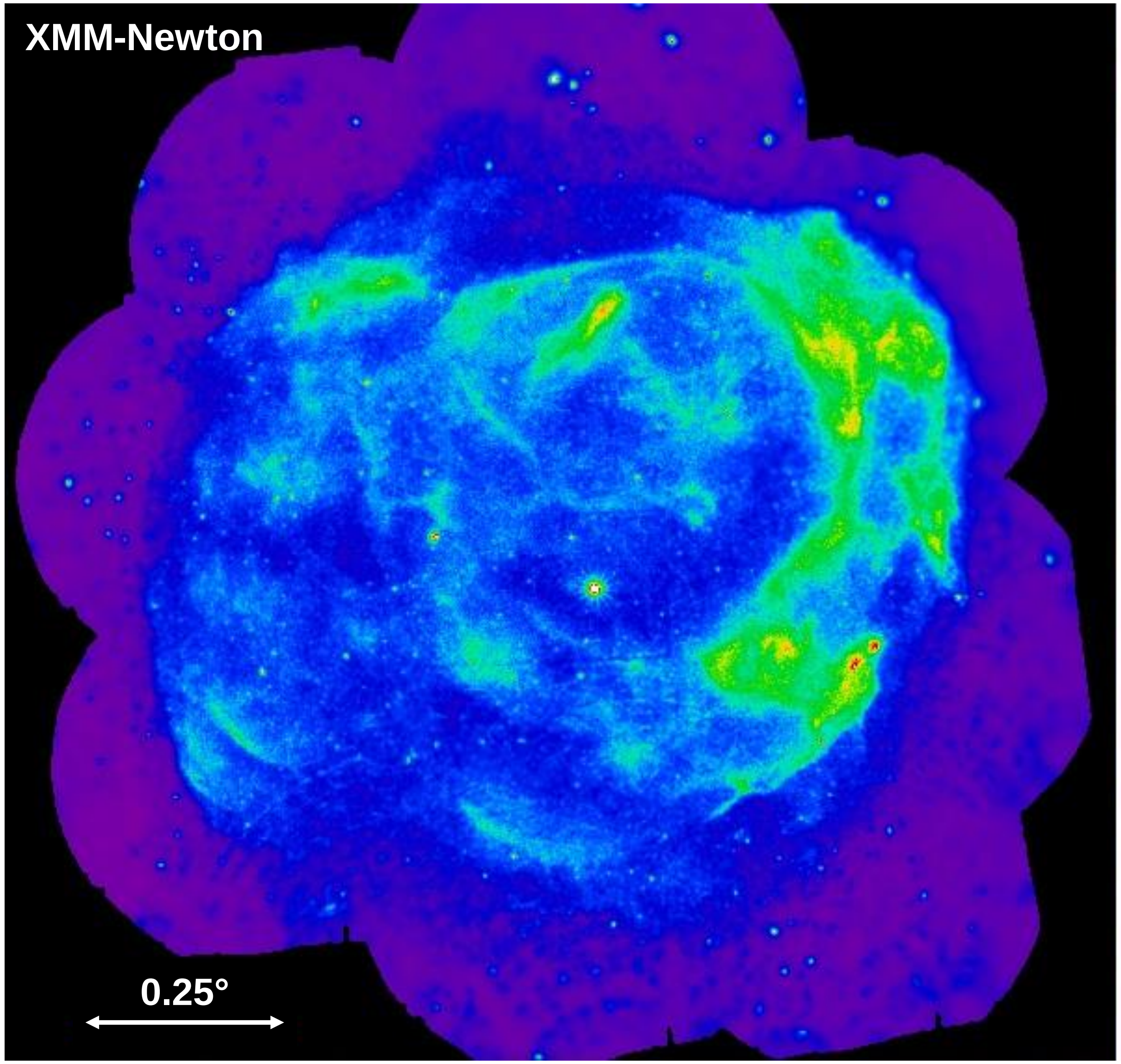
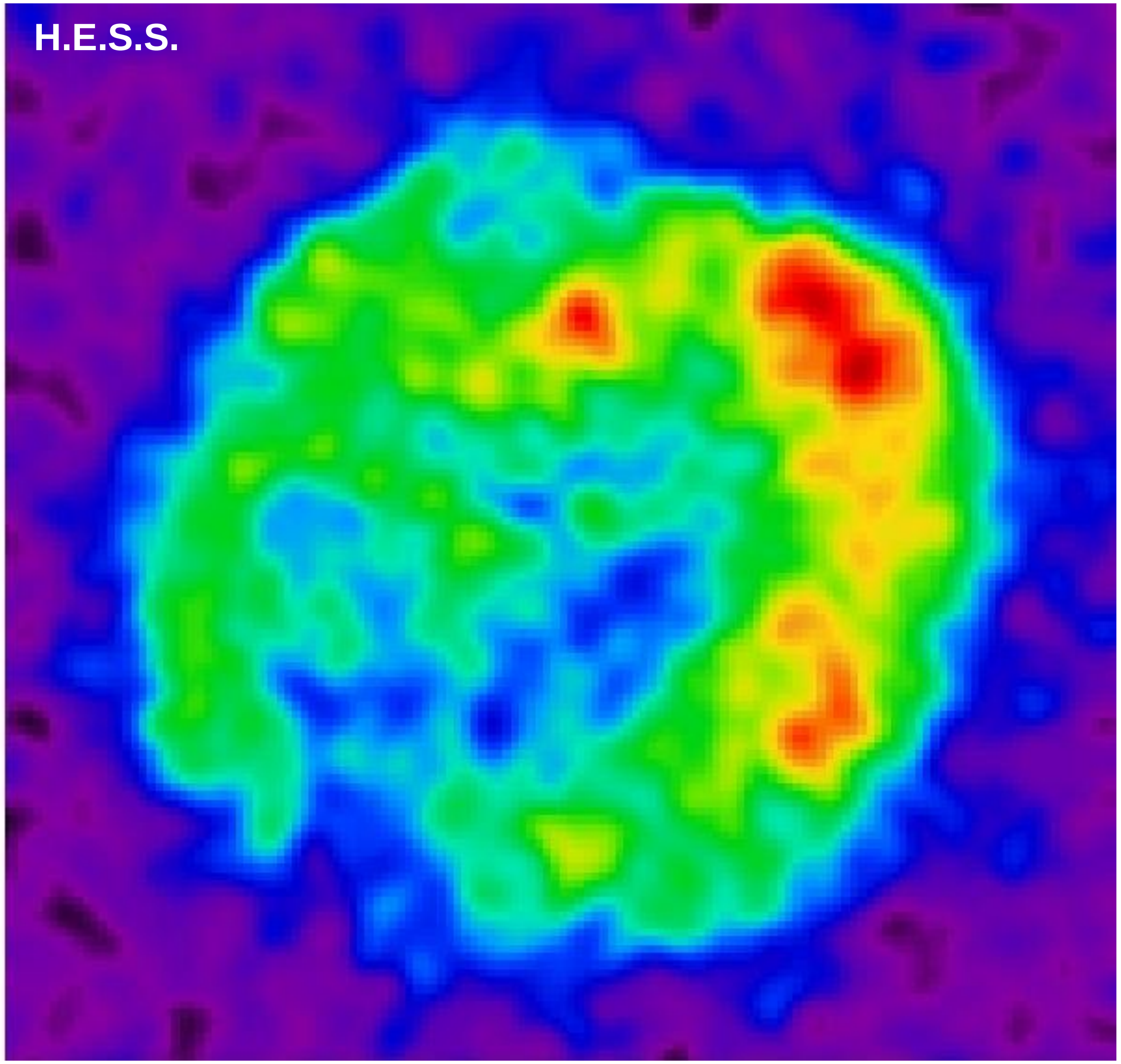
RX J1713.7-3946: X/γ correlation



