HESS J1023-575: Very-high-energy gamma rays associated with a young stellar cluster

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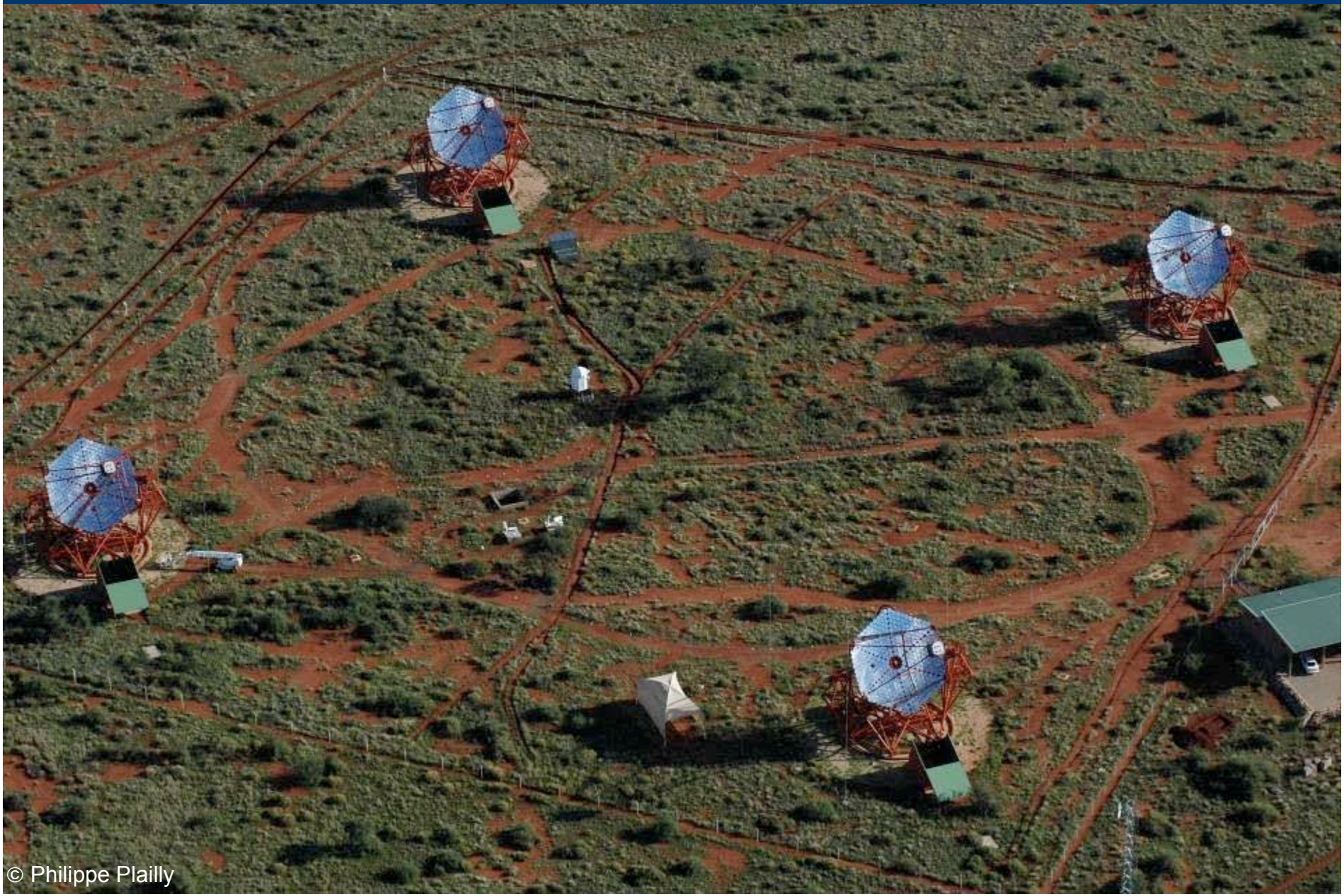
for the H.E.S.S. collaboration

FIRST GLAST SYMPOSIUM, Feb'07

Outline:

- The Scenery
  (why Westerlund 2 ?)
- The H.E.S.S. results
- Interpretations
  (what might work, what will not)

