Sgr A Lobes as a Tidal Disruption Event at the Galactic Center

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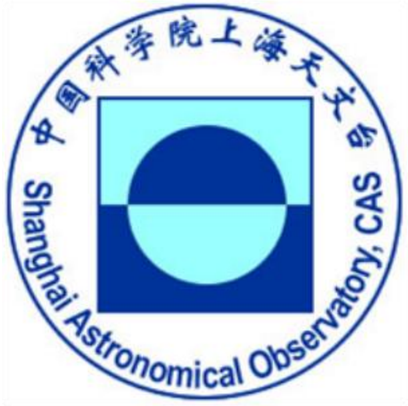
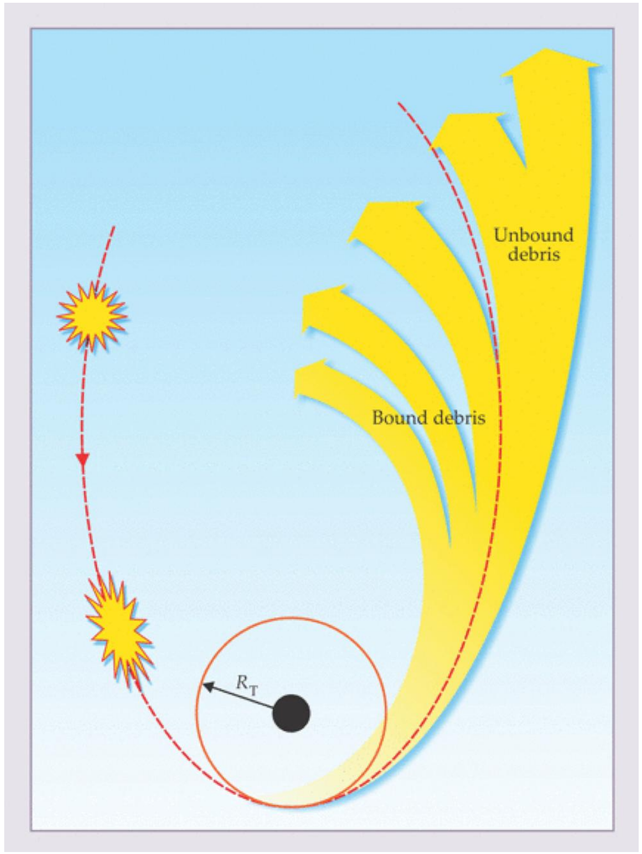
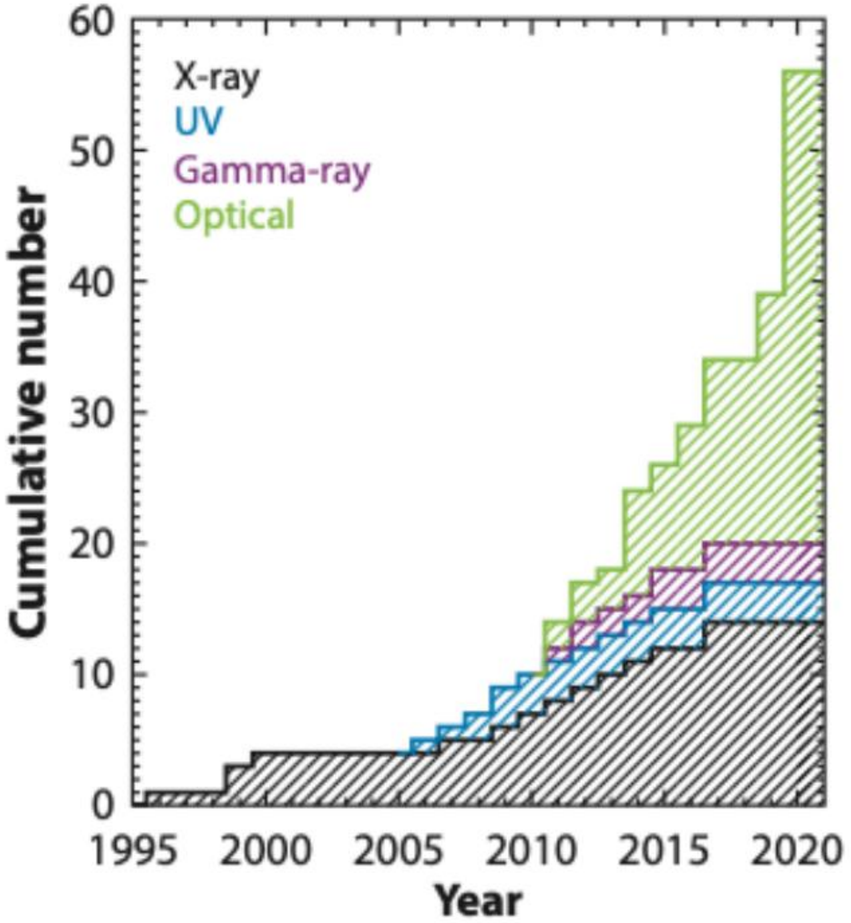


Transient Phenomena and Physical Processes Around Supermassive Black Holes, Shanghai, October 15-18, 2024

