„Galactic fountains persistently fuel the Milky Way galaxy star formation“

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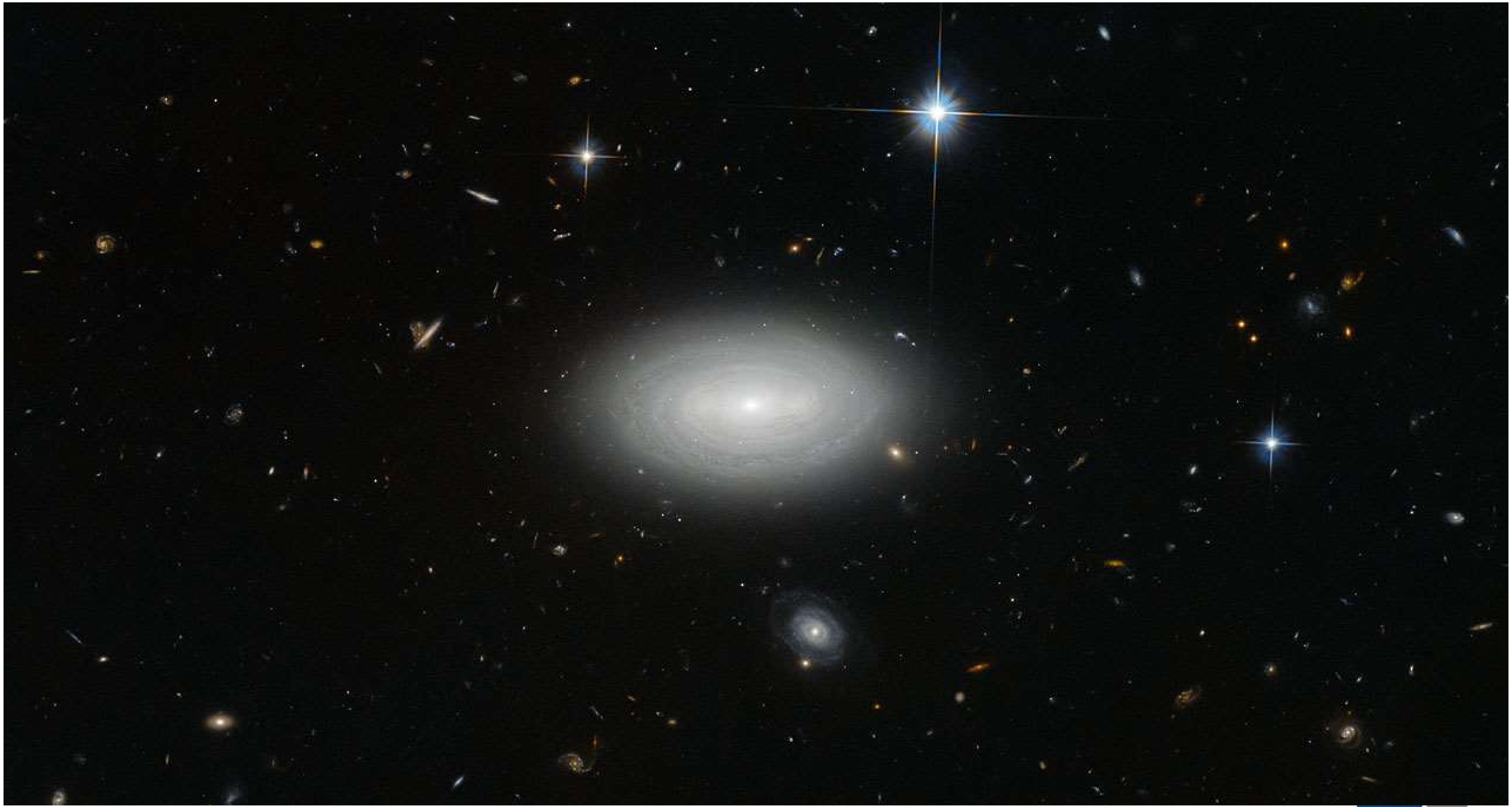
Boötes void galaxy: MCG+01-02-015



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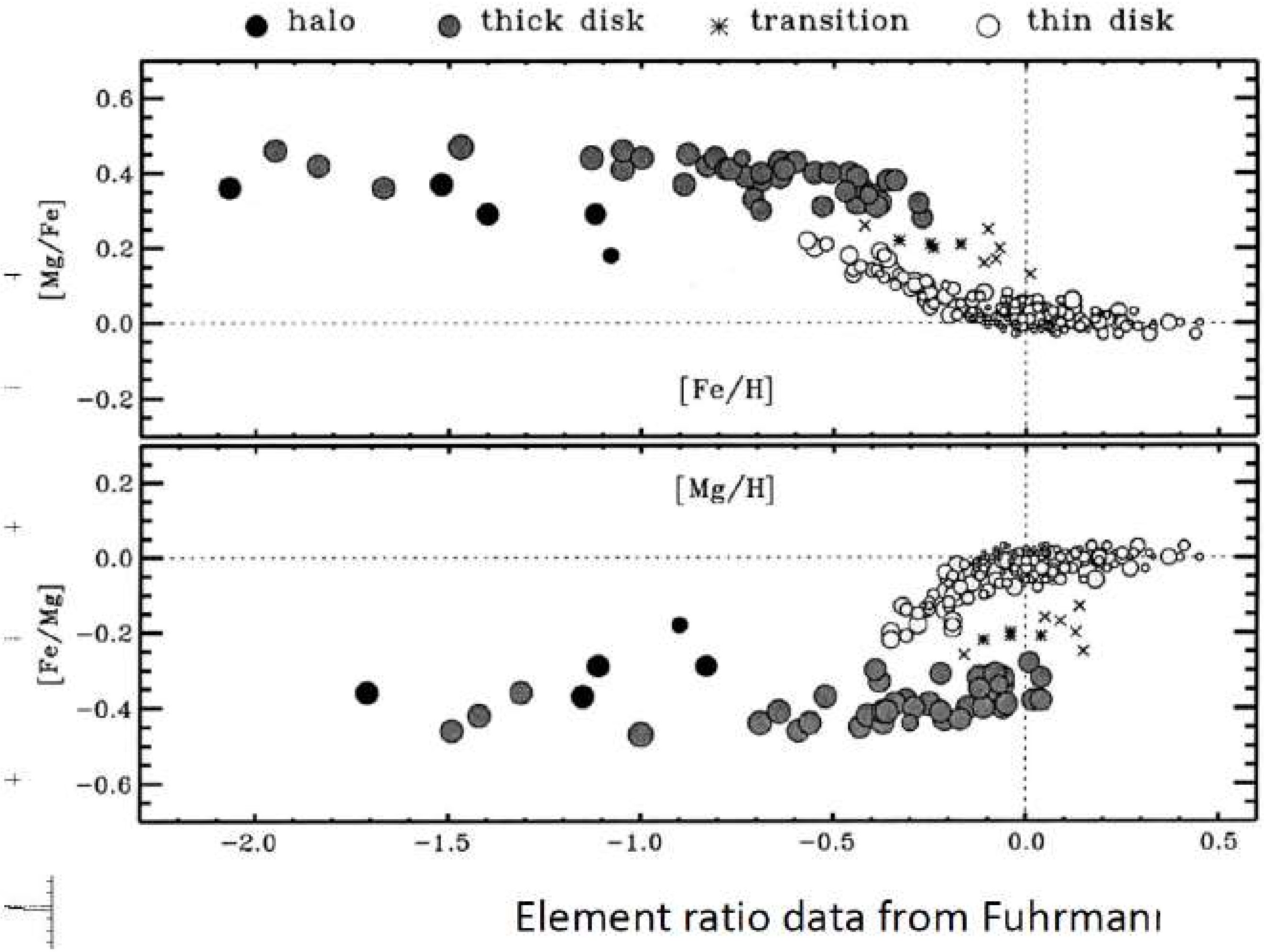
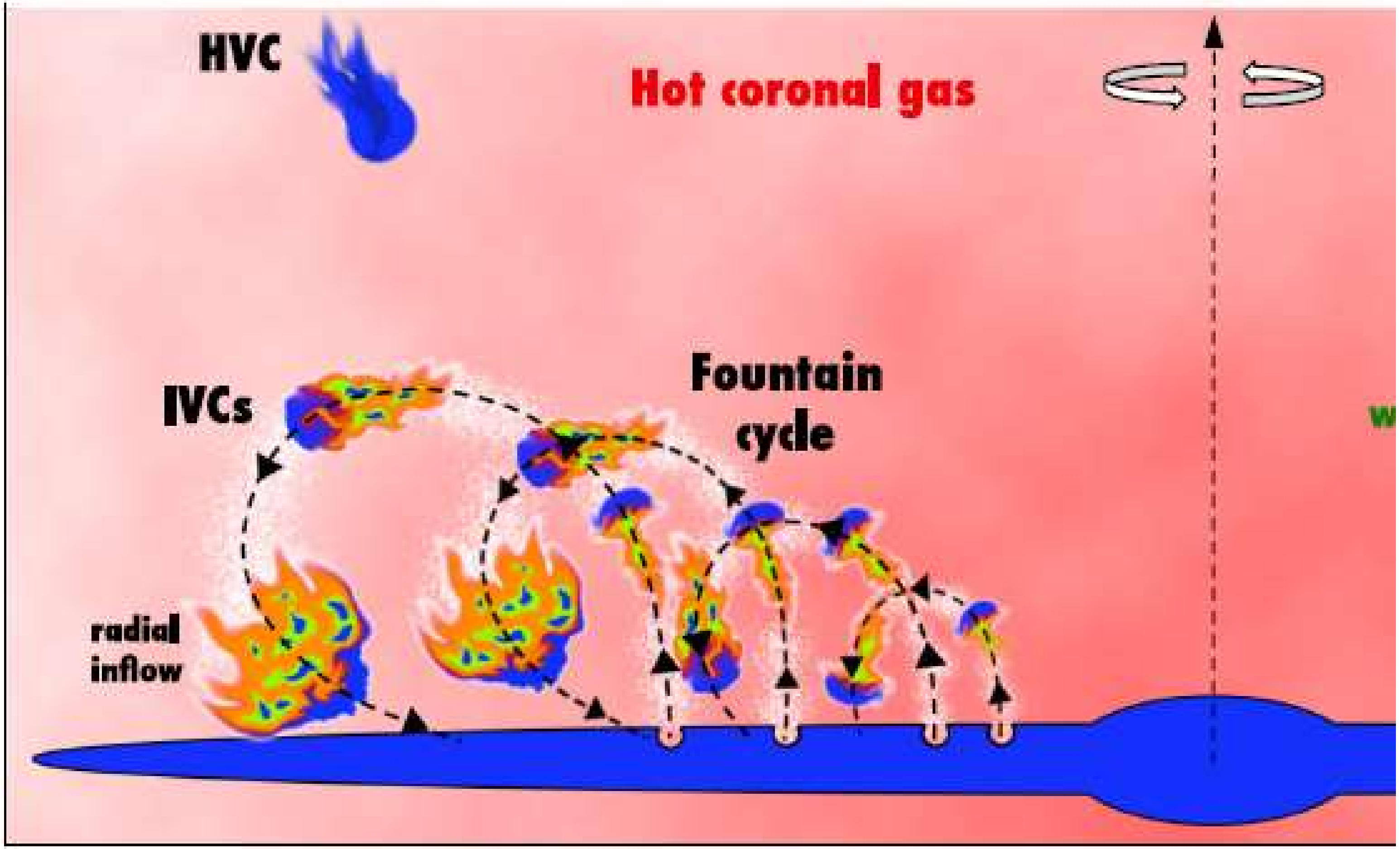
Constant fueling: no evidence for major mergers



