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Name

Western Washington University
Institution

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I. Research

Brief description of research results to date on your project:

Using McDonald Observatory's 82-inch telescope (operated by the University of Texas at Austin), Dr. Reginald J. Dufour succeeded in obtaining spectra of the Ring Nebula at position angle 124° , covering a spectral range from [OIII] 3727\AA to [SII] 6723\AA . This work was carried out in September of 1991. During the 1992 summer, Dr. Dufour carried out the analysis of the McDonald spectra and compared the results with the IUE (UV) spectra of the Ring Nebula. Preliminary results were presented at the IAU Symposium 155 on Planetary Nebulae, held in Innsbruck, Austria, July 13 - 17, 1992.

Communication with NASA Colleague:

During September 1993, two of Dr. Reginald J. Dufour's graduate students, Don Walter and Pat Shopbell, successfully installed IRAF on our NASA/JOVE Sun IPC workstation, *polaris*. But this work by his graduate students was about the only interaction Dr. Dufour and I have had over the past year. He was very busy during 1992/93, since he was serving as assistant chairman of the Space Physics and Astronomy Department at Rice University. And he frequently makes trips to other institutions and Europe. Indeed, his busy travel schedule prevented him from spending even a day at the 1993 NASA/JOVE Retreat in Galveston, Texas, although it was held only an hour's drive from Rice. Dr. Dufour is on sabbatical this 1993/94 academic year. He spent the first part in Mexico, but he plans to also spend some time at the Dominion Astrophysical Observatory, which is near Victoria, British Columbia. I am hopeful that we can get together to finish up a Ring Nebula publication during his time at Victoria. I believe that our collaboration will become more productive in the future, now that I have IRAF running on one Sun workstation (*polaris*) and am about to finish the installation on three additional (and more powerful) Sun workstations (*mizar*, *dubhe*, and *merak*).

Refereed Journal Articles Published:

None yet, but Dr. Dufour and I may be able to write the Ring Nebula paper during his stay in Victoria this summer.

Other Publications:

Nothing serious.

Oral and Poster Papers Presented:

Only the 1993 NASA/JOVE Retreat poster paper, "Spatial Variations in UV-Optical Emission Lines Across the Ring Nebula," co-authored with Dr. Reginald J. Dufour of Rice University. The following is a copy of the abstract:

ABSTRACT

International Ultraviolet Explorer (IUE) satellite spectra of the Ring Nebula (M57 = NGC 6720) were taken 16 - 18 May 1991, using the large aperture (10 x 20 arc sec oval) at low dispersion. SWP and LWP spectra were acquired at seven locations uniformly spaced at 10 arc sec intervals along a southeast to northwest (PA = 124°) line passing through the central star of the nebula. The direction of this line coincided with that of the long axis of the aperture. Since the angular length of the large aperture field of view (20 arc sec) is twice as great as the separation of neighboring exposure fields (10 arc sec), each exposure had a 50% overlap with each of its neighboring exposure fields. This provided continuous spatial variation curves (of prominent UV spectral lines) over the entire diameter (80 arc sec) of the main body of the Ring Nebula (with about 1 arc sec spatial resolution).

Spatial variation curves for the lines CIV 1549Å, HeII 1640Å, CIII] 1909Å, CII] 2326Å, and [NeIV] 2424Å are presented and compared with the corresponding curves for prominent optical lines extracted from longlit spectra taken at McDonald Observatory. Overall, the variations of the UV lines are found to be consistent with a basic model of the ionization and density structure of the nebula.

Acquisition of the IUE observations was supported by NASA grant NAG5-262, and our collaboration was made possible by the NASA JOVE Program.

