CTAO SCIENCE PERSPECTIVE ON COSMIC RAY PHYSICS

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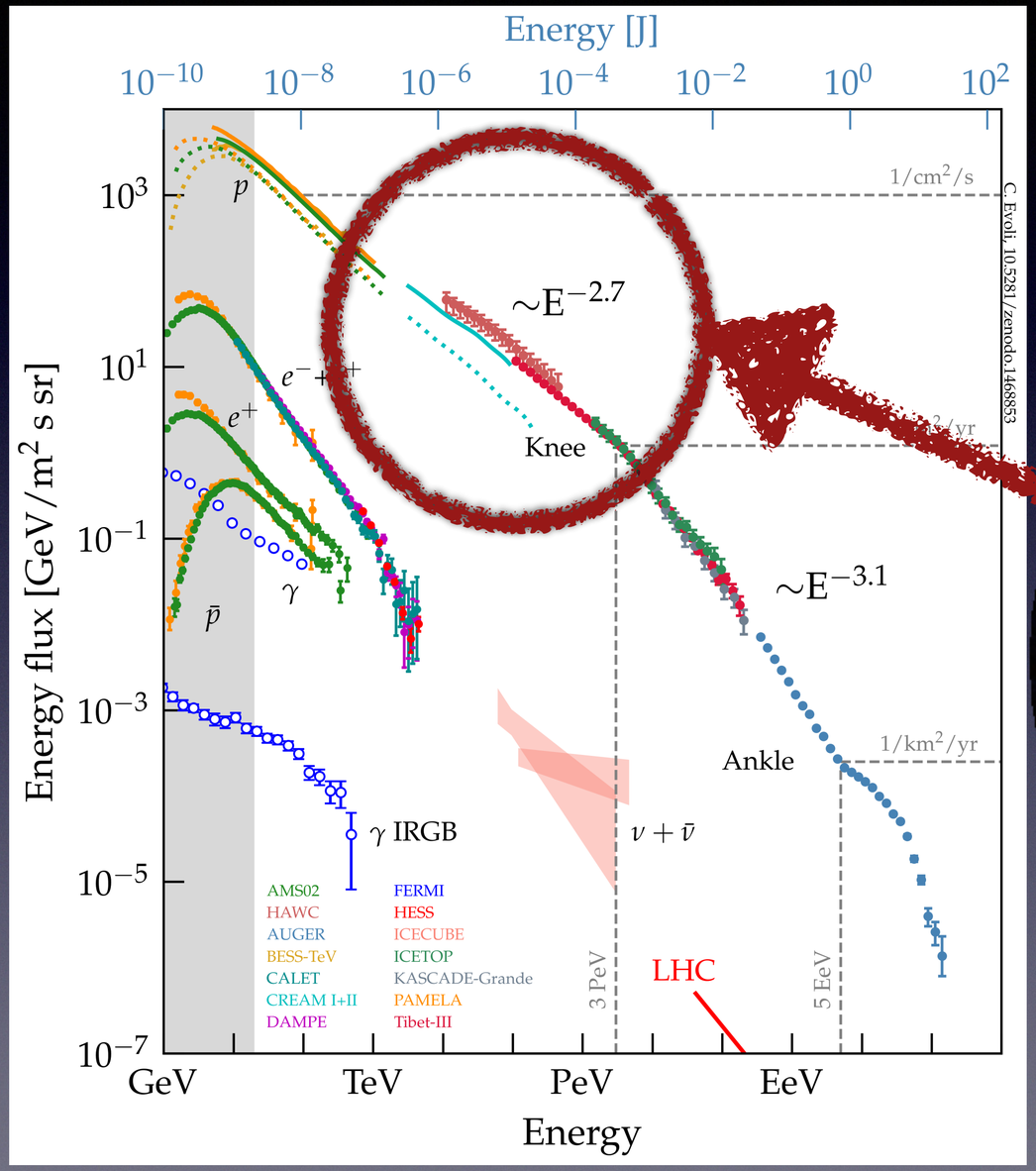
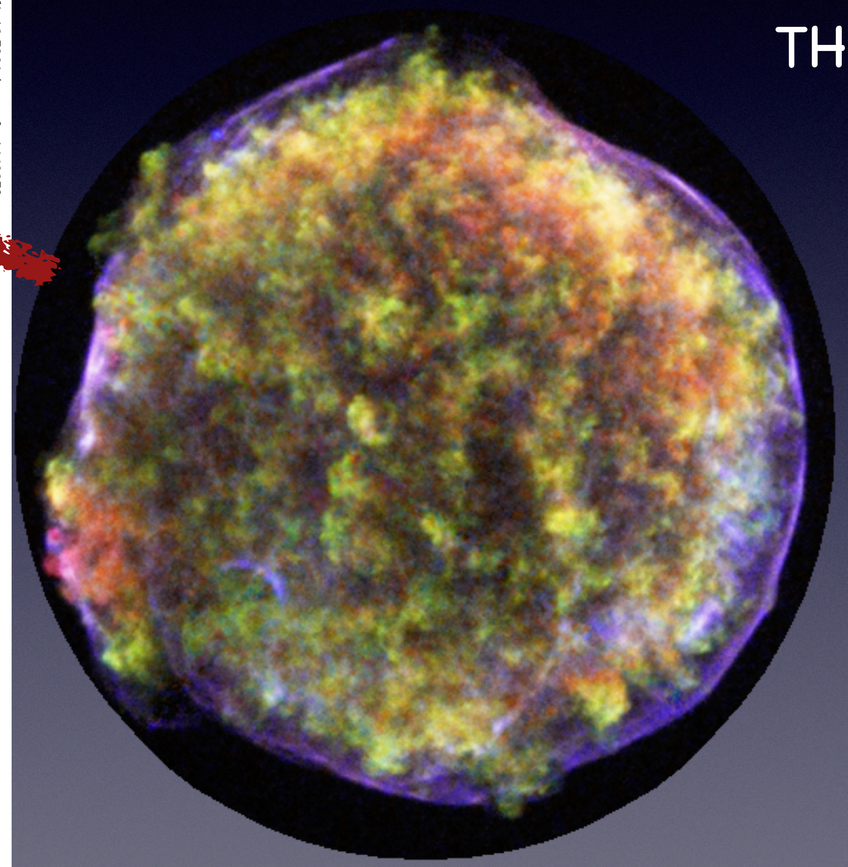
PEVATRONS AND THE CR-SNR PARADIGM



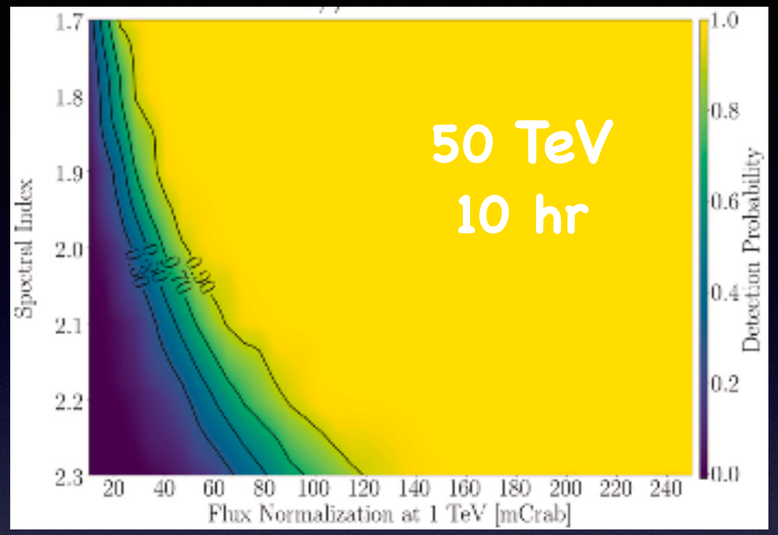


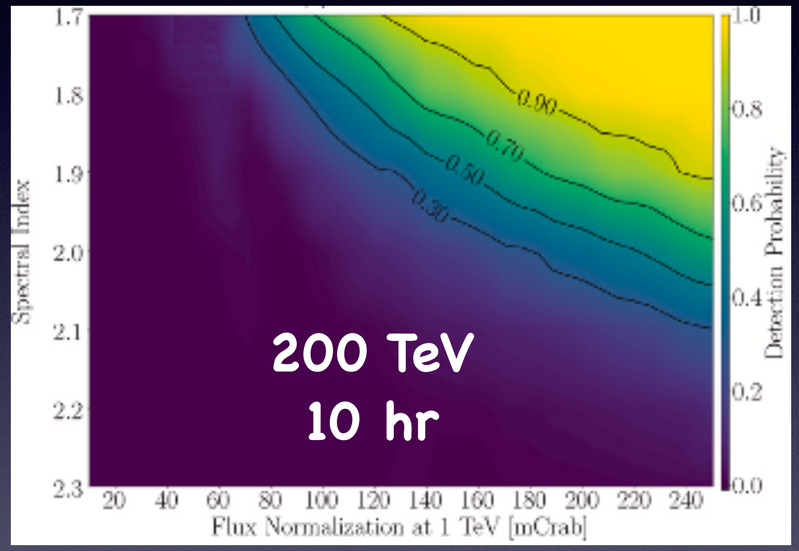
ARE SNRs THE SOURCES OF THE HIGHEST ENERGY PARTICLES IN THE GALAXY?

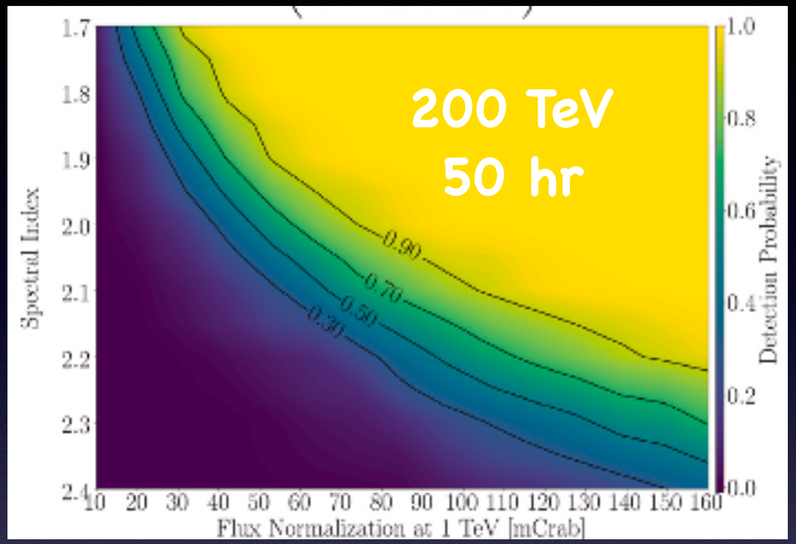
INCONCLUSIVE EVIDENCE FROM GAMMA-RAYS SO FAR

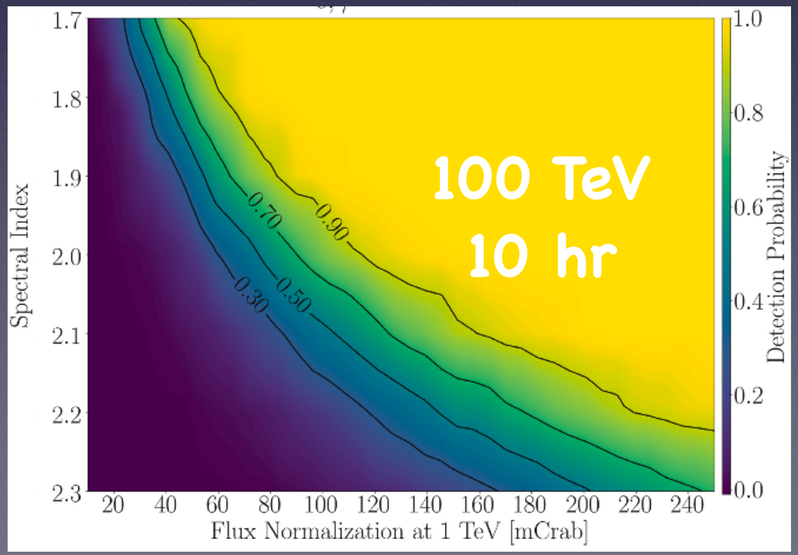
[e.g. EA & Casanova 21]

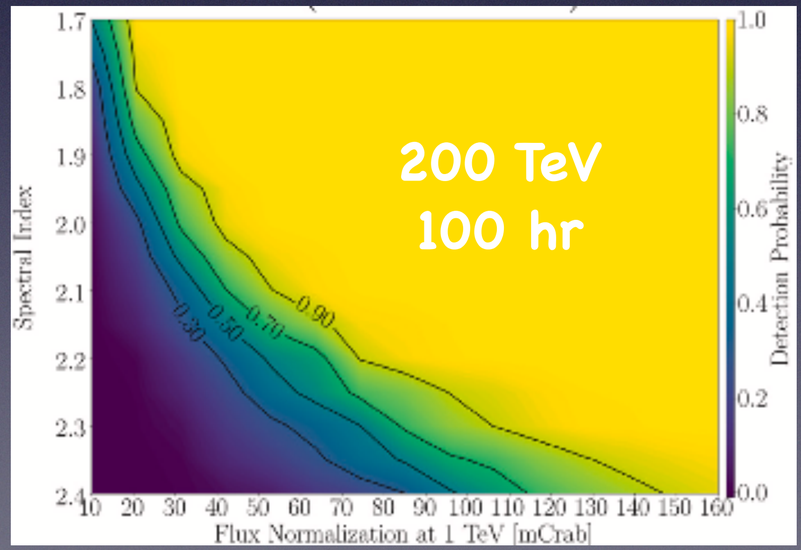
CTAO SENSITIVTY TO PEVATRONS







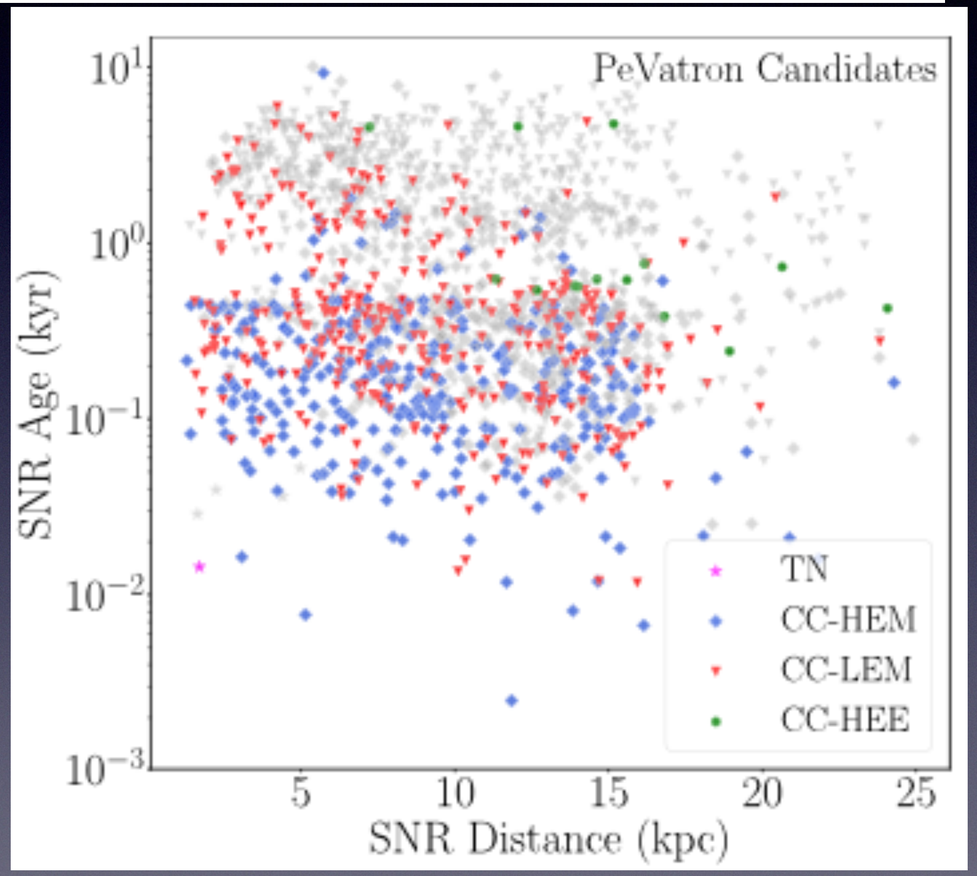


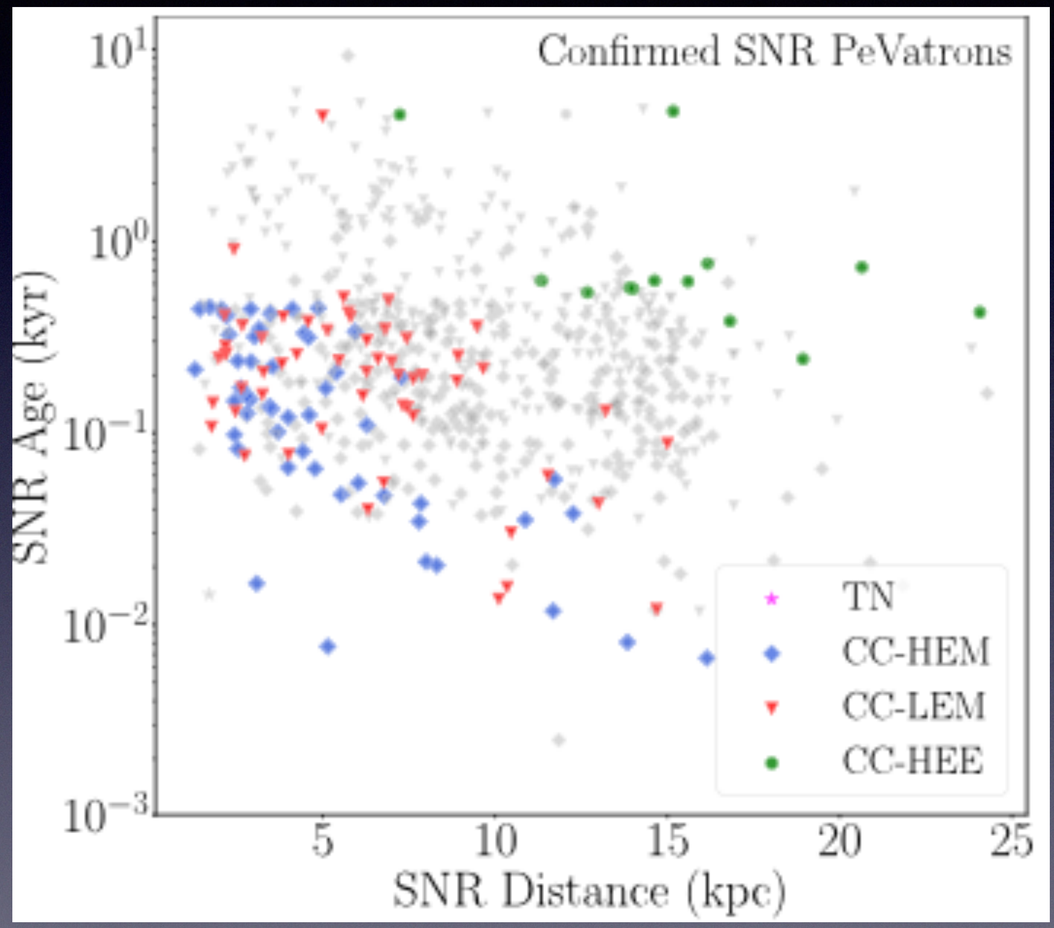


CTA coll. 23
c.a. Angüner, Spengler, Costantini

CTA EXPECTED PEVATRONS

SNR Type	ϵ_{51}	$M_{ej,\odot}$	$\dot{M}_{-5}$	$u_{w,6}$	Rel. rate
TN	1	1.4	–	–	0.32
CC-HEM	1	8	1	1	0.44
CC-LEM	1	2	1	1	0.22
CC-HEE	3	1	10	1	0.02



