



**DIVISION C1**  
**ASTRONOMY EDUCATION AND DEVELOPMENT**  
*Education et Développement de l'Astronomie*

**Newsletter 85 – April 2017**

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**Contributions to this newsletter are gratefully received at any time.**

**This newsletter is available at the following website**  
<http://iaucc1.frm.utn.edu.ar/wp-content/uploads/2012/11/IAUNL85.pdf>

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## [A WELCOME FROM THE EDITORS WITH A NOTE ON EDITORIAL POLICY](#)

Welcome to IAU Commission C1 Newsletter #85, the third to be published new divisional structure of the IAU established at the General Assembly XXIX in Honolulu, August, 2015. (We are continuing the numbering of the newsletter consecutive with the old C46 education newsletter.) This newsletter contains reports on several of our working groups, announcements of some upcoming meetings of interest, and we are pleased to continue the series of informative book reviews by Naomi Pasachoff.

As always, comments and contributions are both needed and welcome. Thanks to everyone who has made a contribution to this edition of the Newsletter. Please note the text in this Editorial highlighted in **RED**.

For the March issue the deadline for submitting material is **Friday 6 October 2017**. If you can include photos or illustrations with any material, please do so in the manuscript. Feel free to encourage others to submit material – anything with an astronomy education or development aspect will be considered.

### **IAU C46 NEWSLETTER – GUIDANCE FOR CONTRIBUTORS**

The editor is happy to accept articles on any aspect of astronomy education or development, including obituaries and other articles on people. 500-2000 words are the approximate upper and lower limits. Shorter contributions, up to a few hundred words, such as meeting announcements, meeting reports, and other news items, are also welcome.

Send contributions to me by email, at [marschal@gettysburg.edu](mailto:marschal@gettysburg.edu). or to the Kathy Eastwood, secretary of CC1 and co-editor of the newsletter: [kathy.eastwood@nau.edu](mailto:kathy.eastwood@nau.edu). Please send manuscripts as a Microsoft Word attachment (much preferred) or include the text in the body of the email. **Illustrations should be sent as separate, individual files**, preferably as JPEGs or TIFFs no larger than about 3 Mbytes each. **Please include contact information for the author, including email and postal address, DO NOT SEND ANYTHING AS A PDF.**

Do not send a preliminary draft unless it is clearly marked as such, but feel free to contact me with preliminary ideas for contributions.

We try to edit as lightly as possible, and we certainly don't care whether US English or British spelling conventions are used, so you may notice an inconsistency in style insofar as such conventions can vary from author to author with no loss of comprehensibility. We also leave local turns of phrase untouched unless the meaning is obscure. Clarity, conciseness, and being interesting or informative are what is needed. Only in rare cases is heavier editing necessary.

### **Notes on Resources and Methods for Education**

I welcome short notes pointing readers to resources useful for education. Such notes can just point to a website, or can include a paragraph describing the nature and application of the resources available. You will find several examples of these notes in this edition. I also welcome longer articles detailing methods and techniques and reports on educational activities and summer schools, and well as studies regarding the impact and effectiveness of such techniques for astronomical learning.

### **Book reviews**

We welcome book reviews. Reviews should generally be of books centered on astronomy education or development or of historical interest for educators. If there's such a book that you think is worth reviewing, please send your review to me.

### **The C1 websites**

The "official" IAU CC1 website is at <http://iaucc1.frm.utn.edu.ar/> The IAU Office of Astronomy for Development (OAD) is at <http://www.astro4dev.org/> and the IAU Office of Astronomy Outreach (OAO) is at <https://www.iau.org/public/>

### **Back issues of the C46 Newsletter, our previous incarnation**

Back issues are available at <http://iaucomm46.frm.utn.edu.ar/newsletters/>. Newsletter 49, October 1998, has been scanned from hard copy, so the quality of reproduction is only modest. This is also the case for earlier ones, edited by John Percy. These extend back to February 1992, but there are gaps.

