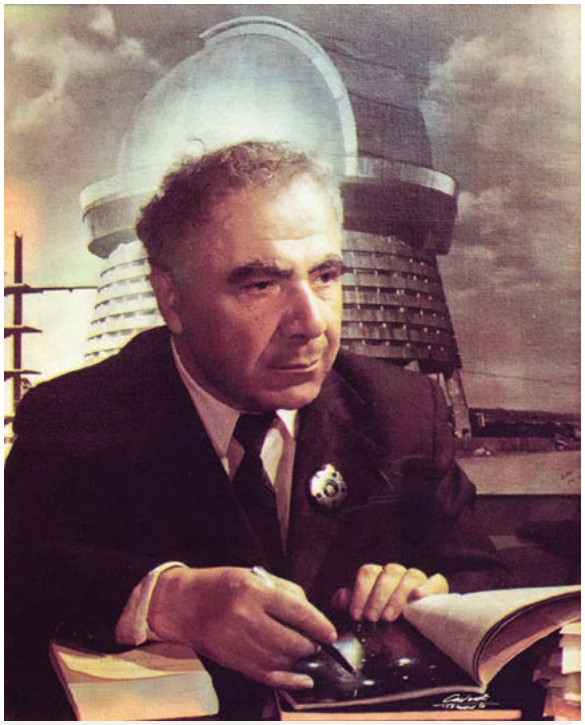
VIKTOR AMBARTSUMIAN AND THE SCIENCE OF BYURAKAN

By Larry Mitchell

Armenia is not a country that most Westerners can pinpoint on a map of the world, nor are they aware of the many scientific accomplishments attributable to this country, located east of Turkey. Byurakan Astrophysical Observatory (BAO) is located near the village of Byurakan, located on the slope of Mount Aragatz, and home to one of the most prolific observatories in the world. It was founded in 1946 by Viktor Ambartzumian (1908–1996) and quickly became one of the main astronomical centers of what was then the USSR. Under Ambartsumian's guidance, Byurakan astronomers have been mainly concerned with the study of unstable and variable objects. Over the years the observatory has discovered thousands of galaxies, star clusters and stellar associations, flare stars, supernovae, Herbig-Haro objects, and nebulae. The largest telescopes have apertures of 2.6 and 1.0 meters.

Today, Viktor Ambartsumian is treated with reverence in Armenia as his contributions to astronomy are huge. He is less well-known in the West because many of his discoveries were made during the unfortunate Cold War. Ambartsumian got an early start by giving a lecture at Yerevan State University when he was only 16 years of age on Einstein's new theory of relativity. His first scientific article was published two years later in 1926. In 1930 he and Dimitri Ivanenko published a well-received paper demonstrating that atomic nuclei could not be made from protons and electrons, and two years later this was confirmed when neutrons were discovered. His 1958 textbook, *Theoretical Astrophysics,* became a classic, and solidified his reputation as a recognized expert in astrophysics, mathematics, and theoretical physics. He was a kind and modest man endowed with a great sense of humor, which won him many scientific friends worldwide. Ambartsumian was elected president of the International Astronomical Union from 1961 to 1964, at the height of the Cold War.

While still in his twenties he reasoned that novae and planetary nebulae were expanding outward. Ambartsumian's 1932 paper, "On the Radiative Equilibrium of a Planetary Nebula," is today considered a cornerstone of the modern theory of gas nebula evolution. His first-ever evaluation of the gas mass ejected in the nebulae shells and the peculiarities of their spectra led to significant advances in stellar evolution. He was still a young man when his discoveries properly identified the changes in the life of a star. While the "established" astronomical community thought these nebulous structures were gravitationally collapsing, he boldly asserted that expansion, rather than contraction and condensation, were the "the basic evolutionary processes in the universe."

