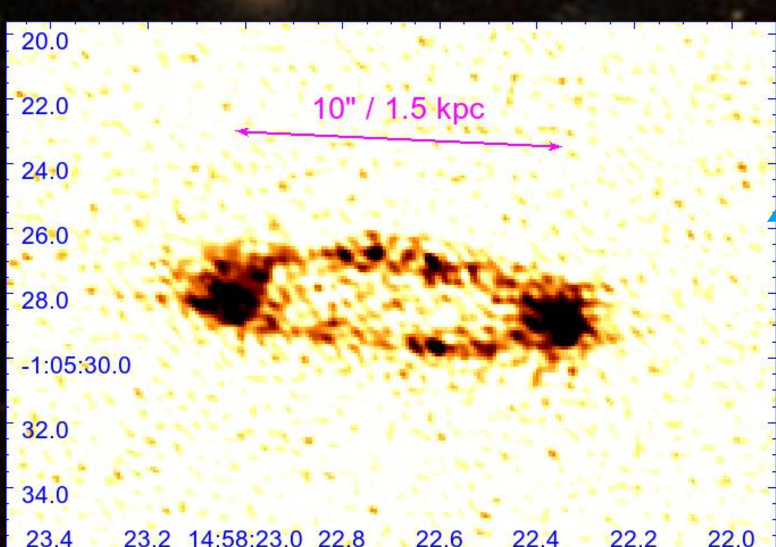
Non-thermal Radio Nuclear Ring in NGC 5792

Yang Yang in LJT team meeting
2021.12.17

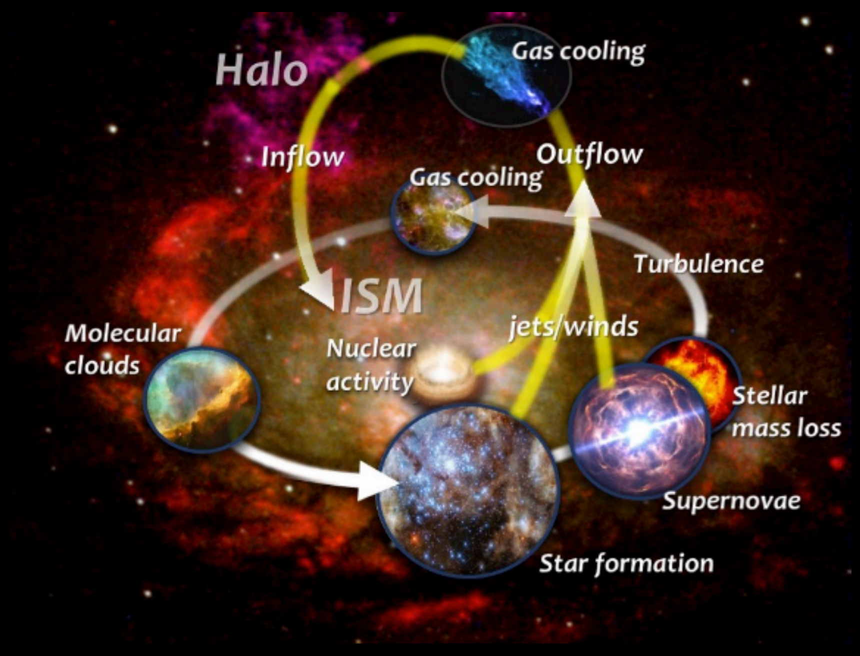
- Ra Dec (J2000) = [14:58:22.71, -01:05:27.9]
- SBb, D=31.7 Mpc



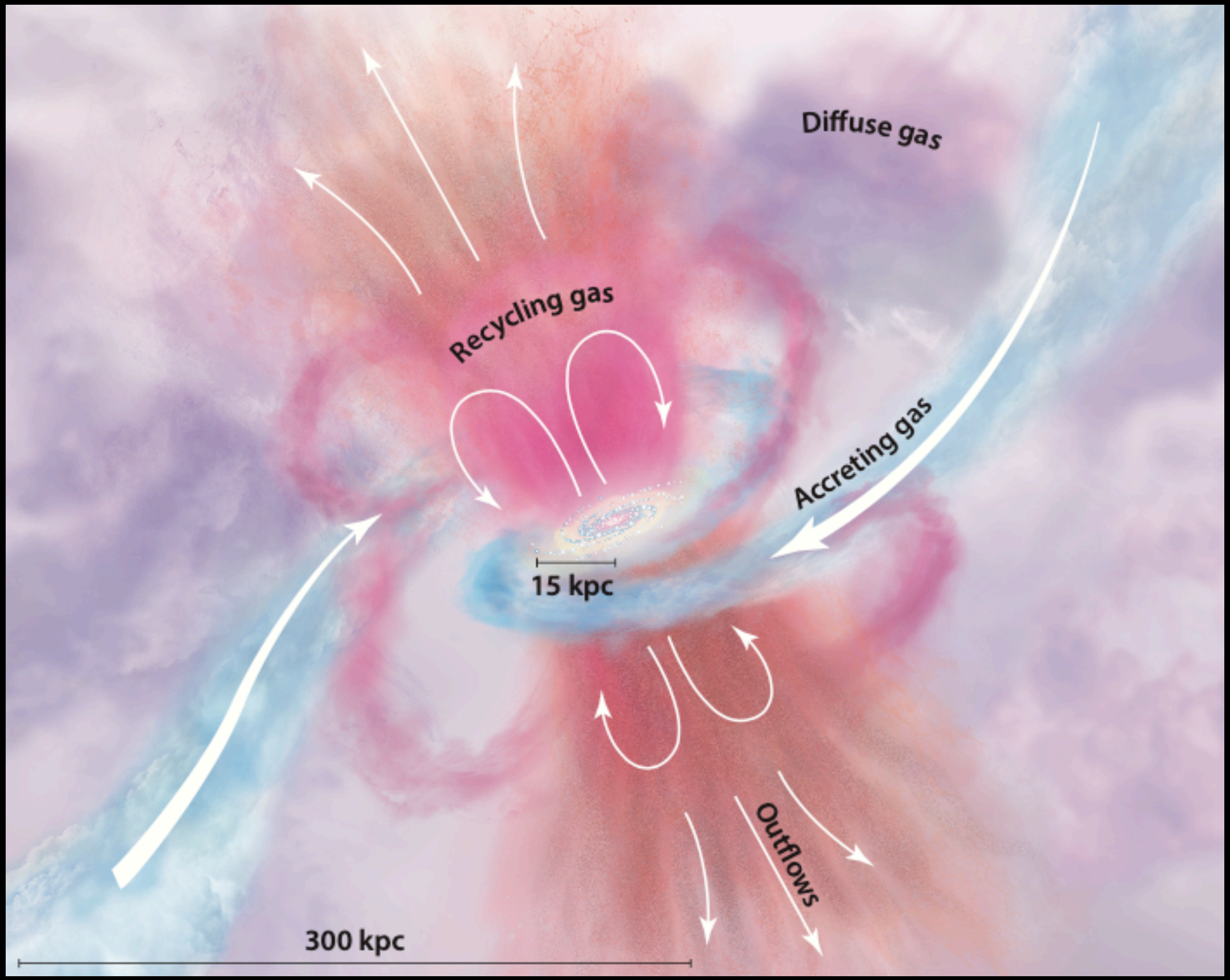
- Outer pseudo ring (diameter of 63 kpc)
- Inner ring (diameter of 22 kpc).
- Nuclear ring (diameter of 1.5 kpc)

