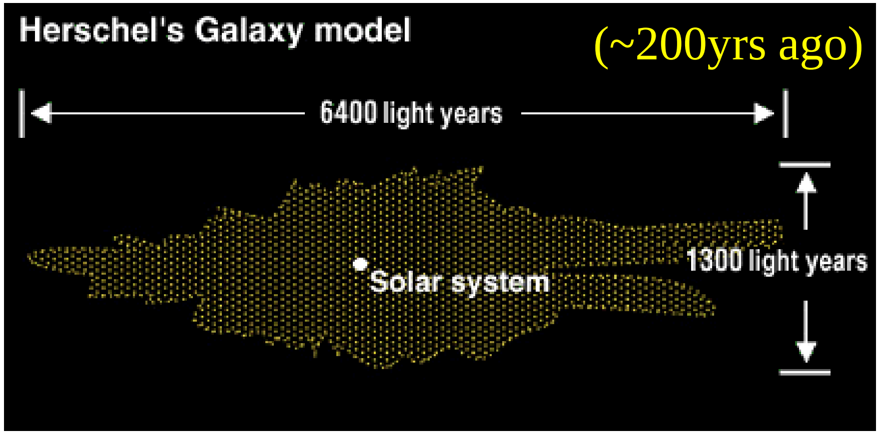
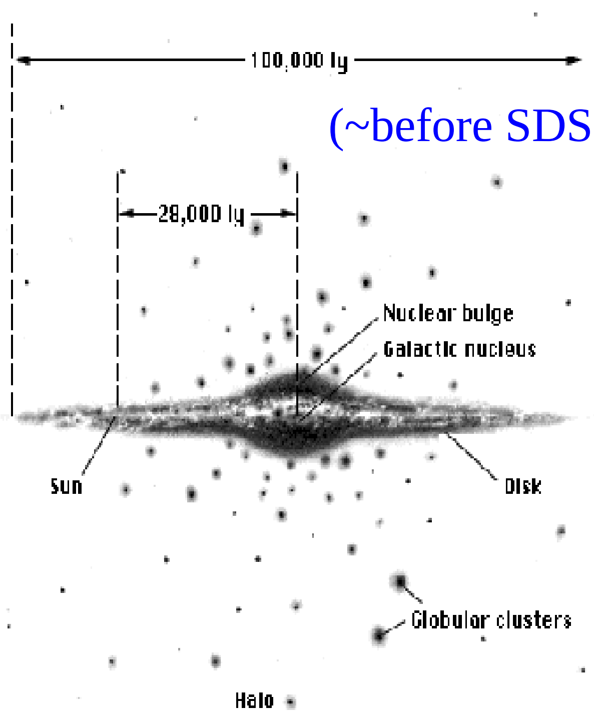
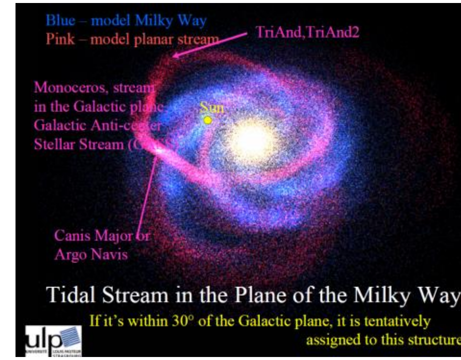