Proposals Awarded:

Agency providing funding:	National Science Foundation	\$ amount:	\$24,697 (NSF)
		WWU match:	\$24,697
		TOTAL:	\$49,394

Title of project/PI: *Undergraduate Astronomical Imaging Laboratory*, by Robert J. Quigley

Period of Performance: August 15, 1993, through January 31, 1996

Primary Use of Funds: Equipment: Three Sun SPARCstations, a laser printer, and associated peripheral equipment

Note: See also the Other Activities section of this progress report for a description of the new Wilder Physics-Geology computer classroom that has been funded by an endowment fund at Western. The equipment of this 20-computer classroom will cost \$102,000. The remodeling expenses of the room will cost \$20,000. The software will cost \$28,000. So the total cost of the new computer classroom will be about \$150,000. It will be shared between the Physics/Astronomy Department and the Geology Department.

Proposals Submitted:

Only the JOVE Augmentation Grant Request (August 15, 1993):

\$17,348.00 was requested from JOVE.

\$12,197.00 would be provided by Western Washington University.

The proposal was for the period June 1, 1994, through May 31, 1995.

Equipment funds (for an automated telescope system suitable for CCD imaging), 1994 summer salary for the PI, and 1994 summer support for one student were the items for which JOVE funds were requested.

Are you utilizing the Internet or other network?

We are using Internet extensively. E-mail communication occurs nearly every day. I frequently am using ftp to obtain program and documentation files from NOAO, ADS, NCSA, and NASA. The World Wide Web [WWW] browser, Mosaic, has been installed on the Sun SPARCstation

10, *mizar*. (It will soon be installed on *polaris*, *dubhe*, and *merak* as well.) John Bradley's image viewer, XV, has also been installed, so we're able to display Hubble images that have been obtained via WWW. Thanks to Internet e-mail, I was able to obtain summer undergraduate research position information about ten summer programs that had not sent posters to WWU. (This information was then passed on to our physics majors.)

Please identify the data sets, if any, used in your research

IUE ultraviolet spectra data from the IUE RDAF (accessed via Internet)

II. Student Involvement

Indicate the impact, if any, that the JOVE Program has had on student enrollment and/or recruitment. Please provide before and after numbers for science majors by discipline, course enrollments, etc.

We are only now at the stage where such impact may occur. The astronomical imaging laboratory course (with an experimental course number, Astronomy 397) is currently being taught (Spring 1994) for the first time at WWU. Four students are enrolled: Khan Klatt, Hung Le, Daniel Whitacre, and Douglas Williams.

The number of Physics/Astronomy majors has been growing by over 10% each year for the past three years. Three years ago it was about 40 (which was the average over the past two decades). It's now nearly 60. It is unlikely, however, that the JOVE Program has been the driving force behind this increase. I believe that the JOVE Program may, however, lead to an increase in the number of students who actually graduate with a Physics/Astronomy degree. The growth in majors has occurred because more students are declaring during their freshman year. (During 1993/94, twenty-four students have declared physics majors thus far, and nearly all of these have been freshmen or transfer students.) Unfortunately, however, we've been losing many of them during their junior year, so there's been no increase in senior-class enrollments, and there's been no increase in the number of students graduating with physics degrees. The astronomical imaging class and the chance to do a JOVE research project may enable us to retain more of the juniors.

Student Research Assistants

We are only now at the stage where students can begin to participate in serious projects. If my JOVE Augmentation Grant Request is funded, it's likely that Khan Klatt would be interested in doing a supported project this summer. He's currently enrolled in the astronomical imaging class, Astronomy 397. He's a Physics/Computer Science B.S. joint major and is currently a junior. He's particularly interested in developing a system that would enable one to run IRAF from an IBM-PC 486-machine.

III. Curriculum Development

New Curricula:

The Department has had twelve full-time faculty for the past twenty years. This spring, Dr. Donald Sprague retired, and the Dean of the College of Arts and Sciences decided to "recapture" the position, i.e., he will not reallocate it to the Department. This means that we will be down to eleven FTE next year. Even worse, another physics professor, Dr. Richard Lindsay, will probably retire at the end of the Fall 1994 quarter, and it appears likely that the Dean will recapture that

position as well. The basic problem is that the Washington State legislature continues to cut university budgets in terms of real dollars. The problem has been exacerbated by the passage of Initiative 601 last November. This initiative may make it impossible to significantly increase state spending, even when the economy recovers.

