X-RAYS FROM THE COSMIC WEB

THE (CURIOUS) CASE OF ABELL 133

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FILAMENTS IN THE COSMIC WEB

20 YEARS AGO: THE RESULTS OF ROSAT

Astron. Astrophys. 302, L9–L12 (1995)

ASTRONOMY
AND
ASTROPHYSICS

Letter to the Editor

Search for X-ray filaments between galaxy clusters

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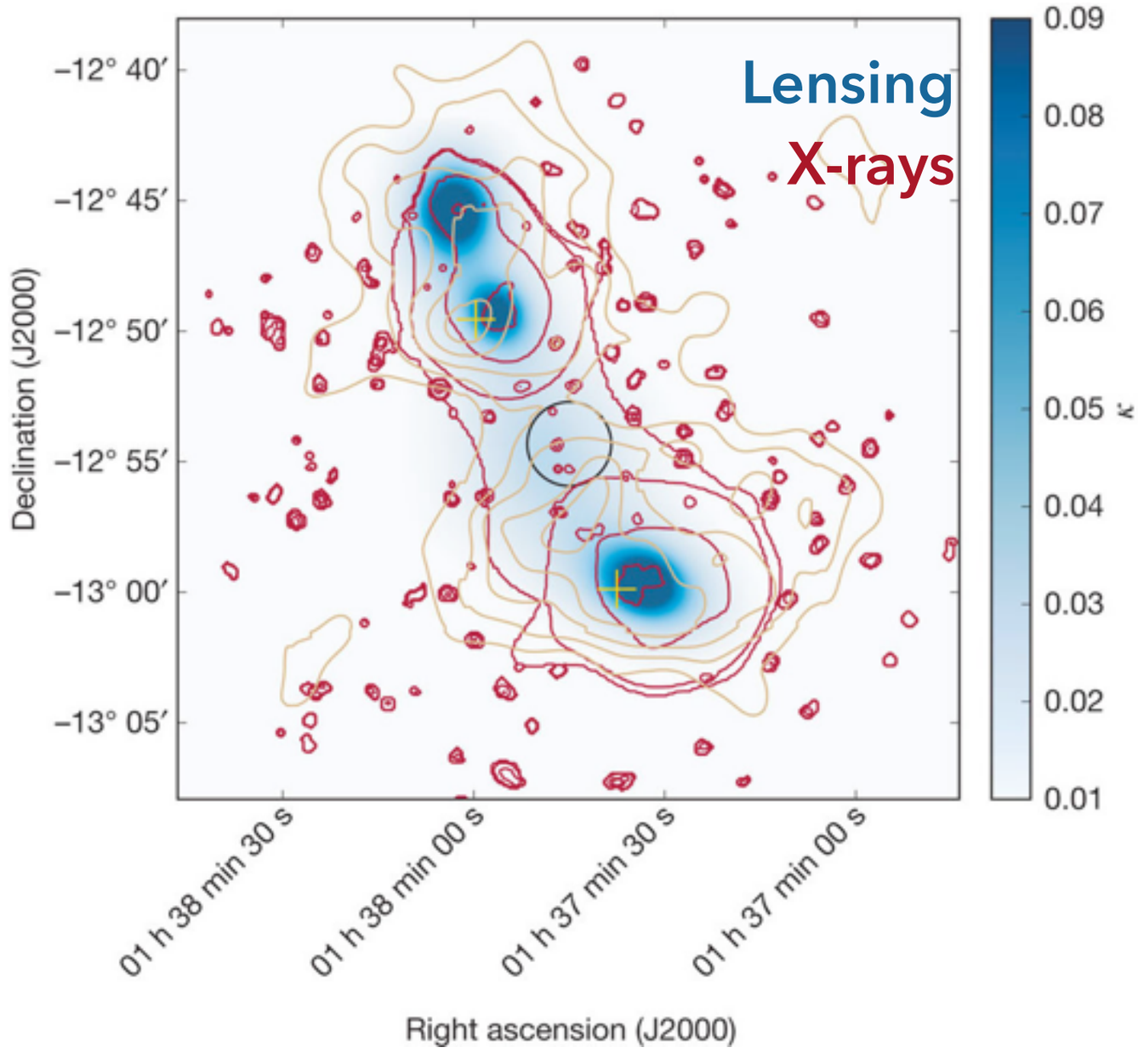
"We do **not** find any filament emission"

10 YEARS AGO: EXPLOITING FORTUITOUS SIGHTLINES

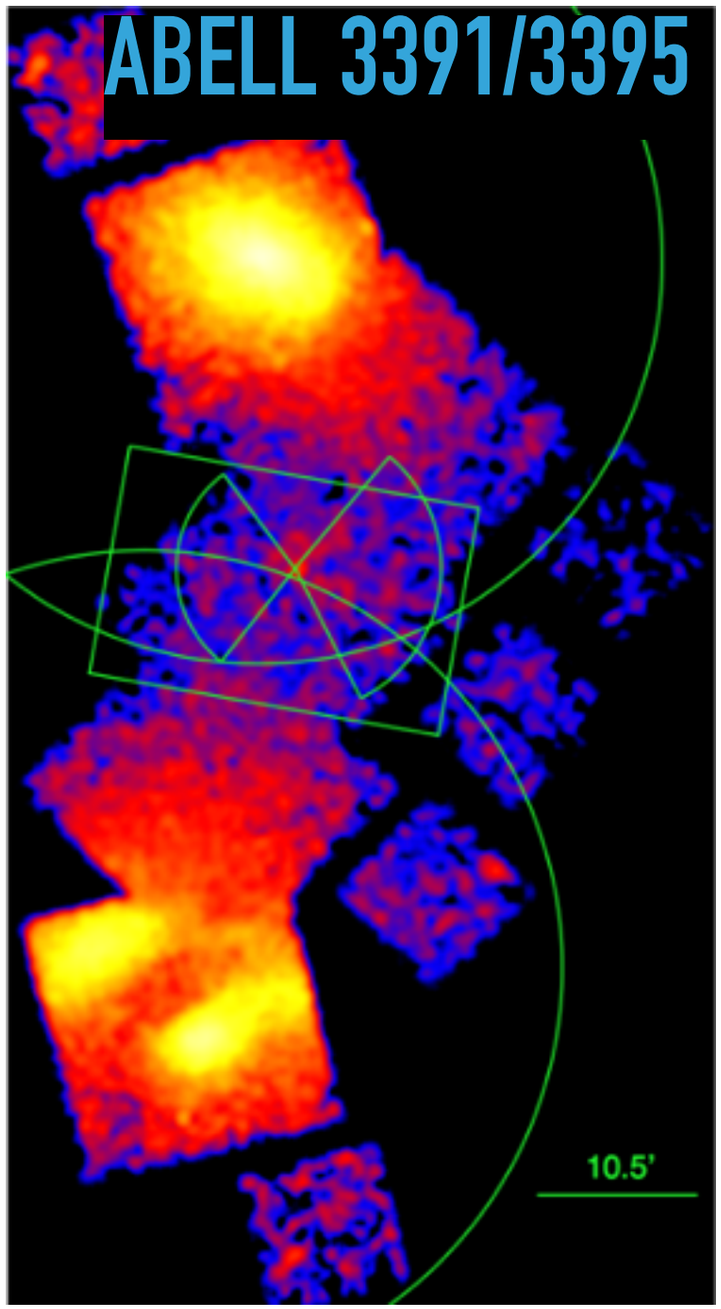
Merger between Abell 222 / 223

Merging **boosts temperature and density** – enhanced visibility, but **biased measure** of "typical" conditions

