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Juan E. Cabanela

Bruce Partridge
Haverford College, bpartrid@haverford.edu

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Juan E. Cabanela

R. Bruce Partridge
Haverford College

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by **Juan Cabanela**
Haverford College
Bruce Partridge
Haverford College
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Abstract

We present a statistical description of the astronomy major as it is offered in U.S. colleges and universities. There is substantial variation from institution to institution, but the physics requirements for the astronomy major are more uniform than the astronomy requirements. There is, on average, little difference between the requirements for the major in four-year colleges and in Ph.D.-granting institutions.

1. INTRODUCTION

By our count, 61 U.S. colleges and universities offer students the option of majoring in astronomy. But what does the astronomy major consist of? Since there is no governing body that "accredits" astronomy programs in the United States (unlike, for example, the case of chemistry, where the Education Committee of the American Chemical Society sets the accreditation standards), each department offering an astronomy or astrophysics major is free to decide the program requirements. Thus considerable variation from one department to another is expected. On the other hand, if we examine astronomy programs likely to produce career astronomers, a "de facto accreditation" may exist; graduate schools in astronomy and related fields will not admit students from sub-par undergraduate programs. As such, the expectations of astronomy graduate schools, and faculty views of these expectations, likely exert the strongest external pressure on the curriculum of undergraduate astronomy programs. Is this pressure gradually creating a "uniform" undergraduate astronomy curriculum in the United States today?

To investigate this possibility and the nature of the major in general, we have examined the academic programs of the 61 U.S. colleges and universities that offer an undergraduate astronomy major. The principal challenge in this study has simply been gathering data from such a wide variety of sources and placing them in a uniform system. Our attempt at a uniform method of describing astronomy programs means we are likely providing a "noisy" description of each program. However, we note that important

trends are often extracted from "noisy" data, as long as enough independent data points exist such that the central limit theorem applies. With 61 independent programs, we can achieve a good understanding of the "mean trends" describing the astronomy major in the United States today. We note explicitly that this paper provides the data as a *description*-- not a *prescription*--of the astronomy major.

2. DATA COLLECTION: COUNTING COURSES

The initial step in this study was to obtain course requirement information for all the undergraduate astronomy programs in the United States. Using a list derived from the American Institute of Physics' (AIP) "roster" of astronomy departments for the year 2000 (Nicholson & Mulvey 2001), we have identified the 61 U.S. colleges and universities that offer programs for an undergraduate astronomy major (see Note 1). These institutions are split roughly 50-50 between baccalaureate and doctoral institutions.

For each of the 61 institutions, we examined the astronomy (or physics) department Web page to locate an online copy of the requirements for the astronomy major (see Note 2). We then typically used the online course catalog for the institution to obtain detailed course descriptions of any astronomy, physics, and mathematics courses required for the astronomy major. In cases where multiple astronomy or astrophysics majors were offered (e.g., B.A. vs. B.S. degree, or honors vs. non-honors), we chose the degree described as appropriate for a student interested in graduate study in astronomy.

Once we located the course descriptions and major requirements, we examined each *specifically required* course in astronomy, physics, and mathematics to determine the basic nature of its scientific content. Following a bit of trial and error, we settled on 25 categories of astronomy courses and 19 categories of physics courses (see Table 1 and Table 2). Some institutions offer courses that cover more than one of these categories; in these cases we attempted to partition the course according to its catalog description. We also kept track of requirements in some related disciplines (mathematics, computer science, chemistry, and geology), but we did not perform a detailed accounting of all the electives offered in these related disciplines (see Table 3).

Instead of engaging in an exact tally of semester or quarter hours, we decided to simply count the duration of a required course at a given institution, $S(course, institution)$, in units of "number of semesters." Senior-level "Topics" courses, which are often taken for a variable number of credit hours, were simply counted as one semester unless detailed information on their duration compared to other courses was available. (In this case partial semester units were assigned.) If an institution was on a trimester system, we assumed a one-trimester course was equivalent to two-thirds of a semester.

We also examined the issue of *elective* courses. Many institutions offer a variety of courses in addition to those specifically required and oblige students to take some (but not all) of these elective courses. Haverford College is an example; we require Stellar Astrophysics and then ask students to select three additional astronomy courses from a list including Extragalactic/Cosmology, General Relativity, Observational Methods, and Non-optical Astronomy. Since we have no way of knowing which students take which electives in which numbers, we choose to simply note which courses were offered as electives (but not specifically required) by each institution and the total number of elective courses a student is obliged to take to complete the major.

