ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

e-Workshop 2020 – October 27-29

JcUVa

The Fermi Bubbles, Nuclear Feedback in our own Backyard

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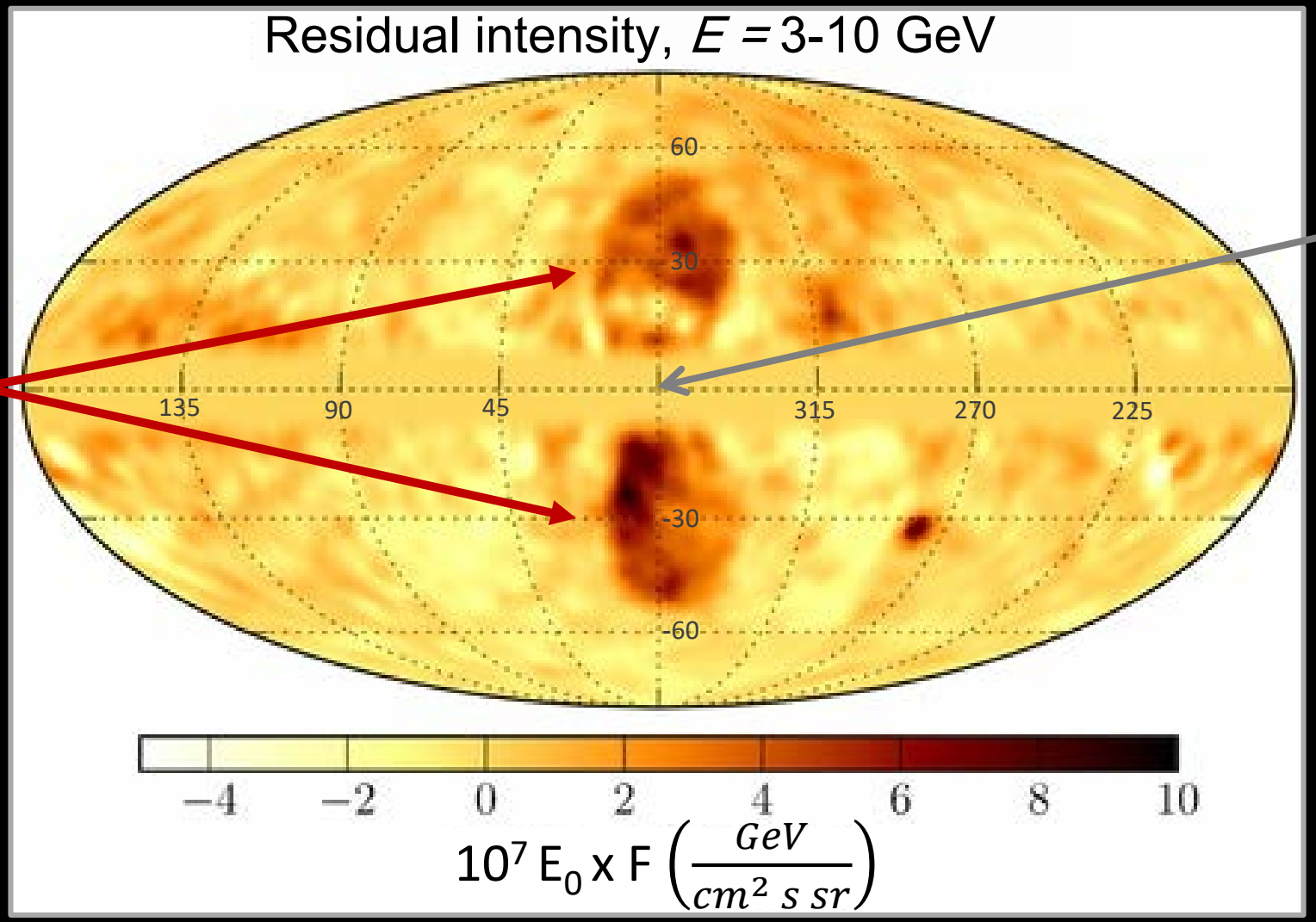
Image Credit: NASA's Goddard Space Flight Center

The Fermi Bubbles in Gamma-Ray Emission



Galactic center

Fermi Bubbles

Fig. 22 from Ackermann+ 2014

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Why study the Fermi Bubbles?

- Want to know how they formed
  (Sgr A* outburst likely)
- Want to understand their effect on the Milky Way halo
- Can compare them to central outflows in other galaxies
  (see Veilleux+ 2020 for a review of outflows both Galactic and extragalactic)

Image Credit: NASA's Goddard Space Flight Center

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The Fermi Bubbles in UV Absorption