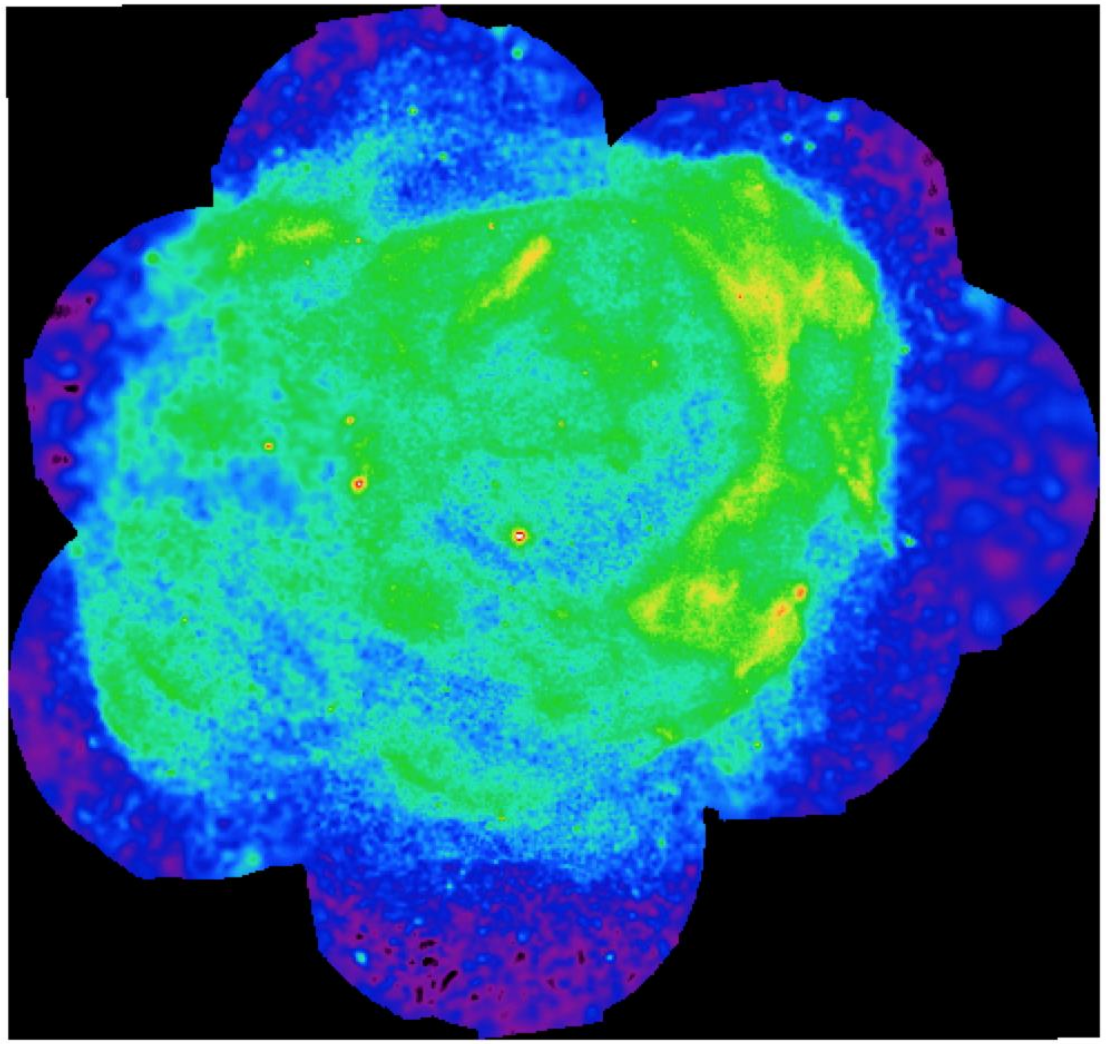


Jean Ballet and Fabio Acero, AIM, CEA Saclay, France

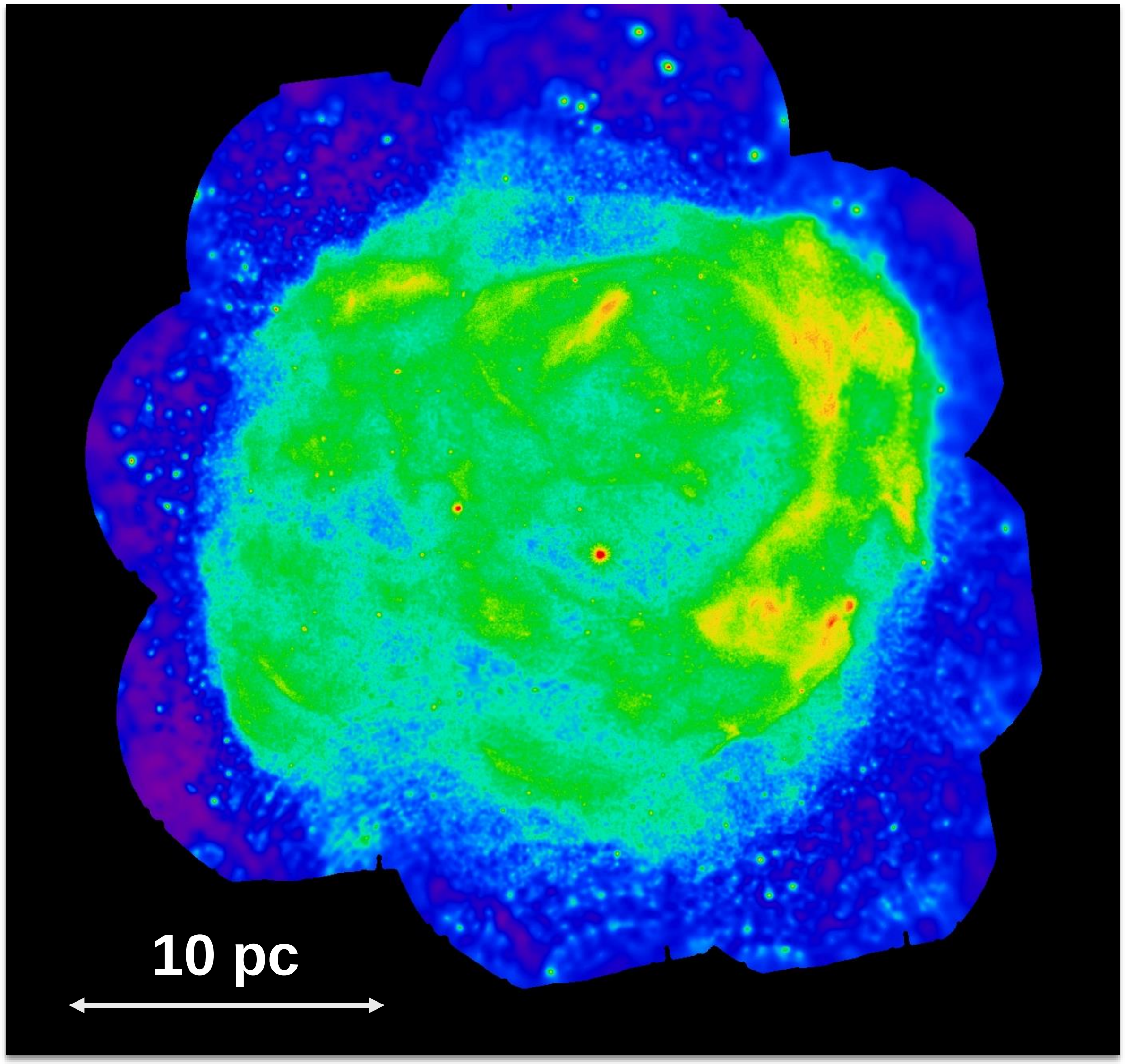
Fermi symposium, 10 October 2022, Misty Hills, South Africa

A new look at RX J1713, CR accelerator prototype

- Core Collapse supernova (CCO)
- Age ~ 1600 yr (historical SN 393). d ~ 1 kpc. 1° diameter
- Young SNR with fast shock ~3500 km/s (X-ray proper motions)
- X-ray emission is synchrotron dominated
- Brightest TeV SNR



