Origins of the Expanding Universe: 1912-1932
September 13-15, 2012
Flagstaff, Arizona

Abstracts

Fred Adams -- *The FUTURE History of Cosmic Expansion (and constituent astrophysical objects)*

The discovery of the cosmic expansion had a profound influence on our understanding of the past history of the universe. This talk outlines the future history of the cosmos as it continues to expand: we consider the evolution of planets, stars, galaxies, and the universe itself over time scales that greatly exceed the current cosmic age. The discussion starts with the effects of accelerated cosmic expansion, which causes every galaxy cluster to become its own island universe. Within these bound structure, the lowest mass stars continue to burn hydrogen over much longer times, and evolve off the main-sequence near the epoch when conventional star formation ends. The stellar population is thus converted into degenerate remnants -- neutron stars, white dwarfs, and brown dwarfs. Although the supply of interstellar gas grows depleted, star formation continues at an attenuated rate through brown dwarf collisions. As the galaxy evaporates via dynamical relaxation, dark matter particles are accreted by white dwarfs, where they annihilate and keep the stellar remnants relatively warm. Over longer time scales, the degenerate objects evolve and sublimate through the decay of their constituent nucleons. When the white dwarfs and neutron stars disappear, black holes are the brightest astrophysical objects, slowly losing their mass as they emit Hawking radiation. After the largest black holes have evaporated, the universe slowly slides into darkness.

Lucia Ayala – *Space, time and structure: galactic redshifts in a historical context*

I will present an overview of the evolution of concepts about large-scale structure of the Universe in western societies since the 16th century until today. The goal is to analyze the relevance of Slipher's discoveries from a general historical perspective, locating the significance of the introduction of redshift in astronomy and western worldview within a comprehensive integrative approach. To do that, I will pay attention to the impact in historical cosmic models of concepts such as space, structure and time, from which other key ideas were derived, namely cosmological evolution, shape, or expansion, among others. The actual shift involved in the discovery of redshifts in galaxies will be especially emphasized as one of the main change of paradigms in this context. Since I am specialized in the visual history of astronomy, the arguments will be woven through some of the most relevant images that visualized each theory (many of which are not sufficiently known by contemporary astronomers), while recurrent misunderstandings and misinterpretations echoed in the traditional historiography will be clarified.

Daniel Armstrong – (Poster Paper)

Ari Belenkly -- *The Big Bang and Accelerating Universe: Alexander Friedman and the Origin of Modern Cosmology*

Ninety years ago, in 1922, Alexander Friedman (1888-1925) demonstrated for the first time that the General Relativity theory admits non-static solutions and thus the Universe may expand, contract, collapse, and even be born. His fundamental equations describing possible scenarios for the evolution of the world provide the basis for the current cosmological theories of the Big Bang and the Accelerating Universe. Friedman's unexpected achievement initially met with strong resistance and since then has been often misrepresented in the literature. This paper clarifies some persistent confusion regarding Friedman's cosmological theory in comparison with corresponding theories by Albert Einstein, Willem de Sitter, Arthur Eddington, and Georges Lemaître. Friedman's little known topological and astronomical ideas of how to check the General Relativity in practice are also described.

Greg Bothun -- *Cosmological Models: Tenacious Myths and Epicycles*

The human study of cosmology has produced a series of cosmological models which everyone believes, in their own time are completely correct. The presence of any anomaly with respect to the predictions of that cosmological model are generally ignored or arbitrarily retrofitted in a way so as to preserve the phenomena.This was the essence of the argument made by Plato in his assignments to his students: "By the assumption of what uniform and ordered motions can the apparent motions of the planets be accounted for" From this charge the epicycle was invented in order to preserve the geocentric cosmology and to account for the observed anomalous (e.g. retrograde) motion of Mars. The crucial scientific and physical question we explore in this talk is whether or not our current cosmology also contains epicycles in the sense that the mysterious elements of Dark Matter (DM) and Dark Energy (DE) are necessary retrofits to explain the observations and yet we know absolutely nothing about the physical nature of either of these entities. How then is this cosmology any different than the Aristotelian truth of Crystalline spheres and perfect circular motions? This talk will detail the evolution of our Cosmological making and the various kinds of scientific and cultural truths that emerge from this endeavor.