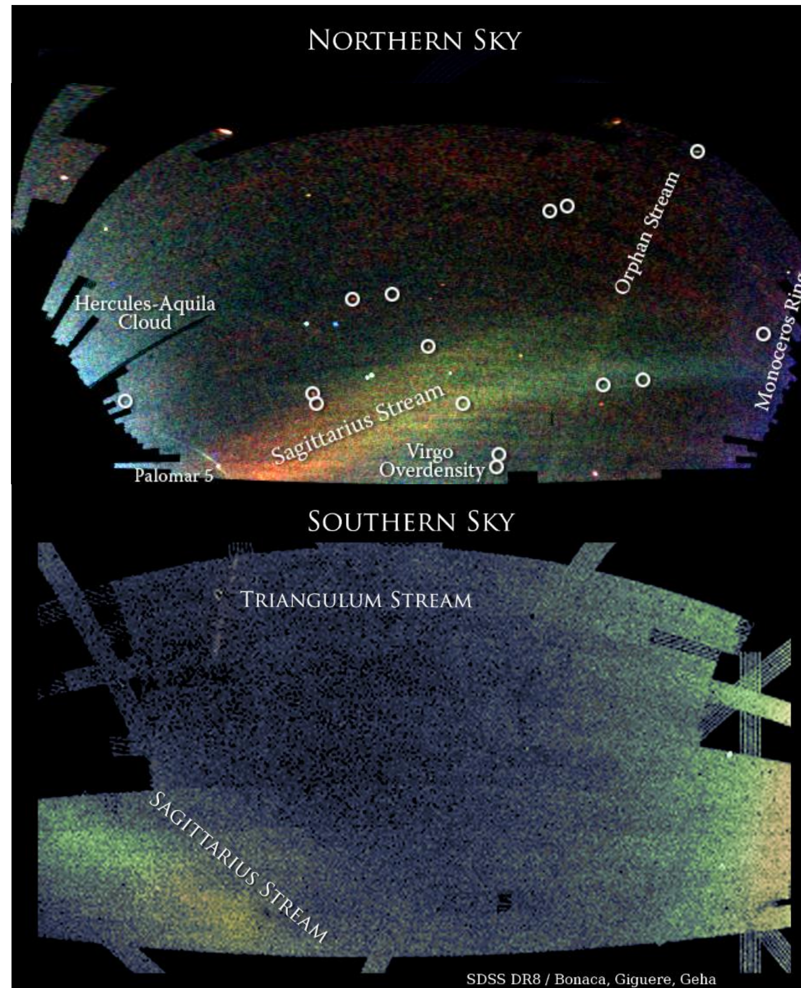
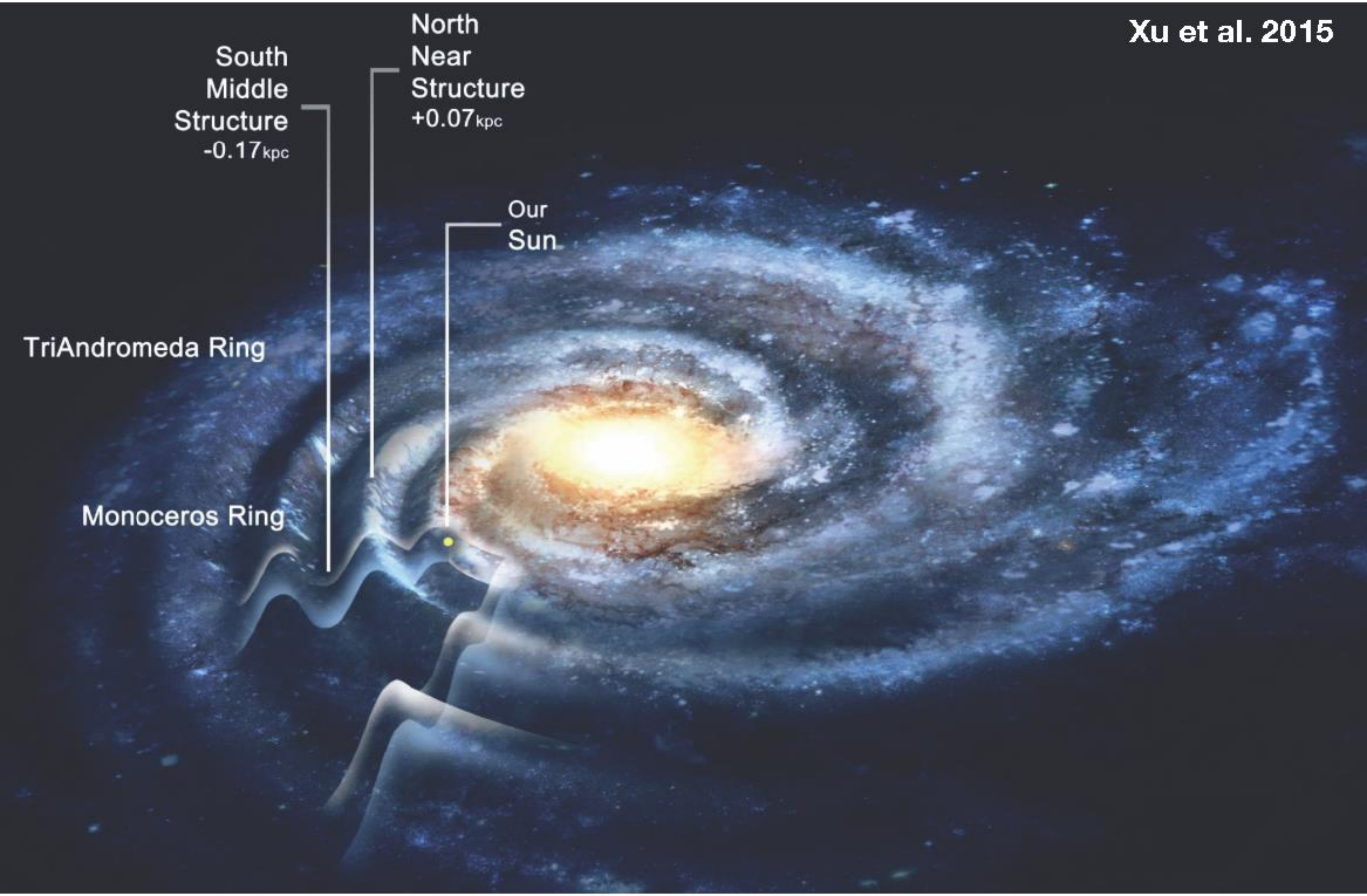
The Galactic disk structure
-- the rings and waves


