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Hydrodynamic Simulations of the Supernova Remnant Puppis A with PLUTO

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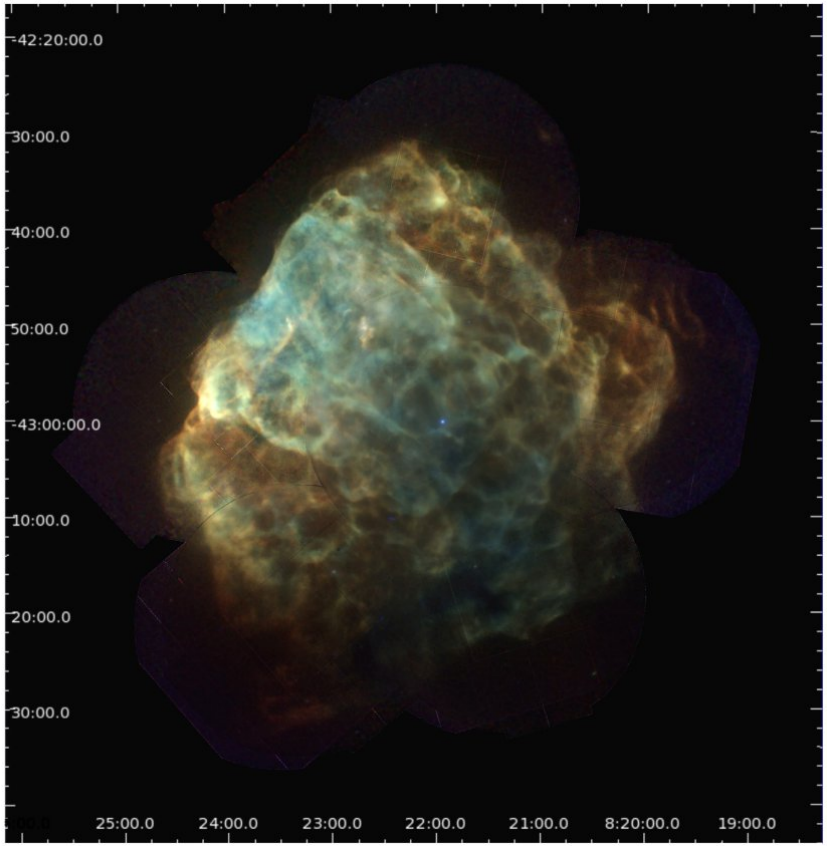
1. Observations of Puppis A – X-rays