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## EDUCATIONAL REPORTS

### IAU OFFICE OF ASTRONOMY FOR DEVELOPMENT UPDATES AS OF MARCH 2017

#### 1. OAD Annual Call for Proposals:

- a. The OAD received 127 expressions of interest and 103 full proposals for projects in the 2017 calendar year. Proposals were sent to review panels (Task Forces) and recommendations to fund 20 projects (for the amount of €106,207) were approved by the OAD Steering Committee. [List of projects funded in 2017](#) at this link.

#### 2. Regional Offices:

- a. Regional offices (currently nine globally) actively participated in the development and implementation of the Expressions of Interest phase of the call. We anticipate even closer involvement of the regions in the next call for proposals.
- b. Quarterly meetings for the Steering Committees of each regional office are carried out with a quarterly telecon with all regional coordinators. A combined business plan across all offices has been adopted as a foundation for collaboration and alignment.
- c. Most recently there has been an expression of interest for the establishment of a European Regional Office and we are expecting a full proposal in the near future.
- d. Several activities were run including workshops by regional offices in Southern Africa and South East Asia.
- e. Applications are open for the [West African International Summer School for Young Astronomers](#) to be held in Ghana July 23 – August 6, 2017.
- f. The next meeting of all nine regional coordinators is planned to coincide with the Middle East and Africa Regional IAU Meeting ([MEARIM](#)) in Ethiopia 22-25 May 2017.

#### 3. Staffing/OAD Team:

- a. Astronomer Dr. Vanessa McBride started in January 2017. We are expecting the IAU to appoint a fundraiser in the near future. Both these appointments came about as recommendations from the external review of the OAD in 2015. Of relevance for Commission C1 members is that Dr. McBride will act a link between the professional astronomer community and the development community, with one of her roles being the liaison between the OAD and IAU Divisions/Commissions. Vanessa has a PhD in astrophysics from the University of Southampton. She has spent the last ten years in astrophysics research and teaching, most recently in a joint position between the University of Cape Town and the South African Astronomical Observatory. Her research interests include X-ray binaries, the Magellanic Clouds and early-type stars.
- b. Ramasamy Venugopal is with us until November 2017 on funding we had received from EU-Space Awareness. He has been invaluable in leading the logistics of the call for proposals.
- c. Dr. Wanda Diaz started her postdoc at the OAD in October 2016, to work on accessibility of astronomical data and science education in general.
- d. Karabo Makola is on a DST internship until May 2017 leading the OAD's communications.
- e. Jack Harvey is a self-funded volunteer from the USA working at the OAD until the end of March 2017 on consolidating data from past projects.

- f. Paul Anthony Wilson joined us in March 2017 as an OAD fellow for 6 months. He will be working on the interface between astronomy and data science.

#### **4. Highlights:**

- a. The OAD released its first Yearbook, an annual publication that reflects on the activities and accomplishments of the OAD and the global community during the year. The Yearbook looks back at all the projects funded across the world and highlights of the year's activities. [Download the OAD Yearbook 2016](#)
- b. Other highlights can be found in our quarterly newsletter at <http://www.astro4dev.org/media/newsletters/>

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## **REPORT OF THE C.C1 WORKING GROUP THEORY AND METHODS IN ASTRONOMY EDUCATION**

This Report corresponds to the activities of the period from Aug 2015 to Oct 2016.

Motivated by the IAU Commissions Reform, a proposal was submitted to the International Astronomical Union General Assembly (IAU) in Beijing (2012) to consider the importance of astronomy education research in the Commission 46 (Astronomy Education & Development) activities (Ros, De Greve and García, 2015). After that, a working group was established on Theory and Methods in Astronomy Education (De Greve, 2013). In brief, the WG needs and goals are as follows:

#### **Needs:**

1. Growing amount of emerging astronomy projects
2. Innovate and adapt teacher training, curricula, pedagogical methods.
3. Develop a promotional strategy for enhancing Astronomical Educational Research (AER).