3. STATISTICAL DESCRIPTIONS OF THE "MEAN" ASTRONOMY MAJOR

The process of tallying courses led to the construction of a matrix showing which courses were required for an astronomy major at each of the 61 institutions (see Note 3). With this matrix, we computed $N_{required}$, the number of schools requiring a given category of course for the major, as well as the number simply offering the course, $N_{offering}$. Using these numbers, we constructed four summary statistics for each category of course:

1. **"Percentage Offering Class":** The fraction of institutions studied that actually offer the course in question, either as a specifically required course or as an elective (e.g., $N_{offering}/N_{institutions}$).
2. **"Percentage Requiring Class":** The fraction of institutions studied which actually require the course in question for the astronomy major (e.g., $N_{required}/N_{institutions}$).
3. **"Mean Semesters Required Overall":** The number of semesters of a given course that are required on average over all institutions. This is computed by summing up the number of required semesters, *S*, for a given course across all institutions, then dividing by the number of institutions (e.g., $\sum_{institution} S(course,institution)/N_{institutions}$). This is a rough measure of how many semesters of a given topic the "mean" astronomy major in the United States was required to take.
4. **"Mean Semesters Required If Required":** The number of required semesters of a given course averaged over all institutions. Computed by summing up the number of required semesters of a given course across all institutions, then dividing by the number of institutions actually requiring that course (e.g., $\sum_{institution} S(course,institution)/N_{required}$). This is a measure of the typical duration of a course if it is required.

These four statistics describe which categories of courses are associated with the "typical" or "mean" astronomy major in the United States today; see Tables 1 through 3 for their values.

In addition to describing the "mean" astronomy major, we can use this matrix to look for systemic differences in course offerings and requirements between baccalaureate and doctoral institutions. (**Note:** Four institutions offer masters degrees as their highest astronomy degree; we are not including them in this analysis.) The four statistics cited above have been recomputed and provided in Table 4 and Table 5 for two subsets of institutions: (1) the 27 baccalaureate institutions that offer an astronomy major; and (2) the 30 doctoral institutions that offer an astronomy major as well as a doctoral degree in astronomy.

Finally, we computed the *total* number of required semesters of coursework for the astronomy major at each institution. We also break this down into the number of semesters of *specifically required* courses, and semesters of *electives* in astronomy, physics, and mathematics necessary to complete the major. These results are condensed into a single data table (Table 6), where we have computed these sums for four subsets of the data: (1) all institutions offering the major; (2) institutions also offering a doctorate in astronomy; (3) institutions offering a masters in astronomy; and (4) institutions offering only the undergraduate degree in astronomy. This data table allows easy comparison of the broad requirements of astronomy majors at baccalaureate institutions versus those offering advanced astronomy degrees.

4. RESULTS

4.1 Specific Required Courses in the "Mean" Astronomy Major

Here we report some overall observations regarding the requirements of the "mean" astronomy major in the United States. First, there is very little uniformity in the definition of the astronomy major, if that definition is recognized as a set of specifically required courses (as summarized in Tables 1 through 3). As an extreme example, we note there are several institutions that do not require any specific astronomy courses for their astronomy majors! That is, while a set number of astronomy courses must be taken to complete the major, no particular astronomy course is required of all astronomy majors. Other institutions require up to nine specific astronomy courses. The only astronomy courses required for the major by more than 50% of the institutions are Introduction to the Solar System, Introduction to Stellar Astrophysics (these two are presumably introductory "gateway" courses), Extragalactic and Cosmology (single course), and Instrumentation/Data Analysis. On the other hand, a wide range of topics are not required by any institutions, including Solar Physics, Advanced ISM, and so on.

Actually, there is more uniformity in the physics requirements of the "mean" astronomy major than in the astronomy requirements. All astronomy majors, for instance, require the standard calculus-based Mechanics and Electricity & Magnetism (E&M) first year courses, and a substantial majority (70%) require Introduction to Quantum Mechanics/Waves/Optics. Other frequent physics requirements include Advanced Electricity and Magnetism, Advanced Mechanics, Optics, and Advanced (Junior/Senior) Quantum Mechanics.

