Searching for

Vulcanoids

by LANDON CURT NOLL

Hunting for minor planets during a total solar eclipse is not as far-fetched as it may seem.

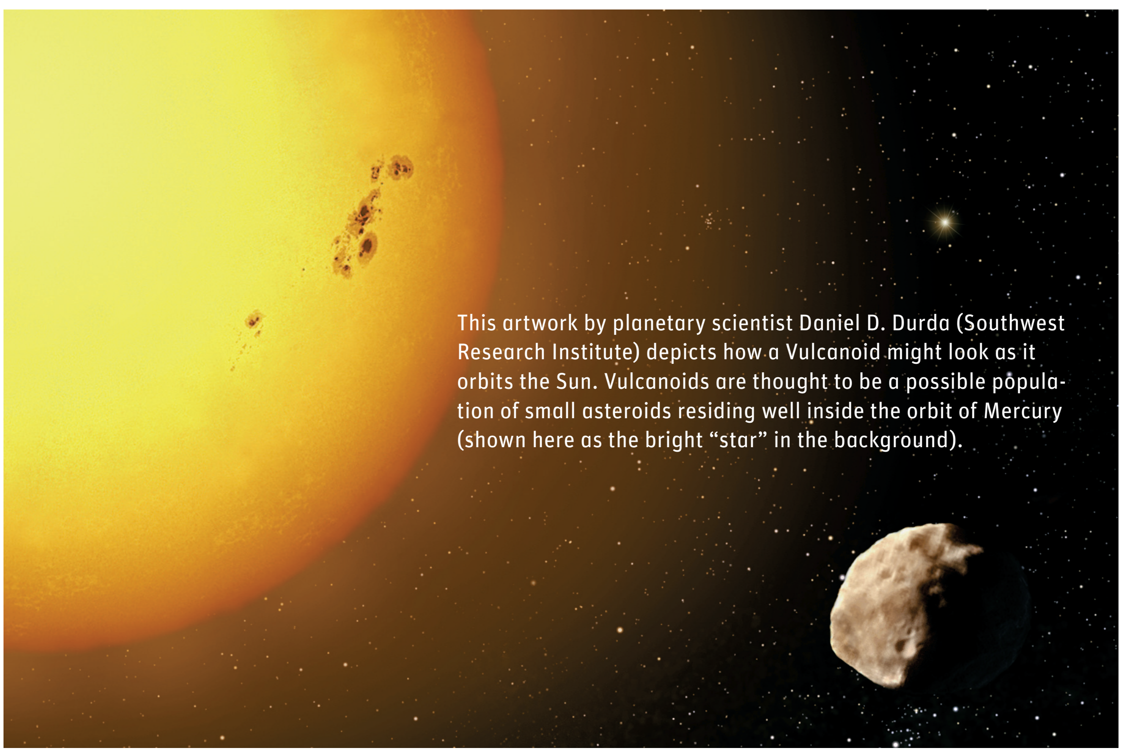
THE TITLE OF THIS ARTICLE may sound like an episode from Star Trek, but to astronomers, this is an inner-solar-system quest that has been in the making since 1859. It's a quest that you can join today!

The innermost region of our solar system is known as the Vulcanoid zone, and it has remained largely unexplored. (Even Mercury has been only partially photographed by just one spacecraft, Mariner 10, and that was in the mid-1970s.) Discovering asteroids lurking in the Vulcanoid zone would greatly add to our understanding of the birth and evolution of our solar system — not to mention those of other Sun-like stars in the Milky Way.

The biggest challenge in searching for Vulcanoids is the intense glare from the Sun. A total solar eclipse, such as the one occurring on March 29th (see page 115), offers an excellent, albeit brief, opportunity to probe this normally hidden zone. With the advent of inexpensive CCDs, powerful image-processing software, and the Internet, amateur astronomers are now in a position to exploit the short window into the Sun's inner sanctum that a total eclipse provides.

WHAT IS THIS VULCAN STUFF ALL ABOUT?

