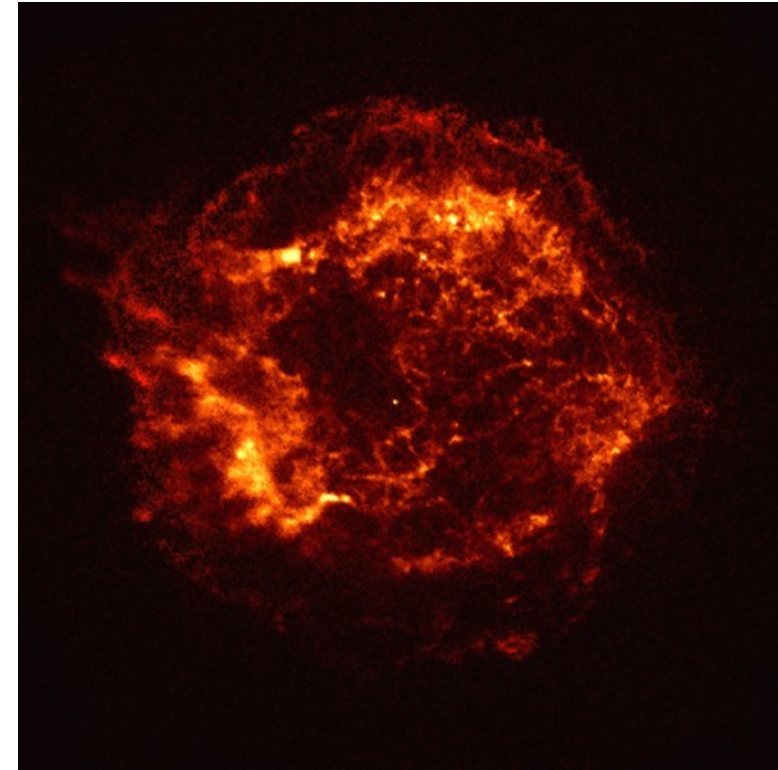


Probing CR acceleration through molecular clouds in the vicinity of SNRs with H.E.S.S.

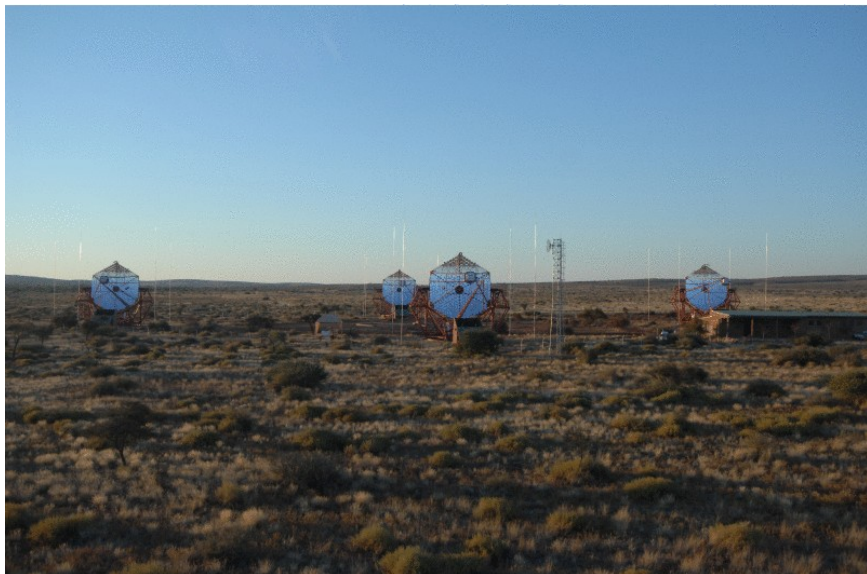
Armand Fiasson for the H.E.S.S. Collaboration

Supernova remnants and cosmic rays

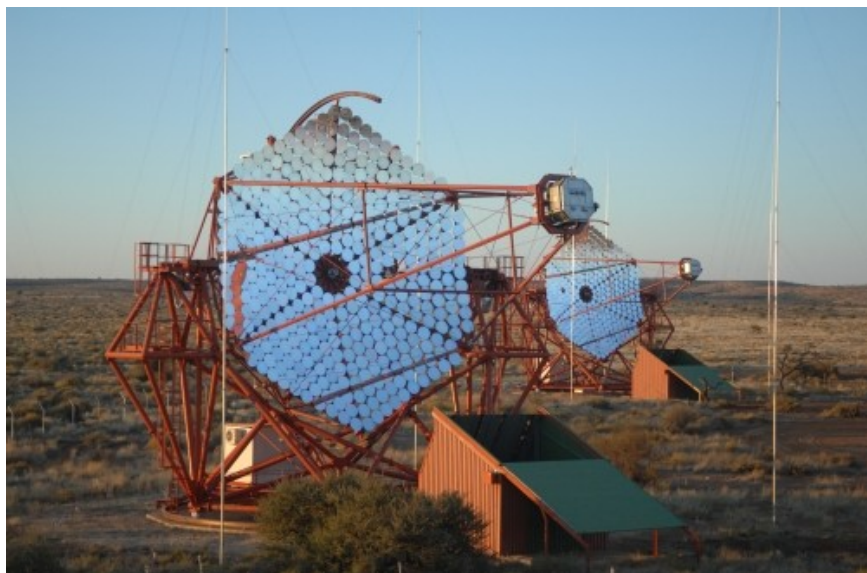
- **Historical candidate for particle acceleration within our Galaxy**
 - Enough energy to compensate propagation losses
- **Acceleration mechanism adapted from the Fermi mechanism**
 - Shell type supernova remnants
 - => blast wave through the ISM
 - Energy gain by multiple passage through the supersonic shock
 - Conversion $\sim 10\%$ of the explosion energy into CRs expected
- **Currently the best candidate**
 - => Still requires an unambiguous experimental confirmation
 - => very high energy gamma-rays are the optimal tracers to confirm this scenario



