

Look up here if you get lost!

Beyond the Feature Vector

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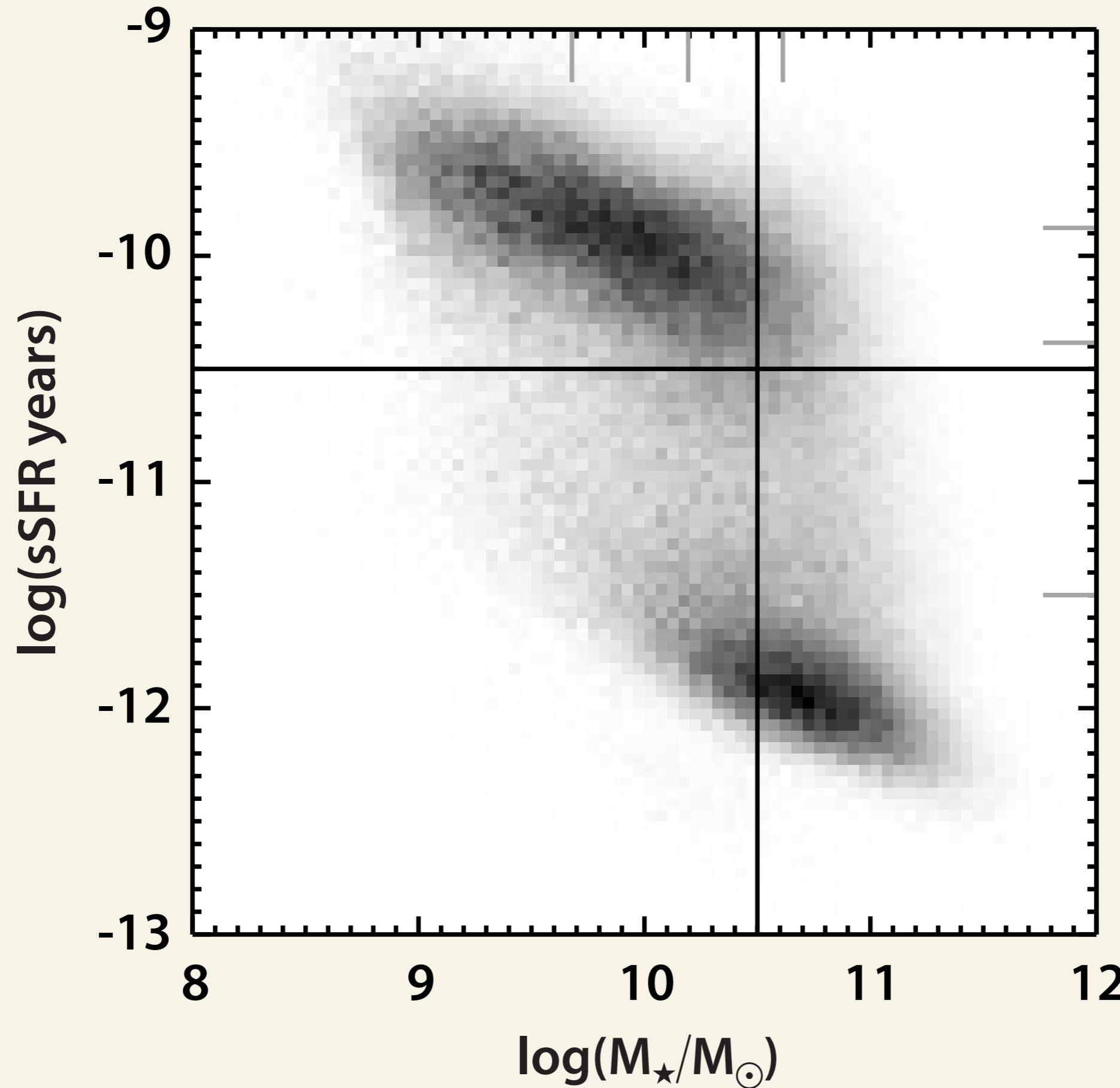
w/ Susan Clark *Columbia*

March 9, 2015 *Big Data Astronomy*

Astronomy has always been a science of catalogs

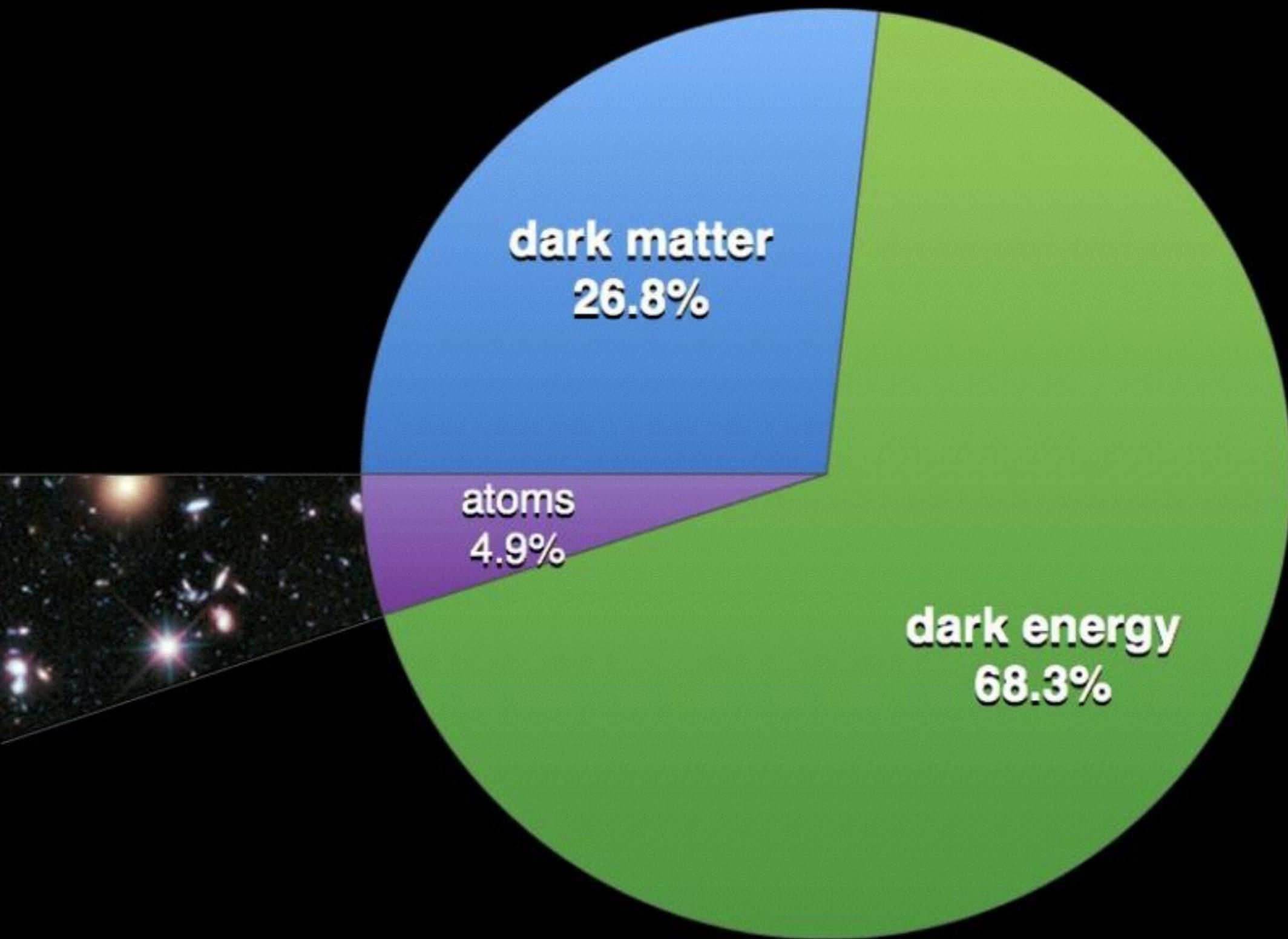
CANCER										AUGUSTUS									
		Arcus	Anguli orientales	Anguli occidentales			Arcus	Anguli orientales	Anguli occidentales			Arcus	Anguli orientales	Anguli occidentales					
Dore m	pres m	pres m	pres m	pres m			Dore m	pres m	pres m			Dore m	pres m	pres m					
Meridies	17 5	90 0	0 0	0 0			Meridies	40 56	113 51	0 0		Meridies	21 10	pres m					
1 0	21 18	122 32	57 38				1 0	43 8	129 57	97 45		1 0	24 32						
2 0	30 17	138 29	41 31				2 0	49 7	143 38	84 44		2 0	32 52						
3 0	41 37	144 18	35 42				3 0	57 42	153 8	74 34		3 0	42 1						
4 0	52 25	145 38	34 22				4 0	67 50	158 47	68 55		4 0	52 29						
5 0	63 47	144 28	35 32				5 0	78 45	161 59	65 43		5 0	63 30						
6 0	74 48	141 30	38 30				6 0	90 30	162 55	64 47		6 0	73 24						
7 0	85 9	137 5	42 55				7 0	0 10	10 0	0 0		7 0	83 16						
7 30	90 0	134 16	45 44				7 0	0 0	0 0	0 0		7 45	90 0					L	
LEO										SCORPIO									
		Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.					
Dore m	Meridies	20 26	102 30	0 0			Meridies	52 36	111 0	0 0		Meridies	24 31						
1 0	24 5	131 6	73 54				1 0	54 23	124 46	97 14		1 0	27 29						
2 0	32 37	147 0	58 0				2 0	59 29	136 55	85 5		2 0	34 48						
3 0	43 8	153 50	51 10				3 0	66 38	146 24	75 36		3 0	44 20						
4 0	54 19	156 5	48 55				4 0	76 15	153 10	68 50		4 0	54 37						
5 0	65 36	155 8	49 52				5 0	86 38	157 45	64 25		5 0	65 16						
6 0	76 46	153 24	51 36				5 0	90 20	158 59	63 21		6 0	75 39						
7 0	87 24	149 6	55 54				7 0	0 0	0 0	0 0		7 0	85 39					V	
7 16	90 0	148 6	56 54				7 0	0 0	0 0	0 0		7 18	90 0						
VIRGO										SAGITTARIUS									
		Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.					
Dore m	Meridies	29 16	111 0	0 0			Meridies	61 26	102 30	0 0		Meridies	33 21						
1 0	32 5	132 30	89 30				1 0	63 0	115 5	89 55		1 0	35 43						
2 0	39 22	147 30	74 30				2 0	67 24	126 29	78 31		2 0	42 26						
3 0	49 3	156 0	66 0				3 0	74 13	136 10	68 50		3 0	50 46						
4 0	59 50	160 7	61 53				4 0	82 48	143 45	61 15		4 0	60 44						
5 0	71 5	161 24	60 36				4 0	90 0	148 6	56 54		5 0	71 52						
6 0	82 22	160 40	61 20				5 0	0 0	0 0	0 0		6 0	81 46						
16 41	90 0	158 59	63 1				6 0	0 0	0 0	0 0		6 48	90 0						
CAPRICORNVS										ARIES									
		Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.					
Dore m	Meridies	64 47	90 0	0 0			Meridies	40 56	66 9	0 0		Meridies	68 52						
1 0	66 15	102 27	77 33				1 0	43 8	82 15	50 3		1 0	70 14						
2 0	70 30	113 35	66 25				2 0	49 7	95 56	36 22		2 0	74 5						
3 0	77 4	122 55	57 5				3 0	57 42	105 26	26 52		3 0	80 6						
4 0	85 18	130 58	49 2				4 0	67 50	111 5	21 13		4 0	87 42						
4 30	90 0	134 16	45 44				5 0	78 45	114 17	18 1		5 15	90 0						
0 0	0 0	0 0	0 0				6 0	90 0	115 13	17 5		0 0	0 0						
AQVARIVS										TAURVS									
		Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.					
Dore m	Meridies	61 26	77 30	0 0			Meridies	29 16	69 0	0 0		Meridies	65 31						
1 0	63 0	90 5	64 55				1 0	32 5	90 30	47 30		1 0	66 55						
2 0	67 24	101 29	53 31				2 0	59 22	105 30	32 30		2 0	70 58						
3 0	74 13	111 10	43 50				3 0	49 3	114 0	24 0		3 0	77 14						
4 0	82 48	118 45	36 15				4 0	59 50	118 7	19 53		4 0	85 10						
4 44	90 0	23 6	31 54				5 0	71 5	119 24	18 36		5 0	90 0						
0 0	0 0	0 0	0 0				6 0	82 22	118 40	19 20		6 0	0 0						
0 0	0 0	0 0	0 0				6 41	90 0	116 59	21 1		0 0	0 0						
PISCES										GEMINI									
		Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.			Arcus	Angu.ori.	Angu.oc.					
Dore m	Meridies	61 26	77 30	0 0			Meridies	29 16	69 0	0 0		Meridies	65 31						
1 0	63 0	90 5	64 55				1 0	32 5	90 30	47 30		1 0	66 55						
2 0	67 24	101 29	53 31				2 0	59 22	105 30	32 30		2 0	70 58						
3 0	74 13	111 10	43 50				3 0	49 3	114 0	24 0		3 0	77 14						
4 0	82 48	118 45	36 15				4 0	59 50	118 7	19 53		4 0	85 10						
4 44	90 0	23 6	31 54				5 0	71 5	119 24	18 36		5 0	90						