More than 100 candidate TDE flares have been detected

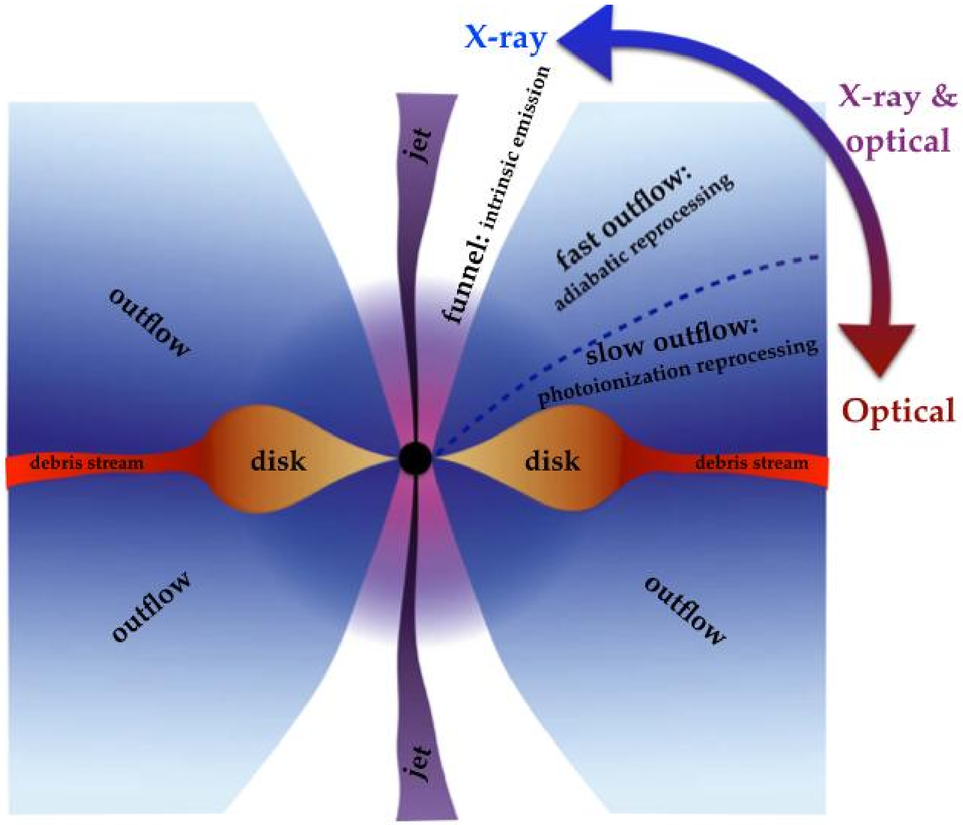


Tidal Disruption Event

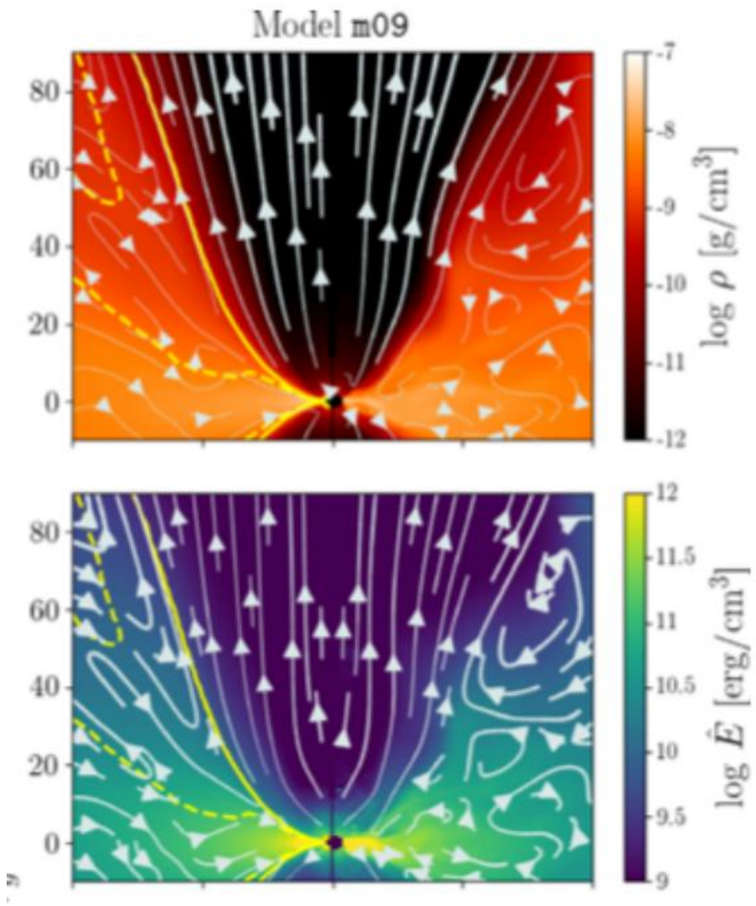


Gezari 2021

TDE Jets and Outflows



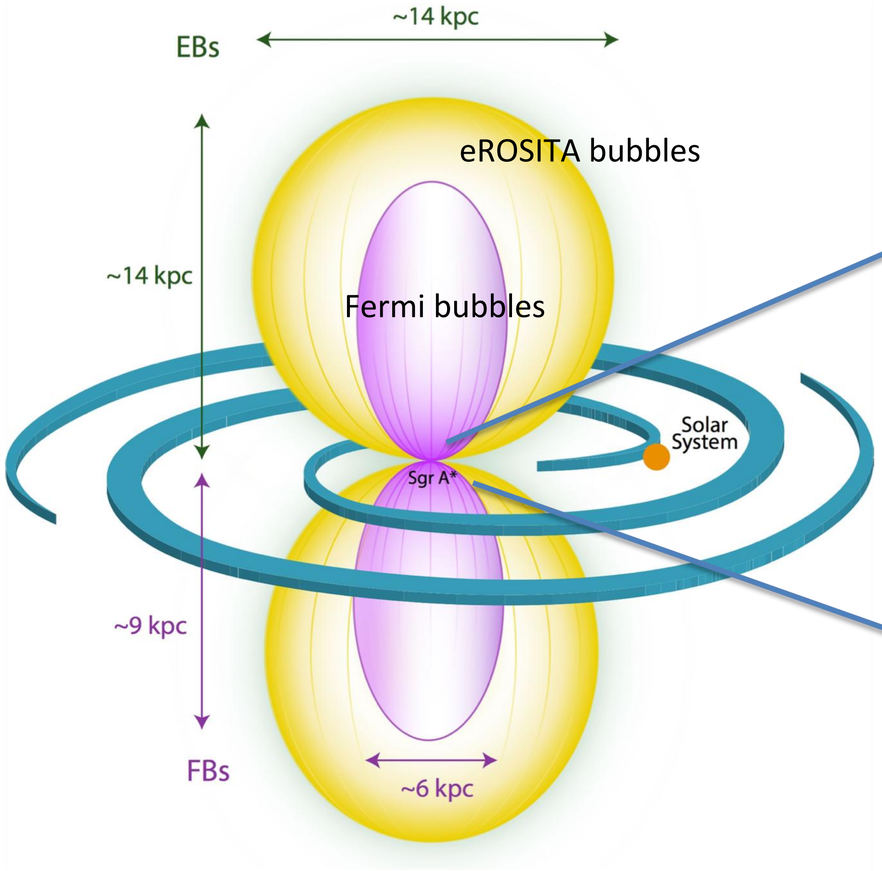
TDE outflows and jets
Dai +2018



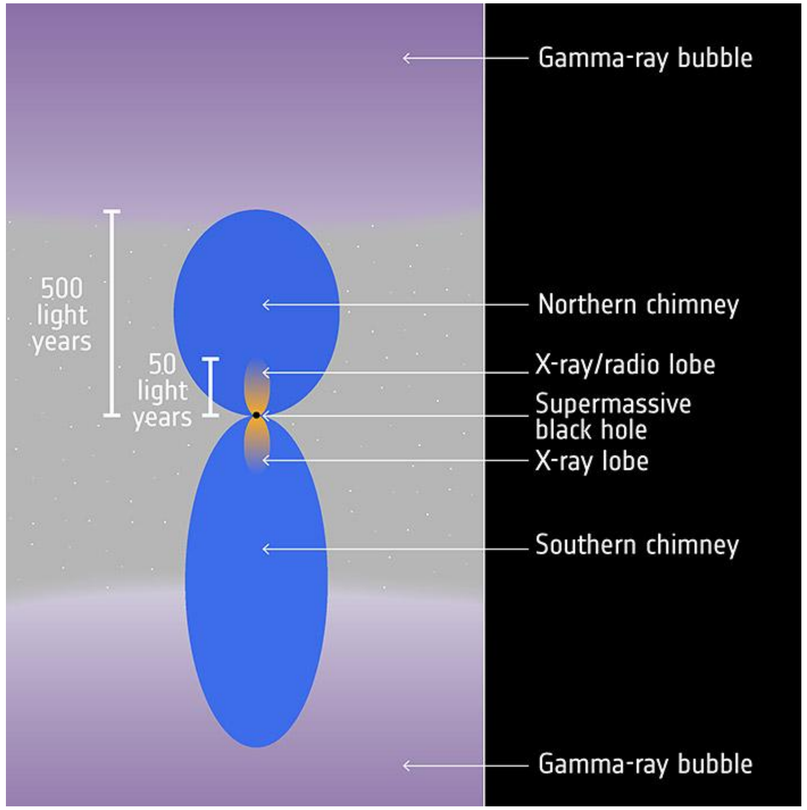
TDE jets in simulations
Curd et al 2019

Observations have found evidence for several TDE jets through radio, X-ray or gamma ray emissions, e.g., Swift J1644+57 (Andreoni+2022), Sw 1644+57 (Bloom+2011), Swift J164449.31573451 (Burrows+2011) …

Galactic Center: Energetic Bubbles

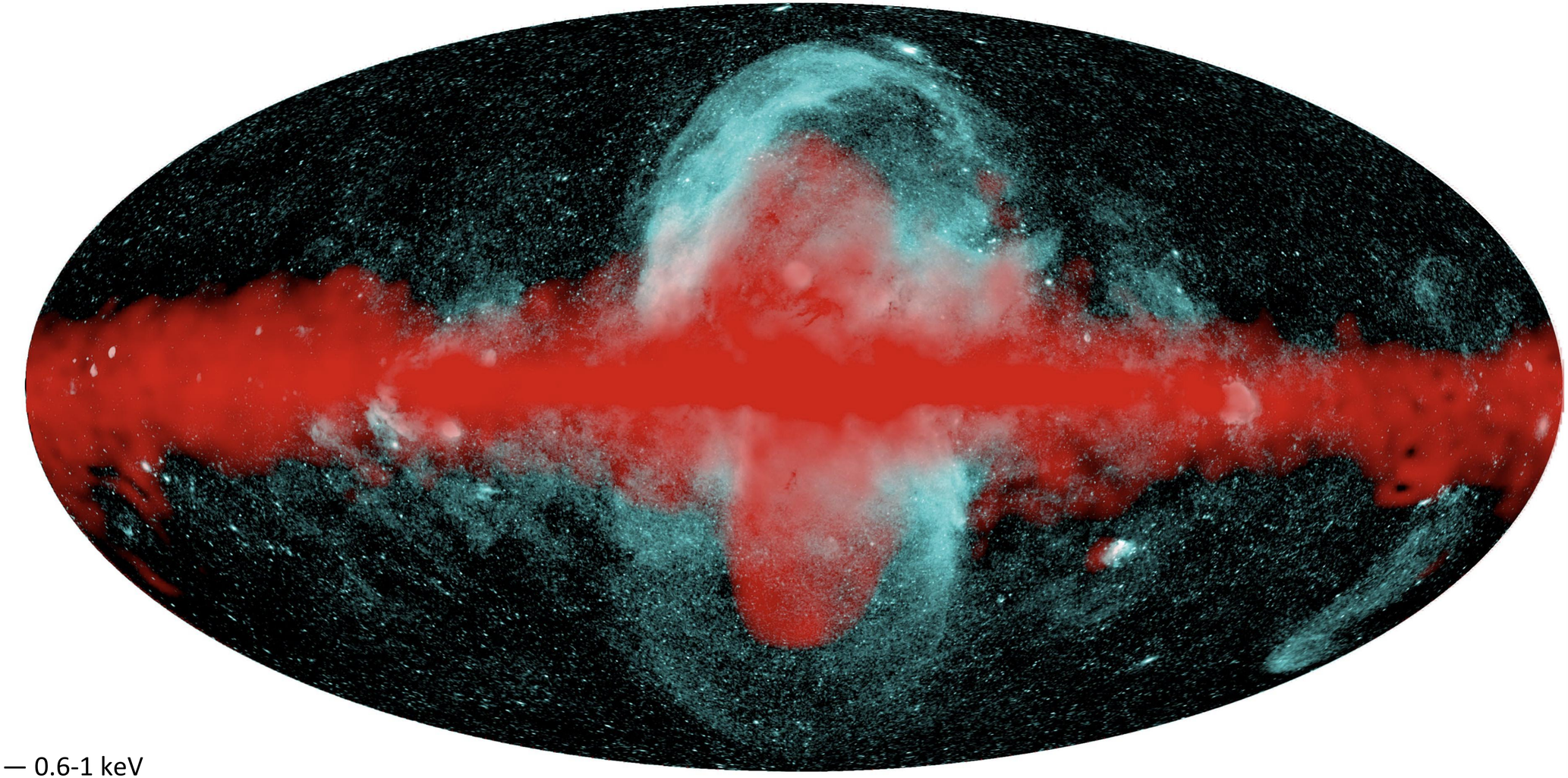


eROSITA and Fermi bubbles



Galactic center lobes and the central X-ray lobes

The eROSITA bubbles (cyan) and Fermi bubbles (red)

