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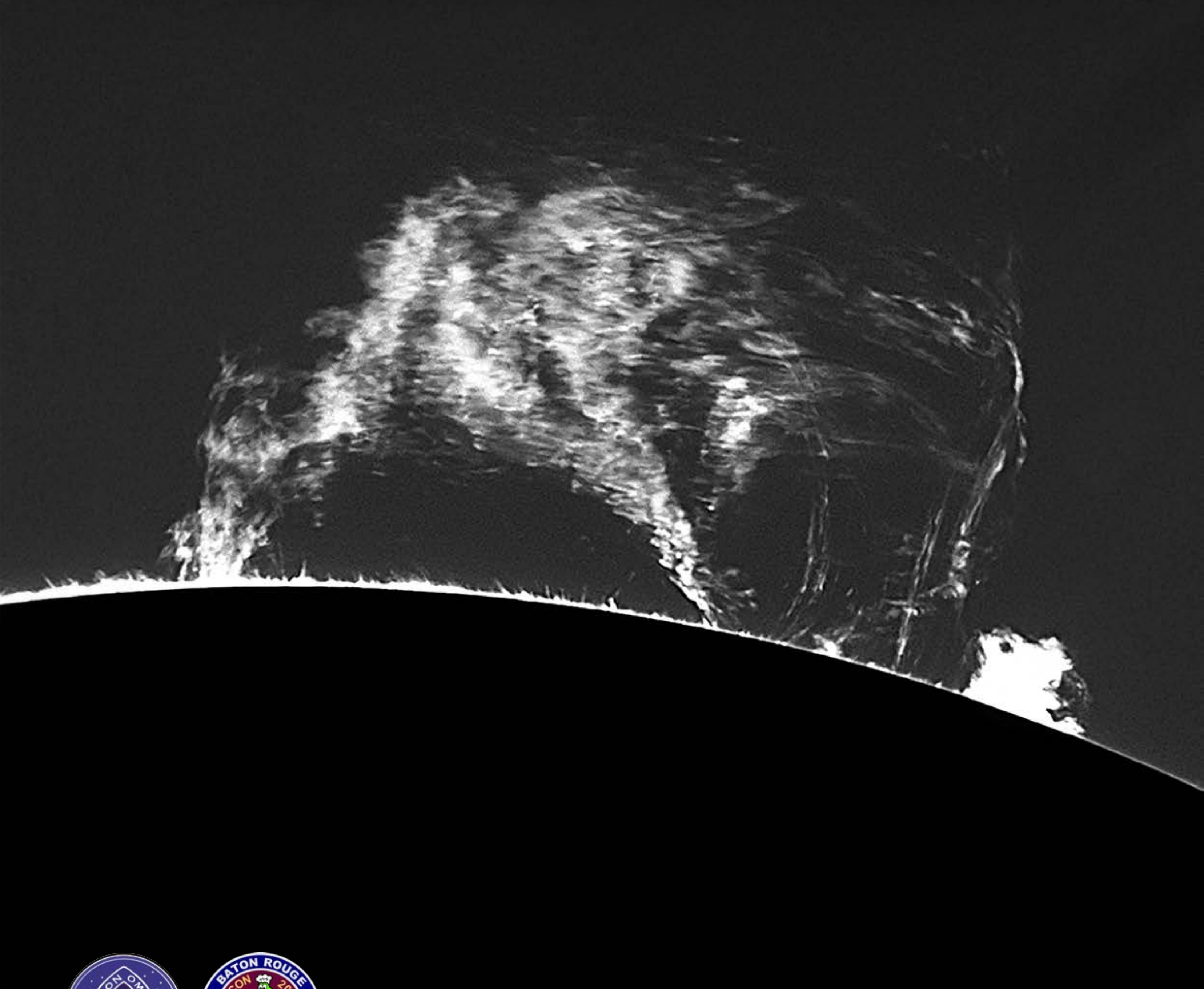
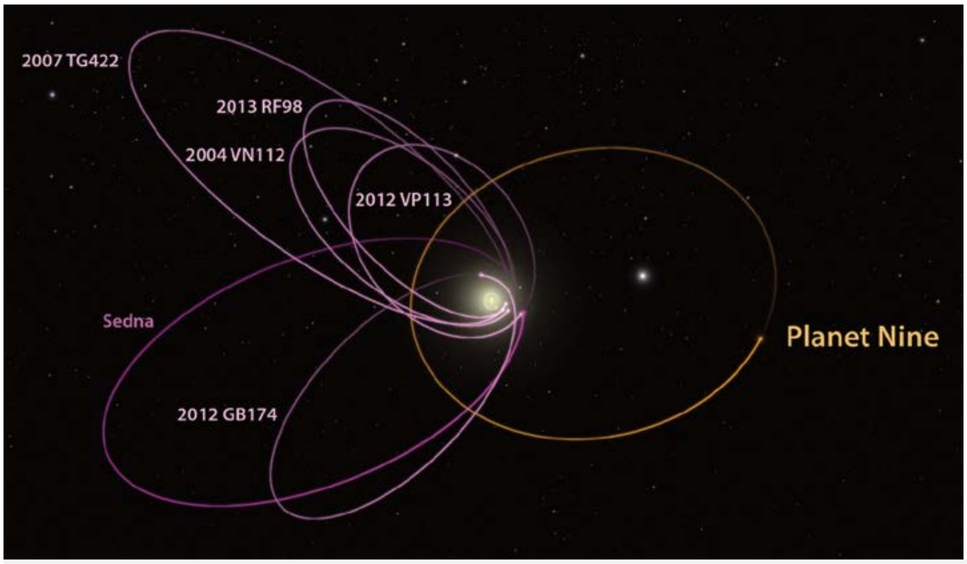
Reflector