#### **Goals (to be promoted):**

- 1) In different regions and continents, surveys and literature reviews of scholarly production that already exists on PhD and MSc theses, published papers in journals and works in proceedings of meetings on Astronomy, Physics and Science Education.
- 2) Meetings, courses, workshops, conferences and journals in regions and continents to enhance AER.
- 3) Structures and well succeeded practices such as GHOU, GTTP, NASE, UNAWE etc.

During the last IAU GA, communication about “A new international agenda for astronomy education research” was presented, in which the WG projects and some existing results were shown (Bretones, 2015).

Since then, many contacts have been made in the GA and after. In a first moment, the surveys of theses, papers and works in different countries and languages have been increased and enhanced.

Within a network of contacts with colleagues, by e-mails and videoconference talks, the following actions were proposed towards that goal:

### Steps for surveys:

- 1) Provide a list of references;
- 2) Get the pdf files of works;
- 3) Make them available online;
- 4) Analyze and classify the works by: year of publication, the authors' institutions, school level, study focus in education, content, kind of academic work, theoretical framework;
- 5) Write and publish papers about the results showing trends and gaps in the production.

Contacts with colleagues committed to these tasks include the following names and countries up to now:

### Contacts and collaborations - countries:

#### 2015

Rosa Doran, Lina Canas, Isabel Almeida Borges – Portugal; Néstor Camino - Argentina and Latin American Countries; Rosa Ros, Bernat Martínez Sebastià – Spain; Talat Saygaç – Turkey; Hidehiko Agata, Kodai Fukushima, Akihiko Tomita- Japan; Michel Faye, Suzanne Faye – France; Pedro Russo – Netherlands; Karen Masters e Derek McNally – England; Tim Slater, Andrew Fraknoi – USA; Hongfeng Guo – China; Youngng Lee - South Coreia; Jayashree Ramadas - India.

#### 2016

Carlos Molina, Ángela Patricia Pérez Henao – Colombia; Valerie Frede, Frederic Pitout – France; Urban Eriksson – Sweden; Aniket Sule – India; Nicoletta Lanciano – Italia; Paulo Maurício – Portugal; Juan Amador Marín Martínez -Spain.

As a consequence of the e-mails and e-talks, many of them have sent a very relevant contribution in the form of lists of references and pdfs of publications that have never been collected and organized. The Table below shows this:

### Received Surveys and Results

Contact/Country	Surveyed Country	Results
Néstor Camino/Argentina	Colombia	8 MSc theses; 28 undergraduate theses
Urban Eriksson/Sweden	European Countries	12 contacts of researchers and works
Paulo Maurício/Portugal	Portugal	51 MSc theses; 2 PhD theses
Frederic Pitout/France	France	7 PhD theses; 31 papers; 2 works
Nicoletta Lanciano/Italy	Italy	4 PhD theses; 17 <i>Laurea</i> theses; 63 papers; 53 works
Aniket Sule/India	India	11 contacts of researchers and works 11 papers; 8 works
Akihiko Tomita/Japan	Japan	1544 papers

As a part of the results obtained by the colleagues, some remarkable questions related to the field and the difficulties to find researchers and papers were made evident. Some of these questions are related to papers severely dispersed and published in many languages and

countries. Some definite examples are:

In this paper, we discuss significances to organize our studies about astronomy educations and out-reach activities in (academic, peer-reviewed) papers. We research the trend of recent (peer-reviewed) papers about astronomy education, and we show that the papers are severely dispersed. For the establishment of astronomical education field as an important branch of academic discipline, broad sharing of knowledge in this field is highly required. (Agata, Karino and Matsumoto, 2015).

It seems to be very few, but I guess there are more AERs in different countries. I have learned that language difficulties is a large barrier and AER persons often only publish in their own language and countries. This makes it increasingly difficult to find them. (Eriksson, 2016)

Even with these difficulties, it is appropriate for each language and country to go on making surveys, not only to establish the field, but also to give visibility to these productions and advertise to the teachers in the schools, students and interested people.

The next steps are related to perform analysis, make them widely available and give visibility to the references and publications.