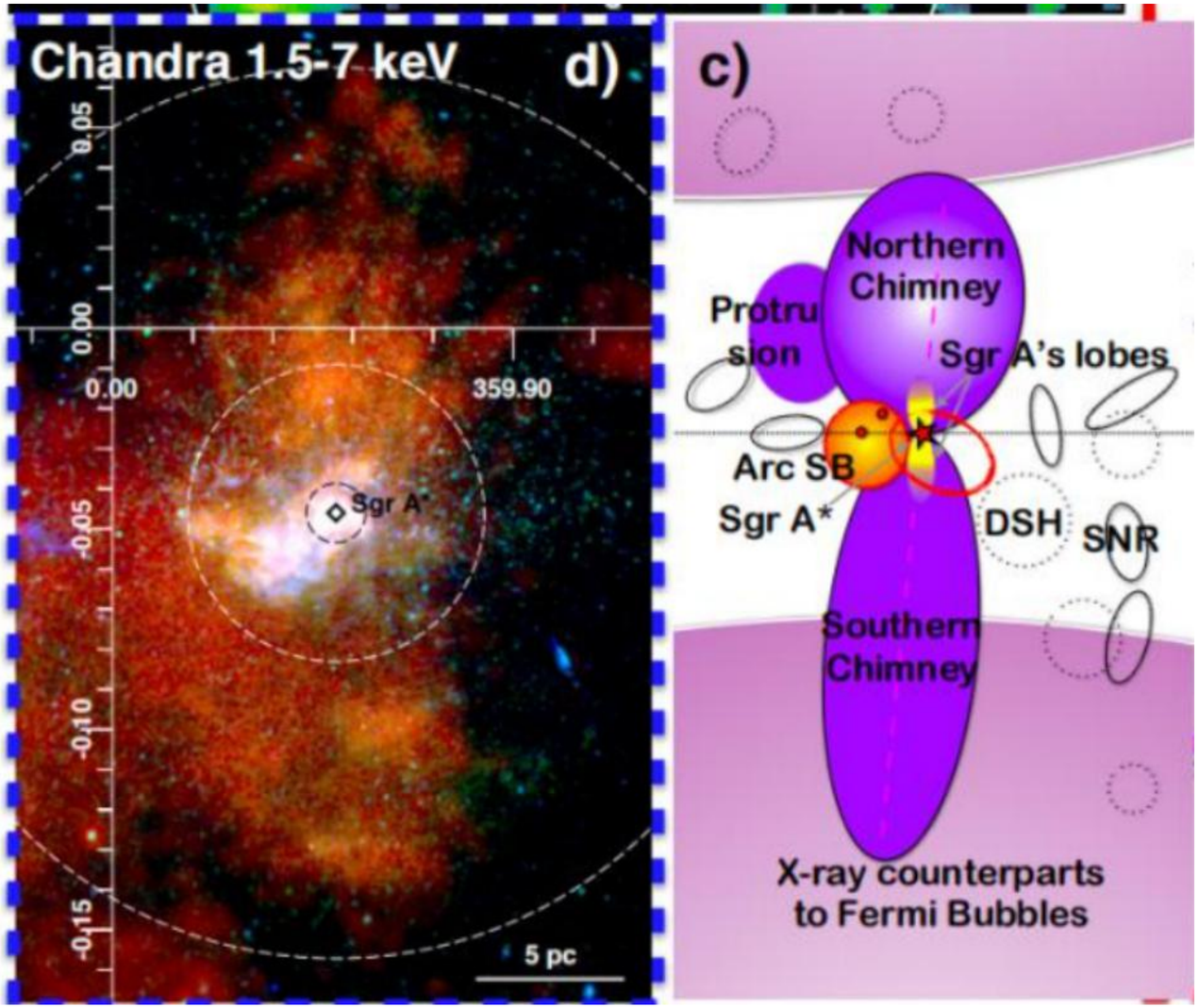


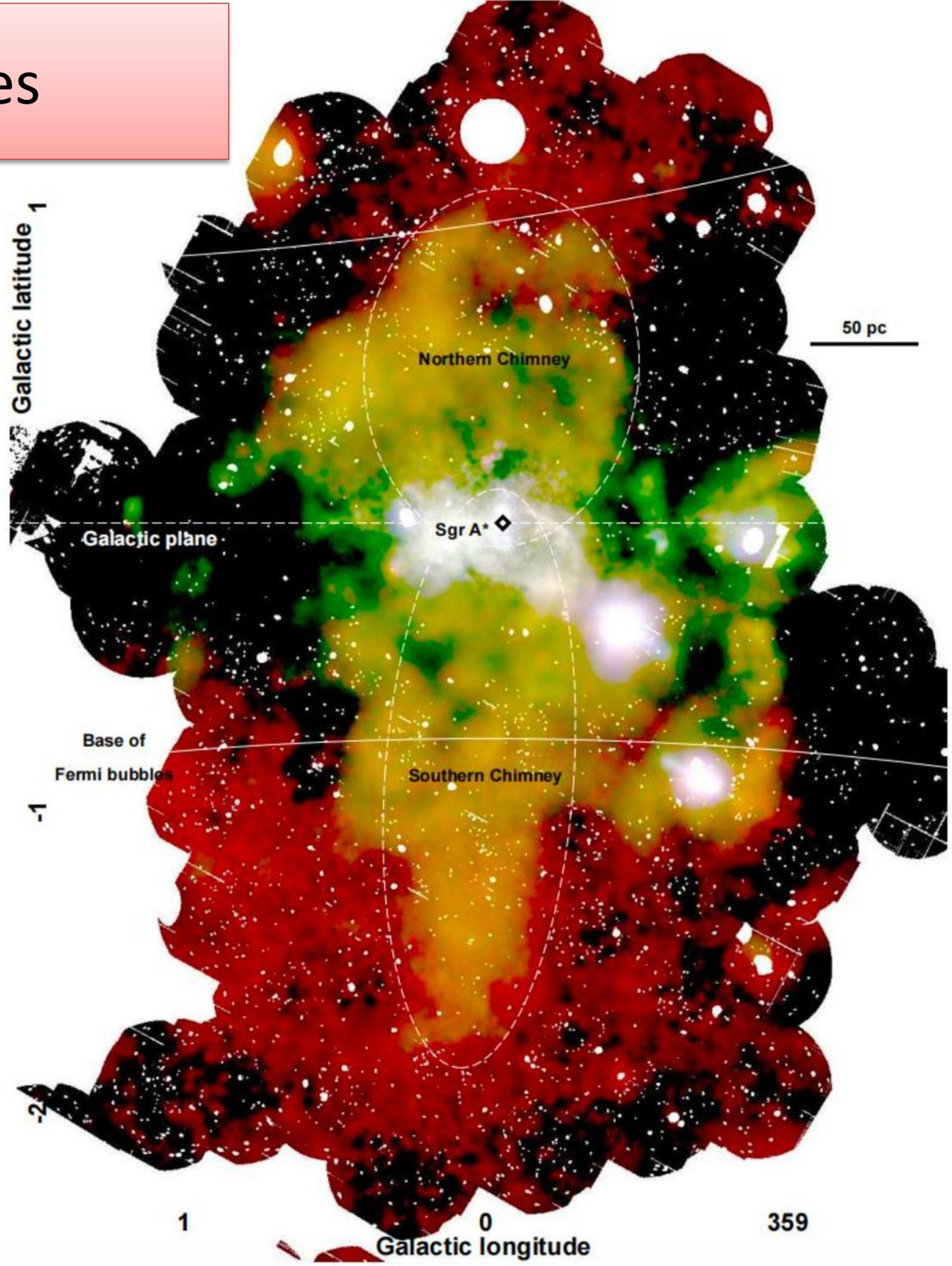
Cyan — 0.6-1 keV

red — Fermi map

eROSITA bubbles (Predehl + 2020)

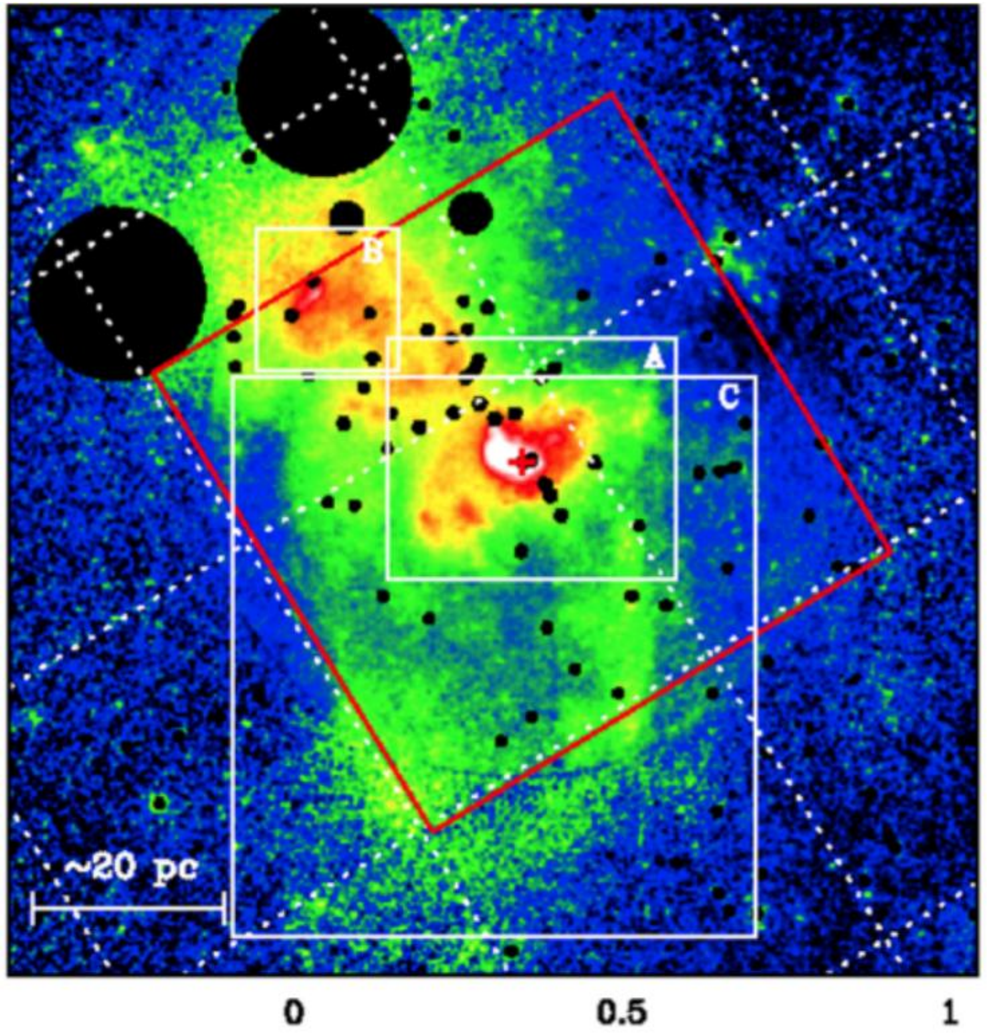
Galactic Center Chimneys and Sgr A Lobes