The High Energy Stereoscopic System (H.E.S.S.)

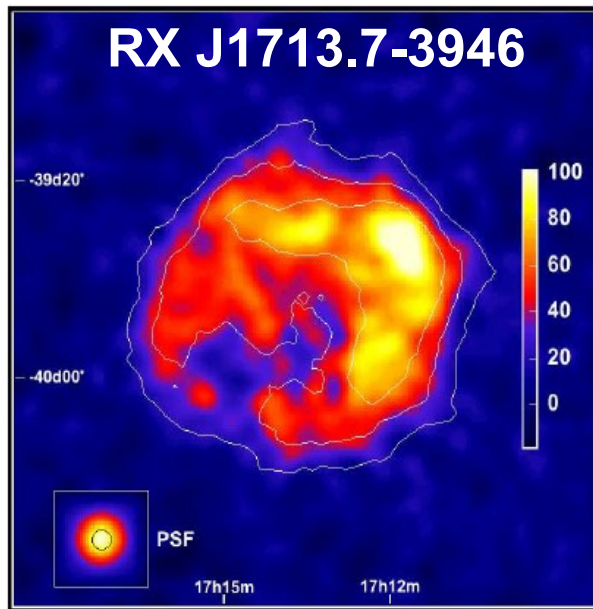


- **Array of 4 Imaging Atmospheric Cherenkov Telescopes**
 - Detects the Cherenkov light from atmospheric showers in stereoscopic mode
 - Large field of view: 5°
 - Energy range: 100 GeV to a few 10 TeV
 - Resolution: $\Delta\theta \sim 0.1^\circ$ and $\Delta E/E \sim 16\%$

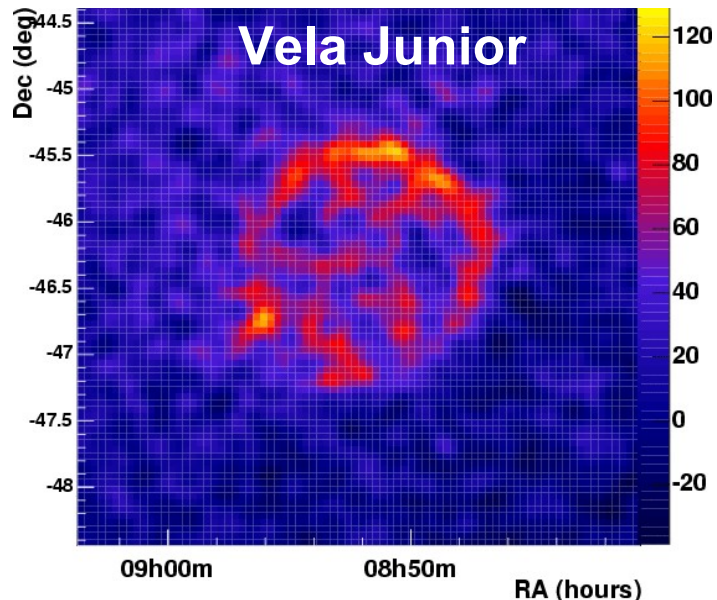


- **Located in the Khomas Highlands of Namibia**
 - Southern hemisphere
 - => Ideal position to observe the inner Galactic plane where most of the emitters are located
- **Construction completed in December 2003**
 - => more than 4 years in full operation mode

Particle acceleration in shell-type SNRs



Aharonian et al. A&A 464, 235 (2007)



