

Proper Motion of the Andromeda Galaxy: The Keystone of Local Group Dynamics

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Image Credit: Robert Gendler 2006



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Is the Local Group bound?

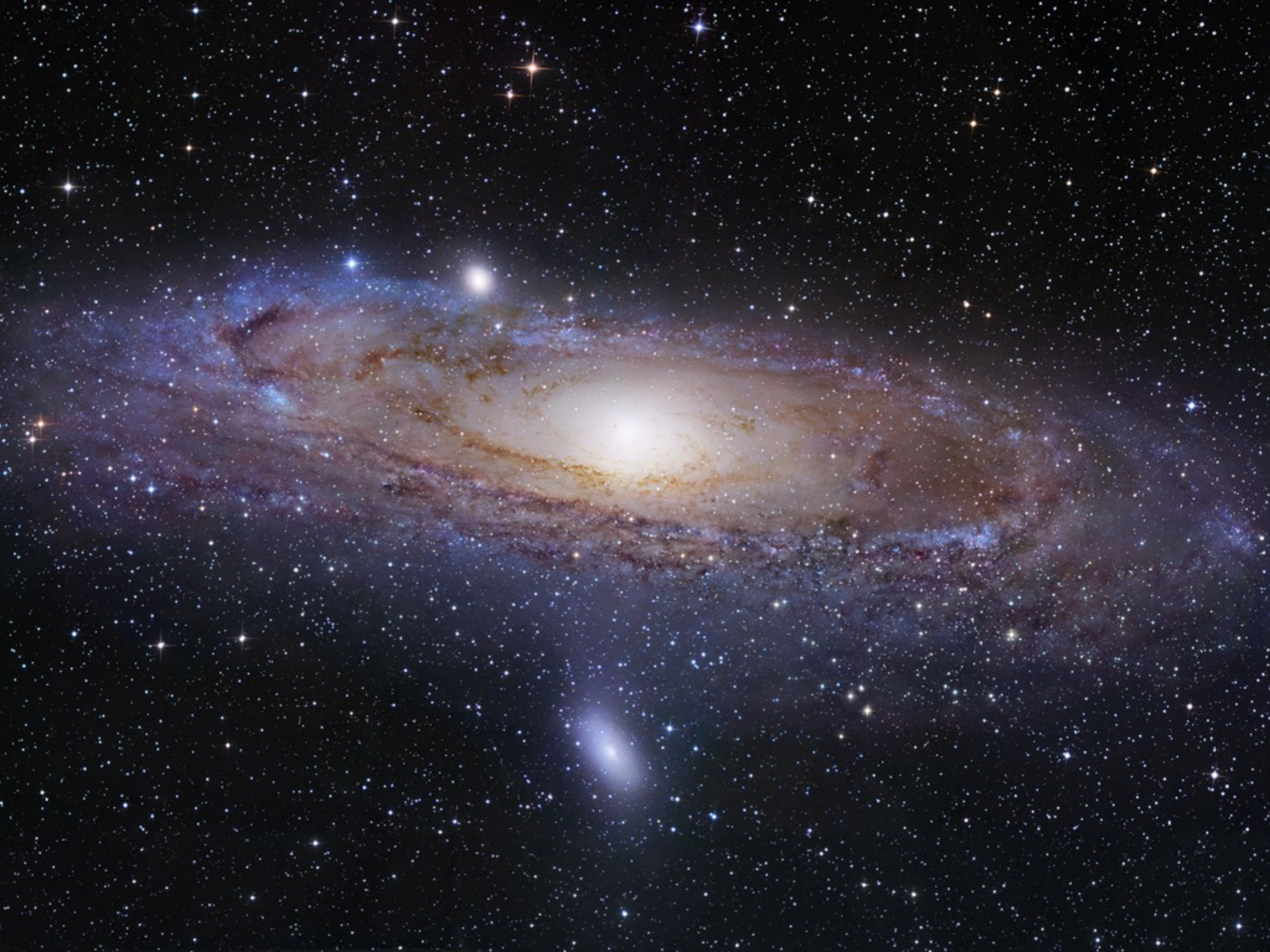
What is its fate?

Does light trace mass?

Dark matter halos: mass, profile, size, shape

Proper Motion of the Andromeda Galaxy: The Keystone of Local Group Dynamics

- *Astrometry* Discovery Area
- Galactic Neighborhood Science Question:
What are the connections between dark and luminous matter?



The Woeful Inadequacy of Extragalactic Maser Observations

Remember:

All masers seen in the Galaxy occur in other galaxies.

But, moving from kpc to Mpc distances,

Resolution down 1000-fold

Sensitivity down 10^6 -fold

1 pc \rightarrow 1 kpc

1 Jy \rightarrow 1 μ Jy

Only a few species (water best)