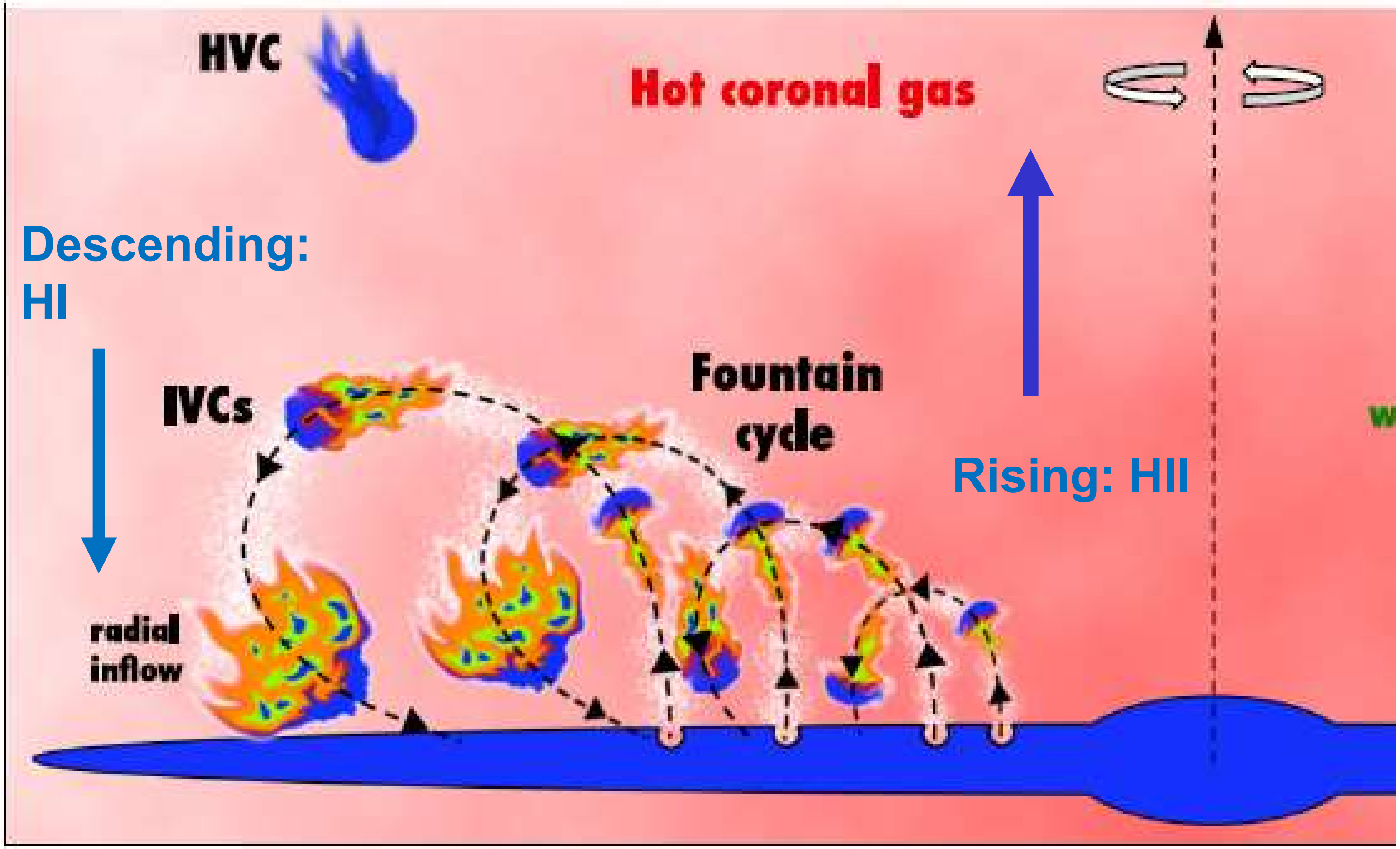
Element ratio data from Fuhrmann

Halo and disk-halo interface



Marasco, Marinacci & Fraternali 2013, MNRAS 443, 1634

Halo and disk-halo interface



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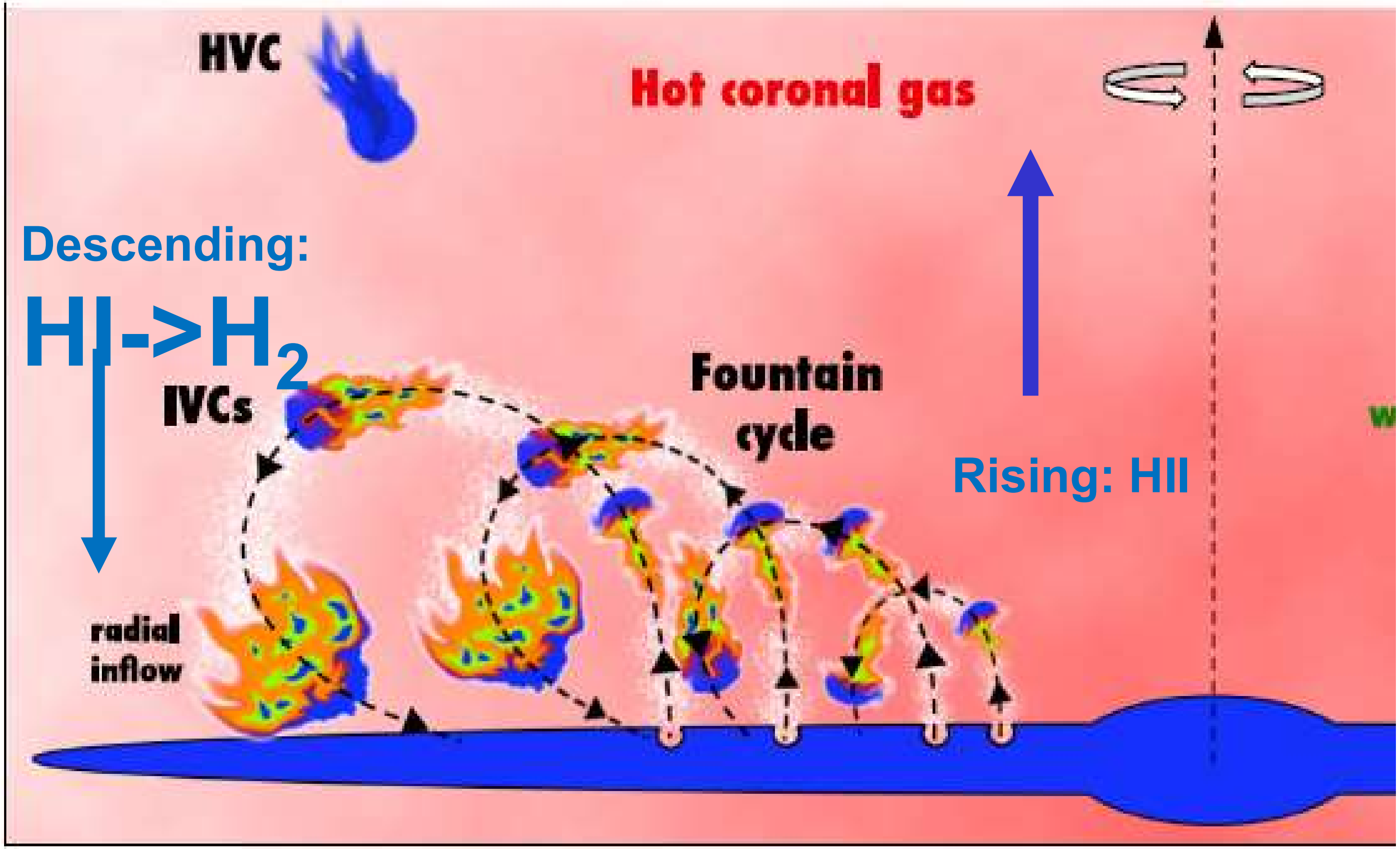
Halo and disk-halo interface



Marasco, Marinacci & Fraternali 2013, MNRAS 443, 1634

Magnani & Smith 2010, ApJ 722, 1685

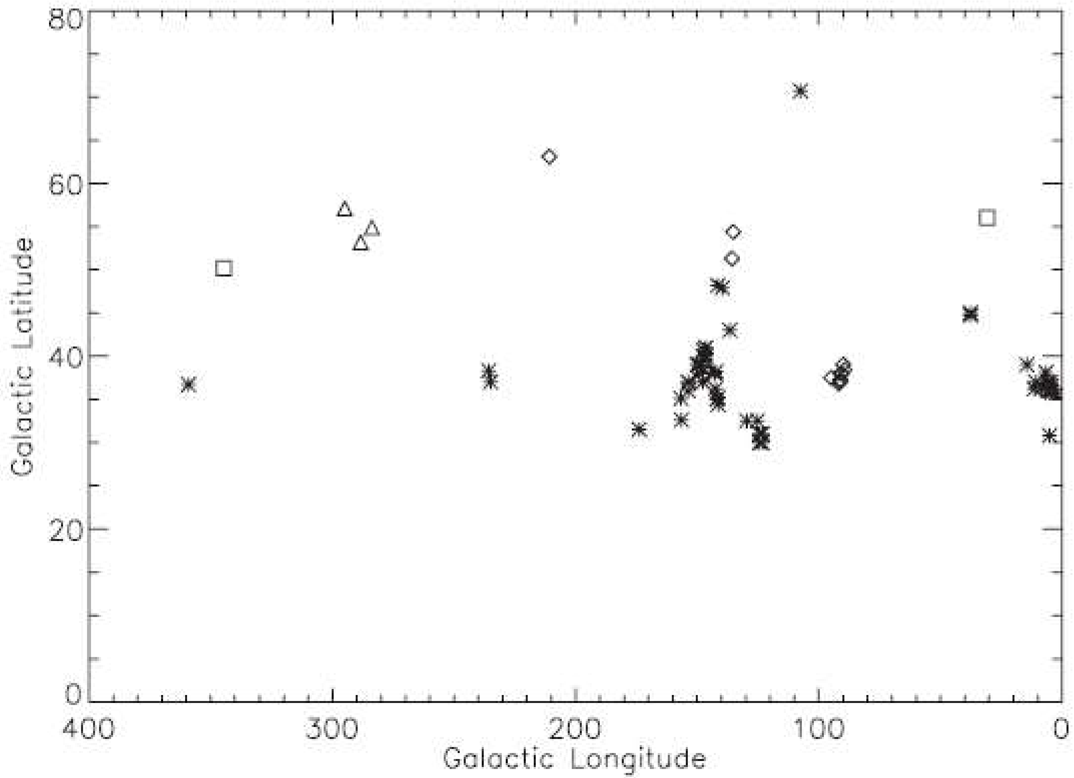
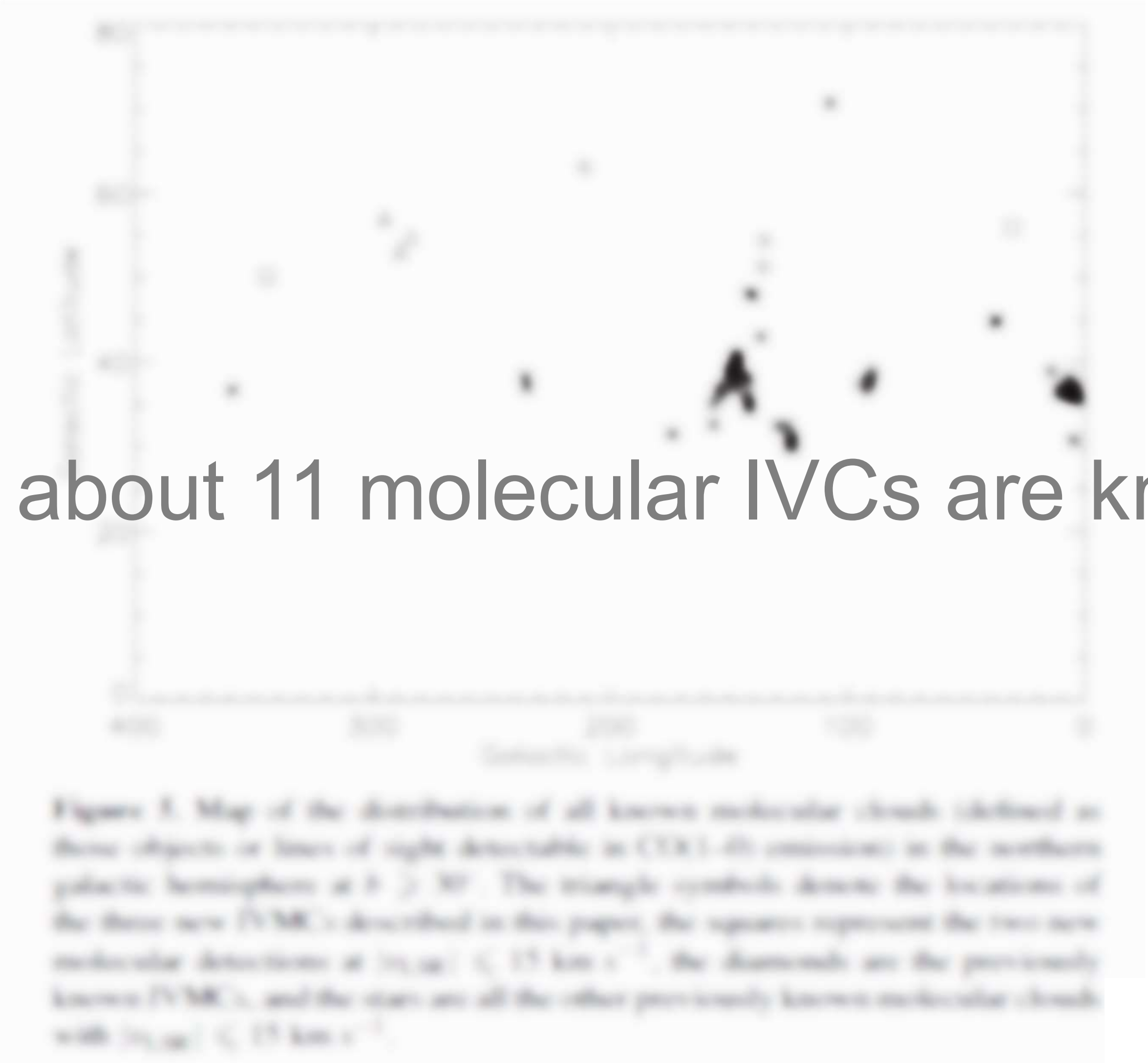


Figure 5. Map of the distribution of all known molecular clouds (defined as those objects or lines of sight detectable in CO(1–0) emission) in the northern galactic hemisphere at $b \geqslant 30^{\circ}$. The triangle symbols denote the locations of the three new IVMCs described in this paper, the squares represent the two new molecular detections at $|v_{\mathrm{LSR}}| \leqslant 15$ km s^{-1}, the diamonds are the previously known IVMCs, and the stars are all the other previously known molecular clouds with $|v_{\mathrm{LSR}}| \leqslant 15$ km s^{-1}.

Magnani & Smith 2010, ApJ 722, 1685



2010 about 11 molecular IVCs are known

Why a new effort?

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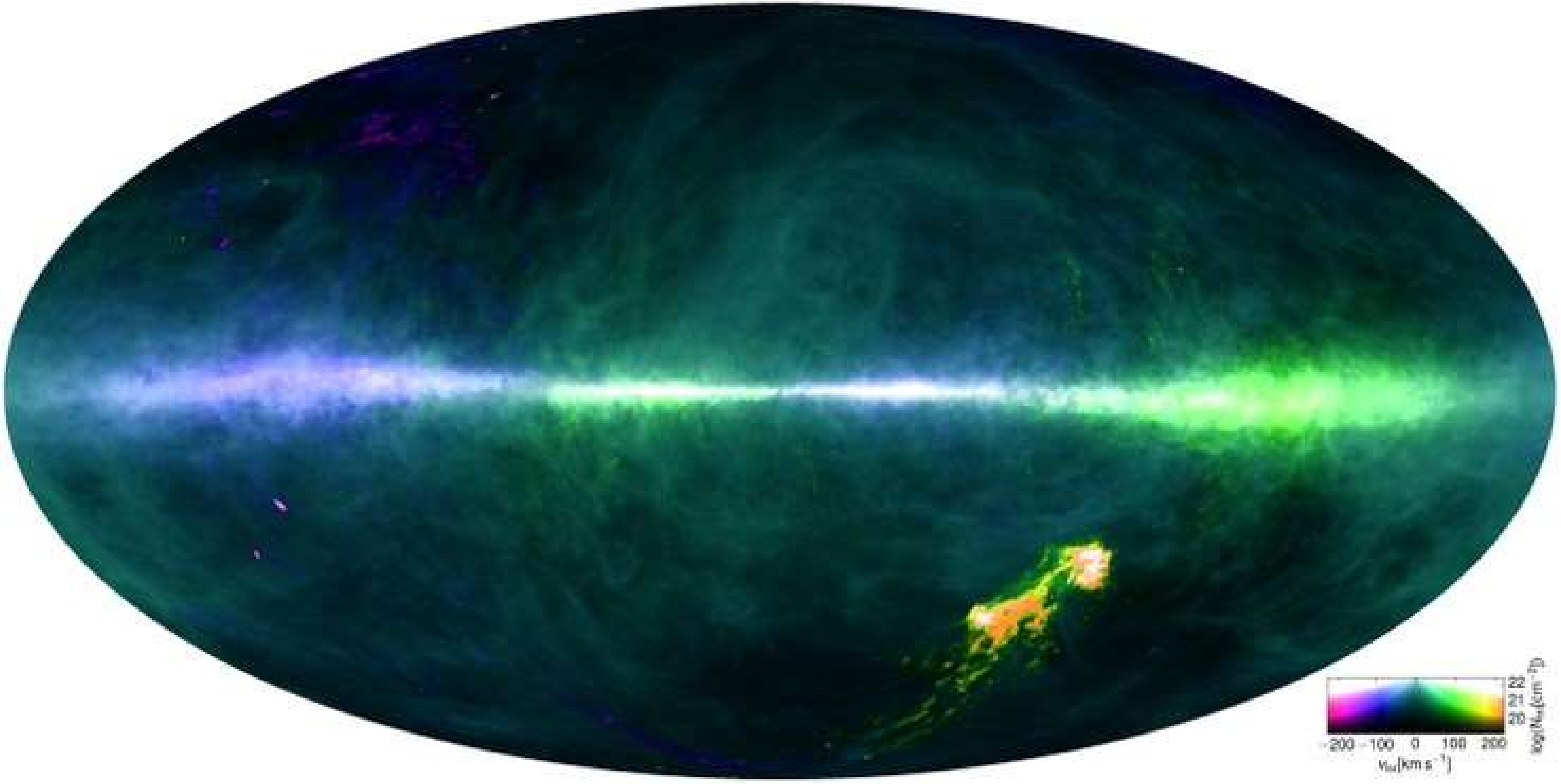
HI4PI, Oct 2016

