Effects of the ICM on the Magnetic Field of a Virgo Galaxy

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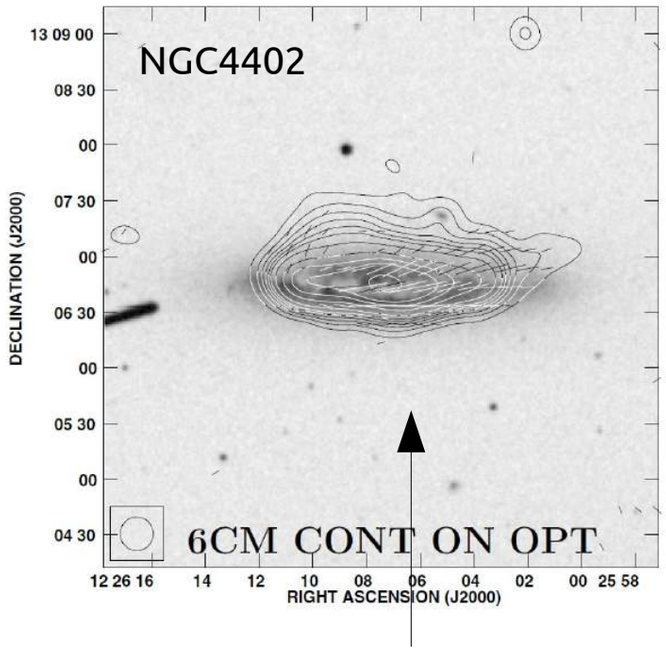
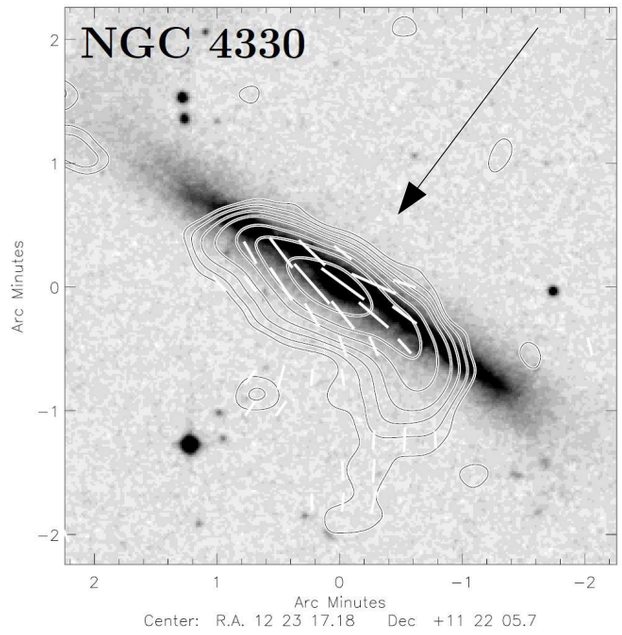
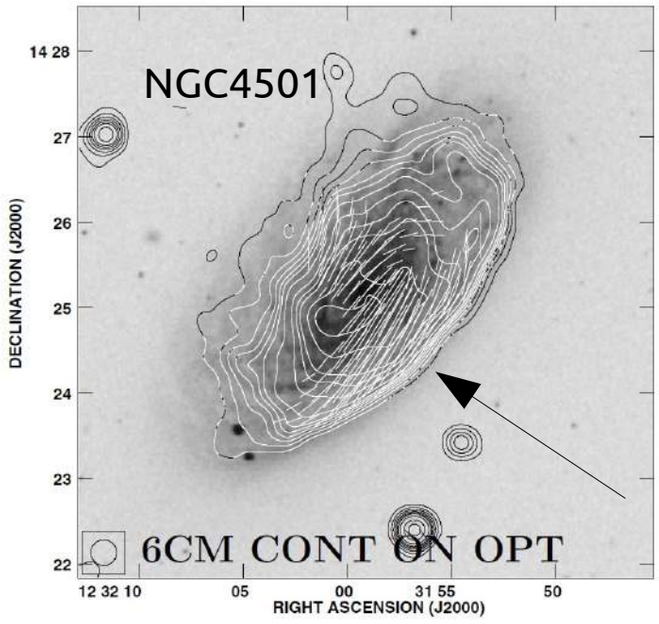
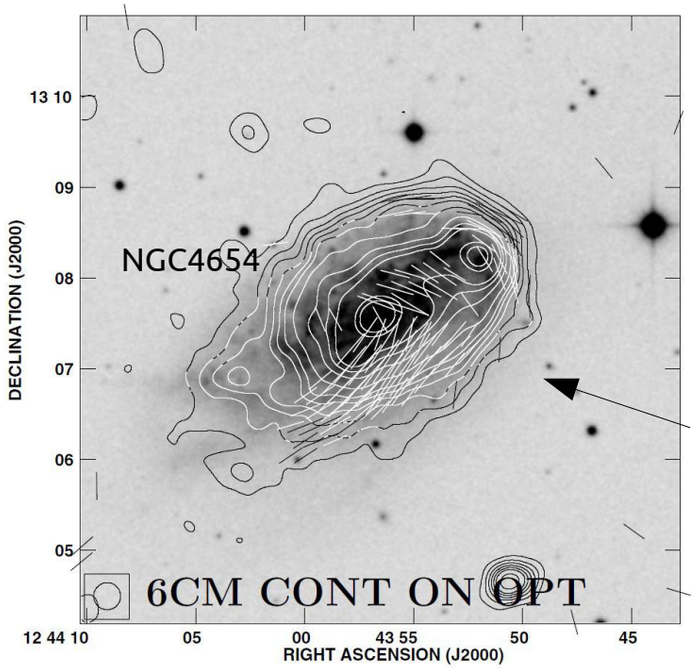
Ram pressure









Vollmer et al. 2013

Ram pressure: the action of the intracluster medium (ICM) on the spiral galaxies of a cluster.

- It removes gas from spirals and decreases their star formation rate.

