

Rotation measure asymmetry reveals a precession of the AGN outflow in a Seyfert galaxy

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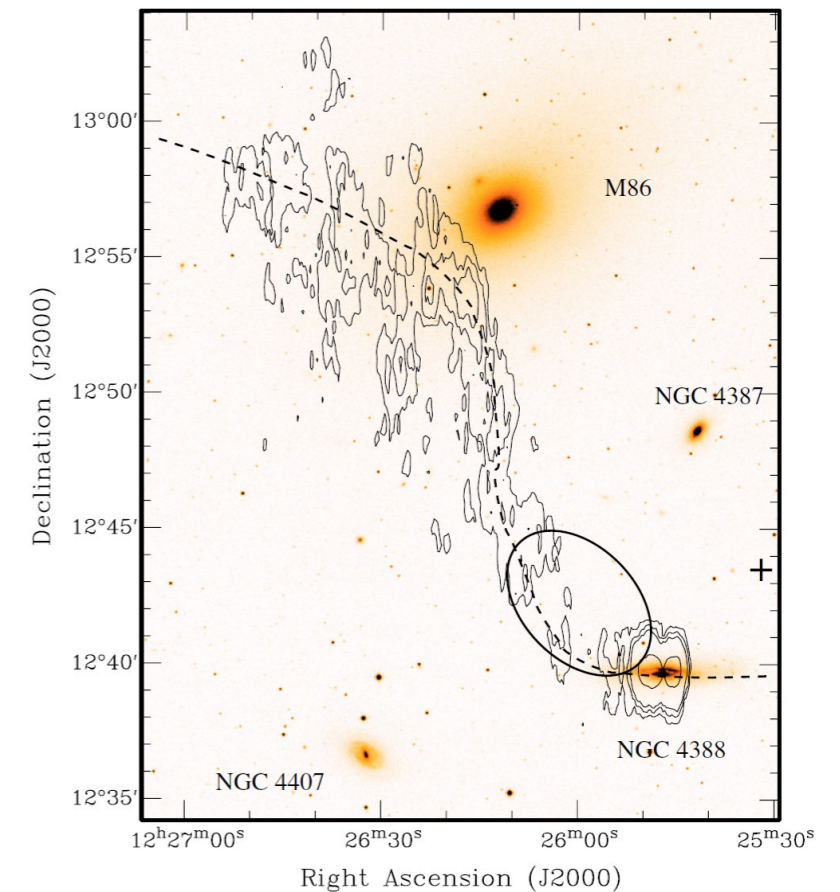


Max-Planck-Institut
für Radioastronomie

Yoshida et al. 2004



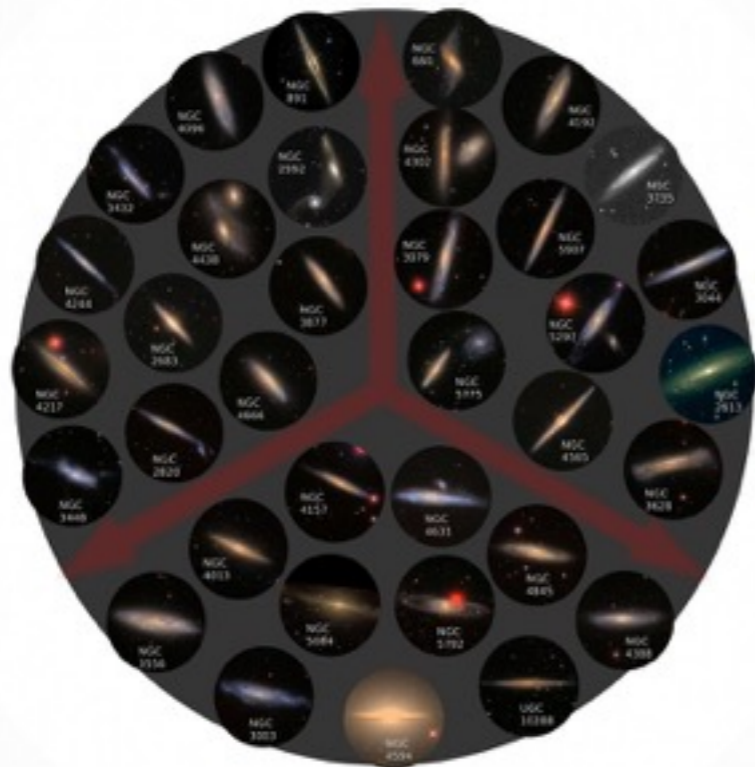
Oosterloo et al. 2008



- Seyfert-2 Sb-type galaxy.
- Moving at 2000 km/s
- Poor content of HI due to interaction (it has lost 85 % of its HI).
- Ionized H α 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.

CHANG-ES
Continuum
HALos in
Nearby
Galaxies
- an
EVLA
Survey



EVLA
Expanded
Very
Large
Array

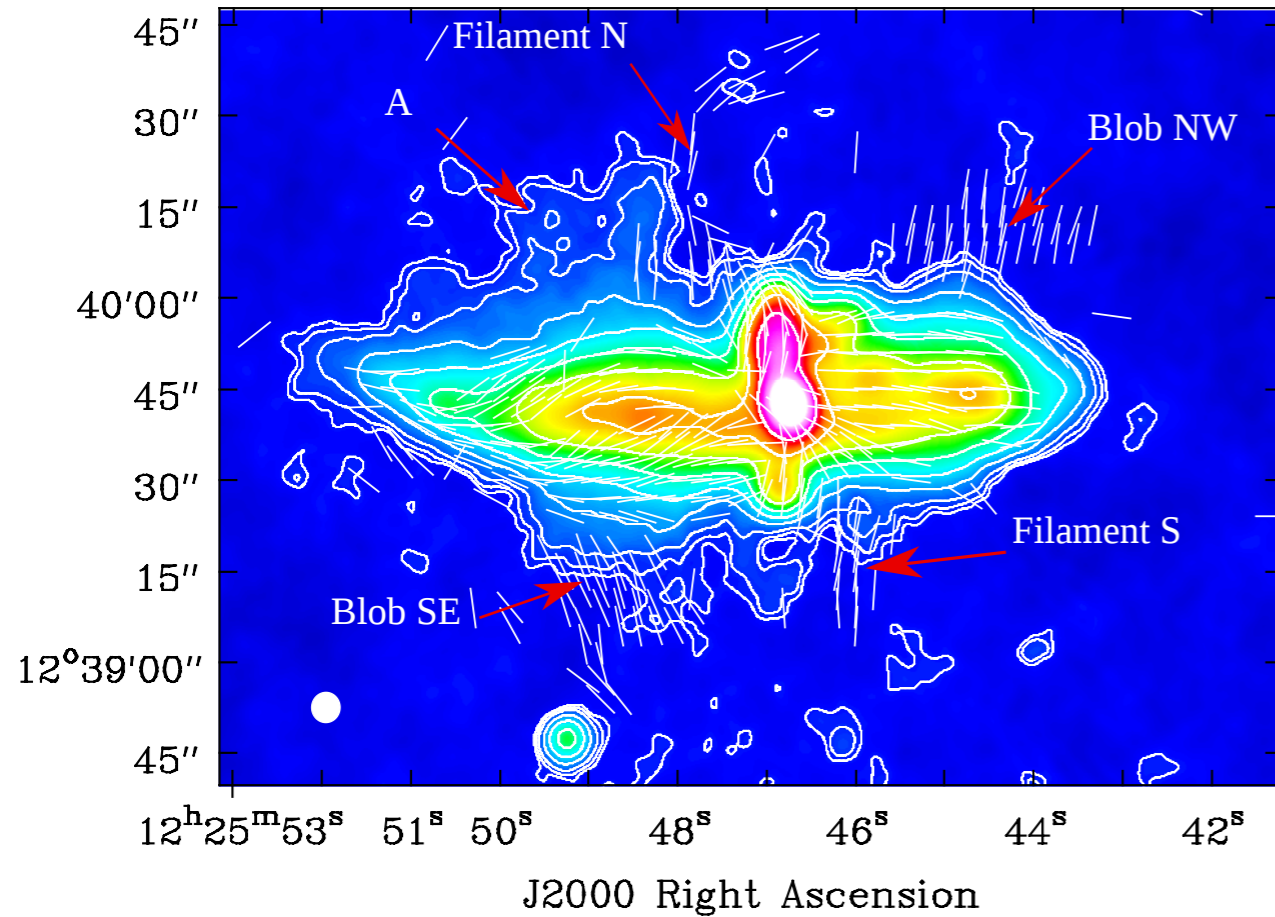


Optical Image credit: SDSS, DSS, CFHT Hawaiian Sky, ESOVIMOS, CTIO AstroDon.