HI4PI collaboration: 2016 A&A 594, A116



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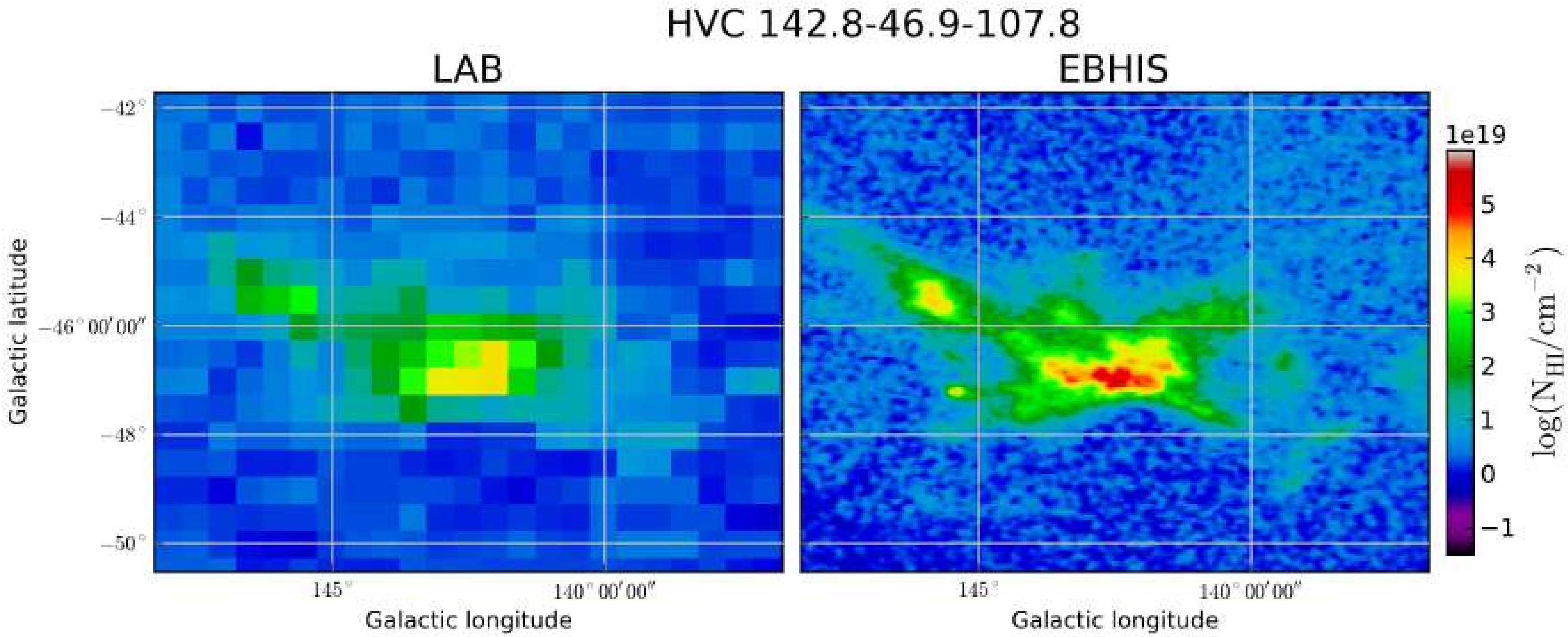
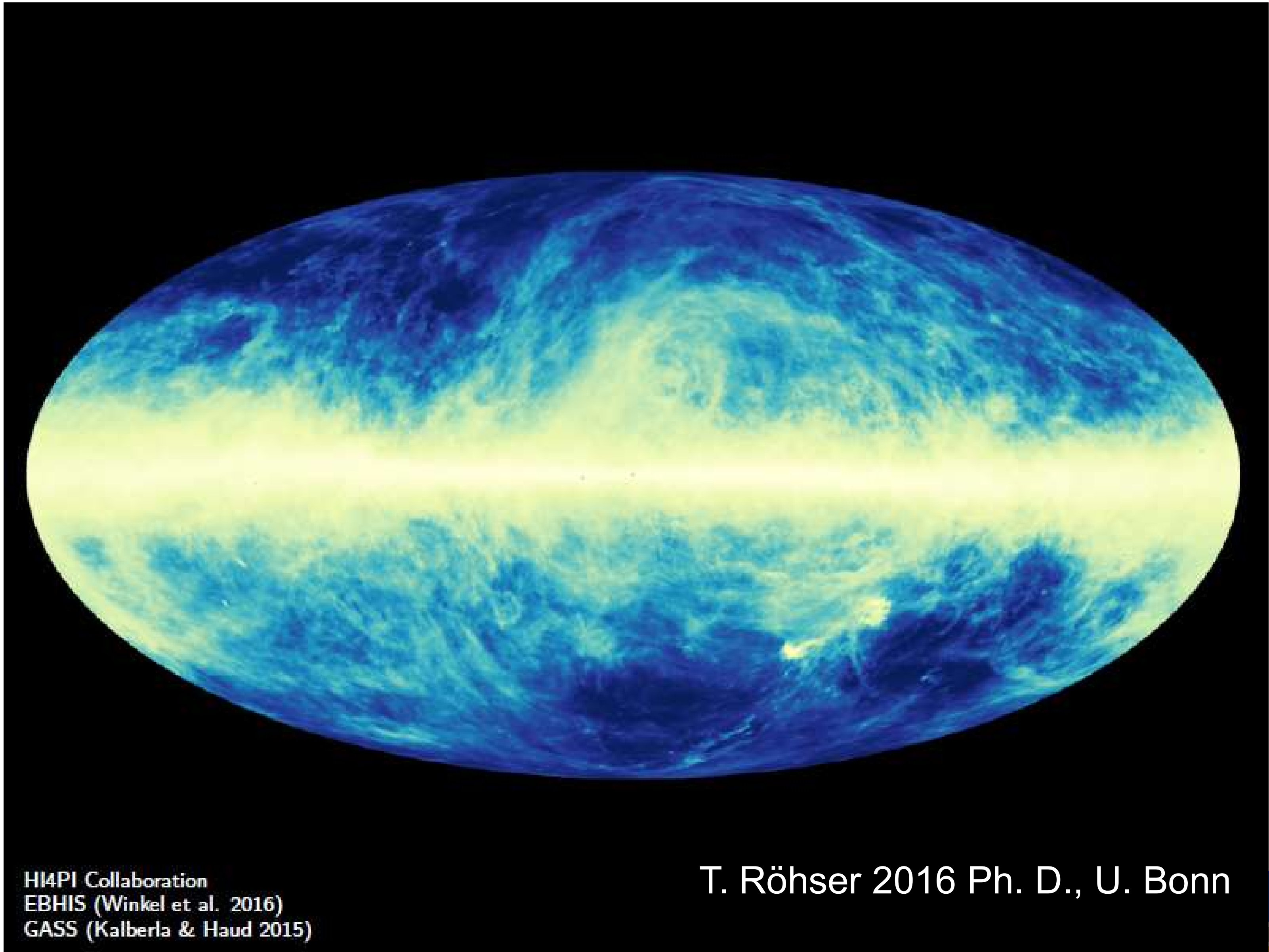
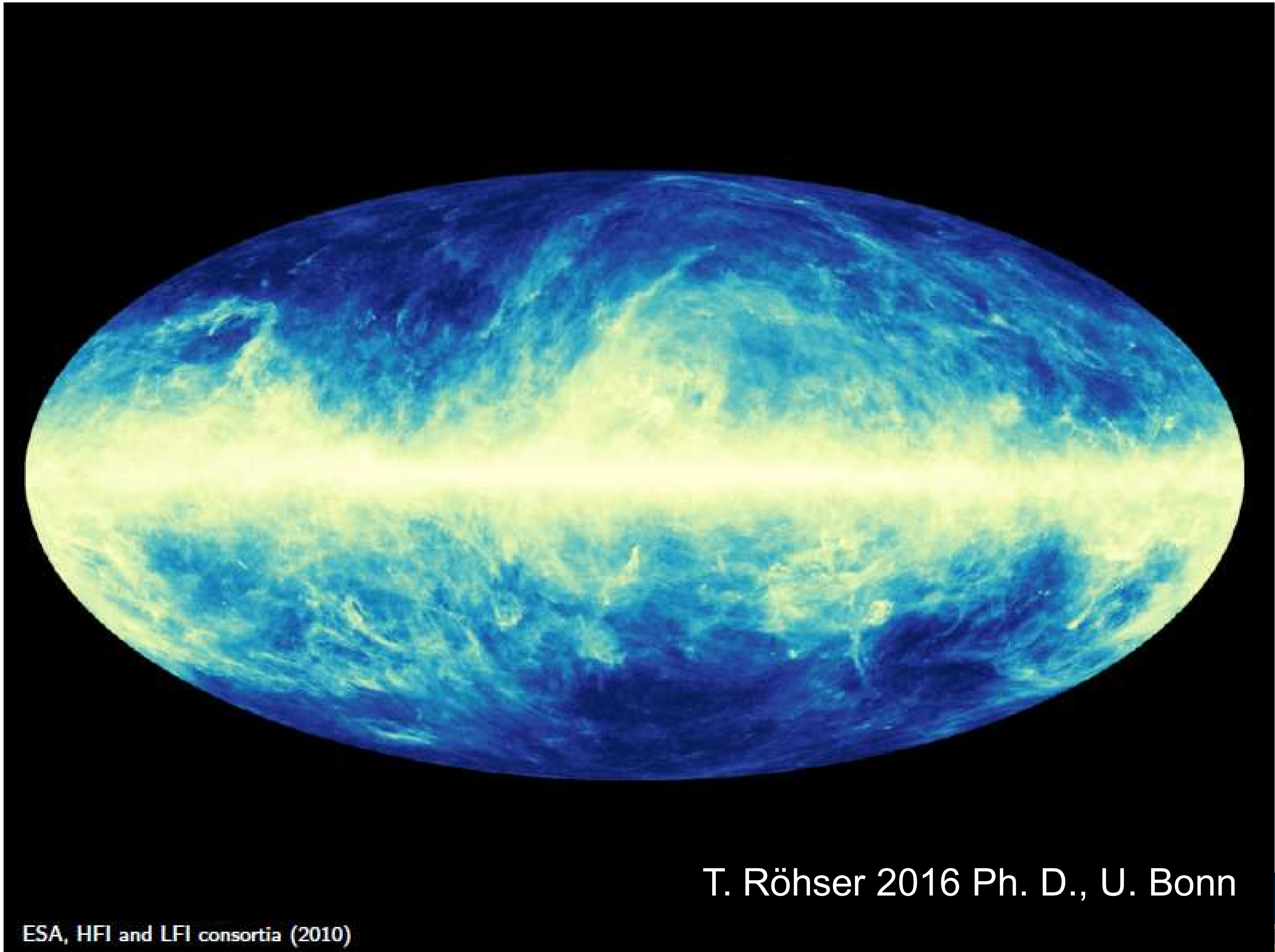
LAB vs. HI4PI



Bachelor thesis: **Vivien Thiel**
Bonn University 2012


HI4PI Collaboration
EBHIS (Winkel et al. 2016)
GASS (Kalberla & Haud 2015)
T. Röhser 2016 Ph. D., U. Bonn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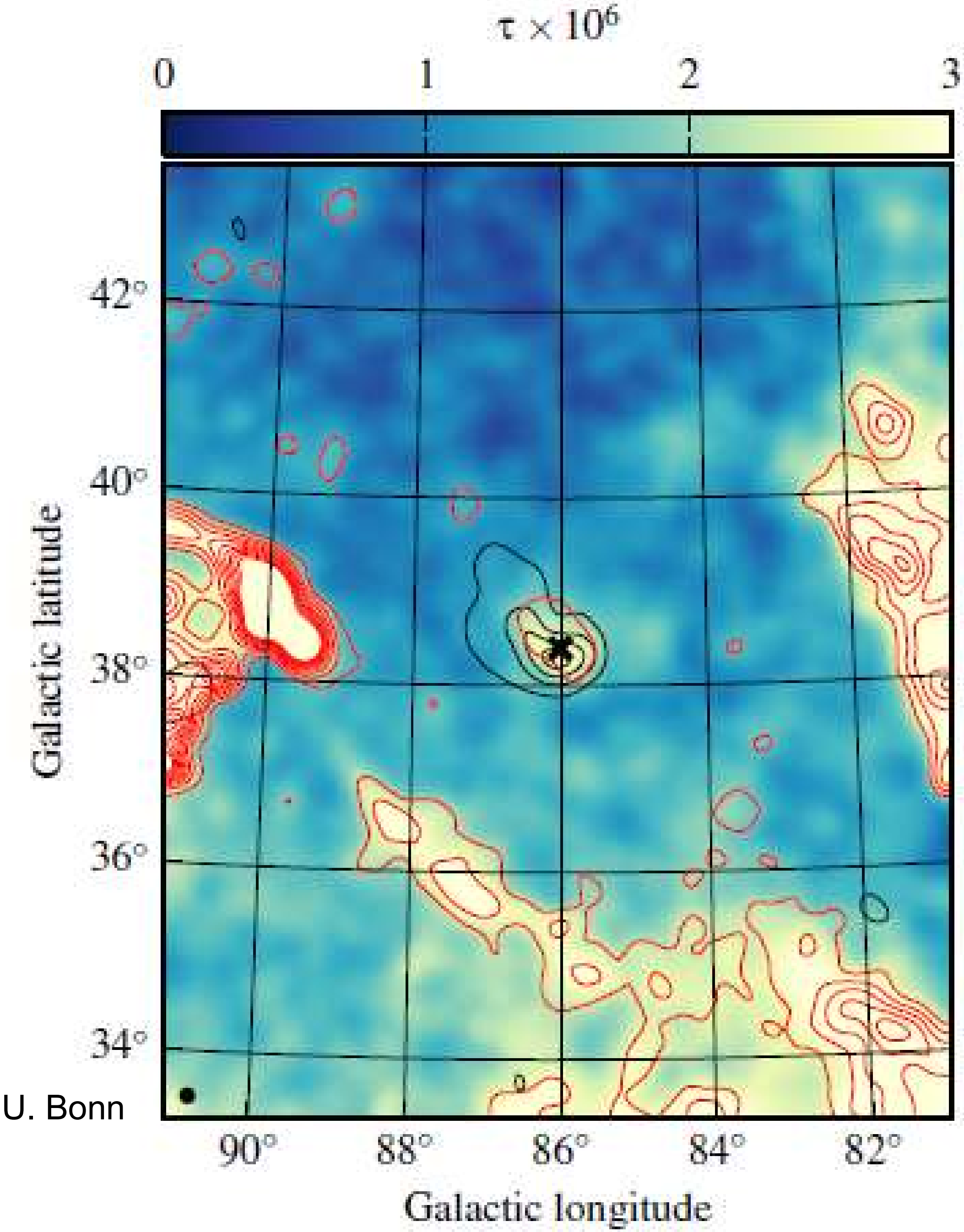
ESA, HFI and LFI consortia (2010)