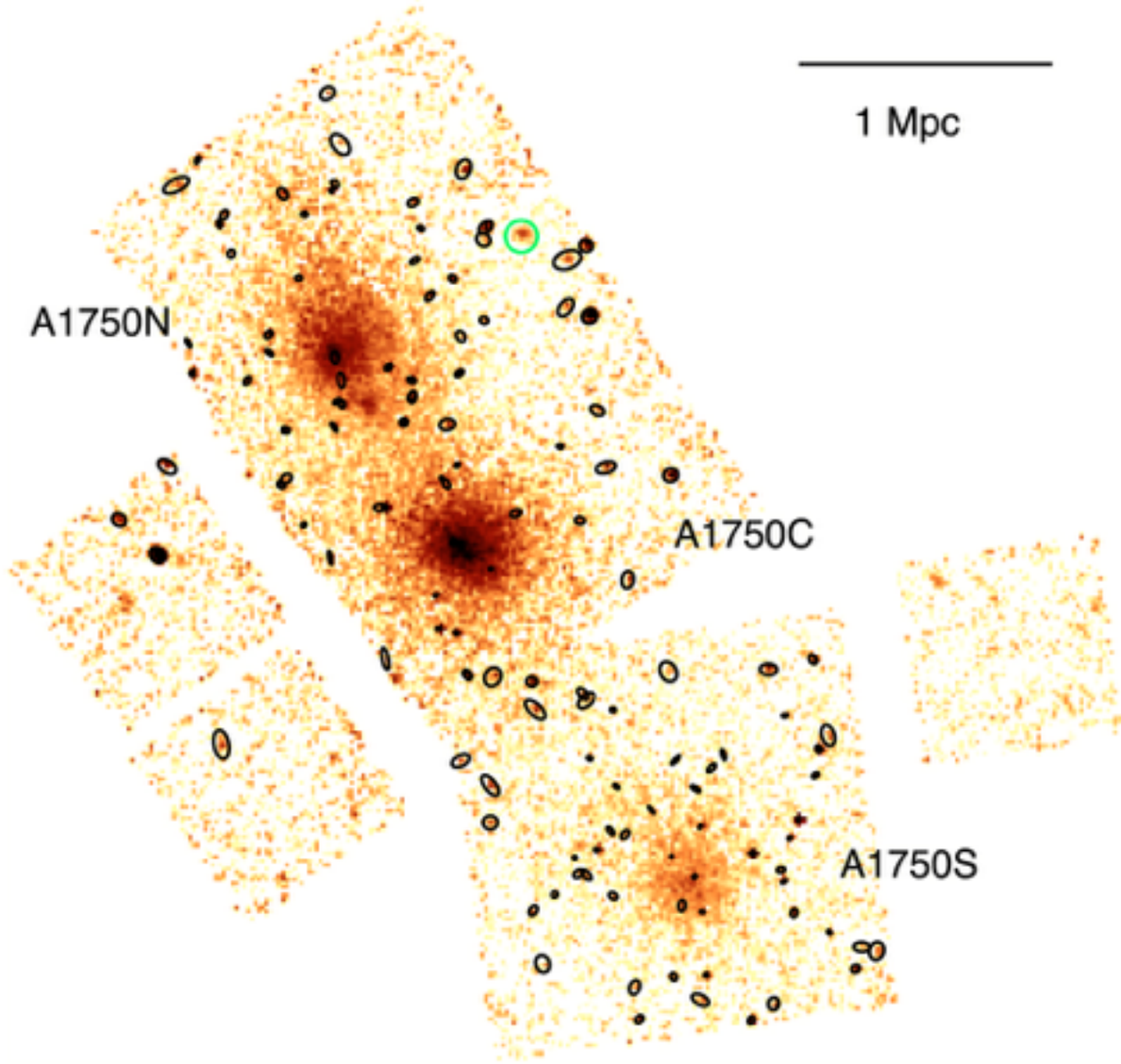


Werner et al. 2008
Dietrich et al. 2012

<10 YEARS AGO: EXPLOITING FORTUITOUS SIGHTLINES

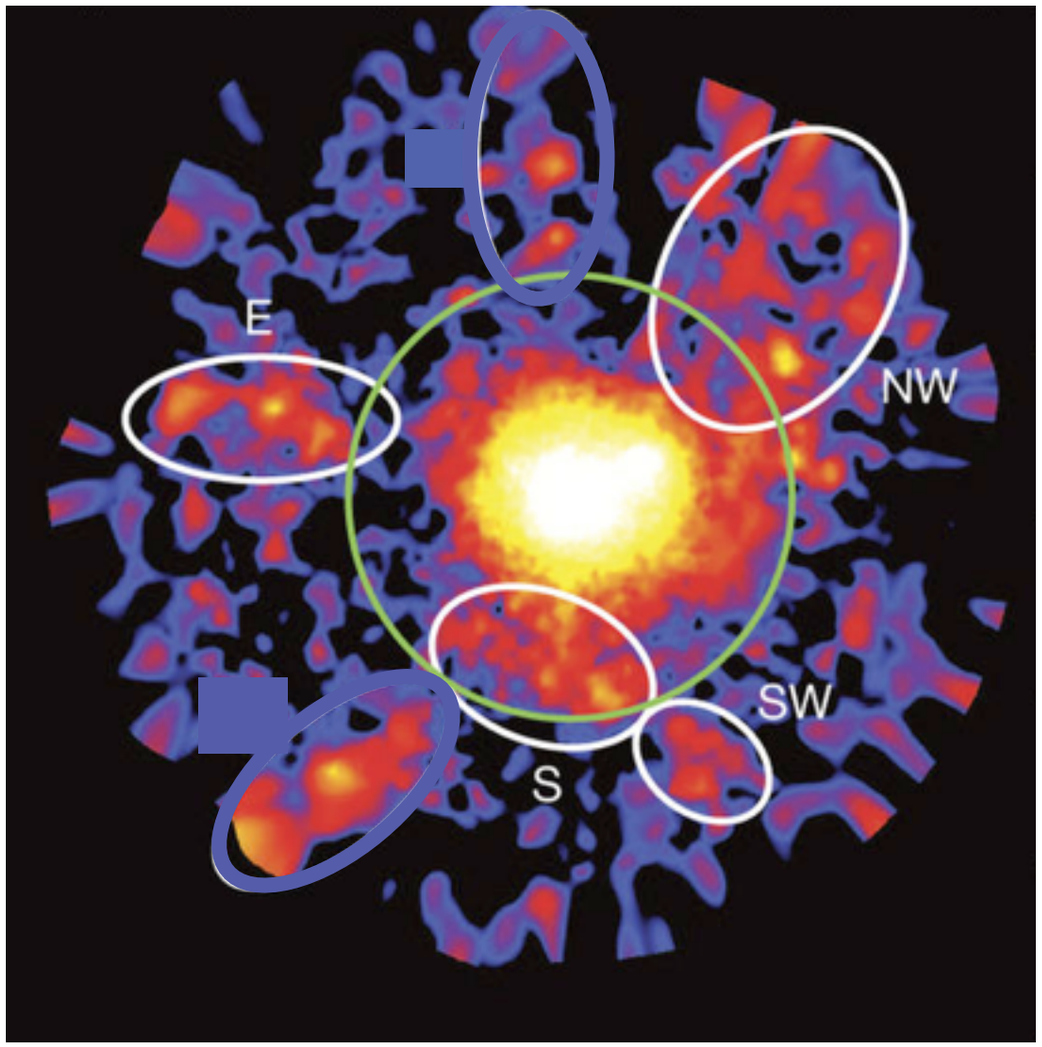


Alvarez et al. 2018
Tittley et al. 2001



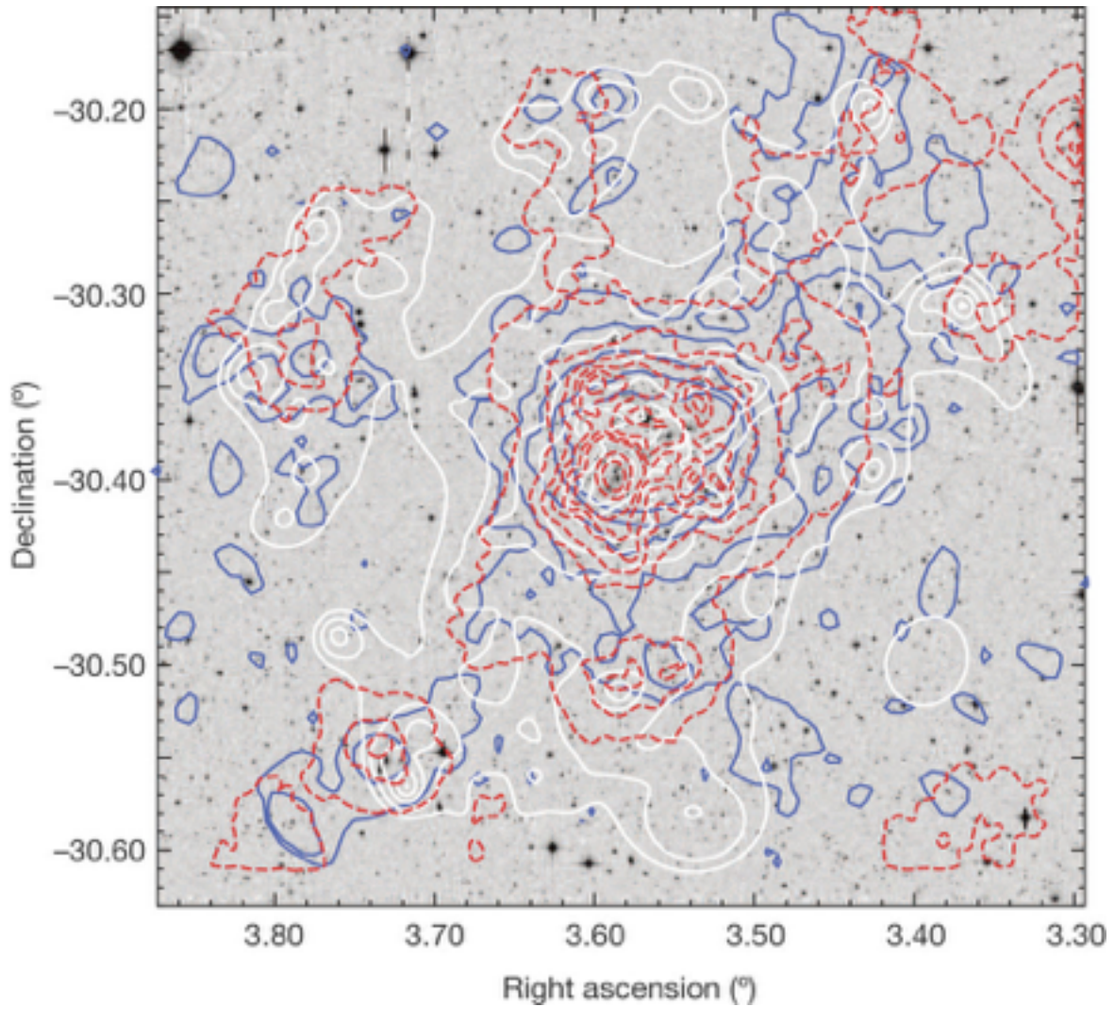
Bulbul et al. 2016

5 YEARS AGO: MAJOR MERGING



The amount of substructure around A2744 is a challenge for ΛCDM

Schwinn et al. 2017



Optical Light
X-Ray
S&W Lensing

Eckert et al. 2015

THE XMM/CHANDRA VIEW

We can see the diffuse gas in filaments, but **we need lucky sightlines**. This means we have a **biased, incomplete view** of the cosmic web.

0–5 YEARS FROM NOW: EROSITA

Astron. Astrophys. 302, L9–L17 (1995)

2022

ASTRONOMY
AND
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Letter to the Editor

Search for X-ray filaments between galaxy clusters

~~Ulrich G. Briel[1] and J. Patrick Henry[1,2]~~ The eROSITA team

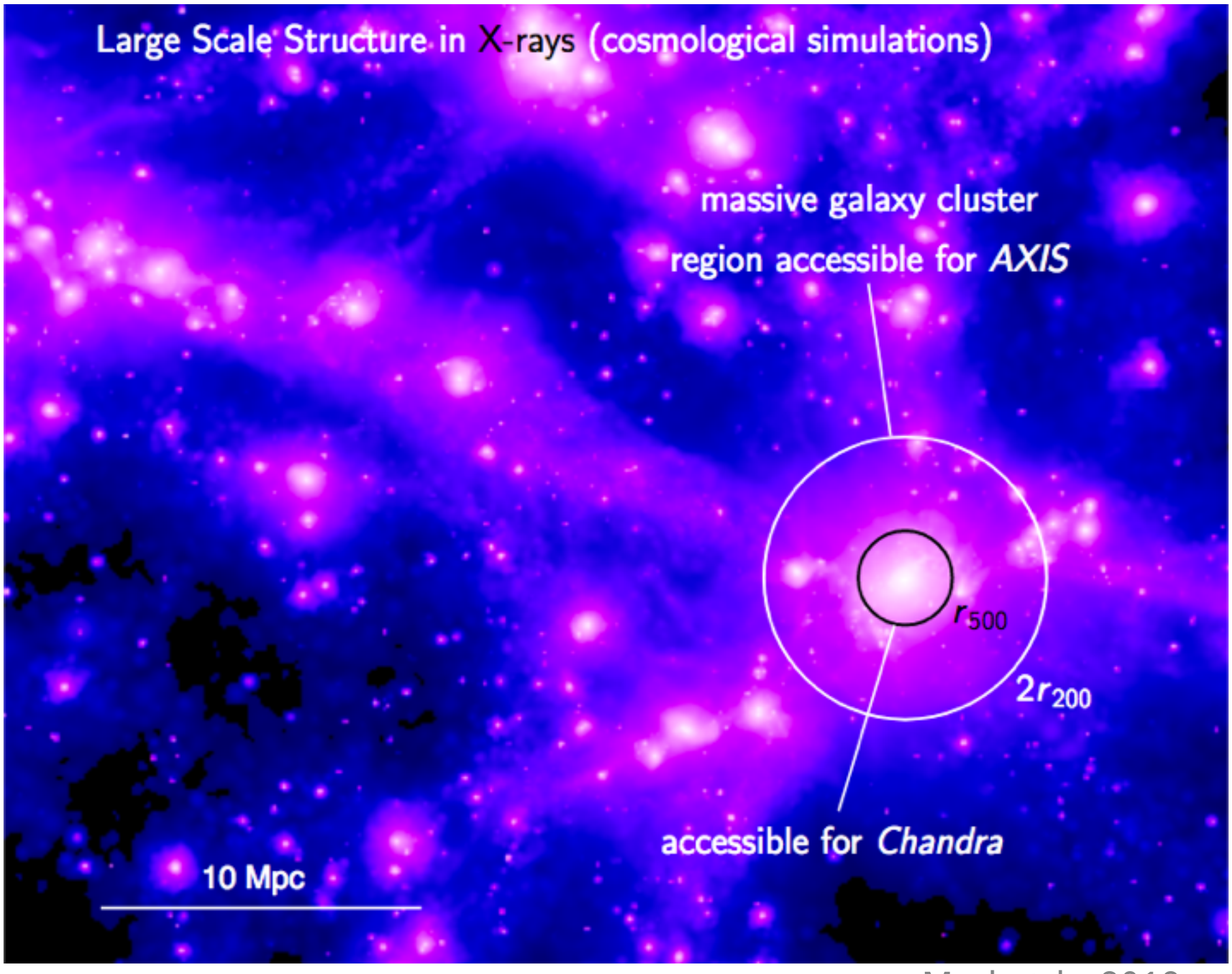
POOR ANGULAR RESOLUTION BUT CAN STACK THEIR WAY TO DETECTING FILAMENTS

"We do ~~not~~ find any filament emission"

10 YEARS FROM NOW: AXIS (PROBE-CLASS MISSION)

Aim to capture twice a cluster's virial radius

May be able to ride out along over densities of filaments

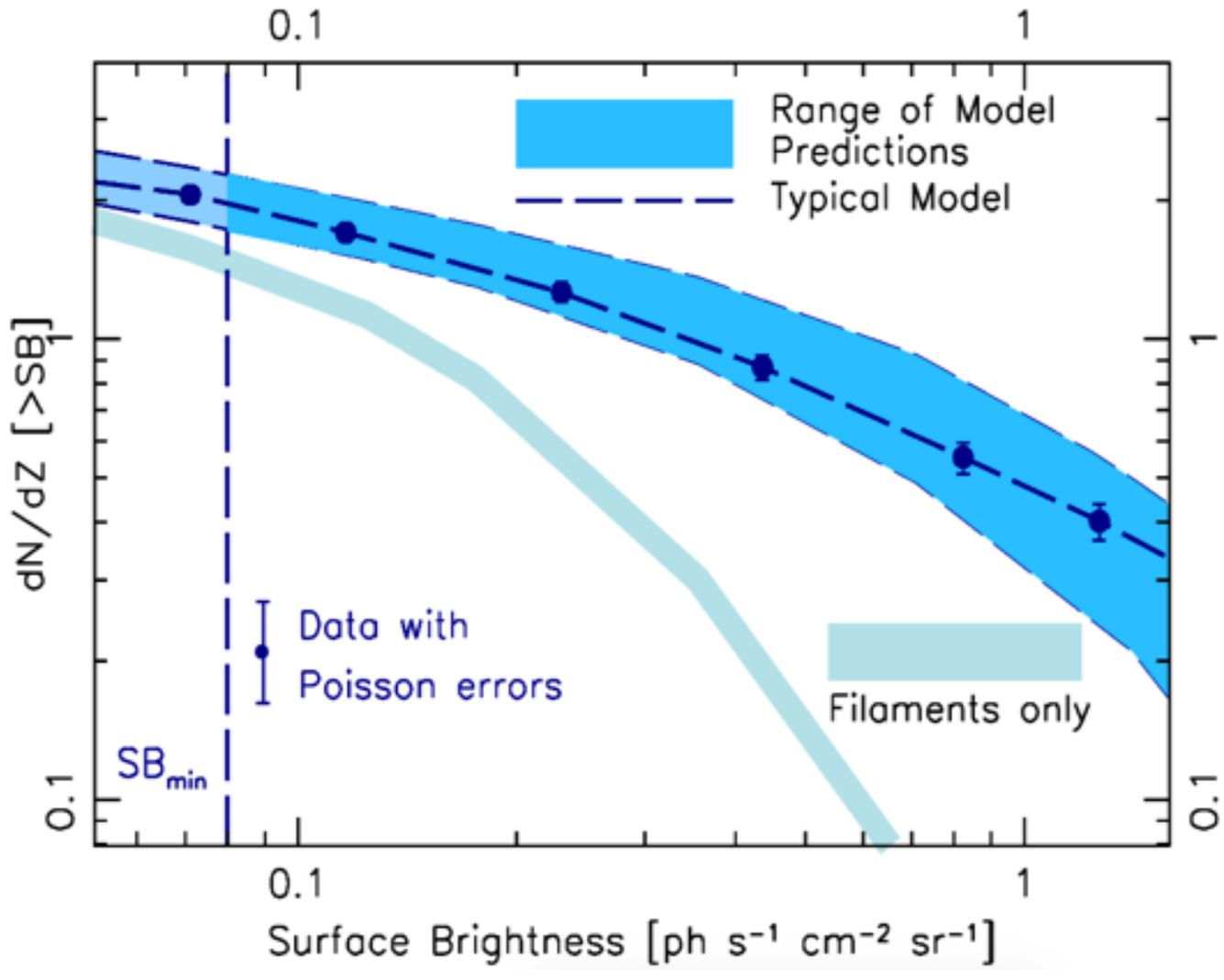


Mushotzky 2018

10+ YEARS FROM NOW: ATHENA

100 ks X-IFU observation
– 4 filaments in emission

About 1,000
serendipitous detections
over 5 year mission

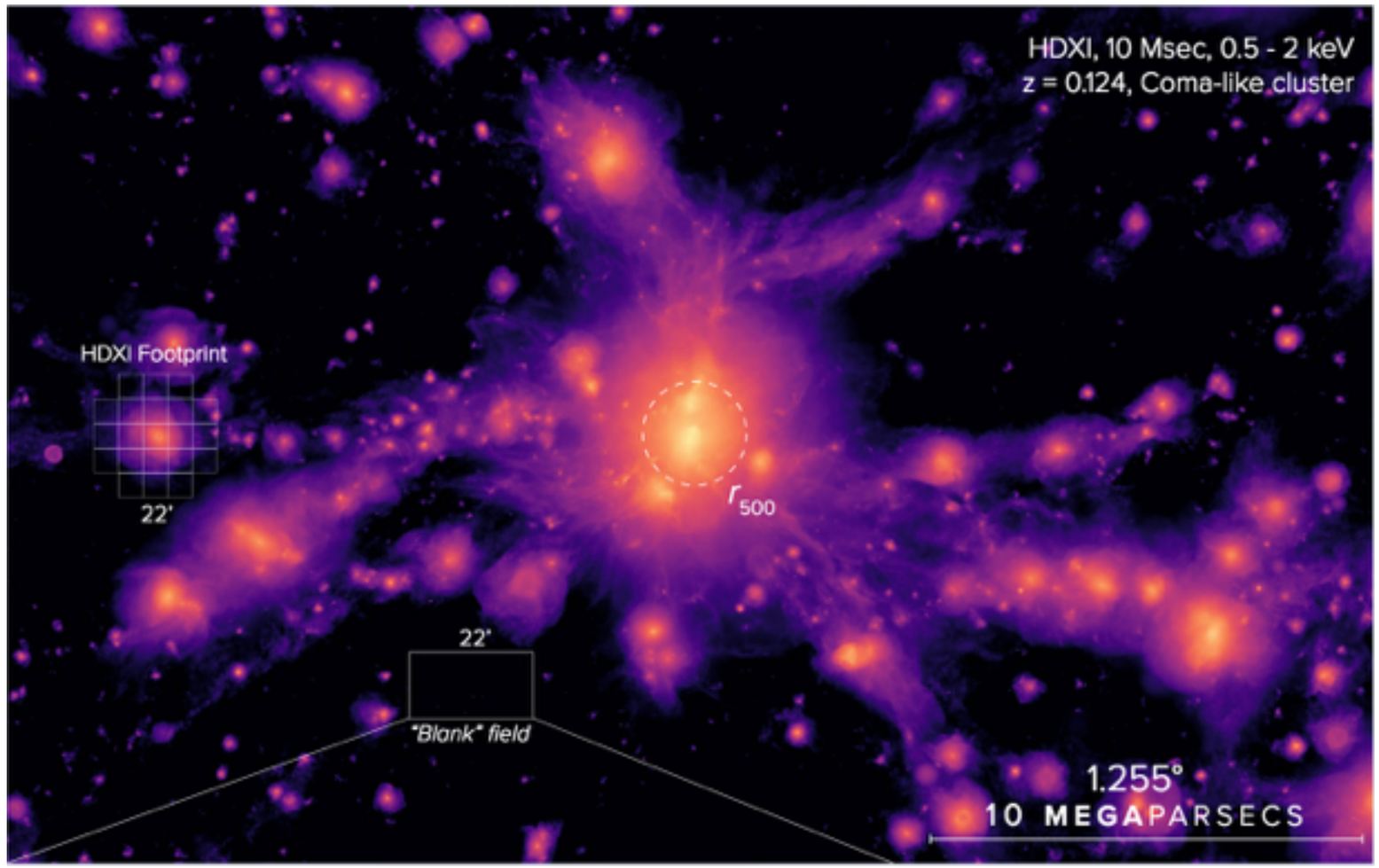


AthenaX Supporting Paper 4
Kaastra et al. 2013

15+ YEARS FROM NOW: LYNX

Planned legacy survey:
10 Ms over 10 sq. deg
(depth of 100ks at all points)