A FOCUS ON MEMBER ACTIVITIES AND EXPERIENCES



The six most distant known objects in the Solar System all have their perihelia in the same region of the ecliptic and are tilted in the same direction. Planet Nine's presumed perihelion is on the other side of the Sun. This location allowed Planet Nine's gravity to wrangle the orbits of the other six extreme trans-Neptunian objects into a common configuration. Planet Nine's gravity may have also tilted the orbits of the other eight planets six degrees away from the plane of the Sun's equator. Image Credit: JPL-Caltech: R. Hurt (IPAC)

outer Solar System.

Only thirty-eight of these objects have been discovered. In 2014, astronomers Chadwick A. Trujillo and Scott S. Sheppard noted that all thirteen ETNOs known at that time had a similar orbital parameter called the *argument of perihelion,* a measure of the angle between the point of perihelion and where the body's orbit crosses the plane of the Earth's orbit (the ecliptic). They suggested that there might be a small planet in the outer Solar System coaxing these objects into similar orbits.

A similar phenomenon is the gaps in Saturn's rings, generated by tiny "shepherding" moons embedded in the rings. Ring particles in the gap ahead of a moon are slowed down by the moon's gravity, causing them to move into lower orbits. Particles behind the moon are pulled toward it. This accelerates them into higher orbits. In both cases, the particles are thrown out of the gap, keeping it clear.

ETNOs are too distant to be much affected by Neptune or the other planets, so the gravity of an unseen planet in the outer Solar System would be free to shepherd the orbits of the ETNOs. Over many thousands of years, it would cause the orbits to slowly align. Caltech professor Mike Brown found the problem interesting and took it down the hall to theoretician Konstantin Batygin. Together they developed models of ETNO orbits and how they would be affected by a planet in deep space.

Their analysis showed the six most distant objects are in elliptical orbits that are aligned in the same direction. If there was nothing to alter their orbits, they should be randomly oriented. They also noticed that the inclinations of these six ETNOs were also aligned. They were all tilted about thirty degrees downward relative to the plane of the ecliptic. To find these six objects to be so aligned is highly unlikely without something to cause their orbits to shift.

While an unseen planet could cause the orbits to align, there were other prospective perturbers. They modeled and discarded many other possibilities. The model that best fit the observations was a planet with a mass of ten Earths that had a perihelion on the opposite side of the Sun from the perihelia of the aligned ETNOs. It would have to be twenty times farther from the Sun than Neptune, roughly fifty-six billion miles (600 AU). They dubbed this massive planet "Planet Nine."

This model also explained the orbits of the dwarf planet 90377 Sedna and the minor planet 2012 VP_{113}, which had been kicked out of the Kuiper Belt by Neptune, but no longer traveled down near it. Planet Nine had reshaped the orbits of these two objects raising their perihelia so they no longer traveled down near Neptune's orbit. The model generated a probability map of the region where Planet Nine may be located, but not its precise location. The highest probability is near the planet's aphelion, roughly in the direction of the constellation Taurus.