CHANG-ES survey:

- 35 edge-on galaxies observed with the EVLA
- L band (1.0 - 2.0 GHz) and C band (4.0 - 8.0 GHz)
- B, C, and D array configuration of the EVLA
- Full stokes polarization

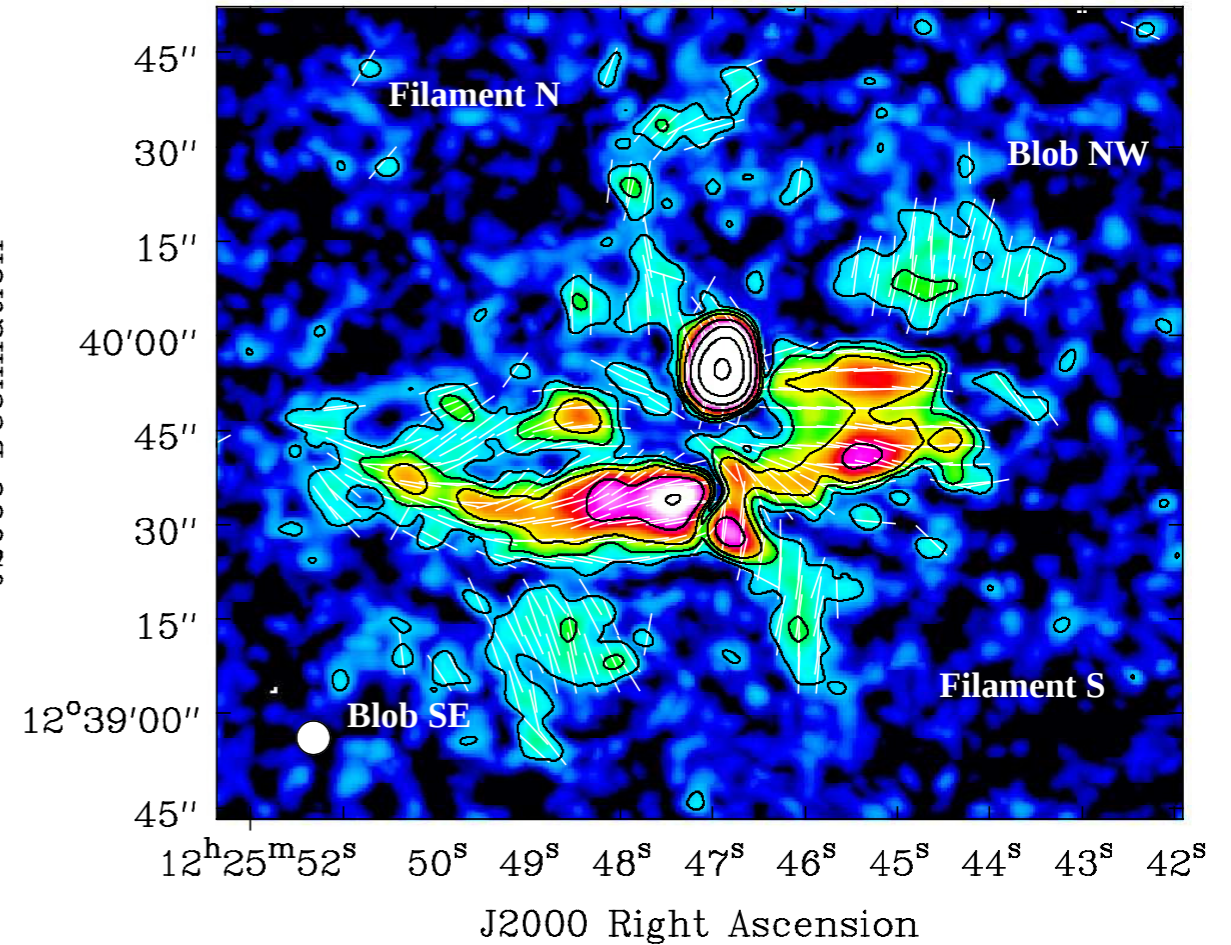
CHANG-ES C-band observations reveal new features in the radio halo of this galaxy.



Total intensity of C band (4.0 - 8.0 GHz) combining C and D array configurations with magnetic field lines