### **Lectures in Colombia: April 2016**

From 05 to 07 April, three lectures by P.S. Bretones were held in Colombia. The main subject was the need of astronomy education, the contribution to astronomy education research and the international projects of the IAU C.C1 WGs and others. More specifically, the WG-TMAE projects on surveys, publications and meetings were shown. The lectures were:

05th (Medellín, Parque Explora):

“El universo en el salón de clases: los astrónomos queremos otra cosa”.

(<https://www.youtube.com/watch?v=ECnwWkMRenQ>)

06th (Medellín, Universidad de Antioquia): “A New International Agenda for Astronomy Education Research”

07th (Bogota, Observatorio Astronómico, Universidad Nacional de Colombia):

“Nuevas Tendencias en la enseñanza de la Astronomía”

(<https://www.youtube.com/watch?v=jBSDYH2d1O0>)

In Colombia some meetings to start the collaboration with the colleagues were held, particularly to develop AER in surveys of works in the countries of the north of South America (Andean region).

### **WG webpage**

The IAU maintains a website for the WG:

[https://www.iau.org/science/scientific\\_bodies/working\\_groups/257/](https://www.iau.org/science/scientific_bodies/working_groups/257/)

At the same time, there was set up the WG webpage aiming to show the activities with more information: ([www.iau-wgtm.ufscar.br](http://www.iau-wgtm.ufscar.br))



Then, the issue of how to show the surveys and results will be discussed with the colleagues. One of the objectives is to advertise the productions in their each countries and languages. Studies like these are supposed to encourage new studies and to bind together the community of the area as well.

## References

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**Chair:** [Paulo S. Bretones](mailto:bretones@ufscar.br) - bretones@ufscar.br  
Sao Paulo, Brazil  
13 November 2016



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## NOTICES AND ANNOUNCEMENTS

### **ROBOTIC TELESCOPES, STUDENT RESEARCH AND EDUCATION CONFERENCE--JUNE 19-22, 2017**

Hacienda Old Town Hotel, San Diego, California

Conference website [www.rtsre.org](http://www.rtsre.org)



#### Conference Synopsis

The *Remote Telescopes, Student Research and Education: Past, Present, Future* conference will focus on the use of remotely-located, relatively small, typically optical robotic telescopes to support, promote and drive research undertaken by high school and undergraduate students for scientific research, while also addressing educational outcomes. The conference will aim to tie diverse strands into a coherent story of where we have been (the past), where we are now (the present), and outline the pathways and challenges going forward (the future). In doing so, we endeavor to provide a synthesis of the relatively disconnected communities surrounding remote telescopes, scientific research, and astronomy education to provide a global picture of the field in its current state. Published, peer-reviewed conference proceedings will feature invited and contributed papers, as well as poster summaries.

There will be significant and broad overlap over the three days of the main conference. Monday focusses on Robotic Telescopes, their history, current major projects and endeavors, Tuesday focusses largely on Student, Teacher and Pro-Amateur Research with the main conference social event occurring in the late afternoon. Wednesday focusses on Education in the broad sense involving projects that have specific education foci and missions as well as broader topics including outlines, design and results from different project approaches, workshops on how to effectively evaluate education projects, and broader topics involving student knowledge, attitudes and the nature of science. The Wednesday evening will hold the banquet for the main conference with a summary speaker. Thursday will be a case study of the Astronomy Research Seminar which has resulted in many published, student co-authored papers.

#### Background to the conference

For several centuries, starting with Galileo, astronomical research was conducted with small optical telescopes by both professional and amateur astronomers. In more recent times,

professional astronomers have transitioned to mainly using large ground and space telescopes for their research, while amateur and student astronomers have supported the professionals with small telescope observations.

Technological development in the late twentieth century, such as robotic telescopes, the Internet, real-time remotely accessed telescopes, high-quantum-efficiency CCD cameras and powerful PCs, taken together, revolutionized small telescope research. Suddenly it was possible for students at schools and universities far and wide to conduct research without purchasing and maintaining telescopes, nor did they need to contend with light polluted skies, poor weather, or long drives to cold, dark observatories.