H.E.S.S. - The instrument and the collaboration



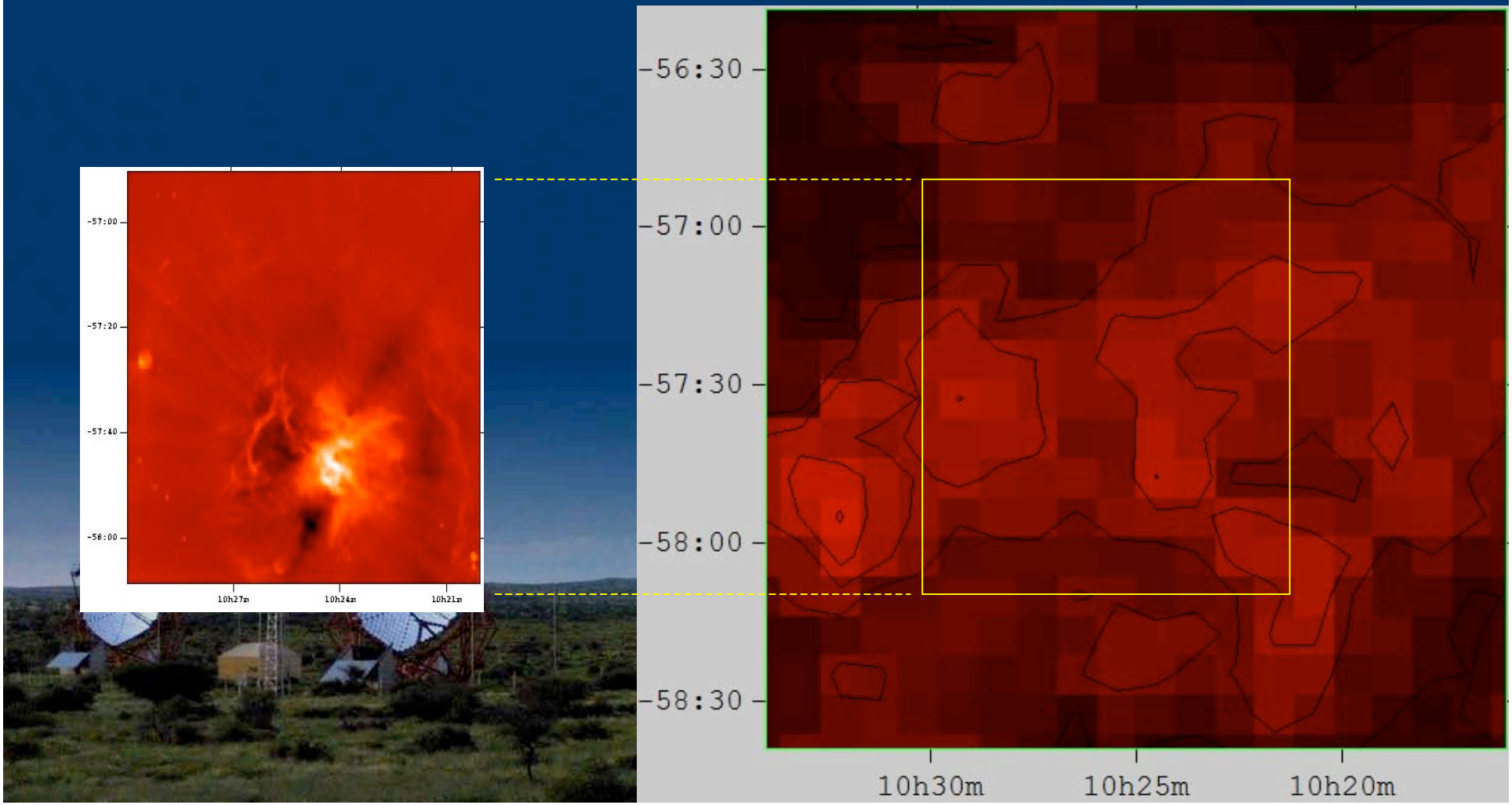
Basic Scenery (radio -> X-ray)