We can visualize our catalogs; apply statistics, learning

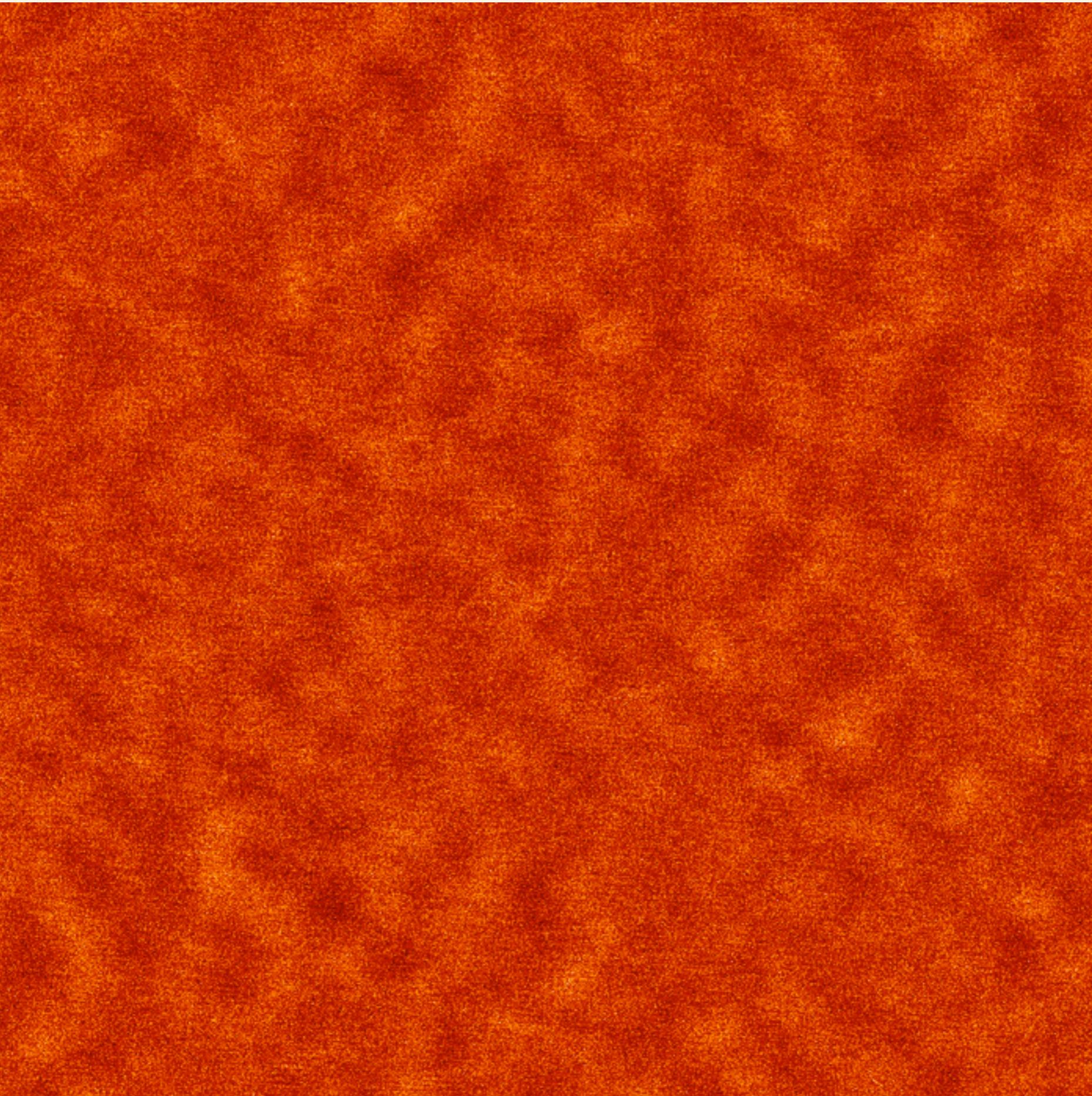


SDSS

Unfortunately, most of the Universe is diffuse

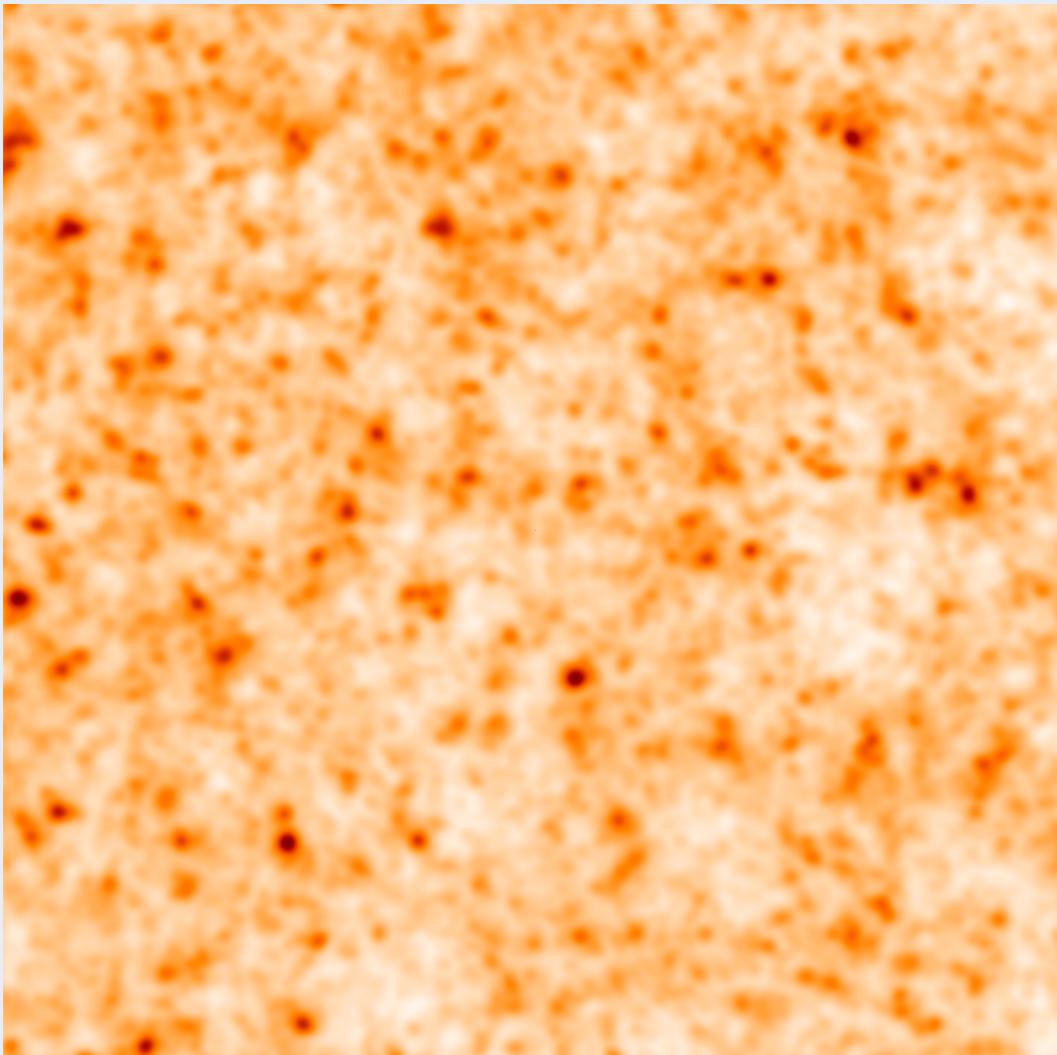


The power spectrum lets us avoid object finding

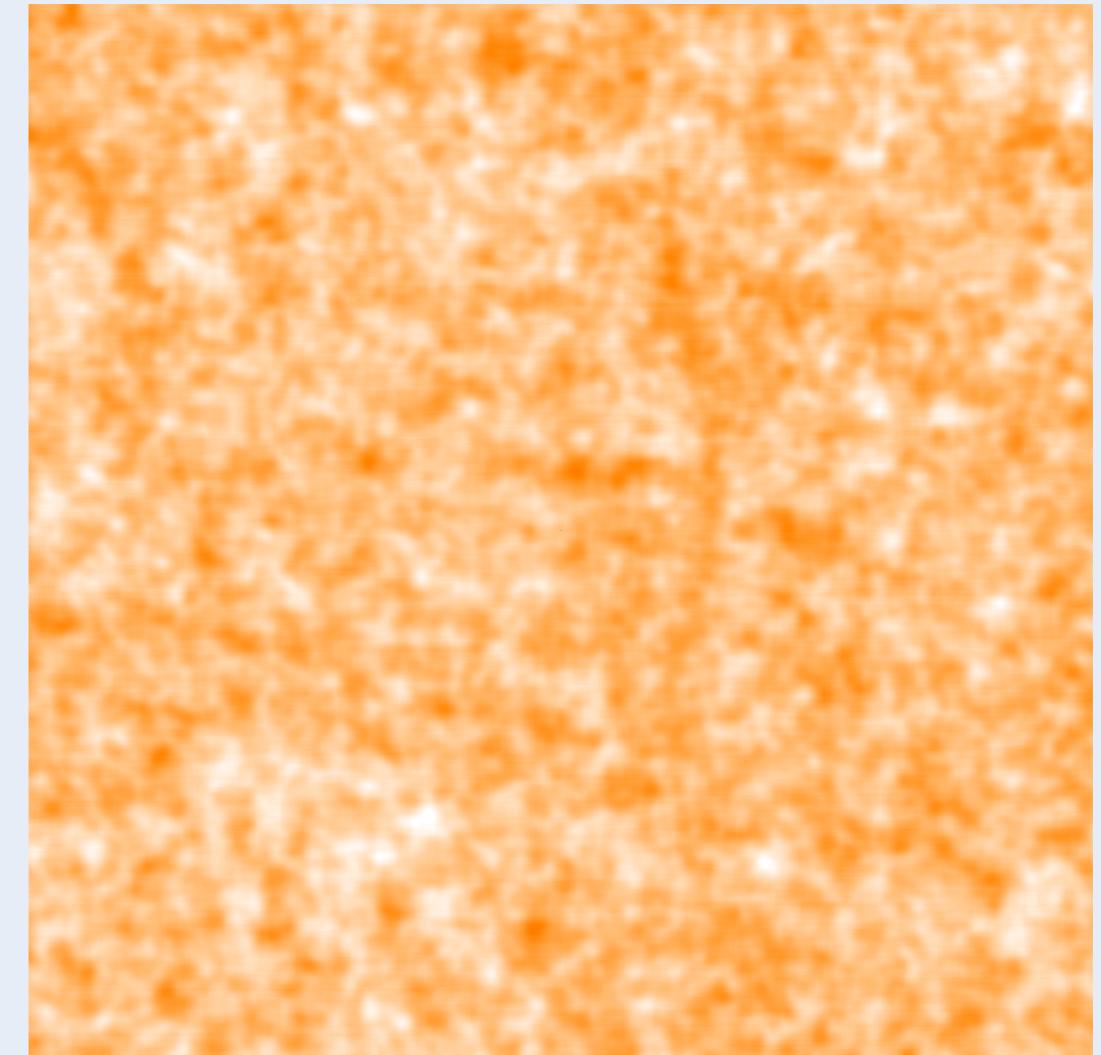


SPT

But: shape informs the non-linear universe



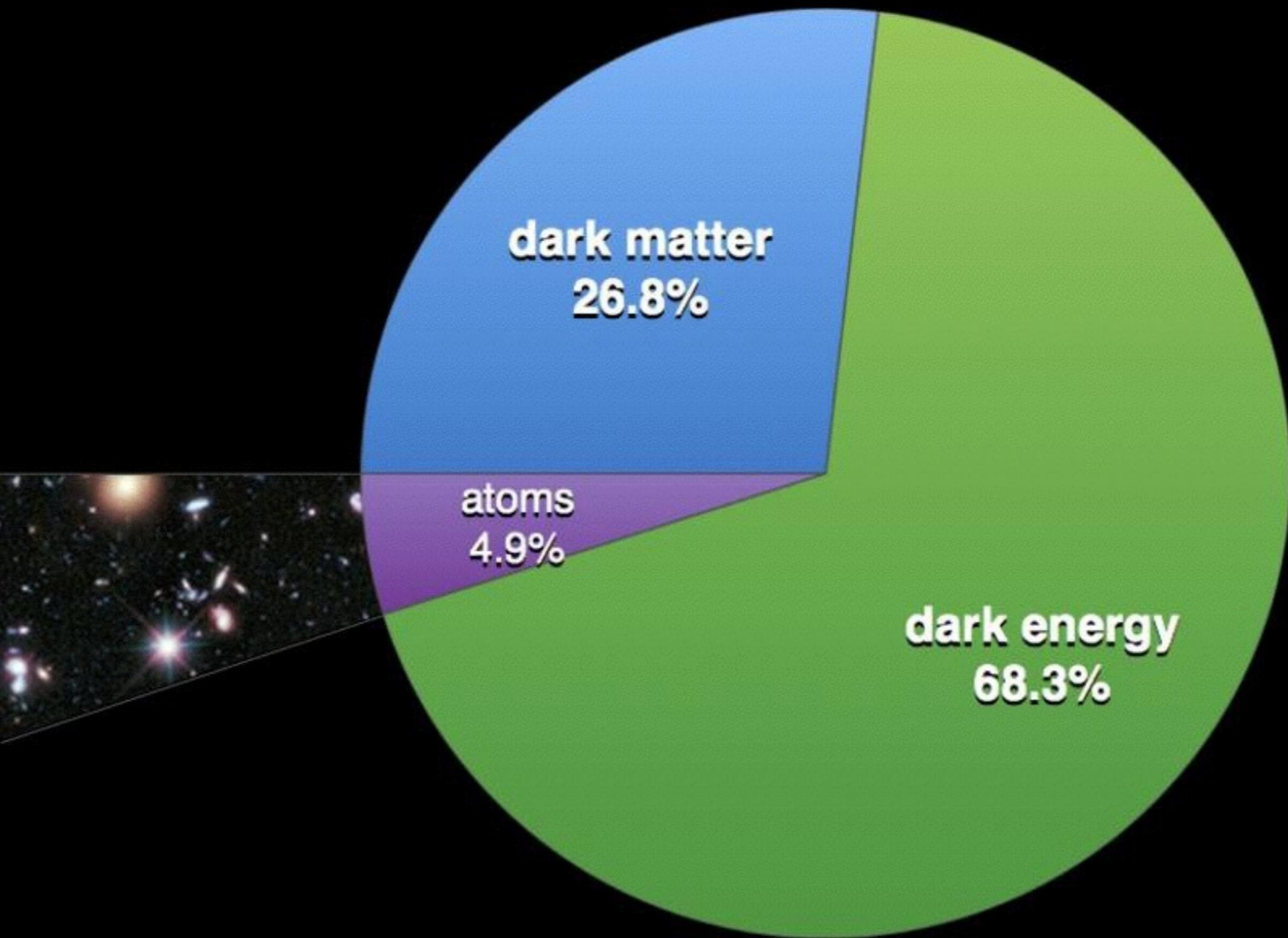
**Simulated
Weak Lensing
Convergence Map**



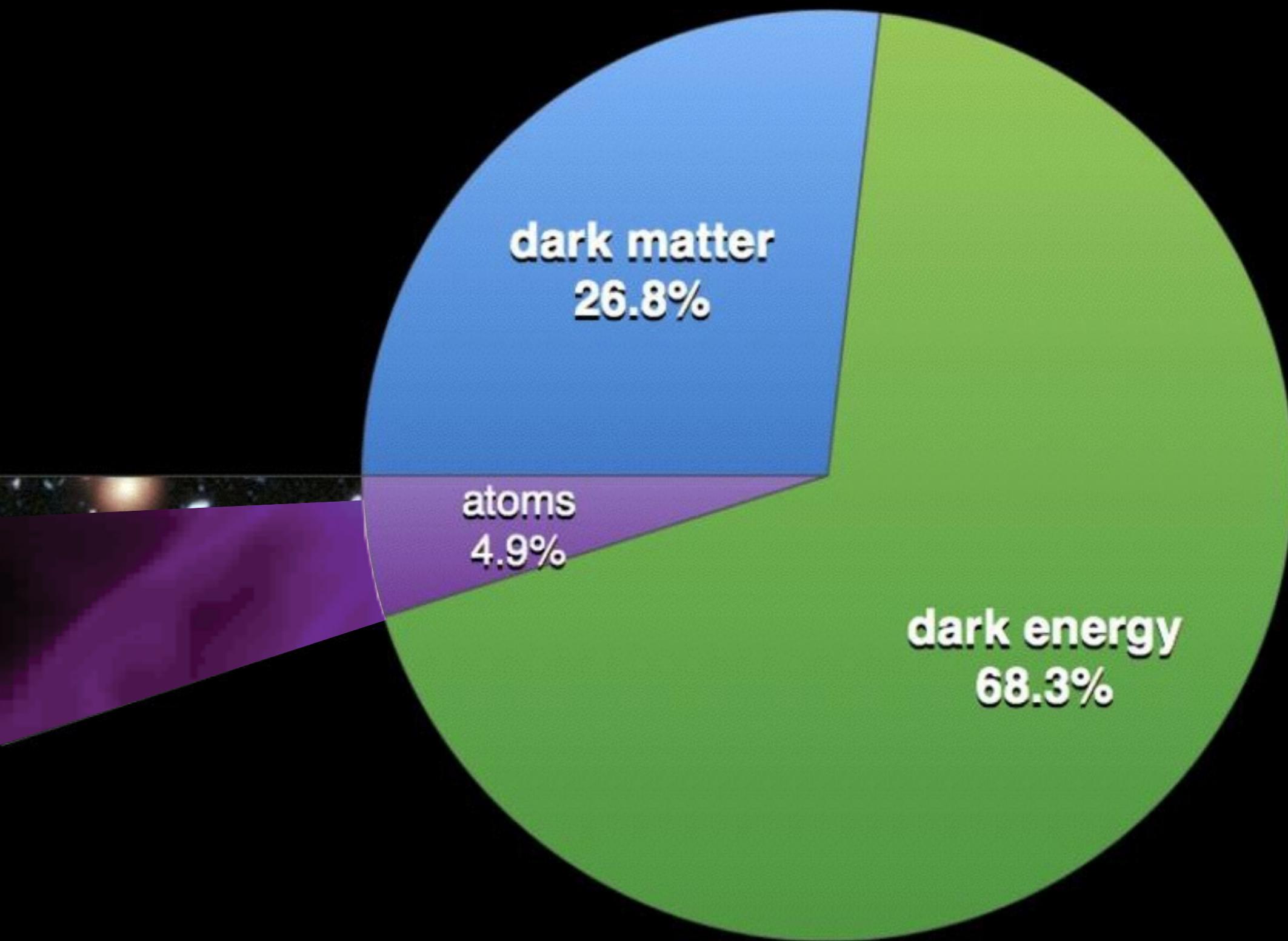
**Simulated
Weak Lensing
Convergence Map
*phases scrambled***