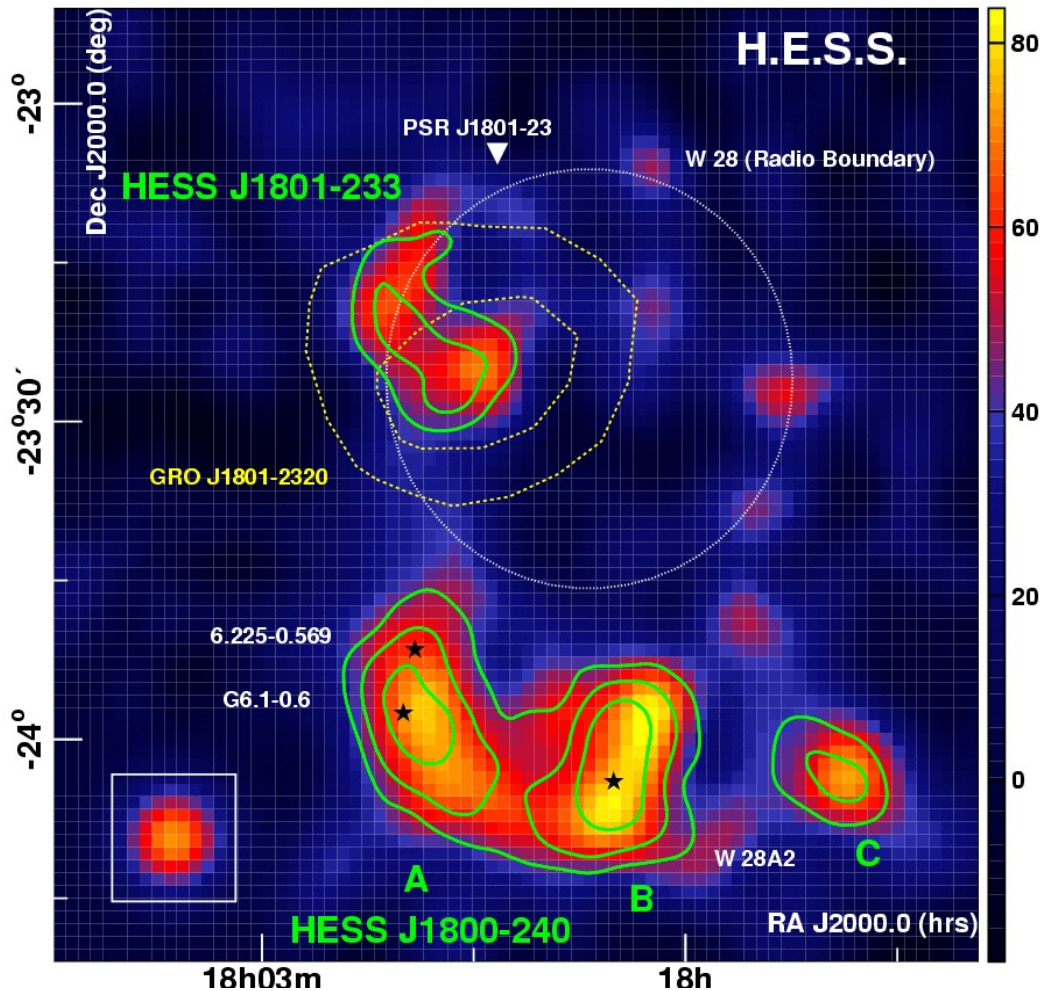
Aharonian et al. ApJ 661, 236 (2007)

- **First shell morphology resolved in VHE gamma-rays by H.E.S.S.**
 - Large angular size compared to the H.E.S.S. PSF
 - Power law with spectral index close to 2 up to 30 TeV
 - => confirm the acceleration of particles with $E > 10^{14}$ eV
 - Correlation with non-thermal X-rays
- **The origin of the gamma-ray emission remains unidentified**
 - Electrons in a low intensity magnetic field (\sim a few μ G)
 - Hadrons in a higher magnetic field ($\sim 100 \mu$ G, predicted by theoretical models)
 - => a hadrons acceleration is not yet confirmed
- **Different behaviour at lower energy**
 - GLAST should help disentangling these scenarios