Big Picture

- Galaxies evolutions: gas flows in IGM, CGM, ISM.
  - Inflow: gas accretion.
  - Outflow: Stellar feedback and AGN feedback.
  - Recycling center in CGM.
- Problems:
  - How galaxies acquire, eject, and recycle their gas are core issues in galaxy evolution.
  - How star formation works.



(Credit: ?)



(Tumlinson et al., 2017)

(Credit: NASA/CXC/STScI/U.North Carolina/G.Cecil)

Our Motivation

- Edge-on galaxies are ideal laboratories for studying gas interchange between star-forming (SF) disks and the surrounding halo.
- CHANG-ES project: 35 edge-on galaxies, radio continuum observations by VLA.
- Our goals:
  - To understand the nature of these interstellar structures.
  - These interstellar structures → energetic phenomena.
  - The activity in nucleus of galaxies.

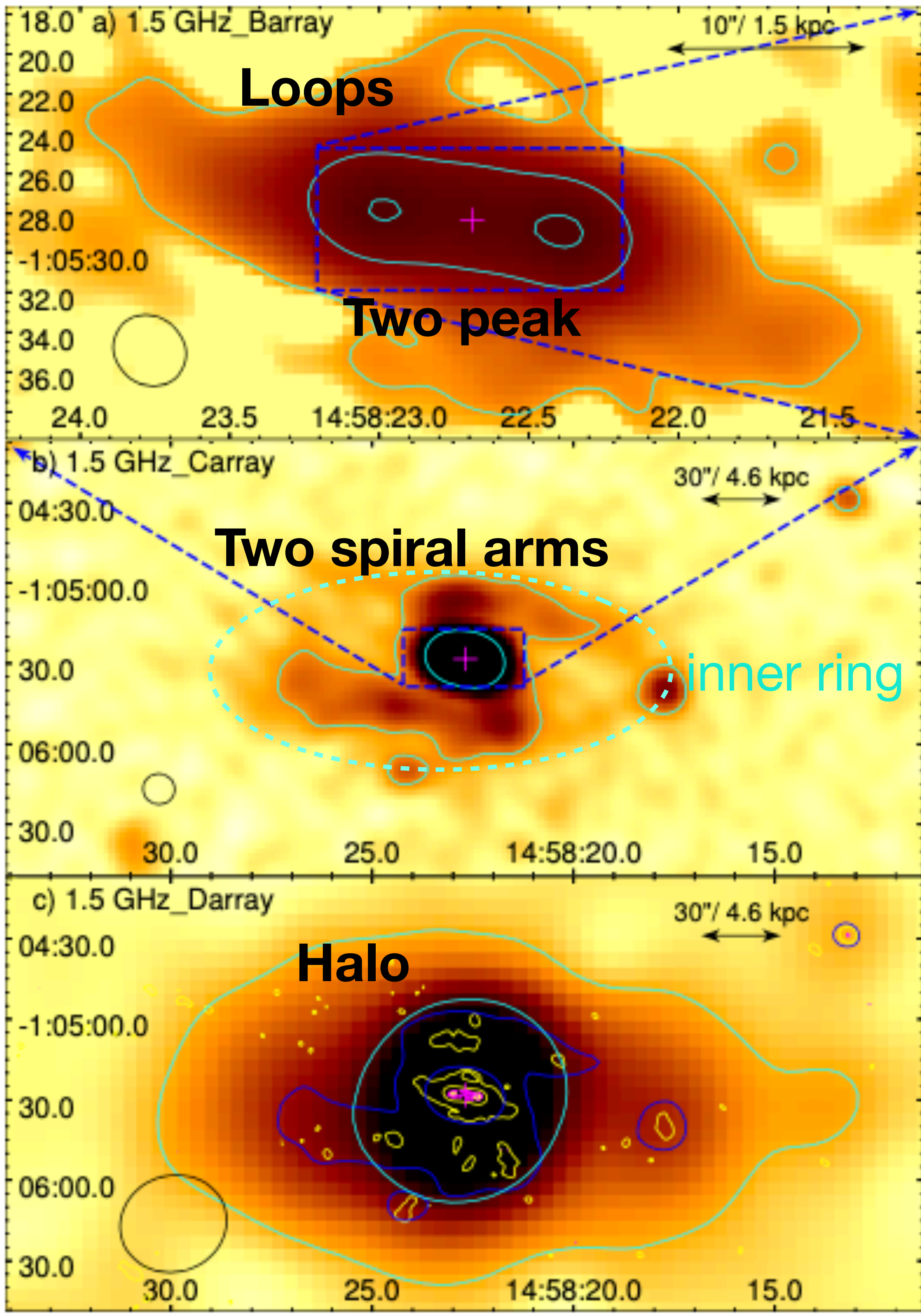
Observations of NGC 5792

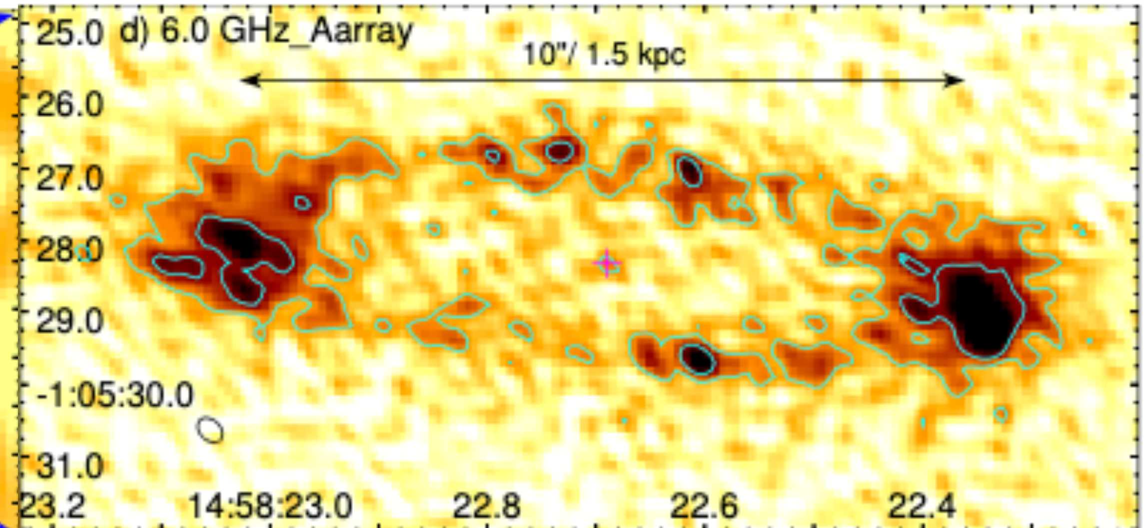
- Radio continuum: CHANG-ES + higher resolution VLA observations.

	1.5 GHz (L band)			6.0 GHz (C band)			9 GHz (X band)
Configuration	D	C	B	D	C	A	A
Observed date	Dec 2011	Mar 2012	Apr 2011	Dec 2011	Feb 2012	Jul 2015	Jul 2015
Spatial resolution (")	35	11	3.5	10	3.0	0.3	0.25
Total time (hr)	7	8.5	7.5	6	4.5	2.3	2.7
Mean rms (uJy)	45	30	20	18	18	4	7

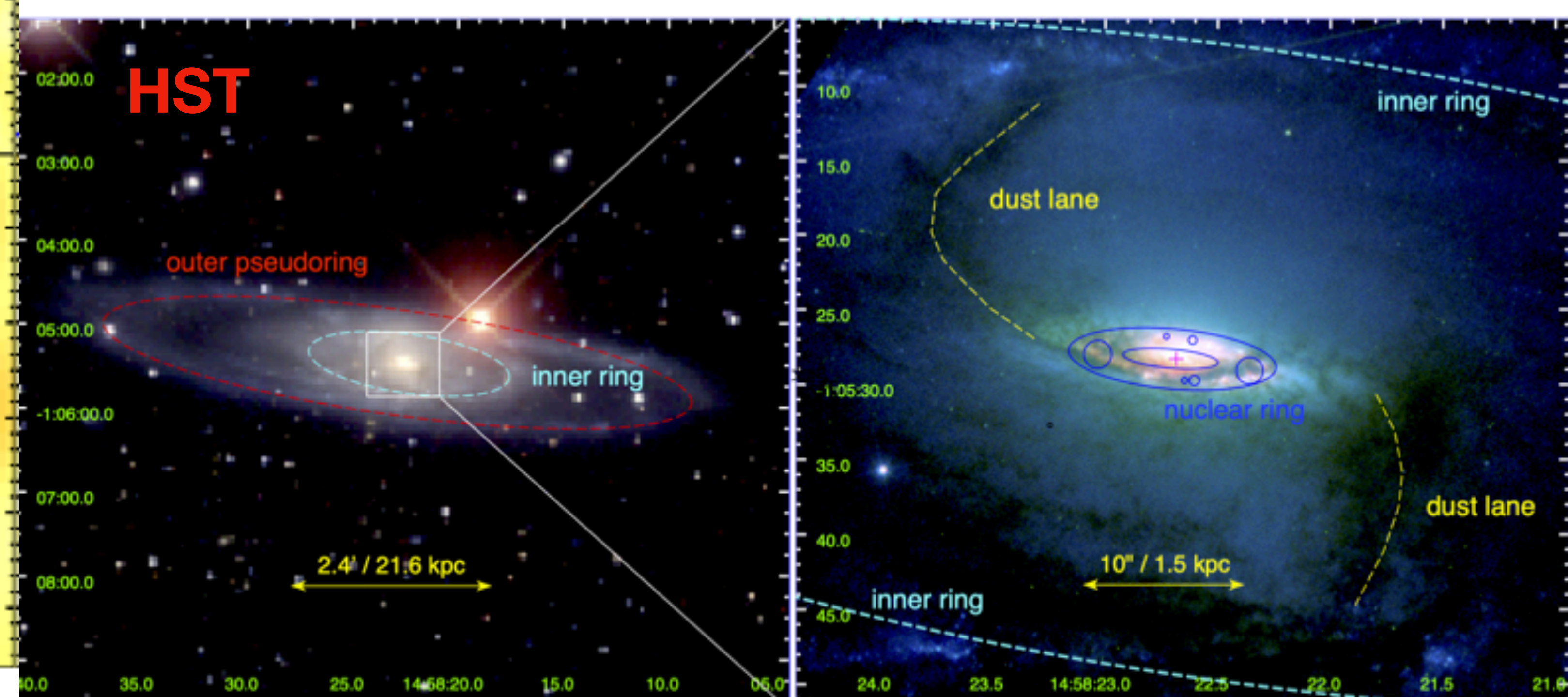
- Ha image: Apache Point Observatory (APO) 3.5m