XMM-Newton
2009 mosaic

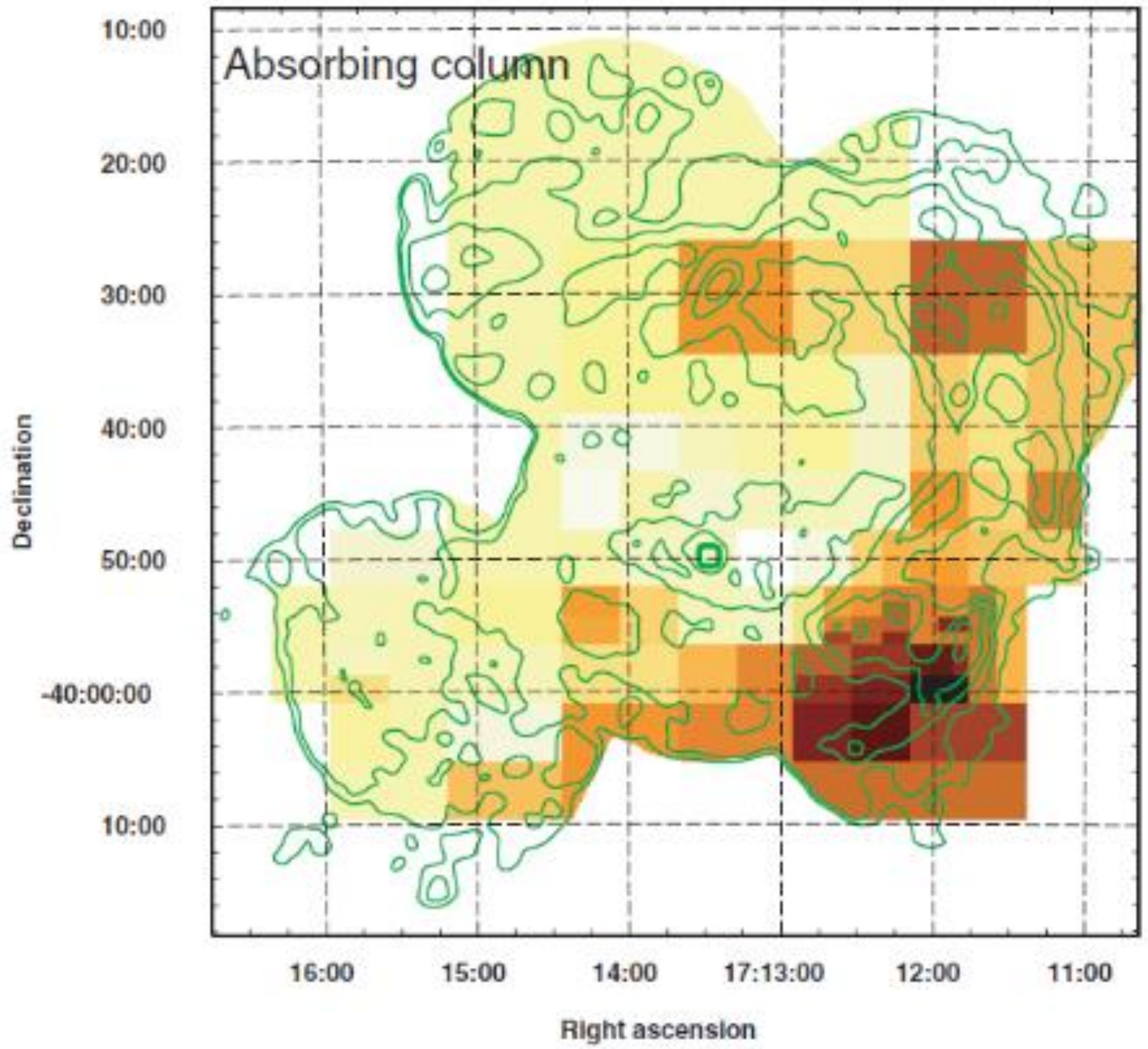


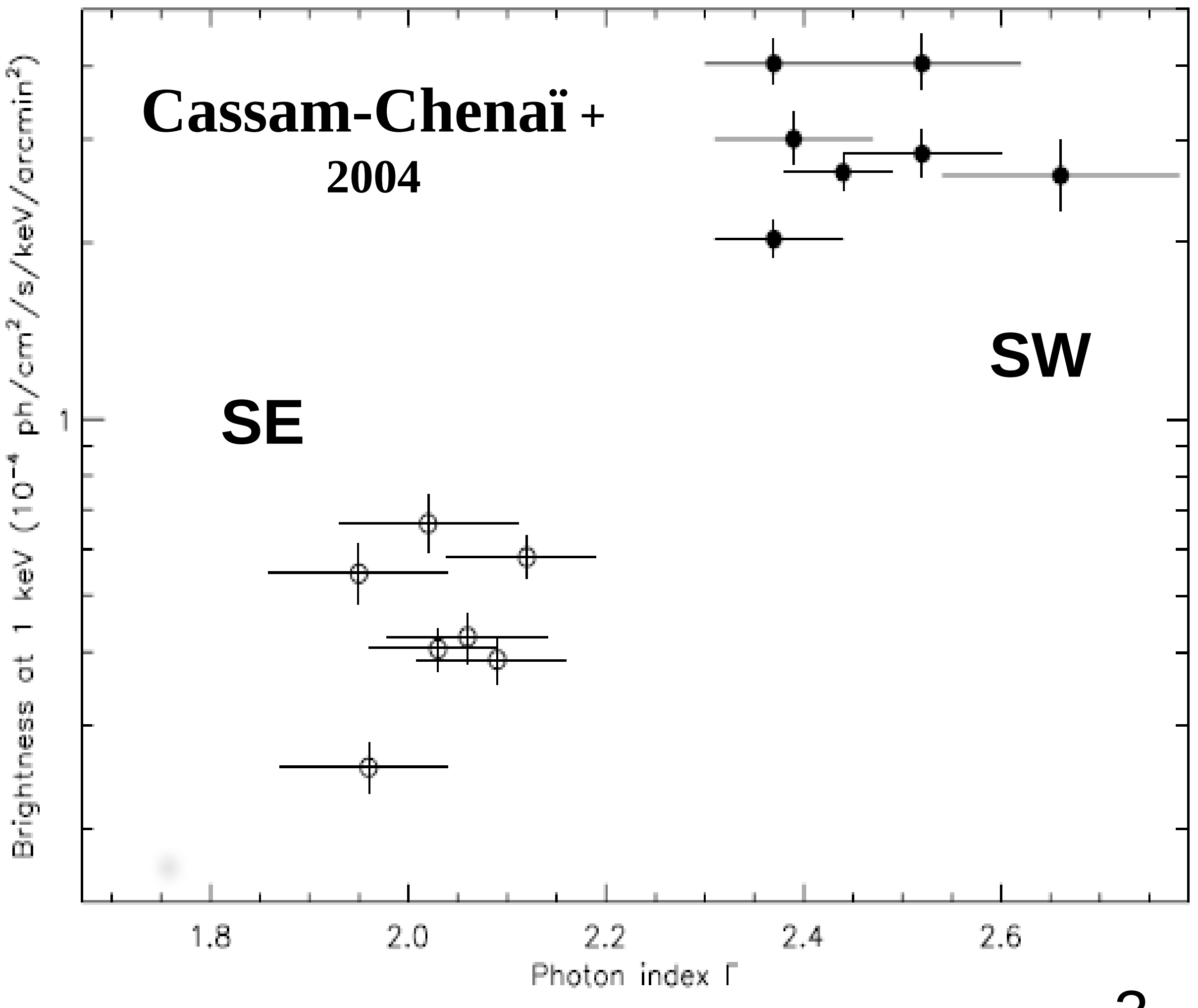
2018 mosaic
Large Program, > 1 Ms exposure

Early XMM-Newton observations

- **Larger absorbing column density toward South West**

- **“Brighter is softer” correlation**
  - Cutoff frequency lower when brighter ➔ cooling-limited e-

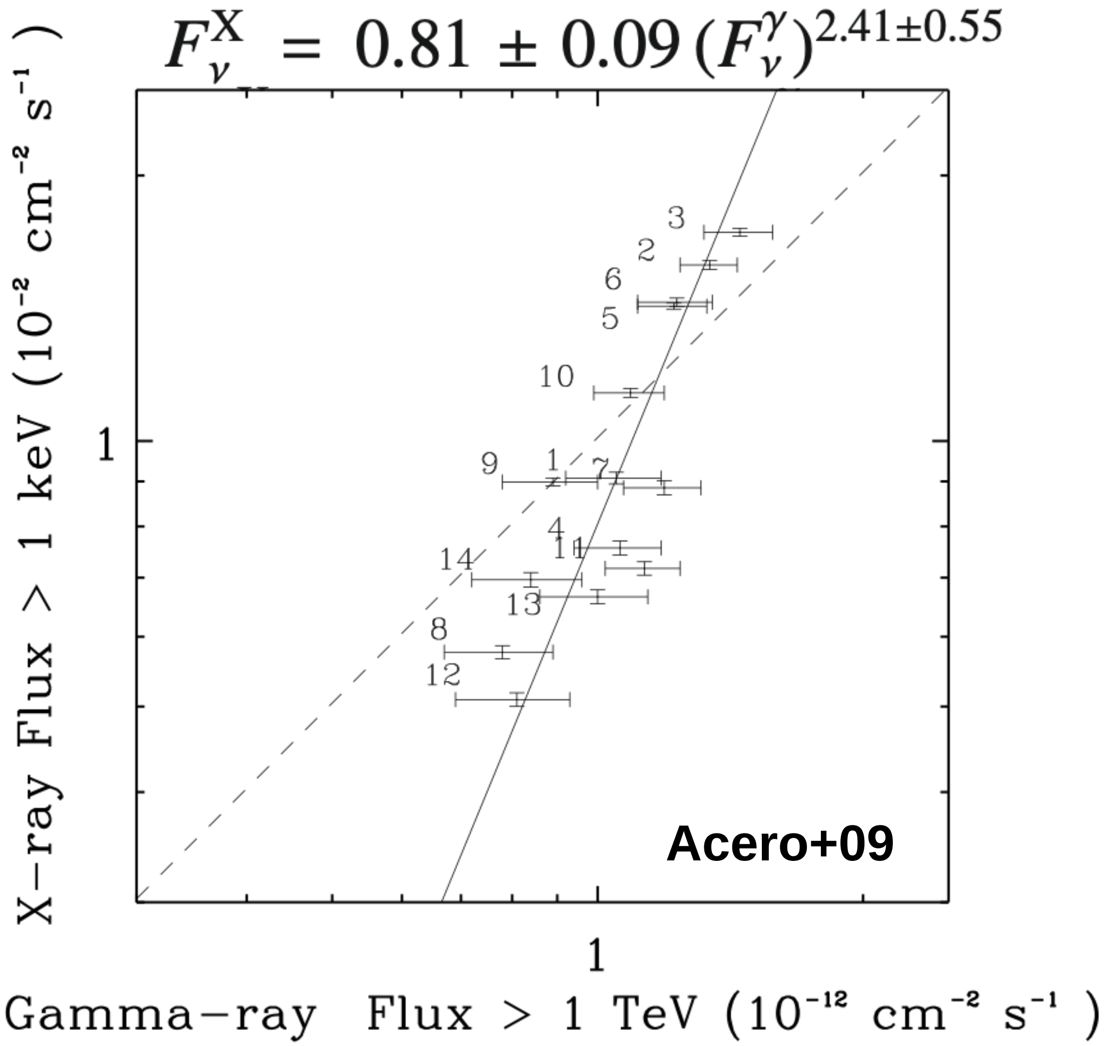




Comparing X-rays and TeV γ-rays

- **Which particle population are we probing ?**
  - **IC: 1 TeV photon comes from ~15 TeV e- + CMB**
  - **Synch: 15 TeV e- radiate at 0.2 keV for B=20 μG**
  - **==> A 1-10 keV X-ray map is not an ideal template for gammas, but it is all we have**

- **Comparing F_X vs F_γ:**
  - **X-ray image has more contrast than gamma**
  - **Possible to understand in leptonic models (see also Yang&Liu 2013) but not fully natural**