In the mid-19th century, French astronomer Urbain J. J. Le Verrier demonstrated that Mercury's motion around the Sun was not behaving as prescribed by Newtonian mechanics. In 1859 Le Verrier proposed that the gravitational effect of a small inner planet, which he later named "Vulcan," could account for Mercury's unusual motion, and the search was on (S&T: October 1998, page 112). Not until 1916 did Einstein's general theory of relativity finally explain Mercury's motion, and searches for the putative intra-Mercurial planet (perhaps several such bodies) were largely abandoned.



This artwork by planetary scientist Daniel D. Durda (Southwest Research Institute) depicts how a Vulcanoid might look as it orbits the Sun. Vulcanoids are thought to be a possible population of small asteroids residing well inside the orbit of Mercury (shown here as the bright "star" in the background).

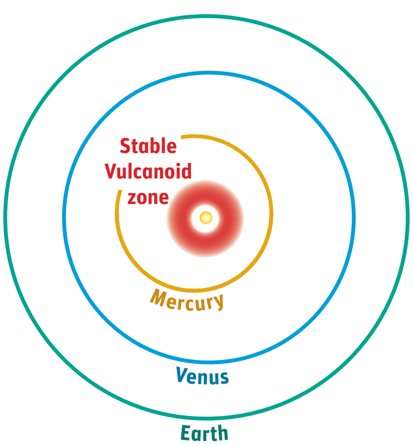
Today we know of no sizable object that permanently occupies the space inside Mercury's orbit. Nevertheless, many astronomers still refer to this region as the Vulcanoid zone, because of its association with the mythical planet Vulcan. A minor planet whose mean distance to the Sun is less than that of Mercury (0.387 astronomical unit, or 57.9 million kilometers) would be considered residing within the Vulcanoid zone. Due to the intense heat of the Sun in this region, the only objects astronomers expect to find here are asteroids.

Why is it important to participate in this search? You have a chance to become part of astronomical history. With a bit of effort and luck, you could be among those to find the very first Vulcanoids!

MODERN VULCANOID THEORY

Recent models by Neil Wyn W. Evans (University of Oxford) and Serge A. Tabachnik (Princeton University Observatory) suggest that Vulcanoid asteroids, if they exist, must reside in a narrow, dynamically stable band in the Vulcanoid zone, close to the ecliptic. Recent updates to their model suggest that objects closer than 0.08 a.u. to the Sun would be perturbed by extreme solar heating and dynamical transport mechanisms and would either be pushed away or pulled in toward the Sun.

Mercury and the other planets place an additional constraint on the stability of the Vulcanoid zone; Evans and Tabachnik's latest model suggests that a Vulcanoid with a mean distance greater than 0.18 a.u. would be ejected from the zone. Thus, any long-term Vulcanoid asteroid should orbit the Sun between 0.08 and 0.18 a.u. As seen from Earth, this zone extends as far as 10.5° from the center of the solar disk. Studies by Daniel D. Durda and S. Alan Stern (Southwest Research Institute) suggest that Vulcanoids are most likely to reside toward the 0.18-a.u. edge of the zone, and that the gravitational pull of Mercury and the other planets could nudge the orbits of these bodies out from the ecliptic plane by as much as 10° or more.



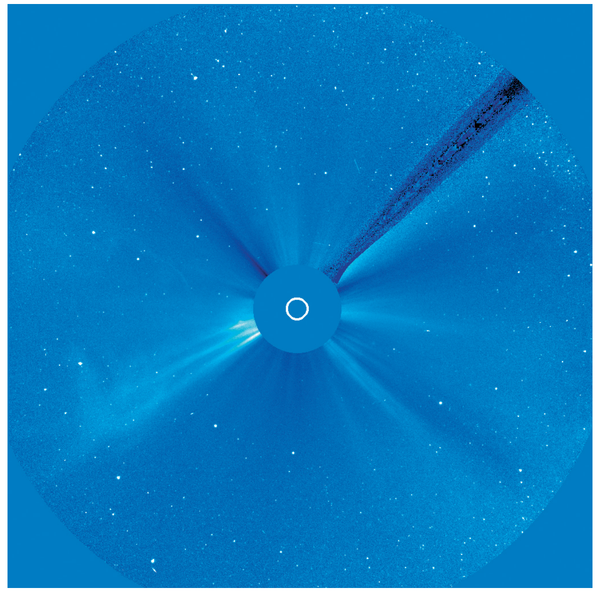
The dynamically stable Vulcanoid zone extends 0.08 to 0.18 astronomical unit (12 to 27 million kilometers) from the Sun.