As a result of this gloomy financial picture, the Department has decided to make dramatic changes in the physics major. We currently offer seven different varieties of physics major, including three concentrations in the physics B.S. (The three concentrations are optics, math-physics, and straight physics.) We now plan to revert to a single, unified curriculum, one that all physics majors would have to follow. We will be offering a smaller number of upper-division classes (reflecting the reduction in faculty), but we hope to have larger enrollments in those classes (since *all* physics majors would have to take them).

This means that the originally planned astronomy concentration will be out, since there will be no concentrations at all in our new major. However, one of the courses required in the new major will be a high-level astronomy course, a course that will be nearly the same as the Astronomy 366 astrophysics class that was originally planned as a companion course to the astronomical imaging laboratory course. And all physics majors will be given the option of doing a senior-year research project (as an alternative to a senior lab course), so the originally planned Astronomy 460 senior research project will be viable in the new major.

The new courses relevant to the JOVE program will be:

Astronomy 356 *Astrophysics (3 cr)*
Prereq: CS210; Physics 223. Introduction to fundamental astronomical concepts and application of physics to stellar systems, the interstellar medium, and gaseous nebulae. Radiation theory; atomic spectra and chemical abundances in stellar atmospheres and gaseous nebulae.
Will be offered every winter quarter and will be required of all physics majors. Expected average enrollment is 20.

Astronomy 360 *Astronomical Imaging Laboratory (3 cr)*
Prereq: CS210; Physics 223, 322; Astro 356. CCD camera fundamentals and use in laboratory experiments and astronomical imaging. Introduction to UNIX workstations, Internet, and astronomy network information services. Image analysis using the IRAF software package. Laboratory.
Will be offered every spring quarter. Will not be a required course for the major. Expected enrollment is 10.

Astronomy 460 *Astronomy Senior Research Project (4 cr)*
Prereq: Astro 356, 360. Astronomy research based on analysis of satellite telescope spectra and images of nebulae, stars, and galaxies, or based on CCD imaging of a "target of opportunity" astronomical event. Grading will be based on the research paper the student will submit at the end of the project.
Will be offered every quarter. Expected annual enrollment is 7. Will be an option that physics majors will have for satisfying the requirement of a senior lab or senior research project.

In some ways, the new major will actually give students better preparation for a JOVE research project. Students will take two quarters of modern physics and two quarters of electronics their sophomore year (in the new major). This will better prepare them for the junior year astrophysics course and the junior year astronomical imaging laboratory. A real bonus of the new major will be that *all* physics majors will take the astrophysics course. Only about 10% of current physics majors take any astronomy at all while at Western. Having all physics majors take astrophysics

should definitely boost interest in the astronomical imaging laboratory (even though that course itself will not be required of the major). Having the astronomy senior research project as an alternative means of satisfying the senior lab requirement should also boost interest.

The JOVE program has definitely had an impact on the planned curriculum, since the possibility of doing an astronomy research project makes it reasonable to require that all majors take an astrophysics course their junior year.

We plan to have all the details of the new major worked out by the end of the current quarter (Spring 1994) so that we can submit the revised major to the Council on Arts and Sciences Curriculum [CASC] this June. Assuming CASC approves the change, the new curriculum would go into effect when the 1995-1997 catalog is published in September 1995.

New Courses:

The new astronomical imaging laboratory course is being taught this quarter (Spring 1994) under the experimental course number, Astronomy 397. (The permanent course number will be Astronomy 360. The course description is given above under that number.) It will also be taught during Spring 1995 as Astronomy 397 (and will receive its permanent course number once CASC approves the new physics major described above).

The Physical Plant finished the remodeling of Bond Hall 13 during March 1994. (A wall was built that separates this room from a larger room used by Telecommunications.) Three excellent desks and swivel chairs, along with a table and a credenza, were acquired at no cost from the Chemistry Department when it moved to a new building. Three high-quality lab tables were acquired from a physics laboratory that is being converted into a joint physics-geology computer classroom.