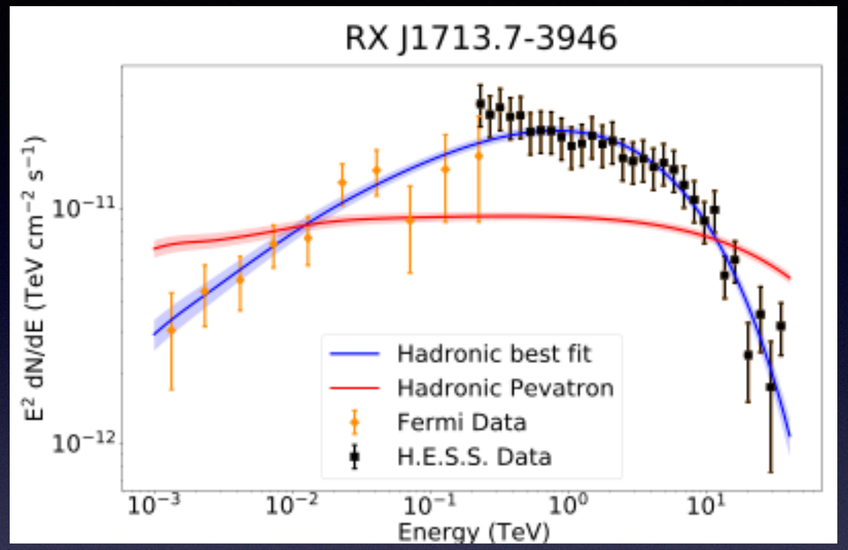


- SNR EVOLUTION [Cristofari+ 13,21]
- $E_{\mathrm{max,p}} = 3\mathrm{PeV}$ AT FE-ST TRANSITION

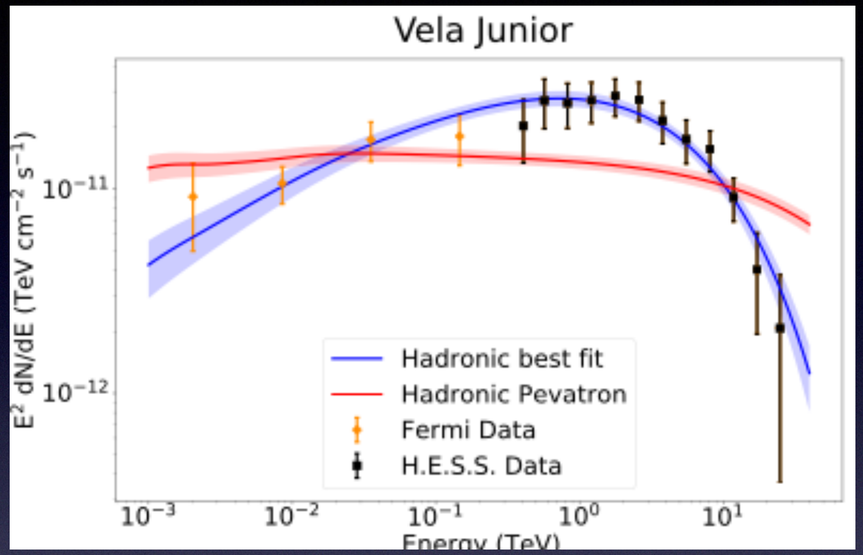
CTA coll. 23
c.a. Angüner, Spengler, Costantini

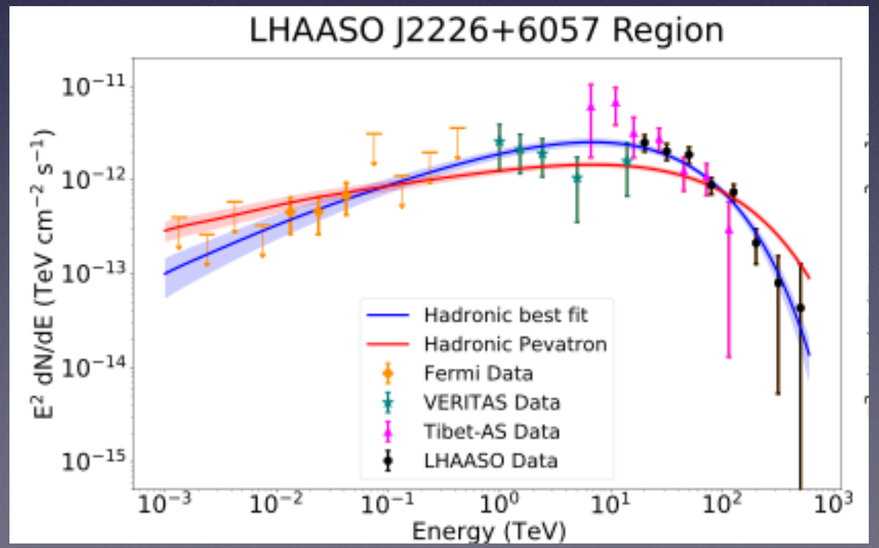
KNOWN SNRs

AND THE IMPORTANCE OF ANGULAR RESOLUTION



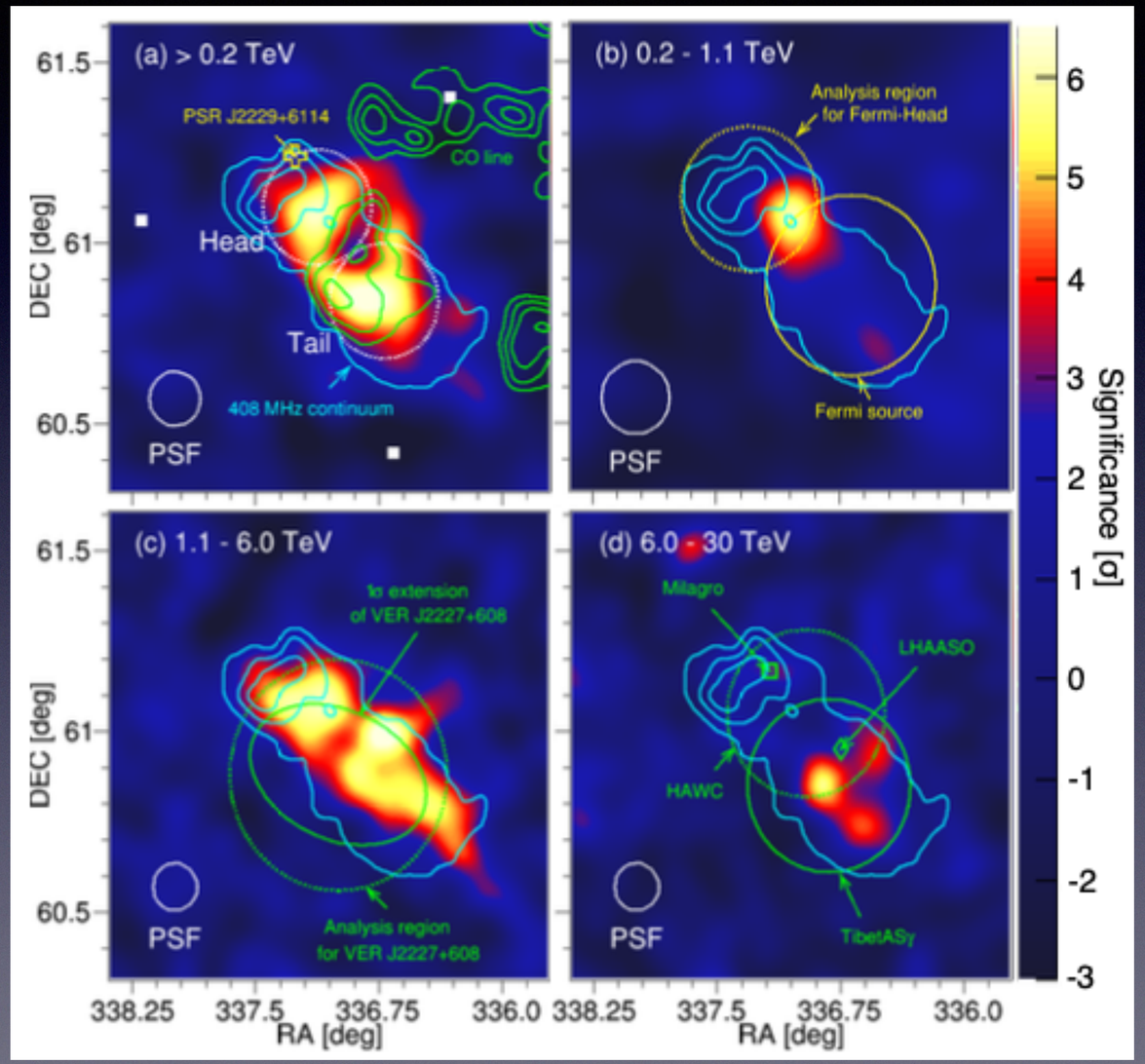
NON PEVATRON



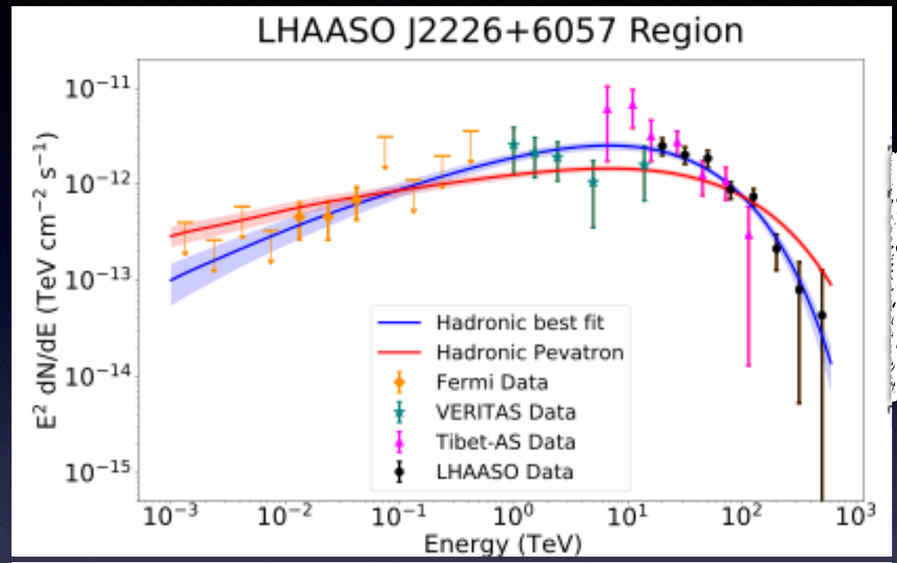


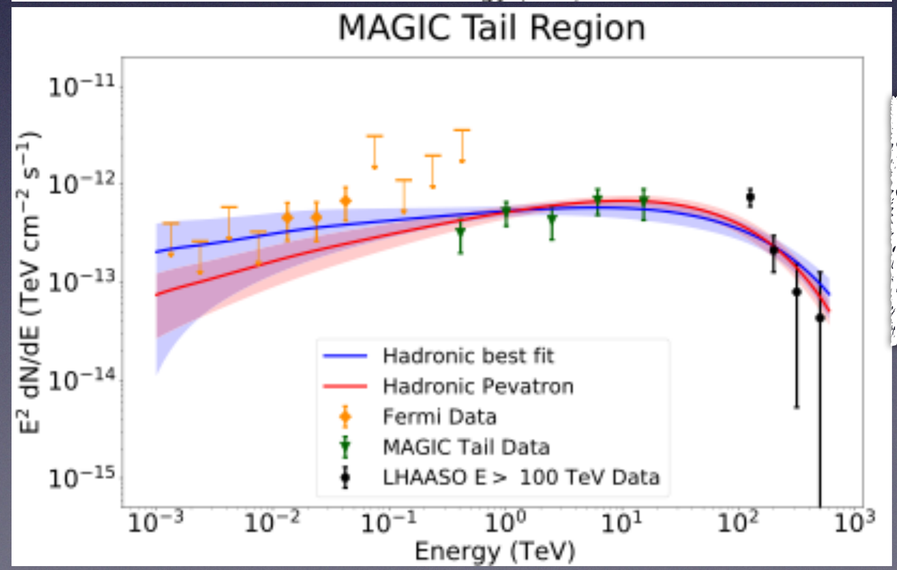
Angüner, Spengler, EA, Casanova 23

BOOMERANG



MAGIC Coll. 2023





Angüner, Spengler, EA, Casanova 23

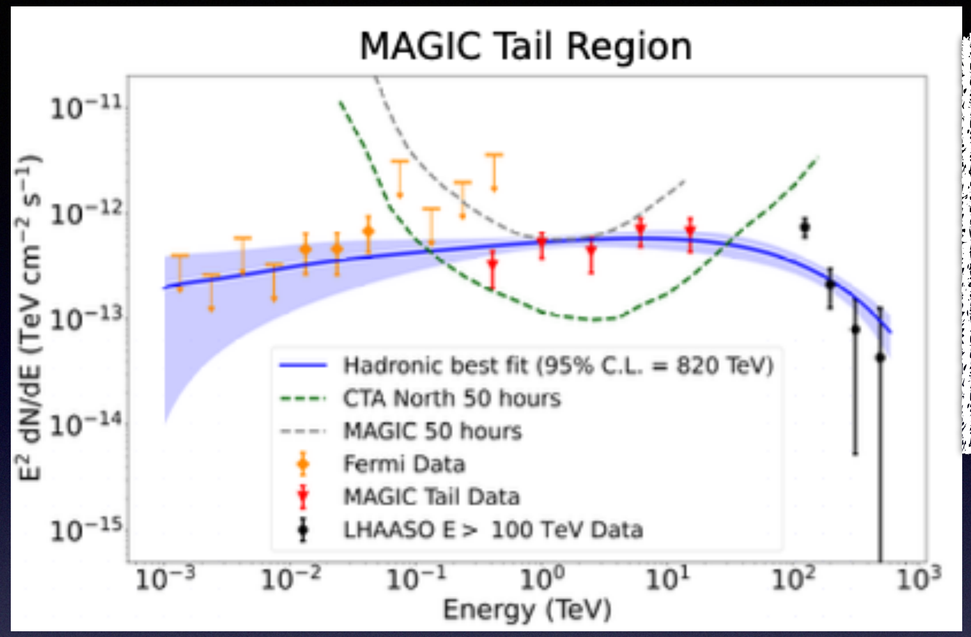
NON PEVATRON

PEVATRON!!!!

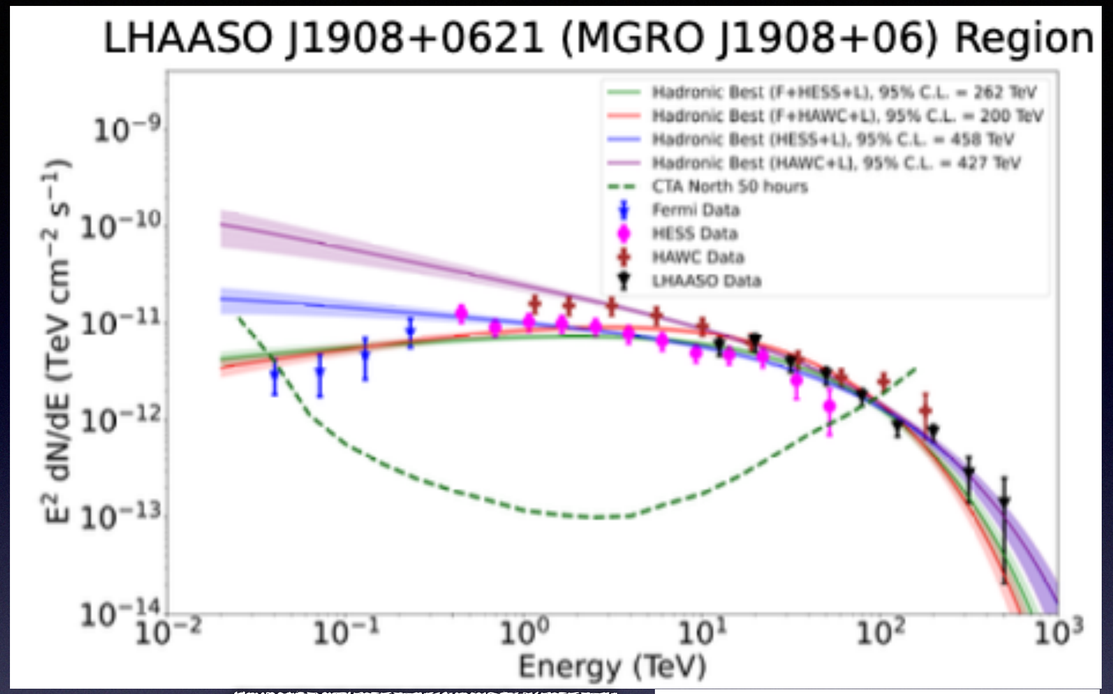
$E_{\mathrm{p,MAX}} > 800\mathrm{TeV}$

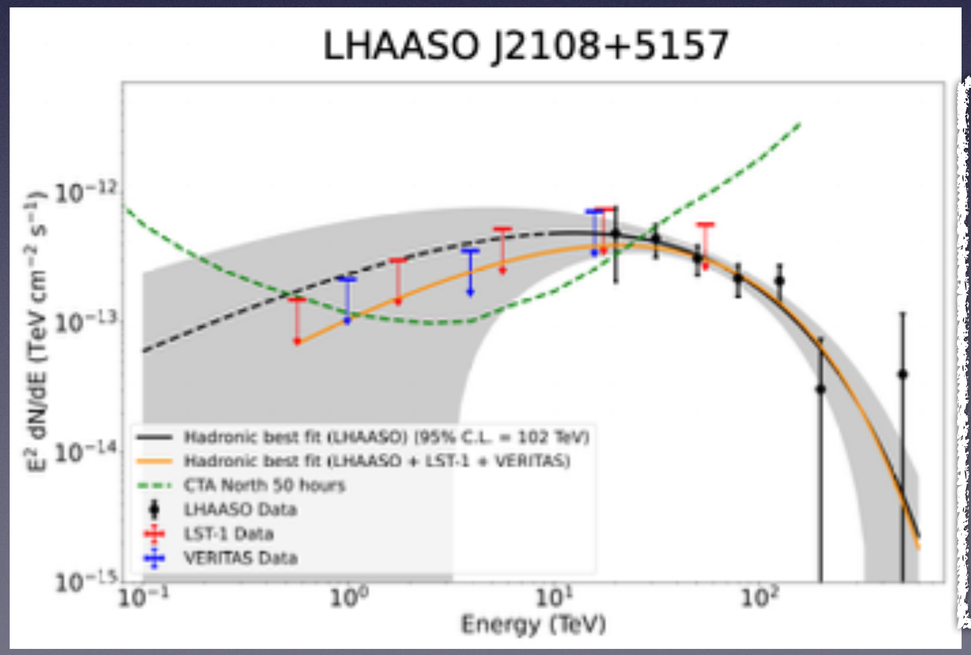
90% C.L.

WITH CTA SENSITIVITY AND RESOLUTION...



FURTHER IMPROVE SPECTRUM WITH CTA NORTH

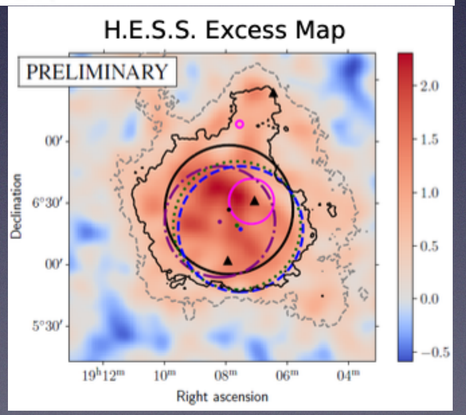




PROMISING (MOLECULAR CLOUDS)

CONSTRAIN HIGH ENERGY SPECTRUM!!!!