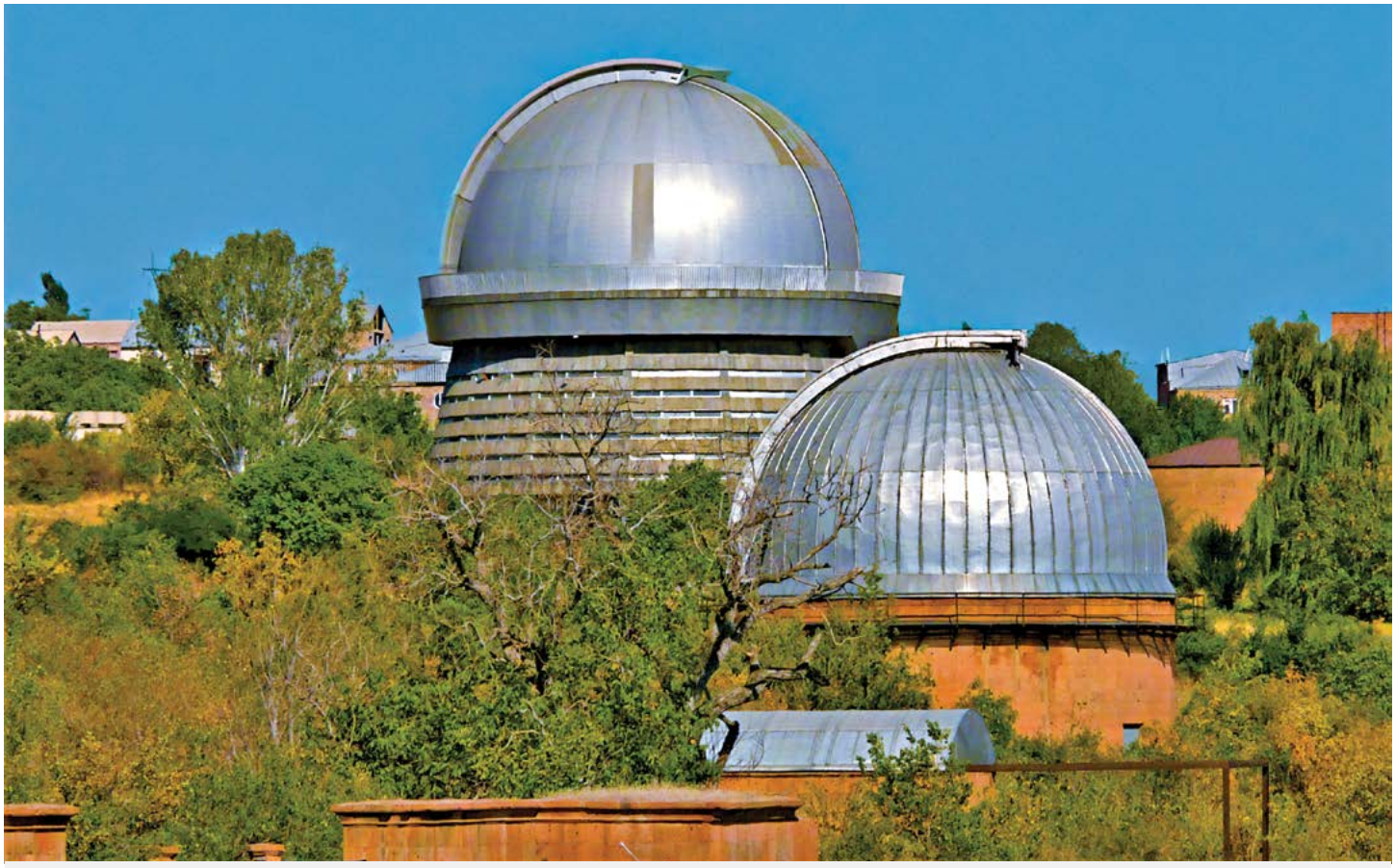


Victor Ambartsumian circa 1970s, unknown photographer, Wikimedia commons

In 1947 Ambartsumian published a famous paper titled "The Evolution of Stars and Astrophysics" where he announced the discovery of a new type of astronomical system known as an OB or stellar association. Before his proposal, the predominant scientific opinion was that all stars were created simultaneously billions of years ago and they are currently only evolving. His proposal that new star formation is underway in the galaxy at the present time proved revolutionary in stellar cosmology circles, and he correctly stated these stellar associations were young, newly formed, and they were expanding. Proof of their youth was often the presence of nebulae and young massive stars which disintegrate in only about 10 million years.

This thought process led to his studies of flare stars, the physics of young stars and his concept of "protostars." He stated that protostars were super-dense protostellar matter in an early, unstable stage of star formation. He discovered that T Tauri stars produce Herbig-Haro objects, which are newly ejected material from the protostar. The T Tauri stage is short-lived and is followed by the star eventually settling down to become a main sequence star. He correctly reasoned that the formation of stellar associations owes itself to the disintegration of massive protostars. These were originally considered radical ideas, but they became universally accepted.