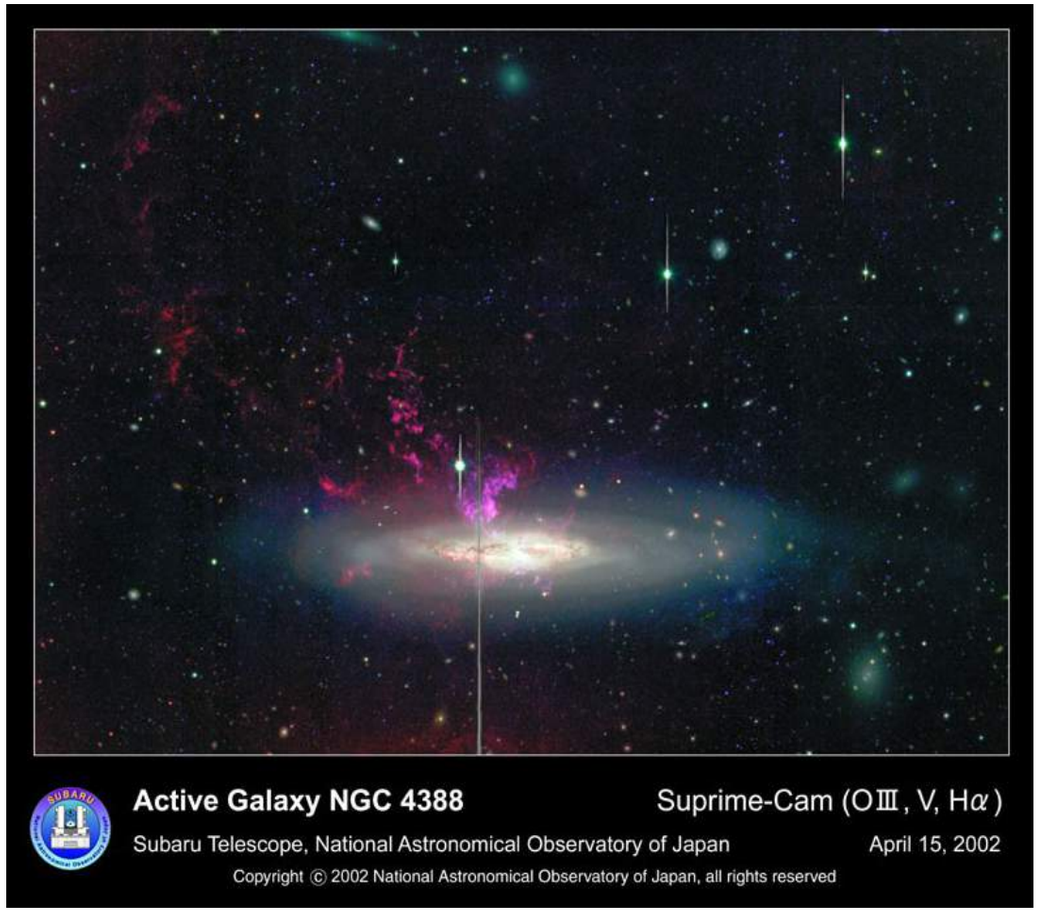
- There is an enhancement of the global magnetic field due to the action of **ram pressure.**

NGC 4388

- Seyfert-2 Sb-type galaxy therefore, it hosts an AGN.

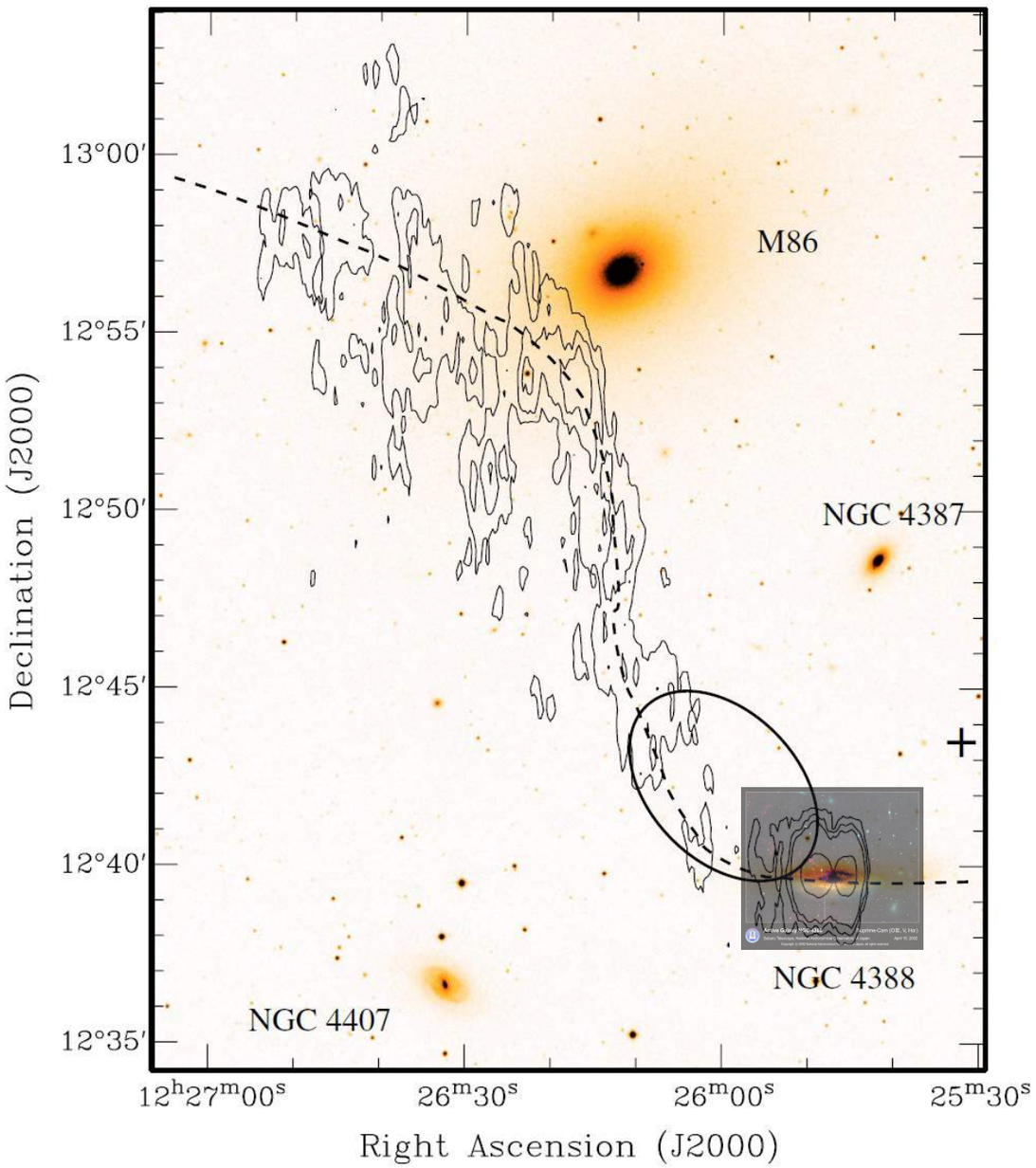
- Close to the cluster core (only 1°.3 from Virgo A).

- Poor content of HI due to interaction (it has lost 85 % of its HI).



