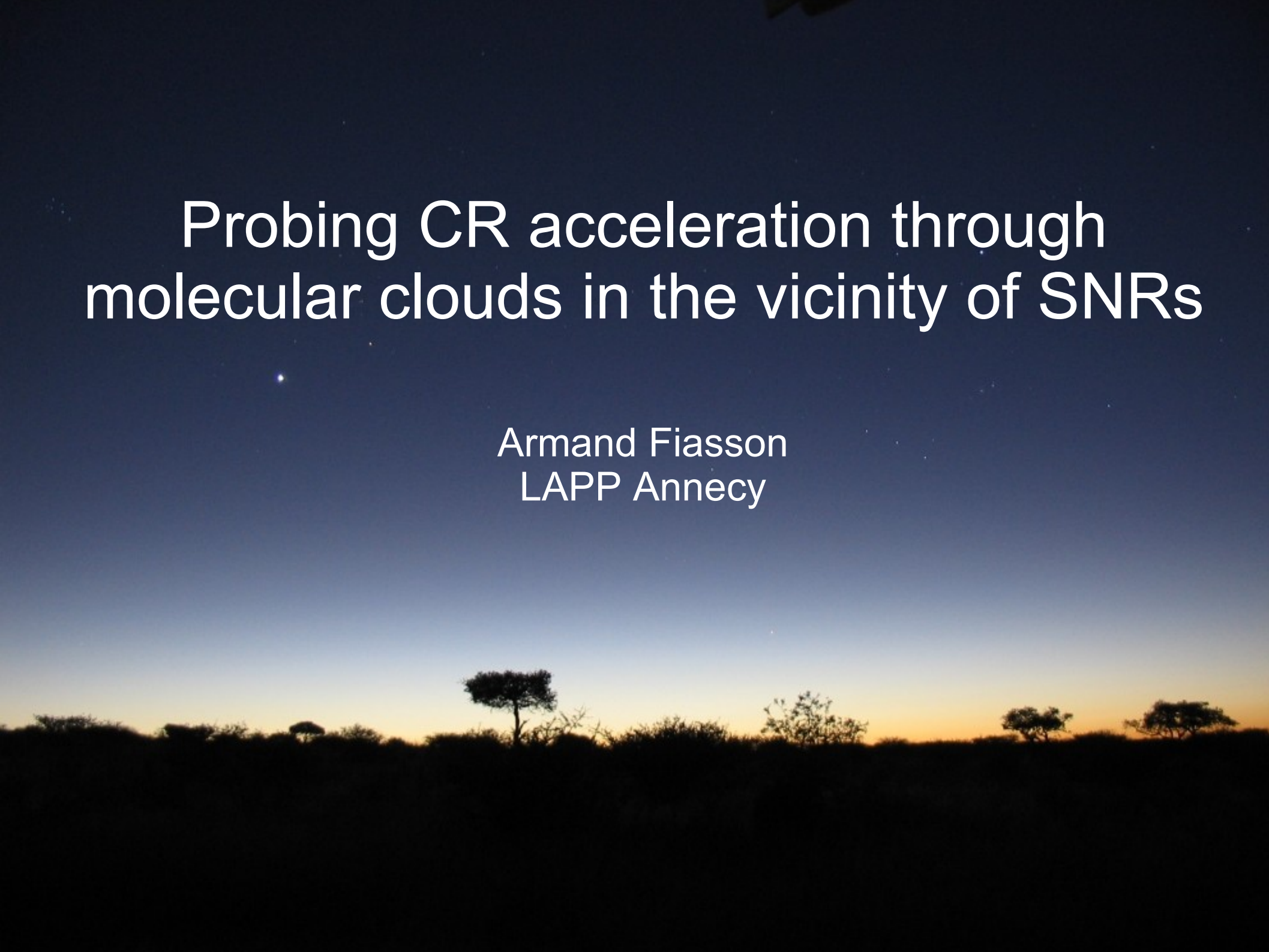
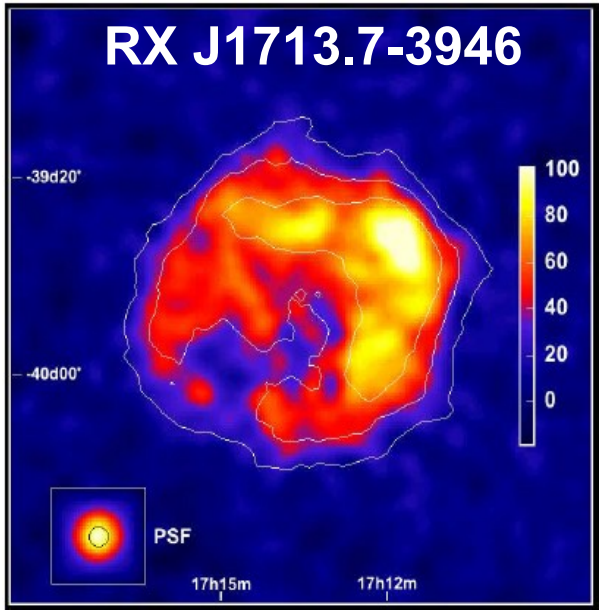