The molecular clouds as a probe for CRs

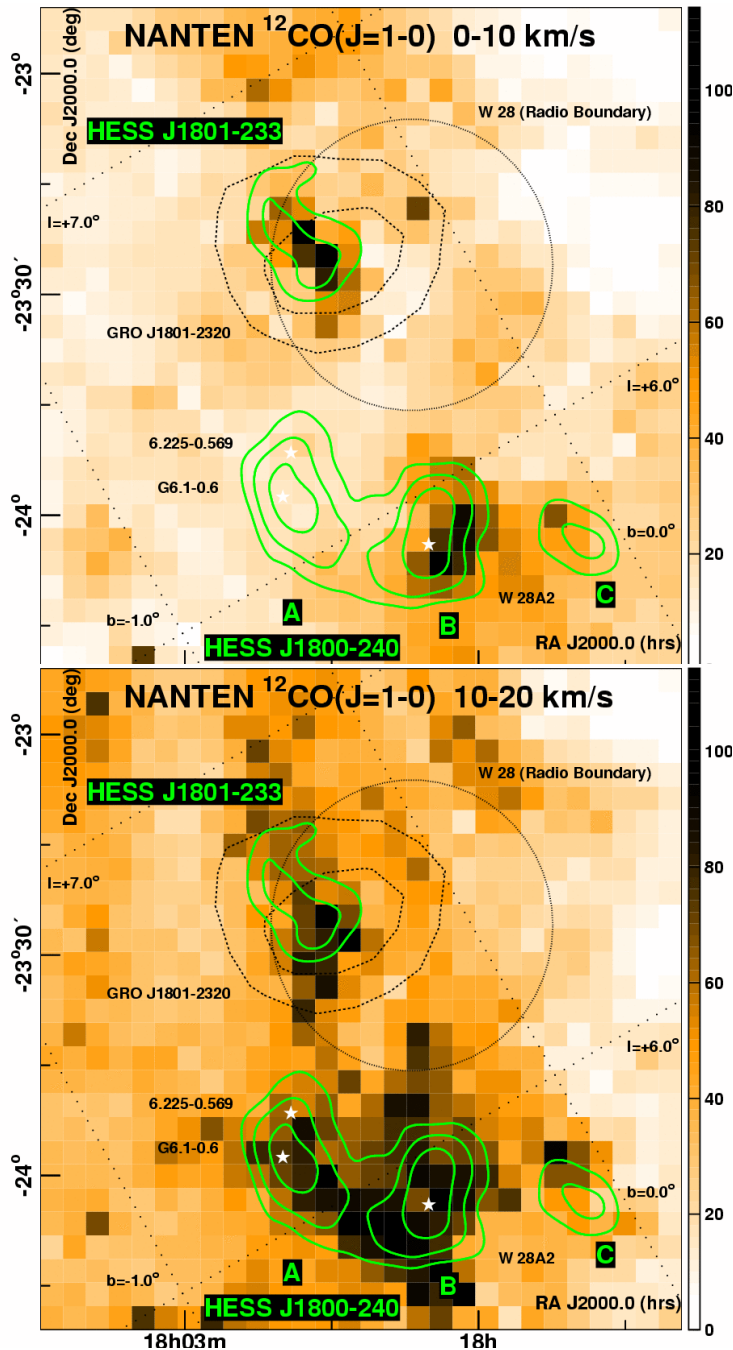
- **Matter target required to produce gamma-ray emission by hadrons**
 - Correlation expected between matter density and the gamma-ray emission
 - => CRs accelerators associated with dense matter concentrations should help discriminate them from electrons accelerators
- **Supernova remnant associated with dense molecular clouds**
 - Natural association: molecular clouds are birth place of massive stars which evolved into SNe
- **Molecular cloud detection**
 - Rotational lines in radio (CO, CS)
 - => line intensity proportional to H₂ density column (main component)
 - Physical association with SNRs indicated by OH masers at 1720 MHz
 - => trace the passage of the blast waves through the clouds
 - => more than 20 associations known

The W28 field



- **Complex region in MWL**
 - Several SNRs
 - Star formation regions
 - H_{II} regions
- **Several VHE gamma-ray sources**
 - Extended emissions
 - Photon index $\Gamma \sim 2.5 - 2.7$
 - => close to SNR G6.4-0.1 (W28)
- **Northern excess coincident with an EGRET source (within W28)**
 - => hadronic scenario likely