Yoshida et al. 2004

NGC 4388



Oosterloo et al. 2008

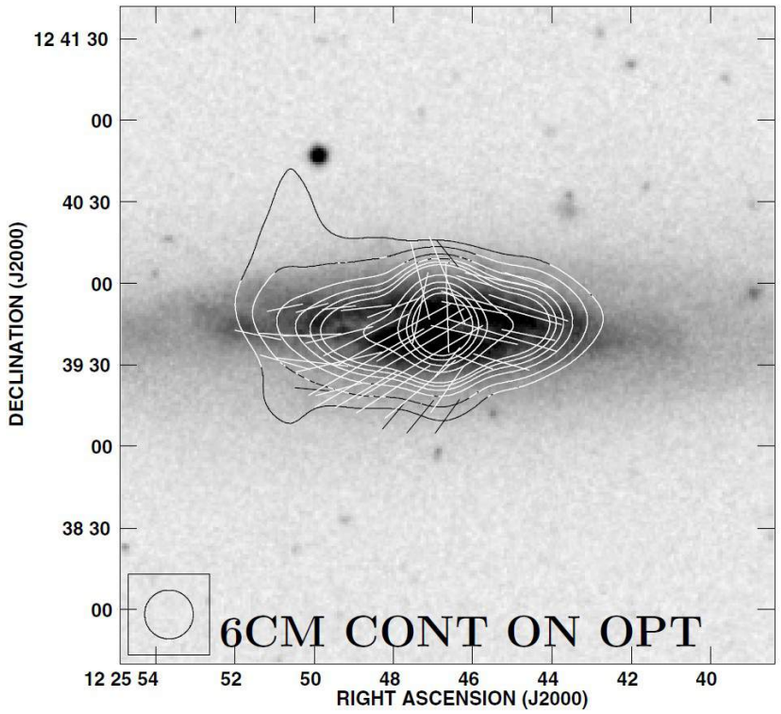
- Moving at 1500 km/s
- Ionized Hα region extending 35 kpc off the galactic plane.
- X-ray emission out to 16 kpc in a similar position as the ionized gas.

ISM strongly affected by the passage through the cluster.

NGC 4388 - New EVLA observations

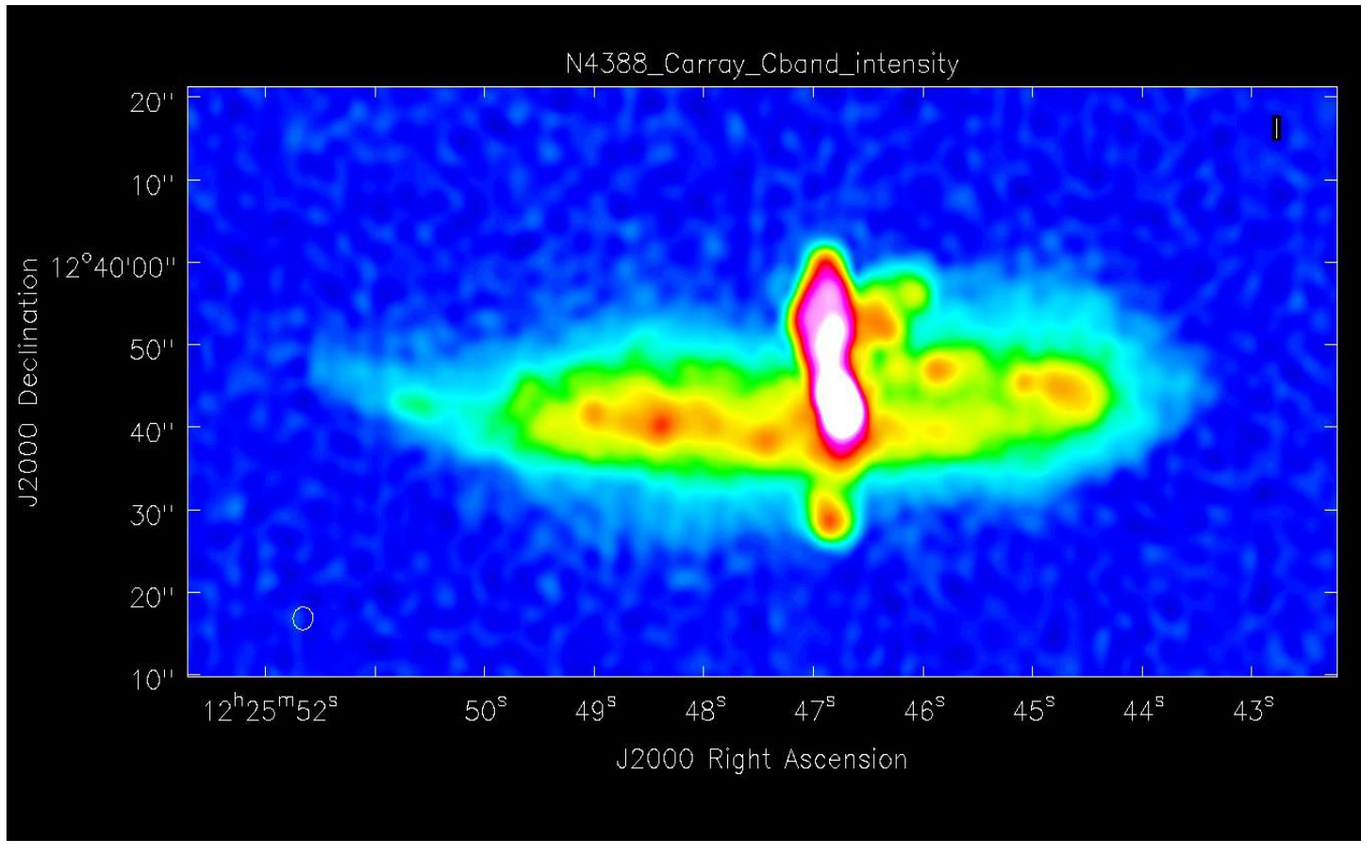
EVLA observations from the CHANG-ES survey at 6 GHz

Total intensity



Total intensity from VLA (Vollmer 2010)

$$\mathrm{rms} = 60\,\mu\mathrm{Jy/beam}$$



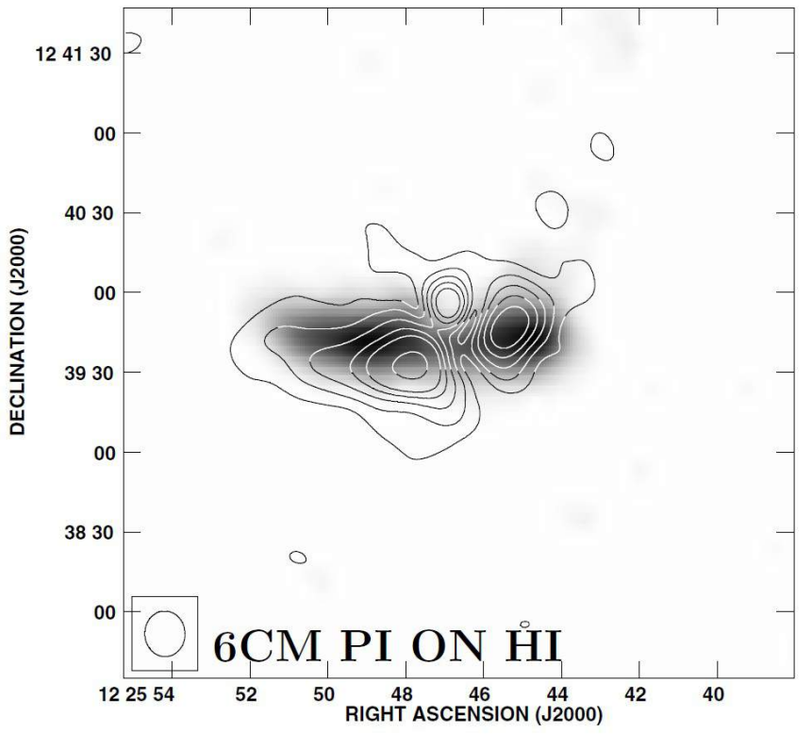
Total intensity from EVLA (Damas-Segovia et al. in prep.)