Only a few 10's of galaxies

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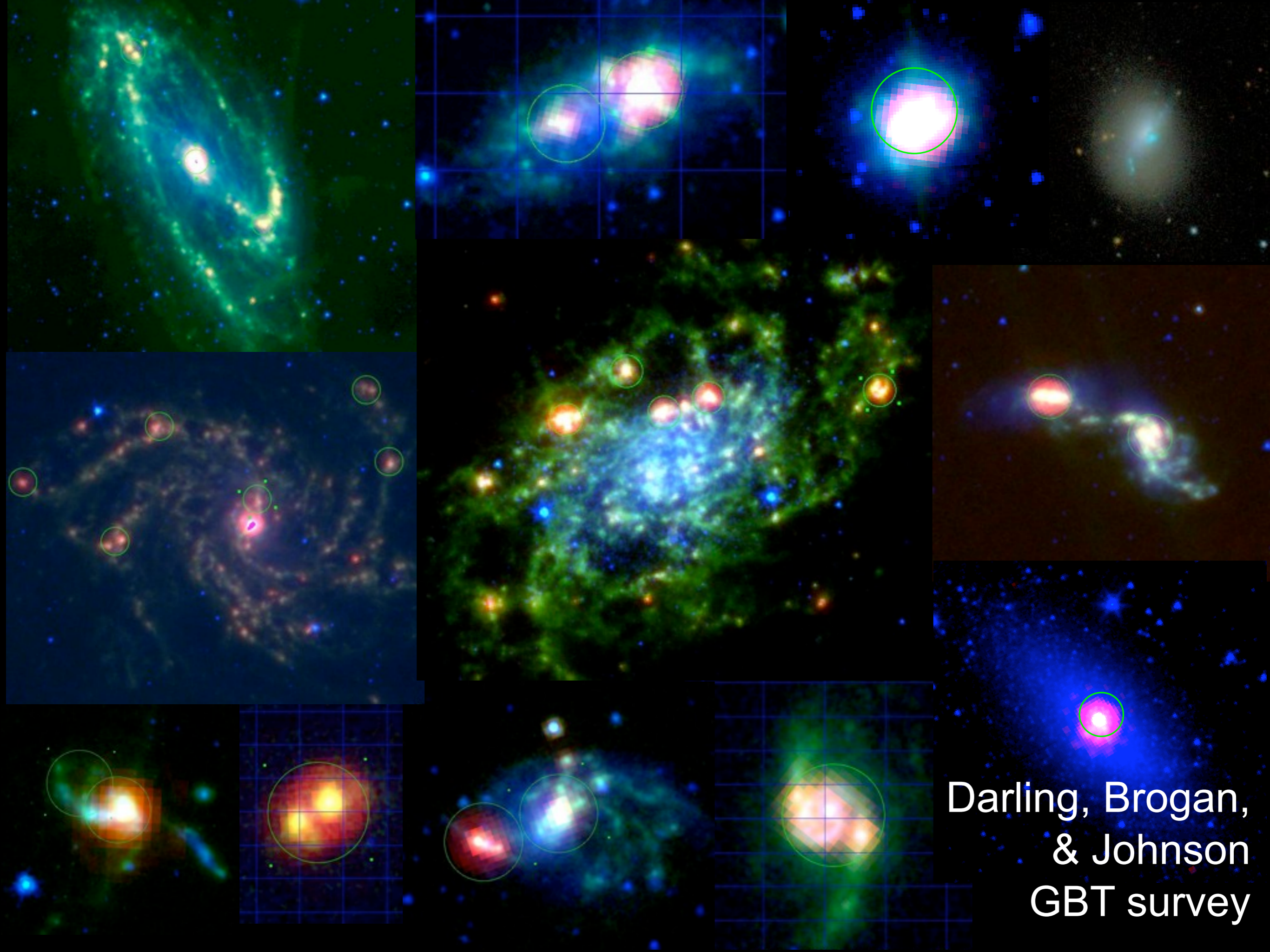
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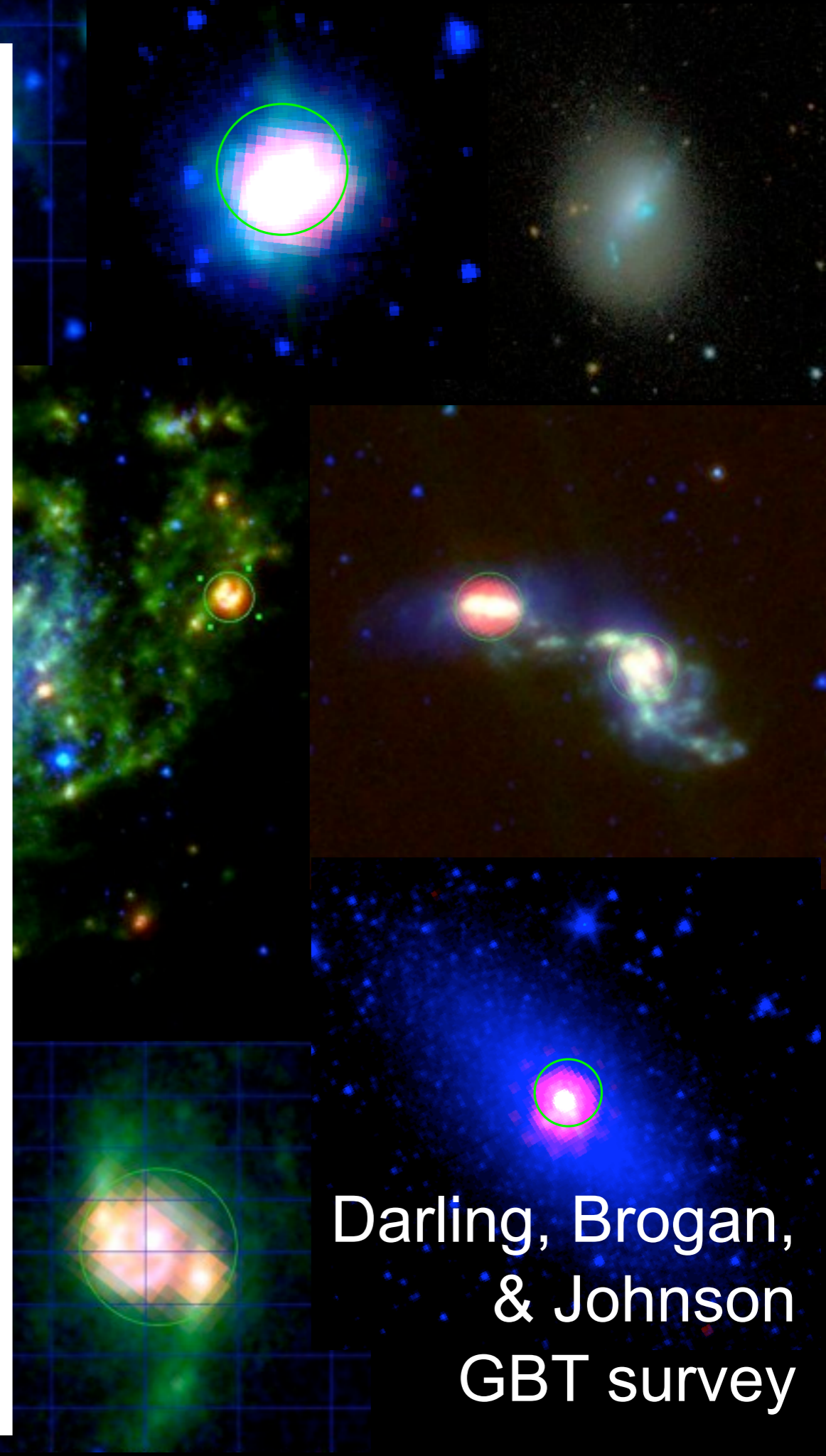
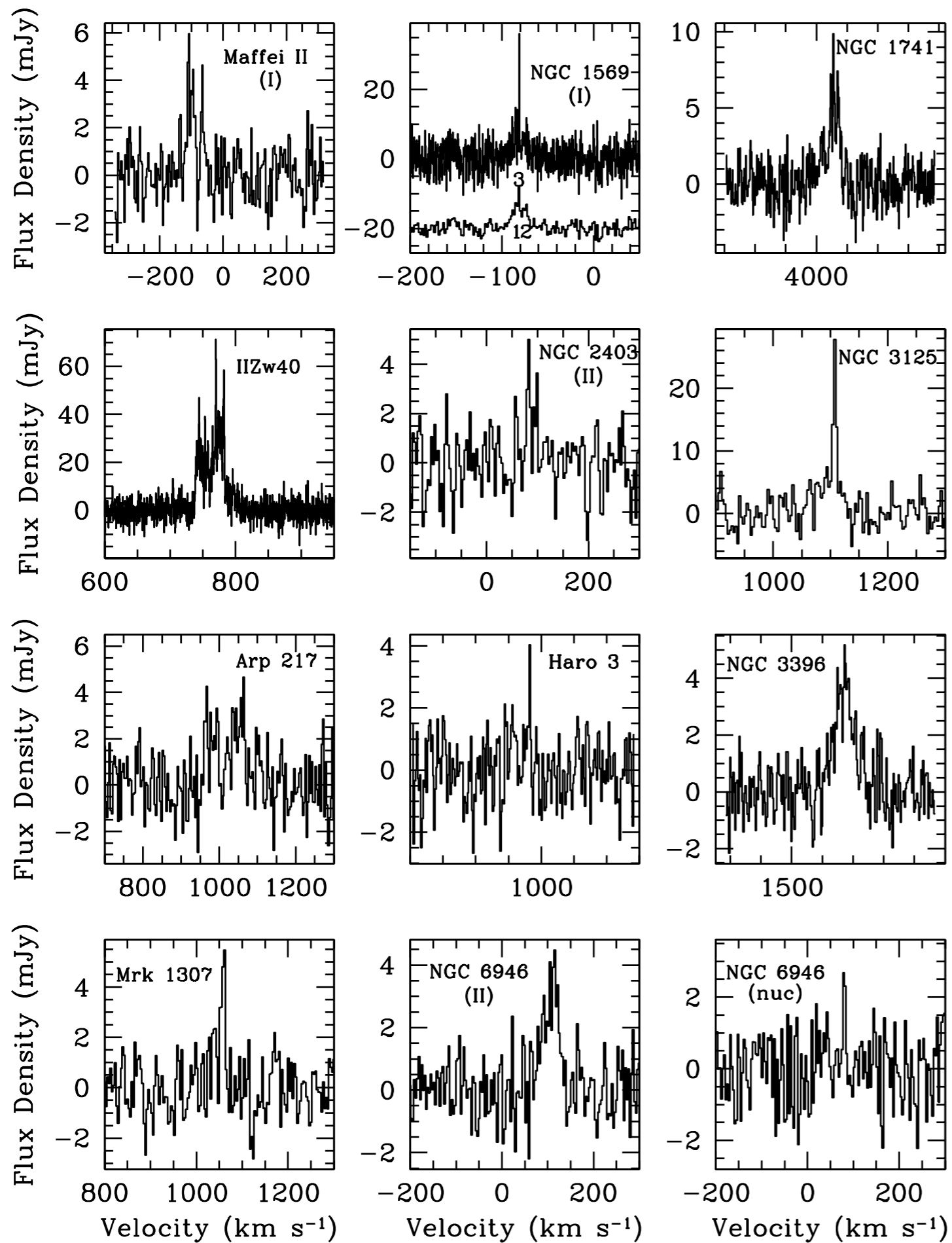
*We now have the
sensitivity to detect
Galactic analog masers*