We also compared the course requirements of Ph.D.-granting institutions to those in four-year colleges (see Tables 4 and 5). In this comparison, we see that the Ph.D.-granting institutions typically require more advanced mathematics courses and are more likely to require Thermal/Statistical Mechanics or Advanced E&M than four-year colleges. Conversely, four-year colleges are more likely to require a combined Extragalactic and Cosmology course, a Galactic Structure/Dynamics course, and a "Topics in Astronomy" course. There is, however, little difference between baccalaureate and Ph.D.-granting institutions in their astronomy *requirements*, although it is clear that Ph.D.-granting institutions do generally offer more advanced astronomy *electives*, such as ISM/Stellar Formation, High Energy, Extragalactic (as a single course), and Cosmology (as a single course). The physics course offerings and requirements are similar regardless of the highest degree offered, though Ph.D.-granting institutions require somewhat more advanced physics.

4.2 Overall Courseload of the "Mean" Astronomy Major

We also investigated the total required courseload for the astronomy major for all institutions. We do not see significant differences in the mean number of required physics or astronomy non-electives or electives across the 61 institutions (see Note 4). For instance, the mean number of semesters of physics and astronomy courses (combined) required to complete the major was 13.1±3.0. Breaking this down into the mean number of semesters of astronomy and physics courses (separately) required for the major, we found this to be fairly uniform at 5.0±1.9 and 7.4±2.5 semesters, respectively. These values do not vary significantly between Ph.D.-granting institutions or baccalaureate institutions. In addition to comparing the mean numbers of required courses, Figures 1 through 3 illustrate that there are no obvious differences in the distributions of the total number of required astronomy and physics courses between doctoral or

baccalaureate institutions.

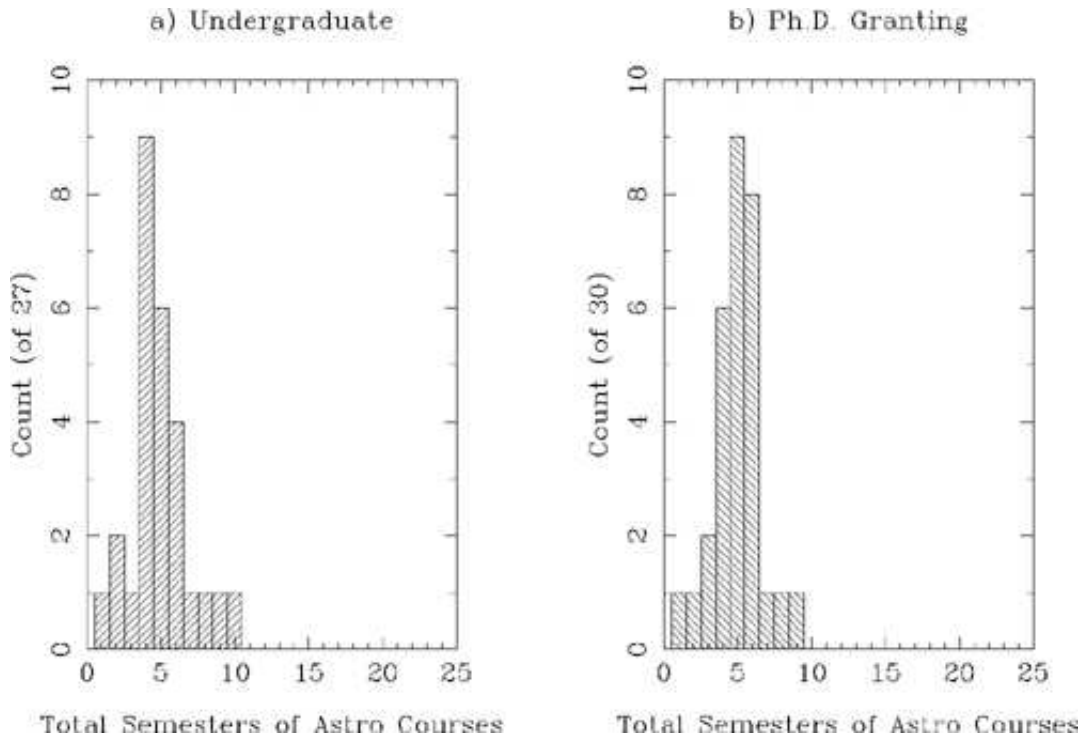

Figure 1. The total number of astronomy courses (required and elective) necessary to graduate with a major in astronomy