radio continuum

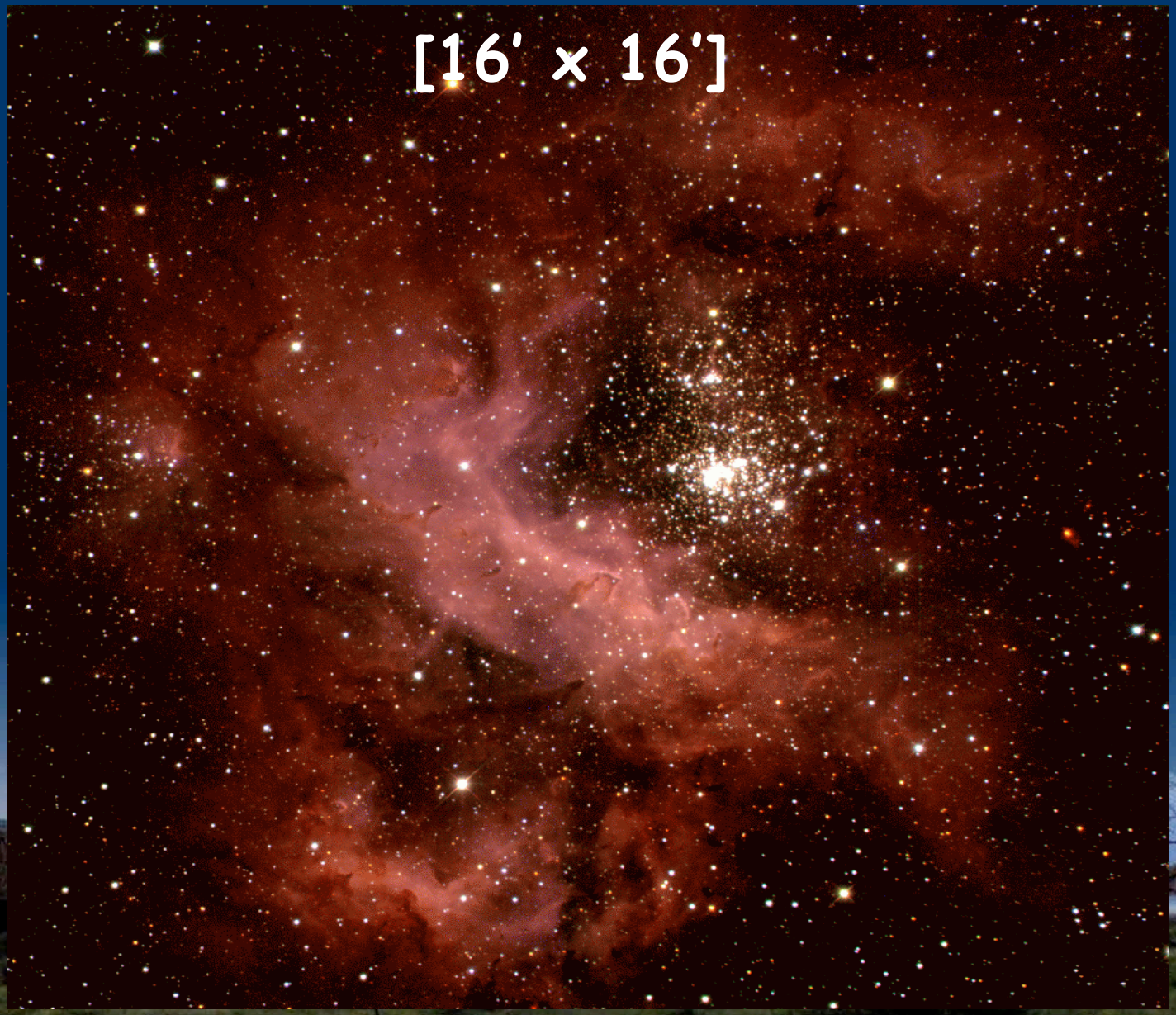
MOST 843 MHz

CO

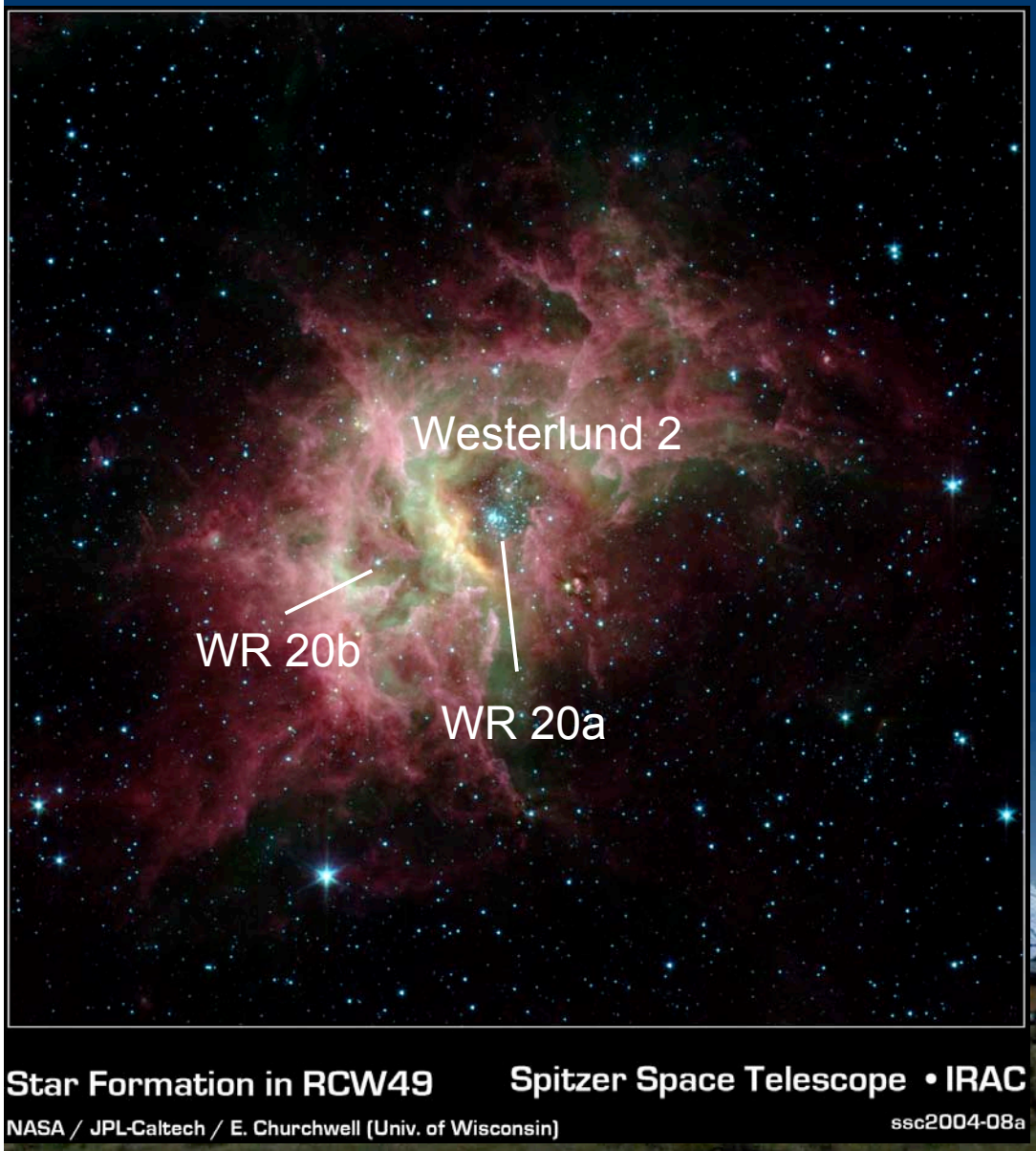
CfA 2001



2MASS (J,H,K-band composite)

