On the chemical abundaces of mixed morphology supernova remnants

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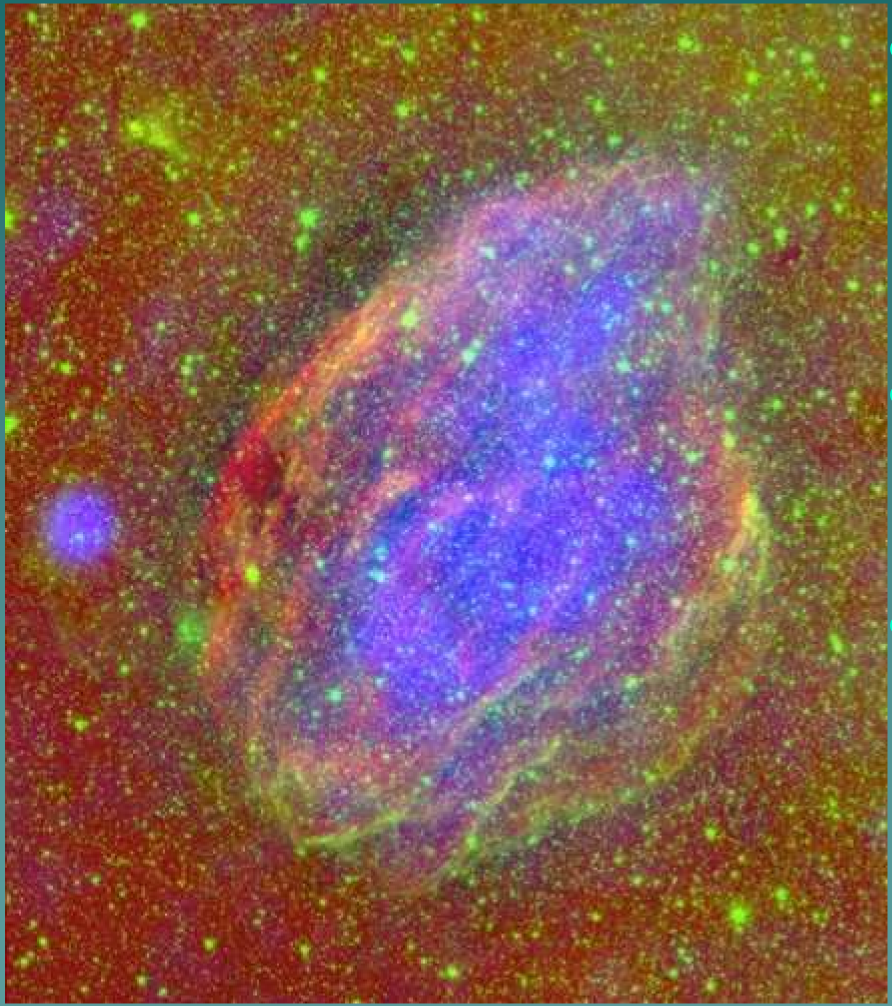
Mixed Morphology SNRs



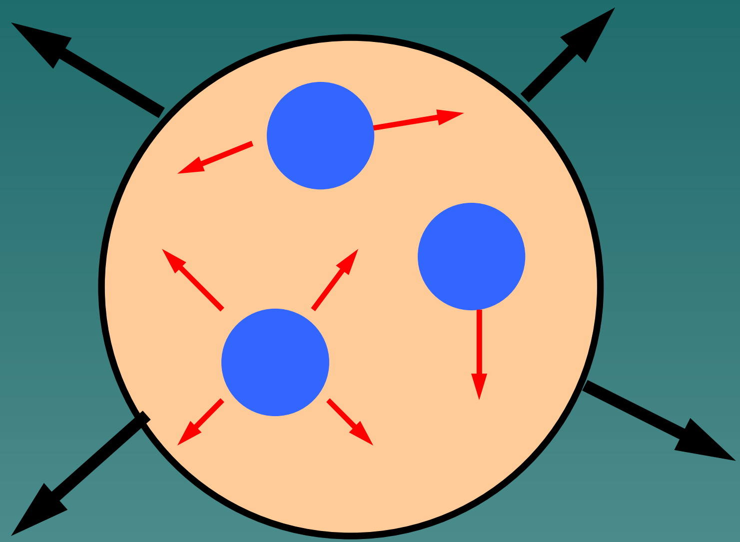
- DEFINITION: shell-like (asymmetric) morphology in the radio band and centrally peaked thermal emission in the X-ray band. Flat kT profile. (Rho et al. 1998)
- They seems to be located close to molecular clouds or high density regions
- *A mechanism responsible for producing such an unexpected morphology has not yet been uniquely identified*

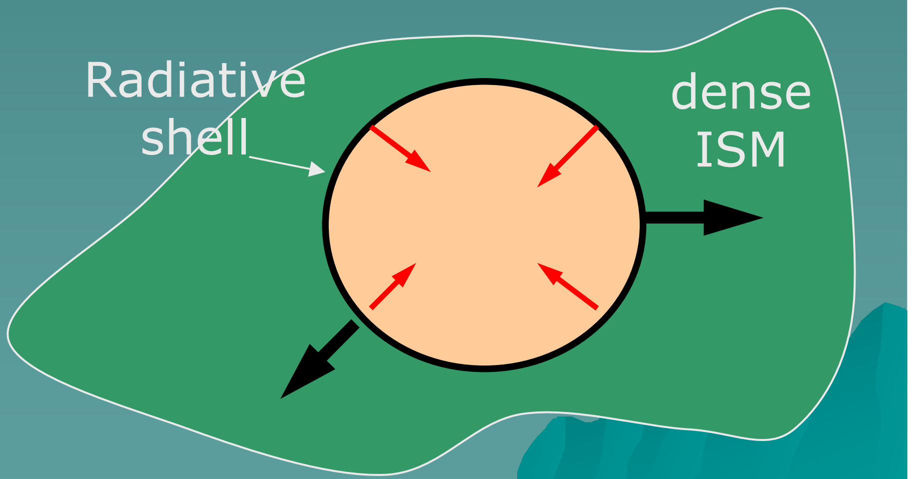
W44 (NRAO / AUI / NSF)

Radio, X-ray (ROSAT, **Rho et al. 1994**), IR (Spitzer, **Reach et al. 2006**)

Cloud evaporation vs. radiative model

- Both models try to increase the central density
  - White & Long (1991), Shelton et al. (1994)
- Both model have general difficulties in reproducing some of the MM SNRs features
  - Surf.bri. profile too shallow
  - Central density too low



