are going to go about doing this is to calculate sunspot data for January to July, 2000, and then go to the other class groups also studying sunspots, and collect all of their data for sunspots. After this we will find the days with low numbers, 0-20, and high numbers, 80-100, of sunspots. Then we will find tornado statistics on the Internet for those days. We will then compare to see if there is any relationship between the number of tornadoes for that day and the number of sunspots.

## *Hypothesis*

We think sunspots will affect the number of tornadoes that occur in North America. We think that the more sunspots seen on the sun will result in more tornadoes transpiring in North America.

## *Procedure*

To do this experiment we will be using sunspot data from the National Observational Astronomy Observatory Research Based Science Education program in Tucson, Arizona. We will analyze the solar images for sunspots, using an image processing program called Scion Image, to count the number of sunspots on the image. We will be doing all of our testing during the school days and finding some the information on tornadoes out of school. Once we gather all of the information we will be comparing the days with the highest and lowest counts of sunspots to how many tornadoes occurred during those days. We will go over all the information to check and make sure we made no big mistakes so it won't have an affect on our results. We will be looking to see if more tornadoes occur when there are more sunspots and fewer tornados occur during low number of sunspots. We will also be looking to see if there is no relationship between the sunspots and tornadoes.

## *Discussion*

The explanation for there not being a relationship between tornadoes and sunspots is that sunspots relate to the magnitosphere of Earth, while tornadoes associate with the weather conditions at the surface at a certain time and a certain place. We were not able to control the fact that we could not find information for tornado statistics on certain date. We could have made a little error, if anything, in erasing some of the good data instead of the bad data while observing the sunspots. This could have affected the number of sunspots we counted that day. We are very sure that it will always turn out to be no relationship between tornadoes and sunspots because there is no correlation shown between the two. We could have had a little more time to test them but it's very doubtful that the results would have changed. These results will be true if tested anywhere at any time.

## *Conclusion*

Sunspots do not have an affect on the development of tornadoes. The number of sunspots didn't induce or repress tornadoes. The sunspots created no pattern for the evolution of tornadoes. The tornadoes vary from day to day and sunspots have no part in the progression of tornadoes. Our hypothesis was correct and there is no correlation between sunspots and tornadoes. Sunspots do not create an energy that creates tornadoes.

**NUMBER OF SUNSPOTS AND TORNADOES IN EACH MONTH**

| YEAR | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | | | | | | | | | | | | |
| # of sunspots | 160 | 155 | 126 | 164 | 179 | 157 | 136 | 135 | 155 | 164 | 148 | 174 |
| # of tornadoes | 5 | 11 | 41 | 137 | 203 | 317 | 95 | 73 | 37 | 43 | 3 | 1 |
| 1981 | | | | | | | | | | | | |
| # of sunspots | 114 | 141 | 136 | 156 | 127 | 91 | 144 | 159 | 167 | 162 | 138 | 150 |
| # of tornadoes | 2 | 25 | 33 | 84 | 187 | 223 | 98 | 64 | 26 | 32 | 7 | 1 |
| 1982 | | | | | | | | | | | | |
| # of sunspots | 111 | 163 | 154 | 122 | 82 | 110 | 106 | 108 | 119 | 95 | 98 | 127 |
| # of tornadoes | 18 | 3 | 60 | 150 | 329 | 196 | 95 | 34 | 38 | 9 | 19 | 96 |
| 1983 | | | | | | | | | | | | |
| # of sunspots | 84 | 51 | 67 | 81 | 99 | 91 | 82 | 72 | 50 | 56 | 33 | 33 |
| # of tornadoes | 13 | 41 | 71 | 65 | 249 | 178 | 99 | 76 | 19 | 13 | 49 | 58 |
| 1984 | | | | | | | | | | | | |
| # of sunspots | 57 | 85 | 84 | 70 | 76 | 46 | 37 | 26 | 16 | 12 | 22 | 19 |
| # of tornadoes | 1 | 27 | 73 | 176 | 169 | 242 | 72 | 47 | 17 | 49 | 30 | 4 |
| 1985 | | | | | | | | | | | | |
| # of sunspots | 17 | 16 | 17 | 16 | 28 | 24 | 31 | 11 | 4 | 19 | 16 | 17 |
| # of tornadoes | 2 | 7 | 38 | 134 | 182 | 82 | 51 | 108 | 40 | 18 | 19 | 3 |
| 1986 | | | | | | | | | | | | |
| # of sunspots | 3 | 23 | 15 | 19 | 14 | 1 | 18 | 7 | 4 | 36 | 15 | 7 |
| # of tornadoes | 0 | 30 | 76 | 84 | 173 | 134 | 88 | 67 | 65 | 26 | 17 | 5 |
| 1987 | | | | | | | | | | | | |
| # of sunspots | 10 | 2 | 15 | 39 | 31 | 18 | 33 | 39 | 33 | 61 | 40 | 27 |
| # of tornadoes | 6 | 19 | 38 | 20 | 126 | 132 | 163 | 63 | 19 | 1 | 55 | 14 |
| 1988 | | | | | | | | | | | | |
| # of sunspots | 59 | 40 | 76 | 88 | 60 | 102 | 114 | 112 | 120 | 125 | 125 | 179 |
| # of tornadoes | 17 | 4 | 28 | 58 | 132 | 63 | 103 | 61 | 76 | 19 | 121 | 20 |
| 1989 | | | | | | | | | | | | |
| # of sunspots | 161 | 165 | 131 | 132 | 139 | 196 | 126 | 169 | 177 | 159 | 173 | 166 |
| # of tornadoes | 14 | 18 | 43 | 82 | 231 | 252 | 59 | 36 | 31 | 30 | 57 | 3 |
| 1990 | | | | | | | | | | | | |
| # of sunspots | 177 | 131 | 140 | 140 | 132 | 105 | 149 | 200 | 125 | 145 | 131 | 130 |
| # of tornadoes | 11 | 57 | 86 | 108 | 243 | 329 | 106 | 60 | 45 | 35 | 18 | 35 |
| 1991 | | | | | | | | | | | | |
| # of sunspots | 137 | 168 | 142 | 140 | 121 | 170 | 174 | 176 | 125 | 144 | 108 | 144 |
| # of tornadoes | 29 | 11 | 157 | 204 | 335 | 216 | 64 | 46 | 26 | 21 | 20 | 3 |
| 1992 | | | | | | | | | | | | |
| # of sunspots | 150 | 161 | 106 | 100 | 74 | 65 | 86 | 65 | 64 | 89 | 92 | 83 |
| # of tornadoes | 15 | 29 | 55 | 53 | 137 | 399 | 213 | 115 | 81 | 34 | 146 | 20 |
| 1993 | | | | | | | | | | | | |
| # of sunspots | 59 | 91 | 70 | 62 | 61 | 50 | 58 | 42 | 22 | 56 | 36 | 49 |
| # of tornadoes | 17 | 34 | 48 | 85 | 177 | 313 | 242 | 112 | 65 | 55 | 19 | 6 |
| 1994 | | | | | | | | | | | | |
| # of sunspots | 58 | 36 | 32 | 16 | 18 | 28 | 35 | 22 | 26 | 44 | 18 | 27 |
| # of tornadoes | 13 | 9 | 58 | 205 | 161 | 234 | 155 | 120 | 30 | 51 | 42 | 4 |
| 1995 | | | | | | | | | | | | |
| # of sunspots | 24 | 30 | 31 | 14 | 15 | 16 | 15 | 14 | 12 | 21 | 9 | 10 |
| # of tornadoes | 36 | 7 | 49 | 130 | 391 | 216 | 162 | 53 | 19 | 74 | 79 | 18 |
| 1996 | | | | | | | | | | | | |
| # of sunspots | 12 | 4 | 9 | 4 | 6 | 12 | 8 | 14 | 2 | 0.9 | 18 | 13 |
| # of tornadoes | 35 | 14 | 71 | 177 | 235 | 128 | 202 | 72 | 101 | 68 | 55 | 15 |
| 1997 | | | | | | | | | | | | |
| # of sunspots | 6 | 8 | 9 | 16 | 19 | 13 | 10 | 24 | 51 | 23 | 39 | 41 |
| # of tornadoes | 50 | 23 | 102 | 114 | 225 | 193 | 188 | 84 | 32 | 100 | 25 | 12 |
| 1998 | | | | | | | | | | | | |
| # of sunspots | 32 | 40 | 55 | 53 | 56 | 71 | 66 | 92 | 93 | 56 | 74 | 82 |
| # of tornadoes | 47 | 72 | 72 | 82 | 310 | 376 | 82 | 61 | 104 | 86 | 26 | 6 |
| 1999 | | | | | | | | | | | | |
| # of sunspots | 62 | 66 | 69 | 64 | 106 | 138 | 114 | 94 | 71 | 117 | 133 | 85 |
| # of tornadoes | 212 | 22 | 56 | 177 | 310 | 289 | 102 | 79 | 56 | 17 | 7 | 15 |

# Do Sunspots Affect Temperature on the East Coast?

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## *Abstract*

Sunspots are large darkened spots covering the sun's surface. They are always present on the sun. Sunspots range in area from anywhere from very small to the size of earth and they rotate with the suns movement. They are caused by magnetic storms on the sun. These storms affect earth's magnetosphere in many ways. We got our information form the national observational astronomy observatory resource based science education program in Tucson , Arizona. We looked at our assigned dates and wrote down the number of sunspots on that day for three months. Our assigned dates were July to December of 2000. Then we looked at the temperatures in our local area for those same dates to see if there was an increase in temperature with an increase in sunspots. After analyzing the available data, our outcome was indecisive.

## *Purpose*

The original purpose of my project was to determine if sunspots had an effect on weather on the east coast. The Scion Image program was used to analyze data on sunspots and their area for the months of July to December of 2000.

## *Background*

Sunspots are magnetic regions with magnetic field strengths that are thousands of times stronger than the earth's magnetic field. They appear in groups with two sets of spots, one of which has a positive or north magnetic field, while the other has a negative, or south, magnetic field. It usually takes a group about 27 days to make one rotation around the sun, rotating faster near the equator and slower near the solar poles. Although they appear small, the average spot is about the size of the earth.

Periods of intense sunspot activity can cause solar flares and coronal mass ejections, which cause parts of the sun's outer atmosphere to practically explode and produce huge bursts of solar wind. Solar wind is a continuous outflow of solar magnetic field and subatomic particles from the corona into the solar system. It takes the solar wind 2 to 4 days to reach the Earth, and they strike the magnetosphere, injecting huge amounts of energy into the magnetic field. This energy often causes auroras, which occur around Earth's north and south geomagnetic poles in regions called aurora ovals. In the past, weather forecasts were often based on auroras. During the Maunder Minimum there was little sunspot activity, little auroral activity, and the climate on Earth was considerably colder than usual. Whether or not there is any connection between these occurances is still unknown, but this data suggests that perhaps sunspots have a slight affect on the temperature.

## *Hypothesis*

The sunspots will have a long term, not short term affect on the weather and climate on the east coast.

## *Procedure*

For our project we used sunspot data for July to December of 2000 from the National Observational Astronomy Observatory (NOAO) Resource Based Science Education program. We looked at the data for three months. We used image processing software, Scion Image, to count the number of sunspots on each of the dates we had data for. As part of a group, we decided what made a large number of sunspots for one day (over 70) and anything below would be medium or low numbers of sunspots, The group decided this after looking at the number of sunspots for a total of three years. We recorded the sunspot counts in a log book for the three months we were assigned. Then we looked up the temperature on the east coast for that time period. In a table, we compared sunspots high counts with temperatures on the east coast before during and after those high counts.

## *Conclusion*

A high sunspot count did not have any affect on temperature on the east coast, compared to temperatures when the sunspot count was lower.

## Sunspot Data July to December

| Date | Number of sunspots | High Temperature | Low Temperature |
|---|---|---|---|
| 7/2/00 | 27 | 85 degrees F | 66 degrees F |
| 7/9/00 | 110 | 86 degrees F | 67 degrees F |
| 7/12/00 | 95 | 84 degrees F | 68 degrees F |
| 7/17/00 | 89 | 84 degrees F | 66 degrees F |
| 7/19/00 | 91 | 80 degrees F | 63 degrees F |
| 7/20/00 | 83 | 78 degrees F | 63 degrees F |
| 7/25/00 | 93 | 77 degrees F | 64 degrees F |
| 9/10/00 | 0 | 84 degrees F | 69 degrees F |
| 9/12/00 | 30 | 83 degrees F | 70 degrees F |
| 9/13/00 | 29 | 84 degrees F | 68 degrees F |
| 9/20/00 | 96 | 85 degrees F | 57 degrees F |
| 10/13/00 | 82 | 76 degrees F | 46 degrees F |
| 10/17/00 | 83 | 65 degrees F | 61 degrees F |
| 11/1/00 | 28 | 62 degrees F | 39 degrees F |
| 11/8/00 | 20 | 66 degrees F | 47 degrees F |
| 11/11/00 | 30 | 60 degrees F | 49 degrees F |
| 11/12/00 | 26 | 57 degrees F | 43 degrees F |
| 11/13/00 | 27 | 56 degrees F | 40 degrees F |
| 11/18/00 | 23 | 46 degrees F | 34 degrees F |
| 11/26/00 | 29 | 58 degrees F | 46 degrees F |
| 12/8/00 | 25 | 45 degrees F | 35 degrees F |
| 12/14/00 | 25 | 38 degrees F | 30 degrees F |
| 12/23/00 | 30 | 28 degrees F | 14 degrees F |
| 12/25/00 | 18 | 28 degrees F | 19 degrees F |

0-30 low
80-100+ high

# *Active Magnetic Longitudes*

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## *Background*

Over the past few decades, studies in solar physics have produced a theory about the internal structure of stars (including our sun). This theory pertains to the longitude of active sunspot regions, or "hot spots", and how certain longitudes show a higher amount of activity than other longitudes. Also, it has been determined that these certain longitudes may have different rotational periods than non-active regions. With these discoveries astronomers may be able to find new and exciting facts about our sun and the stars that make up our universe.

It has been well documented that the sun does go through periods of increased activity along certain longitudes at regular 11 year periods. Observations over long periods of time show that certain longitudes have greater activity than others. Studies have suggested that active longitudes have a rotational period of 27.2753 days. A rotating reference frame of the sun was introduced by R. C. Carrington in 1853. After determining the rotational period of a region, it can be seen if that solar rotation contain active regions.

## *Purpose*

The purpose of this study is to find any commonalties in the origin and behavior of sunspot regions.

## *Hypothesis*

By finding the active longitude of sunspots, their origins will be determined and the reasons to why they are formed will be determined also.

## *Procedure*

1) Start ScnImage Program on your Computer. (It is important that this computer has a ScnImage program.)

2) Download Solar Macro's written to facilitate the determination of possible active longitudes into a designated computer.

3) With ScnImage, use the macros and chart a sunspot's journey across the sun's horizon.

4) Record the spot's Julian date, Heliographic longitude and latitude, Area, Carrington rotation and longitude, and the corrected longitude of each macro along the sunspot's course.

5) Once you have tracked the entire path of the sunspot, calculate the new rotational period of the sunspot.

6) Compare and contrast the new rotational periods and the corrected longitudes of many sunspots.

## *Conclusion*

Upon the observation of many different active regions of the sun, a conclusion was unable to be reached. There were single occurrences found and a small clustering in the area of 140º-180º. Either there was no apparent clustering or there is just not enough data yet. With the collection of more data, a true conclusion may be able to be reached.