rms = $3.5 \mu\text{Jy}/\text{beam}$

resolution ~ 5 arcsec



Polarization intensity of C band (4.0 - 8.0 GHz) with the C configuration

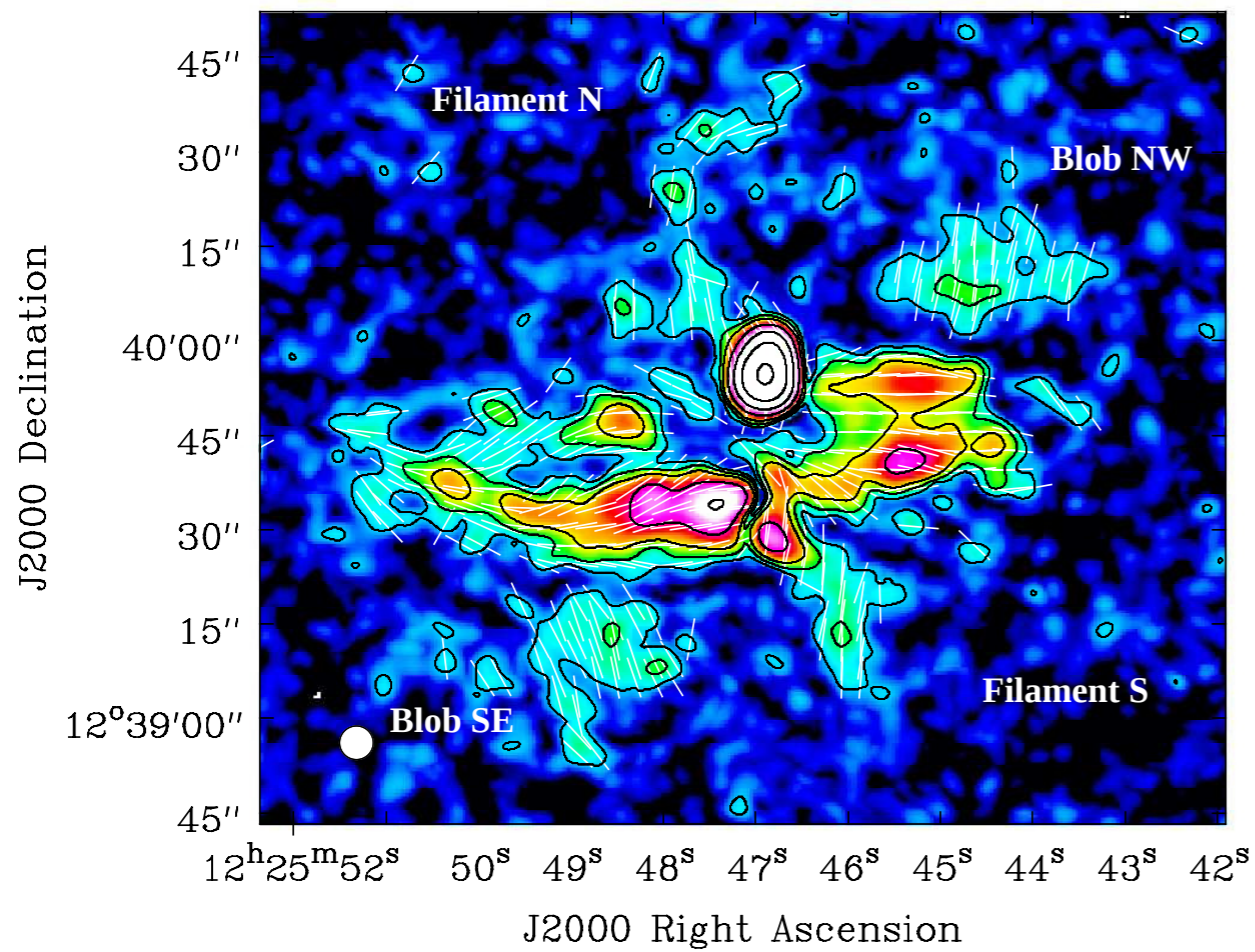
rms $\sim 2.3 \mu\text{Jy}/\text{beam}$

resolution ~ 5 arcsec

Highest sensitivity in a radio map of a galaxy

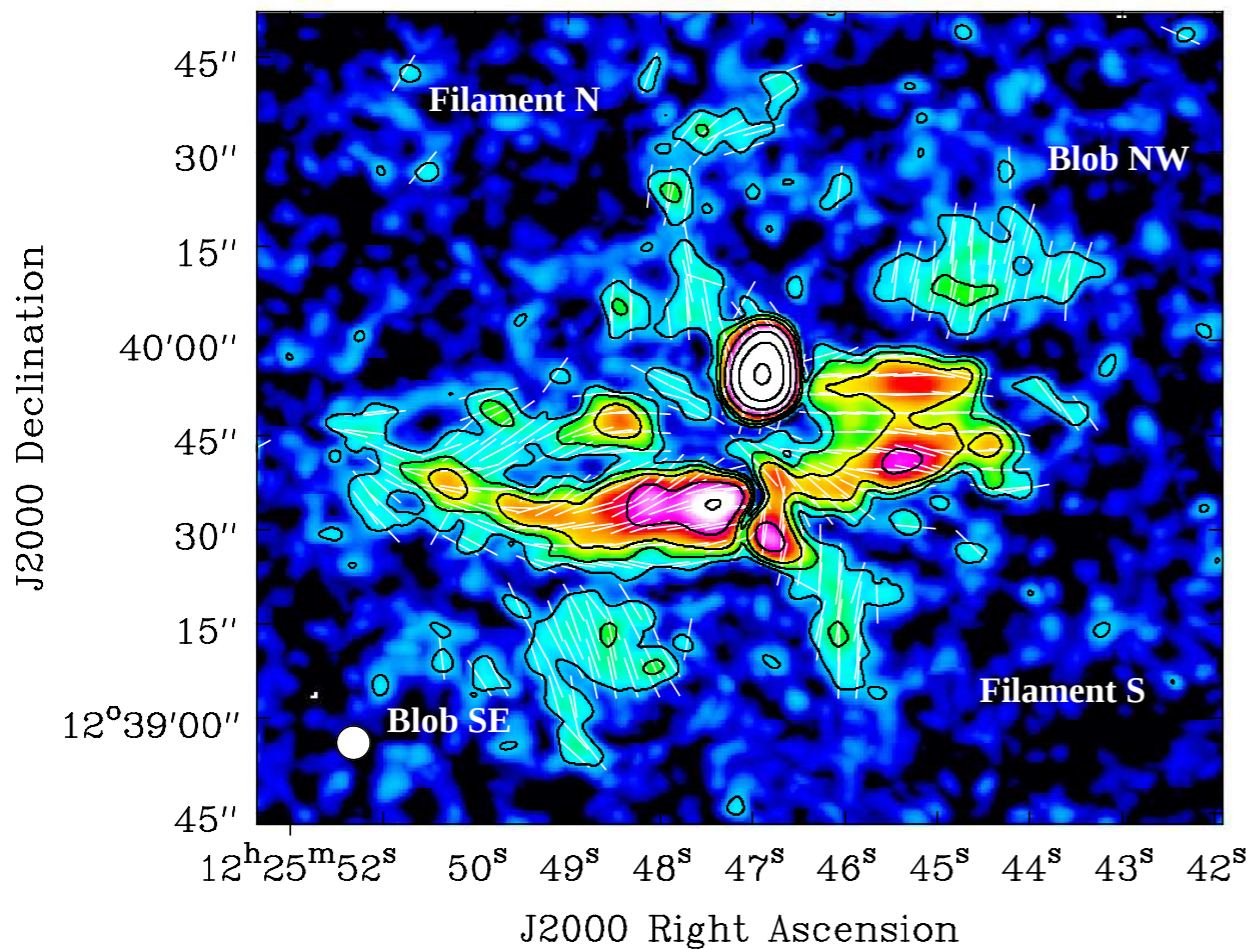
(CHANGES VII. Damas-Segovia et al. 2016)

Precession of the nuclear outflow in NGC 4388?

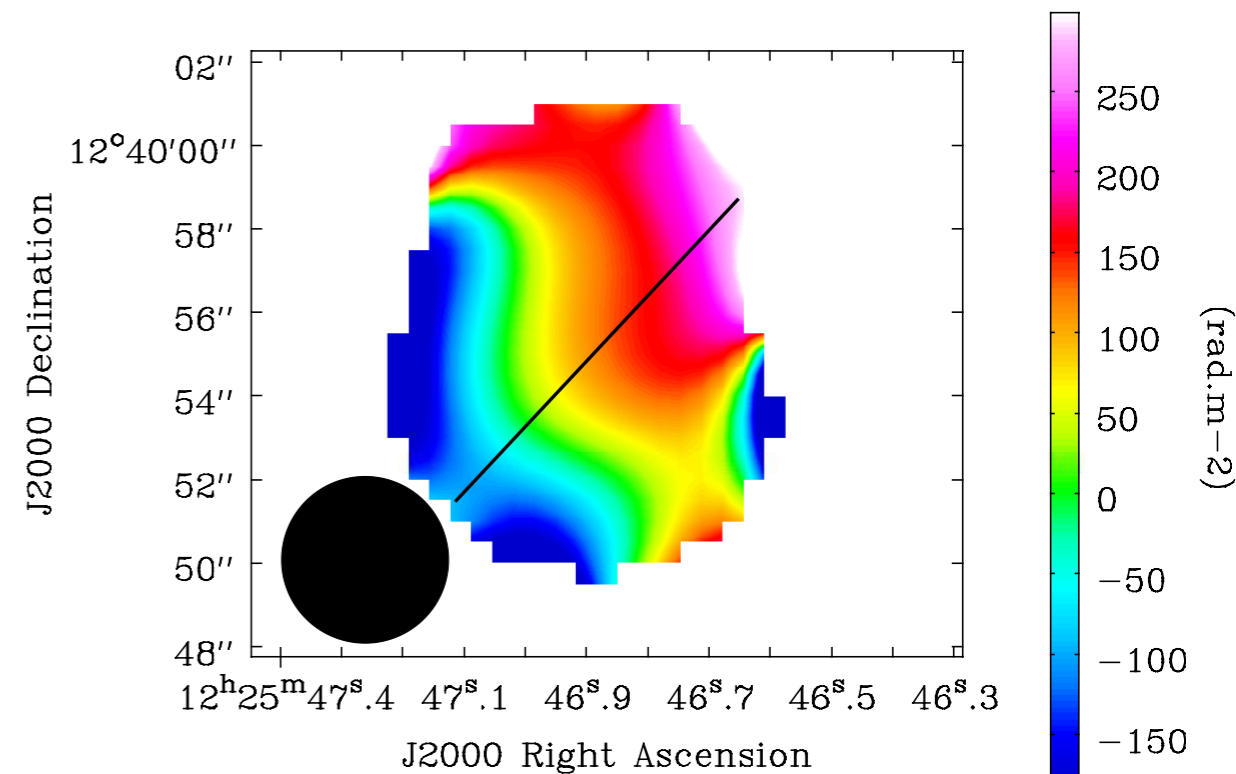


Polarization intensity of C band (4.0 - 8.0 GHz) with the C configuration

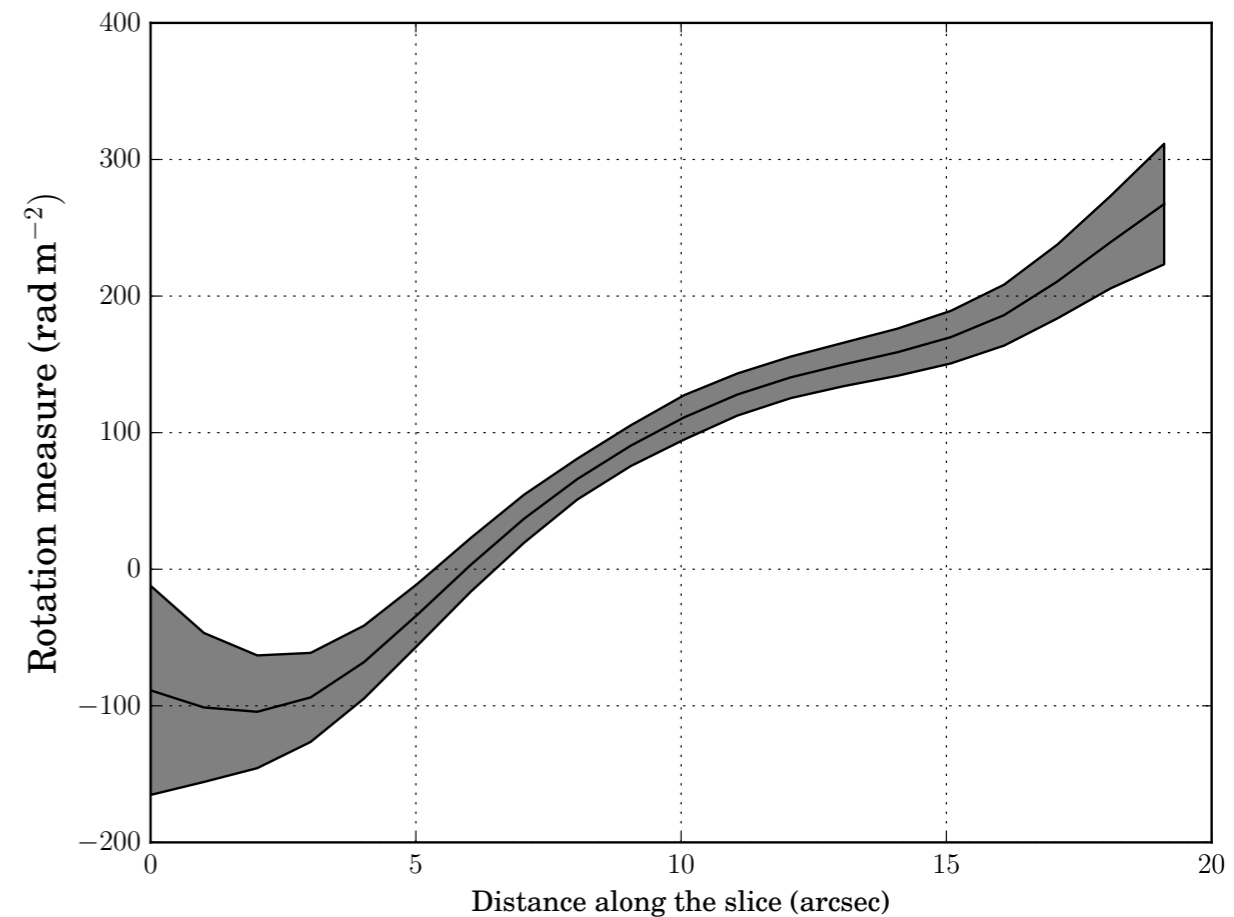
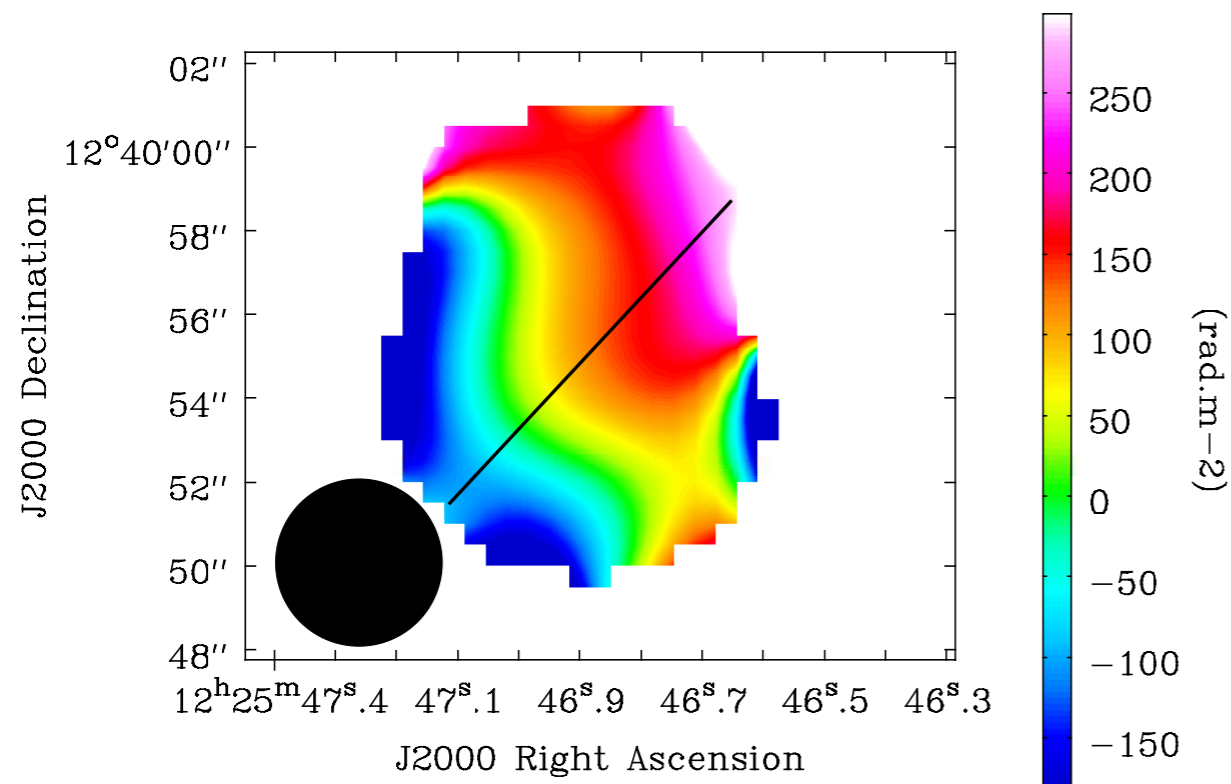
Precession of the nuclear outflow in NGC 4388?



