High Energy Gamma-Ray Emission from the Coma Cluster Region: Deep Morphological and Spectral Studies

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16 July 2021

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

Introduction

- **Radio to Gamma-ray observation of Coma Cluster**

- **Motivation and Methods**

- **Morphological Studies**

- **Spectral Studies**

- **Conclusion**

i)   z=0.023 (about 100 Mpc) (Struble & Rood 1991)

ii)   Linear size of more than 2 Mpc

iii)   Mass ($M \sim 10^{15}$) $M_\odot$

Radio (WSRT) at 352 MHz

X-ray 0.4-2 keV with SRG/eROSITA

S. Brown and L. Rudnick 2011

E. Churazov et al. 2021
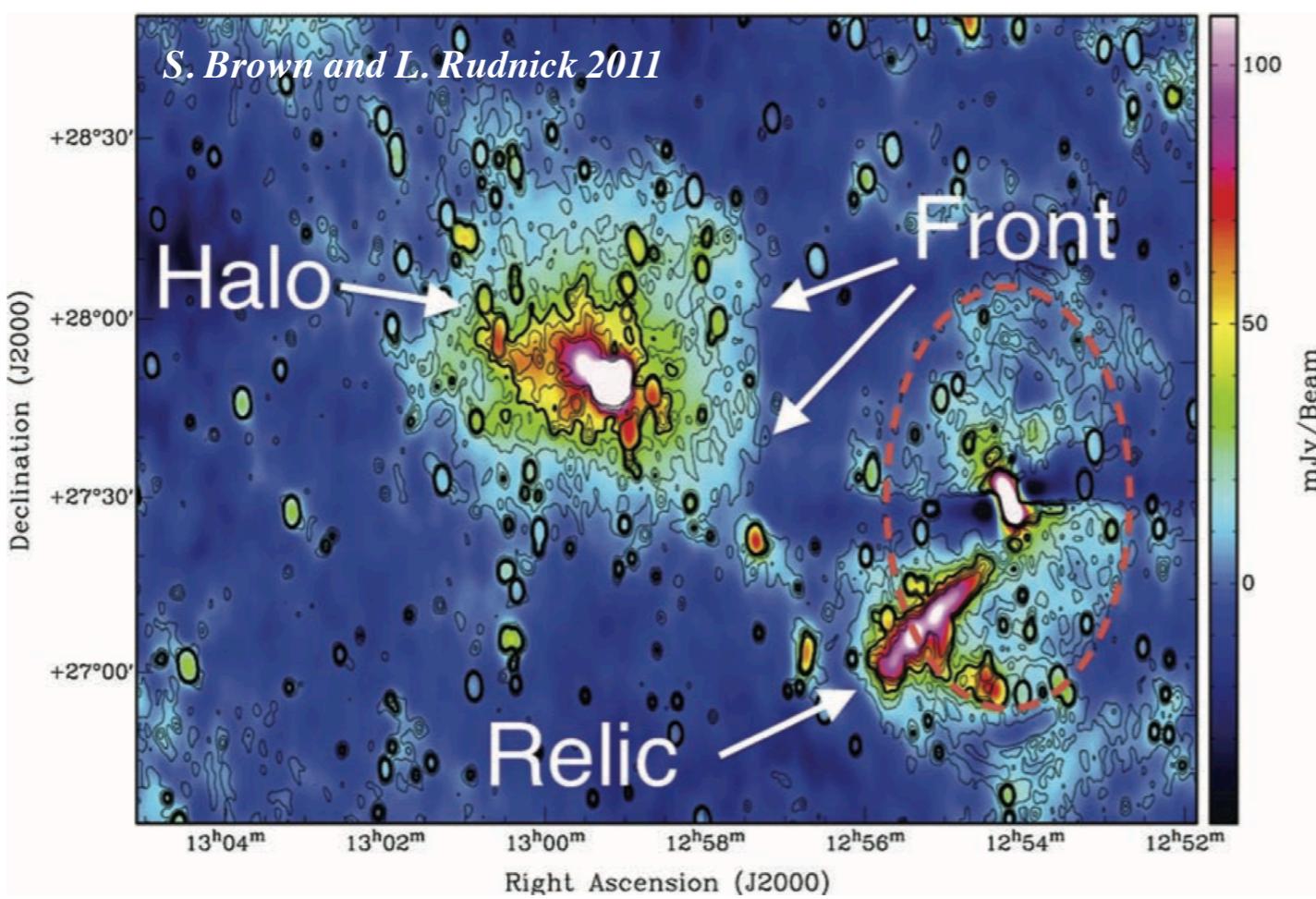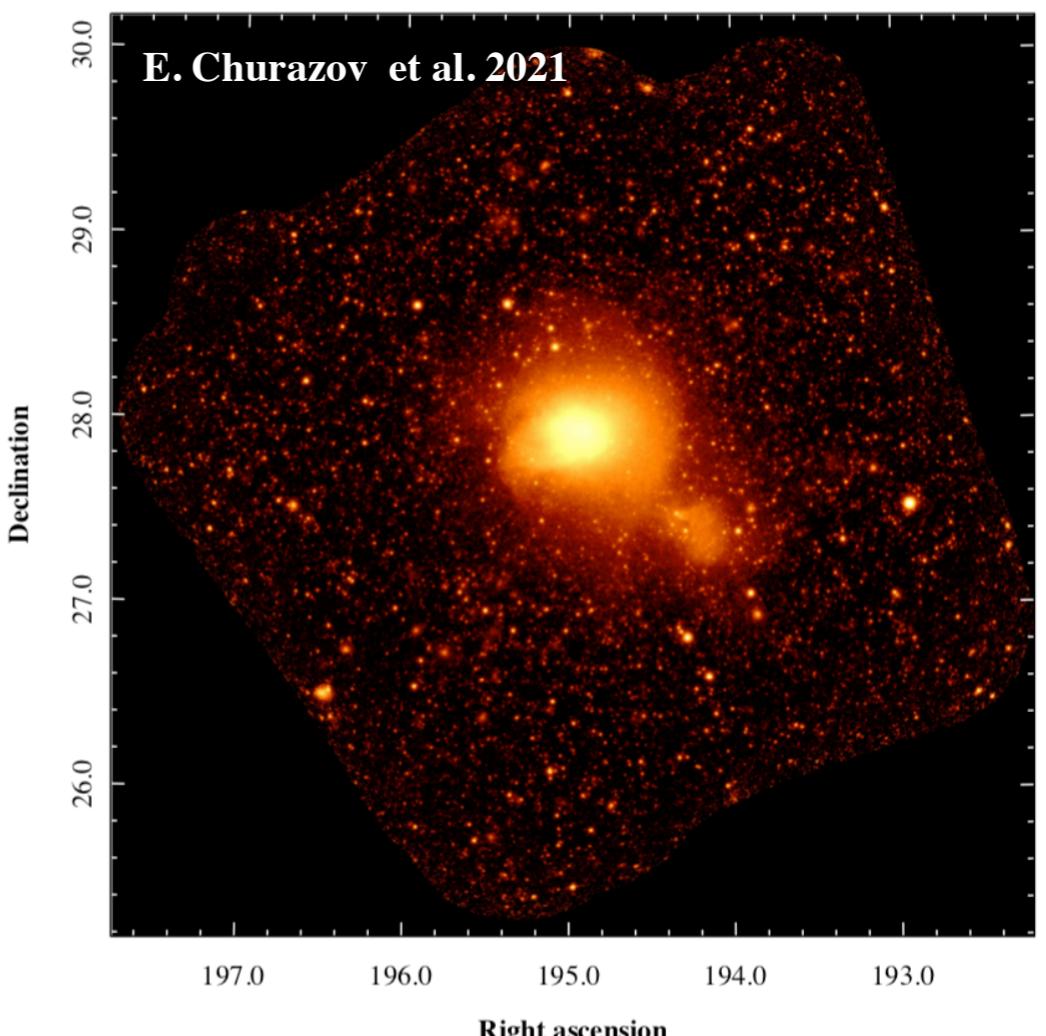
Coma Cluster (Gamma-Ray observations)