## *References*

1. Stagg, Travis; Solar Active Longitudes Teacher's Guide; National Solar Observatory; 2001.
2. Daily Solar Magnetograms 1977-2000; National Solar Observatories; 2001.

| Image Date | Julian Date | Helio. Lat. | Helio. Long. | Area (deg^2) | Carr. Rot. # | Carr. Long. | Corrected Long. | NRP |
|---|---|---|---|---|---|---|---|---|
| 1/29/78 | 2443538.284 | 20.224 | -54.8788 | 28.2912 | 1664.4448 | 145 | 145 | 0 |
| 2/2/78 | 2443542.194 | 19.4436 | -3.0361 | 631.617 | 1664.5904 | 144.4346 | 144.67 | 0 |
| 2/3/78 | 2443543.183 | 21.6567 | 10.3563 | 77.9773 | 1664.6267 | 144.7474 | 145.0517 | 0 |
| 2/7/78 | 2443547.163 | 21.5575 | 62.5649 | 16.4348 | 1664.7725 | 144.4543 | 145.002 | 0 |
|  |  |  |  |  |  |  |  | 27.4013 d |
| 1/27/78 | 2443536.399 | -30.4145 | -65.315 | 14.2209 | 1664.3779 | 158.6444 | 158.6444 | 0 |
| 1/28/78 | 2443537.149 | -30.7809 | -32.9961 | 28.2974 | 1664.4054 | 161.0734 | 160.514 | 0 |
| 1/29/78 | 2443538.224 | -29.6504 | -38.4135 | 33.619 | 1664.4445 | 161.4673 | 160.3485 | 0 |
| 2/2/78 | 2443542.194 | -28.7429 | 14.2447 | 29.1224 | 1664.5964 | 161.7155 | 158.3589 | 0 |
| 2/3/78 | 2443543.185 | -25.8301 | 28.1692 | 22.3359 | 1664.6367 | 162.5603 | 158.6444 | 0 |
|  |  |  |  |  |  |  |  | 26.166 d |
| 1/3/00 | 2451547.19 | -15.6372 | 4.0455 | 3.6342 | 1958.0792 | 335.5345 | 335.3598 | 0 |
| 1/4/00 | 2451548.165 | -15.8903 | 17.135 | 3.3131 | 1958.1149 | 335.7644 | 335.415 | 0 |
| 1/5/00 | 2451549.226 | -15.8844 | 31.8396 | 3.2294 | 1958.1538 | 336.4545 | 335.9304 | 0 |
| 1/6/00 | 2451550.174 | -15.8713 | 44.7616 | 2.6042 | 1958.1886 | 336.8652 | 336.1663 | 0 |
| 1/7/00 | 2451551.184 | -15.8206 | 57.8404 | 1.7304 | 1958.2256 | 336.6169 | 335.7433 | 0 |
| 1/8/00 | 2451552.17 | -15.8932 | 71.0789 | 1.0763 | 1958.262 | 336.7575 | 335.7092 | 0 |
|  |  |  |  |  |  |  |  | 26.9187 d |
| 1/2/78 | 2443511.223 | -18.5697 | -18.5697 | 25.7729 | 1663.4548 | 177.6867 | 177.6867 | 0 |
| 1/3/78 | 2443512.202 | -18.5914 | -5.917 | 23.2917 | 1663.4907 | 177.4219 | 177.4219 | 0 |
| 1/4/78 | 2443513.317 | -19.0351 | 9.5326 | 21.9715 | 1663.5316 | 178.1541 | 178.7798 | 0 |
| 1/6/78 | 2443515.397 | -17.6094 | 36.6484 | 16.1216 | 1663.6079 | 177.8163 | 179.0696 | 0 |
| 1/7/78 | 2443516.34 | -18.3076 | 48.5473 | 11.8474 | 1663.6424 | 177.27 | 178.8342 | 0 |
| 1/8/78 | 2443517.371 | -16.9804 | 60.6902 | 4.1348 | 1663.6802 | 175.8097 | 177.6867 | 0 |
|  |  |  |  |  |  |  |  | 27.9312 d |
| 8/7/78 | 2443728.096 | -26.8963 | -39.8412 | 37.8182 | 1671.4061 | 173.9626 | 173.9626 | 0 |
| 8/8/78 | 2443728.096 | -26.4826 | -25.6264 | 46.1611 | 1671.4439 | 174.557 | 174.8931 | 0 |
| 8/9/78 | 2443730.091 | -26.3238 | -12.9654 | 46.6478 | 1671.4792 | 174.505 | 175.1759 | 0 |
| 8/10/78 | 244323731.1 | -26.1234 | -0.2341 | 48.8629 | 1671.5154 | 174.2301 | 175.2365 | 0 |
| 8/11/78 | 244323732.4 | -26.456 | 16.3394 | 38.5657 | 1671.5643 | 173.1777 | 174.5195 | 0 |
| 8/12/78 | 2443737.117 | -26.1161 | 26.6619 | 38.3027 | 1671.5902 | 174.1969 | 175.8742 | 0 |
| 8/13/78 | 2443734.138 | -26.2637 | 39.7768 | 29.5488 | 1671.6276 | 173.8289 | 175.8416 | 0 |
| 8/14/78 | 2443735.286 | -26.0268 | 32.7133 | 24.0355 | 1671.6697 | 171.6144 | 173.9626 | 0 |
|  |  |  |  |  |  |  |  | 27.9863 d |
| 12/10/78 | 2443853.312 | 20.8896 | -23.1809 | 51.4149 | 1675.9969 | 337.9259 | 337.9259 | 0 |
| 12/11/78 | 2443854.181 | 20.6859 | -11.9178 | 54.8708 | 1676.0291 | 337.6238 | 336.9917 | 0 |
| 12/14/78 | 2443837.379 | 20.9207 | 31.3991 | 56.0088 | 1676.146 | 338.8238 | 336.2932 | 0 |
| 12/15/78 | 2443858.134 | 19.991 | 41.6037 | 48.0775 | 1676.1737 | 339.0646 | 335.9039 | 0 |
| 12/16/78 | 2443859.235 | 21.5371 | 58.7943 | 35.5455 | 1676.2141 | 341.7188 | 337.9259 | 0 |
|  |  |  |  |  |  |  |  | 26.0284 d |
| 8/30/78 | 2443751.0812 | 15.7474 | -67.1260 | 19.6243 | 1672.2488 | 203.2989 | 203.2989 | 0 |
| 8/31/78 | 2443752.1215 | 15.9546 | -52.9104 | 24.6762 | 1672.287 | 203.7841 | 204.8862 | 0 |
| 9/1/78 | 2443753.0924 | 15.8525 | -37.2319 | 32.7989 | 1672.3226 | 206.6488 | 208.8529 | 0 |
| 9/2/78 | 2443754.0847 | 16.1368 | -21.7282 | 42.7058 | 1672.4589 | 209.0546 | 212.3608 | 0 |
| 9/4/78 | 2443756.1125 | 16.6874 | 4.6427 | 36.8784 | 1672.4333 | 208.3931 | 214.1716 | 0 |
| 9/5/78 | 2443757.1972 | 16.8848 | 18.6914 | 41.3085 | 1672.4731 | 208.6673 | 215.0045 | 0 |
| 9/6/78 | 2443758.1187 | 17.0102 | 31.6642 | 35.3073 | 1672.5368 | 209.2028 | 216.9172 | 0 |
| 9/7/78 | 2443759.1771 | 17.0751 | 47.1423 | 30.0791 | 1672.5456 | 209.2028 | 218.0193 | 0 |
| 9/8/78 | 2443760.0791 | 17.3495 | 56.1287 | 25.018 | 1672.5787 | 210.7123 | 220.6308 | 0 |
| 9/9/78 | 2443761.1465 | 16.0045 | 62.8007 | 9.0438 | 1672.6178 | 192.2783 | 203.2989 | 0 |
|  |  |  |  |  |  |  |  | 29.7475 d |
| 9/14/78 | 2443766.298 | 32.6241 | -53.6306 | 41.4686 | 1672.8066 | 16.0082 | 16.0082 | 0 |
| 9/18/78 | 2443770.268 | 33.8089 | -7.2254 | 76.1134 | 1672.9501 | 10.755 | 13.8652 | 0 |
| 9/19/78 | 2443771.3 | 34.4532 | 6.4989 | 70.1908 | 1672.4901 | 10.0523 | 13.9401 | 0 |
| 9/20/78 | 2443772.151 | 34.2293 | 16.5479 | 79.4347 | 1673.0213 | 8.8823 | 13.5476 | 0 |
| 9/21/78 | 2443773.088 | 34.3576 | 28.9866 | 74.2355 | 1673.0556 | 8.9564 | 14.3993 | 0 |
| 9/22/78 | 2443774.162 | 35.3899 | 42.046 | 63.9269 | 1673.095 | 7.8363 | 14.0567 | 0 |
| 9/23/78 | 2443775.084 | 34.0755 | 55.3921 | 53.6471 | 1673.1288 | 9.0102 | 16.0082 | 0 |
|  |  |  |  |  |  |  |  | 28.9824 d |
| 4/2/78 | 2443601.118 | 19.6631 | -61.0556 | 31.5991 | 1666.7507 | 28.6968 | 28.6968 | 0 |
| 4/3/78 | 2443602.098 | 19.338 | -47.5963 | 36.8638 | 1666.7866 | 29.2232 | 29.4946 | 0 |
| 4/4/78 | 2443603.238 | 19.4726 | -32.2172 | 42.2387 | 1666.8284 | 29.552 | 30.0948 | 0 |
| 4/5/78 | 2443604.102 | 19.5052 | -20.5206 | 48.5298 | 1666.8601 | 29.8464 | 30.6606 | 0 |
| 4/6/78 | 2443605.103 | 19.5735 | -8.2527 | 53.1455 | 1666.8968 | 28.9063 | 29.9919 | 0 |
| 4/7/78 | 2443606.271 | 20.1094 | 6.4022 | 52.2684 | 1666.9396 | 28.1444 | 29.5014 | 0 |
| 4/9/78 | 2443608.174 | 21.0468 | 29.5647 | 43.2398 | 1667.0094 | 26.1926 | 28.0924 | 0 |
| 4/10/78 | 2443609.201 | 21.007 | 43.4199 | 30.8871 | 1667.047 | 26.4824 | 28.6536 | 0 |
| 4/11/78 | 2443610.099 | 20.4199 | 55.0431 | 24.2001 | 1667.08 | 26.2542 | 28.6968 | 0 |
|  |  |  |  |  |  |  |  | 27.8476 |
| 5/24/78 | 2443653.1396 | 18.258 | -45.7322 | 66.9587 | 1168.658 | 77.4008 | 77.4008 | 0 |
| 5/25/78 | 2443654.0972 | 18.1636 | -33.7068 | 75.077 | 1168.6931 | 76.7665 | 76.8983 | 0 |
| 5/26/78 | 2443655.0053 | 18.7808 | -21.302 | 94.5488 | 1168.7286 | 76.4142 | 76.6777 | 0 |
| 5/27/78 | 2443656.0743 | 19.0276 | -8.6399 | 108.3921 | 1168.7656 | 75.7584 | 76.0219 | 0 |
| 5/28/78 | 2443657.0674 | 19.2681 | 4.5652 | 114.7393 | 1168.802 | 75.8564 | 76.3834 | 0 |
| 5/29/78 | 2443658.0639 | 19.4655 | 17.5679 | 104.4056 | 1168.8385 | 75.7062 | 76.365 | 0 |
| 5/30/78 | 2443659.0597 | 19.0905 | 30.8825 | 83.1592 | 1168.875 | 75.877 | 76.6675 | 0 |
| 5/31/78 | 2443660.0951 | 18.9496 | 45.1227 | 57.4446 | 1168.9129 | 76.4785 | 77.4004 | 0 |
|  |  |  |  |  |  |  |  | 27.55 |

# A Search for Novae in the Andromeda Galaxy - Year Four

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## *Abstract*

The purpose of this year's Nova Search project was to analyze new and existing observational data for new novae, expand and reorganize our nova database to adjust for the newly available epochs from past years, and to replot the light curves and the map. We created new procedures for determining magnitudes that could not be calculated by using the regular macros method in Scion Image, and used new graphing and fitting routines. We reanalyzed our data to create a nova subclass "AB". Finally, we tested a new hypothesis, stated below.

### *Hypothesis*

In addition to looking for new novae, we wanted to investigate the relationship between the maximum observed magnitude and the class of the nova.

### *Procedures*

This year, there were seven new epochs of data available. The "epoch" column of our data table had to be altered to account for this, as several of the new epochs were in between two older ones. For example, novae which occurred during the 18th epoch of last year's data now occur in the 19th, with the inclusion of a new epoch 18. To make this process easier, we created a data table of all the epochs (Fig 1), showing the new and old numbering, the Julian date and time, the days elapsed from the first epoch, and notes about which epochs were new or renumbered.

Light curves of all the novae which occurred in three or more epochs were plotted using a program called gnuplot (http://www.gnuplot.info). This program provided several advantages over the program used in previous years, including error bars for each data point and more flexibility in formatting the graphs. The curve fits were analyzed using a program called PSIPlot, which gave us correlation value for the fit.

There were several novae, from this year and past years, for which we initially could not get magnitudes because they were too close to the edge of the field. This year, we used two different methods for getting magnitudes: visual bracketing, and smaller photometry circles. For visual bracketing, the magnitudes of two other stars in the same field and epoch as the nova, one brighter, and one dimmer, were used to narrow down the magnitude of the star to a smaller range. The magnitudes of these stars were calculated using the magnitude macro.

On some novae, smaller aperture radii circles were used. This method was used primarily on novae whose outer edges were within 5-10 pixels of the edge of the field. Because the quality of these magnitude determinations is significantly lower, a "Comments" field has been added to the data table.

### *Data*

The data table (Fig. 2) and graphs represent only a portion of all the data collected and analyzed in this project. To see the full report, go to: http://north.gp.k12.mi.us/~maciola/webpages/studentprojects.htm

As in previous years, the nova number assignment begins with the year of discovery (this year's novae begin with 02). The table lists standard star information, calculations of error and magnitudes. For a more complete explanation of how each of these were determined, see our previous publications on the school website listed above. Only novae that were discovered this year (or had magnitudes reported for the first time) are listed.

A total of 24 new novae were discovered this year. Of those 24, only 3 occurred in new epochs. This is attributed to improved software routines and better user-friendliness of the program.

### *Analysis*

After all the novae were graphed and fitted, they were classified as to type NA, NA and NAB. No type

NC novae were found. We read about another category, NAB which was described as “nova that change by more than three magnitudes from their peak in more than 100 days but less than 150 days. So we added this type to our list.

Four representative nova light curves are shown (Fig. 3): They illustrate one of each type, plus an anomaly. The function and fit information are listed below:

```
99-010:
f(x) = 0.0447844711622821*x - 14.9746065615016
r = 0.918

02-010:
f(x) = 0.0266273136206794*x - 30.3615866781706
r = 0.999

02-006:
f(x) = 0.0131403244387472*x + 8.5118476380461
r = 0.986

02-016:
f(x) = 6.14264255359184e-006*x^2 - 0.00724687109728172*x + 19.2555131064004
r = 0.939
```

Nova 02-016 is interesting because it showed a dimming, then rapid brightening before its final dimming phase. This phenomenon warrants further research.

The novae that had light curves were plotted on an image of M31 (Fig. 4) to look for patterns in their distribution. None was found. Finally, the novae were sorted by groups and their maximum magnitudes were averaged.