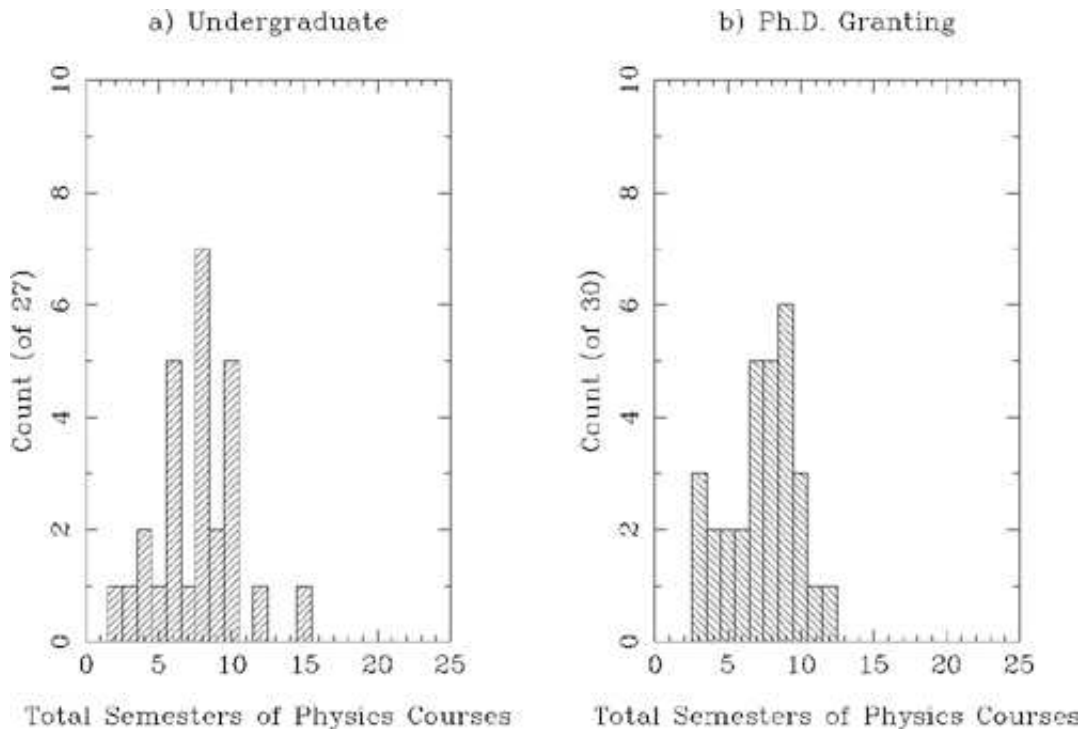

Figure 2. The total number of physics courses (required and elective) necessary to graduate with a major in astronomy

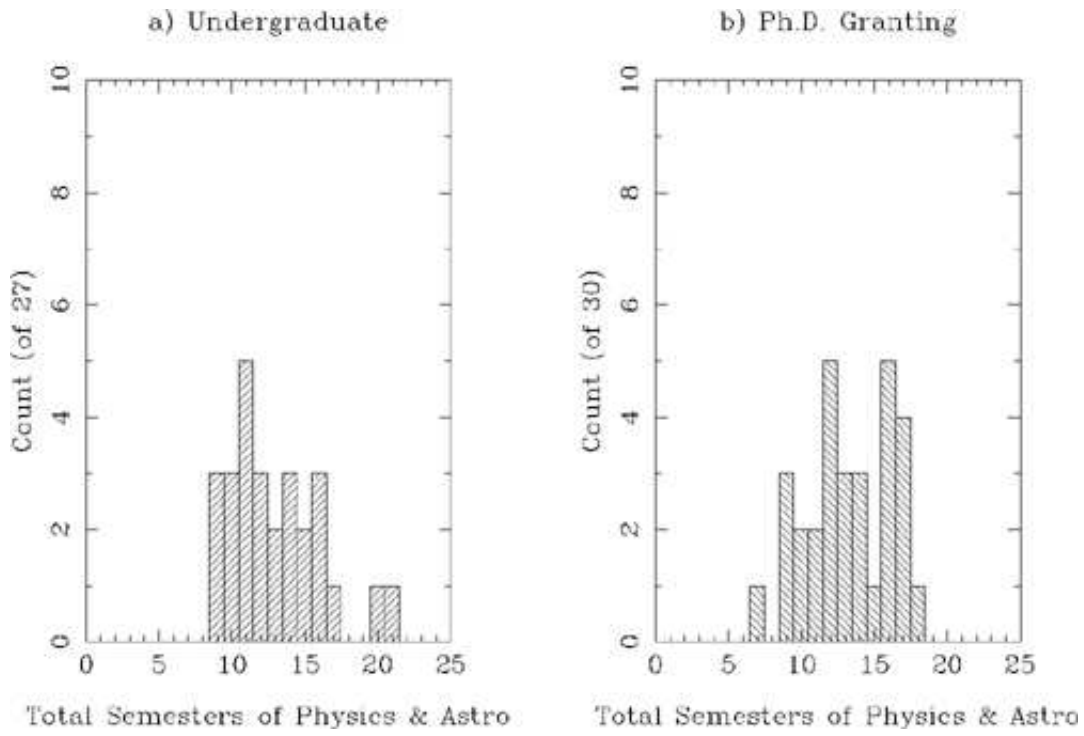

Figure 3. The total number of astronomy and physics courses (required and elective) necessary to graduate with a major in astronomy