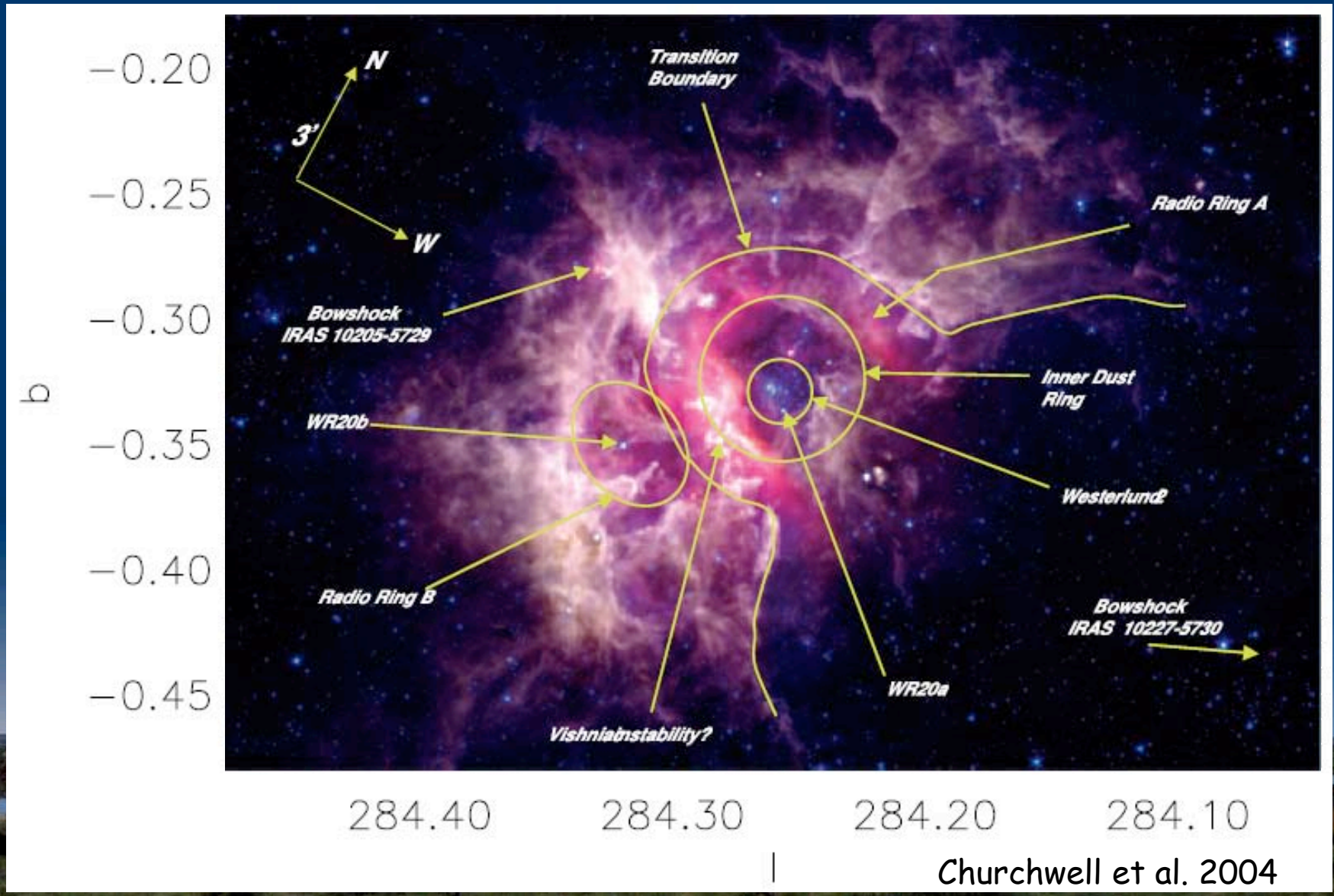


The stellar cluster Westerlund 2
SPITZER 3.6/5.8/8 micron



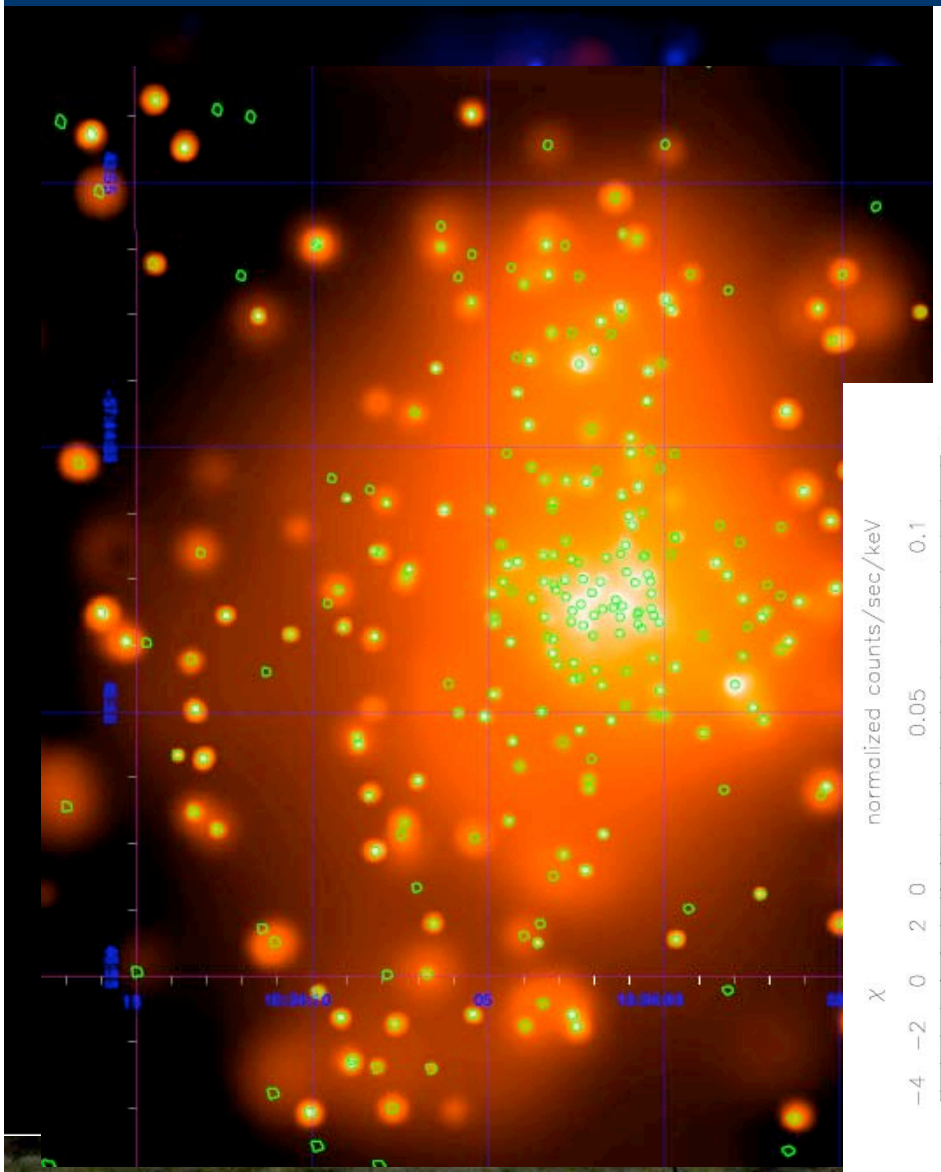
- ionizing cluster of the prominent HII complex RCW 49
- evidence for ongoing star formation
- age estimate 2-3 Myrs
- stellar winds blow cavities around massive Wolf-Rayet (WR) stars
-