Revolutionize our understanding of filaments



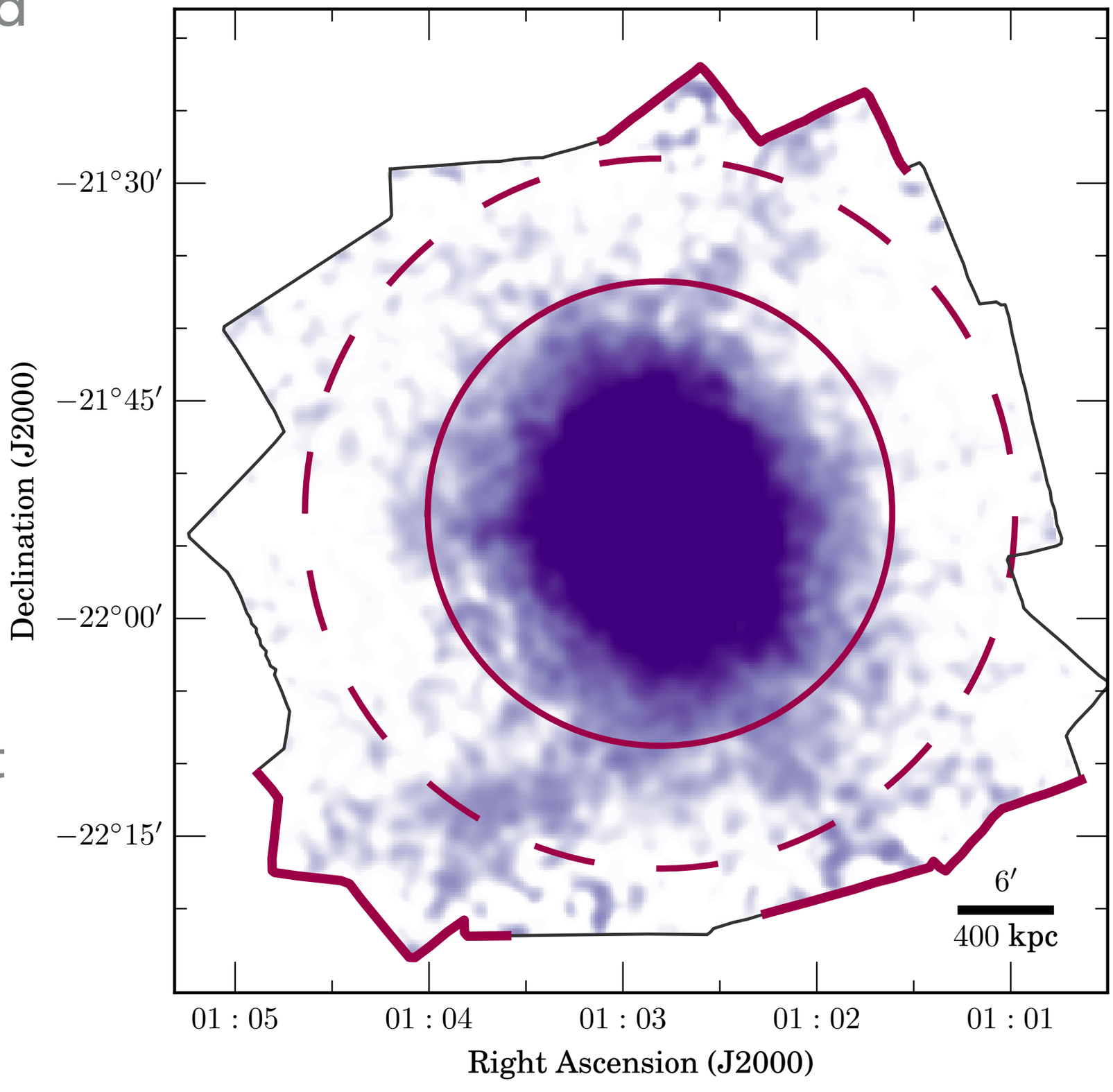
If this is visible at 100 ks depth, targeted cluster observations could provide further detections.

Lynx Concept Study Report

TODAY

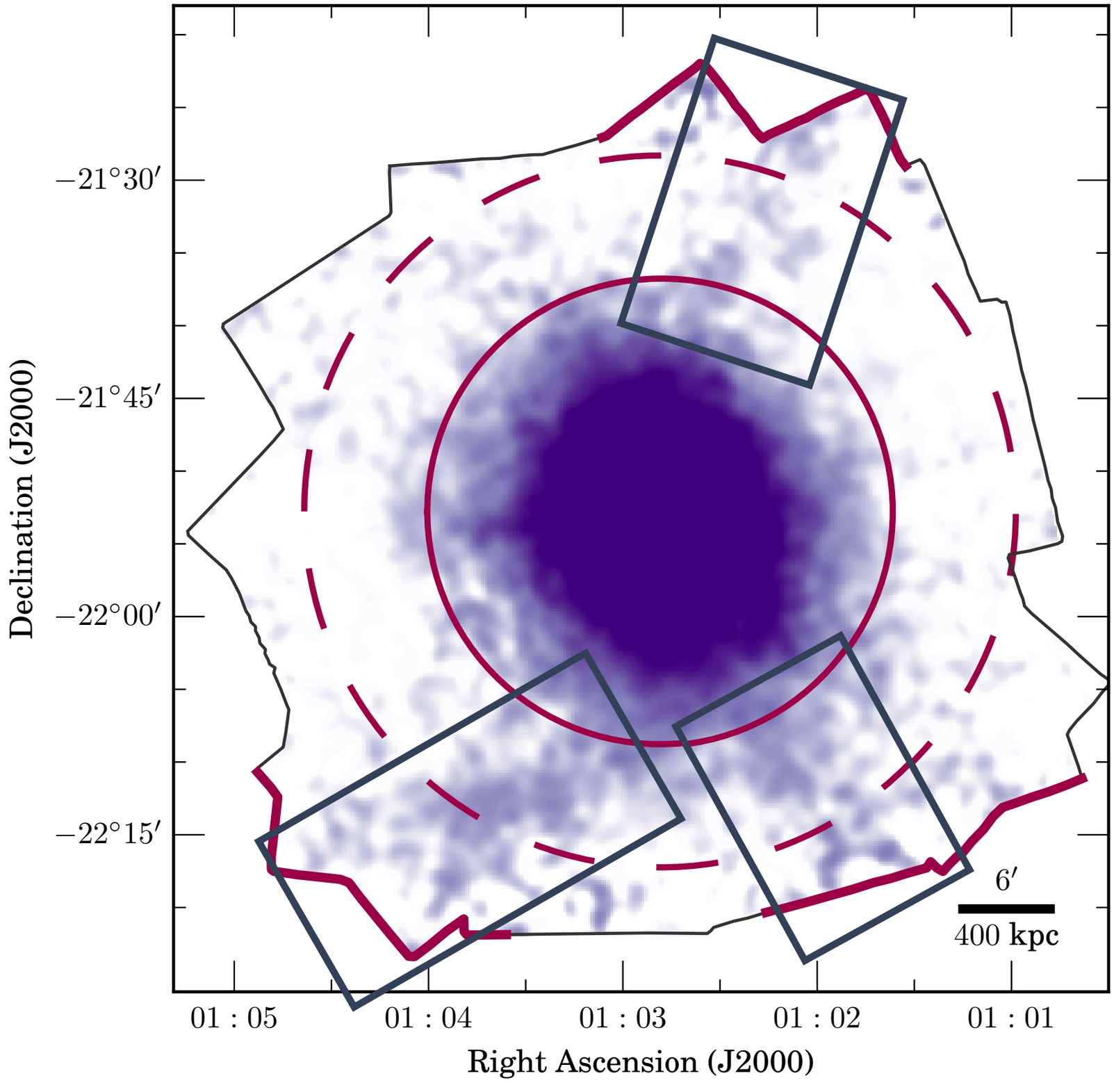
2.4 Ms combined observation covering ~1 square degree.

Depth of at least 100 ks at all points



Abell 133 (z~0.055)

Connor et al. 2018, 2019c



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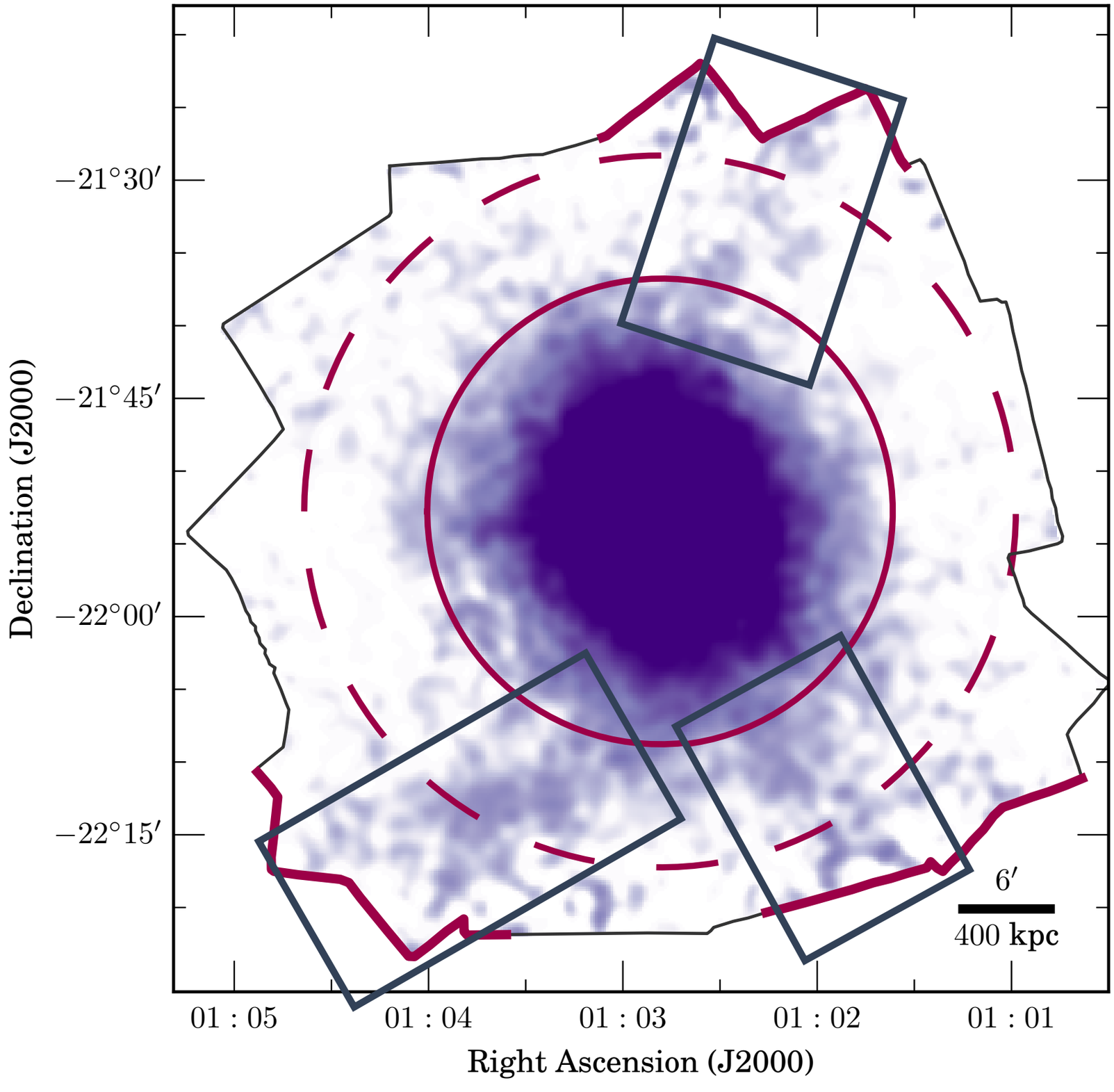

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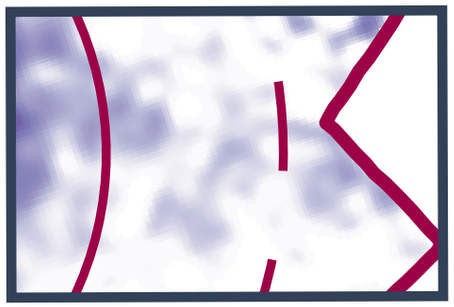
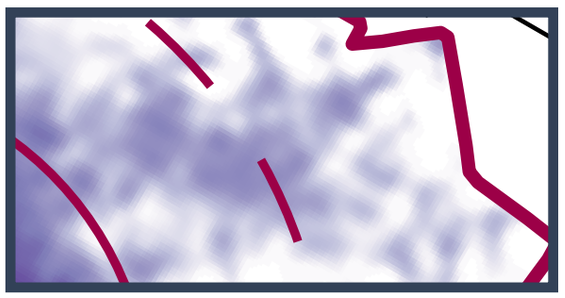
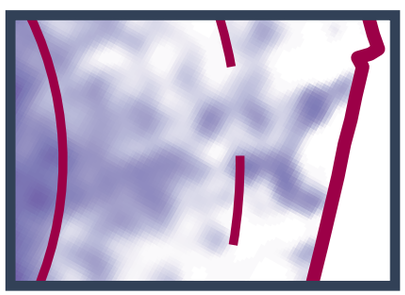