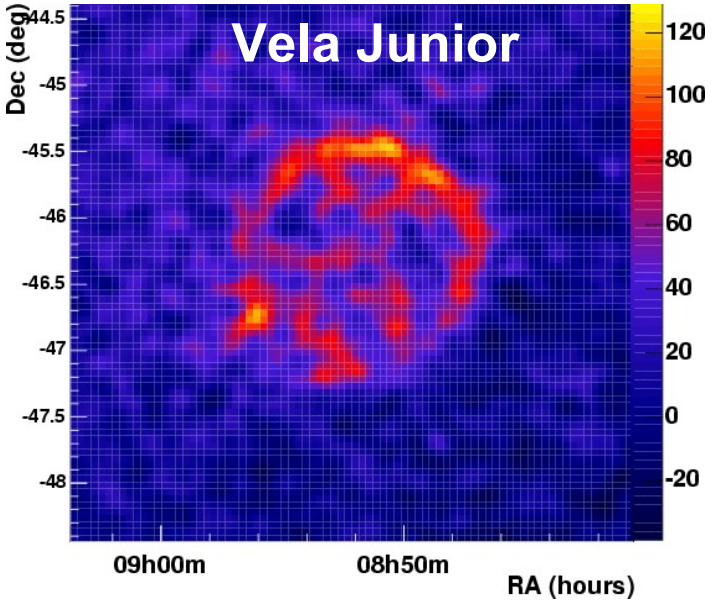
Probing CR acceleration through molecular clouds in the vicinity of SNRs

Armand Fiasson
LAPP Annecy

Particle acceleration in shell-type SNRs



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



Aharonian et al. ApJ 661, 236 (2007)

- **Shell-type SNRs: currently the best candidate**

  => Still requires an unambiguous experimental confirmation

  => VHE gamma-rays are the optimal tracers to confirm this scenario

- **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 (~ a few μG)
  - Hadrons in a higher magnetic field (~ 100 μG, predicted by theoreticals models)

  => a hadrons acceleration is not yet confirmed

The molecular clouds as a probe for CRs

- **Matter target required to produce gamma-ray emission by hadrons**
  - Enhancement of the CR density in the vicinity of an accelerator
  - 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

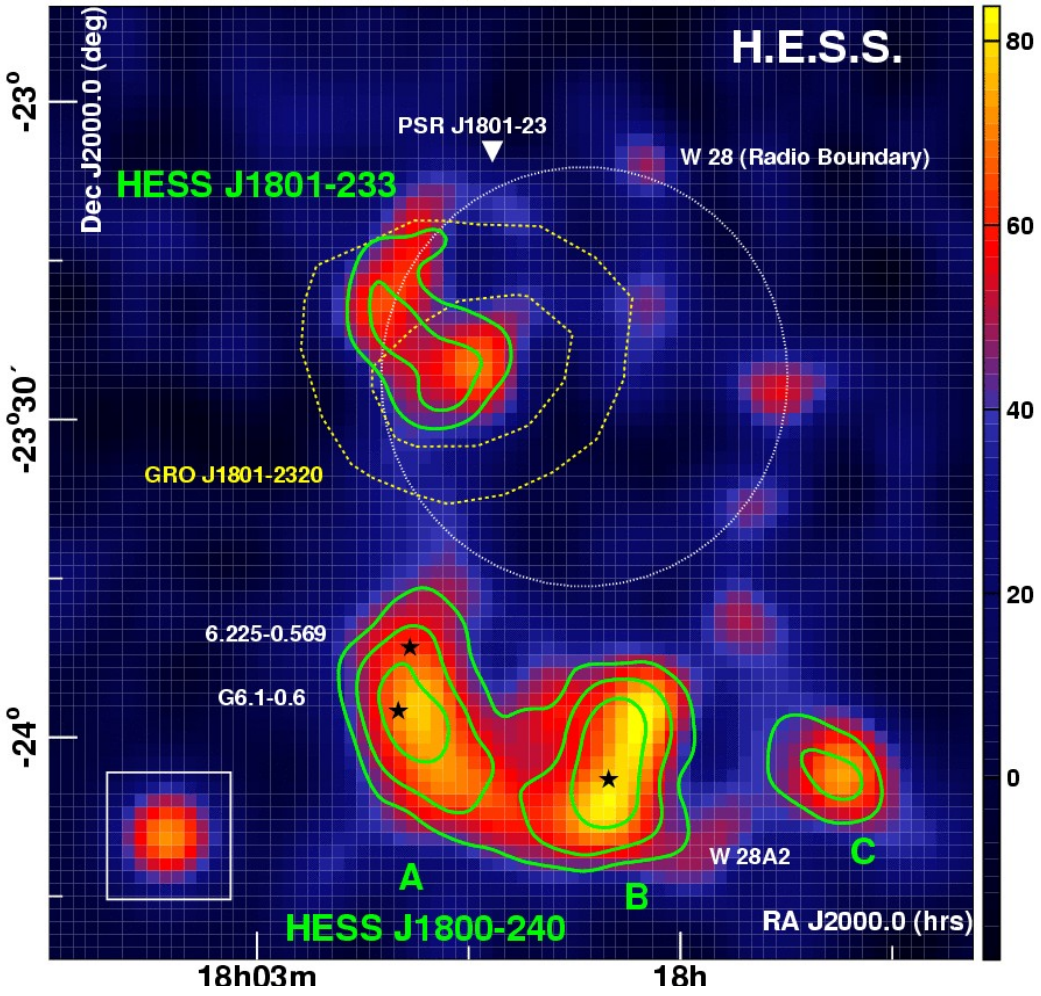
- **Molecular cloud detection**
  - Rotational lines in radio (CO, CS)

    => line intensity proportional to H_2 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

