Scientists Who Made Nuclear Astrophysics

Women

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Here we chronicle the contributions women have made to Nuclear Astrophysics: astronomical observations, visual and spectroscopic identifications, star classifications and catalogues, prediction and discovery of stellar objects, construction of instrumentation, theoretical and experimental discoveries of nuclear materials, physics explanations, mathematical derivations and chemical interpretations of all things -- galactic and beyond.

Female role models reduce the impact on women of "stereotype threat" [1], i.e., of "being at risk of confirming, as a self-characteristic, a negative stereotype about one's social group" [2]. This can lead women scientists to underperform or to leave their scientific career because of negative stereotypes such as that they are not as talented or interested in science as men. Sadly, history rarely provides role models for women scientists; instead it often renders these women invisible [3]. In response to this situation, we present a selection of twelve outstanding women who helped develop nuclear astrophysics - some famous, some less so. The final aim is to produce a calendar, which will be translated into several languages.

[1] See, e.g.,` `Delusion of gender'' Cordelia Fine, 2010, W.W. Norton and Co. ISBN 0-393-06838-2, page 36 and references therein.

[2] Steele & Aronson, 1995, "Stereotype threat and the intellectual test performance of African - Americans" *Journal of Personality and Social Psychology, 69,* 797-811.

[3] ``...by moving a woman to the background, by making her disappear completely from the narrative, by minimising her involvement, by fiddling with the story [...], by diminishing or stealing her work, by confining her to the role of 'wife of' or 'sister of' [or 'assistant of'], auto-erasure…"
http://www.cafebabel.co.uk/society/article/georgette-sand-when-history-makes-women-invisible.html

To honor the women who have influenced the development of Nuclear Astrophysics

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To encourage young scholars to choose Nuclear Astrophysics as their career path and to present to them good role models for the process.

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To educate the scientific community and the general public about the significant role women have played and continue to play in the development of Nuclear Astrophysics.

"If frustrated in one's endeavor by a stone wall or any kind of blockage, one must find a way around – another route towards one's goal."

– a guiding principle formulated by Margaret Peachey Burbidge, 1945, on being turned down for a Carnegie Fellowship due to her gender.

1 Marie Skłodowska Curie
1867 - 1934

Mention nuclear physics and the first name that comes to mind is that of Polish-born Marie Skłodowska Curie. With her husband Pierre, Marie investigated radiation phenomena. She is credited with the development of the theory of radioactivity; the techniques for isolating radioactive isotopes; and the discovery of two chemical elements, polonium and radium. The Curies were awarded the Nobel Prize in Physics in 1903 and Marie won another, in Chemistry in 1911, becoming the first person to claim Nobel honors twice. After Pierre's tragic death in 1906, she accepted his faculty position at the Sorbonne. Marie was a humanitarian who worked to save solders' lives during WWI. She invented and developed a fleet of mobile x-ray vehicles; designed and taught a radiology course; and then, operated one of the x-ray vehicles on the battlefield. She is the founder of the Curie Institutes in Paris and in Warsaw, major centres for medical research today. Marie's outstanding achievements and response to challenges have inspired and will continue to inspire female scientists for generations to come.

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2 Lise Meitner
1878 - 1968

Lise Meitner was born in Vienna and studied Physics, Mathematics and Philosophy at the University of Vienna. In 1906, she was the second woman at the university to receive a doctorate in Physics. She moved to Berlin in 1907 where she met Otto Hahn, with whom she collaborated for the following 30 years. She was the first woman to become a full professor in Germany. Lise Meitner was Jewish; her life in Nazi Germany became increasingly at risk. She fled to Sweden in 1938 where she was able to continue her research. One of her best and most significant scientific achievements was the theoretical explanation of nuclear fission, a work that she published with her nephew Otto Frisch in 1939. Otto Hahn was awarded the Nobel Prize in Chemistry in 1944 for the experimental component of this work. She also studied radioactivity and together with Otto Hahn discovered a number of radioactive isotopes, such as Protactinium 231. Lise Meitner was nominated for the Nobel Prize 48 times (29 in Physics and 19 in Chemistry), but none was ever awarded to her.