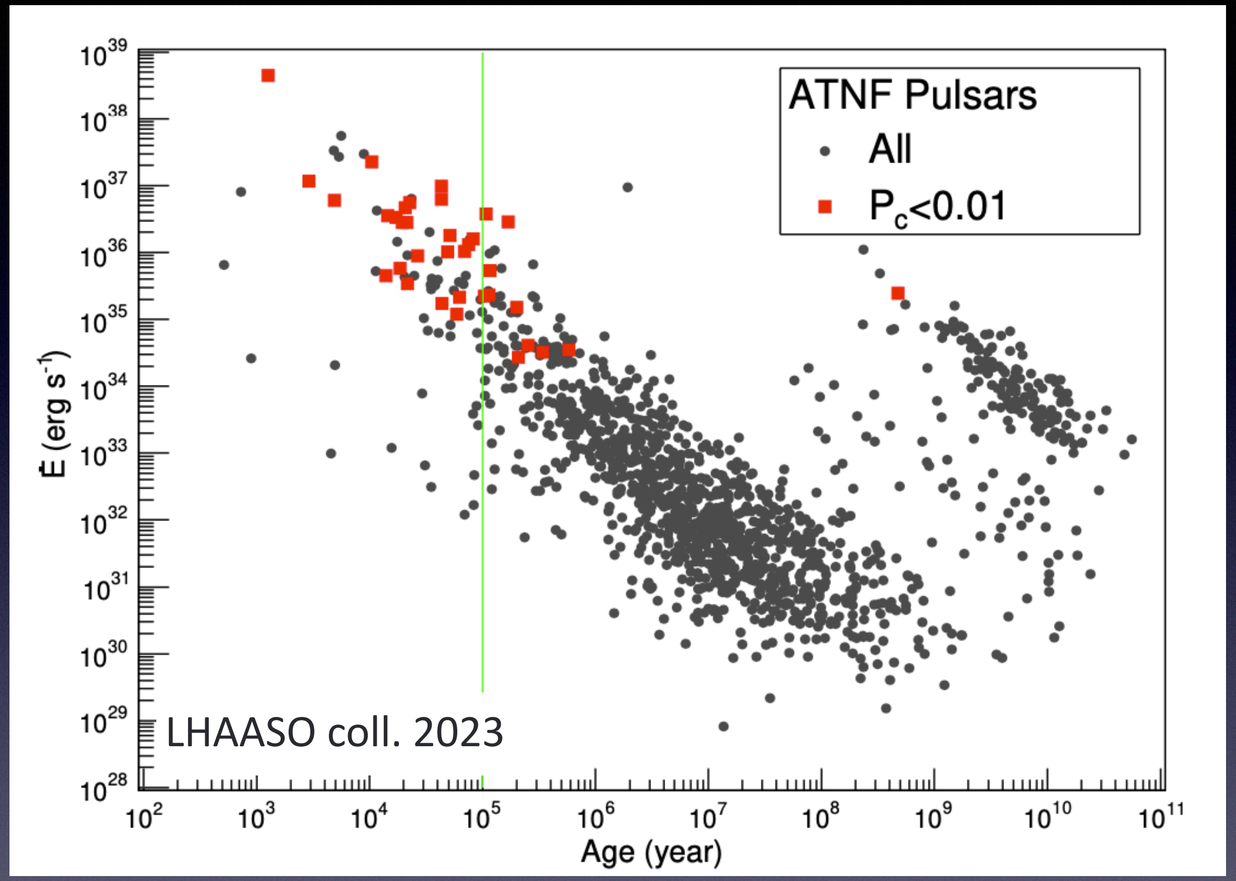
RESOLVE CROWDED REGIONS!!!!

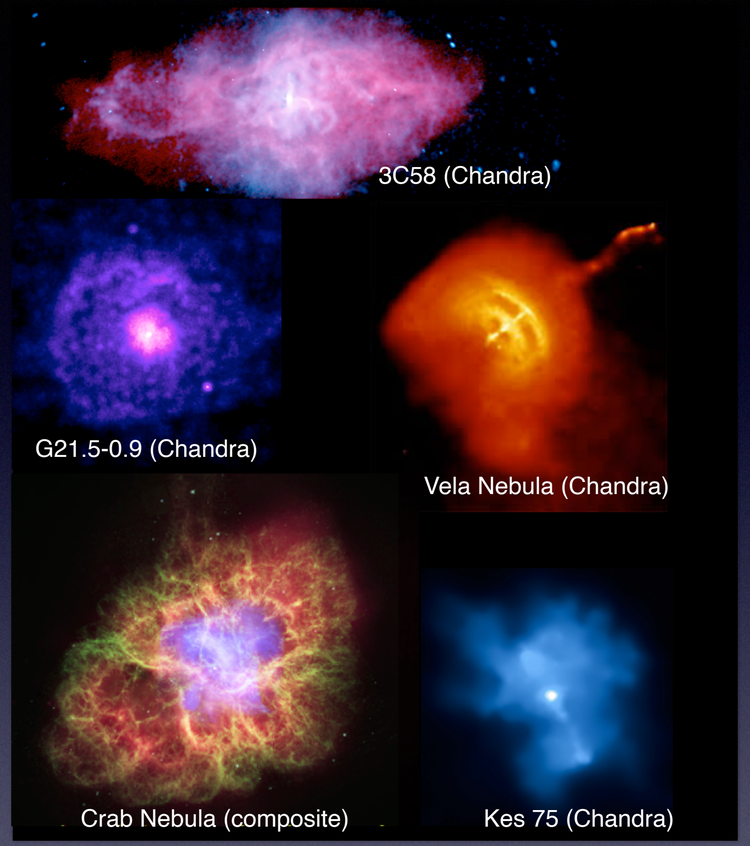


CTA coll. (c.a.Angüner) in progress

GETTING RID OF PULSARS AND PWNe

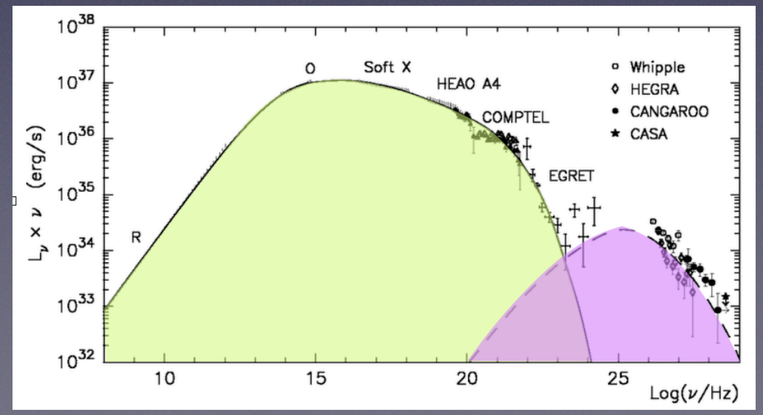
PULSAR ASSOCIATIONS IN 1LHAASO





-35 ASSOCIATIONS WITH PULSARS OUT OF 90 SOURCES
-22 UHE OUT OF 43

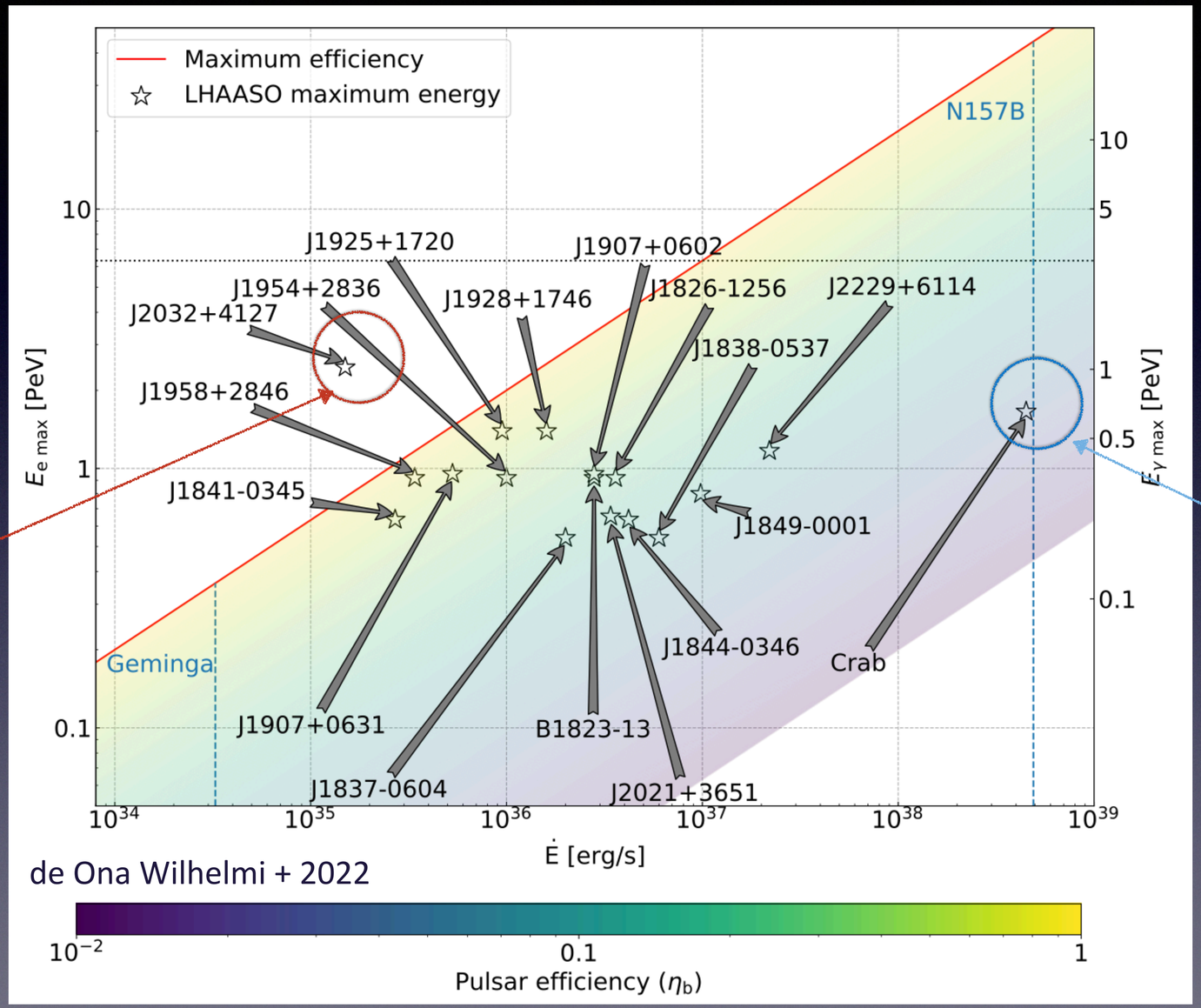
-SIMILAR NUMBERS ALSO WITH DIFFERENT CRITERA [Olmi+ in prep.]



A FEW ASSOCIATIONS EXCLUDED BASED ON THEORY

CYGNUS

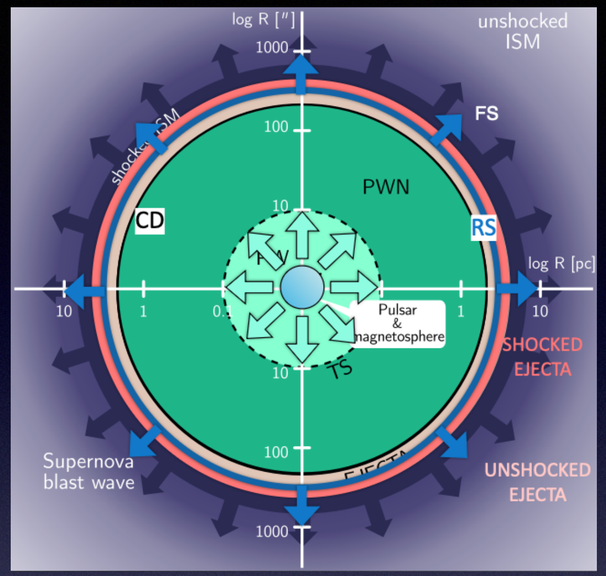
MAXIMUM DETECTED ENERGY ABOVE AVAILABLE PSR POTENTIAL

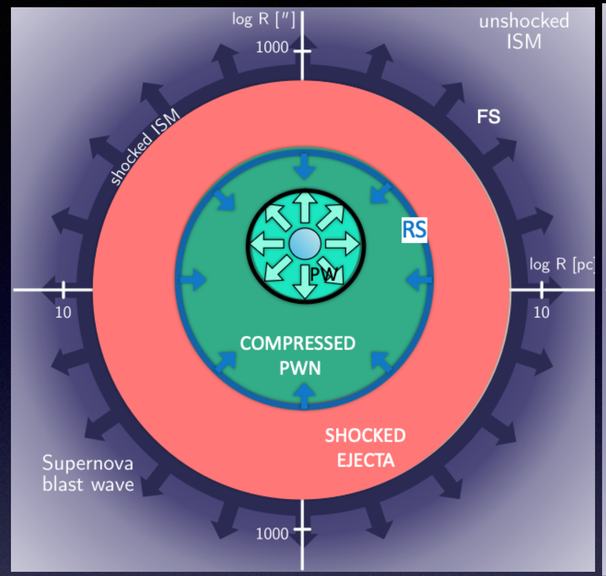


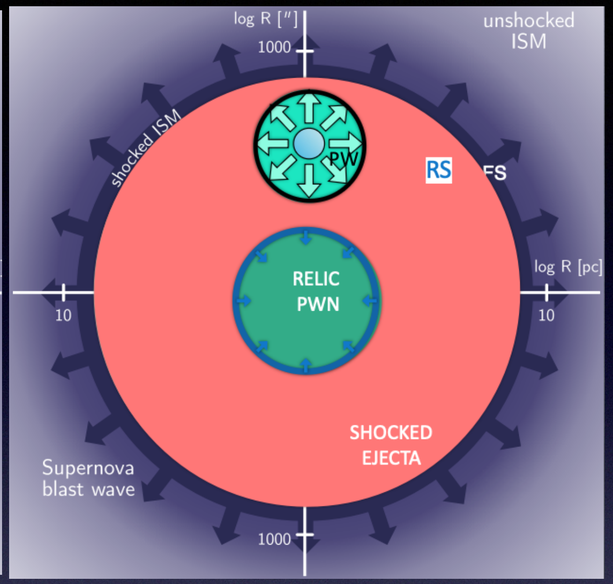
CRAB

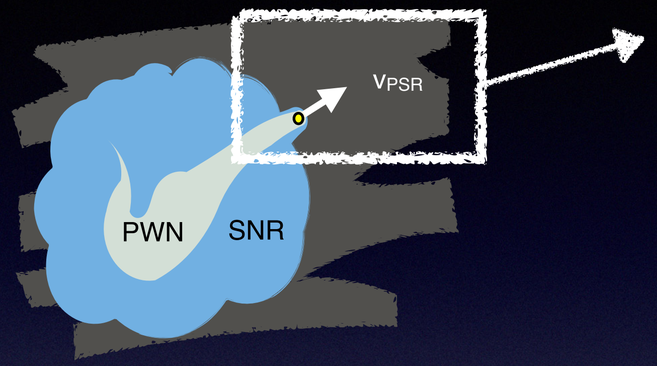
MAXIMUM DETECTED ENERGY WELL BELOW AVAILABLE PSR POTENTIAL

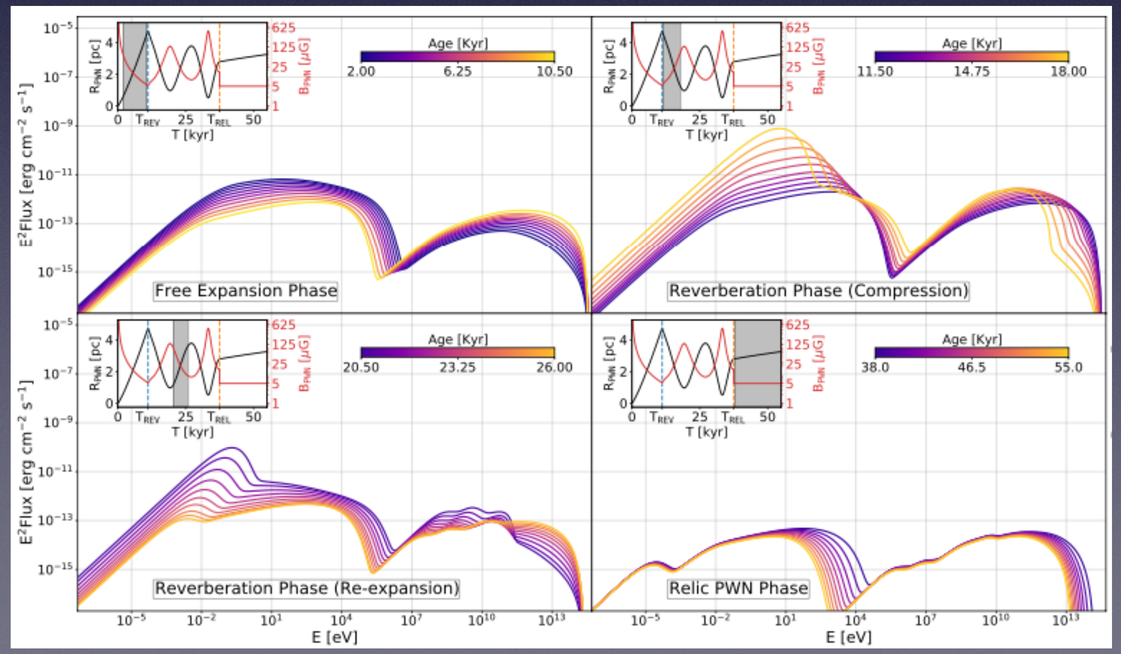
CTA PERSPECTIVES FOR PWNe



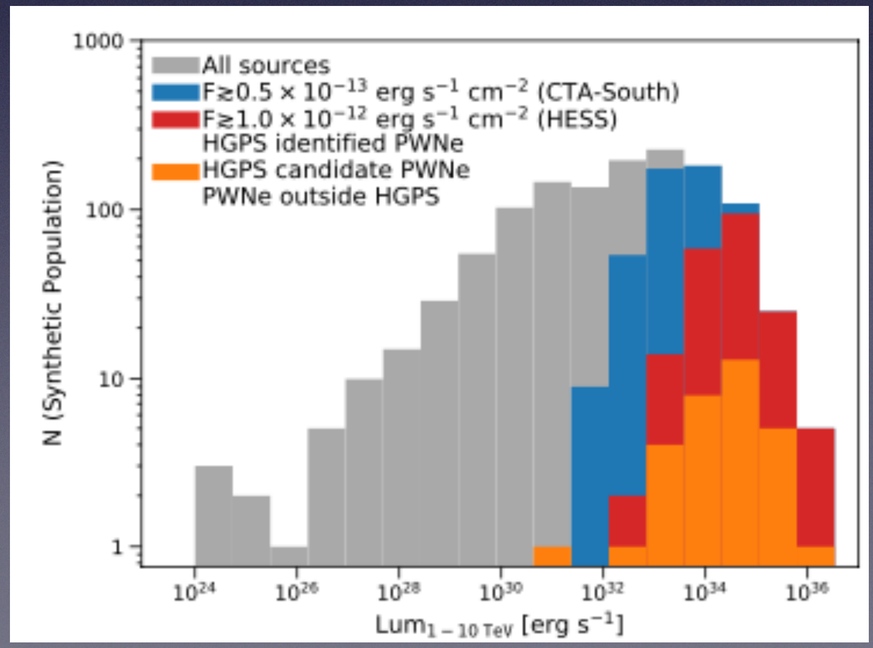




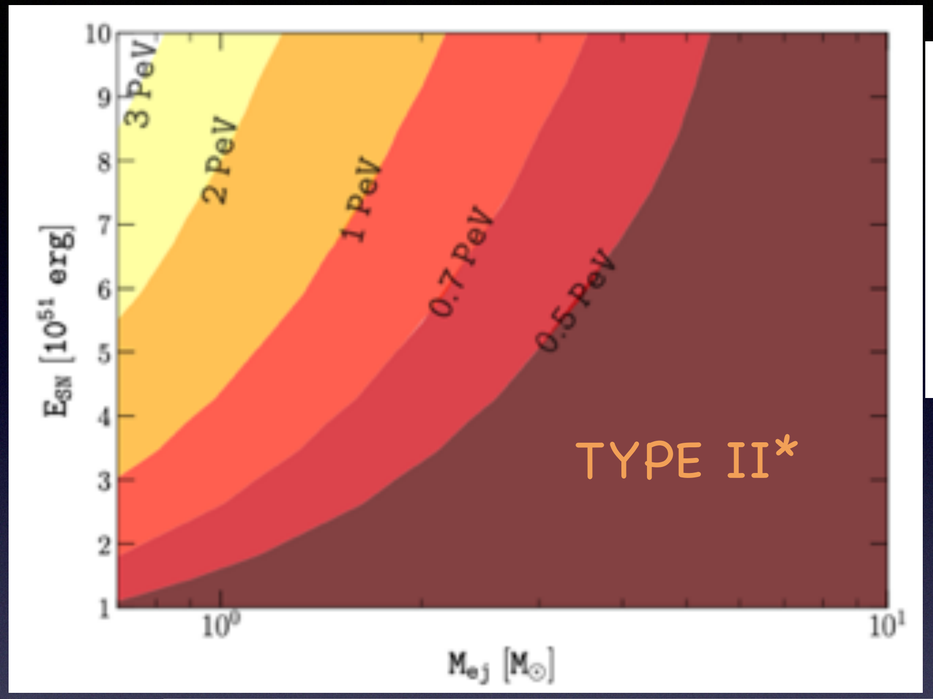




Fiori + 22

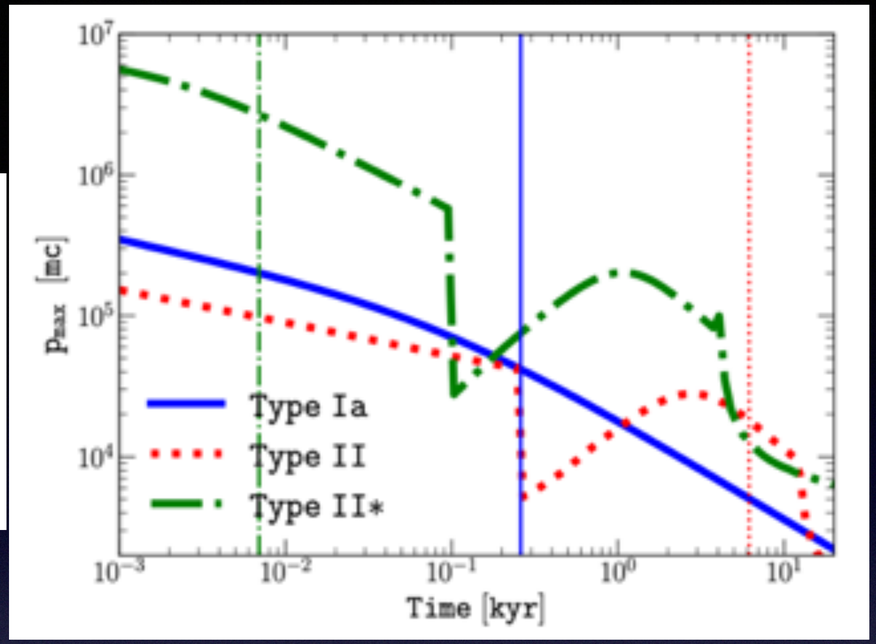


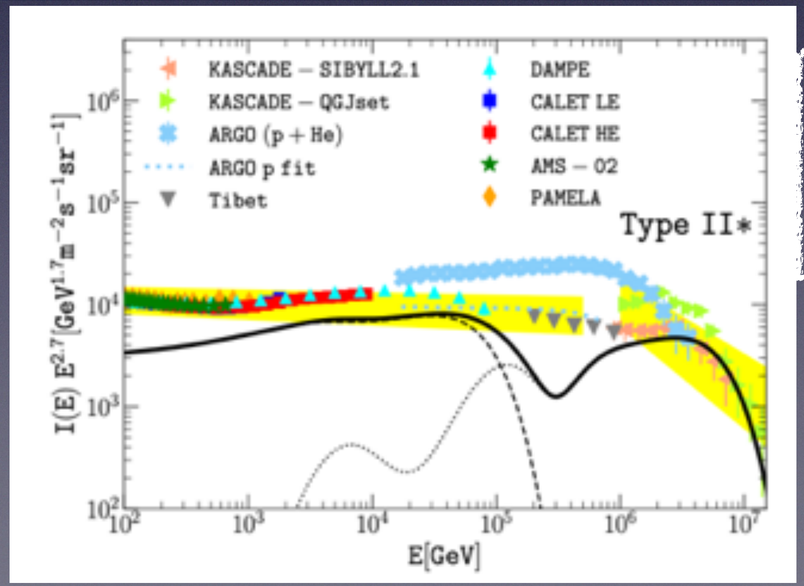
PEVATRON SNRs?