C



B



A

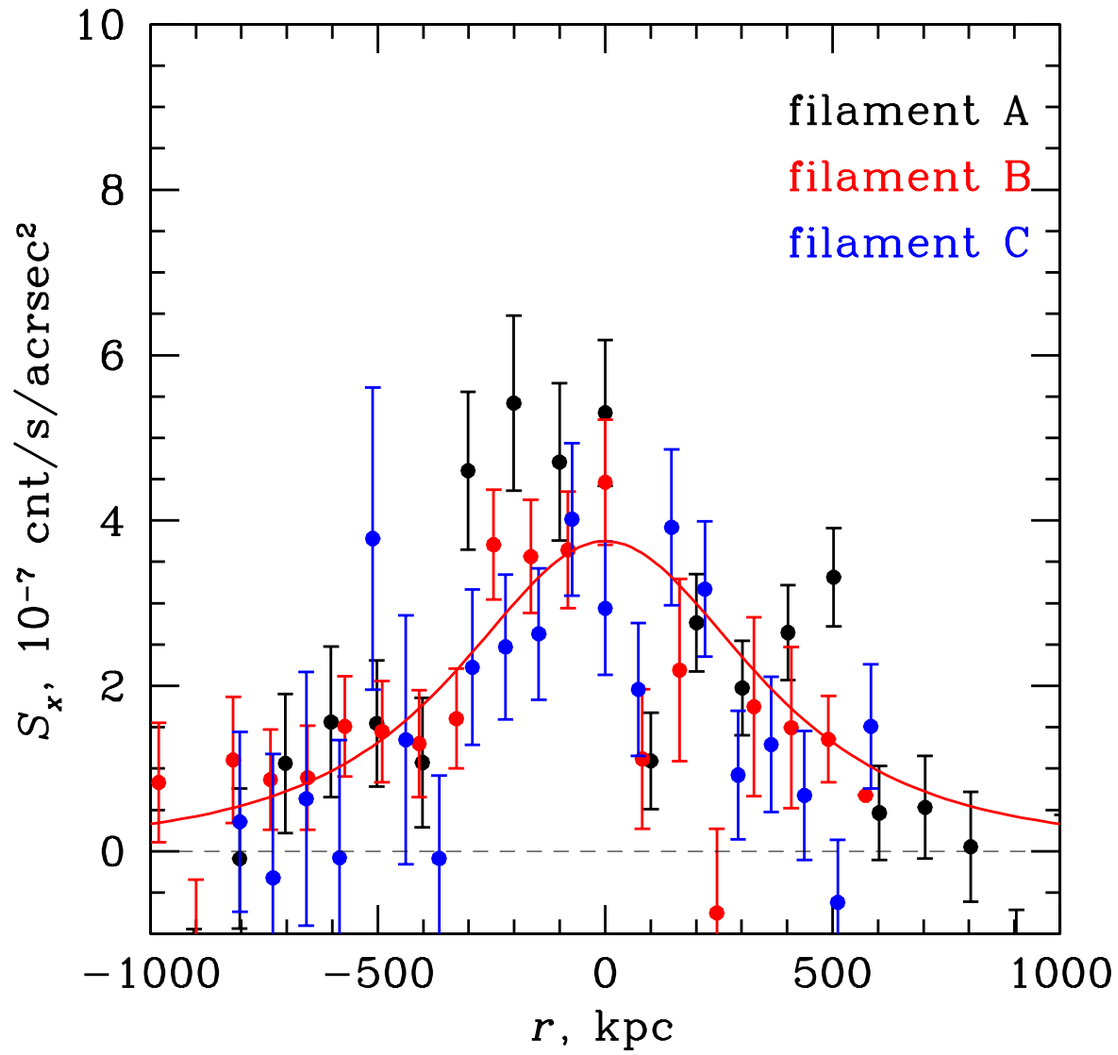
Temperature: 2.0±0.3 keV

Width: $S_x \sim (1+r^2/r_c^2)^{-3\times0.67-0.5}$

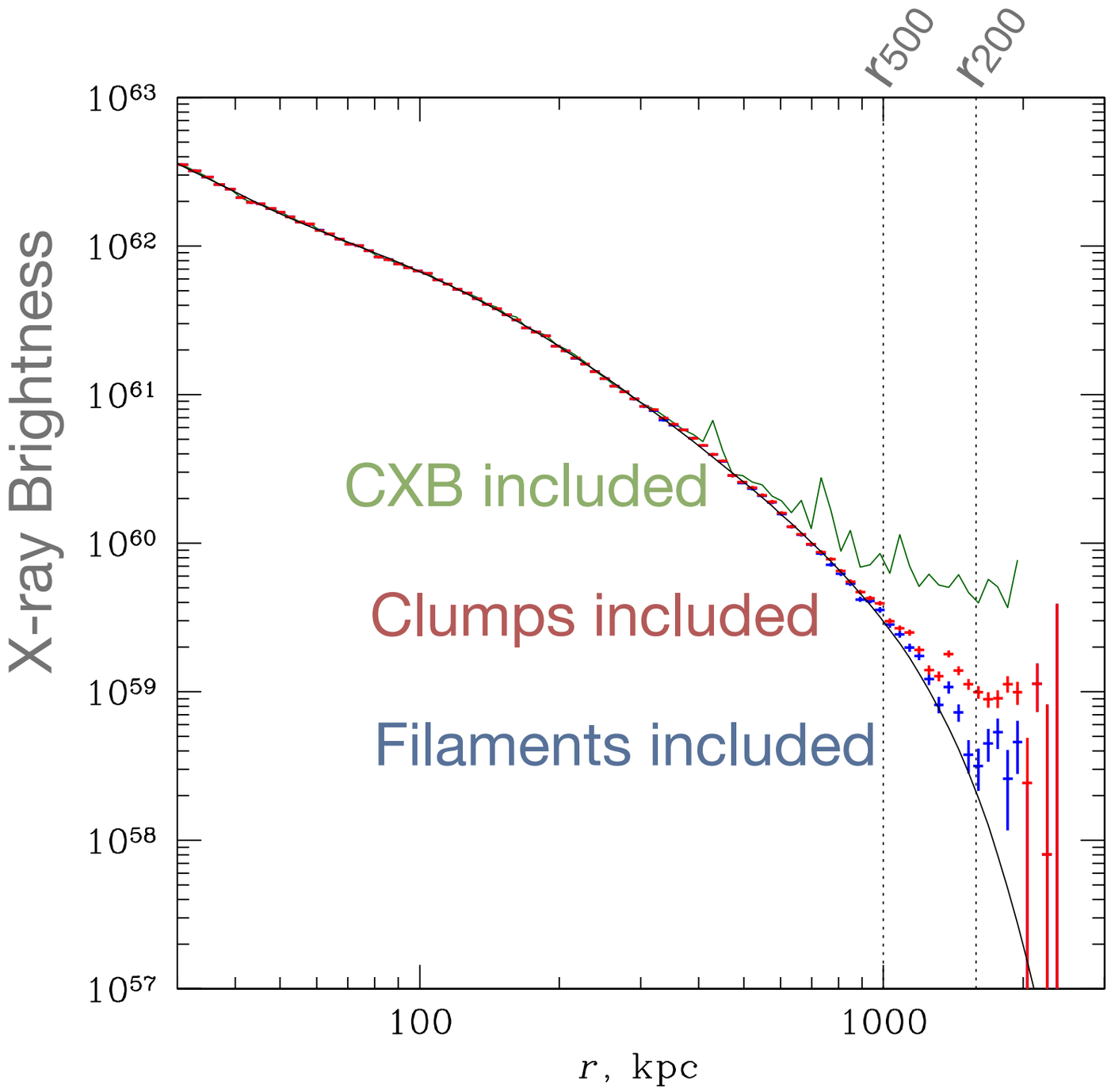
with $r_c \approx 0.5$Mpc

Density: $\rho_{g,0} \approx 1500\ \Omega_b\, h^2\, \rho_c$

Gas content: $M_g / M_{tot} \approx 0.2$



Vikhlinin et al. in prep

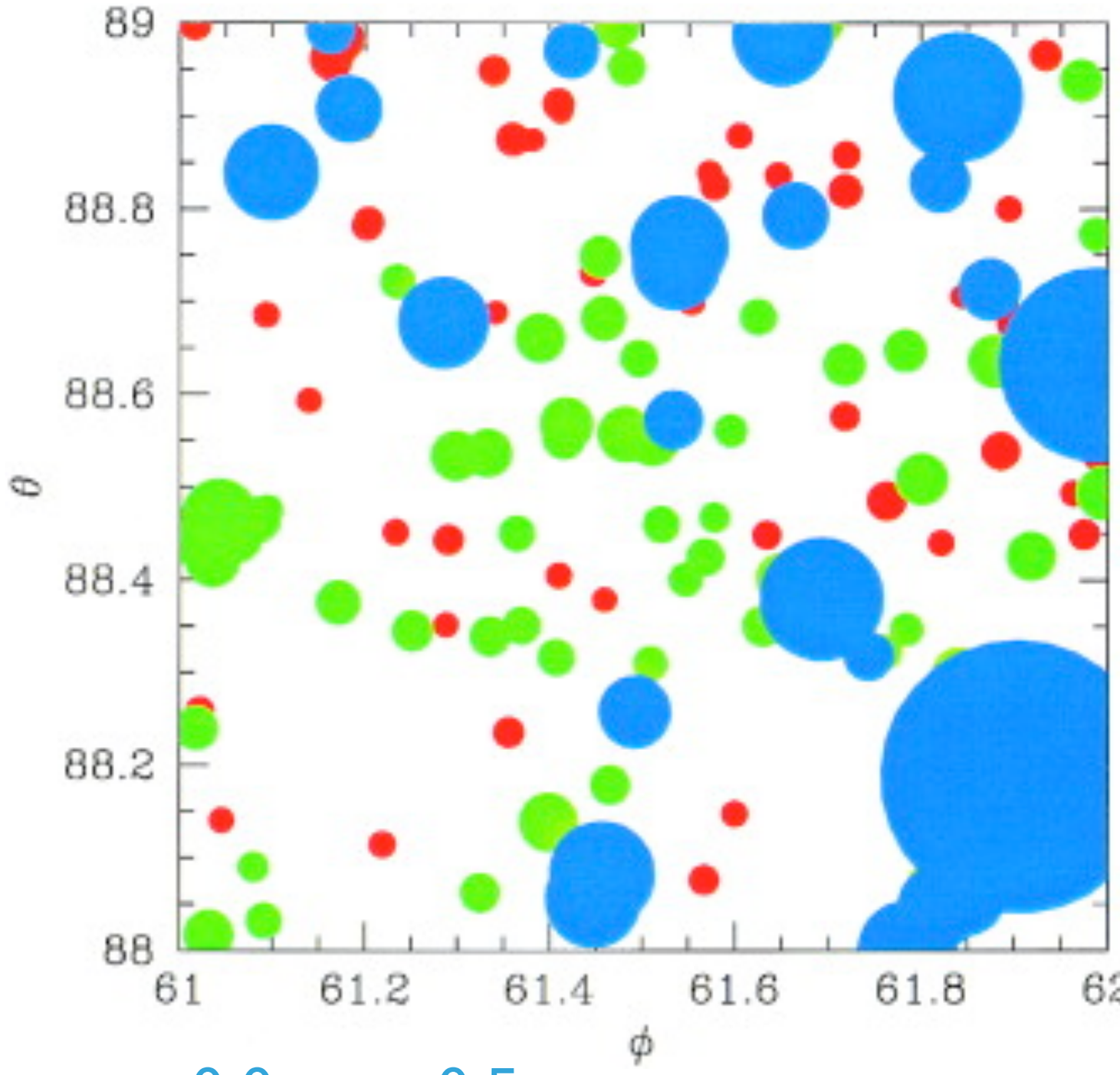


To see filaments, we need to be able to resolve clumps (background clusters?) and individual point sources.