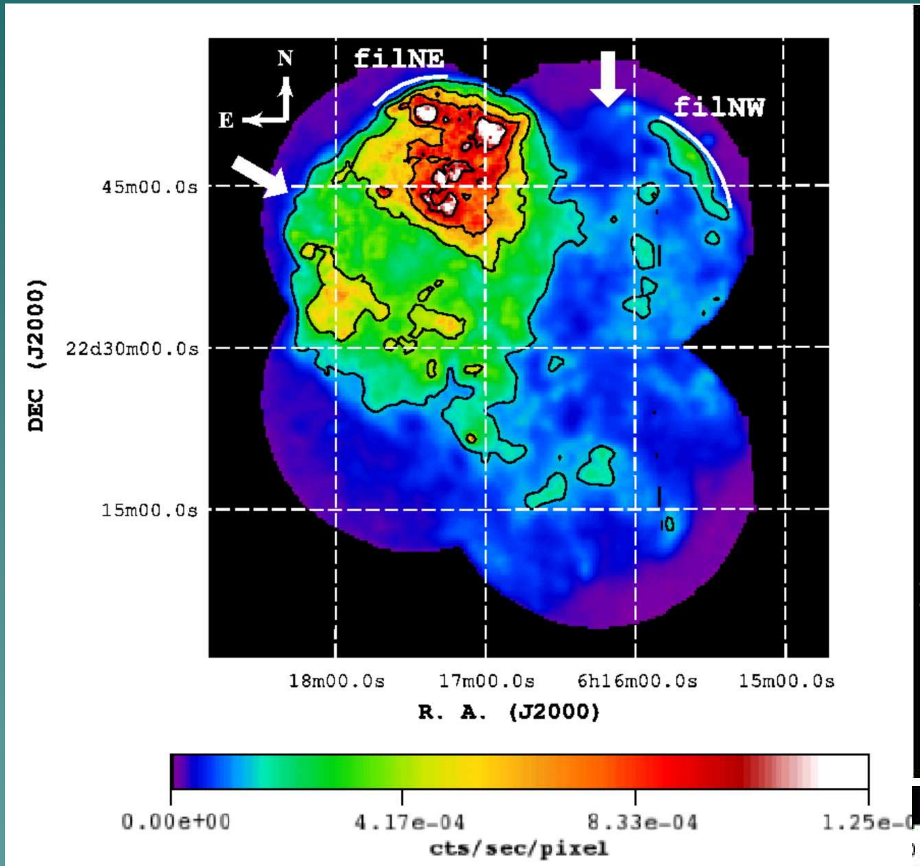


Enhanced abundances in MM SNRs

- Lazendic & Slane (2006) compiled a new list of MM SNRs
  - 10 out of 26 seems to have high Z
  - Multiple and single thermal components (seems not to be related to Z)
  - Evaporating clouds and thermal conduction radiative model do not address the mixing of ejecta and ISM
- In this work, we study the metal abundances of IC443 and G166.0+4.3
  - Listed in Lazendinc & Slane (2006) as standard abundances MM SNRs