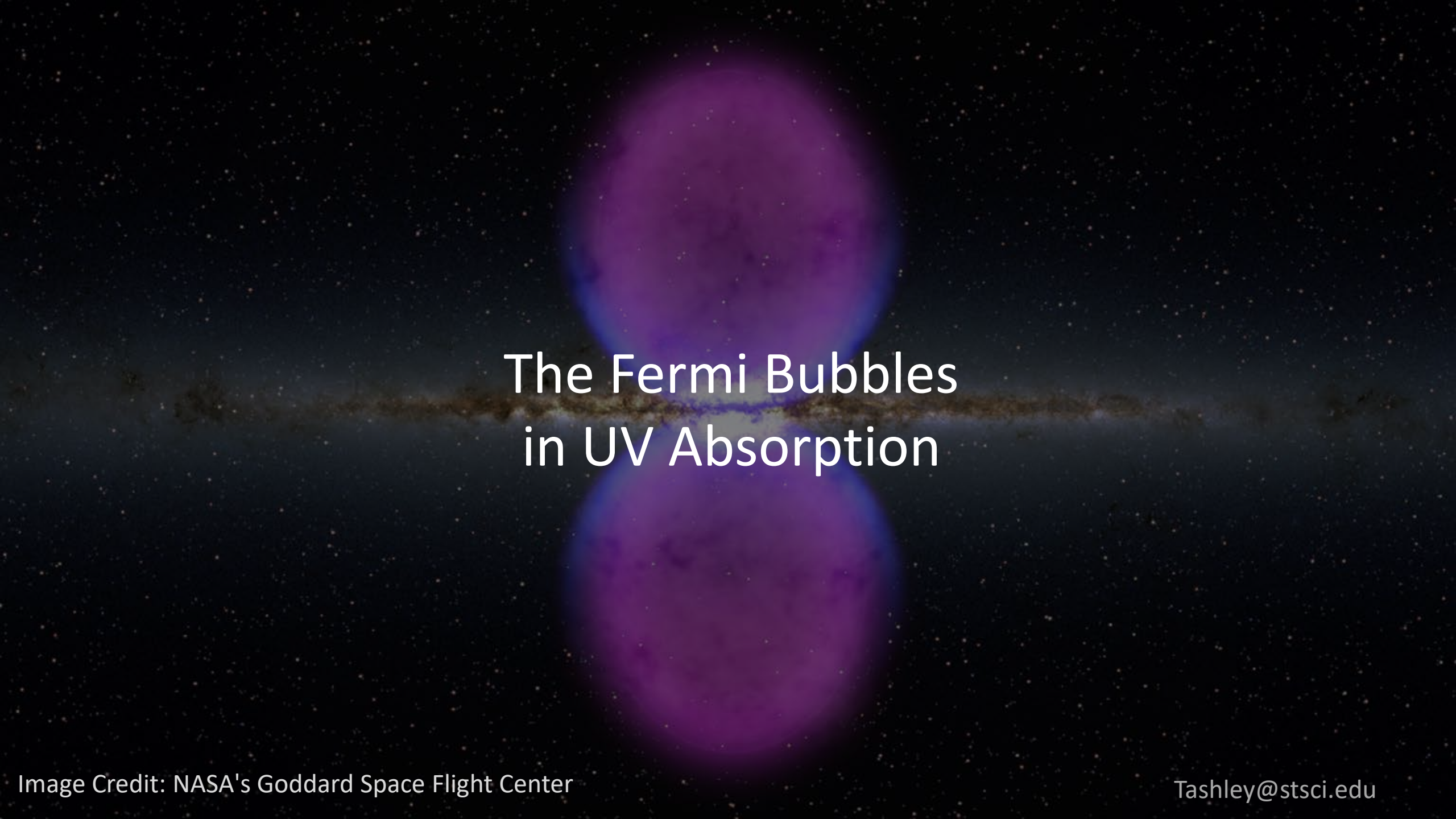

Image Credit: NASA's Goddard Space Flight Center

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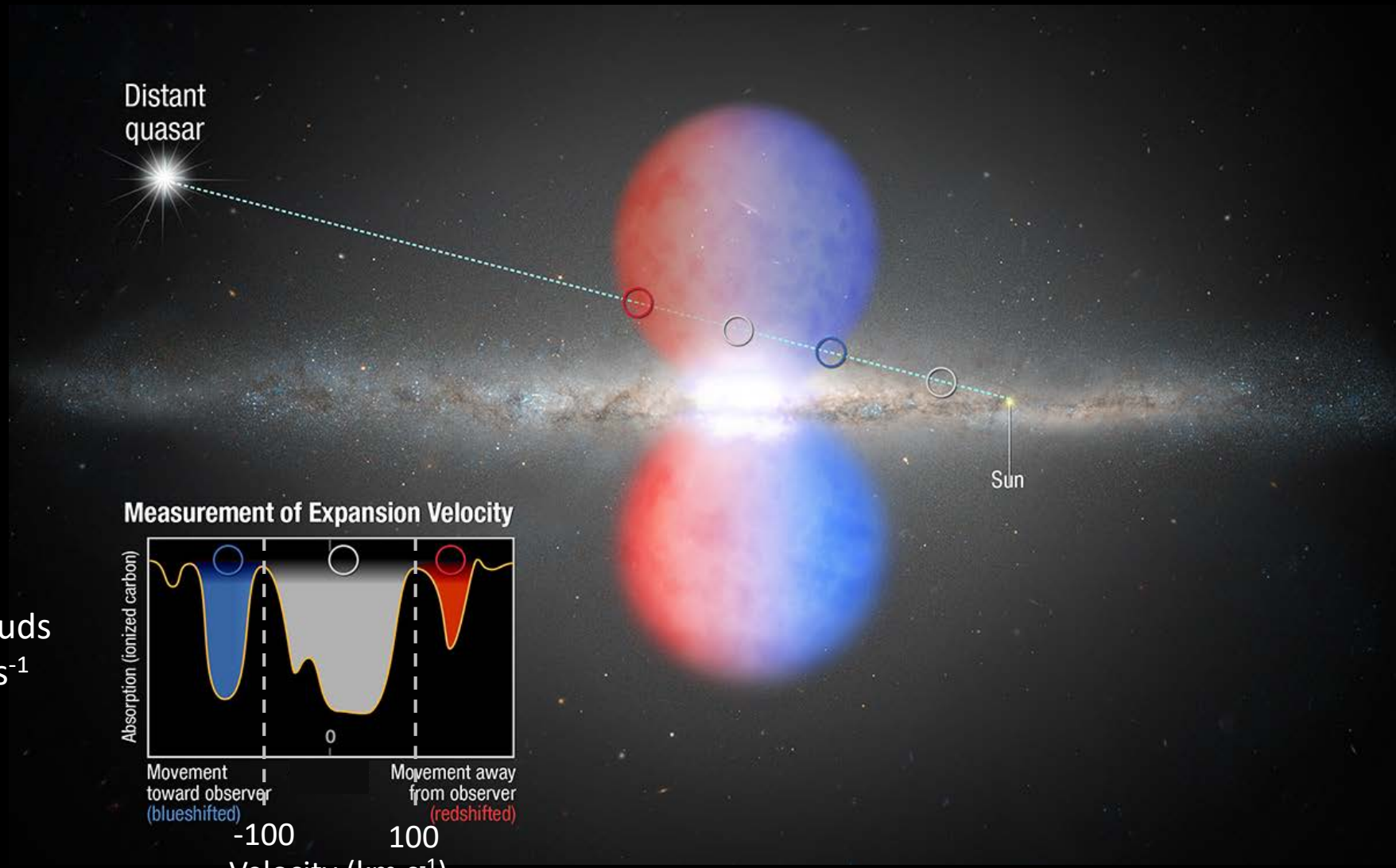
The Fermi Bubbles in UV Absorption



High-velocity clouds
$|v_{LSR}|>100$ km s^{-1}

Image Credit: NASA, ESA, and A. Feild (STScI)

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Background Source Pointings Through/Around Fermi Bubbles