There are 2 type NA, 5 type NAB and 13 type NB novae. The magnitude data for these types are as follows:

| Type | Maximum Magnitude Recorded -Average | Range of Maximums |
|---|---|---|
| NA | 15.79 | 15.67-15.99 |
| NAB | 16.08 | 14.97-17.42 |
| NB | 16.49 | 15.50-17.45 |

## *Conclusions*

There seems to be a relationship between the rate of decline of the nova and its absolute magnitude: the faster the decline, the intrinsically brighter the nova. There does not seem to be a pattern for where these types occur.

| Epoch | UT Date | UT Time | JD | Elapsed | Notes |
|---|---|---|---|---|---|
| 1 | 9/3/95 | 6:13:56 | 2449963 | 0 | |
| 2 | 6/18/97 | 10:38:22 | 2450618 | 655 | |
| 3 | 7/23/97 | 7:46:23 | 2450651 | 688 | |
| 4 | 7/24/97 | 8:49:12 | 2450652 | 689 | |
| 5 | 7/25/97 | 6:30:01 | 2450653 | 690 | |
| 6 | 7/31/97 | 7:44:29 | 2450661 | 698 | |
| 7 | 8/1/97 | 8:16:47 | 2450662 | 699 | |
| 8 | 11/18/97 | 8:10:13 | 2450771 | 808 | |
| 9 | 6/5/98 | 10:35:05 | 2450970 | 1007 | |
| 10 | 7/24/98 | 8:39:49 | 2451019 | 1056 | |
| 11 | 7/25/98 | 7:19:57 | 2451020 | 1057 | |
| 12 | 8/26/98 | 6:08:58 | 2451052 | 1089 | |
| 13 | 9/5/98 | 8:21:21 | 2451062 | 1099 | |
| 14 | 10/15/98 | 4:46:25 | 2451102 | 1139 | |
| 15 | 10/31/98 | 5:29:47 | 2451118 | 1155 | |
| 16 | 11/11/98 | 4:04:46 | 2451129 | 1166 | |
| 17 | 1/27/99 | 2:30:09 | 2451206 | 1243 | |
| 18 | 6/24/99 | 9:42:54 | 2451354 | 1391 | new |
| 19 | 7/20/99 | 7:57:52 | 2451380 | 1417 | old 18 |
| 20 | 6/14/00 | 9:54:22 | 2451710 | 1747 | new |
| 21 | 7/24/00 | 9:14:44 | 2451750 | 1787 | old 19 |
| 22 | 9/13/00 | 4:52:18 | 2451801 | 1838 | new |
| 23 | 9/14/00 | 8:55:41 | 2451802 | 1839 | new |
| 24 | 10/15/00 | 5:48:01 | 2451833 | 1870 | old 20 |
| 25 | 11/10/00 | 3:11:10 | 2451859 | 1896 | new |
| 26 | 1/21/01 | 2:08:38 | 2451922 | 1959 | new |
| 27 | 1/15/01 | 1:47:55 | 2451925 | 1962 | new |

Figure 1

| Nova | SR | Epoch | X | Y | Scale | RA (00h:m:s | Dec (d:m:s) | SS Used | SS Err | Im Err | Comb. Err | Mag | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99-010 | 10 | 3 | 193 | 6 | 0-1000 | 43:03.17 | 41:15:59.7 | 68,71,72 | 0.07 | 0.09 | 0.09 | 15.99 | VB |
| 99-010 | 10 | 4 | 193 | 6 | 0-1000 | 43:03.17 | 41:15:59.7 | 68,71,72 | 0.07 | 0.10 | 0.10 | 15.85 | VB |
| 99-010 | 10 | 5 | 193 | 6 | 0-1000 | 43:03.17 | 41:15:59.7 | 72,73 | 0.06 | 0.23 | 0.17 | 15.92 | VB |
| 99-010 | 10 | 6 | 193 | 6 | 0-1000 | 43:03.17 | 41:15:59.7 | 66,67,72,73 | 0.06 | 0.10 | 0.09 | 16.31 | VB |
| 99-010 | 10 | 7 | 193 | 6 | 0-1000 | 43:03.17 | 41:15:59.7 | 68,71,72 | 0.07 | 0.09 | 0.09 | 16.25 | VB |
| 00-022 | 5 | 9 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.03 | 0.05 | 16.33 | |
| 00-022 | 5 | 10 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 11,12,16 | 0.05 | 0.07 | 0.07 | 16.55 | |
| 00-022 | 5 | 11 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 11,12,16 | 0.05 | 0.00 | 0.05 | 16.65 | |
| 00-022 | 5 | 12 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.05 | 0.06 | 16.20 | |
| 00-022 | 5 | 13 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.02 | 0.05 | 16.37 | |
| 00-022 | 5 | 14 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.04 | 0.06 | 16.87 | |
| 00-022 | 5 | 15 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.02 | 0.05 | 17.07 | |
| 00-022 | 5 | 16 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.02 | 0.05 | 17.16 | |
| 00-022 | 5 | 17 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.03 | 0.05 | 17.74 | |
| 00-022 | 5 | 18 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.05 | 0.06 | 19.30 | |
| 00-022 | 5 | 19 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.01 | 0.05 | 19.60 | |
| 00-022 | 5 | 20 | 287 | 19 | 0-175 | 43:28.58 | 41:21:42.5 | 10,11,14 | 0.05 | 0.06 | 0.07 | 20.00 | |
| 00-025 | 6 | 18 | 177 | 206 | 0-1000 | 43:04.32 | 41:19:35.3 | 18,19,21 | 0.05 | 0.11 | 0.09 | 17.44 | |
| 00-025 | 6 | 19 | 177 | 206 | 0-1000 | 43:04.32 | 41:19:35.3 | 18,19,21 | 0.05 | 0.01 | 0.05 | 17.34 | |
| 00-027 | 10 | 18 | 421 | 91 | 0-1000 | 42:49.59 | 41:15:05.0 | 67,73,74 | 0.05 | 0.01 | 0.05 | 18.12 | |
| 00-027 | 10 | 19 | 421 | 91 | 0-1000 | 42:49.59 | 41:15:05.0 | 67,73,74 | 0.05 | 0.09 | 0.08 | 16.66 | |
| 00-028 | 10 | 18 | 220 | 43 | 0-1000 | 43:01.75 | 41:15:37.9 | 67,73,74 | 0.05 | 0.01 | 0.05 | 16.91 | |
| 00-028 | 10 | 19 | 220 | 43 | 0-1000 | 43:01.75 | 41:15:37.9 | 67,73,74 | 0.05 | 0.09 | 0.08 | 14.67 | |
| 00-029 | 11 | 18 | 92 | 159 | 0-1000 | 42:38.53 | 41:14:18.4 | 97,103,104 | 0.07 | 0.04 | 0.08 | 15.72 | |
| 00-029 | 11 | 19 | 92 | 159 | 0-1000 | 42:38.53 | 41:14:18.4 | 97,103,104 | 0.07 | 0.11 | 0.10 | 16.69 | |
| 01-030 | 6 | 9 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,21,22 | 0.05 | 0.05 | 0.06 | 18.41 | |
| 01-030 | 6 | 10 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,21,22 | 0.05 | 0.02 | 0.05 | 15.81 | |
| 01-030 | 6 | 11 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.10 | 0.09 | 15.70 | |
| 01-030 | 6 | 12 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.04 | 0.06 | 16.05 | |
| 01-030 | 6 | 13 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.02 | 0.05 | 16.33 | |
| 01-030 | 6 | 14 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.12 | 0.10 | 17.03 | |
| 01-030 | 6 | 15 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.03 | 0.05 | 17.43 | |
| 01-030 | 6 | 16 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.02 | 0.05 | 17.31 | |
| 01-030 | 6 | 17 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.07 | 0.07 | 17.96 | |
| 01-030 | 6 | 18 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.14 | 0.11 | 19.59 | |
| 01-030 | 6 | 19 | 135 | 332 | 0-500 | 43:06.86 | 41:18:09.4 | 18,19,20,21 | 0.05 | 0.04 | 0.06 | 19.24 | |
| 01-097 | 11 | 2 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.04 | 0.08 | 15.74 | |
| 01-097 | 11 | 3 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.05 | 0.08 | 16.70 | |
| 01-097 | 11 | 4 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.05 | 0.08 | 16.58 | |
| 01-097 | 11 | 5 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.02 | 0.07 | 16.33 | |
| 01-097 | 11 | 6 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.08 | 0.09 | 16.87 | |
| 01-097 | 11 | 7 | 67 | 31 | 0-1500 | 42:40.05 | 41:15:46.0 | 97,103,104 | 0.07 | 0.02 | 0.07 | 16.66 | |
| 02-006 | 6 | 2 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.05 | 0.06 | 17.14 | r3=9 |
| 02-006 | 6 | 3 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 19,21,24 | 0.06 | 0.01 | 0.06 | 17.42 | r3=9 |
| 02-006 | 6 | 4 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.11 | 0.09 | 17.68 | r3=9 |
| 02-006 | 6 | 5 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.12 | 0.10 | 17.49 | r3=9 |
| 02-006 | 6 | 6 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.02 | 0.05 | 17.82 | r3=9 |
| 02-006 | 6 | 7 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.09 | 0.08 | 17.65 | r3=9 |
| 02-006 | 6 | 8 | 88 | 8 | 0-450 | 43:12.39 | 41:21:49.2 | 18,19,21 | 0.05 | 0.09 | 0.08 | 19.12 | r3=9 |
| 02-007 | 6 | 11 | 404 | 264 | 0-600 | 42:50.59 | 41:18:55.8 | 18,22,24 | 0.06 | 0.11 | 0.10 | 18.71 | |
| 02-010 | 6 | 21 | 505 | 111 | 0-450 | 42:44.54 | 41:20:40.1 | 20,22,24 | 0.06 | 0.10 | 0.09 | 17.42 | r1=2, r2=4, r3=6 |
| 02-010 | 6 | 22 | 505 | 111 | 0-450 | 42:44.54 | 41:20:40.1 | 20,22,24 | 0.06 | 0.13 | 0.11 | 18.36 | r1=2, r2=4, r3=6 |
| 02-010 | 6 | 23 | 505 | 111 | 0-450 | 42:44.54 | 41:20:40.1 | 20,22,24 | 0.06 | 0.16 | 0.13 | 18.35 | r1=2, r2=4, r3=6 |
| 02-010 | 6 | 24 | 505 | 111 | 0-450 | 42:44.54 | 41:20:40.1 | 20,22,24 | 0.06 | 0.07 | 0.08 | 19.41 | r1=2, r2=4, r3=6 |
| 02-010 | 6 | 25 | 505 | 111 | 0-450 | 42:44.54 | 41:20:40.1 | 20,22,24 | 0.06 | 0.09 | 0.09 | 20.29 | r1=2, r2=4, r3=6 |
| 02-011 | 7 | 22 | 107 | 379 | 0-600 | 42:37.62 | 41:17:37.2 | 85,93,94 | 0.07 | 0.05 | 0.08 | 17.57 | |
| 02-011 | 7 | 23 | 107 | 379 | 0-600 | 42:37.62 | 41:17:37.2 | 85,93,94 | 0.07 | 0.03 | 0.07 | 17.62 | |
| 02-013 | 11 | 8 | 14 | 164 | 0-850 | 42:43.22 | 41:14:15.3 | 97,103,104 | 0.07 | 0.06 | 0.08 | 17.43 | |
| 02-014 | 11 | 17 | 6 | 406 | 0-850 | 42:43.80 | 41:11:31.4 | 97,103,104 | 0.07 | 0.10 | 0.10 | 16.30 | VB |
| 02-015 | 11 | 20 | 233 | 58 | 0-850 | 42:30.04 | 41:15:27.0 | 97,103,104 | 0.07 | 0.00 | 0.07 | 15.25 | |
| 02-016 | 14 | 3 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 55,56,57 | 0.07 | 0.07 | 0.09 | 17.27 | |
| 02-016 | 14 | 4 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 55,56,57 | 0.07 | 0.11 | 0.10 | 17.62 | |
| 02-016 | 14 | 5 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.01 | 0.07 | 17.76 | |
| 02-016 | 14 | 6 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.04 | 0.08 | 16.93 | |
| 02-016 | 14 | 7 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.04 | 0.08 | 16.61 | |
| 02-016 | 14 | 8 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.04 | 0.08 | 16.89 | |
| 02-016 | 14 | 9 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.11 | 0.10 | 18.14 | |
| 02-016 | 14 | 10 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.08 | 0.09 | 18.55 | |
| 02-016 | 14 | 11 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.07 | 0.09 | 18.54 | |
| 02-016 | 14 | 12 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.06 | 0.08 | 18.65 | |
| 02-016 | 14 | 13 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.06 | 0.08 | 18.78 | |
| 02-016 | 14 | 14 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.09 | 0.09 | 18.96 | |
| 02-016 | 14 | 15 | 409 | 222 | 0-200 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.07 | 0.09 | 19.21 | |
| 02-016 | 14 | 16 | 409 | 222 | 0-150 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.02 | 0.07 | 19.41 | |
| 02-016 | 14 | 17 | 409 | 222 | 0-150 | 42:50.33 | 41:07:47.8 | 45,46,58 | 0.07 | 0.03 | 0.07 | 19.35 | |
| 02-017 | 14 | 25 | 298 | 268 | 0-150 | 42:57.06 | 41:07:16.2 | 45,46,58 | 0.07 | 0.11 | 0.10 | 17.01 | |

Figure 2

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 02-018 | 11 | 18 | 92 | 159 | 0-850 | 42:38.54 | 41:14:18.4 | 97,103,104 | 0.07 | 0.03 | 0.07 | 15.76 | | |
| 02-018 | 11 | 19 | 92 | 159 | 0-850 | 42:38.54 | 41:14:18.4 | 97,103,104 | 0.07 | 0.11 | 0.10 | 16.66 | | |
| 02-020 | 5 | 10 | 83 | 46 | 0-200 | 43:40.93 | 41:21:24.4 | 10,11,15 | 0.05 | 0.09 | 0.08 | 19.22 | | |
| 02-022 | 15 | 12 | 510 | 226 | 0-1000 | 42:13.30 | 41:07:41.3 | 106,107,108 | | 0.09 | 0.06 | 15.50 | VB | |
| 02-022 | 15 | 13 | 510 | 226 | 0-1000 | 42:13.30 | 41:07:41.3 | 105,106,108,109 | 0.09 | 0.10 | 0.11 | 16.48 | VB | |
| 02-022 | 15 | 14 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 108,109 | 0.09 | 0.03 | 0.09 | 16.65 | VB | |
| 02-022 | 15 | 15 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 108,109 | 0.09 | 0.10 | 0.11 | 17.00 | VB | |
| 02-022 | 15 | 16 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 108,109 | 0.09 | 0.05 | 0.10 | 17.11 | VB | |
| 02-022 | 15 | 17 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 106,108,109 | 0.09 | 0.14 | 0.13 | 18.16 | VB | |
| 02-022 | 15 | 18 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 108,109 | 0.09 | 0.07 | 0.10 | 18.52 | VB | |
| 02-022 | 15 | 19 | 510 | 226 | 0-500 | 42:13.30 | 41:07:41.3 | 108,109 | 0.09 | 0.05 | 0.10 | 18.97 | VB | |
| 02-023 | 12 | 2 | 36 | 240 | 0-200 | 42:11.01 | 41:13:17.8 | 99,101,102 | 0.08 | 0.05 | 0.09 | 18.05 | | |
| 02-027 | 13 | 8 | 368 | 291 | 0-150 | 43:23.76 | 41:24:54.0 | 41,43,46 | 0.09 | 0.11 | 0.12 | 19.93 | | |
| 02-028 | 13 | 9 | 343 | 346 | 0-150 | 43:25.27 | 41:05:08.9 | 41,43,46 | 0.09 | 0.11 | 0.12 | 19.03 | | |
| 02-029 | 13 | 8 | 323 | 386 | 0-150 | 43:26.40 | 41:05:56.0 | 41,43,46 | 0.09 | 0.11 | 0.12 | 19.86 | | |
| 02-030 | 10 | 20 | 458 | 88 | 0-1600 | 42:47.37 | 41:15:07.3 | 67,73,74 | 0.05 | 0.04 | 0.06 | 16.66 | | |
| 02-030 | 10 | 21 | 458 | 88 | 0-1600 | 42:47.37 | 41:15:07.3 | 67,73,74 | 0.05 | 0.03 | 0.05 | 17.41 | | |
| 02-030 | 10 | 22 | 458 | 88 | 0-1600 | 42:47.37 | 41:15:07.3 | 67,73,74 | 0.05 | 0.00 | 0.05 | 17.72 | | |
| 02-030 | 10 | 23 | 458 | 88 | 0-1600 | 42:47.37 | 41:15:07.3 | 67,73,74 | 0.05 | 0.05 | 0.06 | 18.06 | | |
| 02-030 | 10 | 24 | 458 | 88 | 0-1600 | 42:47.37 | 41:15:07.3 | 67,73,74 | 0.05 | 0.03 | 0.05 | 18.91 | | |
| 02-031 | 10 | 20 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.04 | 0.06 | 17.17 | | |
| 02-031 | 10 | 21 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.05 | 0.06 | 16.87 | | |
| 02-031 | 10 | 22 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.00 | 0.05 | 17.46 | | |
| 02-031 | 10 | 23 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.05 | 0.06 | 17.26 | | |
| 02-031 | 10 | 24 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.03 | 0.05 | 17.90 | | |
| 02-031 | 10 | 25 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.07 | 0.07 | 18.04 | | |
| 02-031 | 10 | 26 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.01 | 0.05 | 18.56 | r2=5, r3=9 | |
| 02-031 | 10 | 27 | 469 | 288 | 0-500 | 42:46.68 | 41:12:51.4 | 67,73,74 | 0.05 | 0.07 | 0.07 | 19.01 | | |
| 02-032 | 6 | 11 | 377 | 421 | 0-1000 | 42:52.22 | 41:17:09.3 | 20,22,24 | 0.06 | 0.11 | 0.10 | 17.65 | | |
| 02-033 | 6 | 11 | 284 | 321 | 0-1000 | 42:57.84 | 41:18:16.8 | 20,22,24 | 0.06 | 0.11 | 0.10 | 18.39 | | |
| 02-034 | 5 | 8 | 467 | 82 | 0-250 | 43:17.71 | 41:20:59.4 | 10,13,17 | 0.06 | 0.03 | 0.06 | 17.71 | | |
| 02-035 | 8 | 9 | 23 | 421 | 0-250 | 42:11.81 | 41:17:08.9 | 81,91,92 | 0.08 | 0.12 | 0.12 | 18.21 | | |
| 02-036 | 11 | 11 | 389 | 485 | 0-325 | 42:20.56 | 41:10:36.8 | 97,103,104 | 0.07 | 0.13 | 0.12 | 17.90 | | |

