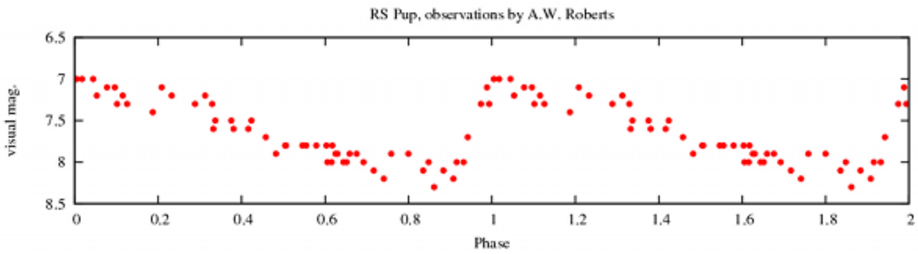
RS Puppis

RS Puppis as imaged with the ESO NTT (from Kervella et al. 2008)

January is a good time of year to observe this month's Variable Star of the Season, **RS Puppis**. A bright, southern gem, RS Pup has been known since the end of the 19th century, and has provided variable star observers and researchers with a bright and interesting target throughout its history. RS Pup is a *delta Cephei star*, or *Cepheid Variable*, a Milky Way member of this cosmically important class of stars that let us measure distances in the universe. However, RS Pup is in a class of its own as a star that produces *light echoes* of its pulsations visible in the nebula that surrounds it. This month, join us as we learn a little more about this lovely southern target of our January skies.

Discovery

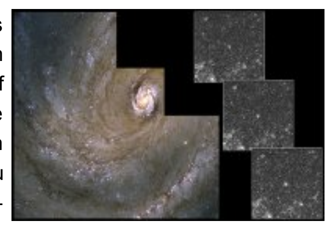
One of the earliest mentions of RS Pup in the literature was in a short report by David Gill, then director of Cape Observatory, that appeared in *Astronomisches Nachrichten* in 1897. Gill was himself passing along the observations of the noted visual observer R.T.A. Innes, a largely self-taught Scotsman who rose to become one of the preeminent observers of the southern hemisphere, and eventual director of the Transvaal Meteorological Department (Republic Observatory at Johannesburg). In his half-page report on suspected variables of J.C. Kapteyn, Gill noted among them observations of star "Cord.ZC. 8h.679" in the Cordoba Zone Catalogue. The star was visually and photographically variable, with variability being visually confirmed Innes: "Mr. Innes' visual observations prove certain variability 6.8 to 7.8, probably in a period of 45 days." Although the nature or the significance of the variability wasn't discussed, it was clear that Innes had already made a good start in understanding this new variable, getting the range and the period reasonably correct (within 10 percent). Although we don't (yet) have Innes' data, we do have those of his fellow southern observer Alexander Roberts from 1899 to 1920. His fine visual observations clearly show the Cepheid-like shape (a steep rise and slower decline), and yield a period of around 41.3 days.



A much longer contribution by Innes in the *Annals of the Cape Observatory* spells out the discovery in more detail. The star is named RS Puppis for the first time, and Innes notes that the discoverer was a "Miss Reitsma", an assistant of J.C. Kapteyn, who examined the plates of the Cape Photographic Durchmusterung, and subsequent photographic and visual evidence pointed toward variability. As Kervella et al point out in their 2008 paper on RS Pup, the period derived for RS Pup was at the time the longest of the delta Cepheids, with only U Car coming close. RS Pup remains one of the longest period Cepheids, in a class with stars like U Car (38.76 days) and SV Vul (45.01 days).

Cepheids as distance markers

Astronomers at Harvard College Observatory recognized in the early 20th century that some types of variable stars can provide an important astrophysical tool to astronomers: the ability to measure distances. The earliest contribution to our understanding of these stars came from the work of Henrietta Swan Leavitt, one of several "Computers" working at Harvard under then-director Harlow Shapley. Leavitt's examination of photographic images of the Large Magellanic Cloud led to the discovery of a number of Cepheid variables in that body. Leavitt also noted that there appeared to be a relation between the periods of these stars and their apparent brightnesses: the longer the period, the brighter the star. Since it was assumed that all of the stars in the LMC field were associated with the LMC (and were therefore at a similar distance from us), one could assume that it was not simply the apparent brightness but the absolute brightness that had a relationship to the period; since all the stars were at approximately the same distance, the differences in brightness had to be intrinsic rather than due to differences in distance.



This relation was famously applied first to RR Lyrae stars in our own Galaxy (as I talked about in the VSOTS article on RR Lyrae itself), but was later used on Cepheids in our own Galaxy. Once you obtain the critical final piece of information -- the zero-point calibration of absolute magnitude -- you can use the observed periods of Cepheids to measure their absolute magnitudes, and then use this absolute magnitude and the apparent magnitude (the magnitude you actually see) to measure the distance. By calibrating the Cepheid period-luminosity relation with very nearby Cepheids with distances measured by other means (like spectroscopic parallaxes of clusters with Cepheids, or trigonometric parallaxes of individual stars), you can then use this relation to obtain distances to Cepheids far more distant than with any other means. In fact, we've used observations of Cepheids in other galaxies to measure distances to galaxies tens of millions of parsecs away; it was the Cepheids that Edwin Hubble used to measure distances to other galaxies, and that pointed him toward the relationship between distance and cosmological redshift.