**ULs 1-10 TeV by HESS are $F_\gamma < (0.1 - 6.1) \times 10^{-13}$ ph cm^{-2} s^{-1}**

Aharonian et al. (2009)
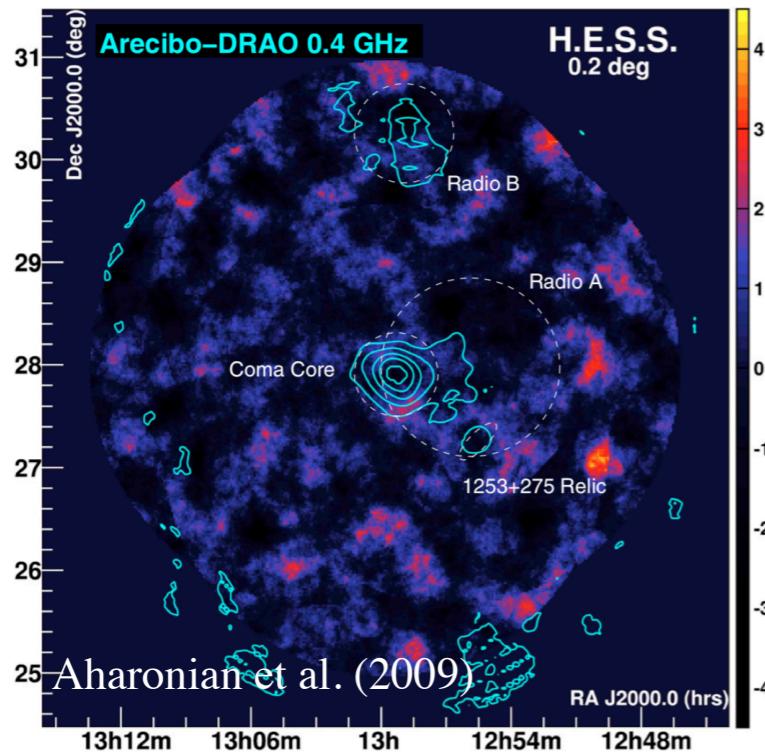
6 years of Fermi- LAT data, low significance gamma-residual, ULs >100 MeV, $F_\gamma \leq 1.7 \times 10^{-9}$ ph cm^{-2} s^{-1}

Ackermann et al. (2016)
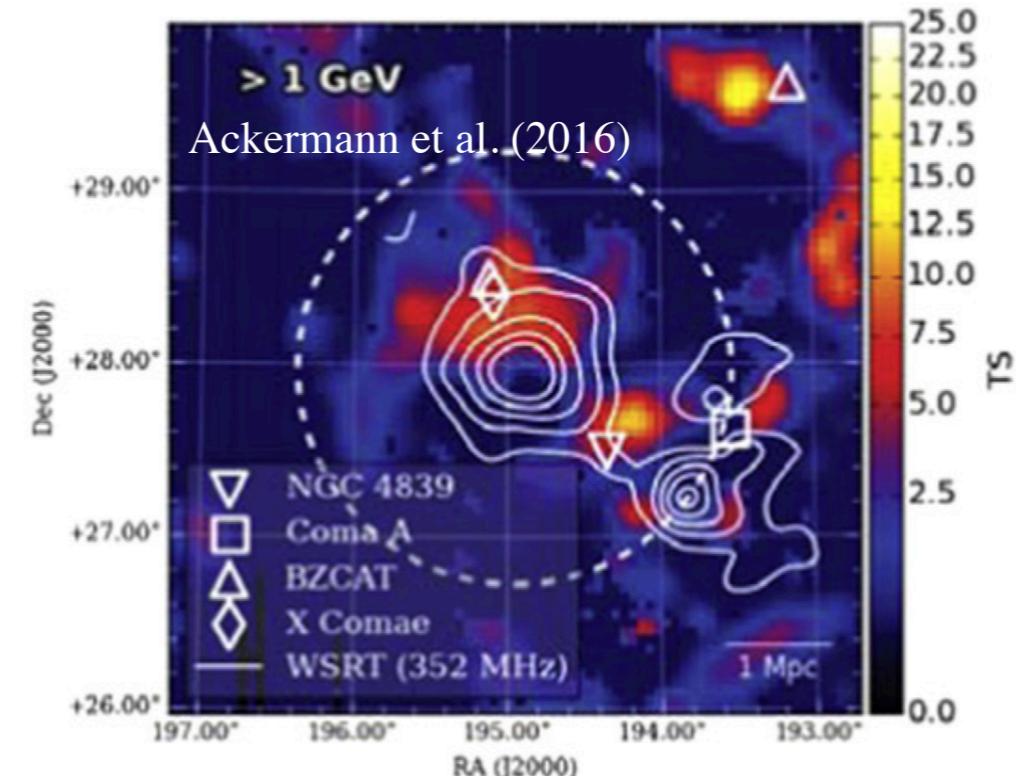
Extended γ-ray emission inside viral radius; $F_\gamma \sim 2 \times 10^{-12}$ erg cm^{-2} s^{-1} with a soft photon index of $\Gamma \sim 2.7$