Figure 2 (continued)

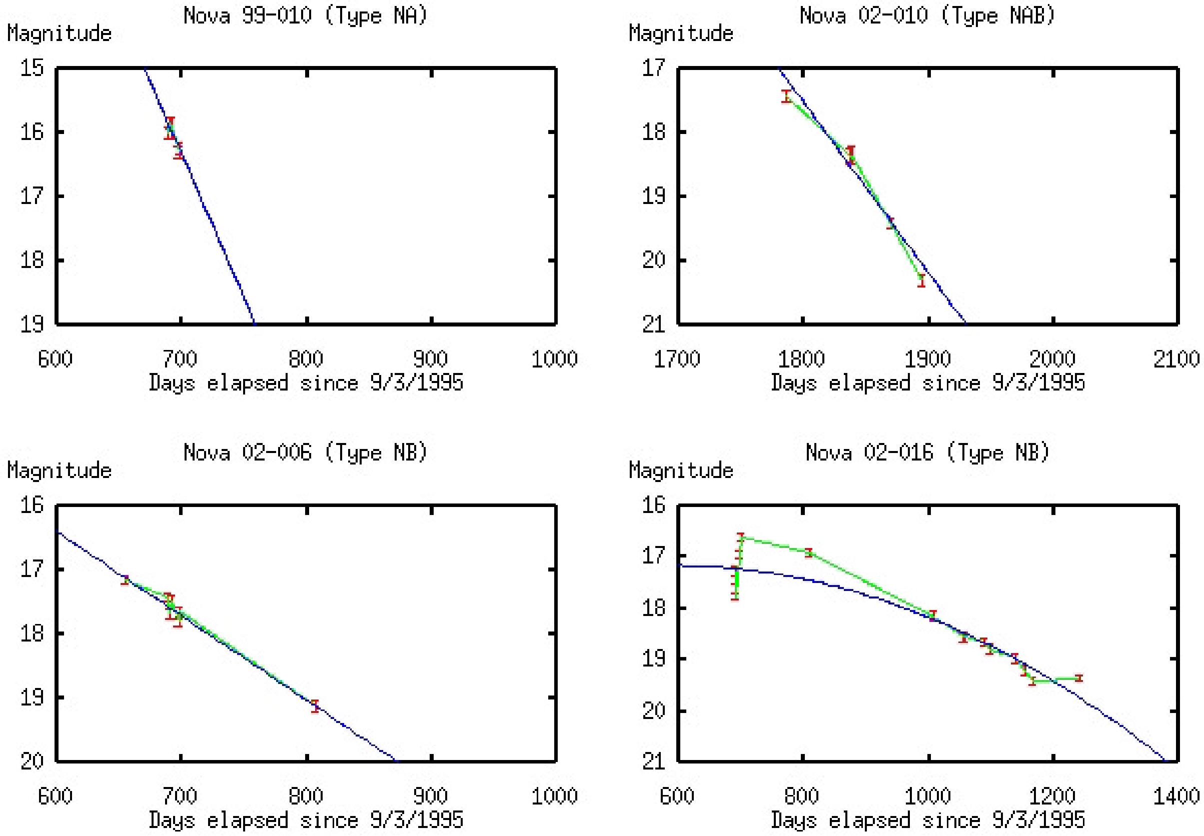
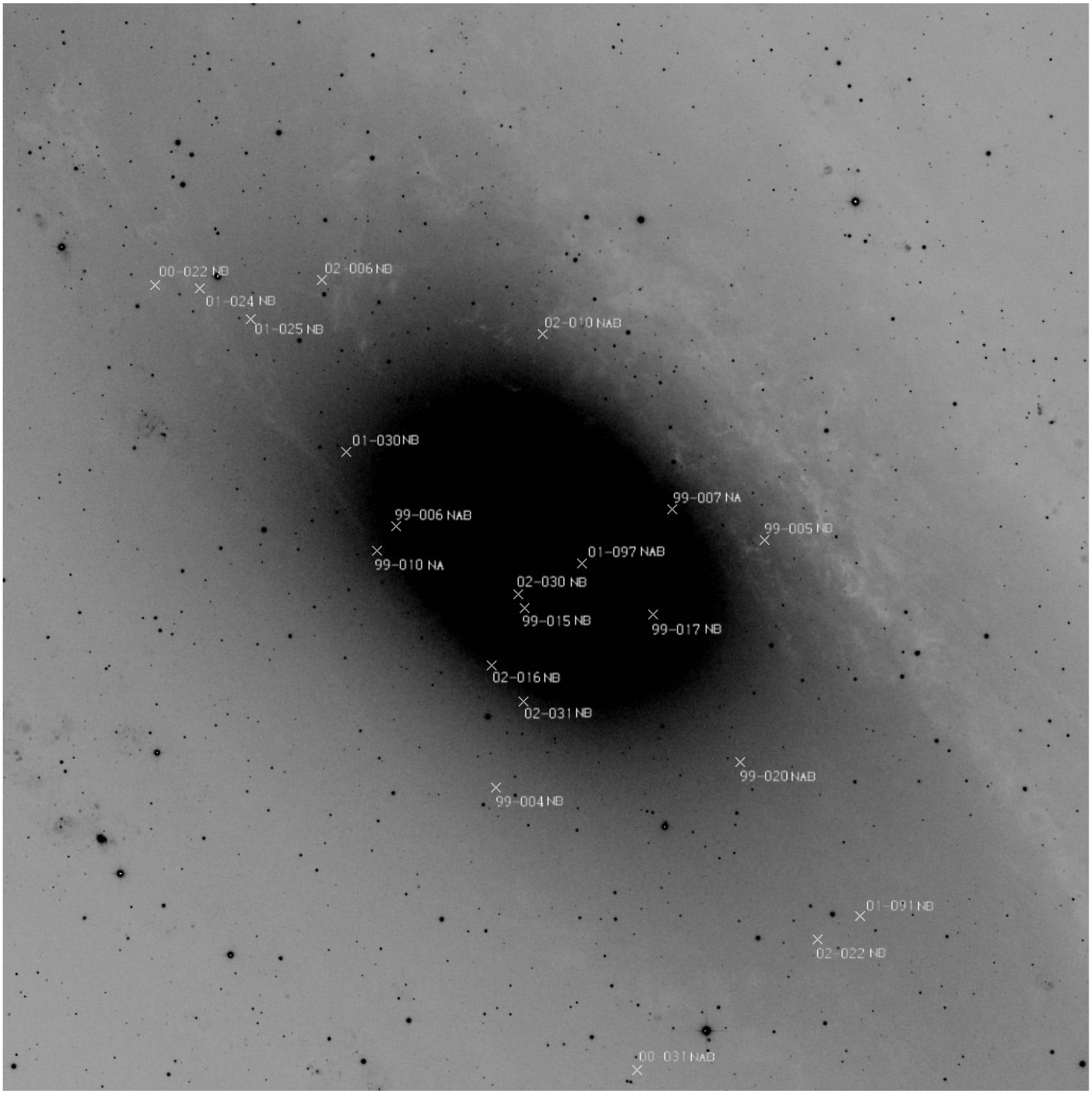


Figure 3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02-030 NB
99-015 NB
99-017 NB
02-016 NB
02-031 NB
99-020 NAB
99-004 NB
01-091 NB
02-022 NB
00-031 NAB

Figure 4

# The Brightness and Life of Novae Near the Galactic Center Compared the Outer Edge

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## Abstract

The brightness and life of novae near the galactic center compared to the outer edge is the topic of the research. It was predicted that the novae near the center would become brighter, but the location would not affect the life of the novae. Novae data was collected and recorded from eight different fields of the M31 data. Four fields near the center and four fields around the outer edge. With the results of the data collected, the novae near the center became brighter than the novae closer to the outer edge. The novae toward the outer edge, on average, had a longer lasting life than the novae toward the center.

## Hypothesis

The novae near the center would become brighter then the novae close to the outer edge. Although the location of the novae, whether it was near the center or not, would not effect the life of the novae.

## Data

Data were collected from the RBSE files in Sicon Image from fields five, six, seven, ten, eleven, fourteen, and sixteen. At least one nova's data were collected from each field and data from two novae were collected in field five and seven. The magnitudes were determined and the life of the novae was calculated by data previously collected.

## Procedure

First, novae were searched for from eight fields on the Scion Image in the M31 data files. After the verification that the "spots" were novae, the magnitudes were calculated and life length was then determined by the data collected and previous data collected. The dates of the first day of the nova's life and magnitude were then put into a spreadsheet in Microsoft Excel and then graphed. The results from the graphs were recorded and then analyzed to form a conclusion.

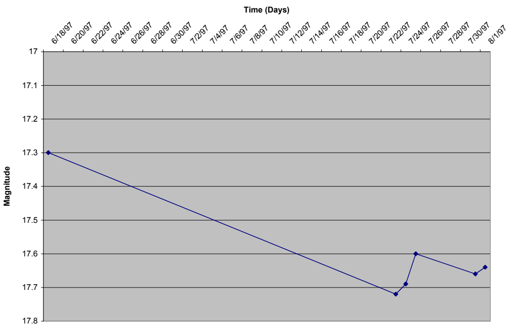
## Analysis and Conclusion

The data collected showed that the novae near the galactic center became brighter than those toward the outer edge of M31. It also showed that the novae that were toward the out edge had a longer lasting life; than that of the novae close to the center. Thus proving part of my hypothesis, saying that novae near the center would become brighter. Although disproving that the location wouldn't matter on the life of the nova.

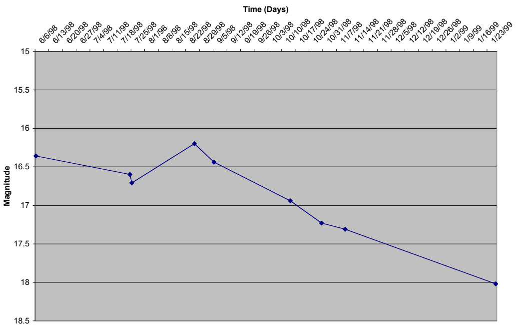
**Life and Brightness of Novae**

| | | | |
|---|---|---|---|
| Field 5, Epoch 2-7 | 44 days | brightest: 17.30 | dimmest: 17.66 |
| Field 5, Epoch 9-17 | 231 days | brightest: 16.20 | dimmest: 18.02 |
| Field 14, Epoch 3-9 | 214 days | brightest: 16.60 | dimmest: 18.11 |
| Field 16, Epoch 2-7 | 44 days | brightest: 16.47 | dimmest: 17.60 |
| | | | |
| Field 6, Epoch 13-17 | 142 days | brightest: 16.27 | dimmest: 17.93 |
| Field 7, Epoch 3-7 | 9 days | brightest: 15.72 | dimmest: 16.00 |
| Field 7, Epoch 10-14 | 72 days | brightest: 15.55 | dimmest: 18.45 |
| Field 10, Epoch 20-25 | 146 days | brightest: 16.82 | dimmest: 18.07 |
| Field 11, Epoch 5-8 | 116 days | brightest: 15.79 | dimmest: 18.05 |

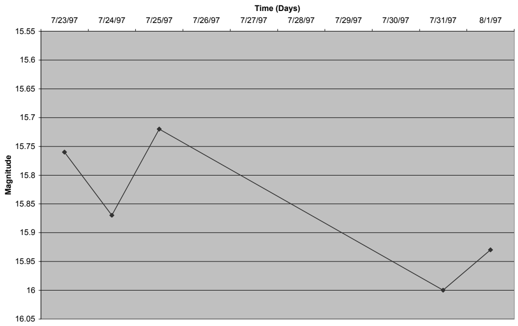
Nova in Field 5, Epoch 2-7



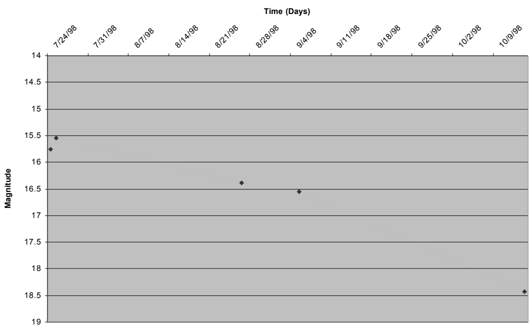
Nova in Field 5, Epoch 9-17



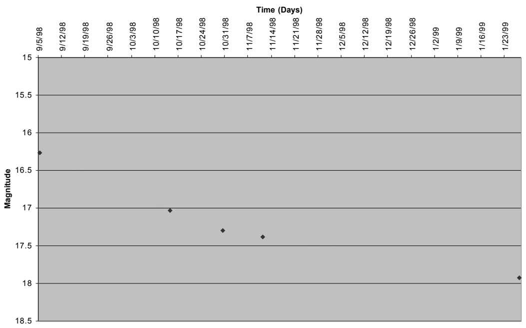
Nova in Field 7, Epoch 3-7



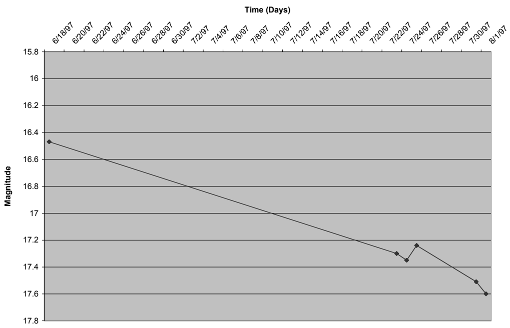
Nova in Field 7, Epoch 10-14



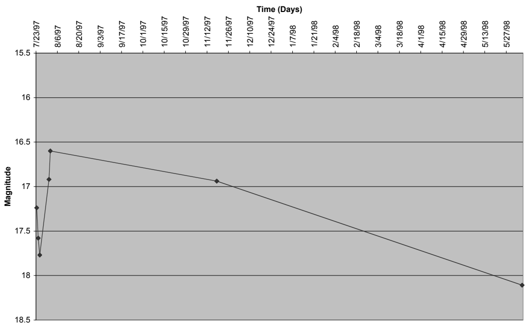
Nova in Field 6, Epoch 13-17



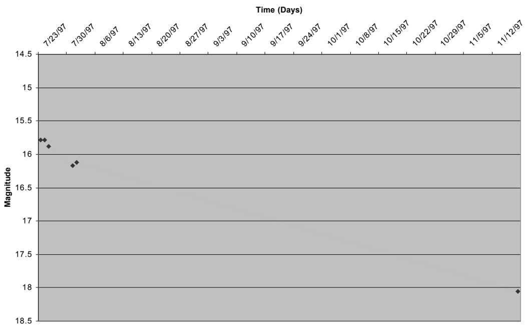
Field 16, Epoch 2-7



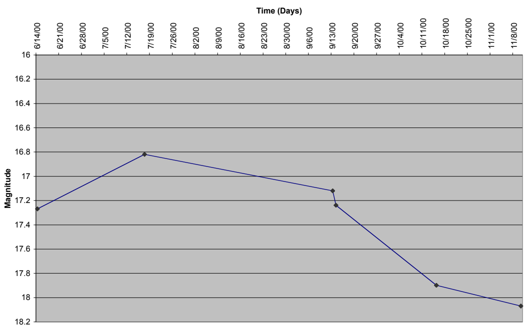
Field 14, Epoch 3-9



Nova in Field 11, Epoch 3-8



Nova in Field 10, Epoch 20-25



# *Correlations of Novae*

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Cummings Middle School, Brownsville, TX
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## *Abstract*

The purpose of our project was to analyze novae in the Andromeda Galaxy. Data sets obtained from the Research Based Science Education (RBSE) program located in Tucson, AZ were used for the project. Each epoch was analyzed with an image processing program, Scion Image. Data was analyzed by finding the number of days each nova was visible and examining the light curves of seventeen novae to determine the peak brightness and the daily magnitude increase and decrease. Using Microsoft Excel, the peak brightness of each nova was plotted against the number of days it was visible. Daily magnitude decrease and increase was also plotted against the number of days each nova was visible, to see if a correlation existed. We categorized the novae into three groups depending on the duration period, Long Duration novae, Medium Duration novae, and Short Duration novae. We also classified them into groups, Bright, Medium, and Dim. Our hypothesis was supported because the three Bright novae were classed as Short Duration. We found that the two Long Duration novae were Dim, which we expected, but then one Dim nova had Medium Duration, while the final four Dim novae lasted for a Short Duration period, which did not support our hypothesis. Most of the short-term novae that we had found were of medium brightness. We would like to examine more novae in the near future to extend our research, and see if future results support our hypothesis.