IVC 86+38



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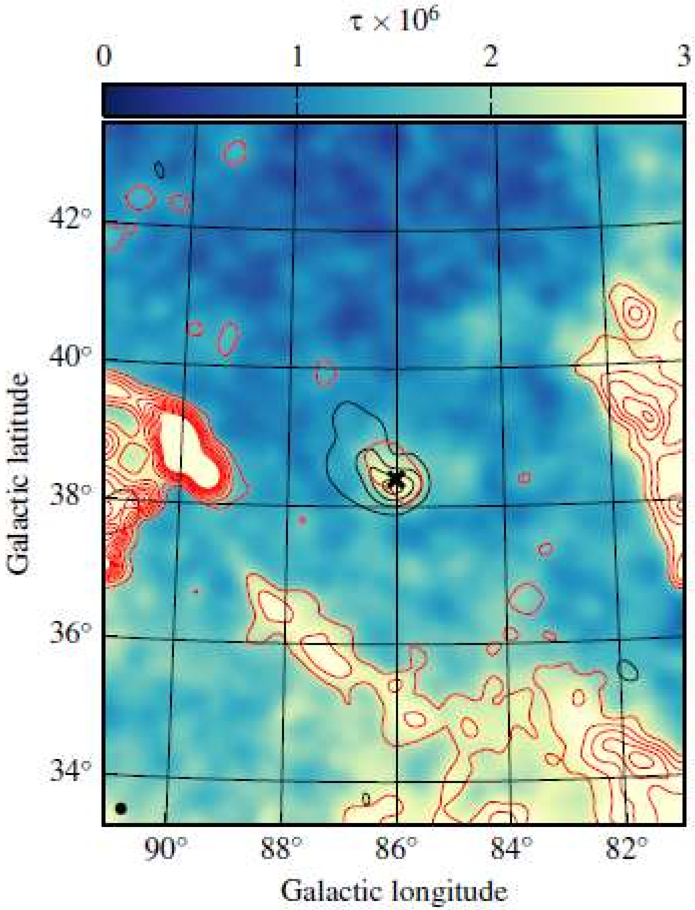
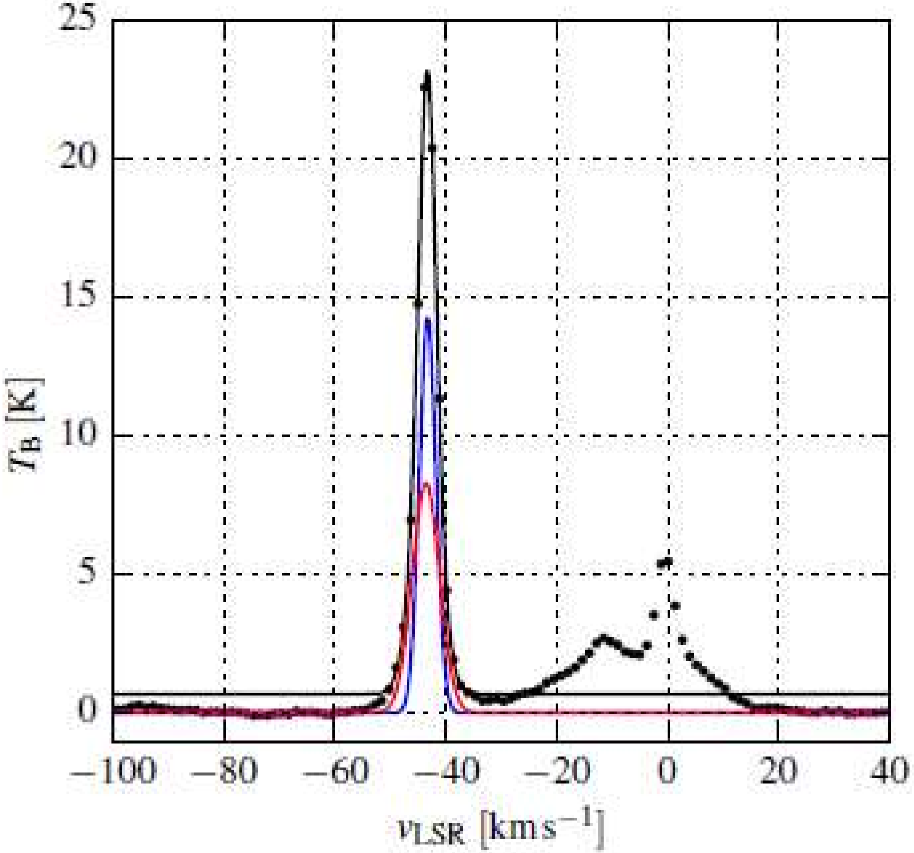
IVC 86+38





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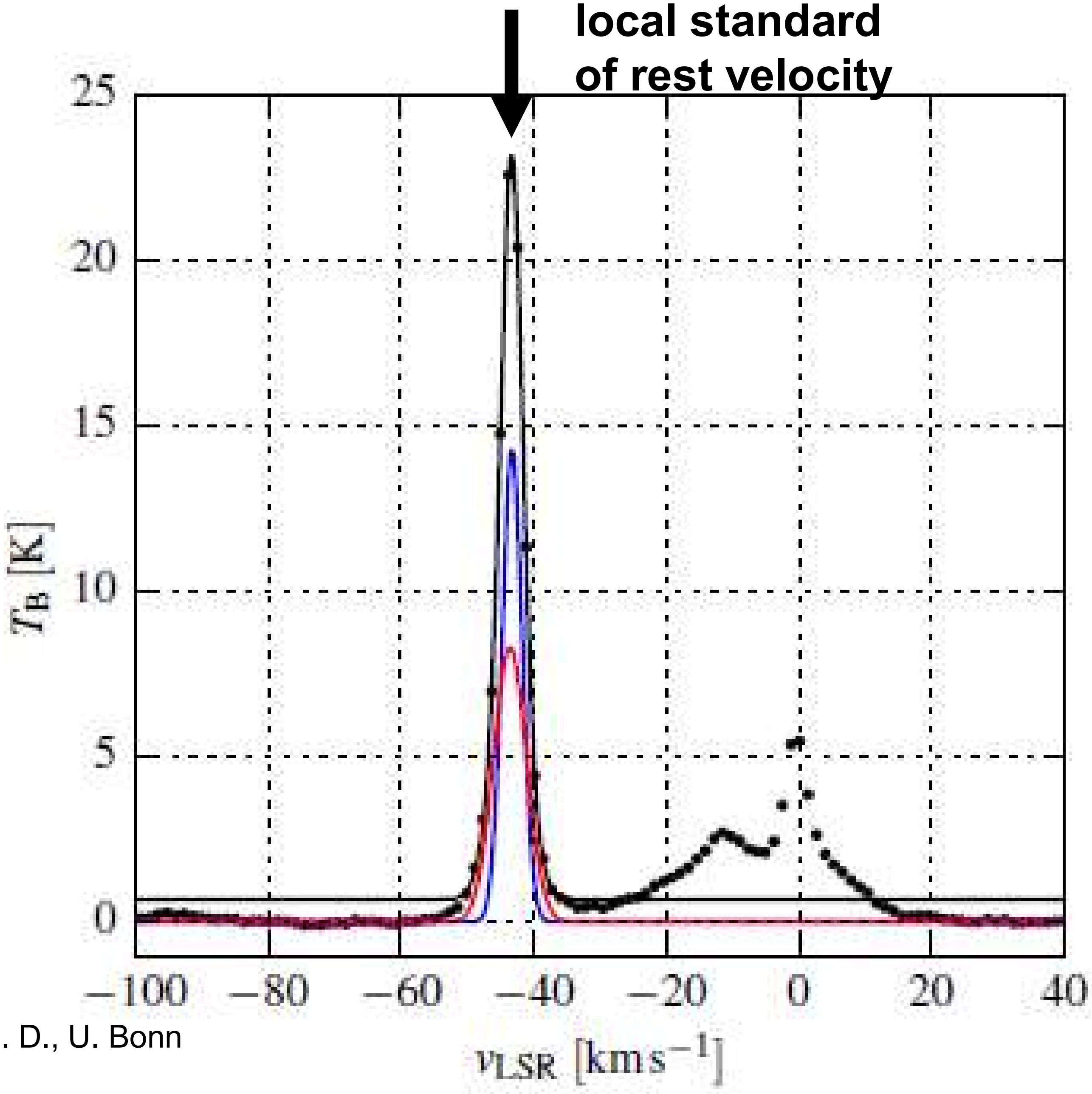
IVC 86+38



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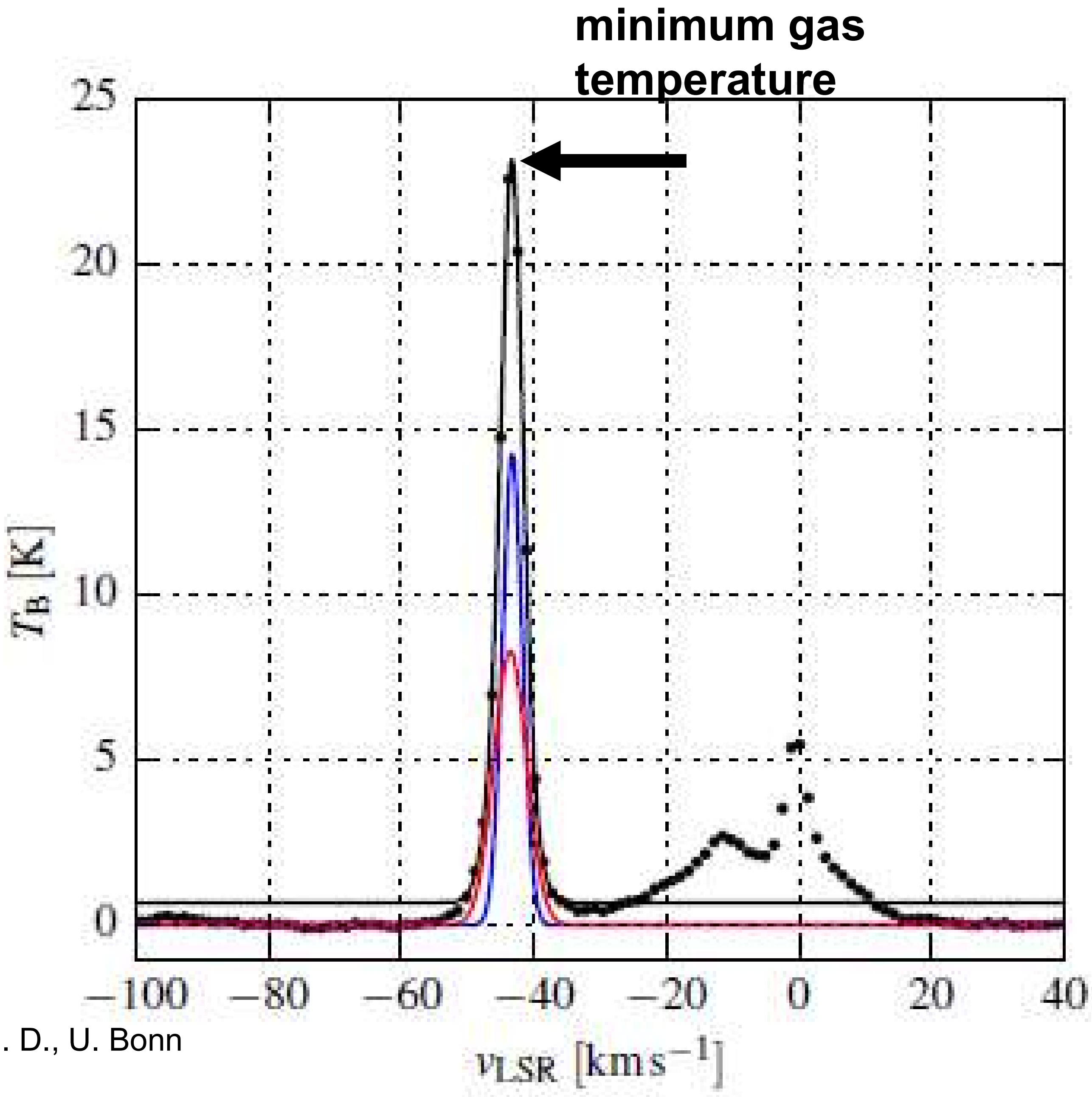

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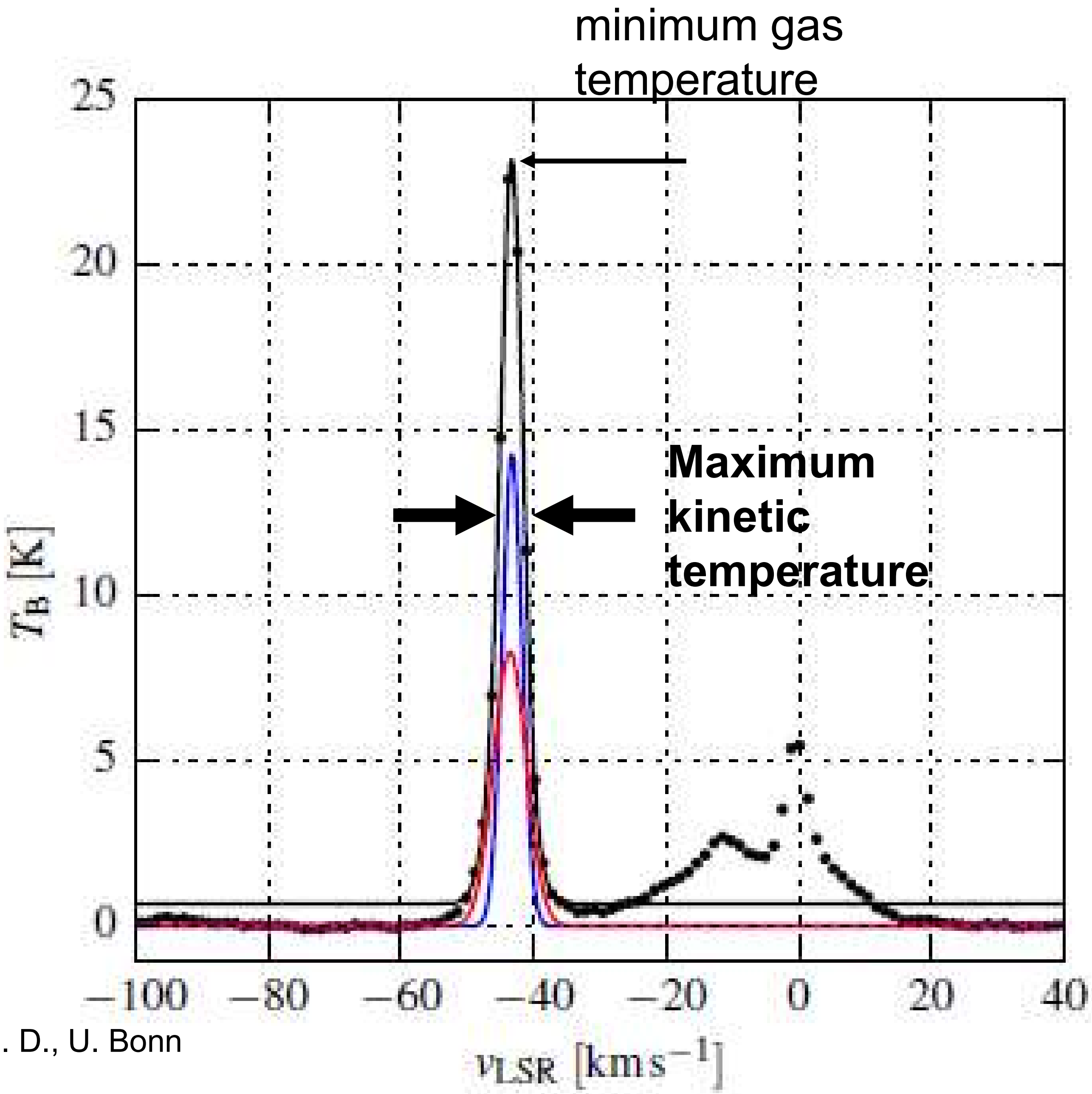