It was envisioned, early on, that as these robotic telescopes proliferated, a flood of students would experience a genuine research experience. In 2003, John Percy said he could "... envision a National (or International) facility, consisting of a large farm of telescopes, and a carefully-developed set of curriculum-connected projects, which could serve tens of thousands of students at any one time." As published "scientists," the hope was that many of these students would become professional research scientists, or at least science-informed citizens that extended our knowledge of the cosmos and discovered innovative solutions to the many problems we face as a global community.

Since the 1990s, hundreds of millions of images have been taken by students at remotely located robotic telescopes—some via queues and other in real time. However, while often educational to some extent, only a small fraction of these observations have led to submissions of research results to data repositories such as the AAVSO or the MPC, and only a miniscule fraction of these voluminous observations have led to student co-authored papers in scientific journals. Clearly an opportunity exists to facilitate and promote active student research using robotic telescopes that results in contributions to science, be they observations added to organized, publicly-accessed data bases or published observational results.

The rapid development of technical and educational technologies over the last few decades has placed us at a point where student research has the potential to truly blossom. This field, however, still lacks the student impact and larger scales that were dreamt of by the early pioneers.

Many of the pioneers and luminaries from the early era of robotic and remote telescopes will be attending this conference and will provide their historical outlines and perspectives. People involved with the numerous current projects tackling current science, engineering, and education challenges will provide outlines of the current playing field and its boundaries. During the conference we will examine past and current student research with remotely-located robotic telescopes, and will suggest how teaching and especially educational evaluation could be improved.

Through a variety of presentations, discussion panels, and forums, the challenges and pathways for the future will be described and potential solutions outlined. We hope that conference participants will share their projects and endeavors, their evaluations of what has worked and not worked, and provide input into our understanding of the current status and potential future directions of student astronomical research and education using remotely located robotic telescopes.

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## **INTERNATIONAL SYMPOSIUM ON EDUCATION IN ASTRONOMY & ASTROBIOLOGY, JULY 3-7 2017**

The International Symposium on Education in Astronomy and Astrobiology will be held 3-7 July 2017 in Utrecht, the Netherlands. This international symposium, co-sponsored by the International Astronomical Union (IAU) and the European Astrobiology Campus (EAC), is designed to bring education research in astronomy in general, and in astrobiology in particular, to the professional scientific community.

Education has always played a large role in the field of astrobiology and in part this workshop is a follow-up to the successful International Workshop on Education in Astrobiology (IWEA) held in Höör, Sweden, in 2013. On the other hand, education research has seldom been the main subject in IAU events, yet the scientific results from this field have a great potential to improve the teaching and learning of astronomy for students of all ages. New results and research methodologies from the cognitive and learning sciences domains can, however, be of large influence on the work of educators but generally, professional astronomers are not fully aware of the results from astronomy education research.

With this first meeting in astronomy education and in combination with the growing subdiscipline astrobiology, we aim to strengthen both fields through cross teaching collaborations. The symposium is designed specifically to expand awareness of the results of the cognitive and learning sciences, as well as to provide a forum for active scholars in astronomy and astrobiology education.

The deadline for abstract submission is 15 April. The early registration deadline is 1 May. For more information, contact [ise2a@uu.nl](mailto:ise2a@uu.nl).

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## BOOK REVIEWS

### **THE GLASS UNIVERSE: HOW THE LADIES OF THE HARVARD OBSERVATORY TOOK THE MEASURE OF THE STARS**

Dava Sobel, *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of the Stars* (New York: Viking, 2016). xii+324. ISBN-9780670016952. HB \$30.00.