## *Purpose*

A nova is a star that rapidly increases in brightness, and then shows a smooth decent to its original state. A nova is actually a system of two stars. One star is a white dwarf while the other one is a red giant. The gravity of the white dwarf pulls hydrogen from the red giant forming an accretion disk. This disk of hydrogen builds up on the surface of the white dwarf, growing hotter and hotter until nuclear fusion occurs. This fusion releases tremendous amounts of energy, which we see as a nova.

The purpose of our project is to analyze recently obtained information from the Andromeda Galaxy to draw general conclusions about the cycles novae experience. We are interested in learning more about their life cycles, brightness, and duration periods.

## *Hypothesis*

Our hypothesis is that there is a correlation between maximum brightness and the amount of time each nova is visible. We assume that the more energy emitted per unit of time when a nova explodes, the brighter the image we will obtain and the faster its deterioration. Conversely, novae that emit less energy are thought to consume their accreted hydrogen more slowly, and will thus be visible for a longer period of time.

## *Materials*

I. Microsoft Excel
II. Microsoft PowerPoint
III. Scion Image
IV. RBSE Journal
V. RBSE CD-ROM v. 6.0
VI. Laptop computer
VII. Nova Data Sheets

## *Procedure*

Data sets were obtained from the Research Based Science Education (RBSE) program located in Tucson, AZ and used for the project. RBSE is based in the offices of the National Optical Astronomy Observatories (NOAO). Dr. Travis Rector, a NOAO astronomer, used the 0.9-meter telescope and the 2.1-meter telescope, both located at the NOAO observatory on Kitt Peak, to take digital images of the central portion of M31 (The Andromeda

Galaxy). The images were stored as files using the FITS format on the RBSE CD-ROM. 20 epochs were photographed between Sept. 1995 and October 2000.

I. Each epoch was analyzed with an image processing program, Scion Image.

II. Novae were identified and the magnitude was measured in each observed epoch.

III. Light curves for each nova were produced with Microsoft Excel to show the magnitude in each epoch.

IV. Data was analyzed by finding the number of days each nova was visible and examining the light curves of seventeen novae to determine the peak brightness and the daily magnitude decrease.

V. Using Microsoft Excel, the peak brightness of the novae was plotted against the number of days it was visible.

VI. A correlation was detected, that the greater the peak brightness the shorter the duration of the novae.

VII. Daily magnitude decline was also plotted against the number of days each nova was visible, to see if a correlation existed.

VIII. A prediction was made that these correlations would also exist for other novae.

## *Data*

We categorized the novae into three groups depending on the duration period, Long Duration novae, Medium Duration novae, and Short Duration novae. We also classified them into groups, Bright, Medium, and Dim. Our hypothesis was supported because the three Bright novae were classed as Short Duration. We found that the two Long Duration novae were Dim, which we expected, but then one Dim nova had Medium Duration, while the final four Dim novae lasted for a Short Duration period, which did not support our hypothesis. Most of the short-term novae had medium brightness, but since they were not the brightest novae, it did not prove us wrong. We would like to examine more novae in the near future to extend our research, and see if future results support our hypothesis.

## *Conclusion*

We categorized the novae into three groups depending on the duration period, Long Duration novae, Medium Duration novae, and Short Duration novae. We also classified them into groups, Bright, Medium, and Dim. Our hypothesis was supported because the three Bright novae were classed as Short Duration. We found that the two Long Duration novae were Dim, which we expected, but then one Dim nova had Medium Duration, while the final four Dim novae lasted for a Short Duration period, which did not support our hypothesis. Most of the short-term novae had medium brightness, but since they were not the brightest novae, it did not prove us wrong. We would like to examine more novae in the near future to extend our research, and see if future results support our hypothesis.

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Astronomy, A Self-Teaching Guide, Fourth Edition, Dinah L. Moche, 1993 by John Willey & Sons, Inc.

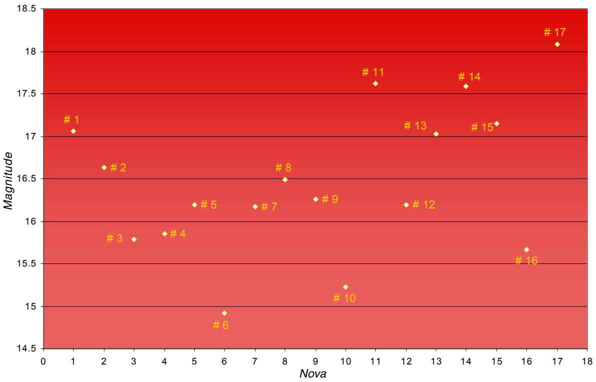
Astronomy Today, Third Edition, Eric Chaisson, Steve McMillan, 1993,1996,1999 by Prentice Hall, Inc.

Encarta 2000, 1993-1999 by Microsoft Corporation

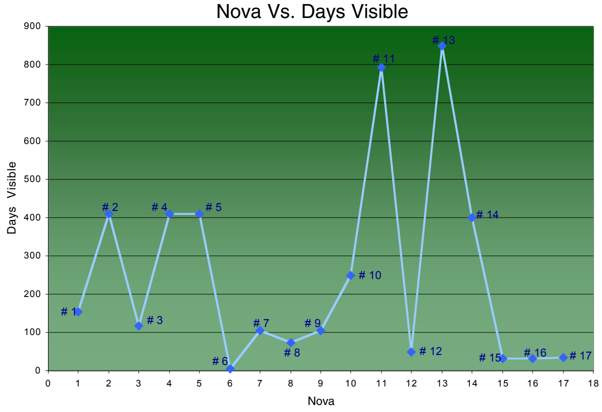
## Results

Comparisons between Novae, Days, and, Peak Brightness

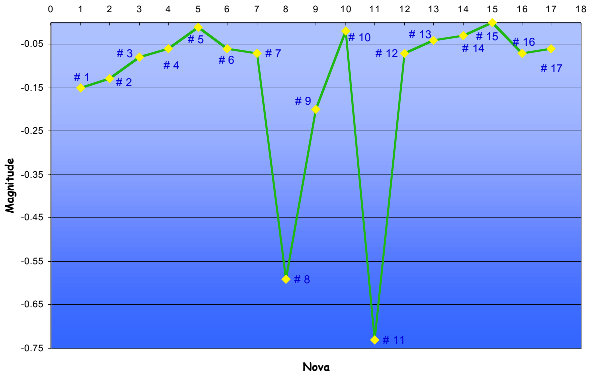
| Nova | Days | Peak Brightness |
|---|---|---|
| Long | Duration | Novae |
| # 11 | 792 | 17.62 |
| # 13 | 850 | 17.03 |
| Medium | Duration | Novae |
| # 14 | 400 | 17.59 |
| Short | Duration | Novae |
| # 1 | 153 | 17.06 |
| # 15 | 32 | 17.15 |
| # 17 | 33 | 18.08 |
| Long | Duration | Novae |
| Medium | Duration | Novae |
| # 2 | 409 | 16.63 |
| # 5 | 409 | 16.19 |
| Short | Duration | Novae |
| # 7 | 105 | 16.17 |
| # 8 | 73 | 16.49 |
| # 9 | 104 | 16.26 |
| # 12 | 48 | 16.19 |
| Long | Duration | Novae |
| Medium | Duration | Novae |
| # 4 | 409 | 15.85 |
| # 10 | 248 | 15.22 |
| Short | Duration | Novae |
| # 3 | 118 | 15.79 |
| # 6 | 4 | 14.92 |
| # 16 | 32 | 15.67 |



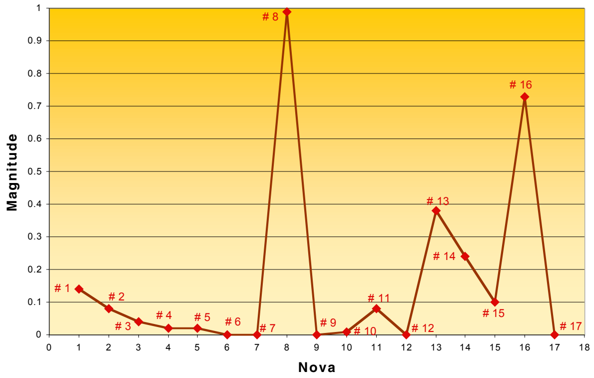
Nova Vs. Peak Brightness



Nova Vs. Days Visible



Nova Vs. Decrease in Daily Magnitude



Nova Vs. Increase in Daily Magnitude

# *The Quest for Novae in the Core of M31*

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## *Abstract*

The search for novae in M31, the Andromeda Galaxy, was made possible by using the Scion Image processing system and images of M31taken at the Kitt Peak Observatory. The data was used to find and locate any possible novae. Features and tools such as animating fields, measuring magnitude, and reading coordinates, help identify novae and their location. Light curves were formed from the magnitude and epochs of each nova. The location of novae was also taken into consideration in order to identify areas with higher concentration of novae.

## *Purpose & Hypothesis*

The purpose of the project is to identify if novae occur in certain areas, specifically in or around the center of the galaxy or if they occur throughout the galaxy at even concentrations. Because older stars are located at the center of spiral galaxies, the project hopes to substantiate that spiral galaxies have more novae occurring in the center.

## *Procedure*

Images of M31 were taken at Kitt Peak National Observatory using a .9-meter telescope. The image of M31 was divided into sixteen fields, or subrasters, each measuring 512 pixels on each side. Each field contains twenty-seven epochs that were taken using a CCD camera.

A blinking technique, which stacked the windows of selected epochs, was used to locate novae. Any possible nova that appeared in one epoch but not the next was magnified to verify if it was an actual nova. After the known magnitudes of the standard stars were entered, the magnitude was then figured and the coordinates were read. The magnitudes and coordinates of the novae were then plotted and graphed to create a light curve. The locations of the novae were plotted on a small mosaic of the fields, which was used to observe places where a larger amount of novae occurred.

## *Error Analysis*

There were a few errors that might have affected the outcome of magnitudes and the coordinates. To measure the magnitude, the declination was adjusted about ten seconds under the actual nova in order to meet the coordinates indicated in the standard star charts. There was a slight range of error in the magnitudes of the standard stars, so the magnitudes of the novae also have a small range of error. Novae that appeared in one epoch were magnified to confirm that they weren't artificial markings made by the CCD camera. The length of time a nova occurred might have been reduced because the images were taken on only certain days throughout the year.

## *Analysis*

Using Microsoft Excel, the data was plotted on line graphs to create a light curve. The line graph has the basic X and Y-axis, X being the epoch and Y being the magnitude. The light curve on some novae may drop dramatically because of the range of time between the epochs. A small amount of novae, about twenty-percent, did appear in fields that contain the outer part of the galaxy but about eighty-percent appeared near and around the nucleus, in subrasters six, seven, ten, and eleven.

Plotting the novae on the small mosaic of the fields helped determine if a relationship existed between the quantity of the novae and their location in the galaxy. Visualized in graphs and charts, very few novae appeared in more than three epochs and their magnitudes did not vary exceedingly due to their location in the Andromeda Galaxy. The persistence of a nova may have been longer, but the length of time between the images may cause it only to appear in one or a few epochs.

### Conclusion

This research was done to determine if spiral galaxies like M31 have a higher concentration of novae occurring in the center. Although a relationship was not found between the intensity and distance of any nova to the center, it was concluded that more novae occur in the center of M31. The research done on spiral galaxies indicates that older stars are found to be at the center, and young stars trace-out the spiral arms.

This research supports my hypothesis, but I would like to see if other types of galaxies, such as elliptical and irregular, also have a certain distribution of old and young stars. Will we find a high concentration of novae occurring in the center of these galaxies or will they be evenly distributed?

### Acknowledgements

In making this research possible, I would like to thank Dr. Travis Rector for the data and procedures used to locate novae. I would also like to thank my teacher, Cynthia Weehler, for her help in making the research and report possible and for her help in gaining knowledge of astronomy.

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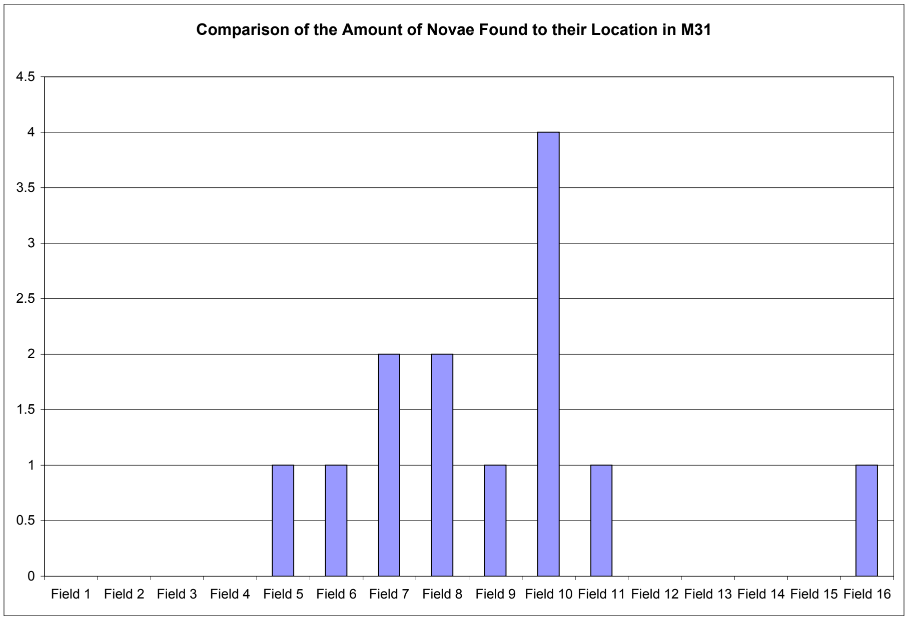
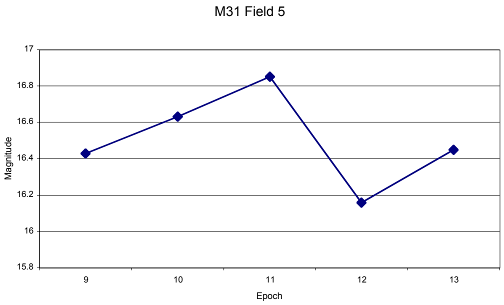
Fraknoi, Andrew, David Morrison, Sidney Wolff. Voyages Through the Universe. Saunders Golden Sunburst Series. Fort Worth: Saunders College Publishing, 1997.