0.2-300 GeV

Shao-Qiang Xi et al. (2018)
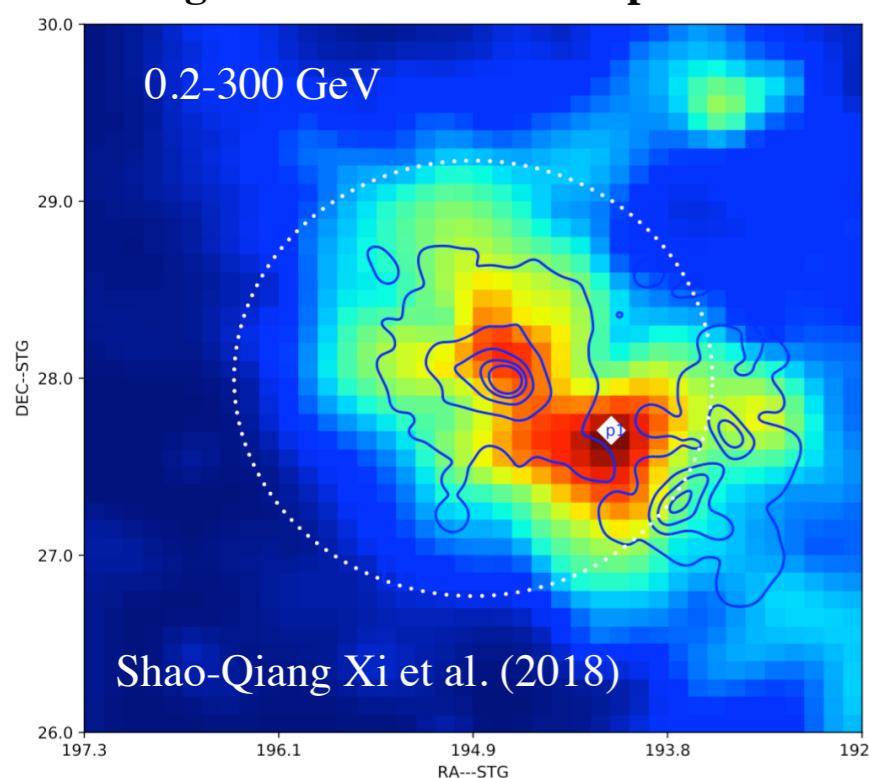
Significant γ-ray signal is observed from the Coma cluster, with a test statistic TS $\approx$27


R. Adam et al. (2021)

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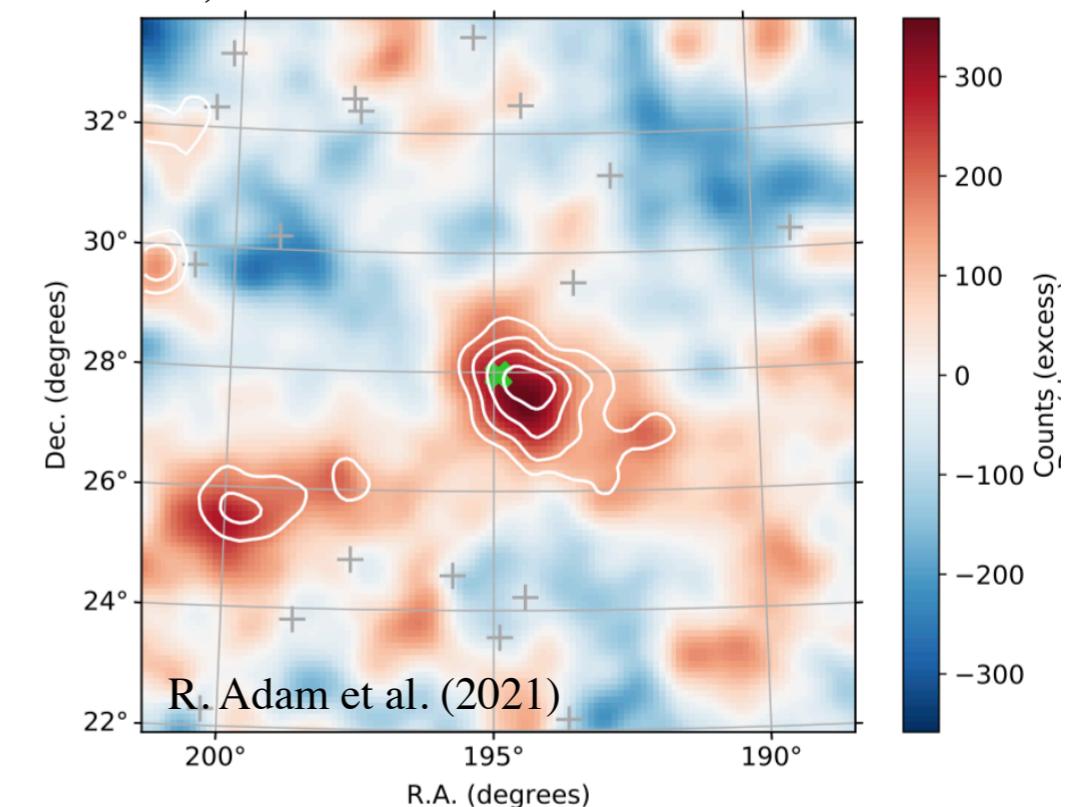
Motivation and Methods