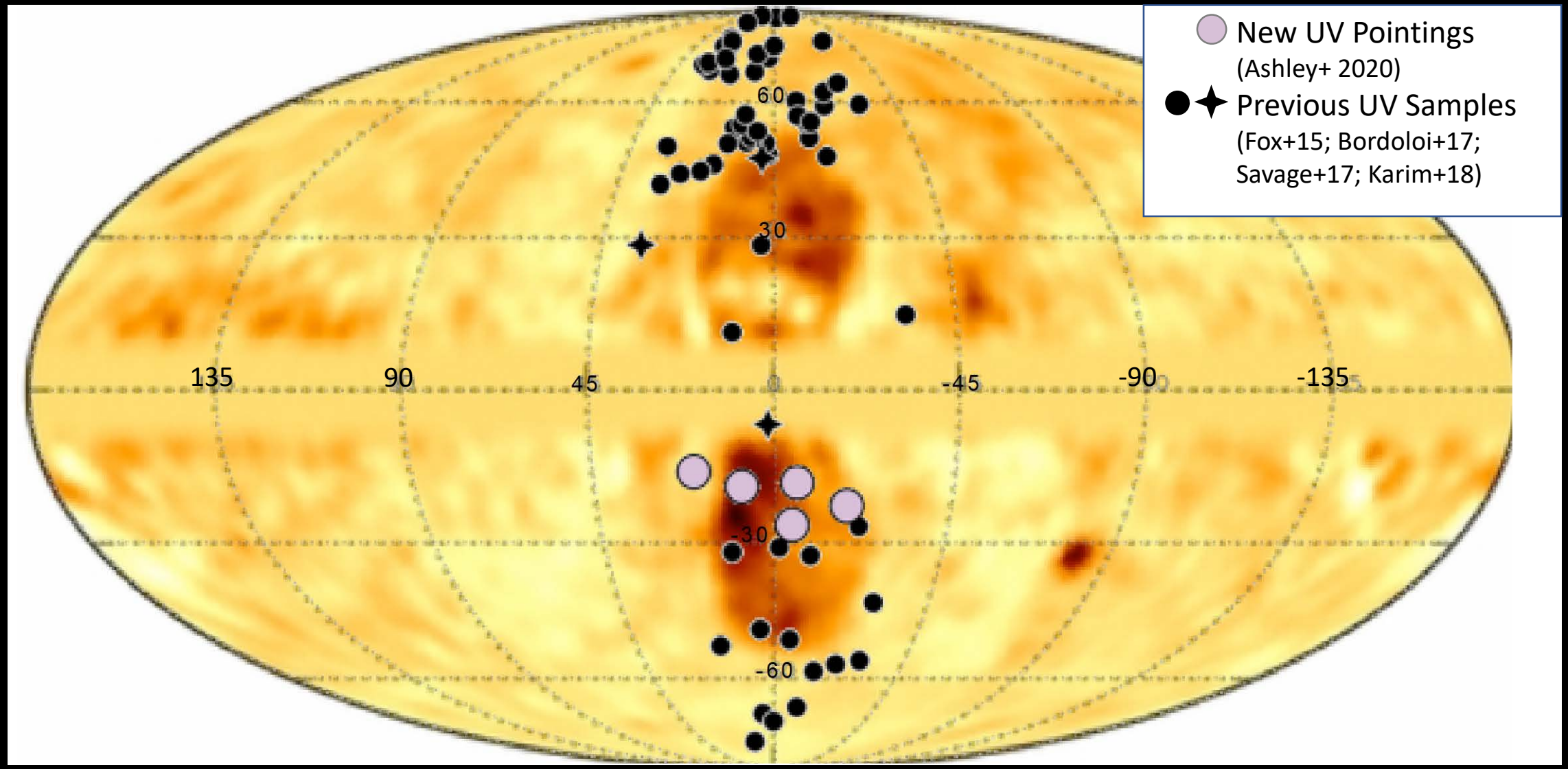

Fig. 22 Ackermann+ 2014

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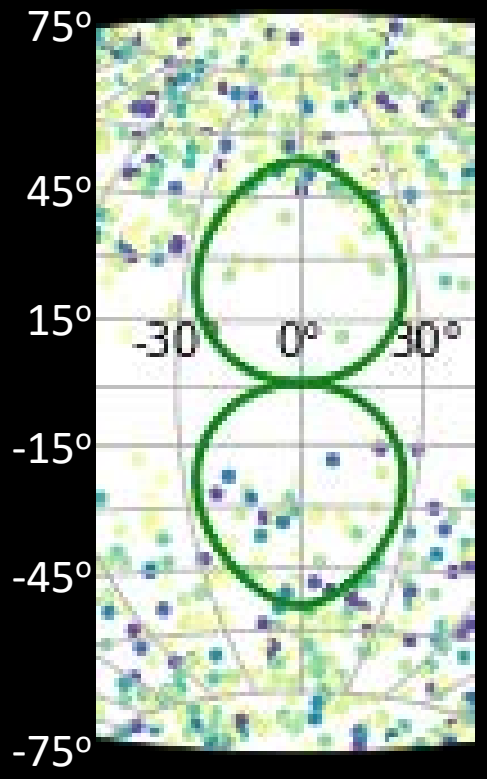
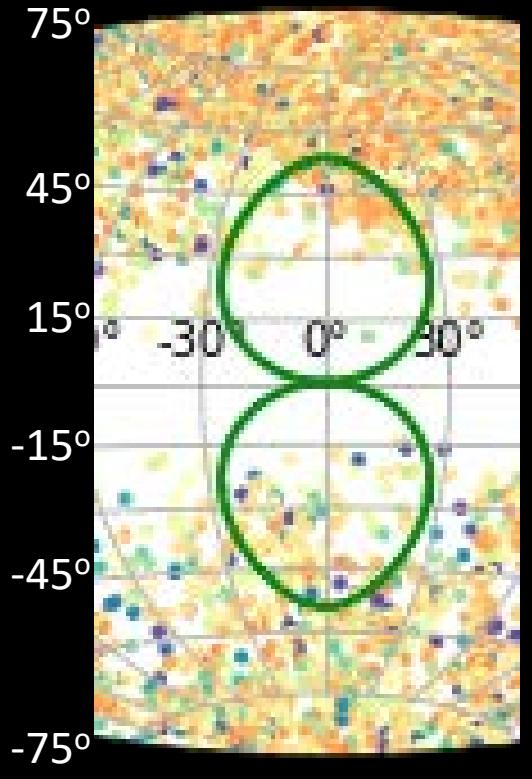
Future UV telescopes