Since 2009, I have served as a book reviewer for the newsletter of IAU Commission 46 for Astronomy Education and Development, and, more recently of IAU Commission C1, its successor. Over those years, I have had free hand in choosing which books to review and in what order. As a colleague, fan, and admirer of Dava Sobel, whom I first met at a September 2001 meeting of The Meteoritical Society held at the Gregorian Pontifical University in Rome, I would have in due course come around to sharing my thoughts on her new book with the readers of this newsletter. Early one January morning, however, I found in my inbox this urgent email request from Beatriz Garcia, the president of the commission (though I have taken the liberty of tinkering with her English): “I just saw a web listing indicating that Dava Sobel (whose books I love!) has written a new book. I think it will be a good choice to include in our newsletter book review column. Annie Cannon is one of my heroes in Astronomy, so...it is a good moment to talk about her and her magnificent work.” So, although Larry Marschall, editor of our newsletter, has several book reviews of mine already lined up and ready to go, I am happy to gratify Beatriz and push Sobel’s fine addition to her impressive oeuvre to the head of the line.

I propose, however, to focus briefly not only on Beatriz’s astronomical hero but also on several of Cannon’s colleagues at the Harvard College Observatory, where they worked for the forward-thinking directors Edward Pickering and his successor, Harlow Shapley. I also propose not only to summarize their work, with which I expect most readers of this review will be familiar, but also to pass on some of the interesting tidbits about their lives that make Sobel’s book so engaging.

Let us begin with the mother of them all: **Williamina Fleming** (1857-1911). Born in Scotland, where she had taught school, she was originally hired by Pickering as a housemaid in 1879. Her intelligence made her stand out, however, and she was reassigned to the observatory in 1881 as a photometric assistant—one of Pickering’s so called “harem” of “computers,” who measured and analyzed Fraunhofer lines on photometric photographic plates and in doing so pioneered systems of stellar classification still in use today and discovered new information about the stars. Author of *The Draper Catalogue of Stellar Spectra*, Fleming not only discovered over 300 variable stars and 59 gaseous nebulae but was also the first woman to discover a nova (she discovered 10 in all), the first woman ever to hold a title at Harvard—“Curator of Astronomical Photographs”—and the first American woman to be elected to honorary membership by the Royal Astronomical Society. She loved her work and had only admiring thoughts about Pickering, except when it came to the matter of her salary. In her journal she complains that she earns considerably less not only than the male assistants at the observatory but also than women in similar positions elsewhere. When she died of pneumonia at the age of 54, she had devoted 30 of those years to the Harvard Observatory. In his obituary in *Harvard Graduates’ Magazine*, Pickering wrote, combining

high praise for her work with the genteel paternalism characteristic of the age, that she “formed a striking example of a woman who attained success in the higher paths of science without in any way losing the gifts and charms so characteristic of her sex.”

Next by order of birth is Beatriz’s favorite, **Annie Jump Cannon** (1863-1941). A Wellesley College graduate, she had studied physics there with Professor Sarah Frances Whiting, who had been Pickering’s protégée during his years at MIT. Cannon had also learned to use Wellesley’s 4-inch Browning telescope, through which she observed the Great Comet of 1882, and learned the basics of spectroscopy. Thanks to this training, she became the first of Pickering’s harem to be assigned telescopic work. A less fortunate aspect of her undergraduate years was her bout with a severe case of scarlet fever, which rendered her deaf. Following graduation with a degree in physics in 1884, she spent a decade mastering the new art of photography. She then returned to Wellesley as an assistant to Professor Whiting, who arranged for her to take an astronomy course newly offered at Radcliffe College, the female institution whose courses were given by moonlighting Harvard faculty. She joined Pickering’s “computers” in 1896, and in 1907 was awarded a master’s degree from Wellesley.

Building on the stellar classes devised by Williamina Fleming and Antonia Maury (about whom, more below), Cannon devised her own system for classifying stars, resulting in the OBAFGKM classification still used today. Although she originally constructed this system based on the strength and appearance of certain spectral lines, eventually it became clear that the classification reflected temperatures, with O stars being hot and blue, and M stars cool and red. After Fleming’s death in 1911, the then Harvard president, Abbott Lawrence Lowell, refused to accede to Pickering’s request that Fleming’s university title be transferred to Cannon. The appointment to an expanded title—William Cranch Bond Astronomer and Curator of Astronomical Photographs—was made 27 years later, under the new Harvard president, James B. Conant. Pickering had long considered Cannon the “leading authority on the classification of stellar spectra, and perhaps on variable stars.” When Cannon in 1913 found herself the only woman on an international committee on Classification of Stellar Spectra, she noted in a letter that “Since I have done almost all the world’s work in this one branch, it was necessary for me to do most of the talking.”

