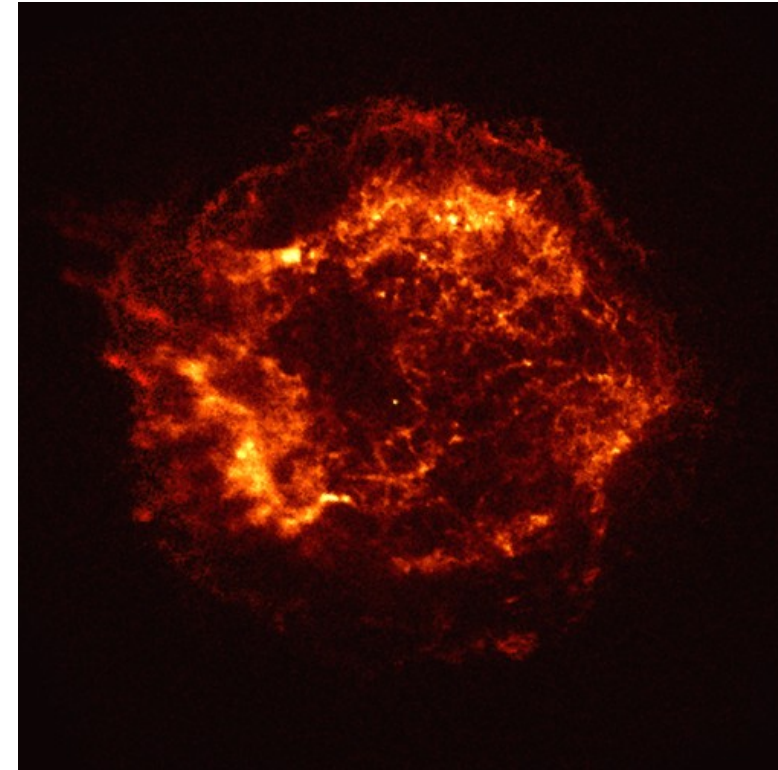


# Probing CR acceleration through molecular clouds in the vicinity of SNRs with H.E.S.S.

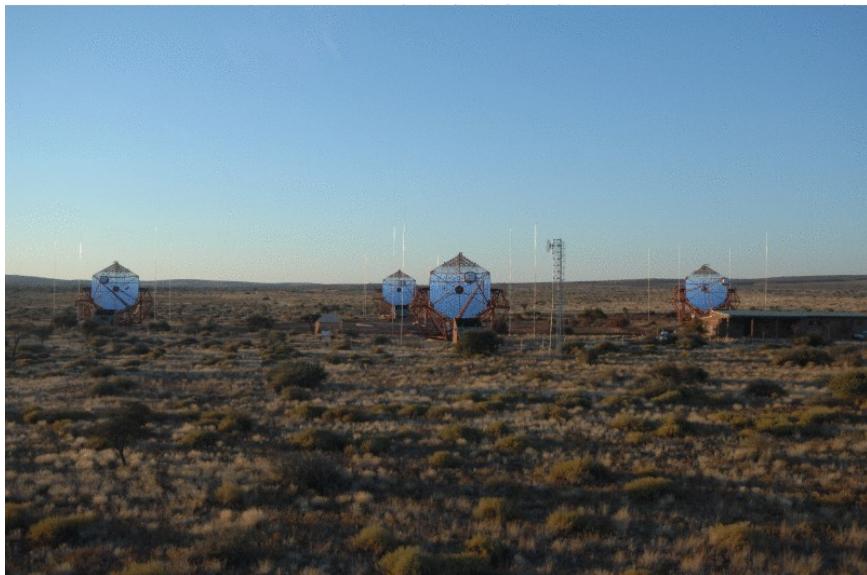
Armand Fiasson for the H.E.S.S. Collaboration

# 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.)



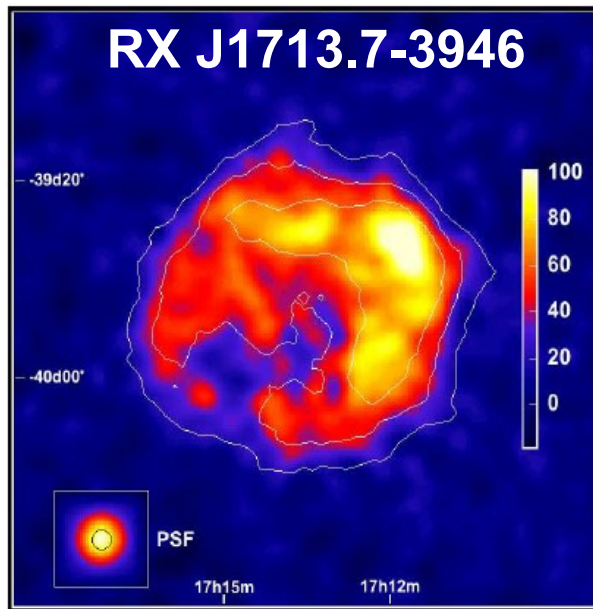
- **Array of 4 Imaging Atmospheric Cherenkov Telescopes**
  - Detects the Cherenkov light from atmospheric showers in stereoscopic mode
  - Large field of view:  $5^\circ$
  - Energy range: 100 GeV to a few 10 TeV
  - Resolution:  $\Delta\theta \sim 0.1^\circ$  and  $\Delta E/E \sim 16\%$