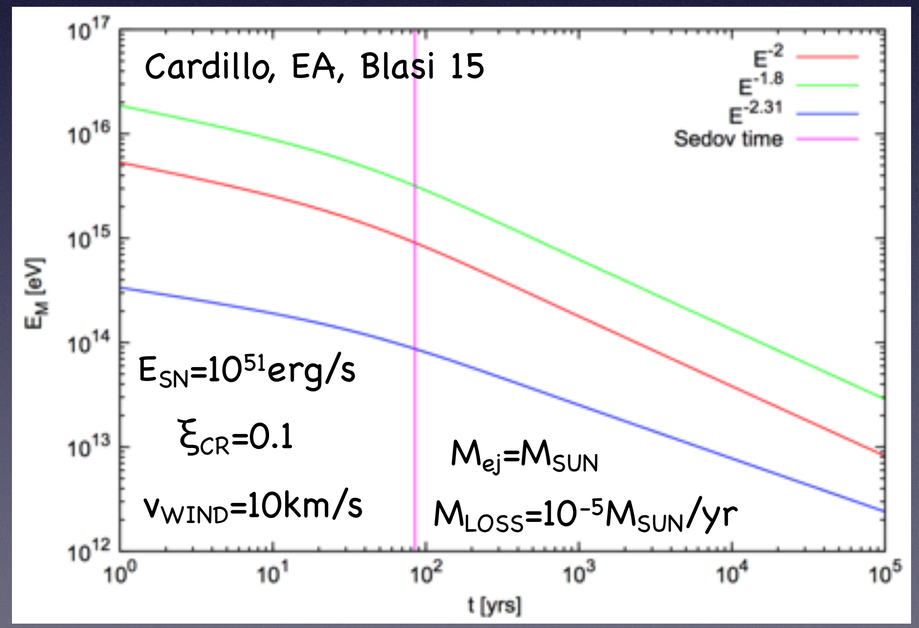
Type	Ia	II	II*
M_{ej} [$M_\odot$]	1.4	5	1
E_{SN} [10^{51} erg]	1	1	10
$\dot{M}$ [10^{-5} $M_\odot$/yr]	–	1	10
u_w [10^6 cm/s]	–	1	1
r_1 [pc]	–	1.5	1.3

Cristofari, Blasi, EA 20





TYPE II* WOULD DOMINATE ALSO AT 10^2–10^4 GeV

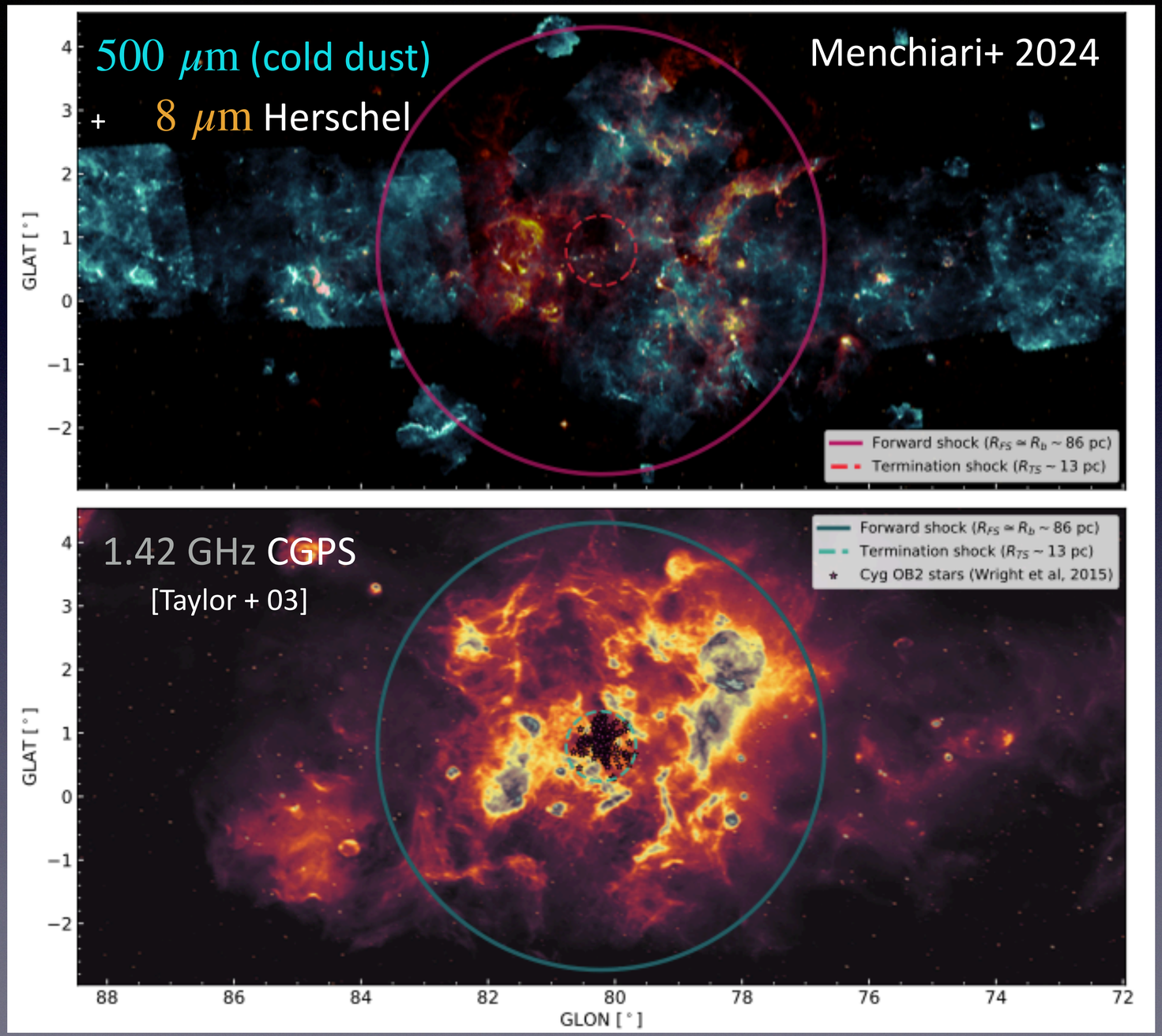


STEEPER SPECTRUM MAKES THINGS WORSE

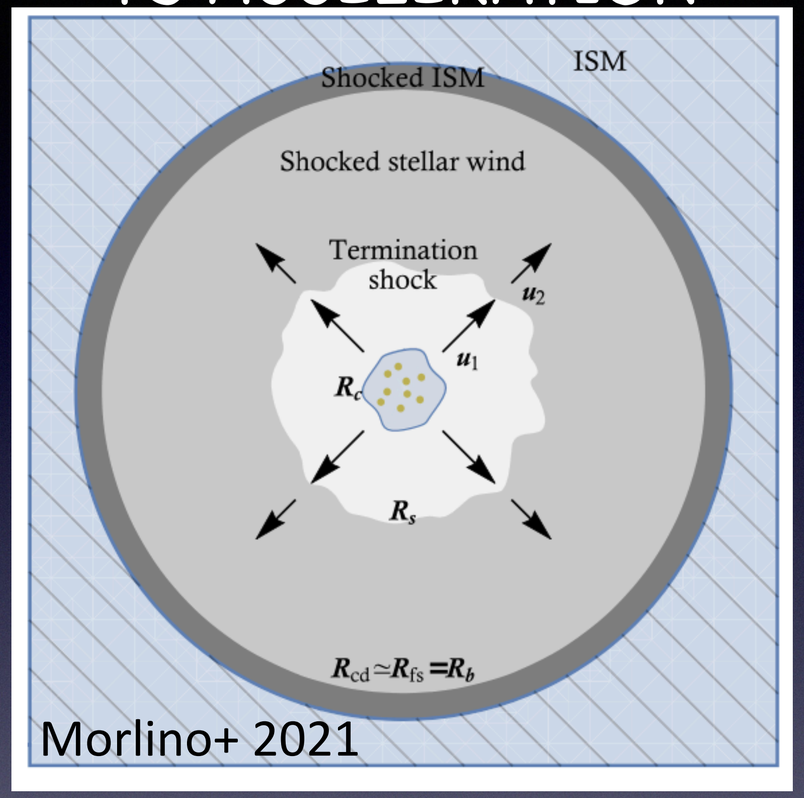
[Cardillo, EA, Blasi 15]

ALTERNATIVE PEVATRONS: STAR CLUSTERS

CYGNUS REGION



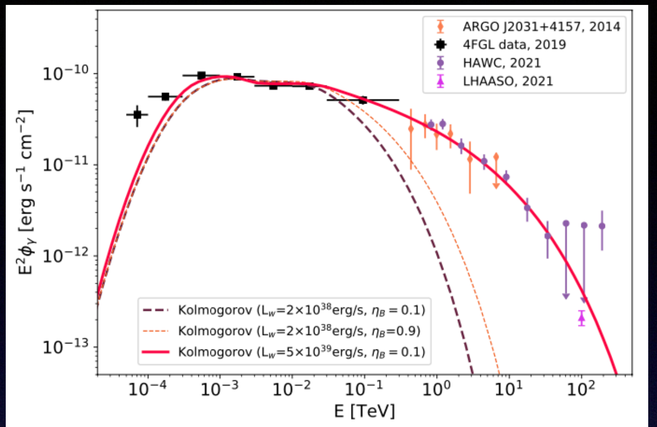
TS ACCELERATION

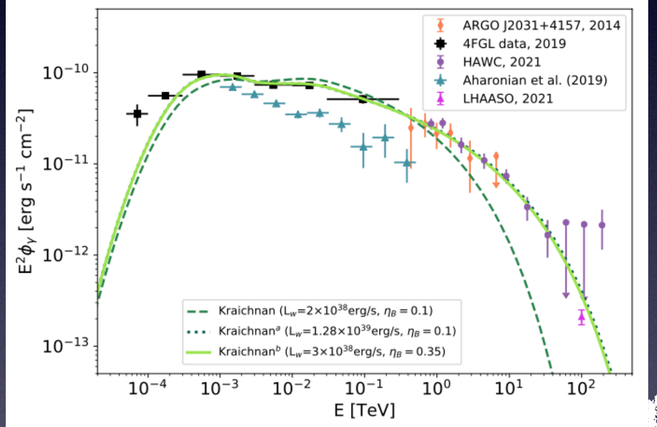


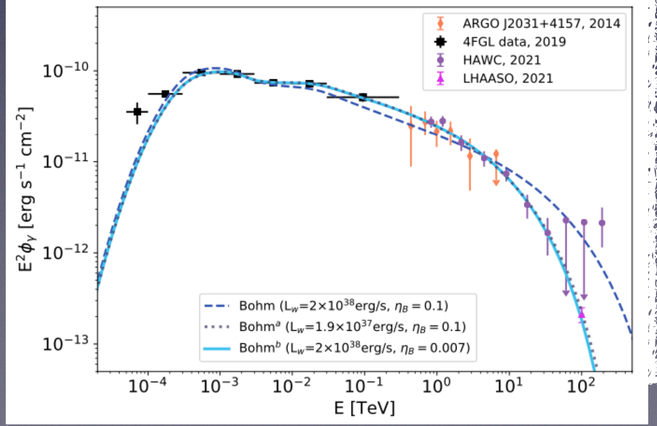
ALSO OTHER SCENARIOS POSSIBLE

[Bykov + 20, Badmaev+ 22, Vieu+ 22,23,24]

GAMMA-RAY SPECTRUM AND MAXIMUM ENERGY

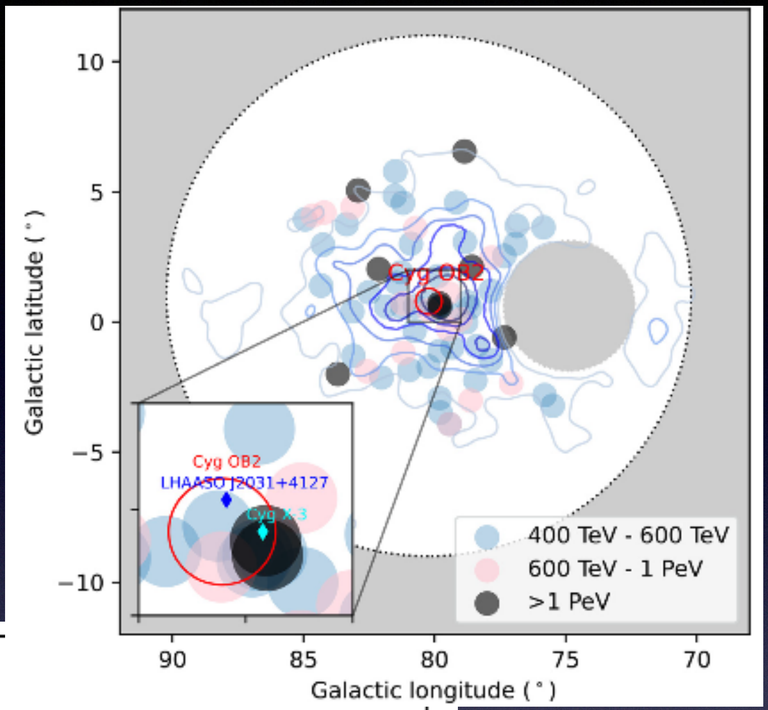




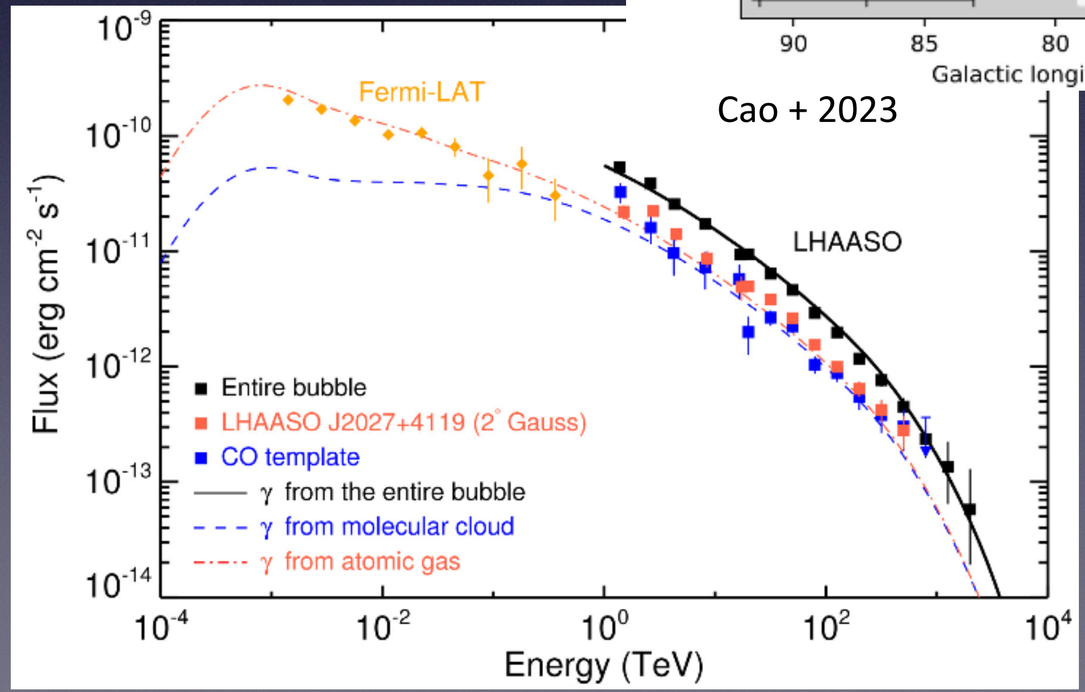


MAXIMUM ENERGY DEPENDS ON TURBULENCE PROPERTIES

KOLMOGOROV ($D \propto E^{1/3}$) IMPLIES TOO LOW $E_{\rm max}$ UNLESS $L_{\rm w} \sim 10^{39}$erg/s