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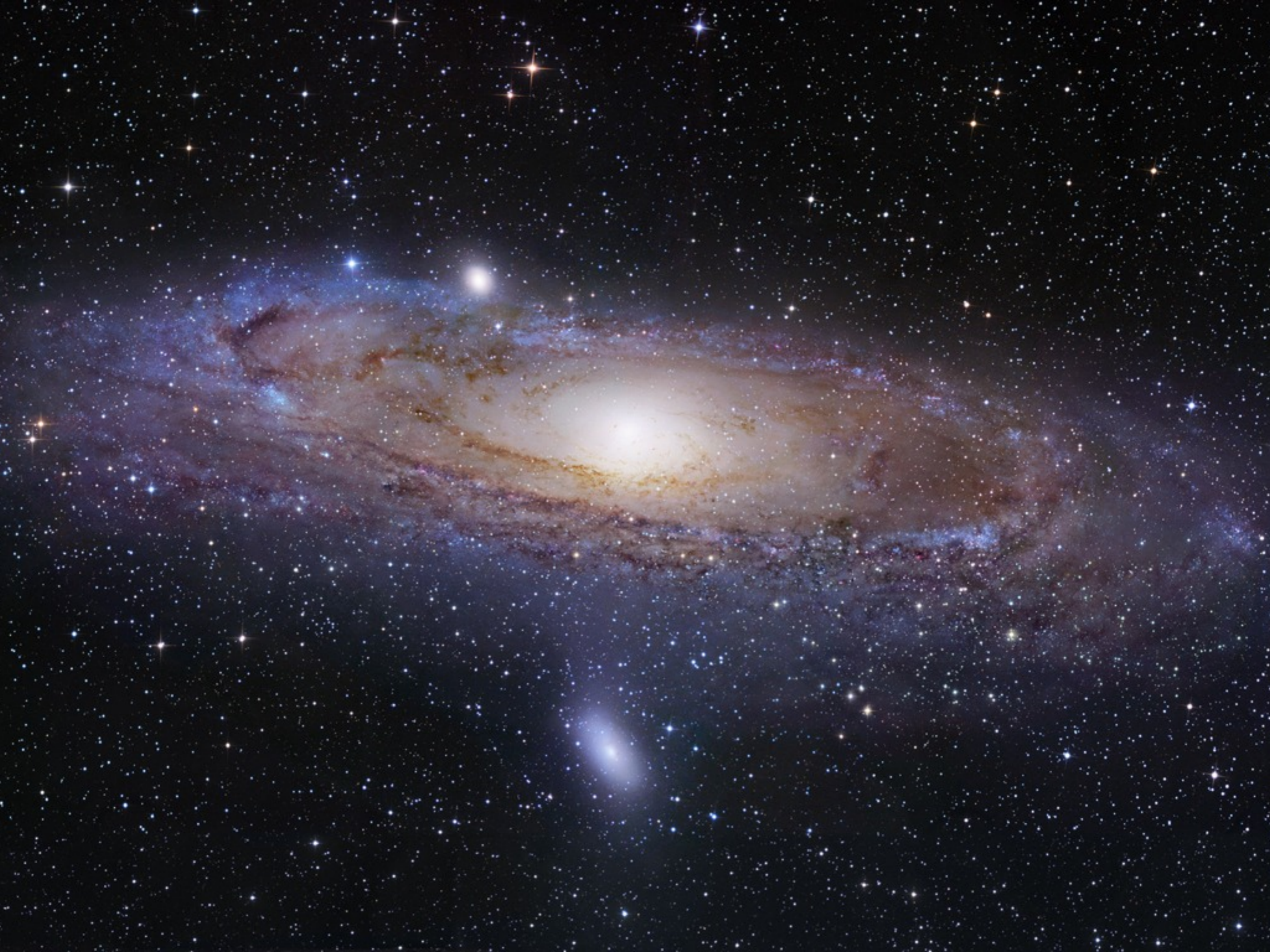
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Darling, Brogan,
& Johnson
GBT survey



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A Water Maser Survey of M31

Problems:

M31 is large!