Polarization intensity of C band (4.0 - 8.0 GHz) with the C configuration



Rotation Measures of the northern hotspot



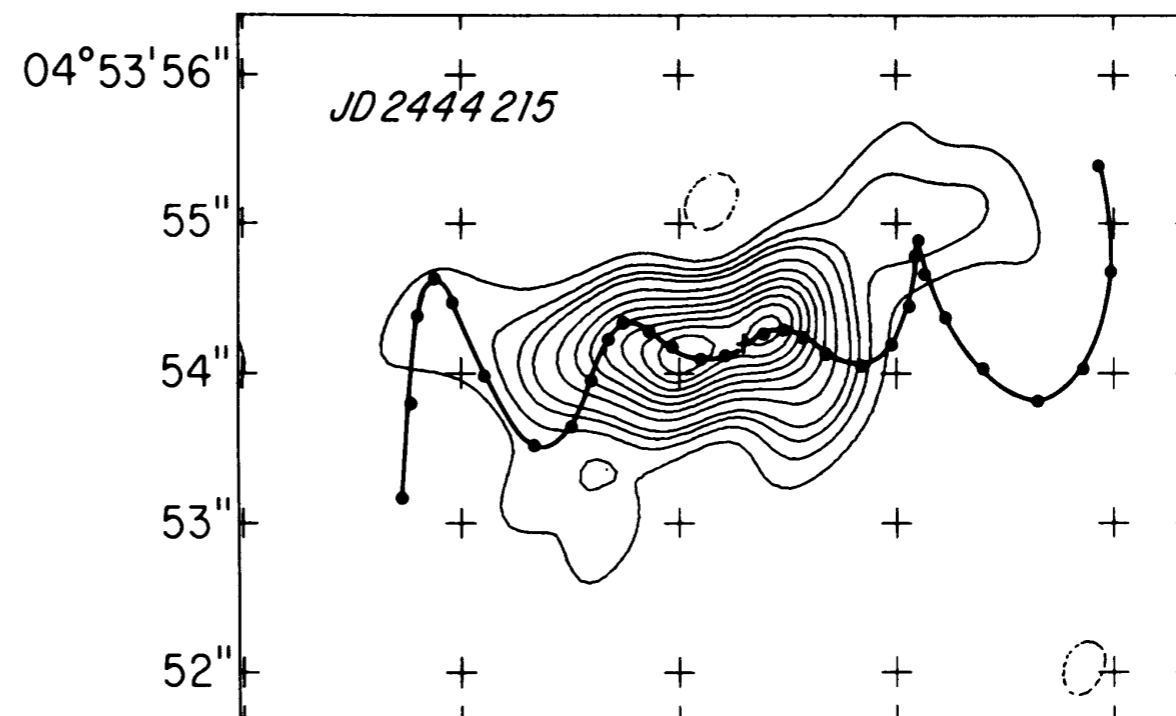
Rotation Measures of the northern hotspot

The symmetry seen in Rotation Measures suggests a helical magnetic field

Twin-jet kinematic model of precession can well reproduce the morphology seen in the **micro quasar SS 433**.