1. Confirm the Gamma-Ray detection from the Coma Cluster

**2. Gamma-Ray Morphology**

3. Gamma-Ray Spectrum
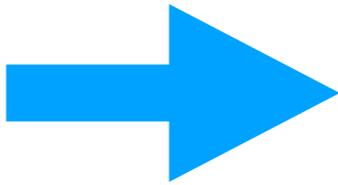
- Fermi-LAT

- Time period - Aug 011, 2008 - Jun 01, 2021

- Energy range -100 MeV-1 TeV

- **Event class - "ULTRACLEANVETO"**

- Standard binned likelihood analysis

Energy Dependant Morphology

Significance map (TS)

100 MeV - 1 TeV
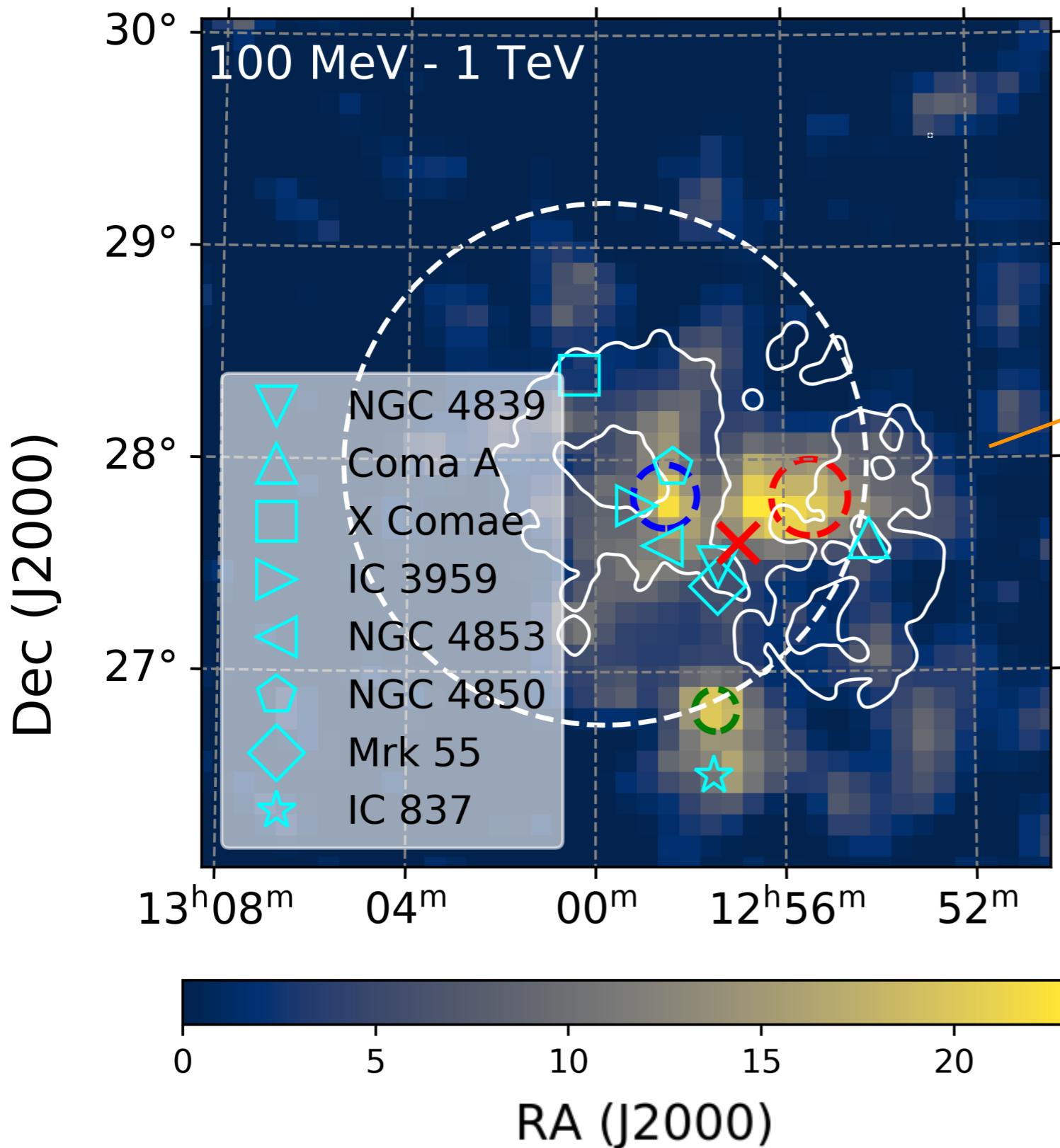
Localised Point like structures
with 68% containment radii

p1   p2

p3

NGC 4839
Coma A
X Comae
IC 3959
NGC 4853
NGC 4850
Mrk 55
IC 837

X The position of
   4FGL J1256.9+2736

Dec (J2000)

RA (J2000)