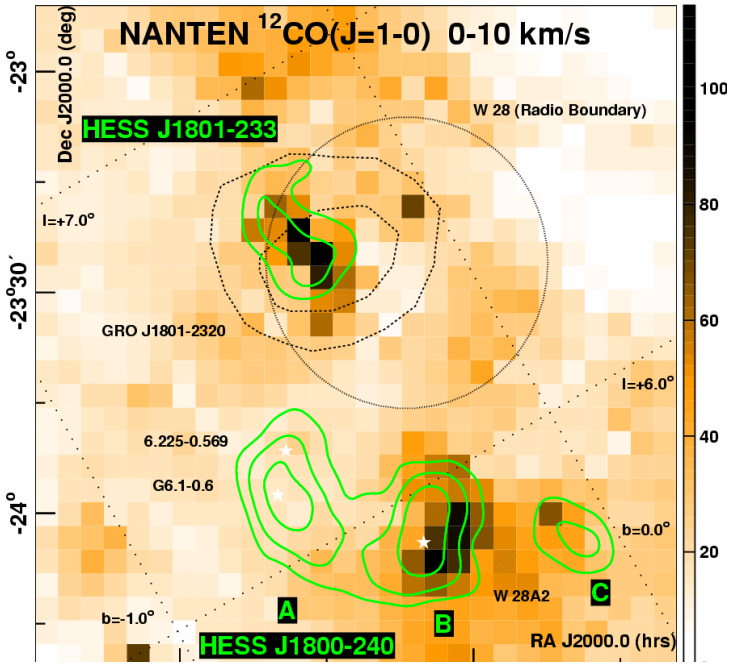


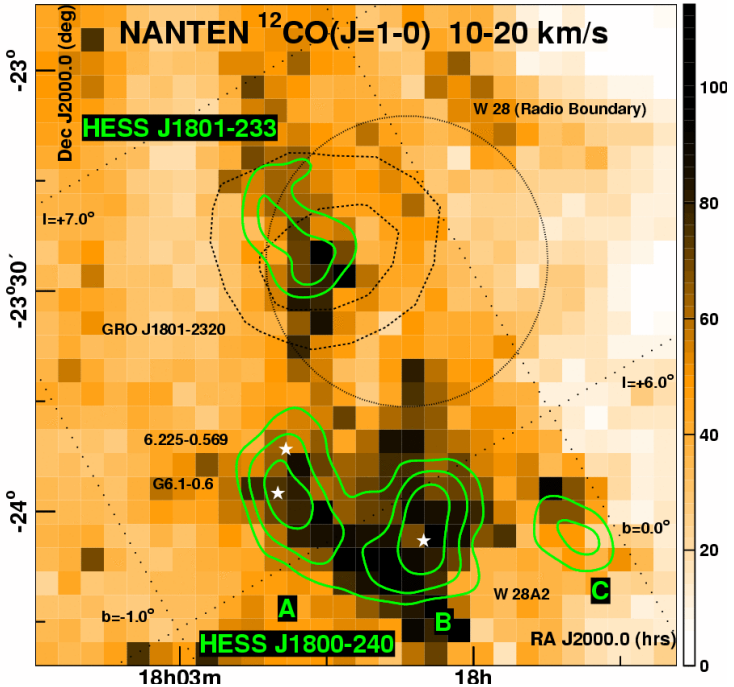
- **Complex region in MWL**
  - Several SNRs
  - Star formation regions
  - H_{II} regions
- **Several VHE gamma-ray sources**
  - Extended emissions
  - Photon index $\Gamma \sim 2.5 - 2.7$

  => 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→0) observations**
  - Presence of OH masers (1720 MHz)
  - Northern gamma-ray emission coincident

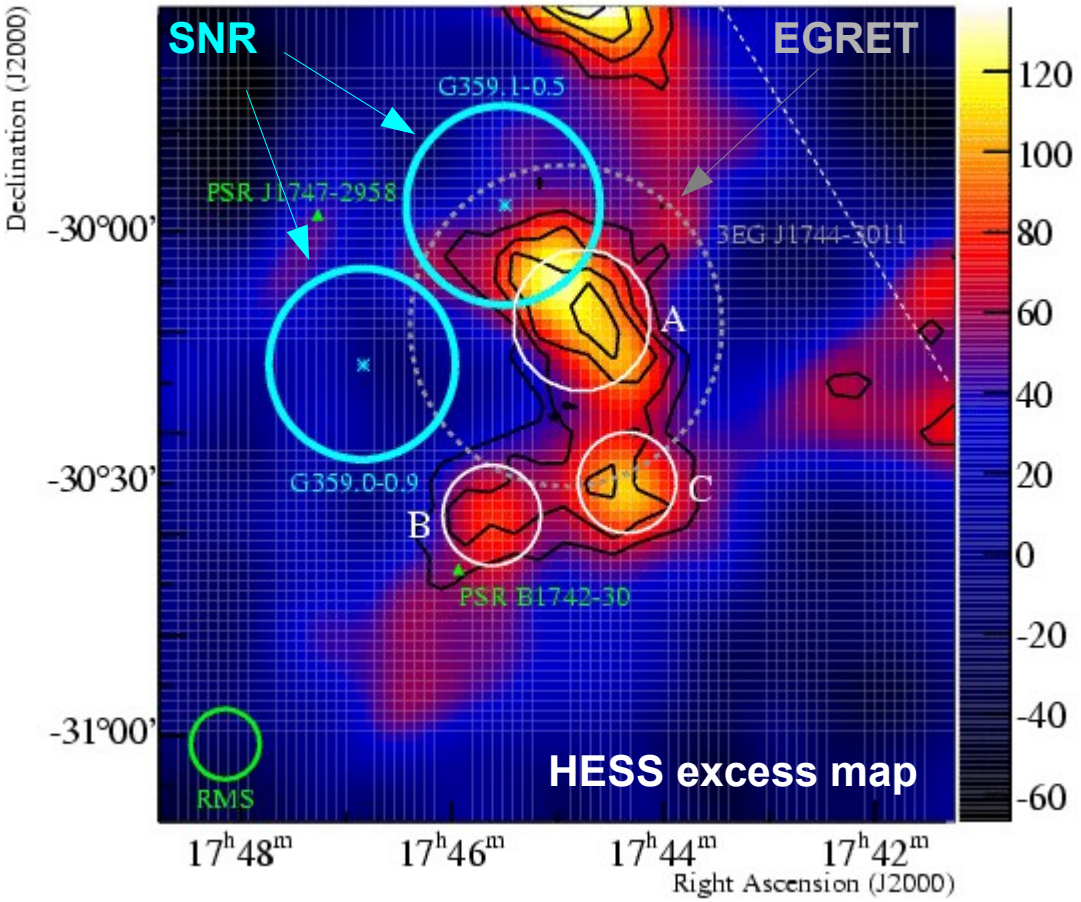
  => Energetics compatible with CRs accelerated within the SNR and interacting with the cloud