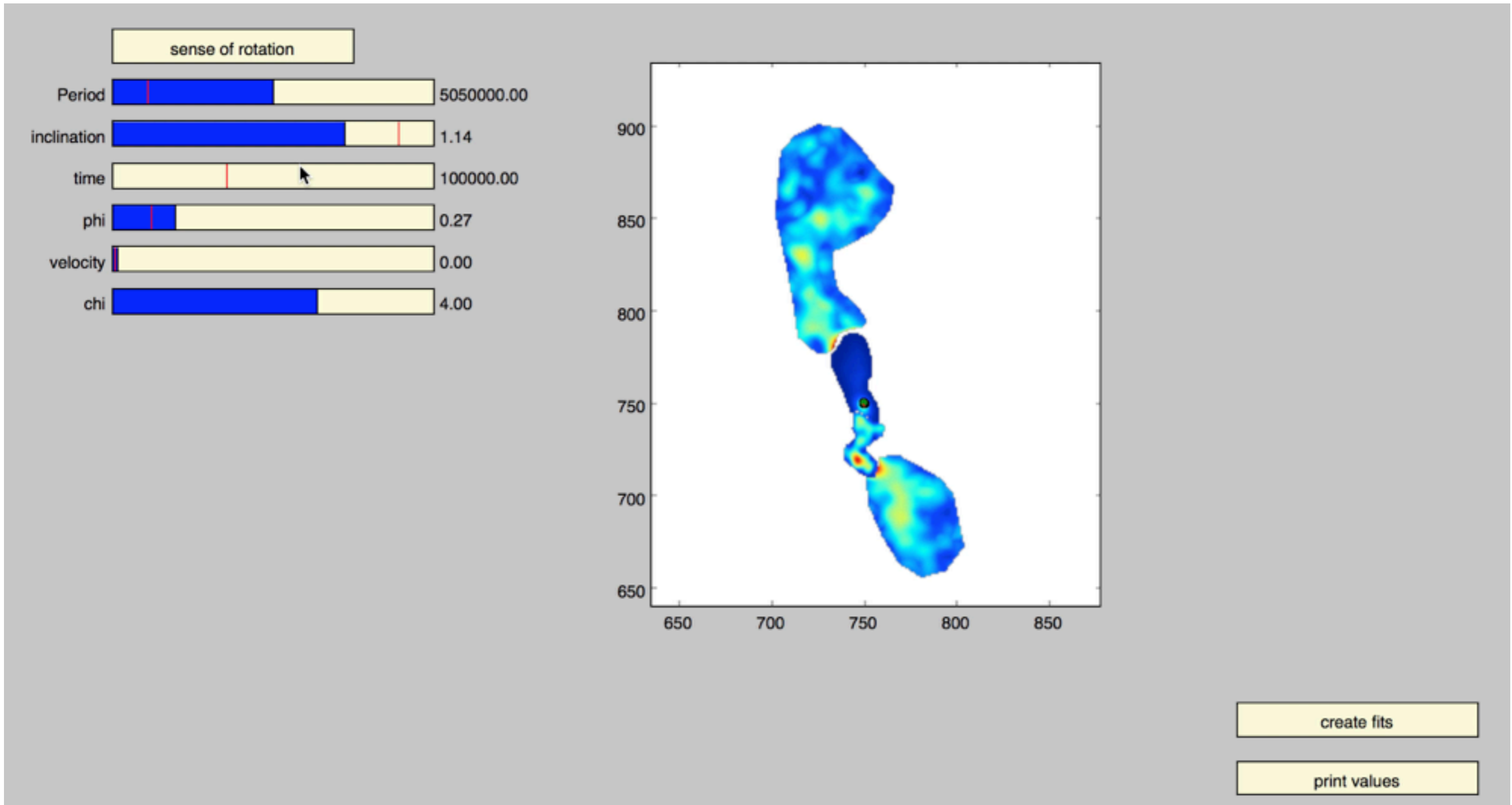
Parameters of the model

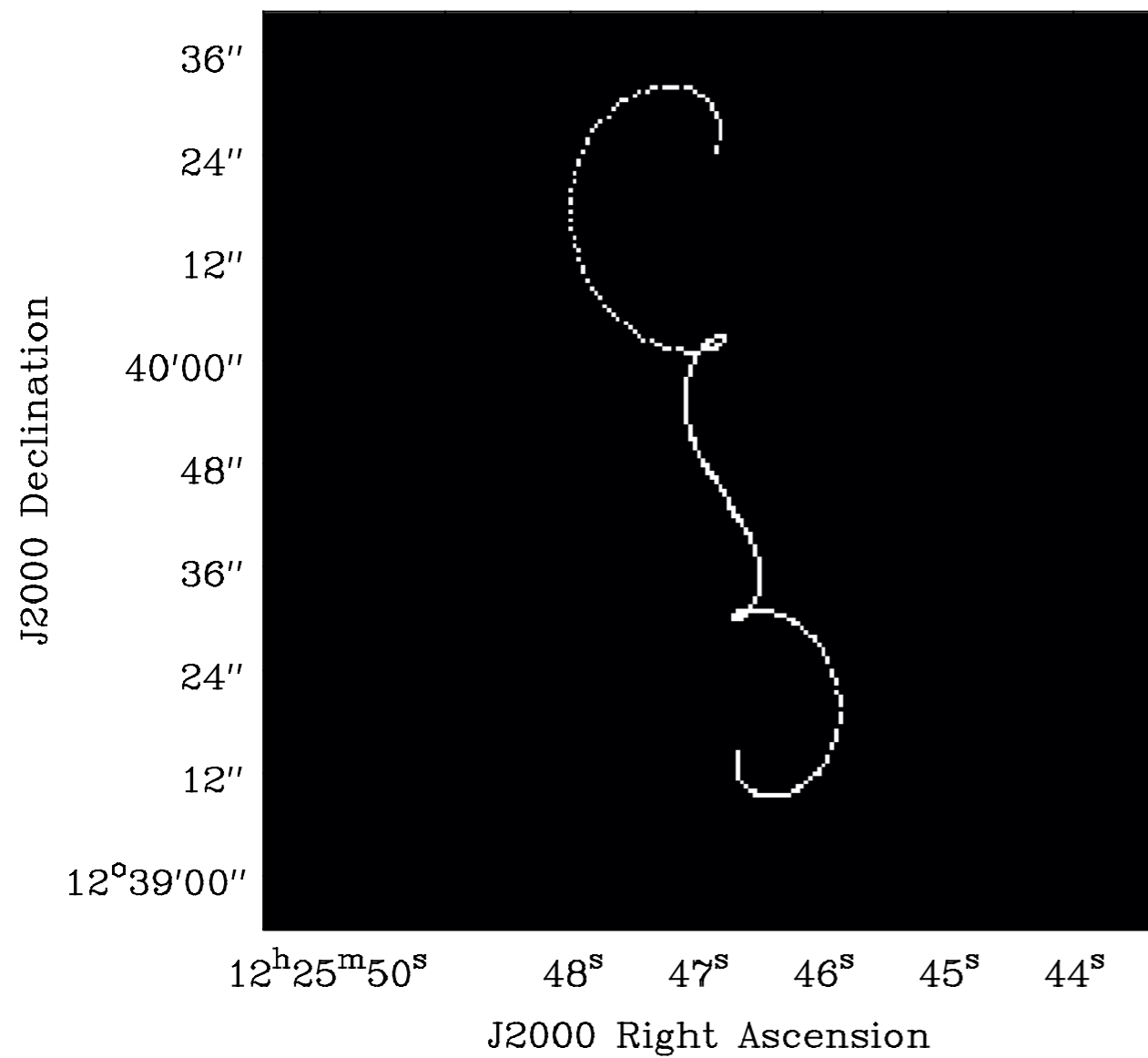
- Time of ejection
- Precession period
- Inclination
- Speed
- Opening angle
- Position angle
- Sense of rotation



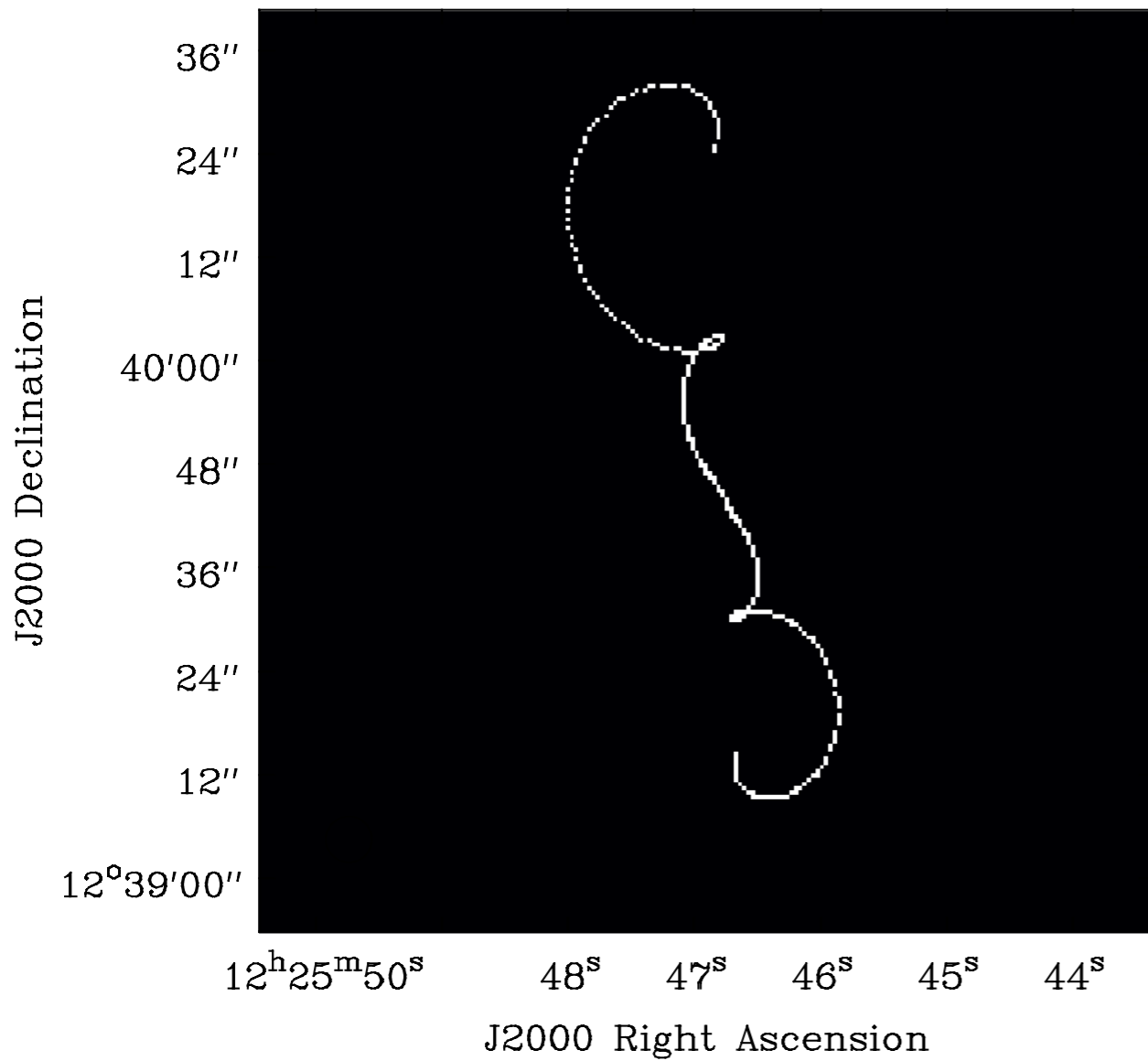
Hjellming and Johnston (1981)

Could this model be applied to the NGC 4388 outflows?