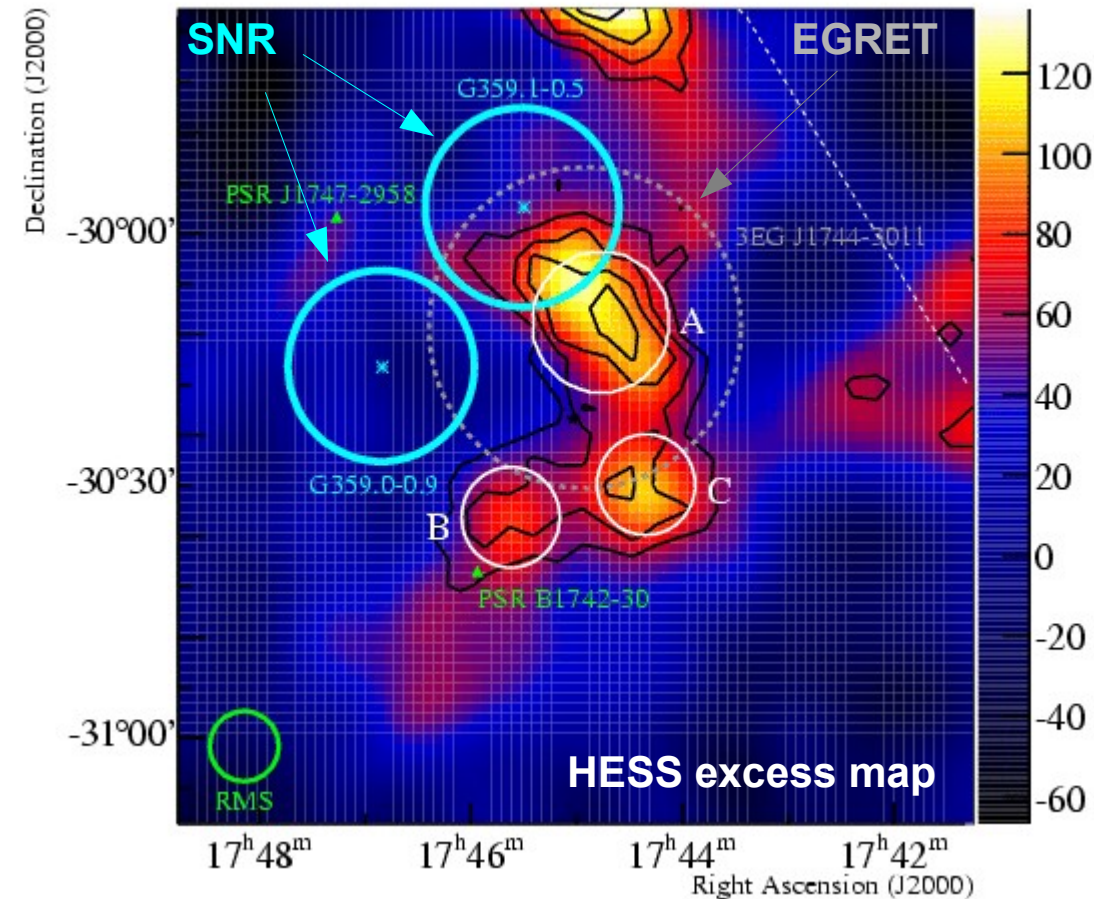
Molecular clouds in the vicinity of W28



- **Interaction of the remnant with a dense molecular cloud seen in NANTEN CO ($J=1 \rightarrow 0$) observations**
 - Presence of OH masers (1720 MHz)
 - Northern gamma-ray emission coincident
 - => Energetics compatible with CRs accelerated within the SNR and interacting with the cloud
- **Molecular clouds seen also in coincidence with the southern excesses**
 - Distances compatible with the SNR
 - Hadronic scenario also possible
- **Alternative scenario possible for the southern emissions**
 - Others SNRs, young stars, open stellar cluster

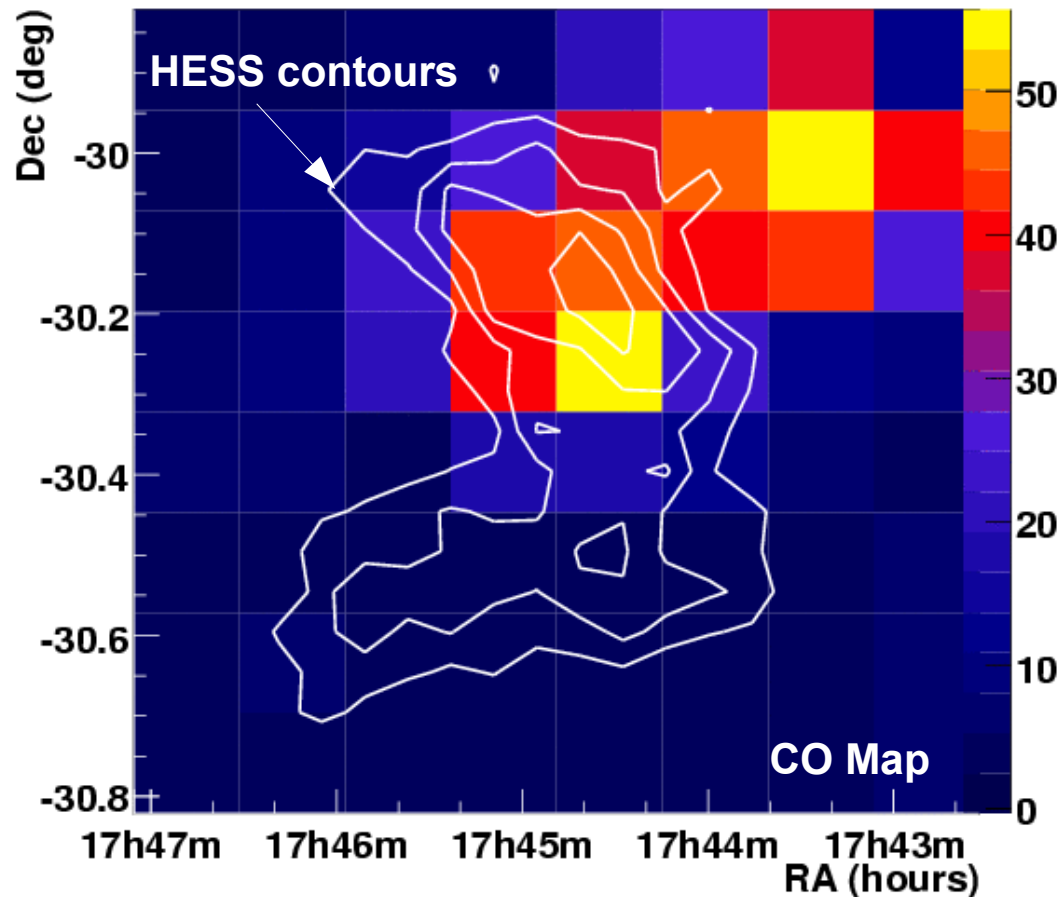
Aharonian et al. A&A 481, 401 (2008)

HESS J1745-303



- **New analysis of this unidentified H.E.S.S. source**
 - Discovered in the galactic scan in 2004
 - Statistics increased in 2005 – 2007
 - => complex morphology, possibly multiple
 - Power law of index $\Gamma = 2.71 \pm 0.11$
- **Still no obvious counterpart for the whole emission**
 - Unidentified EGRET source
- **Pulsar wind nebula powered by PSR B1742-30**
 - Could only explain a fraction of HESS J1745-303

CRs accelerated by G359.1-0.5?



