The Number of Publications Used as a Metric of the NOAO WIYN Queue Experiment

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ABSTRACT

We use the number of papers published in 1998 and 1999 to test the hypothesis that the queue observing mode at WIYN leads to a significantly higher scientific throughput than classical mode observing. We use the papers published from the 4-m, and papers published from the non-queue WIYN time as controls, requiring only that the data be obtained after 1996 August 1, at which time the WIYN queue was in its third full semester of operation, and the WIYN instruments functional and stable. The number of papers published from the queue data is actually 1.5 times smaller (on a per night basis) than from the 4-m, and roughly comparable to (but lower than) the number published from non-queue WIYN time. Thus neither comparison offers any support for the hypothesis that queue leads to a higher scientific throughput. The number of papers is relatively small, but the statistics are sufficiently robust to reject the possibility that queue observing at WIYN leads to a factor of 1.5 enhancement in publication rate with a 99.3% confidence in comparison to the 4-m, and with an 89.9% confidence in comparison with non-queue WIYN time. We consider several explanations, and urge that other observatories planning to employ the queue mode include some controls to provide an objective evaluation of its success.

Subject headings: PAC codes 95.45 95.55; instrumentation: miscellaneous—methods: miscellaneous—sociology of astronomy
1. Introduction

The 3.5-m Wisconsin-Indiana-Yale-NOAO (WIYN) telescope was dedicated on 1994 October 15, and shared-risk observing began in 1995 March. NOAO’s share of the time is 40%, and nearly all of this has been carried out in “queue” mode, where the observations from highly ranked proposals are placed in a queue and executed during nights assigned to the queue program. The observations are carried out by highly experienced professionals, who are extremely familiar with the instrumentation, without the direct assistance of the proposing astronomer. A small fraction of the NOAO time is scheduled out in “classical mode”, with the observers present at the telescope. The time allocated to the university consortium members (roughly 60%) is all carried out in classical mode.

The goal of the NOAO WIYN queue experiment was eloquently described by Silva & De Young (1996) as an empirical test of “the hypothesis that in the face of a high over-subscription rate, the science throughput of WIYN can be maximized by executing the most highly ranked science programs first, completing datasets in a timely manner, allowing a larger range of program lengths, and matching the observing program to the observing conditions on an observation-by-observation basis.”

The WIYN queue has often been described as an “experiment” at least in part because other observatories are considering scheduling some or all of their time in this mode, and NOAO staff have felt that what we can learn from the WIYN queue will be useful to others. In an era that sees both the proliferation of very large (≥8 m) telescopes, but ever-tightening financial resources, observatories are scrambling to understand how to maximize their scientific return.

Queue observing offers a variety of theoretical advantages, as nicely summarized by Mountain (1996) and Boroson et al. (1998). For very highly ranked programs that require rare conditions, queue observing may be the only practical way to acquire such
data. Queue observing naturally allows synoptic observations, and such scheduling easily accommodates target-of-opportunity requests, such as optical follow-ups of gamma-ray bursts or supernovae. Furthermore, as instrumentation becomes more complex, queue observing carried out by dedicated observers may result in more efficient use of telescope time than if the observations were carried out by visitors who use the equipment only occasionally. This contention is partially supported by evidence that observers collect less data on the first night of an observing run than on subsequent nights (Bohannan 1998).

However, there are obvious down-sides to the queue mode. The astronomer is not present at the telescope, and therefore cannot make real-time decisions concerning the data. Serendipity is eliminated, as are the risky programs many of us have snuck in during gaps in our main observing program, and which have sometimes led to the more interesting results. Some of us suspect, rightly or wrongly, that we could better carry out our own observations. And, there is not the same strong sense of “data ownership” that comes with having carried out the observations ourselves: the memory of a night may provide details that are relevant to the interpretation of the reduced data, as well as providing an emotional impetus for seeing the project through to its completion.

There is also a non-negligible expense of running a queue, which is off-set to some degree by the smaller support required for visiting astronomers.

Boroson (1996) has described a simulation program that can be used to test how successfully programs are completed in a queue mode vs. a classical mode, using Monte Carlo sampling of characteristic observing conditions (weather, seeing) for the site. Boroson et al. (1998) used this simulation program comparing queue mode and classical scheduling for two actual semesters (1997) of WIYN programs, concluding that queue scheduling at WIYN has led to a significant gain in efficiency and scientific effectiveness.