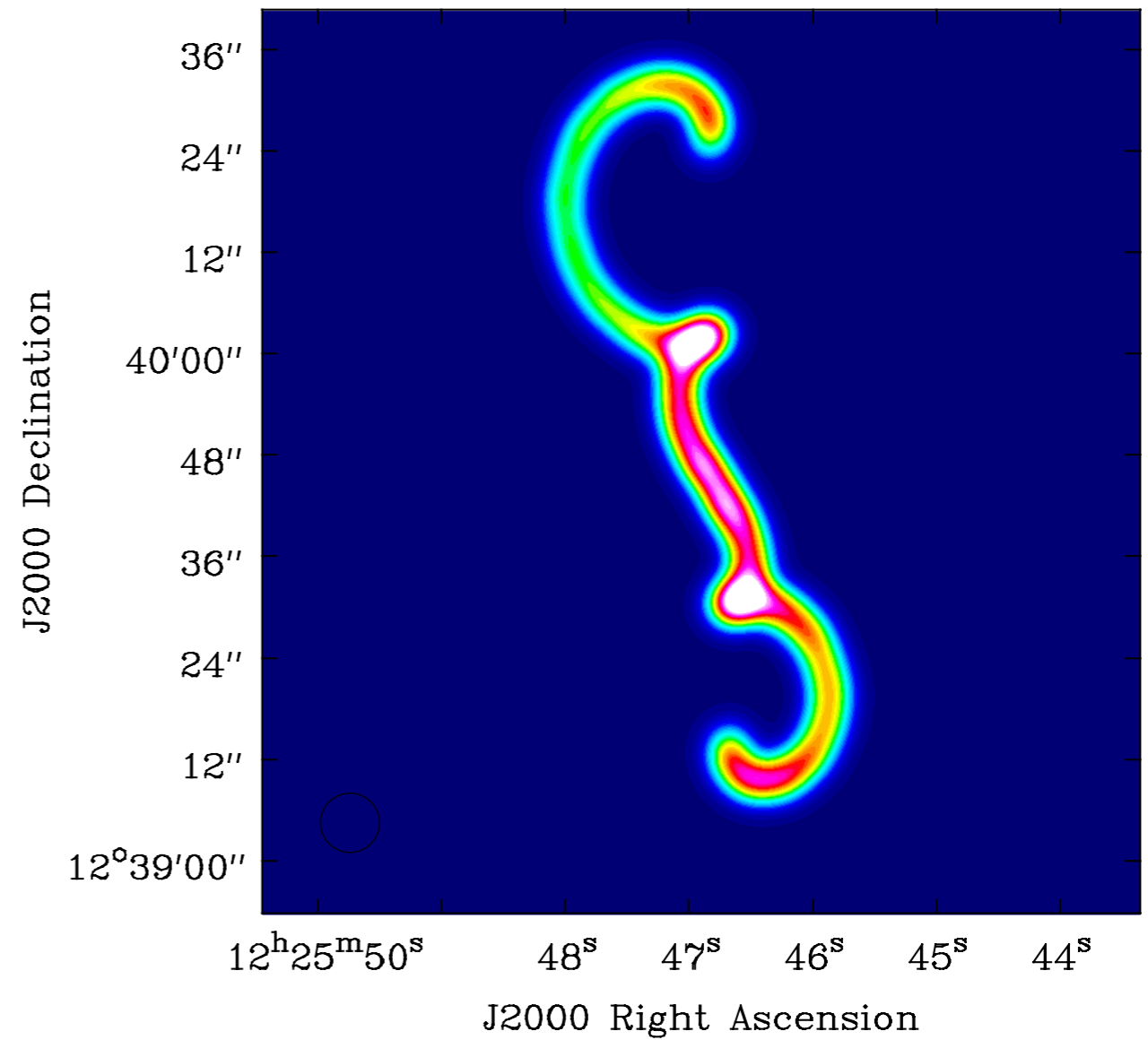




Model on a fits file

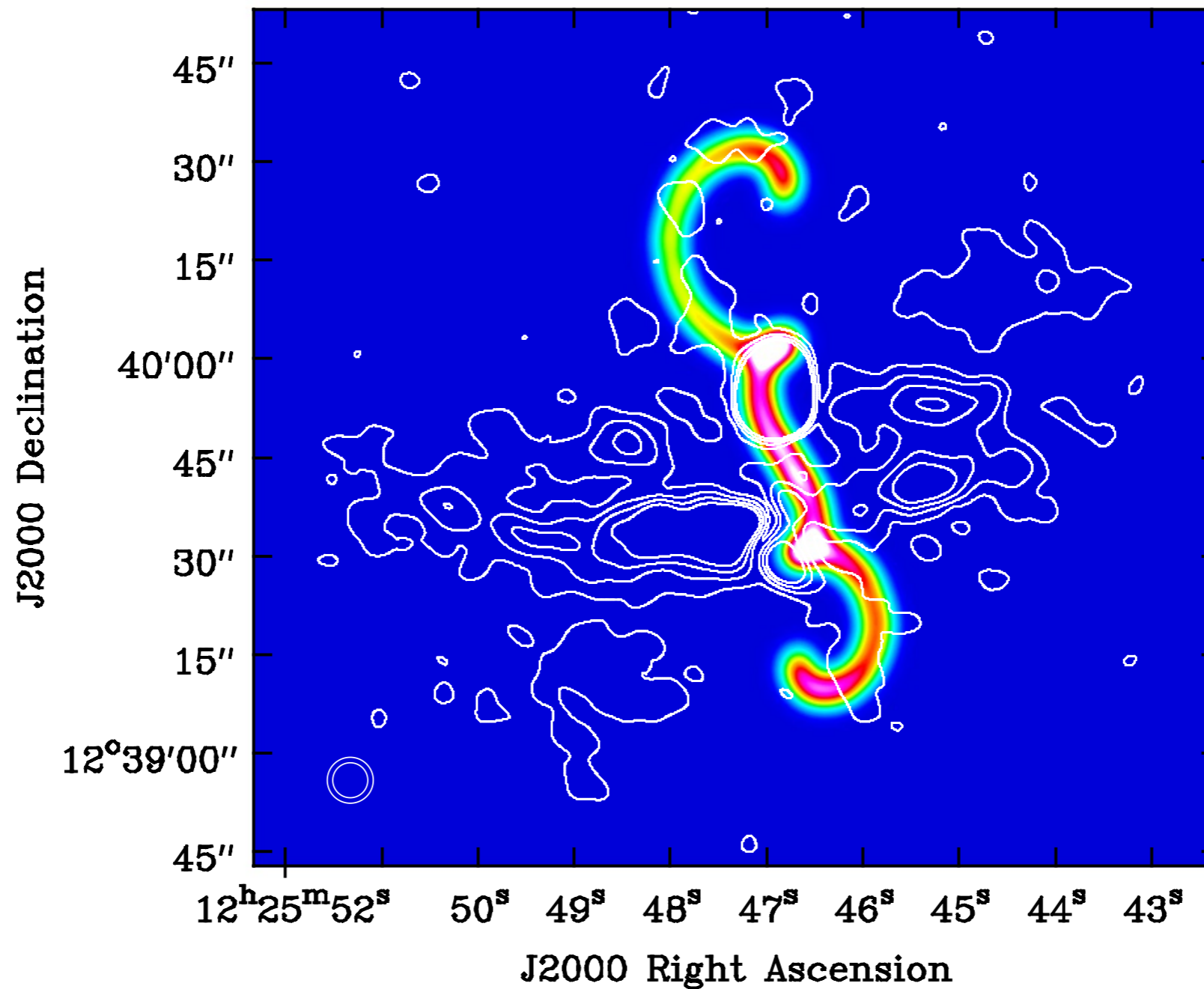


Model on a fits file



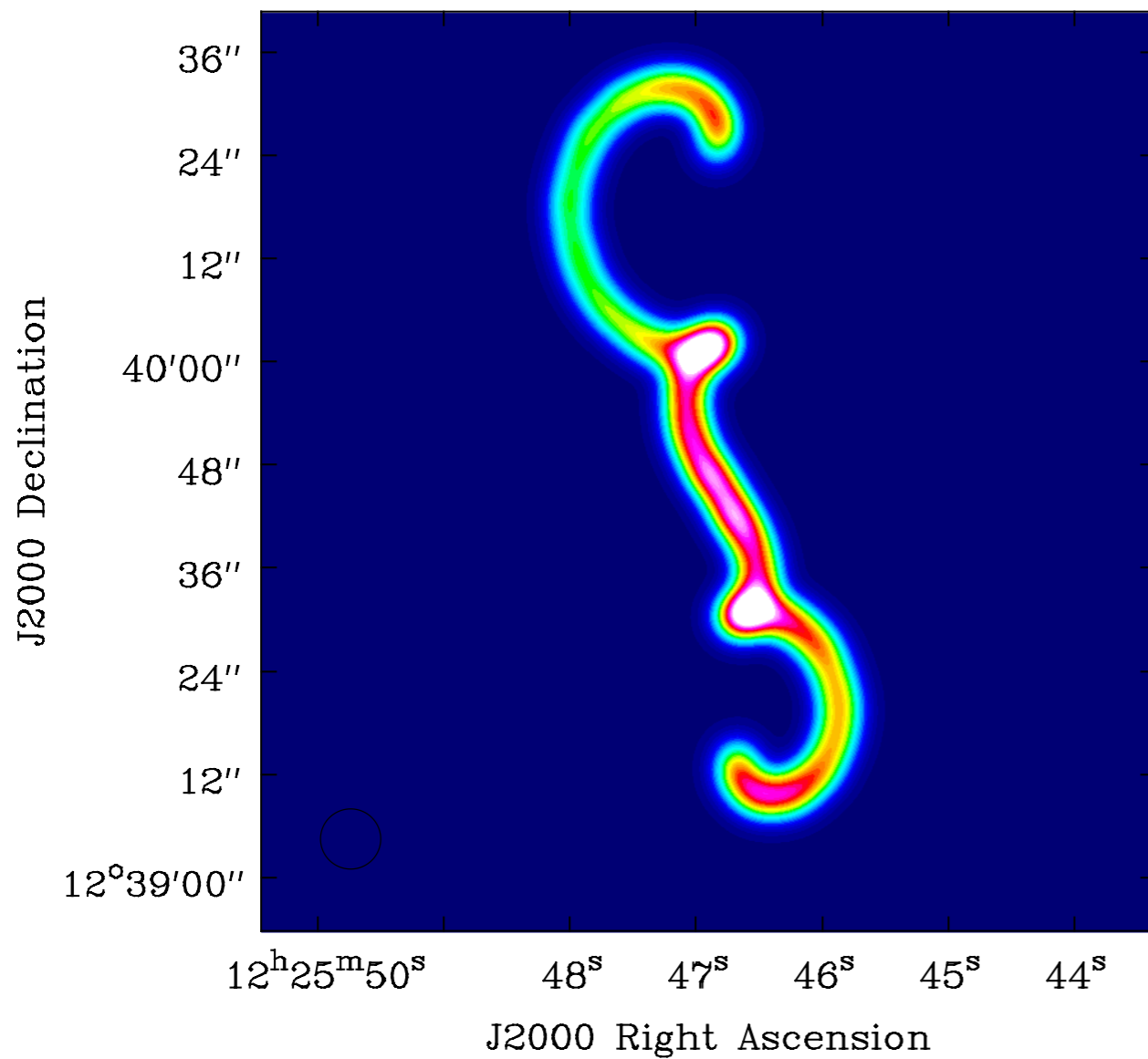
Model smoothed to 5 arcsec

Polarization contours over modeled outflow