- **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)

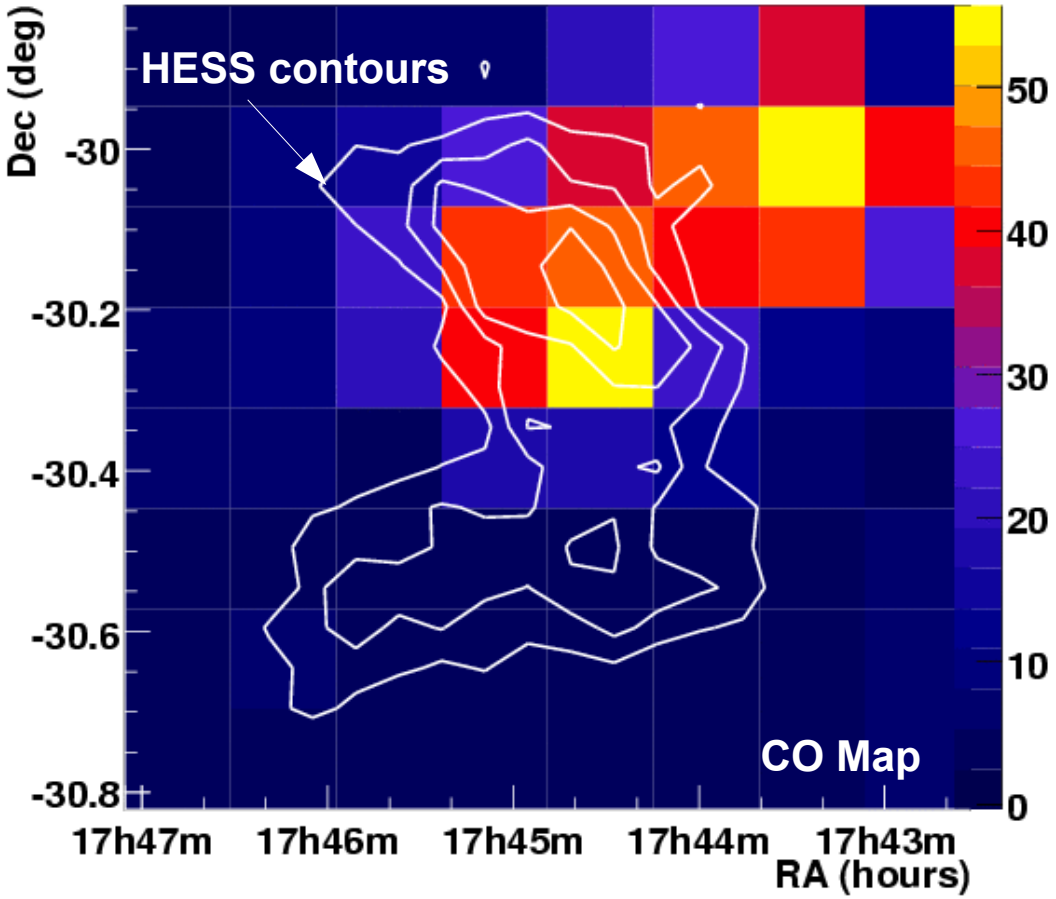
HESS J1745-303



- **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?