Like Fleming before her, Cannon was elected an Honorary Member of the Royal Astronomical Society. Some years later, she became the first woman in the history of the University of Oxford to receive an honorary doctor of science degree. In 1931 she became the first woman to receive the National Academy of Science’s Draper Medal, “for investigations in astronomical physics.” The medal, named for Dr. Henry Draper, a pioneer of stellar photography, was established by his widow, Anna Draper. (Following her husband’s early death in 1882, his widow also funded the Henry Draper Memorial Project, which made possible much of the analysis of the information embedded in Harvard’s glass-plate collection of historical photographs, to which the book’s title alludes.) Only one other woman has received this award in the over 85 years since; in 1989, Martha Haynes shared the medal with Riccardo Giovanelli.

Following her receipt of \$1000 in 1932 as the recipient of the Ellen Richards Research prize of the Association to Aid Scientific Research by Women, Cannon herself endowed a medal in her own name under the auspices of the American Astronomical Society “to be awarded ... to a deserving woman of any nationality.” The first recipient was Cecilia Payne

(later Payne-Gaposchkin, about whom, more below).

Less well-known than Fleming and Cannon but nonetheless a significant figure in astronomical history, and a recurring presence both at the Harvard Observatory and in Sobel's book, is **Antonia Maury** (1866-1952). A niece of Henry Draper and a Vassar graduate with honors in physics, astronomy, and philosophy, Maury joined the Harvard Observatory in June 1888 as the fifteenth female computer. Pickering assigned her the task of studying the spectra of the bright northern stars as part of the Henry Draper Memorial endowed by her aunt. She left the observatory several times, and "often feared she might not receive credit for the years of effort she invested in her classification system" of the spectra of bright northern stars. Maury's focus on "very narrow, very sharply defined hydrogen lines," we learn, influenced Danish astronomer Ejnar Hertzsprung, of the Hertzsprung-Russell diagram.

In 1943, Maury became the fourth recipient of the Annie Jump Cannon Prize. Twenty-six years after her death, the authors of the MK system of stellar classification, which expanded on the Henry Draper Catalogue, dedicated their *Revised MK Spectral Atlas for Stars Earlier than the Sun* "To Antonia C. Maury (1866-1952) Master Morphologist of Stellar Spectra."

**Henrietta Leavitt** (1868-1921) was not involved with the stellar classification project at the Harvard Observatory, but Sobel makes clear that her work on variable stars and her discovery of the period-luminosity relationship has "had an equal, if not greater, impact on progress in Astronomy." In part because Hubble's Law depended on Leavitt's discovery, the executive council of the American Astronomical Society has resolved that the period-luminosity relationship should be routinely known as Leavitt's Law.

Pickering so valued Leavitt's work that, while the standard computer earned twenty-five cents per hour, he paid her a full thirty cents (the equivalent, according to a calculator found with Google, of \$7.37 in 2016). In 1911, Leavitt began to see a correlation between brightness and period in a small number of variables. When Pickering wrote up her results in a *Harvard College Observatory Circular* in 1912, he used the word "law" to describe the relationship Leavitt had demonstrated for twenty-five stars in the Small Magellanic Cloud. Those with higher magnitude had longer periods. Pickering was not the only one to understand that this relationship was a key to determining stellar distances. The scatter-graph developed by Ejnar Hertzsprung in Denmark and Henry Norris Russell in the US, which plotted stars' brightnesses against their temperatures, was strongly influenced by Leavitt's relationship. The diagram was a major step toward understanding stellar evolution.