Now that the queue experiment has run for several years, we thought it would be
worth examining the gain using some real-world measure. As emphasized by Boroson et al. (1998), much of the argument about observing modes can be emotional. We seek some metric that we can use to test the hypothesis enunciated above that the queue observing mode leads to significant improvement in the science throughput. One such simple metric is the number of refereed papers published. This may not be as meaningful in its long-term impact on astronomy as, say, the number of important new discoveries, but at least it has the advantage of being quantifiable, and, if the experimental and control samples are well matched, equitable and fair.

We choose to compare the number of papers produced by the WIYN queue to the following two controls, each with its advantages and disadvantages:

1. The number of papers produced by observations made over the same time period with the Mayall 4-m telescope.

2. The number of papers produced by observations made over the same time period by non-queue use of WIYN; i.e., primarily the time used by the consortium universities.

The first comparison has the primary advantage that both the 4-m and WIYN proposals have undergone similar scrutiny by the same time allocation committees (TACs), which often consider such factors as the past track-record of the proposers as well as the scientific excellence of the proposals. Thus proposers to the 4-m and WIYN will feel similar pressures to publish in a timely manner, and the feasibility of the proposals has been carefully evaluated. Users of the university time may choose to undertake longer-term projects, leading ultimately to more important results, but not processing the same rapid turn around from observing to publication. We offer the second comparison as there may be differences in the actual on-sky performance of the two telescopes that would affect the results: the 4-m is a mature telescope, possibly with fewer teething problems, than the
newer WIYN.

If the queue leads to significantly higher scientific throughput, then we expect that the number of papers published using data obtained via the queue should be significantly greater than those produced by the control samples, after normalization on the basis of the number of scheduled nights.

2. The Data Set

All of the 1998 and 1999 issues of the main US astronomy journals were examined for papers which used 4-m and/or WIYN observations. The complete list of 135 papers is given in Table A1 of the Appendix.

In order to make a fair comparison, we restricted ourselves to only those papers for which the data were obtained in semester “1996B” or later (i.e., after 1996 August 1). This was the third full semester of WIYN queue time, and the first semester in which both the imager and fiber positioner were fully functional. (A non-linearity problem with the S2KB imager chip was discovered and fixed during the 1996A semester, and a mechanical problem which compromised the positioning accuracy of the Hydra fiber positioner was fixed in 1996 March.)

We list in Table 1 the number of papers published during 1998 and 1999. Six papers used both 4-m and WIYN data; we chose to count each of these papers separately for both telescopes, depending upon the date in which the data were obtained for the telescope under consideration; i.e., if the data for WIYN was obtained in 1996B or later, but the 4-m data was obtained prior to 1996, it would count as a WIYN publication but not as a 4-m paper. There were six papers in our list in which the data collected were such a minor component of the paper that we chose not to count the paper at all; only one of these used the WIYN
queue, and in that case the data had been published previously by the original proposers.

3. Results

3.1. Comparison of the WIYN and the 4-m

In order to make a valid comparison, we must first take into account that not as much time is scheduled for the WIYN queue as for the 4-m. We expect the answer is about 40%, as NOAO receives 40% of the time on WIYN, and almost all of this goes to the queue. However, the 4-m is shut down during July and August, while WIYN continues to operate; on the other hand, there are more engineering nights scheduled at WIYN. One could use the total number of clear hours spent observing as the normalization, but these data are hard to extract reliably. Instead, we took the final observing schedules for semesters 1996B, 1997A, 1997B, 1998A, and 1998B, and simply counted the number of nights assigned to the WIYN queue, and to science operations at the 4-m. (For the latter, we included half-night instrument “checkout” nights, as much of this time is typically returned to the observers scheduled on the second half; full-night “check” nights and engineering nights were excluded. We excluded all engineering nights scheduled at WIYN, although occasionally queue observations are obtained during such time.) The numbers of nights so scheduled for the WIYN queue and for the 4-m are 260 and 656 respectively; i.e., the number of nights scheduled to the WIYN queue turned out to be 39.6% of the nights scheduled at the 4-m.