Peter Coles -- *Einstein, Eddington and the 1919 Eclipse Expeditions*

The modern era of cosmology really began with the publication of Einstein's general theory of relativity in 1915 because it was this theoretical breakthrough that allowed cosmologists such as de Sitter, Friedman and Lemaitre to construct the first self-consistent mathematical models of cosmic evolution. The first experimental test of general relativity was Eddington's famous expedition(s) to measure the bending of light at a total solar eclipse in 1919. So famous is this experiment, and so dramatic was the impact on Einstein himself, and so essential was it for the development of relativistic cosmology that history tends not to recognize the controversy that surrounded the results at the time. In this talk I discuss the experiment in its historical context as well as showing the results of a re-analysis of the data using more modern statistical methods. This experiment, and the controversy surrounding it, still provides valuable lessons for modern astronomy and cosmology.

David DeVorkin -- *Henry Norris Russell's Reaction to the idea of an Expanding Universe*

Richard Ellis – *A Century of Redshift Surveys: Past, Present and Future*

I will review the scientific drivers and technical progress in our quest to chart the expansion history of the Universe and the evolution of galaxies. The story takes us from the modest surveys of a few hundred galaxies beyond the Virgo supercluster through the ambitious campaigns of SDSS and 2dF to the Keck and VLT surveys of the highest redshift systems. A new generation of panoramic surveys is upon us and I will conclude with a description of the goals of the Subary Prime Focus Spectrograph - an instrument capable of measuring 100,000 redshifts per night.

John Farrell -- *Georges Lemaître: A Personal Profile*

A brief tour of the life of Georges Lemaître, father of the Big Bang Theory (Version 1.0), from his early days in Charleroi, Belgium, as a student interested in engineering, to his post-World War I entry into the seminary to be a Catholic priest, his years as a graduate student studying Einstein's Relativity at Cambridge, Harvard and MIT, and his famous (and infamous) interactions with Einstein, Eddington, Hubble, Pope Pius XII and Fred Hoyle as he developed the first working model of what became known as the Big Bang theory.

Ken Freeman – *Slipher and the Nature of the Nebulae*

By 1915, Slipher had shown that some of the nebulae had radial velocities in excess of 1000 km/s. At this time, the nature of the nebulae was controversial. In the context of what was known about the kinematics of objects in the Milky Way, the extreme velocities of the nebulae seem like a fairly clear indication of the extragalactic nature of the nebulae. Slipher himself pointed out that his velocities favored the Island Universe concept. But for some reason, his data did not have the impact on the controversy that one might have expected. I am interested in why some major discoveries do not have the impact that they deserve at the time that they were made. Sometimes they are too far ahead of their time and, as in Slipher's case, the discoverer does not really get the credit for the discovery even after its significance is understood. I will briefly discuss some other examples of this phenomenon.

Owen Gingerich -- *The Critical Role of Russell's Diagram*

Chris Impey -- *A Century of Galaxy Redshifts – From a Few Dozen to Millions*

The measurement of galaxy redshifts has changed almost beyond recognition in the past hundred years, progressing from night-long photographic exposures of single targets in Slipher's era to harvesting of tens of thousands of precision CCD redshifts each night. Advances in detector technology and a new generation of large telescopes have driven this change, which maps into a transformation in our view of the expanding universe, from simple detection of linear flow to exquisitely detailed measurement of a filigree of large scale structure imprinted on a decelerating then acceleration expansion. This talk will focus on the innovations that occurred along the way, some technical and some involving the clever use of proxies for, or adjuncts to, collections of stars such as supermassive black holes, supernovae, and gamma ray bursts.

Don Lago – *Edwin Hubble's Silence*

In late 1928 Edwin Hubble was right in the middle of using VM Slipher's redshift data to prove that the universe is expanding, when Hubble's boss George Hale ordered him to drop everything and rush to the Grand Canyon to test it out as a site for his planned 200-inch telescope. (This Grand Canyon episode is a fascinating story in itself). On his way, Hubble stopped at Lowell Observatory and visited with VM Slipher. Both before and after this visit, Hubble wrote to Slipher, and Slipher wrote to others about this visit. There is no indication that Hubble ever said a word about his being in the middle of using Slipher's research to transform the universe. At the least, this silence was symbolic of the silence with which astronomical history would often treat VM Slipher and his work.