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3 Ștefania Mărăcineanu
1882 - 1944

Ștefania Mărăcineanu was born in Bucharest, Romania and graduated from the Faculty of Science of the University of Bucharest in 1910. After a teaching career in secondary schools, at the age of 40, she obtained a fellowship at the Radium Institute in Paris working with Marie Curie on radioactivity. She defended her PhD in 1924, at the Sorbonne with the subject 'Research on the [decay] constant of polonium and the penetration of radio-active substances with metals'. Although she did not explain the phenomenon theoretically nor prove it experimentally, she may have introduced the philosophical concept of artificial radioactivity- the potential of a radioactive element to emit a substance and induce radioactivity in a stable element. Her complex observations which followed after graduation were the subject of intense experimental debates within the international community. In 1930, Stefania returned to Romania and installed the first Radioactive Laboratory where she continued her research. Since 1937, she was a correspondent member of the Romanian Academy of Science, until she died of cancer due to radioactive irradiation.

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4 Cecilia Payne Gaposchkin
1900 - 1979

Cecilia Payne-Gaposchkin was a British-American astronomer. In 1919, she enrolled at Cambridge University and became fascinated with astronomy after attending a lecture by Arthur Eddington on how solar eclipses can be used to test general relativity. She later moved to America, where she received a PhD from Radcliffe College at Harvard. During her PhD, she made the breakthrough discovery that the strength of the stellar spectral lines depend not only on the surface composition of the star, but also on the degree of ionisation at a given temperature. She concluded that hydrogen and helium are much more abundant in stars than all other chemical elements - an idea so revolutionary at the time that she was initially discouraged from publishing her results. In 1956, she became the first woman full-professor at Harvard's Faculty of Arts and Sciences. Later she became the Chair of the Department of Astronomy, being the first woman to ever chair a department at Harvard.

Photo Credit:
Courtesy: Historical Archives, Newnham College Cambridge

5 Maria Goeppert Mayer
1906 - 1972

Magic nucleon numbers, reflected in nuclear properties and in the observed solar abundances, had puzzled physicists for a long time. In 1949, Maria Goeppert Mayer came up with a brilliant solution: couple the nucleon spin with the orbital parameter to define the gaps in the shell structure. She began her studies in Mathematics before pursuing a PhD in Physics at the University of Göttingen, which she obtained in 1930. After marrying, she moved to the United States where her husband had accepted a position at Johns Hopkins University. Strict rules against nepotism prevented the university from also hiring her as a faculty member and she was given a job as an assistant. When the couple moved to Columbia University, Maria was allowed to have an office, but received no salary. Later, she was paid to work for the Manhattan project, holding positions also at the University of Chicago and Argonne National Laboratory. Her work on magic numbers won her the Nobel Prize in 1963 with Hans Jensen for their discoveries concerning nuclear shell structure.

Photo Credit: AIP Emilio Segrè Visual Archives, Born Collection; courtesy of Churchill Archives Centre, Cambridge.

6 Toshiko Yuasa
1909 - 1980

Toshiko Yuasa was the first woman nuclear physicist in Japan. She graduated in 1934 from Tokyo Burnika University where she specialised in spectroscopy and in 1939; she won a prestigious French scholarship. After a month of sailing, she arrived in Paris to start working with Frédéric Joliot-Curie on artificial radioactivity. In 1943, Toshiko was awarded a PhD from the Collège de France on the continuous beta-ray spectrum in artificial radioactive material. As a Japanese national she was forced to evacuate to Berlin in 1944, where she worked only for a few months building a double spectrometer before returning to Japan. Because nuclear research was banned in Japan after the war, she could not continue her academic career there and in 1949, she came back to France to continue her research at CNRS. In 1956, Toshiko published an article warning about the dangers of hydrogen bomb testing at Bikini Atoll. In 2012, Ochanomizu University established a scholarship in her name, supporting Japanese women to study abroad.

Photo Credit: Courtesy Ochanomizu University, History Museum, Yuasa Yuko Materials: Picture 005

7 Georgeanne R. (Jan) Caughlan
1916 - 1994

At the core of nuclear astrophysics are the rates at which nuclei inside stars combine to produce new nuclei. Not surprisingly, such information is one of the most sought after in the community. The very first efforts to provide extensive compilations of nuclear reaction rates based on the most current experimental information were performed by William Fowler and Georgeanne (Jan) Caughlan. Jan's job was to study the experimental data for the reactions important for stars in order to derive their rates. This work resulted in some of the most famous papers in the field, such as Caughlan & Fowler 1988, which has received more than 1100 citations to date. Interestingly, Jan's career followed a very nontraditional path. After receiving her degree in Physics she decided to dedicate herself to raising her five children. Later on, she went back to Physics, obtained her PhD at the age of 48, and became Professor at the age of 58.