Results: radio total intensity maps from hundreds of pc to dozens of kpc

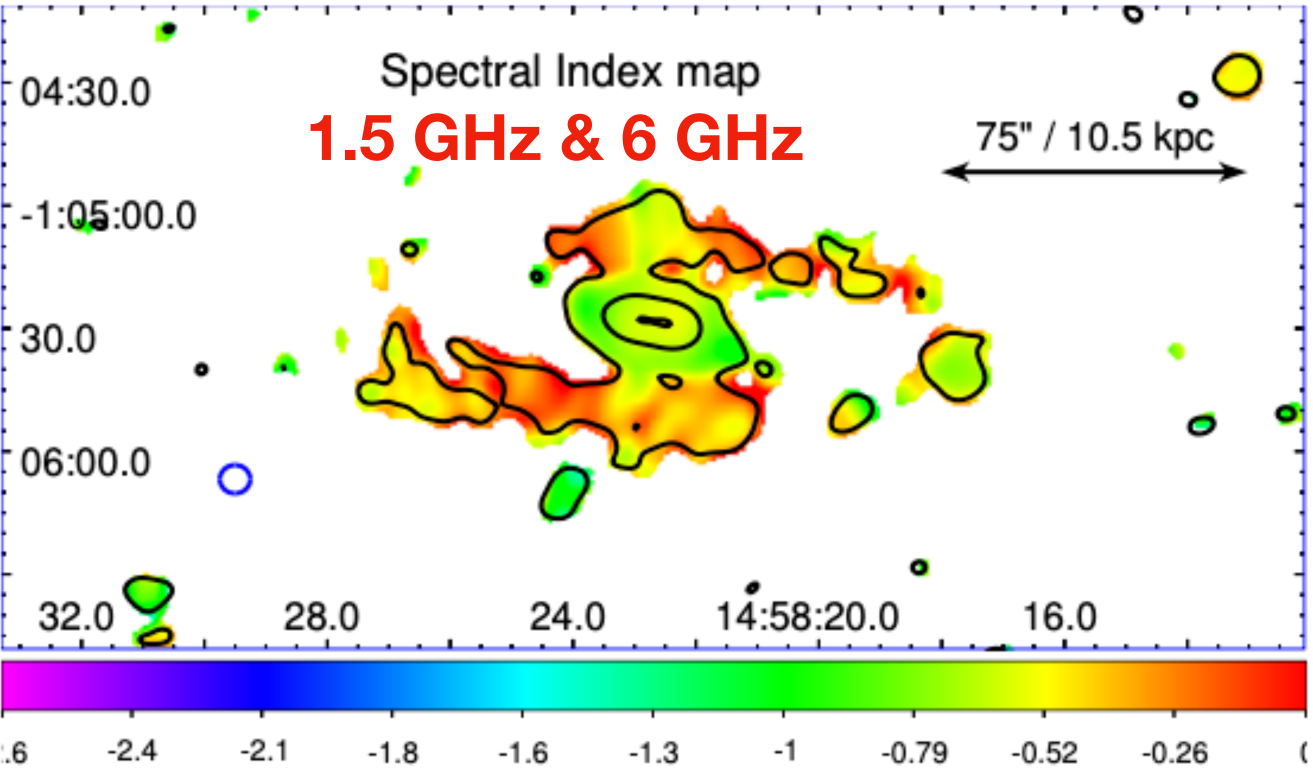


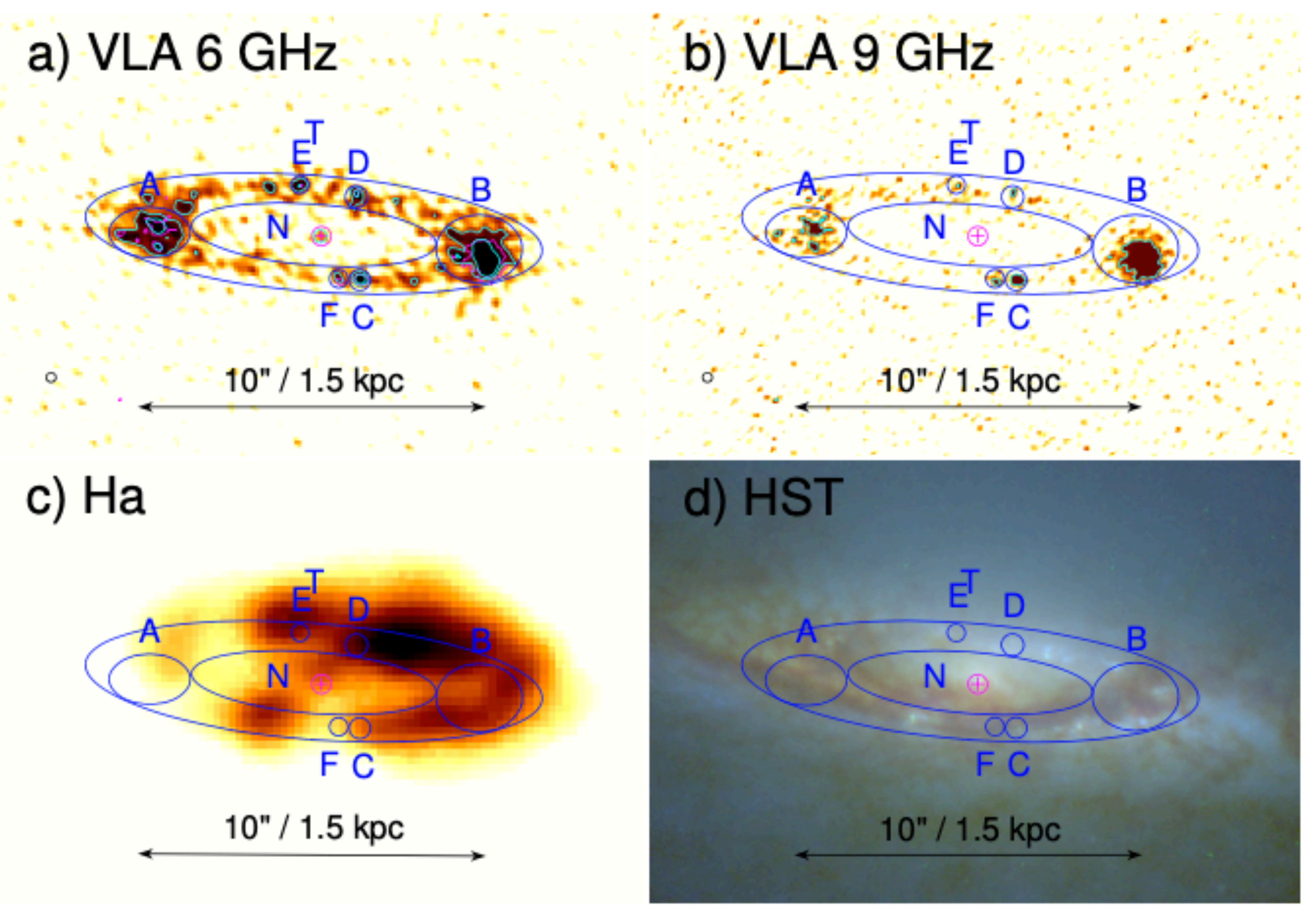


- Loop structure.
- Ring and knots.
- Core with flux density $16 \pm 4\ \mu\mathrm{Jy}\ (\sim 4\sigma)$ at 6 GHz.



Results: physical parameter





- $S \propto \nu^{\alpha}$, $\alpha_{1.5-6\ \mathrm{GHz}} \sim -0.7$, $\alpha_{6-9\ \mathrm{GHz}} \sim -3.0$ in nuclear region

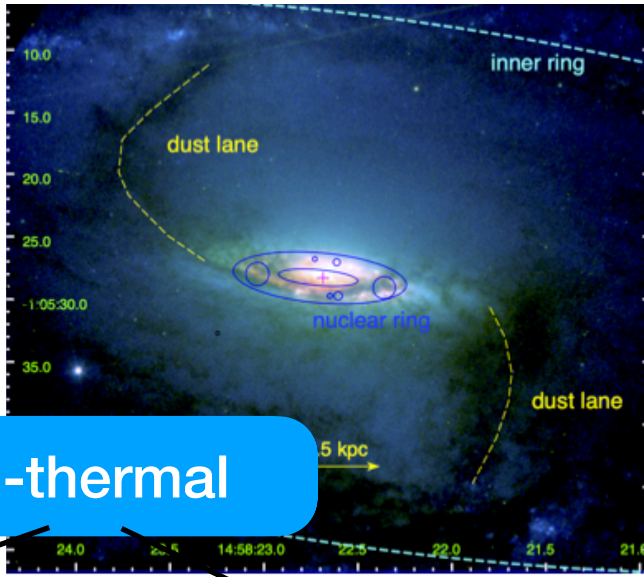
- $F_{\mathrm{H}\alpha,\mathrm{corr}} = F_{\mathrm{H}\alpha,\mathrm{obs}} + 0.042 F_{24\mu m} = 1.1 \times 10^{-12}\ \mathrm{erg\ s^{-1} cm^{-2}}$

$$\frac{S_T}{\mathrm{mJy}} = 1.25 \left(\frac{T_e}{10^4\ \mathrm{K}}\right)^{0.59} \left(\frac{\nu}{\mathrm{GHz}}\right)^{-0.1} \left(\frac{F_{\mathrm{H}\alpha,\mathrm{corr}}}{10^{-12}\ \mathrm{erg\ s^{-1}\ cm^{-2}}}\right)$$

0.66 mJy (13%) at 6 GHz. The nuclear ring is dominated by the non-thermal synchrotron emission at 6 GHz.

- $$\frac{\mathrm{SFR}}{M_{\odot}\ \mathrm{yr}^{-1}} = 5.37 \times 10^{-42} \left(\frac{L_{\mathrm{H}\alpha,\mathrm{corr}}}{\mathrm{erg\ s^{-1}}}\right) = 0.4$$

Discussion: the origin of the excess non-thermal emission



