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FOR RELEASE:
Tuesday, January 6, 2009
10:00 AM PST (1:00 PM EST)

FRONT-LINE ASTRONOMY FROM CENTURY-OLD ARCHIVES

A long-standing astronomical mystery is "What type of star system will explode as a supernova?" It turns out that this question can be resolved by looking at century-old photographs. On studying archival data back to 1890, the result is that *recurrent novae* are the precursors to supernovae. With this knowledge, astronomical theorists can now perform the calculations to make subtle corrections that allow for the promise of precision-cosmology by upcoming programs involving supernovae. The lesson here is that old astronomical archives are valuable resources that can be used to produce unique and front-line science, in ways that no combination of modern telescopes can provide.

Professor Bradley E. Schaefer of Louisiana State University, Baton Rouge, discusses this finding today at a press conference during the 213th meeting of the *American Astronomical Society* (AAS) in Long Beach, California.

In the past decade, one type of exploding stars (called Type Ia supernovae) has been used as distance markers for measuring how fast the Universe is expanding. One result from measuring the brightness of these explosions more than halfway across the Universe has been the discovery of the enigmatic Dark Energy which is 'pushing' the galaxies to higher speeds. A potential problem is that the distant supernovae might be different from nearby events, thus confounding the measures. The only way to solve this problem is to identify the type of stars that explode as Type Ia supernovae so that corrections can be calculated. Many types of star systems have been proposed as being the progenitors of these supernovae, including recurrent novae, double white dwarf binaries, and symbiotic stars. This Type Ia progenitor problem has been a major mystery for over 40 years. The upcoming big-money supernova-cosmology programs require the answer to this problem for them to achieve their goal of precision cosmology.

The most promising progenitor candidate type is the recurrent nova (RN). Ordinary novae are double stars where one star is spilling matter onto a white dwarf star, which accumulates on the surface until enough builds up to trigger a thermonuclear runaway. These novae events are hydrogen bombs with explosive energies equal to a thousand-billion-billion of the biggest Russian H-bombs. Novae have eruptions typically once every 10,000 years, while *recurrent* novae go off much faster, having multiple eruptions every century. To pop-off that fast, the system must have a very high mass white dwarf and a very fast rate of matter falling onto the white dwarf. These are exactly the conditions that will soon make the white dwarf collapse (when it grows more massive than the Chandrasekhar mass) as a Type Ia supernova.

But two big questions arise before we can declare the RN to be the progenitor. First, are there enough RNe to supply the observed supernova rate? Second, does the nova eruption itself blow off more material than is accumulated between eruption (so the white dwarf would *not* be gaining mass)? To answer both questions, we need to measure demographic quantities; including the frequency of eruptions, the mass ejected each eruption, and the number of RN in our Milky Way galaxy. These quantities are difficult to measure and have been previously measured to an accuracy of no better than a factor of a hundred. So to answer the big-money front-line astronomy question, we need a 'new' approach.

The 'new' approach is to use century-old data deep in astronomy archives throughout the world. Schaefer says "Archival data is the *only* way to see the long-term behavior of stars, unless you want to keep watch nightly for the next century, and this is central to many front-line astronomy questions."

For example, the frequency of RN eruptions can be measured by looking at old sky photos that have nearly continuous coverage back to 1890 and count all the discovered eruptions. The mass ejected during an eruption can be measured by measuring eclipse times on old sky pictures, and then looking at the change in the orbital period across an eruption. (With Kepler's Law, as the system mass changes due to the ejection of material, the orbital period changes.) The number of RNe in our galaxy can only be estimated by correcting the observed number (only 10 RNe known) by the discovery efficiency, which depends on the details of the many nova searches over the last century. This efficiency can only be known from close examination of astronomical records worldwide for the last century.

The two primary archives for this study are now housed at Harvard College Observatory in Boston Massachusetts and at the headquarters of the *American Association of Variable Star Observers* (AAVSO) in Cambridge, Massachusetts. Harvard has a collection of half-a-million old sky photos covering the entire sky with 1000-3000 pictures of each star going back to 1890. The AAVSO is the clearinghouse for countless measures of star brightness by many thousands of amateurs worldwide from 1911 to present. Other valuable archives for this RN study are at the Sonneberg Observatory in Thuringen Germany and the Maria Mitchell Observatory on Nantucket Island. (See pictures of the observatory archives at http://www.phys.lsu.edu/recurrentnova/.)

Schaefer is reporting on the results of his massive and exhaustive search through all the relevant astronomical archives around the world. This new database is 100 times larger than all previously published data for the RNe in outburst and 1000 times larger than all previously published data for the RNe in quiescence. This large program has discovered one new RN (V2487 Oph), six new eruptions, five orbital periods, and two mysterious sudden drops in brightness during eruptions. An important result from the archival photometry is that the prototypical RN named U Scorpii (U Sco) will erupt any month now, and already a large worldwide collaboration (dubbed 'USCO2009') has been formed to make concentrated observations (in x-ray, ultraviolet, optical, and infrared wavelengths) of the upcoming event. This is the first time that a confident prediction has identified *which star* will go nova and *which year* it will blow up in.

Another discovery is that the nova discovery efficiency is horrifyingly low, being typically 4%. That is, only 1-out-of-25 novae are ever spotted. With this realization, we see an obvious opportunity for amateur astronomers to use digital cameras to monitor the sky and discover all the missing eruptions. Another implication is that roughly 100 already-catalogued ordinary novae (with only one *known* eruption) are actually RNe (with most of their eruptions in the last century missed). This implication can only be tested by going to archival sky field pictures (like at Harvard) to seek old photographic evidence of the earlier events. A final implication of this low discovery efficiency is that the total number of RNe in our Milky Way must be of order 10,000. Schaefer concludes "With 10,000 recurrent novae in our Milky Way, their numbers are high enough to account for all of the Type Ia supernovae". Thus, archival data provide a strong answer to the first of the two big-time questions.

Another result from the old data is that the orbital periods do *not* change much across the nova eruption, as seen for the two RNe U Sco and CI Aquilae. The derived mass for the material blown off by the nova is much smaller than the amount of material piled onto the white dwarf between eruptions. Thus, the mass of the white dwarf is increasing and its collapse is imminent (well, within a million years or so) to cause a Type Ia supernova. Thus, the second of the two big-time questions is answered.

Schaefer concludes "Archival records have succeeded in answering the front-line questions, while no combination of modern telescopes could possibly answer the questions."

For more information:

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This work was supported by the National Science Foundation