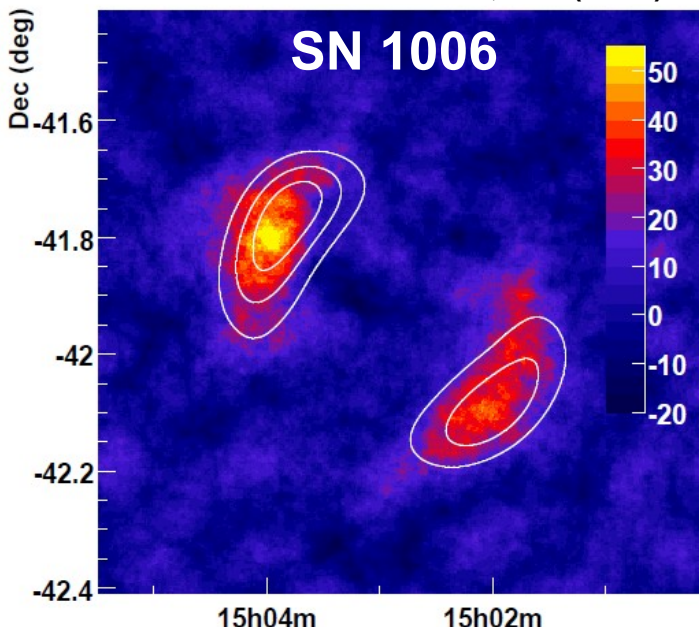
- **Located in the Khomas Highlands of Namibia**
  - Southern hemisphere
  - => Ideal position to observe the inner Galactic plane where most of the emitters are located
- **Construction completed in December 2003**
  - => more than 4 years in full operation mode



# Particle acceleration in shell-type SNRs



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



M. Nauman-Godo et al., Moriond 2009

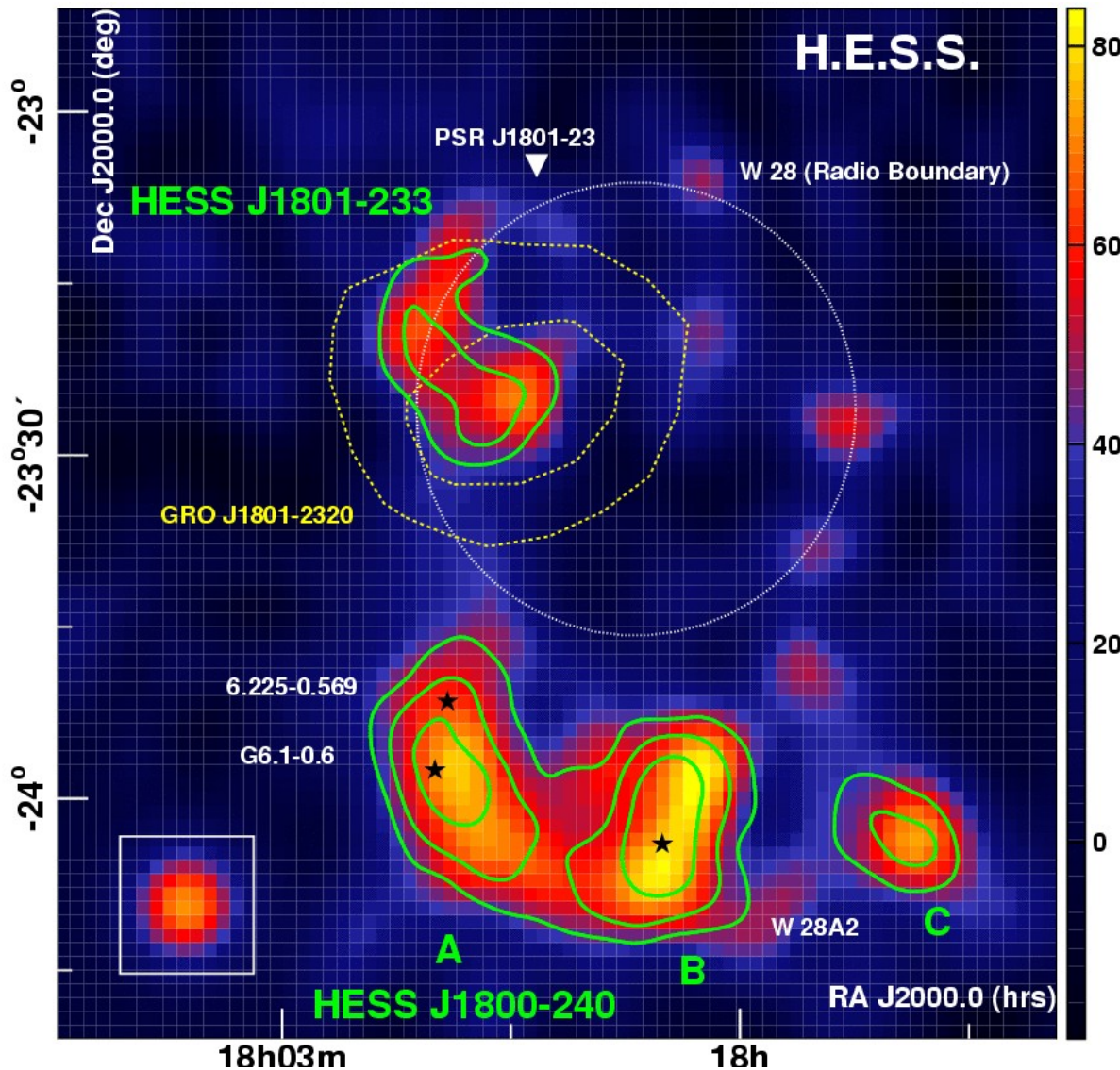
Armand Fiasson

- **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  $\mu$ 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**
  - Fermi should help disentangling these scenarios