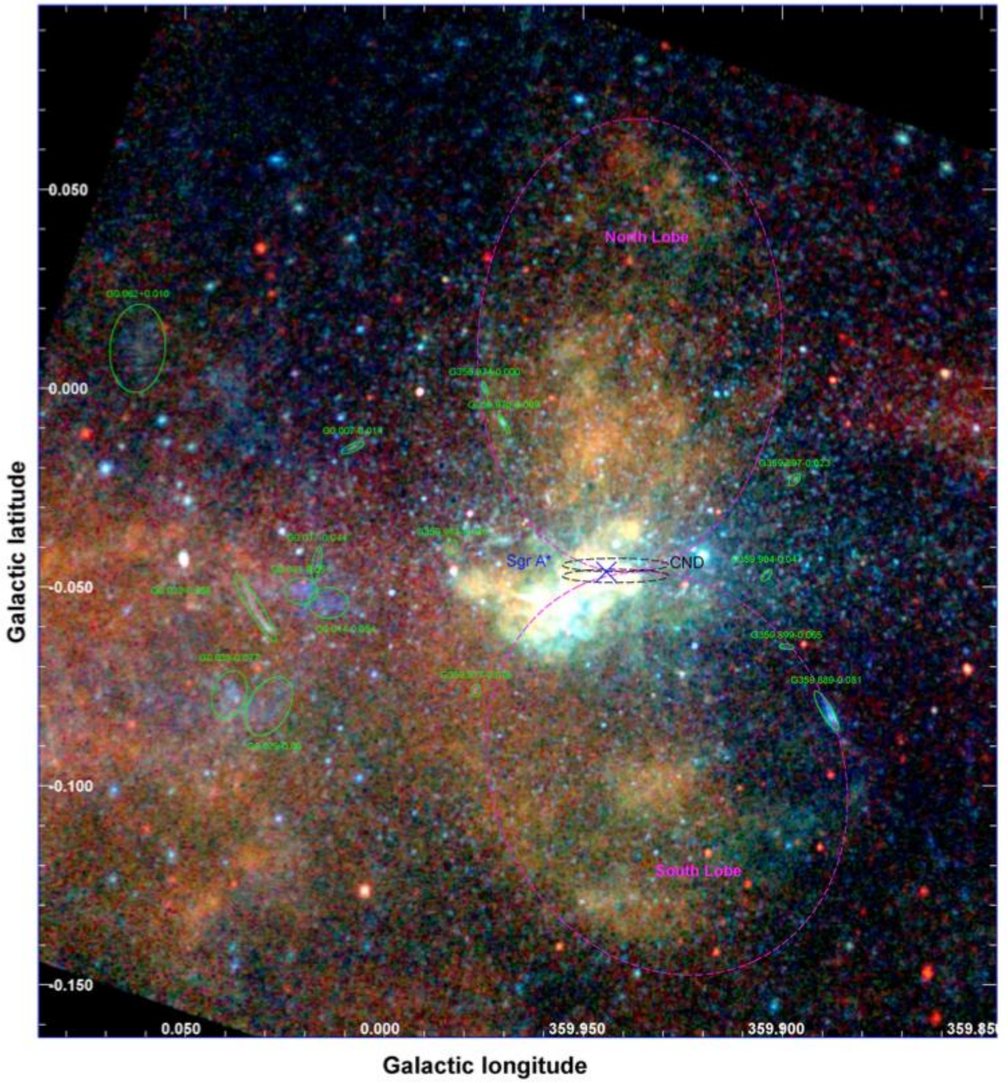


Ponti et al 2019 Nature

The Central 15-pc Sgr A Lobes



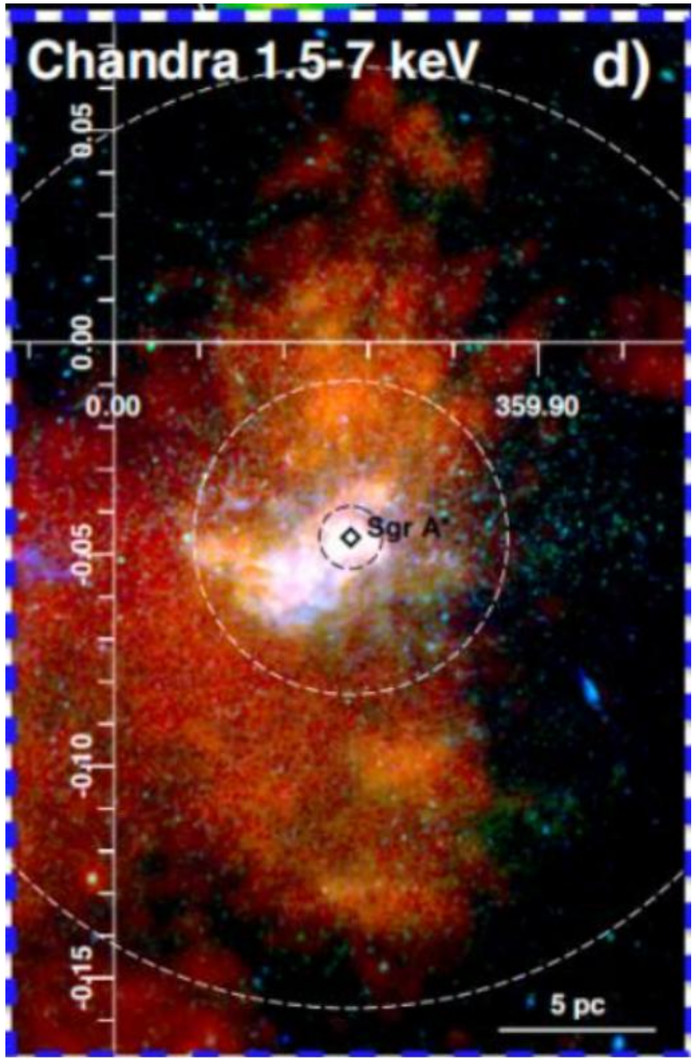
XMM-Newton 2-4.5 keV
Heard & Warwick 2013



Chandra X-rays
Ponti et al 2015, 2019

density: a few /cm^3
T ~ 0.7 - 1 keV
mass ~ few solar mass
energy: ~ 10^{51} erg

Possible Origin of the central 15-pc Sgr A Lobes



Chandra X-rays
Ponti et al 2015, 2019

density: a few /cm^3
T ~ 0.7 - 1 keV
mass ~ few solar mass
energy: ~ 10^{51} erg

Possible origin

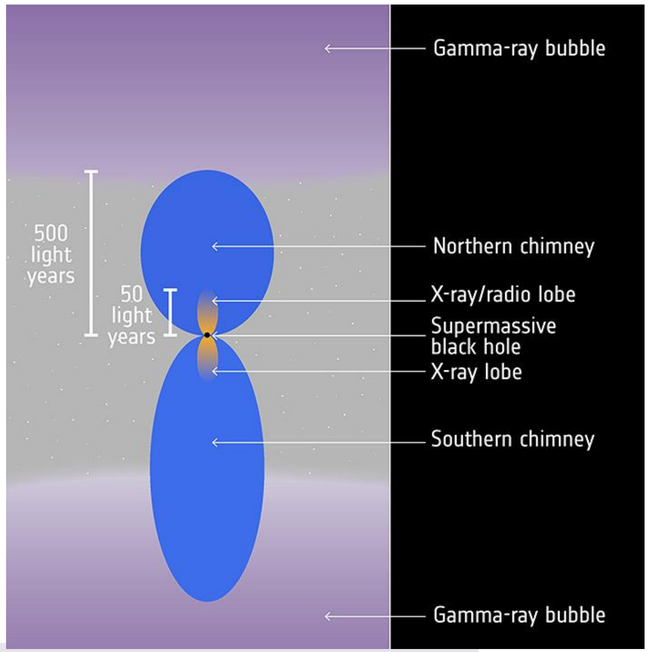
(1) TDE jet/outflow : bipolar, energy consistent

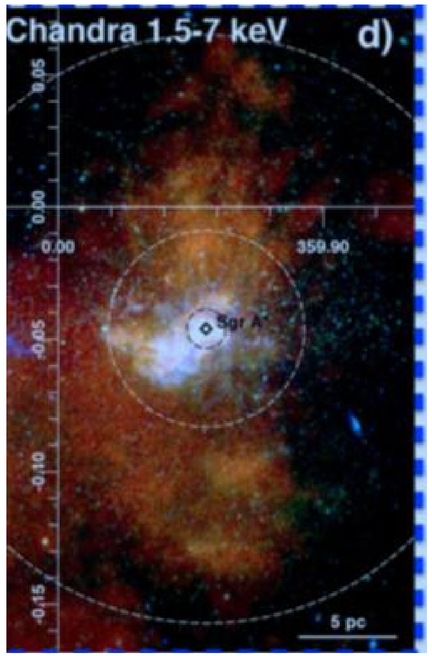
(2) Supernova explosion: energy consistent