Sensitivity to detect Galactic analogs

Low(er) star formation rate (8x less)

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Solutions:

-- Targeted survey of IR sources

-- GBT

-- Large N

A Water Maser Survey of M31

Spitzer 24 micron (Gordon et al 2008)

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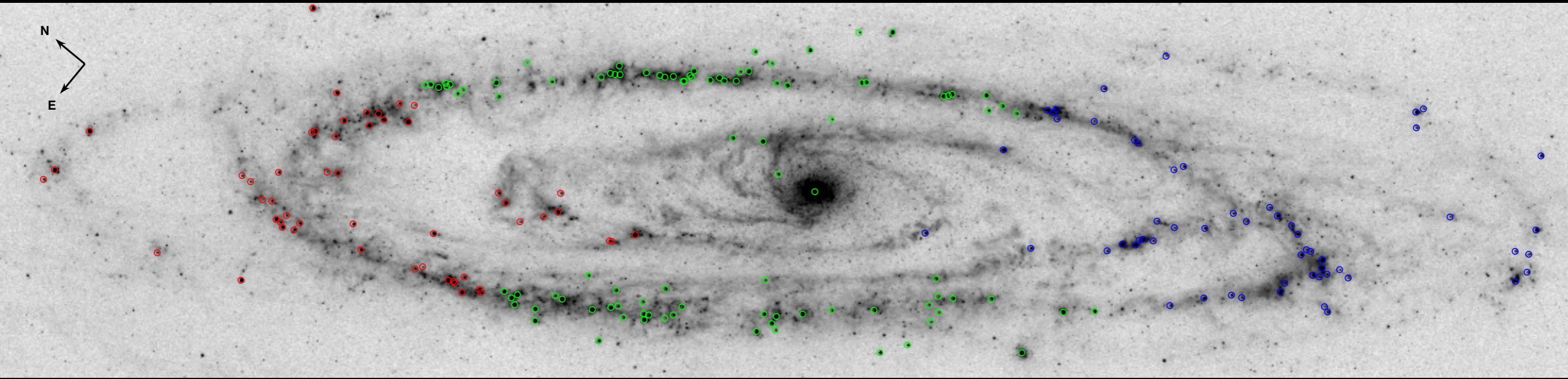
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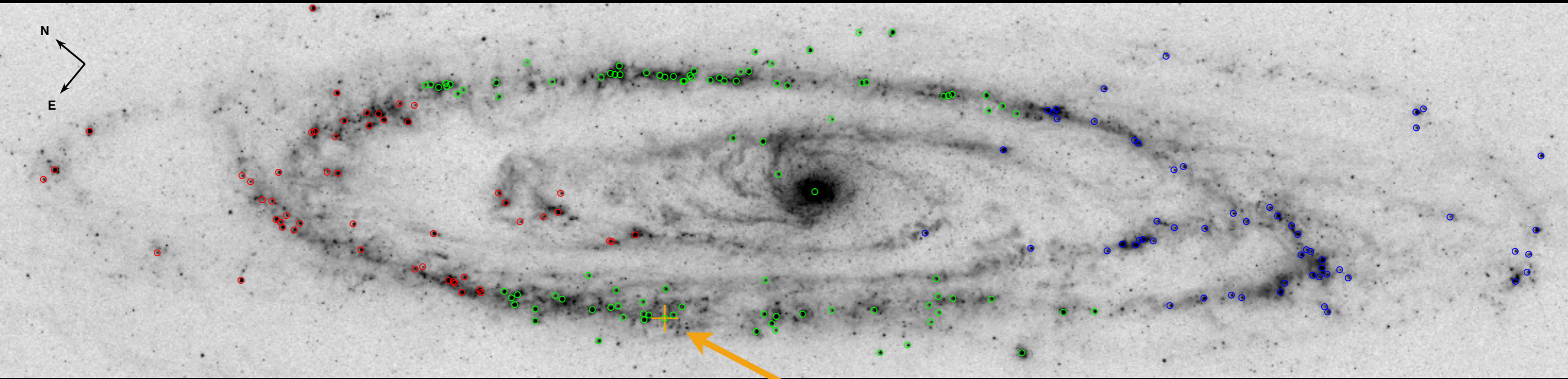
A Water Maser Survey of M31



Green Bank Survey:

- Select compact luminous $24\ \mu\text{m}$ sources
(Spitzer; Gordon et al 2008)
- Sensitivity to detect Galactic analog masers in 5 minutes
200 Jy at 6 kpc (Galaxy) is 12 mJy at 780 kpc (M31)
- 206 sources, 32 hours
- Confirmation/refutation observations of a large fraction