- **Interaction of the SNR G359.1-0.5 blast wave with a matter ring**
 - OH masers at 1720 Mhz towards the boundary of the SNR
 - CO observations reveals a coincidence of a fraction of this ring with the gamma-ray source
 - **Hadronic scenario within this cloud?**
 - Energetics compatible with CRs from the SNR interacting with the cloud
- => ~ 30% of the SN explosion energy into CRs

A&A 483 509A 2008

Aharonian et al. A&A 483, 509A (2008)

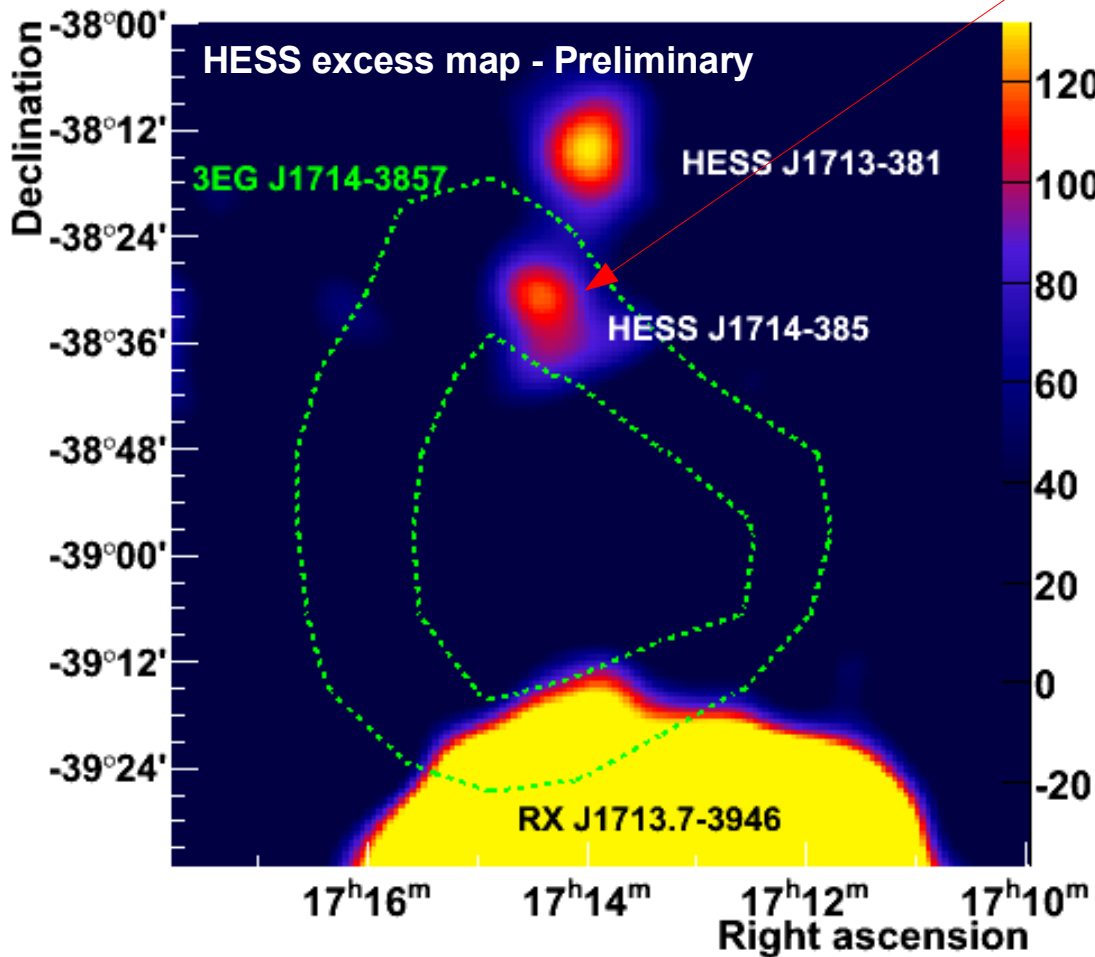
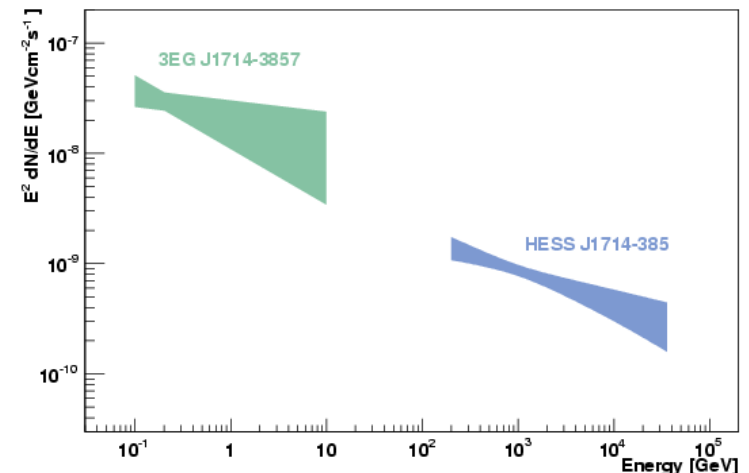
HESS J1714-385 & CTB 37A