While we realize we are working with small numbers of data points, we have used the Kolmogorov-Smirnov (K/S) test to quantify the similarity between the 30 doctoral and 27 baccalaureate astronomy programs. The K/S test measures the likelihood that two distributions are drawn from the same parent distribution (Press 1992). K/S tests on the distributions of total required courses for the astronomy major indicate a 92% likelihood that the distributions of total required courses in astronomy and physics (combined) at undergraduate versus doctoral institutions are drawn from the same parent distribution. Similarly, we find a 97% likelihood of the same parent distribution for total required physics courses and a 57% likelihood of the same parent distribution for total required astronomy courses. The relatively low likelihood in the case of astronomy courses may be traced to the fact that more Ph.D. institutions have five rather than four semesters of required astronomy courses.

5. CONCLUSIONS

We conclude this paper by restating that our goal in this study was not to prescribe any given astronomy curriculum, but to describe the current "mean" requirements of the Astronomy major in the United States. Our review of the degree requirements for the astronomy major at the 61 U.S. institutions offering this degree has shown that the vast majority of institutions require more physics than astronomy courses for the undergraduate astronomy major; a mean total of 7.4 semesters of physics versus 5.0 of astronomy. We have shown that in a very broad sense, there is little difference between the astronomy major obtained at a research university and a small liberal-arts college; the total number of astronomy, physics, and mathematics courses required for the major are comparable regardless of the nature of the institution.

However, these mean totals hide a wide variation between institutions in the specific requirements for the astronomy major. The only absolutely uniform requirements of the astronomy major in the United States are a full year of calculus-based introductory physics and the mathematics courses required to complete these physics courses. A review of physics courses required for the astronomy major shows that four specific upper division courses, Advanced Mechanics, Electricity and Magnetism, Optics, and Quantum Mechanics, are required over 50% of the time. Such absolute uniformity doesn't exist in the required astronomy curriculum, although introductory (second year) stellar astronomy, an extragalactic astronomy/cosmology course, and some sort of instrumentation/data analysis/observational astronomy are required over 50% of the time. Indeed, at some institutions a student majoring in astronomy is only asked to take electives in astronomy, while several physics courses are specifically required! We also noted some differences between the specific courses required at Ph.D.-granting versus baccalaureate institutions, but we found no dramatic differences. We conclude that incoming astronomy graduate students have a much more uniform background in physics than in astronomy.

Some of the variation in the astronomy major may be due to the difference in astronomy requirements in true, stand-alone astronomy majors versus those in astronomy majors constructed essentially by grafting a course or two onto nominal physics majors. To investigate that possibility in detail would deviate from our goal of "describing and not prescribing" the astronomy major, so we will not address the issue in this paper. We simply note that, as our data show, separating the true, stand-alone astronomy major from physics majors with astronomy courses grafted onto them is not simply a matter of comparing Ph.D.-granting institutions with baccalaureate institutions.

We would like to acknowledge the help of our student Megan Roscioli in reviewing early drafts of this paper. This research was supported in part by NSF grant AST 0071192 to Haverford College.

Please note that we welcome feedback that will help us improve our dataset.

Tables

Table 1. Summary of astronomy requirements for all astronomy programs
Any course required by more than 50% of the programs is boldfaced. Any course offered by the majority of programs is in italics.

back to text

	Percentage Offering Class	Percentage Requiring Class	Mean Semesters Required Overall	Mean Semesters Required If Required
Intro. Solar System	0.721	**0.607**	0.451	0.743
Intro. to Stellar	0.820	**0.721**	0.514	0.712
Extragalactic/Cosmology	0.852	**0.689**	0.541	0.786