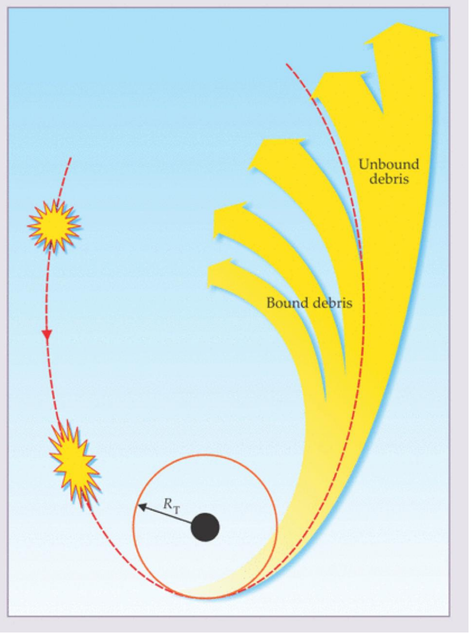
(3) collective stellar outflows from the central star cluster (age ~ 6 Myr)

(4) AGN jet/wind

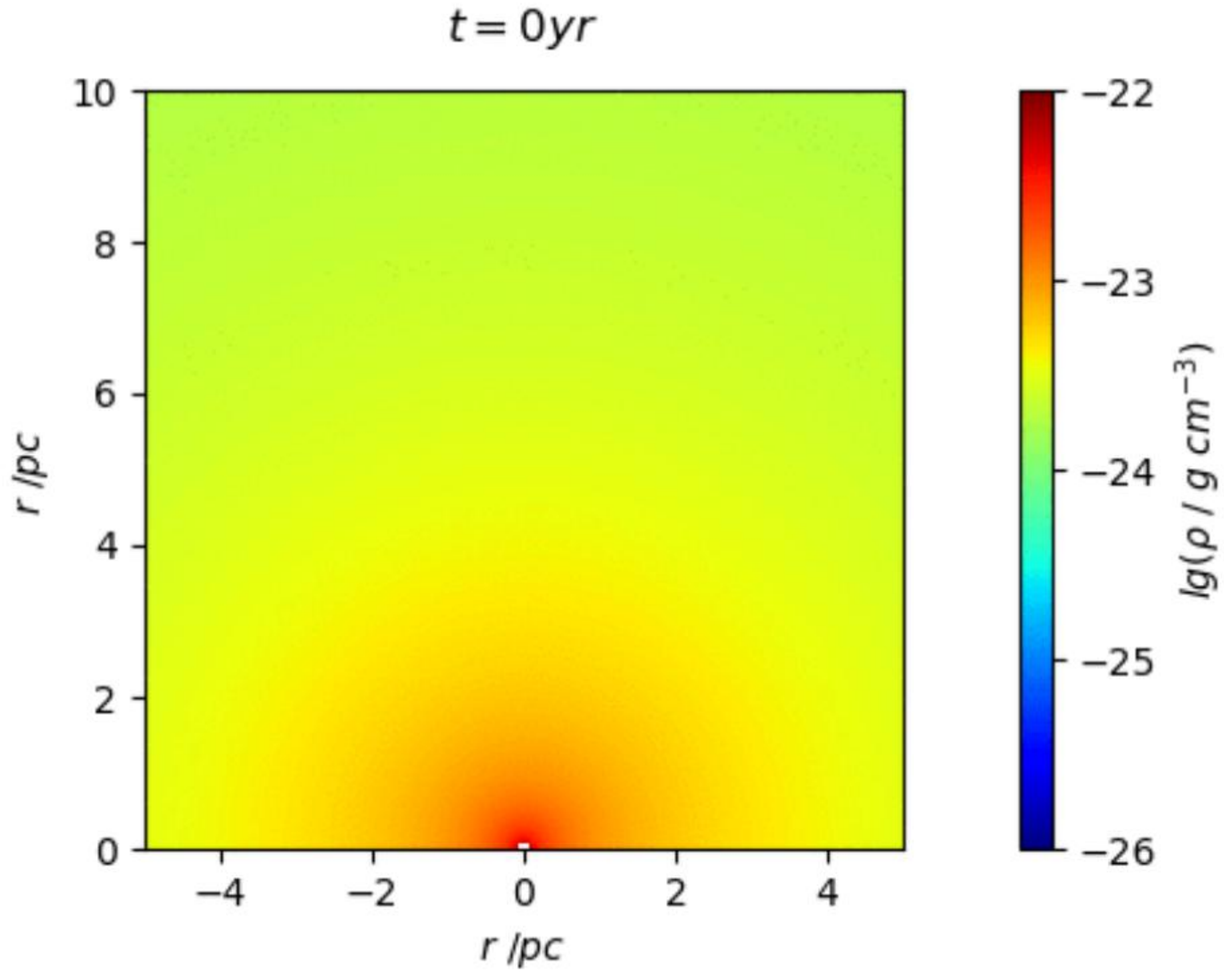
The Central Sgr A lobes: Are they produced by a pair of TDE Outflows in the recent past?







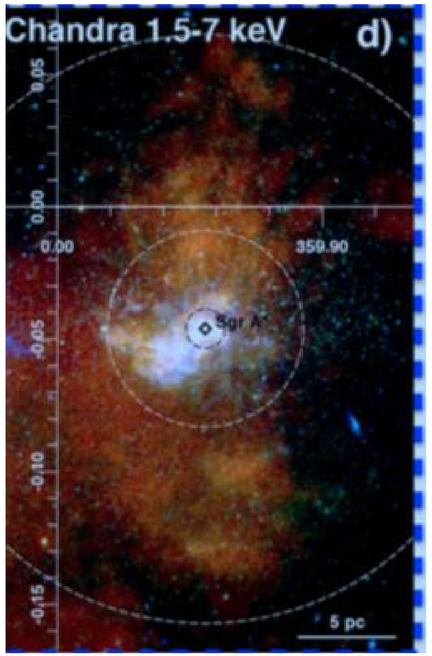
energy: ~ 10^{51} erg (TDE)

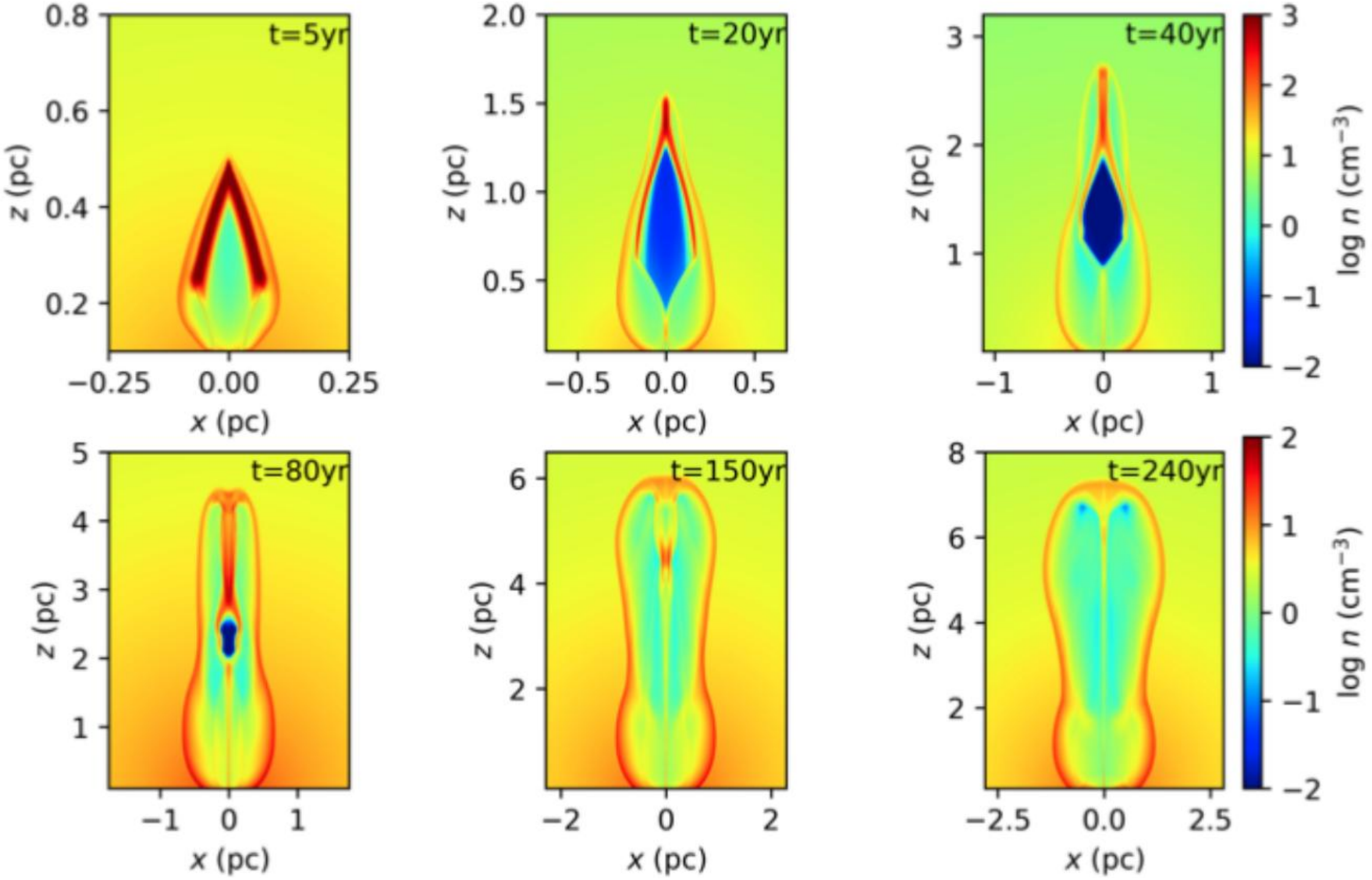


Jet duration: 0.5 year
Jet power: declining with time t^-5/3
Ejecta mass: a fraction of the disrupted star
inner boundary: 0.1 pc
evolving to 15 pc