A Water Maser Survey of M31

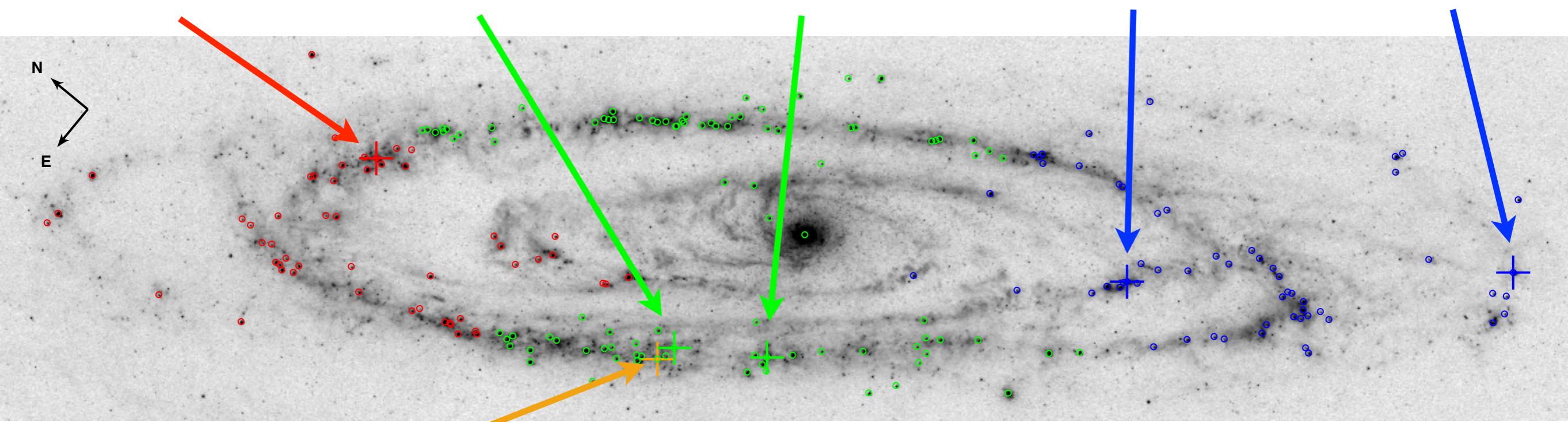
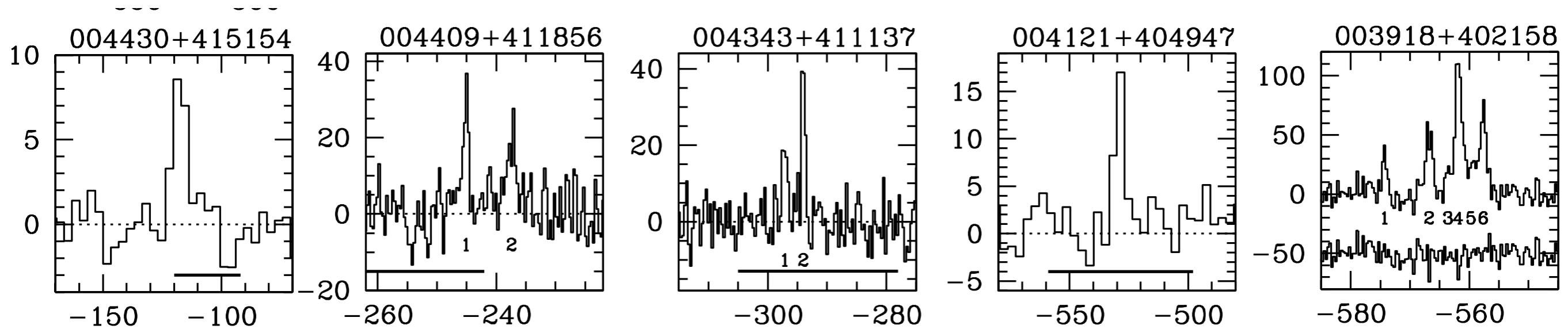


Methanol maser
Sjouwerman et al 2010

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New Masers in the Andromeda Galaxy

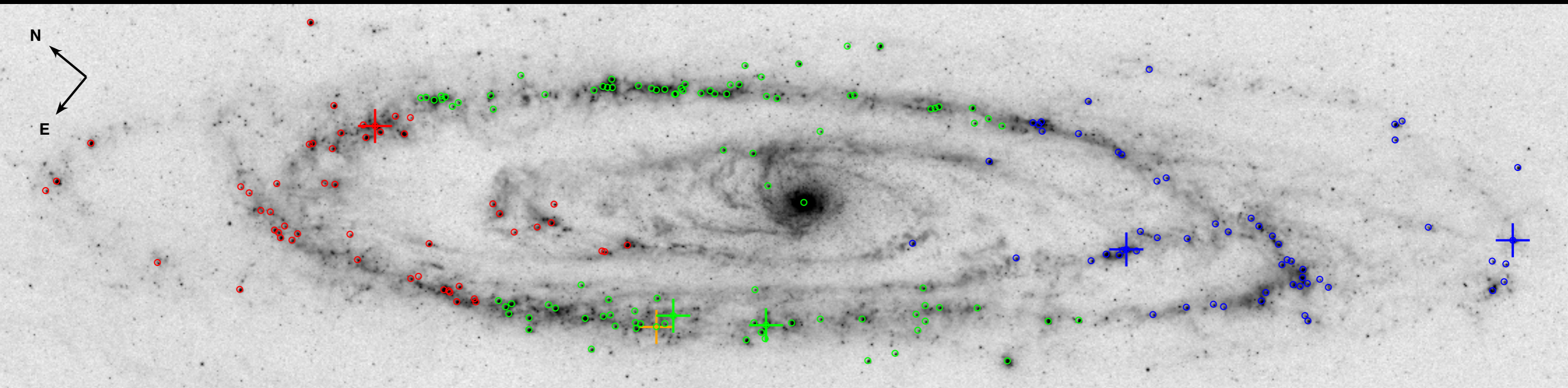


Methanol maser
Sjouwerman et al 2010

CO (1-0) from Nieten et al (2006)

Spitzer 24 μm from Gordon et al (2008)

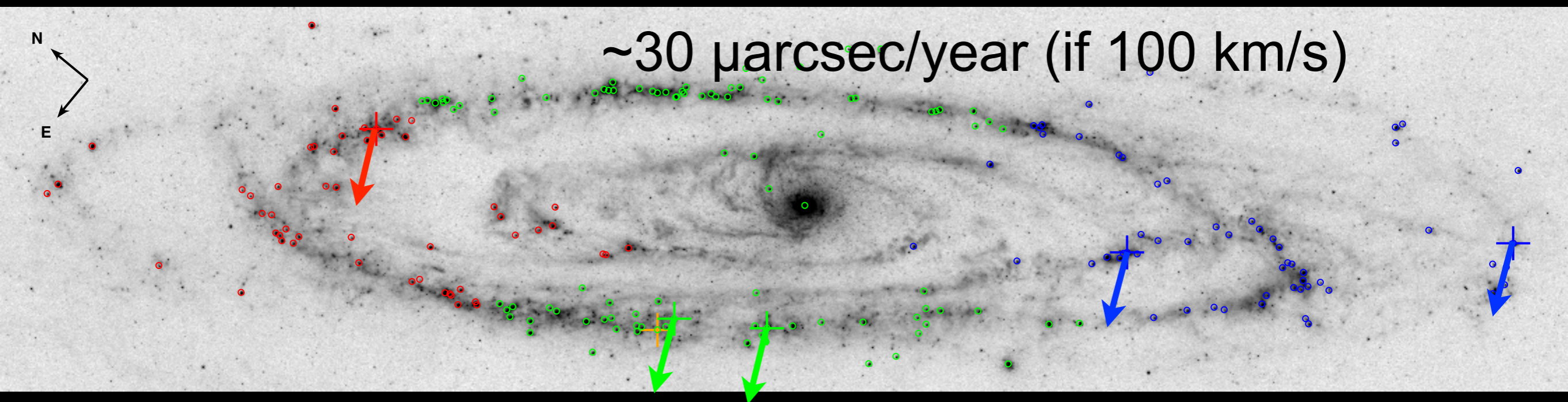
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Green Bank Survey Implications:

- 24 μm selection works, but is not predictive
- Can detect Galactic analog masers in Local Group and beyond! (*up to ~ 20 Mpc*)
- ***Proper rotation, geometric distance possible to ~ 5 Mpc***
- ***Proper motion possible to ~ 20 Mpc (depends on v_{pec})***

Proper Motion \Rightarrow 3-D Velocity

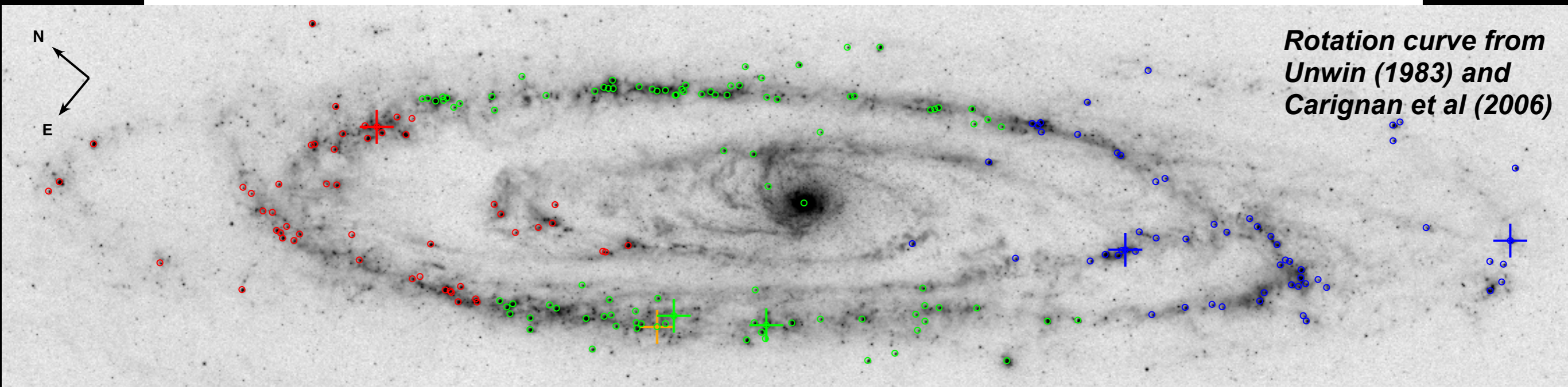
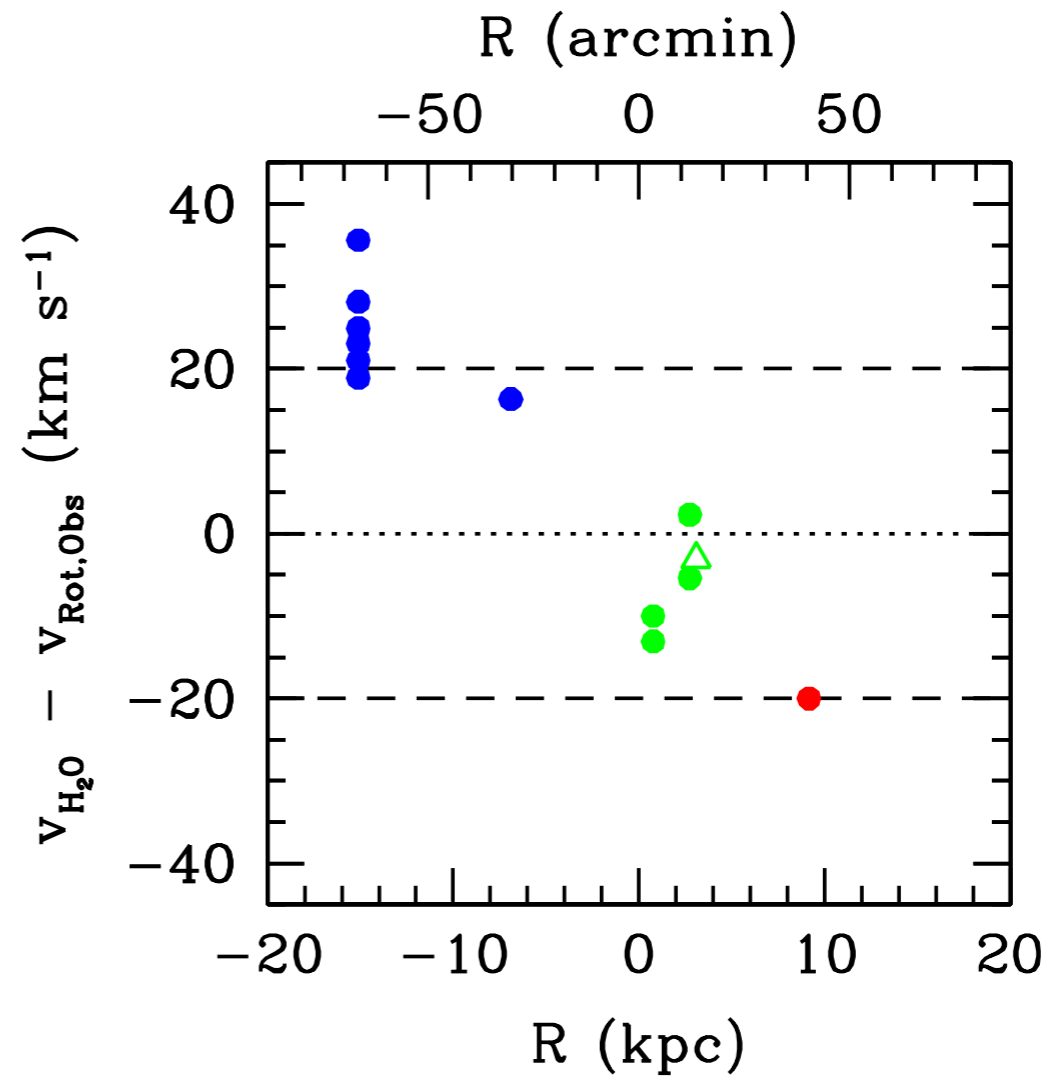
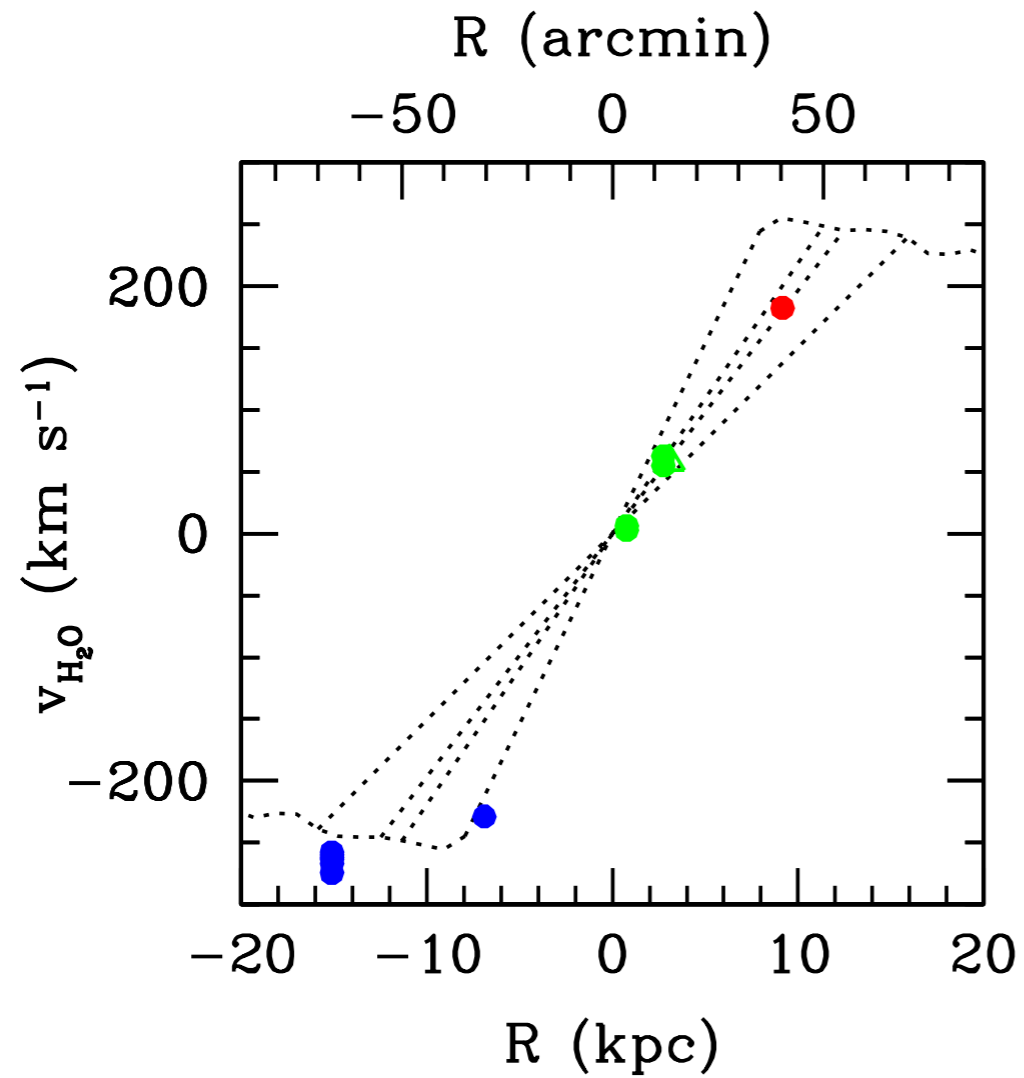