Extragalactic	0.328	0.164	0.080	0.488
Cosmology	0.393	0.098	0.051	0.521
ISM/Stellar Formation	*0.689*	0.393	0.251	0.638
Stellar Structure/Atmopheres/Evolution	*0.656*	0.443	0.327	0.738
Radiative Processes	0.213	0.148	0.072	0.490
Instrumentation/Data Analysis/Observational	*0.869*	**0.541**	0.646	1.194
High Energy	0.230	0.016	0.008	0.500
Galactic Structure/Dynamics	*0.557*	0.246	0.161	0.656
Advanced ISM (2nd Course)	0.082			
Advanced Stellar Evolution (2nd Course)	0.098	0.016	0.033	2.000
SETI/Astrobiology	0.164	0.016	0.016	1.000
Solar Physics	0.033			
Celestial Mechanics	0.082	0.066	0.045	0.688
Archeoastronomy	0.016			
Manned Space Flight	0.016			
Intro. Planetary Sciences	0.016	0.016	0.016	1.000
Planetary Structure/Evolution	0.311	0.098	0.098	1.000
Planetary Radio Astronomy	0.180	0.016	0.008	0.500
Planetary Physics	0.016			
Terrestrial/Planetary Atmospheres	0.049			
Research/Individual Study	0.115	0.033	0.025	0.750

Topics in Astronomy	*0.836*	0.262	0.336	1.281

Table 2. Summary of physics requirements for all astronomy programs
Any course required by more than 50% of the programs is boldfaced. Any course offered by the majority of programs is in italics.

back to text

	Percentage Offering Class	Percentage Requiring Class	Mean Semesters Required Overall	Mean Semesters Required If Required
Character of Physics/Pre-Physics	0.016			
Intro. Classical Mechanics	*1.000*	**1.000**	1.002	1.002
Intro. E&M	*1.000*	**1.000**	0.994	0.994
Intro. QM/Waves/Optics	*0.721*	**0.705**	0.634	0.899
Advanced Mechanics	*0.902*	**0.590**	0.672	1.139
Advanced E&M	*0.951*	**0.623**	0.803	1.289
Optics	*0.787*	**0.557**	0.482	0.865
Jr/Sr Quantum Mechanics	*0.951*	**0.525**	0.597	1.137
Plasma Physics	0.213	0.016	0.016	1.000
Fluid Mechanics	0.148	0.033	0.022	0.665
Math Methods	0.426	0.164	0.175	1.067
Atomic/Solid State	*0.672*	0.279	0.154	0.554
Nuclear/Particle	*0.656*	0.230	0.113	0.494
Electronics	0.377	0.049	0.049	1.000
Advanced Lab	*0.607*	0.164	0.161	0.983

Thermal/Statistical Mechanics	*0.852*	0.443	0.443	1.000
General Relativity	0.279	0.016	0.008	0.500
Computational Physics	0.410	0.148	0.142	0.962
Topics	0.246	0.148	0.270	1.833

Table 3. Summary of requirements in related disciplines for all astronomy programs
Any course required by more than 50% of the programs is boldfaced. Any course offered by the majority of programs is in italics.

back to text

	Percentage Offering Class	Percentage Requiring Class	Mean Semesters Required Overall	Mean Semesters Required If Required
MATHEMATICS				
Calculus	*1.000*	**1.000**	1.938	1.938
Differential Equations	*0.918*	**0.689**	0.577	0.838
Vector Calculus	*0.967*	**0.885**	0.852	0.963
Linear Algebra	*0.820*	0.410	0.305	0.744
PDEs	0.492	0.164	0.117	0.716
Fourier Analysis	0.033	0.016	0.004	0.250
Complex Analysis	0.344	0.049	0.042	0.860
Statistics	0.295	0.016	0.011	0.670
GEOLOGY				
Intro. Geology	0.066			
Remote Sensing	0.033			
COMPUTER SCIENCE				
General CS	0.361	0.148	0.142	0.963
CHEMISTRY				
Intro. Chemistry	0.262	0.131	0.213	1.625
Physical Chemistry	0.033	0.016	0.016	1.000