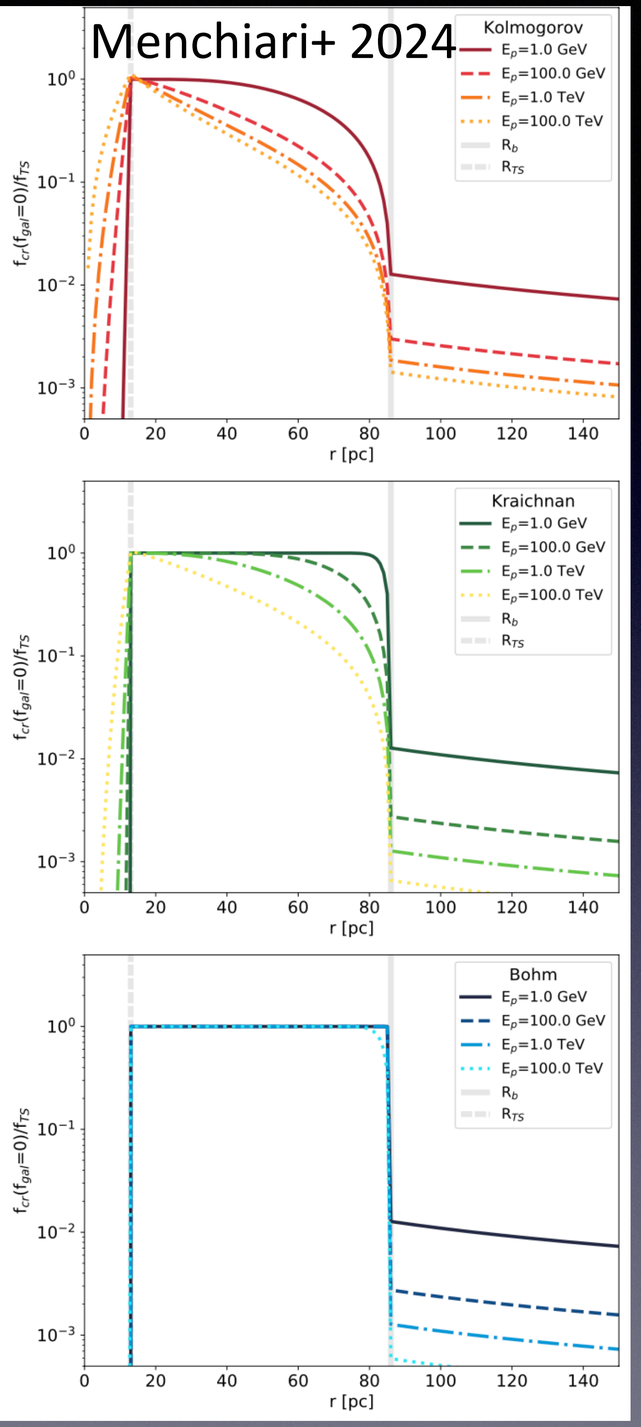


Cao + 2023



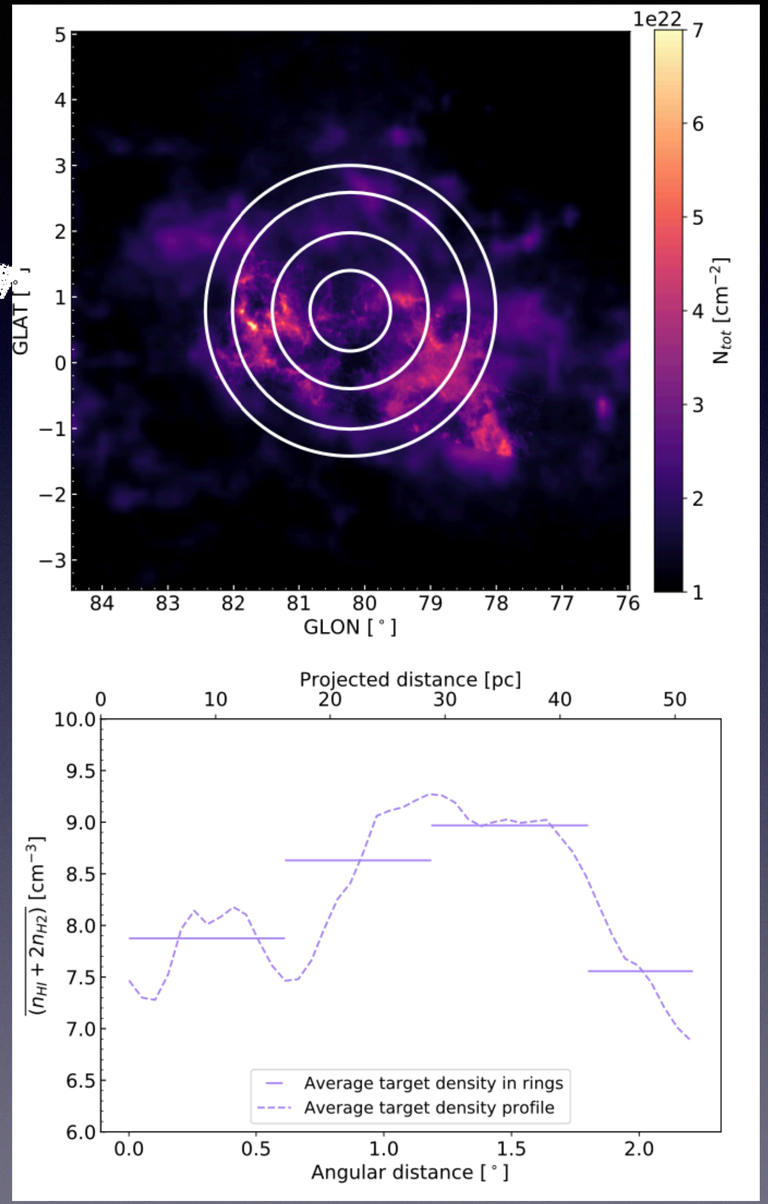
CRs AND GAS MAPS

Menchiari+ 2024



TOTAL GAS DENSITY
(Menchiari+ 2024)

CR
DISTRIBUTION
(based on Morlino+ 2021)



HI from 21cm (CGPS)

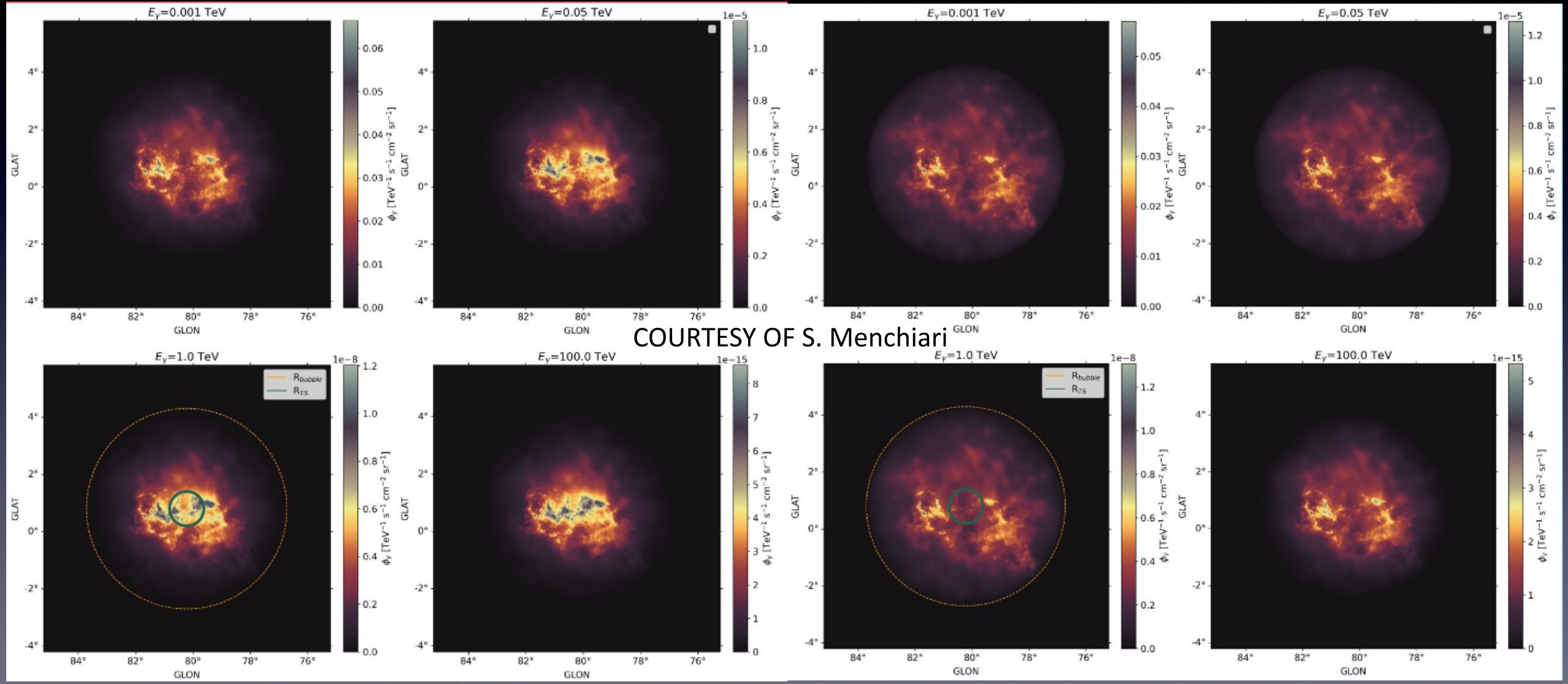
HII from Nobeyama and ^{12}CO GPS (Dame+ 2001)

Circles from Fermi (Aharonian+ 2019) and HAWC analyses (Abeysekara+2021)

SIMULATED EMISSION MAPS: CYGNUS

KOLMOGOROV

BOHM

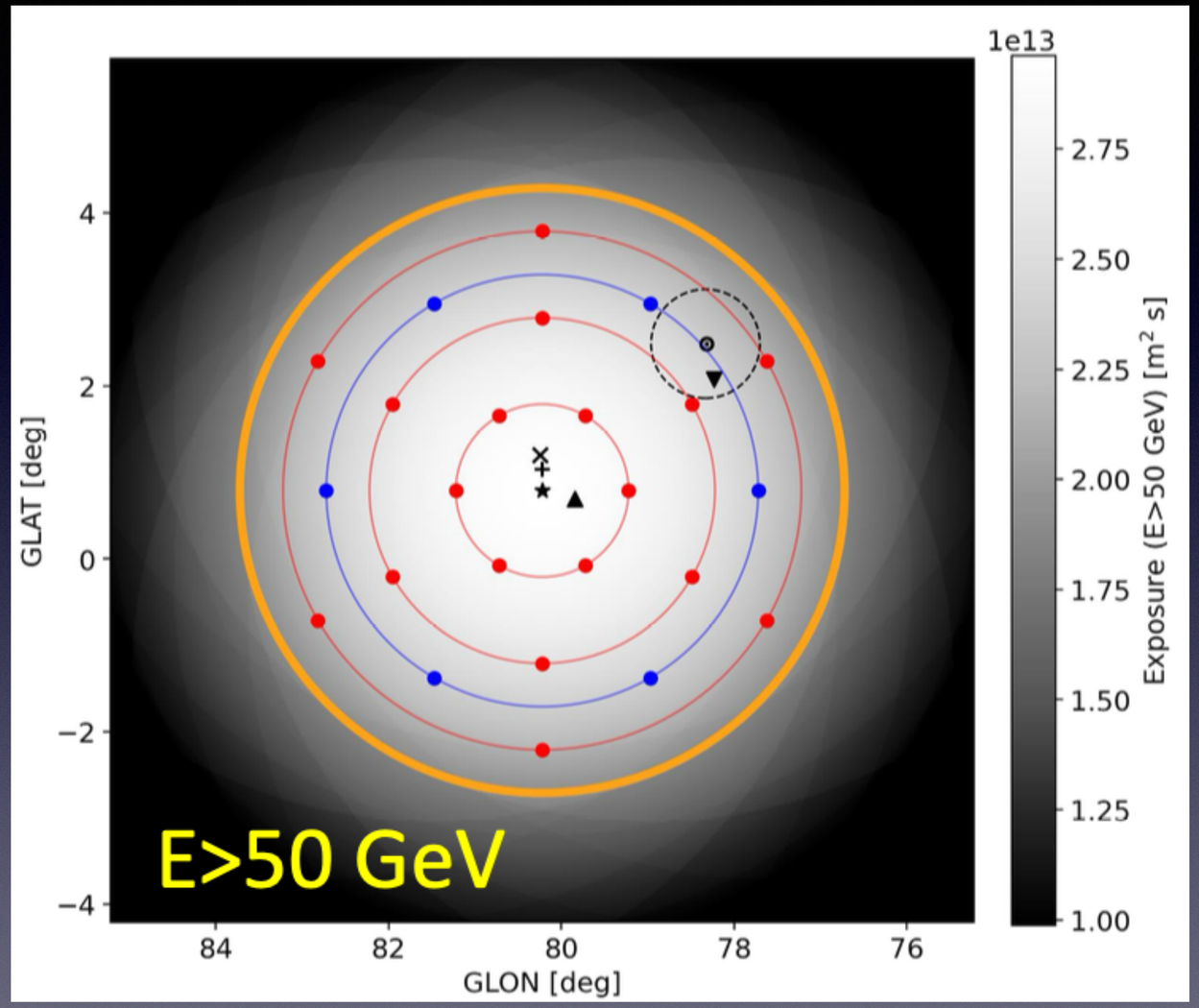


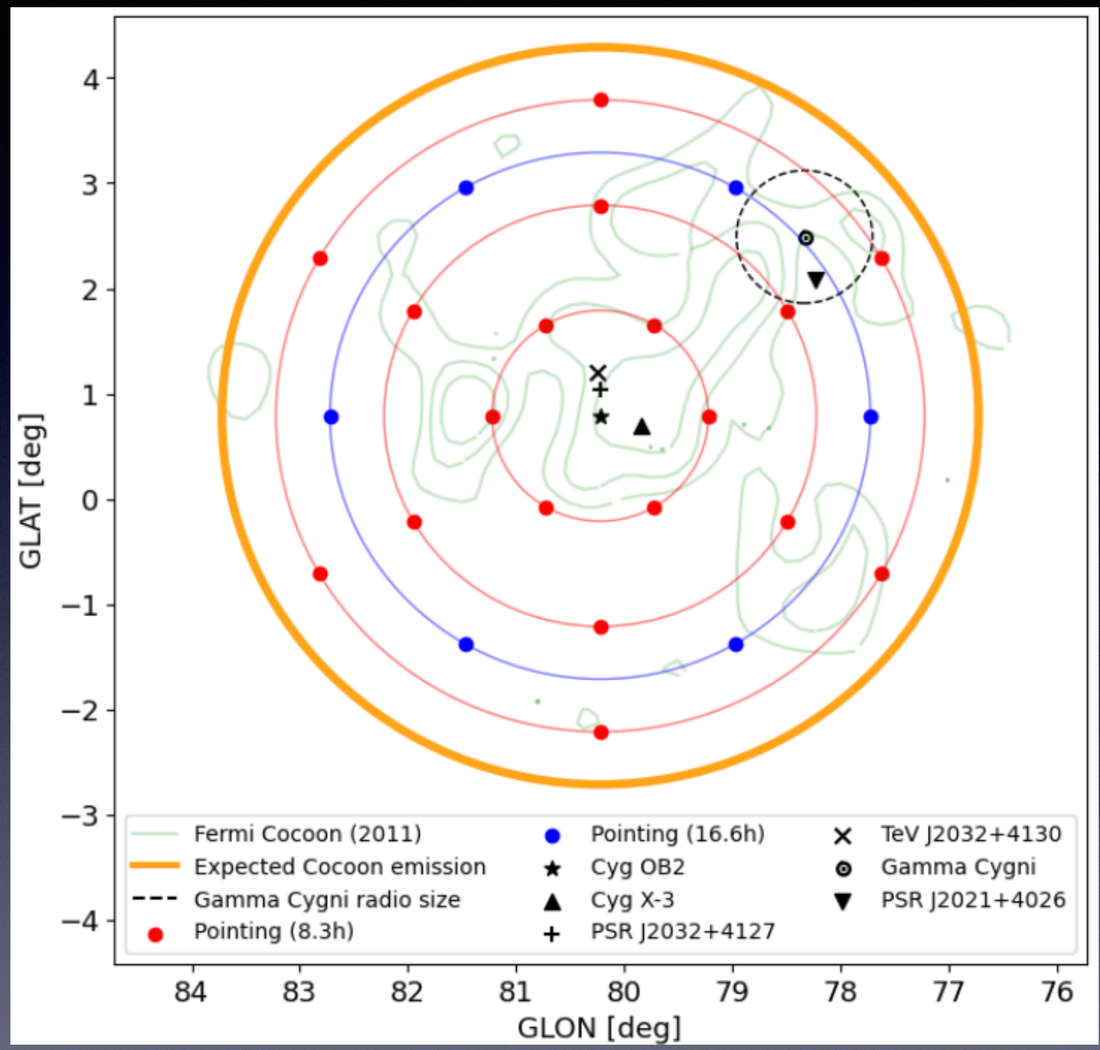
COURTESY OF S. Menchiari

H2: 12CO(J=1-0) CfA (Dame et al, 2001) Lowres. + NRO (Takekoshi et al, 2019) Highres.
(Xco=1.68 1020 mol. cm-2 K-1 km-1 ; -20km/s<v<20km/s)

HI: 21cm from CGPS (Taylor et al, 2003)
(T=150°K ; -20km/s<v<20km/s)

SIMULATED CTA OBSERVATIONS





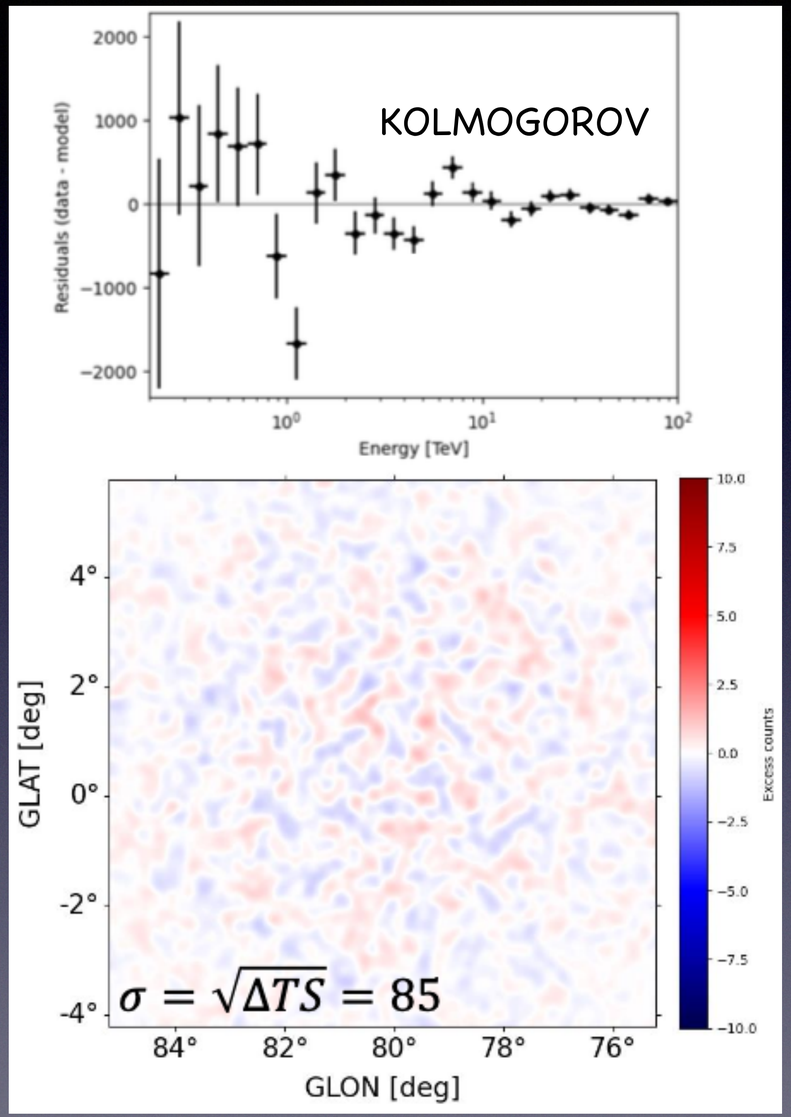
CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