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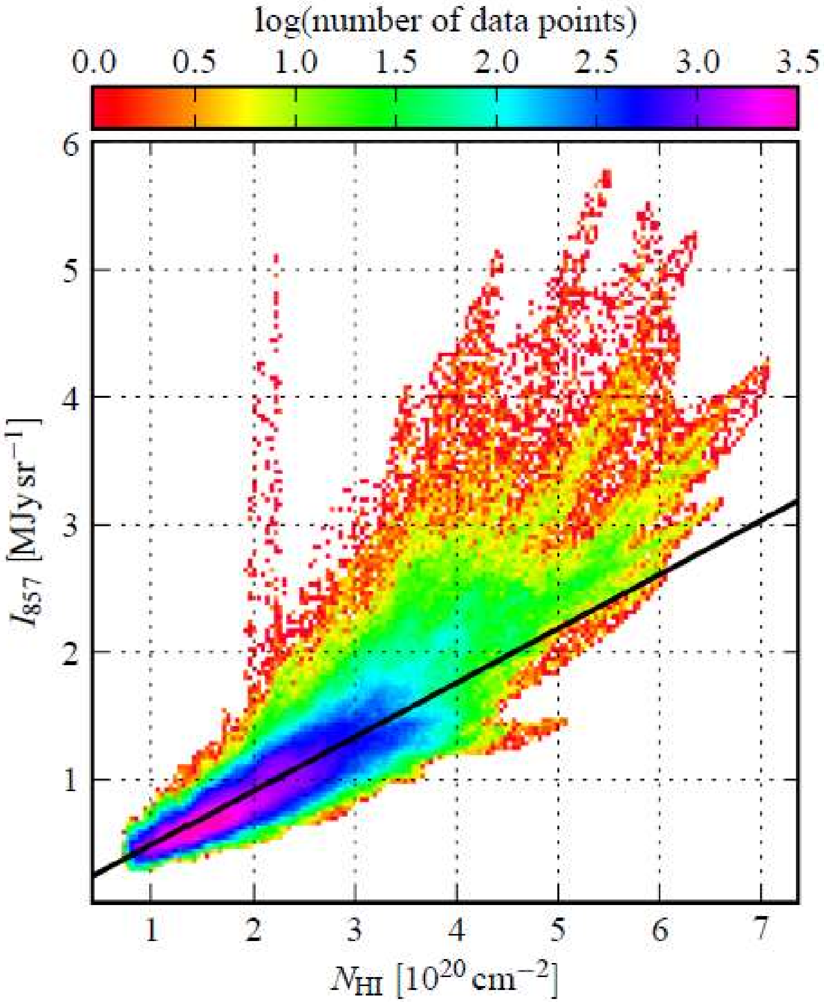
Dust to HI gas

(e.g. Boulanger & Perault 1988)

$$I_\nu = a_\nu + \epsilon_\nu \times N_{\mathrm{H}}$$

$$\boxed{I_\nu} = a_\nu + \epsilon_\nu \times (\boxed{N_{\mathrm{H\,I}}} + 2N_{\mathrm{H_2}})$$

- FIR excess: molecular gas → "missing" H I
- H_2 not easily observable
- No tracers (CO) required



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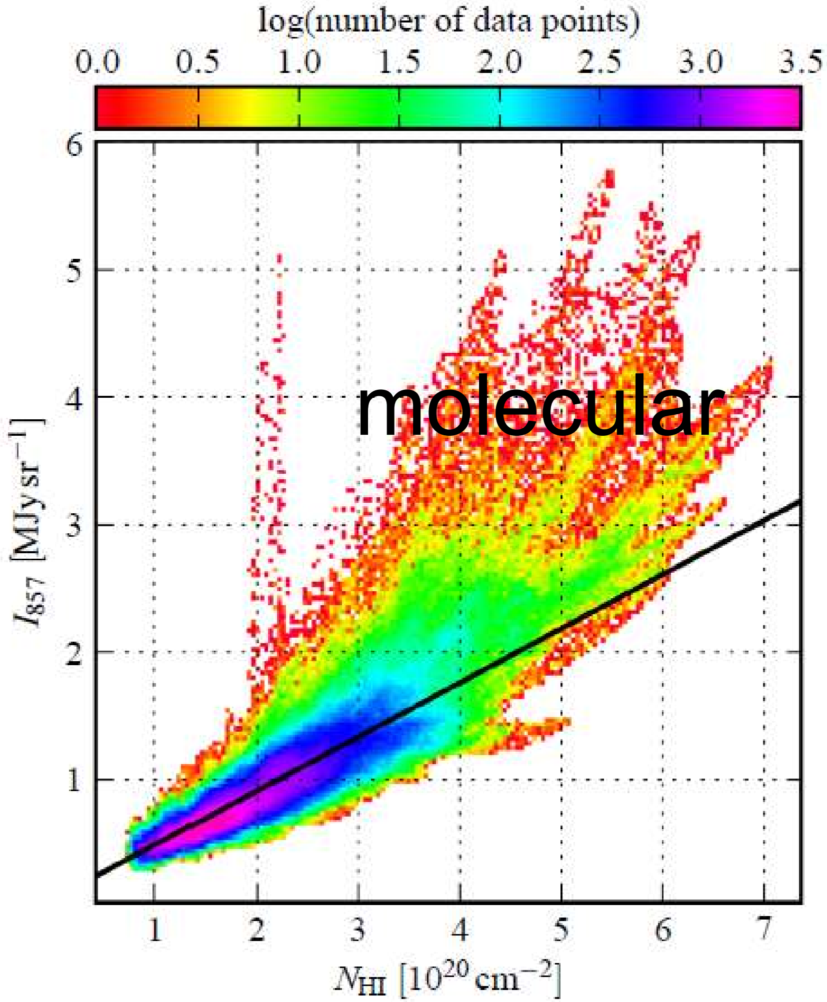

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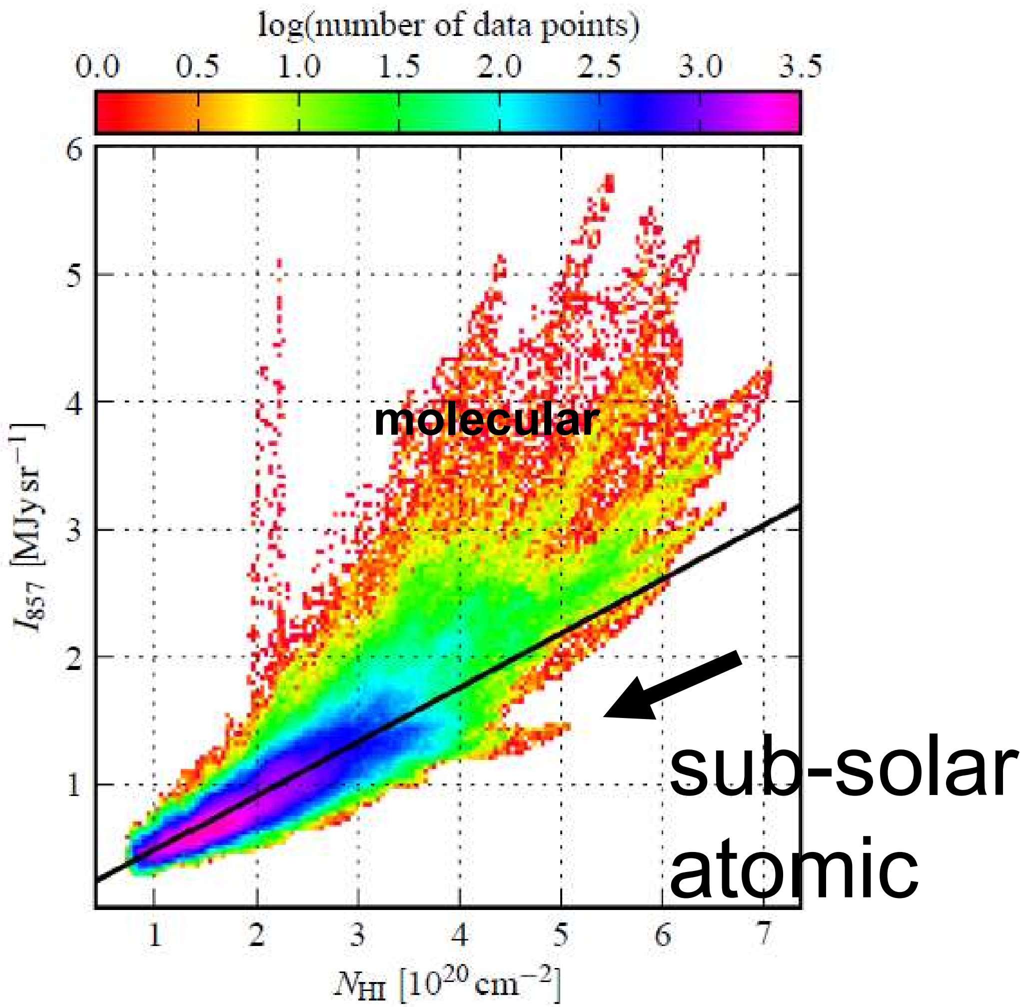

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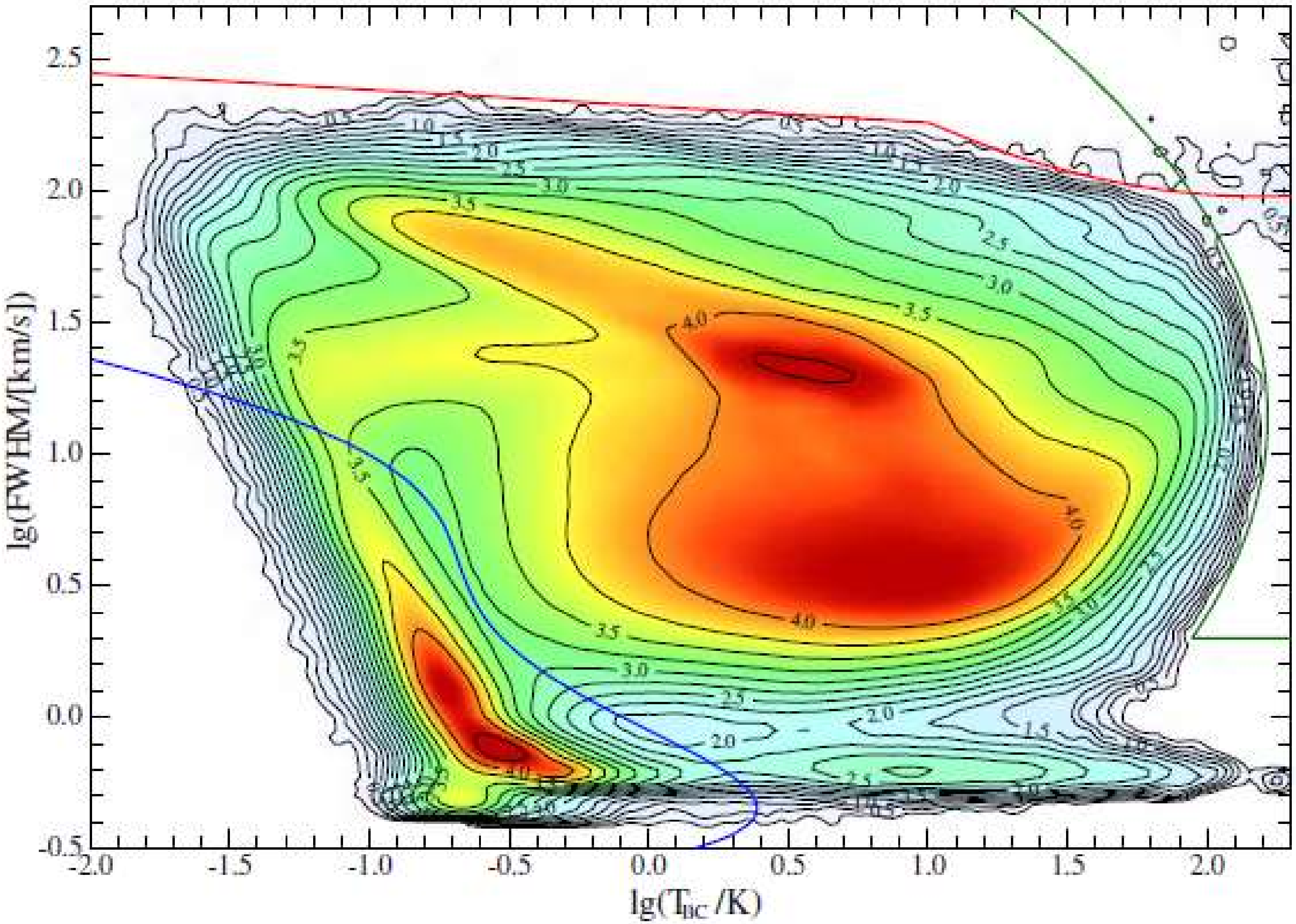
Finding molecular IVCs: Gaussian decomposition



Kalberla & Haud 2015, A&A 578, A78

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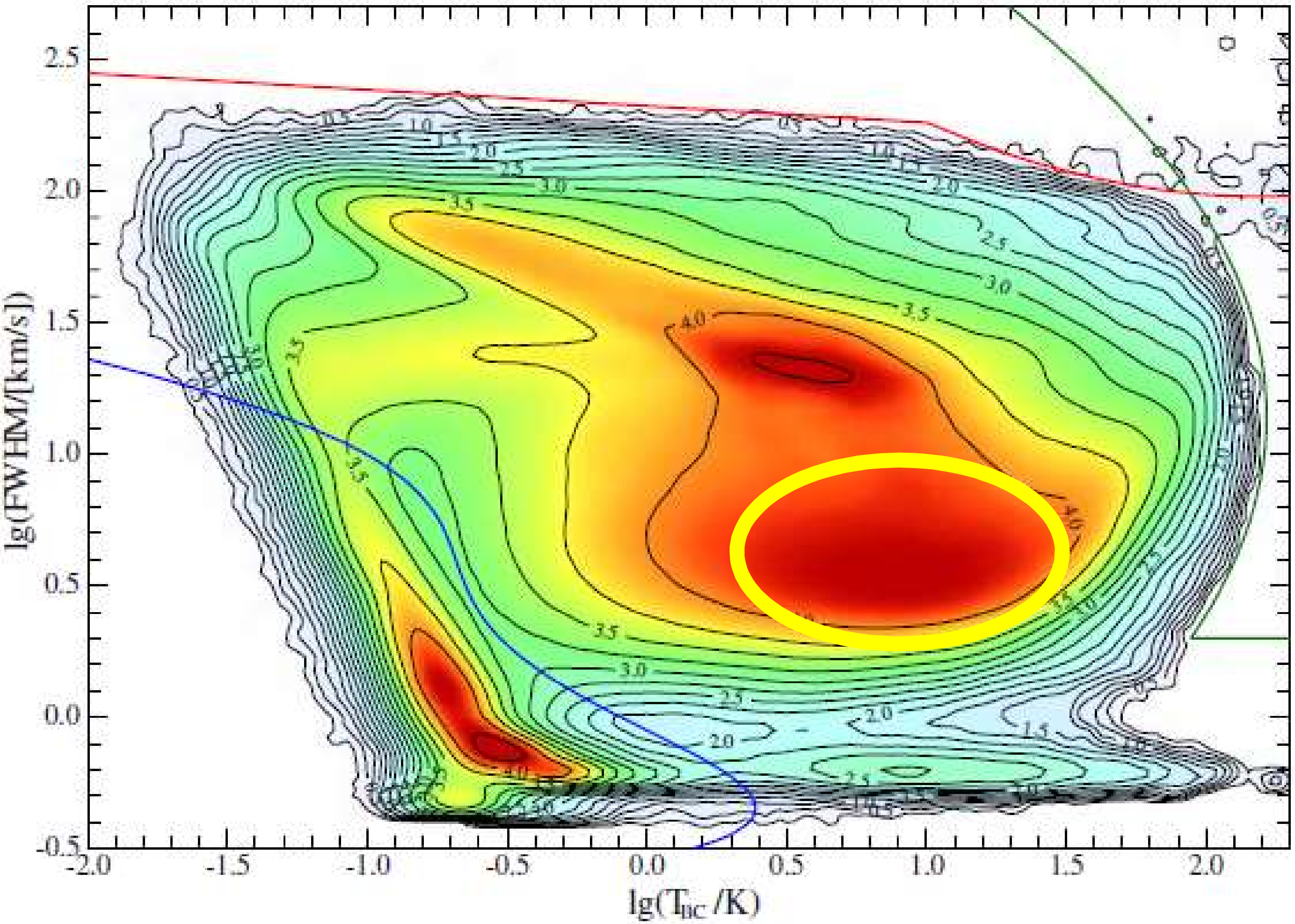