Significance maps (TS)
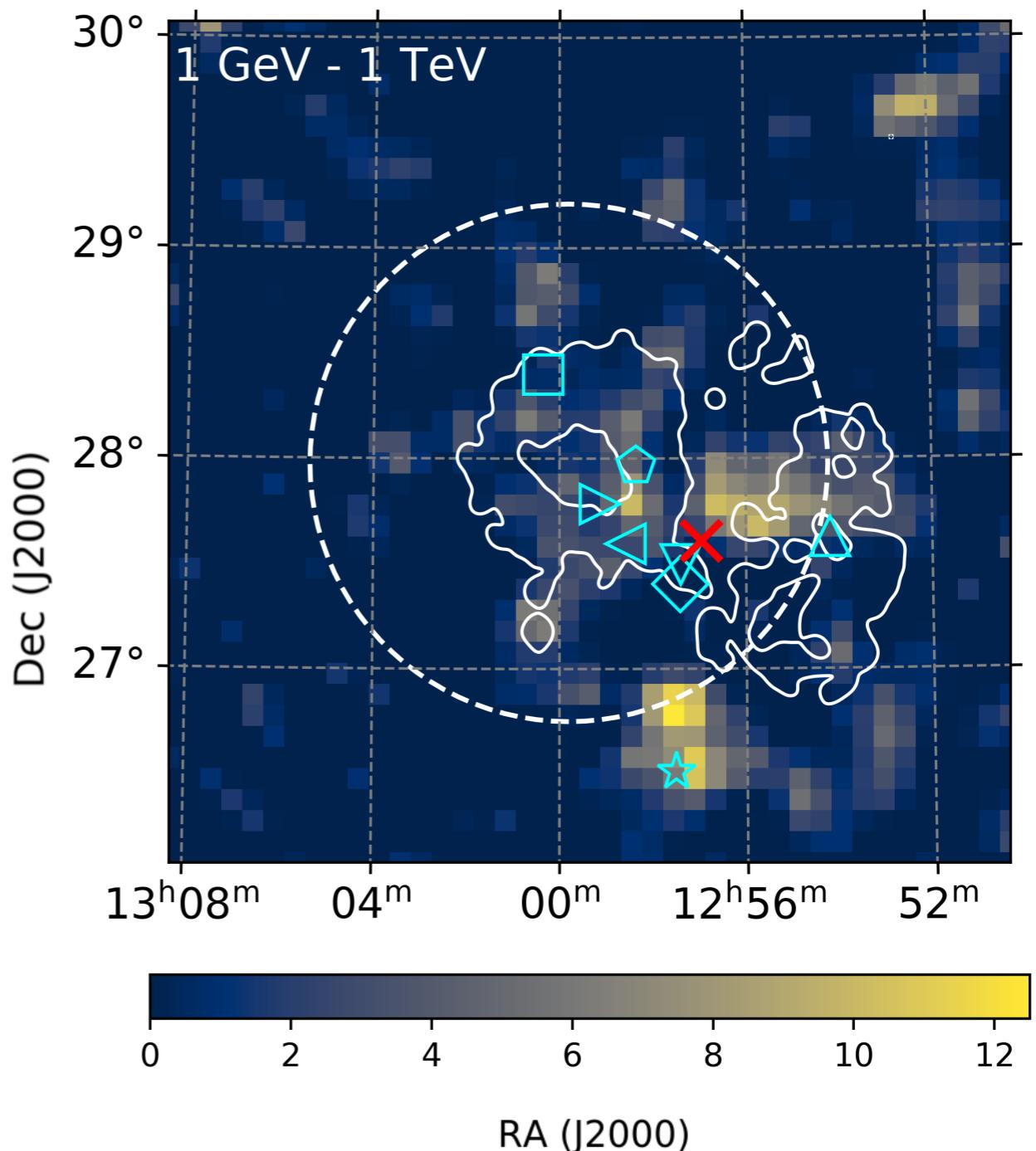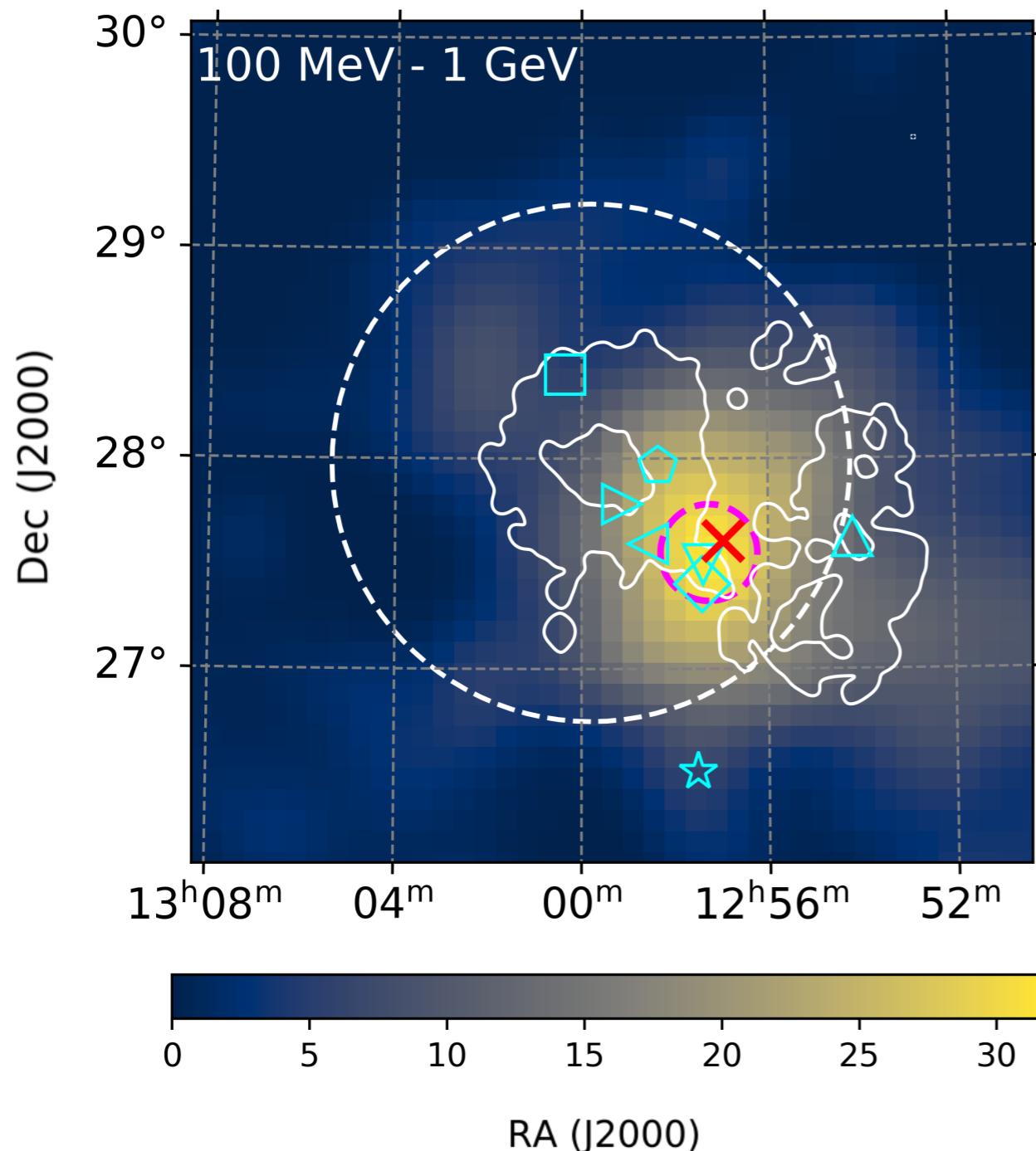
Is there residual extended Gamma-Ray structure?