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8 Edith Alice Müller
1918 - 1995

Edith Alice Müller was born in Madrid of Swiss parents. She finished her studies at ETH Zurich and obtained her PhD in solar physics in 1943. She worked in Zurich, Cambridge (UK), Ann Arbor (USA), Neuchatel and Geneva, becoming full professor in 1972. Edith worked both on the observation and theory of the solar atmosphere. In 1960, while at Ann Arbor, with her collaborators L. Goldberg and L. H. Aller she published a paper that was extremely influential on "The Abundances of the Elements in the Solar Atmosphere". With more than 430 citations, the paper remained a standard for the following 20 years. Edith was fluent in English, French, German, and Spanish and the first woman to be appointed General Secretary of the International Astronomical Union (IAU). She played an important role in promoting Astrophysics and international scientific cooperation. The "Edith Alice Müller Award" will be granted to an outstanding PhD thesis in Switzerland for the first time in 2018 in recognition of her scientific research on the composition of the Sun and for her involvement in promoting Astrophysics internationally.

Photo Credit:
Courtesy R. J. Rutten, Utrecht University

9 E. Margaret Peachey Burbidge
b. 1919

Margaret Burbidge has played a central role in shaping the field of nuclear astrophysics. She has been a pioneer all her life, as a scientist and as a woman scientist. Since childhood, she was fascinated by stars and excessively large numbers. Her interests merged upon reading Sir James Jeans' books on astronomy. She received her PhD from the University of London Observatory in 1943. Her early research focused on chemical abundances in stars. Margaret entered the field of astronomy in the 1940s when it had virtually no women, and in 1945 she was turned down for a Carnegie Fellowship due to her gender. Thanks to her influence, women can observe at any American observatory today. The landmark 1957 paper by M. Burbidge, Burbidge, Fowler, and Hoyle: "Synthesis of the Elements in Stars" thrust the theory of stellar nucleosynthesis into the scientific spotlight. For her pioneering research, Margaret has received 12 honorary degrees and numerous honors, including being a Fellow of the Royal Society of London. She has also held many leadership positions, including being the first woman president of the American Astronomical Society. She is currently Professor Emeritus at the University of California, San Diego.

Photo Credit:
American Astronomical Society (2001) Committee on the Status of Women in Astronomy, A Tribute by Vera Rubin

10 Erika Helga Ruth Böhm-Vitense
1923 - 2017

Erika Böhm-Vitense was the first scientist to accurately describe convective mixing in stellar interiors using a prescription that has been widely adopted for half a century now in all stellar evolutionary codes. Her 1958 paper, written in German, is a crucial contribution to the "mixing-length" theory that to this day remains a puzzle. The paper has been cited more than 1200 times; seventy, of which occurred in 2017. Erika was born in Kurau, Germany, and she obtained her doctoral degree in 1951 in Kiel. In the 1960s and 1970s she combined theory and observations in optical studies of a large variety of objects: from helium stars, to supergiants and open clusters, to name a few. In 1968 she moved to the USA with her husband where she obtained a senior research associate position at the University of Washington and in 1971 she became a Professor. Erika received many awards for her scientific works, including the Annie Jump Cannon Prize from the American Astronomical Society in 1965 and the Karl Schwarzschild Medal from the Astronomische Gesellschaft in 2003.

Photo Credit: Courtesy Department of Physics, University of Illinois at Urbana-Champaign and AIP Emilio Segrè Visual Archives

11 Dilhan Ezer Eryurt
1926 - 2012

Dilhan Eryurt was born in Izmir. After graduating from the Department of Mathematics and Astronomy of Istanbul University, Dilhan completed her doctorate in Astronomy at Ankara University in 1953. After completing her PhD she moved to Canada, and collaborated with G. W. Cameron. Later, she worked at Indiana University, NASA's Goddard Space Flight Center, and the University of California. While at NASA, she was the only woman astronomer working at the institution. Dilhan's work revealed a new, striking fact about the Sun: that it was much brighter and much warmer in the past than it is today. In 1969 she received the Apollo Achievement Award for her contributions to the first landing on the Moon project. Meanwhile, she organized the first National Astronomy Congress in Turkey. She founded the Astrophysics branch within the Physics Department at the Middle East Technical University, later becoming the Chair of the Department and the Dean of the Faculty. Dilhan is regarded as the mother of Astronomy in Turkey, where her life dedicated to science has left a tremendous legacy.