HST/COS/G130M
observational limits

AGN of FUV<18



AGN of FUV<19



LUVOIR/LUMOS
observational limits

AGN of FUV<20

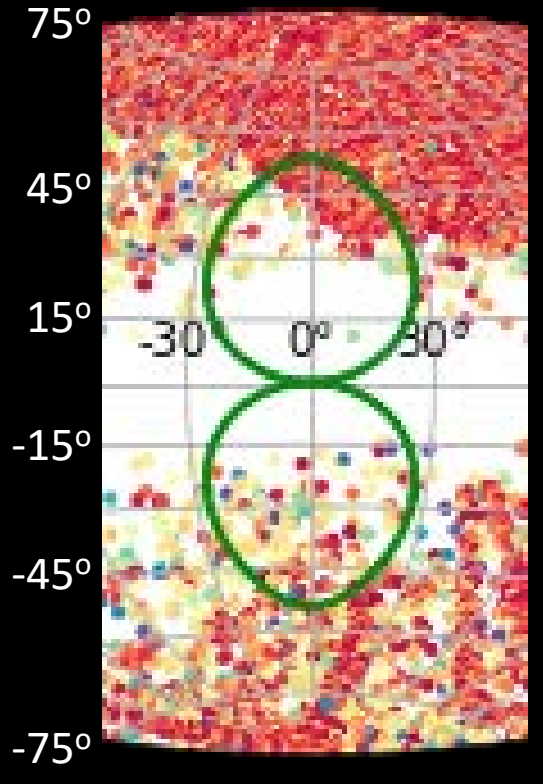


Fig. 4 Fox+2020, Astro2020 Science White Paper

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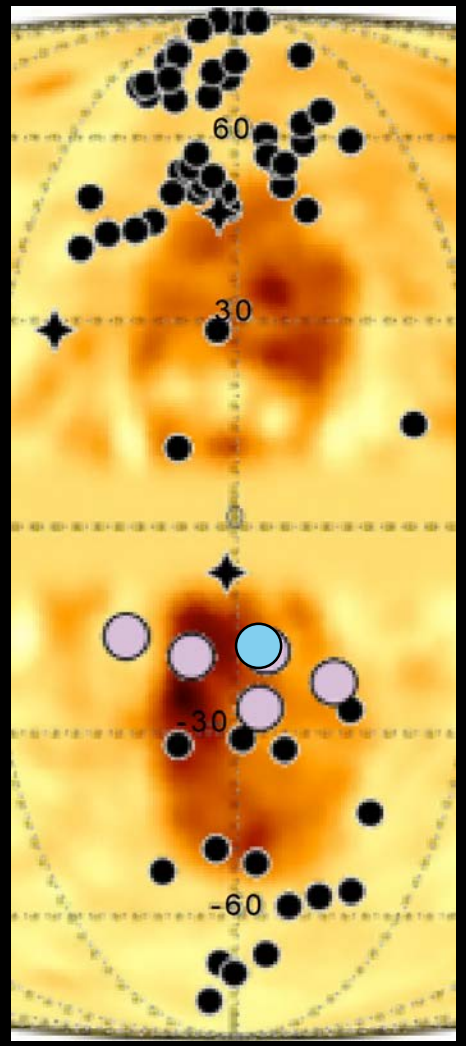
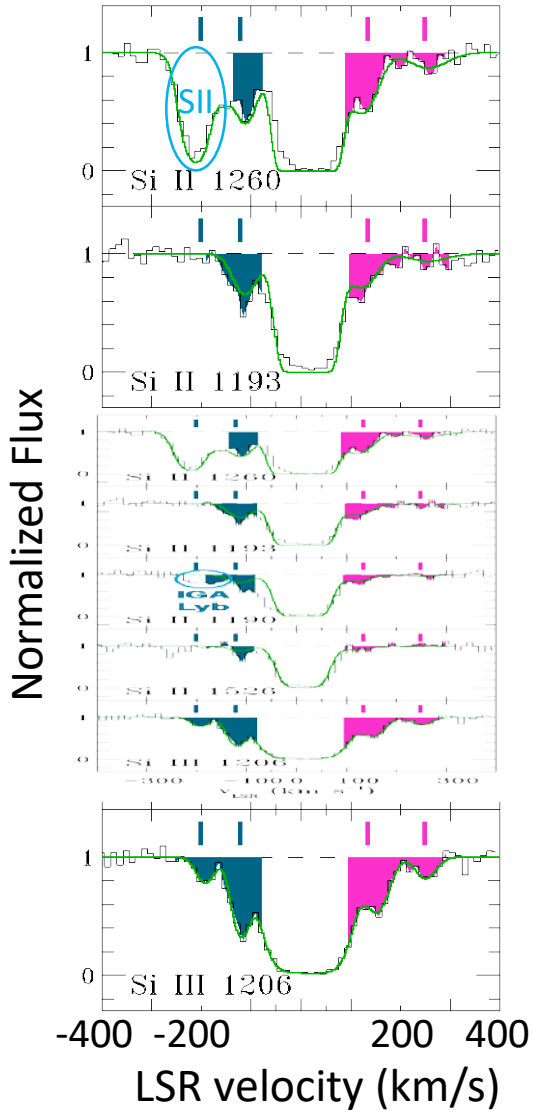
New Low-Latitude Pointing HST/COS data





UVQS J185302-415839

4 detected HVCs
(High-velocity clouds)

Fits to the data

Blueshifted HVCs

Redshifted HVCs

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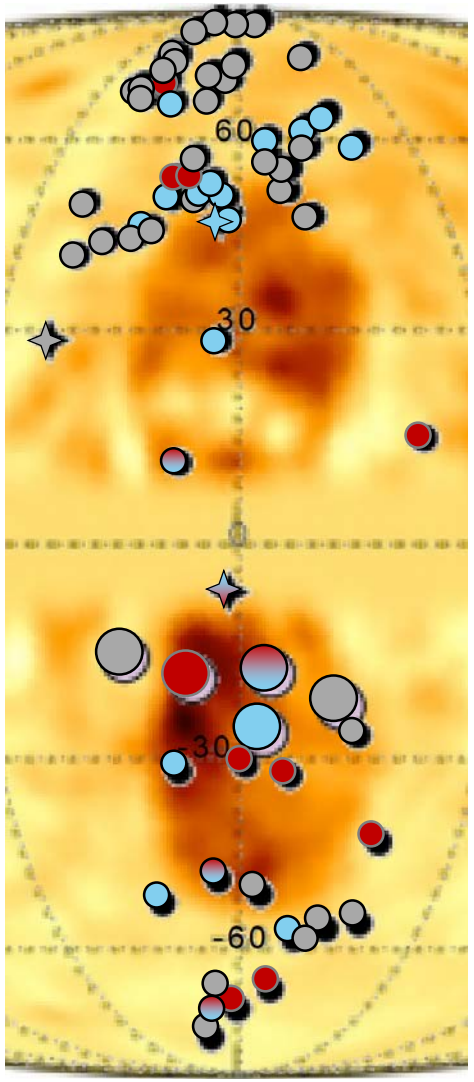
Background Source Pointings Through/Around Fermi Bubbles

Are these HVCs associated with the Fermi Bubbles?

Most likely, yes!