Herschel's Galaxy model
(~200yrs ago)
6400 light years
1300 light years
Solar system


100,000 ly
(~before SDSS)
28,000 ly
Nuclear bulge
Galactic nucleus
Sun
Disk
Globular clusters
Halo


Blue – model Milky Way
Pink – model planar stream
TriAnd,TriAnd2
Sun
Canis Major or
Argo Navis
Tidal Stream in the Plane of the Milky Way
If it's within 30° of the Galactic plane, it is tentatively assigned to this structure


Northern Sky
Hercules-Aquila
Cloud
Orphan Stream
Monoceros Ring
Sagittarius Stream
Virgo
Overdensity
Palomar 5
Southern Sky
Triangulum Stream
Sagittarius Stream
SDSS DR8 / Bonaca, Giguere, Geha


Xu et al. 2015
North
Near
Structure
+0.07kpc
South
Middle
Structure
-0.17kpc
Our
Sun
TriAndromeda Ring
Monoceros Ring

The Astrophysical Journal, 801:105 (25pp), 2015 March 10 doi:10.1088/0004-637X/801/2/105

RINGS AND RADIAL WAVES IN THE DISK OF THE MILKY WAY

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ABSTRACT

We show that in the anticenter region, between Galactic longitudes of $110° < l < 229°$, there is an oscillating asymmetry in the main-sequence star counts on either side of the Galactic plane using data from the Sloan Digital Sky Survey. This asymmetry oscillates from more stars in the north at distances of about 2 kpc from the Sun to more stars in the south at 4–6 kpc from the Sun to more stars in the north at distances of 8–10 kpc from the Sun. We also see evidence that there are more stars in the south at distances of 12–16 kpc from the Sun. The three more distant asymmetries form roughly concentric rings around the Galactic center, opening in the direction of the Milky Way's spiral arms. The northern ring, 9 kpc from the Sun, is easily identified with the previously discovered Monoceros Ring. Parts of the southern ring at 14 kpc from the Sun (which we call the TriAnd Ring) have previously been identified as related to the Monoceros Ring, and others have been called the Triangulum Andromeda Overdensity. The two nearer oscillations are approximated by a toy model in which the disk plane is offset by the order of 100 pc up and then down at different radii. We also show that the disk is not azimuthally symmetric around the Galactic anticenter and that there could be a correspondence between our observed oscillations and the spiral structure of the Galaxy. Our observations suggest that the TriAnd and Monoceros Rings (which extend to at least 25 kpc from the Galactic center) are primarily the result of disk oscillations.