Vikhlinin et al. in prep

But the X-ray sky is full of virialized structures

An independent check is needed to confirm that these are cosmic web filaments



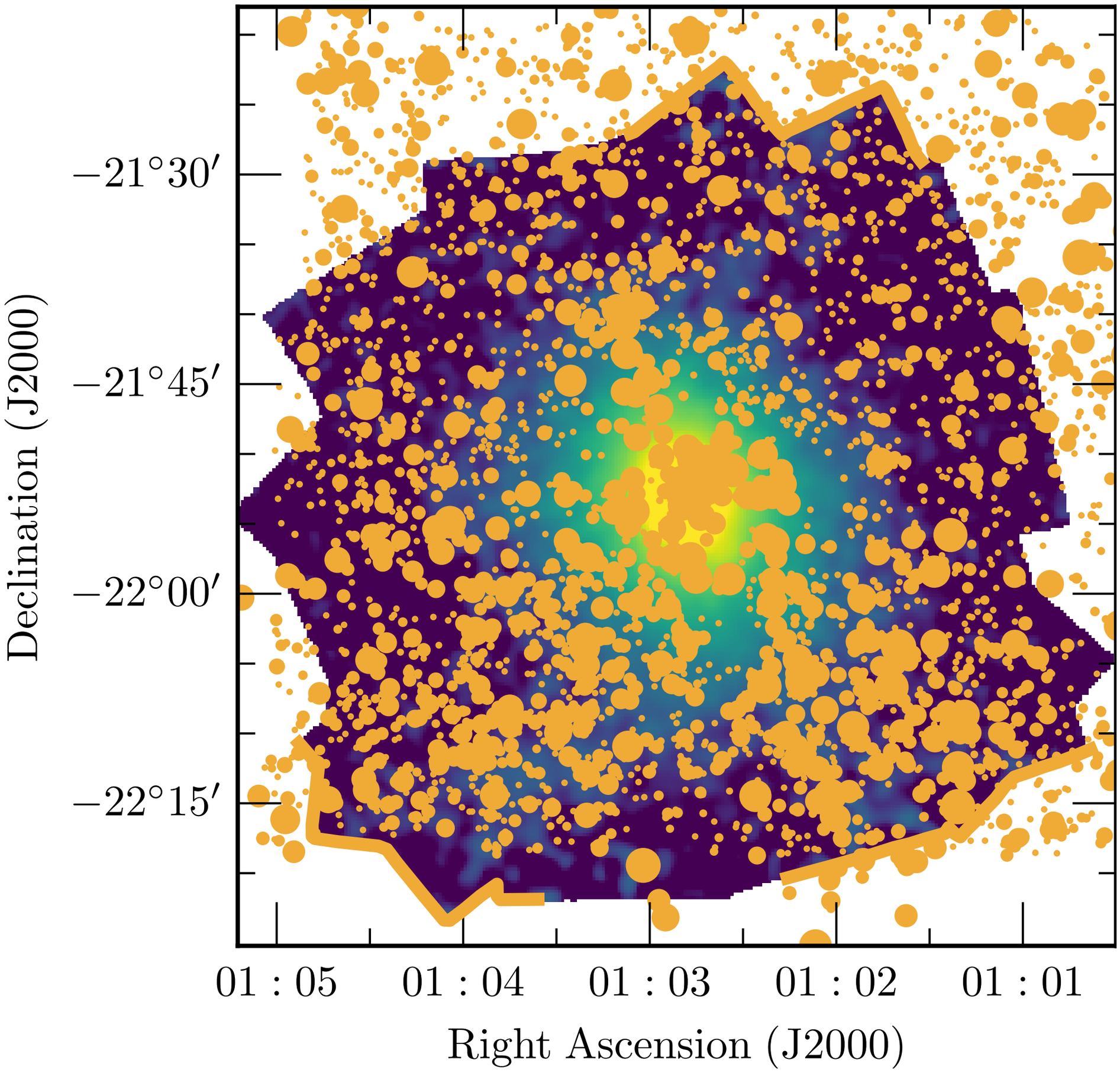
0.0 < z < 0.5

0.5 < z < 1.0

1.0 < z < 1.4

Voit, Evrard, & Bryan 2001

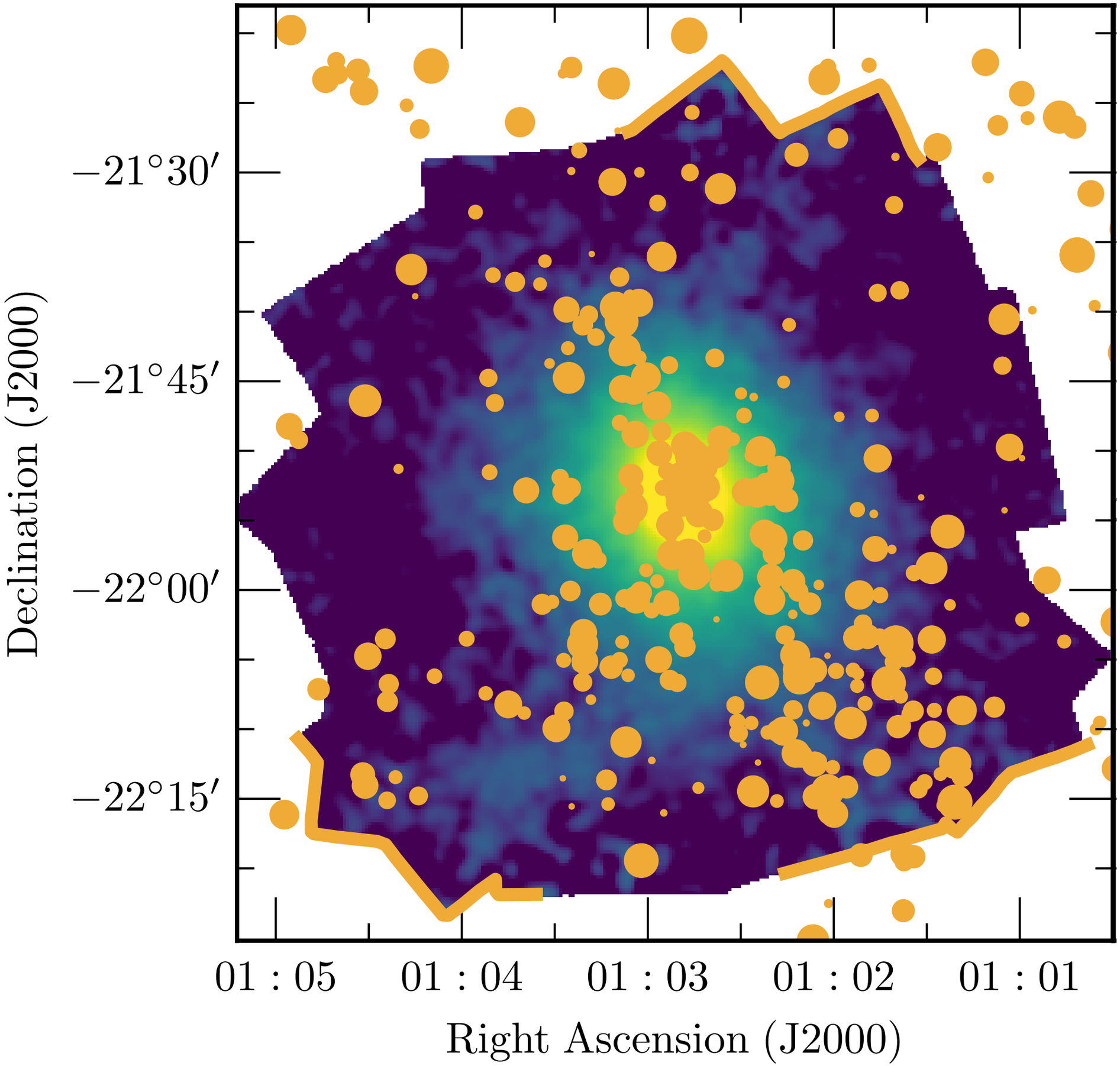
IMACS ABELL133 SPECTROSCOPIC SURVEY



Over 3000 new and archival redshifts

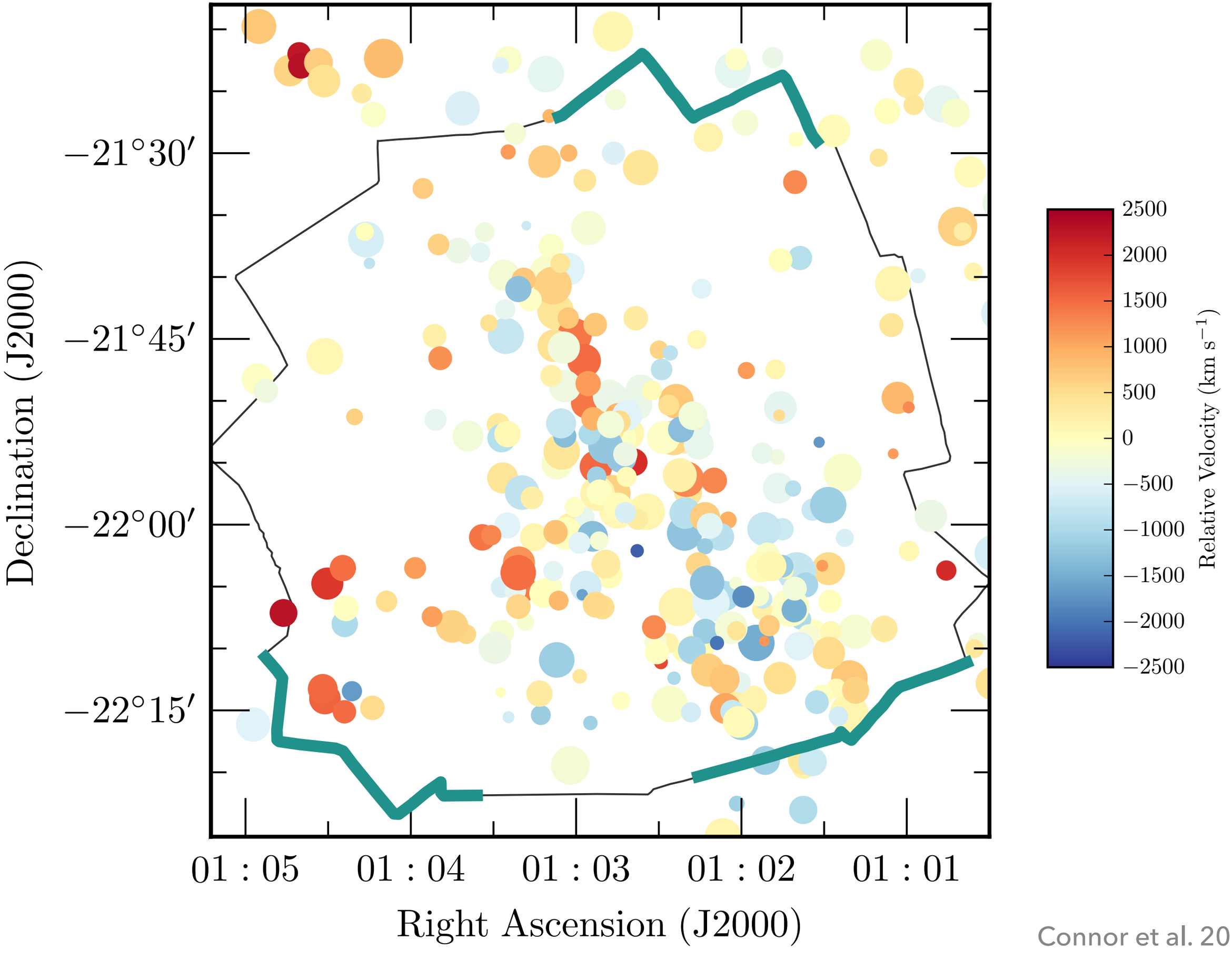
Connor et al. 2018

IMACS ABELL133 SPECTROSCOPIC SURVEY 1



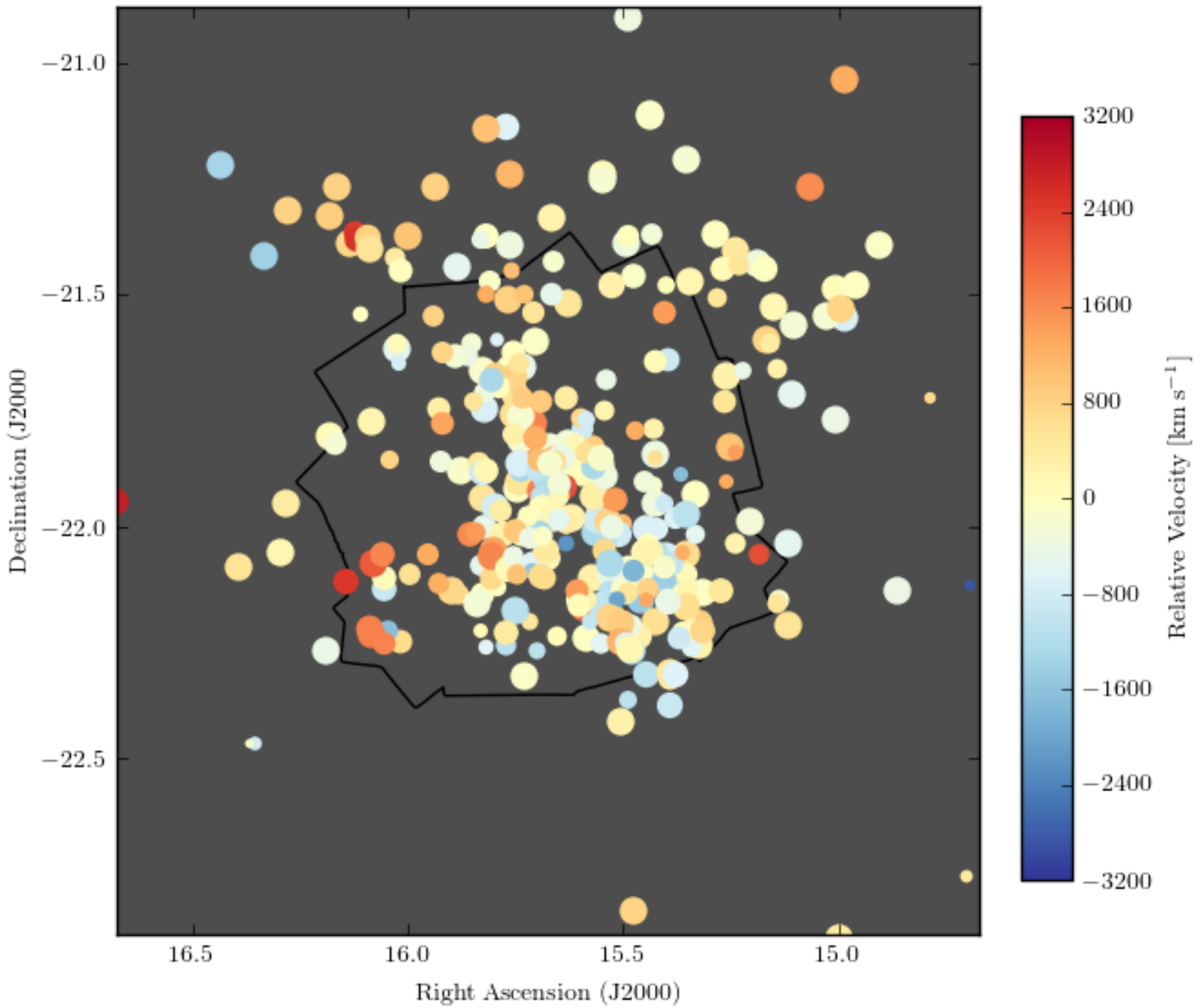
Over 300 identified cluster members