80% (12/15) pointings ***through*** the Fermi Bubbles have associated HVCs

28% (15/54) pointings ***outside*** of the Fermi Bubbles have associated HVCs



New UV Pointings (Ashley+ 2020)

- Redshifted HVC detected
- Redshifted and Blueshifted HVCs detected
- Blueshifted HVCs detected
- No HVCs detected

See Ashley+2020 for more details on the UV observations and analysis

Fig. 22 Ackermann+ 2014

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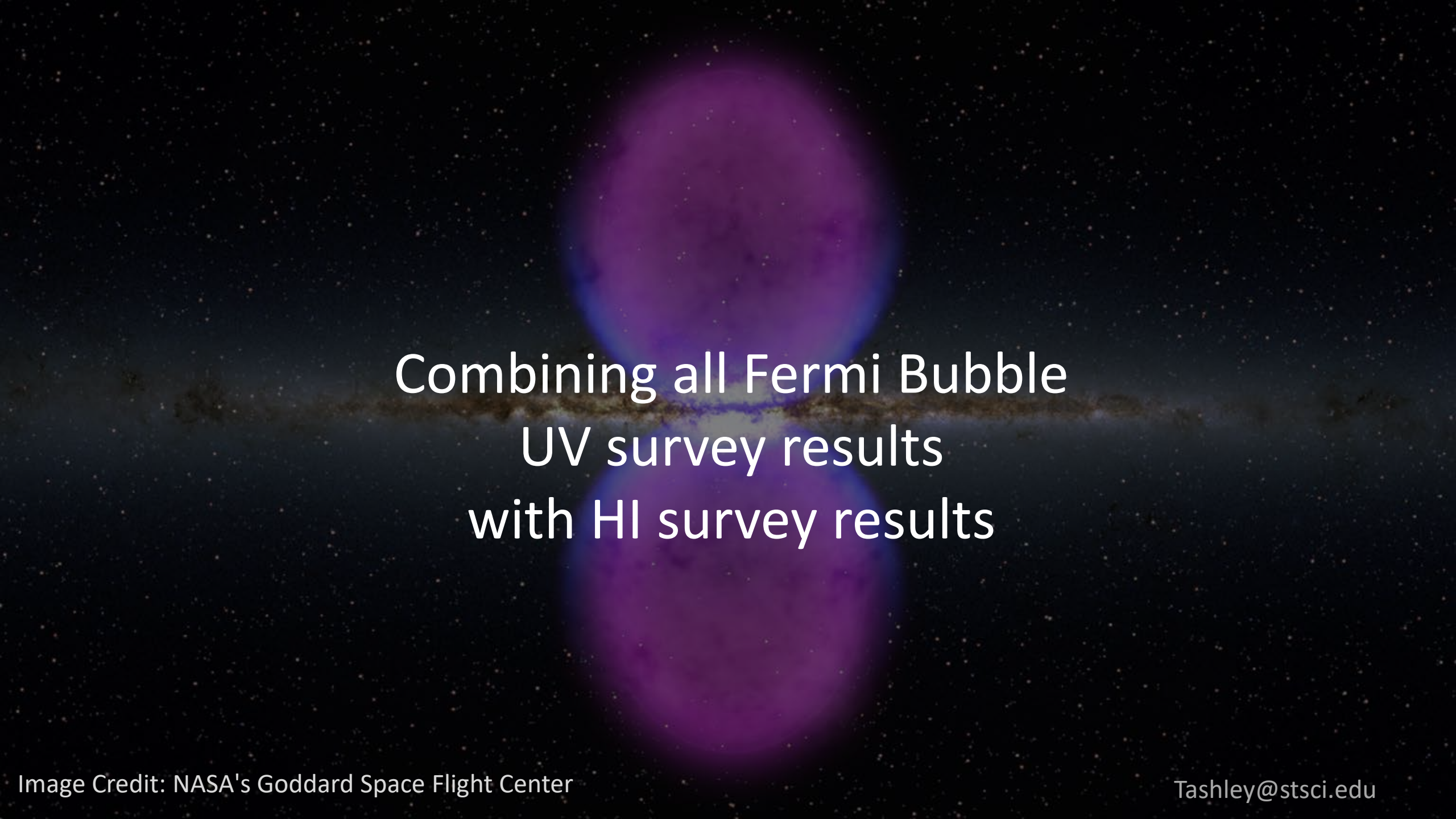

Combining all Fermi Bubble UV survey results with HI survey results

Image Credit: NASA's Goddard Space Flight Center

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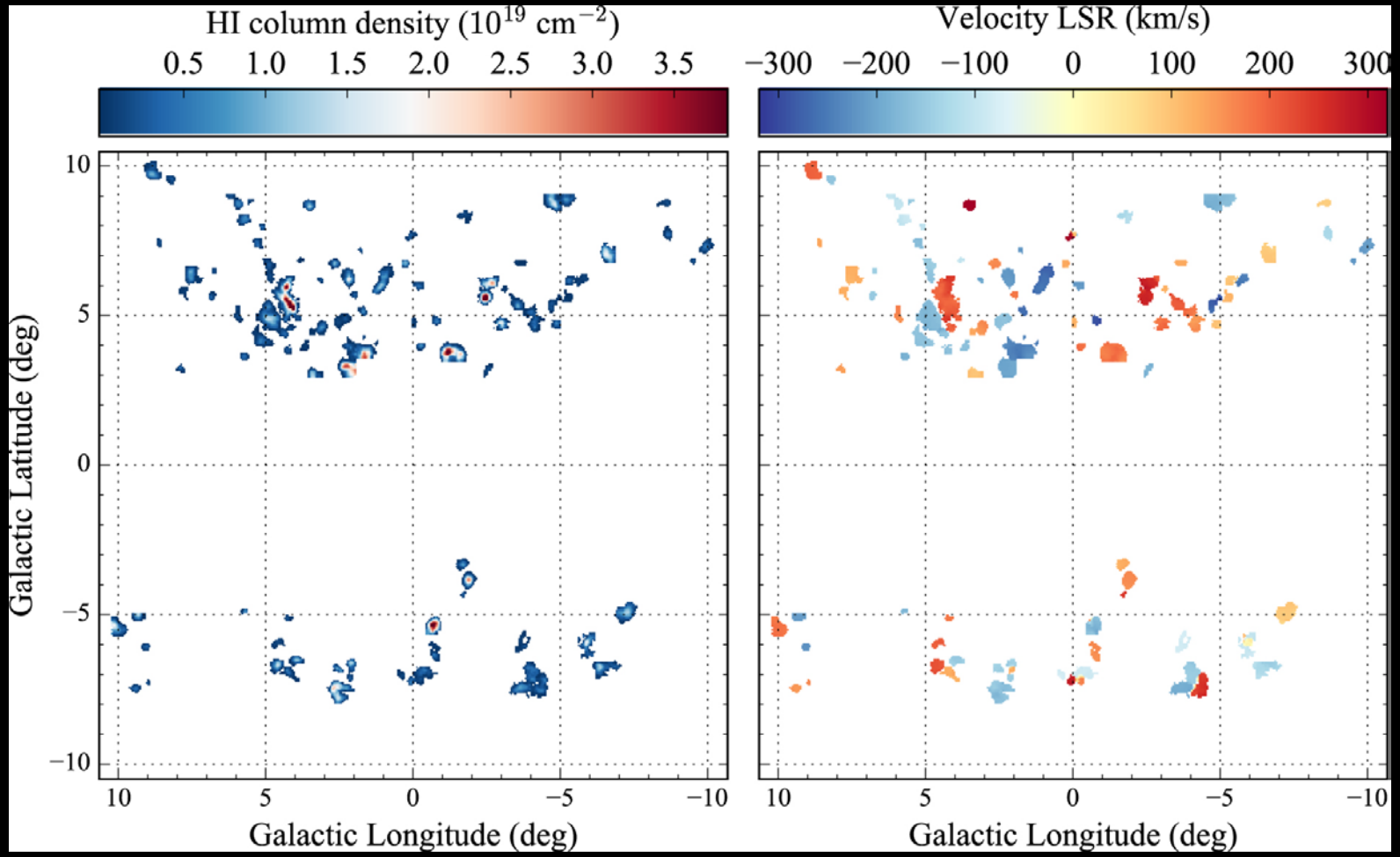
GSR Velocity Profile of the Fermi Bubbles: UV and HI