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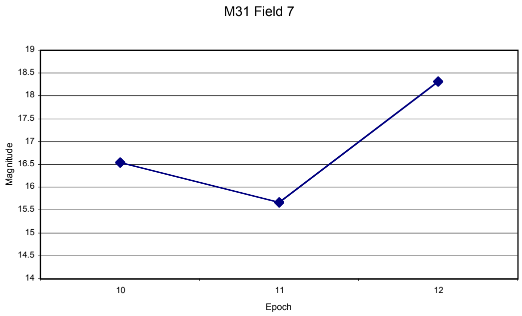
17
16.8
16.6
16.4
16.2
16
15.8
9
10
11
12
13
Epoch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Magnitude
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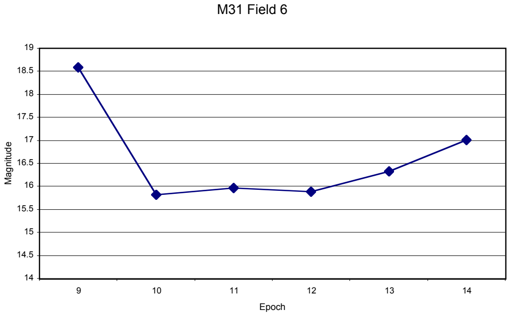
18
17.5
17
16.5
16
15.5
15
14.5
14
10
11
12
Epoch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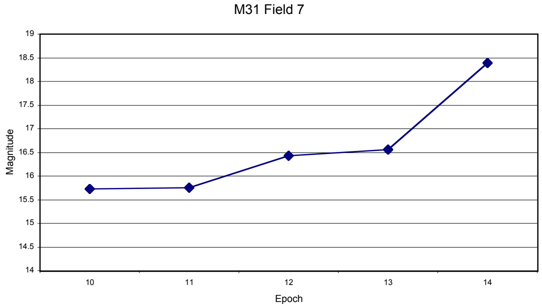
18
17.5
17
16.5
16
15.5
15
14.5
14
9
10
11
12
13
14
Epoch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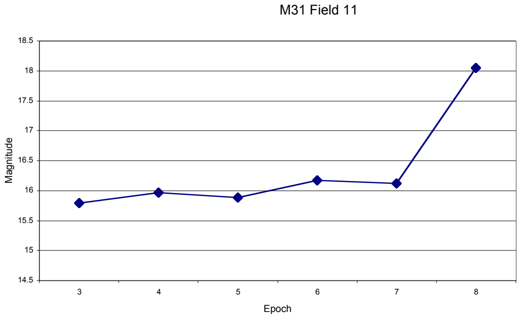
18
17.5
17
16.5
16
15.5
15
14.5
14
10
11
12
13
14
Epoch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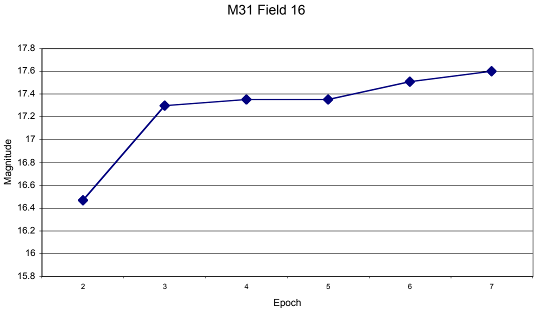
6
7
8
Epoch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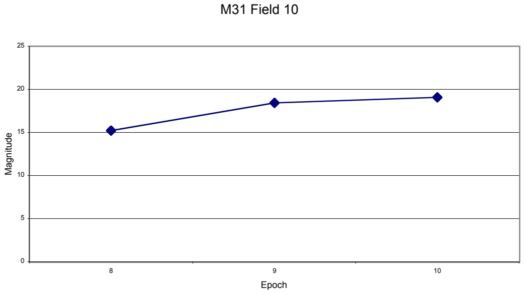
17.6
17.4
17.2
17
16.8
16.6
16.4
16.2
16
15.8
2
3
4
5
6
7
Epoch


M31 Field 10
Magnitude
25
20
15
10
5
0
8
9
10
Epoch

# Distances of Active Galactic Nuclei

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*Teacher: Carl Katsu, RBSE '01*

## Abstract

There is not much known about AGN (Active Galactic Nuclei) galaxies. Much information about AGN are derived from the analysis of information done by those who are not professional Astronomers. This is due to the overwhelming amounts of data that is present and that cannot all be studied. By studying this data much information can be retrieved that may have otherwise taken much longer.

## Introduction

An active galaxy is a source of excess radiation. The excess radiation is usually radio waves, X rays, gamma rays, or some combination. An active galactic nucleus is the central energy source of an active galaxy. To determine the type of AGN galaxy an object is one must analyze the spectra graphs. To identify the different kinds of AGN we have criteria that each galaxy has to prove or disprove. Different types of AGN galaxies are Radio, Quasars and Bl-Lacs. Radio galaxies tend to have narrow emission lines, while quasars have no absorption lines. BL-Lac objects have weak emission lines while normal galaxies have no emission spikes.

## Purpose

The analysis of this data is to reveal the different types of AGN, their red shifts and distances. It is also to determine if certain types of AGN galaxies generally reside at certain distances from Earth.

## Procedure

Spectra data received were gathered by the National Observational Astronomy Observation Research Based Science Education program in Arizona. Spectrums of galaxies were analyzed. According to features that each spectrum had, they were categorized into Normal, Radio, Quasar and Bl-Lacs. After their galaxy type was determined, the spectra were then analyzed for red shift. Observed emission lines were compared with normal line values. Red shifts then were determined with the equation of $1+z=$observed wavelength/ resting wavelength, where $z$ is red shift. Distance was determined with the equation of $d=cz\ \{(1+.5z)/(1+z)\}/H$, where $z$ is red shift, $c$ is the speed of light and $H$ is Hubble's constant.

## Data

The following page contains the data resulting from spectra analysis.

## Conclusion

There seems to be no correlation between the AGN galaxy type and its distance from earth. The distances of the galaxies seem to be at odd distances. If more time and resources could have been devoted to the project then values could be checked thoroughly and red shift values could be more solidly determined.

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"Normal Galaxies". http://www.astr.ua.edu/normal2.html. 2001.

Rector, Travis A. and Wolpa, Brenda A. AGN Spectroscopy. National Optical Astronomy Observatories. Arizona: 2000. 1-32.

Seeds, Michael P. Foundations of Astronomy, 1999 edition. Wadsworth Publishing Company. New York:1999. 132-135, 356-376.

| Id | Observed | Rest | Red shift | Distance mega parsecs | |
|---|---|---|---|---|---|
| ffs0728 | 3138.6 | 3133 | 0.001787424 | 71.43318407 | |
| ffs0752a | 3157.7 | 3133 | 0.007883817 | 314.1193292 | |
| ffs0811b | 4504.7 | 4340 | 0.037949309 | 1490.222439 | |
| ffs0148 | 4068.5 | 3869 | 0.051563712 | 2011.979651 | |
| ffs0813 | 3521 | 3426 | 0.02772913 | 1094.20203 | |
| ffs0847 | 5268.1 | 4861 | 0.0837482 | 3220.492748 | |
| ffs0148 | 7158.4 | 6563 | 0.090720707 | 3477.914363 | |
| ffs0754b | 4099 | 1549 | 1.64622337 | 45366.52644 | |
| ffs0758 | 4090.9 | 2803 | 0.459471994 | 15485.85388 | |
| ffs0816 | 3133.8 | 3133 | 2.55346E-04 | 10.21254884 | |
| ffs0847 | 7014.7 | 6563 | 0.068825232 | 2664.371555 | |
| ffs0859 | 4862.5 | 4861 | 3.08578E-04 | 12.34123545 | |
| ffs1535 | 4334.5 | 1213 | 2.573371805 | 65870.48144 | |
| ffs0040 | 6141.2 | 6563 | -0.064269389 | -2659.060678 | Blue Shift |
| ffs0722 | 4068.5 | 1213 | 2.354080791 | 61118.73024 | |
| ffs0800 | 3650.7 | 3426 | 0.06558669 | 2542.730595 | |
| ffs0811 | 3075.9 | 1909 | 0.611262441 | 19812.62162 | |
| ffs0020 | 4831.2 | 4000 | 0.2078 | 7596.967048 | |
| hd331072 | 5157.617 | 4861 | 0.061019749 | 2370.604467 | |
| hd313643 | 5697.2075 | 1213 | 3.696791014 | 89677.59377 | |
| ev_lac | 6562.1938 | 4861 | 0.349967867 | 12184.18988 | |
| hd187282 | 6562.2865 | 6563 | -1.08716E-04 | -4.348857464 | Blue Shift |
| hd313846 | 6564.6125 | 6563 | 2.45696E-04 | 9.826615612 | |
| hd331054 | 3980.4838 | 3933 | 0.012073176 | 480.0465725 | |
| hd331055 | 3975.9699 | 3933 | 0.010925477 | 434.6575493 | |
| hd331057 | 4866.8624 | 4861 | 0.001206007 | 48.21122576 | |
| hd331059 | 3982.9468 | 3933 | 0.012699415 | 504.7915536 | |
| hd331061 | 3972.6124 | 3933 | 0.010071803 | 400.8635138 | |
| hd331063 | 4862.0588 | 4861 | 2.17815E-04 | 8.711661911 | |
| hd331066 | 4862.0815 | 4861 | 2.22485E-04 | 8.898413643 | |
| hd331078 | 3975.6594 | 3933 | 0.010846529 | 431.5334781 | |
| hd331080 | 4861.92 | 4861 | 1.89261E-04 | 7.569742491 | |
| hd331081 | 6563.7549 | 6563 | 1.15024E-04 | 4.600680112 | |
| hd331083 | 3975.6104 | 3933 | 0.010834071 | 431.0404464 | |
| hd331085 | 3982.9544 | 3933 | 0.012701348 | 504.867885 | |

# *Correlation of the Location of Black Holes and Quasars*

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## *Abstract*

My partner and I have been studying Quasars and Super massive Black holes to see if we can map the location of each to see if there is a stronger correlation between them. We already know that they are related in some way but astronomers are not yet positive on how or why. We can use their Red shifts to help us calculate the distance from one object to the next. By doing this we can easily find the locations of possible Black holes and the locations of Quasars. When we have this done that provides a visual aid for us to see if the calculated location of Quasars and calculated location of Black Holes indicates that there is a strong correlation between them.

## *Background Information*

Einstein's theory of relativity states that there is a certain degree of gravitational lensing. If gravity can be properly viewed as a bending of space produced by mass, then light rays should change their direction upon passing a massive object. Both black holes and quasars are considered massive objects; this is one way in which they can be located. The search to locate and confirm the existence of black holes began in 1970. The process they used was to find one or more objects that were obviously black holes. One problem is that on its own, a black hole is invisible. This creates the need of a companion star or a binary system. A binary system is a grouping of two stars that orbit each other. If there is any amount of gas flowing into a black hole, heat is created and x-ray waves become visible. A black hole is theoretically a star of two or more solar masses, which has collapsed into itself. This body begins to shrink into singularity, the point at which an object obtains a radius of zero and its density and gravity become infinite. The amount of gravity produced by this body is so immense that it begins drawing the matter in it and around it into itself. The amount of gravity produced is so great that nothing can escape from it.

Quasars are also huge celestial bodies in the universe. Quasars were first discovered in 1960. They are generally at the centers of galaxies. Some theoretically contain black holes. The word quasar is short for "quasi-stellar radio source". Despite their brightness, and due to their great distance from Earth, quasars cannot be seen with an unaided eye. Energy from quasars takes billions of years to reach the Earth. The discovery of quasars came about with the detection of large amounts of radio energy. The first body used for the testing of the possibilities of quasars was the star 3C 273, this was also the first confirmed example of a quasar.

Red shift is a shift toward longer wavelengths observed in the lines of spectra of celestial objects. It is referred to as red due to a relationship with the colors of the spectra. The color red is on the lowest end of the spectra. This color represents and is a long wavelength. The long wavelength tells us that something is moving away and is causing a stretch in the wavelength. Edwin Powell Hubble found a link between red shift and the expansion of the universe. He theorized that the Doppler effect caused this red shift. The apparent variation in frequency of any emitted wave as the source of the wave approaches or moves away relative to an observer. This combined with the red shift equation indicates the speed of recession of galaxies and other celestial bodies. Albert Einstein contrived another theory, which is the gravitational red shift or the Einstein shift. Einstein's general relativity theory stated that periodic processes are slowed down in a gravitational field. This shift is noticeable in the spectra of compact massive stars, such as white dwarfs. Large red shifts are often observed in quasars. These are believed to be cosmological. Some scientists now believe the red shifts in quasars are caused by the Einstein shift or another unknown force.

## *Hypothesis*

To find a correlation between the location of possible Black Holes and the location of Quasars. We are mapping out where Quasars are in a specific area in the sky, then taking the coordinates of possible Black Holes in the same area and looking for a correlation between them. We are looking for a even the smallest correlation between distance and or a pattern in the location.

We will test this hypothesis by mapping them out then looking for the relationship.

We believe that we will be able to find a correlation between the location of possible Black Holes and the location of Quasars. There are two other ways that the project could turn out. It is possible that the Black Holes and the Quasars have absolutely no relationship between each other at all. The other way is that we would have not been able to collect enough sufficient data to make a well-educated statement to support our hypothesis.

There are a few factors that would possibly affect our project. The few factors that might affect our project are uncontrollable. We know that it is possible that the limited information on Black Holes would prevent us from finding a vital piece of information to our project. Being that we are only mapping out the object in a small section of the sky, could leave us to find that that section of the sky does not have one or the other(Quasar or Black Hole).

### Procedure

Examining the coordinates of black holes and those of quasars in order to find some relationship between the two. To display this we will use three-dimensional models, which if our hypothesis is correct will show a relationship between the location of quasars and black holes including in them right ascension, declination, and light-years apart due to red shift or blue shift.

### Conclusion

The data my partner and I collected were non conclusive. All we were able to accomplish was to make two dimensional graph of the locations of 20 Quasars and 17 Black Holes. There seems to be little correlation between the location of the two in the data we have graphed so far.

### Acknowledgements

Johns Hopkins University Applied Physics Lab Space Department Programs Office, Mr. Bob Farquhar and Mr. David Dunham for supplying information which aided in the completion of the project; and Mr. Richard Terry for the effort of supplying information and contacts.

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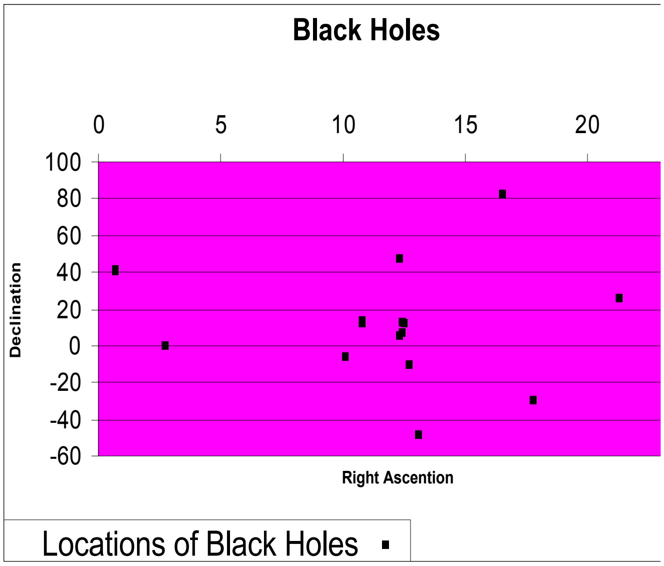
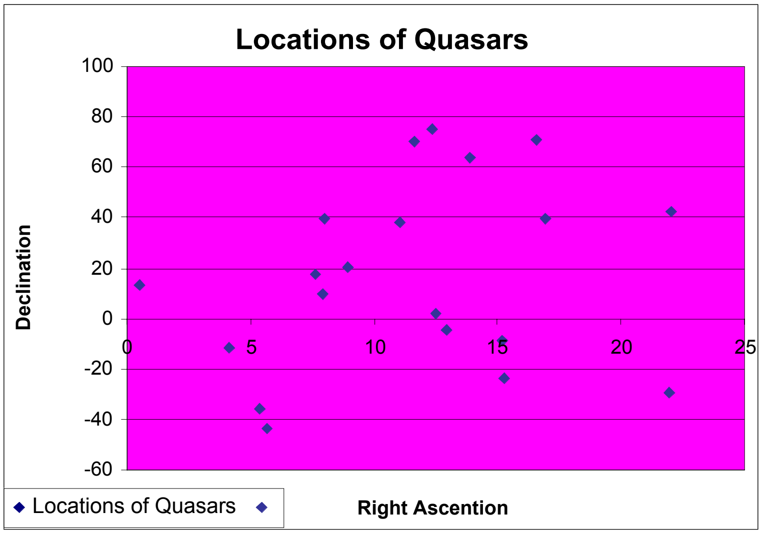
http://www.astr.ua.edu/keel/agn/forest.html

http://www.astr.ua.edu/keel/agn/q0957.html

|  |  |  | Black Holes |  |  |  |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |
|  | RA |  |  |  | DEC |  |
| 17 | 45 | 40 |  | -29 | 0 | 28 |
| 0 | 42 | 41.9 |  | 40 | 51 | 55 |
| 0 | 42 | 44.4 |  | 41 | 16 | 8 |
| 10 | 5 | 14.1 |  | -7 | 43 | 7 |
| 12 | 39 | 59.4 |  | -11 | 37 | 22 |
| 10 | 47 | 41.7 |  | 13 | 59 | 0 |
| 10 | 47 | 49.9 |  | 12 | 34 | 57 |
| 12 | 23 | 38.8 |  | 7 | 3 | 19 |
| 12 | 30 | 32.1 |  | 12 | 29 | 27 |
| 12 | 25 | 3.7 |  | 12 | 53 | 15 |
| 12 | 30 | 49.7 |  | 12 | 23 | 24 |
| 12 | 19 | 22.8 |  | 5 | 49 | 36 |
| 21 | 18 | 33.1 |  | 26 | 26 | 55 |
| 16 | 32 | 33.6 |  | 82 | 32 | 17 |
| 2 | 42 | 40.2 |  | 0 | 0 | 48 |
| 12 | 18 | 57.9 |  | 47 | 18 | 16 |
| 13 | 5 | 26.2 |  | -49 | 28 | 15 |





|  | RA |  | Quasars | Dec |  |  |
|---|---|---|---|---|---|---|
| 0 | 29 | 13.7 |  | 13 | 16 | 4 |
| 4 | 7 | 48.4 |  | -12 | 11 | 37 |
| 5 | 22 | 57.9 |  | -36 | 27 | 31 |
| 5 | 38 | 49.8 |  | -44 | 5 | 9 |
| 7 | 38 | 7.4 |  | 17 | 42 | 21 |
| 7 | 57 | 6.7 |  | 9 | 56 | 34 |
| 7 | 57 | 59.9 |  | 39 | 20 | 27 |
| 8 | 54 | 48.9 |  | 20 | 6 | 32 |
| 11 | 4 | 27.3 |  | 38 | 12 | 32 |
| 11 | 36 | 26.8 |  | 70 | 9 | 24 |
| 12 | 21 | 44.1 |  | 75 | 18 | 37 |
| 12 | 29 | 6.8 |  | 2 | 3 | 7 |
| 12 | 56 | 11.2 |  | -5 | 47 | 21 |
| 13 | 53 | 15.8 |  | 63 | 54 | 45 |
| 15 | 12 | 50.6 |  | -9 | 6 | 0 |
| 15 | 17 | 41.8 |  | -24 | 22 | 19 |
| 16 | 34 | 29 |  | 70 | 31 | 32 |
| 16 | 53 | 52.2 |  | 39 | 45 | 37 |
| 21 | 58 | 51.9 |  | -30 | 13 | 30 |
| 22 | 2 | 43.3 |  | 42 | 16 | 40 |