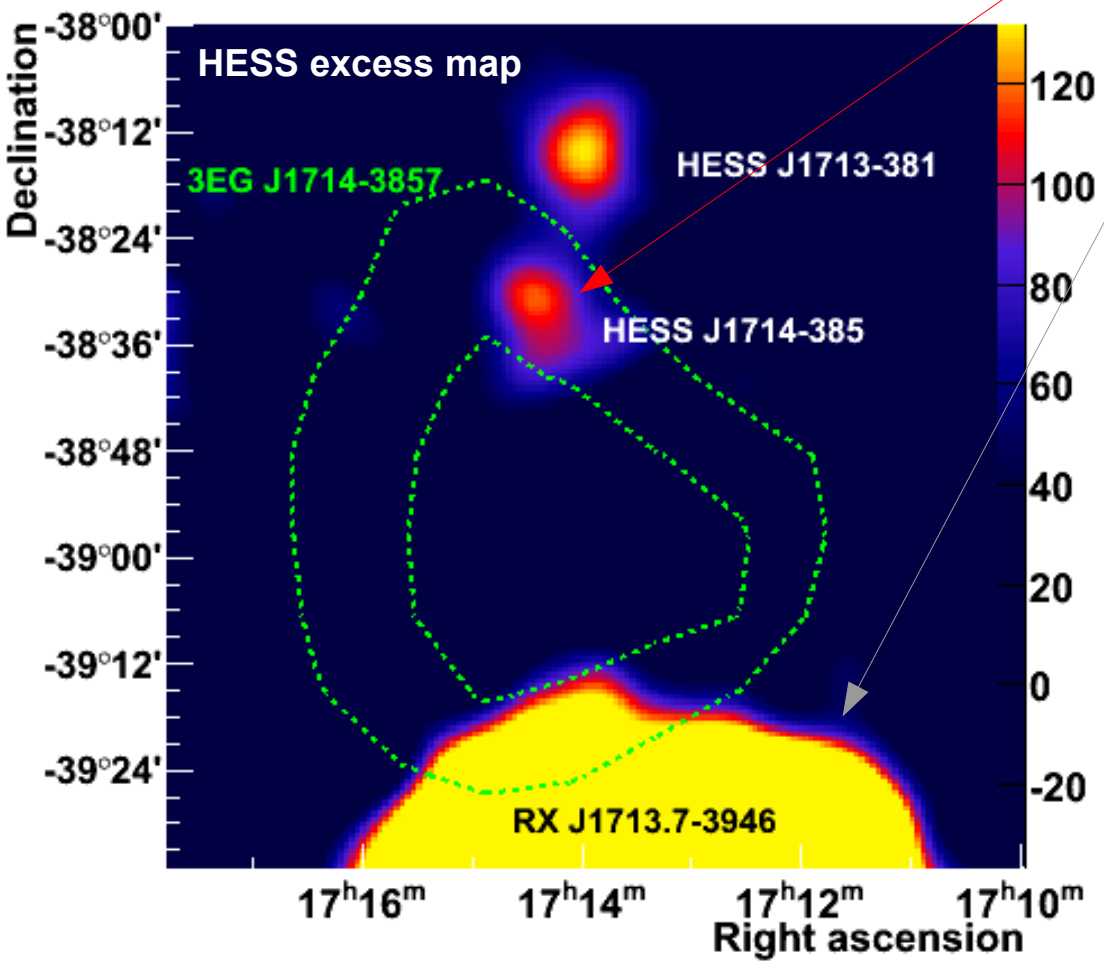


- **Interaction of the SNR G359.1-0.5 blast wave with a matter ring**
  - OH masers at 1720 MHz towards the boundary of the SNR
  - CO observations reveals a coincidence of a fraction of this ring with the gamma-ray source
- **Hadronic scenario within this cloud?**
  - Energetics compatible with CRs from the SNR interacting with the cloud

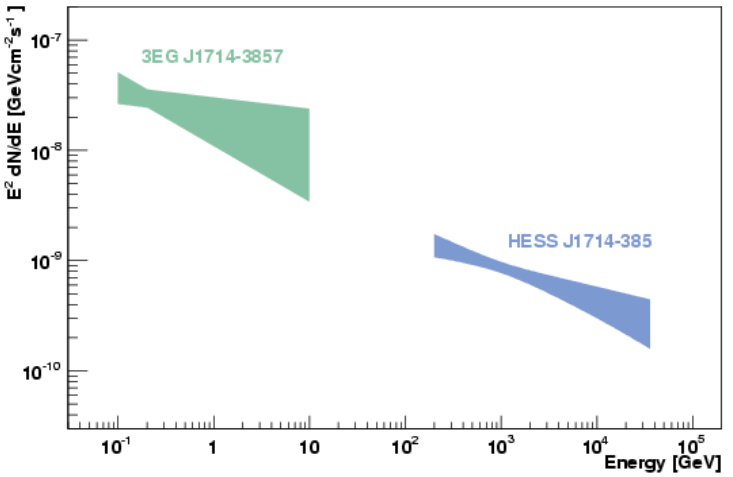
  => ~ 30% of the SN explosion energy into CRs