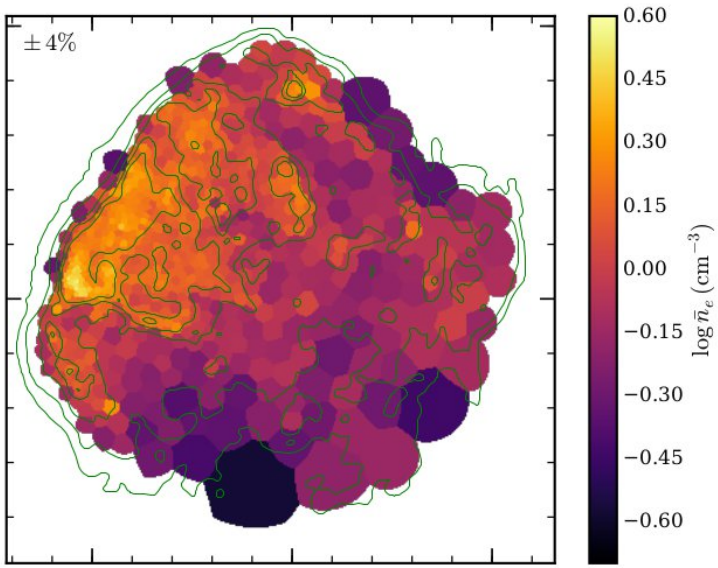
0.3 - 0.7 keV Chandra + XMM Newton

0.7 - 1.0 keV Dubner et al. 2013

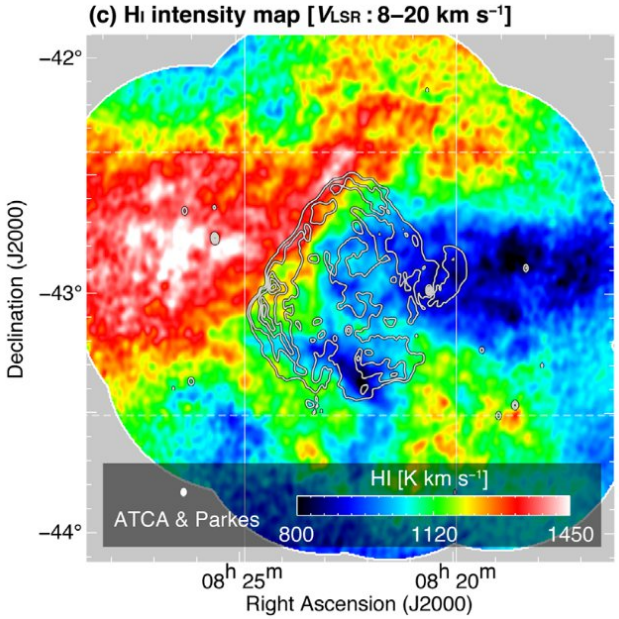
1.0 - 8.0 keV

- Galactic core-collapse SNR
- peculiar shape in X-rays: “nested boxes”
- distance
  1.3 kpc (Reynoso et al. 2017)
- $R \sim 10.6$ pc
- age: ~ 4000 yrs (e.g. Mayer et al. 2020)

Density Distribution



Density map (Mayer et al. 2022)