Ambartsumian is most widely known for his studies and discoveries in extragalactic

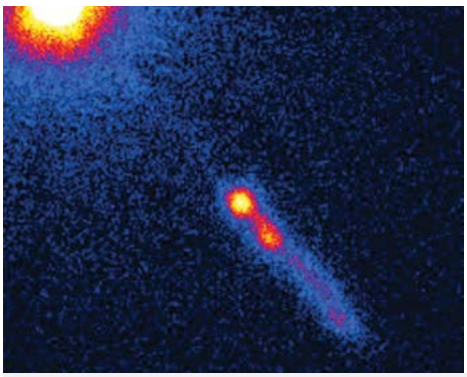


Part of Byurakan Observatory, Photo by Rita Willeart via Wikimedia Commons, Creative Commons Attribution 2.0 Generic License

astronomy. Before Ambartsumian, radio galaxies were thought to be the product of a collision, and the radio lobes were thought to be condensing inward. In 1956, he discovered that radio signals were coming from *outside* the Milky Way, the giant radio lobes could not happen due to the collision of two galaxies, and the lobes were expanding outward. He stated in his textbook *Theoretical Astrophysics* that radio galaxies may represent systems in close proximity that were formed from super-dense formations of stellar material. He did not say "black holes," a term not used until 1964, but he was getting close to the concept.

Before Ambartsumian, mainstream astronomy assumed that "spiral nebulae" (galaxies) were fully formed quiescent systems originating with the Big Bang, which had a rich past and they would not change radically in the future. These structures were composed of millions of stars and were therefore huge gravitational centers where absolutely nothing could escape. In 1908, Edward Fath of Lick Observatory discovered that some galaxies (for example, M77) had unusually bright central regions, and this was followed up by Carl Seyfert of McDonald Observatory in 1943 who wrote a paper about galaxies whose spectra contained bright and unusually broad hydrogen emission lines. These were indications that gas clouds within the nuclei of these galaxies attain record velocities; these objects became known as "Seyfert galaxies." However, Seyfert said nothing about the cause of this activity. In a series of papers beginning in 1954, Ambartsumian proved that an explosion is occurring in the nuclei of these galaxies. His theory was based upon a newly formed young object he discovered which he posited was ejected from the core of the spiral galaxy NGC 3561, as it is being ripped apart by its nearby massive elliptical galaxy, NGC 3561A. This object has become known as "Ambartsumian's Knot" and is the progenitor of a new class of galaxies known as blue compact dwarf (BCD) galaxies.

He presented his findings at the scientific Solvay Conference in Liege, Belgium, in 1958 and it caused a huge sensation. It took courage to present these ideas to a group of influential astronomers who he knew would reject any idea of the origin of galaxies in any formation process other than the Big Bang. Not only was he stating that galaxies actually eject material, but he also proposed that new galaxies are being formed in our time. Some of the leading astronomers of the day, Jan Oort, Allan Sandage, and Subrahmanyan Chandrasekhar, all rejected his ideas. However, when an optical quasar (3C 273) was discovered in 1963 and a jet 200,000 light-years long of material being ejected from the core was seen, they recognized that Ambartsumian had been right all along, congratulating him on his monumental discovery. Sandage later reflected that "today, not one astronomer would deny the mystery



Chandra X-ray image of the 3C273 quasar and its jet of ejected matter. When first observed in 1963, this object served to vindicate Ambartsumian's theory. Credit: NASA

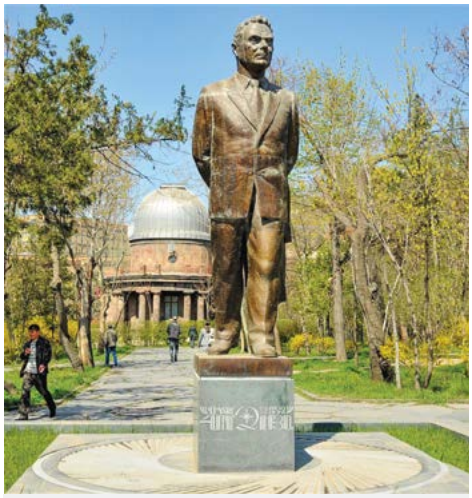
surrounding the nuclei of galaxies or that the first to recognize the rich reward held in this treasury was Viktor Ambartsumian." Today we know that this "active galactic nuclei" (AGN) phenomenon, which occurs in galaxies with active centers, is due to a feeding black hole or a super massive star-forming region.