In 2000, a team led by Durda used images from the Large Angle and Spectrometric Coronagraph aboard the Solar and Heliospheric Observatory (SOHO) spacecraft to conduct the most extensive search to date for Vulcanoids as faint as magnitude +8.0 (*S&T*: August 2000, page 26). Although the team failed to find a single one, the existence of fainter Vulcanoids is clearly a possibility. If the largest Vulcanoids are just under the search limits (that is, between 20 and 60 km in diameter), then the team estimates that there could be as many as 1,800 to 42,000 Vulcanoids larger than 1 km!

FINDING VULCANOIDS

There may be plenty of Vulcanoids out there, but how can they be discovered? A CCD camera coupled to a telescope is clearly essential. As many CCD users know, it's possible to record fairly faint stars even near a full Moon at night, and the sky during a total solar eclipse has a similar brightness. Here are a few things to consider that might help increase your chance of success.

If you plan to do the search during a total solar eclipse, test your telescope setup on the zenith weeks or months before you head off to your observing site. You can simulate the typical range of sky conditions at totality by taking CCD exposures of a cloudless, moonless sky at dusk or dawn. Capture images of the zenith when the Sun's center is between 4.25° and 5.25° below the ideal horizon (ignoring small obstructions along the horizon, such as trees, houses, and hills). Your test images will help you determine the optimum exposure time to use during the eclipse. (Taking an exposure while part of the Sun's disk is uncovered could saturate the CCD, so plan to have a 4-second margin of safety on either side of the length of totality.)



This view of the Sun's corona and its surroundings was captured by the Large Angle and Spectrometric Coronagraph aboard the Solar and Heliospheric Observatory (SOHO) spacecraft on New Year's Day 2005. The small white circle in the central occulting disk represents the size of the Sun. SOHO / LASCO CONSORTIUM (NASA / ESA)

Determine the faintest star you can record at or near the zenith. If you can capture stars fainter than 8th magnitude, then your setup has what it takes to hunt for Vulcanoids.

You will greatly improve your ability to image faint Vulcanoids by preventing wavelengths that are shorter than orange from reaching your camera. Vulcanoids are likely to be Mercury-like in color, greatly favoring the red and near infrared (IR) colors. By filtering out the blue of the sky background (from O^2 Rayleigh scattering), the green of the corona (e.g., Iron emission lines), and the yellow from Sun (scattered into the sky from outside the lunar shadow), you will significantly reduce background noise without sacrificing the brightness of potential Vulcanoids. Recent Vulcanoid hunters have used OG 590 (090) and RG 630 (091) Wratten filters to image stars as faint as +13.5 magnitude during the 2008 August 1 eclipse.

Another technique that holds great promise is to use cameras that are sensitive to both visual and near IR wavelengths. The surface temperature of objects residing within the stable Vulcanoid zone could be as high as 825°C (1517°F) due to their close proximity to the Sun. Such objects are expected to be strong radiators in the IR portion of the spectrum. SLR cameras made sensitive to the near IR, such as those modified by MaxMax (www.maxmax.com), offer a relatively inexpensive near IR detector solution while avoiding the cooling and thermal shield problems associated with chilled mid and far IR sensors. A near IR sensitive SLR camera combined with a deep red filter such as a Wratten RG 695 (092) filter is an excellent choice for Vulcanoid hunting.

Select your target area. During totality, you can avoid most of the glare from the corona by keeping your camera aimed at least 2.5° away from the center of the Sun. While Vulcanoids should favor the ecliptic, their orbits might be inclined to the solar-system plane by 10° or more, so pick where you aim your telescope accordingly.