- $\sigma_{\mu} \propto t^{-3/2}$

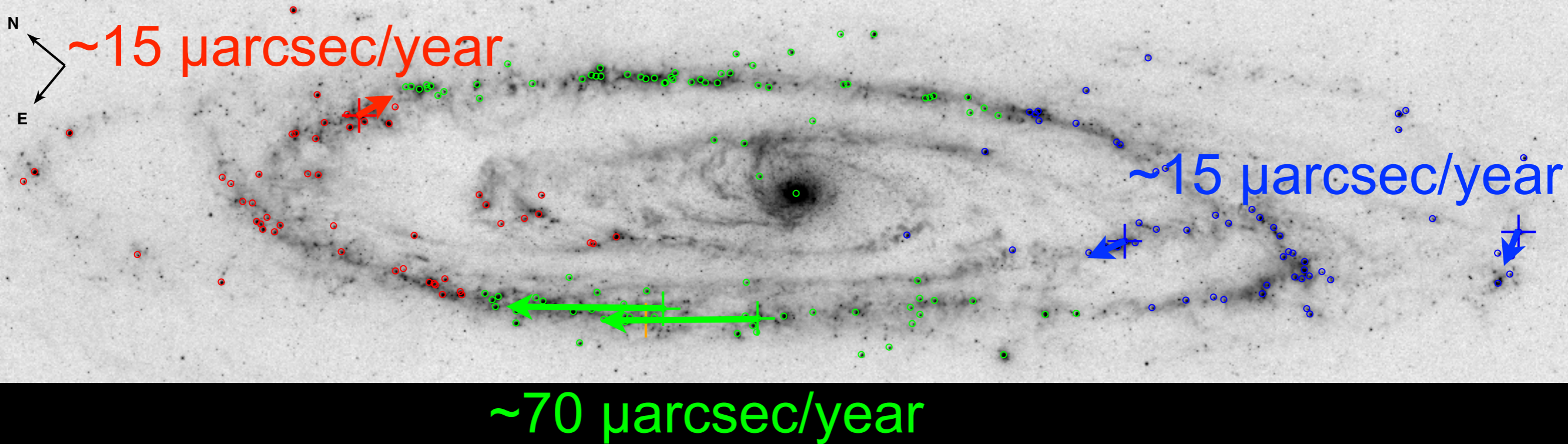
- Expect $\sim 6\sigma$ detection in ~ 3 years