Clouds in a bipolar outflow

Figure 2, Di Teodoro+ 2018 (Green Bank Telescope data)

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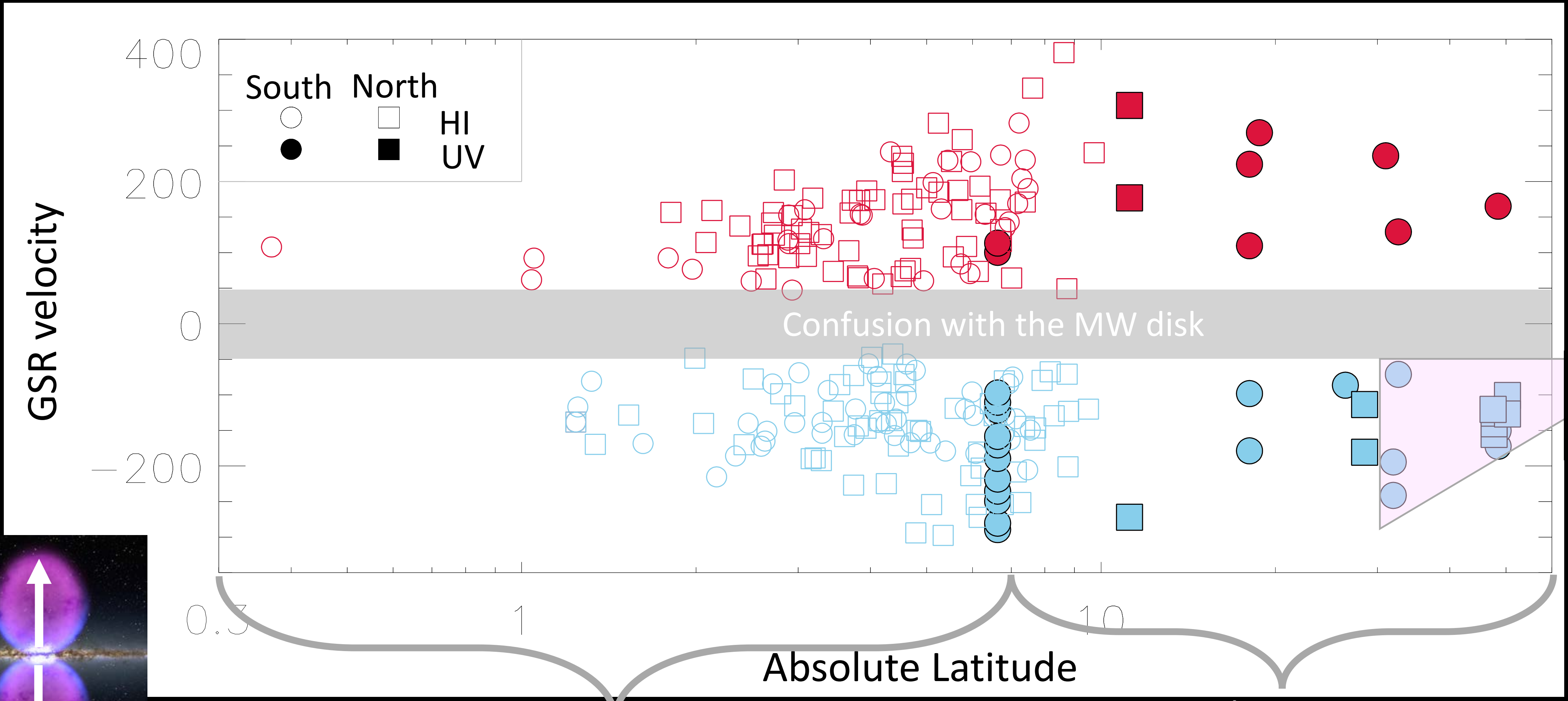
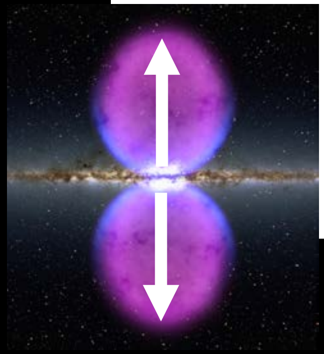
GSR Velocity Profile of the Fermi Bubbles: UV and HI





Acceleration (Lockman+2020)

Coasting/Slight Acceleration
(Ashley+2020)

HI: Lockman+20, Di Teodoro+18, McClure-Griffiths+16

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GSR Velocity Profile of the Fermi Bubbles: UV and HI