- The excess non-thermal emission in nuclear ring at 6 GHz.

Thermal (free-free) → Massive star formation in H II → Instantaneous SF

Non-thermal → CREs initially accelerated by SNRs, SN → ~10 Myr ago SF

Non-thermal → AGN

- Synchrotron-based SFR of 1.2 $M_{\odot}\ yr^{-1}$ (Ha-based SFR of 0.4 $M_{\odot}\ yr^{-1}$,). This result indicates that the nuclear ring in NGC 5792 underwent more intense star forming activity in the past, and now the star formation in the nuclear ring is in the low state.

- The $B_{\text{eq}} \propto (K_0\ I_\nu / l)^{1/(\alpha+3)}$ (Beck 2005) of the knots change between 77 and 88 μG with the synchrotron emission at 6 GHz. The strong magnetic field may prevent the collapse of gas to form massive stars (Tabatabaei et al. 2018).

Discussion: SF on the nuclear ring

- How do these knots (concentrated star-forming regions) form on the ring?
    - “Popcorn” & “pearls on string” model.
- What affect the SFR on the ring? The SFR in the nuclear region, ~ 0.4 $M_\odot \ yr^{-1}$, is at a low level.
    - The strength of non-axisymmetric perturbations in galaxies.
    - The inflow rate to the gas.
    - The magnetic field strength.