Softness ratio maps

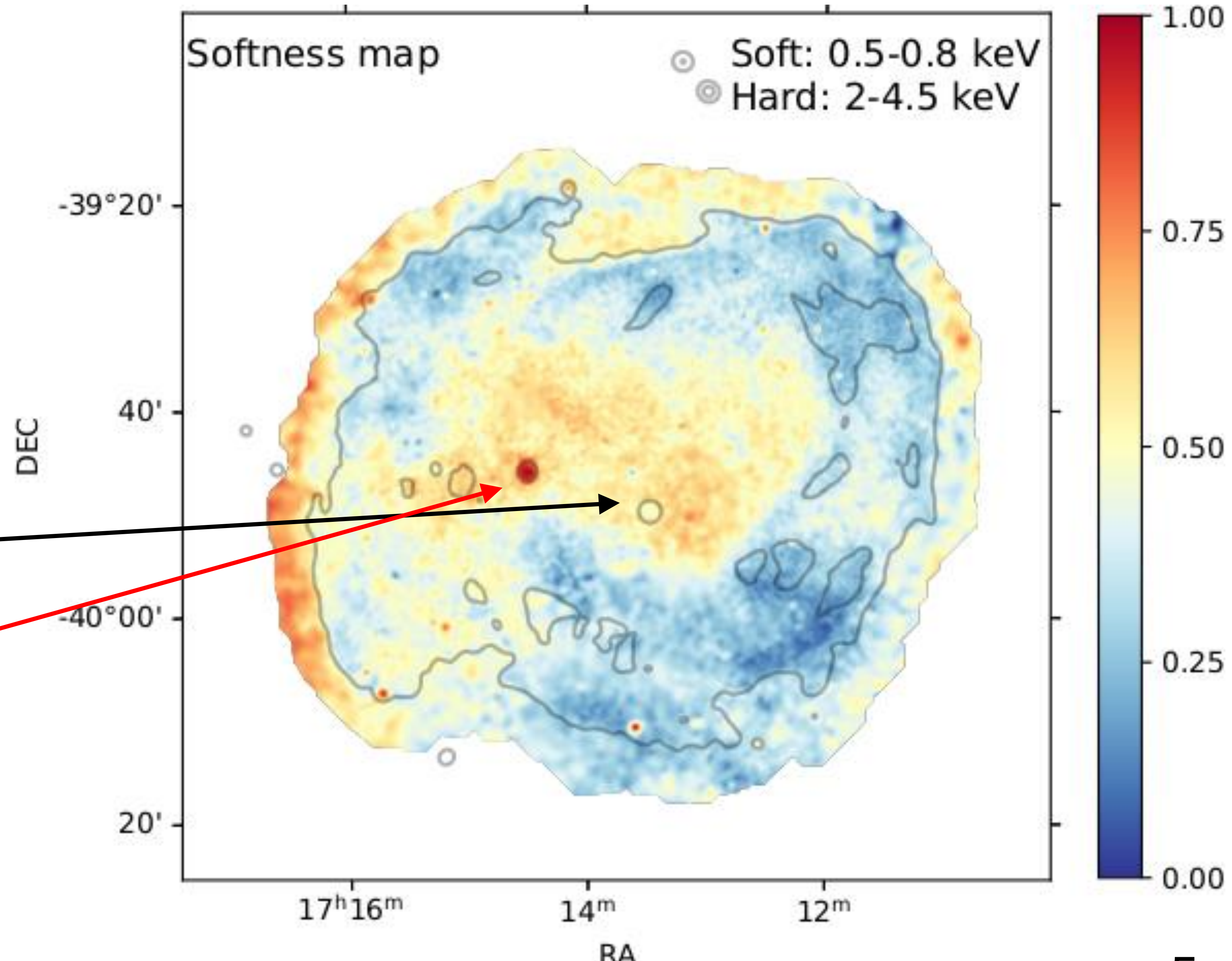
- **Same adaptive smoothing to all energies, meant to be not too strong at either low energies nor high energies**
- **Softness = 1 / (1 + HighEnergy/LowEnergy)**

When the soft band is below 1 keV, the softness map shows absorption effects

South West is bluer (more absorbed) than other filaments

Center is less absorbed

The CCO is barely visible here, but a soft slightly extended feature (thermal) is obvious. Possibly an illuminated clump in the progenitor's wind (Tateishi et al 2021)



Softness ratio maps

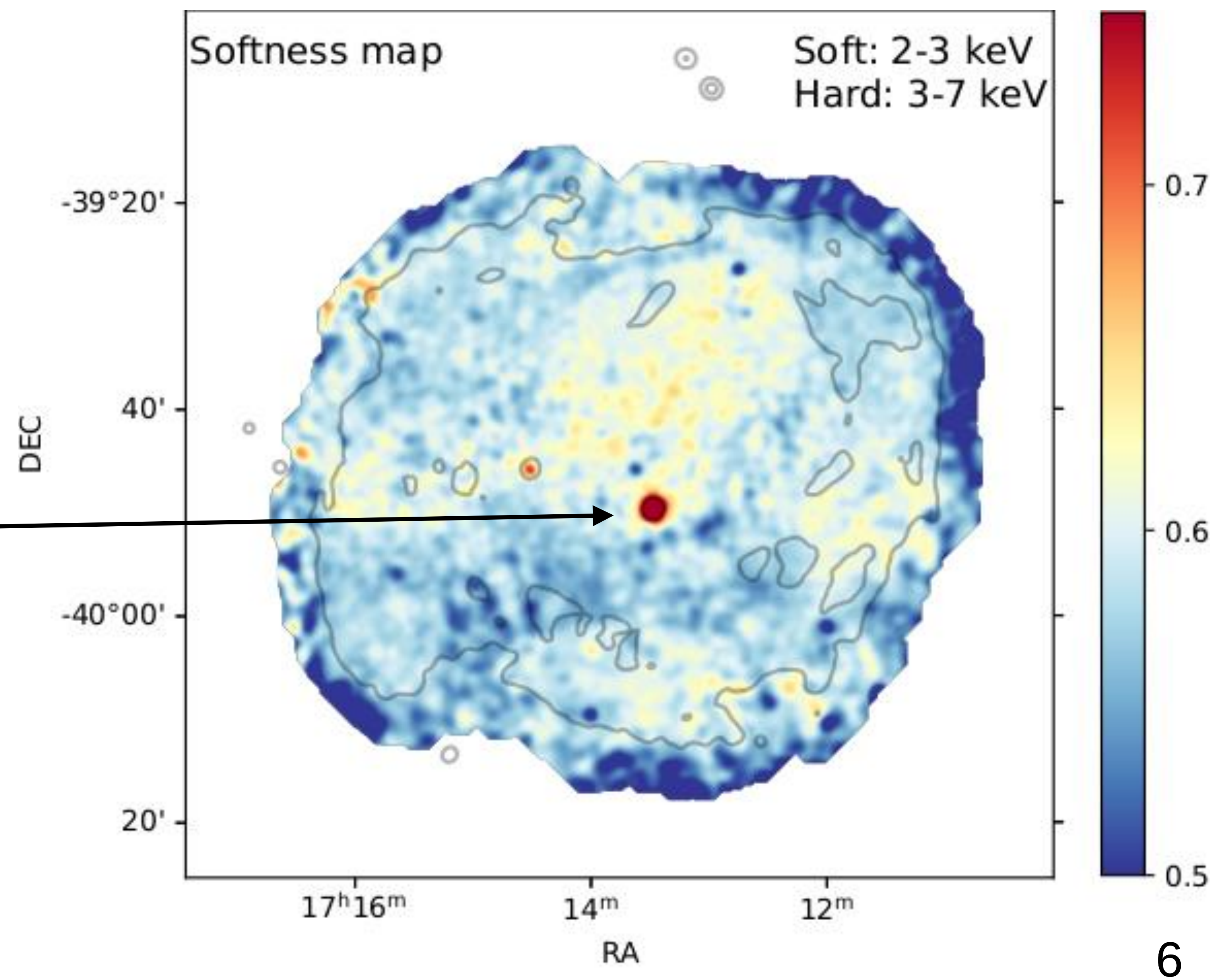
- **Same adaptive smoothing to all energies, meant to be not too strong at either low energies nor high energies**
- **Softness = 1 / (1 + HighEnergy/LowEnergy)**

Adjacent bands ➔ softness map less extreme (from 0.5 to 0.75)

Soft band above 2 keV ➔ more intrinsic effects (little absorption)

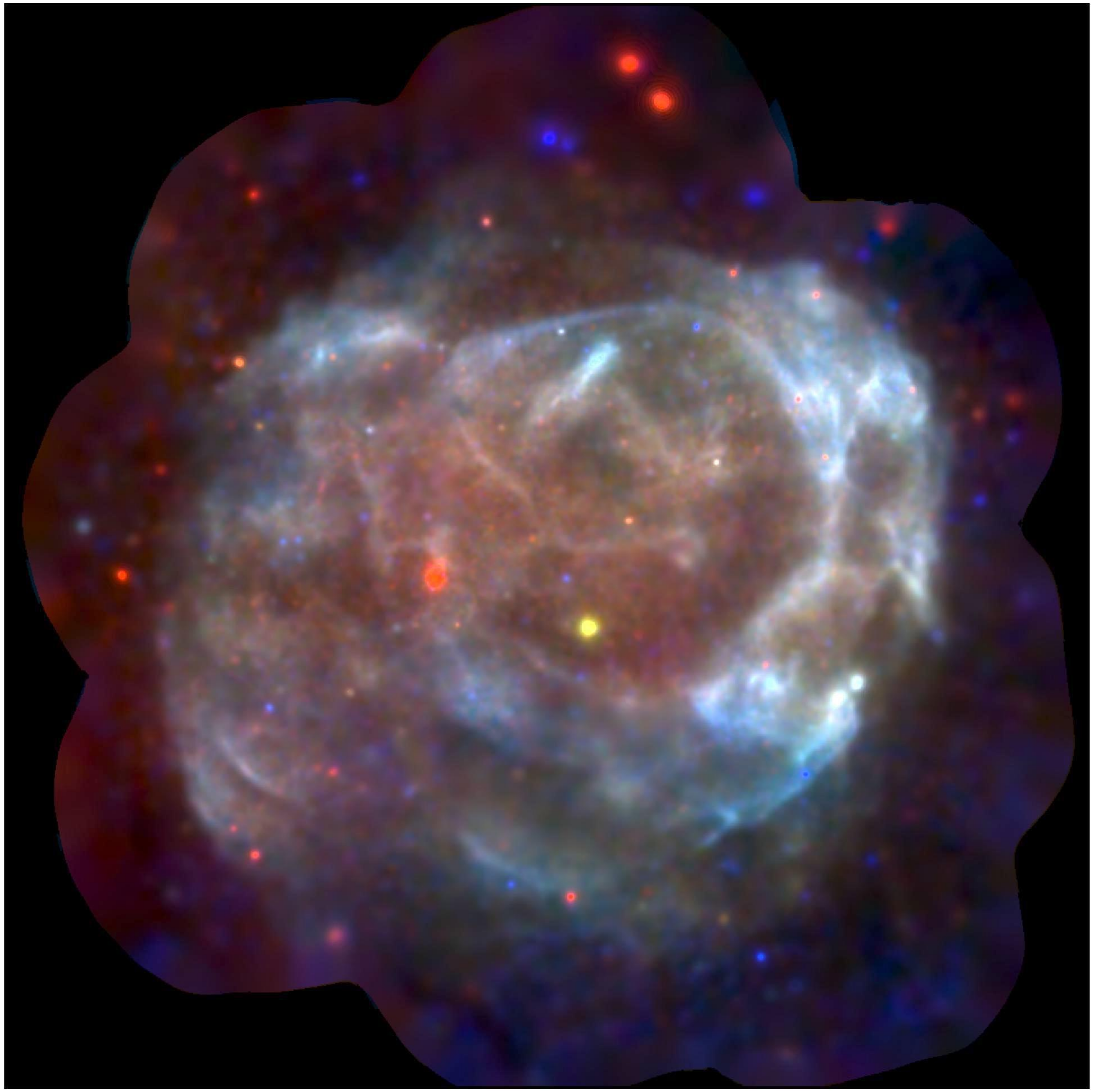
Interior tends to be softer

The CCO is much softer than the SNR when moving to several keV (thermal emission vs quasi power law)