Joseph Marcus -- *Another Underappreciated Lowell Observatory Achievement: The First Infrared Observation of a Comet*

The first infrared observation of a comet is widely and wrongly attributed to that of C/1965 S1 (Ikeya-Seki) by Becklin and Westphal. It is Lowell Observatory staff astronomer Carl O. Lampland (1873-1951) who must claim that honor, as former Director Art Hoag (1921-1999) reminded us in 1984. Using a sensitive radiometer designed by Coblentz, Lampland successfully took difficult measures of comet C/1927 X1 (Skjellerup-Maristany) in broad daylight over Dec. 16-19 with the 40-inch reflector on Mars Hill. There are parallels between these observations and Vesto M. Slipher's of the redshifts of spiral nebulae. Each were pioneering. Each were presented at American Astronomical Society meetings where they were enthusiastically received. Each were published as extended abstracts in Popular Astronomy. And each fell into relative obscurity with priority credit to fall to later workers. The wound in Lampland's case was partly self-inflicted – ever the perfectionist, he never turned his abstract into a formal paper. I have retrieved Lampland's radiometric observations of C/1927 X1 from his diaries and logbooks in the Lowell Observatory archives and find that they are eminently usable. I present a preliminary view of their reduction, now in progress.

Harry Nussbaumer -- *Slipher's redshifts as support for de Sitter's universe?*

Modern cosmology began in 1917 with Einstein and de Sitter. For the first few years it was mainly a matter for the theoreticians with, however, Slipher's redshifts as strong support for de Sitter. Eddington's book on general relativity, published in 1923, got the observers going: in 1924/25 Wirtz, Silberstein, Lundmark and Strömgren were inspired be de Sitter's redshift prediction; also Hubble in 1929 referred to de Sitter. In 1925 Lemaître found the snare in de Sitter's theory; it violated the principle of homogeneity. In 1927 he developed his theory of the dynamical universe, with the linear velocity-distance relationship $v=Hr$. Based on Slipher's nebular redshifts and Hubble's distances he showed the universe to be expanding, and calculated the coefficient H. With Lemaître's work Slipher's redshifts were given a completely different meaning to what they had in de Sitter's theory.

John Peacock -- *Slipher, galaxies and cosmic velocity fields*

William Putnam – *An Introduction to V. M. Slipher*

Kevin Schindler -- *Serendipity and the Acquisition of the Lowell Spectrograph*

In 1900 Lowell Observatory assistant Andrew Douglass advised his boss Percival Lowell to purchase a state-of-the-art spectrograph from instrument maker and recent Allegheny Observatory acting-director, "Uncle John" Brashear. While the instrument was initially intended to meet multiple scientific goals of the Observatory, particularly regarding the study of planetary atmospheres and the rotation periods of planets, it also fulfilled a little-known obligation between Percival Lowell and Brashear that dated back to an accident occurring several years before. If not for this unusual incident that led to the purchase of the spectrograph, the future of Lowell Observatory and, on a larger scale, unmasking of the nature of the expanding universe, would likely have played out much differently.

Robert Smith -- *V.M. Slipher: Master of the Spectrograph*

For some 15 years in the early years of the twentieth century, V.M. Slipher's mastery of the Lowell spectrograph enabled him to do extremely significant research in a range of areas. It is now generally agreed that his most important findings centered on the spectral shifts of spiral nebulae, results that were to be crucial to the development of ideas about the expanding universe. In this talk I will place Slipher's redshift researches into the context of the contemporary debates on the nebular hypothesis and the nature of the spirals, but I will also briefly examine what brought him to Lowell, his route to mastery of the spectrograph, and briefly discuss some of his findings in other areas in order to better understand his studies of redshifts and their reception.

Sangmo (Tony) Sohn – *The Proper Motion of M31: Historical Puzzle Solved*

A hundred years ago, Slipher's measurement of the Doppler velocity of the Andromeda galaxy M31 provided our first insights into the relative motions of galaxies. However, the proper motion of M31 always proved too difficult to measure, despite attempts dating back to the 19th century. We recently obtained the very first measurement of the M31 proper motion using the unique observational capabilities of the Hubble Space Telescope. So this classical problem has finally been solved, and the full M31 velocity vector is now known. I will describe our measurements and the implications of the results for our understanding of the past and future of the Local Group.