$$\mathrm{rms} = 6\,\mu\mathrm{Jy/beam}$$

NGC 4388 - New EVLA observations

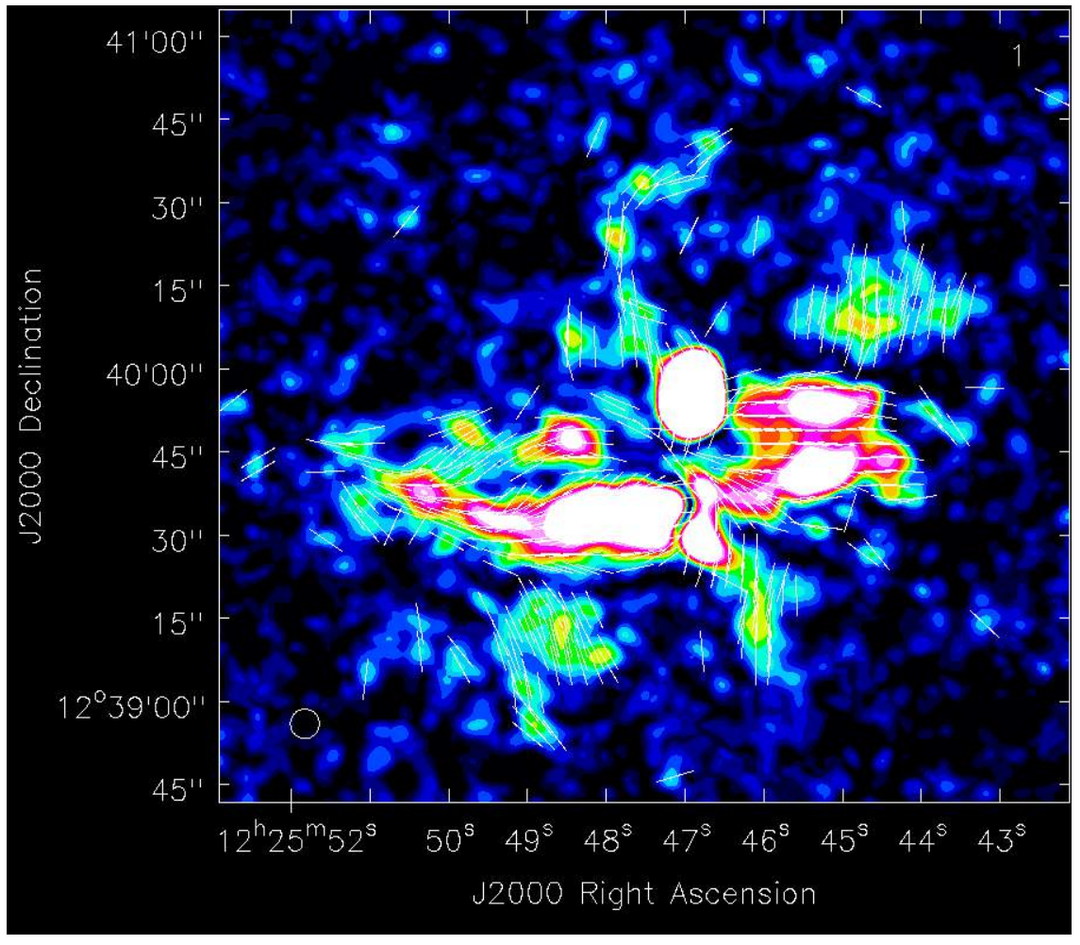
EVLA observations from the CHANG-ES survey at 6 GHz

Polarization



Polarized emission from VLA (Vollmer 2010)

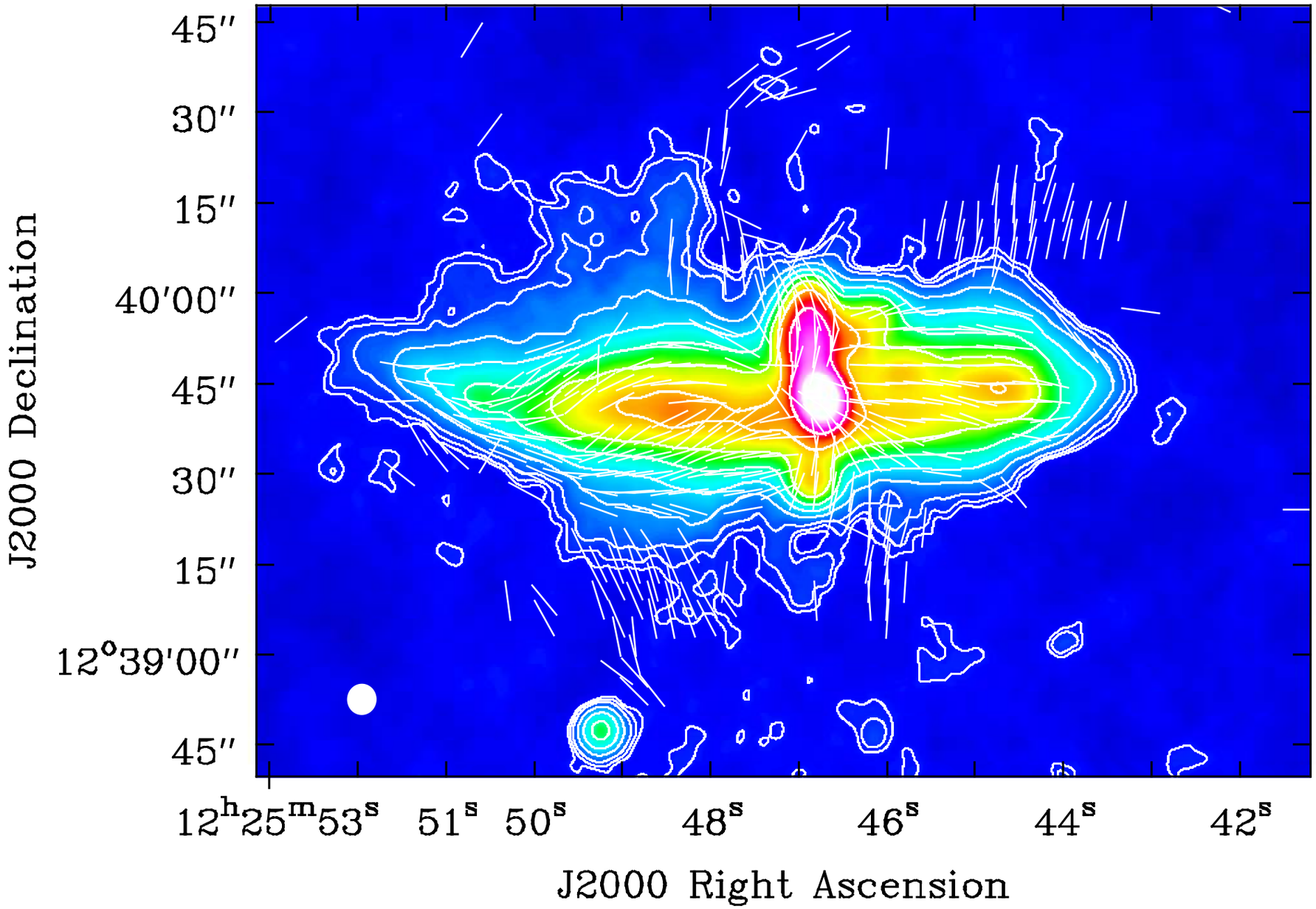
$$\mathrm{rms} = 10\,\mu\mathrm{Jy/beam}$$