- Recently discovered by H.E.S.S.

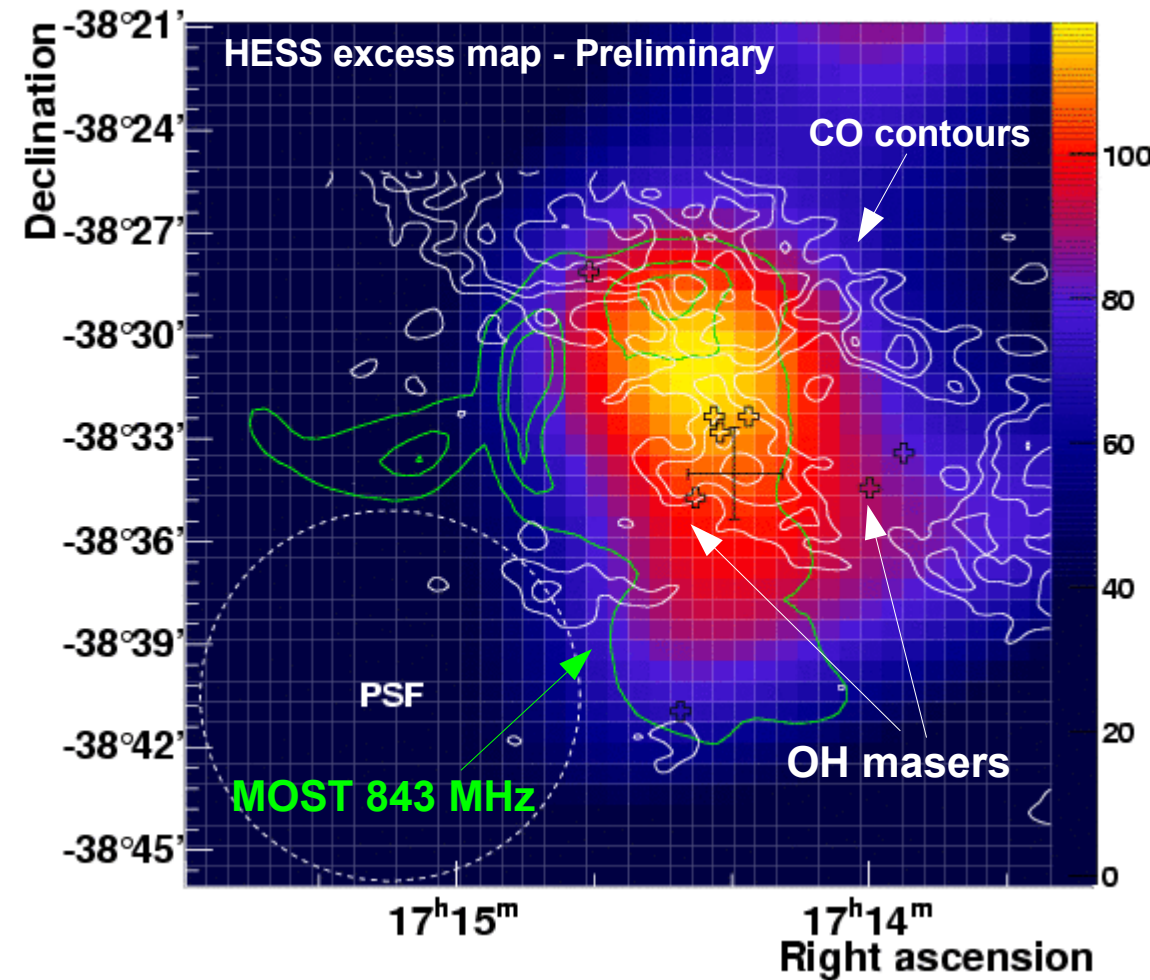
- Close to RX J1713.7-3946
- Coincident with SNR G348.5+0.3 (CTB 37A)
- Power law with spectral index $\Gamma = 2.30 \pm 0.13$
- Extended source: $\sigma \sim 4'$