courtesy Z. Haiman; Kratochvil+ 11

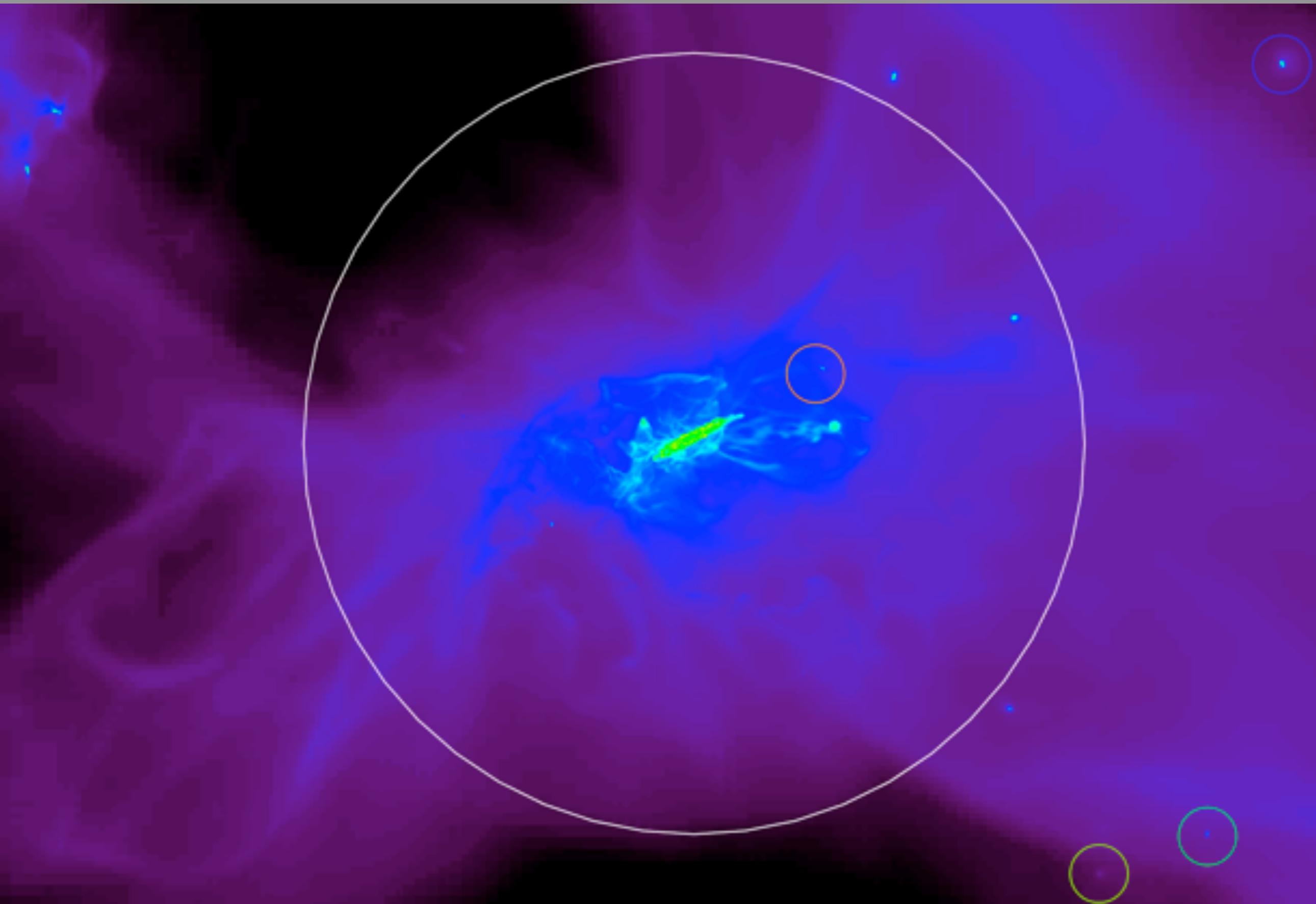
It's worse than that!



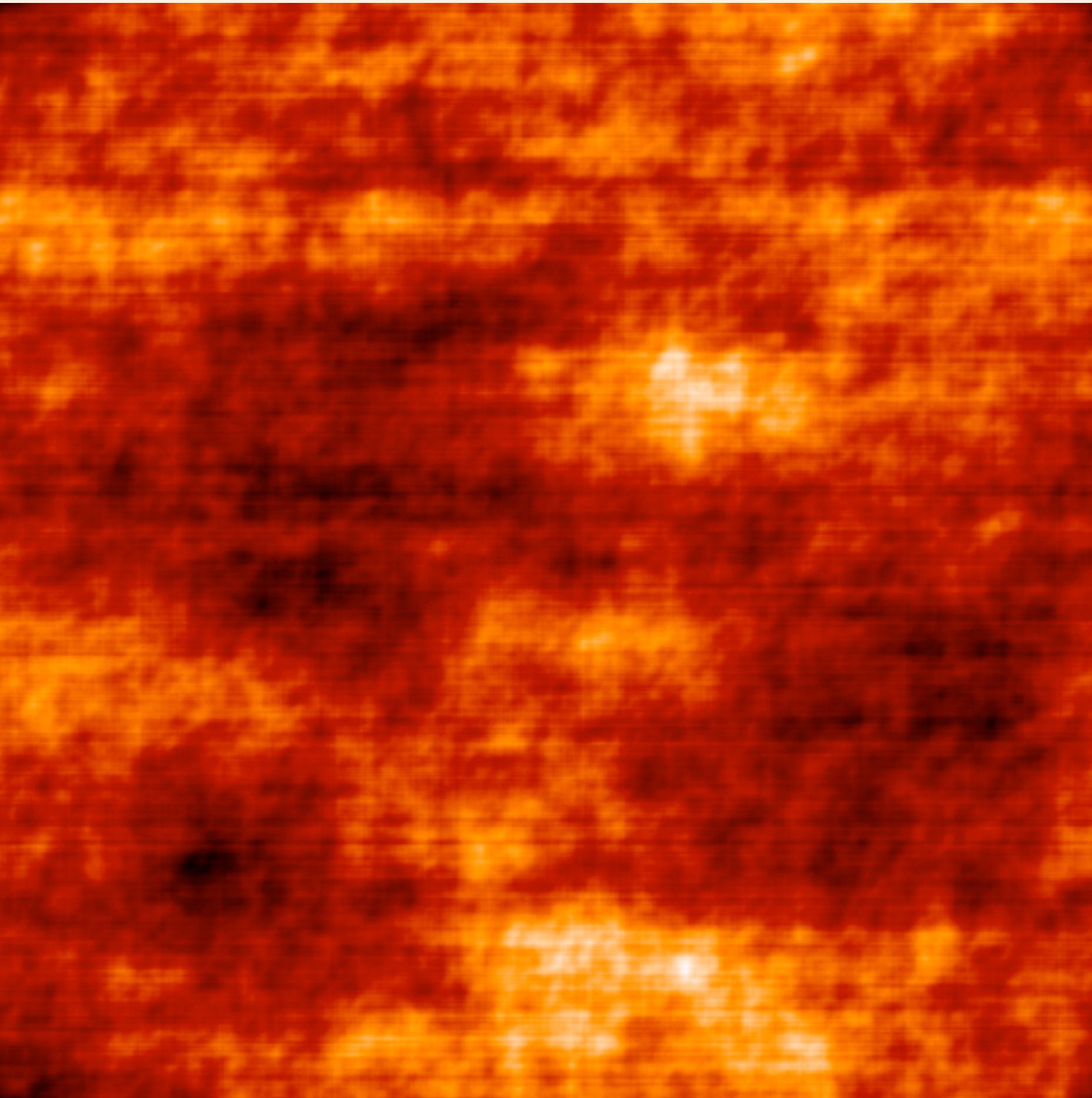
It's worse than that!



Most of our atoms are in the CGM/WHIM/IGM



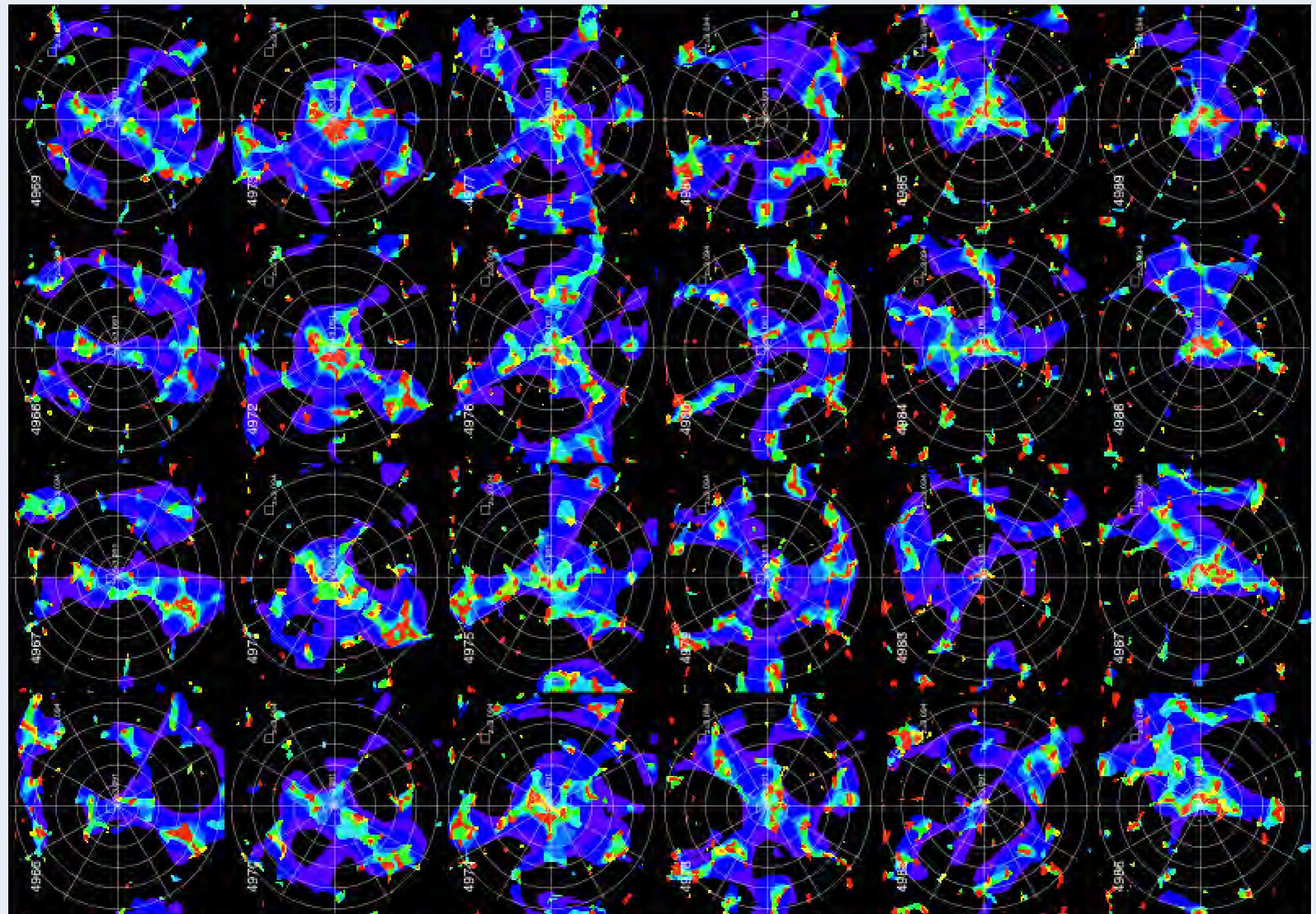
In the modern universe, we need to interpret shape/phase



GASS



Soon we'll be swimming in images of the diffuse phase



is it all just *weather*?

if not, it *how do we interpret it?*

GALFA-HI is the largest Galactic HI survey

Arecibo 305 m



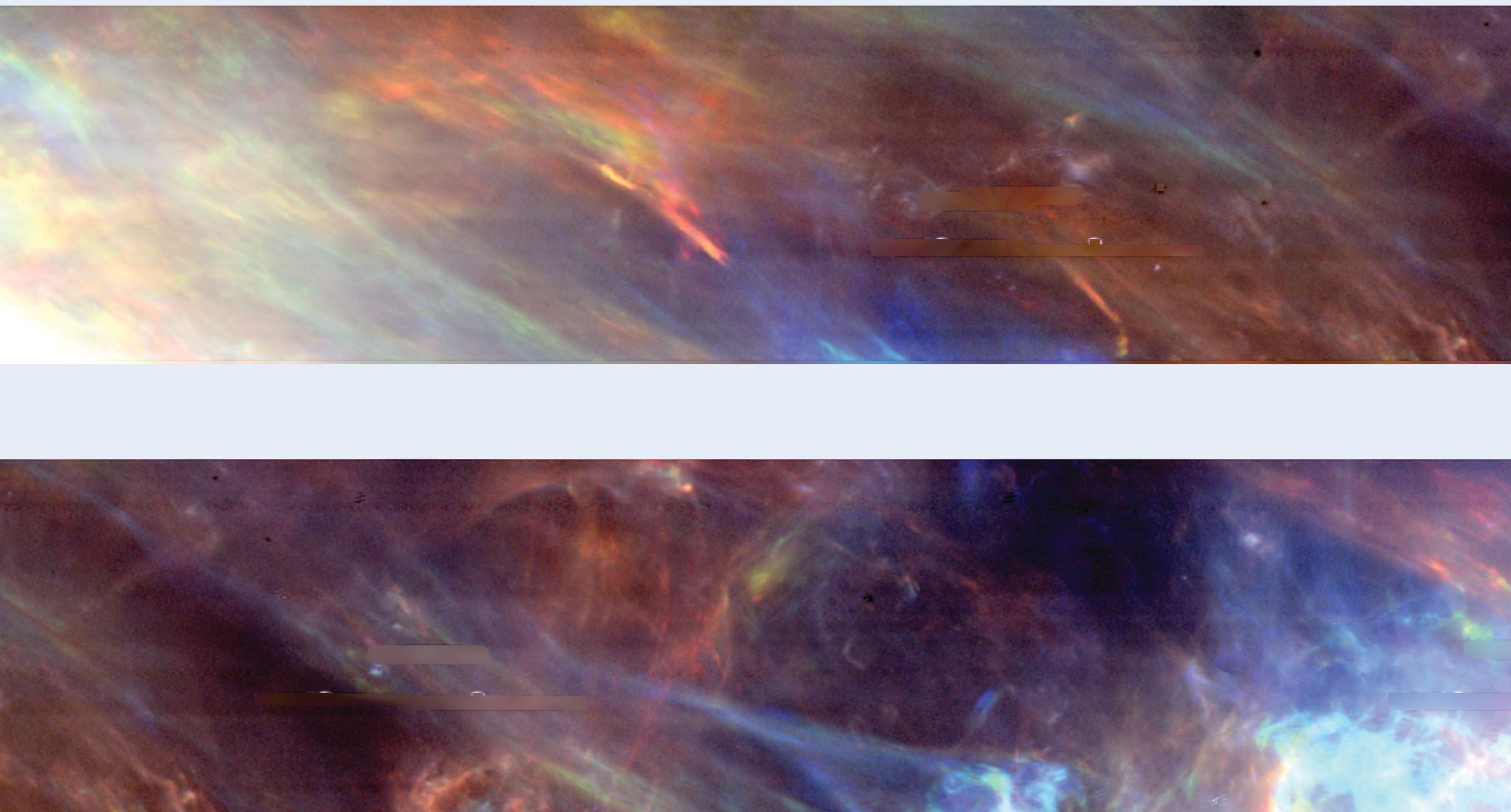
Why we were the first to see fibrous features: resolution **LAB Survey: 2005**



3^o

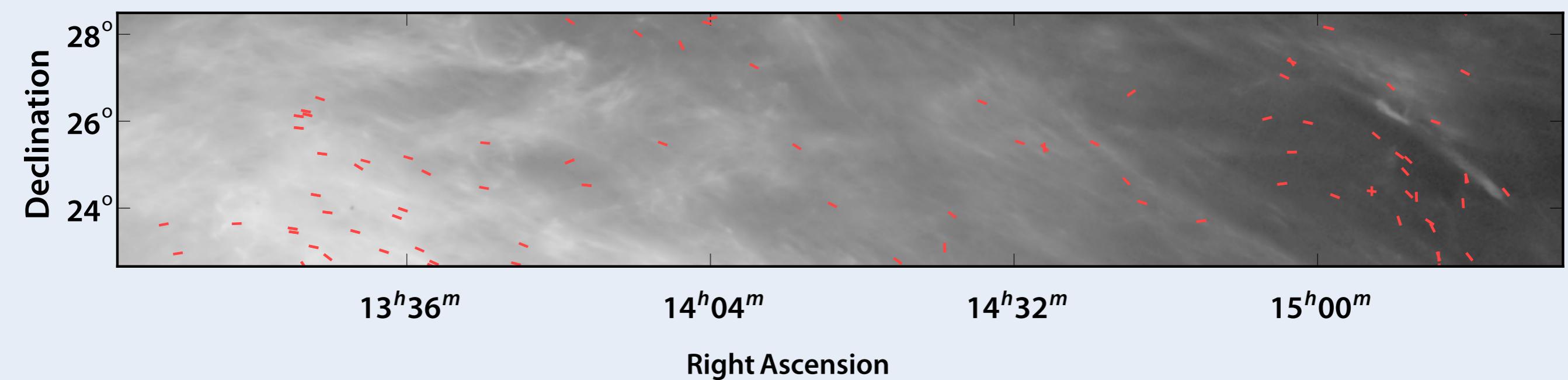
Why we were the first to see fibrous features: resolution