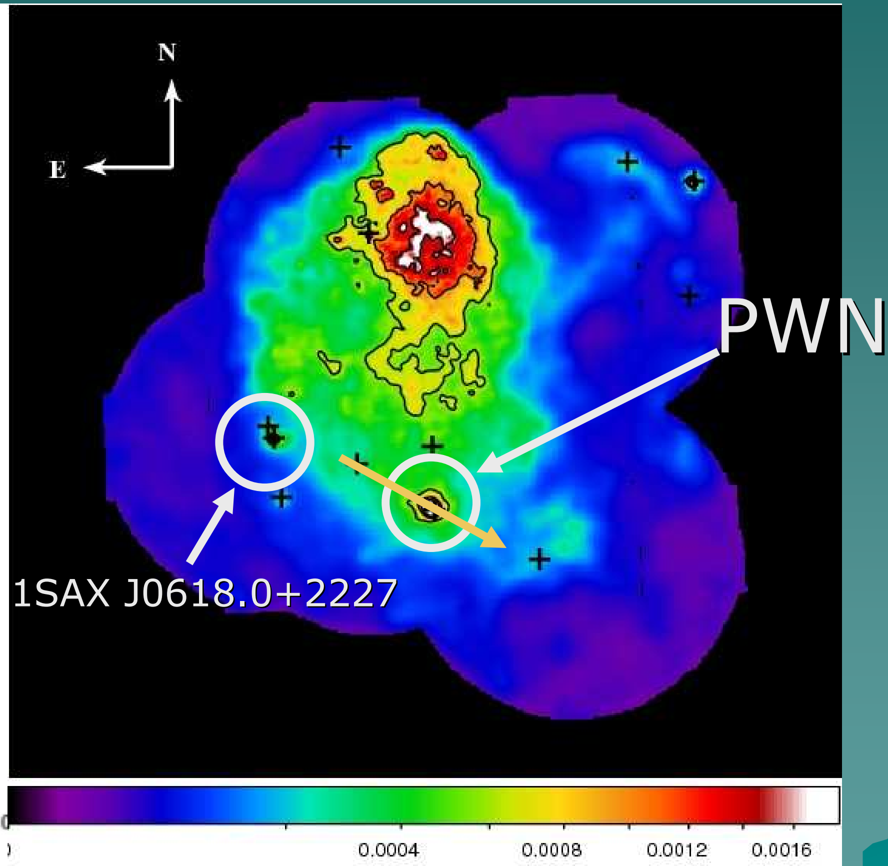
IC443 X-ray emission

EPIC Count-rate 0.5-1.4 keV



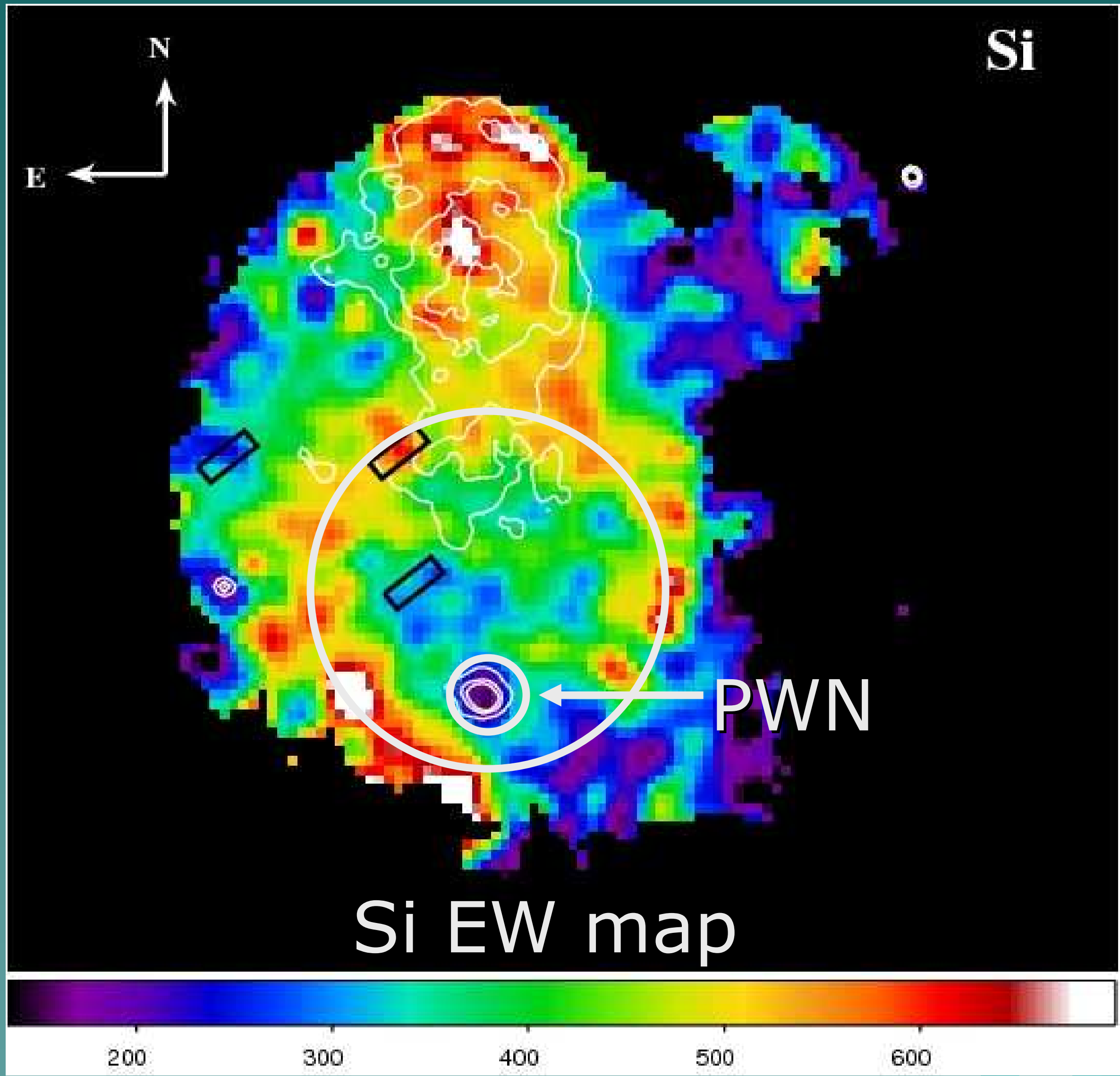
Troja et al. 06, ApJ, 649, 258

EPIC Count-rate 1.5-5 keV



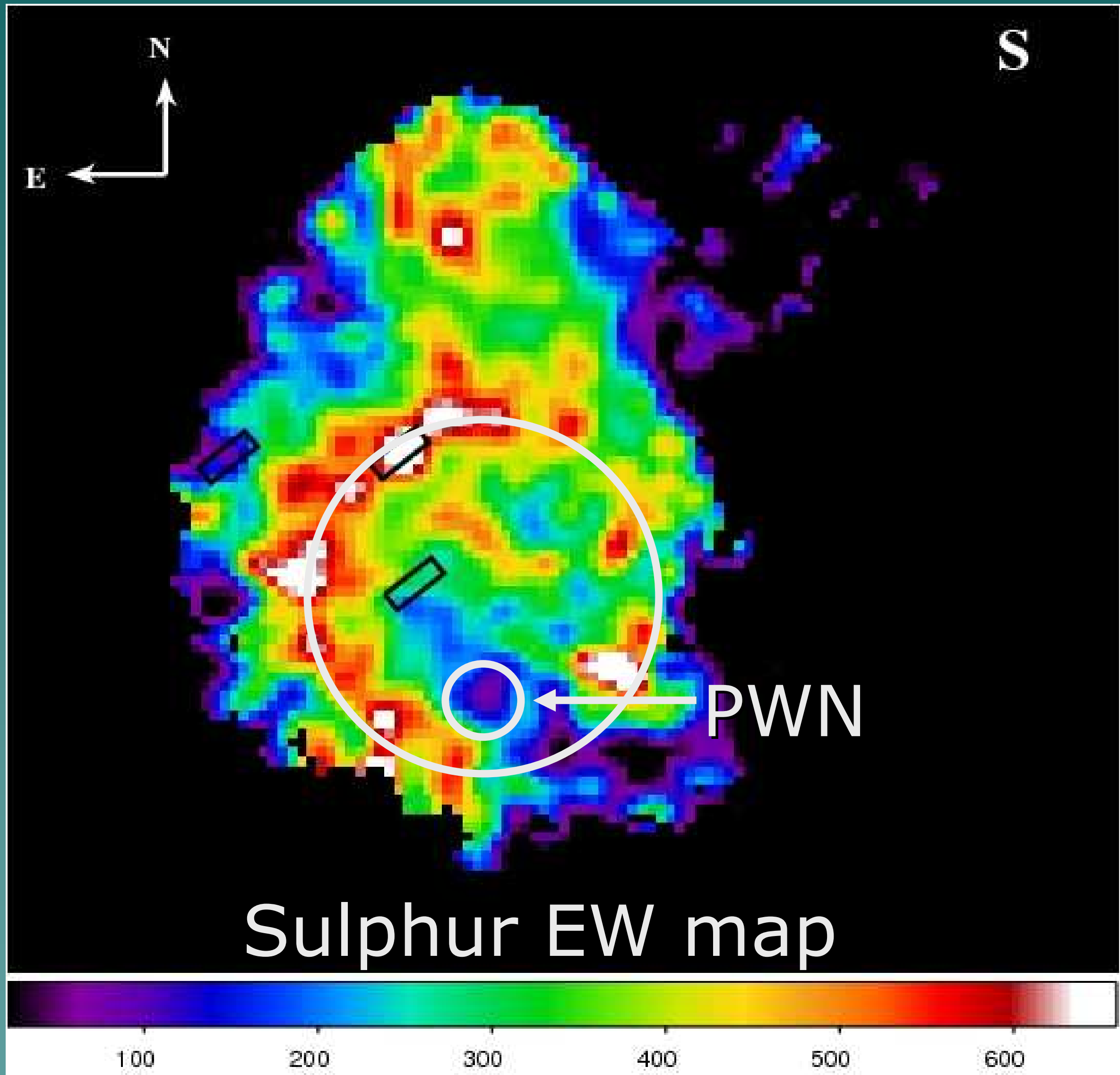
Troja et al. 08, A&A, in press