Connor et al. 2018



Connor et al. 2018

LARGER SCALES



Connor et al. 2018

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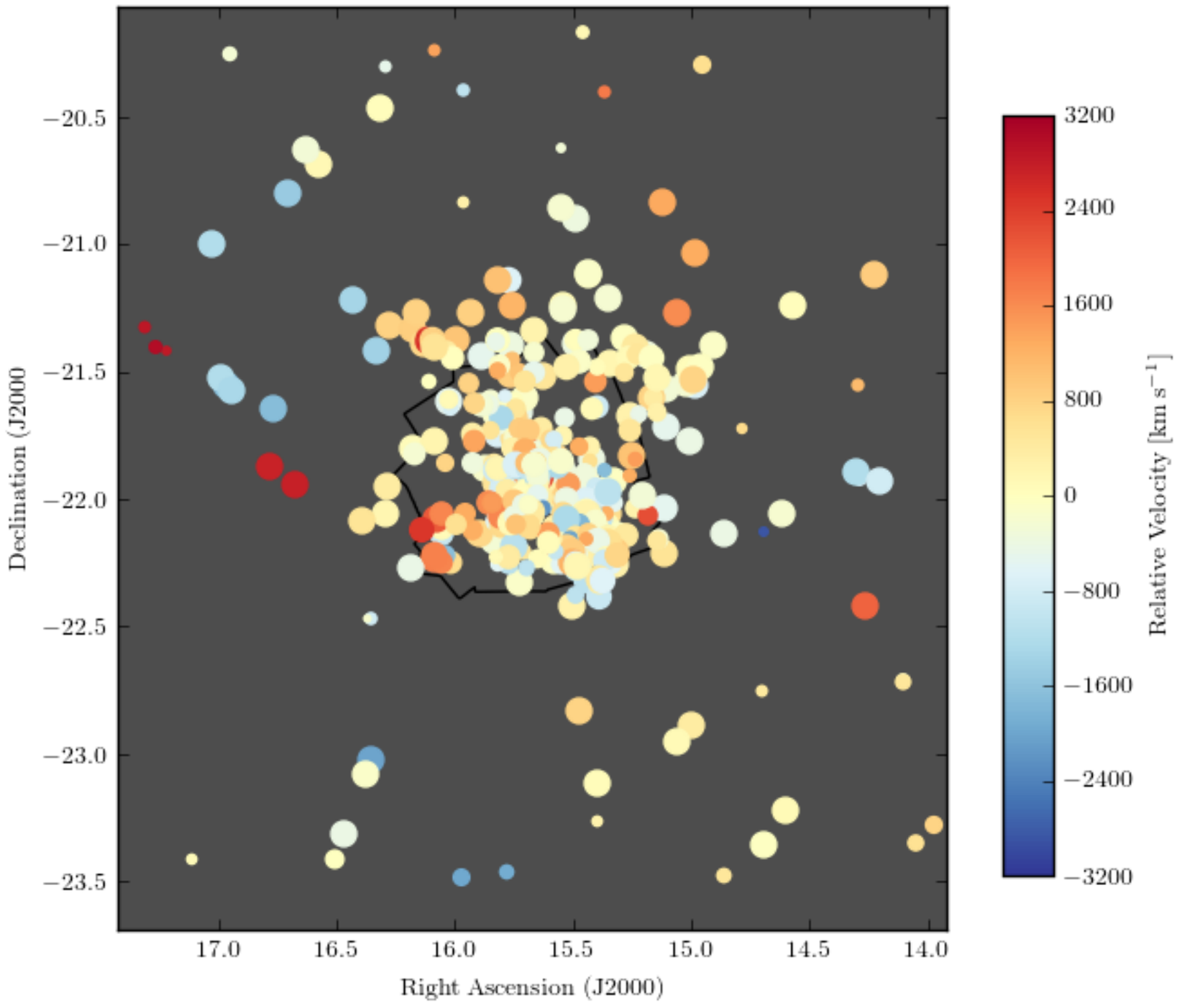

Connor et al. 2018

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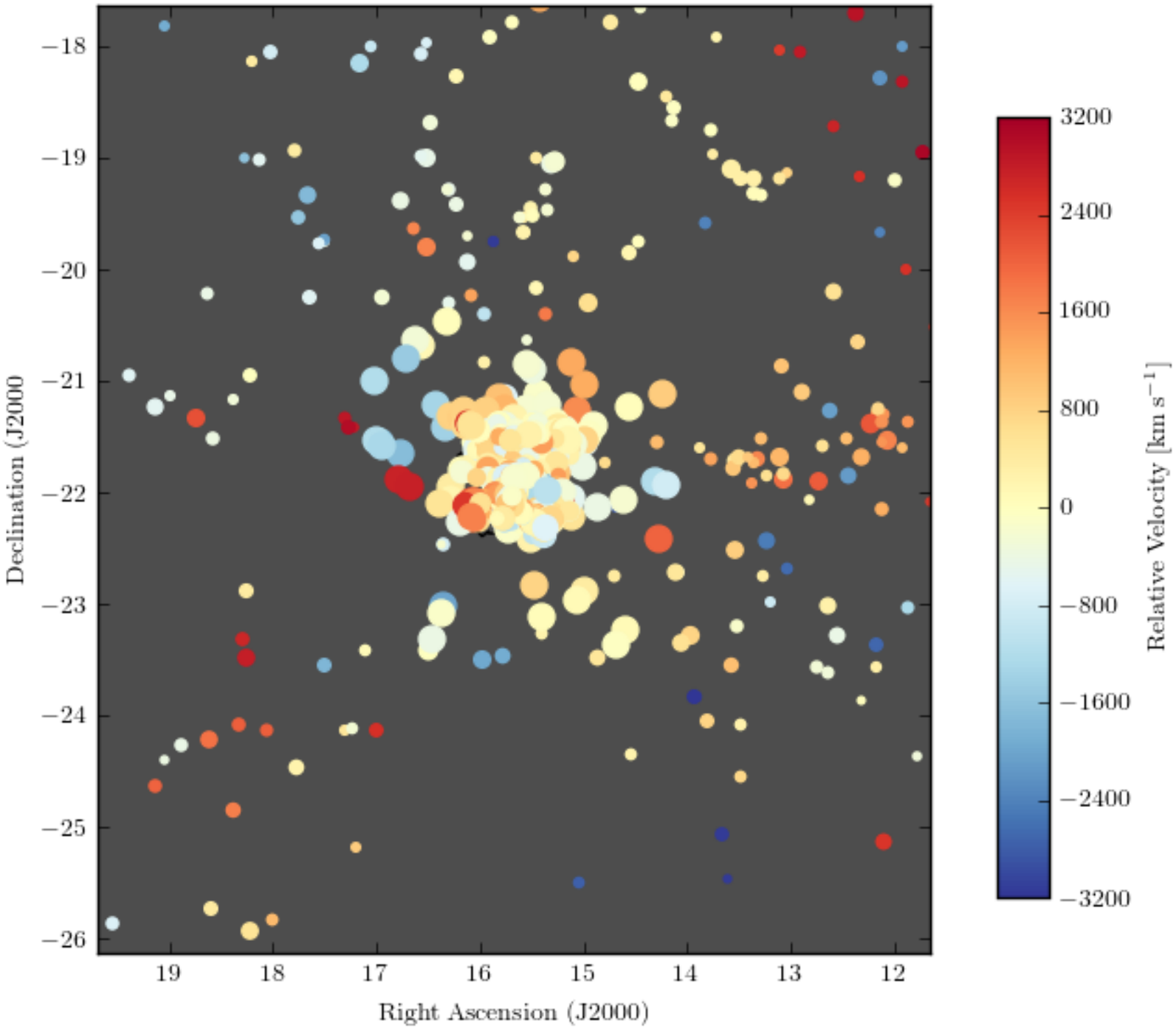

Connor et al. 2018

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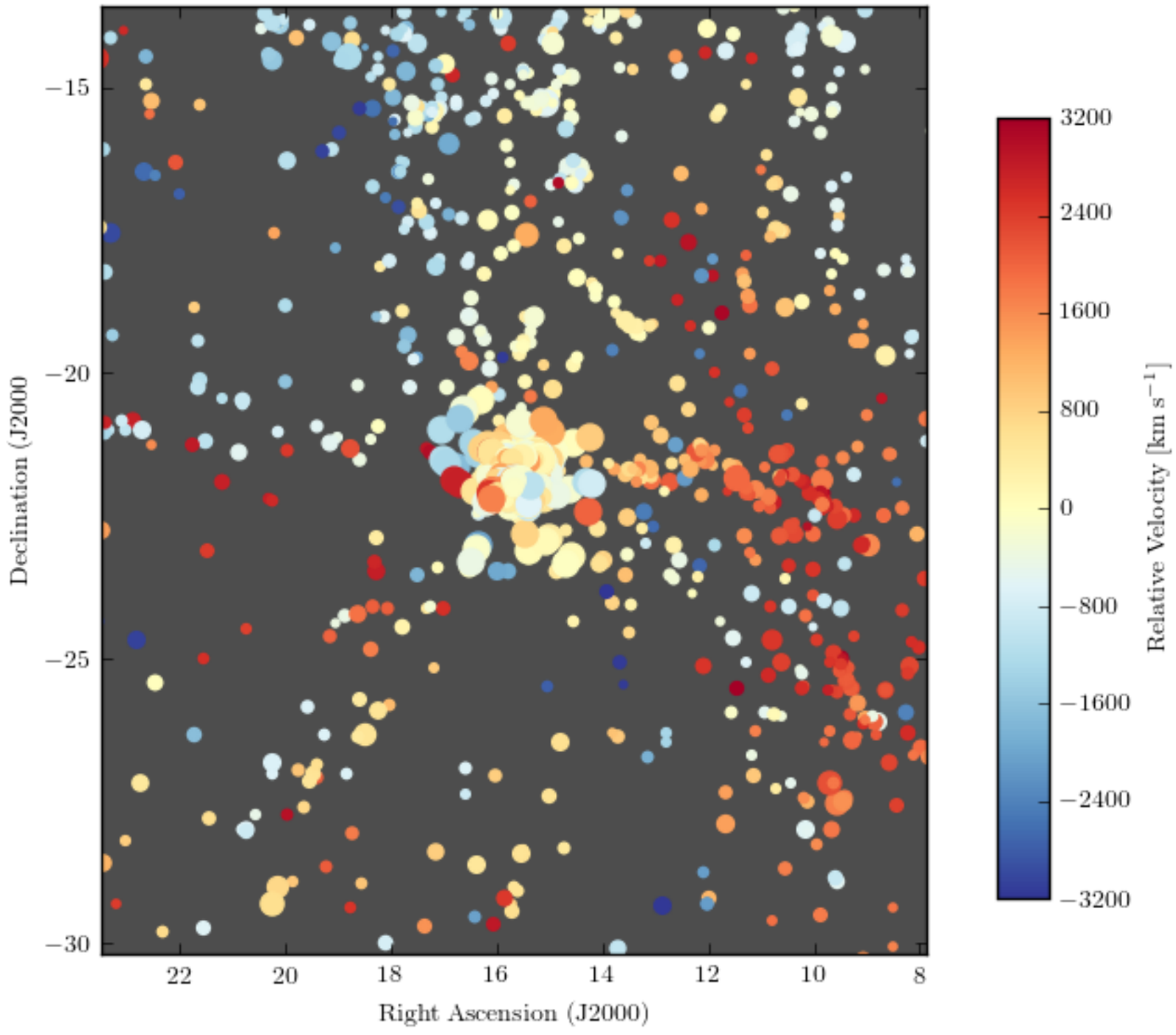

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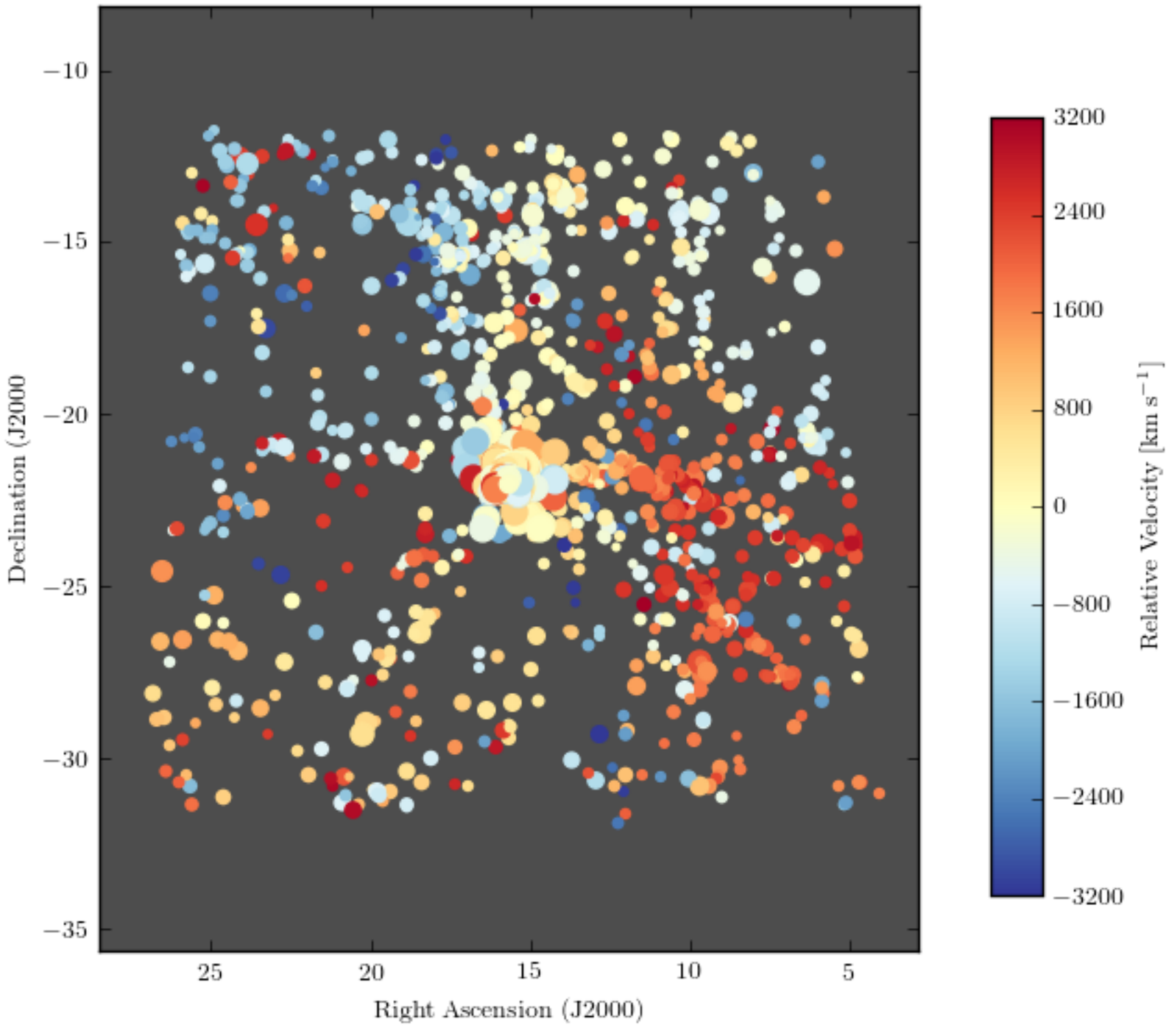
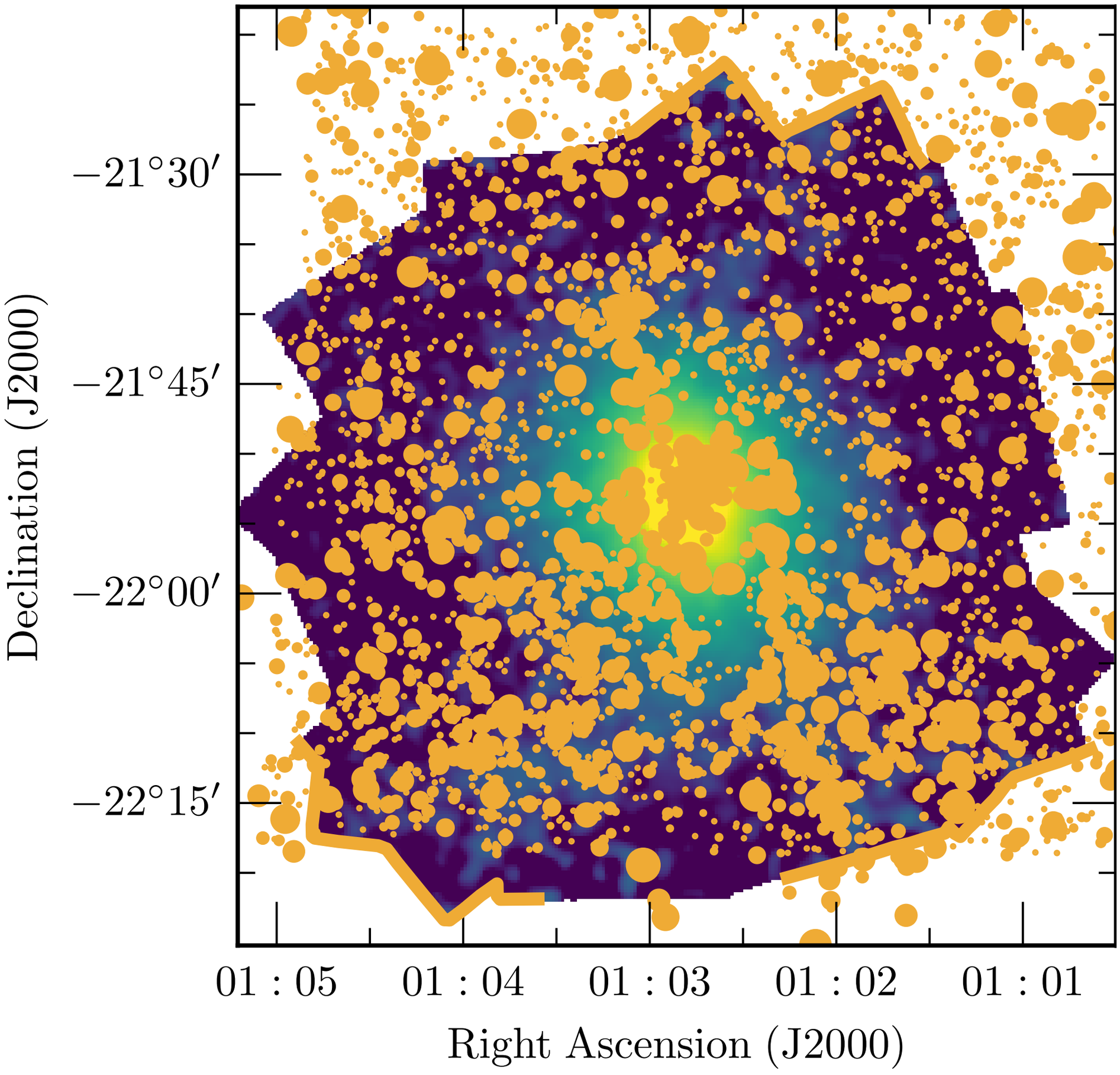