The NASA/JOVE Sun IPC workstation, *polaris*, was moved to BH 13, along with a Sun SPARCprinter that runs under NeWSprint 2.1. IRAF, SunPC, and an older version of ADS are installed on this computer. The internal drive has only 207 MB, but a 424-MB external drive (*mars*) provides adequate disk space for OpenWindows 3, IRAF, and the student accounts. An additional 1.05-GB external drive (*saturn*) was purchased this term with NASA/JOVE funds and is connected to *polaris*. This new drive provides each student with a disk partition of over 100 MB for his CCD image files. The Sun IPC workstation has an Ethernet connection and acts as the mail server for the other computers on the Internet subdomain, physics.wvu.edu.

Two new Sun SPARCstation 5 machines were ordered (under the NSF ILI grant) shortly after Sun's March 29, 1994, announcement of this new model. Each new machine came with a 1.05-GB internal drive, 32 MB of RAM, and a 20" color monitor. Each runs at 85 MHz. Each was ordered with a built-in 3.5" floppy drive and a double-speed CD-ROM drive. SunOS 4.1.3_U1 has been installed on both new machines (*dubhe* and *merak*). The IRAF and SAOimage files have been copied to the internal drives, but IRAF has not yet been installed and checked out. The new version of the Astrophysical Data System [ADS], the WWW browser Mosaic, and the image viewer XV will also be installed on these two new workstations. The floppy and CD-ROM drives also need to be physically installed (the CD-ROM drives haven't arrived yet). The new machines will be moved to BH 13 once all this software and hardware have been installed.

Four students are currently enrolled in Astronomy 397: Khan Klatt, Hung Le, Daniel Whitacre, and Douglas Williams. Each has been issued a key to BH 13 so that he can come in at any hour to work on *polaris*. Khan Klatt also does some of his work by remote login. Daniel Whitacre is

a student computer consultant in the new Chemistry computer laboratory, so he does some of his work remotely from a machine in that room.

Because everything is new, and equipment is still being added and changed, a formal syllabus has not been followed this first time. The following listing shows what has been done and what is planned for the remainder of this quarter:

Lab Exercise 1

Setting up the OpenWindows 3 workspace. Practice exercises in copying files, customizing the Workspace>Programs menu, inserting .cshrc file alias commands (and other editing tasks), and setting up the IRAF directory and IRAF loginuser.cl file.

Lab Exercise 2

Working through the examples of "Preliminary Test Procedure for IRAF," by Jeannette Barnes of NOAO.

Lab Exercise 3

Working through some of the examples of "A Beginner's Guide to Using IRAF," by Jeannette Barnes of NOAO.

Lab Exercise 4

Learning how to load images into SAOimage, how to apply scaling transformations to these images, and how to carry out other SAOimage operations.

Lab Exercise 5

IRAF Tutorial Exercise 1, by Jeannette Barnes. The student learns how to take two images—which are of the same object, but slightly shifted—and shift one image so that it is registered with the other. Image arithmetic operations are then carried out using the two registered images. Two types of plots are also made.

Lab Exercise 6

IRAF Tutorial Exercise 2, by Jeannette Barnes. The student learns how to do preliminary reductions of CCD data: overscan subtraction, bias subtraction, dark subtraction, and flat fielding. Bias frames are averaged. Flat frames are also averaged and normalized. The overscan region is subtracted from each frame. A second method of performing the same operations, using the CCDRED package, is also carried out. This exercise creates the image files that will be used in a following exercise, IRAF Tutorial Exercise 4.

Lab Exercise 7

IRAF Tutorial Exercise 3, by Jeannette Barnes. The operations of the previous exercise are carried out on frames showing spectra (rather than object images). This exercise creates the spectroscopic files that are used in a following exercise, IRAF Tutorial Exercise 5.