IC443 metal abundance



Troja et al. 08, A&A, in press

IC443 metal abundance



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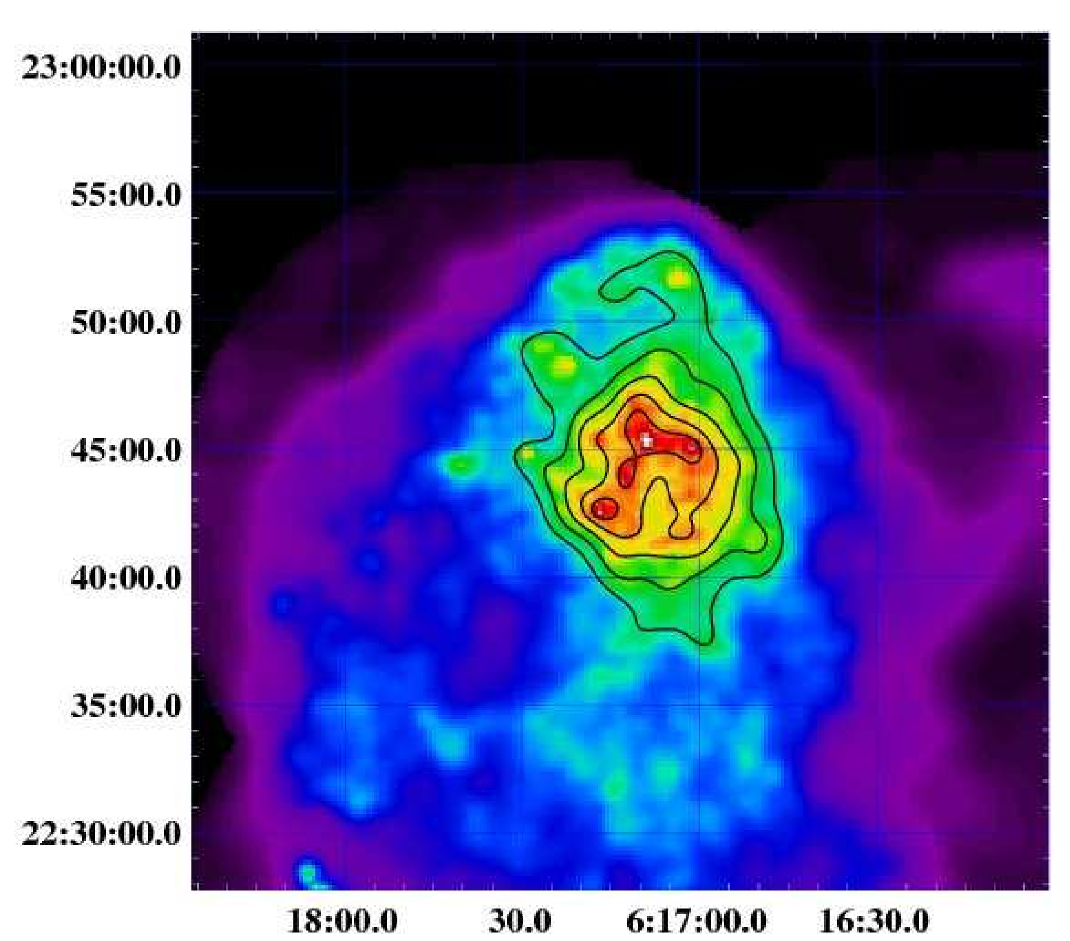
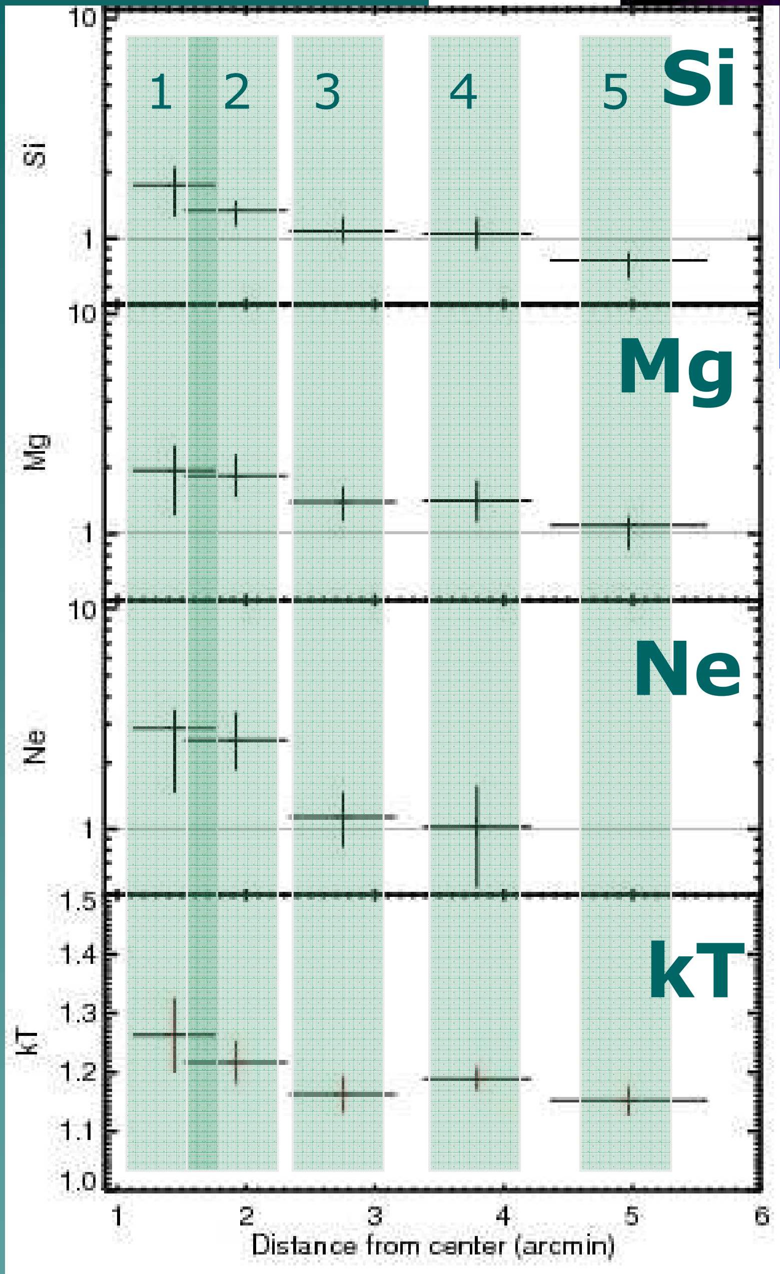
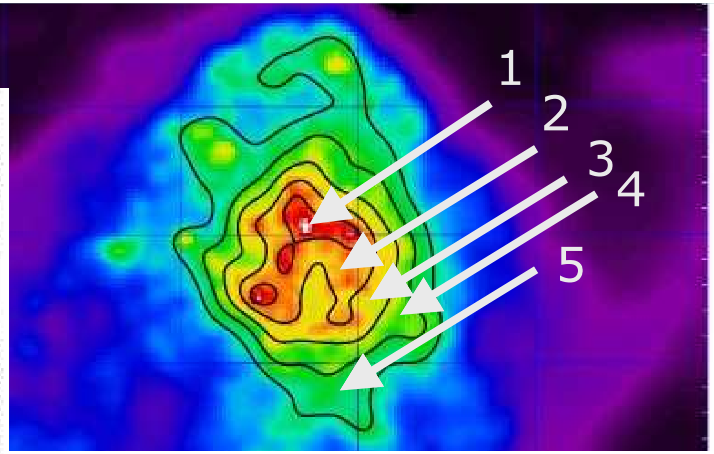
More in IC443 metallicity