If the hypothesis described above is correct, we would expect the number of publications based upon WIYN queue data to be significantly greater than 40% of those produced by the 4-m. Instead, we find in Table 1 that there were only 9 papers produced by WIYN queue data as opposed to 34 papers produced by the 4-m; i.e., 26%. Thus there are actually 1.5 times fewer papers published (on a per night basis) based on queue WIYN data relative
to those based on 4-m data. This comparison does not support the hypothesis of greater science throughput by the WIYN queue.

Can we rule out the hypothesis given the small number statistics? If we assume the simplest model that a $1\sigma$ uncertainty in the number of publications $N$ is simply the $\sqrt{N}$, then the $1\sigma$ error on the 0.26 ratio of WIYN to 4-m publications is 0.13. What does it mean for there to be a “significant” enhancement in the scientific throughput? Boroson et al. (1998) discuss how their simulation predicts this will depend upon program type, TAC grade, and so on, and that overall about 2.5 times as many programs will be completed by queue observing than with classical observing. We take here a more conservative approach: certainly a 50% increase (a factor of 1.5) would be cause for celebration. Were this enhancement present, we would expect there to be $1.5 \times 39.6\% = 59.4\%$ as many WIYN queue papers as 4-m papers. We observe $0.26 \pm 0.13$ We thus can reject such an increase at a $+2.5\sigma$ level; i.e., with a 99.3% confidence.

### 3.2. Comparison of Queue vs. Non-Queue Time at WIYN

Of the 731 nights scheduled for science at WIYN during 1996B through 1998B, we find that 260 nights were scheduled for queue observations (35.6%), 27 nights were scheduled for NOAO classical observations (3.7%), and 444 as university time (60.7%). If queue observing produced a significantly higher scientific throughput, we would expect significantly more

\[ 1.0 - 0.5 \times (1.0 - A_G(\| x - \mu \| /\sigma)), \]

where $A_G$ is the integral probability of the normal distribution with a mean of $\mu$ and a standard deviation of $\sigma$; see, for example, Fig. C-2 in Bevington (1969).
than 36% of the papers produced by WIYN data to be based on data obtained with the queue. Instead, of the 28 total WIYN papers in our sample, 9 (32%) were produced from queue data. This is essentially the same fraction of time on WIYN used by the queue (36%), and therefore does not suggest that queue provides a significant advantage.

While the data fail to offer any support for the hypothesis, at what level can we reject the claim, given our limited statistics? Using the same argument as above that we would hope for a factor of 1.5 enhancement over the non-queue publication rate, we can ask at what level can we exclude the queue publications amounting to $1.5 \times 35.6\% = 53.4\%$ of the total. The uncertainty in our ratio 0.32 ratio is 0.17. Thus we can exclude a 50% enhancement at the +1.3$\sigma$ level; i.e., with an 89.8% confidence.

Nevertheless, it is clear that queue observing does fare better in this comparison than it did in comparison to the 4-m control, although still failing to produce a higher number of publications. Several explanations come to mind. One possibility is that the 4-m simply operates more efficiently than WIYN (at least in the time period when most of the data were acquired), and that it was thus easier to obtain usable data at the 4-m. It is possible that review of queue proposals by an outside TAC leads to a higher publication rate than time used by the universities, who have a preallocated amount of time, which is divided up internally. (As suggested earlier, the university time may be spent on longer-term programs than the NOAO portion.) Finally, the 4-m supports a wider complement of instrumentation (such as infrared imaging and spectroscopy) than WIYN, which plausibly provides greater coverage of astronomical disciplines and thus involvement in a wider variety of publications.

Although the numbers are small, the very high publication rate for NOAO time that is scheduled classically at WIYN suggests that it may be the TAC process rather than the telescope or instrumentation which explains why the queue does better in this comparison than it does in comparison to the 4-m: 14% of the WIYN papers were produced by the
small (3.7%) time allocated to non-university classical observing. The classically scheduled NOAO time undergoes the same rigorous review as the queue proposals, and thus is under the same pressure to publish rapidly.