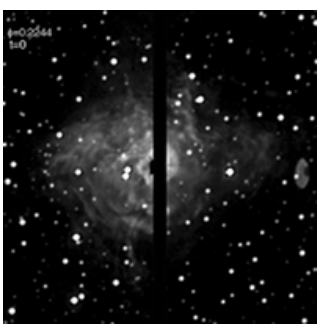
Closer to home, Cepheids have helped us determine the size and shape of our own Milky Way Galaxy. The classical Cepheids are more massive than the Sun, and thus their lives are measured not in billions of years, but in tens or hundreds of millions. Thus the classical Cepheids are more likely to be found in parts of the galaxy with recent star formation -- often in open clusters, and nearly always within the Galaxy's spiral arms, where all star formation occurs. Once you understand how to get the distance of a Cepheid based on the period-luminosity relation, you can then map the spiral arms where they're found. Such work has been done using Cepheids since the 1950s (Kraft & Schmidt 1963, Kraft 2009), and we now know quite a lot about the structure of our own Galaxy based in part on these critically important stars.

Cepheids are one of the most fundamental and useful targets of astrophysicists, and have justifiably been one of the most intensely studied of all the astrophysical objects for nearly a century. Our knowledge of them is still incomplete, although much of the work now done to understand them involves subtleties of their properties such as calibrations of the PL-relation zero point, measurements of extinction toward Cepheids, and the relation between the chemical properties of Cepheids and their PL relation. As time goes on, our understanding of Cepheids will improve, and thus will our measurement of the universe in which we live.

Light echoes: a new way to measure distances? Almost....

Bengt Westerlund of the Uppsala Southern Station at Mt. Stromlo presented a paper on RS Pup at the 107th meeting of the AAS in New York in December of 1960, a longer paper appeared in PASP the following year. Westerlund's paper noted the existence of nebulosity around RS Pup of about 3 arcminutes in diameter, and suggested that the nebula could possibly reflect the varying light from RS Pup, and might therefore also be variable. A decade later, R.J. Havlen of Arizona's Steward Observatory, measured variations in the brightness of the nebula that matched those of the variations of the star itself -- the nebula was *echoing* the pulsations of RS Puppis. These light echoes have been seen elsewhere in the cosmos, from the rings around Supernova 1987A to the delicate dust clouds around V838 Mon. How are they created? Just like sound echoes, they come from material distributed around the light source, in this case RS Pup itself. Imagine RS Pup as being surrounded by dust clouds and other material, and then imagine RS Pup undergoing a pulsation. The light of the star travels radially outwards from it in all directions. The light that comes directly toward us along the line of sight reaches us first. But then imagine what happens to a light beam that intersects a dust cloud in a different direction. A small amount of light from the cloud will be scattered in all directions *including ours.* We see that light a short time later, the amount it takes for light to go from RS Pup to the cloud, and then from the cloud to us.

Several other researchers investigated the circumstellar matter around RS Puppis over the ensuing decades, both to study the material itself and search for the light echoes. In 2008, a group of observers led by Pierre Kervella of the Observatoire de Paris used the European Southern Observatory's New Technology Telescope at La Silla, Chile to obtain very clear images of these echoes propagating outwards from RS Pup. They then used geometric arguments involving the time it took for the echoes to reach the clouds and the angular size of the nebula to estimate the *linear distance* from RS Puppis to the clouds. This is significant because with all of that information together, you can use simple geometry to measure **the distance from RS Puppis to us**. This was potentially an exciting new way to calibrate the Cepheid period-luminosity relation. However, it didn't quite work. Howard Bond and William Sparks, both of whom were involved in the observations of V838 Mon, published a rebuttal paper in 2009 discussing some of the assumptions that went into the study, namely that the knots of nebular material that we see are distributed equally around the star, and thus the average lies on the plane of the sky. But as Bond and Sparks point out, this observation is actually biased, since dust tends to scatter light in its forward direction. (This is why it's hard to drive toward the rising or setting Sun when you have a dirty windshield.) We preferentially see bright knots of material nearest our line of sight, and not equally in all directions around the star. Because of this, the geometric assumptions that Kervella et al used don't really work correctly until you take account of the biases.



Despite this, the light echoes around RS Puppis still have great interest for us. First, further investigation of other Cepheids now suggests that RS Pup is not unique, but simply the most obvious example of a Cepheid with material around it. Closer investigation of other Cepheids have revealed the presence of circumstellar matter as well. Since Cepheids are stars late in their lives, the existence of mass loss isn't surprising, although the amount of mass present in these clouds (perhaps 0.03 solar masses) is noteworthy. Second, Cepheids themselves are not unique as objects with large amounts of circumstellar material. Certainly objects like R CrB stars, classical novae, and objects like V838 Mon are known to have lots of dust, but so do very young stars like T Tauri stars. Ortiz et al. very recently published observations indicating the presence of light echoes from young stars in the southern cluster NGC 6726 that contains R CrA and S CrA. They found multiple light echoes that they attribute to these two stars, suggesting that the rich circumstellar environment around these stars might be a promising place to look for light echoes.