Key words: Galaxy: disk – Galaxy: kinematics and dynamics – Galaxy: structure

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Flare in the Galactic stellar outer disc detected in SDSS-SEGUE data

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Abstract

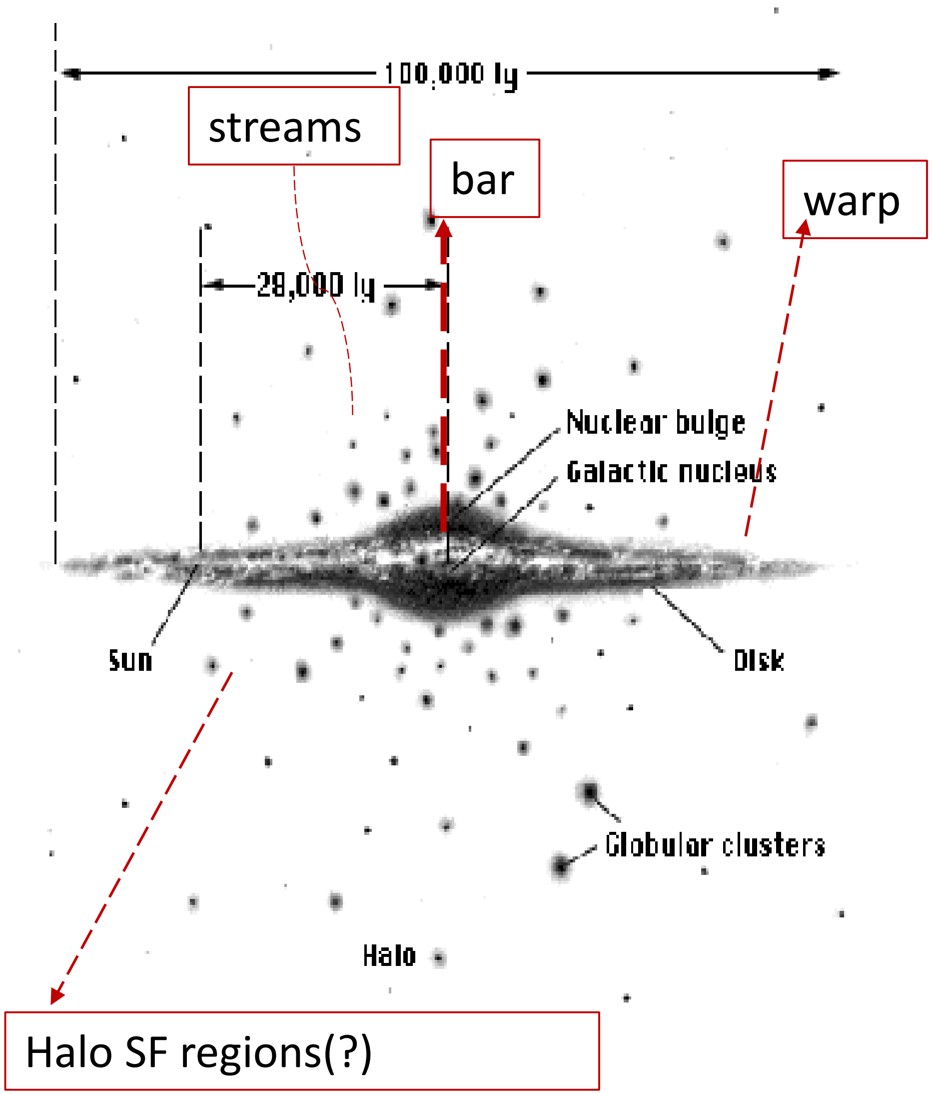
Aims. We explore the outer Galactic disc up to a Galactocentric distance of ≈30 kpc to derive its parameters and measure the magnitude of its flare.

Methods. We obtained the 3D density of stars of type F8V-G5V with a colour selection from extinction-corrected photometric data of the Sloan Digital Sky Survey – Sloan Extension for Galactic Understanding and Exploration (SDSS-SEGUE) over 1400 deg^2 in off-plane low Galactic latitude regions and fitted it to a model of flared thin+thick disc.

Results. The best-fit parameters are a thin-disc scale length of 2.0 kpc, a thin-disc scale height at solar Galactocentric distance of 0.24 kpc, a thick-disc scale length of 2.5 kpc, and a thick-disc scale height at solar Galactocentric distance of 0.71 kpc. We derive a flaring in both discs that causes the scale height of the average disc to be multiplied with respect to the solar neighbourhood value by a factor of $3.3^{+2.2}_{-1.6}$ at R = 15 kpc and by a factor of 12^{+20}_{-7} at R = 25 kpc.