- Counterpart candidate for the EGRET source 3EG J1714-3857

- Spectral compatibility

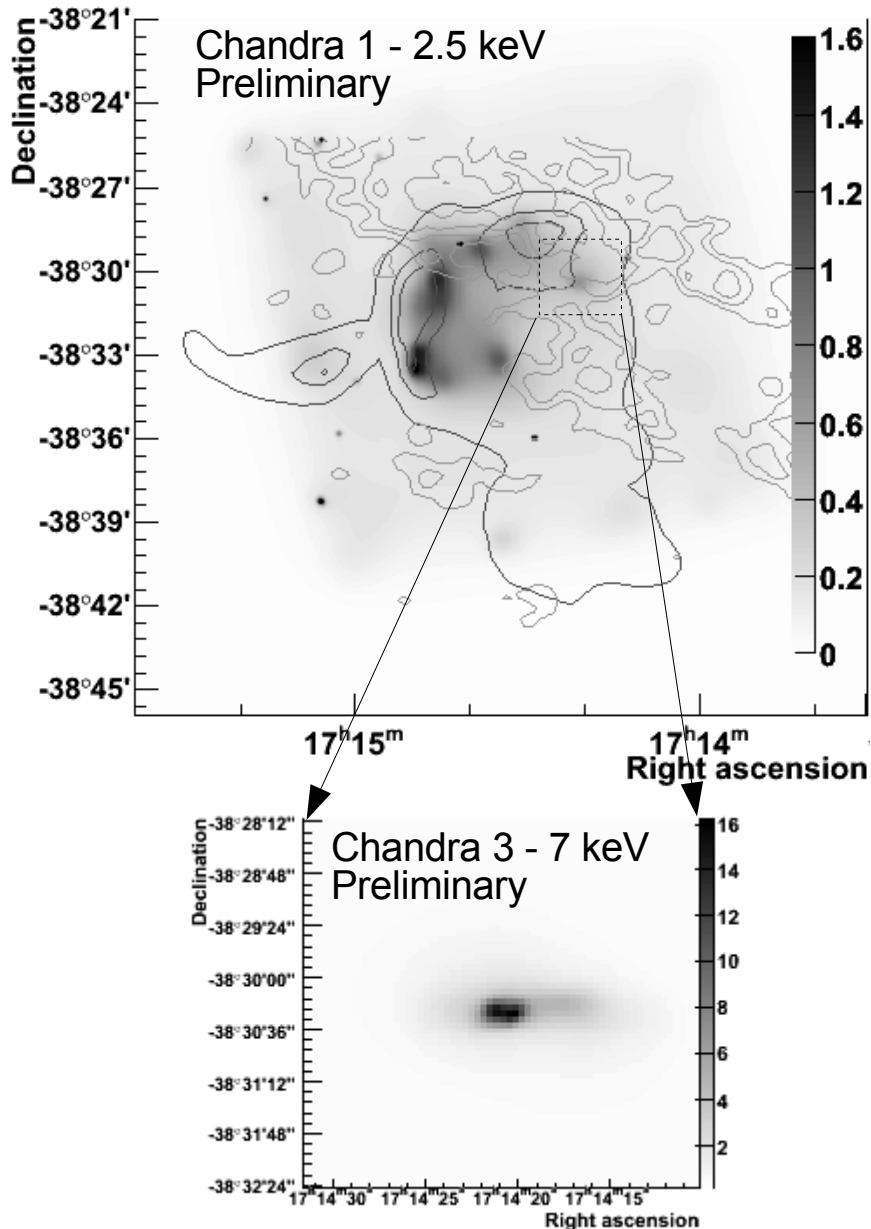


CRs in molecular clouds?



- **SNR interacting with several molecular clouds**
 - OH masers (1720 Mhz)
 - Dense molecular clouds detected in CO observations
 - **Hadronic scenario?**
 - Gamma-ray energetics compatible with CRs accelerated by CTB 37A
- => [4% - 30%] of the SN explosion energy into CRs

Or a PWN?



- **Recent X-ray observations**

- Chandra & XMM-Newton
- Complex region in X-rays

- **Thermal emission discovered from the interior of the remnant**

- **PWN candidate discovered coincident with the remnant**

- Possibly associated with CTB 37A
- X-ray luminosity implies a spin-down luminosity around 10^{37} erg/s
- => ~0.1% conversion in gamma-rays
- => scenario possible

Aharonian et al. submitted to A&A
arXiv: 0803.0702

Summary

- **The detection of gamma-rays towards shell-type SNRs does not confirm unambiguously that CRs are accelerated within these objects**
- **Molecular clouds in the vicinity of SNRs could help disentangle leptonic and hadronic scenarios**
- **Several associations of this type have been observed by HESS**
 - Physical associations revealed by OH masers at 1720 MHz
 - EGRET counterpart possible to lower energy for all of them
 - A hadronic scenario is possible for each case

=> Gamma-ray flux compatible with CRs accelerated by the SNR
- **A leptonic scenario cannot be excluded for some of them**

=> But accumulation of indications that CRs are accelerated within SNRs