Photo Credit:
Courtesy METU Physics Department

12 Beatrice Muriel Tinsley
1941 - 1981

Beatrice Tinsley was a true pioneer of the chemical evolution of galaxies. In her 1980 review article on "Evolution of the Stars and Gas in Galaxies" we find a brilliant explanation of the modelling of galaxies and beautiful predictions, which we still discuss, today using data from large telescopes and fast supercomputers. Her family emigrated when she was very young, from England to New Zealand and she made up her mind to become an astrophysicist at the age of 14. In 1963 she moved to the United States. With her PhD dissertation awarded by the University of Texas in 1967, she started her journey into achieving international fame as a cosmologist. Her work was considered revolutionary with the discovery that the Universe was in a state of infinite expansion. In 1978, she became the first female Professor of Astronomy at Yale University. Her shining career was snuffed out prematurely when she died from cancer at the age of 40. But her papers will never die - her research area is being further developed today by many female researchers, notably Francesca Matteucci and Monica Tosi.

Photo Courtesy of
Brian Tinsley, U. of Texas at Dallas and
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Fun Facts

Curium, Cm (element 96) was named to honor Marie and Pierre Curie.

Meitnerium, Mt (element 109) was named to honor Lise Meitner.

Marie Curie invented the first "radiologic car" – a mobile, military hospital, x-ray unit with photographic processing equipment for use during WWI.

In order for Marie Curie to take one of her radiologic cars to the WWI battlefield, she had to first learn to drive, to change flat tires, and to clean the carburetor of a car.

Marie Curie's daughter, Irene Joliot-Curie and grand-daughter, Helene Langevin-Joliot became nuclear physicists and Helene's son, Yves Langevin became an astrophysicist.

In 1960, Asteroid 5490 Burbidge was named to honor Margaret Burbidge.

Nineteen years after receiving a PhD in France, Toshiko Yuasa earned a second doctorate in Japan from Kyoto University.

Cecilia Payne-Gasposchkin worked as a "Human Computer" for the Harvard College Observatory, reading spectroscopic lines on glass plates in order to interpret star composition and temperature. [The Glass Universe –Dava Sobel, Viking Press 2016.]

In 2009, the University of Canterbury formed the Beatrice Tinsley Institute for New Zealand Astronomy and Astrophysics.

Marie Curie offered to melt down her gold Nobel medals to help the WWI effort in France but the French National Bank refused to accept her offer.

Asteroid 7000 Curie was named for Marie and Pierre Curie. It was discovered on 11/6/1939 by Fernand Rigaux at Uccle, Belgium. [L.D. Schmadel, Dictionary of Minor Planet Names, 3rd ed., Springer 2013]

Lise Meitner was listed as inventor on a US patent for the preparation of radiothorium. The patent was filed (and owned) by a German company, Dr. Knöfler & Co. It was a valid patent until 1933 (expiring because it reached its maximum legal lifetime of 20 years). [Radiothorium is now known as Thorium-228.] Patent US1076141.

Toshiko Yuasa moved to France after WW II and worked at the CNRS. During the time there, she filed two patent applications, one (FR1145132) for a "Calculation rule in particular for radioactivity measurements" and one (FR1235474) for a "stereo-camera."

Mount Tinsley, a mountain in Fiordland, New Zealand was named in honor of Beatrice Tinsley. It is located in the Kepler Mountain range, height 1537 m, 15 km west of Te Anau in Manapouri, GR.

Asteroid 3087 Beatrice Tinsley, a minor planet, discovered at Mt John Observatory, New Zealand in 1981 – the year Beatrice Tinsley died was named in her honor.

In 2003, Romfilatelia, Romania's stamp issuing authority released a set of 3 stamps called 'Women and Inventics'. The 1LEI stamp features a photo of Marie Curie with Stefania Maracineanu's name on it. [TheStampCollector.net/Romanianinventics.html.]

At the start of WWI, Marie Curie hid her supply of Radium in a bank vault in Bordeaux.

Dilhan Ezer Eryurt bequeathed all of her assets to the Directorate of National Education in Turkey for the construction of a kindergarten and a girl's dormitory.

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