Conclusions. The flare is quite prominent at large R and its presence explains the apparent depletion of in-plane stars that are often confused with a cut-off at $R \gtrsim 15$ kpc. Indeed, our Galactic disc does not present a truncation or abrupt fall-off there, but the stars are spread in off-plane regions, even at z of several kpc for $R \gtrsim 20$ kpc. Moreover, the smoothness of the observed stellar distribution also suggests that there is a continuous structure and not a combination of a Galactic disc plus some other substructure or extragalactic component: the hypothesis to interpret the Monoceros ring in terms of a tidal stream of a putative accreted dwarf galaxy is not only unnecessary because the observed flare explains the overdensity in the Monoceros ring observed in SDSS fields, but it appears to be inappropriate.

Structure of the Galaxy

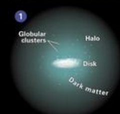


THE MILKY WAY

NATIONAL GEOGRAPHIC

M80
HUBBLE HERITAGE TEAM

Home galaxy of Earth, the Milky Way is a spiral-shaped system of a few hundred billion stars. Bright regions of recently formed stars highlight its arms, while older stars explode or expel their outer layers as beautiful planetary nebulae, then fade away and die. A thick swarm of orange and red stars marks the galactic bulge, encapsulating the star-packed galactic center. At its core may lie a black hole, a region so dense that not even light can escape its gravitational pull. All objects in the Milky Way orbit the galactic center, much like planets in Earth's solar system revolve around the sun. But the scale is staggering: Light from a star at one edge of the galaxy takes about 100,000 years to reach the opposite side.

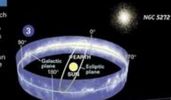


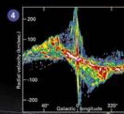
GUIDE TO THE GALAXY

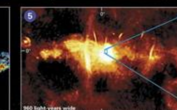
1 Far beyond the galactic disk, yet drawn by its gravity, lone stars and globular clusters wander the galaxy's halo. Regions of dark matter—unseen but felt through its gravitational effects—extend beyond that.

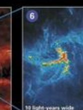
2 Vast clouds of interstellar dust block much of our night sky view of the Milky Way, which from our position in the flat galactic disk appears as a fuzzy band of light. Infrared satellites can see through the dust to reveal the galaxy's structure.