As part of his explanation of what happens in the cores of Seyfert galaxies, Ambartsumian found that gas outflows were collimated bursts of material which sometimes formed young blue satellite objects, and that AGNs play a decisive role in the birth and evolution of galaxies. He also discovered that the emission of galaxies which contain AGNs frequently have an ultraviolet excess in their spectra. At the time, very few of these UV-excess objects were known, so he instructed Beniamin Markarian to conduct a prism survey for these objects, which he famously accomplished in a set of two surveys. In 2011 the Markarian Survey entered UNESCO's "Memory of the World" documentary heritage list.

Other areas in which Ambartsumian was active include the determination of the age of our galaxy, star formation in molecular clouds, the evolution of galaxies, pulsars, and studies of rarefied plasmas in gaseous nebulae. He wrote 20 books and booklets, published over 200 scientific papers, and was a member of 28 academies from all over the world. Every two years the $500,000 Viktor Ambartsumian Prize is awarded to an outstanding scientist from any country. Halton Arp recounts how Jan Oort once told him, "You know, Ambartsumian was right about absolutely everything." This true genius died in August 1996 in Byurakan and is buried next to the Grand Telescope tower.

A few words should be said about other BAO astronomers. Beniamin Markarian discovered in 1961 that the chain of galaxies emanating from M84 and M86 were gravitationally bound and became known as the "Markarian Chain" of galaxies. In doing so, he also discovered the heart of the Virgo Galaxy Cluster. He worked on the physics of stars and stellar clusters but is best known for his Markarian object surveys for UV-excess objects, conducted on the 1.0-meter Schmidt telescope. His first Byurakan survey lasted from 1965 to 1980 and was published in 1989. His second survey was conducted from 1978 to 1991 and published in 2005 after his death. He discovered 1,515 UV-excess galaxies, which became known as "Markarian galaxies," and to date over 2,500 professional papers have been devoted to these galaxies and stellar objects. Misha Kazarian extended the hunt for UV-excess galaxies which did not overlap Markarian's work, finding an additional 706 objects. Kazarian is also considered an expert in stars and nebulae and has published over 100 scientific papers.

Marat Arakelian was a brilliant astrophysicist who proved the extragalactic origin and evolution of quasars and analyzed approximately 800 faint galaxies and quasars. He published over 100 professional papers but is best known for his catalog of 621 Arakelian galaxies published in 1975. He wanted to know if there is a correlation between high surface brightness (HSB) galaxies and AGNs, and he proved there was. Unfortunately, Arakelian suddenly passed away at the height of his productivity at the young age of 54.



Statue of Ambartsumiam in Yerevan. Photo by Soghomon Matevosyan, Via Wikimedia Commons, Creative Commons Attribution-Share Alike 4.0 International license

A faint compact group of galaxies was found by Ambartsumian in 1957; these were so dim they were originally thought to be a faint compact group of stars. Ambartsumian instructed Romela Shahbazian to search for more of these objects. She examined over 200 Palomar Observatory Sky Survey (POSS) prints and discovered 377 of these groups, which came to be known as Shahbazian compact galaxy groups. They contain a high percentage of elliptical galaxies and are billions of light-years away.

Byurakan Astrophysical Observatory is also a center for the study of nebulae. In 1965, Elma Parsamian and Violetta Petrosian published a catalog of 106 cometary nebulae and Parsamian independently published a catalog of 534 hydrogen-alpha stars located within M42, the Orion Nebula. During her career she has published 136 professional scientific papers. Grigor Gurzadyan authored over 200 papers and ten books devoted to the structure of planetary nebulae, flare and binary stars, and gamma-ray repeaters. In the 1960s, Gurzadyan predicted the dynamics of magnetic fields within planetary nebulae, which were not officially discovered until 2005.

All of these people were inspired by the genius of Viktor Ambartsumian and today the discoveries continue. Areg Mickaelian, who has published over 300 scientific articles, is the director and lead scientist overseeing a huge curriculum, among which are the foundation of the IAU Regional Astronomical Center in 2015, the creation of the Armenian Virtual Observatory (ArVO) in 2005, and the well-attended regular Byurakan International Summer Schools for young researchers and students since 2006. The Byurakan Astrophysical Observatory may be the most prolific observatory for discoveries related to astronomy and theoretical astrophysics of any observatory anywhere in the world. ✶