Lab Exercise 8

IRAF Tutorial Exercise 4, by Jeannette Barnes. The image files created in Lab Exercise 6 (IRAF Tutorial Exercise 2) are used to obtain instrumental magnitudes of selected field stars and to then calibrate the magnitudes to a standard photometric system. Aperture photometry is used.

Lab Exercise 9

IRAF Tutorial Exercise 5, by Jeannette Barnes. The spectra files created in Lab Exercise 7 (IRAF Tutorial Exercise 3) are used to extract 1-d images. Two arc spectra are also extracted. Wavelength calibration is then carried out. Wavelengths of major lines are measured.

In future offerings of the course, after we have obtained and set up a CCD camera system and associated telescope equipment, we will have exercises involving actual CCD imaging—both in a laboratory imaging experiment and in telescope night-sky work.

Amended Courses or Augmented Courses:

As described earlier (in the New Curricula section), the current astrophysics course, Astronomy 416, will be transformed into a junior-level course, Astronomy 356, that every physics major will take in the new unified curriculum.

Reading or independent study courses:

As described above, Astronomy 460 will be created as a senior research project course.

IV. Outreach

Students:

The Department continues to offer planetarium shows to elementary school classes. Unfortunately, we are still using our old Spitz Model A planetarium, located in Haggard Hall. About 30 elementary school students attend these sessions each quarter.

Dr. Leslie Spanel, in our department, has been attempting to convince the administration that one of the lecture halls in the new Science Education building should be built so that it could double as a planetarium. (This building will be the third building of the new science complex. The first, the Chemistry building, went into service last fall [1993]. The second, the Biology building, is currently under construction and should become operational by Spring 1995. The Science Education building should be built and in service by Fall 1997.) The Dean of the College of Arts and Sciences is supporting Dr. Spanel's proposal, so we are hopeful that we may have a new planetarium by Fall 1997 and that we can then greatly expand our outreach to elementary school students.

Teachers:

Dr. James Stewart, in our department, has been actively engaged in "Operation Physics," a summer program that has brought a total of over 200 science teachers to Western over the past four summers to learn more effective techniques of teaching physics. Many of these have been high school teachers. During the 1994 summer, his summer institute will run from July 6 through July 16, and will be designed for 45 elementary and middle school teachers. The theme this summer will be "Astronomy and Energy." As his brochure describes it, the institute this summer "will study principally solar and lunar astronomy, integrating it with a study of energy by exploring the use of solar energy for heating your home." Dr. Stewart's workshops are funded by state and federal grants.

Public:

- (1) I served on a science panel at Westercon, a science fiction convention held over the Fourth of July weekend (1993) in Bellevue, Washington. The panel's topic was "Creation of Solar Systems." About 50 people were in the audience.
- (2) I was an invited science panelist at Viking Con 14, a science fiction conference held at WWU, August 13 - 15, 1993. (Vernor Vinge, the author of *Fire Upon the Deep*, was the guest of honor.) I served on three panels: "Whatever Happened to the Space Program?", "The Real Cutting Edge" (a discussion of recent developments in science), and "Unpopular Science" (an examination of areas of science that are currently being neglected). About 40 people were in the audience of each panel discussion.

V. Summer Programs:

For students:

None yet. The plan is to develop a program that will be coordinated with our planned astronomical imaging laboratory, so that students who have taken the lab course will be prepared to work on summer research projects, either at Western or at universities and observatories offering undergraduate summer research programs.

For teachers:

See the earlier description (in the Teachers section of Outreach) of Dr. James Stewart's Summer 1994 Operation Physics institute for 45 elementary and middle school teachers. Astronomy will be a major topic of this summer's workshop.

VI. "Roadblocks" to Progress/Suggestions

The principal roadblock was lack of equipment, and this has been removed by the NSF ILI grant I received last August. The additional equipment has justified the remodeling of a room (Bond Hall 13) for the equipment to be set up in. This new room is as close to ideal as one could hope for at *any* university (and will provide a much better lab space than that of the University of Washington's imaging laboratory). There is room for CCD imaging experiment lab tables as well as for the three Sun workstations and the laser printer.