Li & Guo,2024

The TDE Jet Model of the Central Sgr A lobes: Jet Evolution





Li & Guo, 2024 submitted

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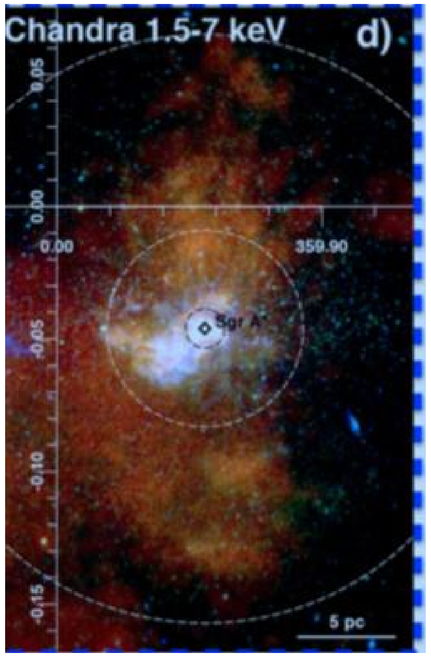
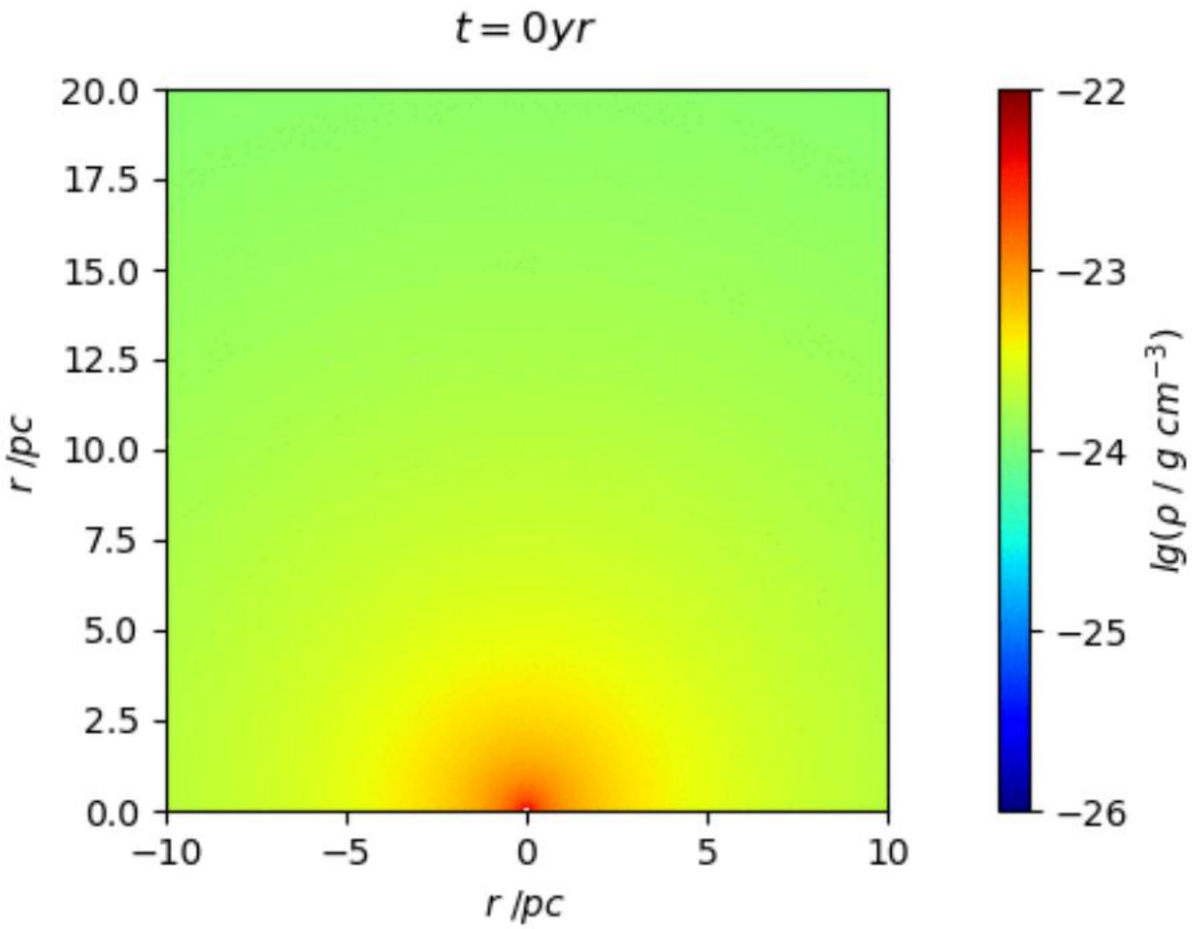
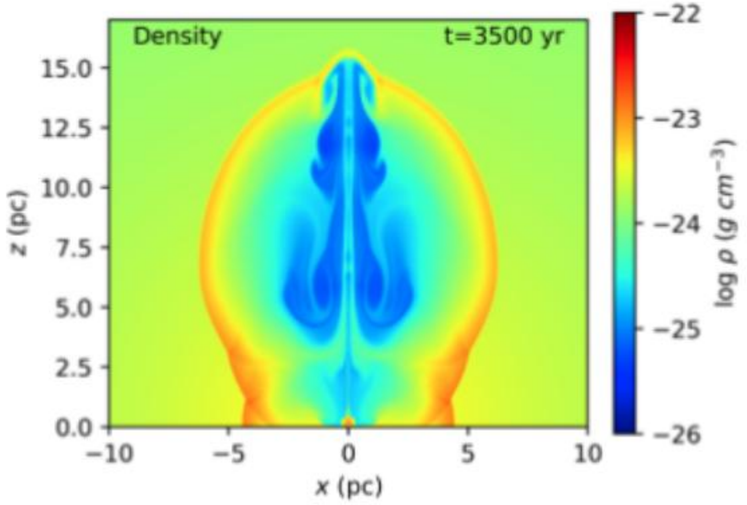
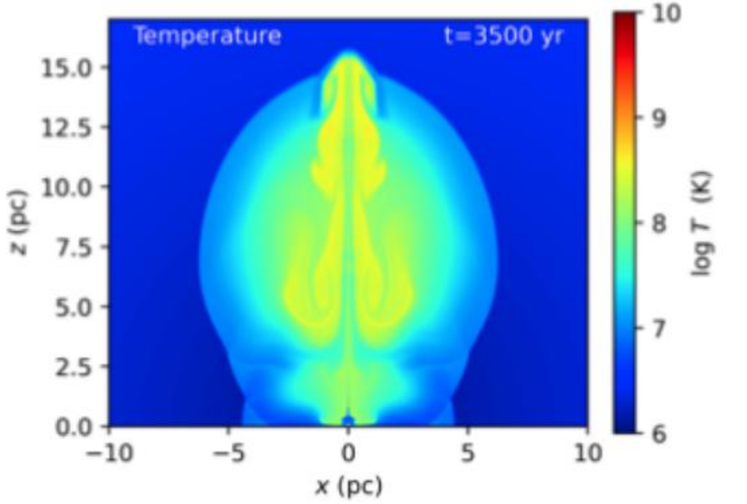


