

**BORDER TRADING:
THE AMATEUR-PROFESSIONAL PARTNERSHIP
IN VARIABLE STAR ASTRONOMY**

by

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Introduction

Modern science studies scholarship has emphasized the fluidity of the boundaries of science, and the interplay between society, politics, and the laboratory. Bruno Latour takes this one step further, describing how the scientific laboratory recreates itself in the larger world, turning ordinary French farms into controlled environments where Pasteur's microbes can be both demonstrated and eradicated.¹ At the same time, Peter Galison has emphasized the complex social structure *within* the scientific community: in physics, the separate traditions of theory, experiment, and instrumentation may proceed on quasi-independent trajectories, but are nonetheless inextricably bound by constant scientific exchange in the “trading zones” at their boundaries.² My approach combines a little of each perspective. In what follows, I explore the dynamics of a trading zone that flourishes not within the traditional laboratory, but rather at the boundary between the laboratory and its larger world extension. In astronomy, the partnership of amateurs and professionals in conducting variable star research has been an institutionalized form of exchange for most of this century. Taking a partly historical, partly sociological view, I analyze first the participants and then the mechanics of the exchange, focusing primarily on examples based in North America.

Background

The popularity of amateur astronomy – an estimated 250,000 North Americans consider themselves amateur astronomers – provides a striking example of science successfully translated beyond the observatory walls. The ever-evolving worldview of professionals is propagated and transformed as a nervous public is reassured that the orbit of an Earth-bound asteroid will not lead to collision, and as the readers of *Sky & Telescope* train their telescopes on Europa and wonder about the possibility of life under its frozen surface. The amateur-professional partnership in research involves only a small number of the most dedicated amateurs. Yet in certain areas such as meteor counting, comet and supernova discovery, and variable star observation, amateur participation is completely routine.

The oldest organization coordinating amateurs and professionals in variable star observation is the American Association of Variable Star Observers (AAVSO), formally established in 1911 in cooperation with the Harvard College Observatory (HCO). However, the AAVSO credits the idea to the German Friedrich Argelander, who in 1844 issued an “Appeal to the Friends of Astronomy” requesting amateur observations of variable stars.³ Sir John Herschel had the same idea at about the same time as Argelander, writing that variable star observation (VSO) “holds out a sure promise of rich discovery, and one in which astronomers in established observatories are almost of necessity precluded from taking part by the nature of the observations required.”⁴ In

¹ Latour, “Give Me a Laboratory and I Will Raise the World”

² Galison, *Image and Logic*, Chapter 9

³ Mayall, “The Story of the AAVSO”

⁴ quoted in Hoffleit, “Preludes to the Founding of the AAVSO” pp. 107-8

other words, tracking the changing brightness of variable stars requires many, many observations at all hours, and until recently at least, professionals did not have the resources to adequately study these stars without help. On the other hand, by the mid 19th-century a reasonably well-off amateur could buy a telescope capable of such observations.⁵

The number of observers working with the AAVSO has grown quickly from the original 15 (there were 564 observers in 1997), and the database of observations is now growing by roughly 350,000 data points per year.⁶ Meanwhile dozens of smaller organizations have sprung up in Australia, South Africa, all over Europe, and Japan, many of them sharing members with the AAVSO. The mid 20th-century saw a big increase in organizations and participation, particularly after the launch of Sputnik.⁷ The spread of charge coupled devices (CCDs) and photoelectric photometry (PEP) has enabled the study of fainter variables and smaller fluctuations, while the growth of email and Internet technology has promoted the development of international collaborations focused on variables with rapid and irregular variations that require frequent observation. The AAVSO interprets “variable star research” quite broadly, including several special sections in addition to its basic visual observing program: PEP and CCD photometry teams, a solar division that monitors sunspots, nova and supernova search groups, sections focused on particular types of variable stars, and a gamma ray burst team (currently being assembled⁸).

The Participants

Who are the people that make this partnership work, and what kind of people are they? I will answer this question first historically, then sociologically.

Historical origins of the participants in the VSO collaboration

From a historical perspective, the amateur-professional collaboration in variable star astronomy arose as one of several late 19th-century solutions to the problem of how amateur participation in astronomy research could continue despite increasing professionalization of the discipline. As John Lankford points out, the words “amateur” and “professional” largely define each other in opposition; these words entered the English language within forty years of each other, as these categories began to emerge in the second half of the 18th-century.⁹ Although wealthy “Grand Amateurs”¹⁰ like William

⁵ Rothenberg & Williams, “Amateurs and the Society During the Formative Years,” p. 42; also relevant, Chapman, *The Victorian Amateur Astronomer*, p. 234

⁶ Mattei, “Director’s Report” (1998), p. 184

⁷ Schweitzer *et al.*, “Variable Star Observing Around the World,” esp. p. 115

⁸ Carlson, “Gamma-Ray Bursts Come Home”

⁹ Lankford, “Amateurs and Astrophysics,” p. 276

¹⁰ Here I adopt the terminology of Allan Chapman, who identifies as “Grand Amateurs” those who inherited or married sufficient money to build state-of-the-art private observatories, often with hired staff, and who had unlimited leisure time to pursue astronomy. These amateurs clearly formed a separate group

Parsons, Lewis Rutherford, and Henry Draper had the time, money, and skills to compete directly with professionals through much of the 19th-century, by the end of the century even these amateurs could no longer keep up with the ever-increasing telescope apertures and specialized knowledge of professionals. Astrophysics, originally pioneered largely by amateurs, became one of the most carefully guarded professional domains by the turn of the century.¹¹ Meanwhile, the Grand Amateurs' poorer cousins (those who had to work for a living and do astronomy on the side) had already found what would be an enduring niche: small-aperture astronomy, focusing on planetary and other solar system science, and the study of variable stars. After some smaller scale attempts to organize, in 1890 the British Astronomical Association (BAA) was formed, in part to provide an organization friendlier to amateur research than the Royal Astronomical Society.¹² A variable star section within the BAA followed in 1895.

Naturally the increasing exclusiveness of professional research did not sit well with all amateurs, particularly when controversies over the validity of amateur research results arose. Professionals had the tendency to assume that their superior equipment, if not their superior knowledge, should not be questioned, although the eventual outcomes of several such controversies went both ways.¹³ At the same time, especially in England, the tradition of gentlemanly science free of material “interests” clashed head-on with the notion of paid professionals.¹⁴ Some gentleman amateurs outspokenly denounced publicly funded science as a mercenary activity antithetical to the search for impartial truth.

By the time the AAVSO was formed in 1911, professional astronomers considered not-so-grand amateurs with professional training in other fields to be their ideal partners in variable star work. Pickering himself had encountered some difficulties working with an independent-minded amateur who refused to adopt HCO standards, so the amateur founder of the AAVSO, William Tyler Olcott, must have seemed quite a relief. “A professional himself (law), Olcott accepted the hierarchical structure and intellectual control that Harvard College Observatory established over variable star observations. He acknowledged the superior knowledge of professional astronomers and seemed satisfied to be able to do his part to advance knowledge.”¹⁵ For his part, Pickering had a history of open-mindedness toward traditionally excluded, but intelligent and cheap labor – “Pickering's girls” at HCO included Annie Jump Cannon, Henrietta Swan Leavitt, and Williamina Fleming.¹⁶ Historically, many of the most dedicated professional leaders of

from the comfortable but not self-sufficient middle class (doctors, lawyers, etc.) amateurs who led in the formation of astronomical societies like the British Astronomical Association (Chapman, *Ibid.*, p. xiii).

¹¹ For example, see Hufbauer, “Amateurs and the Rise of Astrophysics”

¹² Chapman, *Ibid.*

¹³ Lankford, *Ibid.*; Lankford, “Amateur versus Professional: The Transatlantic Debate...”; Lankford, “Amateurs versus Professionals: The Controversy over Telescope Size...”

¹⁴ Chapman, *Ibid.*, e.g. pp. 6-8

¹⁵ Rothenberg & Williams, *Ibid.*, pp. 47-48

¹⁶ Hoffleit, *Women in the History of Variable Star Astronomy*. While Pickering did offer opportunities to the traditionally excluded, there was also an element of exploitation. For example Hoffleit writes of Antonia Maury, “She was the most original thinker of all the women Pickering employed; but instead of encouraging her attempts at interpreting observations, he was only irritated by her independence and departure from assigned and expected routine.” (*Ibid.*, p. 3) Hoffleit herself worked on variable stars at

the AAVSO have been descendants of Pickering and/or his “girls,” including all three directors.¹⁷ However, over time the organization has transformed from a small group centered around Pickering's research to a large, bureaucratized service organization that provides data to scientists worldwide.

Over the years, variable star astronomy has been a haven for the marginalized – both amateurs and women – and the struggle for resources and respect has become a recurrent tale for both individual and institutional participants. Although many of the great astronomers of the 19th century were amateurs, written histories of astronomy often refer to them as professionals, with the tacit implication that their achievements are incompatible with “merely” amateur status.¹⁸ The status of variable star astronomy is also not quite what it was in Pickering's day.

Troubles struck the AAVSO when Donald Menzel became director of HCO, decided to tear down the building in which the AAVSO had its headquarters, and diverted all but \$7,000 of their \$100,000 operating budget to solar research, his own field of expertise.¹⁹ With the \$7,000 protected by a legal technicality, the AAVSO struggled to survive with its director working *pro bono* for some time, before the organization finally achieved independent financial stability. Even today the AAVSO lacks funding for key projects,²⁰ and the CBA has likewise operated on a tight budget, “orphaned in the world of science funding.”²¹ Variable star workers command neither the prestige nor the budgets of

HCO under Henrietta Swope, during Harlow Shapley's directorship, but with characteristic modesty hardly mentions herself in her own book on the history of women in variable star astronomy! (Levy, “Astronomy's First Lady”)

¹⁷ Mayall, “The Story of the AAVSO,” p. 9 and p. 12 (note election of Hoffleit as president); Mattei, “The Director looks back”

¹⁸ Williams, “Criteria for Selection of an Astronomer as an Amateur” (esp. Table 2)

The modern dictionary definition of the term amateur – “one who engages in a pursuit, study, science, or sport as a pastime rather than as a profession” (Webster's Ninth New Collegiate Dictionary) – probably does not capture its 19th-century connotations, nor for that matter its unfairly pejorative 20th-century ones. Interestingly, today's amateur astronomers seem to have their own collective definition of the term amateur: it means simply “unpaid,” and its connotations, all positive, derive from its etymological root “to love.” Thomas Williams (an amateur astronomer as well as a historian) advocates the “pay/no pay test” to delineate amateurs from professionals for historical purposes. Implicit and sometimes explicit in this definition is the idea that “professionals do it for the money” and not for love. It is interesting to note that this definition resonates with the anti-mercenary instincts of the 19th-century British gentleman amateurs. Furthermore, by sidestepping the issue of how training, resources, modes of work, and social context define an individual, the amateurs' simple definition guards against the appropriation of amateur heroes by professionals.

¹⁹ The official AAVSO histories that describe this episode (e.g. Mayall, *Ibid.* and Mattei, “The Founding of the AAVSO”) are quite tactful in not blaming Menzel for what happened, but “oral history” and embedded offhand remarks (e.g. in Levy, “Astronomy's First Lady”) suggest that the community felt attacked and betrayed by Menzel, who also presided over the destruction of the HCO photographic plate stacks.

²⁰ For example, see Carlson, *Ibid.*

²¹ The phrase is excerpted from a rather unorthodox acknowledgements section in a recent article: “We thank the NSF for financial support through grant AST96-18545, and especially the Research Corporation for explicit support of the CBA, which has been somewhat orphaned in the world of science funding. We hope this paper gives a glimpse into the power of periodic studies made feasible by a network of small backyard telescopes, aided by CCDs, computers, and tenacious humans.” (Skillman *et al.*, “Superhumps in Cataclysmic Binaries” p.12) David Skillman is the amateur co-founder of the CBA.

cosmologists, who as one professional puts it “seem to hold the whip hand nowadays.”²²

Throughout the 20th century, technological possibilities have strongly shaped the composition of the amateur population, in which amateur researchers form but a small minority. In the 1920's, amateur telescope making (ATM) took off when Albert Ingalls and Russell Porter teamed up to produce a regular ATM column in *Scientific American*.²³ Thomas Williams argues that the participants in the ATM movement had different goals than amateur researchers – they loved the process of grinding lenses and assembling mounts, and their “star parties” were focused on comparing equipment and recreational stargazing. Amateur researchers, by contrast, were a small minority with different publications and organizations, less interested in popularization and more in contributing to astronomical knowledge.²⁴

After 1970 high-quality mass-marketed telescopes as well as easy-to-build Dobsonian scopes appeared on the scene, and in the ensuing decades amateurs have acquired advanced capabilities in astrophotography, PEP, and CCD imaging.²⁵ This development has brought many professionals outside of the AAVSO into closer contact with amateurs, as small collaborations centered on PEP and CCD photometry of variable stars have emerged, such as the Center for Backyard Astrophysics (CBA). Within the last two years, Meade has introduced computer-controlled telescopes with entry-level pricing, and two manufacturers have started selling CCD spectrographs for amateur telescopes.²⁶ As these products spread in the next few years, it will be interesting to see whether amateur research finds new converts.

A sociological portrait of the participants in the VSO collaboration

To get a better understanding of the modern VSO community, I engaged in a “cultural immersion” experiment starting in the spring of 1999. I began by interviewing a professional AAVSO council member who was an amateur member of the AAVSO as a teenager. At about the same time I started reading the AAVSO email discussion group postings daily. I also visited AAVSO headquarters, interviewed Director Janet Mattei, and examined the individual survey responses to an internal member survey the AAVSO had conducted earlier in the year but had not yet analyzed. In June I posted a survey to several VSO mailing lists (AAVSO, CBA, and the Japanese-run VSNET), to gather information about how participants became involved, why they do it, and how they view each other. Then in July I attended the joint meeting of the Astronomical Society of the Pacific (ASP) and the AAVSO, held in Toronto and focused on the theme of amateur-professional collaboration. I believe that this was the first large meeting devoted to this theme since 1987.²⁷ While there, I learned from a variety of very relevant talks and

²² From the survey described in the Appendix.

²³ Williams, “Albert Ingalls and the ATM Movement”

²⁴ Williams, “Getting Organized”

²⁵ Williams, *Ibid.*

²⁶ As featured in recent issues of *Sky & Telescope*. See in particular February 1999.

²⁷ In 1987 the International Astronomical Union held a colloquium on this topic (“Stargazers”).

posters, and also engaged fully in the offline social and information exchange of the meeting, as I was graciously invited to parties, the CBA's private planning meeting, and a dinner organized by all the historians. I also distributed more copies of my survey in paper form, and personally interviewed eight survey respondents in depth, while also meeting and talking with many others. Some of the survey results are discussed here; the full report is given as an Appendix.

I should perhaps point out that I was by no means an anthropologist “playing the stranger” in these proceedings. Because scientists are generally distrustful of historians and sociologists of science, I clearly indicated my status as a graduate student in astrophysics. At the Toronto meeting, I participated in scientific discussions and interacted as a scientific insider, albeit of the foreign extragalactic-astronomy variety. I believe that my insider status was critical to this study. I was able to show a genuine and detailed interest in the participants' work (in fact, this was my first in-depth exposure to the subject of variable stars as well as to amateur astronomy, and both fascinated me independent of this project). I gained trust through personal interaction: certain respondents made it clear that they were responding only because of my serious participation, as judged by my traveling all the way to Toronto and/or my attempt to contribute usefully to scientific and organizational discussions.

The next two sections characterize the amateurs and professionals involved in the variable star partnership (and to some extent, involved in any amateur-professional collaboration). I will first focus on personal histories and demographics, then describe the value systems participants share.

Personal Histories & Demographics

The portrait given here is based on approximately 60 survey responses, or very roughly 5-10% of the relevant population.²⁸ The question immediately arises, how representative is the survey? The fact that a large fraction of the surveys were distributed through the Toronto conference implies that the survey will be biased toward fairly dedicated participants,²⁹ as well as those who have time or money to travel. Particularly in the case of the AAVSO, section heads and other leaders were more likely to attend the conference than the rank and file, leading to a survey bias toward accomplished and well-equipped observers. Confirming this view, when the AAVSO invited suggestions on how to increase meeting attendance in a recent internal survey, a couple of members replied along the lines of “I'm too much of a novice to feel comfortable.”³⁰

²⁸ The relevant population is not easy to estimate. The AAVSO is by far the biggest player, with over 550 observers enlisted, but there are dozens of smaller organizations. On the other hand, there are probably many dormant observers in the AAVSO. A. J. Meadows says it had 1300 members in 1986 (Meadows, “Twentieth-Century Amateur Astronomy” p. 23) but gives no reference. The professional pool that actually works directly with amateurs appears to be small (as opposed to those who get amateur assistance via a database without direct contact), but again this is not easy to estimate.

²⁹ As one measure of dedication, sixty percent of amateurs and twenty-five percent of professionals in the VSO partnership survey said they observe on the majority of clear nights. (See Appendix.)

³⁰ AAVSO internal member survey.