Indeed, at the moment there seem to be no roadblocks. The remaining problems are:

- (1) To finish installing the software and hardware of the two new Sun SPARCstation 5's
- (2) To install networking software, NFS, NIS, and PC-NFS, that will enable the four Sun workstations to be used in a more coordinated way, and that will enable a new 486 PC-type machine (*alcor*) to be used in concert with the Sun workstations
- (3) To obtain the CCD camera equipment and set it up
- (4) To obtain the computer-controlled telescope that will be used with the CCD camera system
- (5) To solve the current SunPC bug problem that is preventing us from running the U.S. Naval Observatory's MICA program in the SunPC PC-emulation window

- (6) To obtain CASC approval for the new unified physics major curriculum and to develop the new astrophysics course (Astronomy 356) so that it supports the astronomical imaging laboratory course and astronomy senior research projects

These are not so much problems as things to do. They simply take time. I foresee no major difficulties in carrying out any of the above tasks.

VII. Other Activities

- (1) The Physics/Astronomy Department and the Geology Department wrote a joint proposal for a new 20-computer classroom last December. The WWU Administration has approved the proposal. It will be funded by the Wilder Endowment Fund, which is an endowment at Western that supports improvement in the teaching of science, mathematics, and business. The Wilder fund will contribute \$78,000 to the new computer classroom, and contributions from other sources will enable the total equipment cost of \$102,000 to be covered. The Provost has allocated an additional \$17,500 to the Physics/Astronomy Department for software for the Wilder lab computers. (He also allocated \$10,500 to the Geology Department for geology software for the lab.) Remodeling costs for the room will total approximately \$20,000. The total cost of the new computer classroom will thus be about \$150,000.

Twenty 486DX2-66 machines will be installed in Bond Hall 401 (a former lab room that will be extensively remodeled). The machines will have Mathcad Plus 5.0, Mathematica, The Sky for Windows, Interactive Physics II, Electronics Workbench 3, Microsoft Word for Windows 6.0, and Microsoft Excel 5.0.

Robert Mutel, of the University of Iowa, has developed CCD observation projects for his astronomy classes, and he has made use of a number of MS-DOS or Microsoft Windows astronomy applications packages, including The Sky for Windows, Megastar, Guide 2.0, Epoch-2000, Personal Observatory, PC-Sky, PC-Vista, Distant Suns, and Dance of the Planets. I believe that we can also make use of such software packages in our astronomical imaging laboratory (and in some senior project work) by having the new Wilder lab computers networked with the Sun workstations of the imaging lab. Robert Mutel has done this with Sun's PC-NFS 5.0, software that we have also acquired.

- (2) For the second year, a summer research programs list for undergraduate physics majors was created, printed, and distributed to students. Twenty-three programs were on the list this year. Cathy Cox was accepted for two of the programs, and she plans to attend the one at Lehigh University. Corey Nevers was accepted by the SERS program of Lawrence Berkeley Laboratory and is currently engaged in a project there. I anticipate that at least three more students will participate in such programs this summer.
- (3) To give our students a better idea of what becomes of our graduates, a number of our alumni were invited to give talks to the Department this year. These were:
- Dr. Steve O'Brien, of Spectra Diode Laboratories. He spoke on "Semiconductor Diode Lasers: Is the Sky the Limit?" (November 22, 1993)
 - Dr. Lynne D. Green, of Cogswell College North. She spoke on "Simulation of High-Performance Electronics." (February 1, 1994)
 - Scott C. Burkhart, Deputy Division Leader of the Laser Engineering Division of Lawrence Livermore Laboratory. He spoke on "Laser-Driven Inertial Confinement Fusion." (March 3, 1994)

- **Dr. Lauren Likkel, of Washington State University. She spoke on "Molecules in Planetary Nebulae." (May 2, 1994)**
- **Jin Kang, of the Center for Research in Electro-Optics and Lasers, University of Central Florida. He spoke on "Nonlinear Optics for Ultrafast Computers and Communications." (May 10, 1994)**