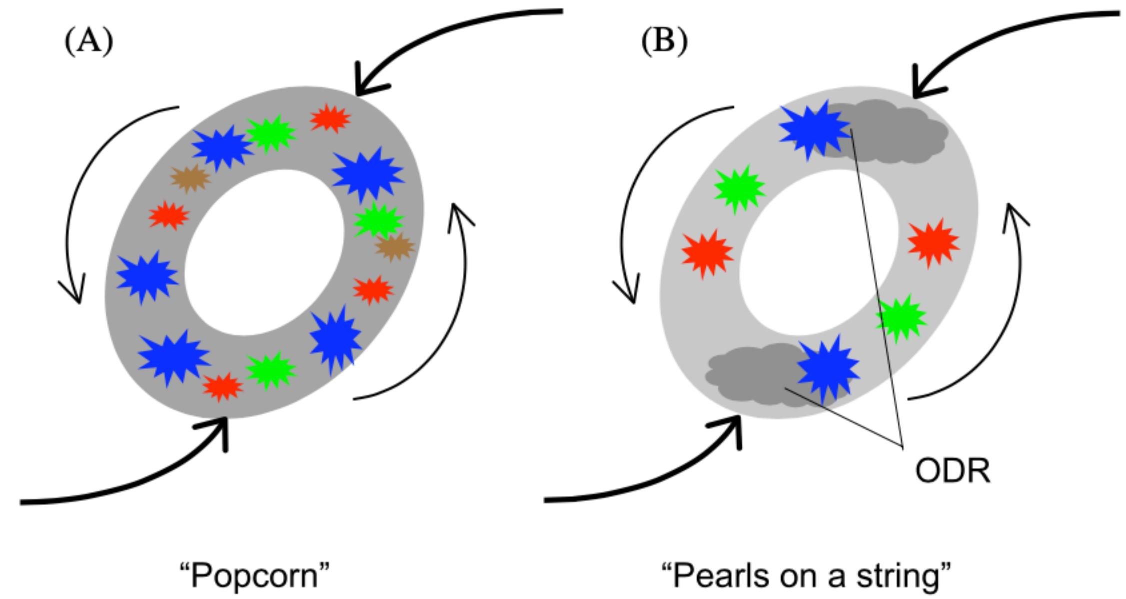


Figure 7. Illustration of two candidate scenarios for star formation in a nuclear ring. Dark gray areas denote dense, cold gas that is conducive to star formation. The various star symbols denote young stellar clusters, their colors signify the cluster age in the sense that age increases from blue to green to red. A clear age sequence is expected only in the “pearls on a string” scenario (see Section 4.1 for discussion).

(Boker et al., 2008)

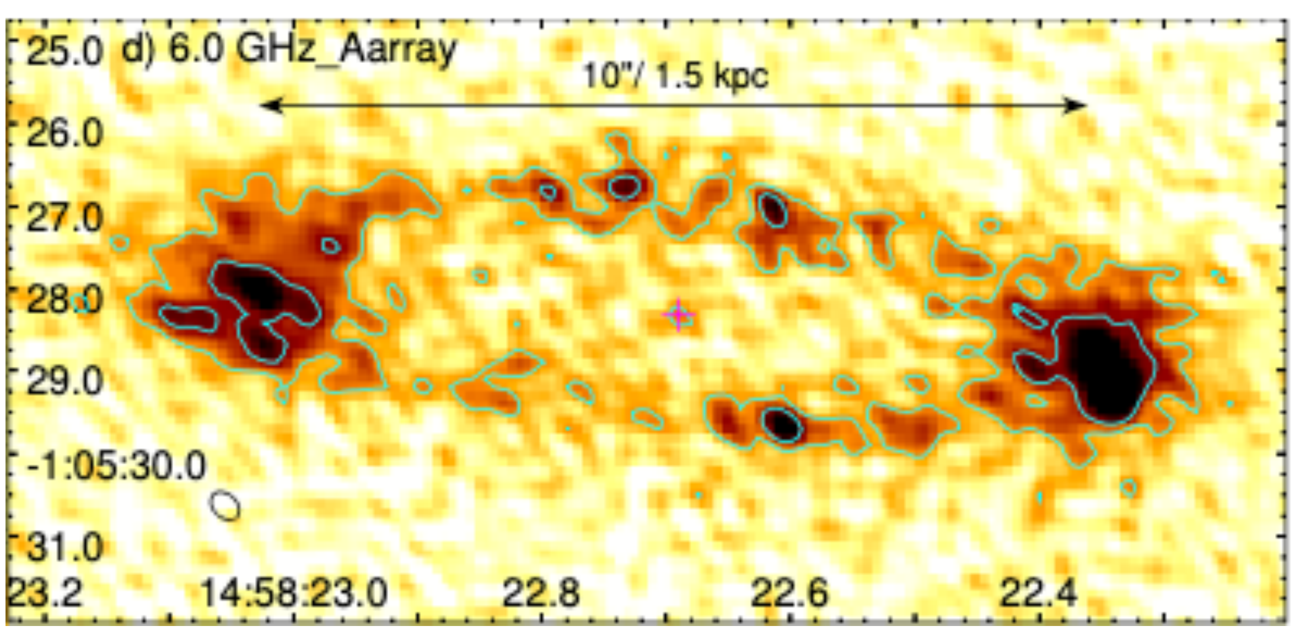
Discussion: AGN in the center

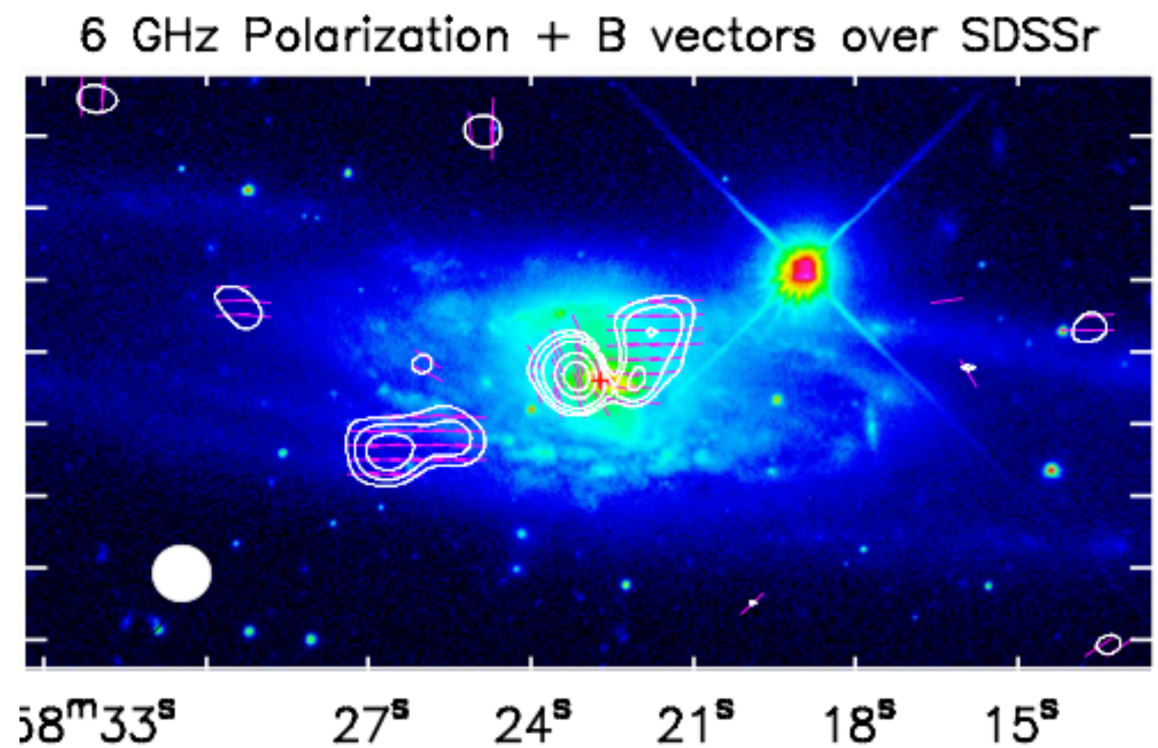
- A compact core with flux density $16 \pm 4\ \mu\mathrm{Jy}\ (\sim 4\sigma)$ at 6 GHz, spectral index of core ≤ 0.7