GALFA-HI Survey: 2011

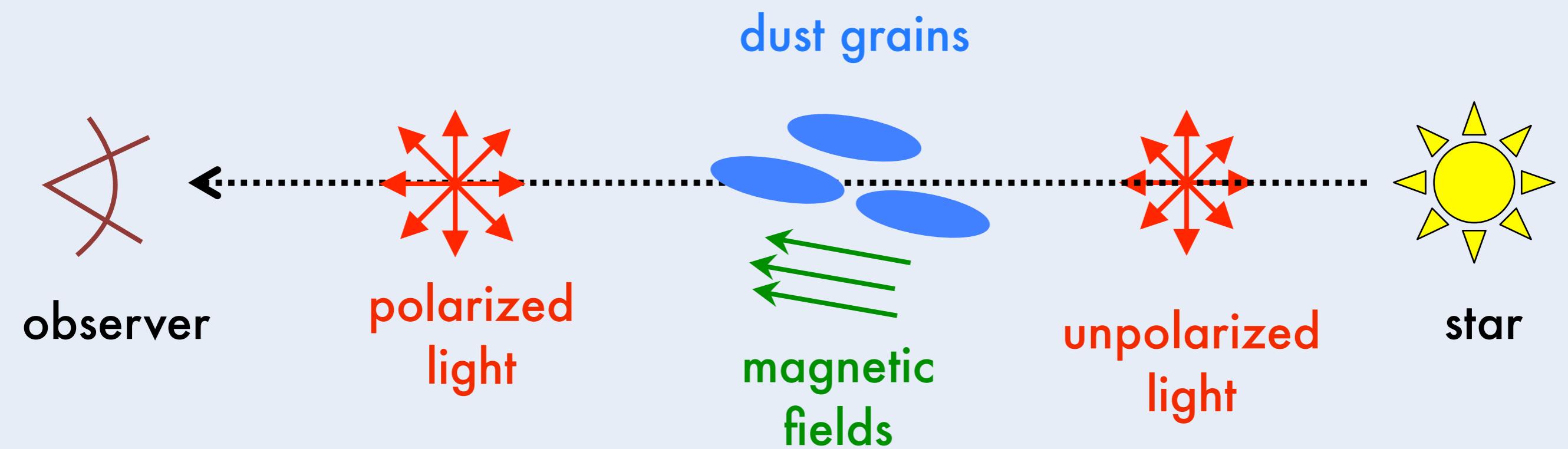


3^o

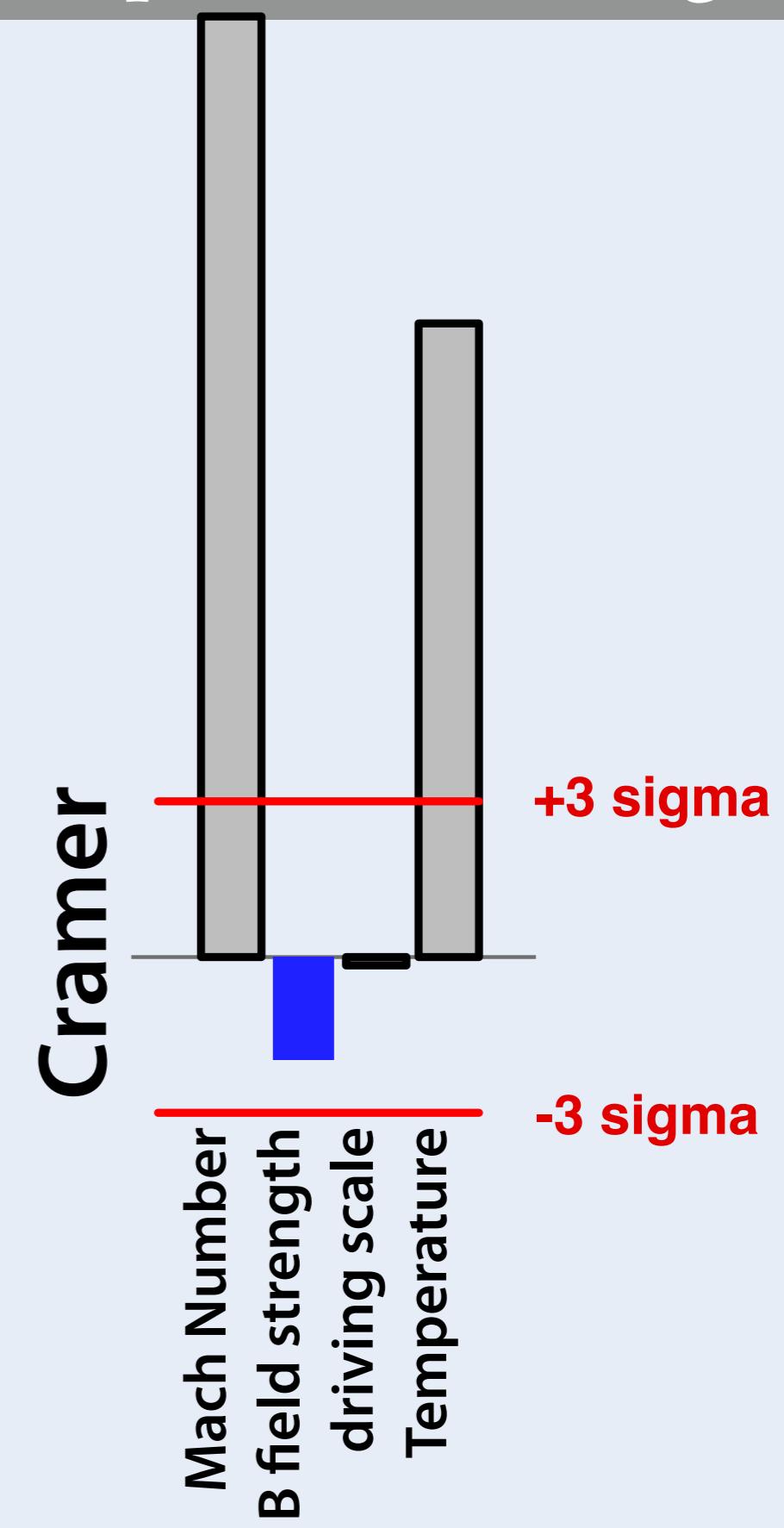
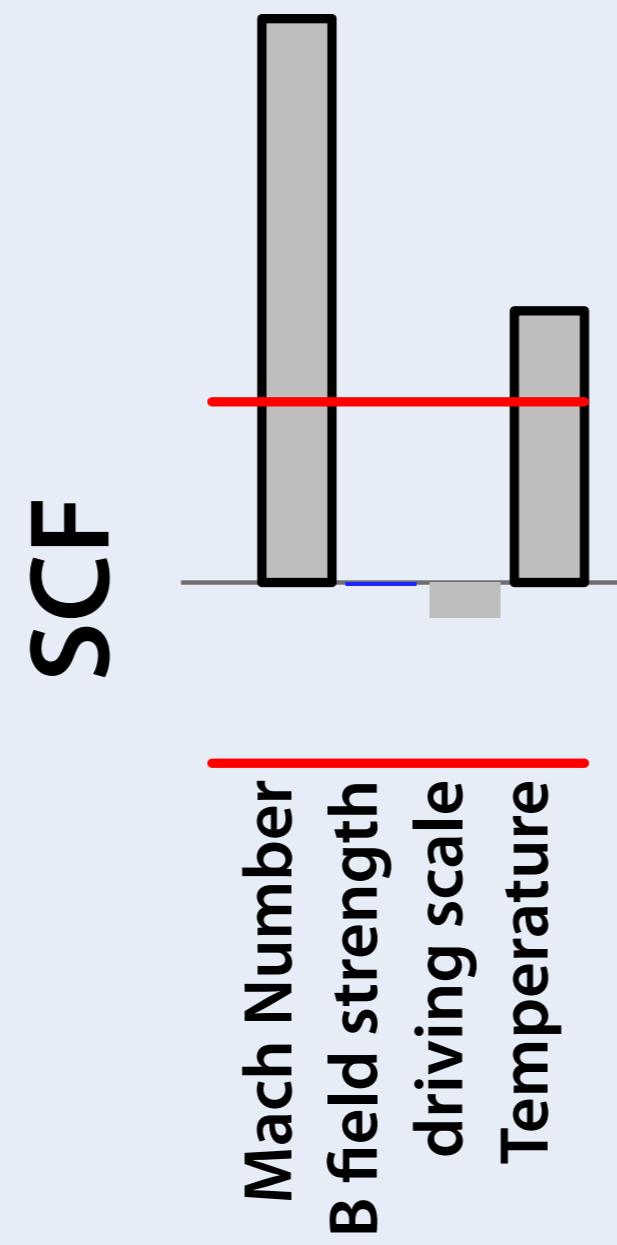
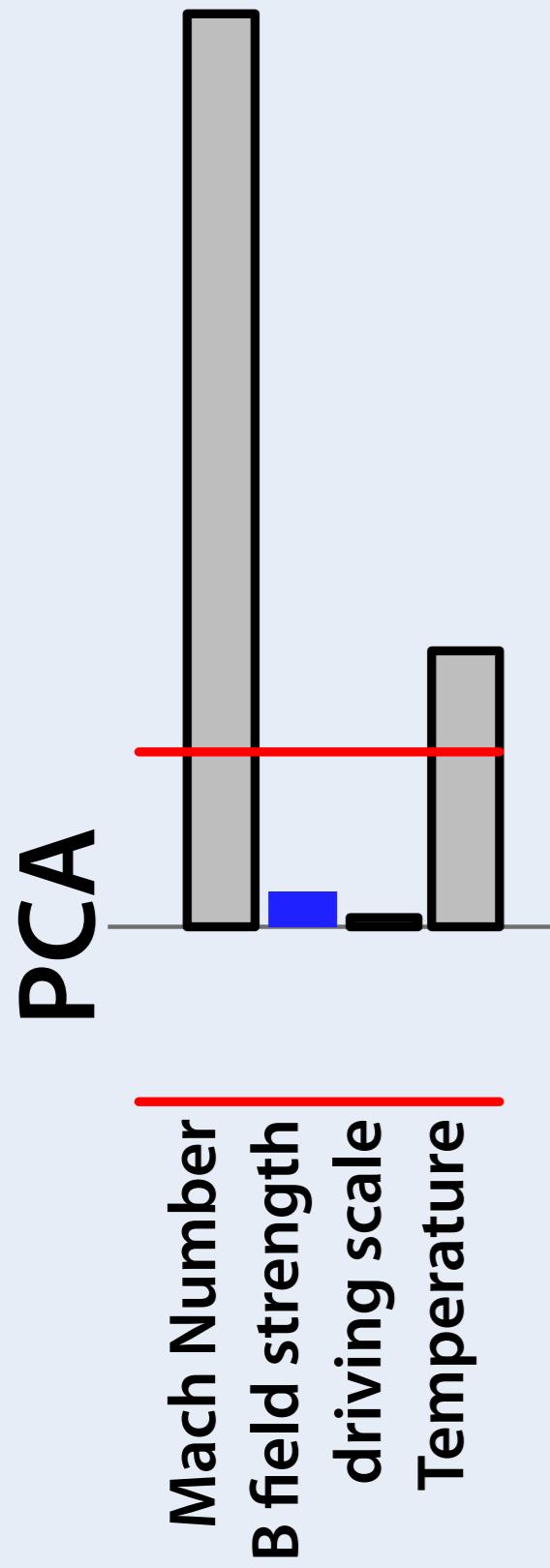
...that seemed to correlate with magnetic fields



brief digression: B fields are critical, but hard to observe



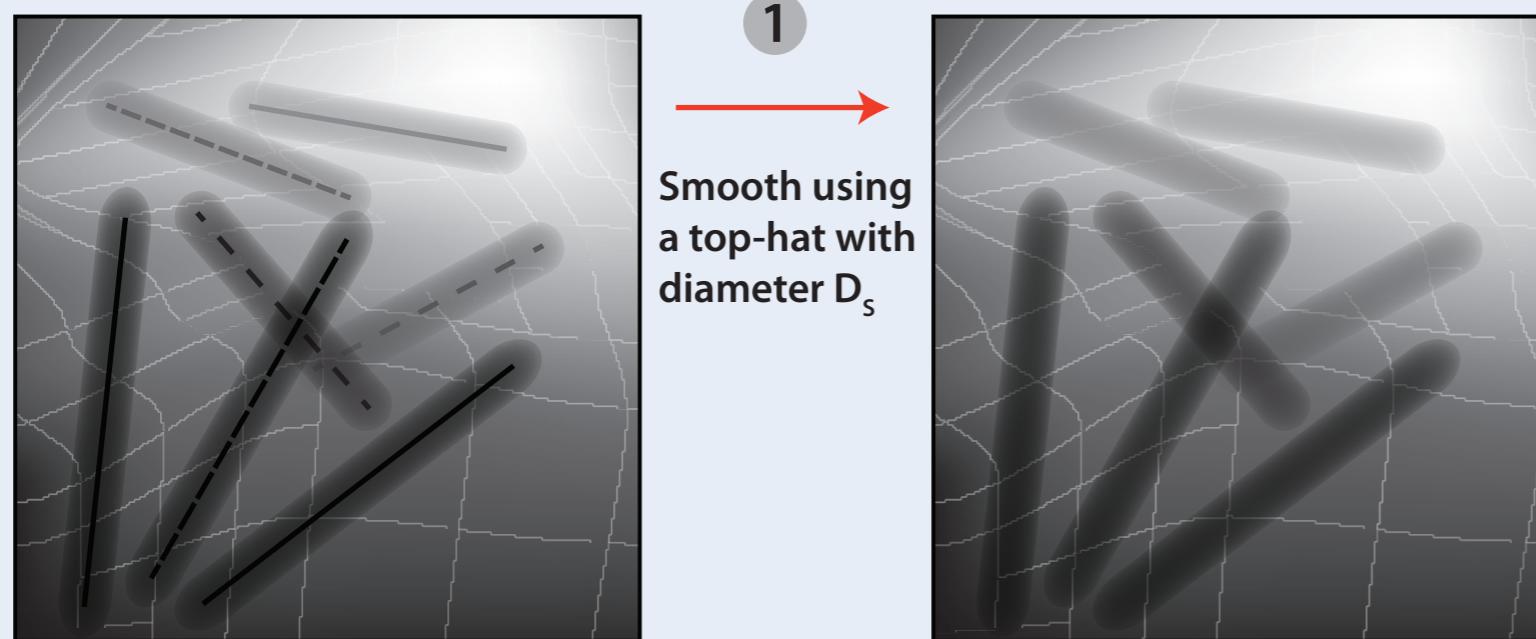
Magnetic fields cannot be ‘learned’ from phase-less images



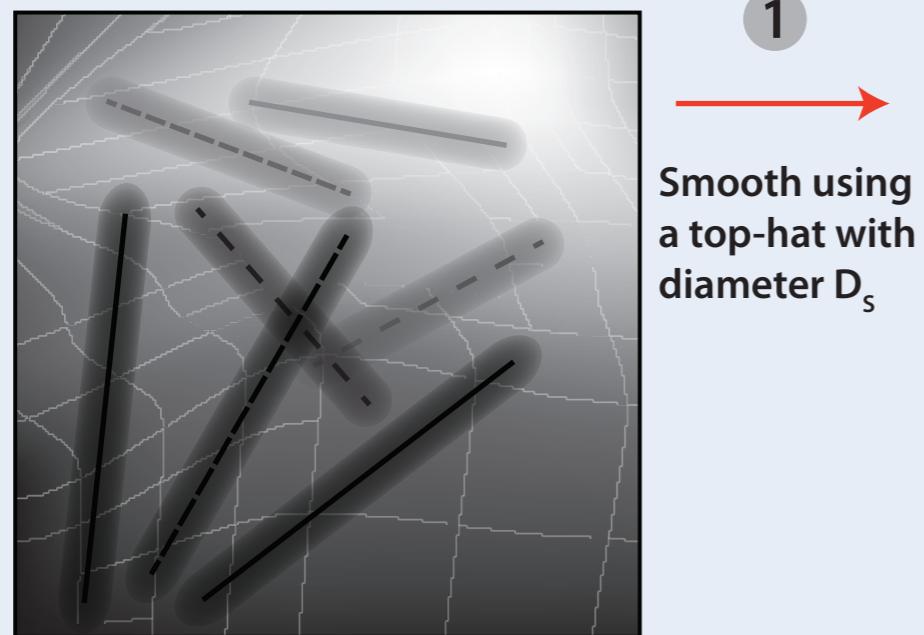
We developed the Rolling Hough Transform (RHT)