# *Quasars: Redshift vs. Luminosity*

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## *Abstract*

Quasars are super-luminous active galaxies that form around a central black hole. Since quasars are only found extremely far away, it can be concluded that they were formed much earlier than most normal galaxies. If a relationship between a quasar's age, distance, and luminosity exists, then the age and distance of objects nearby the quasar could also be determined. In this study, 95 quasars from FIRST data were analyzed. After a series of calculations, it has been found that a more distant quasar is more luminous than a quasar that is closer to the observer. The redshifts grow higher as the quasar moves further and further away. The range of redshifts of the studied quasars is 0.27 to 4.54. For these redshifts, the luminosity range is from 1.57e40 to 1.7e44. Notice that there is a general increase in the luminosity of these quasars as their redshifts increase. The increase in luminosity is proportional to the cube of the quasar's redshift. The following article will include a more in-depth study and conclusion for the FIRST quasar data.

### *Purpose*

The purpose of this study is to determine a relationship between the luminosities and the redshifts of 95 quasars from the FIRST survey data.

### *Hypothesis*

There is a graphical function that represents the decay of a quasar's luminosity over time.

### *Procedure*

All active galactic nuclei (AGN's) from the FIRST survey data were opened in Graphical Analysis. Using their emission lines, each AGN was analyzed to determine which ones were quasars and which were just normal galaxies. All AGN's that were determined to be quasars were recorded in Microsoft Excel (see chart on next few pages). Data was found using the calculations below. Flux was analyzed over a 4000-angstrom range. After calculating the redshift and luminosity of each individual quasar, the data was graphed for all of the quasars. As observed, the luminosity was greater for quasars with higher redshifts. This graph is included on the last page.

### *Calculations*

Red Shift = [Wavelength of element (observed)/Wavelength of element (known)]-1

Distance = {cz[(1+.5z)/(1+z)]}/Ho
c = 3E+5 km/s
z = Red Shift
Ho = 25 km/s per million light years

Luminosity = 4pfd2(1+z)2
f = flux
d = distance from Earth to the quasar
z = Red Shift

### *Data*

The data tables are shown in the appendix.

### *Analysis*

After collecting data on the elemental composition, velocity, distance, flux, and luminosity of each quasar, the data was sorted by increasing red shift. From this data, a graph was created in Graphical Analysis showing red shift on the x-axis and luminosity on the y-axis. In concordance with previous research done on quasars and their luminosity, the graph showed a general trend where increase in red shift yielded a proportional increase in luminosity. By using several of the Automatic Curve Fit functions, three graphs were found to fit the raw data within a reasonable margin of error.

## *Conclusion*

Although the Gaussian equation displayed the smallest mean square error, a close examination of the line between red shifts of 0 and 2.5 shows that the curve is slightly above the 'meat' of the graph. Most likely, the sporadic and possibly erroneous data plots on the right side of the graph significantly altered the correct equation. Considering only the data plots between red shifts 0 and 2.5, the Power equation displayed an acceptably precise line over the data plots. Even considering the data plots on the right side of the graph, the Power equation's line fell equally in between the data plots. If our calculations were correct, then these equations hold true:

Luminosity = 114.03(z^2.9347)E+40 where z = the red shift of the object

Red Shift = (Luminosity/114.03E+40)^(1/2.9347)

The accuracy of the equation would improve if more quasars of red shift greater than 2.5 were analyzed. Unfortunately, there is not much data collected on such distant AGN's. If, however, the data of distant quasars displayed on the attached graphs are correct, a new conclusion could be drawn; either there is no precise relationship between a quasar's luminosity and its red shift, or only a general trend exists. It seems more probable, though, that further examination of distant quasars would yield data plots that generally follow the graph of the functions presented in this article.

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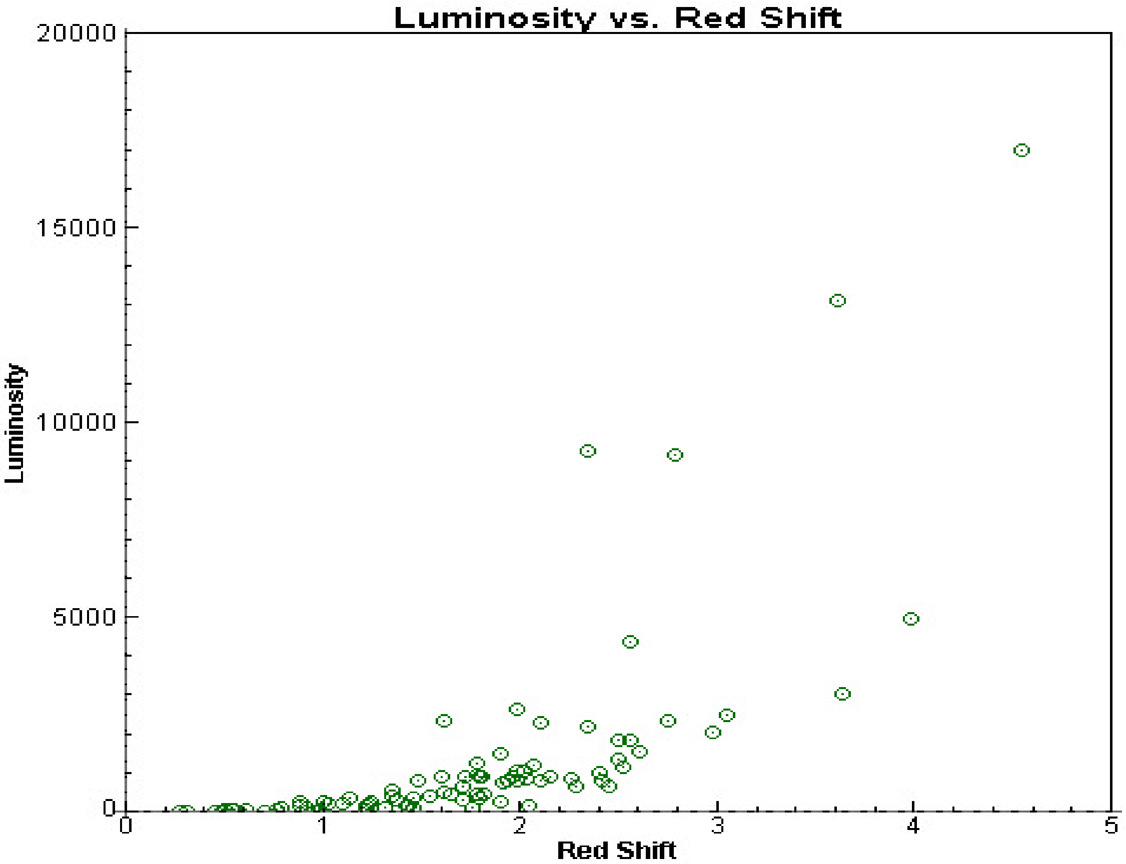
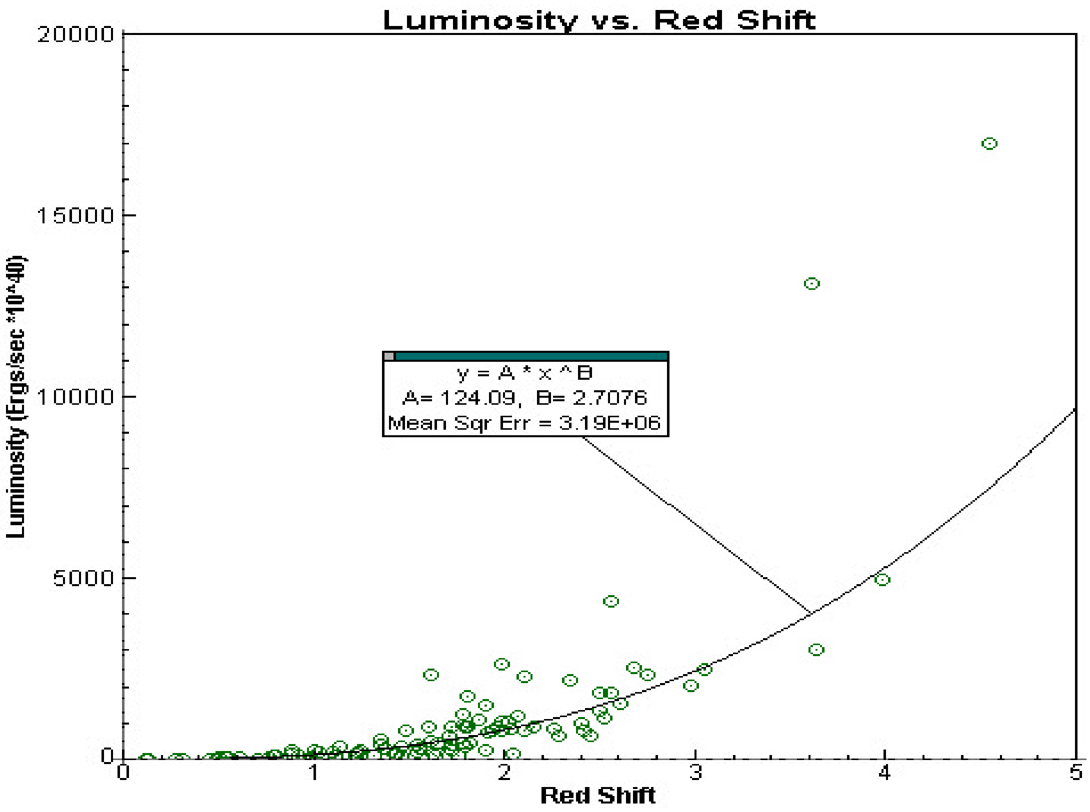
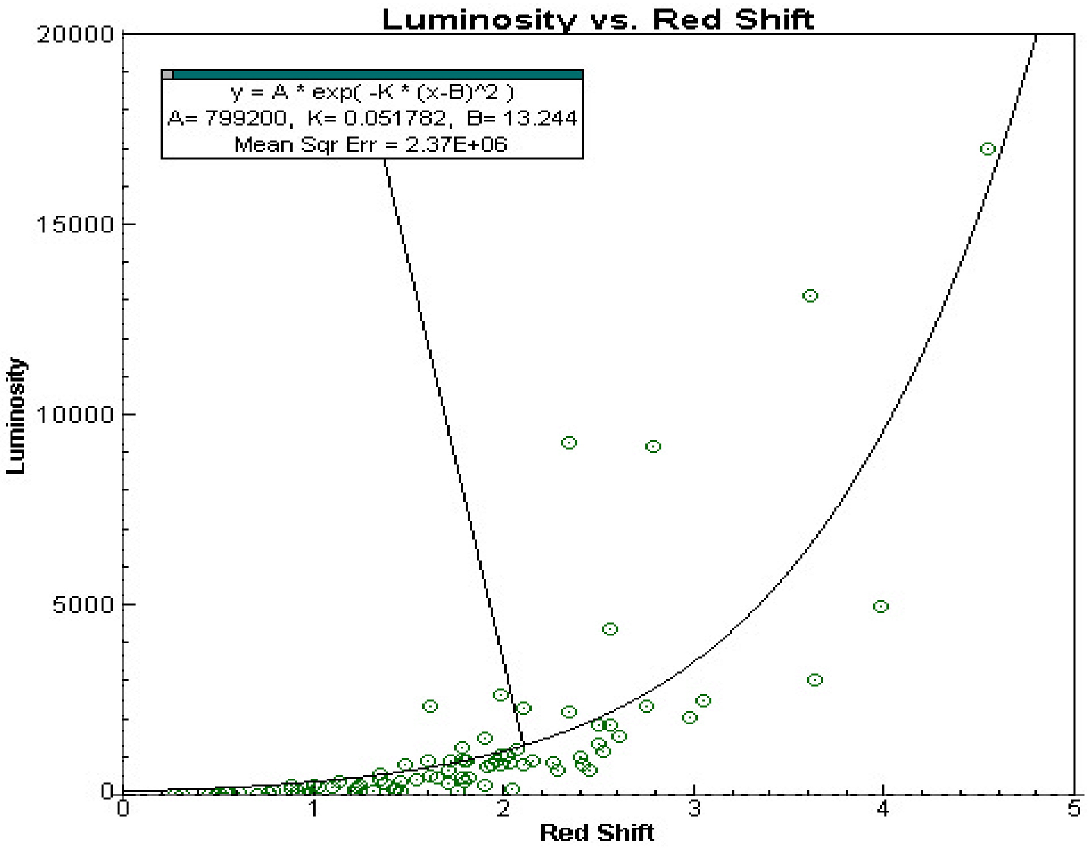



Luminosity vs. Red Shift
Luminosity (Ergs/sec *10^40)
20000
15000
10000
5000
0
0
1
2
3
4
5
Red Shift
y = A * x ^ B
A= 124.09, B= 2.7076
Mean Sqr Err = 3.19E+06