Polarization with RM-synthesis (Damas-Segovia et al. in prep.)

$$\mathrm{rms} = 1\,\mu\mathrm{Jy/beam}$$

NGC 4388 - New EVLA observations



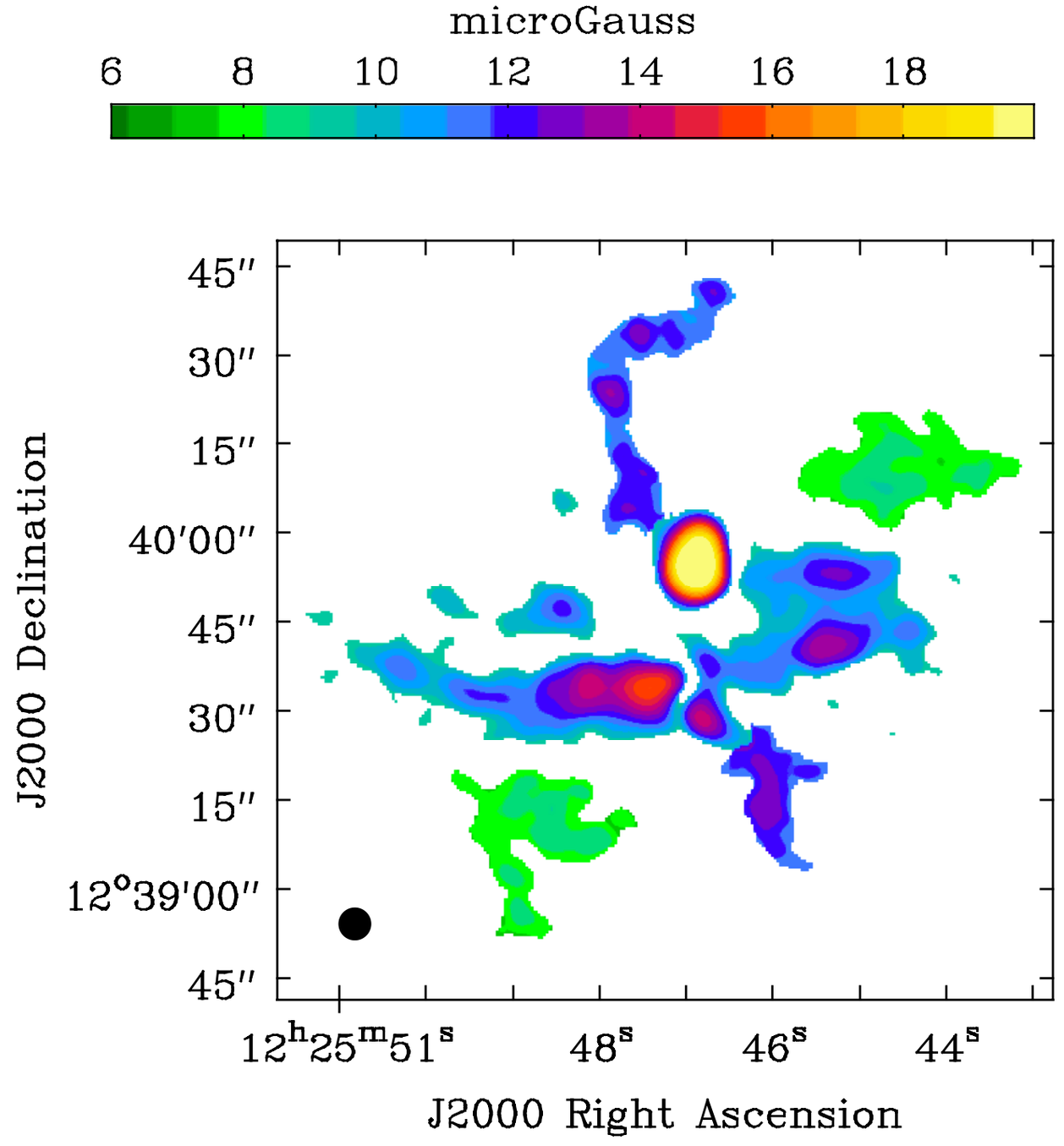
Total intensity combining C and D array configurations

$\mathrm{rms} = 3.5\,\mu\mathrm{Jy/beam}$

NGC 4388 - Magnetic Field Strengths

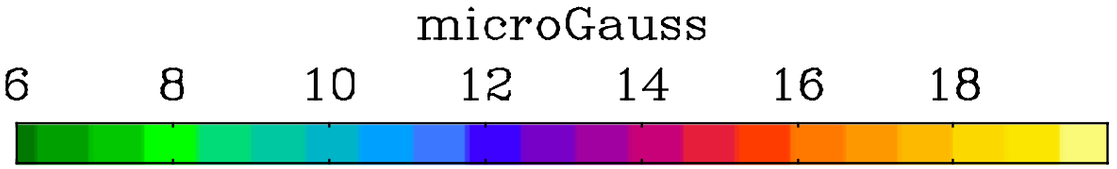
Total magnetic field computed from revised formula of equipartition (Beck and Krause, 2005)

	B_{ord} (μG)	B_{tot} (μG)
Inner outflow N	-	67
Outer outflow N	23	45
Outflow S	14	30
Arm/disk SE	16	23
Arm/disk NW	13	21
Blob NW	9	12 [b]
Blob SE	9	12 [b]
Arc N	13	-
Arc S	13	-