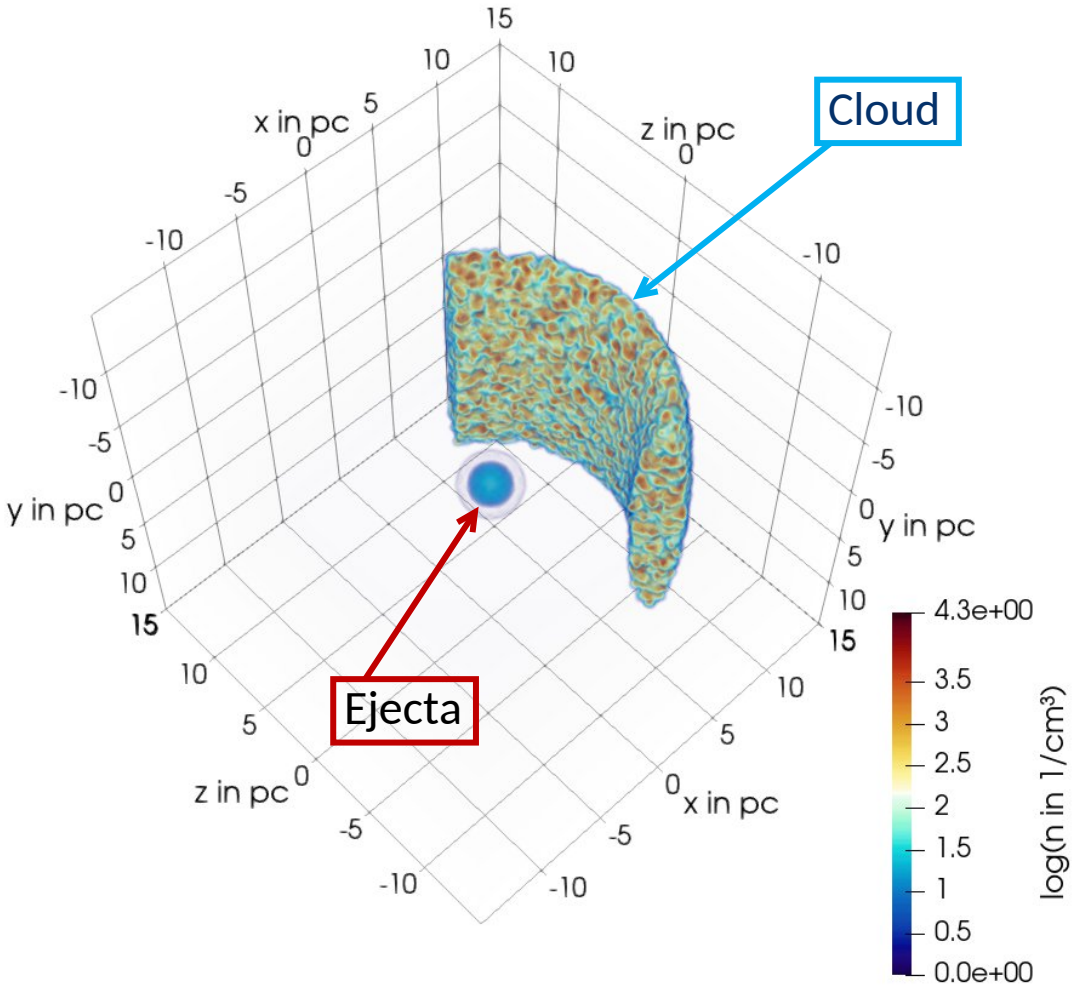


HI radio map
> density of cloud: 230 cm^{-3}
(Aruga et al. 2022)

→ HD model setup for Puppis A with constraints from observations
→ focus on reproducing the X-ray morphology

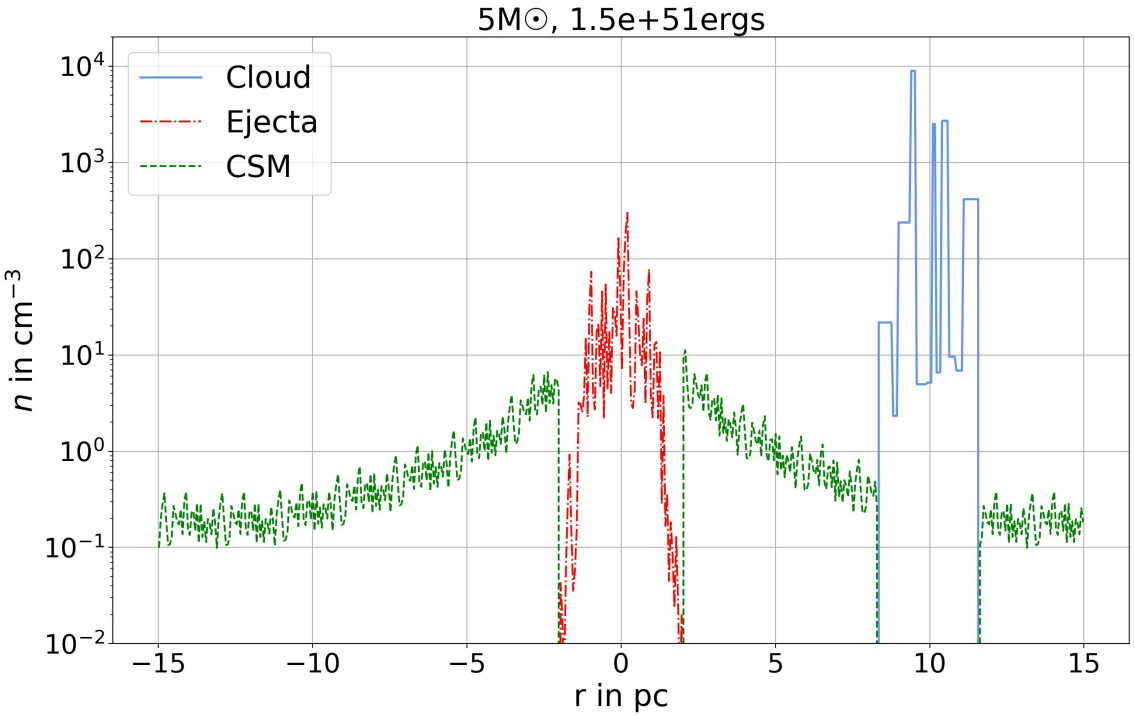
2. Hydrodynamical Simulations - 3D Initial Conditions

- HD simulations with PLUTO (Mignone et al. 2010)
- $M_{\mathrm{ejecta}} = 5\ \mathrm{M}\odot$
- $E_{\mathrm{kin}} = 1.5 \times 10^{51}\ \mathrm{erg}$
- Chevalier density profile (Chevalier 2005), ejecta clumping
- higher density cloud at $10\ \mathrm{pc}$ ($\mathrm{n} \sim 200\ \mathrm{cm}^{-3}$, based on Aruga et al. 2022)
- ambient density: power law profile with index 2