The basic demographics of the sample show a predominantly male population,³¹ typically age 35-65 with a few outliers. My questionnaire did not request nationality, nor would the small sample support international comparisons, however it is clear from information such as email addresses that at least 20% of respondents come from outside North America: Japan, Australia, South Africa, the Netherlands, Switzerland, Argentina, etc. Defining exactly who is a professional and who is an amateur can be tricky,³² so I asked people to classify themselves to see what self-definition would emerge.³³ The strongest indicators of amateur/professional status appear to be formal degrees in astronomy and paid employment in astronomy. Type of work also serves as an indicator, with professionals focusing on research for publication and amateurs focusing on observation, but there is considerable crossover here.

To put this survey in a more general context, one can compare with the survey of sociologist Robert Stebbins, who interviewed 30 amateur and 28 professional astronomers working near his location in Canada.³⁴ His survey participants included the full range of amateurs from armchair astronomers through serious contributors like the VSOers of my survey, and he also sampled a broader range of professionals, covering all specialties and not necessarily interested in variable stars or in working with amateurs. His sample was also largely male with a broad range of ages, but confined to Canadians.

Stebbins reports that amateur and professional astronomers in his survey represent two minimally overlapping sets of individuals.³⁵ Although their initial exposures to astronomy come from similar sources, the amateur respondents are far more impressed by their early telescope experiences than are the professionals, who are motivated more to explain the sky than to observe it. Stebbins argues that the most common reason why amateurs do not become professionals is that they prefer observation to analysis and/or believe themselves not good enough at advanced math and physics. He finds a few who cannot pursue astronomy professionally due to other occupational commitments or “idiosyncratic reasons.” Stebbins concludes that amateurs “generally have neither the inclination nor the aptitude for professional or advanced empirical and theoretical work in the discipline. That is, seasoned amateur astronomers are very likely to remain amateurs

³¹ The shortage of female amateur VSOers, and the relative abundance of female professionals in the collaboration (compared to my vague sense of what to expect from working in extragalactic astronomy), struck me as I sorted the AAVSO internal survey. When I asked an AAVSO staff member about this, she said that it had always been that way. The statistics are so small that I have not attempted to pursue any kind of serious analysis, however the marginalization of females provides an interesting counterpoint to the marginalization of amateurs, from both historical and sociological perspectives. Females are apparently much more common in amateur natural history and archaeology societies (Stebbins, “Science Amators” p. 293; Meadows, *Ibid.*, p. 21). I included a question in my survey inviting speculation on this topic, the results of which may be found in the Appendix.

³² See for example Lankford, “Amateurs and Astrophysics”; and Rothenberg & Williams, “Amateurs and the Society”

³³ However, see Appendix for details on reclassification of 3 individuals who classified themselves “Amateur/Professional.”

³⁴ Stebbins, “Avocational Science”; Stebbins, “Looking Downwards”; Stebbins, “Science Amators?”; Stebbins, “Amateur and Professional Astronomers”

³⁵ Stebbins, “Looking Downwards”

and not to be recruited to the ranks of the professionals.”³⁶

This picture contrasts strikingly with the data obtained here for the VSO partnership community. The amateurs and professionals in this community strongly overlap, with 2/3 of the professionals reporting that they were or still are amateurs as well, and 1/5 of the amateurs reporting semi-professional status: life histories that include teaching astronomy, graduate level training in astronomy, or brief periods of astronomy-related employment. Although a larger fraction of the professionals use PEP or CCD equipment, nonetheless nearly 2/3 of the amateurs also use such equipment. Furthermore, 95% of the amateurs described themselves as comfortable reading technical journals such as the *Proceedings of the Astronomical Society of the Pacific* or the *Astrophysical Journal*. Although my survey did not collect data on current occupation, those who happened to mention their work were typically professionals, often in technical fields – e.g. aerospace engineering, industrial chemistry, biochemistry/biophysics, medical research/practice, and software engineering. Others were usually involved in education or the military, while a handful mentioned unrelated careers (administrative law, inventory control). In comparing the skills of amateurs and professionals, both groups judged that amateurs operate at an equivalent or nearly equivalent level to professionals, but with a different emphasis in their skills. It seems quite likely that the strong overlap of skills and experiences between the professionals and amateurs in this community enables and facilitates the variable star research partnership.

The great majority of both amateurs and professionals in the VSO survey described astronomy as a childhood or teenage interest.³⁷ In recalling their first attraction to astronomy, approximately 3/4 of the survey sample described being inspired by the beauty or fascination of the sky itself, with no significant difference between amateurs and professionals. Neither the professionals nor the amateurs in the survey placed a strong emphasis on telescopes: only about 15% of each group mentioned an early telescope. The survey responses do not show the split found by Stebbins, as there is no evidence that early experiences with a telescope *per se* were any more inspirational for amateurs than for professionals.³⁸ Furthermore, the common stereotype of amateur astronomers as telescope-makers first and lovers of the heavens second does not seem to fit VSOers very well. When asked which aspects of astronomy are part of “why they do it,” only 15% of amateur VSOers cited instrumentation as a key pleasure, roughly the same percentage as for professionals. Where the two groups differ on telescopes is in their overall experience: on average, amateurs spend more time on instrumentation. While nearly 1/2 of the amateurs surveyed said they do some instrumentation and enjoy it, only 1 in 5 professionals said the same. This result is only marginally statistically significant given the small number of professionals, however it agrees with my impression of the prevailing professional culture, in which the shortage of professional astronomers with instrumentation skills is currently a problem. Enjoyment and involvement may be a bit circular here: one could easily argue that amateurs are *forced*

³⁶ Stebbins, “Looking Downwards” p. 12

³⁷ The percentages are 80-90%, even higher than what Stebbins reports for the broader amateur and professional populations (2/3 in both cases). (Stebbins, “Amateur and Professional Astronomers” p. 446)

³⁸ Stebbins, “Looking Downwards” pp. 7-8

to become familiar with their equipment to a much greater degree than professionals, who may use observatories maintained by others or may not observe at all, and therefore a natural consequence is that a greater fraction of amateurs actually have the opportunity to discover that they enjoy instrumentation work. In any case, such work rarely *motivates* the VSOer's participation in astronomy.

As mentioned, the professionals I surveyed spend less time observing or planning observations than the amateurs do, which is no surprise given the division of labor in the VSO partnership. Furthermore, only 20% of the professionals described visual observing as one of the reasons why they do astronomy, whereas 60% of the amateurs gave it that priority. The demographics of the sample confirm this picture, within the marginal statistical significance of the survey: a higher proportion of amateurs come from rural or suburban backgrounds where one might expect relatively dark skies. These numbers are consistent with Stebbins' results: he finds that an affinity for observation is typical of the general population of amateurs, whereas for only 20% of his professional sample could he trace the decision to seek a career in astronomy to the attraction of observation.³⁹ On the other hand, at least within the VSO survey sample, the two groups agree on observation planning: over half enjoy the process, but only a handful would list it among their motivations to do astronomy.

Stebbins' conclusions on why amateur astronomers do not become professionals do not apply particularly well to the variable star observers I surveyed. Although enjoyment of pure observation certainly plays a role, lack of technical ability or inclination is not obvious in this group of amateurs. Perhaps reflecting their generally high level of technical competence, only four amateur VSOers mentioned their own intelligence or mathematical abilities as reasons to remain amateur, out of twenty-three who commented on the choice to become amateur or professional. About 3/4 of the twenty-three respondents seriously considered becoming professionals, and at least 1/2 of them gave up the dream of becoming professionals due to factors perceived to be out of their control: poor job prospects, financial pressures, doubt in their own abilities, or the lack of educational opportunities. Some of the stories were sobering. One amateur remembered being counseled by his college adviser that he should forget astronomy because there were no jobs: "This was one of the saddest days in my life." Another amateur with whom I became friends told me quite bluntly: "You are living my dream."

On the other hand, roughly 15% of amateurs described their involvement in astronomy as a sort of unexpected surprise, as they discovered or rediscovered astronomy later in life by accident. Interestingly, no professionals described their involvement in these terms, and all but the one graduate student in the group have undergraduate or higher degrees in astronomy, suggesting a clear intentionality in their career paths.

Value Systems

Both professionals and amateurs in the VSO survey share what they consider basic scientific values: carefulness, integrity, accuracy, and perfection of results. A skeptical

³⁹ Stebbins, "Amateur and Professional Astronomers" p. 449

outlook on the world, stressing empirical proof and critical thinking, also characterizes both groups. Finally, the two groups share a deeper appreciation of the universe in poetic, spiritual, or philosophical terms.

Although only 15% of each group mentioned public outreach or teaching as an important value, in practice the professionals are much more likely to commit time to it.⁴⁰

Amateurs often described themselves as loners, and the majority prefer to be alone while observing.⁴¹ When a beginning VSOer posted a somewhat guilty email to the AAVSO discussion group asking how people handled public interruptions of observing sessions, a flurry of responses suggested escape techniques.⁴² Furthermore, amateur VSOers typically spend much less time helping beginners than do professionals, and perhaps as a corollary, most of them described themselves as self-taught.

Perhaps the most important difference between amateur and professional variable star astronomers centers on why they do what they do. Amateur VSOers are much more likely to make an explicit commitment to the advancement of science, the growth of human knowledge, and the search for truth. At a basic level, amateurs say they “do it for love,” although certain other rewards such as prizes, recognition, and authorship may also provide motivation.

If one can gain some insight into people by examining their heroes, then it is clear that contribution to science is the paramount value shared by amateur VSOers, and Stebbins finds that even the more general amateur population reveres heroes of the same stamp.⁴³ One of the most highly regarded observers in AAVSO history was Leslie Peltier, once described by Harlow Shapley as “the world's greatest non-professional astronomer.”⁴⁴ Peltier's autobiography *Starlight Nights* inspires new VSOers even now.⁴⁵ Late in his life, Peltier emphasized difficult faint object work, providing precious “inner sanctum” observations other VSOers could not obtain with their equipment, although this meant giving up the race for lifetime observing leadership in number of observations.⁴⁶ In both my survey and the AAVSO's own internal survey, a few amateurs commented that the AAVSO's prizes for high observing totals “put a damper on things,”⁴⁷ and many observers put their own personal emphasis on quality rather than quantity of

⁴⁰ This disparity does not necessarily contradict the conventional wisdom that amateur participation in astronomy helps to popularize astronomy for the general public, as some help is better than no help. Meadows states that 10-20% of amateur astronomers in general popularize outside of their local clubs, in which case the VSOers are not doing too badly. (Meadows, *Ibid.*, p. 22)

⁴¹ Roughly 2/3 of amateur survey respondents prefer observing alone. Only 1/3 of professionals said the same; however, quite a few did not comment, perhaps because they rarely observe (e.g. theorists) or observe remotely (e.g. users of satellite telescopes).

⁴² AAVSO email discussion list, spring 1999

⁴³ Stebbins writes that “The most honored people are the masters who make original contributions to the science, have close associations with the professionals, and know well their specialty.” (Stebbins, “Avocational Science” p. 47)

⁴⁴ Quoted in Williams, “Contributions of Amateurs to Astronomy” p. 7

⁴⁵ I found numerous mentions of Peltier throughout my “immersion” experience and one survey respondent specifically mentioned *Starlight Nights* as a major source of inspiration.

⁴⁶ Williams, *Ibid.*

⁴⁷ The quote is from the AAVSO internal member survey.

observations. On the other hand, authorship of scientific publications does motivate some amateur VSOers, who clearly view this reward as consistent with their overall goal of contributing to science.

One could argue that professionals have similar goals of contributing to science, implicit in their career choices; however about half the amateur respondents and even a couple of the professionals took a more negative view, describing professionals (or at least some of them) as motivated by prestige, money/job security, or a “publish or perish” mentality. I am sure this caricature contains an unfortunate degree of truth, however one should also consider that amateurs have somewhat of a love/hate relationship with professionals, many of whom treat them with condescension. Furthermore, for those amateurs who would have been professionals but had to give up that dream, it may be difficult not to view the current set of practitioners as ungrateful and unworthy of such a privileged profession. After all, professionals do not exactly wear their hearts on their sleeves, and even if in a reflective moment they may express a deeper appreciation of the universe, they are more often focused on getting the job done.⁴⁸ In fact, one professional survey respondent described the unguarded enthusiasm of amateurs as a benefit of working with them: “It reminds me of why I got interested in astronomy.”

Mechanics of the Exchange

How does the amateur-professional partnership actually work? How do participants communicate, what do they have to trade, and what are the ground rules? I will address the three parts of this question separately.

Communication

Two modes of interaction

The VSO partnership operates in two modes, direct and mediated. In the direct mode, amateurs and professionals communicate in person, by phone or by email. Using the Internet, direct collaborations may span the globe, as does the CBA. However, it is helpful for participants to meet directly from time to time, as several members of the CBA did at the Toronto meeting. In the mediated mode, an organization such as the AAVSO collects amateur observations submitted by mail, computer disk, or email, and makes them available to professionals, who contact the AAVSO staff in order to obtain data. Recently the AAVSO has introduced some “self-serve” capabilities through its website, and these will expand in the future.

The AAVSO staff may also receive requests for specific observations, for example monitoring a particular star for signs of an outburst so that satellite observations can be precisely timed. In some cases, the request may be forwarded to observers in the form of

⁴⁸ Jean-Louis Heudier beautifully expresses the tension between the business and the wonder of science: “Consider Halley’s Comet and what a number of consistent observations and calculations were needed to change it from a marvel into a mundane object.” (Heudier, “Comet Halley” p. 207)

an alert message, increasingly via email, asking for observations to be sent to headquarters. Alternatively, more advanced requests such as requests for CCD observations may prompt the organization to act as a matchmaker, putting amateurs and professionals in touch, but then leaving them to communicate directly. In general, mediated partnerships most often involve visual data, whereas direct partnerships most often involve PEP or CCD data. Visual observers may rarely see another VSOer or meet the AAVSO staff, although the organization has made some effort to set up mentoring relationships between beginning and advanced amateur VSOers, and members with email may participate in the recently created discussion list. Except for those willing to travel to the twice-yearly meetings, direct contact with other VSOers occurs through local astronomy clubs or at their own initiative. On the other hand, some members have developed a sense of family, particularly those who travel to meetings, and the *AAVSO Newsletter* promotes this spirit.

Pidgins and Creoles

Peter Galison has suggested that trading zones may be characterized by the development of local exchange languages, some of which may eventually turn into permanent creoles, for example the field of phenomenology that bridges the gap between theory and experiment in particle physics.⁴⁹ Although variable star astronomy has followed a very different history, with amateurs present from the start, by now the VSO partnership does seem to have a life and a language of its own. While unmediated organizations such as the CBA may require only that amateurs and professionals learn some of each other's languages – for example, professionals must learn the language of amateur instrumentation, and amateurs must learn professional jargon – the AAVSO has clearly developed its own sphere of communication, with an independent journal and a distinct body of knowledge. The *Journal of the AAVSO* presents a free mix of astrophysics, do-it-yourself instrumentation, history of astronomy, and studies of human vision, by both amateur and professional authors. Many members are relatively fluent in all of these subjects, as judged by survey responses and the AAVSO email discussion list.⁵⁰ While the *JAAVSO* is not competing with the *Astrophysical Journal*, it provides an alternative technical forum, accessible to advanced amateurs both as readers and as authors. Other publications such as the *AAVSO Newsletter* further enhance the sense of a distinct community.

Goods to trade

The Mediated Mode

From the professional's point of view, the mediated exchange seems to be an outrageously good deal. The professional gets free observations at essentially no cost. Amateurs are not even included as co-authors. (For some professionals, sharing

⁴⁹ Galison, *Ibid.*, p. 837.

⁵⁰ Although amateur VSOers do not profess a noticeably greater interest or involvement in the history of astronomy than professionals (see Appendix), both general amateur and AAVSO publications include a fair bit of historical material.

authorship with amateurs can be an issue, either because of status consciousness, stinginess, or a fear that other status-conscious professionals will doubt their results.) Perhaps the AAVSO will be acknowledged, or director Janet Mattei even included as a co-author, but Mattei is a professional and the AAVSO has worked hard to rise above professional biases against amateurs, by standardizing observing procedures and carefully monitoring the data quality from individual observers.⁵¹ Occasionally a single amateur does require recognition, perhaps as the discoverer of a supernova, but since these discoveries enter the public domain through International Astronomical Union circulars, again the amateur need not be named as a co-author. As one professional respondent to my survey explained, “I personally feel quite guilty that I should ask an amateur to provide, out of the goodness of his heart, data which I know full well will enhance my own professional reputation and not his, but have been assured that the knowledge (to an amateur) that purpose-made observations help to formulate a new scientific result is in itself a most important reward.”

Of course amateurs aren't about to enter into an exchange with nothing in it for them. In the first place, professionals forget that they themselves originally chose to go into astronomy because it is appealing for its own sake – after all, the paycheck isn't that big. Robert Stebbins describes a variety of rewards that all amateur astronomers enjoy, both serious and casual: the satisfaction of developing and applying new talents, skills, or knowledge; intellectual and spiritual enrichment; relaxation and entertainment; and the thrill of seeing rare or fascinating phenomena.⁵² The participants in my survey clearly partake of all of these benefits.

However, the most important reward is more fundamental. For many of the amateur participants, the opportunity to provide useful data is a part of what makes life meaningful for them. While Stebbins suggests that making a genuine scientific contribution represents a “thrill” for an amateur,⁵³ I find that for serious VSOers, making a contribution represents something much deeper: a commitment to a value system. Many visual observers are profoundly anxious about the possibility that automated telescopes and huge CCD monitoring campaigns may put them “out of business,”⁵⁴ even though some openly describe what they do as “grunt work.” Amateurs fear exactly what Stebbins finds to be true: most professionals do not believe that astronomy would go on significantly differently without them.⁵⁵ Perhaps the fear hits home because, as Stebbins suggests, commitment to an avocation is one way to hold onto a sense of being in charge

⁵¹ Mattei, personal interview; and Garnavich, personal interview. Mattei notes that quality control is very important for the AAVSO because of biases against amateurs and against visual data: “Some professional astronomers see a few discrepant points and say, ‘What do you expect? Amateurs.’”