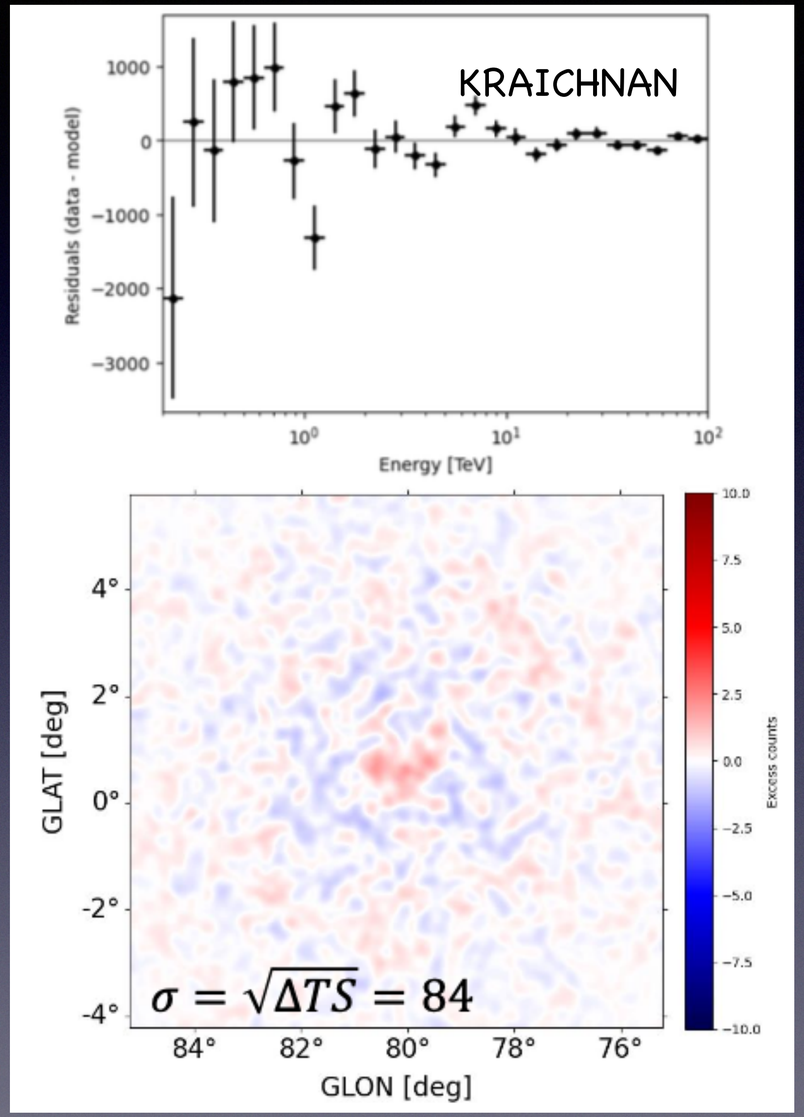
COURTESY OF S. Menchiari

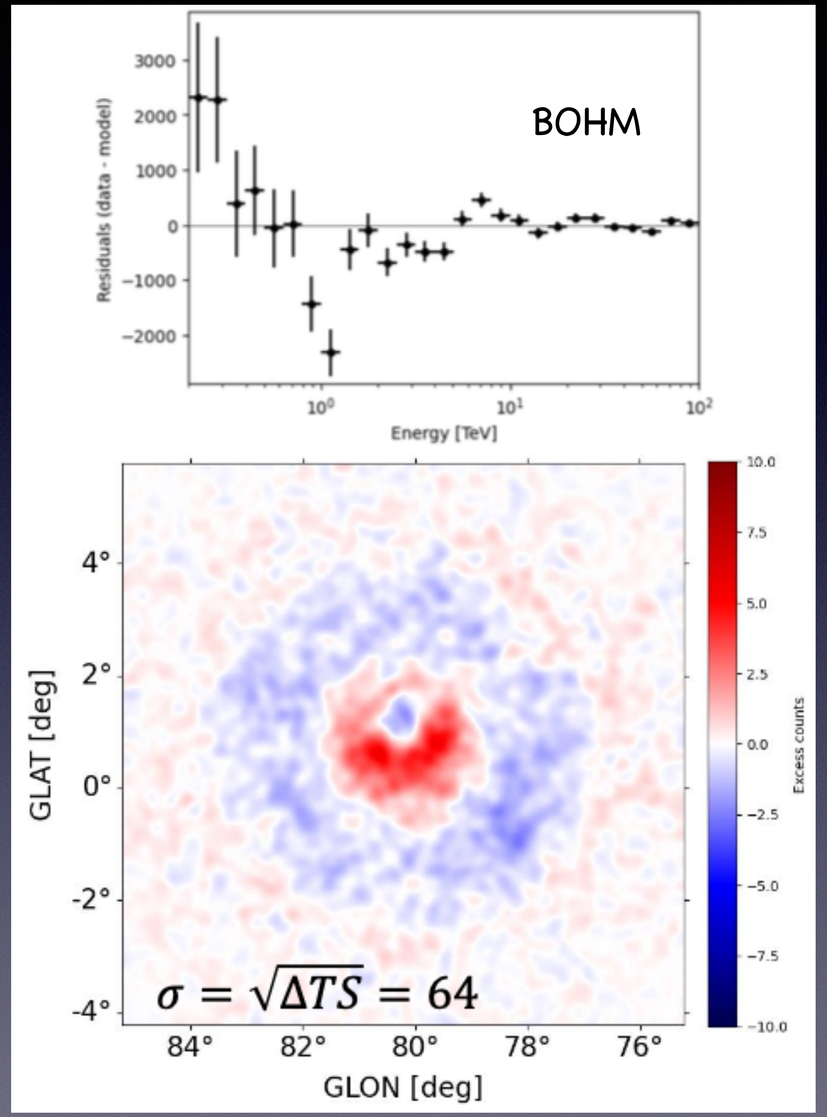
Pointings: Hexagonal grid
(average distance ≈1°, time=200h)

UNVEILING THE TURBULENCE IN CYGNUS OB2

UNDERLYING KOLMOGOROV SPECTRUM





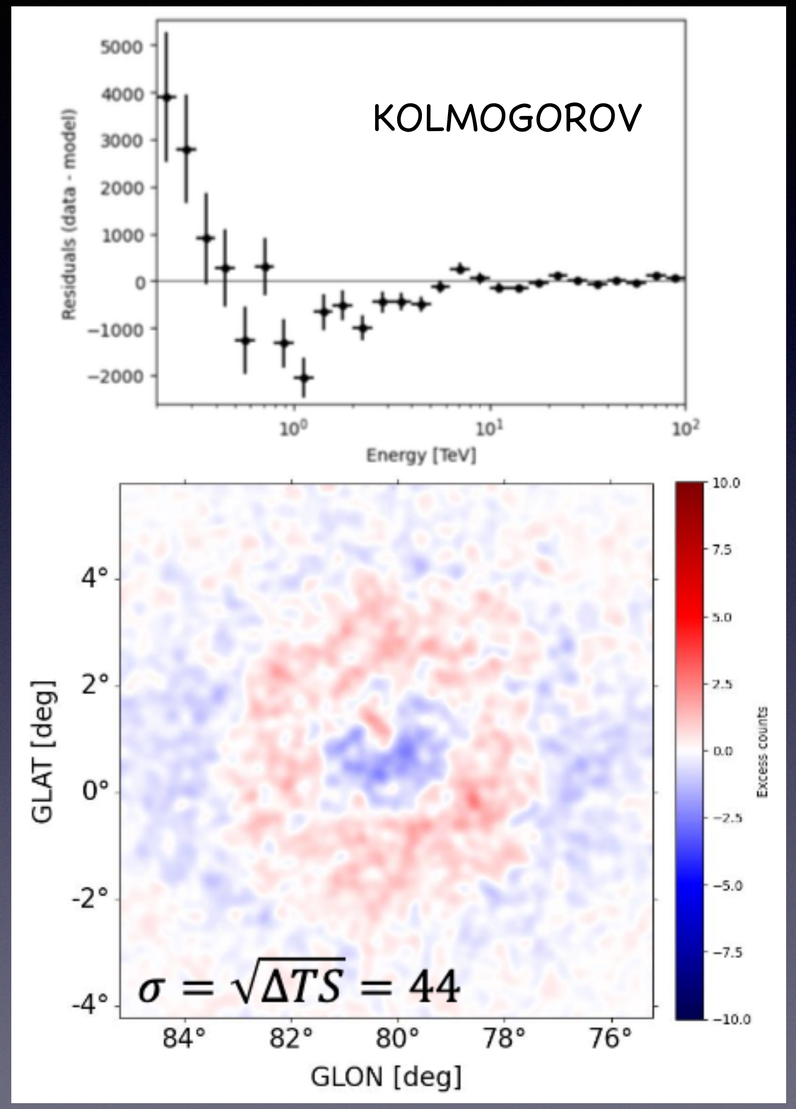


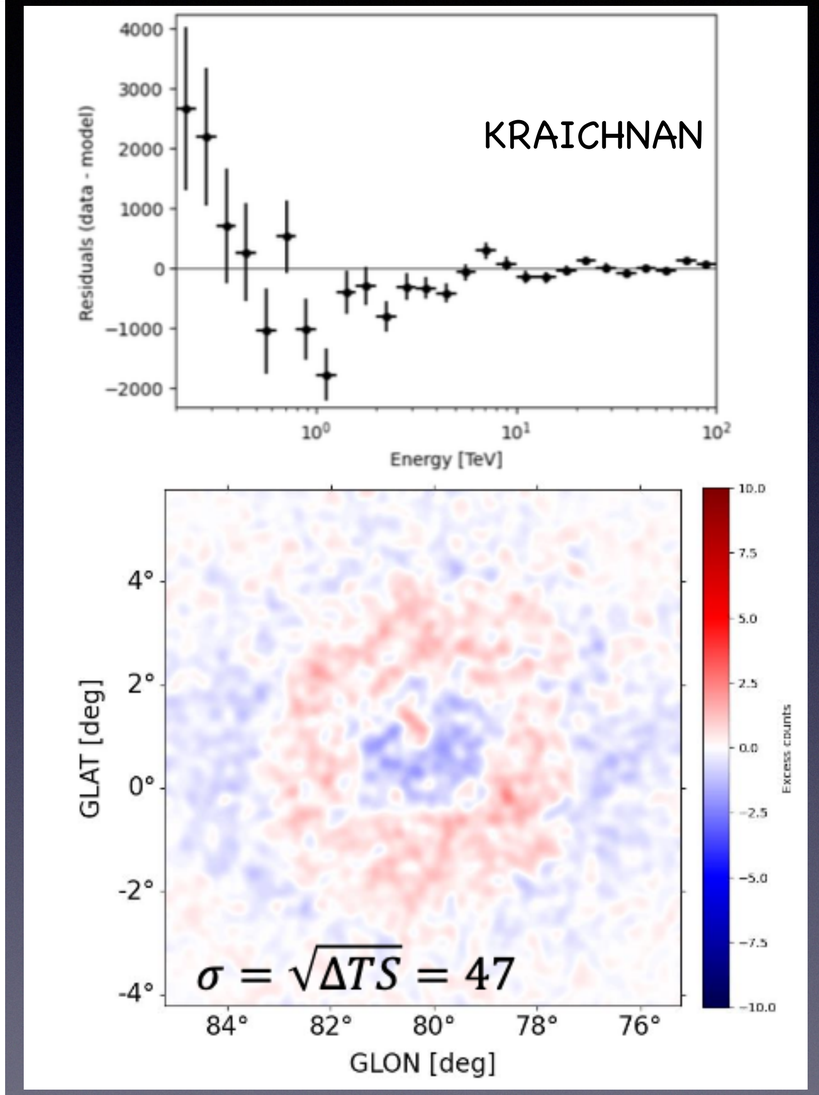
CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

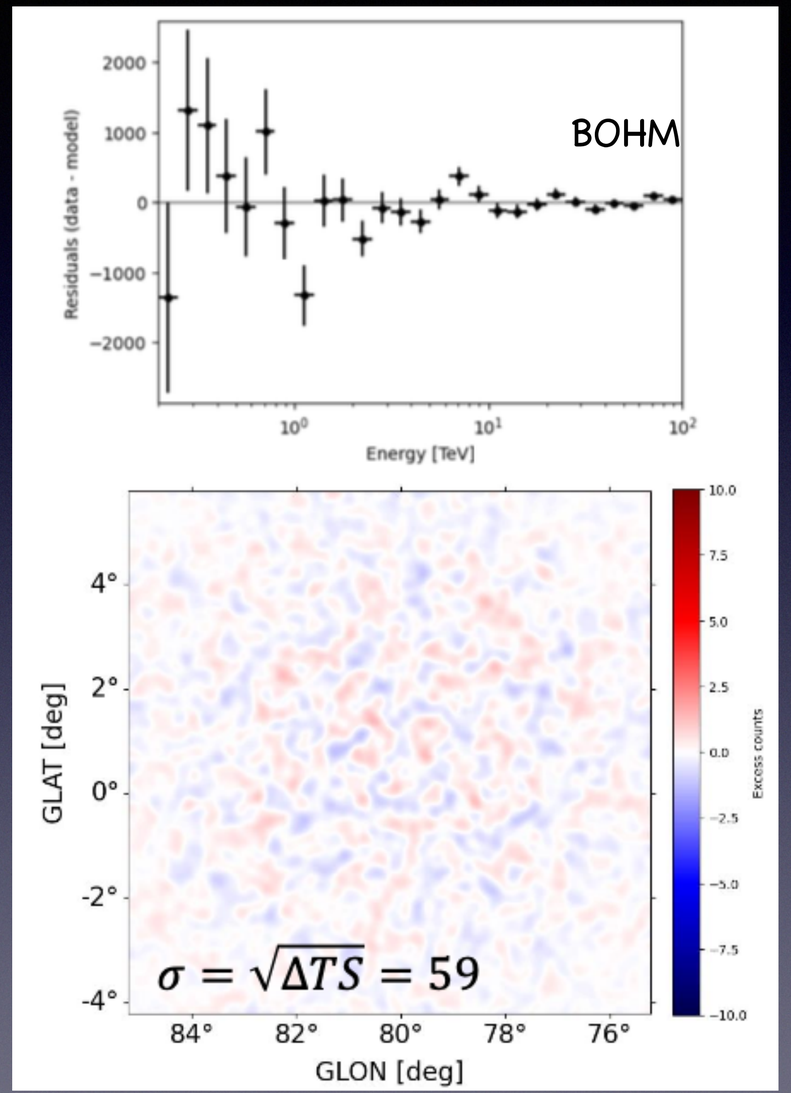
COURTESY OF S. Menchiari

UNVEILING THE TURBULENCE IN CYGNUS OB2

UNDERLYING BOHM SPECTRUM







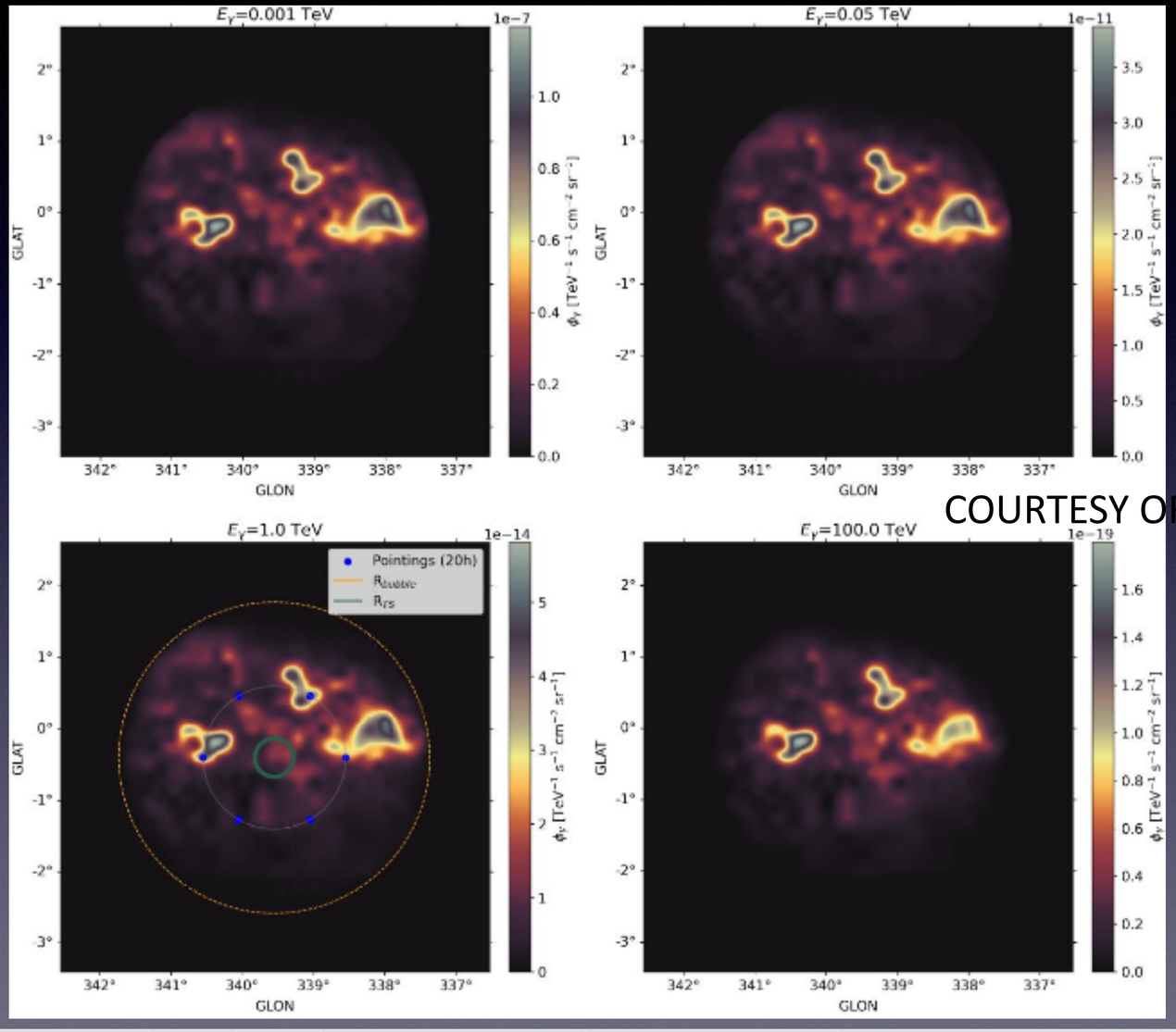
CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