Amateur astronomers can participate in the search for Planet Nine. The Zooniverse Catalina Outer Solar System Survey and the Zooniverse SkyMapper Planet 9 projects are both out of data, but may get more in the future. The Zooniverse Backyard Worlds project *(zooniverse.org/projects/marckuchner/backyard-worlds-planet-9)* uses archival data from the Wide-field Infrared Survey Explorer (WISE) spacecraft. Each field is represented by four images that are "blinked" in sequence. Any moving object, like Planet Nine, will appear as a moving dot. Only thirteen percent of the available images have been examined so far. There is plenty of opportunity for citizen scientists to participate in the first planetary discovery in 176 years.

—Berton Stevens

Deep-Sky Objects

JEWELS IN THE CROW'S NEST

Some of the best galactic star clusters visible during the winter lie along the Milky Way in the constellations Canis Major and Puppis. Canis Major is easy to find because the constellation contains Sirius, the brightest star in the night sky. In clear dark skies, the Milky Way is readily visible on the east side of Sirius. The constellation Puppis borders Canis Major on the east and south sides. The constellation is much larger than Canis Major and spans twice the distance in the north-south direction. All of Puppis is visible from south of 35 degrees north latitude. Those in the northern half of the contiguous 48 states are still able to see a majority of the star clusters in Puppis when the constellation transits during clear winter nights.

Canis Major is the big dog, in mythology, one of two hunting dogs associated with Orion. The other hunting dog is depicted as the constellation Canis Minor. Both dogs follow Orion across the sky as the constellations rise in the east and set in the west.

The constellation Puppis has a more convoluted history than Canis Major. The constellation was originally part of a much larger constellation known as Argo Navis (the Ship Argo). In mythology Argo was the ship built by Argus and was used by Jason and the Argonauts (of which one was Argus) as they searched for the Golden Fleece.

Some astronomers thought that Argo Navis was too large a constellation. It was 28 percent larger than the next largest constellation and contained more than 160 naked-eye stars. Therefore in 1755, the French astronomer Nicolas Louis de Lacaille broke Argo Navis into three ship parts: Carina (the keel), Puppis (the poop deck) and Vela (the sails). He also added the constellation Pyxis (the ship's compass). In breaking up Argo into smaller parts, de Lacaille did not rename any of the stars. So Puppis does not have any stars named Alpha, Beta, etc., as the brightest stars in Argo Navis ended up in other constellations.

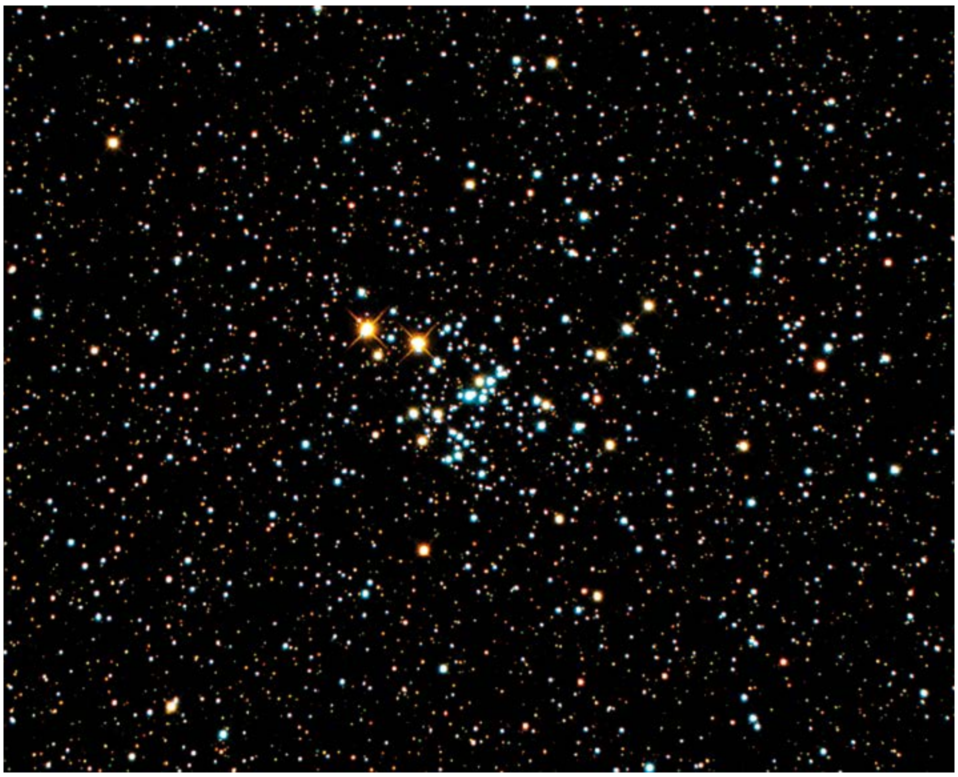
Canis Major and Puppis combined contain four Messier objects: M41, M46, M47, and M93. All four are open clusters. The brightest of these is M41, found just below (south) of Sirius. The pair M46 and M47 is found 14 degrees northeast of M41. Most amateur astronomers routinely view these three winter Messier objects. But M93 is often neglected since it is the smallest, southernmost, and faintest of these four Messier objects. To me it is a fine cluster with colorful stars as worthy as the others on my observing list.