Luminosity vs. Red Shift
Luminosity
20000
15000
10000
5000
0
0
1
2
3
4
5
Red Shift
y = A * exp( -K * (x-B)^2 )
A= 799200, K= 0.051782, B= 13.244
Mean Sqr Err = 2.37E+06

| AGN Object # | Redshift | Elemental Confirmation | Velocity (km/s) | Distance (M. L.Y.) | Flux (ergs/sq. cm/s.) | Luminosity (ergs/sec) |
|---|---|---|---|---|---|---|
| ffs0905 | 0.27 | Hα, Hß, OI | 70370.09 | 2895.591 | 1.18E-13 | 1.56795E+40 |
| ffs0859 | 0.31 | Hα, Hß, OIII | 79095.03 | 3279.847 | 1.06E-13 | 1.92753E+40 |
| ffs0816 | 0.45 | Hß, OIII, CII | 106607.6 | 4562.069 | 1.04E-13 | 4.45293E+40 |
| ffs1537 | 0.46 | OIII, Hα | 108404.6 | 4650.411 | 3.53E-13 | 1.59763E+41 |
| ffs1157 | 0.485 | OIII, MgII, Hß, Hα | 112805.7 | 4869.596 | 4.64E-13 | 2.38302E+41 |
| ffs0742b | 0.5 | Hß, OIII, CII | 115384.6 | 5000 | 8.54E-13 | 4.71655E+41 |
| ffs1706 | 0.54 | Hα, Hß, MgII | 122042.9 | 5343.896 | 7.25E-13 | 4.81667E+41 |
| ffs1534b | 0.555 | MgII, OIII | 124460 | 5471.479 | 4.35E-13 | 3.08781E+41 |
| ffs0811 | 0.61 | MgII, CIII, OIII | 132966.8 | 5933.292 | 4.58E-13 | 4.09846E+41 |
| ffs0740 | 0.71 | OIII, MgII, CII | 147098.7 | 6751.228 | 1.15E-13 | 1.50565E+41 |
| ffs1533 | 0.766 | MgII, OIII | 154324.9 | 7198.492 | 3.69E-13 | 5.8578E+41 |
| ffs1639 | 0.79 | Hα, Hß, OIII | 157282.2 | 7388.045 | 6.00E-13 | 1.03044E+42 |
| ffs0847 | 0.88 | CIII, MgII, OIII | 167678.2 | 8088.511 | 5.83E-13 | 1.32293E+42 |
| ffs1606 | 0.88 | MgII, OIII | 167678.2 | 8088.511 | 1.03E-12 | 2.33312E+42 |
| ffs0737 | 0.92 | CIII, MgII, OIII | 171970 | 8395 | 3.01E-13 | 7.67031E+41 |
| ffs1608 | 0.96 | Hα, Hß, CIII | 176074 | 8698.776 | 5.50E-14 | 1.56836E+41 |
| ffs1448 | 0.975 | Hß, OIII, CIII, MgII | 177566.6 | 8812.025 | 2.36E-13 | 7.01301E+41 |
| ffs1630 | 1.01 | Hß, CIII, MgII | 180954.7 | 9074.925 | 7.06E-13 | 2.30522E+42 |
| ffs1030 | 1.025 | Hß, OIII, H, Mg | 182367.4 | 9187.037 | 5.47E-13 | 1.85713E+42 |
| ffs1557 | 1.1 | CIV, MgII | 189094.3 | 9742.857 | 4.77E-13 | 1.96148E+42 |
| ffs1620 | 1.14 | CIII, Hß, MgII | 192465.4 | 10036.26 | 8.17E-13 | 3.69719E+42 |
| ffs0301 | 1.22 | CIV, CIII, MgII | 198792.3 | 10617.3 | 6.22E-14 | 3.38896E+41 |
| ffs1349 | 1.221 | CII, CIII, OIII, MgII | 198868 | 10624.51 | 2.81E-13 | 1.53791E+42 |
| ffs1546 | 1.23 | CIV, MgII | 199546.3 | 10689.42 | 3.20E-13 | 1.78412E+42 |
| ffs1628 | 1.25 | Hß, CIII, MgII | 201030.9 | 10833.33 | 4.63E-13 | 2.6994E+42 |
| ffs1534c | 1.29 | CIII, MgII | 203909.3 | 11119.91 | 3.66E-13 | 2.32686E+42 |
| ffs1143 | 1.318 | MgII, CIII, OIII, OII | 205854.6 | 11319.56 | 1.22E-13 | 8.23047E+41 |
| ffs1708 | 1.35 | Hß, CIII, MgII | 208010.7 | 11546.81 | 5.74E-13 | 4.14751E+42 |
| ffs1334a | 1.356 | CIII, MgII, OIII, CII | 208407.2 | 11589.31 | 7.41E-13 | 5.42219E+42 |
| ffs1517 | 1.37 | CIII, MgII | 209323.1 | 11688.35 | 4.25E-13 | 3.204E+42 |
| ffs0733 | 1.42 | CIII, CIV, SiIV | 212490.5 | 12040.66 | 1.56E-13 | 1.29584E+42 |
| ffs0732 | 1.43 | MgII, CIV, SiIV | 213105.2 | 12110.86 | 1.56E-13 | 1.32186E+42 |
| ffs1408 | 1.46 | CIII, CIV | 214912.9 | 12320.98 | 1.14E-13 | 1.03062E+42 |
| ffs1501 | 1.46 | Hß, OIII, CIII, CIV | 214912.9 | 12320.98 | 3.57E-13 | 3.2217E+42 |
| ffs1257 | 1.489 | MgII, CIII, CIV | 216610.2 | 12523.39 | 8.05E-13 | 7.67967E+42 |
| ffs1614b | 1.54 | CIII, CIV, MgII | 219480.4 | 12877.8 | 3.65E-13 | 3.83401E+42 |
| ffs1306 | 1.599 | CIV, CIII, MgII, OIII | 222628.6 | 13285.42 | 7.71E-13 | 9.02095E+42 |
| ffs0722 | 1.61 | CIV, Lα, SiIV | 223196.1 | 13361.15 | 4.04E-13 | 4.82335E+42 |
| ffs0800 | 1.62 | Lyα, CIII, CIV | 223706.8 | 13429.92 | 1.94E-12 | 2.35259E+43 |
| ffs1254 | 1.647 | CIV, MgII, CIII, CII | 225061.9 | 13615.28 | 3.66E-13 | 4.66715E+42 |
| ffs0747 | 1.71 | Lyα, CIII, CIV | 228092.9 | 14045.98 | 4.38E-13 | 6.22316E+42 |
| ffs1334b | 1.712 | CIII, CIV, MgII, NeV | 228186.2 | 14059.61 | 2.16E-13 | 3.07514E+42 |
| ffs1335 | 1.718 | CII, CIII, CIV, MgII | 228465.2 | 14100.49 | 6.23E-13 | 8.98434E+42 |
| ffs1545 | 1.76 | CIII, CIV | 230375 | 14386.09 | 5.95E-13 | 9.20067E+42 |
| ffs1011 | 1.78 | CIV, MgII | 231258.9 | 14521.73 | 2.69E-13 | 4.29498E+42 |
| ffs1602 | 1.78 | CIII, CIV | 231258.9 | 14521.73 | 7.83E-13 | 1.25202E+43 |
| ffs1210 | 1.788 | CIII, CIV, Hy | 231607.9 | 14575.92 | 5.94E-13 | 9.61987E+42 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| ffs1019 | 1.793 | CIV, MgII | 231824.8 | 14609.77 | 5.47E-13 | 8.93447E+42 |
| ffs1039 | 1.8 | CIV, MgII, OI, H | 232126.7 | 14657.14 | 2.14E-13 | 3.53769E+42 |
| ffs1152 | 1.801 | CIII, CIV, MgII, CII | 232169.7 | 14663.91 | 5.25E-13 | 8.68485E+42 |
| ffs1359 | 1.823 | CII, CIII, CIV, SiIV | 233105.4 | 14812.6 | 2.54E-13 | 4.35408E+42 |
| ffs0957 | 1.905 | CIV, MgII, OII | 236434.1 | 15364.6 | 7.60E-13 | 1.48509E+43 |
| ffs0928 | 1.91 | Lyα, CIII, CIV | 236629.3 | 15398.14 | 3.86E-13 | 7.5989E+42 |
| ffs1106 | 1.94 | MgII, CIV, OII | 237782.6 | 15599.18 | 3.72E-13 | 7.67949E+42 |
| ffs1052 | 1.96 | MgII, CIV, Hy, NeV | 238534.7 | 15732.97 | 4.16E-13 | 8.85502E+42 |
| ffs1047 | 1.98 | CIV, MgII, OIII, NII | 239273.7 | 15866.58 | 4.83E-13 | 1.06071E+43 |
| ffs1131 | 1.98 | MgII, CIV, Hß, NeIII | 239273.7 | 15866.58 | 1.20E-12 | 2.63093E+43 |
| ffs1119 | 1.99 | MgII, CIV, Hß, NeIII | 239638.4 | 15933.31 | 3.51E-13 | 7.80789E+42 |
| ffs1054 | 2.02 | MgII, CIV, Hα, Hy | 240713.8 | 16133.25 | 4.43E-13 | 1.03241E+43 |
| ffs1036a | 2.03 | MgII, Lyα, NeIII, Na | 241066.1 | 16199.8 | 3.60E-13 | 8.50858E+42 |
| ffs1112 | 2.05 | MgII, Lyα | 241761.7 | 16332.79 | 6.76E-14 | 1.646E+42 |
| ffs1036b | 2.07 | Lyα, MgII, Hy, OII | 242445.5 | 16465.6 | 4.69E-13 | 1.17649E+43 |
| ffs0955 | 2.11 | CIV, CIII, Lyα | 243778.6 | 16730.74 | 2.92E-13 | 7.76997E+42 |
| ffs1658 | 2.11 | Lyα, CIII, CIV | 243778.6 | 16730.74 | 8.67E-13 | 2.30336E+43 |
| ffs1351 | 2.149 | Lyα, CIV, CIII, MgII | 245035.8 | 16988.63 | 3.11E-13 | 8.73883E+42 |
| ffs1318 | 2.264 | Lyα, CIV, MgII, SiIV | 248514.2 | 17745.76 | 2.50E-13 | 8.22242E+42 |
| ffs1005 | 2.28 | MgII, Lya, Hß, OIII | 248972.6 | 17850.73 | 1.84E-13 | 6.19448E+42 |
| ffs1616 | 2.35 | Lyα, CIII, CIV | 250910.2 | 18308.96 | 5.95E-13 | 2.19808E+43 |
| ffs1619 | 2.35 | Lyα, CIII, CIV | 250910.2 | 18308.96 | 2.51E-12 | 9.26421E+43 |
| ffs1627 | 2.41 | MgII, OIII, CIII | 252486.9 | 18700.47 | 2.50E-13 | 9.96606E+42 |
| ffs1238 | 2.416 | Lyα, CIV, CIII, SiIV | 252640.5 | 18739.56 | 1.98E-13 | 7.94955E+42 |
| ffs1656 | 2.45 | Lyα, CIII, CIV | 253497.4 | 18960.87 | 1.57E-13 | 6.60655E+42 |
| ffs1001 | 2.5 | CIII, Hß, NeIII, Na | 254717 | 19285.71 | 4.15E-13 | 1.85497E+43 |
| ffs1006 | 2.5 | CIII, Hß, NeIII, Na | 254717 | 19285.71 | 2.95E-13 | 1.32102E+43 |
| ffs1723 | 2.52 | Lyα, CIII, CIV | 255191.8 | 19415.45 | 2.53E-13 | 1.1612E+43 |
| ffs1406 | 2.56 | CIV, Lyα | 256119.8 | 19674.61 | 3.75E-13 | 1.80614E+43 |
| ffs1535 | 2.56 | CIV, Lyα | 256119.8 | 19674.61 | 9.07E-13 | 4.3692E+43 |
| ffs1144 | 2.605 | CII, CIII, Lα | 257130.7 | 19965.64 | 3.00E-13 | 1.52644E+43 |
| ffs1641 | 2.75 | Lyα, CIV, CIII | 260166 | 20900 | 3.85E-13 | 2.32057E+43 |
| ffs1724 | 2.79 | Lyα, CIII, OIV | 260947.9 | 21156.89 | 1.45E-12 | 9.17566E+43 |
| ffs2341 | 2.98 | Lyα, MgII, CIV | 264371.4 | 22372.46 | 2.62E-13 | 2.03963E+43 |
| ffs0738b | 3.05 | Lyα, CIII, CIV | 265522.2 | 22818.52 | 2.95E-13 | 2.47369E+43 |
| ffs1223 | 3.617 | CaII, Lyα | 273114.3 | 26402.45 | 8.95E-13 | 1.30519E+44 |
| ffs1410 | 3.64 | CIII, Lyα | 273368.4 | 26546.9 | 2.02E-13 | 3.00224E+43 |
| ffs1430 | 3.98 | CIII, Lyα | 276744.5 | 28675.18 | 2.46E-13 | 4.92777E+43 |
| ffs1450 | 4.54 | CIV, Lyα | 281067.5 | 32156.97 | 5.44E-13 | 1.69519E+44 |
| ffs0749 | 1.56 | CIII, CIV | 220567.7 | 13016.25 | 2.86E-13 | 3.11473E+42 |
| ffs0754b | 1.64 | CIII, CIV | 224713.9 | 13567.27 | 9.54E-14 | 1.20125E+42 |
| ffs0811a | 1.87 | CIII, CIV | 235043.1 | 15129.41 | 5.82E-13 | 1.07681E+43 |
| ffs0811b | 2.68 | Ly, CIII | 258741.3 | 20449.57 | 4.58E-13 | 2.54355E+43 |
| ffs0817 | 0.12 | OIII, Hα | 33853.8 | 1362.857 | 5.97E-13 | 1.36476E+40 |
| ffs0912 | 1.72 | CIII, CIV | 228557.8 | 14114.12 | 1.55E-13 | 2.23927E+42 |
| ffs1018 | 1.81 | CIII, CIV | 232554.7 | 14724.77 | 1.03E-12 | 1.73749E+43 |
| ffs1047b | 0.8 | MgII, Hα | 158490.6 | 7466.667 | 4.83E-13 | 8.57031E+41 |
| ffs1424 | 0.13 | Hα, Hß | 36483.82 | 1470.265 | 6.78E-13 | 1.83791E+40 |

# *The Blue-Side Suppression of Ly $\alpha$ in Quasars*

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## *Abstract*

In this investigation, quasars with redshifts ranging from 0.00049 to 5.41 were used with Ly $\alpha$ visible in the spectrum to examine the proposed blue-side suppression of the Ly $\alpha$ emission line. This was done using 12 spectrographs from the RBSE Journal, 9 from NASA, and 200 from the Sloan Digital Sky Survey. To account for spectral error, regression lines were taken to the blue- and red- sides of Ly $\alpha$. An integral was determined within 200 Å of Ly $\alpha$ using the regressed lines. A flux ratio was determined from the integrals, and a graph correlating the ratios and redshifts was constructed. From the results of this lab, redshift and flux ratios seem to be inversely related. Based on the standard deviation calculated from the final graph, further data relating subsets of the redshifts were obtained.

## *Purpose*

The purpose of this investigation was to determine if there is any direct or inverse relationship between the blue-side suppression of Ly $\alpha$ and the redshift of a given quasar.

## *Procedure*

Using identified characteristic feature of quasars spectrograms; the quasars from the RBSE catalog were identified. The other catalogs (SDSS and NASA) were solely quasars. The presence of Ly $\alpha$ was determined, and following this confirmation, its position on the graph was found.

In calculating the redshifts of the spectrograms, Ly $\alpha$ was always used to give uniformity to the varying graphs. Next, a regression line was taken for a 400 Å spread on both sides of the Ly $\alpha$ spike. Utilizing these regression lines, the integral for a 200 Å spread was calculated to the blue-side and red-side of the Ly $\alpha$ emission line.

By calculating the ratio of the blue-side integral to the red-side integral, a relatively uniform comparison of blue-side suppression between spectrograms was obtained. A graph relating the redshift to the flux ratio was constructed.

Utilizing the formula, StdDev = (1/n)(_(Pn – L)^2,0,n)^(1/2) where Pn equals the flux ratio and L equals the flux ratio of the corresponding redshift on the regression line, the standard deviation for the entire graph was calculated. Next, the standard deviation was calculated within each integer domain. Graphs were created for both of these standard deviations using the slope of the regression line.

## *Error Analysis*

While the regression lines did help to account for any potential error in the raw spectrographic data, it did not allow for a true value for the integral. In addition, the missing redshift range on the final graph could support or contradict the trend shown by the data. Another potential problem in the data collection was the varying sources for the spectrographic data, which provided graphs with inconsistent continuum types. Regarding the subset standard deviations, the number of points for redshifts less than 2 and greater than 5 provided insignificant data points to validate the standard deviation in these domains.

## *Conclusion*

The trend of the data shows a tendency for higher redshift quasars to possess a greater blue-side suppression as detected on earth. It has been proposed that intervening intergalactic clouds of neutral hydrogen cause this trend. The variations from the determined regression line support the evidence for the random distribution of these clouds, but there is no quantitatively inverse relationship between the two values. Due to the relationship of distance and redshift, the data also supports the theory that more distant quasars possess greater blue-side suppressions of Ly $\alpha$. It is probable that if data were obtained for the missing redshift range the points would lie in the vicinity of the regression line.

With regard to the standard deviation, the determined value of .1619 shows little variance and further supports the trend that apparently exists in the final graph. The standard deviations determined for each validated redshift domain show that little variance exists between these domains.

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