**** Arrows are schematic cartoons ****

Rotation and Peculiar Velocities



Proper Rotation \Leftrightarrow Geometric Distance

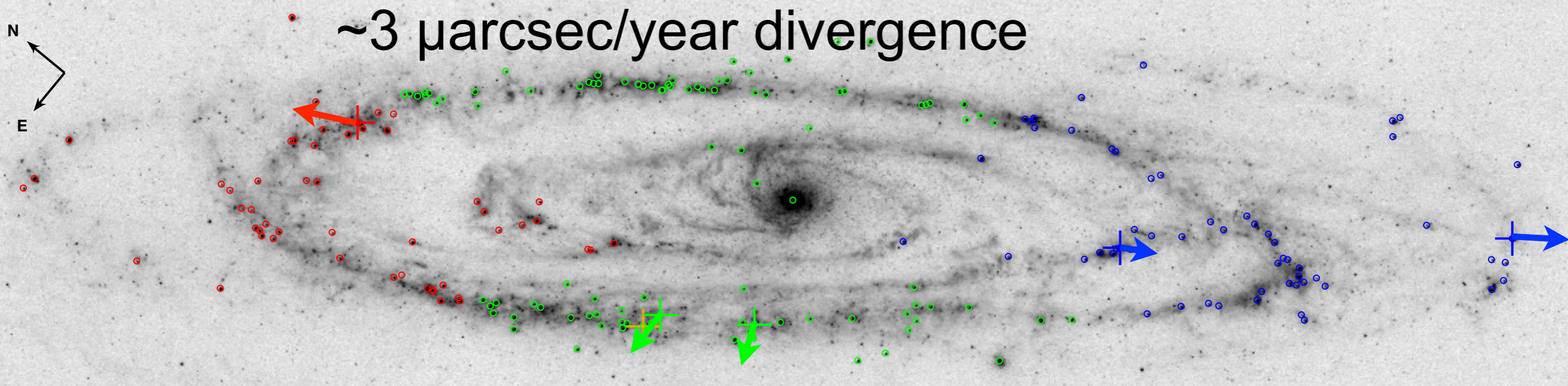


$$D = V_{\text{Rot}} / \mu_{\text{Rot}}$$

- Distance error gets \sim equal contributions from rotation curve uncertainty and proper motion uncertainty (initially)
- Expect $\sim 10\%$ uncertainty (initially)

(c.f. Brunthaler et al work on M33)

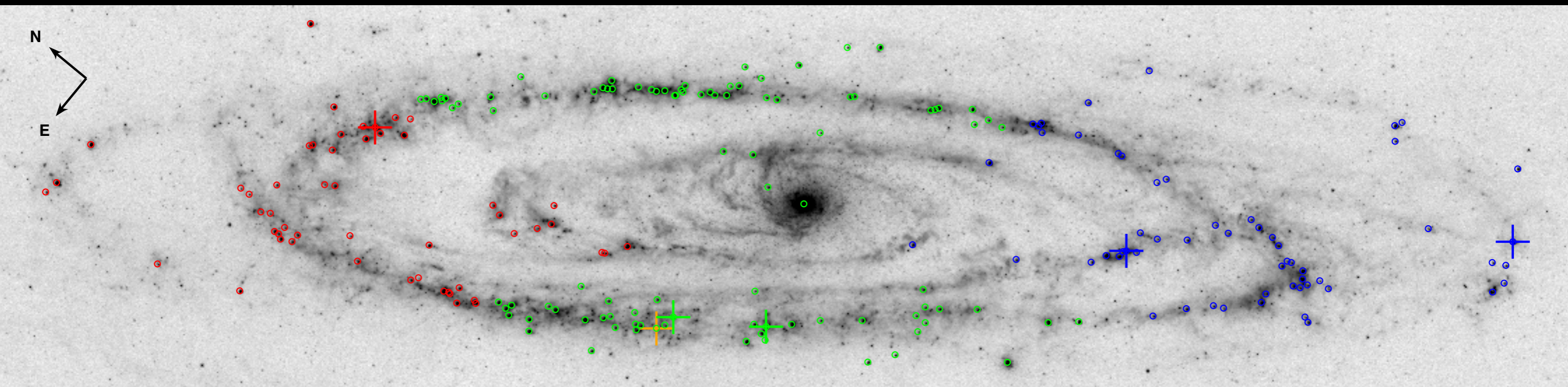
Moving “Cluster” \Rightarrow Diverging Masers



$$\mu_{\text{Div}} = -V_r \theta / D$$

- M31 gets larger on the sky as it approaches
- Largest maser separation is 1.8°
- Detectable in ~ 10 years?
- Cute, but useful?

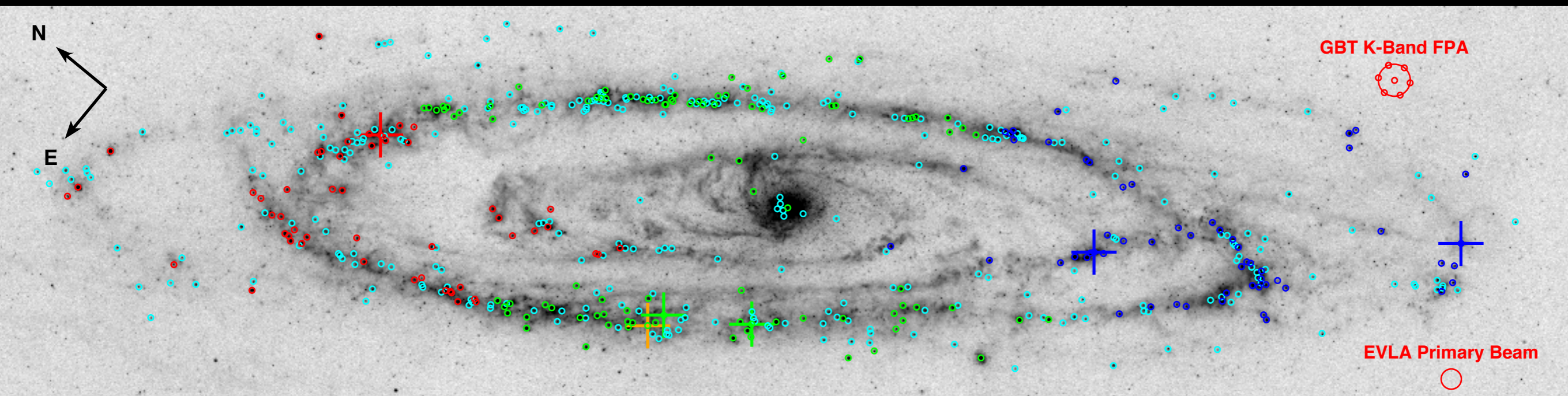
Building a Comprehensive Maser Network for Proper Motion Studies



24 μm identifies maser sites but is not predictive

\Rightarrow Additional masers are likely!

Building a Comprehensive Maser Network for Proper Motion Studies



24 $m\mu$ identifies maser sites but is not predictive

⇒ Additional masers are likely!

The Future

The Proper Motion of the Andromeda Galaxy

Keystone for Local Group kinematics, Dark Matter

Proper rotation yields distance

Moving cluster distance

Proper Motion of Other Galaxies

Galactic analog masers detectable to ~ 20 Mpc

Proper rotation, geometric distance possible to ~ 5 Mpc

Proper motion possible to ~ 20 Mpc

Bearing on Dark Matter

The End