3D Simulations – Initial Density Distribution

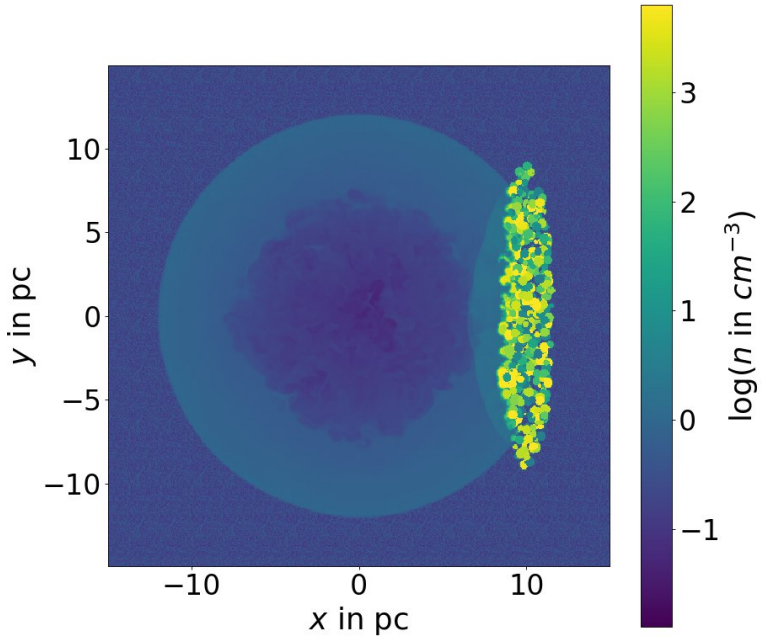
Initial density profile:



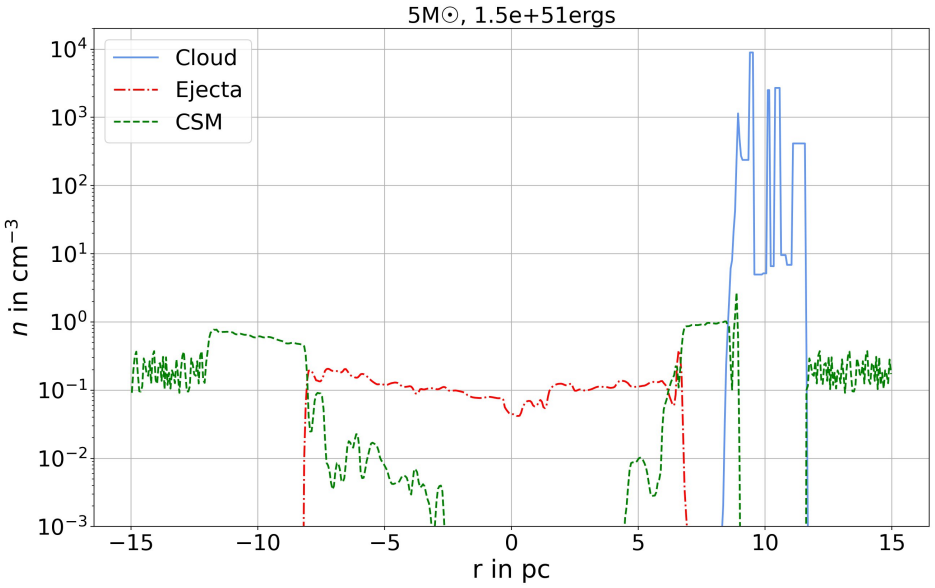
→ random density clumping implemented in cloud, ejecta, and CSM

3D Simulations – Results after 5000 Years

Density distribution:



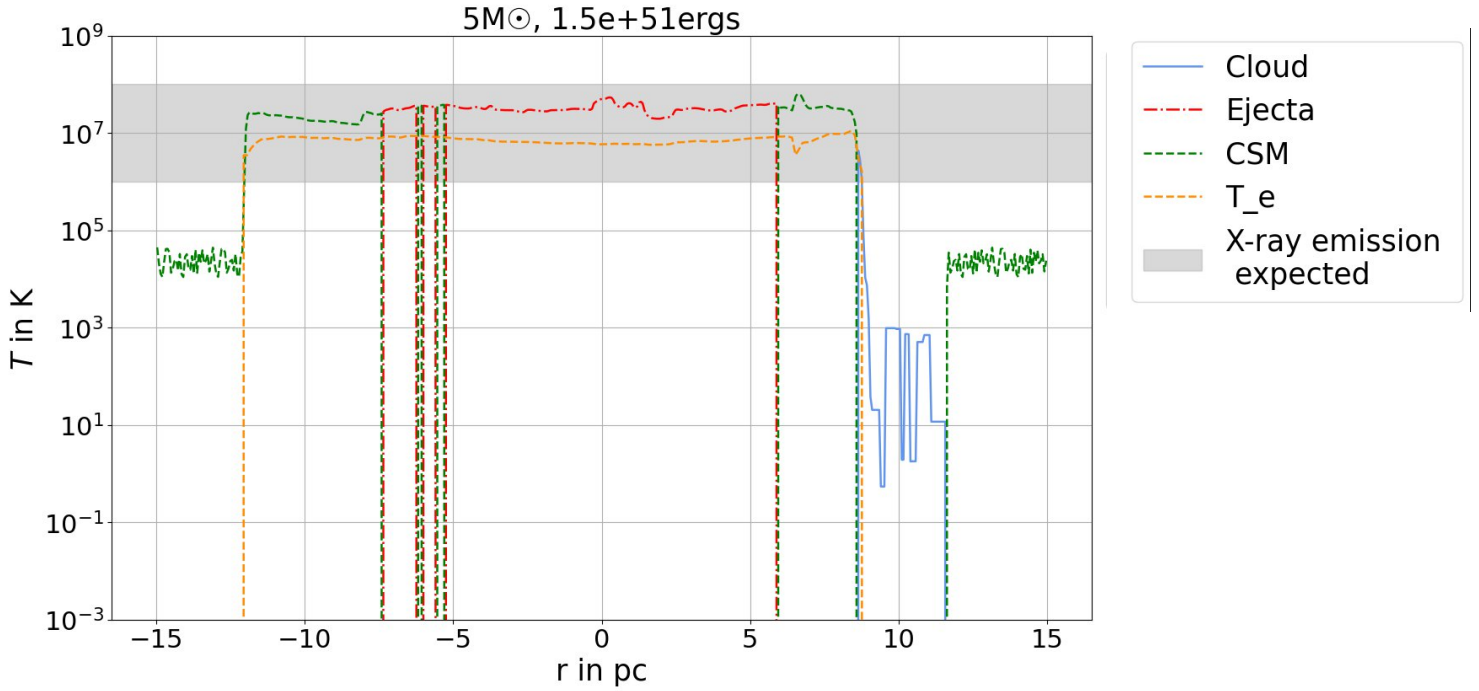
Density profile:



→ X-ray emission should be dominated by shocked ISM

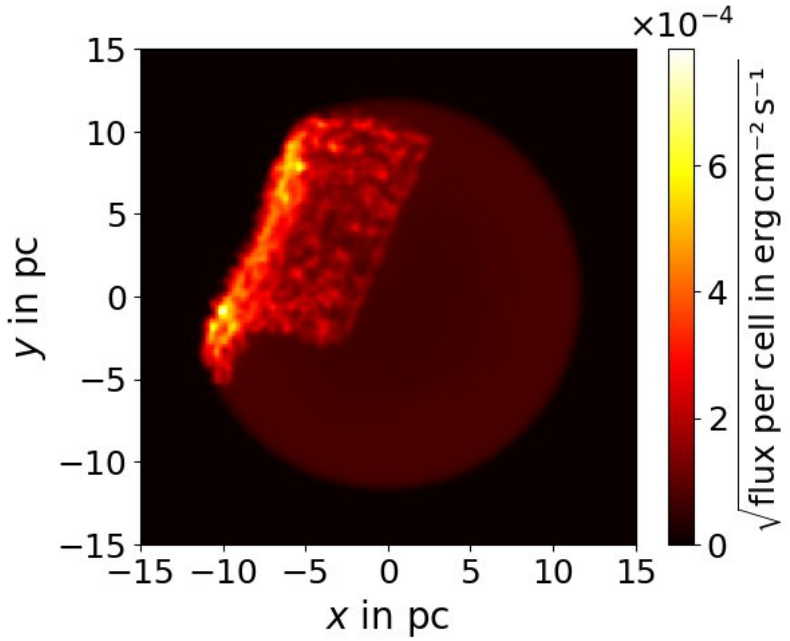
3D Simulations – Results after 5000 Years

Temperature profile:

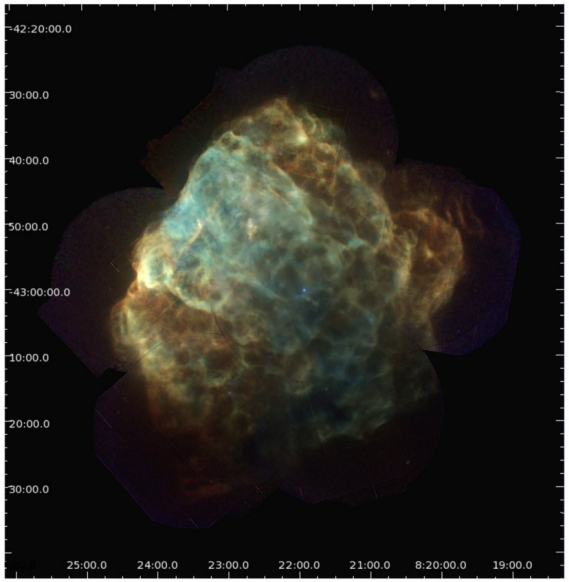


→ temperature of plasma components high enough to emit thermal X-rays

3. Comparison of Simulation Results and Observations –X-ray Maps



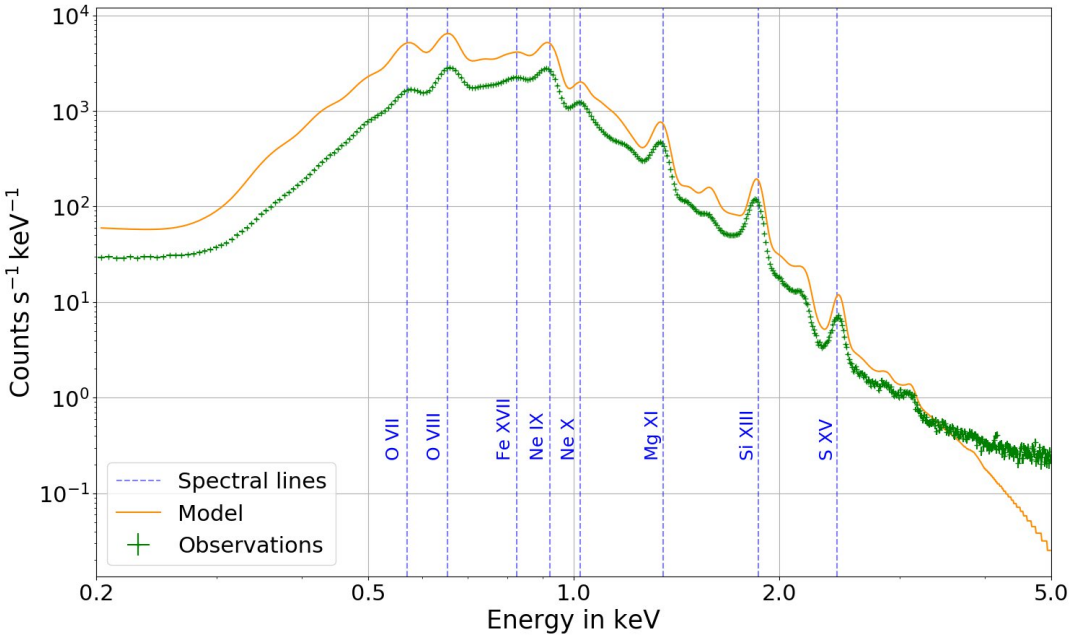
Synthetic X-ray map 0.3-10 keV



Chandra + XMM 0.3-8.0 keV
Dubner et al. 2013

→ model reproduces shape of Puppis A in X-rays well, especially Bright Eastern Knot

3D Simulations – eROSITA X-ray Spectra



Observational data: Mayer et al. 2022

→ synthetic X-ray spectrum reproduces the observed spectrum very well at higher energies

→ excess below 0.7 keV probably due to variations in absorption

4. Summary and Outlook

- development of HD model of Puppis A with PLUTO
- current model shows very promising results (X-ray morphology and spectra)

However:

- model is not able to reproduce exact plasma conditions, X-ray emission in south-western part of the remnant

→ limitations of the model

→ modifications necessary, e.g. explore more parameters, move to MHD simulations, more complex ambient environment

Thank you for your attention!