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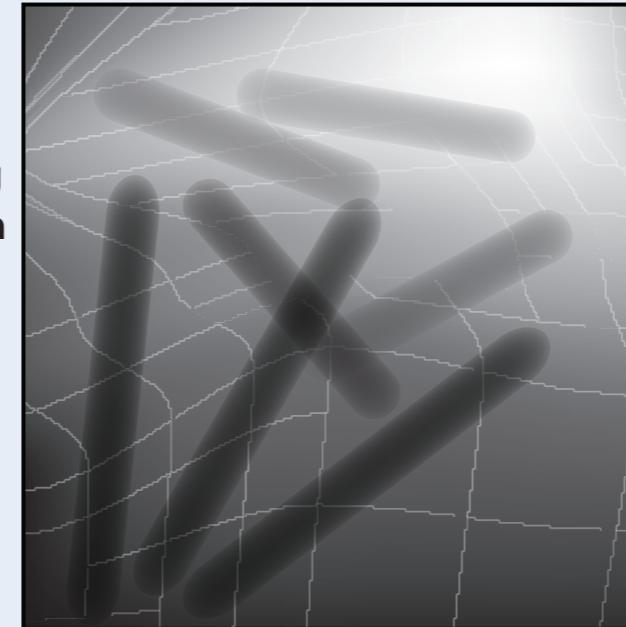


We developed the Rolling Hough Transform (RHT)



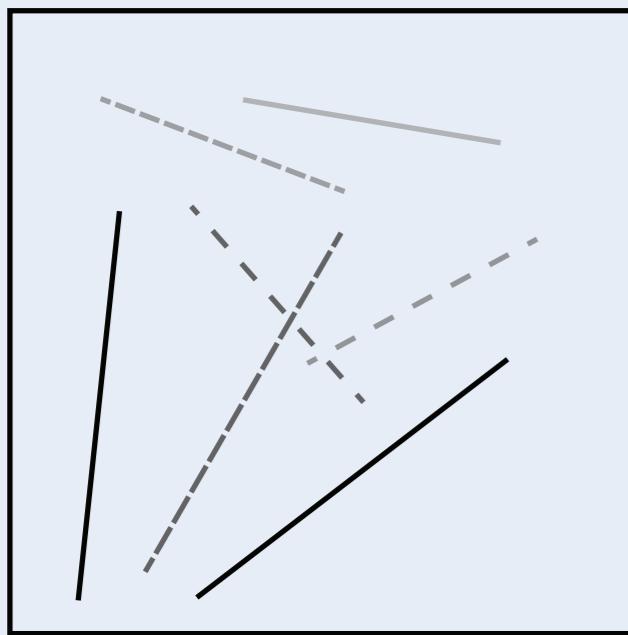
1
→

Smooth using
a top-hat with
diameter D_s



2

Subtract smoothed
component to unsharp mask

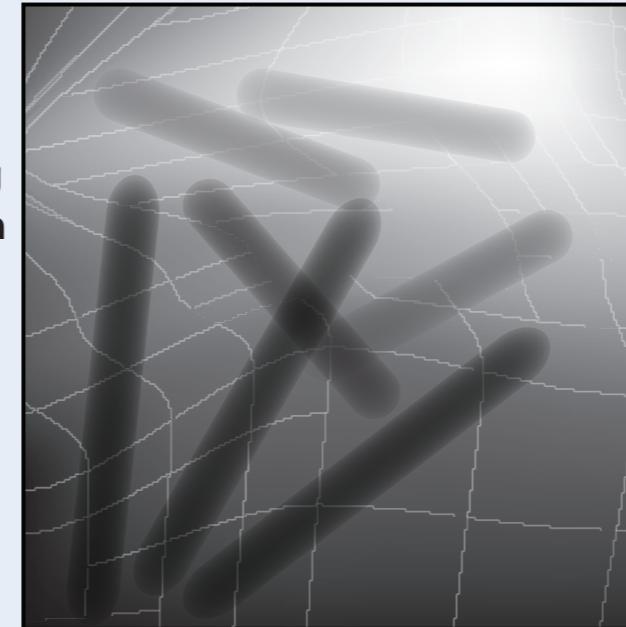


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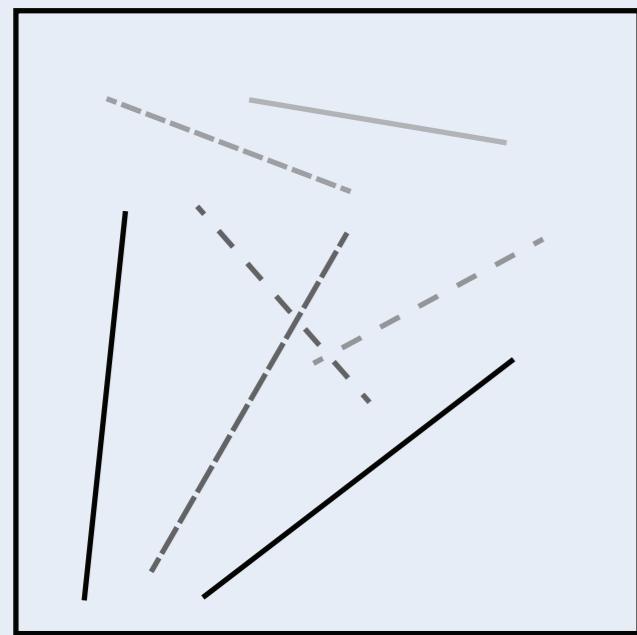
1

Smooth using
a top-hat with
diameter D_s



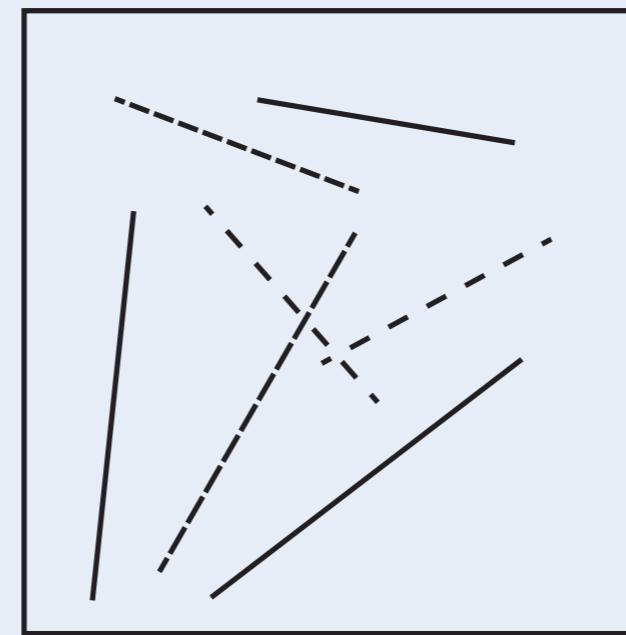
2

Subtract smoothed
component to unsharp mask

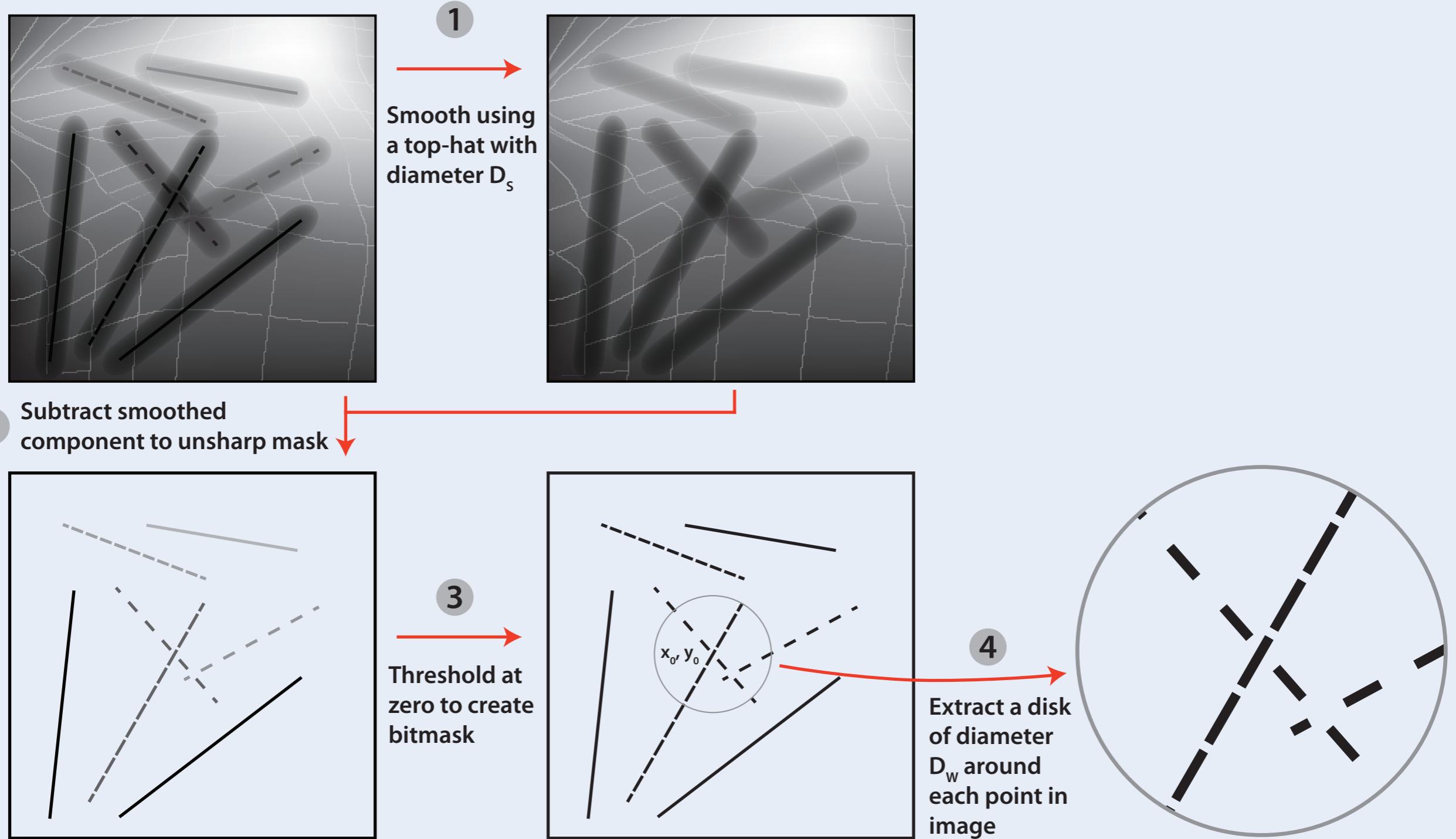


3

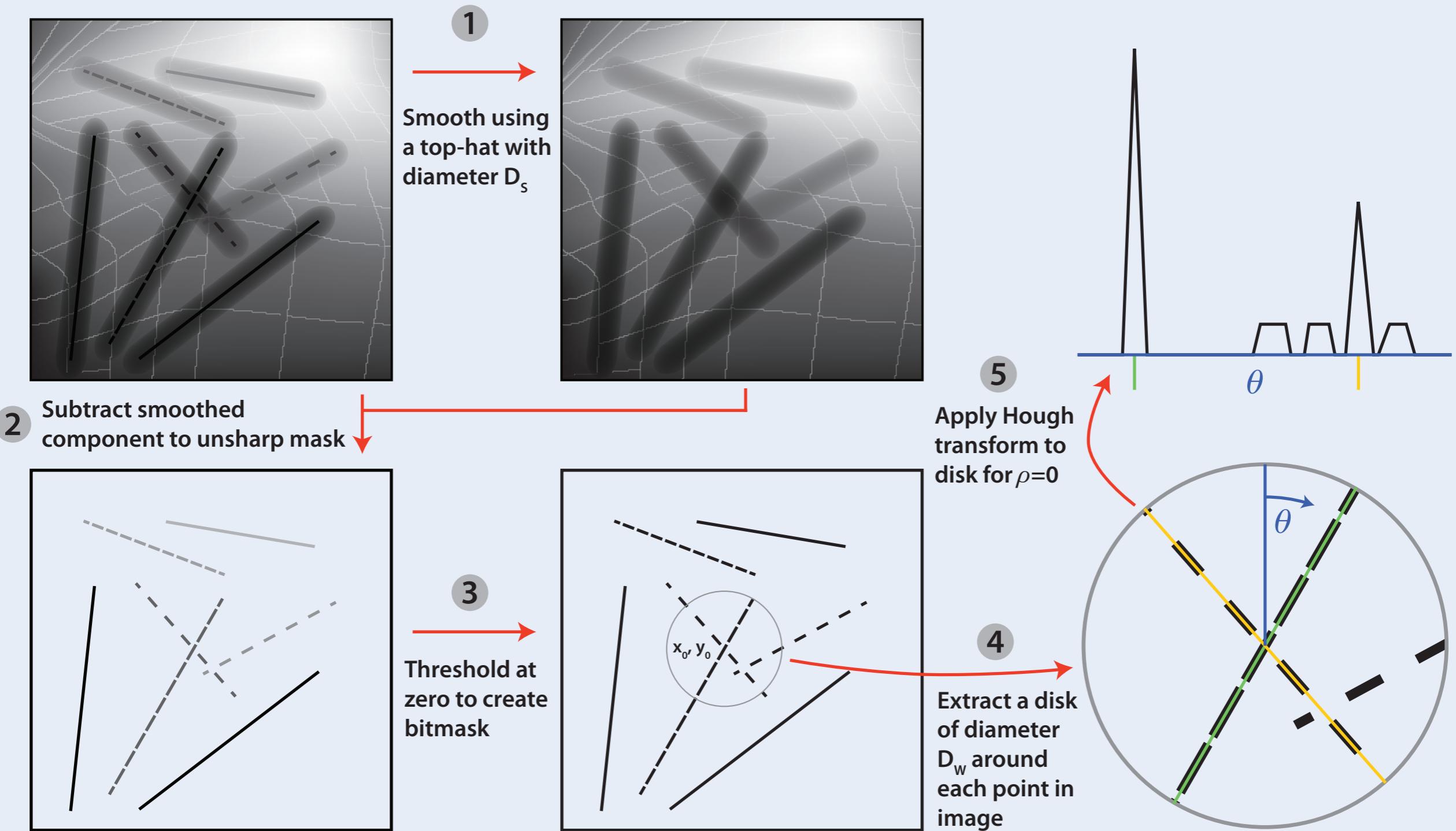
Threshold at
zero to create
bitmask



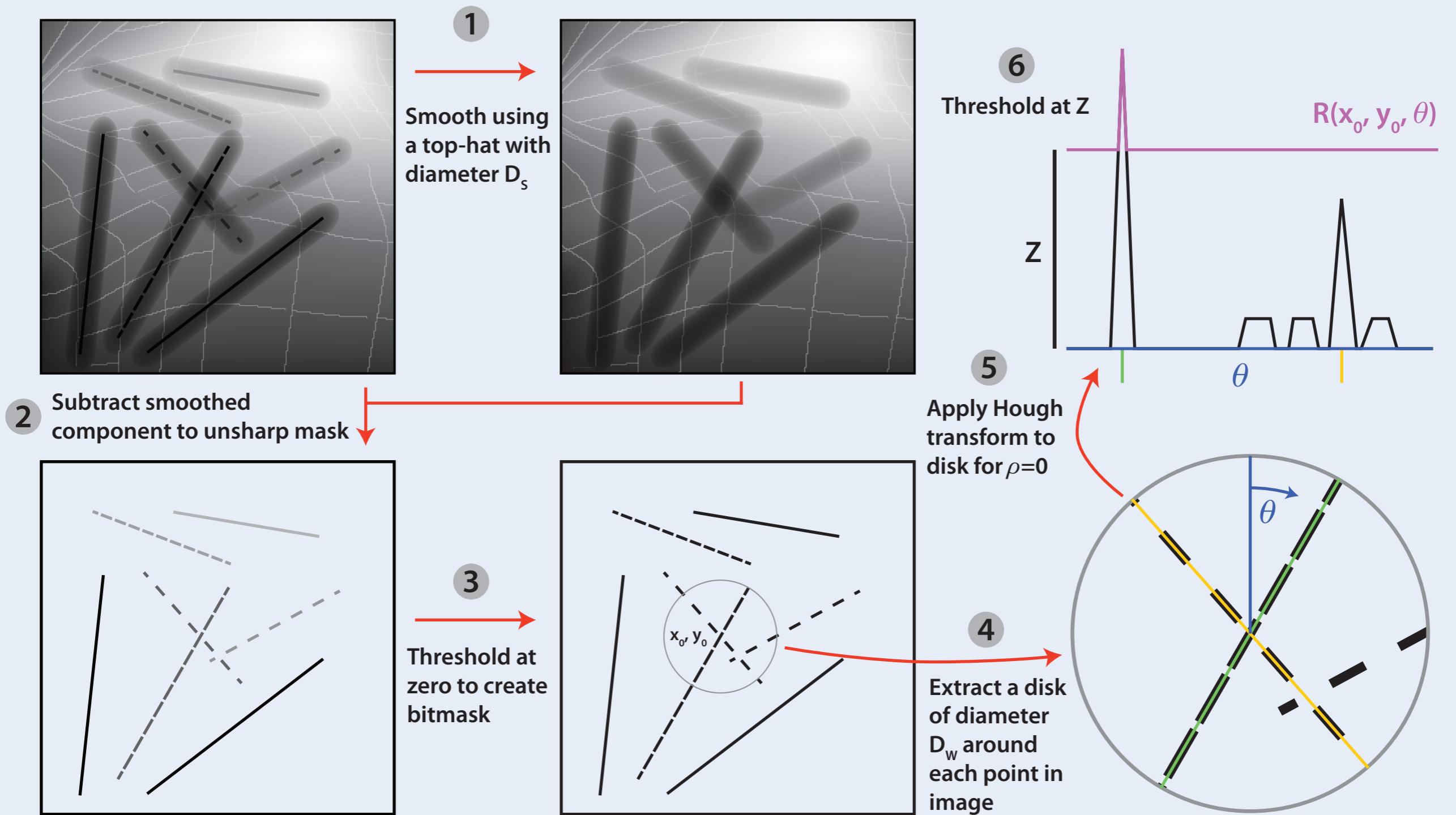
We developed the Rolling Hough Transform (RHT)