# The molecular clouds as a probe for CRs

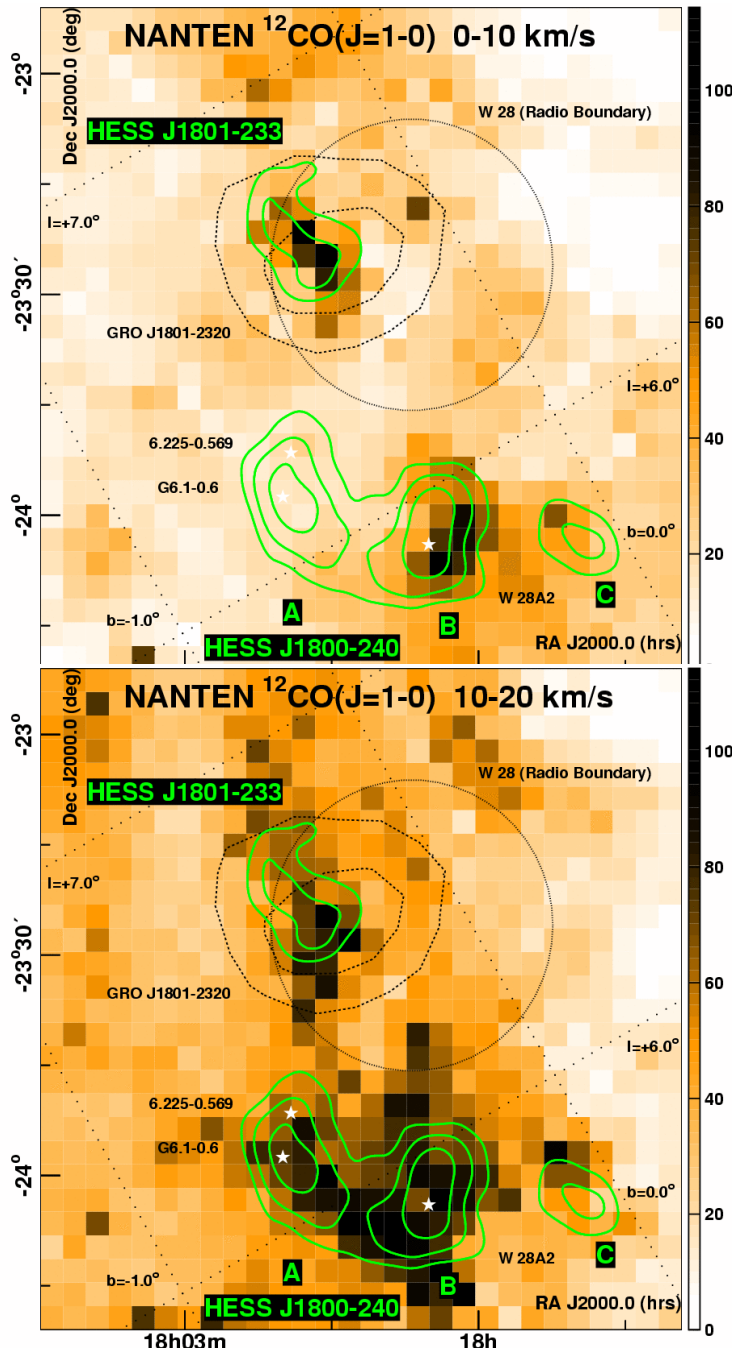
- **Matter target required to produce gamma-ray emission by hadrons**
  - Correlation expected between matter density and the gamma-ray emission
  - => CRs accelerators associated with dense matter concentrations should help discriminate them from electrons accelerators
- **Supernova remnant associated 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 H<sub>2</sub> density column (main component)
  - Physical association with SNRs indicated by OH masers at 1720 MHz
    - => trace the passage of the forward shocks through the clouds
  - => more than 20 associations known

# The W28 field



- **Complex region**
  - Several SNRs
  - Star formation regions
  - H<sub>II</sub> 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