4. Discussion

Arguably, the WIYN queue has been as well run as it is possible for any queue to be. A survey carried out of astronomers who had proposed for queue time suggests that people were very satisfied with the quality of the data they received (Boroson et al. 1998); some might expect that maintaining data quality to be the hardest part of a queue. Yet the evidence so far fails to support the suggestion that queue observing leads to a higher scientific throughput, at least as measured by the number of publications. Why does this differ from the dramatic predictions of simulations that suggest that a much higher percentage of programs should be completed by the queue mode?

We have read through the papers based upon the WIYN queue data and have several observations of our own to offer. First, let us consider the advantage that queue offers in providing easy “target of opportunity” (TOO) observations. Of the full set of 11 papers (ignoring the 1996B cutoff), four rely on the TOO advantage of queue for optical followup of gamma-ray bursts (Galama et al. 1998) or supernovae (Jha et al. 1999; Perlmutter et al. 1999; and Riess et al. 1998). Although WIYN played a role in these important studies, our examination of these papers suggests that it was a relatively minor role, with the majority of the data coming from elsewhere. For instance, there are considerably more data from the CTIO 4-m (which is classically scheduled) than from WIYN in the Riess et al. (1998) study. Inspection of these papers suggest that there is no lack of ways for large groups to acquire such data. The number of authors on these four papers range from 17 to 42, and with a large number of participants being a reflection of the degree (and method?) of telescope
access. Thus TOO use of WIYN may not be more significant simply because there are other ways of obtaining such data.

One of the other purported advantages for queue observing is the ability to take advantage of particularly good conditions, and indeed some programs may not be completed any other way. However, this advantage is larger the greater the range of conditions. For instance, if the frequency histogram of delivered image quality (DIQ) is very sharply peaked, then queue offers less of an advantage, as all programs will obtain something like the median seeing. At WIYN the median DIQ (at $R$) is 0.8 arcseconds, and 0.6 arcsecond or better images are achieved 18% of the time (Green 1999). Of the 11 queue papers listed in Table A1, Armandroff, Jacoby, & Davies (1999) is one of the clearest examples of taking advantage of the queue to obtain the best DIQ. The study utilized sub-arcsecond conditions (0.8 arcsec at $B$, 0.6 arcsec at $V$, and 0.7 arcsec at $I$) for deep imaging of a newly discovered dwarf member of the Local Group, Andromeda VI, after confirming its nature using imaging at the 4-m. Nevertheless, these DIQ values are not all that different than the median values.

However, it may be that the sociological issues raised in the introduction dominate. The use of queue may reduce the sense of “data ownership,” and given situations of “data saturation,” we are more likely to publish the data more rapidly if we have acquired them ourselves. The use of “queue mode” on $HST$ has been perceived as being highly successful, although a meaningful control sample is hard to find for comparison; however, one important difference comes to mind, namely that observing time (to US proposers) usually comes with grants, providing a financial incentive to produce results rapidly, coupled with a 1-year proprietary period for unique data. An additional consideration is that $HST$ supplies the user with fully reduced data, unlike WIYN, which provides basic calibration data and requested standard observations, but which does not attempt a “pipe-line”
reduction. However, our own experience with *HST* data is that customized reductions are often needed in order to provide the data most meaningful for a particular application.

Finally, it may be that we simply have not been sufficiently patient. As is evident from the 4-m publications, only one-third of the 4-m papers in the past two years relied purely on “new” data (i.e., all data obtained in the past 3.5 years). While our control samples explicitly took this into account, we are nevertheless comparing numbers that are on the tails of the distribution of how quickly data finds its way into the literature. This may be particularly true if the datasets from the WIYN queue were to be larger than that in the control samples, or if they take longer to reduce. Current plans call for discontinuing the WIYN queue at the end of semester 2000A, but continuing to provide some synoptic and target of opportunity service observing beyond that. It will be interesting to re-examine the literature five years from now using data obtained in 1996B-2000A as the selection criterion.

We note that the quantity we would most like to measure is “quality”, but this is of course harder to do in an objective manner. Citation rates might provide one means, but not enough time has past for these to be meaningful. Counting the number of papers is some measure of the “output” of a telescope, but it is not necessarily the best; it does have the advantage of being objective and reproducible, qualities usually assumed to be desirable in any experiment.