Charles Messier discovered M93 in 1781 using his 3.3-inch refractor. He added it as the 93rd entry in his catalog of objects he did not want to confuse with comets. While not the southernmost object in Messier's catalog, M93 only rises as far as 17 degrees above the horizon from Paris where Messier observed.

M93 can be found 1.5 degrees northwest of the star Asmidiske (Xi Puppis), a third-magnitude star in the northern half of Puppis. The cluster shines at magnitude 6.19, not much fainter than M46. But it will appear fainter from mid-latitudes since it is lower in the sky. The light from M93 passes through more of our atmosphere than the light from M46. Thus, it experiences more atmospheric dimming or extinction. M93 has a diameter of 20 arcminutes and lies 3,400 light-years away.

M93 contains a colorful assortment of red, orange, and blue stars, and in 8-inch or larger telescopes, the stars sparkle like jewels. The cluster contains around 80 stars of eighth magnitude and fainter. A few stars that appear associated with the cluster are actually foreground stars, which is true of many open star clusters. The cluster has a wedge shape with the sharp edge pointing southwest. Some of the brighter stars east and south of the wedge are members of the cluster.

The brightest stars in the center of M93 are blue giants. The short lifespan of these stars tells us the cluster is approximately 100 million years old. The cluster contains red giant stars, too. Two of the brighter ones, both eighth magnitude, mark the point of the wedge. One of these, the one furthest from the cluster's center, is actually a foreground star only one-quarter as far away as the main cluster.



The image of M93 was captured with an eight-inch f/8 Ritchey–Chrétien Cassegrain with a 0.8× focal reducer/field flattener yielding f/6.4. The exposure was 60 minutes using an SBIG ST-2000XCM CCD camera. In the image north is up and east to the left.

This winter when sailing around the myriad galactic star clusters in the southern winter Milky Way, make sure that M93 is on your waypoint list. The cluster sits high on the mast of the former Argo Navis, but you won't need to be in a crow's nest to find it.

—Dr. James Dire

Opportunity Knocks at the *Reflector*

AD COORDINATOR NEEDED

After seven years of service to the *Reflector*, Carla Johns is stepping down as the magazine's advertising representative. Thank you, Carla, for helping make the *Reflector* the excellent publication that it is today!

Amateur astronomy has a wide field of view, featuring all sorts of interesting events and cool equipment. The Astronomical League is seeking someone to help amateur astronomy by volunteering to be part of the *Reflector* magazine team, and to assume the duties of the *Reflector* advertising representative. This is an opportunity to interact with star party and convention organizers, merchandise vendors, and equipment manufacturers while gaining a firsthand view of the state of the hobby.

The responsibilities of this volunteer position include:

- **Coordinate all incoming advertisements from multiple sources**
- **Send ad placement deadline reminders to all advertisers**
- **Review ads for spelling, grammar, image placement, correct information and contact advertisers to make any necessary changes**
- **Send all ads to design editor for placement**
- **Proofread draft issues to ensure all ads are included and accurate**
- **Generate invoices for each advertiser and send via email or hard copy (with complimentary current issue)**
- **Send invoices to treasurer to track payments**
- **Follow up with our treasurer to ensure invoices are paid in a timely manner**
- **Identify (and contact) potential new advertisers**
- **Field emails and answer questions from advertisers**
- **Track revenue for each issue**

We estimate about 10 hours per month should be adequate to fulfill all the above duties.

As Carla enthusiastically states, "This is a great opportunity to connect with star party organizers and industry experts across the U.S.!"

If this fun and important role is for you, please send your name to *Reflector* managing editor Ron Kramer at *managingeditor@astroleague.org.*