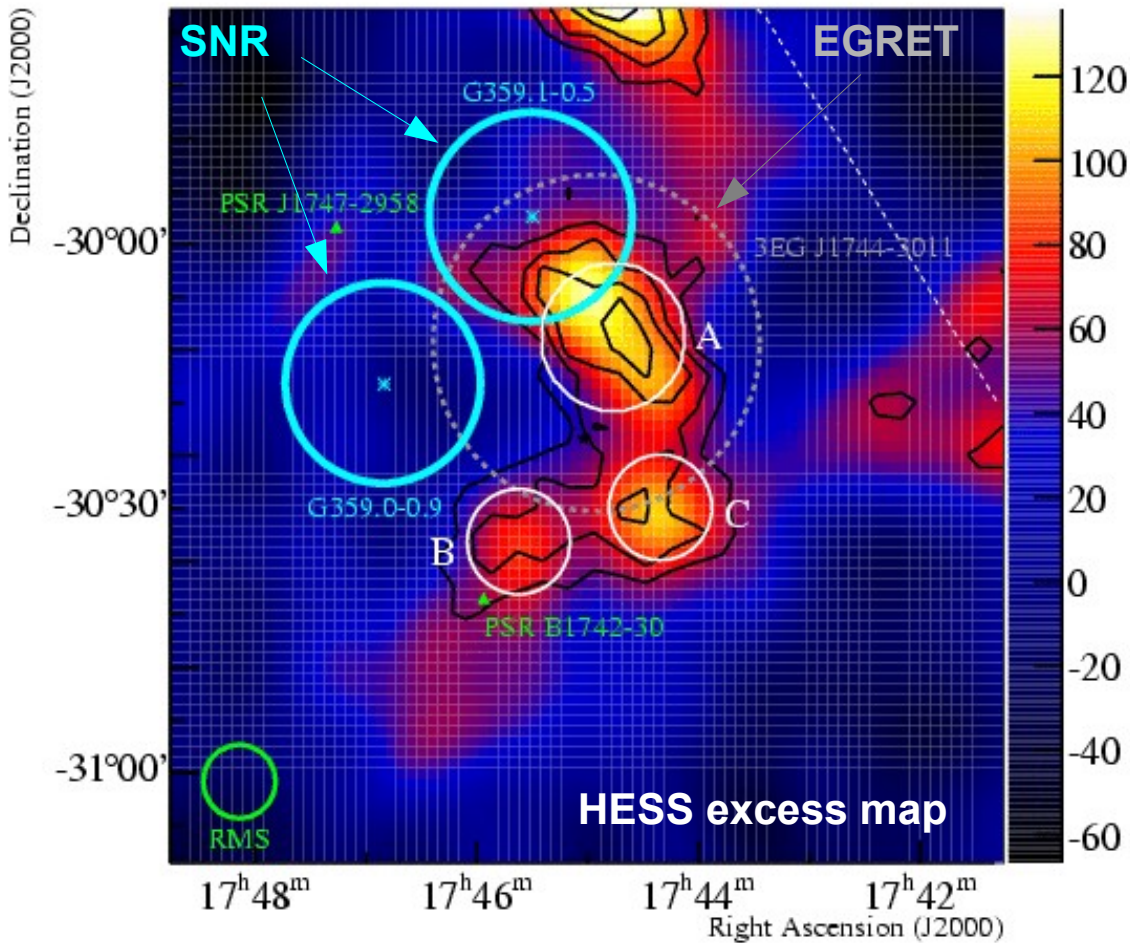


- **Interaction of the remnant with a dense molecular cloud seen in NANTEN CO ( $J=1 \rightarrow 0$ ) observations**
  - Presence of OH masers (1720 MHz)
  - Northern gamma-ray emission coincident
- => Energetics compatible with CRs accelerated within the SNR and interacting with the cloud
- **Molecular 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)