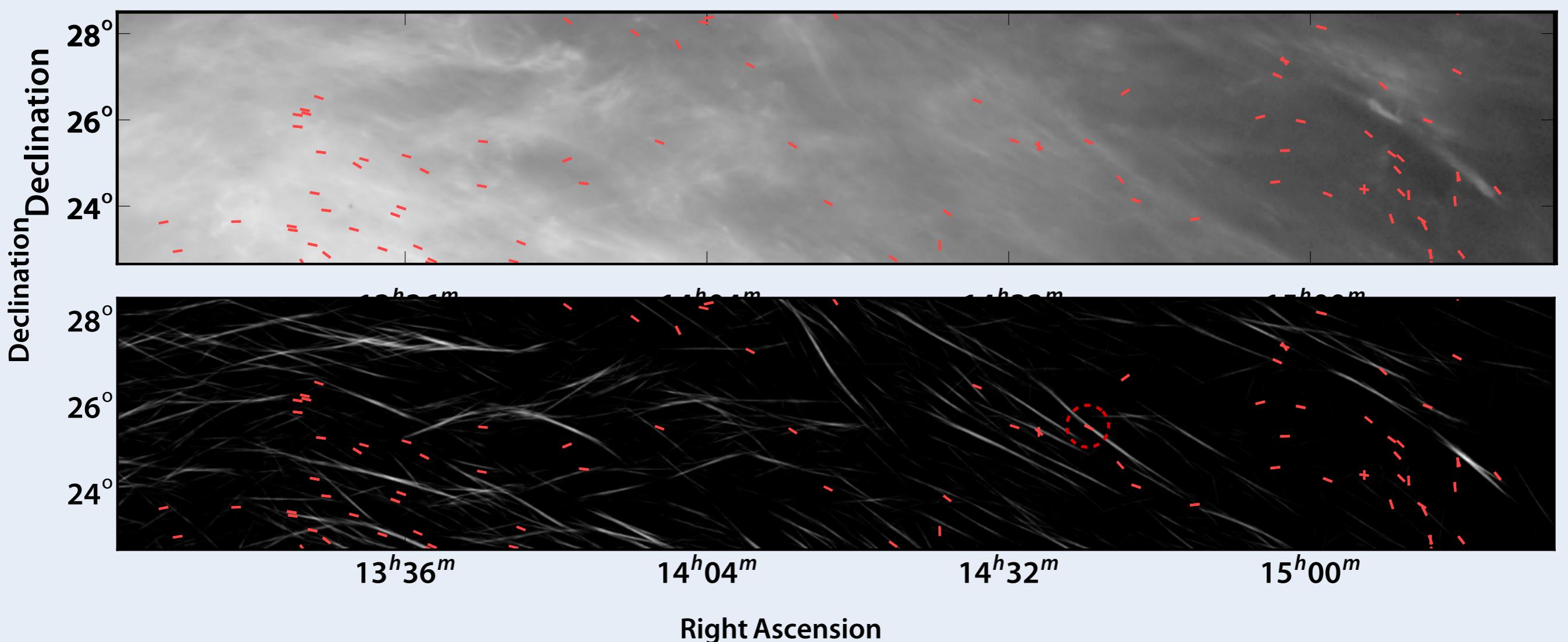
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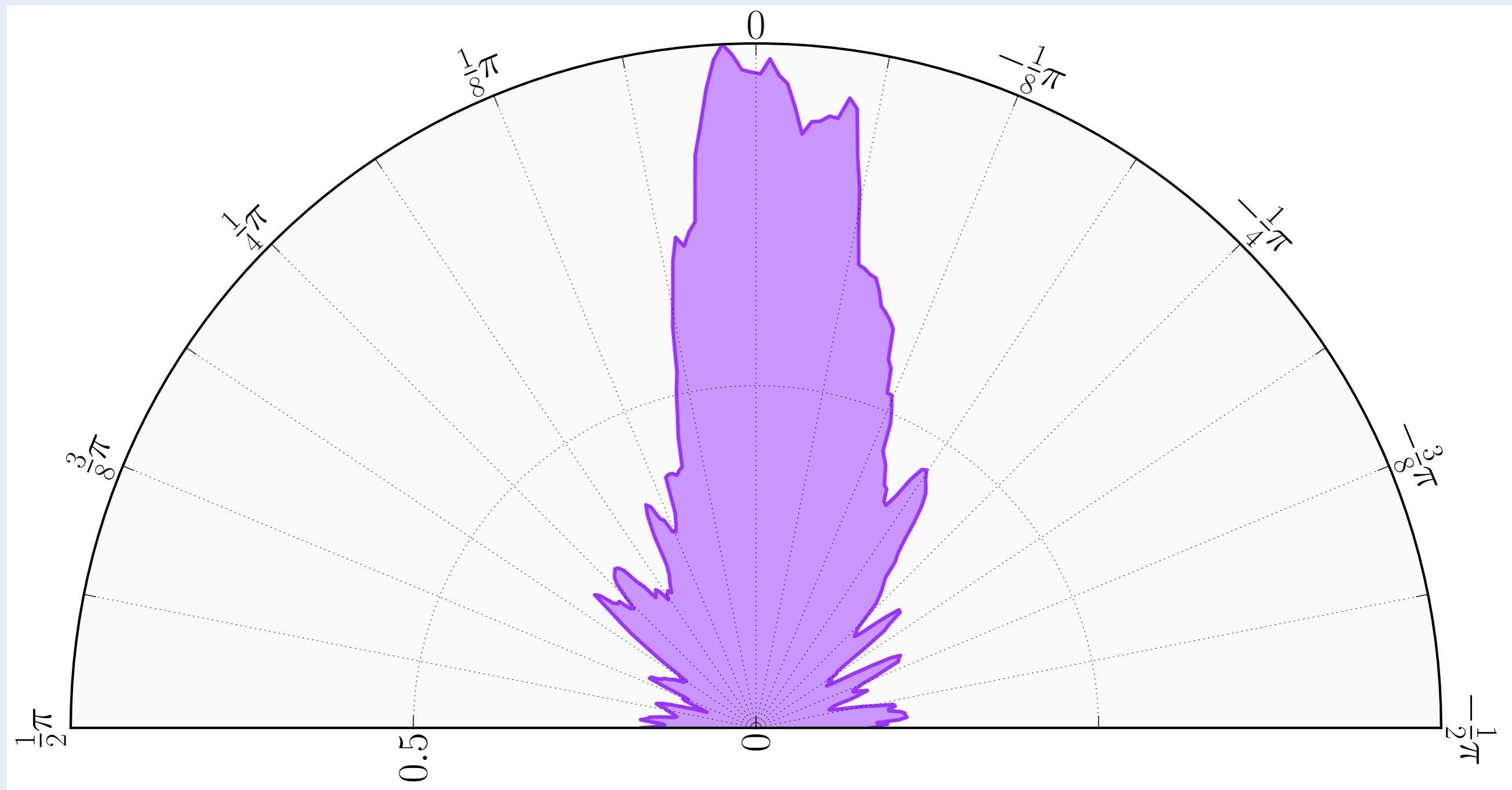
We developed the Rolling Hough Transform (RHT)



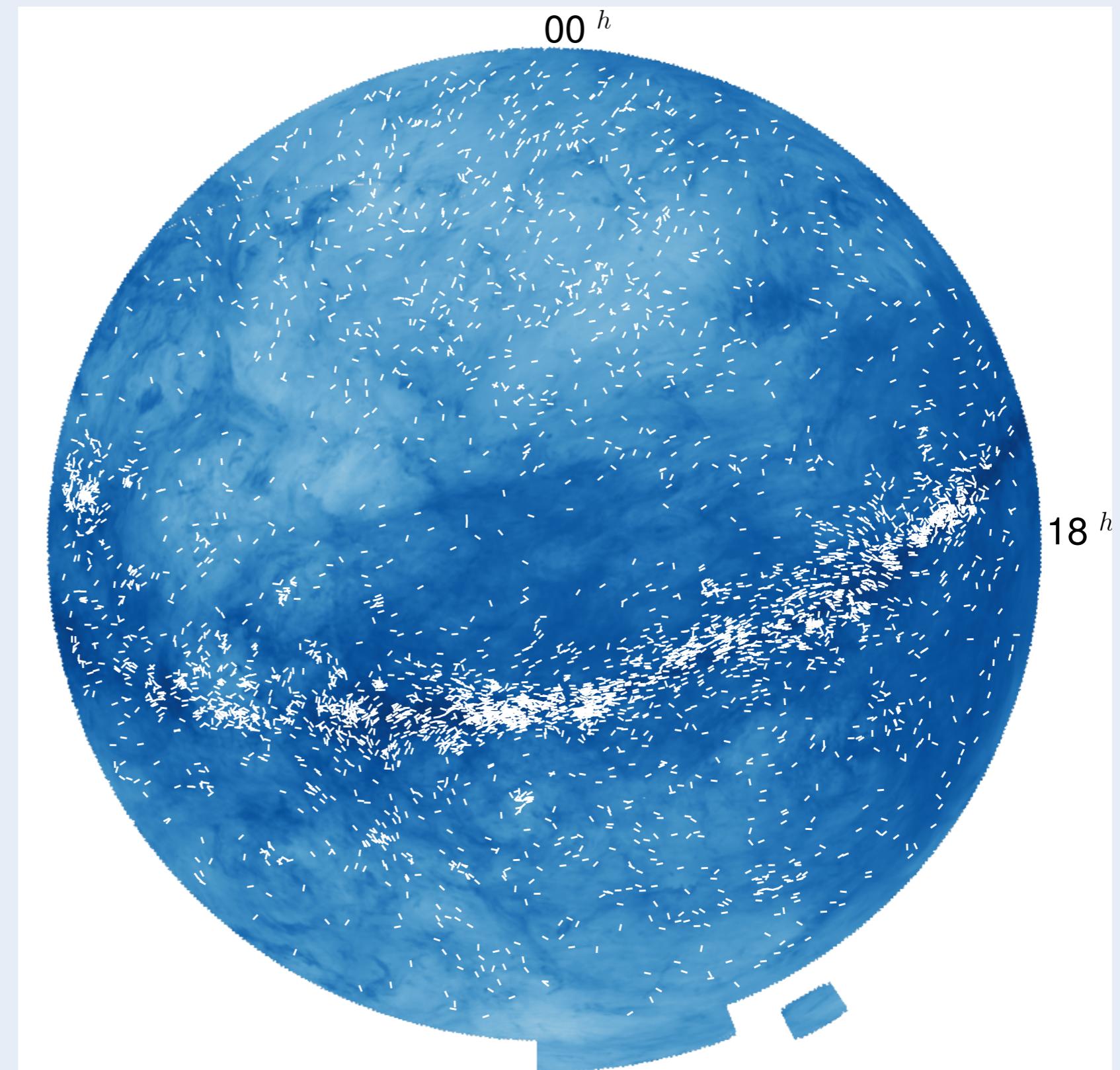
We now have a metric with which to measure correlation



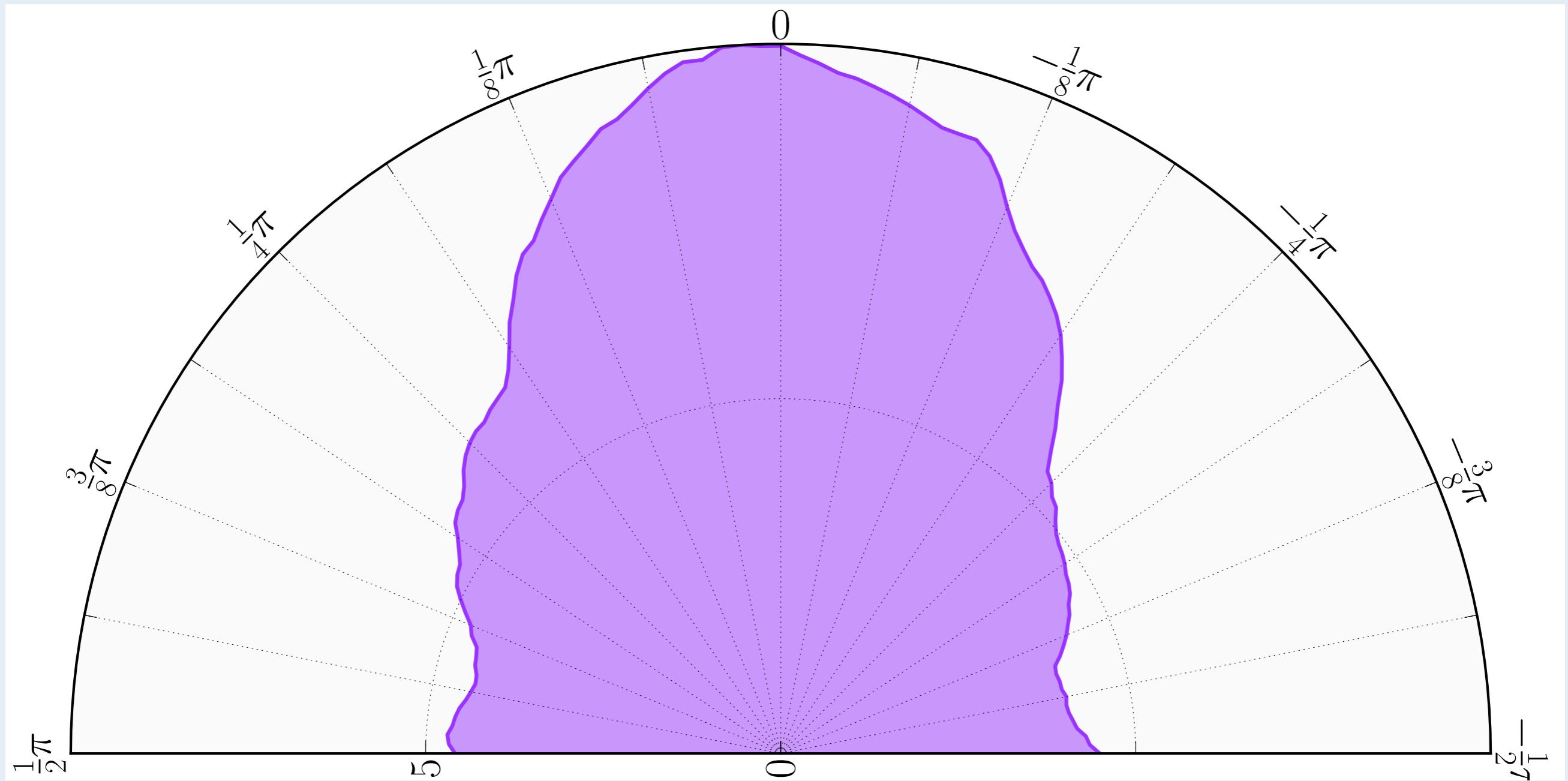
Linear features correlate nicely with starlight polarization