Gamma-ray defined bubbles

X-ray defined bubbles

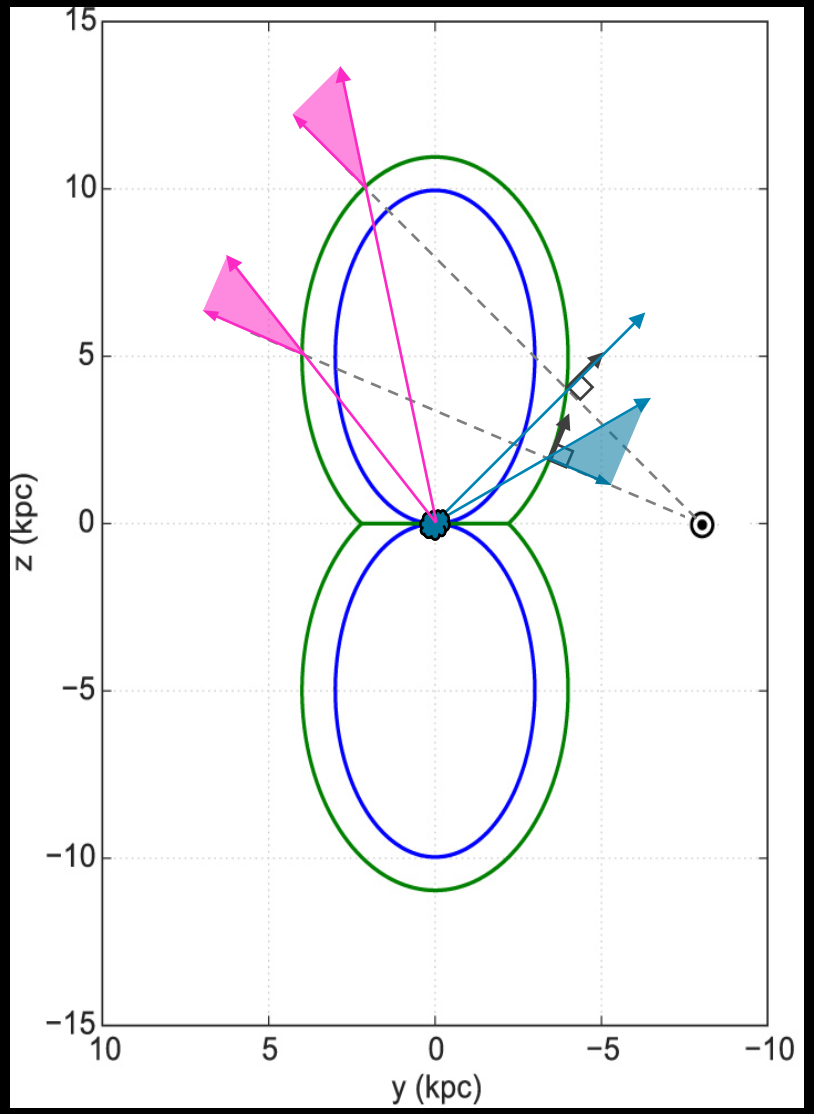

Fig. 5 Miller+ 2016 (with R=8 kpc)

Projected velocity of ~0 km/s at b≈45° for radial outflow

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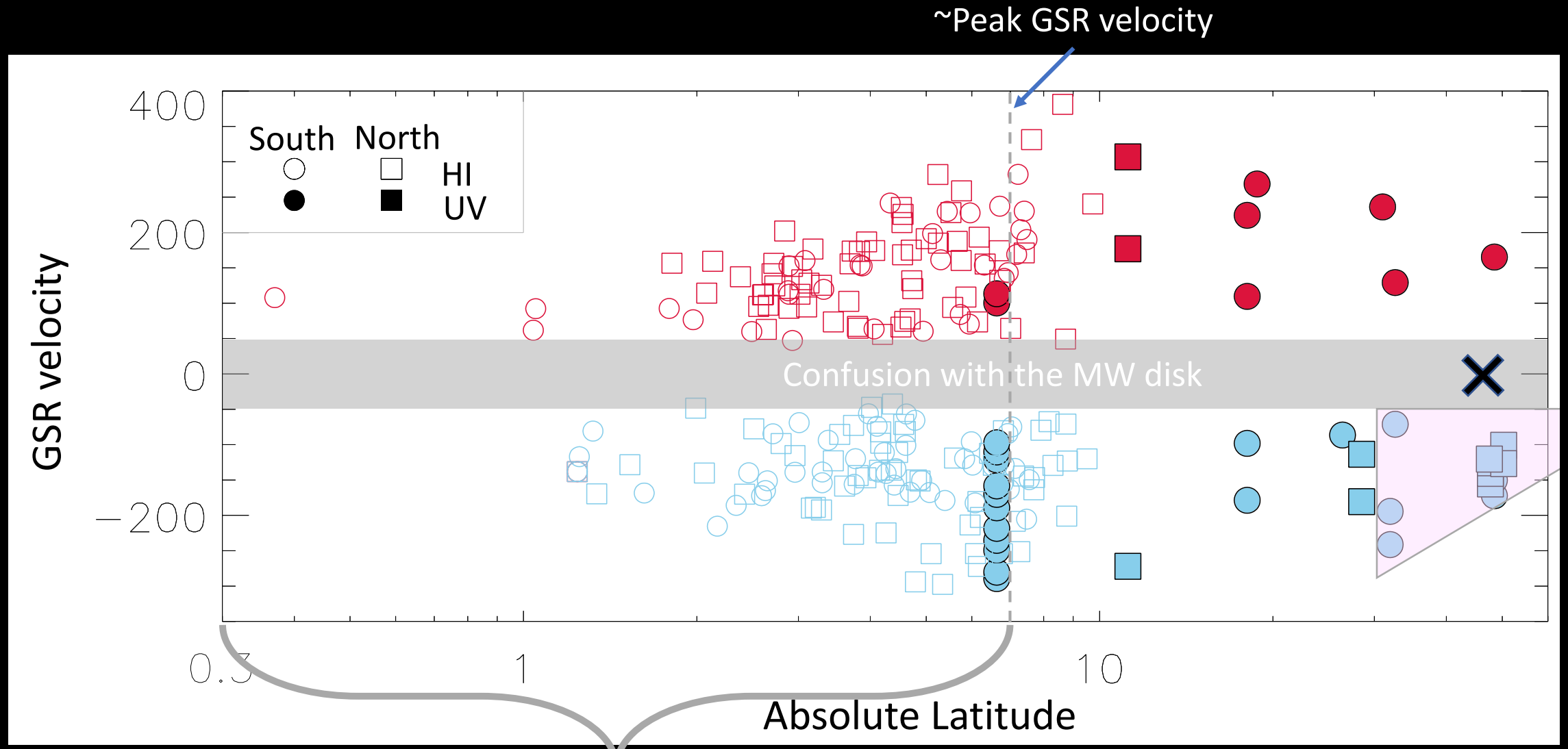
GSR Velocity Profile of the Fermi Bubbles: UV and HI



HI: Lockman+20; Di Teodoro+18+; McClure-Griffiths+16

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GSR Velocity Profile of the Fermi Bubbles: UV and HI