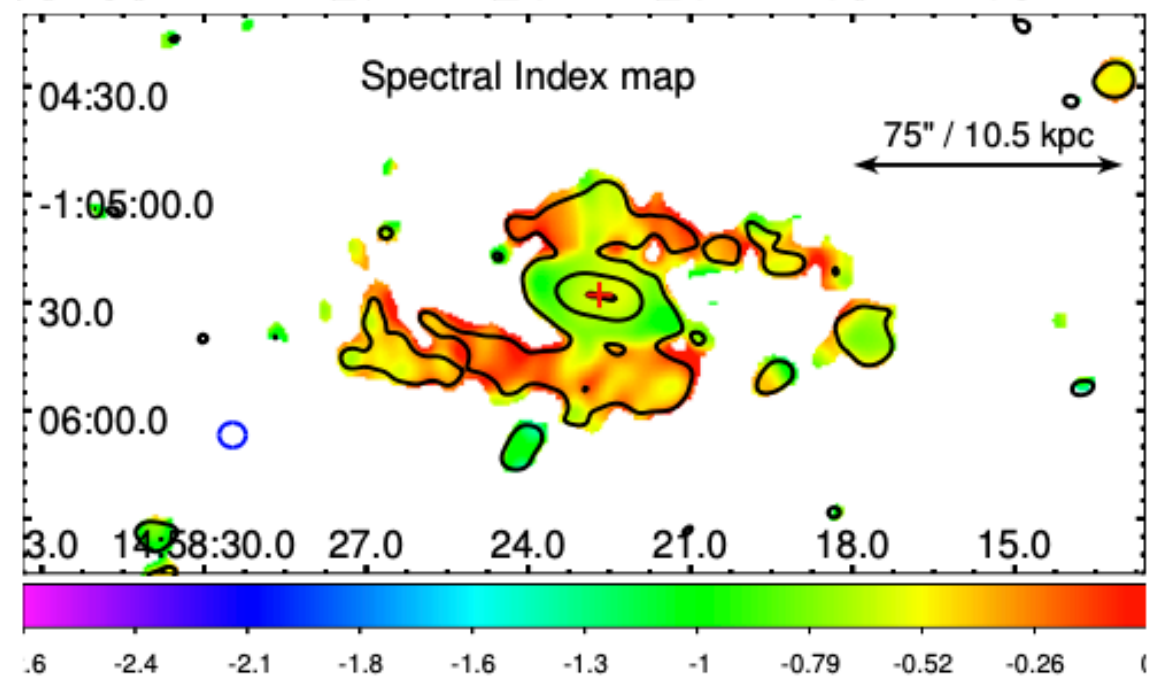
- Two apparent polarized lobes on kpc scales.

- The optical core seems to be obscured by dust.

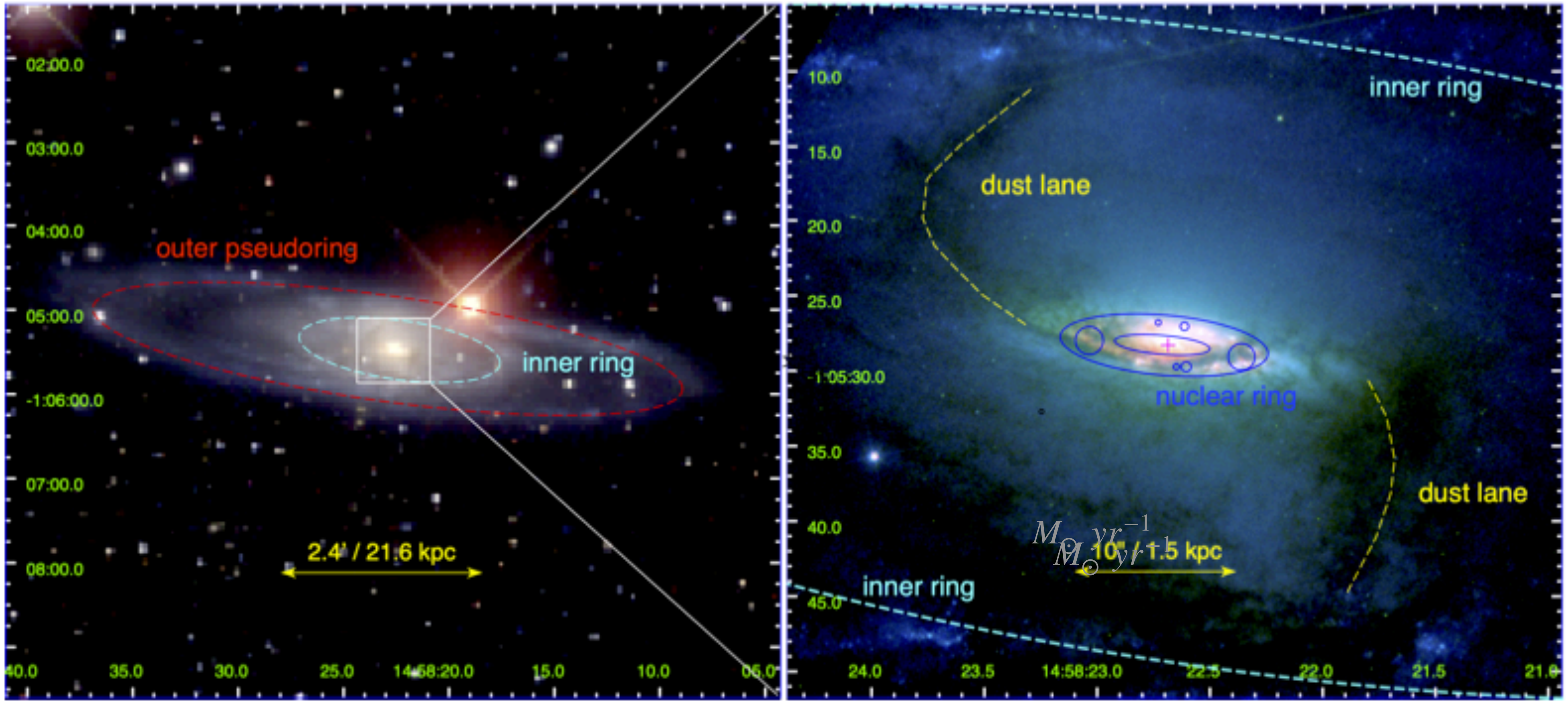
- $L_{0.2-12\ \mathrm{keV}} \sim 2.4 - 20 \times 10^{39} \mathrm{erg\ s^{-1}}$, with $M_{BH} \sim 10^{7.15} M_{\odot}$ (Davis et al. 2014). The Eddington ratio $\sim 10^{-5}$ indicate a LLAGN.