True-color map

- **Same adaptive smoothing to all energies, meant to be not too strong at either low energies nor high energies**
- **R = 0.5 – 0.8 keV**
- **G = 1 – 2 keV**
- **B = 4 – 6 keV**
- **Sqrt scaling**



The SNR is harder than the wind clump and the CCO, as before

Point sources tend to be either soft (foreground stars) or hard (background AGN and Galactic sources)

Background emission is redder (less absorbed) to the North East than the South West

Original Goals of the Large Program

- **Measure proper motion of the shock around the SNR**
  - **Constrain external densities, acceleration mechanism**

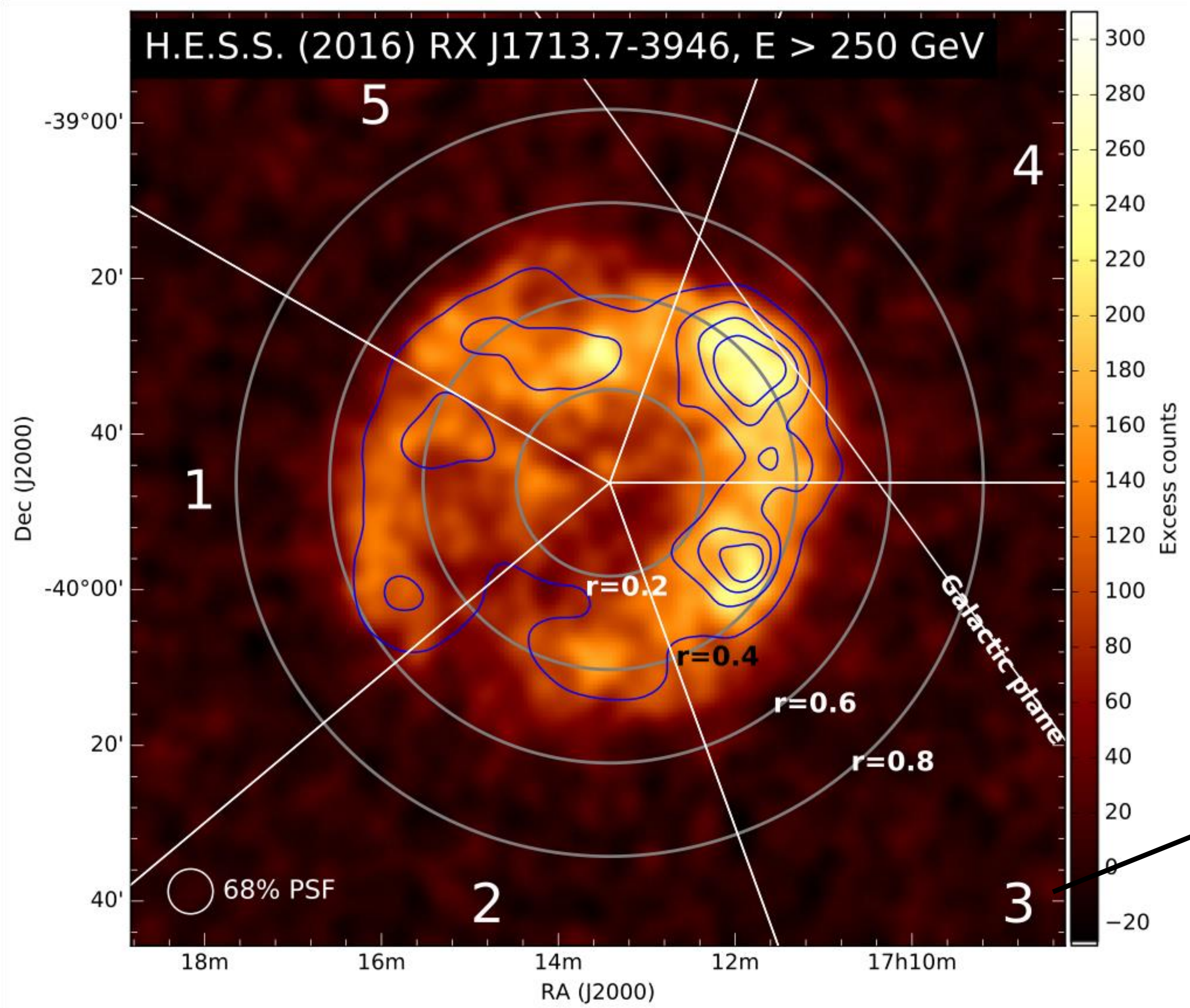
- **Map the thermal emission from ejecta and shocked ISM**
  - **Progenitor of SN, external densities**

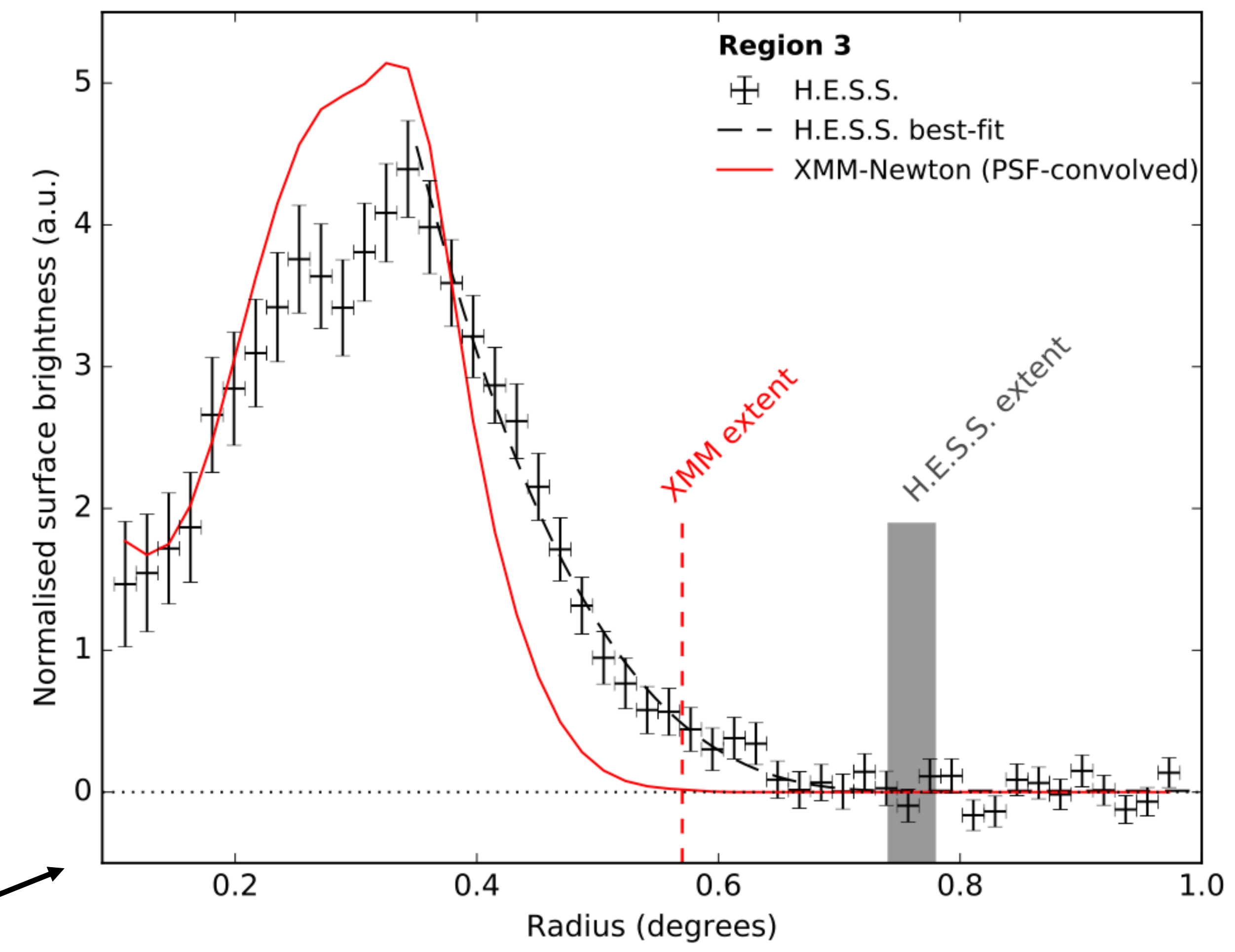
- **Study shock/clump interaction**

- **Revisit the X-ray vs TeV comparison**
  - **Do the gamma-rays extend further out than X-rays?**