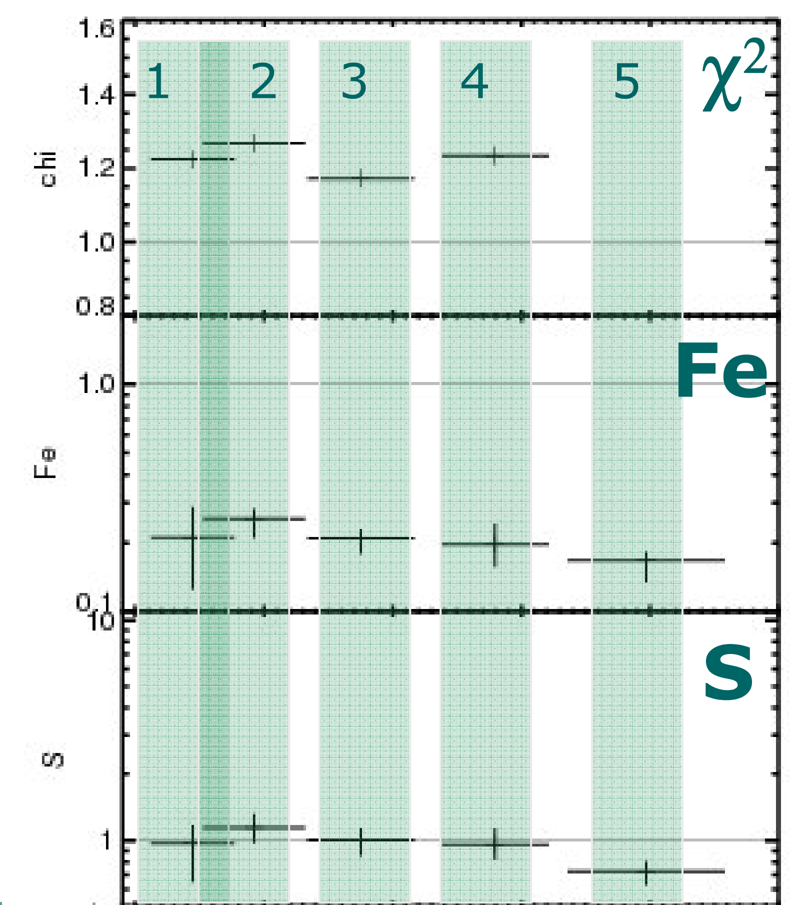
- Extraction regions defined in term of surface brightness contours
- Cross-region contamination may be an issue
  - SAS support still experimental
- Look for variations of temperature and metallicity vs. surface brightness



Si
Mg
Ne
kT
1 2 3 4 5
Distance from center (arcmin)

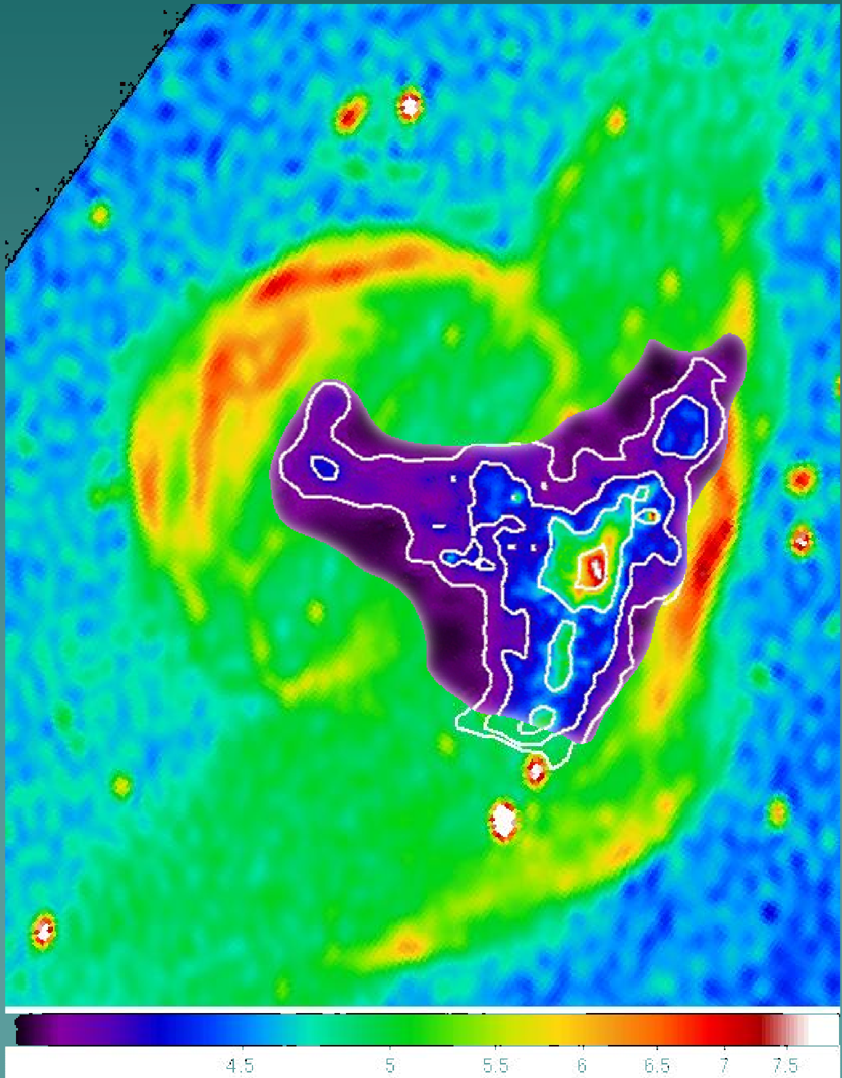


1
2
3
4
5



χ^2
Fe
S
1 2 3 4 5

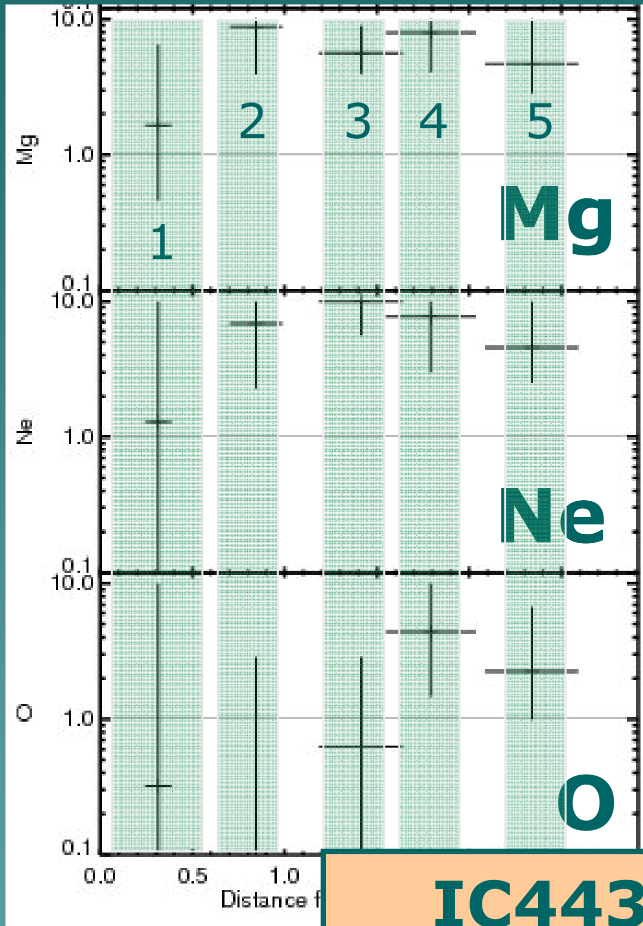
G166.0+4.3 (a.k.a VRO 42.05.01)