Matt Stanley -- *The Varieties of Universal Expansion: Eddington and the Big Bang*

A.S. Eddington was one of the handful of astronomers conversant with all of the observational and theoretical factors at play in early 20th-century cosmology. He constantly grappled with precisely what "expansion" meant and what implications that had for the construction of cosmological models. His efforts in this area help show the profound technical, conceptual, and philosophical difficulties that attended the early ideas regarding an expanding universe.

Joseph S. Tenn – *What Else Did V. M. Slipher Do?*

When V.M. Slipher gave the 1933 George Darwin lecture to the Royal Astronomical Society, it was natural that he spoke on spectrographic studies of planets. Less than one-sixth of his published work deals with globular clusters and the objects we now call galaxies. In his most productive years, when he had Percival Lowell to give him direction, Slipher made major discoveries regarding stars, galactic nebulae, and solar system objects. These included the first spectroscopic measurement of the rotation period of Uranus, evidence that Venus' rotation is very slow, the existence of reflection nebulae and hence interstellar dust, and the stationary lines that prove the existence of interstellar calcium and sodium. After Lowell's death in 1916 Slipher continued making spectroscopic observations of planets, comets, and the aurora and night sky. He directed the Lowell Observatory from 1916 to 1954, where his greatest achievements were keeping the observatory running despite very limited staff and budget, and initiating and supervising the "successful" search for Lowell's Planet X. However, he did little science in his last decades, spending most of his time and energy on business endeavors.

Laird Thompson -- *Vesto Slipher and the development of nebular spectrographs*

While the earliest attempts to detect photographic spectra of galaxies—by Huggins (1888), Scheiner (1899), and Fath (1908)—showed only limited success, in the period from ~1906 to 1912 Slipher (1913) made great strides to improve both the signal-to-noise and the stability of his spectra. Only by doing so was Slipher able to measure the first galaxy Doppler shifts. I will briefly review from a technical perspective the steps involved: photographic sensitization, nebular spectrograph design, and consistent observing methods. By identifying fast spectrograph camera lenses as the key component in nebular spectrographs, Slipher pointed the way for Mt. Wilson astronomers Humason and Hubble to confirm the velocity-distance relationship in the period 1928 to 1931.

William Tifft -- *The Nature of the Redshift (Poster Paper)*

Beginning in the 1970s studies of the redshift effect at Steward Observatory and the National Radio Astronomy Observatory developed evidence that the redshift was an intrinsic non-dynamical property of galaxies. Some of the introductory work was done at Lowell Observatory. A summary of some of the key professionally published references and evidence is presented. More details may be found at SASTPC.org where summary seminars and published professional references may be accessed. A comprehensive book on the subject is in preparation as is a cosmology based upon properties of space and time consistent with the observational evidence.

Virginia Trimble – *Way Before Hubble*

My father was almost a year old when Vesto Melvin first turned his spectrograph toward M31, so 1912 is not quite as long ago for me as it is for most of you. Nevertheless, you almost certainly know about Lemaitre (and his primordial atom). He wrote several papers with Sandoval Vallarta, who was first author on the first paper of Richard Feynman, who.... And quite possibly you have heard about HP Robertson, Lundmark, Carl Wirtz, de Sitter, Slipher himself, Shapley (who was against it all for as long as he could be), and the slight oddities of Silberstein and Strömberg (who tried to include globular clusters in their plots).

Ah, but what about the contributions of OH Truman and RK Young & WE Harper? Then there was GF

Paddock, who was the first to include a K term in fitting the radial velocities of spirals, found that it was about 100 times what was required for B stars, but thought it would go to zero when more radial velocities had been measured. He also retired from Lick still at the rank of Assistant Astronomer. My unsung hero, however, is A. Dose, whose 1927 "Dose constant" had units in which the numerator was km/s and the denominator was the log of angular diameter in arc-minutes. It is left as an exercise for the audience to convert this to km/s/Mpc or $(\text{time})^{-1}$.

Incidentally, if you attempt to find out more about A. Dose by modern methods, you will have to wade through a countably infinite number of papers that want to tell you how many micromoles per milliliter of methotrexate it takes to equal one spoonful of sugar.

Michael Way -- *Dismantling Hubble's Legacy*

Much of Edwin Hubble's legacy relies upon his supposed discovery of 3 fundamental relationships/quantities in Astrophysics that were the basis for much of 20th century cosmology. I will discuss how others prior to Hubble either discovered these first or were major (unattributed) contributors to these discoveries.