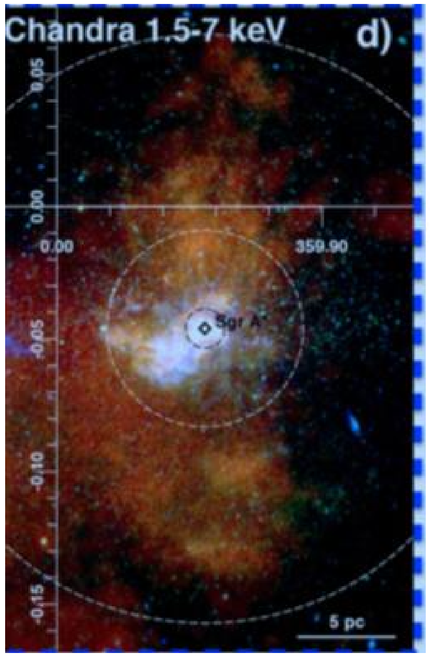


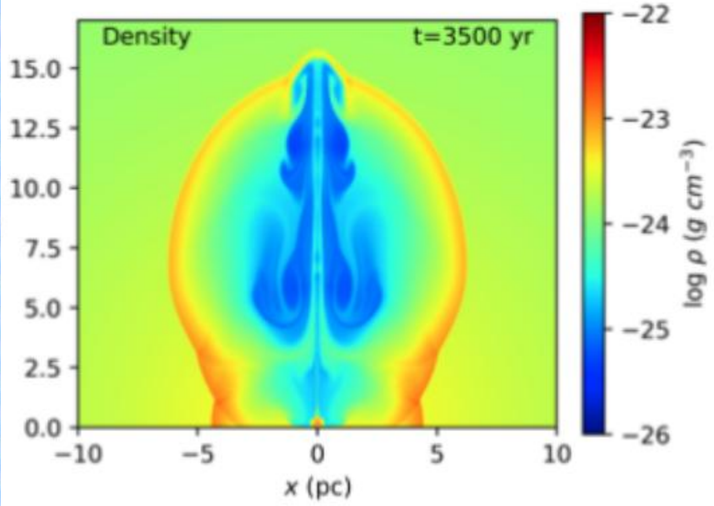


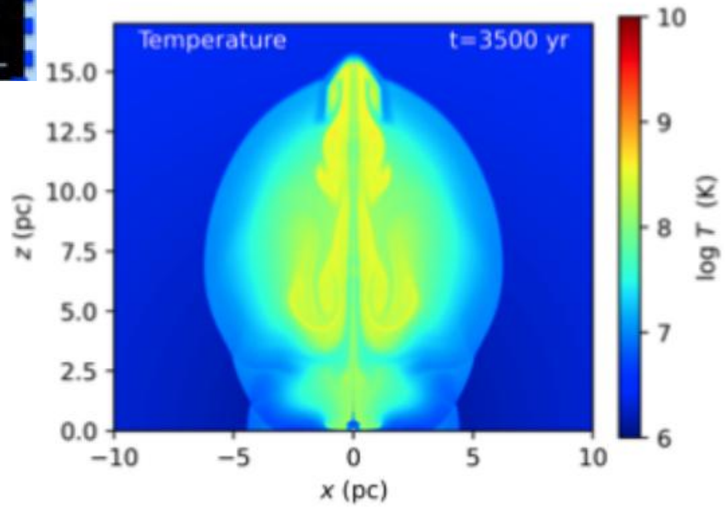


Li & Guo, 2024 submitted

The TDE model of Sgr A lobes: Comparing with X-ray observations







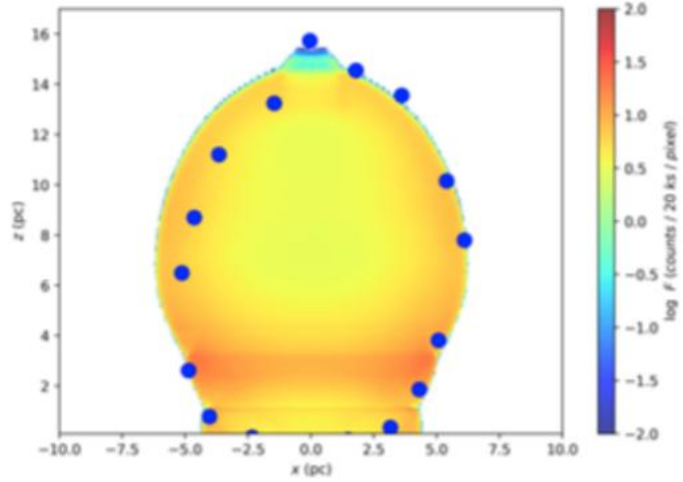
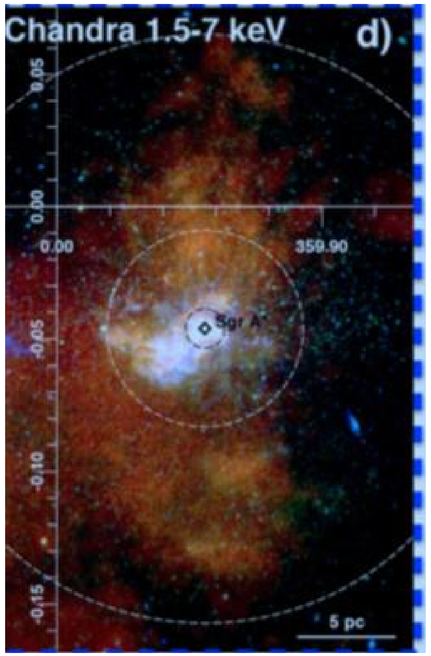
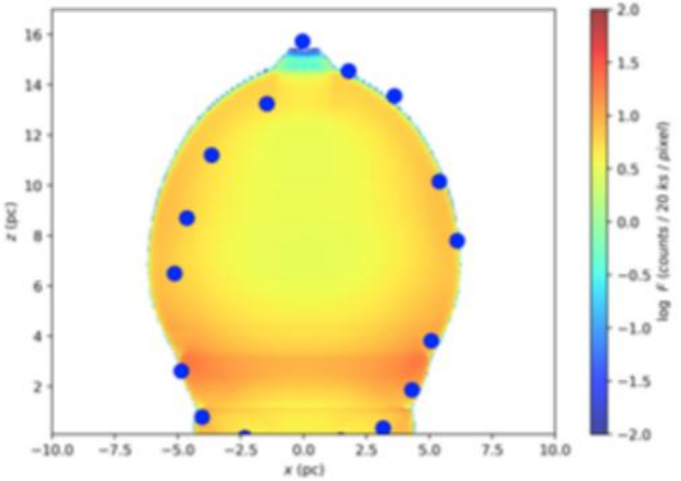


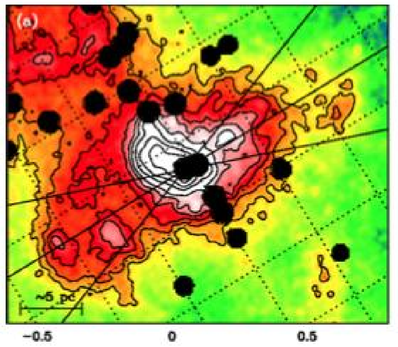
Figure 3 Synthetic $2-4.5$ keV X-ray surface brightness distribution at $t = 3500$ yr in our fiducial run FR. The morphology of the simulated lobe fits quite close to the observed northern Sgr A lobe delimited by the blue dots [16]. The absorption of X-ray emission by the intervening neutral materials has been taken into account, and the predicted X-ray surface brightnesses of the simulated Sgr A lobe is roughly consistent with the observations [15].

Li & Guo, 2024 submitted

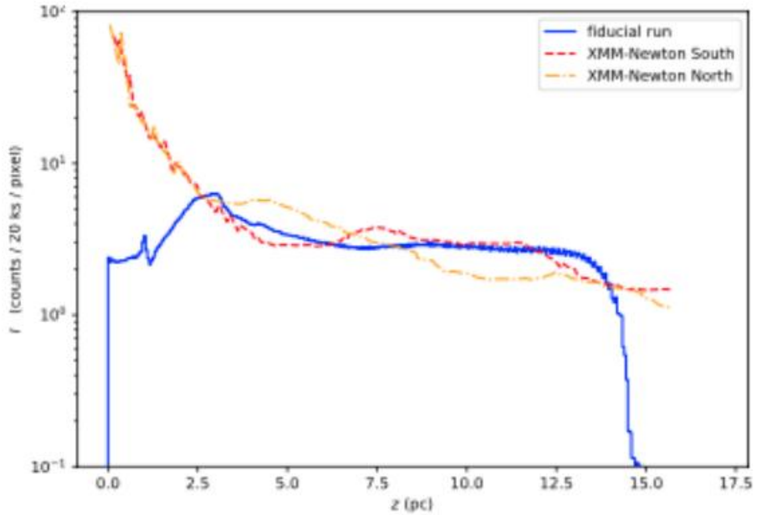
The TDE model of Sgr A lobes: Comparing with X-ray observations

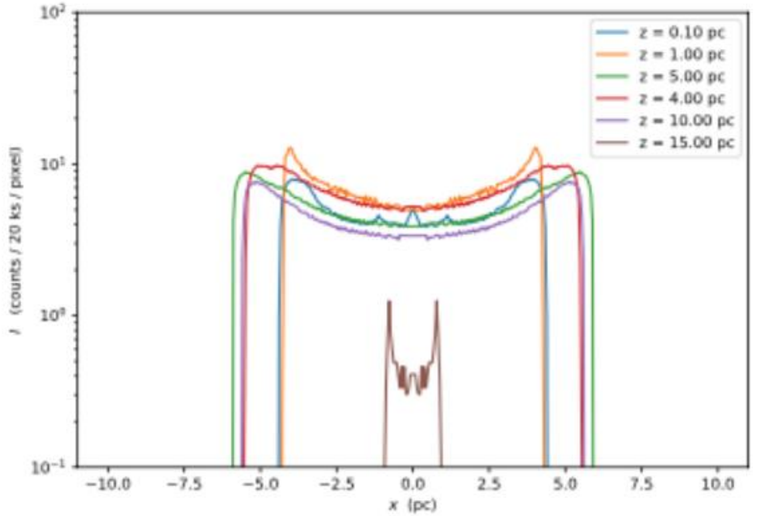






Heard & Warwick 2013





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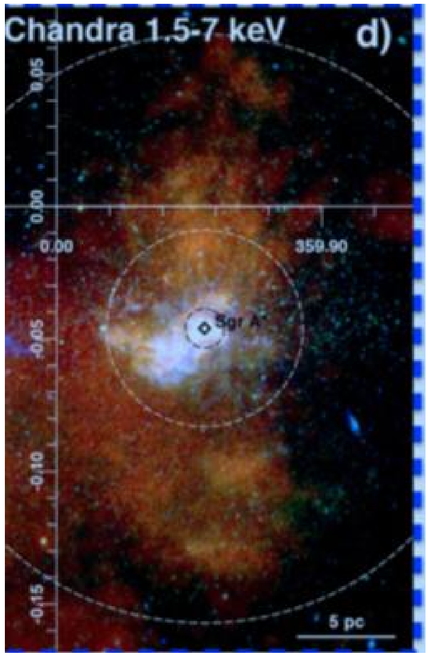
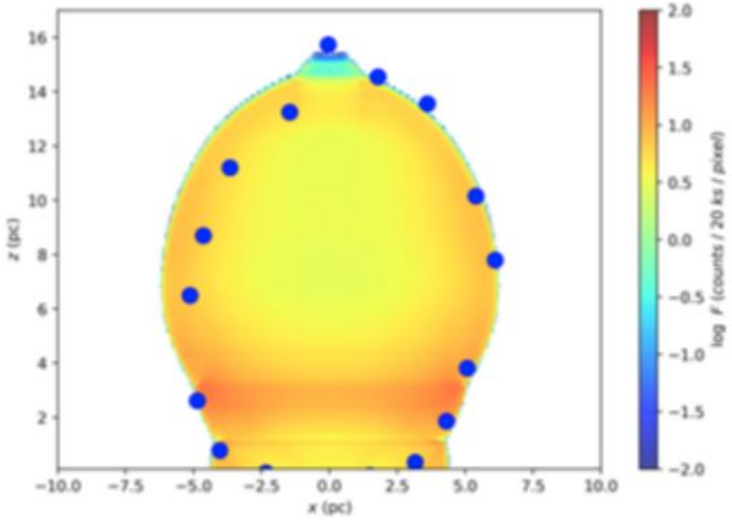
Li & Guo, 2024 submitted

The Central Sgr A lobes: A TDE jet event in our own galaxy 3500 years ago?