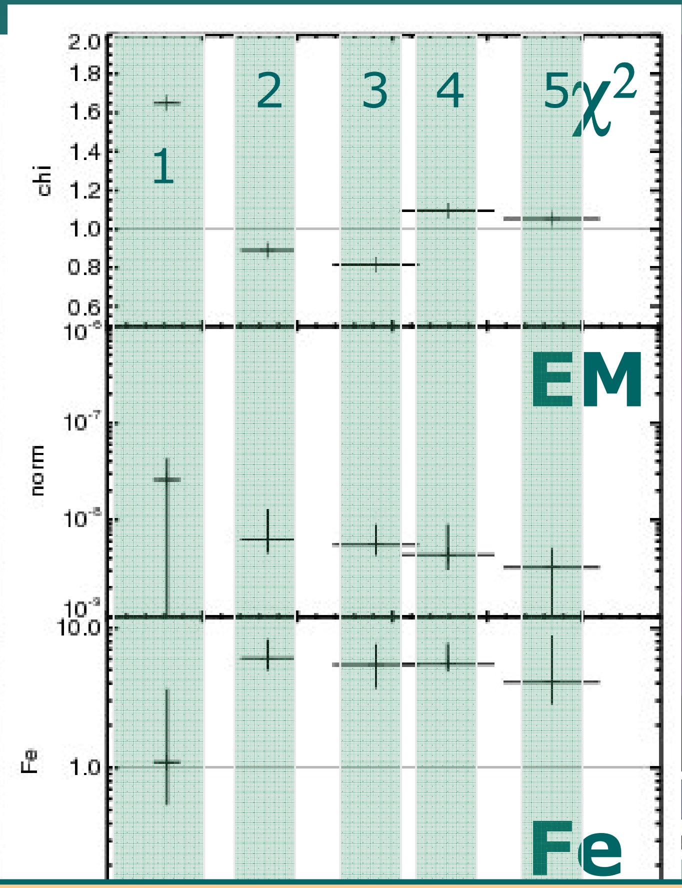


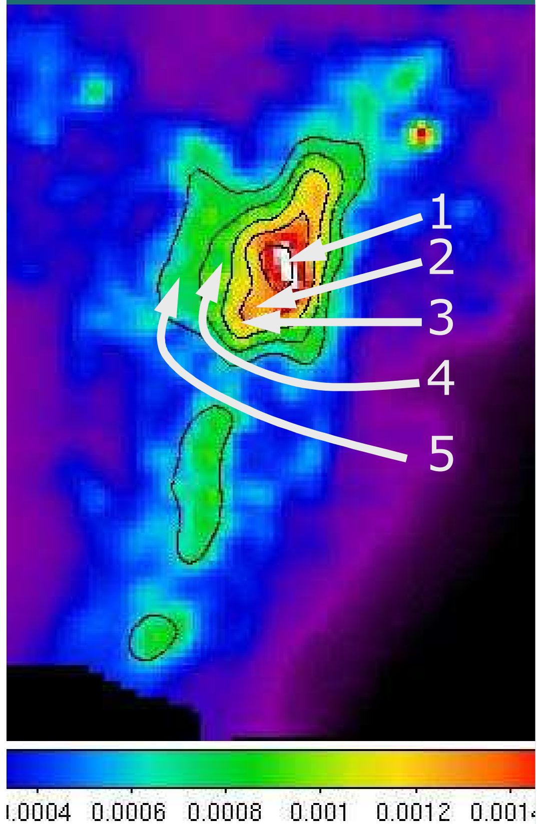
- **Interesting radio morphology (small shell and large "wing")**
- **X-ray emission centrally peaked (between shell and wing, perhaps in the hot tunnel)**
- **Possibly explained in terms of expansion in a "hot tunnel", bounded by 2 dense regions**

G166.0+4.3 (Vro 42.05.01)
1420 MHz CGPS DRAO radio image
XMM-Newton/EPIC image (0.3-5 keV)

Abundances of G166.0+4.3



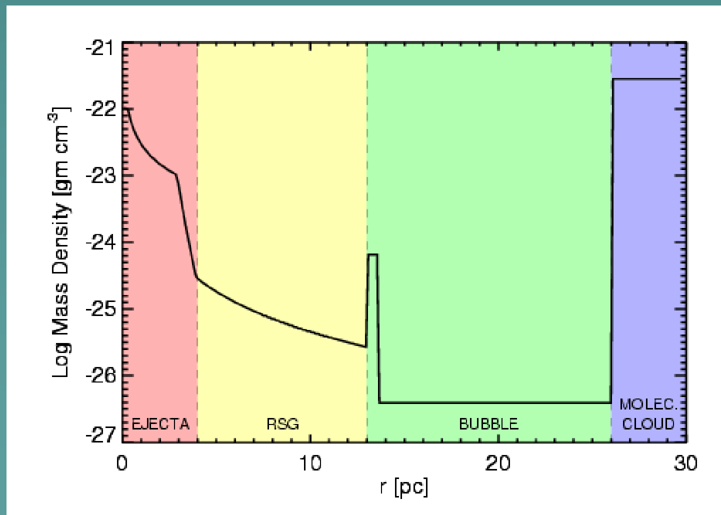




IC443 and G166.0+4.3 both show evidence of high metal abundances!!!