This presentation

Revisiting XMM/HESS extension

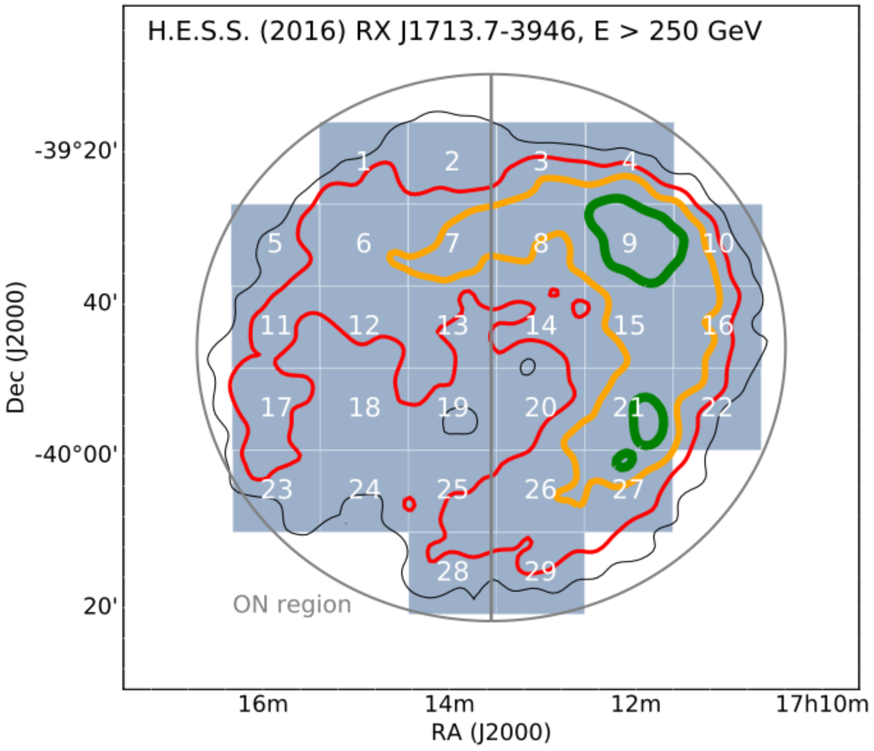


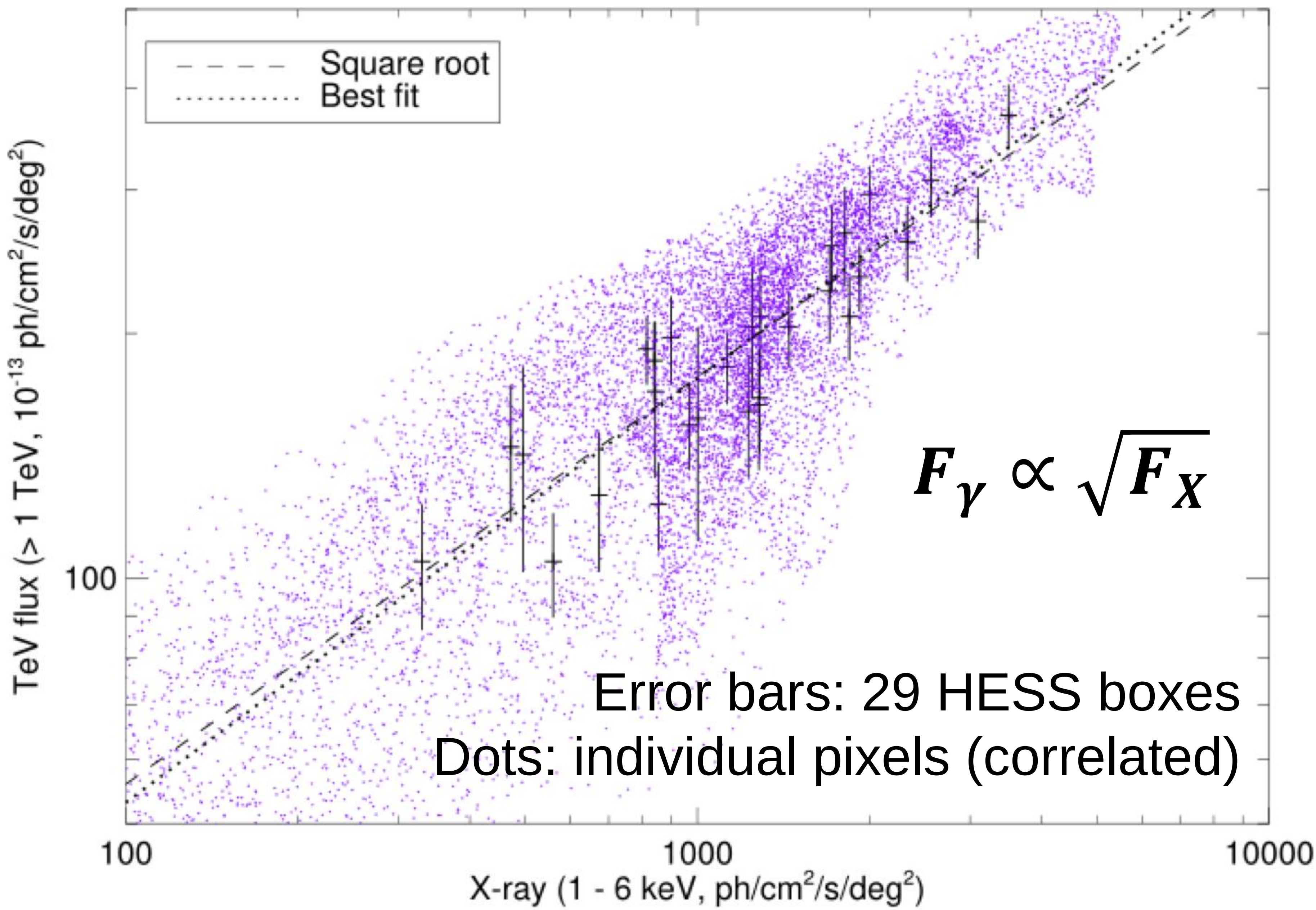


Gamma-rays extend further than X-rays ?
Escaping protons in region of interaction ?