Table 4. A summary of astronomy requirements for the astronomy major at institutions offering only undergraduate degrees in astronomy versus institutions also offering doctorates

back to text

	Percentage Offering Class		Percentage Requiring Class		Mean Semesters Required Overall		Mean Semesters Required If Required	
	PhD	***BS/BA***	**PhD**	***BS/BA***	**PhD**	***BS/BA***	**PhD**	***BS/BA***
Intro. Solar System	0.700	*0.741*	0.600	*0.630*	0.445	*0.469*	0.741	*0.745*
Intro. to Stellar	0.900	*0.741*	0.800	*0.667*	0.586	*0.454*	0.733	*0.681*
Extragalactic/ Cosmology	0.833	*0.852*	0.600	*0.778*	0.464	*0.624*	0.773	*0.802*
Extragalactic	0.467	*0.222*	0.233	*0.111*	0.096	*0.074*	0.411	*0.667*
Cosmology	0.500	*0.333*	0.167	*0.037*	0.071	*0.037*	0.425	*1.000*
ISM/Stellar Formation	0.867	*0.519*	0.433	*0.370*	0.297	*0.228*	0.685	*0.616*
Stellar Structure/ Atmospheres/Evolution	0.667	*0.667*	0.400	*0.481*	0.270	*0.364*	0.674	*0.756*
Radiative Processes	0.233	*0.222*	0.133	*0.185*	0.061	*0.096*	0.458	*0.516*
Instrumentation/Data Analysis/Observational	0.900	*0.815*	0.567	*0.481*	0.653	*0.568*	1.152	*1.179*
High Energy	0.333	*0.148*		*0.037*		*0.019*		*0.500*
Galactic Structure/ Dynamics	0.500	*0.593*	0.133	*0.333*	0.056	*0.247*	0.418	*0.741*
Advanced ISM (2nd Course)	0.100	*0.074*						
Advanced Stellar Evolution (2nd Course)	0.100	*0.111*		*0.037*		*0.074*		*2.000*

SETI/Astrobiology	0.133	*0.185*		*0.037*		*0.037*		*1.000*
Solar Physics	0.033	*0.037*						
Celestial Mechanics	0.133	*0.037*	0.100	*0.037*	0.058	*0.037*	0.583	*1.000*
Archeoastronomy		*0.037*						
Manned Space Flight		*0.037*						
Intro. Planetary Sciences	0.033		0.033		0.033		1.000	
Planetary Structure /Evolution	0.367	*0.296*	0.100	*0.111*	0.100	*0.111*	1.000	*1.000*
Planetary Radio Astronomy	0.300	*0.074*		*0.037*		*0.019*		*0.500*
Planetary Physics	0.033							*0.500*
Terrestrial/Planetary Atmospheres	0.067	*0.037*						*0.500*
Research/Individual Study	0.133	*0.111*		*0.074*		*0.056*		*0.750*
Topics in Astronomy	0.800	*0.852*	0.167	*0.296*	0.167	*0.389*	1.000	*1.313*

Table 5. A summary of physics and mathematics requirements for the astronomy major at institutions offering only undergraduate degrees in astronomy versus institutions also offering doctorates

back to text

	Percentage Offering Class		Percentage Requiring Class		Mean Semesters Required Overall		Mean Semesters Required If Required	
	PhD	***BS/BA***	**PhD**	***BS/BA***	**PhD**	***BS/BA***	**PhD**	***BS/BA***
Character of Physics/Pre-Physics		*0.037*						

Intro. Classical Mechanics	1.000	*1.000*	1.000	*1.000*	0.978	*1.029*	0.978	*1.029*
Intro. E&M	1.000	*1.000*	1.000	*1.000*	1.000	*0.986*	1.000	*0.986*
Intro. QM/Waves/Optics	0.767	*0.667*	0.767	*0.630*	0.639	*0.611*	0.833	*0.971*
Advanced Mechanics	0.933	*0.889*	0.633	*0.519*	0.700	*0.630*	1.105	*1.214*
Advanced E&M	0.967	*0.926*	0.700	*0.519*	0.917	*0.667*	1.309	*1.286*
Optics	0.733	*0.815*	0.533	*0.556*	0.453	*0.475*	0.849	*0.855*
Jr/Sr Quantum Mechanics	0.967	*0.926*	0.633	*0.444*	0.733	*0.496*	1.158	*1.116*
Plasma Physics	0.267	*0.148*		*0.037*		*0.037*		*1.000*
Fluid Mechanics	0.167	*0.111*	0.067		0.044		0.665	
Math Methods	0.467	*0.407*	0.200	*0.148*	0.189	*0.185*	0.945	*1.250*
Atomic/Solid State	0.733	*0.593*	0.267	*0.259*	0.136	*0.123*	0.510	*0.476*
Nuclear/Particle	0.733	*0.630*	0.233	*0.259*	0.119	*0.123*	0.511	*0.476*
Electronics	0.267	*0.481*	0.033	*0.074*	0.017	*0.093*	0.500	*1.250*
Advanced Lab	0.700	*0.556*	0.167	*0.148*	0.178	*0.130*	1.066	*0.875*
Thermal/Statistical Mechanics	0.900	*0.778*	0.533	*0.333*	0.517	*0.352*	0.969	*1.056*
General Relativity	0.267	*0.259*						
Computational Physics	0.400	*0.444*	0.133	*0.185*	0.133	*0.173*	1.000	*0.932*
Topics	0.067	*0.444*	0.067	*0.222*	0.050	*0.519*	0.750	*2.333*