(Damas-Segovia et al. in preparation)

Modeled outflow



Modeled outflow with direction along the line of sight

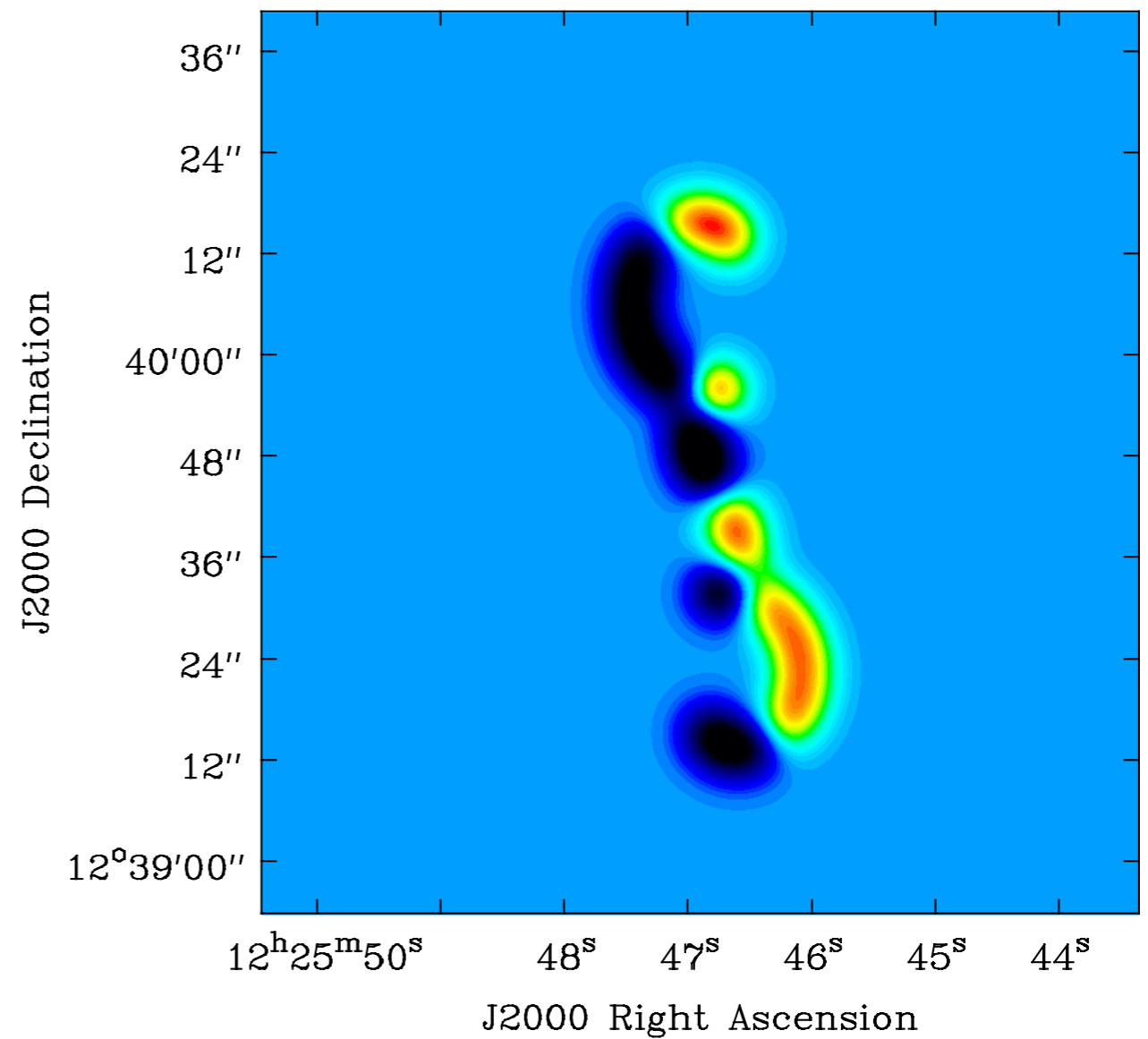
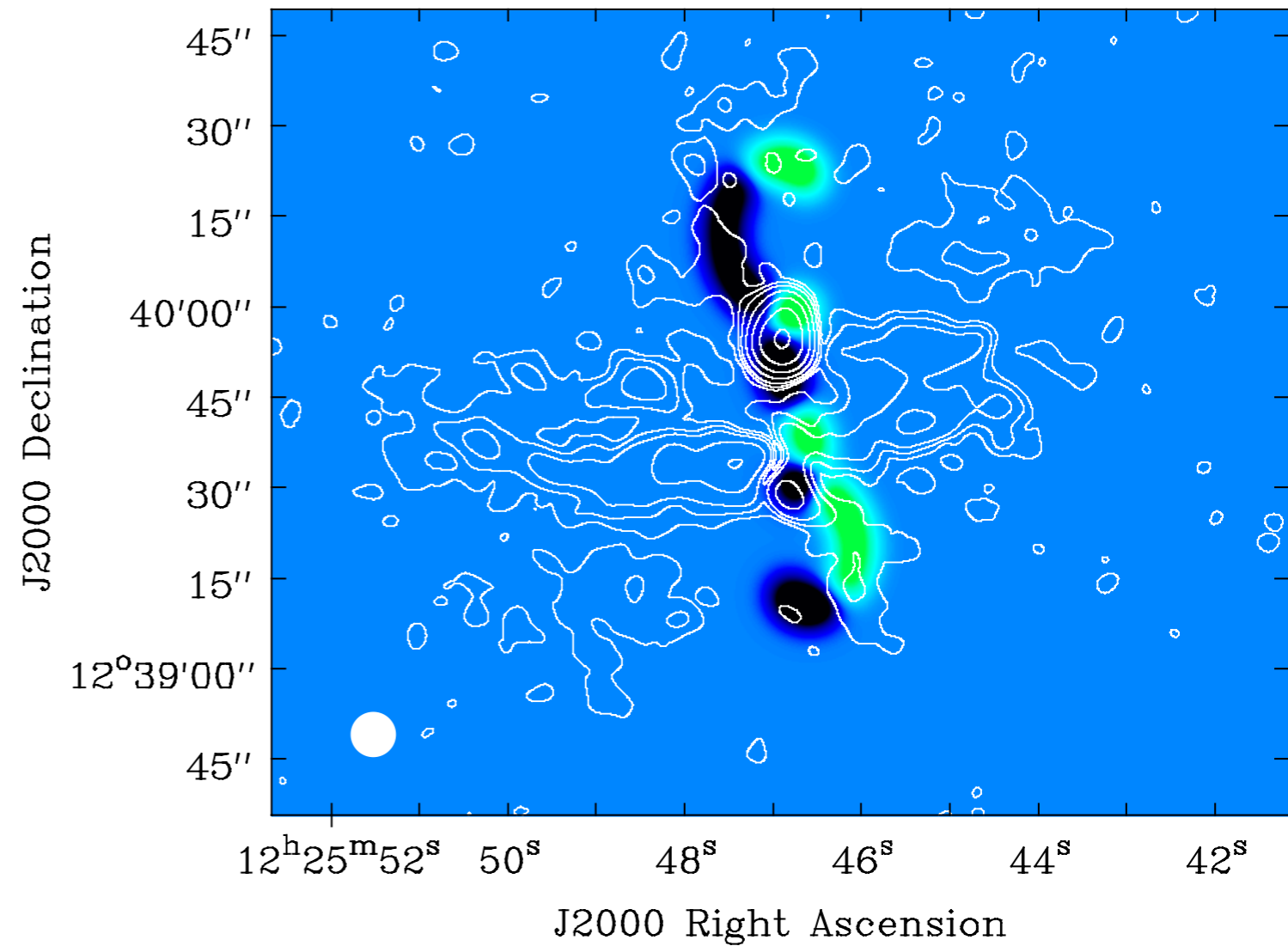
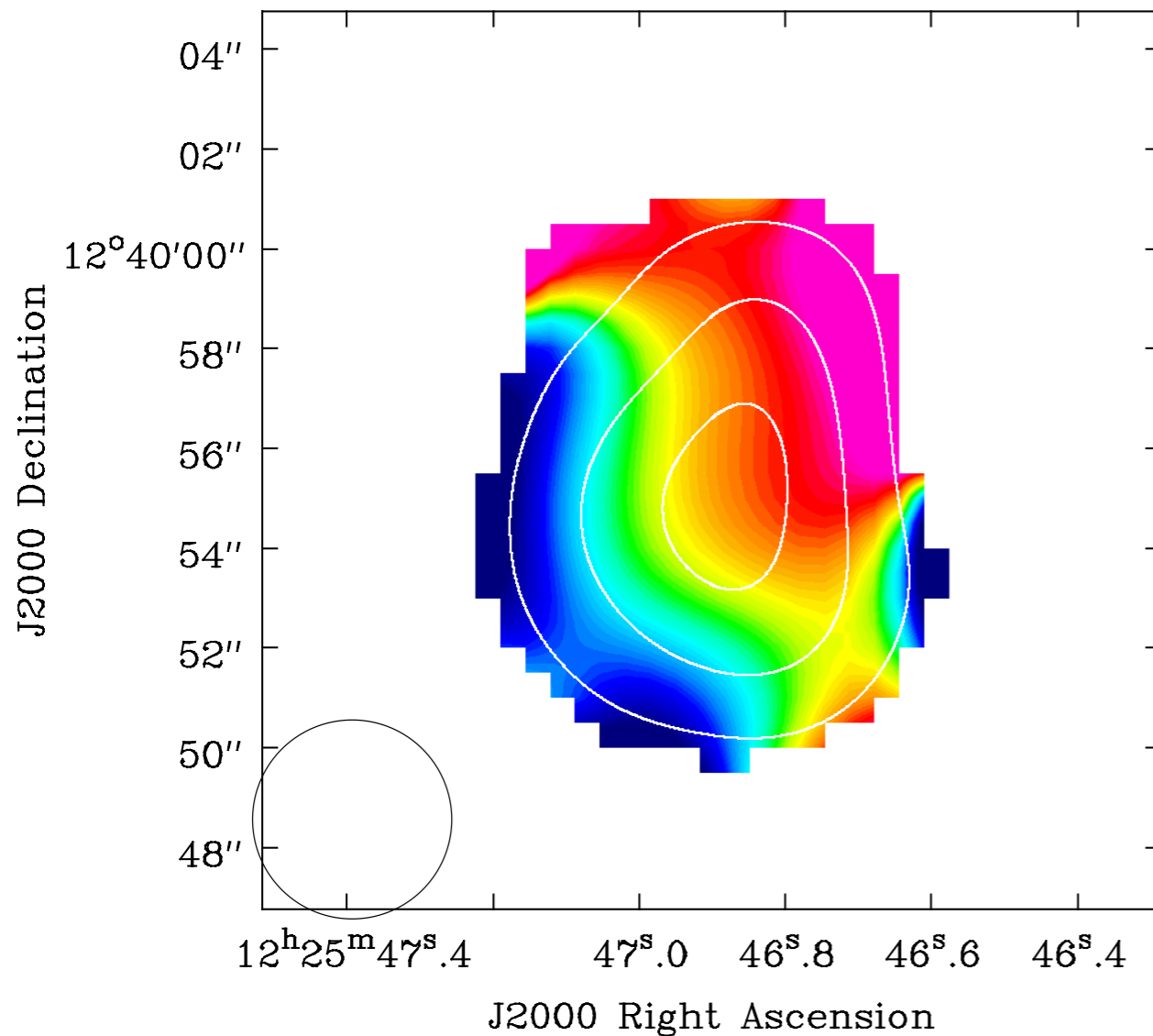