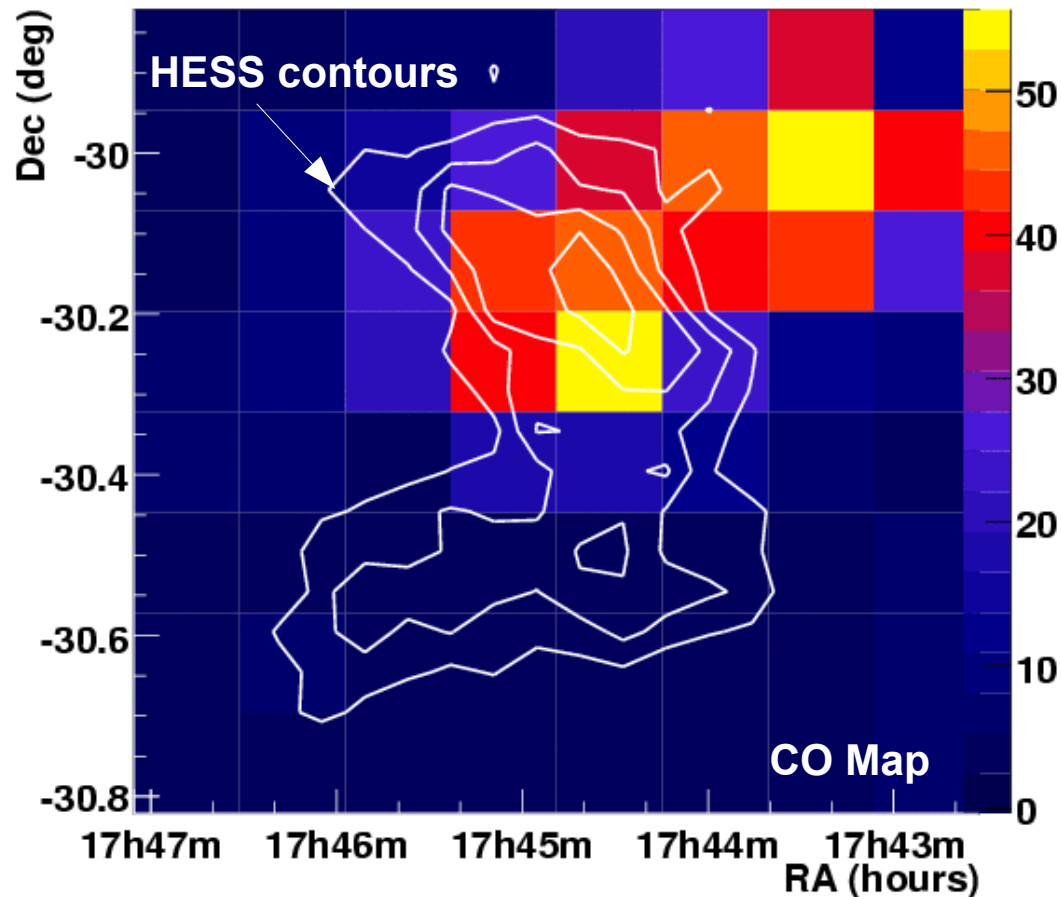
# The mysterious source HESS J1745-303



- **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
  - Photon 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



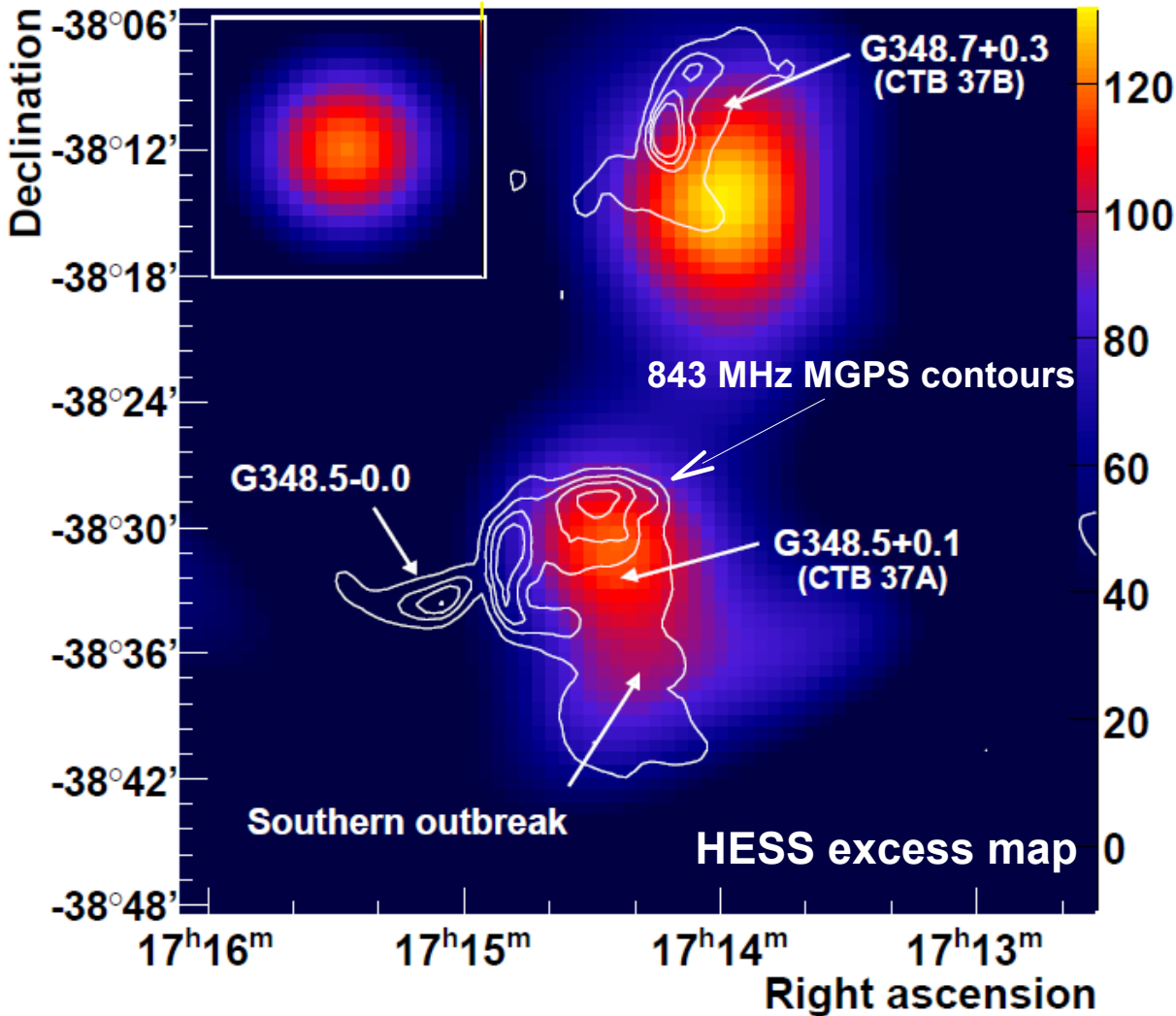
# CRs accelerated by G359.1-0.5?