Nevertheless, our results suggest that it may benefit observatories to evaluate their queue programs using some external measure, such as the number of publications, if suitable controls can be defined.

Helmut Abt, Dave De Young, David Sawyer, Dave Silva, and Sidney C. Wolff were kind enough to provide thoughtful comments on the manuscript. We also benefited conversations with Taft Armandroff, Bruce Bohannan, and Abi Saha on the issues of queue observing.
5. Appendix

In Table A1 we present the list of papers published in the *Astronomical Journal*, the *Astrophysical Journal* (Parts 1 and 2), and the *Publications of the Astronomical Society of the Pacific* during 1998 and 1999 that used data from the 4-m and/or WIYN. We list the dates of the first data obtained (from the relevant telescope). Often this information was directly obtained from the paper, but in many cases we had to contact the authors, or inspect the observing schedule or list of queue programs to determine the actual data or semester.
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Boroson, T., Harmer, D. L., Saha, A., Smith, P. S., Willmarth, D. W., & Silva, D. R. 1998, SPIE, 3349, 41

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Green, R. 1999 NOAO Newsletter No. 60, 38

Jha, S. et al. (41 additional authors) 1999, ApJS, 125, 73

Mountain, M. 1996, in New Observing Modes for the Next Century, ed. T. Boroson, J. Davies, & I. Robson (San Francisco: ASP), 235

Perlmutter, S. et al. (31 additional authors) 1999, ApJ, 517, 565

Riess, A. G. et al. (19 additional authors) 1998, AJ, 116, 1009

Silva, D., & De Young, D. 1996, NOAO Newsletter 45, 36

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This manuscript was prepared with the AAS LaTeX macros v4.0.
|                  | Mayall 4-m |        | WIYN       |        |
|------------------|------------|--------|------------|--------|
|                  |            | All Modes | Queue | N-Classic | Univ.  |
| Total:           | 98         | 39      | 11        | 5      | 23     |
| ≥1996B:          | 34         | 28      | 9         | 4      | 15     |
| Citation | 4-m Mayall | WIYN–Queue | WIYN–NOAO Classical | WIYN–University |
|----------|------------|------------|---------------------|-----------------|
| 115, 436 |            |            |                     | 1995 Jul        |
| 115, 535 |            |            |                     |                 |
| 115, 573 |            |            |                     | 1995 Oct        |
| 115, 975 |            |            |                     | 1996 Oct        |
| 115, 1329 | 1996 Apr   |            |                     |                 |
| 115, 1869 |            |            |                     | 1996 Sep        |
| 115, 2018 |            |            |                     | 1997 July       |
| 115, 2044 |            |            |                     | 1996 Mar        |
| 115, 2059 | 1991       |            |                     |                 |
| 115, 2074 | 1998 Jan   |            |                     |                 |
| 116, 102 | 1994 Mar   |            |                     |                 |
| 116, 146 | 1996 Oct   |            |                     |                 |
| 116, 455 | 1996 Jan   |            |                     |                 |
| 116, 549 | 1996 Oct   |            |                     |                 |
| 116, 673 | 1994 Nov   |            |                     |                 |
| 116, 707 | 1993 Nov   |            |                     |                 |
| 116, 1066 | 1996 Nov   |            |                     |                 |
| 116, 1074 | 1992 Oct   |            |                     |                 |
| 116, 1221 | 1998 May   |            |                     |                 |
| 116, 1367 |            |            |                     | 1997 Apr        |
| 116, 1396 | 1997 Oct   |            |                     |                 |
| 116, 1412 | 1996 Jan   |            |                     |                 |
| 116, 1789 |            |            |                     | 1995 Jul        |
| 116, 2287 | 1997 Oct   |            |                     |                 |
| 116, 2984 | 1998 Jun   |            |                     |                 |
| 117, 75  |            |            |                     | 1997 May        |
| 117, 181 |            |            |                     | 1997 Apr        |
| 117, 308 | <1996B     |            |                     |                 |
| 117, 548 |            |            |                     | 1997            |
| 117, 1023 | 1993       |            |                     |                 |
| 117, 1402 | 1996 Apr   |            |                     |                 |
| 117, 1890 | 1982       |            |                     |                 |
| 117, 2077 |            |            |                     | 1997            |
| 117, 2666 | 1994 Mar   |            |                     |                 |
| 117, 2919 | 1997 Oct   |            |                     |                 |
| 118, 76  | 1993       |            |                     |                 |
| 118, 777 | 1998 May   |            |                     |                 |
| 118, 236 | 1989       |            |                     |                 |
| Citation | Date of First Data<sup>a</sup> |
|----------|--------------------------|
| 118, 509 | 1982                     |
| 118, 633 | 1998 Jun                 |
| 118, 719 | 1993                     |
| 118, 1220| 1998 Jan                 |
| 118, 1542| 1998 Jan                 |
| 118, 1657| 1997 Oct                 |
| 118, 1806| 1992 Sep                 |
| 118, 2002| 1997 Apr                 |
| 118, 2184| 1998 Jan                 |
| 118, 2409|                         |
| 118, 2466| 1997 Nov                 |
| 118, 2511| <1982                    |
| 118, 2547| 1997 Jul                 |
| 118, 2751|                         |
| 118, 2775|                         |
| 118, 2940| 1998 Dec                 |