⁵² Stebbins, “Science Amators?”

⁵³ Stebbins, *Ibid.*, p. 296

⁵⁴ One respondent to the AAVSO’s internal member survey wrote:

“I wish someone would respond to the question of the future of the visual observer. We all know that in the early days all observers were visual but just as today when the modern telescopic giants have become big cameras and use CCD and PEP techniques and no one looks through them anymore... will not the same thing be happening to visual AAVSO'ers? One of the oft-stated reasons for the AAVSO is that there are so many variables and not enough professionals to keep track of them but just as today when even comets are more and more being discovered by automatic cameras that never sleep, won't AAVSO observations be someday mainly done by automatic self calibrating telescopes that in a few nights of work can eclipse the annual records of even Dani Overbeek in South Africa?”

⁵⁵ Stebbins, “Amateur and Professional Astronomers” pp. 441-2

of one's life in the 20th century.⁵⁶ One amateur I interviewed for my survey explicitly made the same connection, suggesting that serious observers would be very discouraged if “shunted to the side” by automated technology, and drawing an analogy to the inner cities of North America. “The less people have to do that is meaningful, the more hope decays.”

Thus, amazingly, it becomes Janet Mattei's job to convince professionals of the value of free observations at no cost, because as it turns out, it is the AAVSO and its amateur observers who have the most to lose if the amateur-professional partnership falls apart. Furthermore, it is also Mattei's job to reassure the observers that their observations go to good use. Her articles, talks, and end of year reports provide essential positive feedback, which few observers are in a position to doubt.⁵⁷ In fact, observers' fears about being put out of business by robotic telescopes have gone largely unanswered, perhaps because the only answer is “time will tell” and the professional leaders of the AAVSO have no desire to fan the flames of anxiety. Mattei believes that there will always be a place for traditional visual observers,⁵⁸ and while the jury is still out, she has a good track record to support her optimism.

Over the years, both Mattei and her predecessors have done a remarkable job of opening up markets for amateur participation, and working to make the AAVSO indispensable. The organization started by providing data necessary for a basic understanding of variable star periods and light curves (plots of brightness vs. time). The visual database, as the oldest database, provides a unique source of information on long-term stellar variability, and from an organizational point of view, also provides essential long-term continuity for observers. However, such data does not guarantee the organization's future – as one amateur respondent to my survey pointed out, in this case professionals may lack the AAVSO's long-term vision. However, the organization has also kept up with the changing times. As early as the 1930s, the AAVSO began coordinating its own visual observing program with outside programs.⁵⁹ During World War II, VSOers assisted in providing information on solar activity and sunspot counts no longer available from Zurich: “Since this information was important for communication, the U.S. government asked Harvard College Observatory to monitor sunspots... This responsibility was delegated to the AAVSO, and the solar division was established... this division soon engaged itself not only in monitoring sunspots but also monitoring solar granulation, colors of sunspots, spot configuration, and foreshortening of sunspot groups.”⁶⁰ After the war, the organization participated in the U.S. government's Moonwatch program, which mobilized amateur astronomers to monitor Sputnik and later other man-made satellites from 1957-1975.⁶¹ The AAVSO's involvement in space research really took off after

⁵⁶ Stebbins, “Avocational Science” pp. 34-35, 47

⁵⁷ One former AAVSO member at the Toronto meeting commented that the AAVSO kept promoting study of eclipsing binary stars, but he didn't see eclipsing binaries in the journals, so he began to doubt what he was hearing; however he was the only person I met who questioned AAVSO research priorities, apart from those who worried about the threat of automated telescopes.

⁵⁸ MacRobert, “The Lure of Variable Stars”

⁵⁹ Mattei, “Coordination of Visual Observing Programs” p. 68

⁶⁰ Mattei, “The Founding of the AAVSO” p. 114

⁶¹ Mattei, *Ibid.*; Cornell, “The Moonwatch Program”

1973, when a group of x-ray astronomers at MIT accidentally made the first detection of x-rays from a cataclysmic variable (CV) star. Using AAVSO records, the scientists confirmed that the star had been at visual light maximum at the time. Ever since that time, the AAVSO has played a major role in supporting space-based research on CVs, by providing visual or CCD data and outburst notification for x-ray and UV satellite observing programs.⁶² Observers share in the excitement, often receiving mission patches or other space souvenirs, personal thank-you letters, or sometimes co-authorship when they provide critical data. CV data requests represented about 1/2 of all AAVSO data requests in 1984, and about 1/4 in 1996.⁶³ More recently, the organization has sought to diversify: educational programs and services represented 23% of its work from 1996-1997, and in 1998 it completed an educational initiative, "Hands-On Astrophysics," intended to expand these services and recruit young variable star observers.⁶⁴ Although this program does not involve existing amateurs extensively, it will help provide a solid financial base for the organization. Finally, the AAVSO is just now beginning a gamma-ray burst follow-up program for its CCD observers, and excitement in the email discussion group is palpable.⁶⁵

The Direct Mode

Amateurs and professionals working in a direct partnership have a more complicated trade relationship, but many of the same things are exchanged. For professionals, the collaboration requires more work, both in terms of coordinating individual efforts and in terms of providing scientific motivation, mentoring, and encouragement. Even extremely advanced amateurs who have repeatedly published in professional journals stress the importance of professionals taking the time to teach and explain.⁶⁶

For both sides, the potential rewards exceed those of the mediated partnership. For the professional, the data is of a higher quality, typically CCD or PEP data, and can be directly tailored to the projects of interest. Quality control and assurance become much easier, and errors can be corrected. Although working with observers means an initial time commitment, they may eventually reach a high level and share the work of researching and writing papers, leading to a higher level of productivity. More intangibly, the professional enjoys the personal benefits of interacting with enthusiastic and highly intelligent amateurs -- in the words of Joe Patterson, the professional co-founder of the CBA, "you meet a higher class of people -- more independent minds."⁶⁷

On the amateur side, working directly with a professional implies a more definite commitment, and amateurs in such relationships emphasize the importance of not letting

⁶² Mattei, "Coordination of Visual Observing Programs"

⁶³ Mattei, "Visual Observing of Variable Stars"; Mattei, "Director's Report"

⁶⁴ Mattei, "Director's Report"; and Garnavich, personal interview.

⁶⁵ AAVSO email discussion list, January 2000.

⁶⁶ Offutt, "Brief Case Histories of Five Successful Professional-Amateur Collaborations"; Boltwood, "An Amateur Astronomer's Experiences"; interviews for VSO partnership survey; Alberto Sadun makes the same point from a professional perspective (Sadun, "A Few Observations")

⁶⁷ CBA group interview

the professional down with bad data.⁶⁸ Without the AAVSO's quality control as a buffer, the amateur has greater responsibility, but in turn a greater sense of ownership and a deeper involvement in the production of scientific results. As for all VSOers, the bottom line is contributing to science. In the view of David Skillman, the amateur co-founder of the CBA, one of the primary responsibilities of professionals in amateur-professional partnerships is to ensure that amateur contributions have an impact: "Until it gets into a journal, it's as if we never did it." The AAVSO's CCD photometry section, at the time of the Toronto meeting, was just beginning to set up a partnership with a professional. Confirming Skillman's point, the section had been unable to do much with the data, despite its being a high-quality color-filtered data set. However, the section leader (also the AAVSO president) described plans to use the data for valuable science projects in the near future with professional collaboration.⁶⁹

By now of course Skillman is quite capable of lead-authoring a paper himself, as are many in the CBA collaboration. Another CBA member, when giving a talk at the Toronto meeting, put up a transparency showing 63 scientific publications on which he was a co-author, to demonstrate what gave him the enthusiasm to keep going. When I asked members of the CBA why the majority of AAVSO observers were indifferent to authorship on scientific papers, I was told "They've never tasted it."⁷⁰ In a poster paper on successful professional-amateur collaboration, a CBA member who also publishes extensively on faint moving objects such as comets wrote "it is exhilarating to be accepted in a team of professionals as 'one of us.'" He also provided some guidelines for amateurs and professionals in such partnerships, concluding the professional section with: "The amateur's only reward is your approval of his/her results; it costs you nothing to include the amateur as a co-author on your paper, but, to the amateur, it has a value beyond your imagination."⁷¹

Ground rules

Many of the ground rules of the amateur-professional collaboration are the same as those for any human interaction: respect, generosity, and an attempt to understand the other's point of view. These points recurred throughout the Toronto meeting, in all of my interviews and personal correspondence, and in all of the literature on the subject. Sadly, professional bias has made it important to repeat these points over and over; however, some professionals have been highly successful in working with amateurs, and they set an example for others.

Respect and generosity notwithstanding, all amateur-professional collaborations do involve some kind of hierarchy, and many successful participants have distilled two basic rules from their experiences: 1) early contact between amateurs and professionals must be sensitive to that hierarchy and 2) amateurs should not compete with professionals on their own turf.

⁶⁸ Offutt, *Ibid.*; Boltwood, *Ibid.*; interviews for VSO partnership survey

⁶⁹ Walker, personal interview

⁷⁰ CBA group interview

⁷¹ Offutt, *Ibid.*

As Thomas Williams describes it, when William Olcott first contacted Pickering at HCO, Pickering was interested, but the two did not work closely until Olcott had demonstrated the value of “his” observers.⁷² In general, as one professional puts it, professionals have an “embarrassment of riches” in both highly trained Ph.D.'s and large aperture telescopes, so amateurs must somehow prove themselves in order to get the professional's attention.⁷³ Joe Patterson tells the story of how David Skillman attracted his attention: first, Skillman attended a presentation by Patterson, and asked well-posed questions about photometry, and second, Patterson realized that Skillman might provide something Patterson didn't have time for.⁷⁴ In general, cold contacts are tough, and things get easier once an amateur has broken in and can get “referrals.” One amateur currently in a successful amateur-professional partnership studying blazars described some disasters that occurred in his previous attempts at collaboration, when he was not sensitive to the fact that free data might not always be valued by professionals.⁷⁵ In many cases, professionals are actually suspicious of amateur data, and therefore the amateur must go overboard in checking results to avoid losing the professional's trust early on.

There are two reasons for not competing with professionals. At one level, many amateurs believe that the professional simply has greater knowledge and time to devote to research, and there is no point in competing. In direct collaborations, amateurs will typically defer to professionals as “the experts.” For example, notwithstanding the egalitarian tone of the CBA planning meeting that I attended, Patterson was given complete veto power over amateurs suggestions for new research directions such as gamma ray burst follow-up or polarization studies.

At another level, not competing is also a recognition of and submission to a power relationship. Professionals have taken exception to overly independent amateurs at several points in American history, and friendly professionals may not be able to protect amateurs from those who feel threatened. One of the earliest episodes, described by Marc Rothenberg and further elaborated by Thomas Williams, involved the founding of the AAVSO itself.⁷⁶ In a dark footnote to the standard origin story, the AAVSO at its formation represented the death knell of the Society for Practical Astronomy, an alternative amateur organization that promised to be more like the British BAA in encouraging a broad range of independent amateur research. In encouraging the formation of the AAVSO, professionals semi-deliberately discouraged independent amateur research.

From the beginning, the AAVSO institutionalized a division in which competition between amateurs and professionals was almost impossible. Observers sent in data but did not have access to their own or others' observations in the database, and so could not attempt their own research. In fact, one of my survey respondents recalls that before

⁷² Williams, “Getting Organized”

⁷³ Sadun, *Ibid.*

⁷⁴ CBA group interview

⁷⁵ Boltwood, *Ibid.*

⁷⁶ Rothenberg, “Organization and Control”; Williams, “Getting Organized”

email and VSNET made the rule unenforceable, the AAVSO used to discourage observers from sharing data, arguing that they would influence each other's results.

Again, however, as with the arrival of the ATM era and the CCD age, amateurs' opportunities may be shaped by technology: in this case the Internet. As the AAVSO increasingly makes its database available on the Web, amateurs will be newly empowered to attempt their own research projects. Meanwhile, amateur-professional partnership opportunities are expanding onto the Internet, robotic surveys notwithstanding. The American Astronomical Society has recently established a Working Group on Professional-Amateur Collaboration, chaired by Janet Mattei of the AAVSO, which plans a database of potential amateur participants that professionals can peruse, with information about interests, experience, and instrumentation.⁷⁷

Conclusion

With its characteristic subversiveness, the Internet widens trading zones and erases boundaries in science, enabling globally networked VSO partnerships and providing amateurs with many of the tools of professional science. These changes may destabilize the hierarchy of the VSO partnership and allow direct competition between amateurs and professionals, but ultimately it is on such unclarity of borders that the VSO community thrives. In the VSO exchange, poor fences make good traders. Cooperation and mutual respect are facilitated by the strong overlap in educational background, technical skills, and scientific values between amateur and professional VSOers, to the point that each group includes former members of the other. The formation of a trading community with its own language and literature has helped professionals to step beyond the bounds of mainstream science and helped amateurs to enter within it, enabling an exchange that is both between scientists and scientists, and also between scientists and the public.

While it would be easy to take a Marxian view of amateur observers who provide data to professionals without fully understanding or participating in the data analysis, their explicit idealism and passionate love of the night sky do not fit the profile of labor alienated from its product. Rather, for these amateurs, the exchange itself satisfies a more fundamental human need than does anything materially exchanged: to participate in the VSO exchange is to participate in science, and thereby to contribute to an enterprise that gives meaning and perspective to human life. What is shared becomes real; what is traded takes on meaning. The details of scientists' equations and graphs are not the point; the empowerment of contributing to a successful human effort to make sense of the world is. David Skillman, amateur co-founder of the CBA, seeks only the same as Tycho Brahe: "not to have lived in vain."⁷⁸ Deep within the trading zone between professional scientists and the public, advanced amateurs such as Skillman hold professionals to the contract of publicly funded astronomy: to share with the public our sense of wonder, discovery, and understanding, in exchange for the privilege that is our working lives.

⁷⁷ Beatty, "Working Group"

⁷⁸ CBA group interview

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Appendix: Survey of Variable Star Astronomers

Introduction

I conducted a survey of astronomers involved in the variable star partnership community during the summer of 1999, initially distributed on several variable star email lists run by amateur-professional partnership organizations (the AAVSO, the CBA, and VSNET), and later distributed as a paper survey at “Partners in Astronomy,” the 111th annual meeting of the ASP, co-organized with the AAVSO and the RASC and held in Toronto. Below I describe the survey sample, reproduce my self-introduction to the participants and the survey itself, and then summarize the survey results.

Survey Sample

I received 62 responses to the survey, 46 amateurs and 16 professionals. Eight of these I interviewed in person for the answers to the longer survey questions. The low fraction of professionals responding likely reflects their lower attendance at the Toronto meeting compared to amateurs. On the other hand, one professional respondent did not actually complete the survey, complaining that the survey was not appropriate for professionals; it is possible that others felt the same way. Interestingly, not a single member of the headquarters staff of the AAVSO chose to respond, although they were fully aware of my project and very supportive in providing resources. Perhaps their duties are so heavily administrative that they did not see themselves as the appropriate target population for the survey, but this is just speculation. The organizers of VSNET and the CBA did respond.

One semi-professional amateur respondent likewise did not actually complete the survey, complaining that it required too much time; however he wrote some comments I have used in the long answer section. Doubtless many other potential amateur respondents chose not to reply because of one simple fact about amateur VSOers: they tend to be skeptics and strong individualists, and many of them don't answer surveys as a matter of principle. This description applies even to many who did respond – they often did so only after meeting me and either deciding I was “okay” or finding themselves intrigued by my project.

Leaving out the 2 respondents who did not complete the survey, the base sample consists of 45 amateurs and 15 professionals, unfortunately well within the realm of small number statistics. Because the community is small, the results may still be somewhat representative, especially when they exceed the nominal “square root N” uncertainty. On the other hand, the sample is clearly biased toward the most active members of the VSO partnership, because they were more likely to attend the Toronto meeting.

EMAIL SELF-INTRODUCTION

Hello,

I am a graduate student in astrophysics and the history of science at Harvard. I am researching the nature of the amateur-professional partnership in variable star astronomy: what each side gets out of it, how it works, and how the training, values, and goals of the two communities compare.

I am looking for both professionals and amateurs willing to either fill out an easy & painless survey (below) or sit for a short interview at the Toronto ASP meeting. I will be happy to share the results with any interested contributors, as well as the administrators of several variable star groups (AAVSO, CBA, etc.), who have generously facilitated my project.

Please reply to skannappan@cfa.harvard.edu.