Kalberla & Haud 2015, A&A 578, A78

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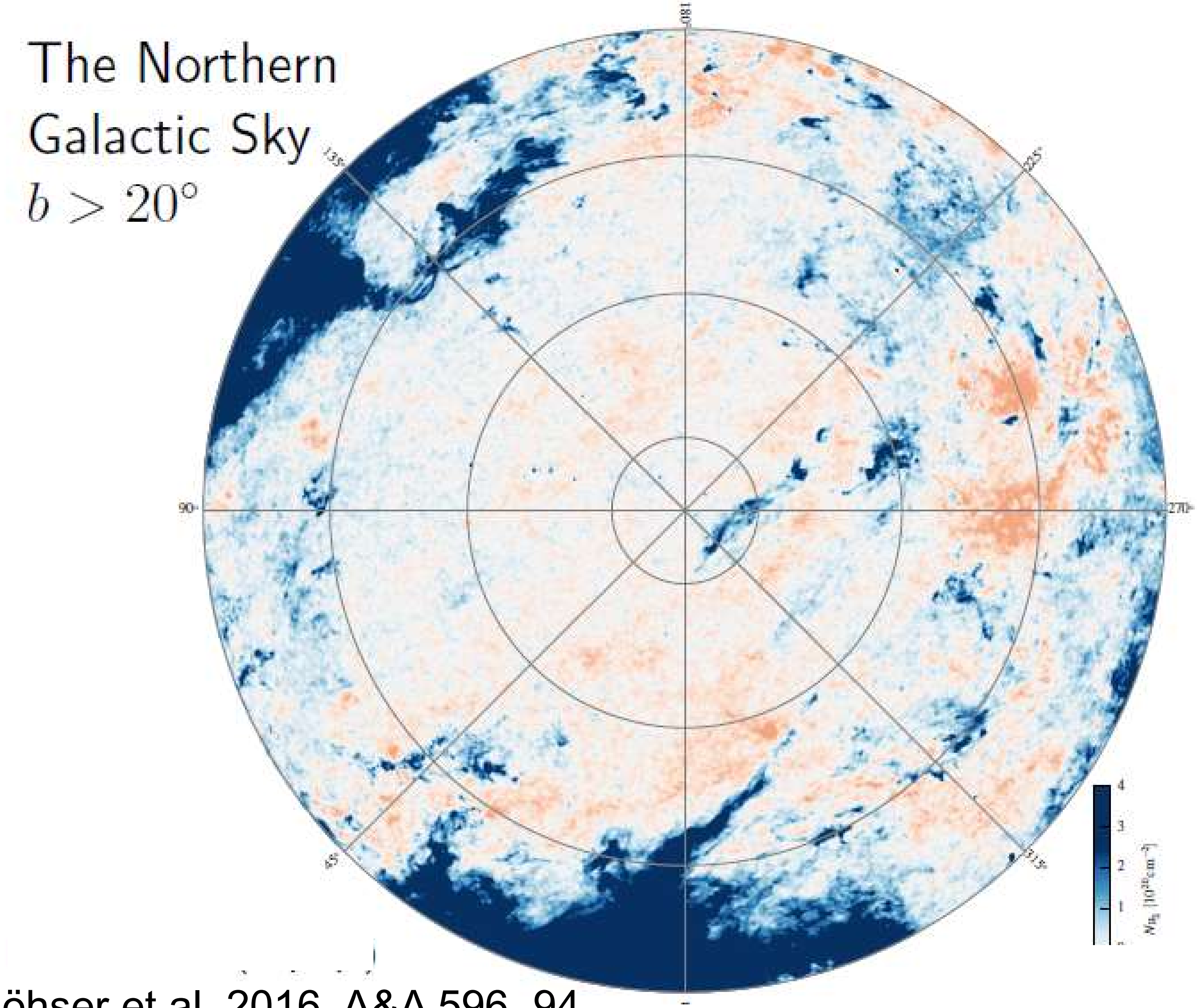
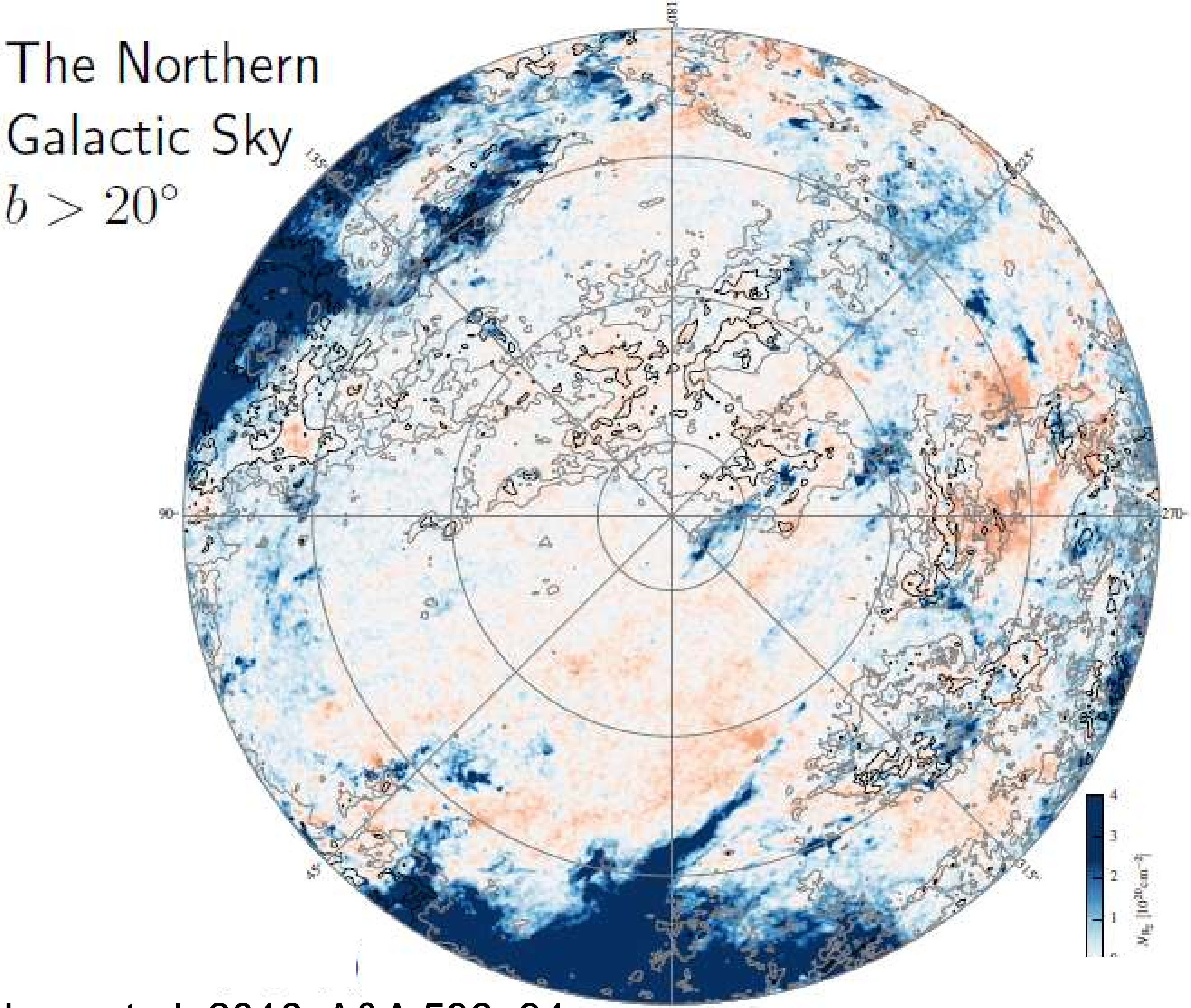
North



Röhser et al. 2016, A&A 596, 94

North



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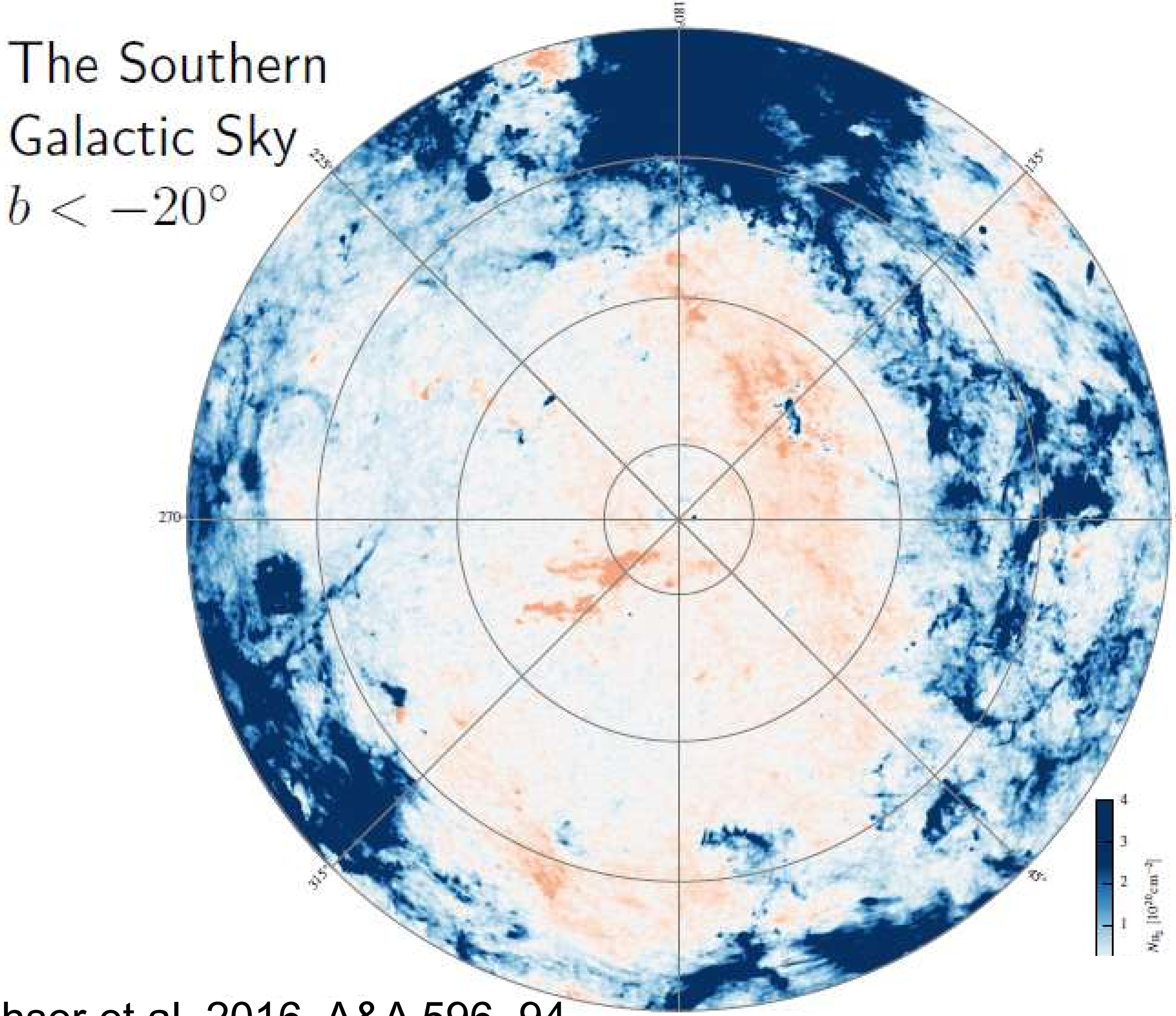
South



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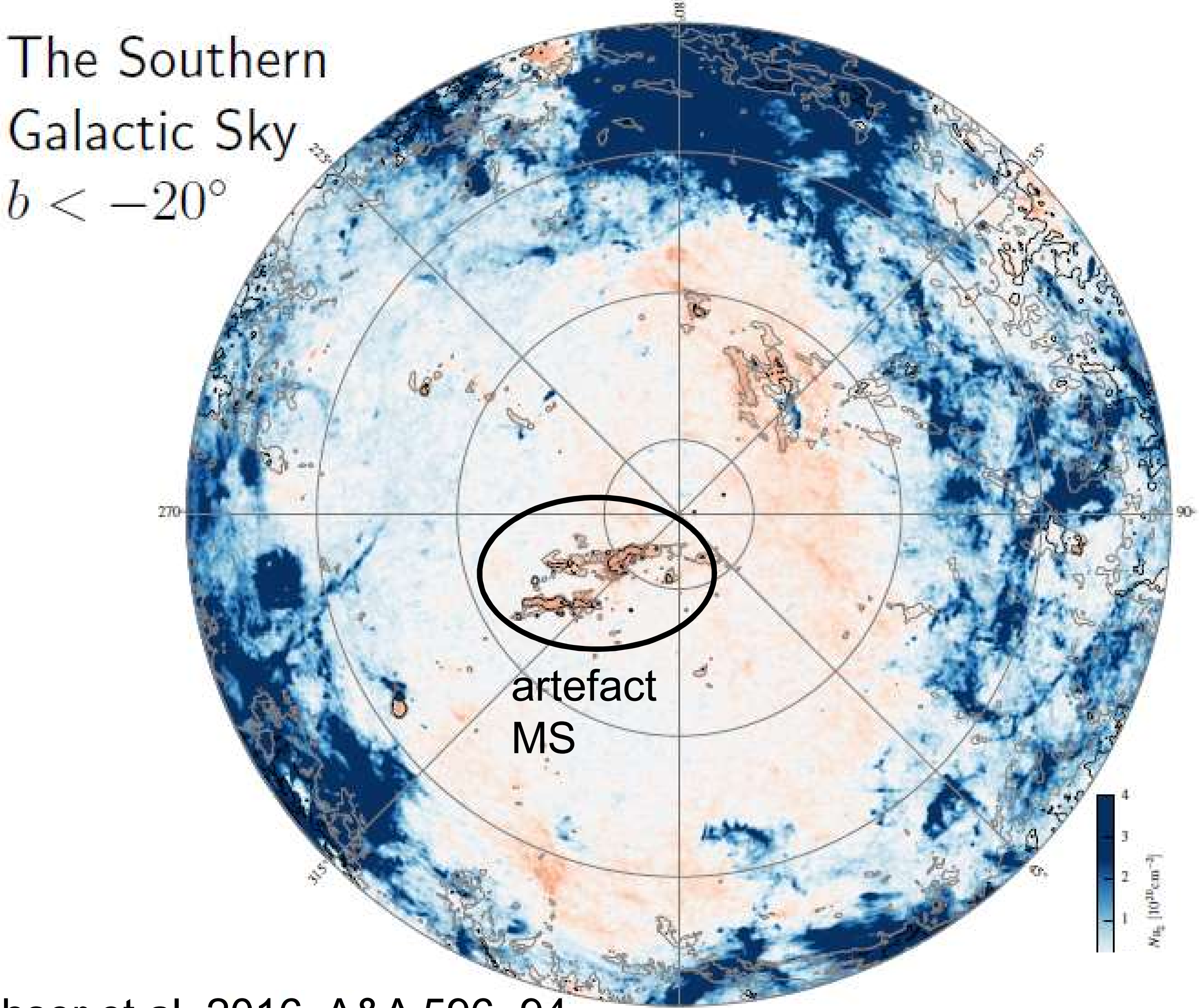
South



Röhser et al. 2016, A&A 596, 94

North-south asymmetry

Total numbers of FIR excess IVCs ~ 1000!!!!