XMM-Newton 2-4.5 keV



X-ray Surface Brightness

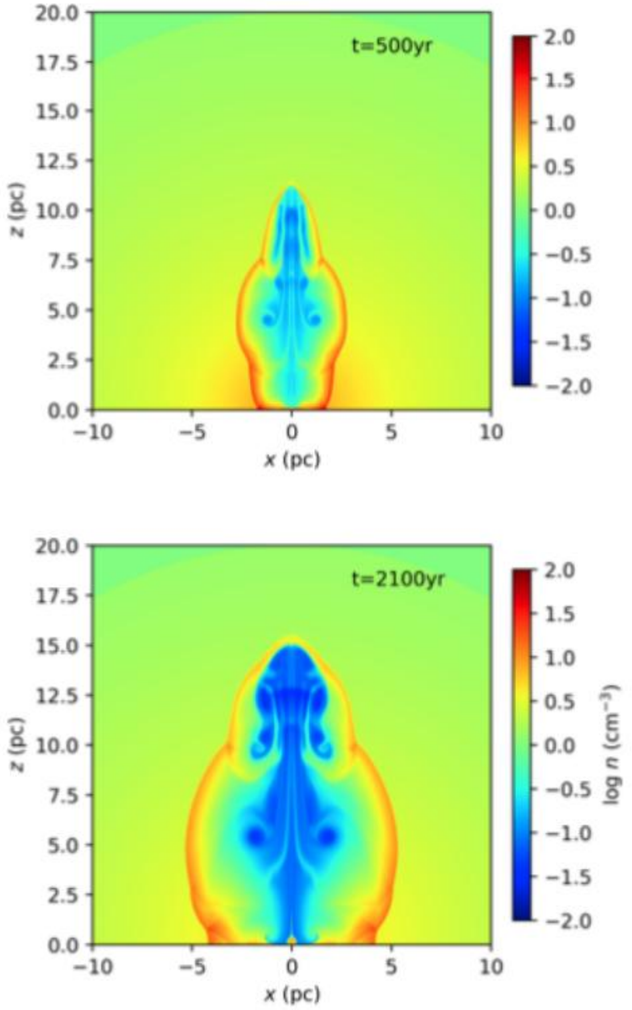
Model fits the observed morphology, gas density, T, and X-ray surface brightness distribution quite well

emission-weighted average density: 5.90 /cm^3
emission-weighted average T ~ 1.02 keV

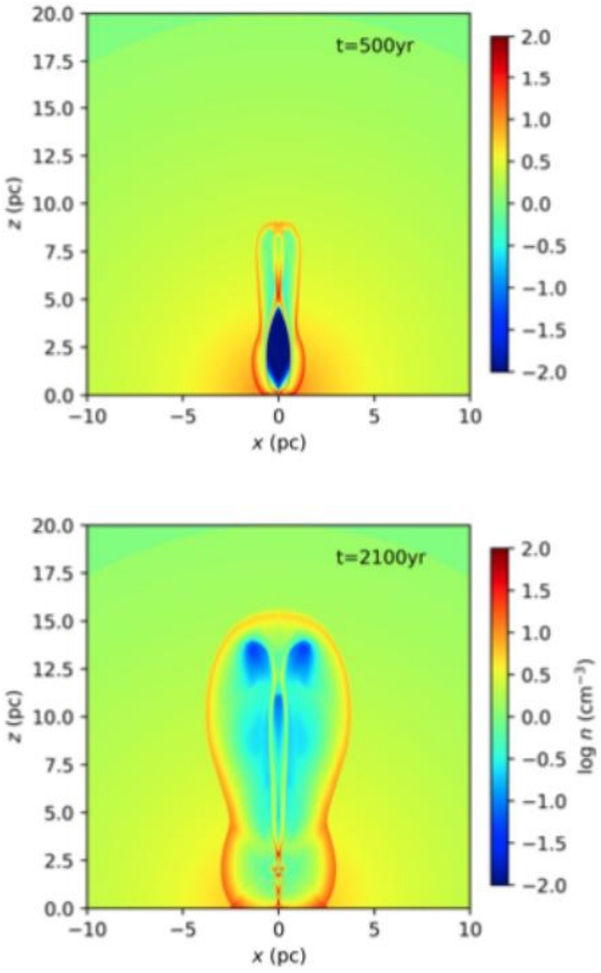
Total injected mass 0.05 solar mass
total injected energy 9.7 X 10^{50} erg
half-opening angle 15 degree
lobe age: 3500 year

TDE rate expected in the Milky Way ~ once in 10000 years

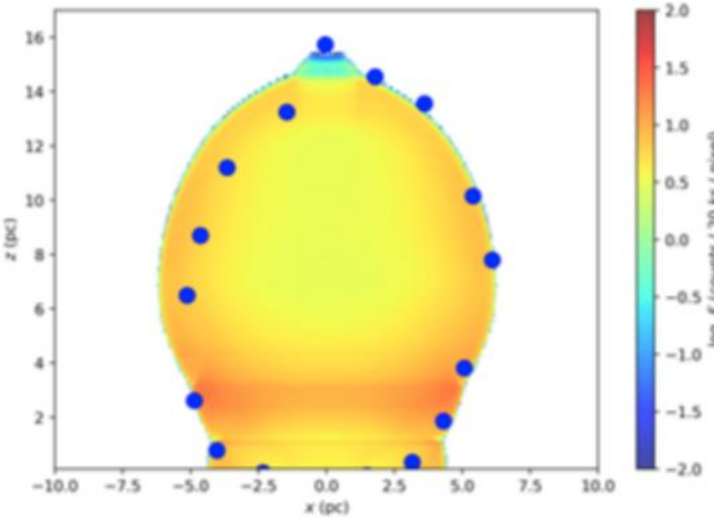
Parameter study: very-light thin jet and wide massive wind



Very-light thin jet
ejecta mass: 0.005 solar mass
half opening angle : 5 degree



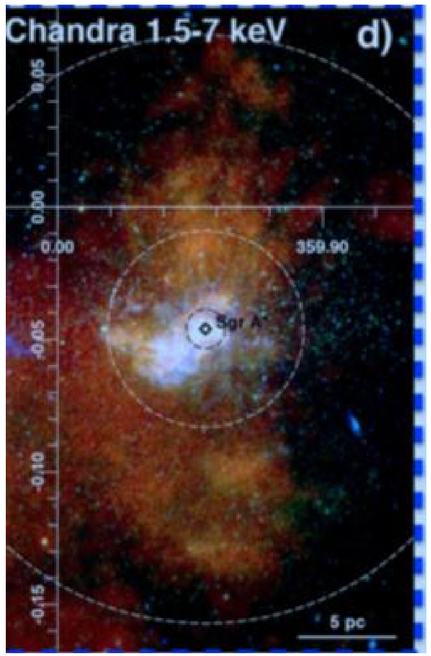
wide massive wind
ejecta mass: 0.2 solar mass
half opening angle : 60 degree



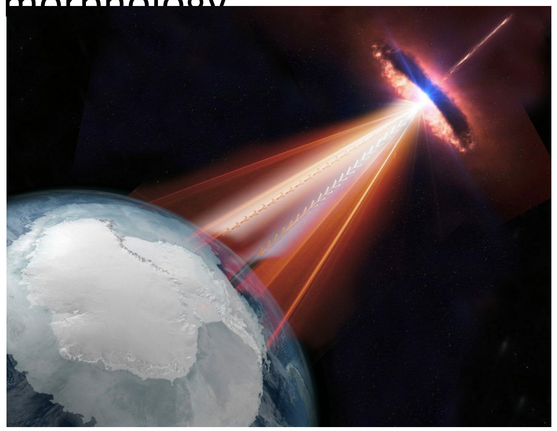
light thin jet in our fiducial run
ejecta mass: 0.024 solar mass
half opening angle : 15 degree

Li & Guo,2024

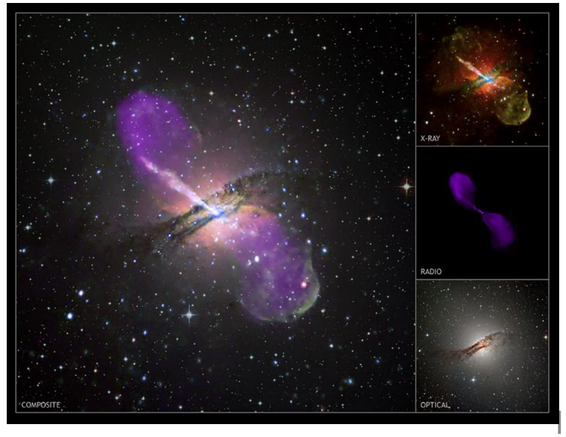
Summary



- A TDE jet event occurring about 3500 years ago could naturally produce the observed bipolar Sgr A lobes, which is roughly consistent with the TDE occurrence rate.
- The best-fit TDE jets eject a total mass of 0.05 solar mass, and a total energy of about 10^51 erg, occurring about 3500 years ago and lasting for about 0.5 years.
- The jet evolution in the circumnuclear medium produces a shock-delimited lobe, reproducing the observed morphology, density, temperature, and X-ray emission of the Sgr A lobes
- The lobe morphology and other properties are affected by jet parameters. Very light thin jets and wide massive outflows are not consistent with the observed lobe morphology



blazar



radio galaxy