Many thanks,
Sheila Kannappan

Name : _____

VARIABLE STAR ASTRONOMERS QUESTIONNAIRE

- ___ 1. Age?
- ___ 2. Male or Female?
- ___ 3. Years of serious amateur astro (e.g. VSO, comet search,etc.)?
- ___ 4. Years involved in astro as a hobby (total years serious+casual)?
- ___ 5. Years employed as professional astronomer or in grad training?
- ___ 6. Currently professional or amateur? (P/A)
- ___ 7. Undergrad or higher degree in astronomy? (Y/N)
- ___ 8. Was astro a childhood-teenage interest? (Y/N)
- ___ 9. Childhood socioeconomic background? Code: U=urban,S=suburban,R=rural +
P=poor,M=middle class,W=wealthy e.g. "suburban middleclass"=SM
- ___ 10. Comfortable reading technical journals (PASP, JAAVSO, ApJ)? (Y/N)
- ___ 11. Use PEP or CCD instruments? (Y/N)
- ___ 12. Observe mostly alone? (Y/N)
- ___ 13. Prefer observing alone? (Y/N)
- ___ 14. Observe on majority of clear nights? (Y/N)

15. Please categorize the 12 items listed below according to:

- A = this is a big part of what I love about astronomy & why I do it
- B = this is an aspect that adds to my enjoyment but is not why I do it
- C = this is important or unavoidable, but I don't enjoy it much
- D = I don't do this because it doesn't appeal to me particularly
- E = I don't do this but wish I had the time/money/training/opportunity

- ___ telescope & instrument design/construction (including sky testing)
- ___ setting up for observations (advance planning, working at computer during the night to set up pointing & exposures, etc.)
- ___ visual observing with or without a telescope (including enjoying the night sky while a long CCD exposure is underway)
- ___ reducing & working with data *without* the goal of publication (analysis, artistic projects, etc.)
- ___ preparing & submitting observations to a database for use by other people's research programs
- ___ work on analysis, theory, and writeup for one's own research program
- ___ developing personal knowledge of astronomy (reading, classes,etc.)
- ___ social/information exchange with amateurs
- ___ social/information exchange with professionals/grad students
- ___ recruiting, teaching, advising, or mentoring beginning astronomers
- ___ popularization for the general public incl. writing, speaking, showing non-astronomer friends the night sky, intro classroom teaching
- ___ researching or learning about the history of astronomy

16. For the same items, please estimate the percentage of time you give each: (12 items -- please make them add to 100%)

- ___ telescope & instrument design/construction (including sky testing)
- ___ setting up for observations (advance planning, working at computer during the night to set up pointing & exposures, etc.)
- ___ visual observing with or without a telescope (including enjoying the night sky while a long CCD exposure is underway)
- ___ reducing & working with data *without* the goal of publication (analysis,artistic projects,etc.)
- ___ preparing & submitting observations to a database for use by others' research programs
- ___ work on analysis, theory, and writeup for one's own research program
- ___ developing personal knowledge of astronomy (reading, classes,etc.)
- ___ social/information exchange with amateurs

OVER→

Name : _____

- ____ social/information exchange with professionals/grad students
 - ____ recruiting, teaching, advising, or mentoring beginning astronomers
 - ____ popularization for the general public incl. writing, speaking, showing non-astronomer friends the night sky, intro classroom teaching
 - ____ researching or learning about the history of astronomy
- 100%

17. Please tell briefly how you got interested in astronomy, why you chose to go either the professional or the amateur route, and what people or organizations played a role along the way.

18. What form has your training as an astronomer taken: who were your teachers/role models, what skills have you learned (broadly), and what values and goals do you believe you share with your segment of the astronomical community?

19. Has your involvement in astronomy affected your philosophical worldview more broadly, e.g. about religion, the credibility of professional scientists & the scientific enterprise, or the validity of nonscientific approaches such as astrology or alternative medicine?

-----optional further questions-----

20. If you have an opinion, please speculate as to why there are so few women among amateur variable star observers, yet quite a number of women among professionals who study variable stars.

21. If you have an opinion, please describe your perception of the differences in motivations, skills, and values between amateurs and professionals, and indicate whether your view is based on direct collaboration or indirect impressions.

Survey Results

I. Broad Overview of Survey Sample

1. Age

Amateurs		Professionals	
Average	49	Average	50
Median	51	Median	52
Range	16-68	Range	21-92

2. Sex

Amateurs		Professionals	
M	43	M	11
F	2	F	4

Note: One of the two female amateurs is a high school student who intends to become a professional.

3. Years of serious amateur astronomy

Amateurs		Professionals	
Average	18	Average	7
Median	19	Median	0
Range	1-43	Range	0-31
		Blank	1

4. Years of amateur astronomy (serious + casual)

Amateurs		Professionals	
Average	30	Average	16
Median	30	Median	17
Range	8-50	Range	0-38
		Blank	1

5. Years of professional astronomy

Amateurs		Professionals	
Average	0.5	Average	27
Median	0	Median	24
Range	0-7	Range	1-70

6. Currently professional or amateur

Amateurs		Professionals	
Total	45	Total	15
Semi-pro	9	Also Am	10
		ATP	7

Notes:

- 1) "Semi-pro" = nonzero years spent in graduate level astronomy training or in astronomy-related employment
- 2) "Also Am" = nonzero years spent doing amateur astronomy
- 3) "ATP" = amateur turned professional (comparison of years spent as a professional and an amateur indicates that these individuals were first amateurs and remain/remained amateurs throughout most of

their professional careers)

4) Reclassifications: The original survey responses included 3 marked as "amateur/professional," which I recategorized as follows:

1 -> Professional: This individual was completely professionally trained and performing independent research, but he thought of himself as an amateur first because he wanted to emphasize his love and enthusiasm for the subject. Although I reclassified him as a professional, his amateur experience is reflected in the results of questions 3 and 4. He is one of the ATP's.

2 -> Amateur: These two individuals teach astronomy at the introductory level, but do not perform independent research. They do not have advanced degrees. Because similar respondents had classified themselves as "amateur," I reclassified these two as "amateur" as well. However I also marked their responses as "semi-professional," along with the seven others like them, and I looked for any differences between the rest of the amateurs and the semi-professionals. The only significant differences were that, essentially by definition, the semi-professionals represent a large fraction of those with undergrad or higher degrees in astronomy, and they also all use PEP or CCD equipment.

7. Undergrad or higher degree in astronomy

<u>Amateurs</u>		<u>Professionals</u>	
Yes	5	Yes	14
No	38	No	1
Blank	2	Blank	0

Note: The one professional without a degree in astronomy is a graduate student.

8. Was astronomy a childhood-teenage interest

<u>Amateurs</u>		<u>Professionals</u>	
Yes	40	Yes	12
No	5	No	3
Blank	0	Blank	0

9. Childhood socioeconomic background

<u>Amateurs</u>		<u>Professionals</u>	
Urban	5	Urban	6
Suburban/Rural	38	Suburban/Rural	7
Blank/"Varied"	2	Blank	1
Poor	9	Poor	2
Middle Class	30	Middle Class	13
Wealthy	2	Wealthy	0
Blank/"Varied"	4	Blank	0

10. Comfortable reading technical journals

<u>Amateurs</u>		<u>Professionals</u>	
Yes	43	Yes	15
No	2	No	0
Blank	0	Blank	0

11. Use PEP or CCD instruments

<u>Amateurs</u>		<u>Professionals</u>	
Yes	29	Yes	12
No	16	No	2
Blank	0	Blank	1

12. Observe mostly alone

<u>Amateurs</u>		<u>Professionals</u>	
Yes	39	Yes	11
No	5	No	1
Blank	1	Blank	3

13. Prefer observing alone

<u>Amateurs</u>		<u>Professionals</u>	
Yes	30	Yes	6
No	13	No	5
Blank	2	Blank	4

14. Observe on majority of clear nights

<u>Amateurs</u>		<u>Professionals</u>	
Yes	27	Yes	4
No	17	No	7
Blank	1	Blank	4

II. Breakdown of Activities – Time Spent & Level of Enjoyment for Each (Questions 15 & 16)

Survey respondents were asked to rate each of 12 activities according to the following scale.

- A = this is a big part of what I love about astronomy and why I do it
- B = this is an aspect that adds to my enjoyment but is not why I do it
- C = this is important or unavoidable, but I don't enjoy it much
- D = I don't do this because it doesn't appeal to me particularly
- E = I don't do this but wish I had the time/money/training/opportunity

Respondents were then asked the percentage of time spent on each activity. Five of the 60 respondents were unable to make the percentages add to 100, however all the totals came between 90 and 110. At the end of the appendix are histograms showing the distribution of percentages for each group, with shading indicating those who say they enjoy the activity (A or B), do not enjoy it (C or D), or wish they could do it (E).

1. Telescope & Instrument Design/Construction/Testing

<u>Amateurs</u>	<u>Professionals</u>
A: 8	A: 2
B: 13	B: 1
C: 3	C: 2
D: 18	D: 8
E: 2	E: 2
Blank: 1	Blank: 0

2. Setting up for Observations (advance planning, computer control during the night)

<u>Amateurs</u>	<u>Professionals</u>
A: 6	A: 2
B: 28	B: 6
C: 9	C: 3
D: 1	D: 2
E: 0	E: 0
Blank: 1	Blank: 2

3. Visual Observing (including casual stargazing during a long CCD exposure)

<u>Amateurs</u>	<u>Professionals</u>
A: 26	A: 3
B: 14	B: 7
C: 1	C: 0
D: 3	D: 2
E: 0	E: 1
Blank: 1	Blank: 2

4. Data Reduction & Analysis Not for Publication

<u>Amateurs</u>	<u>Professionals</u>
A: 17	A: 5
B: 12	B: 2
C: 4	C: 2
D: 7	D: 5
E: 3	E: 0
Blank: 2	Blank: 1

5. Preparing & Submitting Observations to a Database for Others' Research

<u>Amateurs</u>	<u>Professionals</u>
A: 20	A: 3
B: 13	B: 5
C: 7	C: 2
D: 4	D: 4
E: 0	E: 0
Blank: 1	Blank: 1

6. Analysis, Theory, and Write-up for One's Own Research

<u>Amateurs</u>	<u>Professionals</u>
A: 12	A: 13
B: 10	B: 1
C: 1	C: 1
D: 7	D: 0
E: 14	E: 0
Blank: 1	Blank: 0

7. Developing Personal Knowledge of Astronomy (reading, classes)

<u>Amateurs</u>	<u>Professionals</u>
A: 29	A: 11
B: 13	B: 4
C: 0	C: 0
D: 0	D: 0
E: 2	E: 0
Blank: 1	Blank: 0

8. Social/Information Exchange with Amateurs

<u>Amateurs</u>	<u>Professionals</u>
A: 11	A: 4
B: 30	B: 8
C: 1	C: 2
D: 1	D: 0
E: 0	E: 1
Blank: 2	Blank: 0

9. Social/Information Exchange with Professionals

<u>Amateurs</u>	<u>Professionals</u>
A: 11	A: 6
B: 25	B: 7
C: 1	C: 2
D: 1	D: 0
E: 4	E: 0
Blank: 3	Blank: 0

10. Teaching, Mentoring, or Recruiting Beginning Astronomers

<u>Amateurs</u>	<u>Professionals</u>
A: 9	A: 4
B: 17	B: 6
C: 5	C: 0
D: 5	D: 2
E: 7	E: 2
Blank: 2	Blank: 1

11. Popularization for the General Public

<u>Amateurs</u>	<u>Professionals</u>
A: 13	A: 4
B: 18	B: 10
C: 2	C: 1
D: 5	D: 0
E: 5	E: 0
Blank: 2	Blank: 0

12. Researching or Studying the History of Astronomy

<u>Amateurs</u>	<u>Professionals</u>
A: 9	A: 4
B: 12	B: 4
C: 4	C: 1
D: 14	D: 4
E: 4	E: 2
Blank: 2	Blank: 0

III. Original Interest & Its Development Along Amateur or Professional Lines (Question 17)

Approximately 3/4 of the survey sample were inspired to pursue astronomy by the beauty or fascination of the sky itself, with no significant difference between amateurs and professionals. Out of thirty-nine amateur responses to this question, twenty-three mention unaided viewing of the night sky – often referring to its beauty, to particular events such as comets, eclipses, or Sputnik, or to learning the constellations – while an additional six mention technologically aided viewing (telescope sessions, NASA photos, or planetarium shows). Out of fifteen professional responses, eight mention unaided viewing and an additional three mention technologically aided viewing. (In both groups, some of those who mention unaided viewing also mention aided viewing.)

Also in equal proportion, about a third each of amateurs and professionals mention the role of a parent, teacher, or other role model in awakening or developing interest, while another (possibly overlapping) third mention organizations, clubs, or camps. The same fraction of professionals identify books, magazines, or TV or radio shows as a source of inspiration, while only 20% of amateurs cite such media; however the difference between the two groups is only marginally statistically significant. Mentions of school classes/general interest in science follow a similar statistical distribution.

One interesting difference between amateur and professional VS astronomers is that a sizable number of amateurs (seven out of thirty-nine respondents) described their initial exposure to astronomy as an accident. For example, several spent long hours under the night sky, e.g. serving military watches, and decided to learn about it. Others found their interest in astronomy rapidly accelerated by the unexpected assignment to teach an astronomy course. No professional described his or her interest in these terms. As might

be expected, these “accidental astronomers” usually got into astronomy late in life, so choosing between amateur and professional astronomy was never an issue for them, and they typically did not comment on this part of the question.

Twenty-three amateurs did discuss why they had chosen the amateur vs. professional path. Eleven of these indicated that they would have become professional astronomers had they not been discouraged by poor job prospects, financial pressures to leave school and/or obtain a higher salary, or the lack of nearby schools offering a degree program. Two of the eleven, plus another two outside that group, described themselves as not smart enough or not good enough at math. Thus over 1/2 of the respondents did not so much choose to become amateurs as give up the dream of becoming professionals, due to factors they considered out of their control. An additional group of four described a mix of reasons for their choices including some matters of preference (“professionals are too specialized”, “amateurs get more telescope time”), but also highlighting factors out of their control such as job prospects. Another three mentioned no obstacles, simply stating that they preferred the amateur lifestyle. Two more cited higher priority interests than astronomy (ROTC, history). Finally, one actually plans to become a professional, as she is presently a high school student. In total, approximately 3/4 of the twenty-three amateurs who commented on career choices seriously considered becoming a professional astronomer.

In contrast, only two professionals commented on their career choices. One stated that becoming an amateur never occurred to her. The other simply observed that job prospects for astronomers were good at the time he was entering the field, in the post-Sputnik era.

IV. Training & Socialization (Question 18)

Nearly 2/3 of the amateur respondents to this question (twenty-four out of thirty-eight) described themselves as self-taught. In contrast, less than 1/4 of professionals (three out of thirteen) described themselves in those terms, all three of whom had spent some time as amateurs. On the other hand, 100% of professionals mentioned formal classroom training, whereas only about 30% of amateurs mentioned classes. One professional noted that he did not have a Ph.D. degree, which was unusual.

Respondents described a variety of experiences that involve learning through personal interaction: mentoring experiences, learning from role models and/or teachers, being trained in a collaboration, or being involved in a club or other astronomy organization. About 85% of professionals cited interactive experiences, whereas only about 45% of amateurs mentioned them. This result should not be taken purely at face value: for example, one amateur who did not mention personalized training in response to this question, nonetheless in separate correspondence described having received considerable assistance from professional astronomers in getting started in research. Broadly speaking, however, this result is consistent with the prevalence of self-taught individuals among amateurs.

Over 1/2 of respondents did not comment on what they had learned in their training. Roughly 40% of the remainder of both amateurs and professionals described having learned ideals of scientific carefulness, integrity, accuracy, and perfection of results. Comments on specific skills learned in training were rare; a few amateurs did mention such things as working with equipment, finding their way around the sky, and making variable brightness estimates, while a couple of professionals mentioned specific academic subjects. Other respondents described more global values and goals consistent with a scientific worldview or love of astronomy. Because these global values and goals were mentioned in response to several questions – this question, the next question, and the last question regarding the differences between amateurs and professionals – I have pooled the responses under section V below.

V. Broader Worldview (Question 19, also Questions 18 & 21)

Establishing the base sample for comparisons on this topic is difficult, because respondents commented on worldview, values, and goals in several places. For question 19 specifically, there were 36 amateur respondents and 14 professional respondents; however I also use answers from questions 18 and 21 below as appropriate.

One clear difference between amateurs and professionals centers on the degree to which they make their commitment to the advancement of science explicit. Over 1/2 of amateur respondents referred to this commitment directly – most commonly literally using the word “contribution.” Others emphasized helping professionals via the amateur-professional collaboration, while a partially overlapping minority used even more idealistic language: increasing human knowledge, making discoveries, or searching for truth. In contrast, only two professionals, both former amateurs, described their goals in such idealistic terms. Another two mentioned values of collaboration or publishing careful results, but did not explicitly link these values to the advancement of science. For both amateur and professional respondents, only a small fraction – about 15% of each – emphasized public outreach or teaching.

A skeptical outlook on the world appears to be common among both the professionals and the amateurs who responded. Over 1/2 of professionals and over 1/3 of amateurs described a skeptical approach to the world, stressing empirical proof and critical thinking. The difference between the two groups is only marginally statistically significant given the small professional sample. Very roughly half again of the skeptics also mentioned a skeptical/realistic assessment of the fallibility of professionals and/or current scientific knowledge. No one defended astrology. A few in each group advocated keeping an open mind with respect to alternative medicine.