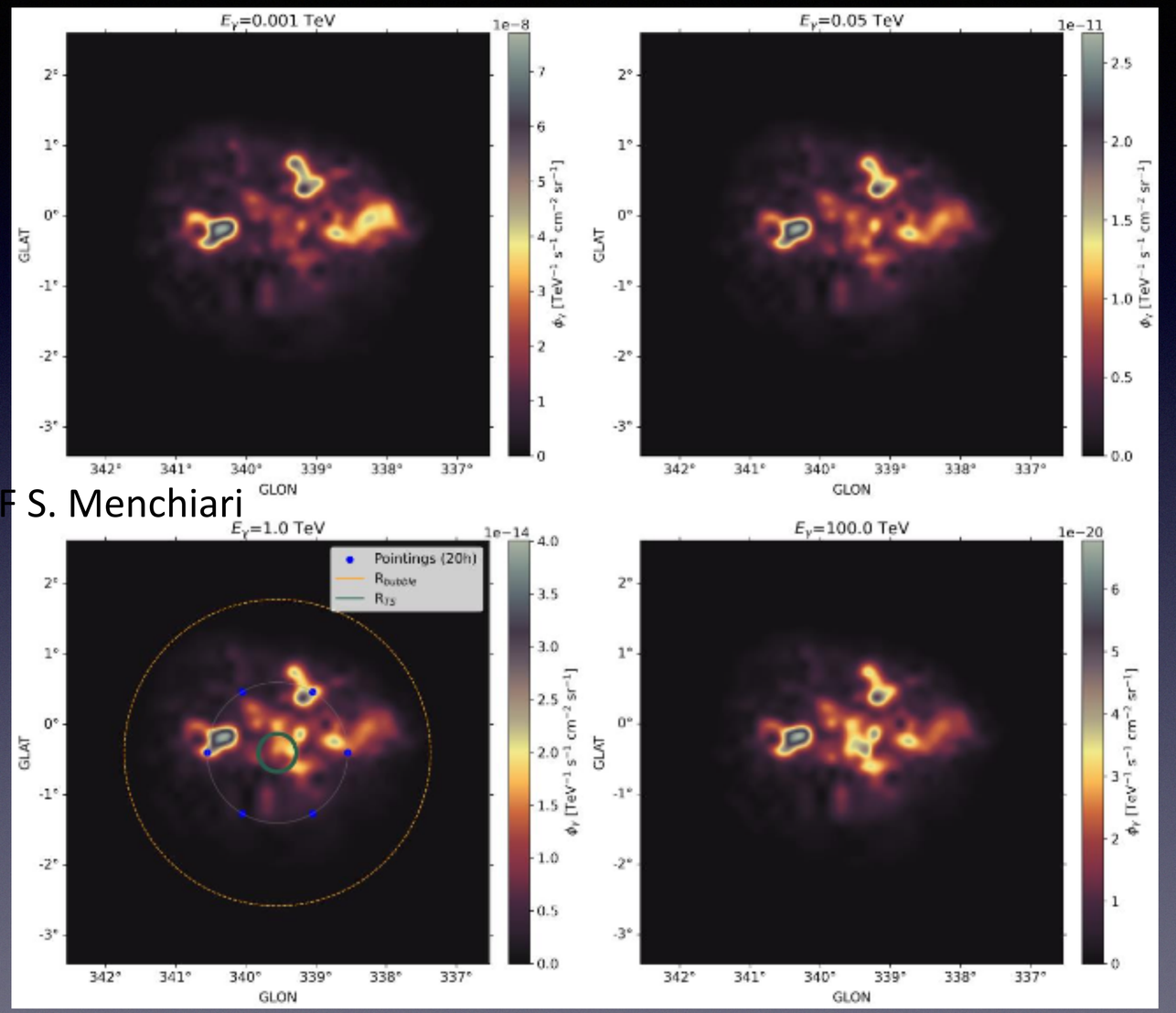
COURTESY OF S. Menchiari

SIMULATED EMISSION MAPS: WD1

KOLMOGOROV

BOHM





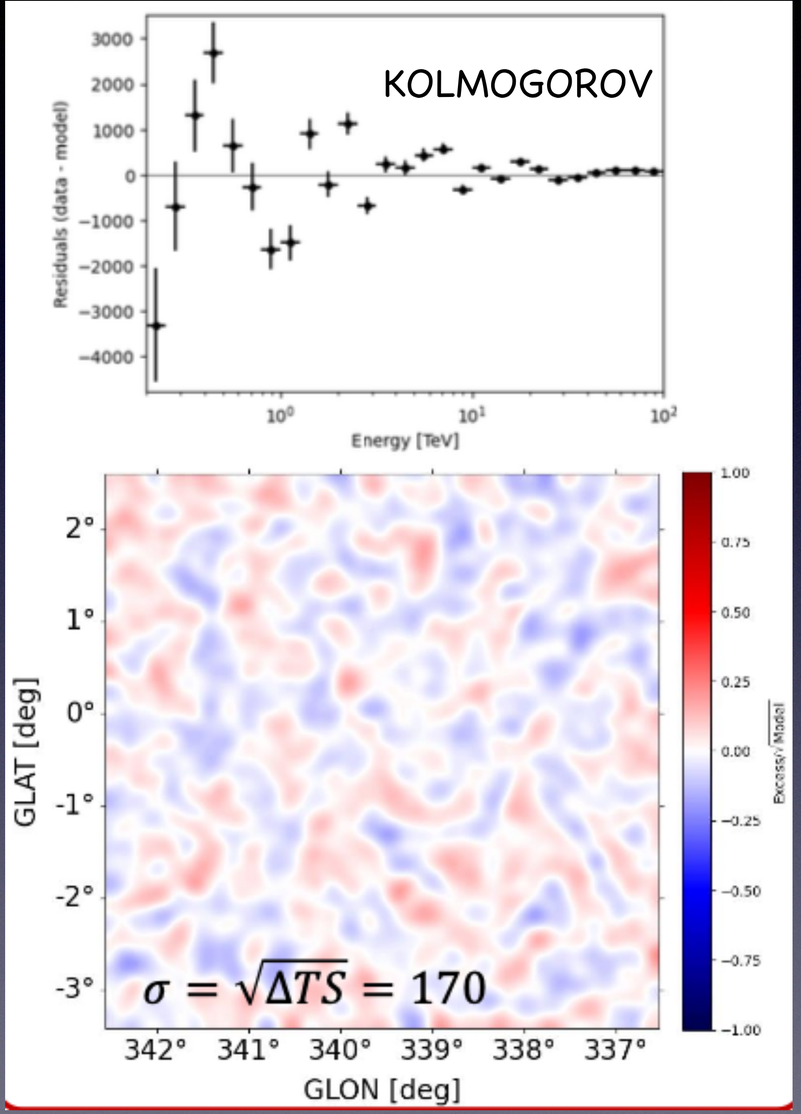
COURTESY OF S. Menchiari

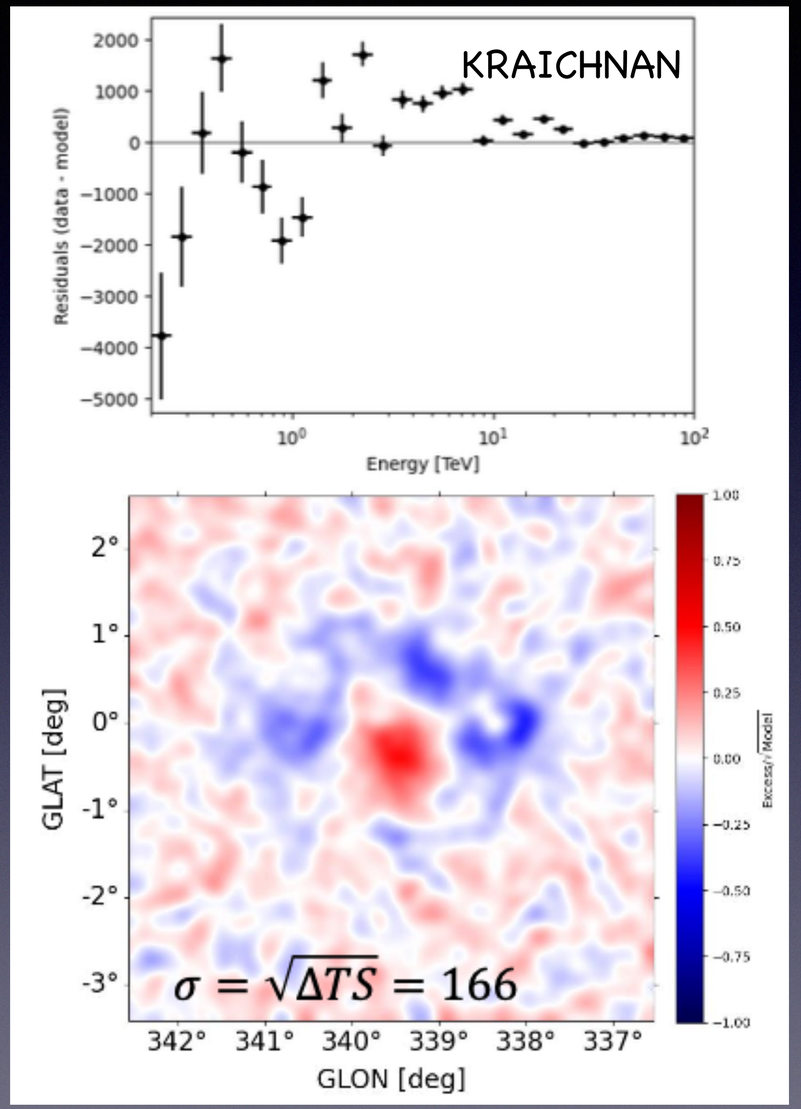
H2: 12CO(J=1-0) CfA (Dame et al, 2001) Lowres. + NRO (Takekoshi et al, 2019) Highres.
(Xco=1.68 1020 mol. cm-2 K-1 km-1 ; -20km/s<v<20km/s)

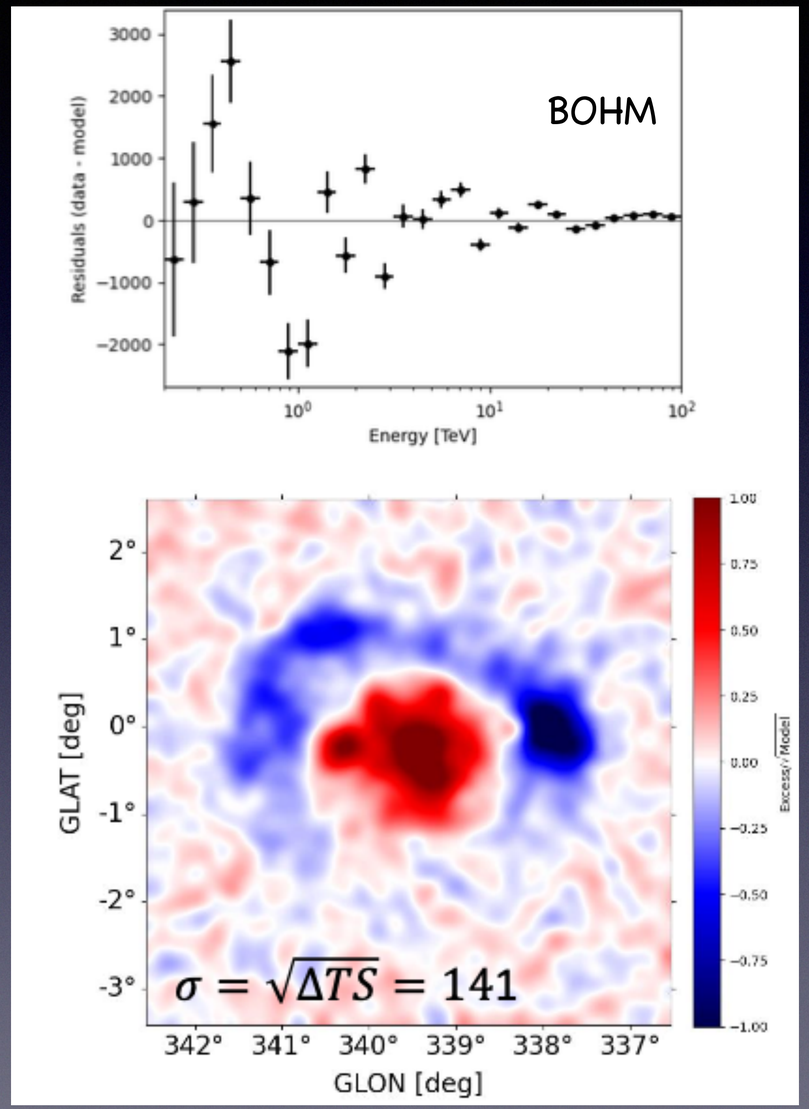
HI: 21cm from CGPS (Taylor et al, 2003)
(T=150°K ; -20km/s<v<20km/s)

UNVEILING THE TURBULENCE IN WD1

UNDERLYING KOLMOGOROV SPECTRUM





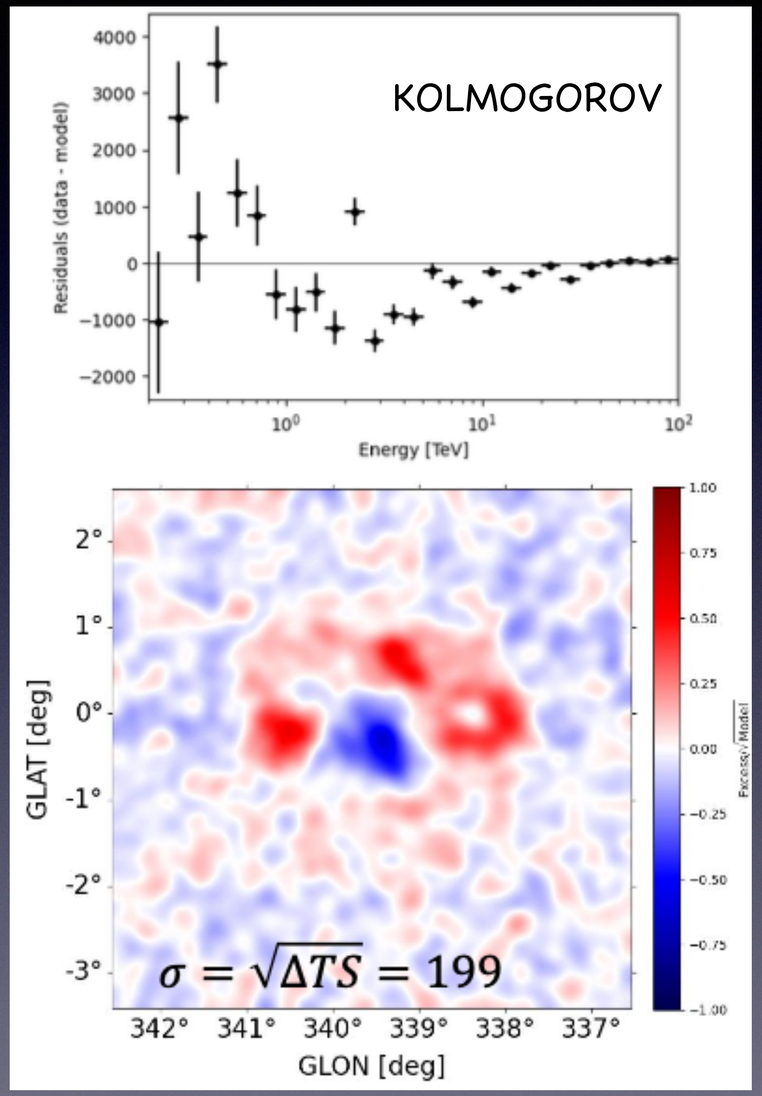


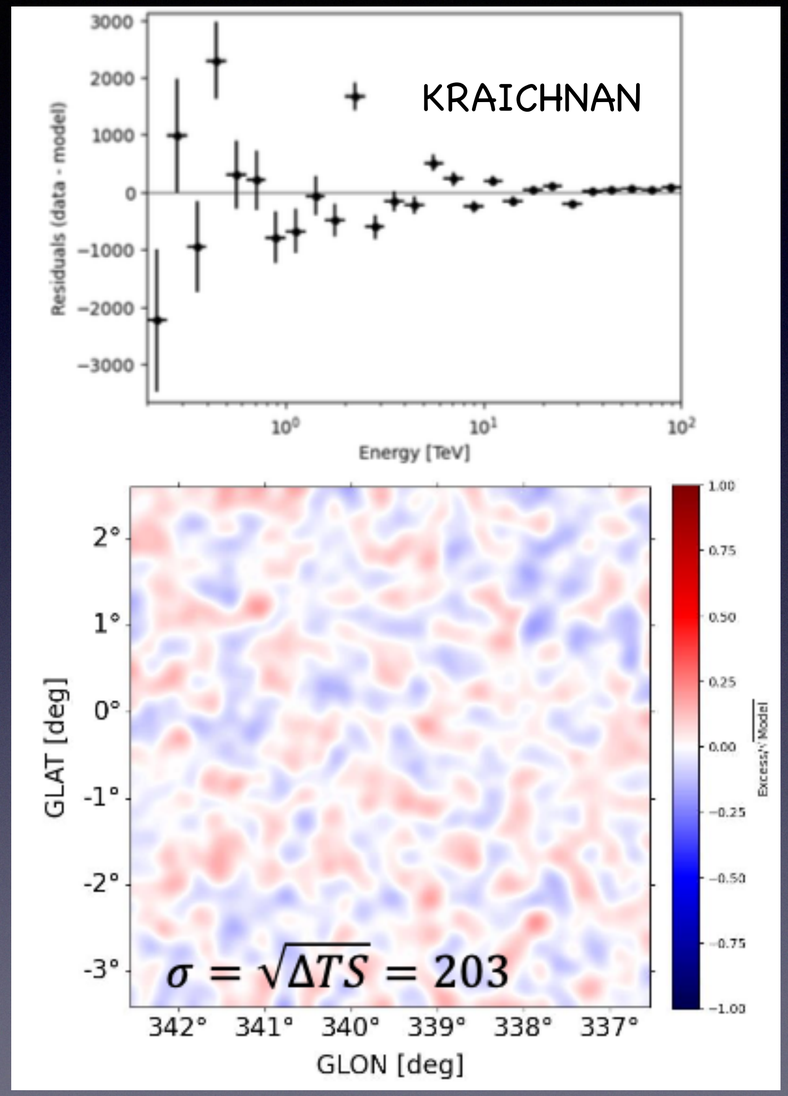
CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

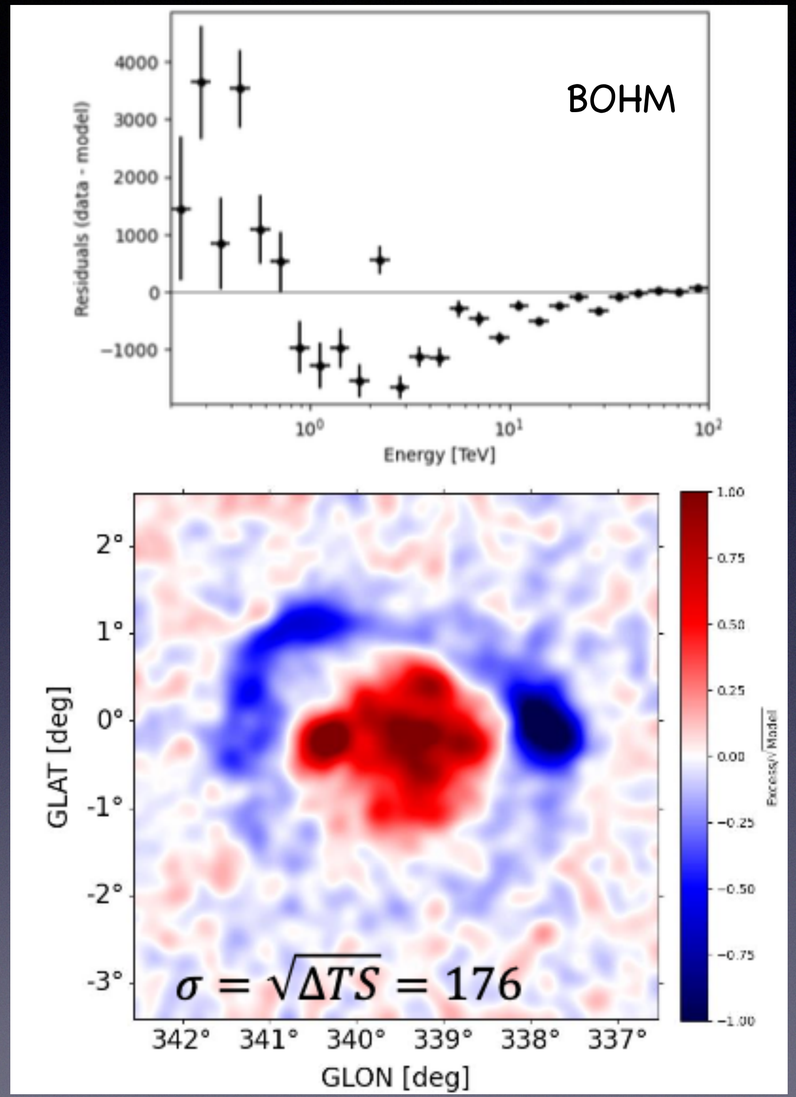
COURTESY OF S. Menchiari

UNVEILING THE TURBULENCE IN WD1

UNDERLYING KRAICHNAN SPECTRUM





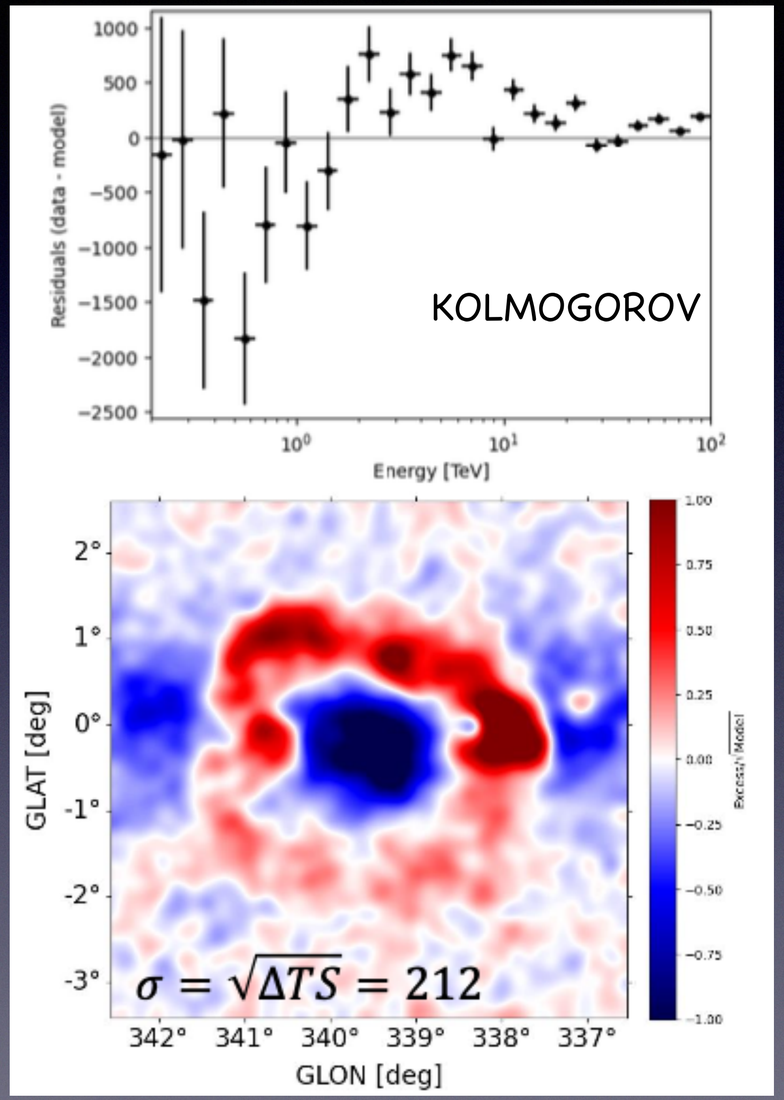


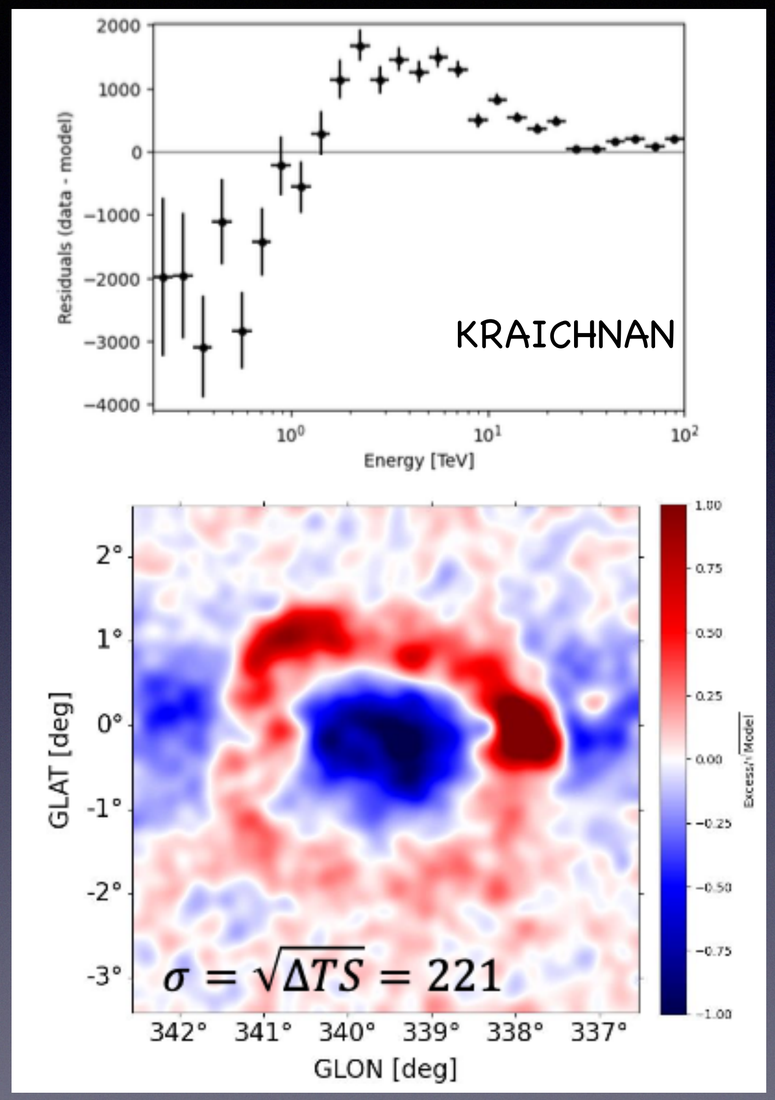
CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