Ordered magnetic field

NGC 4388 - Total Magnetic Field Strength

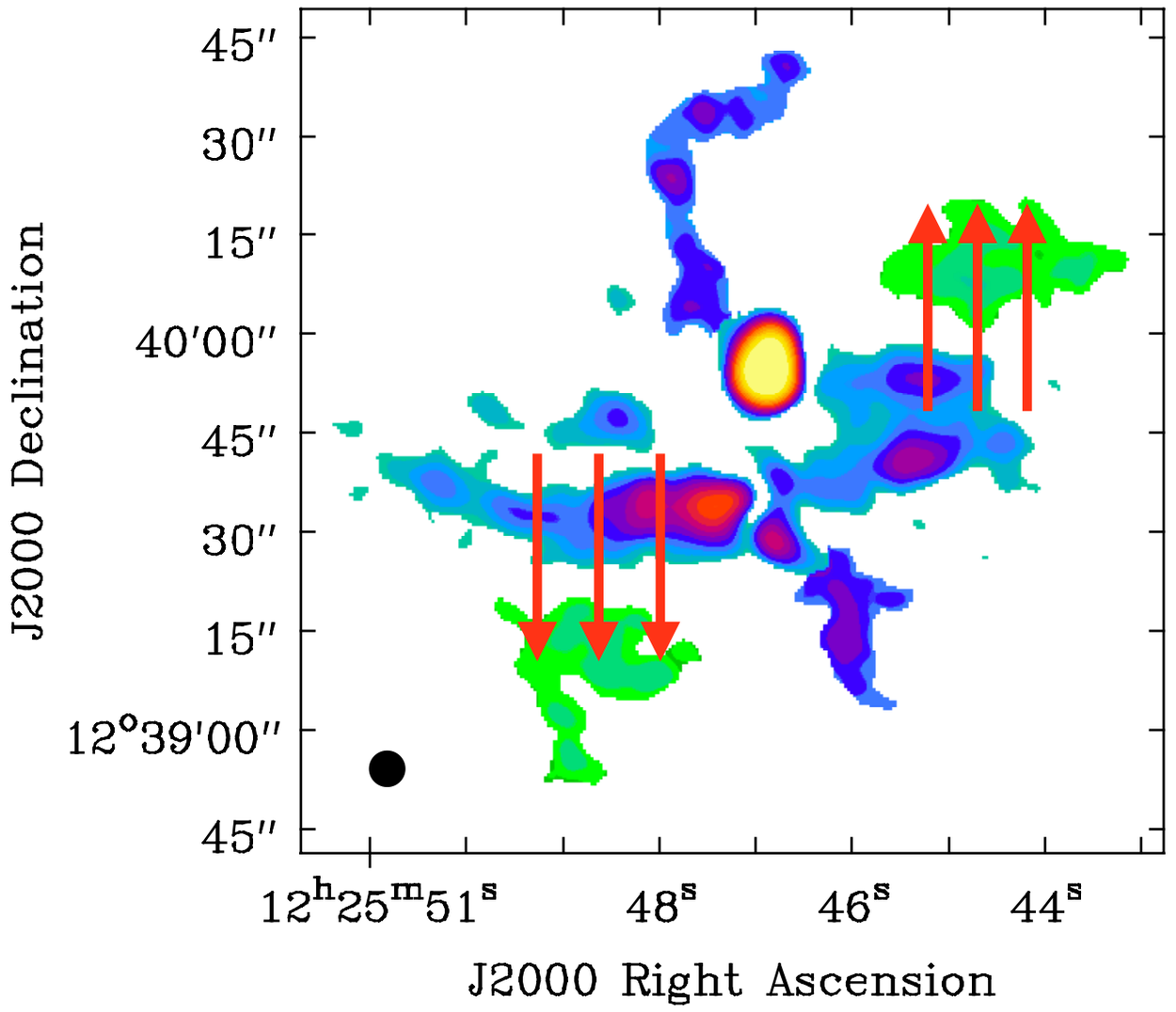


Synchrotron life time for an electron that travels from spiral arm to polarized blobs:

$$t_{syn} = 1.06 \times 10^9 \,\mathrm{yr} \cdot \left(\frac{B}{\mu G}\right)^{-\frac{3}{2}} \left(\frac{\nu}{GHz}\right)^{-\frac{1}{2}} \simeq 10.4\,\mathrm{Myr}$$