Notwithstanding the less idealistic and perhaps more skeptical language of the professionals, both groups are equally likely to view the universe in terms of spirituality, wonder, or a sense of cosmic perspective. About 1/3 of both amateur and professional respondents spoke in terms of delight, awe, poetry, a sense of cosmic order, or a quasi-

religious response to the sky or the universe. Another approximately 15% of each group spoke of how astronomy strengthened their traditional religious beliefs, for example citing the biblical Psalm: “The heavens declare the glory of God...” Finally, about 1/3 of both amateurs and professionals (partially overlapping with the previous groups) referred to the sense of perspective that studying the universe gave them, sometimes contrasting that with the pettiness or transience of human existence.

VI. Women in Variable Star Astronomy (Question 20)

Twelve professionals and twenty-nine amateurs responded. Partly due to the poor wording of the question, respondents focused sometimes on the shortage of female amateur VSOers, sometimes on the relative abundance of female professionals in variable star work, and sometimes on the more general shortage of females in either amateur or professional astronomy at large. The majority of respondents were male, and very few mentioned having spoken with female colleagues about the issues or having seen statistics. Given the speculative nature of the question and the wide range of answers, a statistical breakdown would be largely pointless. However, a simple list of some of the explanations put forward may be of interest. Stars represent “votes” from the handful of women responding. Items are in no particular order.

1. More females have been getting into amateur astronomy recently, but they tend to be young, whereas VSOers tend to be older, possibly due to the financial demands of the hobby.
2. Women are intimidated by the predominance of males in clubs, and therefore don't join.
3. Lovesick males in clubs pester and annoy women amateurs, so they quit.
- ***4. Women have less free time, because they more often are balancing job plus family responsibilities, so hobbies are difficult to fit in.
5. Obnoxious, macho, or sexist males in clubs drive women away.
6. Professional women in variable star astronomy represent the modern descendants of the tradition established at HCO under Pickering in the 19th century.
7. Good women are rare.
8. Society's stereotypes guide women away from astronomy.
9. Women's eyes are biologically less sensitive to small differences in brightness of light.
10. Women astronomers are more likely to become professionals than amateurs because they prefer safety/practicality to risk-taking/dreaming.
- *11. Observing alone at night is unsafe or perceived to be unsafe for women.
12. Women do not have good role models due to the absence and/or historical invisibility of older women astronomers.
13. Women should not be forced to do something they don't want to do.
14. Some men actively discriminate against women or ostracize them.
15. There is only a small pool of interested women to draw from.
16. Women like tasks such as classification, hence prefer variable star astronomy as a subfield within astronomy.
17. The general popular fear of science affects women more.

18. Women don't usually have hobbies.
- *19. VSOing is antisocial and/or obsessive, which women are not.
20. Corollary of 19: women prefer star parties.
21. Astronomy should be popularized in women's magazines.
22. The observed tendencies are an artifact of small number statistics.
- *23. Variable star work at the professional level is relatively uncompetitive/low pressure and so attracts women.
24. The necessity of lifting heavy telescope equipment makes amateur astronomy difficult for women.
- *25. Women professionals feel a connection with or have been mentored by the leadership of the AAVSO, which has traditionally been largely female.
26. Women prefer mathematics to working with telescope equipment.

VII. Comparing Amateurs & Professionals (Question 21)

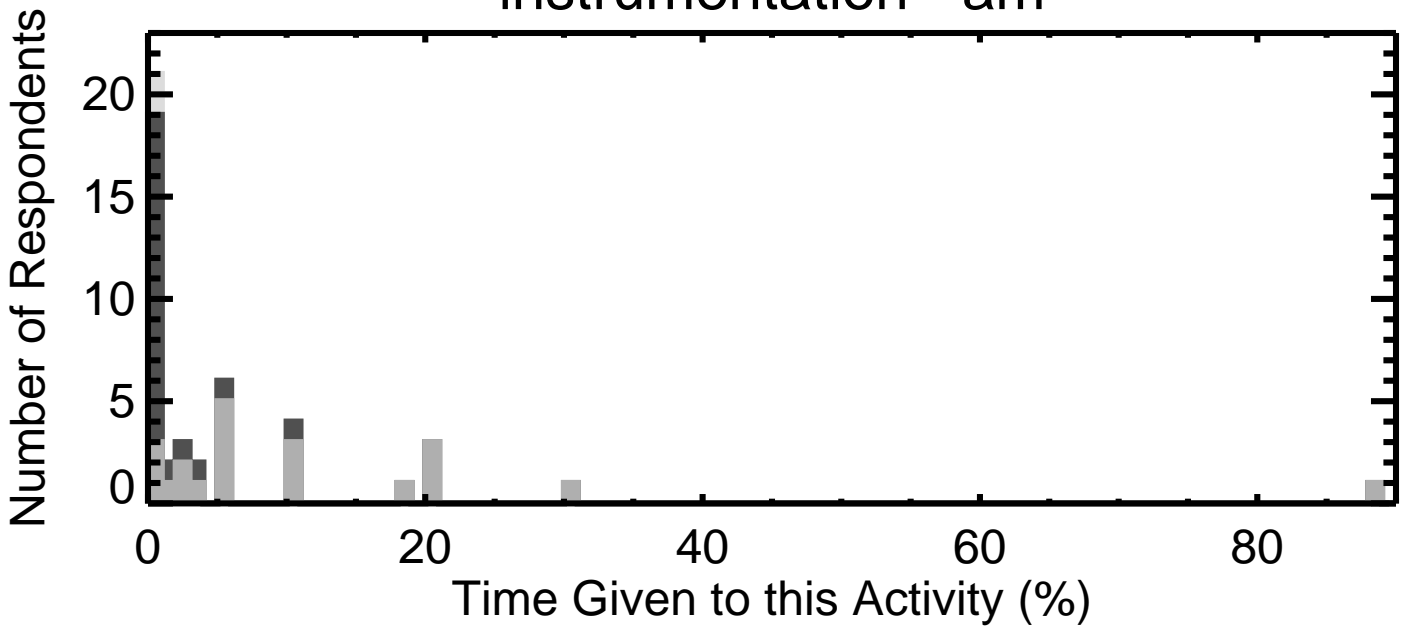
Only 21 amateurs and 6 professionals answered this question. Overwhelmingly, both amateur and professional respondents stressed the high level of skills among amateurs, often also counseling against professional snobbery. Roughly half of both groups described the equivalence or complementarity of the skills of amateurs and professionals. Only five respondents suggested that amateurs' skills were in any sense "less than" professionals', with a couple specifically mentioning math or technical skills, but three of these (including the one professional of the five) cautioned that amateurs know much more than one might think. To balance these out, three amateurs commented that some amateurs were better than professionals or had a broader range of skills.

Amateurs and professionals agreed in characterizing how the two groups differ in their primary activities and work preferences. The differences are most commonly characterized in terms of the opposition between on the one hand *love of the sky, observing, data, and process* and on the other hand *drive for understanding, theory, analysis, and results*. These comments support the conclusions found in section II.

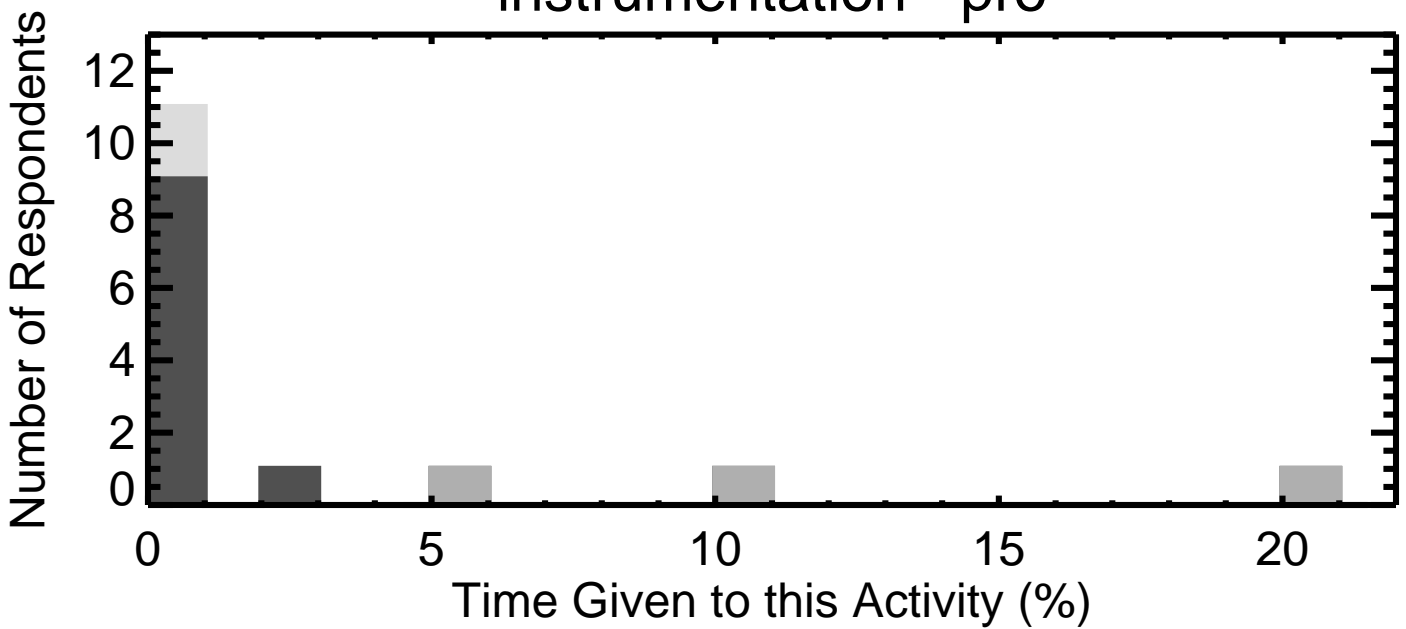
Both groups perceived professionals as having less honorable motivations than amateurs. About 1/3 of all respondents explicitly stated that amateurs "do it for love," but only one person suggested that some professionals might also do it for love. No one criticized the motivations of amateur VSOers, but roughly 1/2 of the amateurs as well as two of the professionals described professionals (or at least some of them) as motivated by prestige, money/job security, or a "publish or perish" mentality. Only one amateur and one professional pointed to the positive value of publication in spreading knowledge. Three amateurs noted that professionals tend to lose their sense of wonder, and conversely one professional described the enthusiasm of amateurs as one of the benefits of participating in the VSO collaboration: "It reminds me of why I got interested in astronomy." On a related note, six of the amateurs pointed to the flexibility and voluntary nature of their work, often contrasting it with the professional's lack of choice in doing his or her job.

- enjoy
- don't enjoy
- wish had time/opportunity

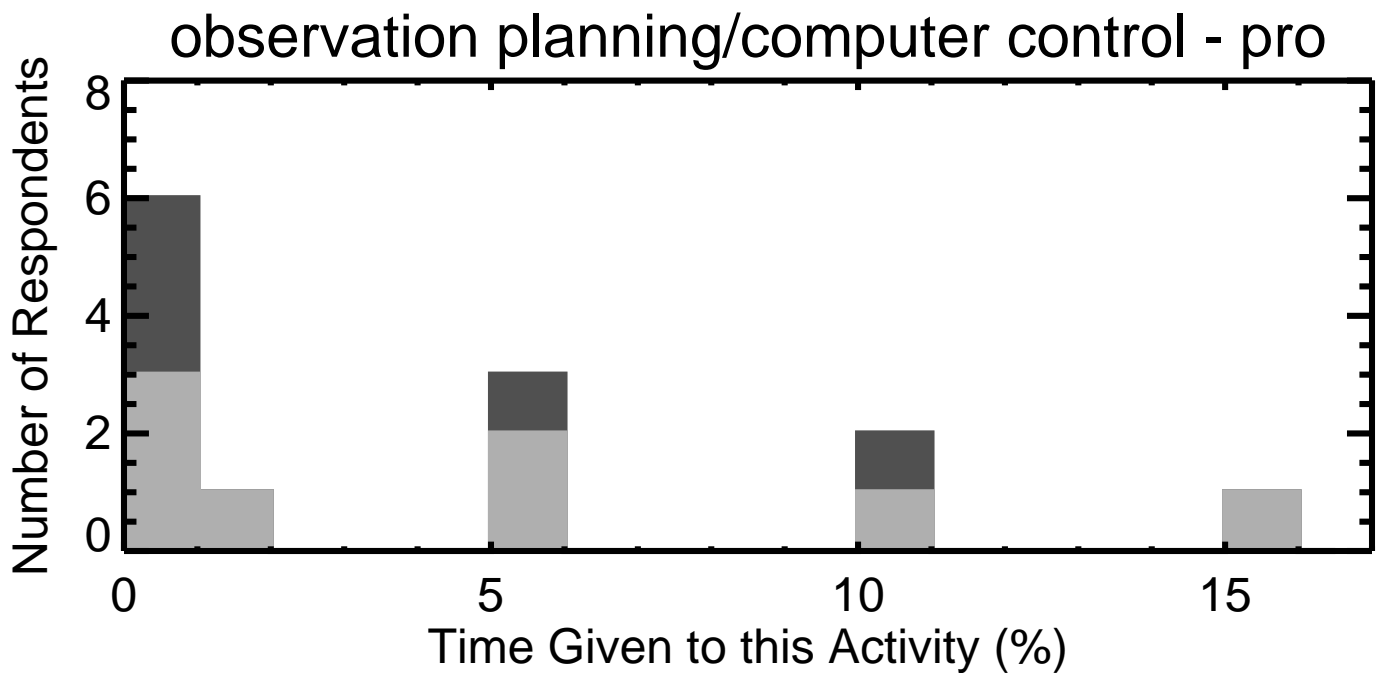
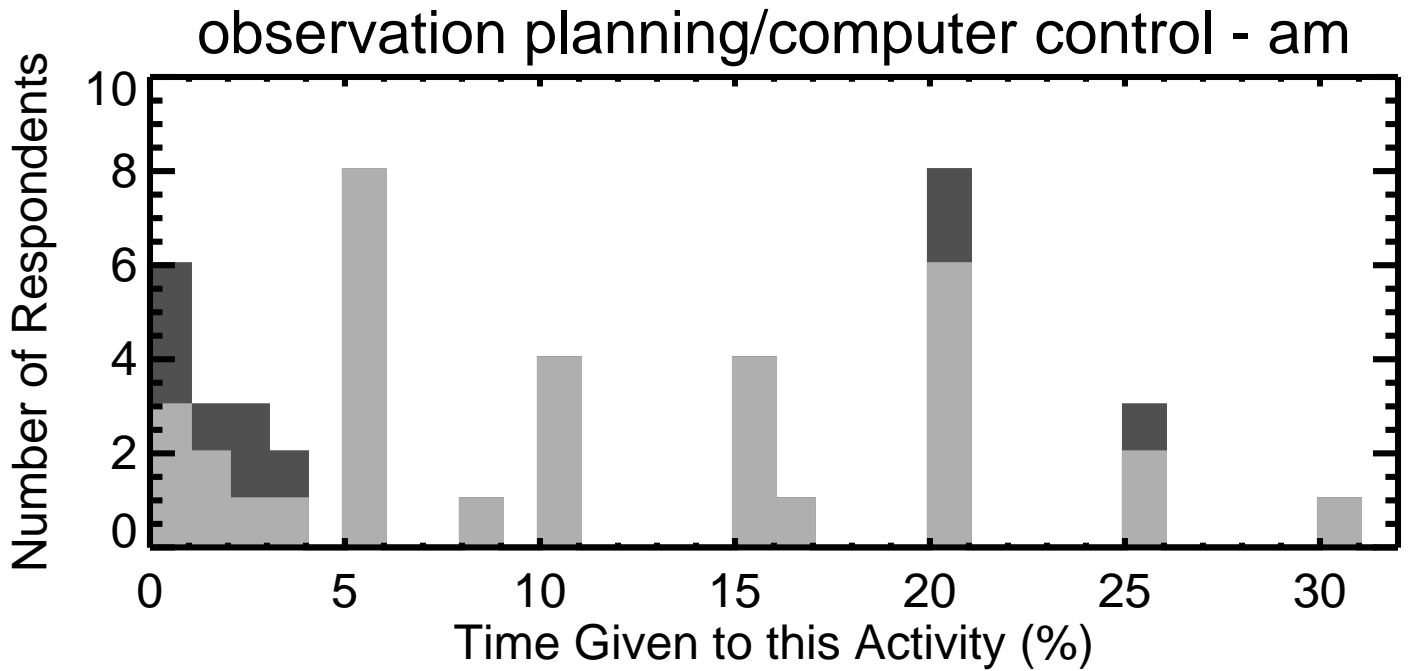
instrumentation - am