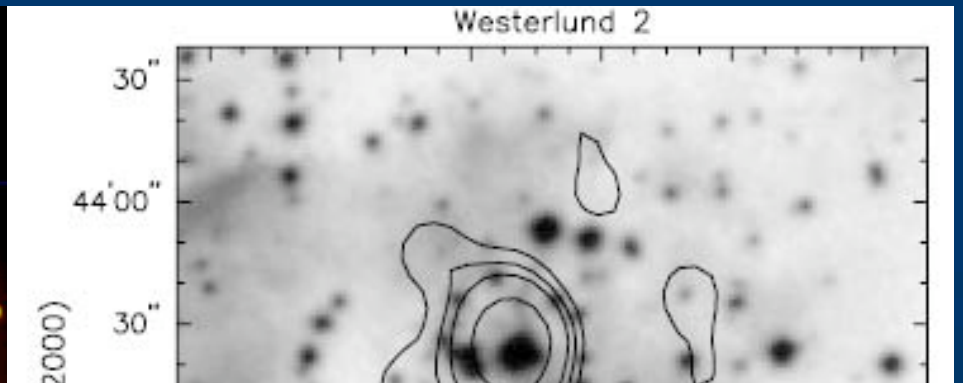
SPITZER 3.6/5.8/8 micron

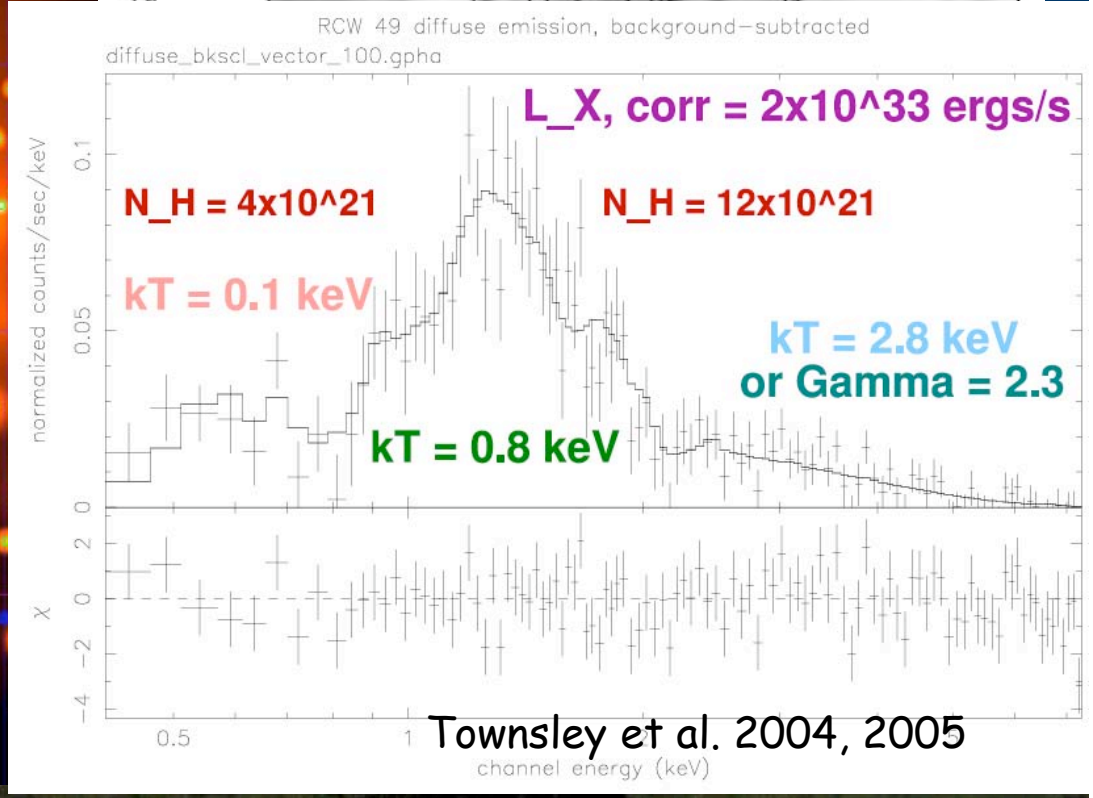


Churchwell et al. 2004

Chandra 36 ksec [17' x 17']