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

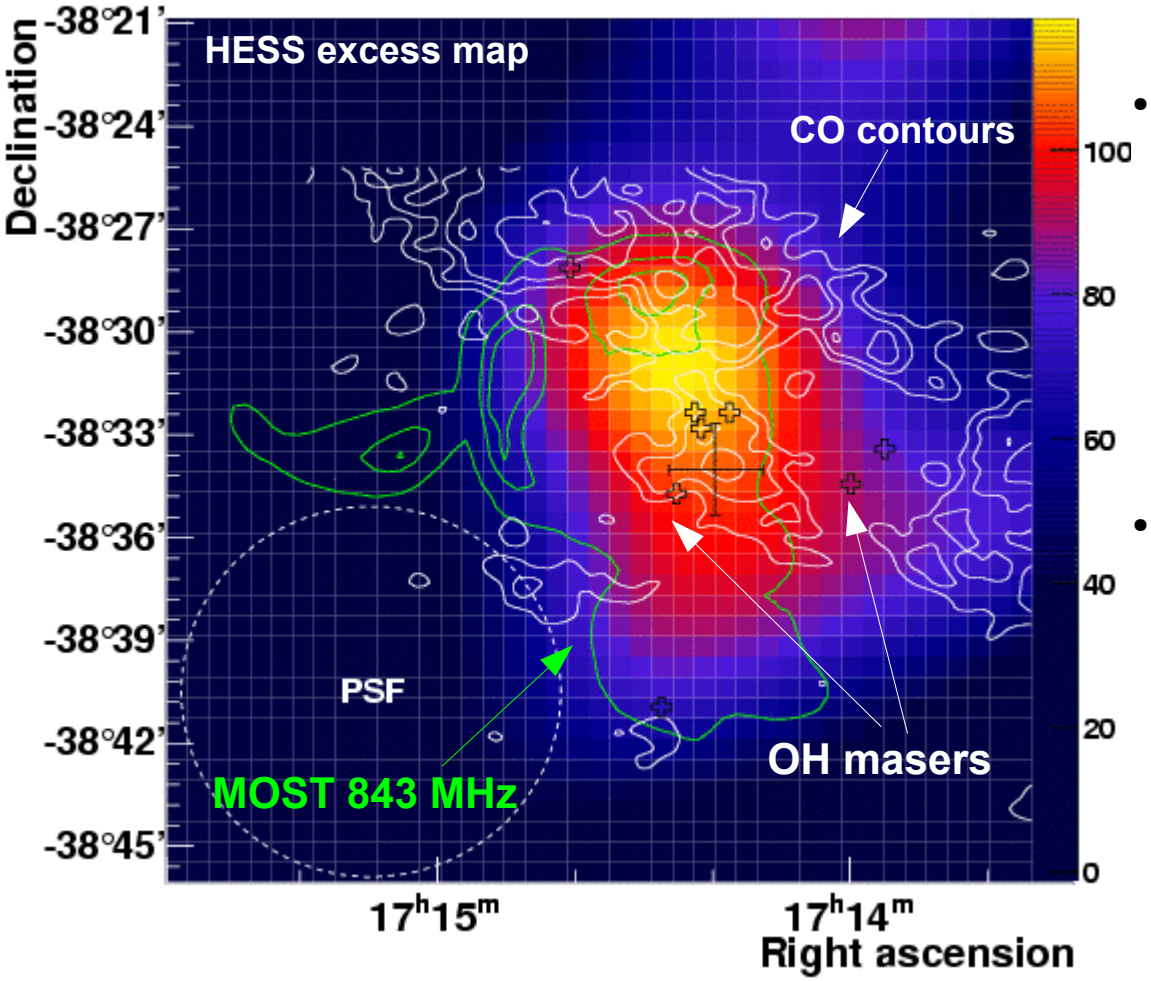
HESS J1714-385 & CTB 37A



- **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 compatibilty



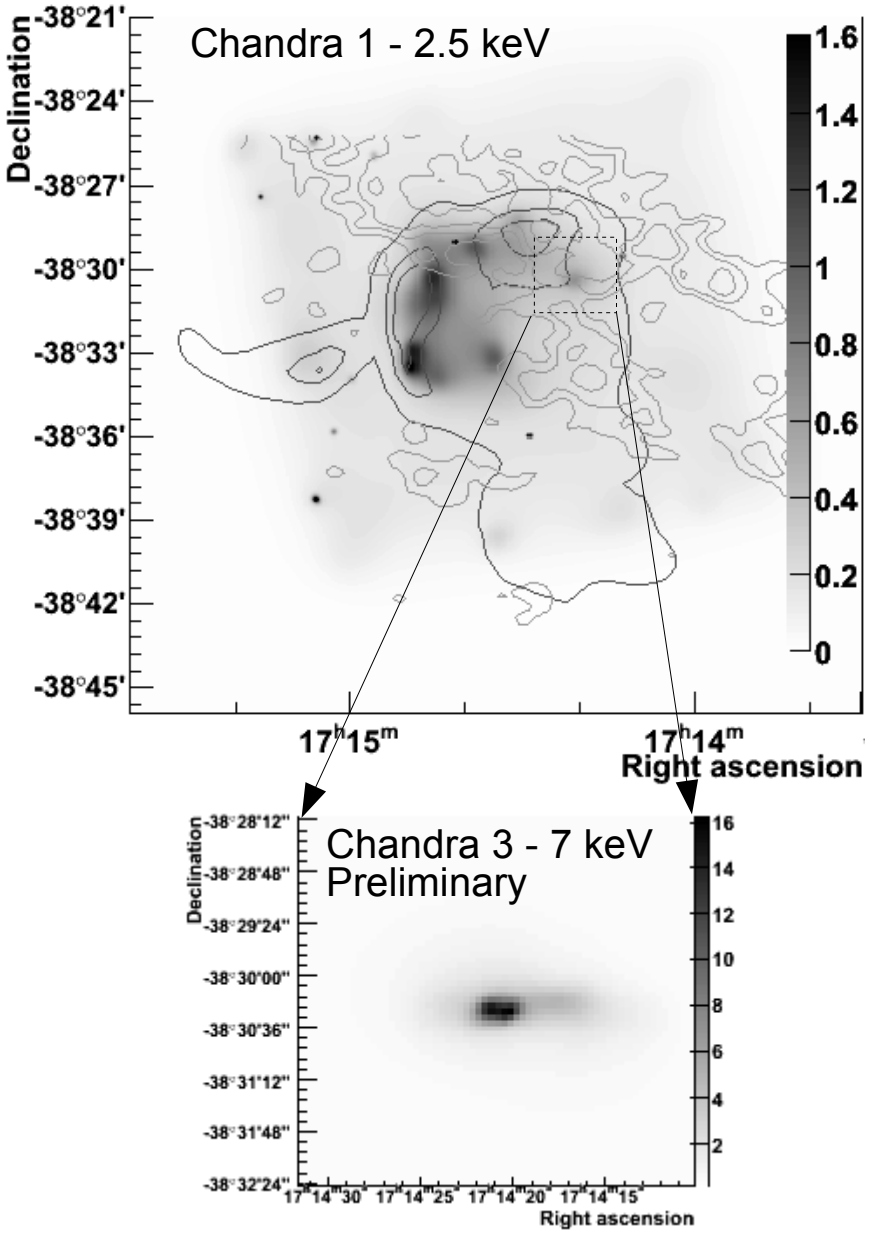
CRs in molecular clouds?



- **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?