- **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

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

# HESS J1714-385 & CTB 37A

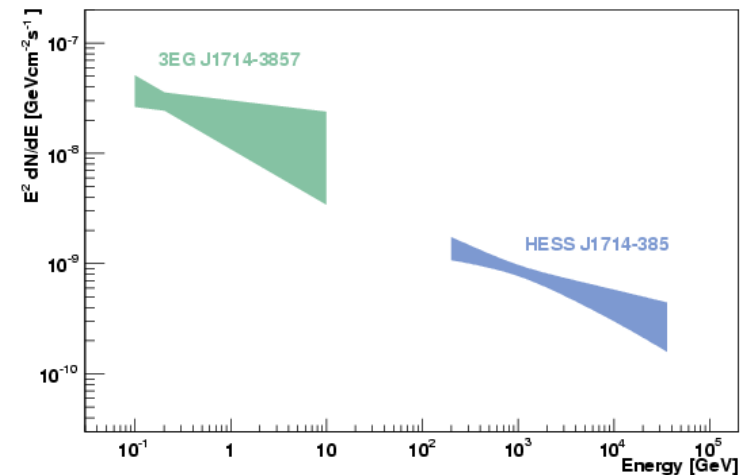


- Recently discovered by H.E.S.S.

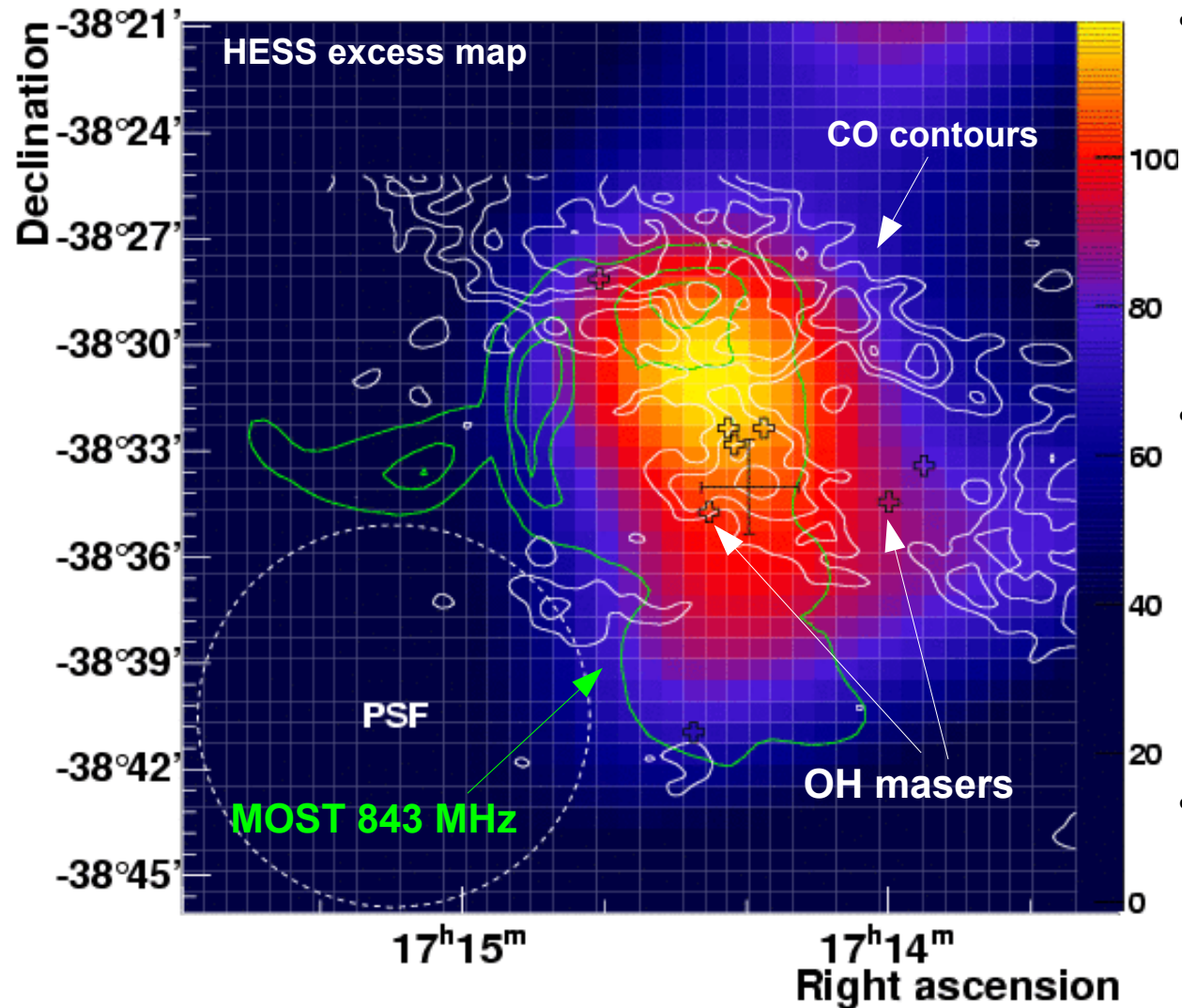
- Close to RX J1713.7-3946
- Coincident with SNR G348.5+0.3 (CTB 37A)
- Power law with spectral index  $\Gamma = 2.30 \pm 0.13$
- Extended source:  $\sigma \sim 4'$