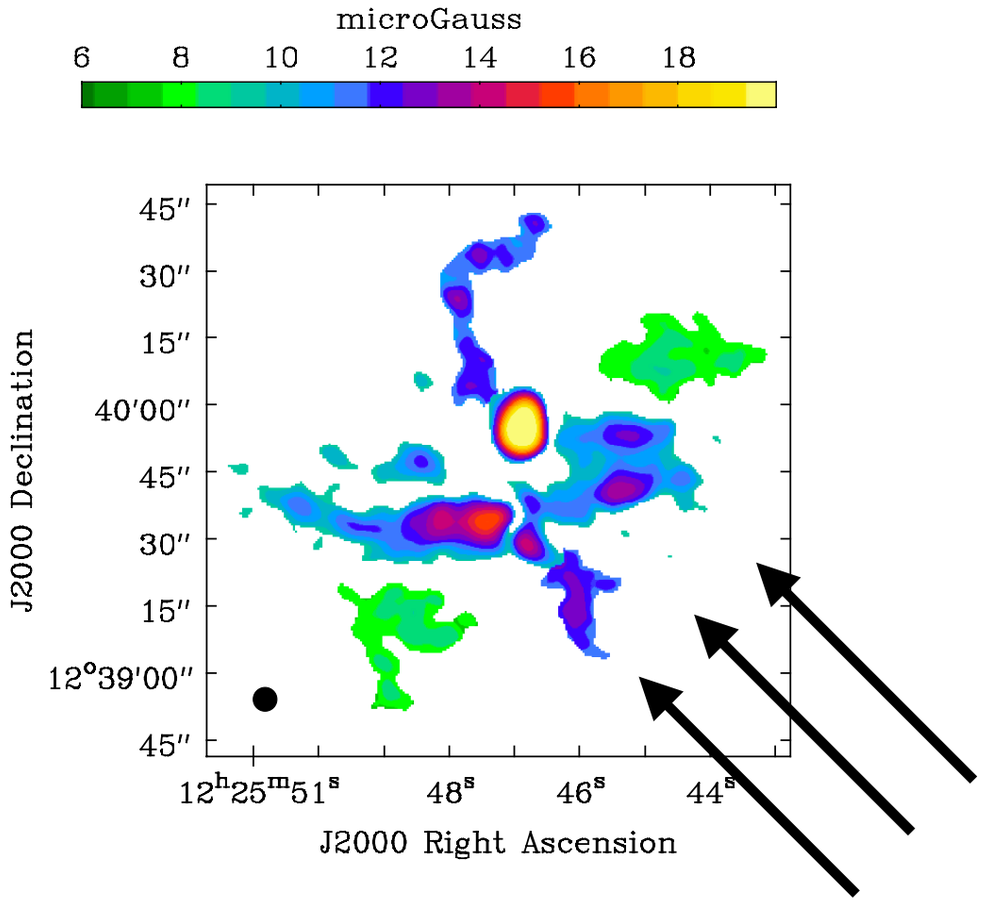
$$v \approx 300\,\mathrm{kms}^{-1}$$

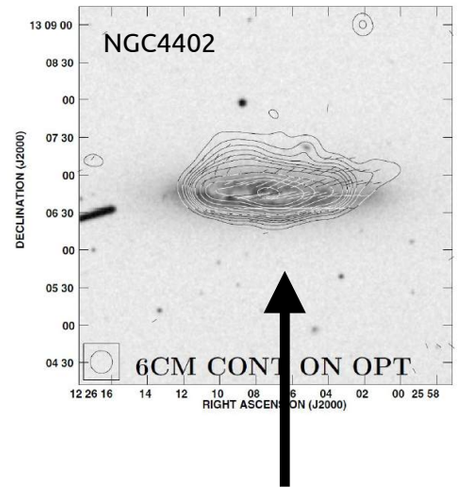
Typical velocity for galactic winds

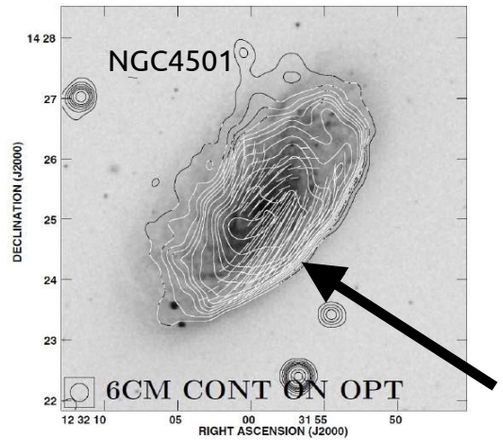


Ordered magnetic field

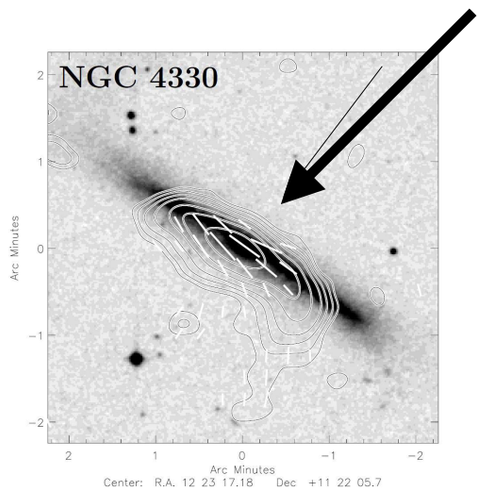
NGC 4388 - Total Magnetic Field Strength





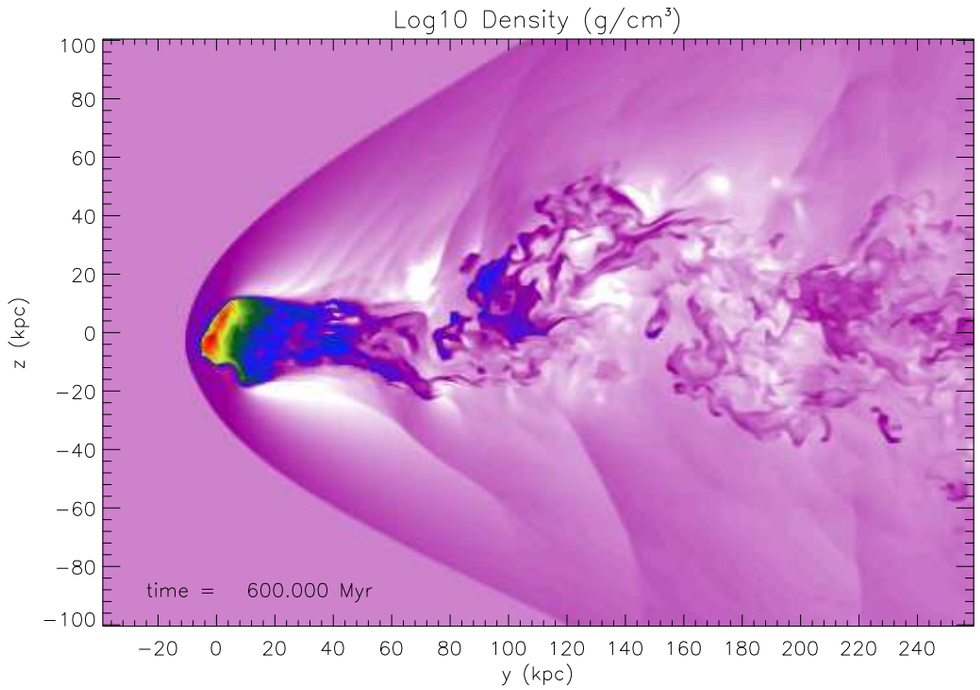


Ram pressure does not affect NGC 4388 like it does in other galaxies. It should remove all features we see in the southern part of the halo.



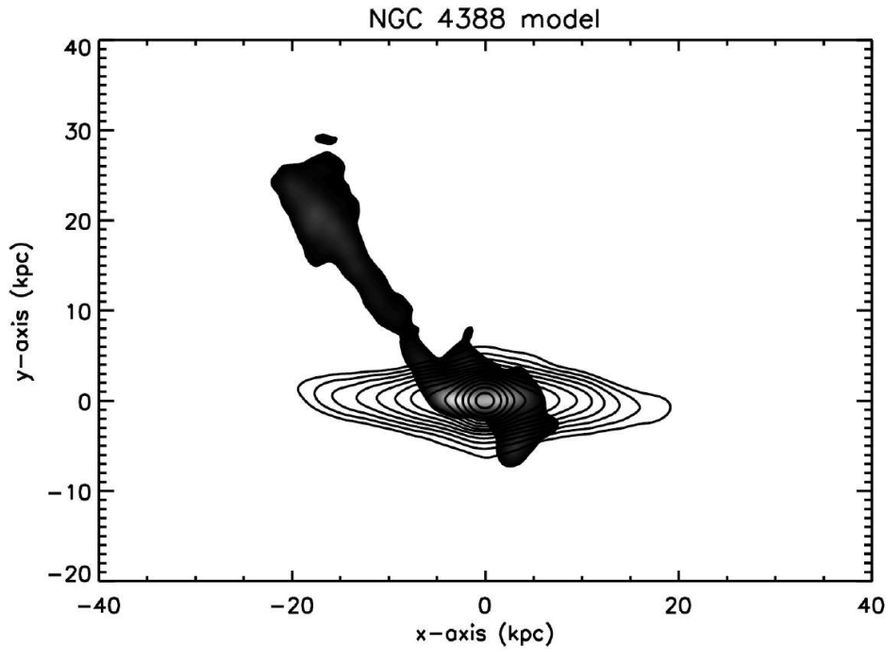
NGC 4388 - Models vs Observations

HD model



Roediger et al. 2006

Sticky particles model



Vollmer et al. 2003

Models predict a ram-pressure of $1.67 \times 10^{-11}\,\mathrm{erg\,cm^{-3}}$

To resist against ram pressure → $B \geq \sqrt{8\pi P_{\mathrm{ram}}} \sim 20\mu G$