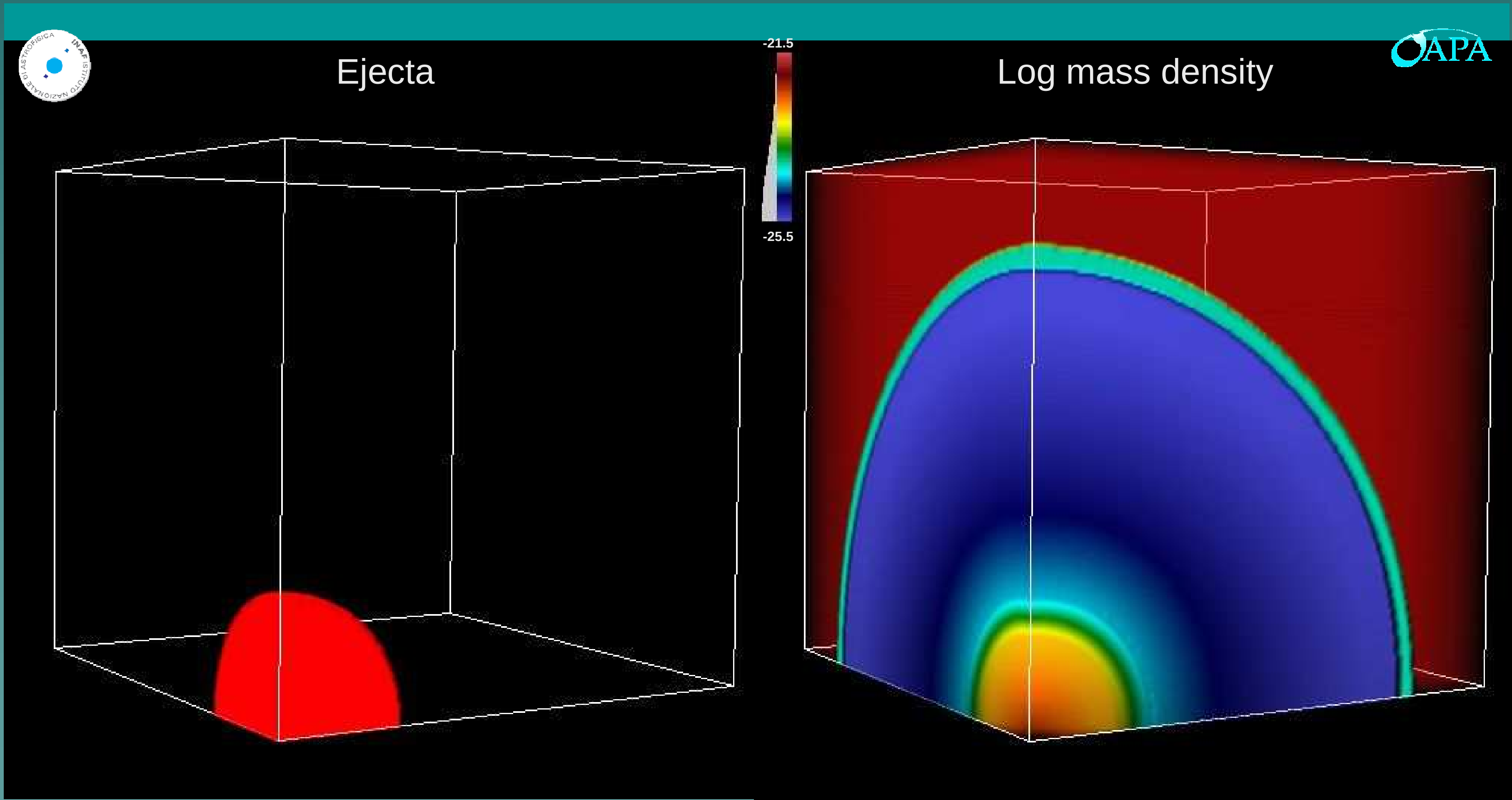
A new model for MM SNRs

- We explore the possibility that MM SNRs are the results of interaction with progenitor CSM
- 3D HD model
  - Thermal conduction includes flux saturation effects
  - Ejecta mat. with enhanced metallicity
  - 8-fold symmetry assumed
  - FLASH code



MM-SNRs: 3D modeling

Ejecta concentrated at the center of the SNR



MM-SNRs: 3D modeling

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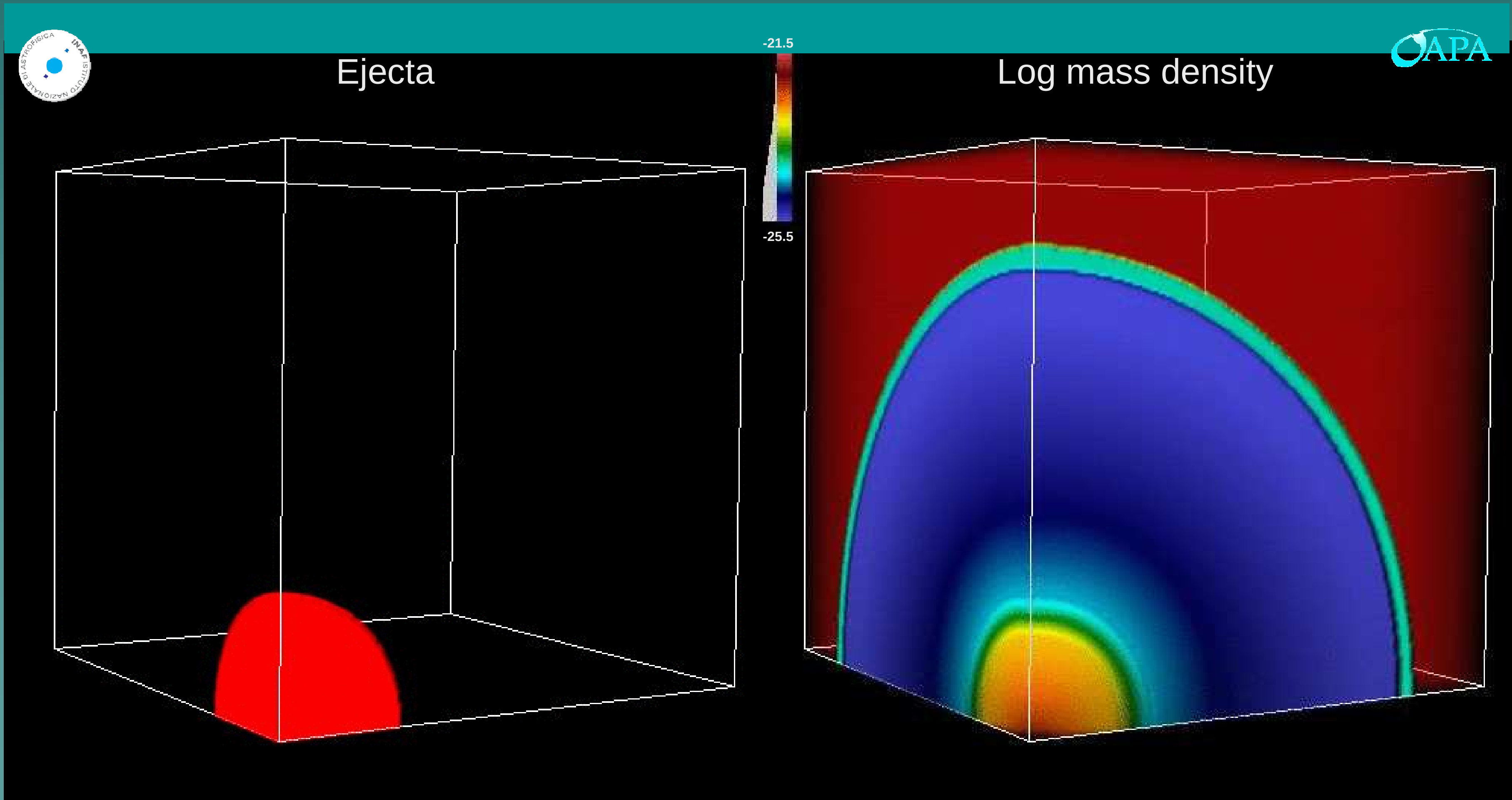