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

- Spectral compatibility



# CRs in molecular clouds?

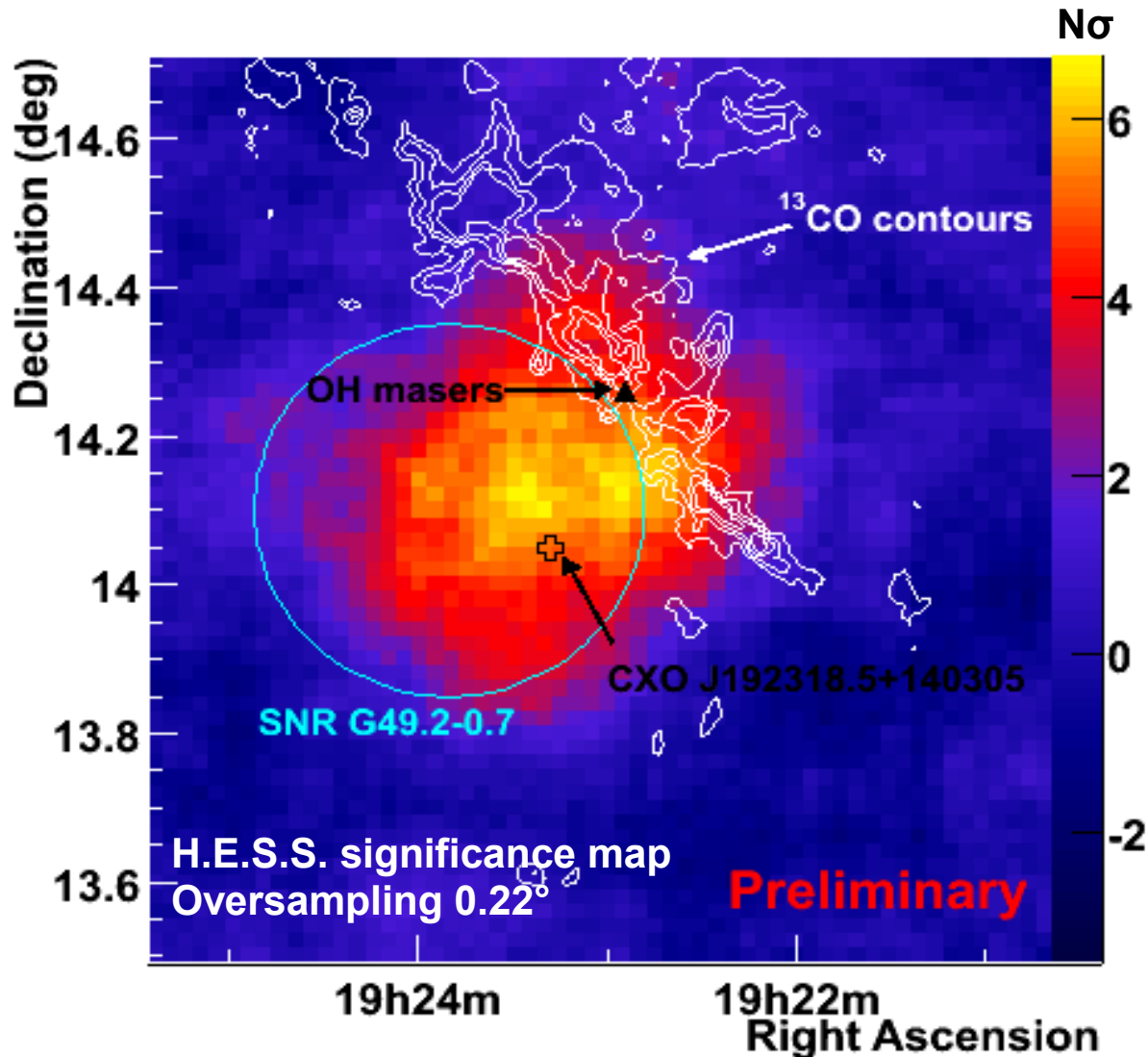


- **SNR interacting with several molecular clouds**
  - OH masers (1720 MHz)
  - Dense molecular clouds detected in CO observations
- **Hadronic scenario?**
  - Gamma-ray energetics compatible with CRs accelerated by CTB 37A
  - ⇒ [4% - 30%] of the SN explosion energy into Crs
- **Competitive leptonic scenario**
  - PWN candidate seen in X-rays
  - Possibly associated with CTB 37A

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# A new candidate: HESS J1923+141



- W51 region observed in 2007-08  
=> Discovery of a new source of VHE gamma-ray by H.E.S.S.
- Extended source compared to the H.E.S.S. PSF
- Flux over 1 TeV = 3% of the flux from the Crab Nebula over 1 TeV
- Several possible associations: PWN, star forming region and shocked molecular cloud