Observing RS Pup

RS Puppis is a bright and easy to spot star for southern hemisphere observers. It's a particularly good Cepheid for visual observers since it has a high amplitude and long-period. It's one of many targets of the Bright Cepheids Program of Variable Stars South -- the umbrella organization that grew from the RASNZ Variable Star Section. New Zealand observer Stan Walker is leading this campaign to follow a number of Cepheids for several years in order to measure period changes over time. Many Cepheids -- particularly the more evolved ones like RS Pup -- evolve relatively rapidly, and period changes can become apparent within a few years. On their website you can find more information about their observing program, along with charts and tips for making the highest quality visual observations you can. From the standpoint of a researcher who uses visual observations, your data will be most helpful if we're able to put them in context of other observers, and the easiest ways to do this are (a) use a standard chart (very important!) and (b) to follow the star for awhile. It's easier for us to see how you compare to other visual observers when we have many observations and can see how your data compare over a cycle or two, rather than simply trying to figure how your one or two data points fit in with everyone else's. (That's true for any star, but is especially true for stars with amplitude of one magnitude or less!) Chart team leader Michael Simonsen suggests using a 5-degree (300 arcminute) chart with a limiting magnitude of 8.0 to concentrate on the visual comparison stars most relevant to RS Pup throughout its range.

Those of you with CCD cameras can also follow RS Pup if you use the same care as you would with any other bright star. Observations made in more than one filter are especially useful since the color of the star changes over the pulsation cycle along with the luminosity. The nebulosity around RS Pup is about three arcminutes in diameter, and you might be able to detect it by overexposing RS Pup itself (just don't submit an overexposed magnitude of RS Pup!). The image of the nebula shown at the top was made by mechanically blocking the light of the star -- even so, the center of the frame is heavily overexposed. Try to adjust your exposure times to see if you can bring out the nebula. We'd be interested to see what you can do!

RS Puppis is a fascinating star that will certainly continue to be an interesting target for a long time to come, and it's one that everyone can contribute observations of -- at least if you're able to reach southern skies! RS Pup is another example of a star undergoing changes late in its life, and study of such stars can teach us a lot about the way stars evolve and eventually die. While it does so, it also serves as one of many important cosmic mileposts that help us measure the size of our universe. We have a number of Cepheids in the AAVSO observing program, from nearby stars like delta Cephei (a 3rd magnitude star of Northern Skies) all the way out to the recently-highlighted project, the faraway Cepheid M31_V1, pulsing dimly in the Andromeda Galaxy at V=19.0. Whatever your capabilities and mode of observing, there are Cepheids for you to enjoy -- and to help expand our knowledge with your observations.

The January 2011 Variable Star of the Season was written by Dr. Matthew Templeton, AAVSO.

Further Reading

- Davis, K, 2002, "Zeta Geminorum", VSOTS, March 2002
- Malatesta, K., 2000, "Delta Cephei", VSOTS, September 2000
- Templeton, M.R., 2010, "RR Lyrae", October 2010 AAVSO Variable Star of the Season
- The AAVSO's M31_V1 project: Alert Notice 422, "M31_V1's Light Curve is Taking Shape", "A Portrait of a Distant Cepheid"
- ESO Press Release: "Light echoes whisper the distance to a star", ESO 0805 (2008)
- Bond, H.E. & Sparks, W.B., 2009, "On geometric distance determination to the Cepheid RS Puppis from its light echoes", A&A 495, 371
- Feast, M.W., 1999, "Cepheids as Distance Indicators", PASP 111, 775
- Feast, M.W., 2008, "The nebulosity and distance of the Cepheid RS Puppis", MNRAS 387, 33
- Gill, D. (editor), 1903, "Revision of the Cape Photographic Durchmusterung, Part II. Variable stars, miscellaneous stars, etc", Annals of the Cape Obs. 9, 2.1 (text by R.T.A. Innes)
- Havlen, R.J., 1972, "The nebulosity surrounding the galactic Cepheid RS Puppis", A&A 16, 252
- Kervella, P., et al., 2008, "The long-period Galactic Cepheid RS Puppis I. A geometric distance from its light echoes", A&A 480, 167
- Kraft, R.P., 2009, "An Astronomical Life Salted by Pure Chance", ARA&A 47, 1
- Kraft, R.P. and Schmidt, M., 1963, "Galactic Structure and Galactic Rotation from Cepheids", ApJ 137, 249
- Ortiz, J.L. et al, 2010, "Observation of light echoes around very young stars", A&A 519, 7
- Voute, R., 1939, "RS Puppis", Annals of the Bosscha Obs. 8, 31
- Westerlund, B., 1961, "The Nebulosity around RS Puppis", PASP 73, 72

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