694 MIVCs towards the northern sky

389 toward the southern sky

Large clouds (> 35 arcmin)

	northern Galactic hemisphere		southern Galactic hemisphere	
	$v_{\mathrm{LSR}} < -20\,\mathrm{km\,s^{-1}}$	$v_{\mathrm{LSR}} > +20\,\mathrm{km\,s^{-1}}$	$v_{\mathrm{LSR}} < -20\,\mathrm{km\,s^{-1}}$	$v_{\mathrm{LSR}} > +20\,\mathrm{km\,s^{-1}}$
# AIVCs	86	8	23	0
# MIVCs	161	1	24	20
# NIVCs	288	22	31	5

Röhser et al. (2016), A&A 596, 94

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MIVCs: tiny extent and mass, but many

	d [pc]	T_{kin} [K]	n_{HI} $[cm^{-3}]$	p/k_B $[K\,cm^{-3}]$	f_{mol}	M_{HI} $[M_\odot]$	M_H $[M_\odot]$
northern MIVCs$^-$	6.2	412	4.7	1766	0.51	33	67
southern MIVCs$^-$	10.2	440	7.2	2920	0.37	165	300
southern MIVCs$^+$	13.3	388	3.2	980	0.57	170	400

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Too faint and too tiny to detect them beyond the Magellanic Cloud System

Röhser et al. (2016), A&A 596, 94

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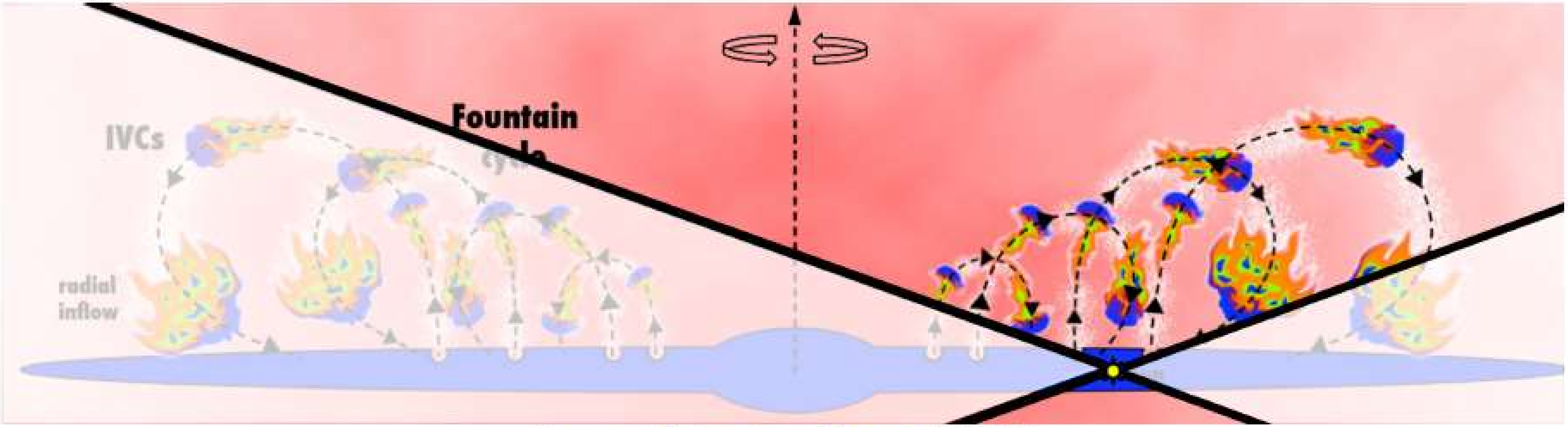
Total local mass of IVCs 3.1 10^6 M_{sun}

Up to 0.5 $M_{sun} a^{-1}$

Only 10% of the Milky Way halo is probed

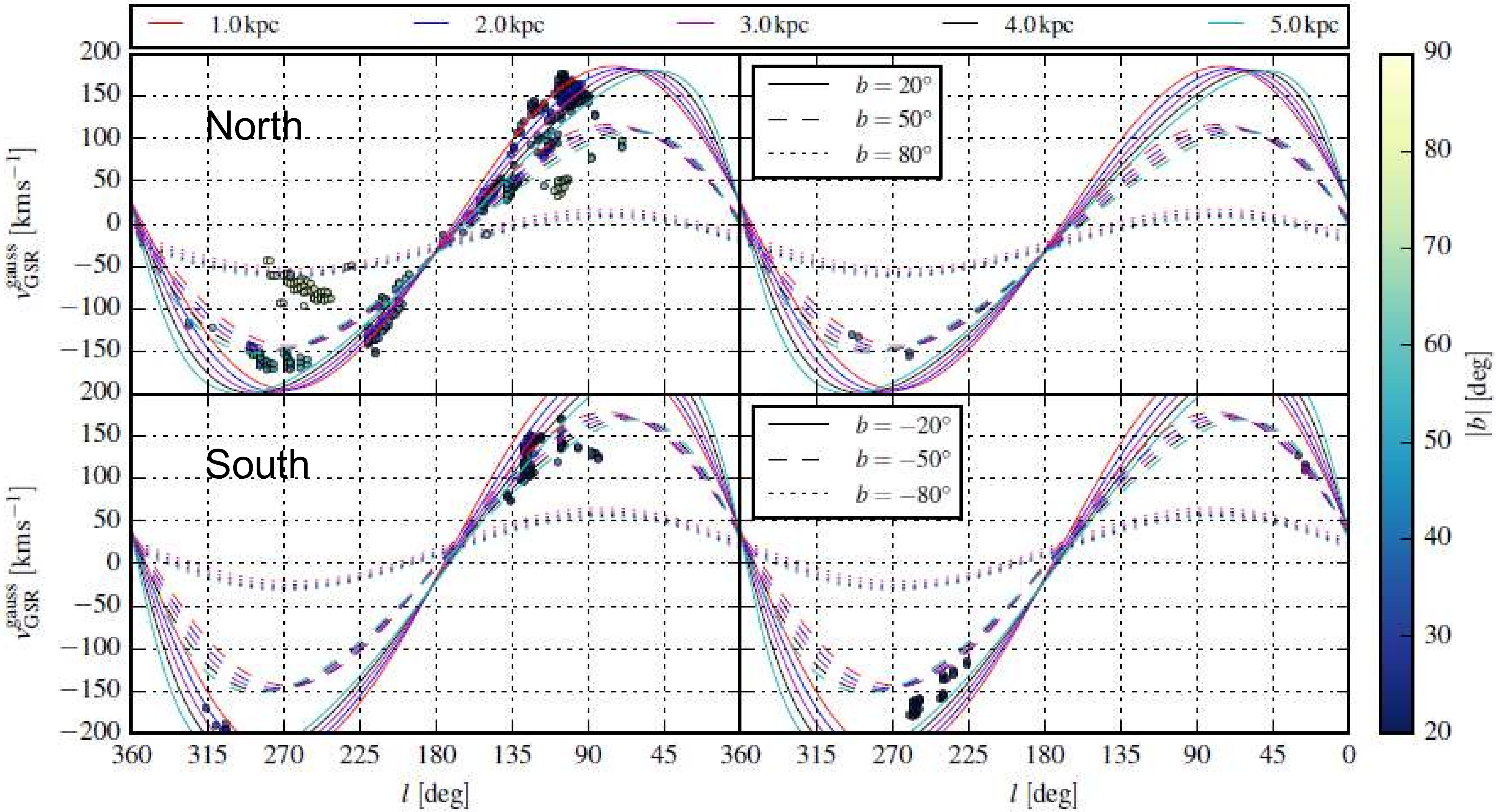
Röhser et al. (2016), A&A 596, 94

- Hydrodynamical simulations of Galactic fountains (Melioli et al. 2008)
- Plane-parallel slab at $z = 2\,\mathrm{kpc}$
- $v_\mathrm{z} = -100\,\mathrm{km\,s^{-1}}$



Marasco, Marinacci, and Fraternali (2013)

Co-rotation



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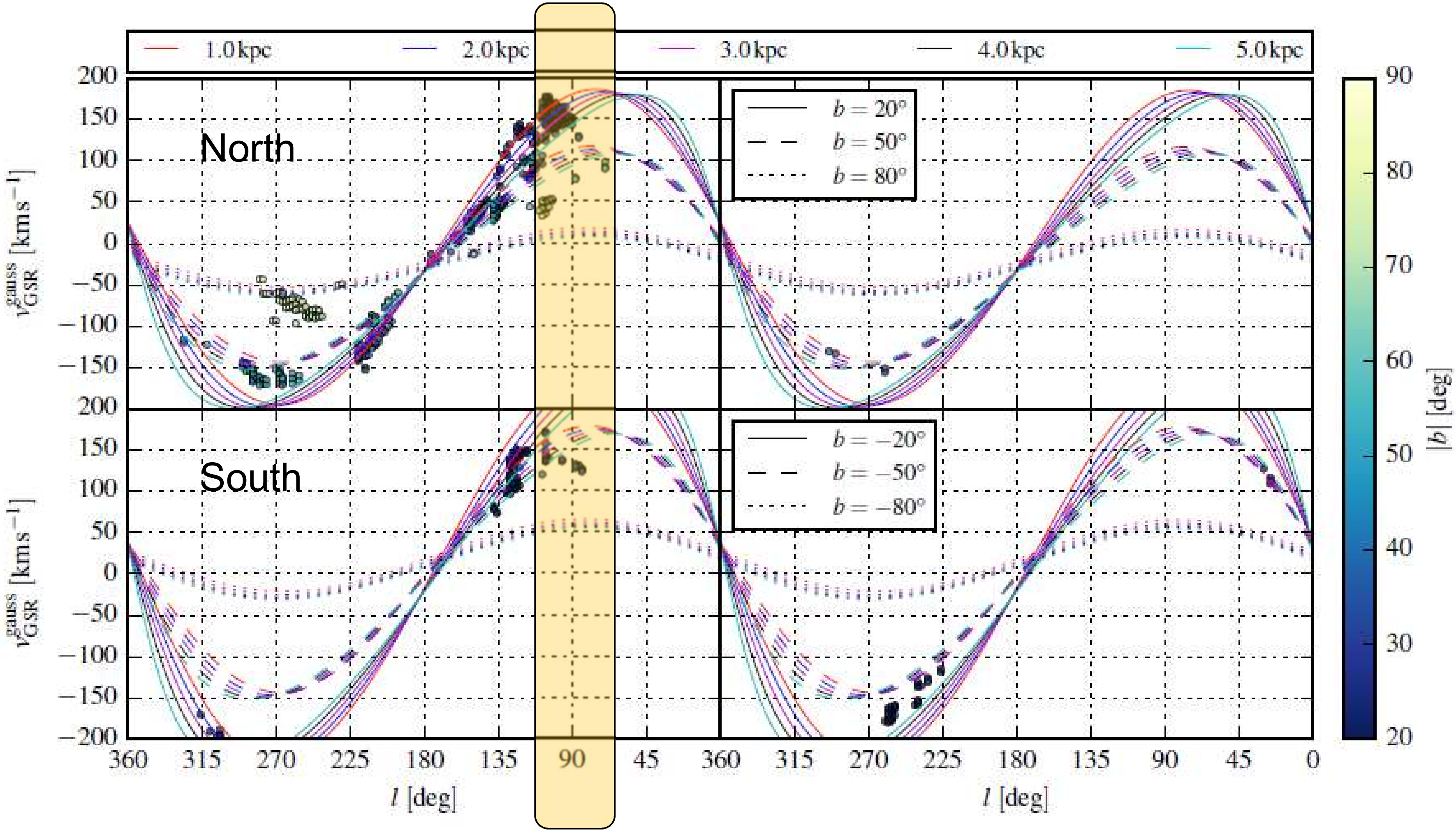
Co-rotation



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What next?