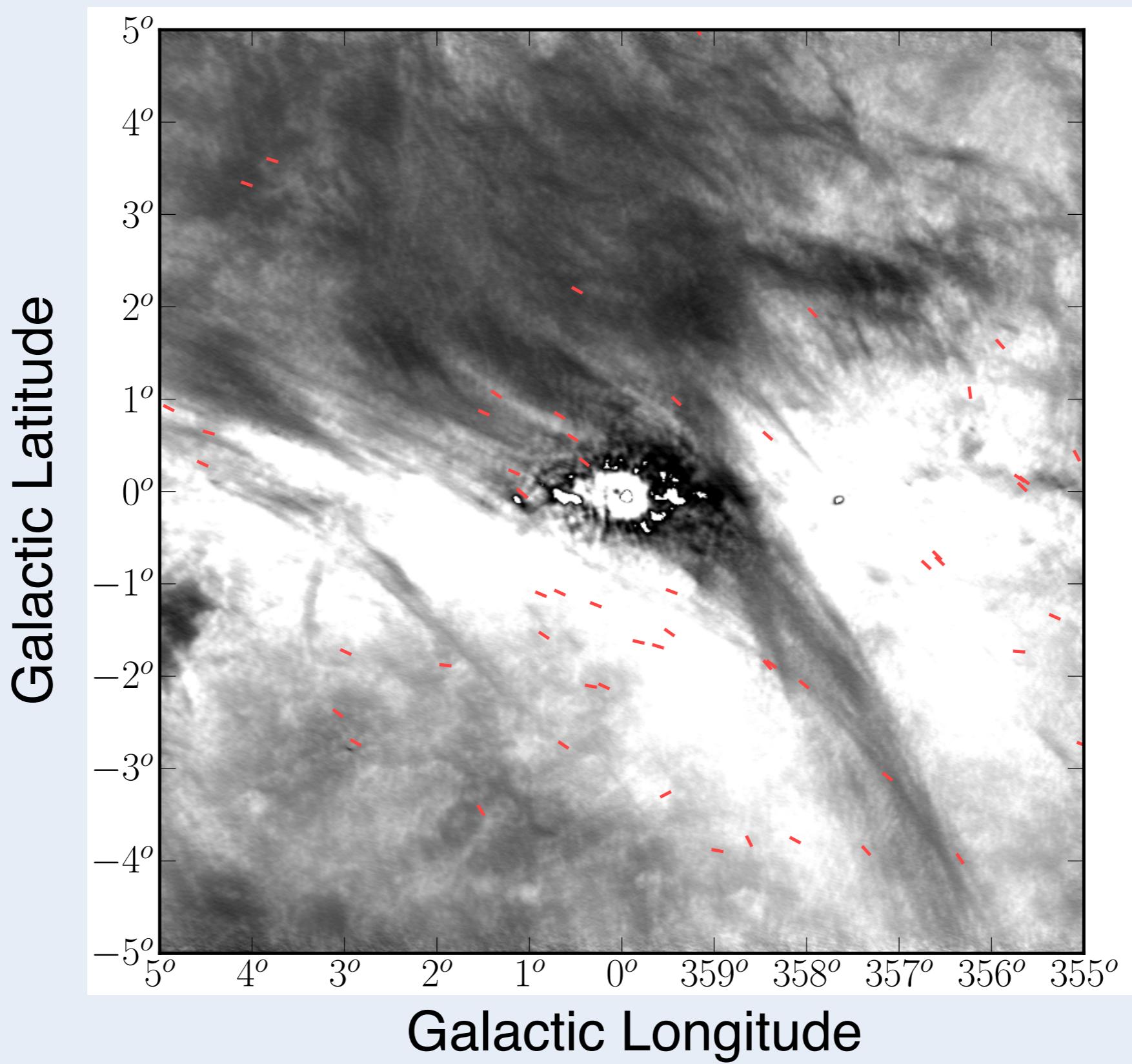
We examine the same correlation in the Southern Sky



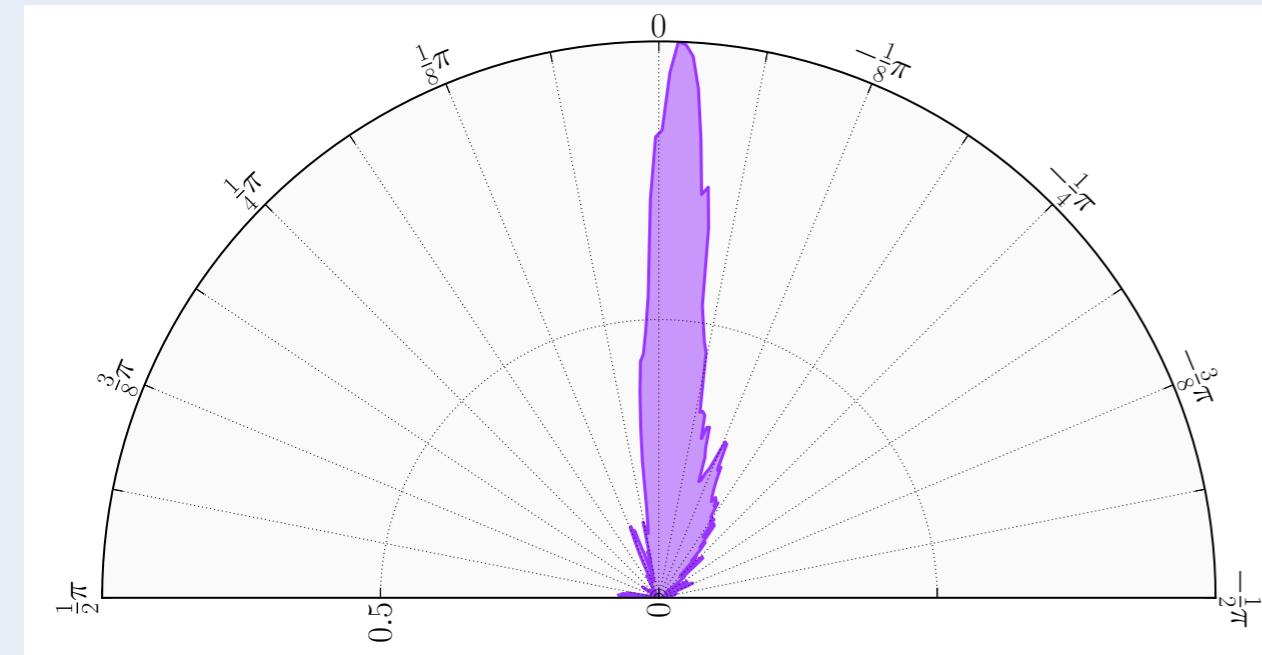
A weaker correlation: ubiquitous but not scale-free



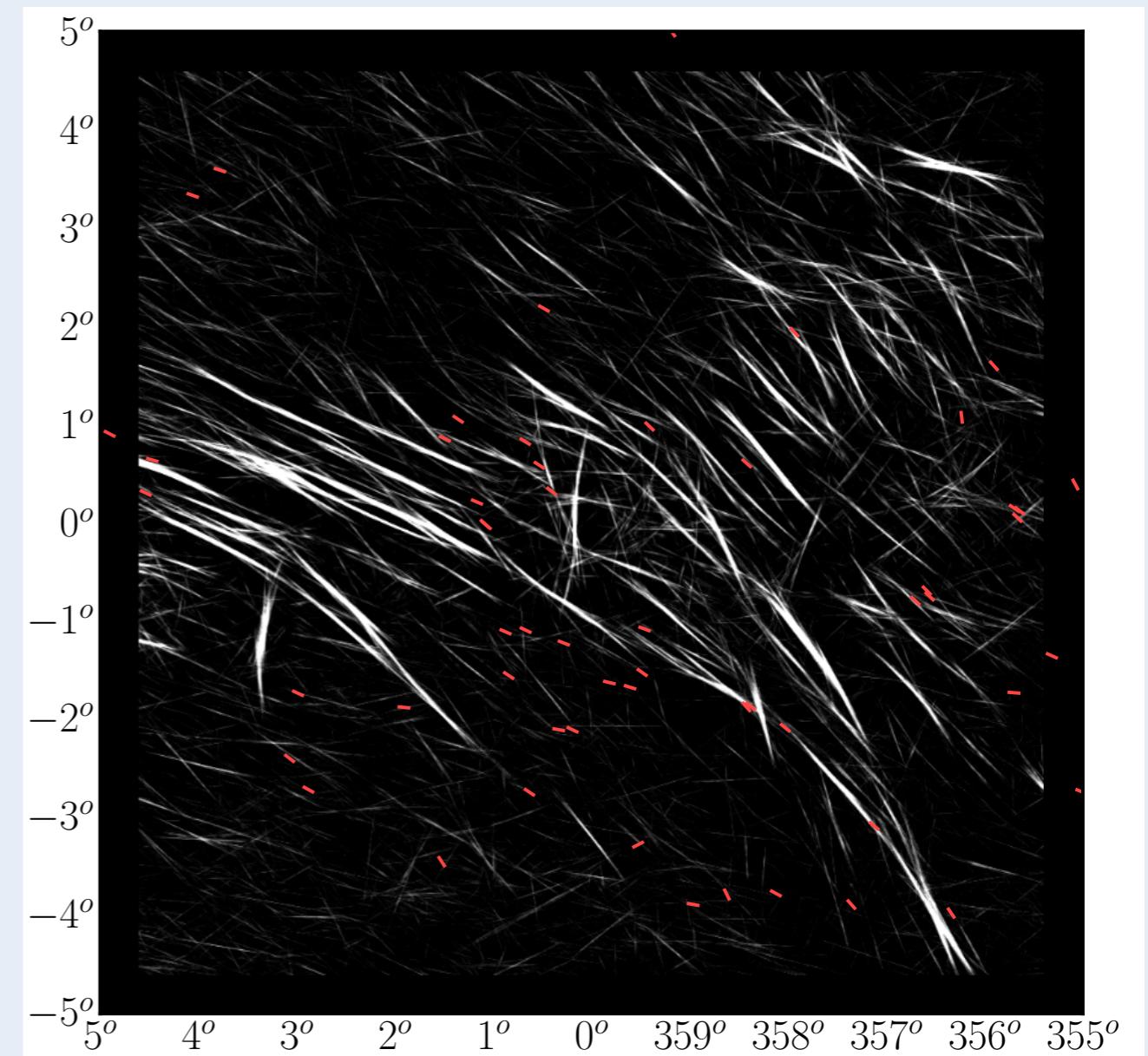
We can also apply the method to denser media