Extended Diffuse Gamma-Ray Emission
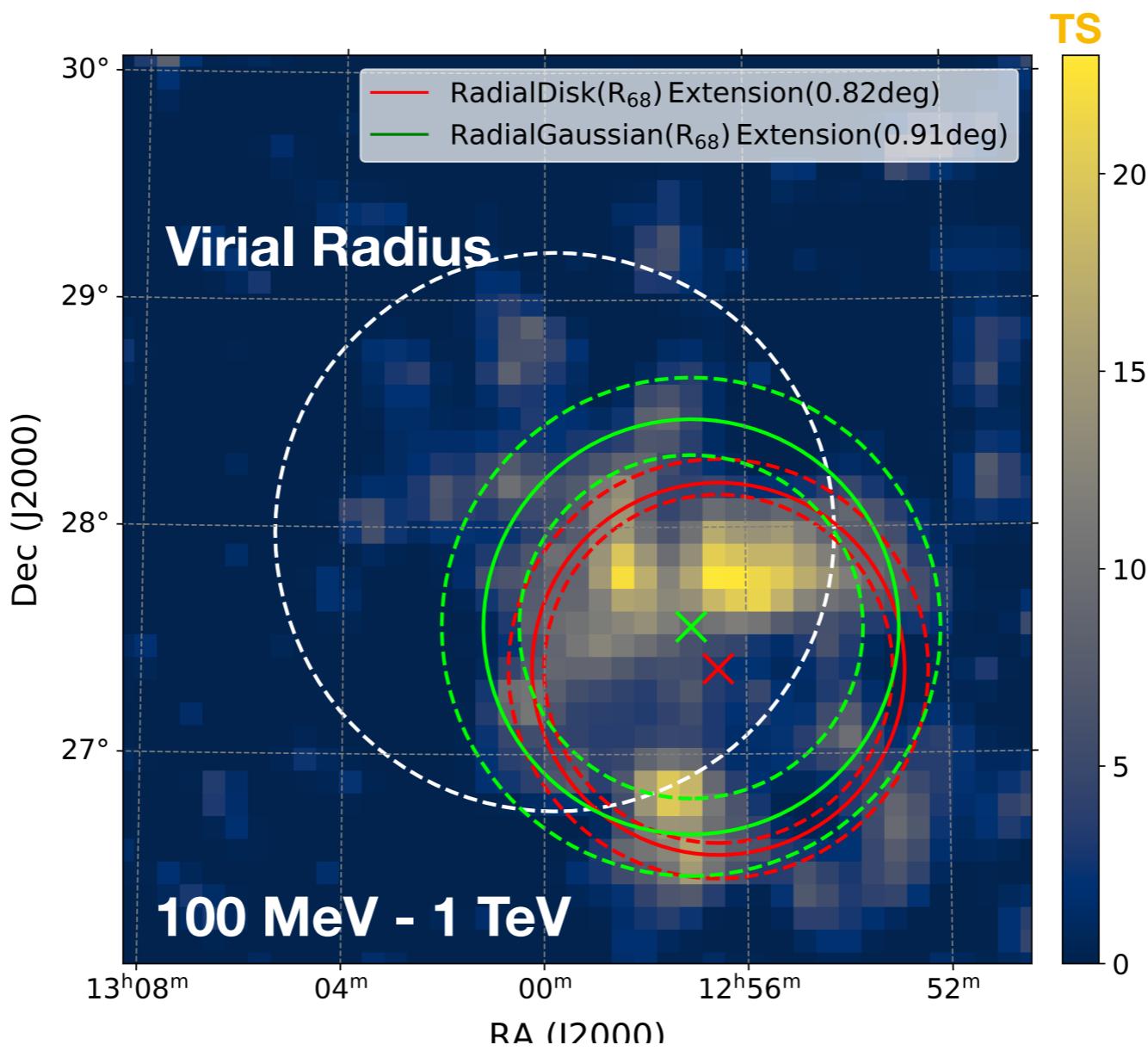
| Spatial model	RA$_{J2000}$ [deg]	Dec$_{J2000}$ [deg]	R$_{68}^{pos}$ [deg]	TS	R$_{68}$ [deg]	TS$_{ext}$
RadialDisk	194.14 ± 0.14	27.38 ± 0.13	0.19	56.4	$0.82^{+0.10}_{-0.05}$	29.3
RadialGaussian	194.27 ± 0.17	27.56 ± 0.17	0.26	55.0	$0.91^{+0.18}_{-0.16}$	9.8
$p_1 + p_2 + p_3$						
p_1	194.63 ± 0.08	27.83 ± 0.13	0.15	17.5	-	-
p_2	193.86 ± 0.15	27.82 ± 0.10	0.18	16.8	-	-
p_3	194.37 ± 0.06	26.82 ± 0.07	0.10	15.8	-	-