3 Earth's orbit around the sun lies at a severe angle to the galactic plane.







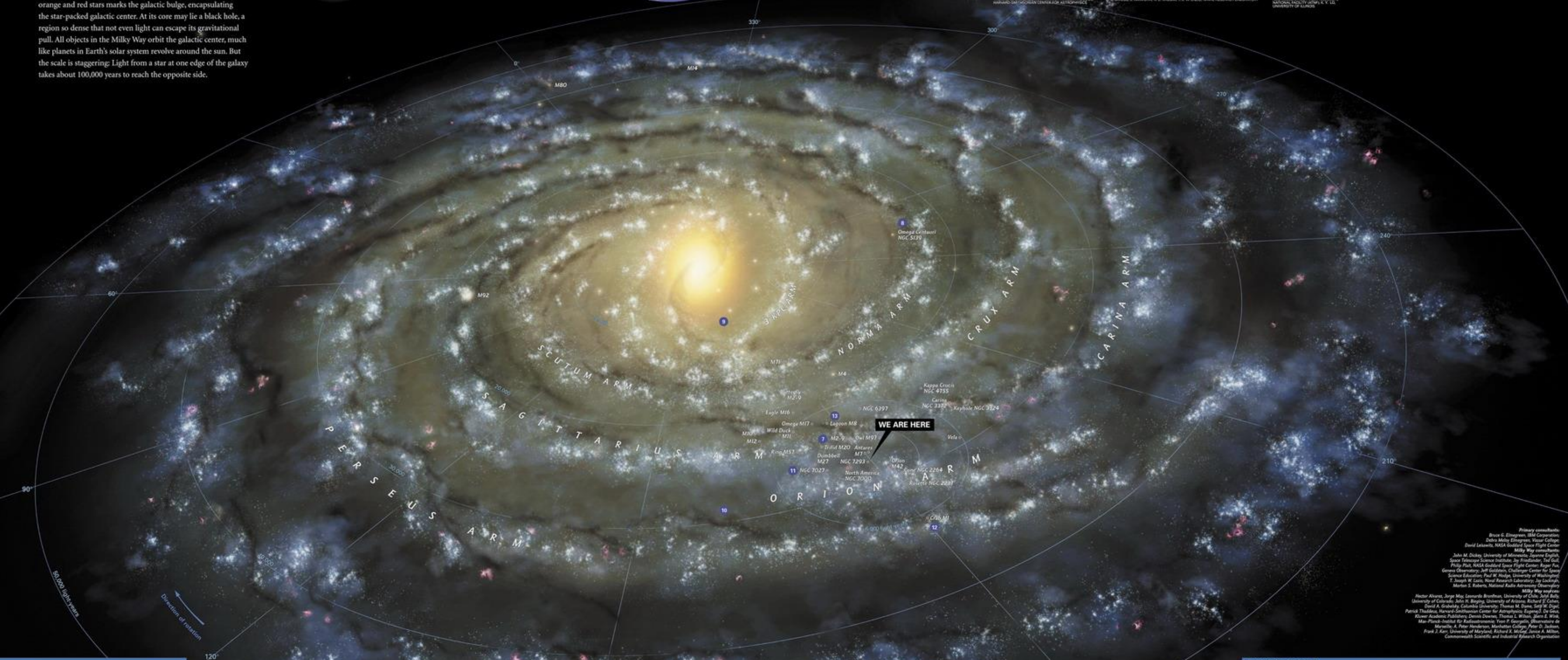


A TURBULENT HEART

4 A graph based on a radio survey reveals the whirlpool motion of molecular gas in the inner part of our galaxy: gas moving away from Earth (top half) and toward Earth (bottom half). The densest gas appears white; least dense, blue.

5 Massive amounts of energy are released near the center of the Milky Way, producing electrons that race along magnetic field lines, illuminating remnants of stellar explosions.

6 Probing even deeper into the core, a radio image details a spiral of hot gas that is falling toward what may be a black hole some 2.6 million times as massive as the sun.



This computer-generated image of the Milky Way—one perspective of a 3-D model newly compiled for NATIONAL GEOGRAPHIC—incorporates the actual positions of hundreds of thousands of stars and nebulae.

- Globular star cluster
- Interstellar gas and dust
- Nebula
- Younger star region (OB stars)
- Molecular cloud
- Galactic bulge or center (older star region)

Reference numbers for galaxies, nebulae, and star clusters
IC (Index Catalog)
M (Messier)
NGC (New General Catalog)

Coordinate system centered on galactic center

Primary consultants:
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Milky Way consultants:
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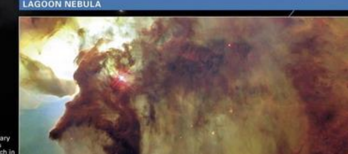
Milky Way sources:
Hector Alvarez, Jorge May, Leonardo Bronfman, University of Chile; John Bally, University of Colorado; John H. Bieging, University of Arizona; Richard S. Cohen, David A. Grabelsky, Columbia University; Thomas M. Dame, Seth W. Digel, Patrick Thaddeus, Harvard-Smithsonian Center for Astrophysics; Eugene J. De Geus, Kluwer Academic Publishers; Dennis Downes, Thomas L. Wilson, Jörn E. Wink, Max-Planck-Institut für Radioastronomie; Yvon P. Georgelin, Observatoire de Marseille; A. Peter Henderson, Manhattan College; Peter D. Jackson, Frank J. Kerr, University of Maryland; Richard X. McGee, Janice A. Milton, Commonwealth Scientific and Industrial Research Organisation

PLANETARY NEBULA M2-9

BRUCE BALICK, UNIVERSITY OF WASHINGTON; VINCENT ICKE, LEIDEN UNIVERSITY; GARRELT MELLEMA, STOCKHOLM UNIVERSITY; NASA

LAGOON NEBULA



ADELINE CAULET, EUROPEAN SPACE AGENCY; NASA

Exotic kaleidoscopes of the Milky Way, colorful nebulae and star clusters are found throughout Earth's galaxy. Even a run-of-the-mill star may eventually produce a nebula of surpassing beauty.

7 Just as our sun will do in its death throes some five billion years from now, a dying star expanded into a red giant and was transformed into the nebula M2-9 (above). At its center shines a small, hot core, which will cool and fade over eons to come. Its stellar wind, streams of charged particles, rushes outward in opposite directions, like exhaust from back-to-back jet engines. This bipolarism, revealed by the Hubble Space Telescope, is common among planetary nebulae. Ultraviolet light from the star heats M2-9's gases and makes them glow.