Although Leavitt received no formal awards, a few years after her death from cancer in December 1921, a letter came in her name to the Observatory from Sweden from an admirer who was unaware she was no longer among the living. Mathematician Gösta Mittag-Leffler, an advocate for the recognition of women's contributions to science, wrote Leavitt. Having learned of her discovery of the period-luminosity relationship, he was "seriously inclined to nominate you to the Nobel prize in physics for 1926." Shapley, who read the letter addressed to his deceased colleague, was granted permission to share its contents confidentially with Leavitt's mother and brother, who survived her.

Last but certainly not least in my summary of some of Sobel's group of pioneering

women researchers at the Harvard Observatory is **Cecilia Payne-Gaposchkin** (1900-1979). Longtime readers of this newsletter may recall my writing about her in two previous reviews, of Stuart Clark's *The Day Without Yesterday*, the third volume of his trilogy, *The Sky's Dark Labyrinth*, and Sylvia Boyd's *Portrait of a Binary: The Lives of Cecilia Payne and Sergei Gaposchkin*. Payne, a graduate of Cambridge University's women's college, Newnham, attended a lecture given by Shapley at the Royal Astronomical Society in London. She introduced herself to him, and he encouraged her to come to the Harvard Observatory. He also arranged for her to receive a Pickering Astronomical Fellowship for Women, named in honor of his predecessor. Unlike anyone else at the Harvard Observatory, she had not only some knowledge of the new quantum physics but had actually rubbed shoulders at the Cavendish Laboratory with two Nobel laureates in the field: Ernest Rutherford, the so-called Father of the Nucleus, and his protégé Niels Bohr, father of the Bohr atom. Shapley was determined that she become the first woman astronomer to earn a Ph.D. for her work at the observatory. When he suggested, however, that she continue Leavitt's photometric work, she insisted on following "her own research agenda, applying the new theories of atomic structure and quantum to the analysis of stellar spectra." Her training made it possible for her to "read a new subtext" in the "runic line patterns, which had helped her predecessors sort the stars into categories.... Each spectrum's thousands of Fraunhofer lines registered the leaping of electrons from one energy level to another as they orbited atomic nuclei."

Payne's doctoral thesis was the first research effort to provide evidence that the stars were made primarily of hydrogen and helium. Princeton's Henry Norris Russell, the international expert on stellar composition, admired Payne's research but balked at the results, which seemed impossible. Confident in her work, Payne nonetheless revised the thesis for publication, adding the phrase "almost certainly not real." Some years later, Russell, based on calculations he collected at the Hooker Telescope at Mount Wilson in Pasadena, but citing Payne's earlier work, published his conclusion that the sun and other stars were, in fact, composed primarily of hydrogen and helium.

Payne remained at the Harvard Observatory, where Shapley remained a staunch supporter. His efforts to have her appointed to the university faculty failed under Harvard president Abbott Lawrence Lowell, but in 1938 Payne-Gaposchkin was appointed Phillips Astronomer by Harvard president James B. Conant. The title, however, did not make her a member of the college faculty or even of the astronomy department. It was not until 1956 that she was named a [full] professor, making her the first woman at Harvard to be promoted to that title. In 1957 she became head of the astronomy department, but not until 1958 did the Harvard Corporation name her the Phillips Professor of Astronomy. Her \$14,000 a year salary, however, was much lower than that of her male colleagues.

Sobel mentions in the course of her sweeping history of the women astronomers at the Harvard College Observatory the New Year's Eve 1929 performance of *The Observatory Pinafore*. Although she doesn't mention the fact in the text, Cecilia Payne played the starring role of Josephine. In her section "Remarks" at the back of the book, however, she notes that the Harvard-Radcliffe Gilbert and Sullivan Players put on "an abridged concert performance" of the work at the American Academy of Arts and Sciences in Cambridge in October 2000, as part of a symposium held in honor of the centenary of Payne-Gaposchkin's birth.



There is much more to Sobel's book than I have noted here, but enough already! Let me end by including a picture of a T-shirt sold at the January 2017 meeting of the American Astronomical Society, which honors three of Sobel's women. I am sure you can figure out who is who.

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