Calculus	1.000	*1.000*	1.000	*1.000*	1.758	*2.130*	1.758	*2.130*
Differential Equations	0.900	*0.963*	0.833	*0.593*	0.724	*0.491*	0.868	*0.828*
Vector Calculus	0.967	*0.963*	0.967	*0.815*	0.891	*0.815*	0.922	*1.000*
Linear Algebra	0.767	*0.852*	0.533	*0.222*	0.387	*0.167*	0.725	*0.750*
Partial Differential Equations	0.600	*0.370*	0.233	*0.111*	0.164	*0.083*	0.701	*0.750*
Fourier Analysis		*0.074*		*0.037*		*0.009*		*0.250*
Complex Analysis	0.367	*0.333*	0.067	*0.037*	0.078	*0.009*	1.165	*0.250*
Statistics	0.300	*0.296*	0.033		0.022		0.670	

Table 6. A Summary of the "Mean" Astronomy Major Requirements in the United States

This is a breakdown of the mean number of semesters of astronomy, physics, and related courses required for the undergraduate astronomy major in the United States based on course catalogs from the academic year 2001-2002. The standard deviation around that mean is also listed in parentheses.

back to text

	All	*PhD*	*MS*	*BS/BA*
Number of Departments	61	30	4	27
Non-Electives Required for Major				
Total Semesters of Astronomy Non-Elective	3.89 (2.07)	3.61 (1.83)	4.88 (2.95)	4.05 (2.2)
Total Semesters of Physics Non-Electives	6.74 (2.66)	6.80 (2.52)	7.00 (1.78)	6.63 (2.97)
Total Semesters of Math Non-Electives	3.85 (0.94)	4.02 (0.99)	3.50 (0.58)	3.70 (0.92)
Electives Required for Major				

Total Semesters of Astronomy Electives	1.08 (1.42)	1.40 (1.38)	0.00 (0.00)	0.89 (1.48)
Total Semesters of Physics Electives	0.69 (1.33)	0.54 (1.24)	0.00 (0.00)	0.96 (1.48)
Total Semesters of Astronomy or Physics Electives	0.75 (1.66)	0.87 (2.05)	1.50 (1.91)	0.52 (1.05)
Total Semesters of Astronomy/Related Fields Electives	0.35 (0.94)	0.65 (1.23)	0.00 (0.00)	0.07 (0.38)
Total Required Courseload for Major				
Total Semesters of Astronomy Required	4.95 (1.88)	4.97 (1.64)	4.88 (2.95)	4.94 (2.03)
Total Semesters of Physics Required	7.43 (2.52)	7.35 (2.41)	7.00 (1.78)	7.59 (2.8)
Total Semesters of Physics & Astronomy Required (including Electives)	13.14 (3.01)	13.18 (2.99)	13.38 (2.56)	13.05 (3.2)
Number of Electives Available				
Number of Astronomy Electives Available (est.)	4.10 (3.25)	5.03 (3.36)	2.25 (3.3)	3.33 (2.9)
Number of Physics Electives Available (est.)	4.52 (3.17)	4.37 (3.33)	4.00 (1.41)	4.78 (3.23)

Notes

Note 1: We eliminated one department from the AIP's original list. Marlboro College in Vermont has a program where students design their own majors. They do not offer an explicit "astronomy" major and do not list degree requirements. back to text

Note 2: As a clarification, we define undergraduate astronomy majors to include any astronomy or astrophysics degree offered separate from the physics degree at a school. back to text

Note 3: Click here for this matrix, which is in Microsoft Excel format. back to text

Note 4: Ph.D.-granting institutions do require on average one semester more of mathematics than undergraduate institutions, which is roughly a one standard deviation difference. back to text

References

Nicholson, S., and Mulvey, P .J. 2001, Roster of Astronomy Departments with Enrollment and Degree Data, 2000, *American Institute of Physics*, Pub. No. R-395.7.

Press, W. H., Teukolsky, S. A., Vetterlin, W. T., & Flannery, B. P. 1992, *Numerical Recipes in C (Second Edition)*, New York: Cambridge University Press.

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67 - 84