instrumentation - pro

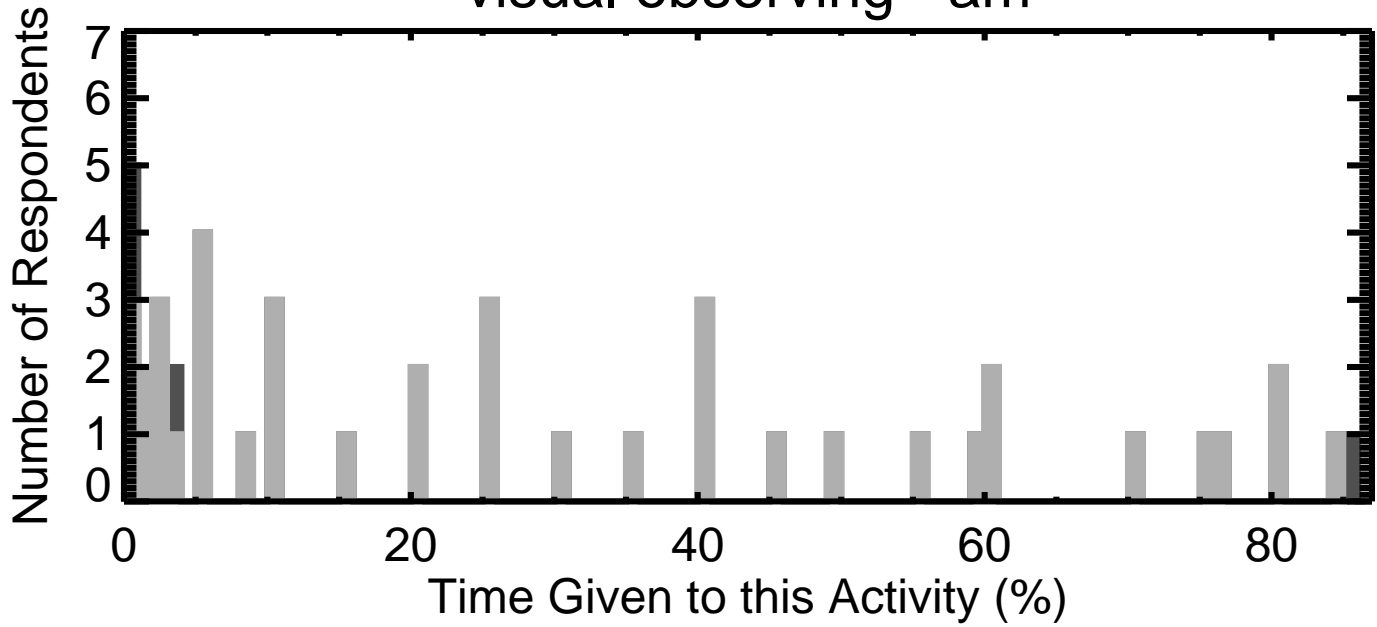


- enjoy
- don't enjoy
- wish had time/opportunity

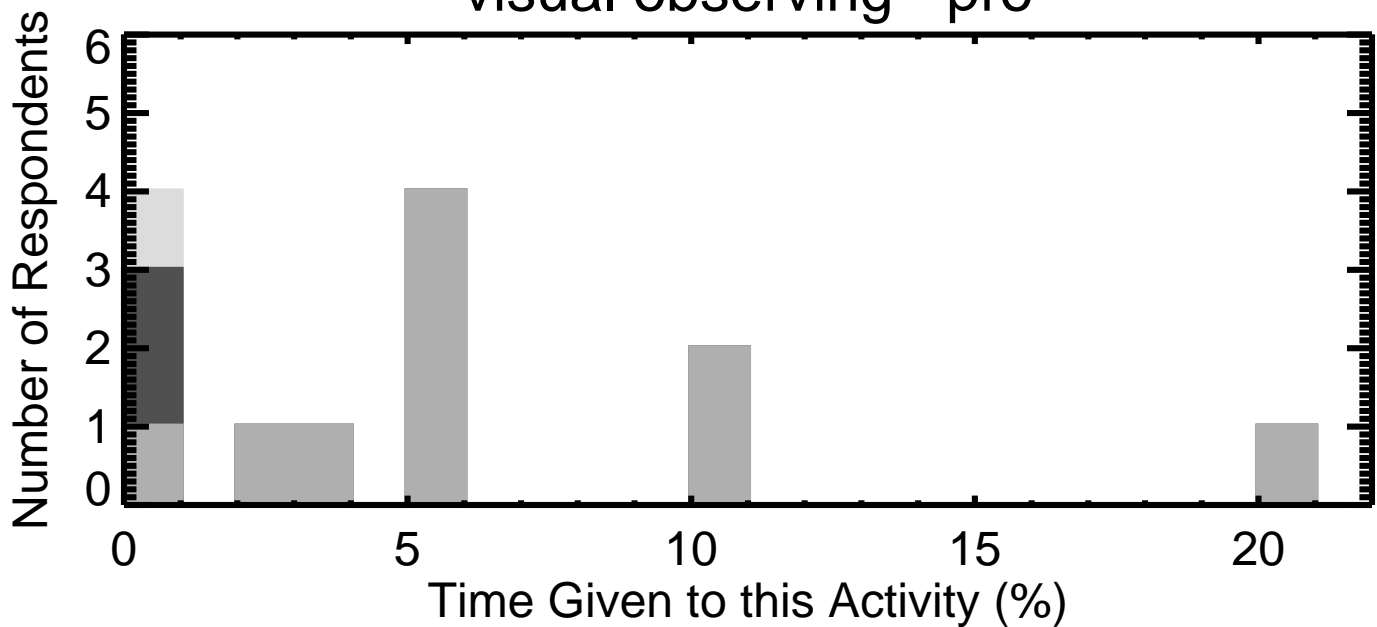


- enjoy
- don't enjoy
- wish had time/opportunity

visual observing - am

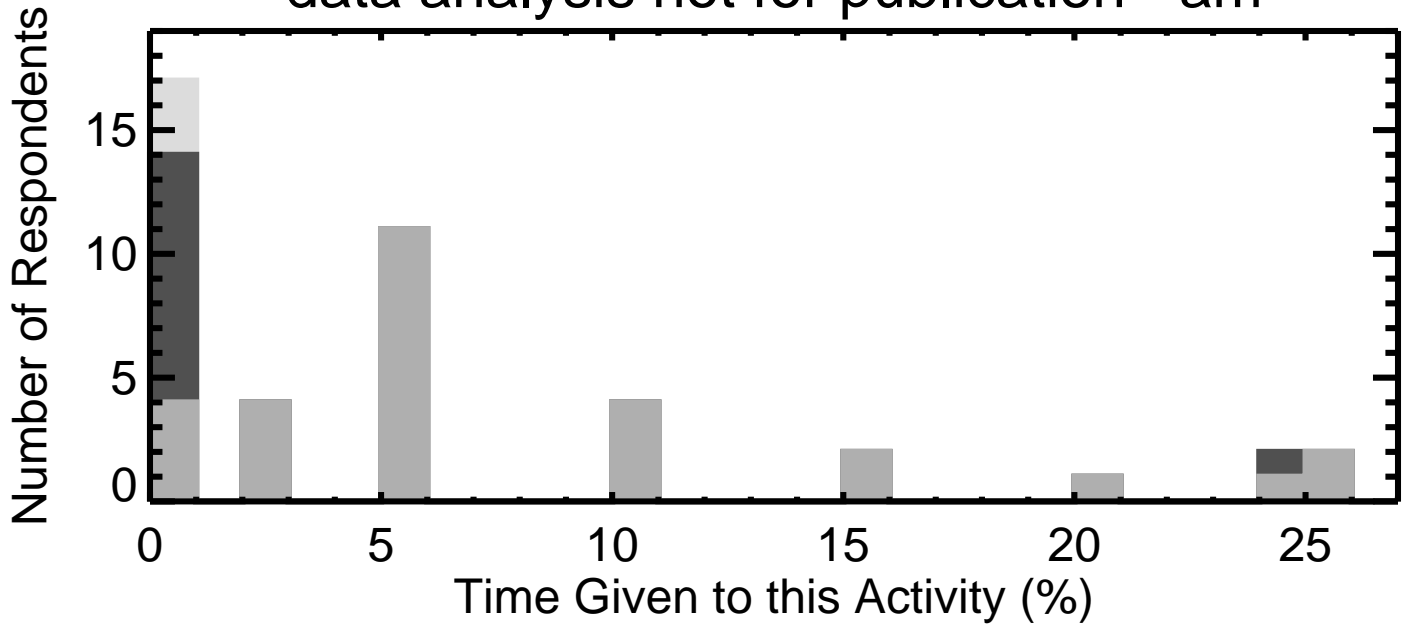


visual observing - pro

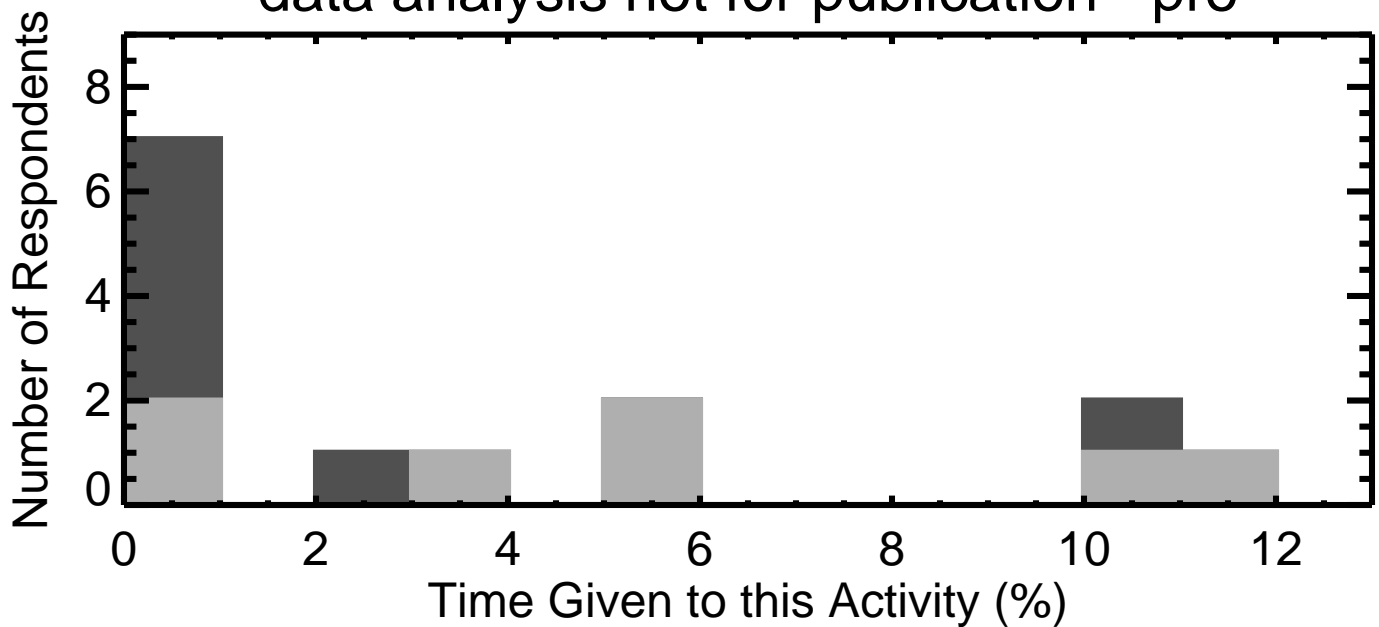


- enjoy
- don't enjoy
- wish had time/opportunity

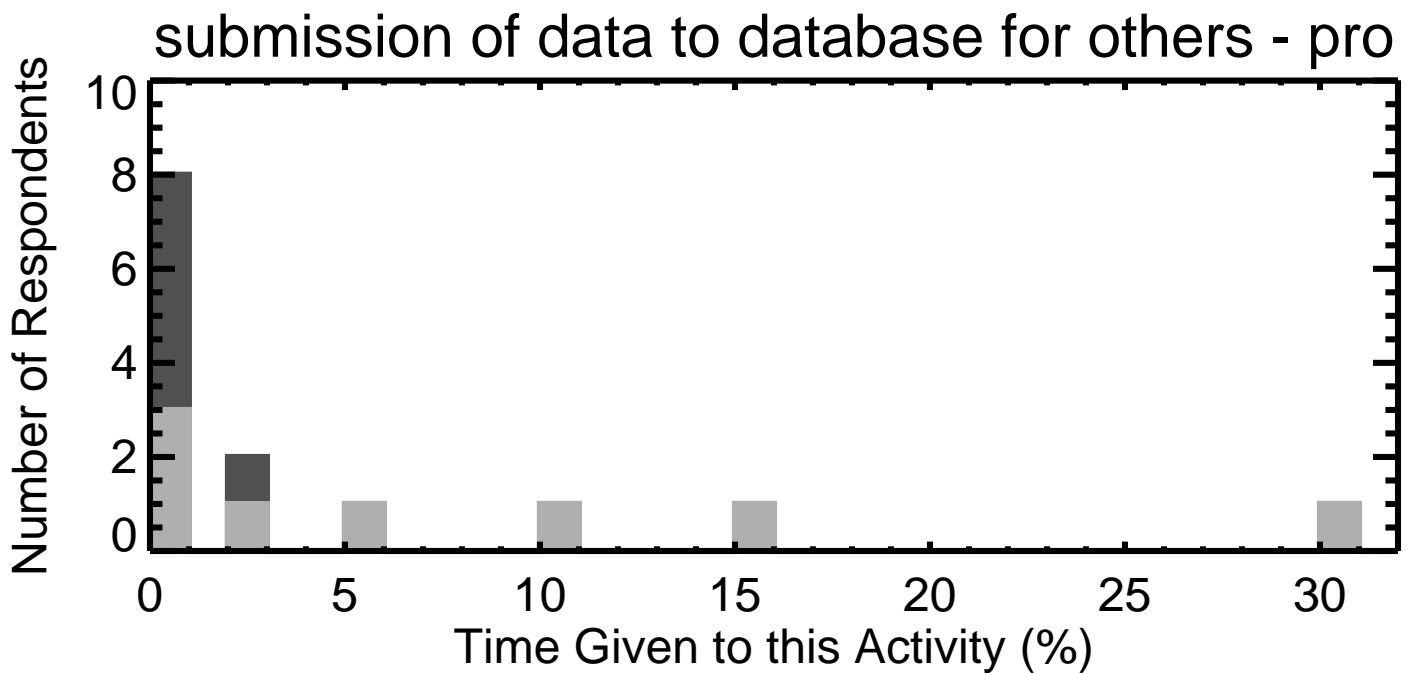
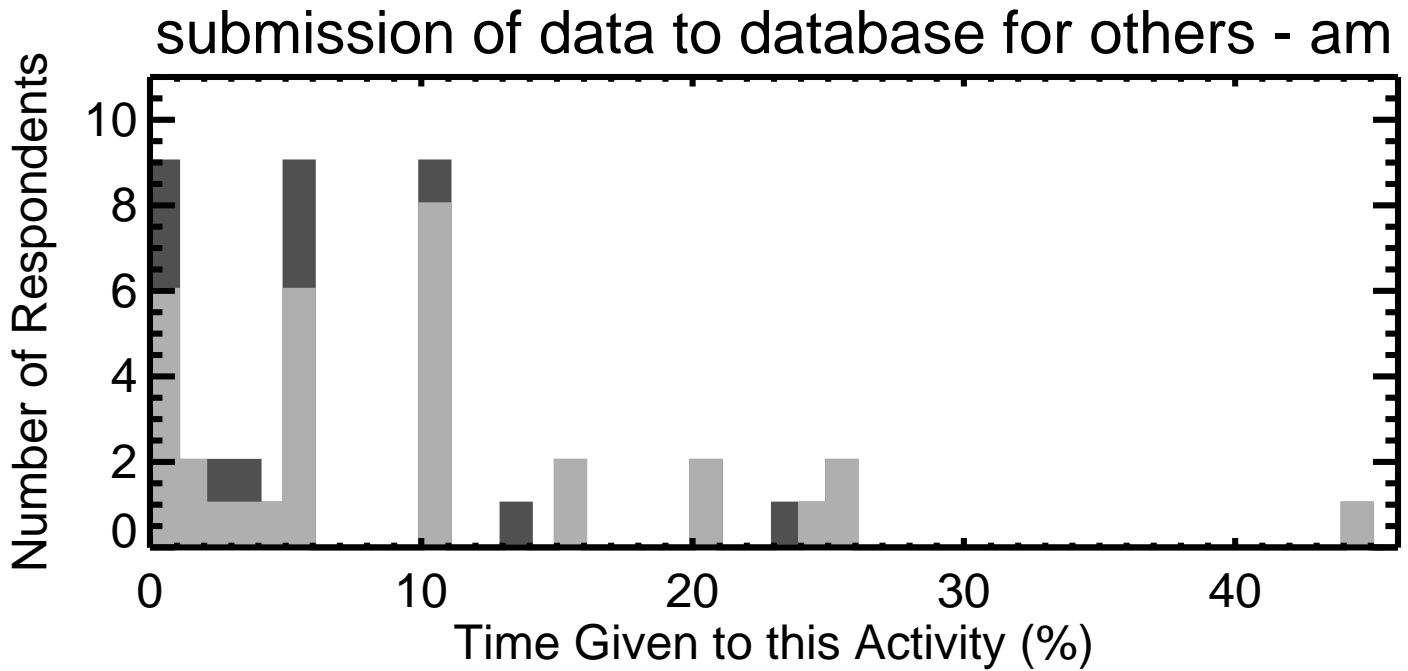
data analysis not for publication - am