X-ray data: XMM in 1-10 keV

X/γ flux correlation

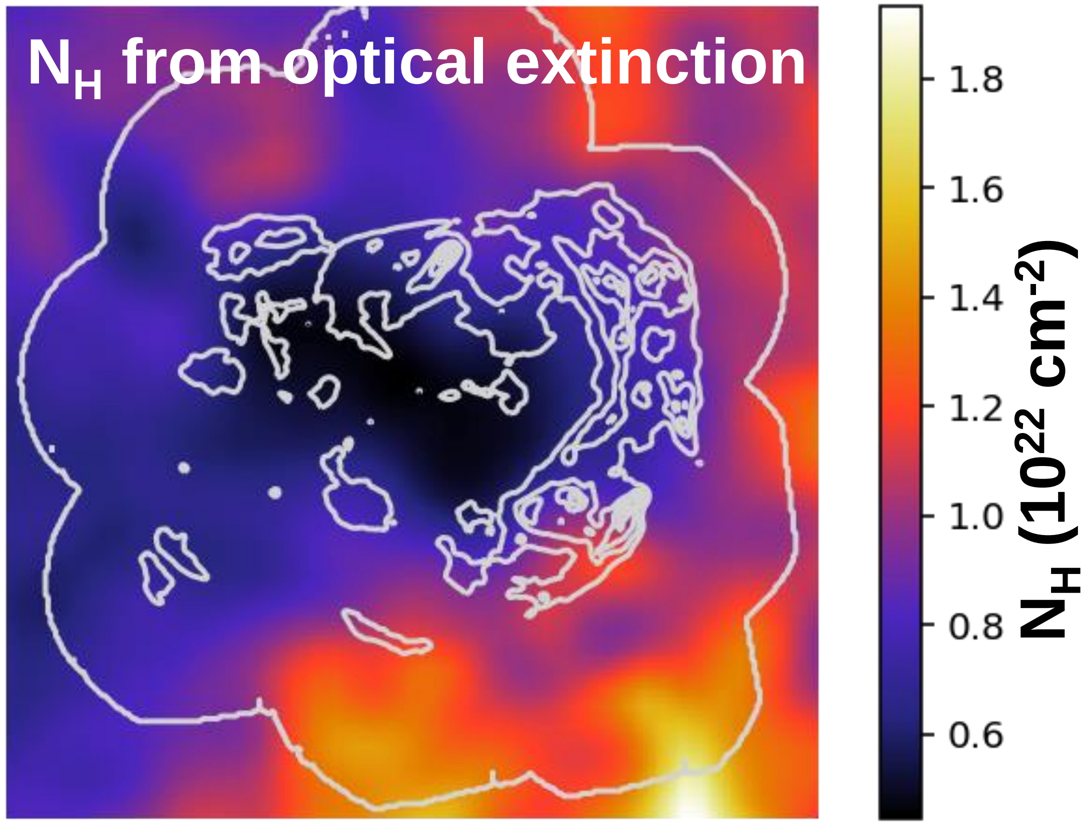


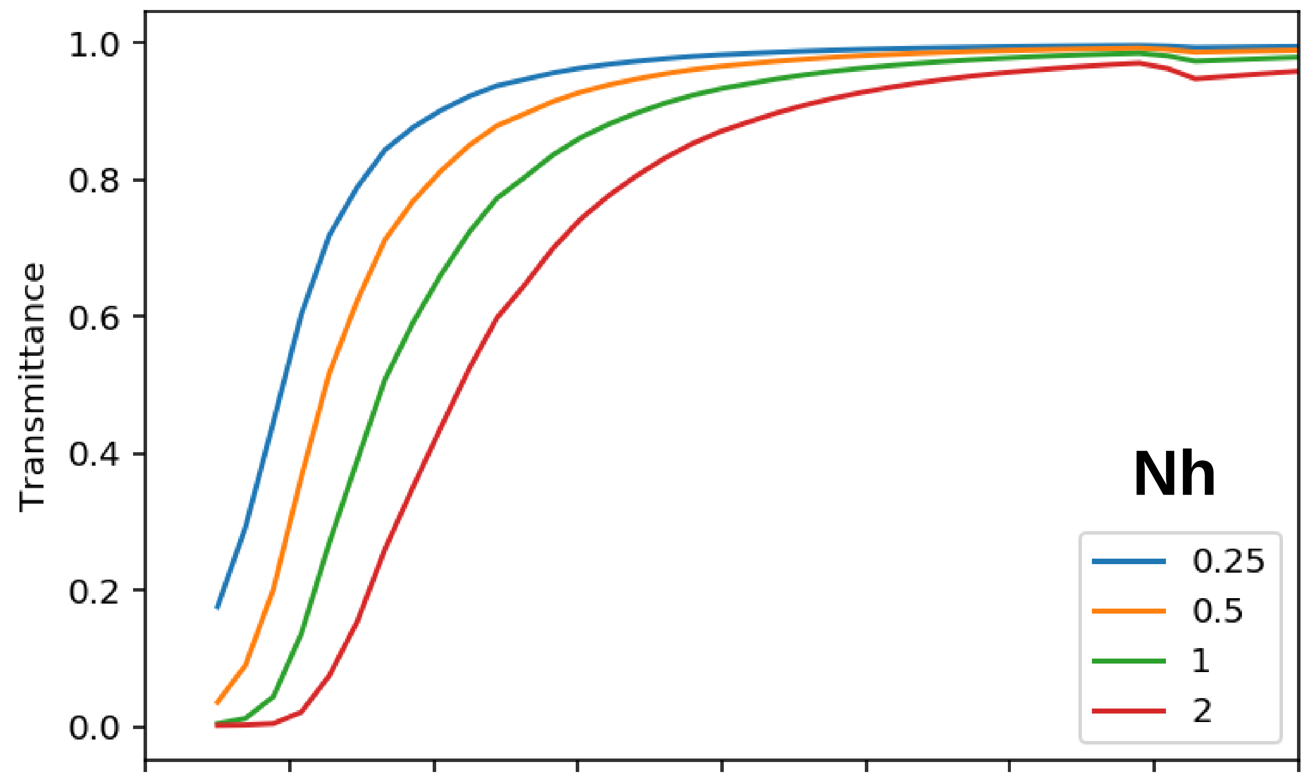


- **Comparing F_X vs F_γ:**
  - **X-ray image (smoothed to HESS PSF) has more contrast than gamma**

Absorption along line of sight

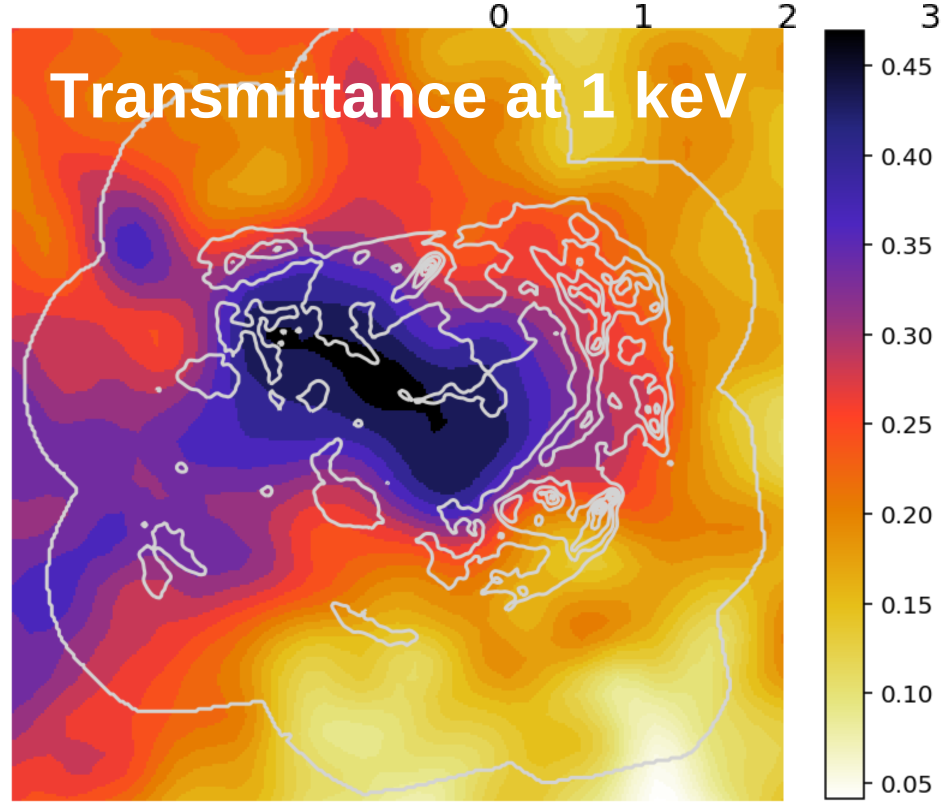
- **Absorption plays an important role even above 1 keV**





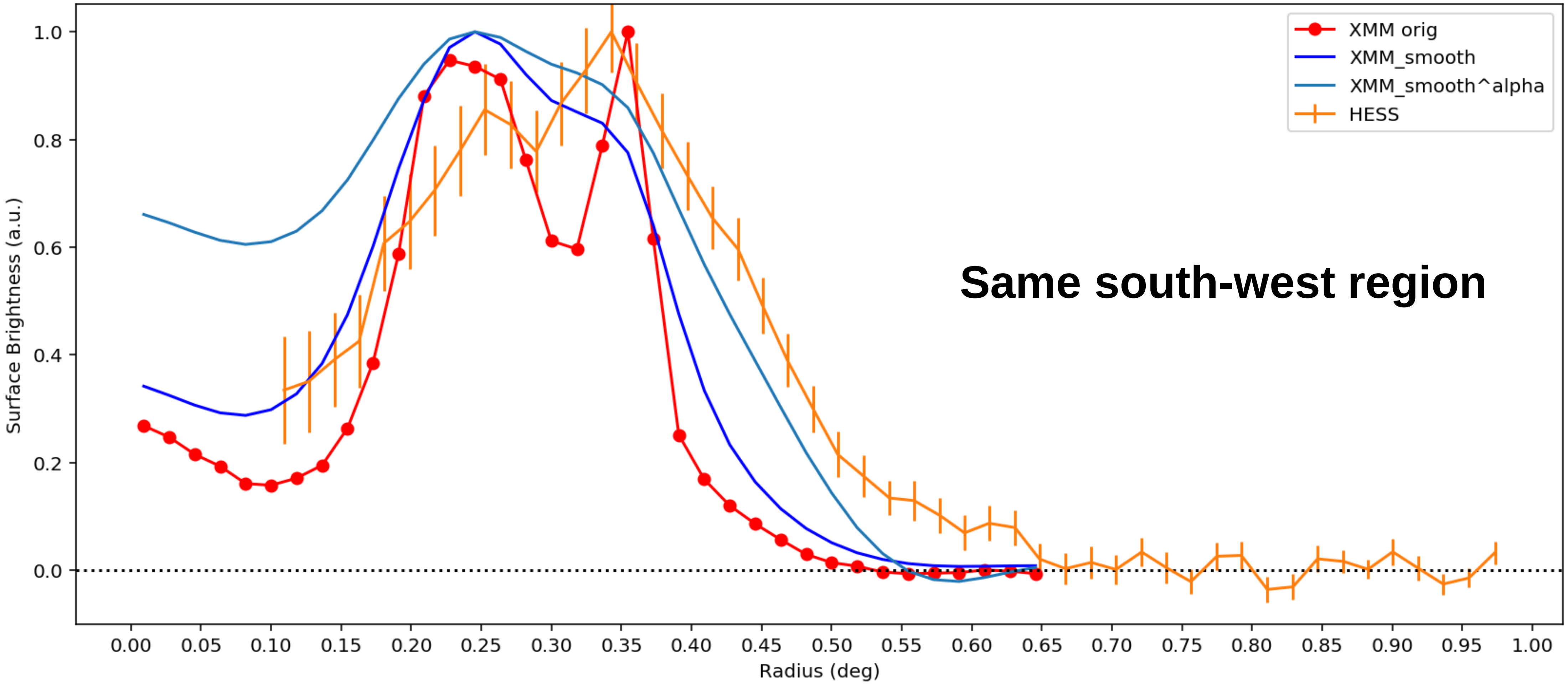
Good correlation with first softness map ➔ assume this is a good measure of column density in front of SNR

