Galactic Streamlines

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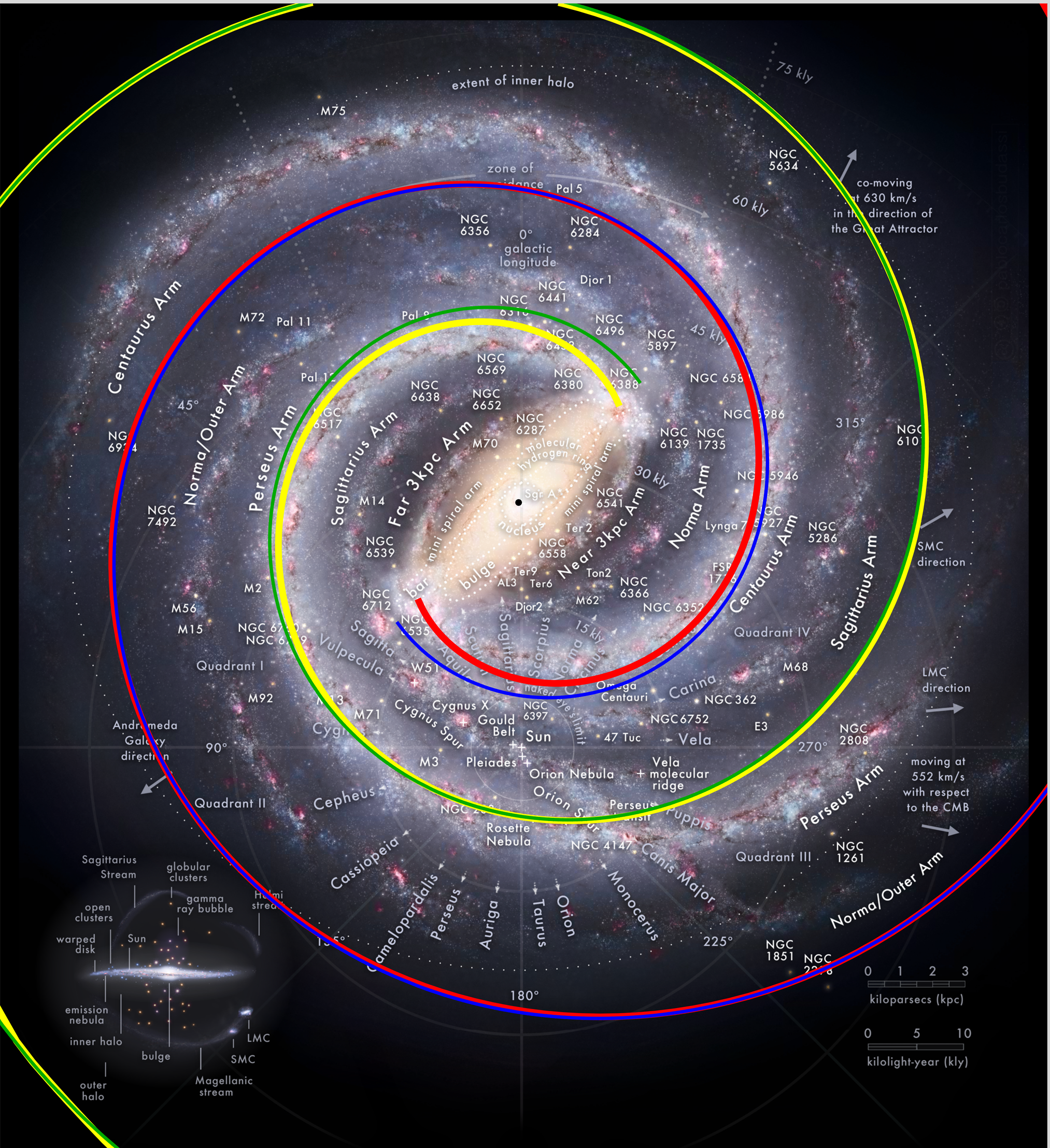
Streamlines computed by George and Johansson (2023) for the ***Milky Way*** using azimuthally averaged data of Eilers et al (2019) superimposed on artist's rendition of NASA star observations.



In galaxy studies astronomers have historically focused on measuring the azimuthal velocity component, V_ϕ, since the term $\rho V_\phi^2/r$ in the radial momentum equation dominates in the balancing of the inward gravitational force. However, a few years ago Eilers et al (2019) published results from measurements of both V_ϕ and V_r, the radial velocity component, in the Milky Way. It now became possible to study the effects of other terms in the momentum equations. Moreover it also became possible to represent the data in the form of *streamlines*, i.e., lines that are everywhere tangent to the local velocity field, and which we, working in Fluid Mechanics, are used to.

The streamlines here are based on azimuthally averaged measurements of V_ϕ and V_r. Therefore the streamlines do not represent true paths of the motion of the stars, i.e., they are not path lines. We believe though that they still give a qualitatively representative picture of the flow pattern.

The streamlines are shown by red and yellow lines originating at the beginning of the principle arms of the Milky Way. We see that they follow a spiral pattern similar to the principle arms, but soon start to deviate appreciately from them, and do so at an increasing rate farther out from the center. Clearly the average motion of the stars seems to approximately follow the spiral arms, but only in a qualitative sense.

It has been argued that the spiral arms should form logarithmic spirals. We have also investigated this issue here. Two logarithmic spirals have been fitted to the streamlines, and are shown in the figure by dotted lines. We notice that, except for the region near the central bulge, the logarithmic lines follow the streamlines much more closely than the spiral arms. The picture covers only the visible part of the Milky Way. Outside this inner region the space is filled with dust and gas, which is also part of the galaxy, and the velocities have been measured also in this outer region. Although not shown in the figure the logaritmic spirals continue to follow the streamlines, and do so extremely well in this outer region.

References

W. K. George and T. G. Johansson, Presentation at the 76th Annual Meeting of the APS Division of Fluid Dynamics, Washington DC, November 2023.

A.–C. Eilers, D. W. Hogg, H.–W. Rix, M. K. Ness; The Circular Velocity Curve of the Milky Way from 5 to 25 kpc, *The Astrophysical Journal*, 871:120 (2019).

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