data analysis not for publication - pro

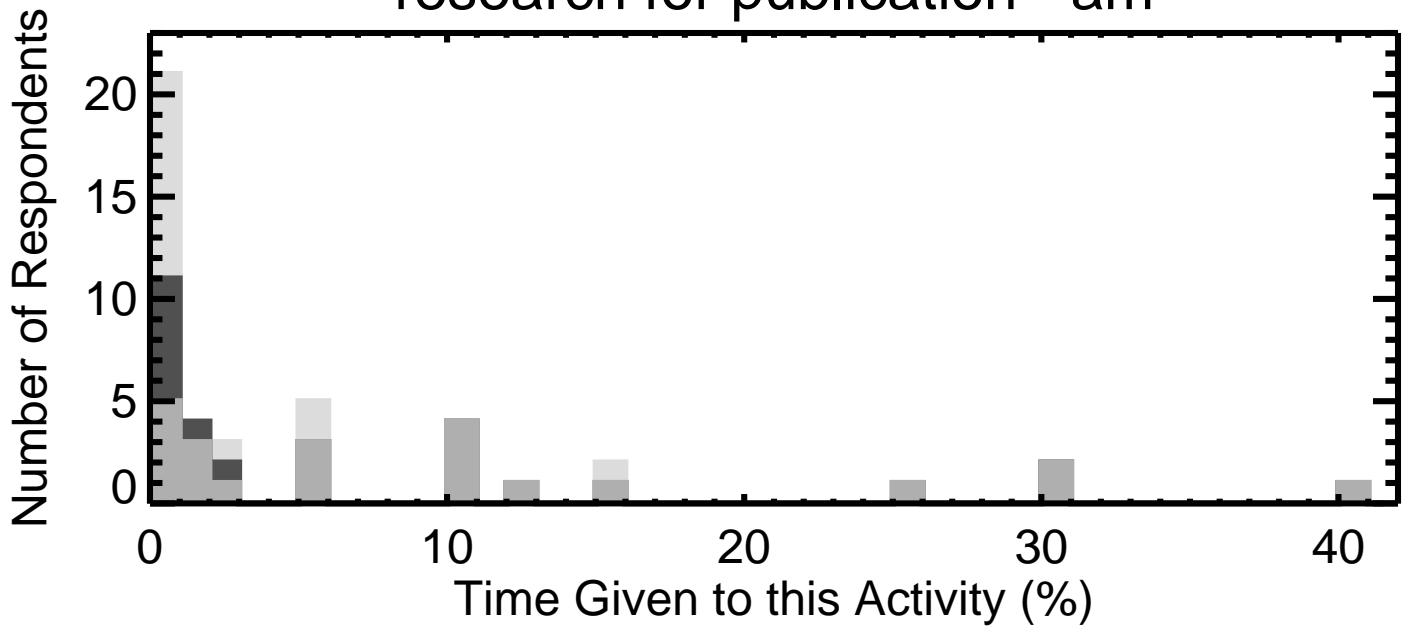


- enjoy
- don't enjoy
- wish had time/opportunity

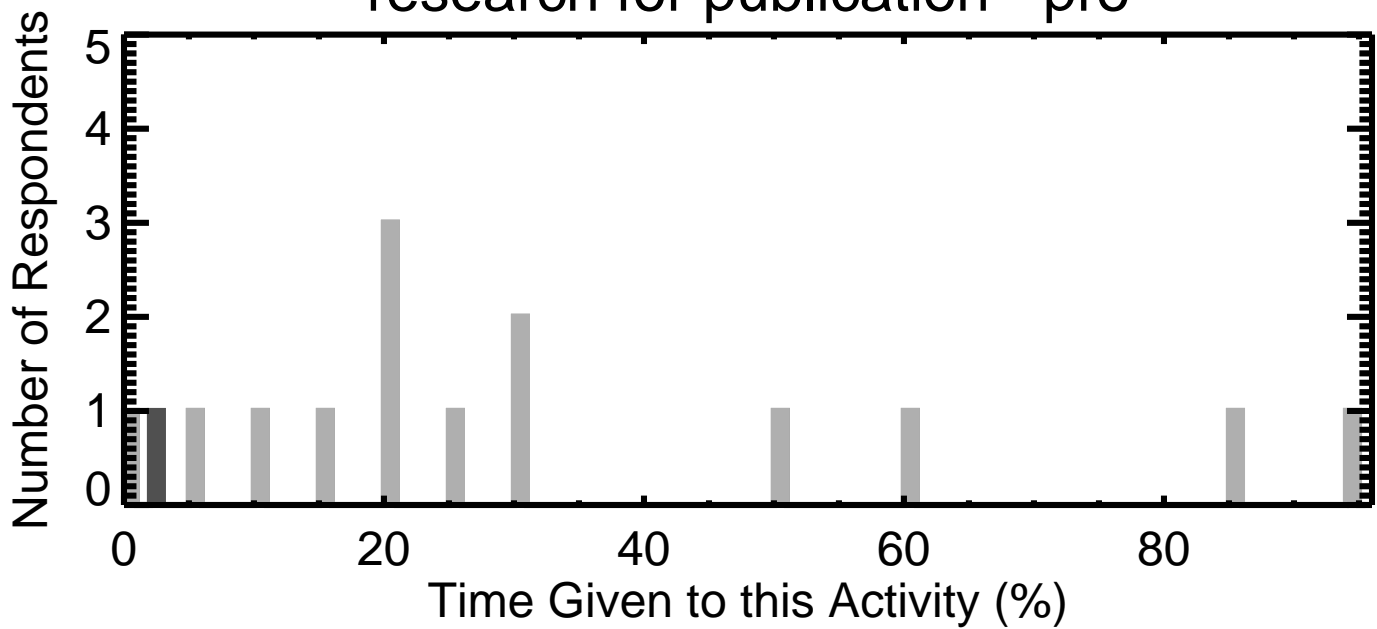


- enjoy
- don't enjoy
- wish had time/opportunity

research for publication - am

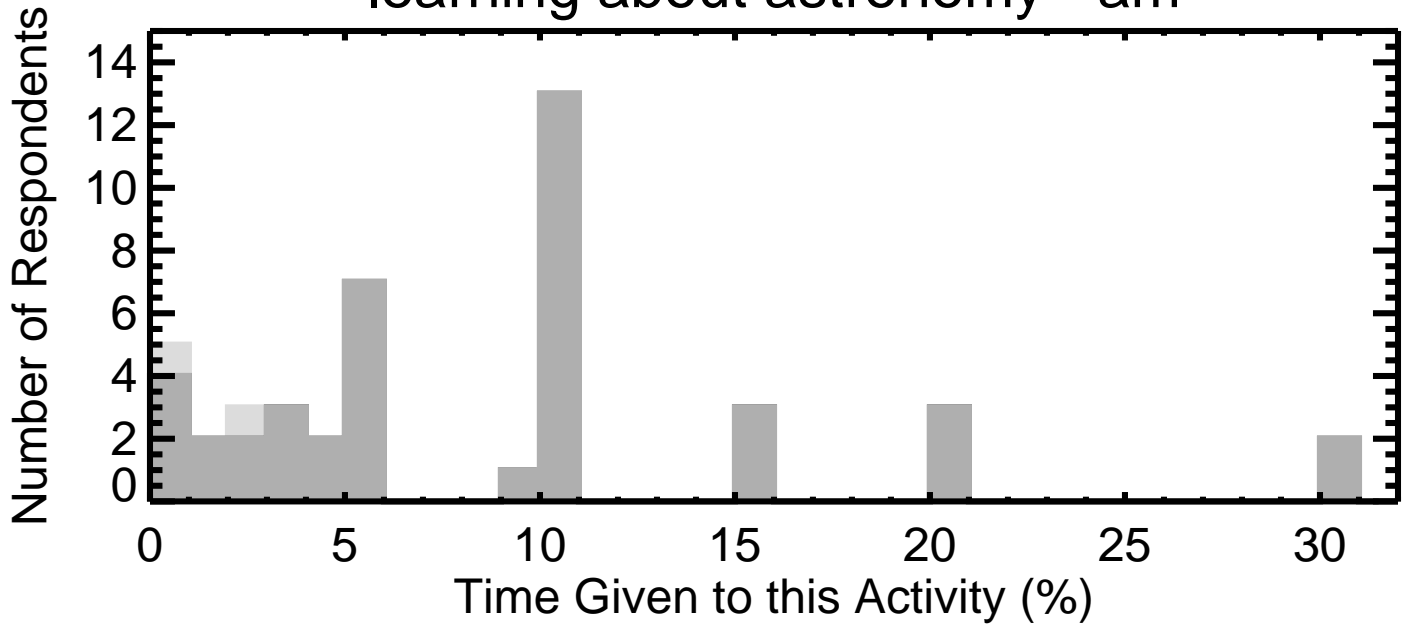


research for publication - pro

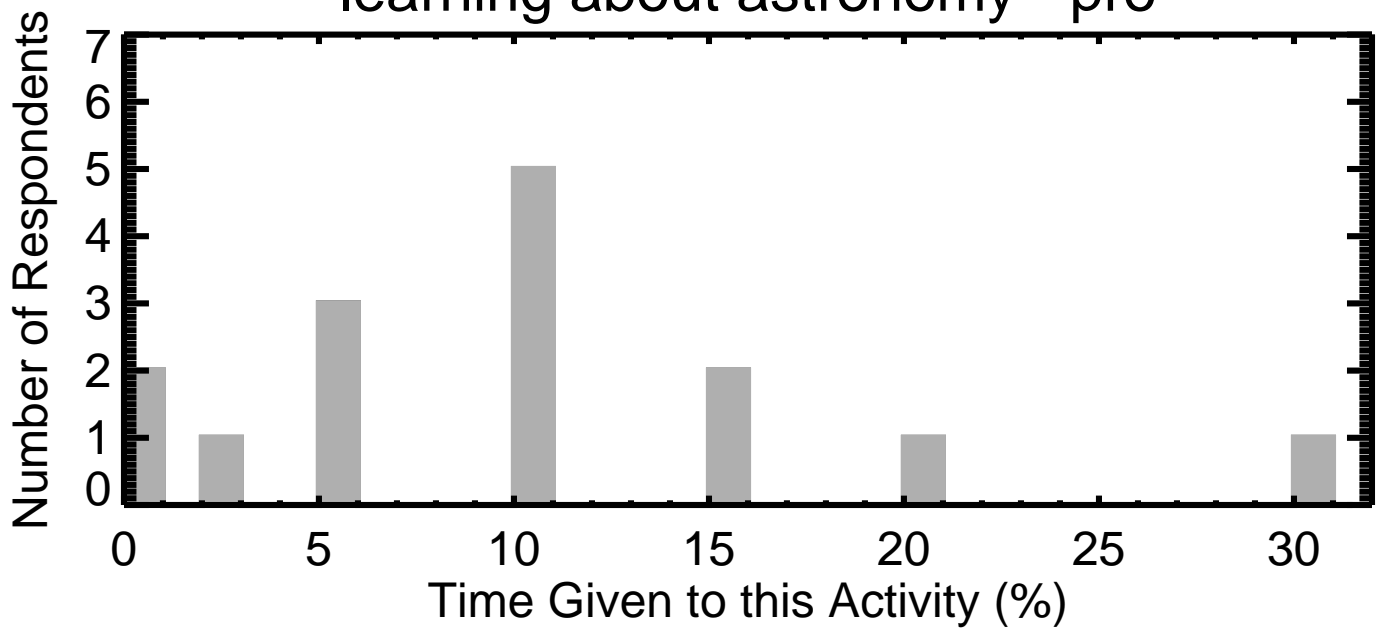


- enjoy
- don't enjoy
- wish had time/opportunity

learning about astronomy - am

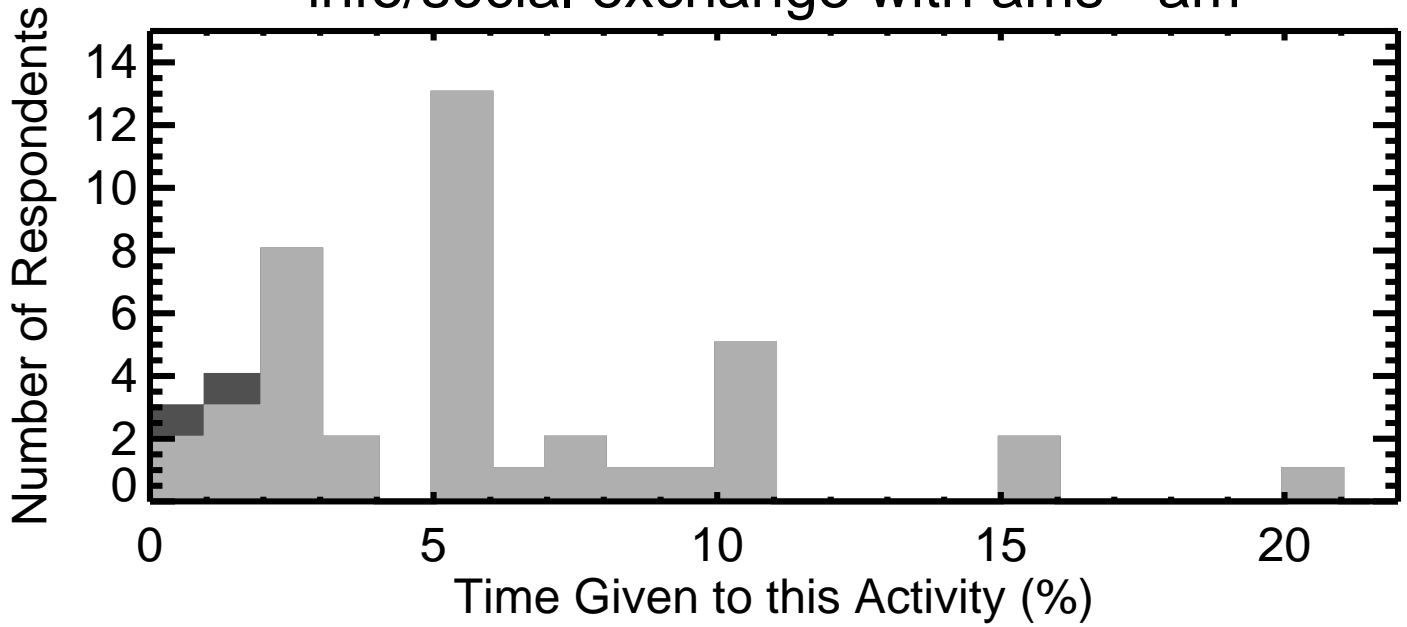


learning about astronomy - pro

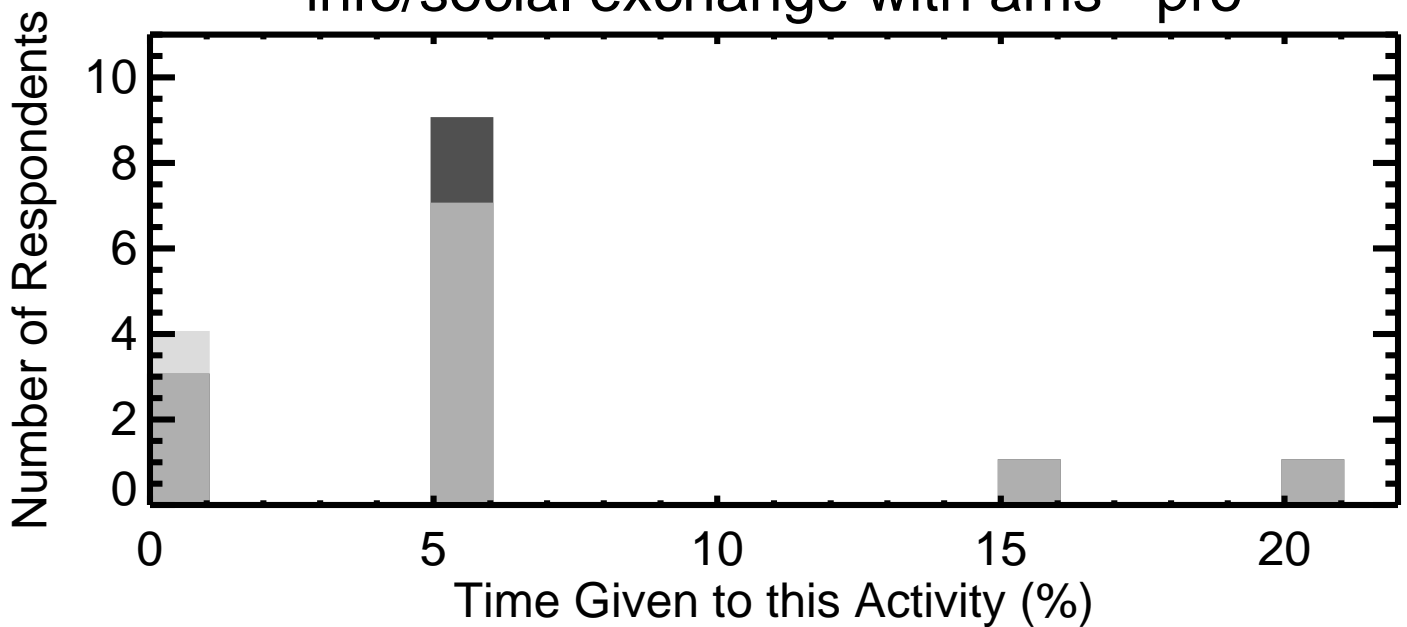


- enjoy
- don't enjoy
- wish had time/opportunity