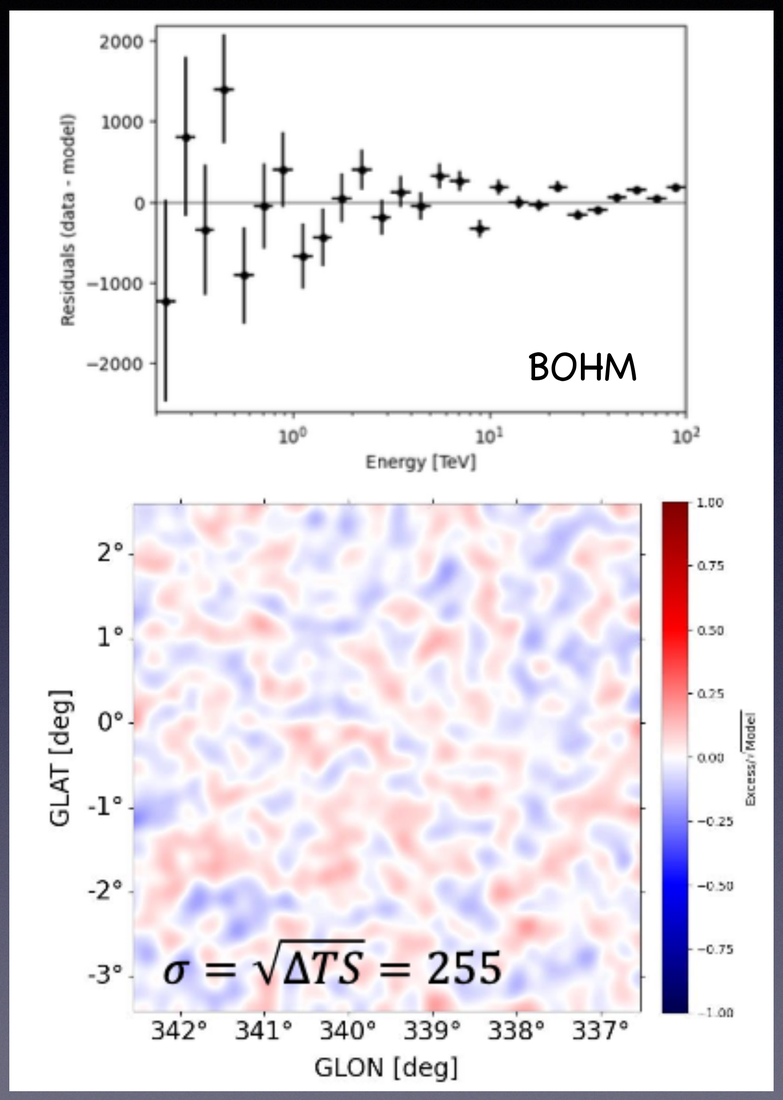
COURTESY OF S. Menchiari

UNVEILING THE TURBULENCE IN WD1

UNDERLYING BOHM SPECTRUM



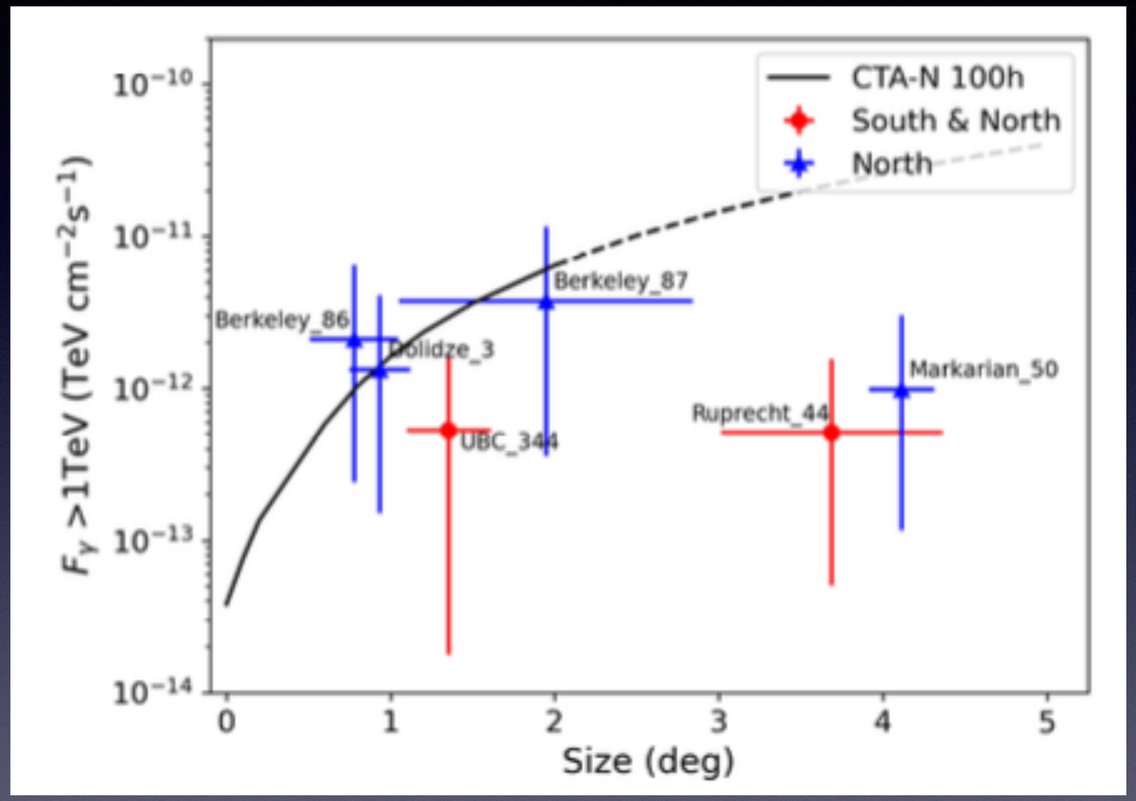


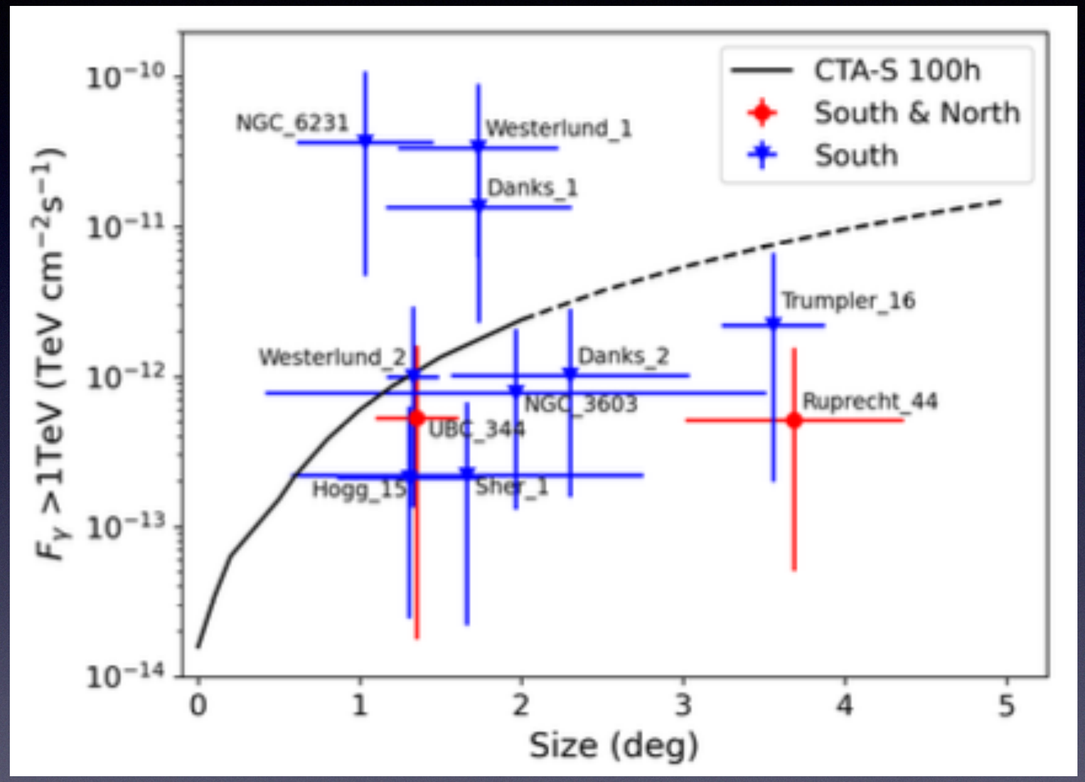


CTAO CP on *Star Forming Regions*
CTA coll (c.a. Marcowith)

COURTESY OF S. Menchiari

CTA PROSPECTS FOR YMSC DETECTION





STAR CLUSTERS FROM GAIA DR2 CATALOG
ACCELERATION AT SNRs AND CLUSTER TS

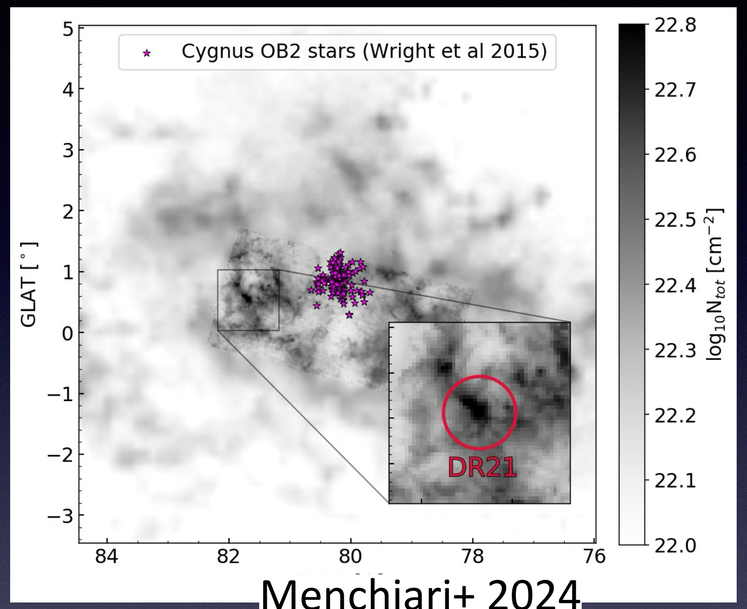
→

~ 10 NEW STAR CLUSTERS
1–5 PEVATRONS

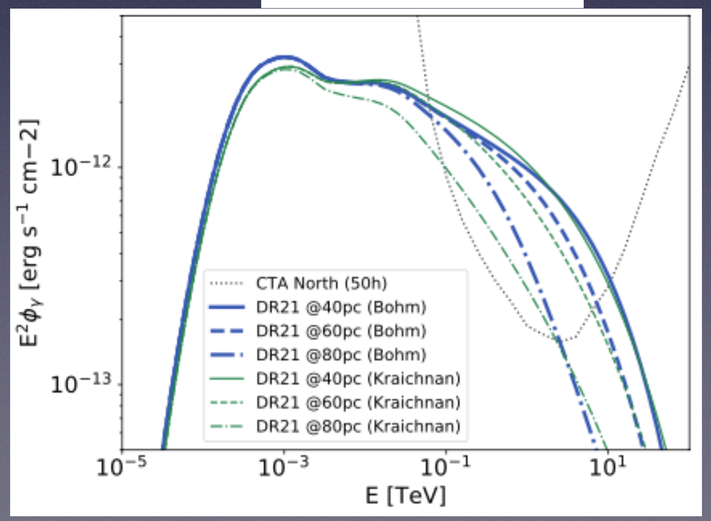
Mitchell+ 2024, submitted

INDIVIDUAL CLOUDS WITH CTA

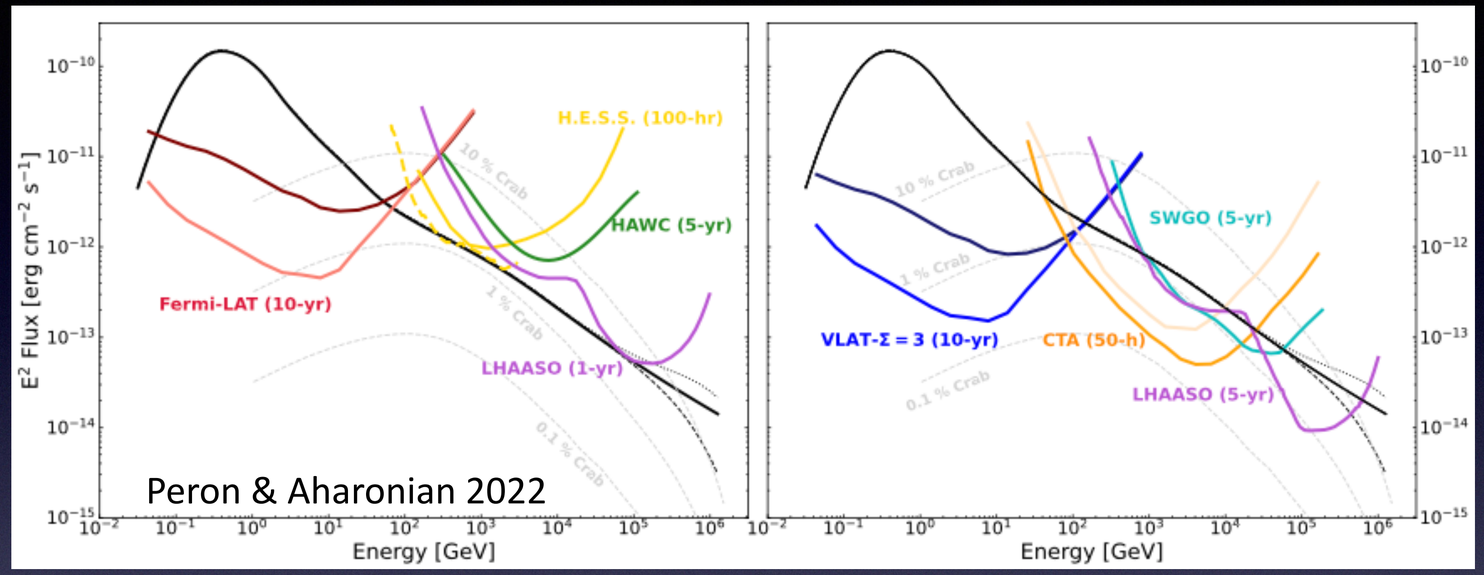
ACCELERATOR VICINITY



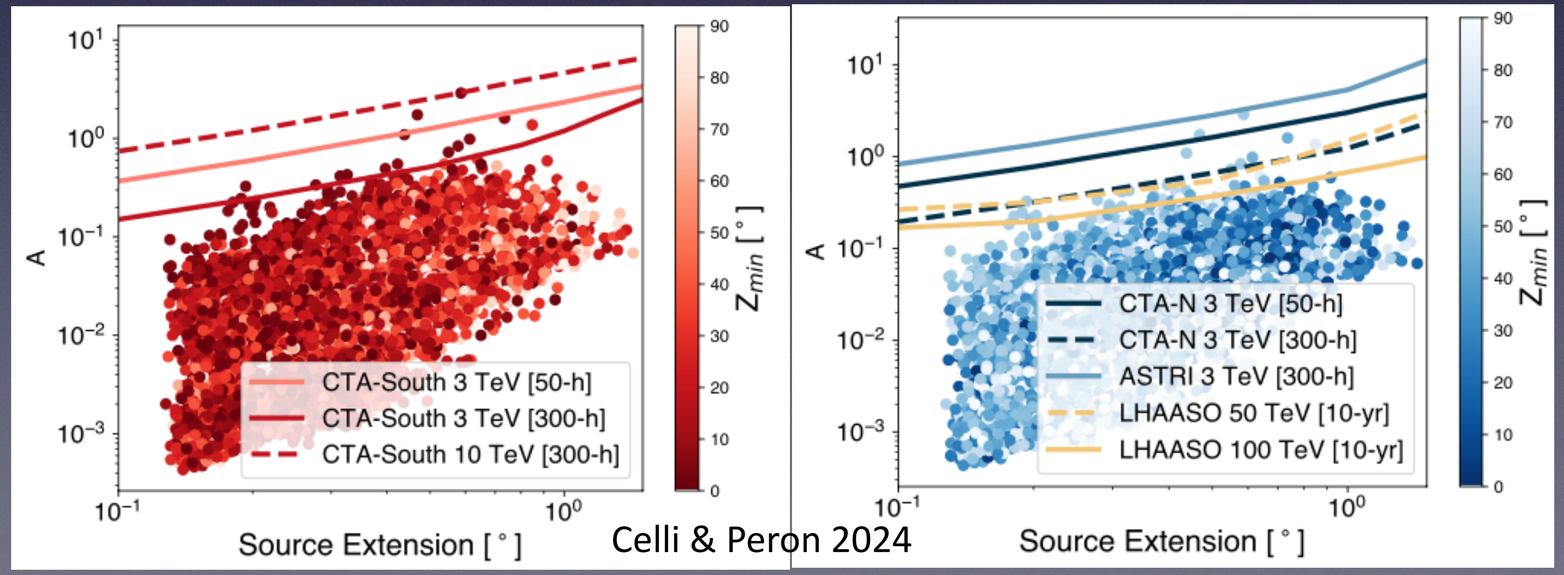
Menchiari+ 2024



IN THE GENERAL ISM



Peron & Aharonian 2022



Celli & Peron 2024

SUMMARY

THE COMBINATION OF ANGULAR RESOLUTION AND SENSITIVITY OFFERED BY CTA WILL ALLOW US TO:

- DETERMINE THE ABUNDANCE OF PEVATRON SNRS AND UNVEIL THEIR HIGH ENERGY SPECTRUM (BOTH TO BE COMPARED WITH THEORY!)

- CLARIFY WHETHER OTHER CLASSES OF ACCELERATORS CAN REACH PeV ENERGIES (EXCLUDING PSRs AND PWNe IN THE FIRST PLACE! AND UNVEILING THE CONDITIONS IN THE ACCELERATION REGION)

ULTIMATELY, UNVEIL THE NATURE OF THE MOST POWERFUL ACCELERATORS IN THE GALAXY