Other types of nebulae exist in our galaxy, including dark nebulae rich in microscopic dust that blocks our view of stars beyond. When a star adjoins a dark nebula, the dust particles reflect starlight and the black cloud seems to have a silver lining.

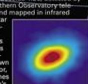
PATRICK SEITZER, UNIVERSITY OF MICHIGAN

8 The million-plus stars packed into a globular cluster such as Omega Centauri (right) are senior citizens of the Milky Way. Unlike human retirees, however, every star in the cluster is about the same age, billions of years older than our 4.6-billion-year-old sun.

HUBBLE HERITAGE TEAM

9 Peering between dust clouds toward the central bulge of the Milky Way, the Hubble Space Telescope focused on a rare clear region in the Sagittarius star cloud (above right). These Sagittarius stars formed at different times; most are older than the sun. They sparkle like an assortment of gems on a jeweler's velvet pad.

10 In some dark clouds lurk strange objects like G339.88-1.26, detected by a European Southern Observatory telescope in Chile and mapped in infrared light (right). A star 20 times as massive as the sun and 10,000 times brighter, it sports a disk of circumstellar dust, shown here in false color, about 20,000 times wider than Earth's orbit. Light from the hot star is absorbed by and warms the dust, making it glow.

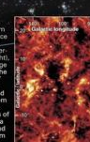


EUROPEAN SOUTHERN OBSERVATORY

11 As stars like the sun die, they become factories for interstellar dust. Celestial soot—the remnants of its red giant stage—surrounds the tiny hot central star of NGC 7027 (above right). Blown outward, the soot would obscure our view of the center of NGC 7027 were it not for this remarkable composite image in infrared and visible light from the Hubble Space Telescope.

WILLIAM B. LATTER, CALIFORNIA INSTITUTE OF TECHNOLOGY; NASA

Clouds of interstellar dust (right), strewn over huge regions along the central plane of the Milky Way, are not thick and smooth but seem as frothy as the head on a glass of beer. Supernova shock waves and stellar wind from evolving stars may have shaped this surprising pattern.



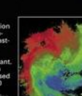
FRANK VAROSI, WILLIAM H. WALLER, NASA; INFRARED ASTRONOMICAL SATELLITE; SKYVIEW

When a massive star comes to the end of its nuclear fuel supply, it collapses and then rebounds in a brief, powerful explosion, or supernova. The Chinese called these celestial fireworks guest stars and recorded one such event in the constellation Taurus in July 1054 that was visible in broad daylight.

JEFF HESTER, PAUL SCOWEN, ARIZONA STATE UNIVERSITY; NASA

12 In that location today astronomers find the fast-expanding Crab Nebula (left), a supernova remnant. At its heart lies a pulsar—a collapsed star—whirling 30 times a second.

Satellite galaxies of the Milky Way host equally remarkable celestial phenomena. In the Large Magellanic Cloud (above right), 180,000 light-years from Earth, clumpy, filamentary clouds of hydrogen gas reveal their stately march in a radio map from the Australia Telescope Compact Array. The lower half of the cloud (blue) is rotating toward the Earth while the topside (red) turns away.



SUNGEUN KIM, UNIVERSITY OF ILLINOIS; LISTER STAVELEY-SMITH, ATNF

13 Glistening along the spiral arms of the galaxy, bright emission nebulae mark regions where new stars are forming. The Lagoon Nebula (above), about 5,000 light-years distant, is easily detected with the naked eye as a fuzzy spot in the southern constellation Sagittarius. Wide-field images show that it covers more of the sky than does the full moon. Where there was once only a vast dark cloud, radiation from the brightest and most massive young star in the nebula, Herschel 36, heats and ionizes the gas across a wide region. Despite the brilliance of the Lagoon Nebula and similar objects like the famous Orion Nebula, such areas are usually little more than hot blisters on the flanks of giant interstellar clouds.

With new tools, astronomers are unraveling the nature of the Milky Way and measuring distances to stars and nebulae with greater accuracy. Still, they ask, how did the Milky Way form in the first place? How and when did the arms form? How many more planets circle nearby stars besides the 102 already discovered? And the biggest question of all: Do any of them harbor life?

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