Sum over energy after correcting for absorption



Radial profiles: 1-6 keV

Profile with NO absorption correction

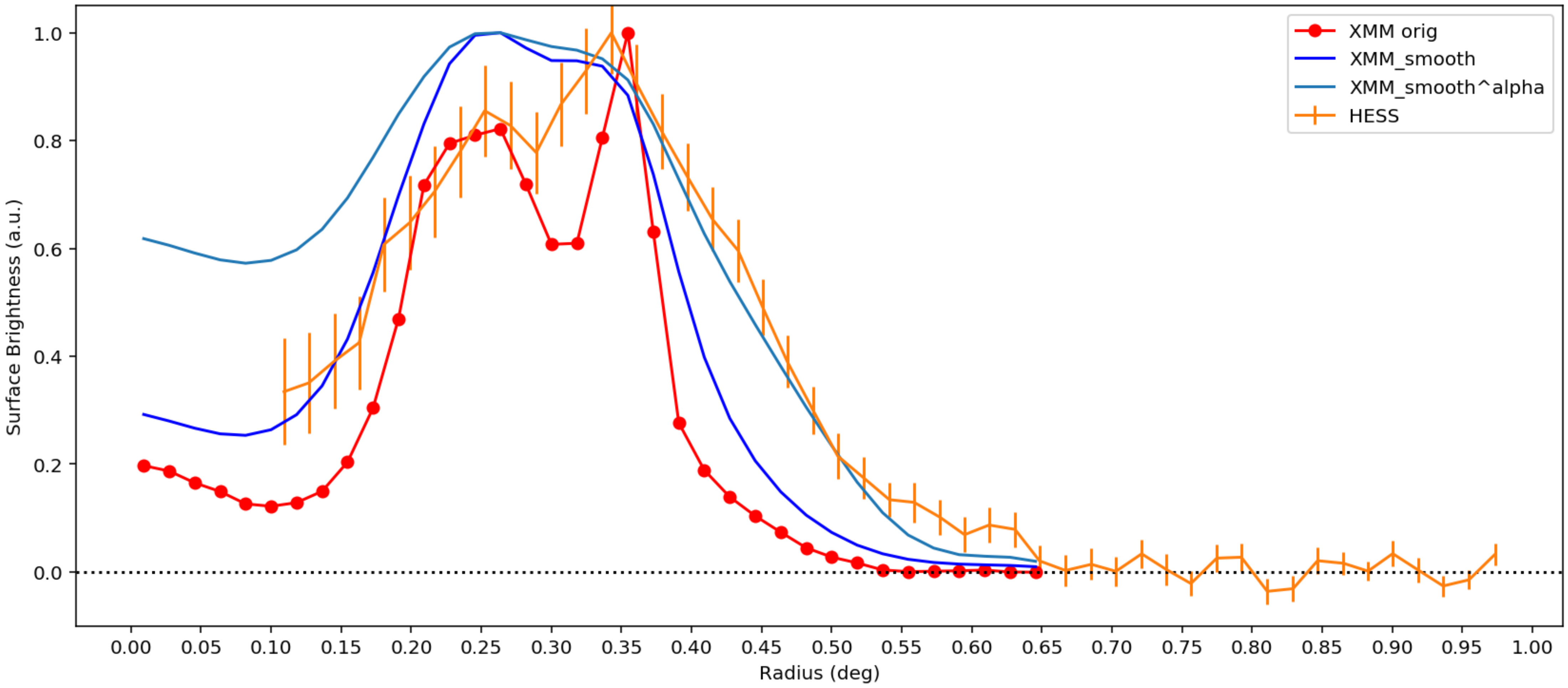


alpha=0.5

Accounting for the F_γ α $\sqrt{F_X}$ correlation already has a sizable effect

Radial profiles: 1-6 keV

Profile with absorption correction to NHref=0

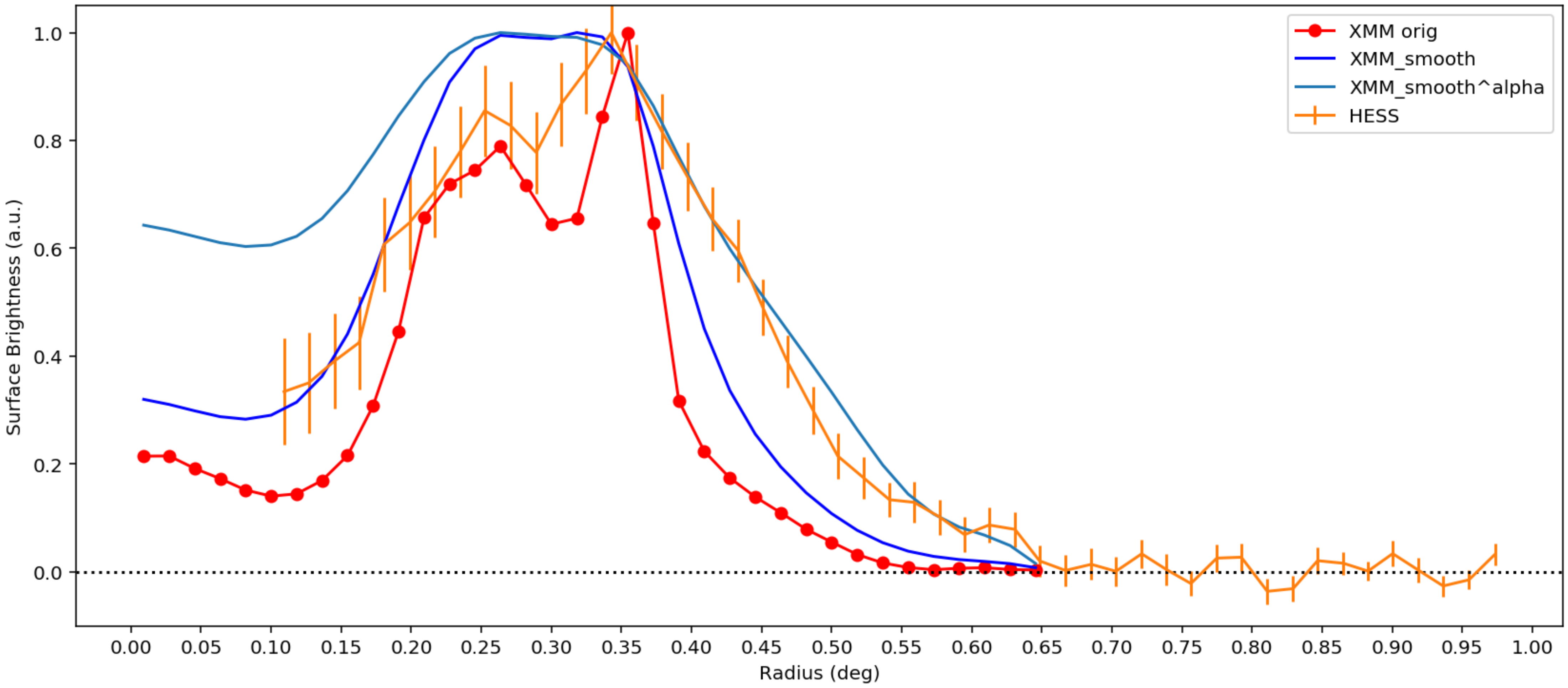


alpha=0.5

X/γ difference is much reduced wrt HESS study after correcting for absorption

Radial profiles: 0.9-2 keV

Profile with absorption correction



alpha=0.5

X/γ difference is even more reduced wrt HESS study when going to lower X-ray energies, but more uncertain

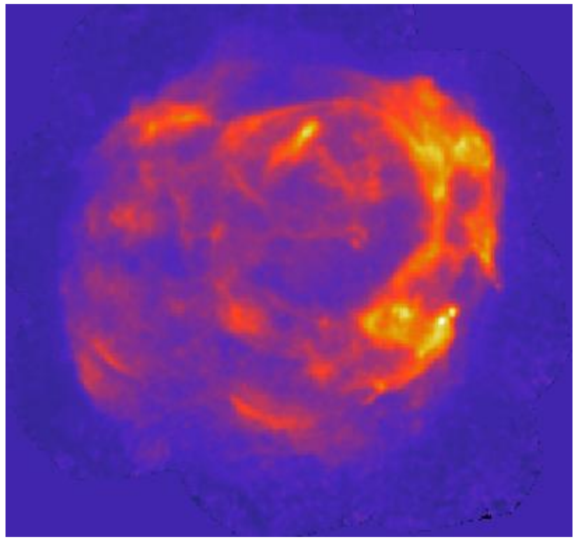
Conclusions

- **Deep, homogeneous X-ray coverage across the entire remnant**
- **Confirms F_γ α $\sqrt{F_X}$ correlation**
- **Escaping protons ? New profile has:**
  - **Increased X-ray coverage in radius and statistics**
  - **Correction for F_γ α $\sqrt{F_X}$ correlation**
  - **Correction for absorption along the line of sight**
  - **Exploring energy ranges closer to the TeV electrons**
- **New profile shows that X/γ difference is reduced**

Backup

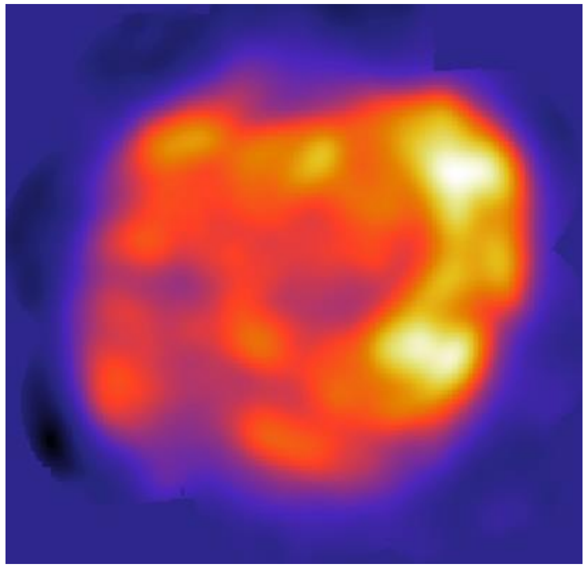
Constructing X-ray profiles

- CubeXMM = (XMM_cube* - Astro_BKG_Cube) / cube_transmittance



- ImageXMM = SUM(CubeXMM, Energies) =>

- ImageXMM_smoo = PSF_HESS+(ImageXMM) =>



*: all point sources are inpainted
+: PSF from HESS RXJ DL3 public release shrunk by 2

Conclusions

- X/γ and flux/slope correlations are important constraints
- **No hadronic model** can explain the larger contrast in X-rays than γ-rays. This is also consistent with the non detection of thermal X-ray emission at the blast wave
- "brighter is softer" correlation in X-rays implies that electrons are **cooling-limited**
- "**magnetic driven**" model of Yang & Liu 2013 predicts the right X/γ correlation but results in "brighter is harder" X-rays
- "**density driven**" correlation of Acero et al 2009 works but implies that energy density of accelerated particles is proportional to ρ instead of ρV^2_{sh}
- "**pressure driven**" correlation can work only if pressure is nearly proportional to density
- All those relations predict "brighter is softer" in γ-rays as well. Not observed (but not very constraining yet)