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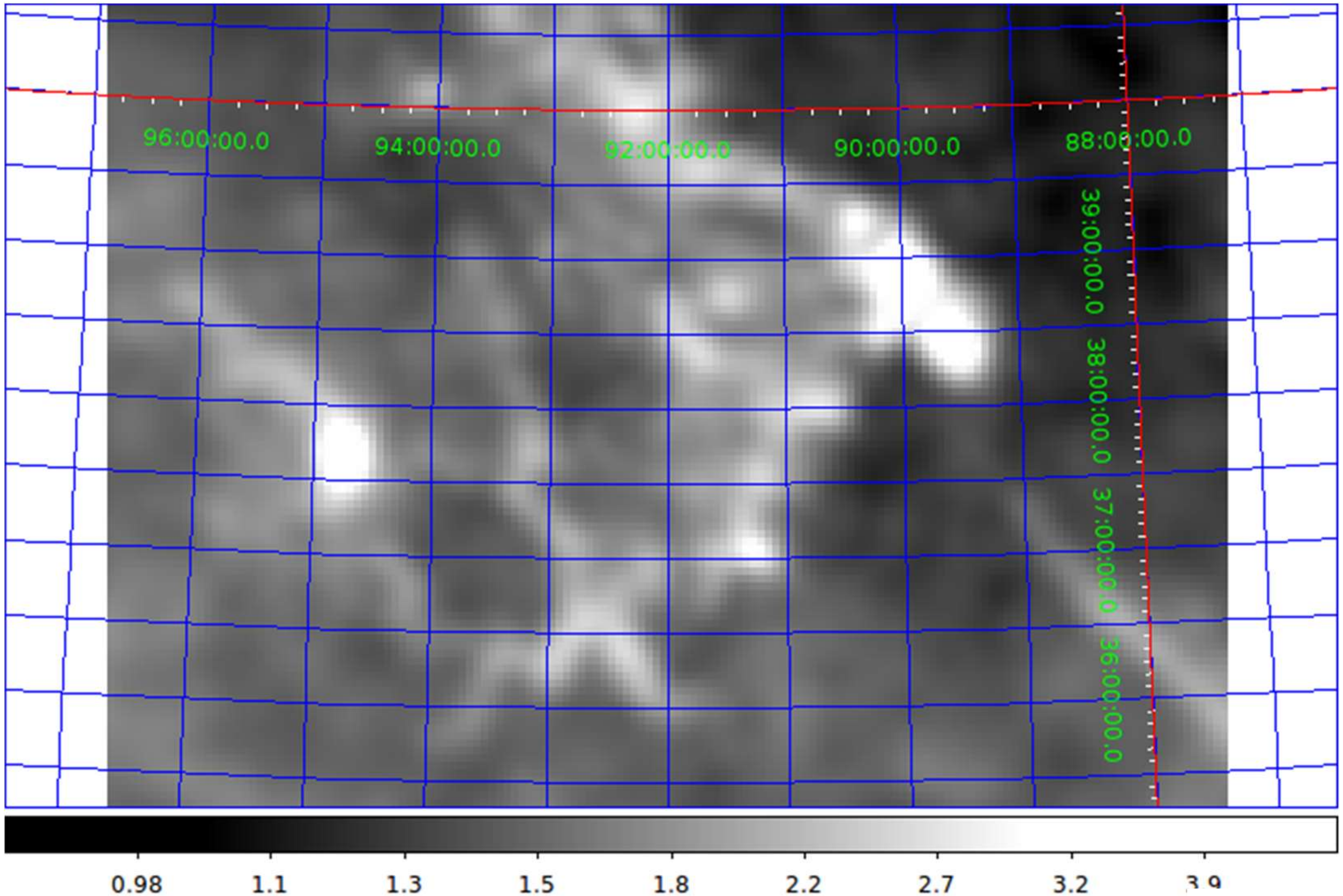
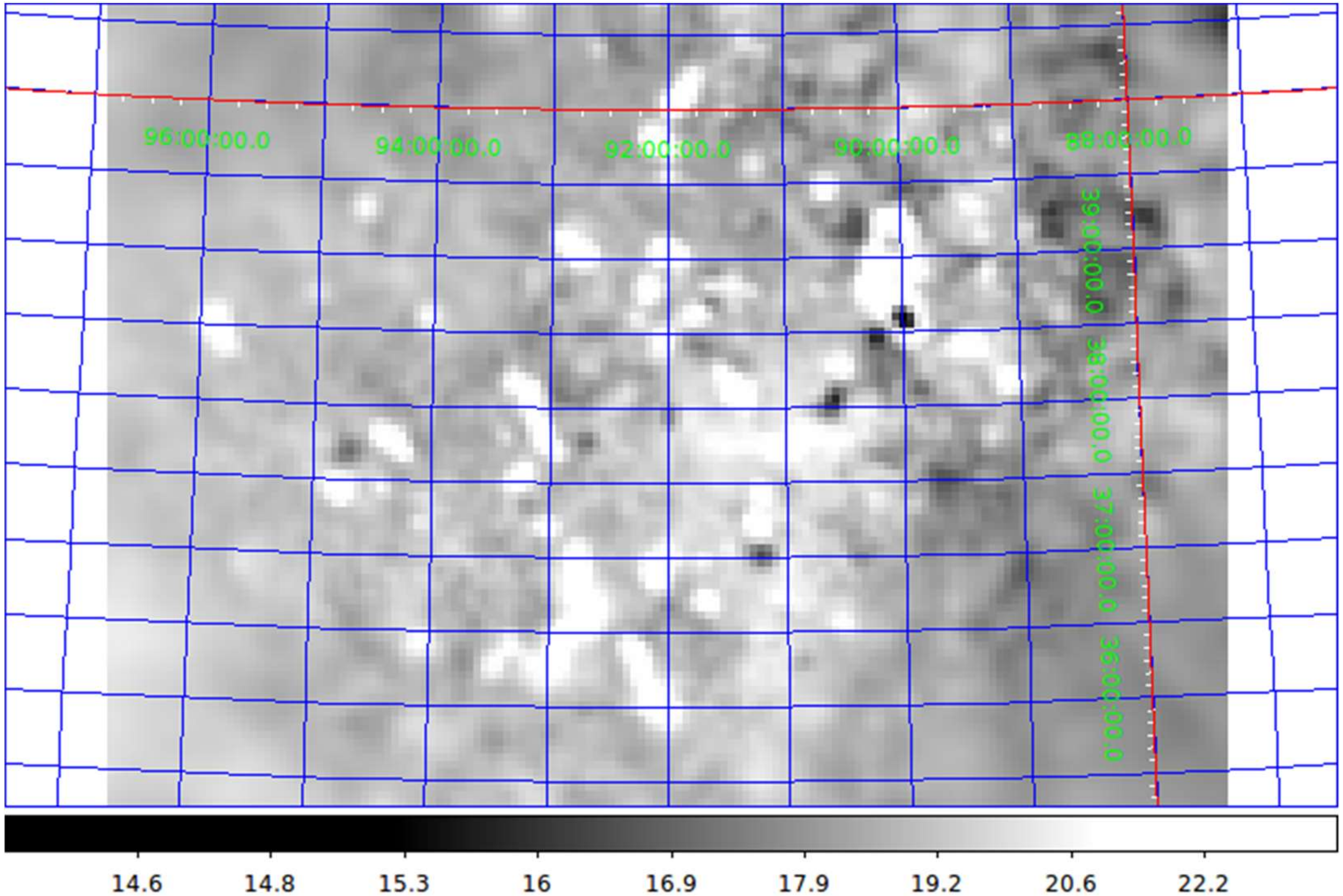
Planck FIR map



Planck dust temperature map



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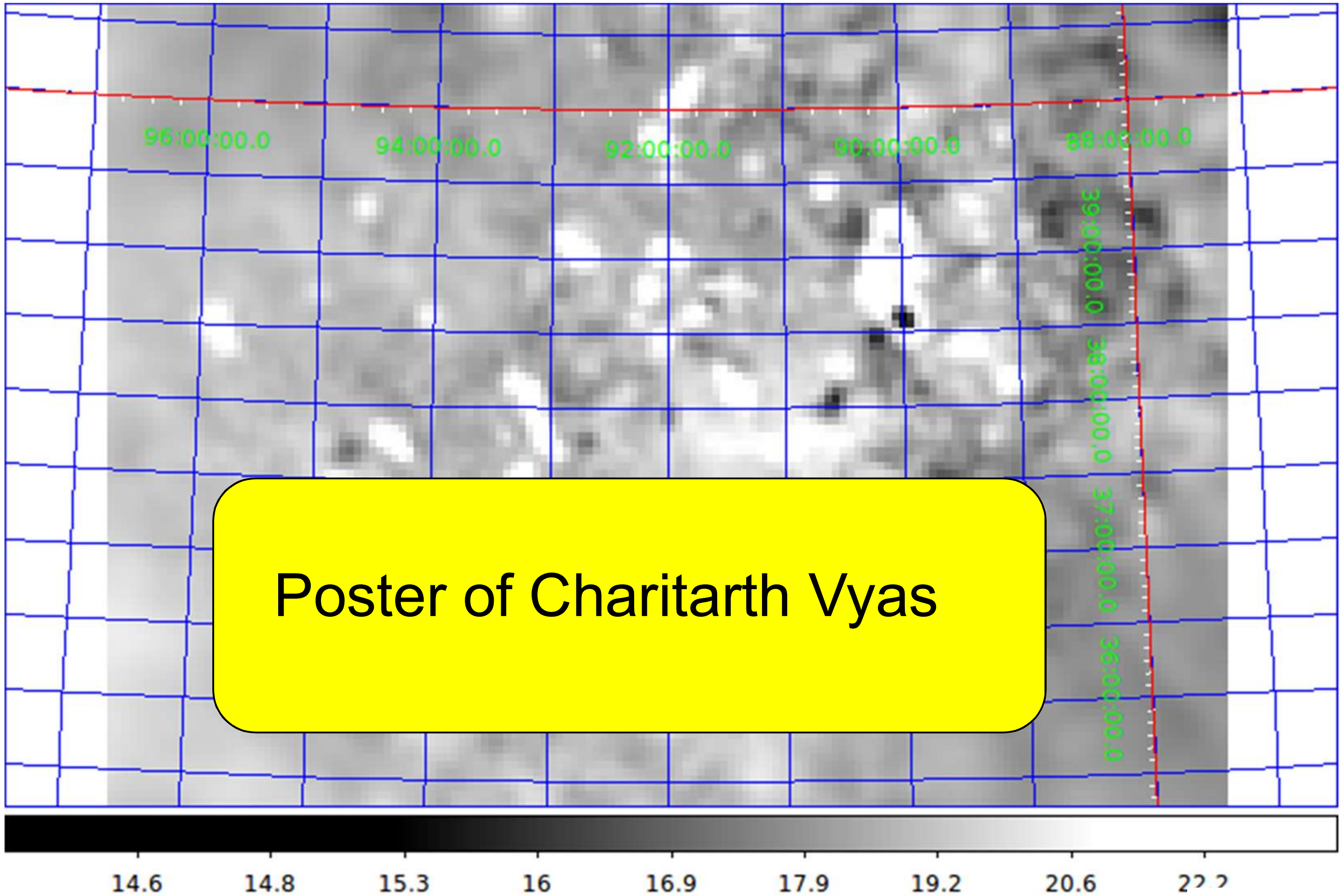

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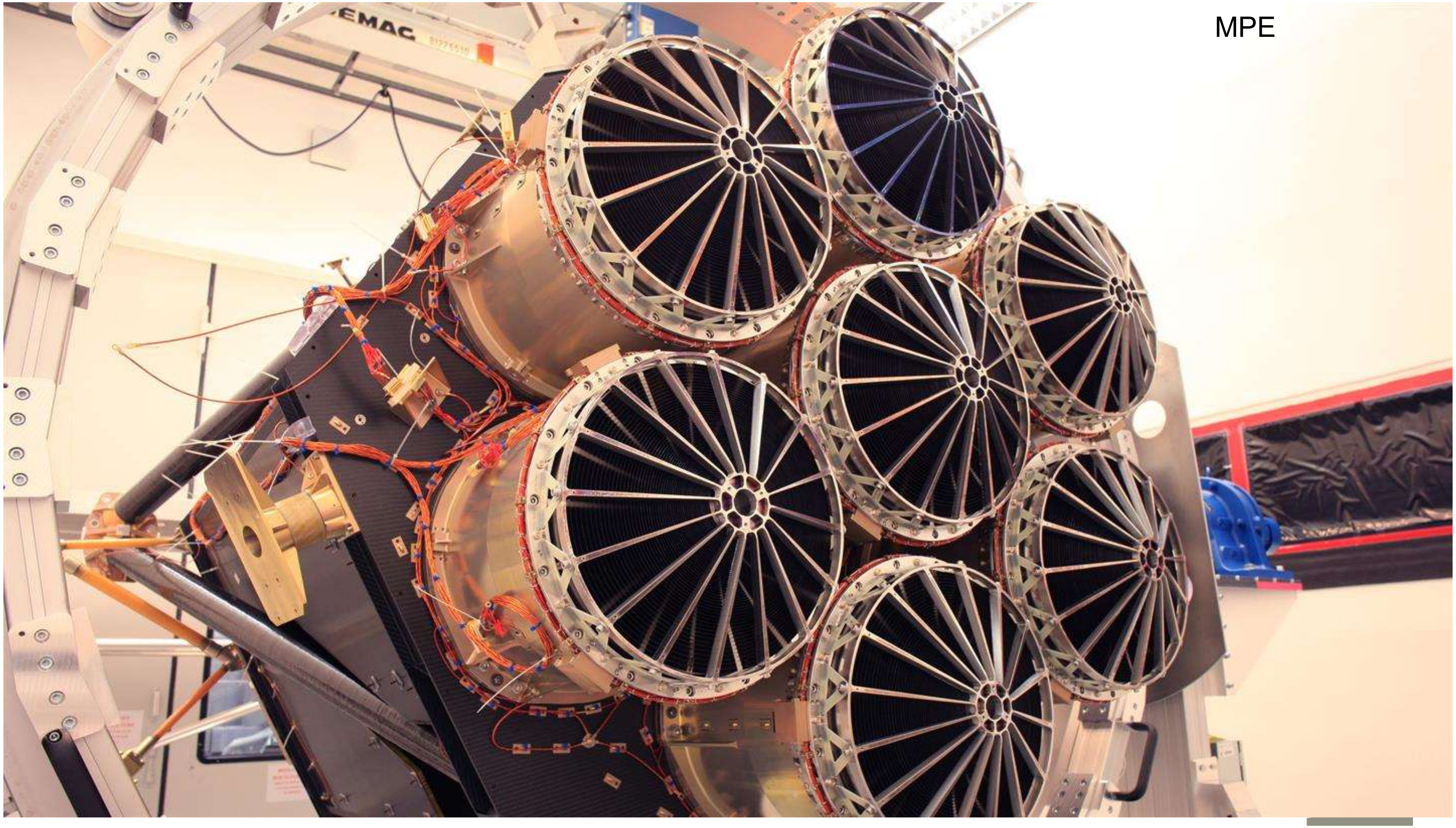
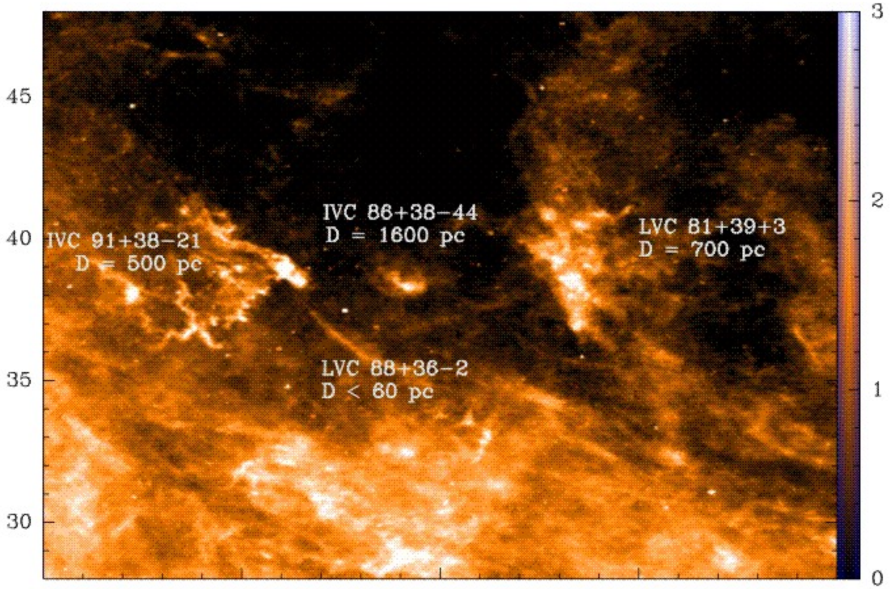
eRosita (2019): X-ray full-sky survey



CO-dark Gas: correlation with X-rays



HI 21-cm column density

0.25 keV ROSAT

J. Kerp „X-ray astroomy“ 2003

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Results

- **two orders of magnitude more** molecular IVCs than previously identified (1000 MIVCs)
- at LAB resolution factor of four more molecular IVCs (232 MIVCs)
- Extent about 10pc, about a few hundred solar masses, **undetectable in external galaxies**
- the IVC follow **slightly lagging the galactic rotation**
- adopting 500 pc scale height yields 0.05 to 0.52 solar masses per year
- a marked **north-south** and **positive-negative** rad. velocity **asymmetry**
- consistent with a **Galactic fountain origin**

Thank you

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