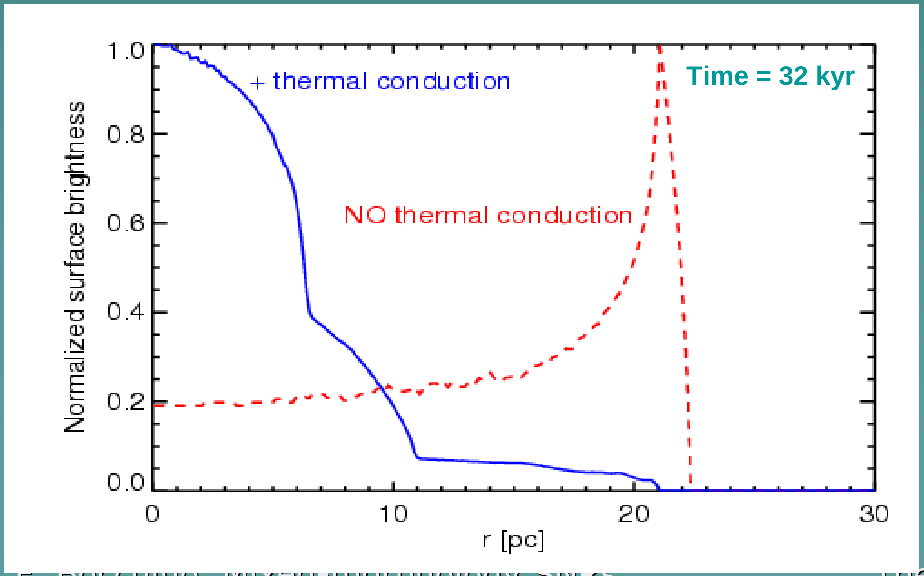
X-ray emission

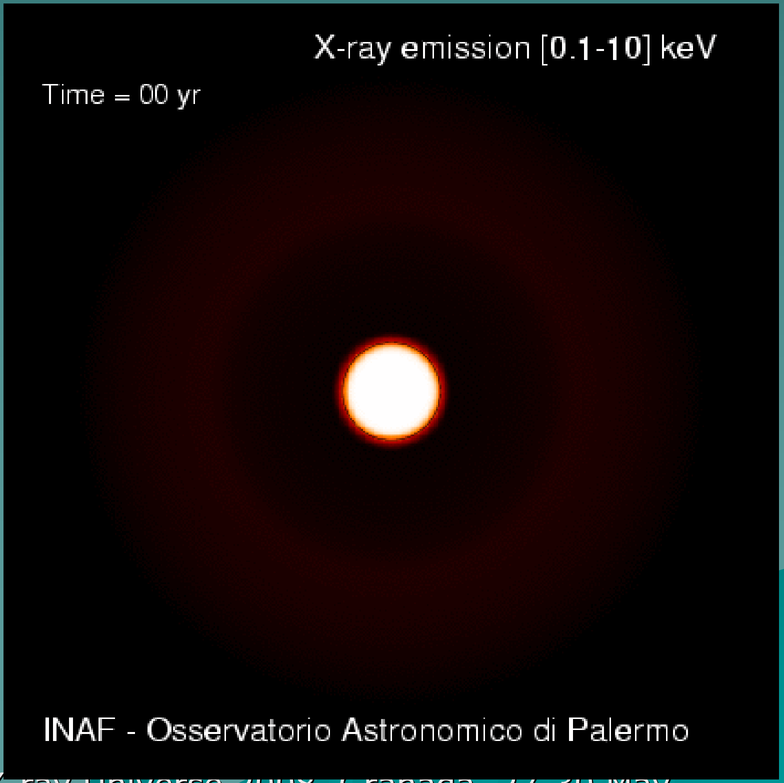
Morphology in the X-ray band changes during the evolution

Phase I: maximum X-ray emission at the (forward) shock front
-> shell-like morphology

Phase II: X-ray emission centrally peaked
-> MM SNRs

Thermal conduction very effective and contributes to enhance central emission



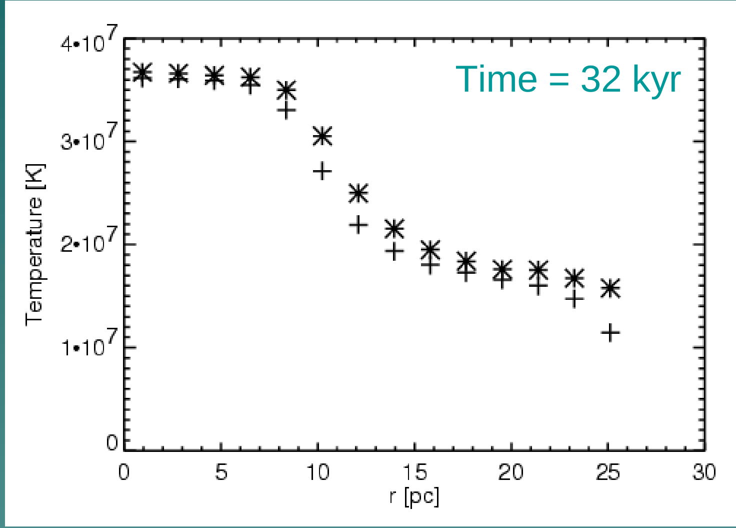


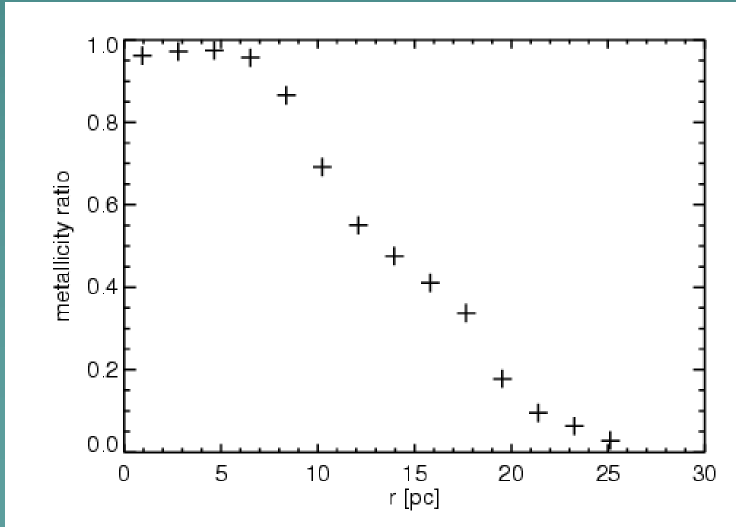
Temperature and Metallicity

During the MM phase:

- Temperature decreases with radial distance
- Average T of shocked ejecta > average T of shocked CSM
- Enhanced metallicity at the center of the remnant
- Metallicity gradually decreases with radial distance

Agreement with observations of metal-rich MM SNRs?





Conclusion

- Emerging new class of remnants
  - MM SNRs with enhanced metallicity
  - What fraction of MM belongs to the new class?
  - IC443 and VRO are high-Z, once thought to be low-Z
    - High-Z MM SNRs may be very common
- (M)HD simulations of CSM-shock interactions
  - May help to understand MM, even with high Z, easing the difficulties of traditional models
    - kT, n and Z profiles are desperately needed…
      - Challenging data analysis task