The RHT is sharply aligned with the B field



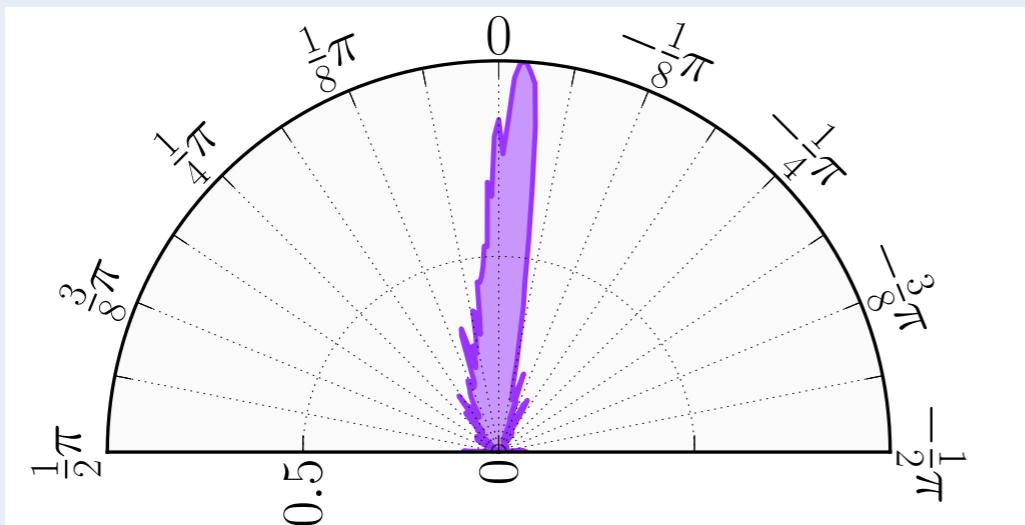
Galactic Latitude



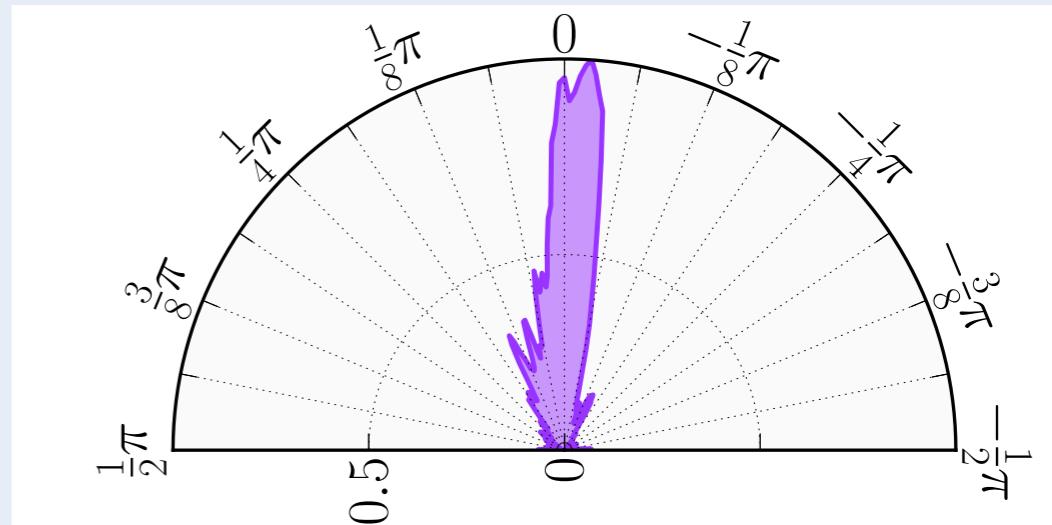
Galactic Longitude

The coherence is stronger on smaller scales

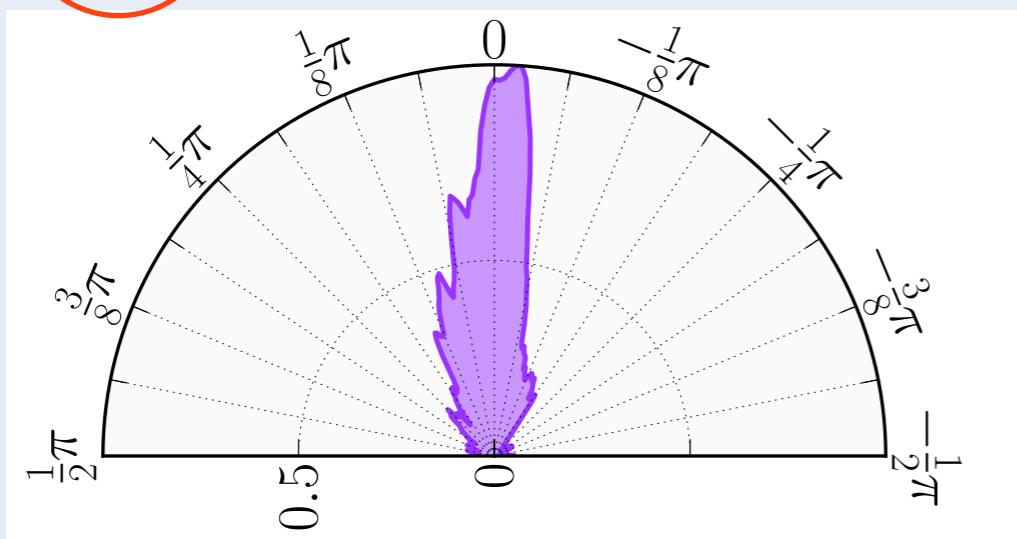
○ $2.3' = 0.08 \text{ pc}$



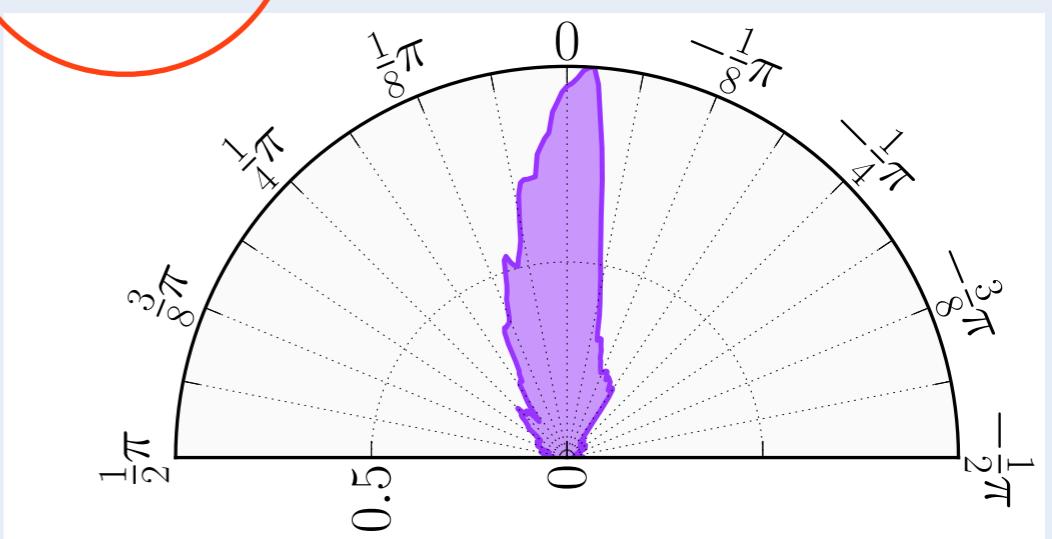
○ $5.8' = 0.2 \text{ pc}$



○ $17.5' = 0.6 \text{ pc}$



○ $29' = 1.1 \text{ pc}$

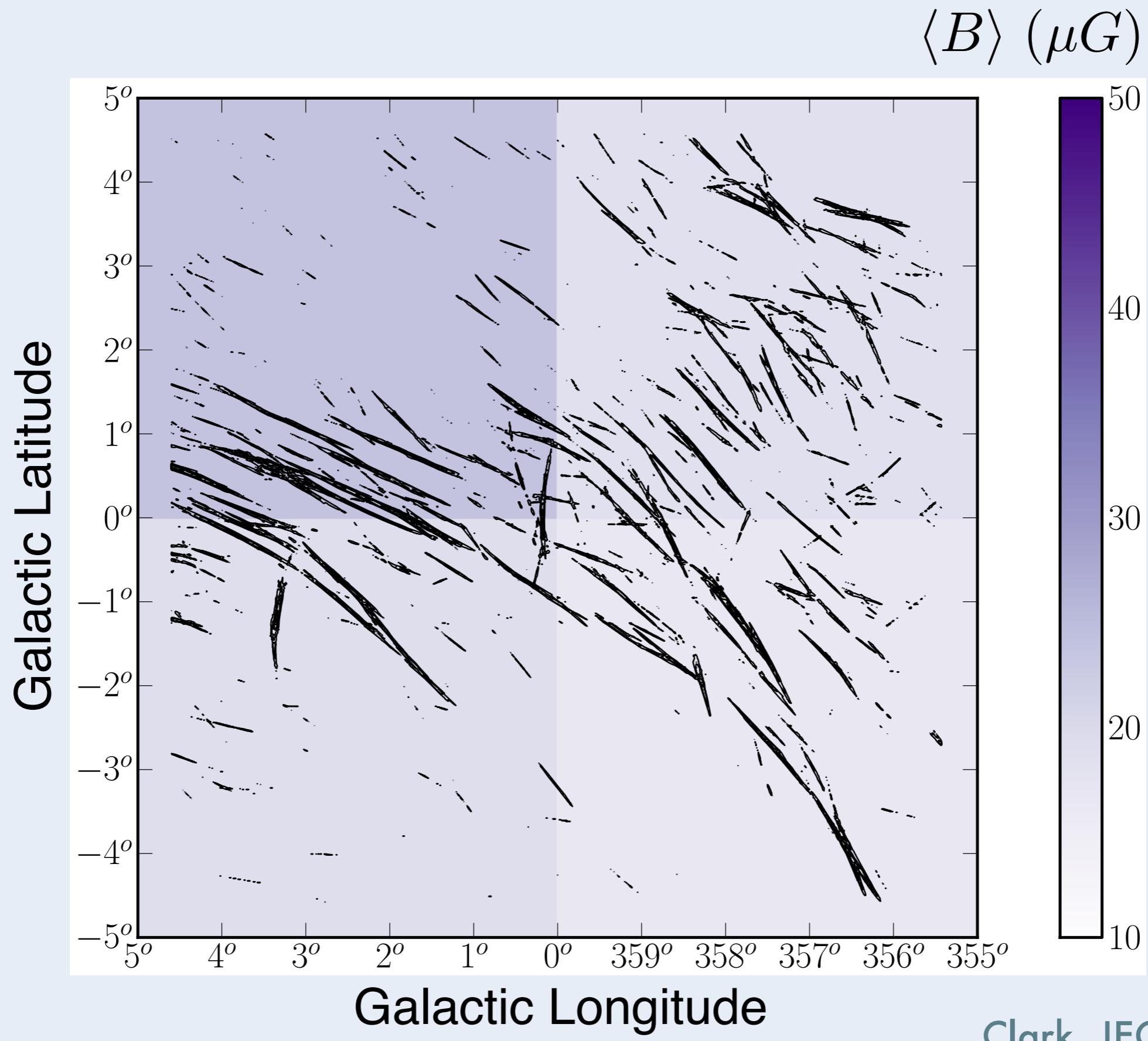


The Chandrasekhar-Fermi method measures field strength

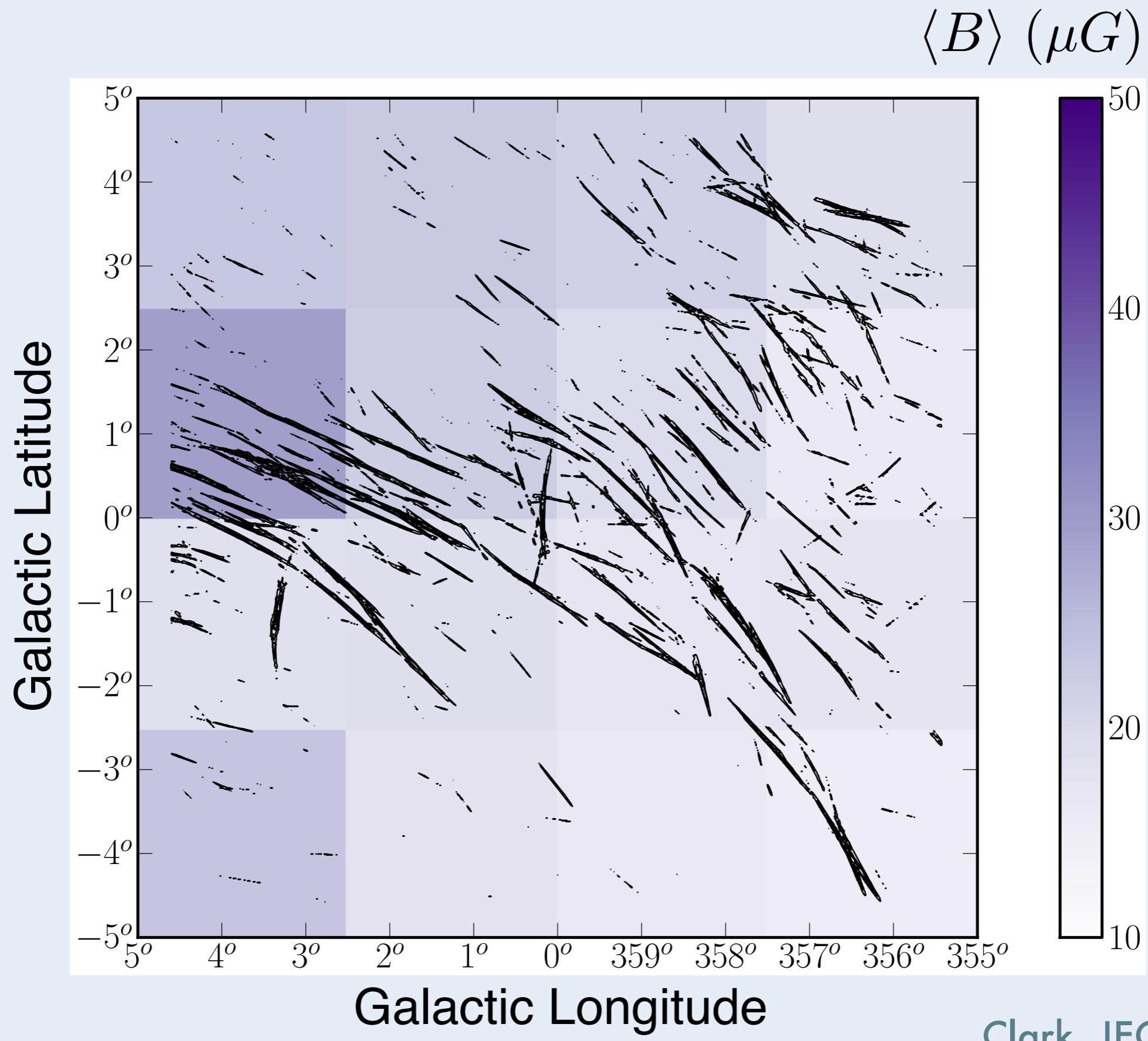
$$\langle B \rangle^2 = \xi 4\pi \rho \frac{\sigma_v^2}{\sigma(\tan \delta_p)^2}$$

$$\delta_p \equiv \theta_p - \langle \theta_p \rangle$$

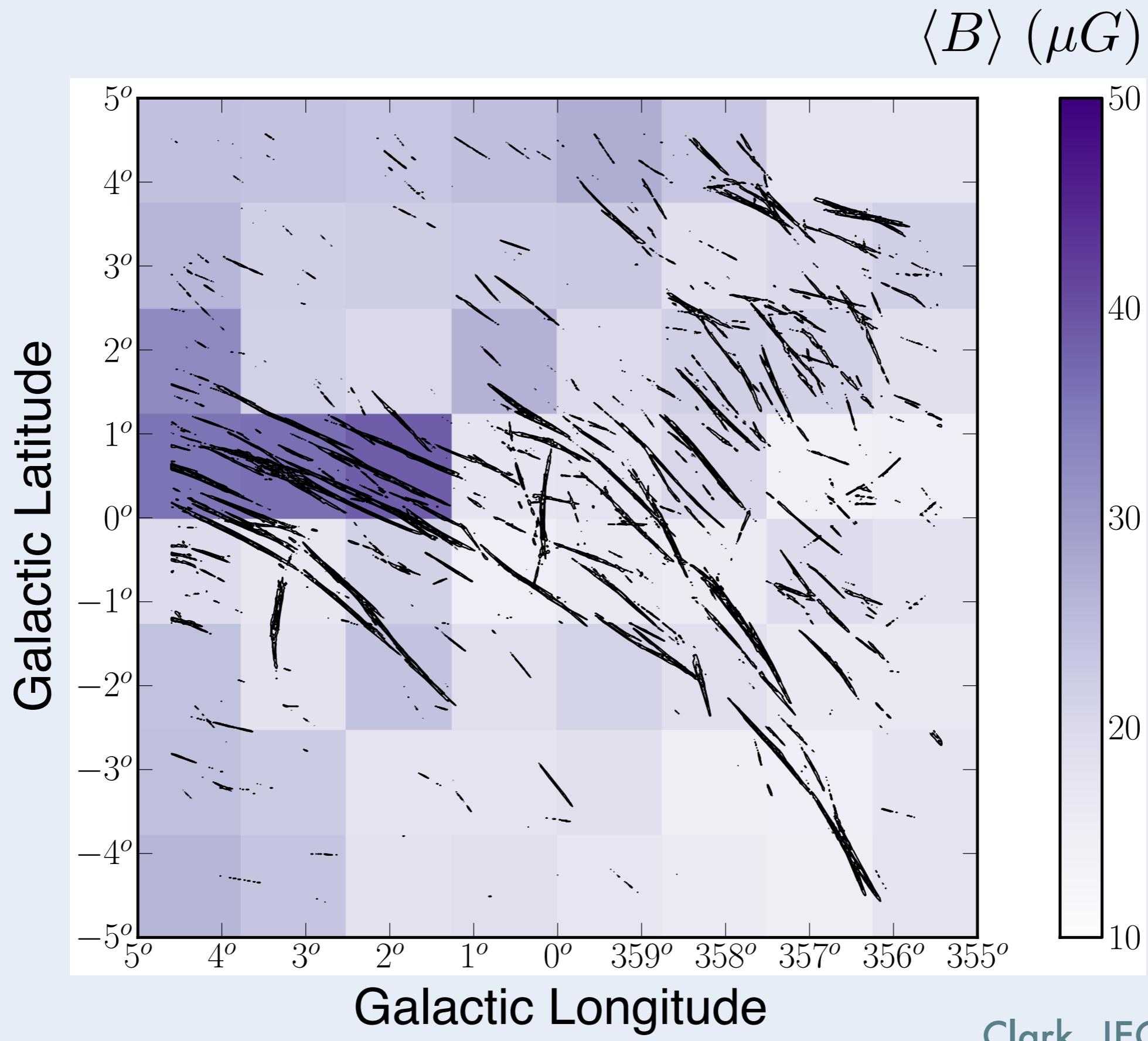
May be a way forward to resolved field strength estimates



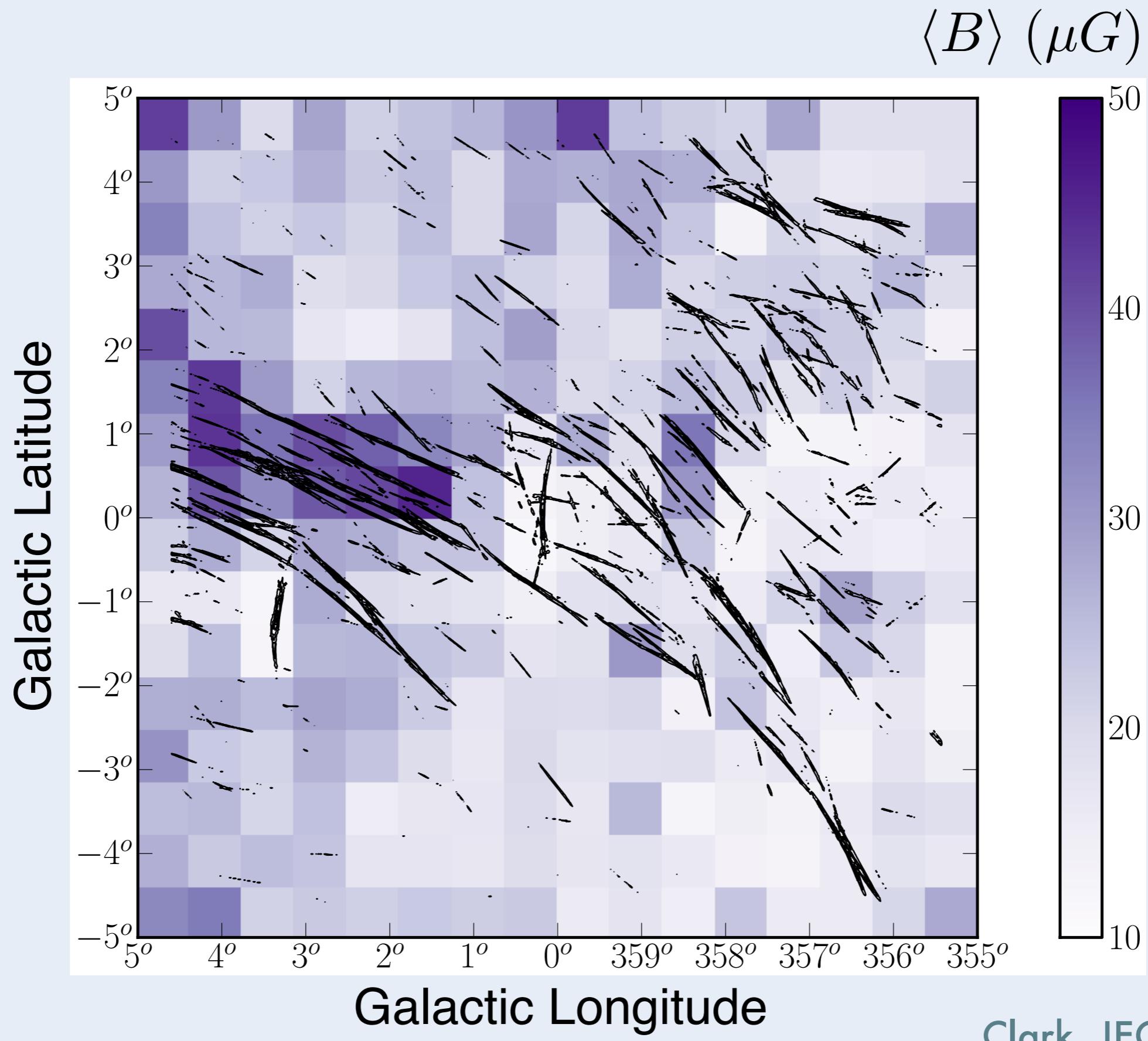
May be a way forward to resolved field strength estimates



May be a way forward to resolved field strength estimates



May be a way forward to resolved field strength estimates



Shape information from images
of the diffuse phase of the universe
can be used to measure its
underpinning **physical processes**