Spectral Model Parameters
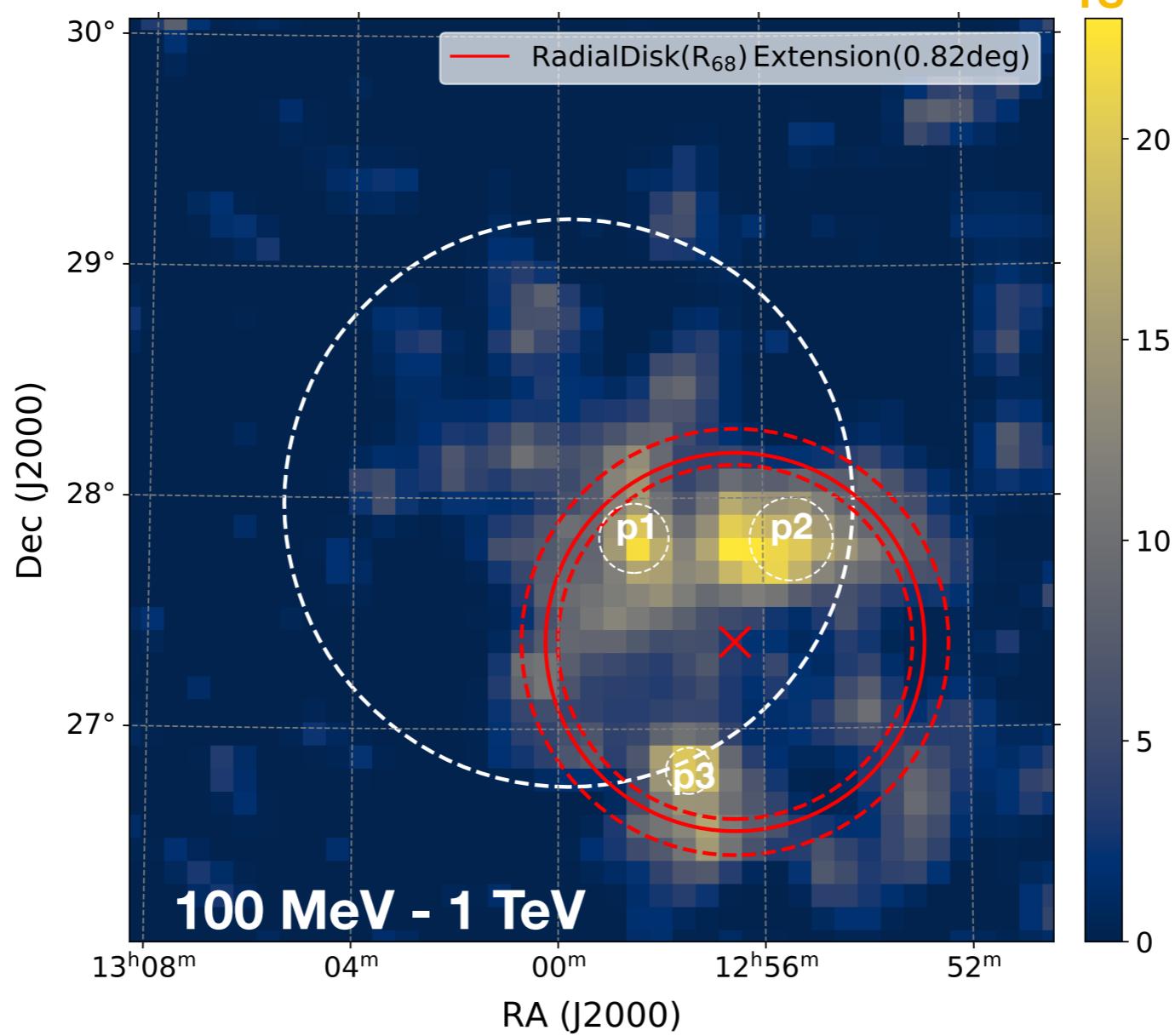
| Spatial model	Energy flux $[10^{-12} \times \mathrm{erg\ cm^{-2}\ s^{-1}}]$	Index	TS	$\log(\mathcal{L})_{\mathrm{max}}$	Δ_{AIC}	N_{dof}
Disk	3.84 ± 0.67	2.23 ± 0.11	51.6	-313141.3	-	-
$p_1 + p_2 + p_3$				-313135.0	-4.7	4
p_1	1.05 ± 0.37	2.47 ± 0.23	17.2			
p_2	1.16 ± 0.39	2.53 ± 0.24	16.4			
p_3	0.93 ± 0.35	2.08 ± 0.24	15.4			
Disk + $p_1 + p_2 + p_3$				-313131.7	-7.2	6
Disk	1.54 ± 1.06	2.09 ± 0.26	5.62			
p_1	0.82 ± 0.37	2.44 ± 0.28	11.1			
p_2	0.86 ± 0.43	2.56 ± 0.32	8.8			
p_3	0.75 ± 0.39	1.99 ± 0.30	9.4			

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~ 50 GeV with Index = 2.23 ± 0.11

Gamma-Ray: 100 MeV - 1 TeV
Fermi-LAT (our work)
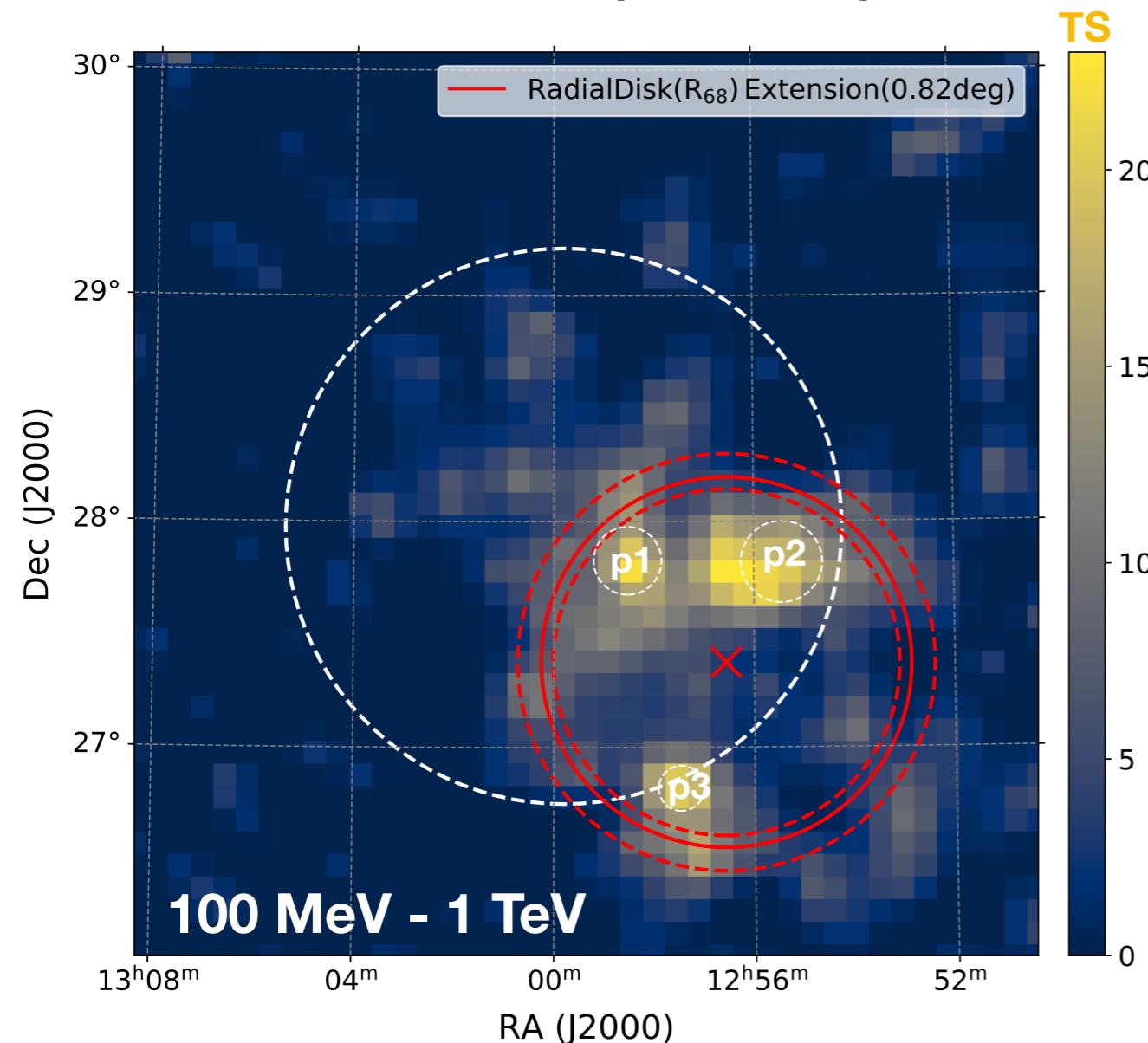
X-ray 0.4-2 keV with SRG/eROSITA