Connor et al. 2018

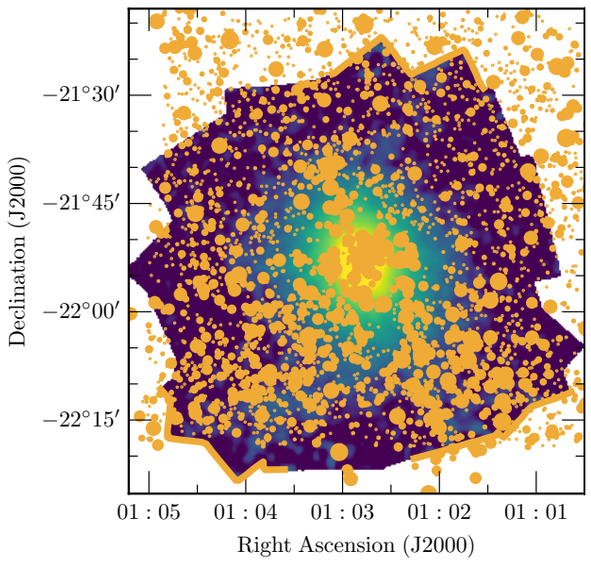
IMACS ABELL133 SPECTROSCOPIC SURVEY 1



Over 3000 new and archival redshifts

Connor et al. 2018

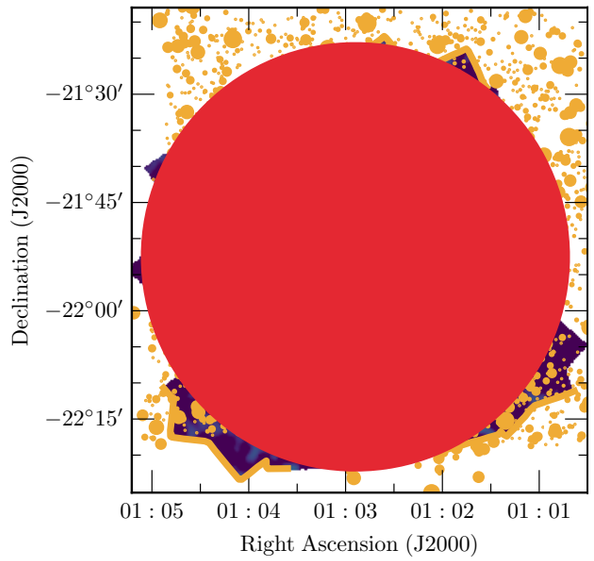
IMACS ABELL133 SPECTROSCOPIC SURVEY 2



Over 10000 new and archival redshifts

Connor et al. in prep

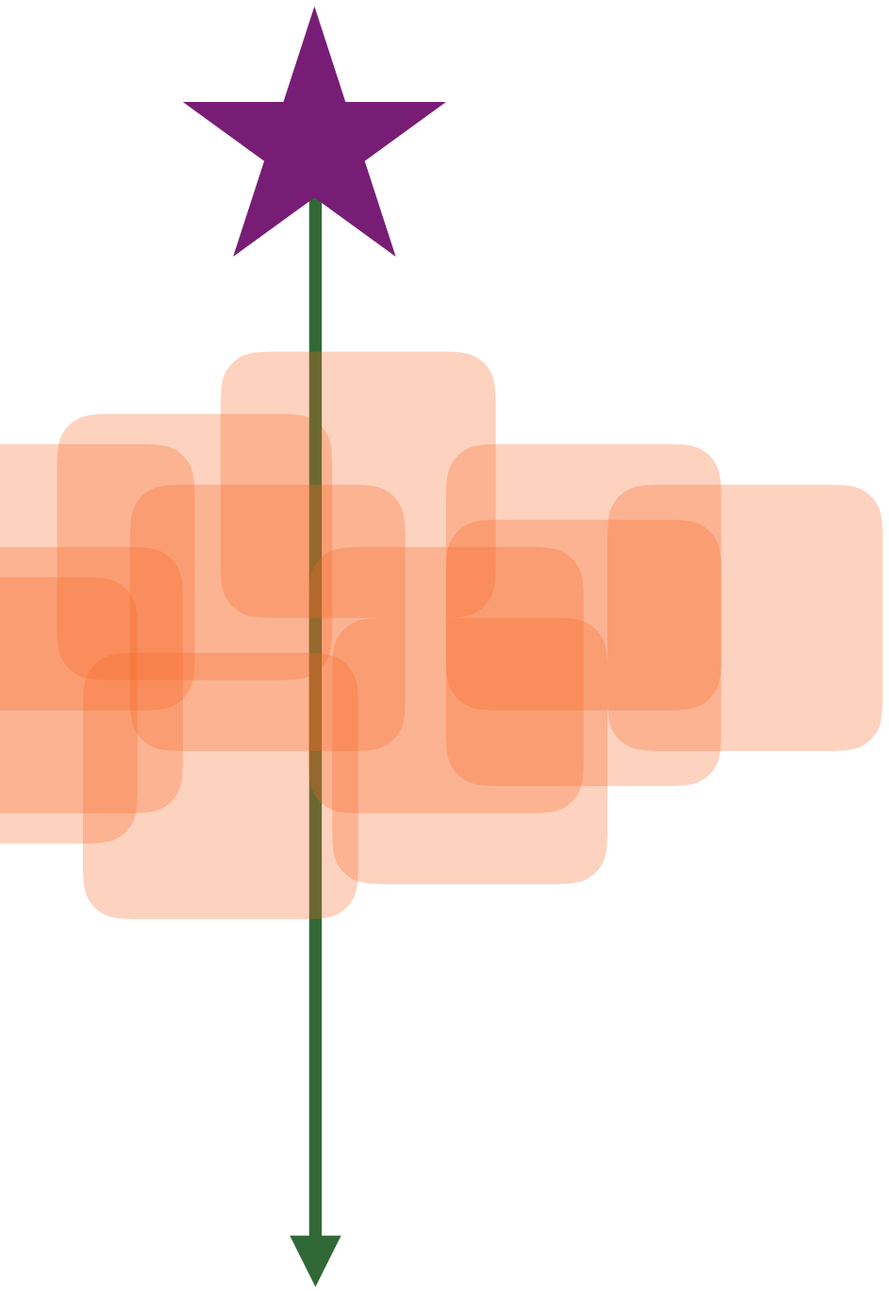
DUPONT ABELL133 SPECTROSCOPIC SURVEY

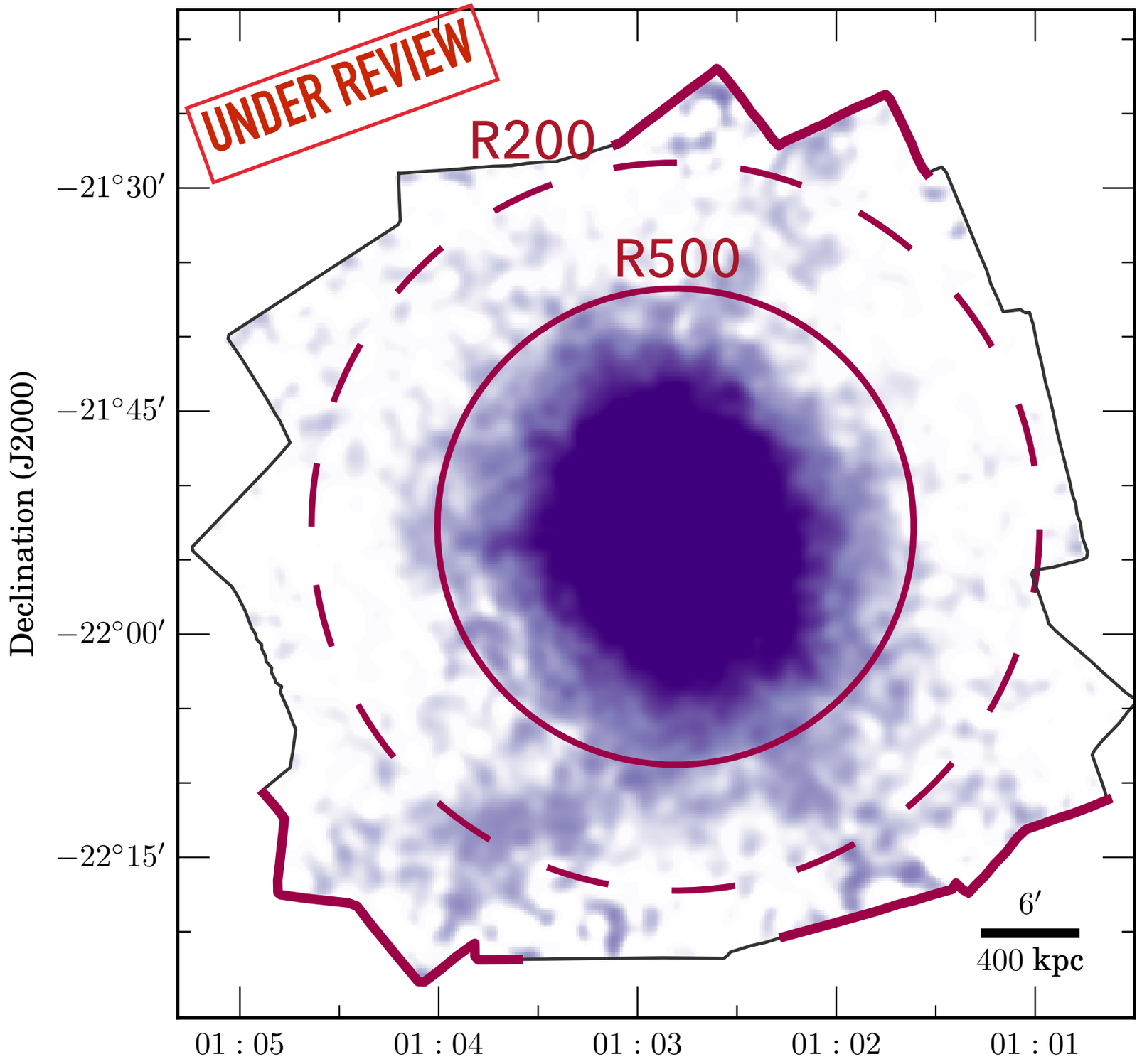


Complete survey of all r<20 mag galaxies in virial radius

Connor et al. in prep

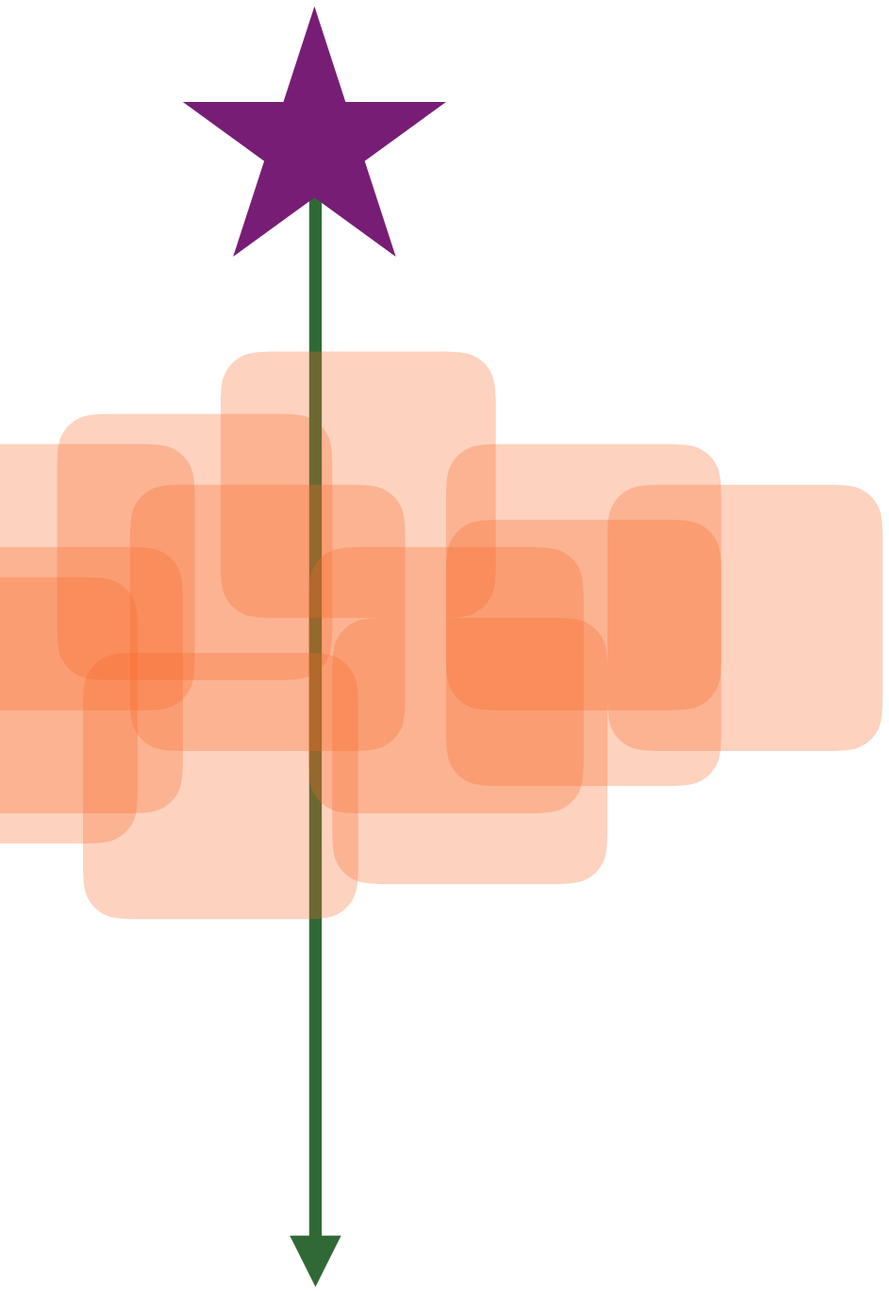
CONDITIONS OF THE FILAMENT

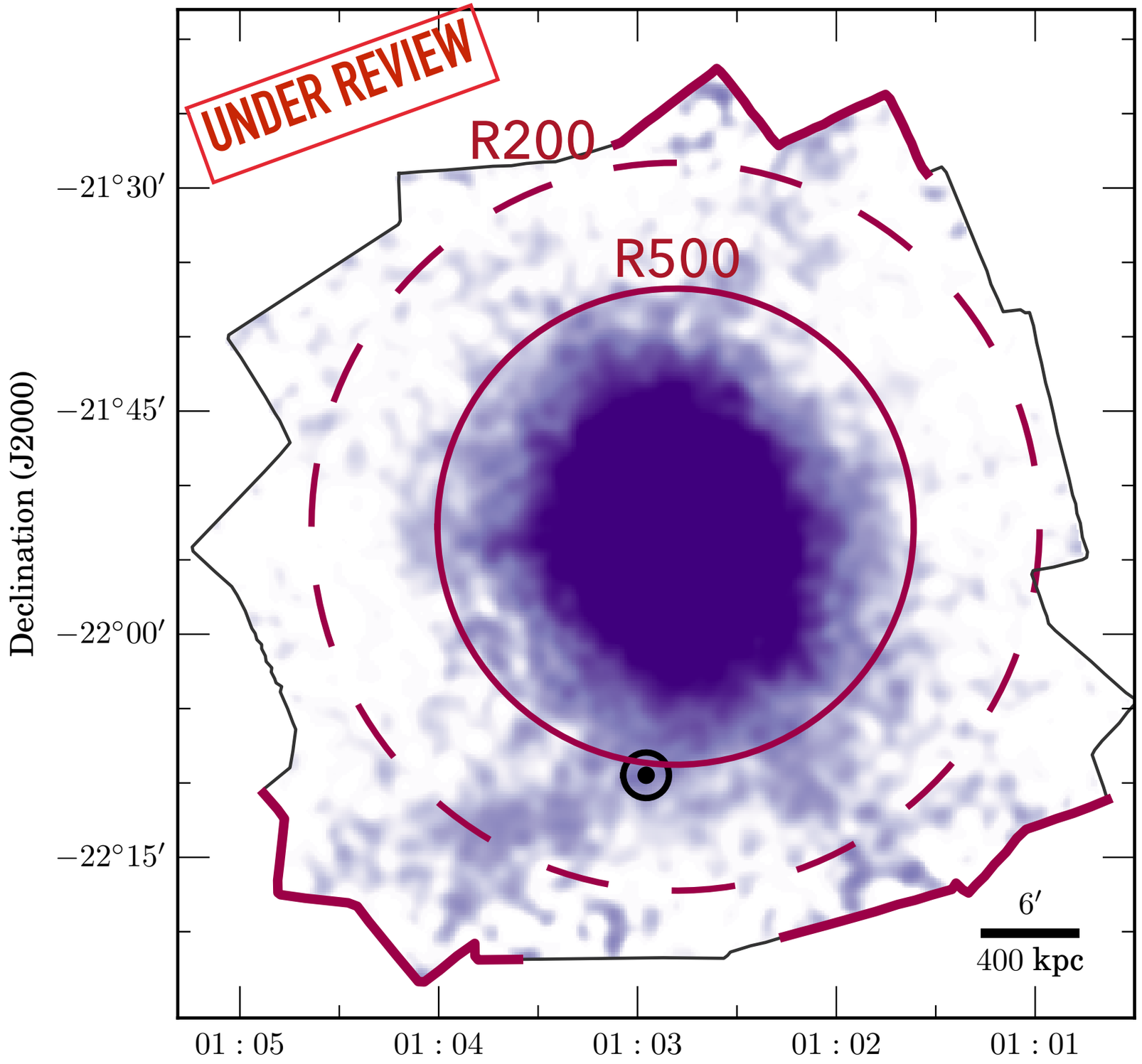




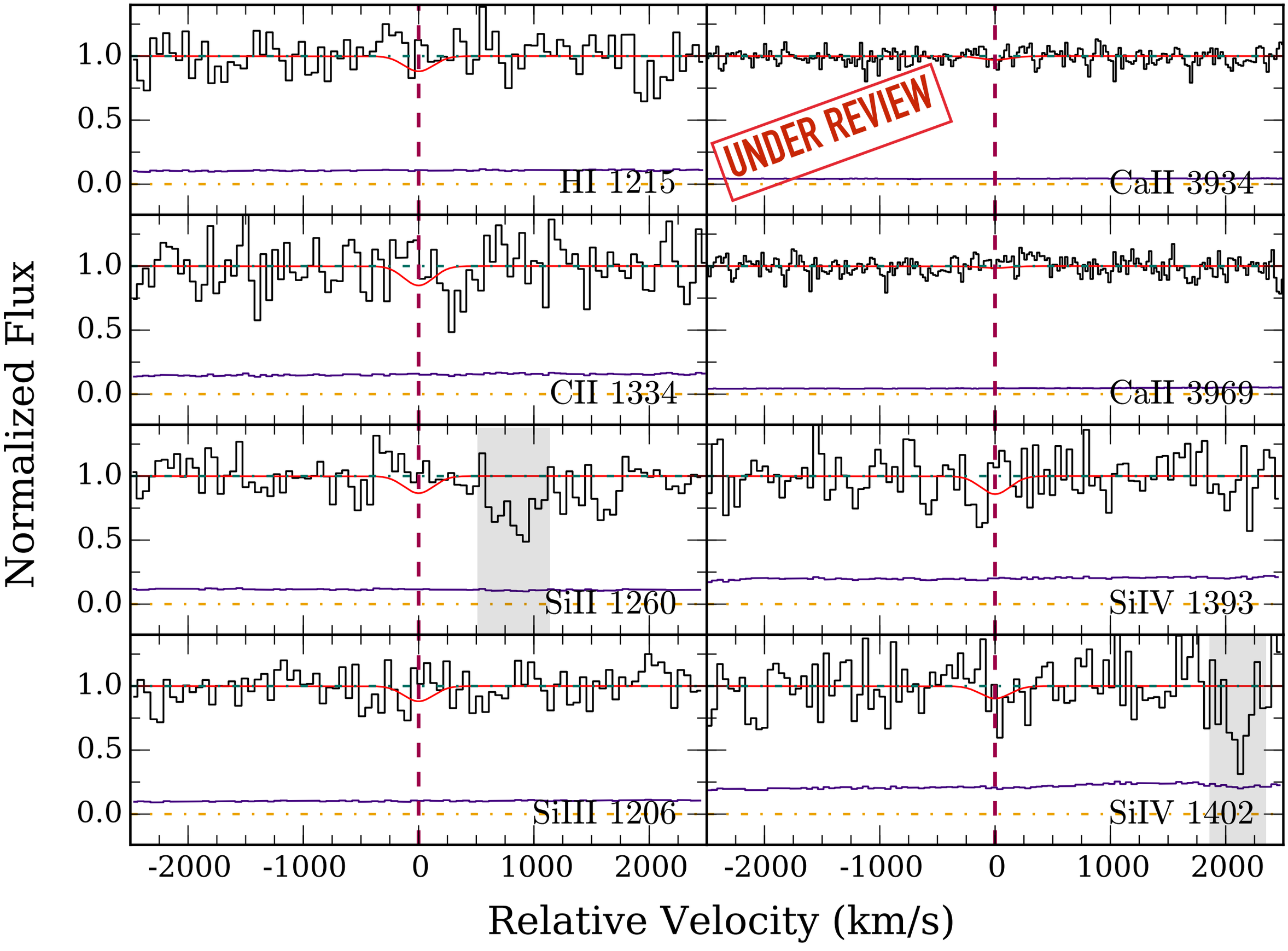
Connor et al. 2019c

CONDITIONS OF THE FILAMENT





Connor et al. 2019c



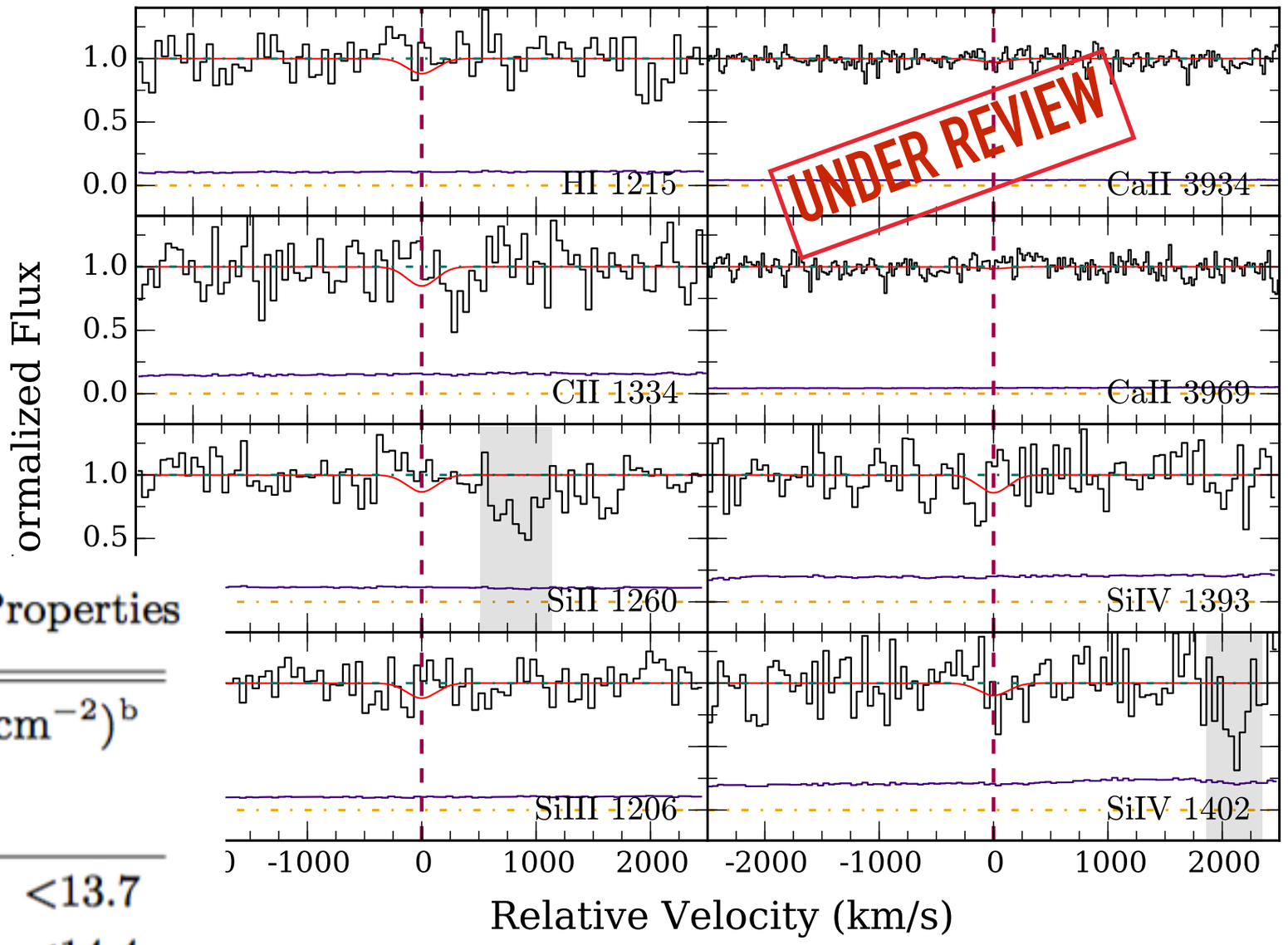
Connor et al. 2019c

Table 1. Constraints on Absorption Properties

Species	Transition (Å)	W_r[a] (mÅ)	$\log(N/\mathrm{cm}^{-2})$[b]
H I	1215	<160	<13.7
C II	1334	<238	<14.4
Ca II	3934	<127	<12.2
Si II	1260	<177	<13.4
Si III	1206	<153	<13.1
Si IV	1393	<231	<13.7

[a] All reported values are 2σ upper limits

[b] Converted from the upper limit on W_r assuming $b = 20$ km s^{-1}.



No HI absorption detected at this position

All cold gas heated this close to cluster?

Is the cold gas just clumpy?

Connor et al. 2019c

SUMMARY

We are entering the era of observing filaments of the Cosmic Web in X-ray emission

Abell 133 is the practice for this future

Redshift surveys needed to match the gaseous and galaxy components of the filaments

Filaments: 2 keV

Galaxies match X-rays

ABELL 133

Large-scale structure mapping underway

Limits on cooler gas from COS absorption lines