The diverse history of counterrotating galaxies

Tjitske Starkenburg
Flatiron Research Fellow
Center of Computational Astrophysics
Flatiron Institute, New York

In collaboration with: Laura Sales (UCR), Shy Genel (CCA/Columbia), Christina Manzano-King (UCR), Gabriela Canalizo (UCR)
Polar ring galaxy NGC2685: *the Helix galaxy*
First kinematic observations that show rotation along the minor axis: Ulrich 1975
NGC4550: Rubin et al. 1992 show gas–star counterrotation, and an indication of a secondary stellar disk rotating with the gas.

Rix et al. 1992 show that the line-of-sight velocities are bimodal.
NGC 2551 – stellar-ionized gas counterrotation
Sil’chenko et al. 2009
NGC 2551 – stellar-ionized gas counterrotation
Sil’chenko et al. 2009
(Vogelsberger et al. 2014; Genel et al. 2014)

\[ 2 \times 10^9 < M_{\text{sun}} < 5 \times 10^{10} \]

\( \sim 12000 \) galaxies

Define stars – gas co/counterrotation by the angle between \( L_{\text{gas}} \) and \( L_{\text{stars}} \) vectors

\( \sim 1\% \) counterrotating (angle > 90 degrees)

\( \sim 5\% \) polar disks (45 < angle < 135 degrees)
Edge-on Face-on

Face-on Edge-on

Stars

Gas

Edge-on Edge-on

Edge-on kinematics

Edge-on kinematics
General properties of all (blue) and counterrotating (red) galaxies
Circularity = \frac{j_{\text{circ}}}{r v_{\text{circ}}(r)}
16% of the gas is counterrotating
0% of the stars is counterrotating

- **23%** of the galaxies has > 10% of the **stars** counterrotation
- **9%** of the galaxies has > 20% of the **stars** counterrotation
- **0.05%** of the galaxies has > 50% of the **stars** counterrotation

- **6%** of the galaxies has > 10% of the **gas** counterrotation
- **3%** of the galaxies has > 20% of the **gas** counterrotation
- **1%** of the galaxies has > 50% of the **gas** counterrotation

0% of the gas is counterrotating
14% of the stars is counterrotating
1 clear example of total gas – stars counterrotation

\[
\begin{align*}
\log M_\star &= 10.32 \\
\log M_{\text{gas}} &= 9.38 \\
\log M_{\text{tot}} &= 11.54
\end{align*}
\]
Counterclockwise / Multi Spin / Polar Disk Galaxy

\[ M_{\text{star}} = 2 \times 10^{10} \, M_{\text{sun}} \]
\[ M_{\text{gas}} = 2 \times 10^9 \, M_{\text{sun}} \]
\[ M_{\text{tot}} = 3 \times 10^{11} \, M_{\text{sun}} \]

Circularity = \( j_{\text{circ}} / r \, v_{\text{circ}}(r) \)
Gas – stars counterrotation, once established, can be long-lasting.
Conclusions

Pure **gas-stars** counterrotating galaxies constitute a **small** fraction of all galaxies. **Inclined (“polar”)** disk galaxies and **kinematic subcomponents** are more often expected. They are however not un-common in global galaxy properties.

For **total gas-stars counterrotation** the galaxy seems to need to loose its (co-rotating) gas. This can be done by strong (AGN) feedback or ram-pressure stripping. Counterrotating galaxies may help constrain feedback?

The detailed history of counterrotating galaxies can be quite diverse!