**Astrophysical Journal**

| Citation | Date of First Data<sup>a</sup> |
|----------|--------------------------|
| 492, 62  | 1995 Apr                 |
| 492, 461 | 1993                     |
| 492, L21 | 1996A                    |
| 493, L27 |                         |
| 494, L185|                         |
| 495, 100 | 1996B(?)                 |
| 495, 933 | 1996A                    |
| 496, 103 | <1995                    |
| 496, 803 |                         |
| 497, 227 | 1994 Mar                 |
| 497, 294 | 1996 May                 |
| 497, L13 | 1997 May                 |
| 497, L75 |                         |
| 499, 577 | 1989                     |
| 499, 828 | 1988                     |
| 500, 173 | 1996 Apr                 |
| 500, 188 | 1994 Mar                 |
| 500, L105| 1997 May<sup>b</sup>     |
| 500, L11 | 1997 Oct                 |
| 501, 137 | 1996 Dec                 |
| 501, 153 | 1996 Aug                 |
| 501, 624 | 1994 Nov                 |
| Citation | Date of First Data | 4-m Mayall | WIYN–Queue | WIYN–NOAO Classical | WIYN–University |
|----------|--------------------|------------|------------|---------------------|-----------------|
| 502, 16  | 1995 Jun           | ·          | ·          | ·                   | ·               |
| 502, L39 | 1995 Jun           | ·          | ·          | ·                   | ·               |
| 503, 109 | 1997 Mar           | ·          | ·          | ·                   | ·               |
| 503, 543 | 1996 May           | ·          | ·          | ·                   | ·               |
| 504, 935 | ·                  | 1997A      | ·          | ·                   | ·               |
| 505, 174 | 1996 Feb           | ·          | ·          | ·                   | ·               |
| 505, 199 | 1985               | ·          | ·          | ·                   | ·               |
| 505, 793 | 1996 Aug           | ·          | 1996 Oct   | ·                   | ·               |
| 506, 33  | 1993               | ·          | ·          | ·                   | ·               |
| 506, 222 | 1994 Apr           | ·          | ·          | ·                   | ·               |
| 507, 210 | 1991 Nov           | ·          | ·          | ·                   | ·               |
| 507, 46  | 1995 Apr b         | ·          | ·          | ·                   | ·               |
| 507, 558 | 1994               | ·          | ·          | ·                   | ·               |
| 508, 200 | ·                  | ·          | ·          | 1995 Jul            | ·               |
| 508, 397 | 1992 Oct           | ·          | ·          | ·                   | ·               |
| 509, 93  | 1996 Feb           | ·          | ·          | ·                   | ·               |
| 510, 82  | 1994               | ·          | ·          | ·                   | ·               |
| 510, 197 | 1997 Oct           | ·          | ·          | ·                   | ·               |
| 510, 197 | 1996 Jan           | ·          | ·          | ·                   | ·               |
| 510, 251 | 1997 Sep           | ·          | ·          | ·                   | ·               |
| 511, 639 | 1994 Mar           | ·          | ·          | ·                   | ·               |
| 511, L1  | 1997 Apr           | ·          | ·          | ·                   | ·               |
| 512, 125 | 1978b              | ·          | ·          | ·                   | ·               |
| 513, 34  | 1996 Apr           | ·          | ·          | ·                   | ·               |
| 513, L25 | 1997 Feb           | ·          | ·          | ·                   | ·               |
| 514, 746 | 1994               | ·          | ·          | ·                   | ·               |
| 515, 169 | 1995 Sep           | ·          | ·          | ·                   | ·               |
| 515, 191 | 1995 Sep           | ·          | ·          | ·                   | ·               |
| 515, 487 | 1993 Oct           | ·          | ·          | ·                   | ·               |
| 516, 563 | 1995 Mar           | ·          | ·          | ·                   | ·               |
| 517, 40  | 1996A              | ·          | ·          | ·                   | ·               |
| 517, 130 | 1987 May           | ·          | ·          | ·                   | ·               |
| 517, 565 | ·                  | 1995A      | ·          | ·                   | ·               |
| 517, 692 | 1998 Apr           | ·          | ·          | ·                   | ·               |
| 518, 167 | 1996 Nov           | ·          | ·          | ·                   | ·               |
| 519, 610 | 1997 Jun           | ·          | ·          | ·                   | ·               |
| 520, 751 | 1992 Apr           | ·          | ·          | ·                   | ·               |
| 520, L103| ·                  | 1998 Aug   | ·          | ·                   | ·               |
| 521, L37 | ·                  | ·          | ·          | 1995 Dec            | ·               |
### TABLE A1—Continued