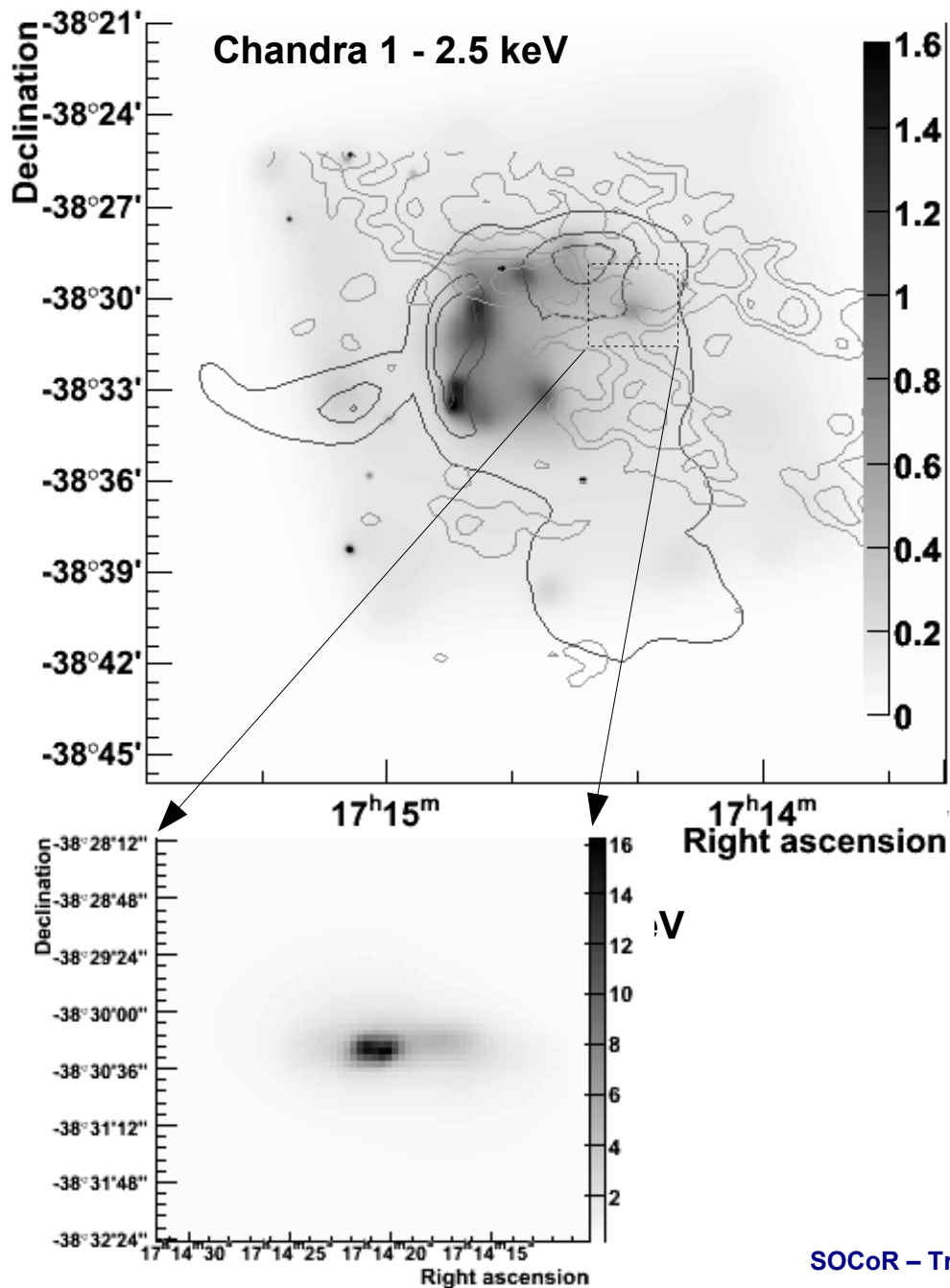
# Summary

- **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
  - Another associations detected by MAGIC & VERITAS: IC443
- **A leptonic scenario cannot be excluded for some of them**
  - => But accumulation of indications that CRs are accelerated within SNRs

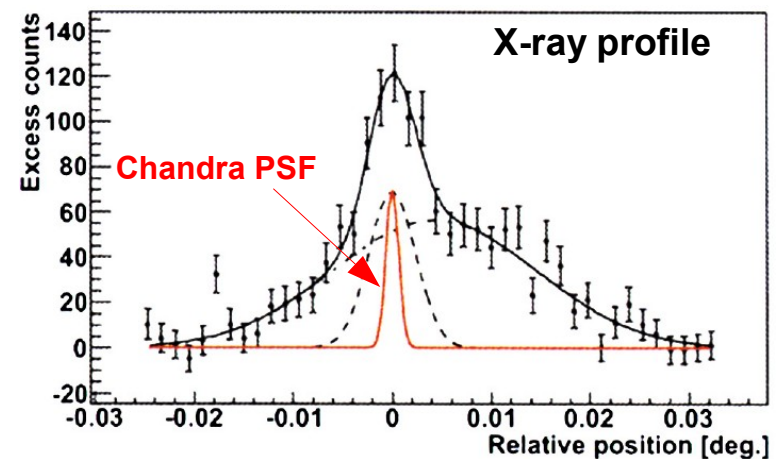




# Or a PWN?



- Recent X-ray observations by Chandra & XMM-Newton
  - => Complex region in X-rays
- Thermal emission inside the remnant
- PWN candidate discovered coincident with the remnant
  - Possibly associated with CTB 37A
  - Spin-down luminosity around  $10^{37}$  erg/s
  - =>  $\sim 0.1\%$  conversion in gamma-rays



Aharonian et al. A&A 490 685A (2008)