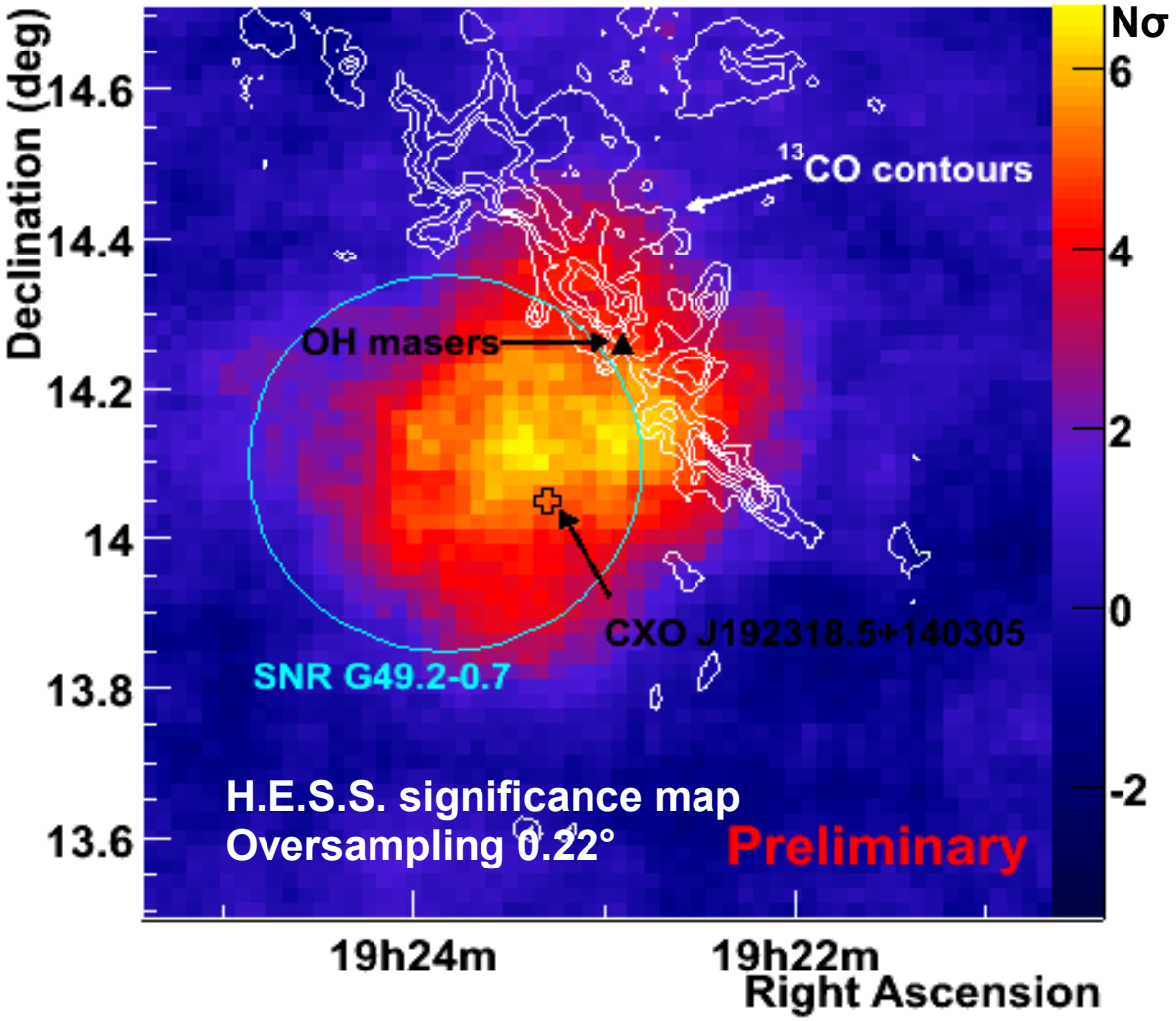
- **Recent X-ray observations**
  - Chandra & XMM-Newton
  - Complex region in X-rays
- **Thermal emission discovered from the interior of the remnant**
- **PWN candidate discovered coincident with the remnant**
  - Possibly associated with CTB 37A
  - X-ray luminosity implies a spin-down luminosity around 10^{37} erg/s

=> ~0.1% conversion in gamma-rays

=> scenario possible

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

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

- Integrated flux over 1 TeV equivalent to 3% of the flux from the Crab Nebula

- Several possible associations: PWN, star forming region and shocked molecular cloud

Summary

- **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 assocations revealed by OH masers at 1720 MHz
  - EGRET counterpart possible to lower energy for most of them
  - A hadronic scenario is possible for each case

  => Gamma-ray flux compatible with CRs accelerated by the SNR

- **But a leptonic scenario cannot be excluded for most of them**

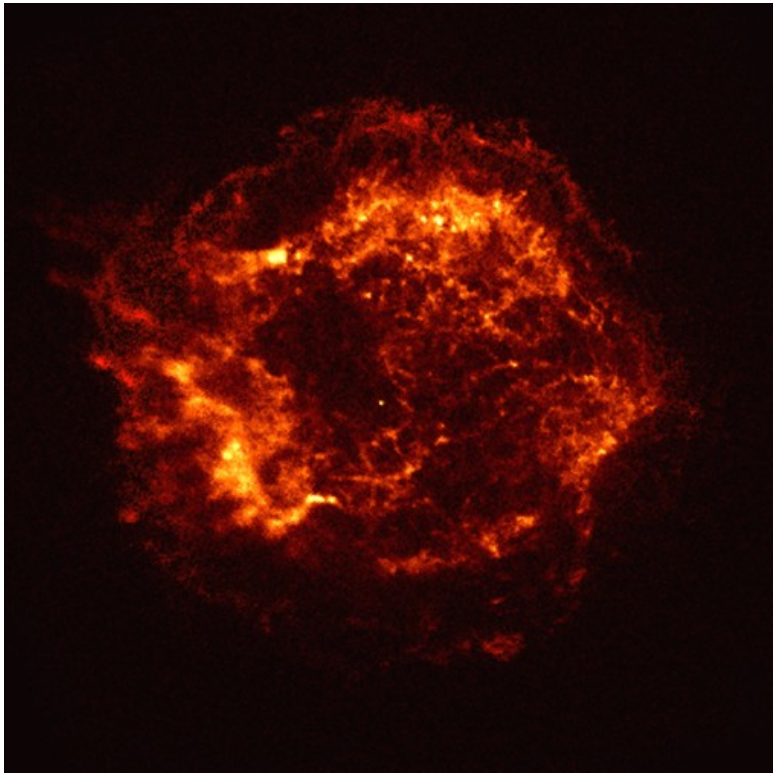
  => But accumulation of indications that CRs are accelerated within SNRs