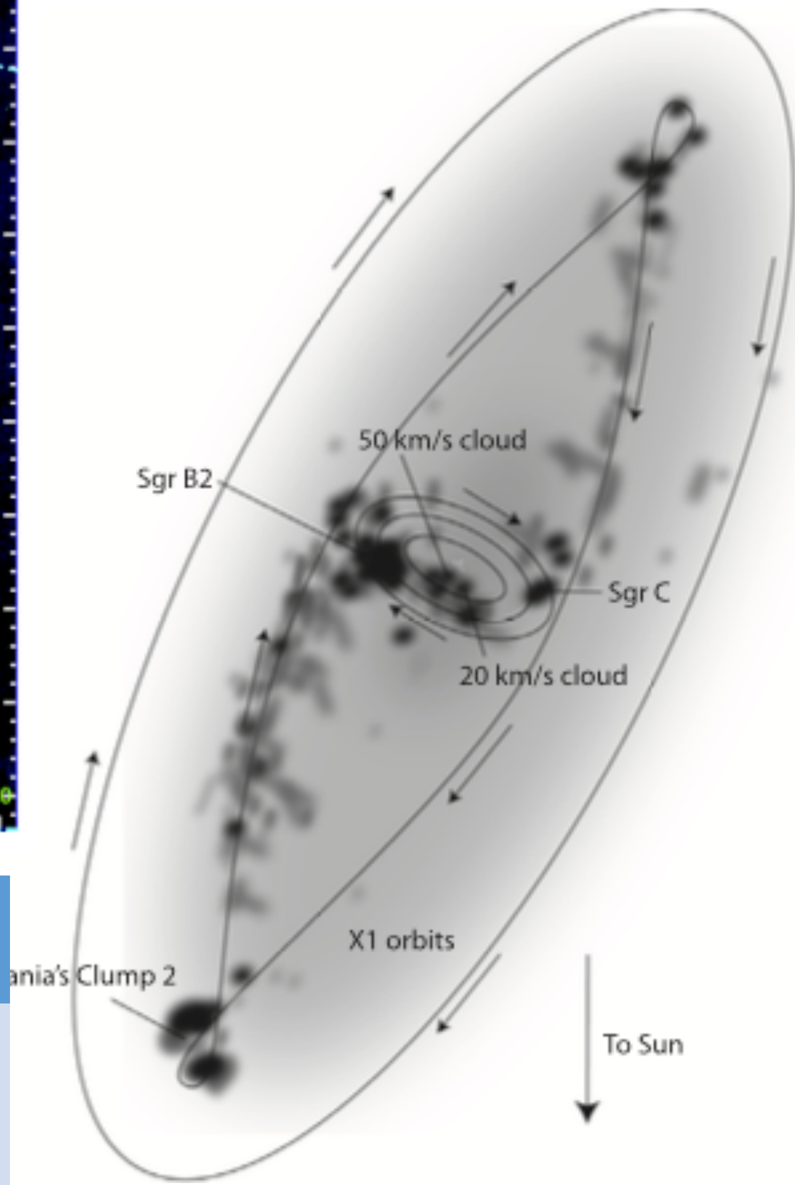




Discussion: comparison with the center of our Galaxy



	NGC 5792	Galaxy
Morphology	Nuclear ring and LLAGN	CMZ and LLAGN
Diameter	1.5 kpc	400 pc
Stellar mass	10^11 M_sun in 72 kpc	10^11 M_sun in 30 kpc
SFR (M_sun yr^-1)	0.4	0.08-0.15
Mass inflow	Further observations	low mass inflow rate



(Bally et al., 2010)

Summary

- We detected a radio nuclear ring in the 6 and 9-GHz images.

- By disentangling thermal and non-thermal emission, we found that the nuclear ring is dominated by the non-thermal synchrotron emission. The possible origin of the excess non-thermal emission may associate the past star forming process.

- The SFR in the nuclear region, ~ 0.4 $M_{\odot}\ yr^{-1}$, is at a low level among the range that the SFR in the nuclear ring of normal barred galaxies spans.

- We found that the nuclear radio ring surrounds a faint and compact (r ~ 50 pc) radio core at the center of NGC 5792 in the 6 GHz image, with a flux density of 16 ± 4 μJy.

Thanks for your attention!