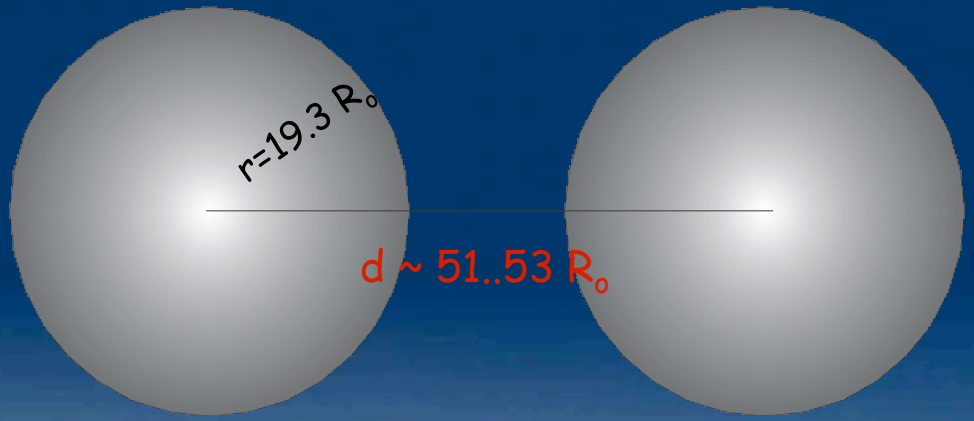


Townsley et al. 2004, 2005

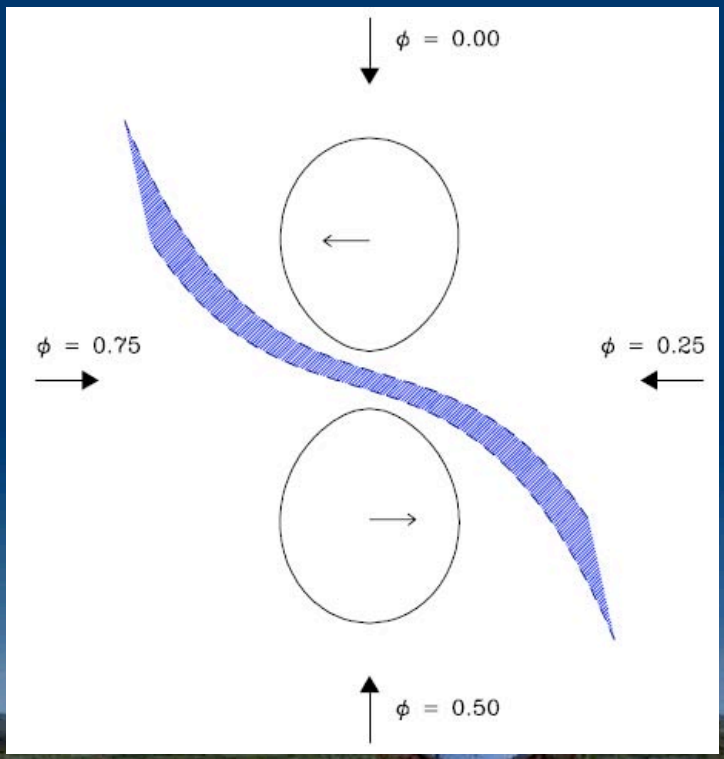
Therein: young, hot & massive stars

-> 8 evolutionary earlier then O7, 2 WRs, and in particular WR20a, the most massive measured stars in our Galaxy (WN6+WN6 binary)

orbital period: 3.686 d



Parameter	Value
Mass ($M_\odot$)	82.7 ± 5.5 (primary)
Mass ($M_\odot$)	81.9 ± 5.5 (secondary)
L_{bol} ($L_\odot$)	$(1.15 \pm 0.15) \times 10^6$
T_{eff} (K)	43 000 ± 2000
$\dot{M}$ ($M_\odot$ yr^{-1})	8.5×10^{-6}
R_* ($R_\odot$)	19.3 ± 0.5



Rauw et al. 2005

The H.E.S.S. observations

(1) Location & Significance

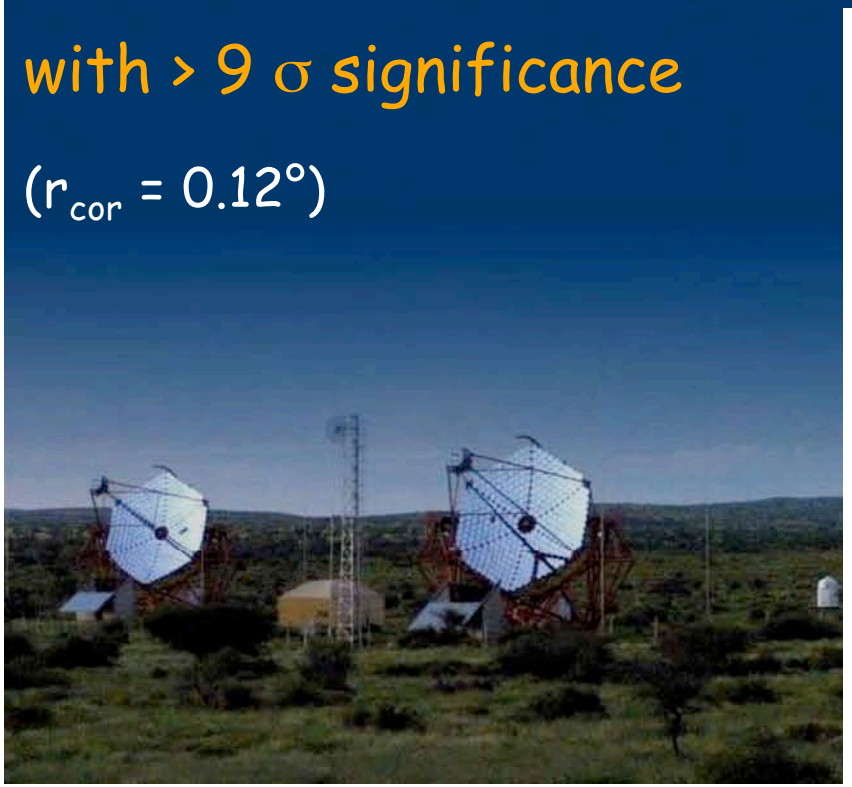
~ 14h data, 12.9 h lifetime, majority taken between March and June 2006, at 36°... 53° zenith angles -> E_{thres} = 380 GeV