  => Follow-up search for a gamma-ray emission from shocked molecular clouds could be an efficient complement to Fermi observations at lower energy

Back-up

Supernova remnants and cosmic rays

- **Historical candidate for particle acceleration within our Galaxy**
  - Enough energy to compensate propagation losses



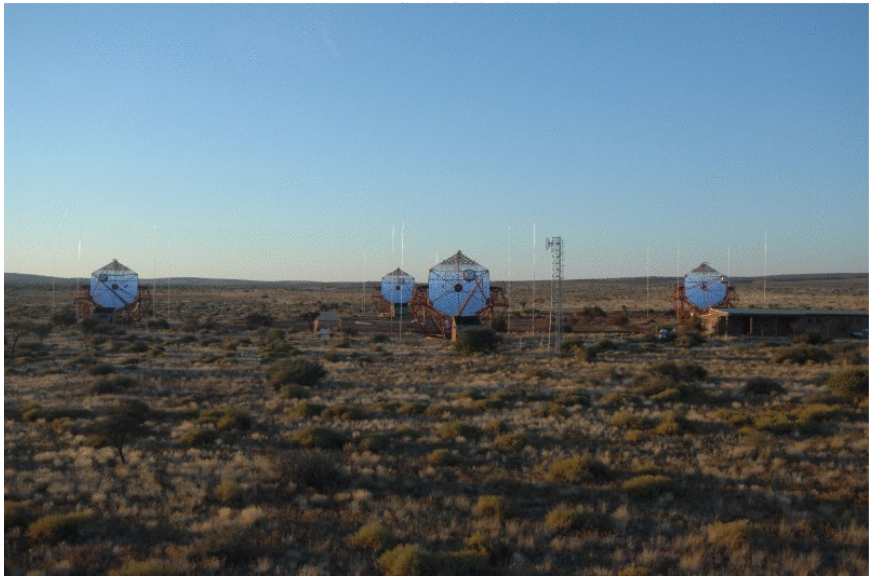
- **Acceleration mechanism adapted from the Fermi mechanism**
  - Shell type supernova remnants

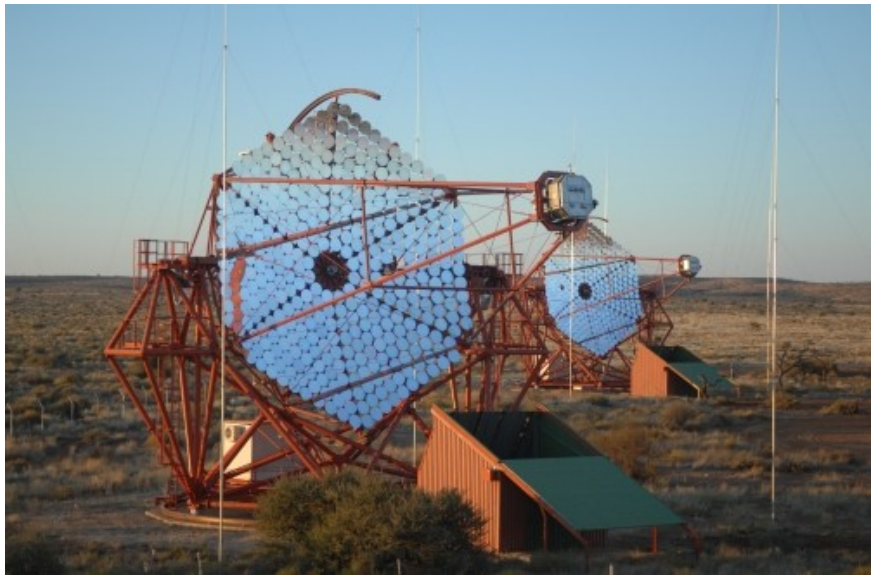
  => blast wave through the ISM
  - Energy gain by multiple passage through the supersonic shock
  - Conversion ~10% of the explosion energy into CRs expected
- **Currently the best candidate**

  => 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: $\Delta\theta \sim 0.1°$ and $\Delta E/E \sim 16\%$

- **Located in the Khomas Highlands of Namibia**
  - Southern hemisphere

  => Ideal position to oberve the inner Galactic plane where most of the emitters are located

- **Construction completed in December 2003**

  => more than 4 years in full operation mode

HESS J1923+141: Possible counterparts

- **Morphological study is in progress**
  - Test of variability of the index over the source

- **Several possible counterparts**
  - **PWN detected by Chandra CXO J192318.5+1403035**
    - Spin-down luminosity implied by the X-rays ~ 3×10^{36} erg/s at 6 kpc

    => conversion of less than 1/1000 of this luminosity into gamma-rays

  - **Shocked molecular clouds in the vicinity of SNR G49.2-0.7**
    - Presence of 1720 MHz OH masers coincident with the rim of the remnant
    - Elongated molecular cloud coincident with the rim of the remnant and the masers

    => hadronic scenario possible

=> new H.E.S.S. source coincident with a OH maser emitting SNR