info/social exchange with ams - am

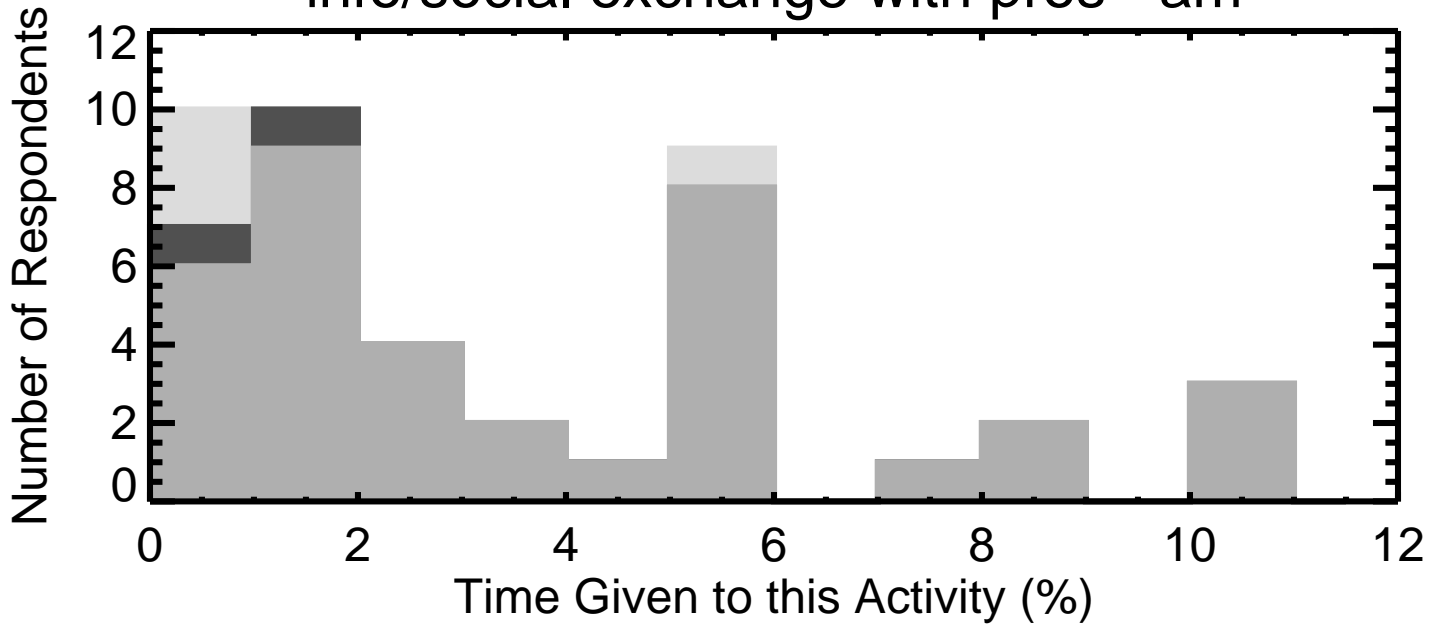


info/social exchange with ams - pro

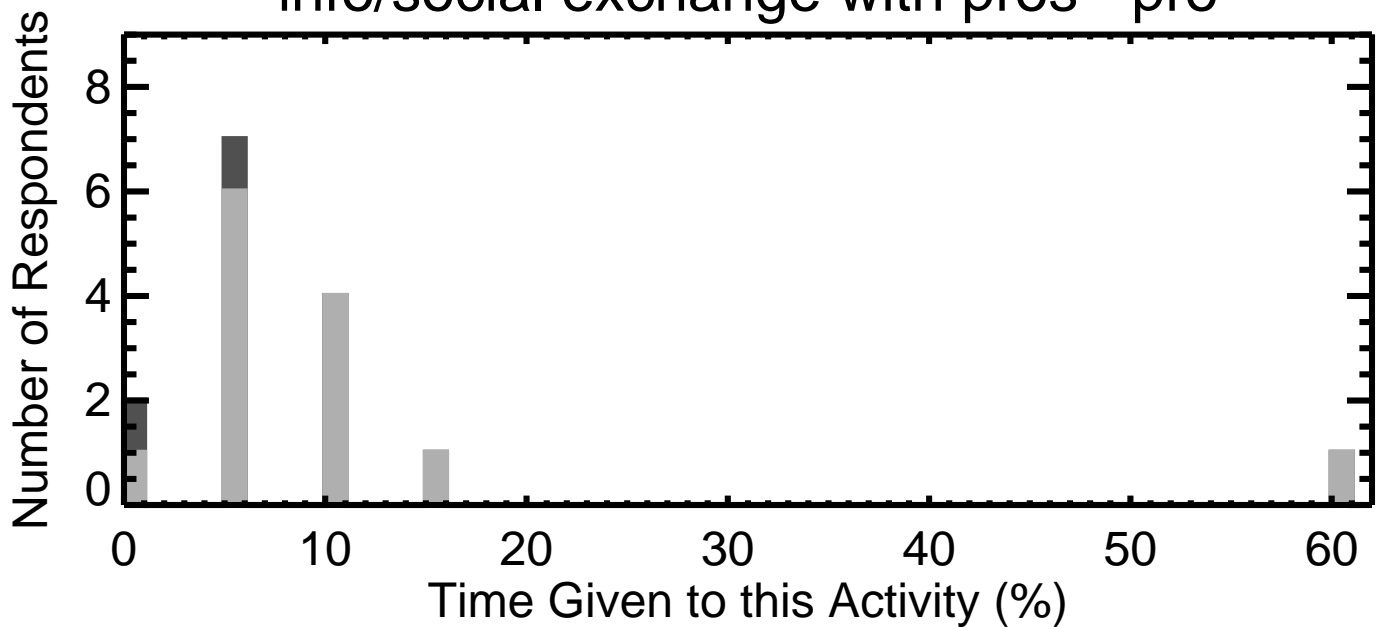


- enjoy
- don't enjoy
- wish had time/opportunity

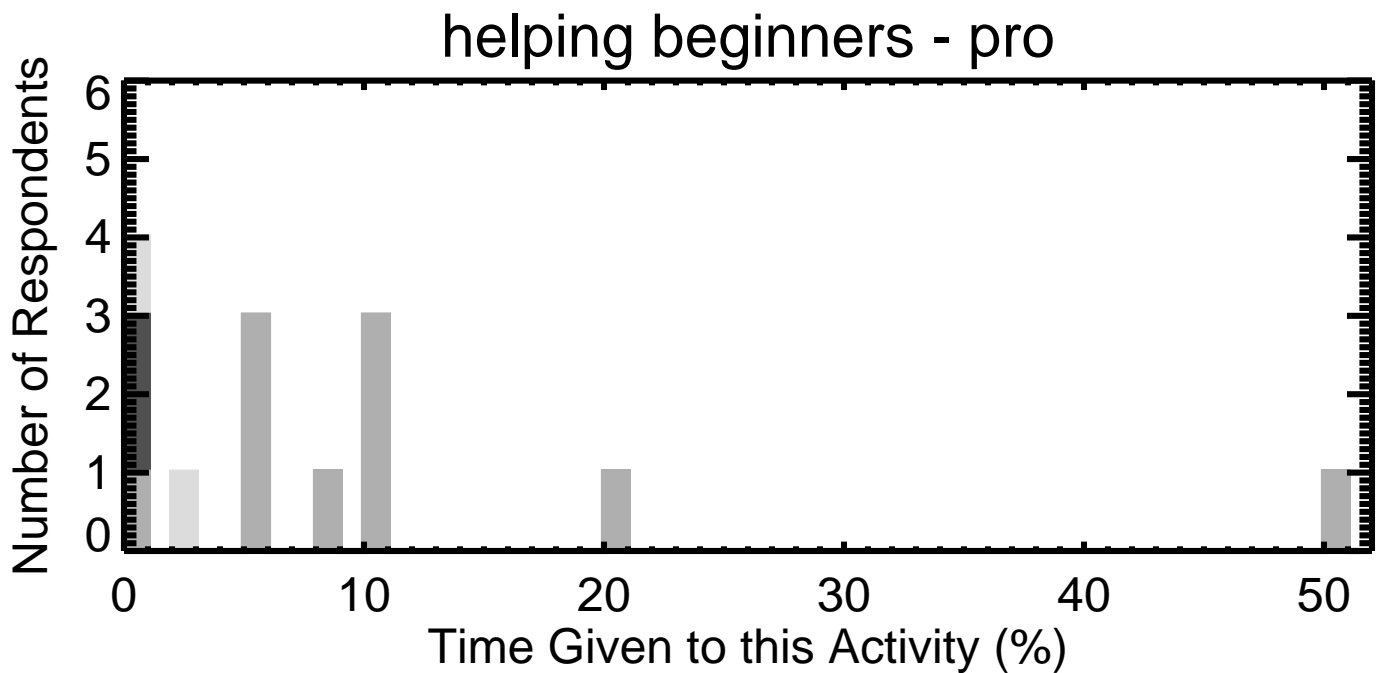
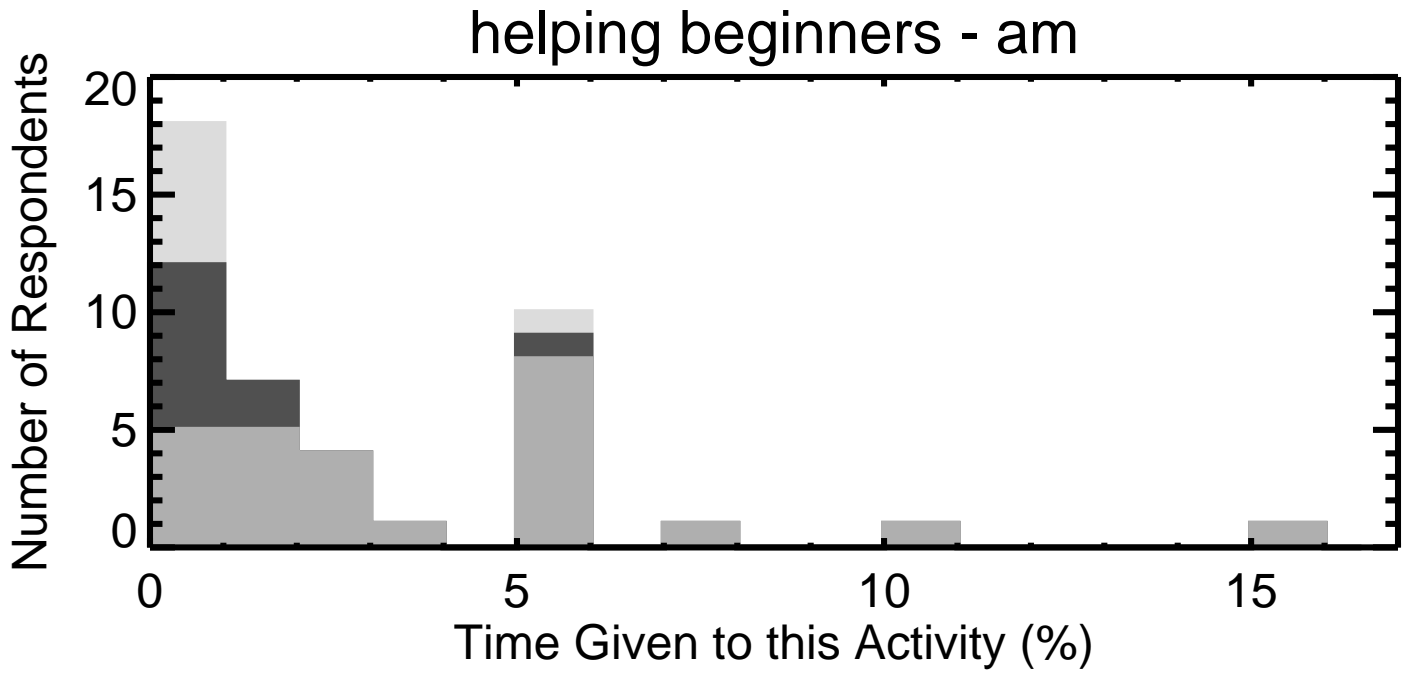
info/social exchange with pros - am



info/social exchange with pros - pro

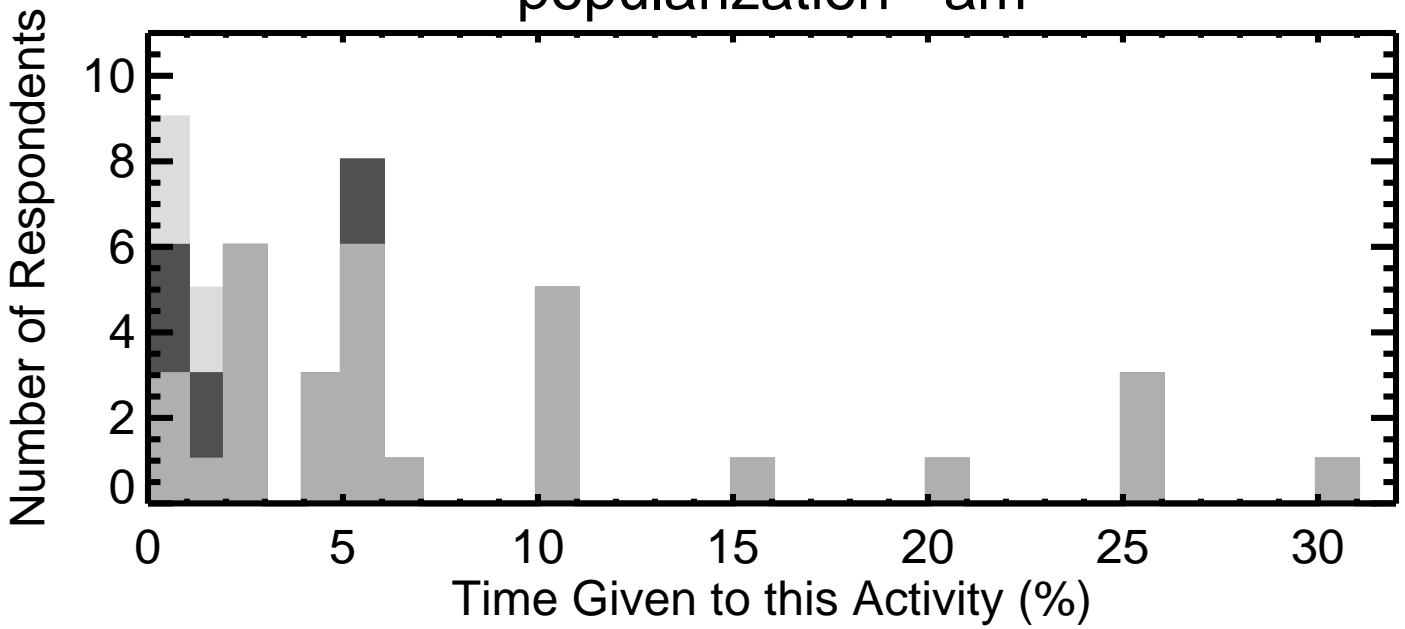


- enjoy
- don't enjoy
- wish had time/opportunity

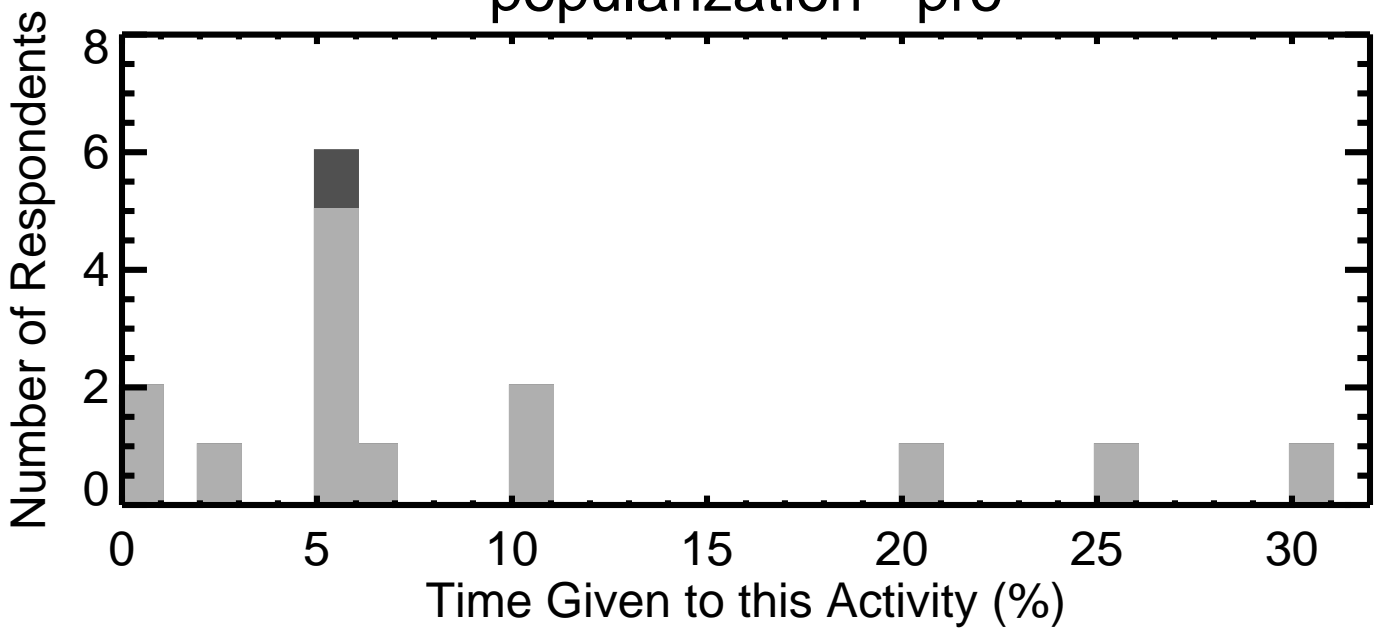


- enjoy
- don't enjoy
- wish had time/opportunity

popularization - am



popularization - pro



- enjoy
- don't enjoy
- wish had time/opportunity