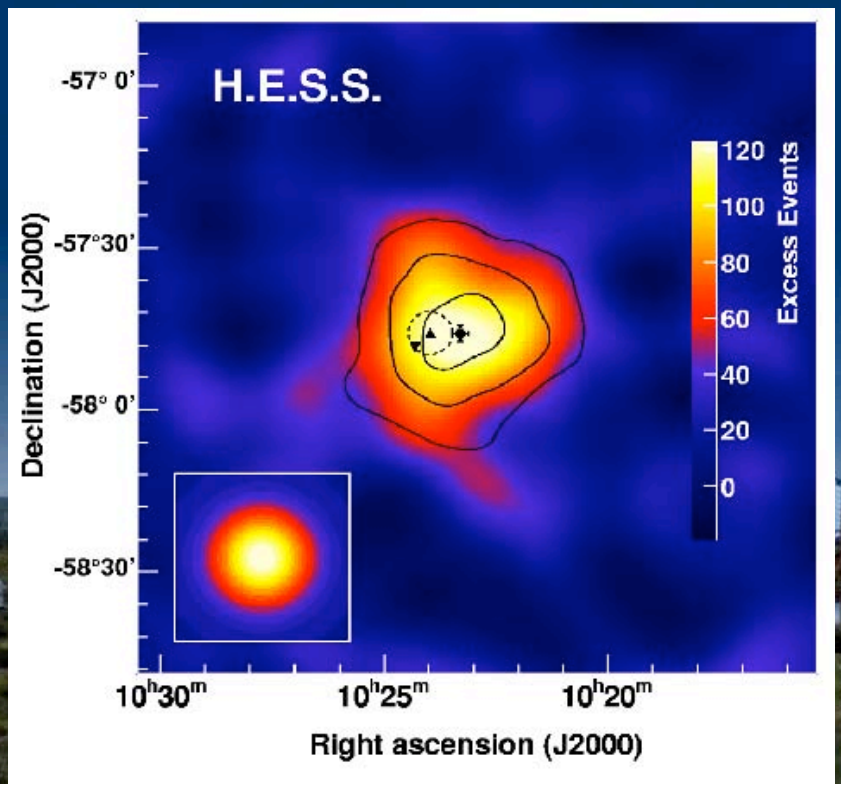
Excess at the location

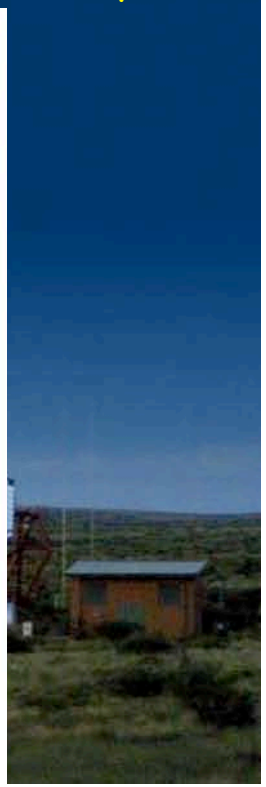
RA: 10h23m18s ± $12s_{stat}$ DEC: -57°45′50″ ± 1′30″$_{stat}$ (±20″$_{syst}$)

with > 9 σ significance

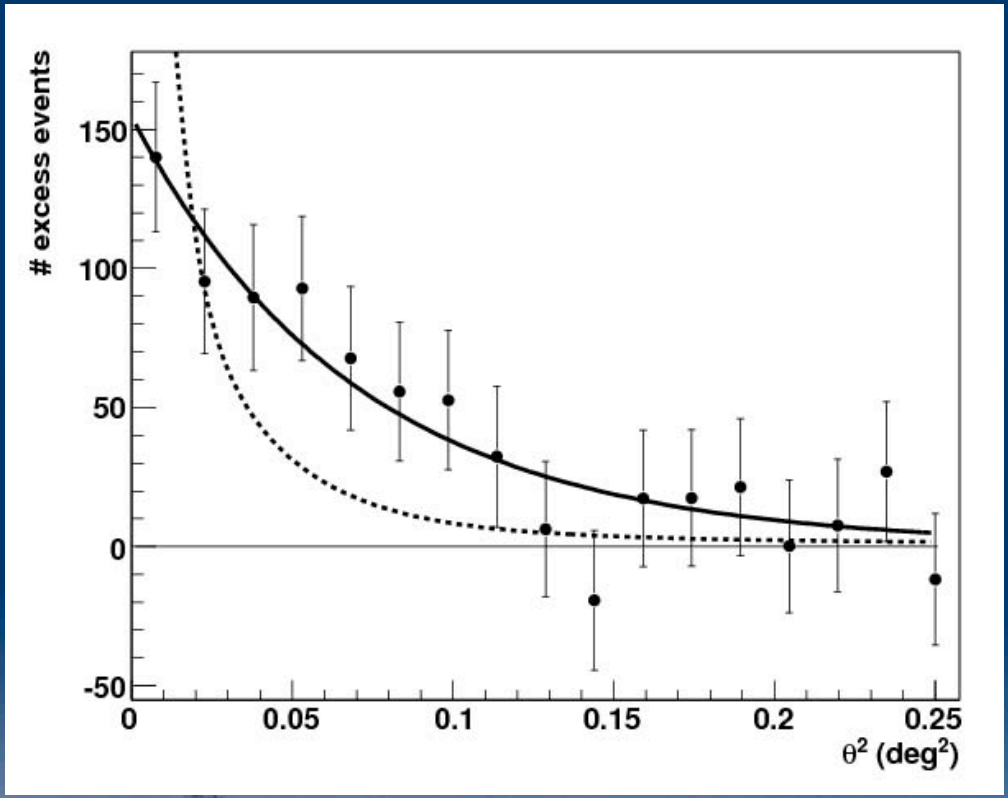
(r_{cor} = 0.12°)