If possible, try to setup at the eclipse site and align the clock drive of your camera on the night before the eclipse. Unfortunately, early access to an eclipse site is not always possible. Worse yet, clouds may force you to move or your setup may get bumped out of alignment prior to totality. To be prepared, print out the coordinates of the center of the Sun at 1-minute intervals between 1st and 2nd contact (the partial eclipse phase prior to totality). Or better yet, print out the coordinates of the two points where the edges of the lunar and solar disks overlap for each minute prior to totality. Use these coordinates to help align your camera mount and to locate your Vulcanoid observation point.

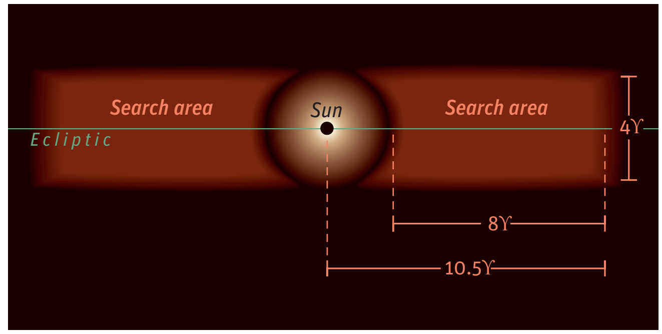
Even experienced eclipse chasers often get so caught up in the frenzy and emotion at the onset of totality that carefully laid plans become chaotic. So prior to the eclipse, practice setting up, alignment, and acquiring your Vulcanoid search coordinate during the daytime. Practice it until you become very familiar being able to setup in a reasonable amount of time. Bring enough spare parts and batteries just in case. Create and use a checklist that even includes the obvious. More than one person has forgotten to remove a lens cap at the right time!

Upcoming Eclipses

Date		Maximum duration
2009	July 22	$6^m\ 39^s$
2010	July 11	$5^m\ 20^s$
2012	Nov. 13	$4^m\ 02^s$
2013	Nov. 03	$1^m\ 40^s$
2015	Mar. 20	$2^m\ 47^s$
2016	Mar. 09	$4^m\ 09^s$
2017	Aug. 21	$2^m\ 40^s$

Consider using a camera interval timer or some automatic method of taking multiple bracketed exposures (e.g., multiple sets of 3 images separated by an f-stop centered around the optimal exposure time). The brightness of the sky during totality varies from eclipse to eclipse, so exposure bracketing helps hedge your exposure estimate. By taking multiple images during totality, you can take advantage of image stacking in order to reduce noise and improve your ability to detect faint objects.

If you're working alone, one possible strategy is to look for Vulcanoids moving relative to background stars. At 0.08 to 0.18 a.u., a Vulcanoid in a circular orbit around the Sun would complete one revolution in 8.26 to 27.9 days. Thus, in a pair of short exposures, say, 4 minutes apart, the asteroid would move as much as 0.5 arcminute on the sky.



This diagram (drawn to scale) shows the prime Vulcanoid search area during totality. To reduce glare from the corona, aim your CCD-equipped telescope at least 2.5° from the Sun's center.

A far better strategy is for a pair of observers working in tandem to position themselves in different countries along the eclipse path. If their times of totality were widely separated (by 30 minutes or more), then a Vulcanoid recorded by both observers would be more easily identified by "blinking" the images, that is, alternately viewing the images in quick succession. Such an image set would add information about the asteroid's orbit and would help in acquiring it again after the eclipse.

THE NEXT ECLIPSES

Vulcanoid hunters are encouraged to take advantage of the upcoming total solar eclipses listed at left.

This undertaking clearly requires the talents and efforts of many skilled observers. To collaborate with others searching for Vulcanoid asteroids, please send E-mail to eclipse@vulcanoid.org. Comments and questions are also welcome.

Good luck and clear skies!

Landon Curt Noll is a computer security specialist for Cisco Systems and an associate member of the American Astronomical Society. He enjoys giving talks at Fremont Peak Observatory (www.fpoa.net) and adding new observations to his astronomy page (www.isthe.com/astro.html).