| Citation | 4-m Mayall | WIYN–Queue | WIYN–NOAO Classical | WIYN–University |
|----------|------------|------------|---------------------|-----------------|
| 522, 199 | ⋮          | ⋮          | ⋮                   | 1996 Nov        |
| 522, 338 | 1997 Sep   | ⋮          | ⋮                   | ⋮               |
| 524, 1000| 1998       | ⋮          | ⋮                   | ⋮               |
| 524, L103| ⋮          | ⋮          | ⋮                   | 1999 Jun        |
| 525, 466 | 1998 Dec   | ⋮          | ⋮                   | ⋮               |
| 525, 659 | <1984      | ⋮          | ⋮                   | ⋮               |
| 526, 274 | ⋮          | ⋮          | 1997 Nov            | ⋮               |
| 526, 665 | ⋮          | ⋮          | ⋮                   | 1995 Dec        |
| 527, 110 | 1994 Mar\(^b\) | ⋮          | ⋮                   | ⋮               |
| 527, 219 | 1997 Jan   | ⋮          | ⋮                   | ⋮               |

**Astrophysical Journal Supplements**

| Citation | 4-m Mayall | WIYN–Queue | WIYN–NOAO Classical | WIYN–University |
|----------|------------|------------|---------------------|-----------------|
| 114, 133 | 1992 Sep   | ⋮          | ⋮                   | ⋮               |
| 117, 89  | 1990 Sep   | ⋮          | ⋮                   | ⋮               |
| 118, 353 | ⋮          | ⋮          | ⋮                   | 1996 Aug        |
| 119, 1   | 1994       | ⋮          | ⋮                   | ⋮               |
| 119, 189 | 1991 Apr   | ⋮          | ⋮                   | ⋮               |
| 121, 417 | 1994       | ⋮          | ⋮                   | ⋮               |
| 125, 73  | ⋮          | ⋮          | 1998 May            | ⋮               |
| 125, 489 | 1996 Oct   | ⋮          | ⋮                   | ⋮               |

**Publications of the Astronomical Society of the Pacific**

| Citation | 4-m Mayall | WIYN–Queue | WIYN–NOAO Classical | WIYN–University |
|----------|------------|------------|---------------------|-----------------|
| 111, 685 | 1990 Sep   | ⋮          | ⋮                   | ⋮               |
| 111, 1233| 1993 Jun   | 1996 Aug   | ⋮                   | ⋮               |

\(^a\)In the cases when only the observing semester could be ascertained, we list that information. “A” refers to the period of 1 February through 31 July, and “B” from 1 August through 31 January of the following year.

\(^b\)Minor use; not counted.