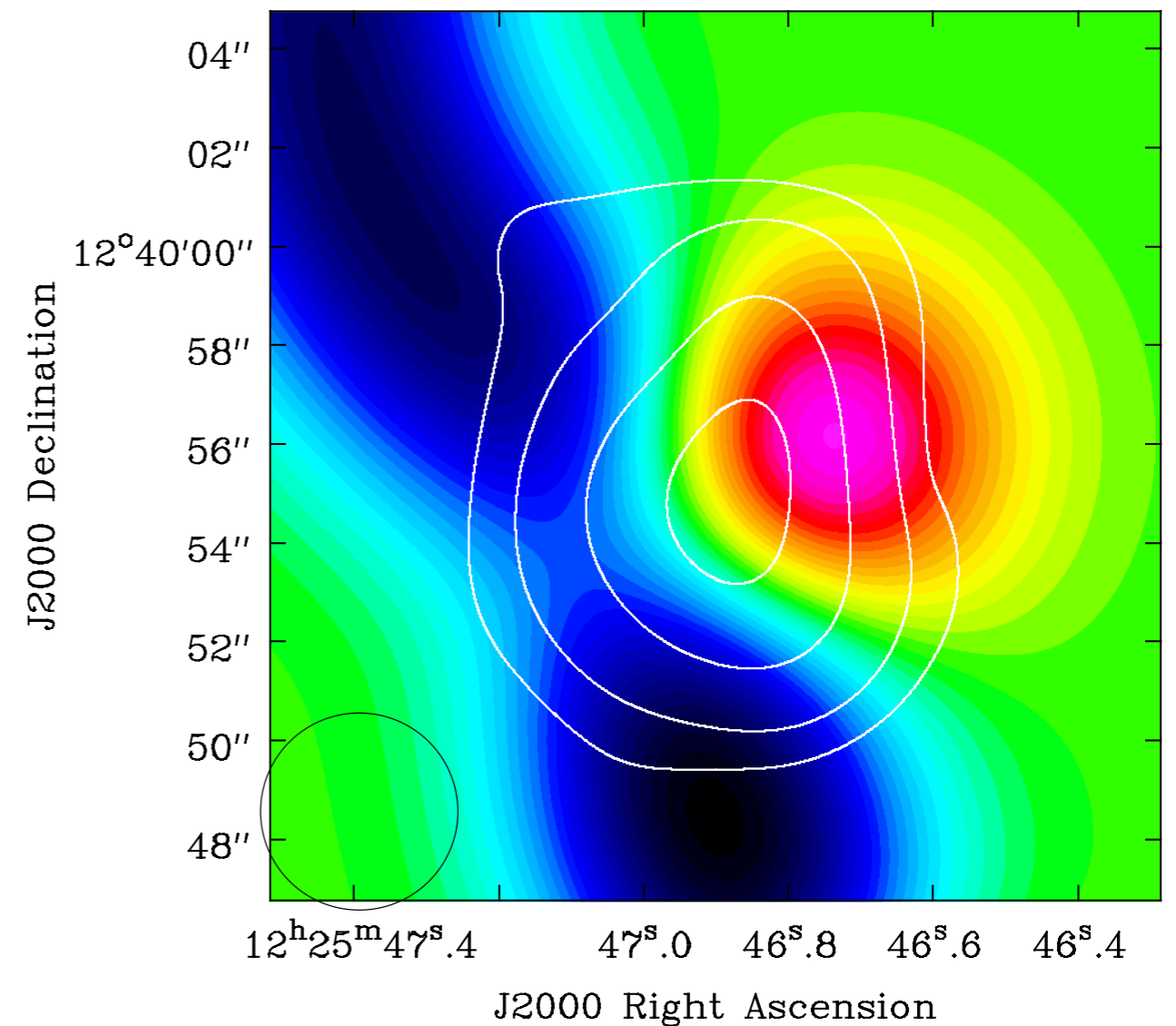
Table 4.1: Precession parameters for NGC 4388

Parameter	Value
i (deg)	15 – 50
ψ (deg)	3 – 10
χ (deg)	13
v_{north} (km s ⁻¹)	1300 – 2300
v_{south} (km s ⁻¹)	500 – 1000
s_{rot}	+1
P (yr)	$(3.5 - 4.5) \times 10^6$
t (yr)	$(6.0 - 8.0) \times 10^6$





Rotation Measures of the northern hotspot



Modeled direction at the northern hotspot

We find similarity between the rotation measures map of the northern outflow and the modeled direction of the precession model.

(Damas-Segovia et al. in preparation)

- The **highest sensitivity radio map of a galaxy** shows completely new features in NGC 4388.
- For the first time we are able to detect the **southern counter part** of the nuclear outflow.
- A **precession model** can explain the morphology of the radio outflows seen in this galaxy.
- The **Rotation Measures** of the northern hotspot match to the **direction along the line of sight of the model**. This implies that the magnetic field and the nuclear outflow follow the same direction.