NGC 4388 - Models vs Observations

Observations: $12\,\mu\mathrm{G}$ Models: $20\,\mu\mathrm{G}$

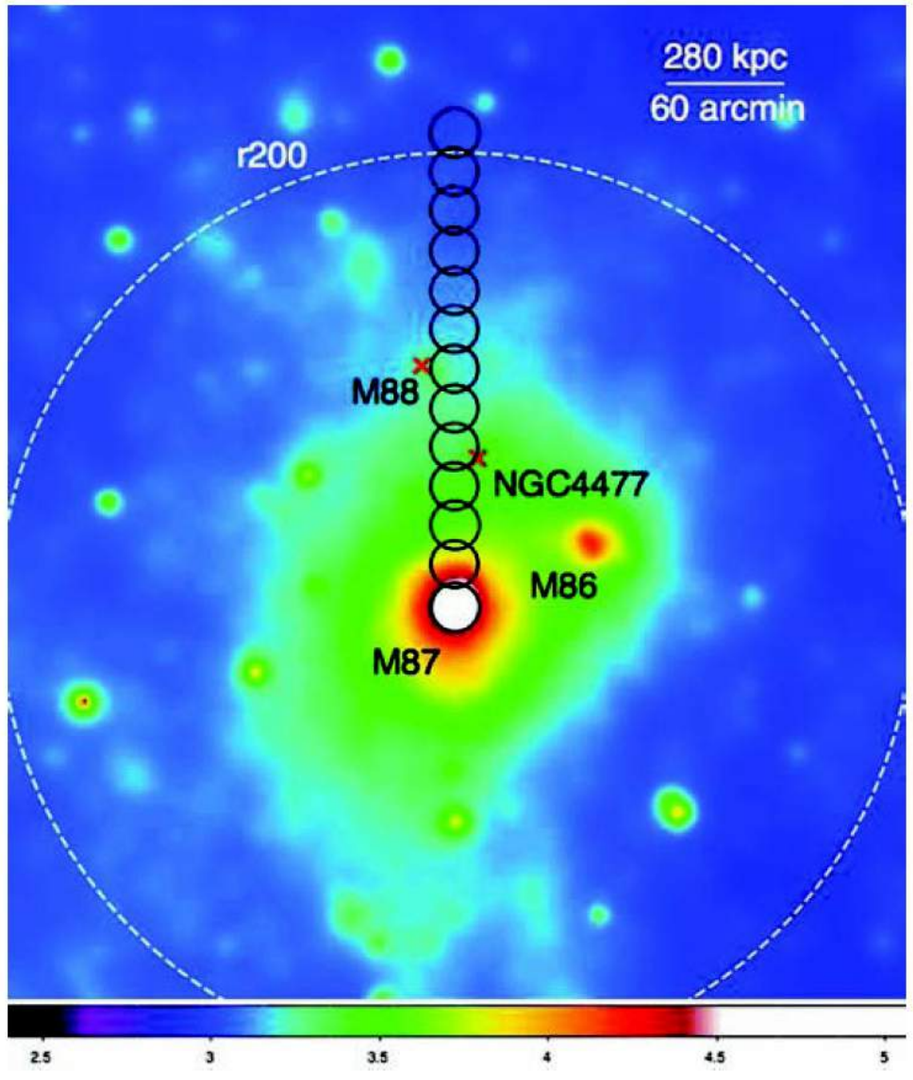
Two possible explanations to obtain at least $20\,\mu\mathrm{G}$

- Energy losses of CRE may be large: K ratio between proton and electron is >>100.
- Equipartition is not valid out in the halo.

↓

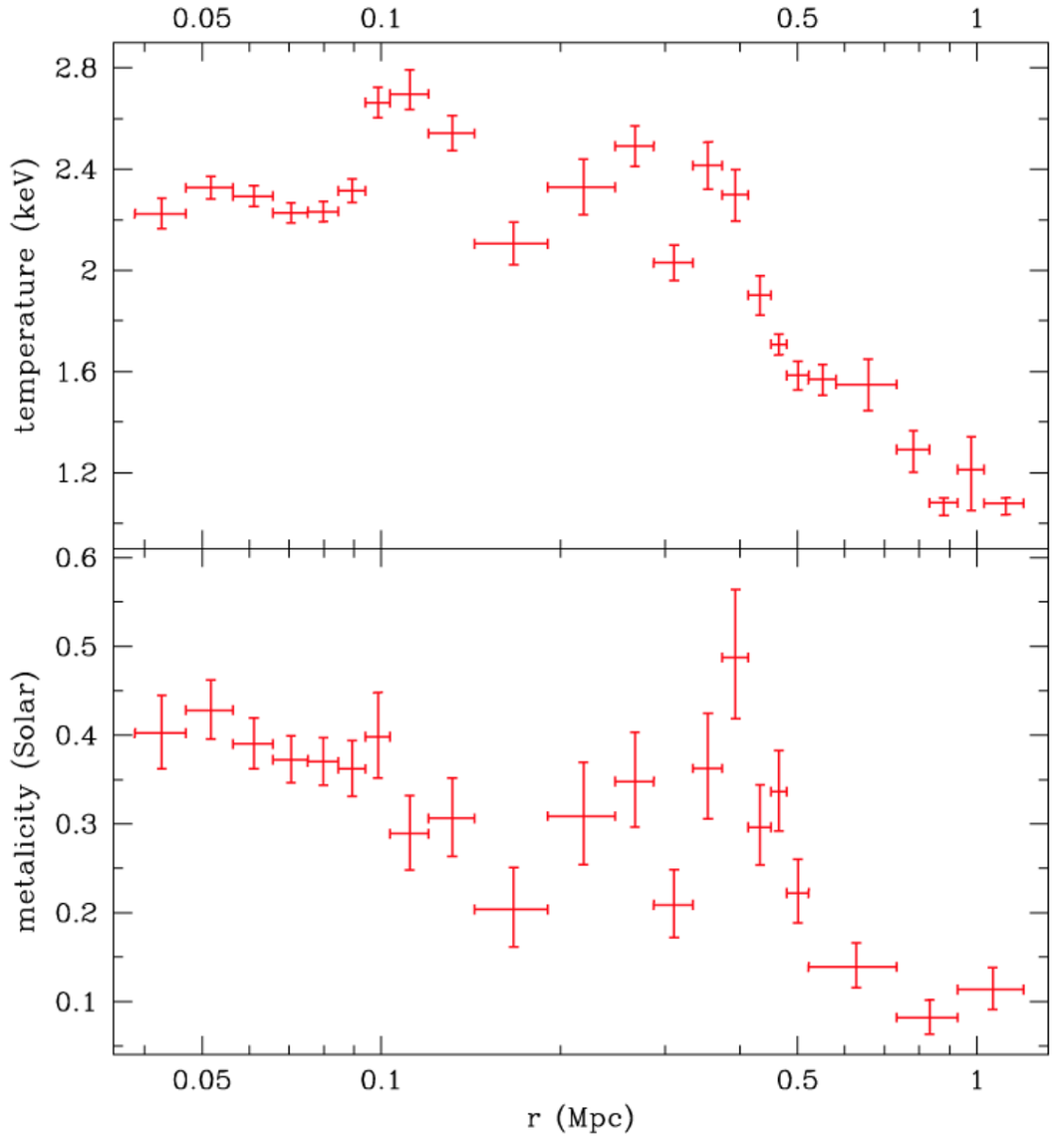
Unreasonably high speed for a galactic wind $\mathrm{v} \sim 600\,\mathrm{kms}^{-1}$

NGC 4388 - Models vs Observations



XMM-Newton image (0.5-2.0 keV) image of the Virgo cluster

(Urban, O. et al. 2011)



Change in temperature and metallicity of the ICM at 450 kpc of the center

Conclusions

- Polarization observations of CHANG-ES show for the first time the **southern outflow** of NGC4388.

- RM-synthesis **reaching very high signal to noise (1 muJy/beam)** shows **extensions of both nuclear outflows out to ~ 5 kpc.** These features contradict current models for this galaxy.

- We claim that the blobs seen in polarization are **galactic winds** driven by star formation in the spiral arms with speeds of ~ **300 km/s**.

- Probably models overestimate the ram pressure at the present time due to the **non-homogeneous** phase of the Virgo cluster beyond ~ **450 kpc**.