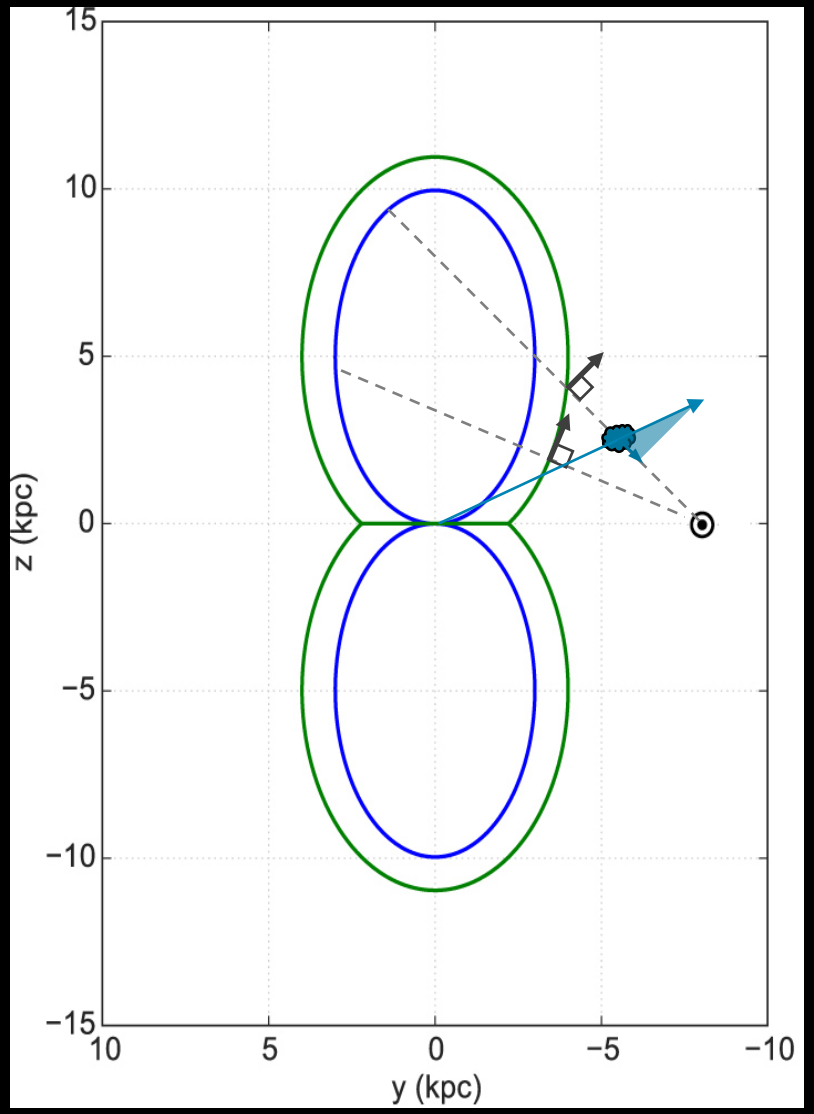

Fig. 5 Miller+ 2016 (with R=8 kpc)

Evidence for clouds in front of bubbles

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GSR Velocity Profile of the Fermi Bubbles: UV and HI models

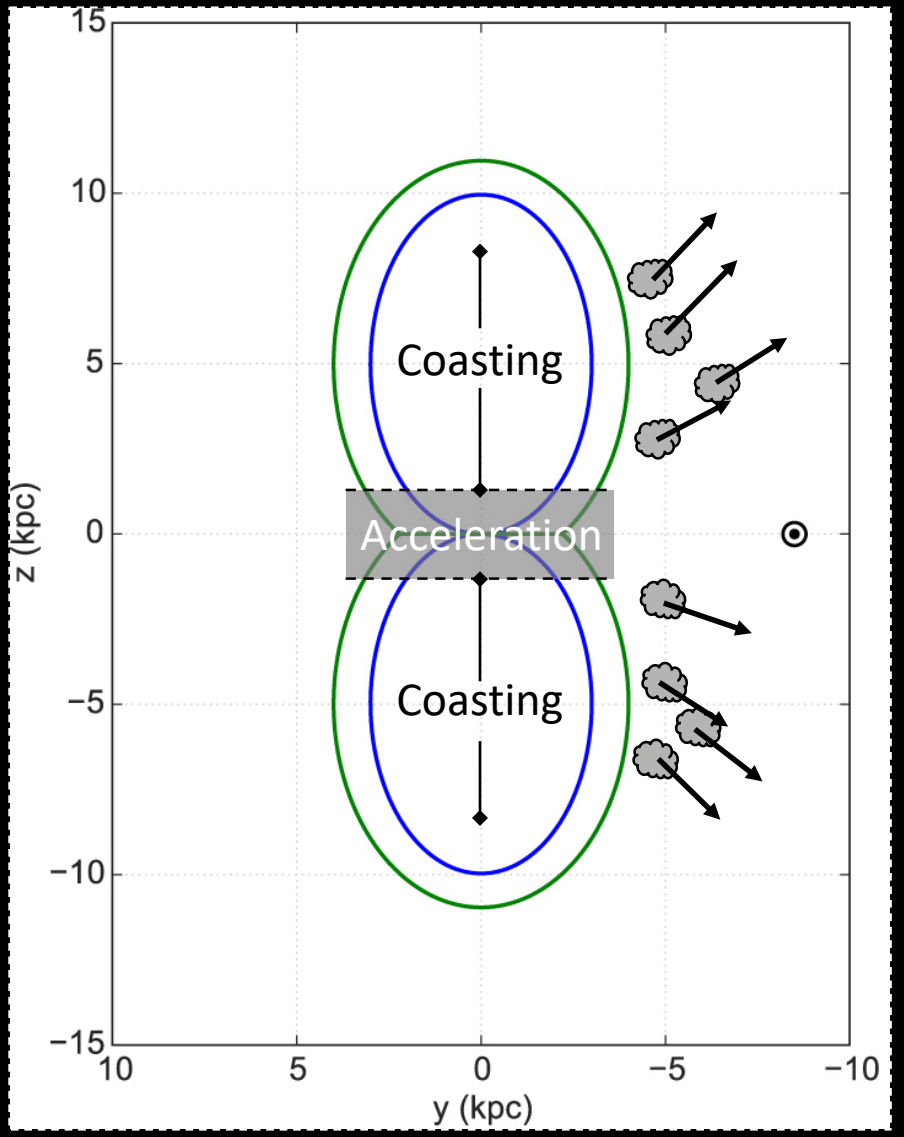

Fig. 5 Miller+ 2016

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Conclusions

- Future UV telescopes will allow us to use background sources of FUV >18 mag, increasing the density of observable AGN by ten.
- There are a group of anomalous velocity clouds that likely lie in front of the Fermi Bubbles.
- For more details see Ashley+ 2020, ApJ, 898, 128.

Image Credit: NASA's Goddard Space Flight Center

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