E. Churazov et al. 2021
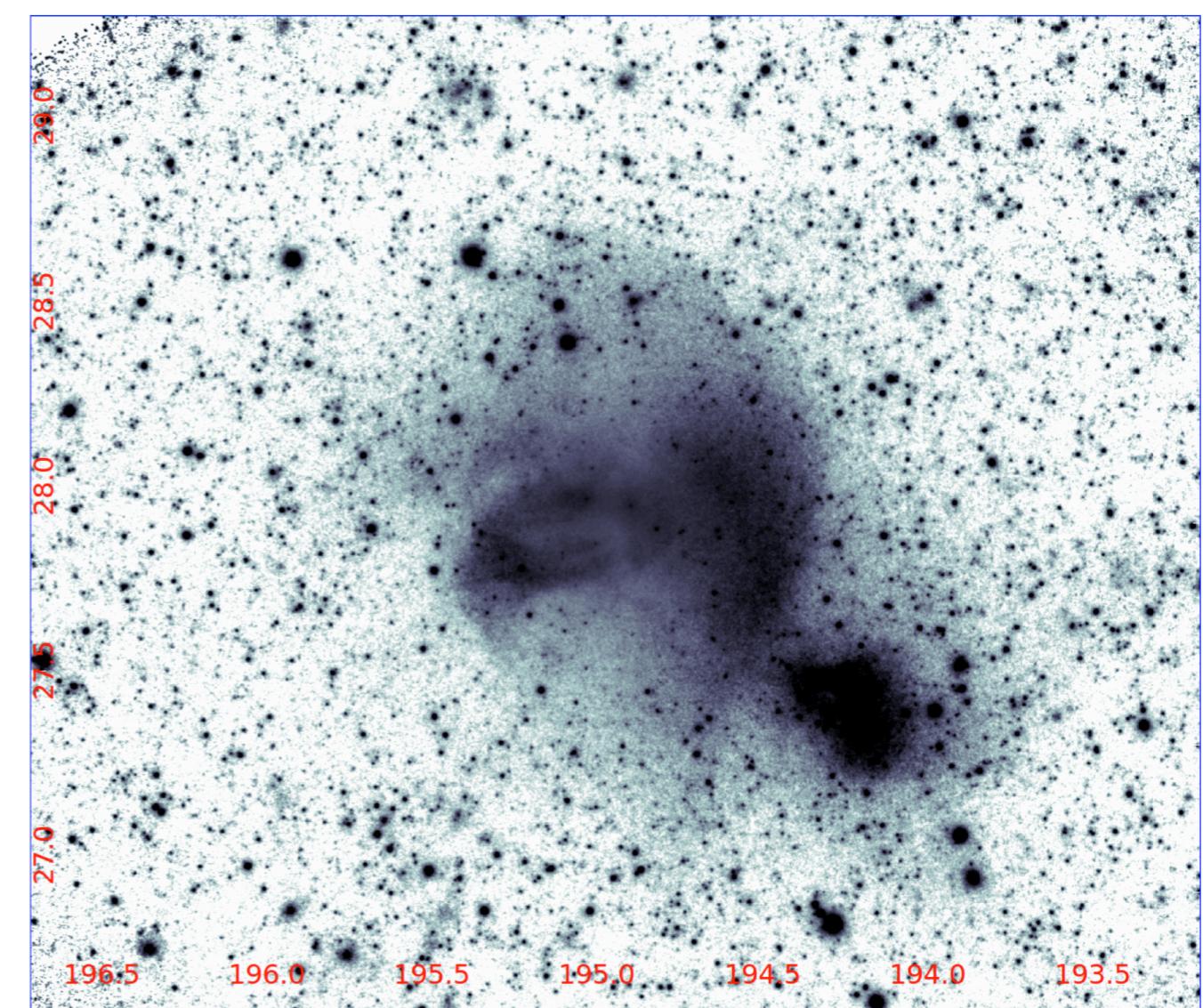
Conclusion

- **Confirmation of the detection of Gamma-Ray Emission from Coma Cluster with Fermi-LAT (100 MeV - 100 GeV)**

- **Complex Gamma-Ray Structure** → **Point Like structures**
  → **Extended diffuse Gamma-ray structure**

- **Gamma-Ray Spectrum extends up to ~50 GeV with hard photon index 2.2**

- **Possible correlation with X-ray**

Thank you !

Next

1) Systematics Studies
2) Theoretical interpretation