The H.E.S.S. observations
(2) Morphology

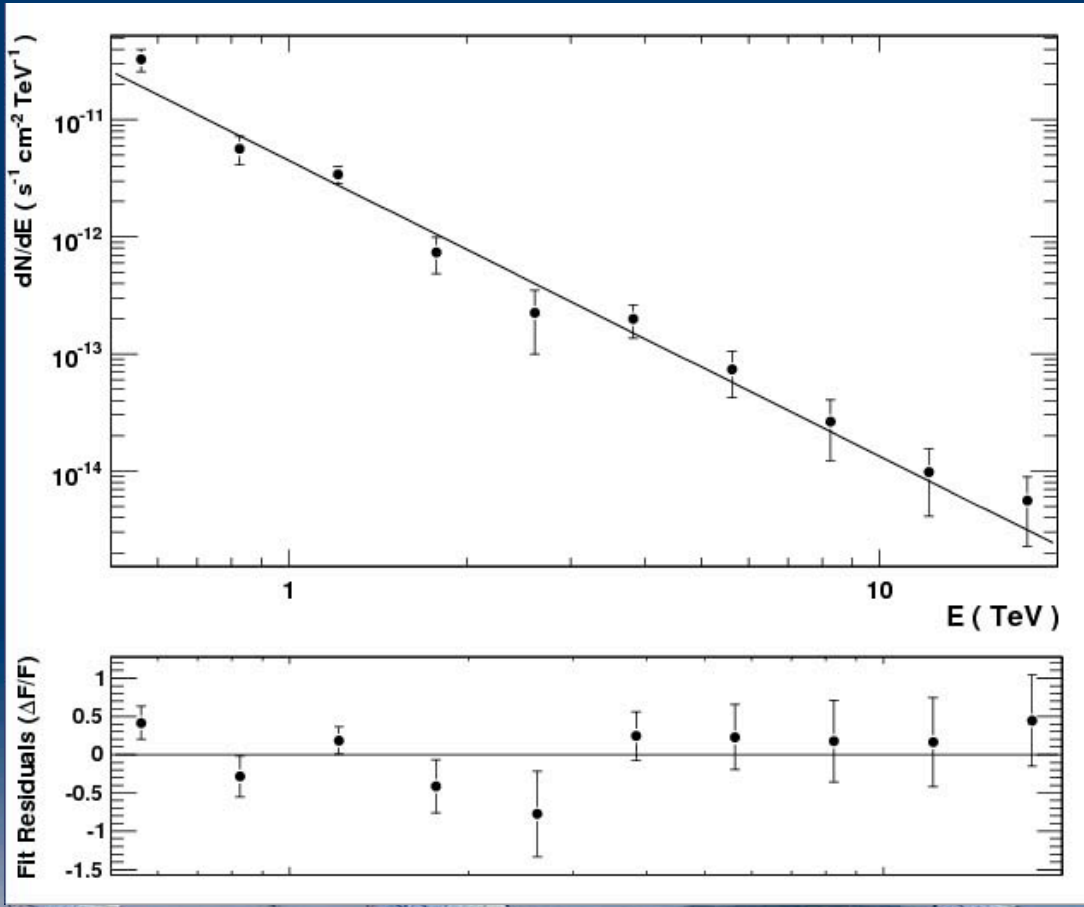


dashed line:
PSF for point source

solid line:
is a fit of the PSF
folded with a Gaussian

-> source extended with $\sigma = 0.18° \pm 0.02°$

The H.E.S.S. observations
(3) Spectrum & Flux



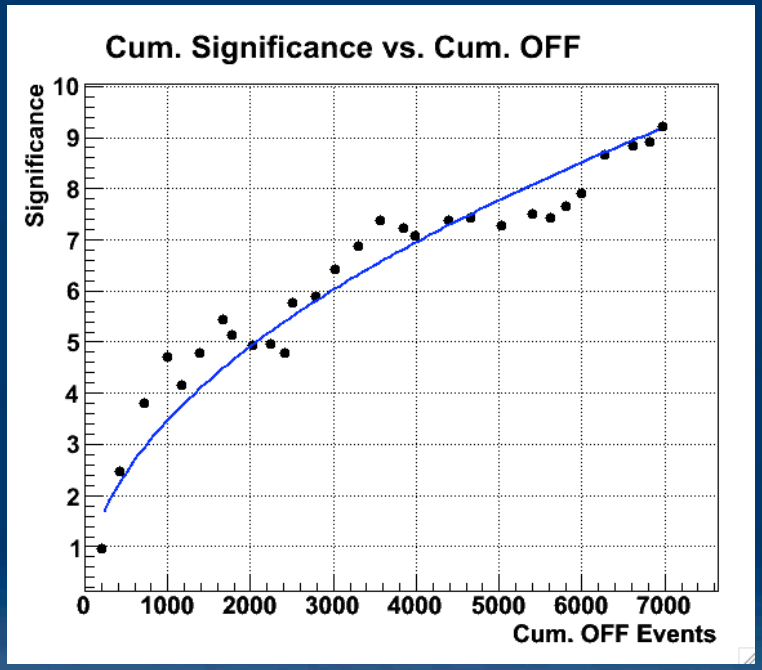
photos taken from a 85% containment radius (0.39°) around the best fit position

power law with a photon index

$\Gamma = 2.53 \pm 0.16_{stat} \pm 0.1_{syst}$

Flux: $F_{E>380} = 1.3 \pm 0.3 \times 10^{-11}$ cm^{-2} s^{-1}

The H.E.S.S. observations
(4) Variability & Periodicity

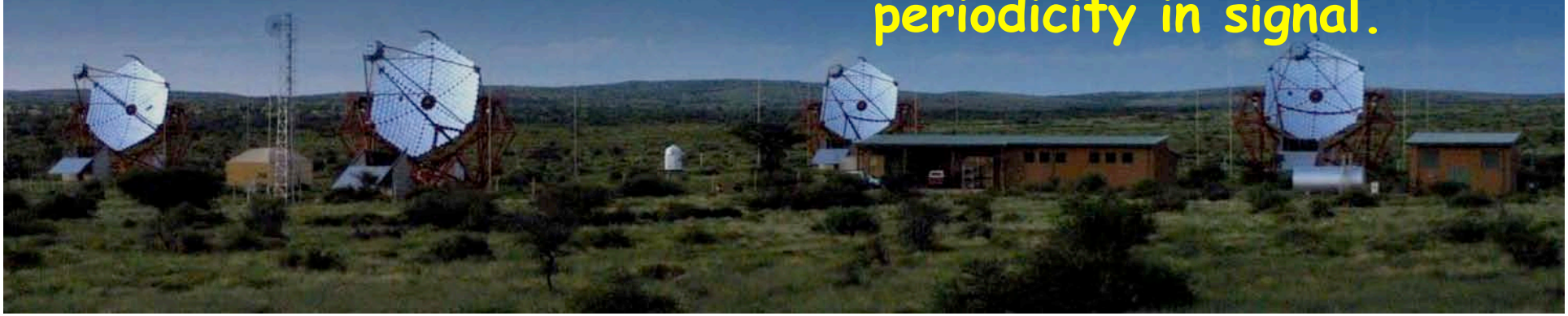


Steadily accumulating significance over time

(plotted here vs. cumulative OFF events)

No evidence for significant flux variability

No evidence for periodicity in signal.



What to do with it?

Wide range of scenarios …

Colliding Wind Scenarios (leptonic)

γ-ray production (optically-thin := no casc) IC of relativistic electrons with the dense photospheric stellar radiation fields in the wind-wind collision zone [Eichler & Usov 93, White & Chen 95, Benaglia & Romero 03, A. Reimer et al. 06]

Colliding Wind Scenarios (hadronic)

γ-ray as neutral pion decay products, where mesons produced by inelastic interactions of relativistic nucleons with the wind material [White & Chen 92, Benaglia et al. 01, Benaglia & Romero 03, A. Reimer et al. 06]

IC pair cascades initiated by high-energy neutral pion decay photons (from nucleon-nucleon interactions in the stellar winds) [Bednarek 2005]

Collective Wind Scenario in young stellar cluster or OB-association

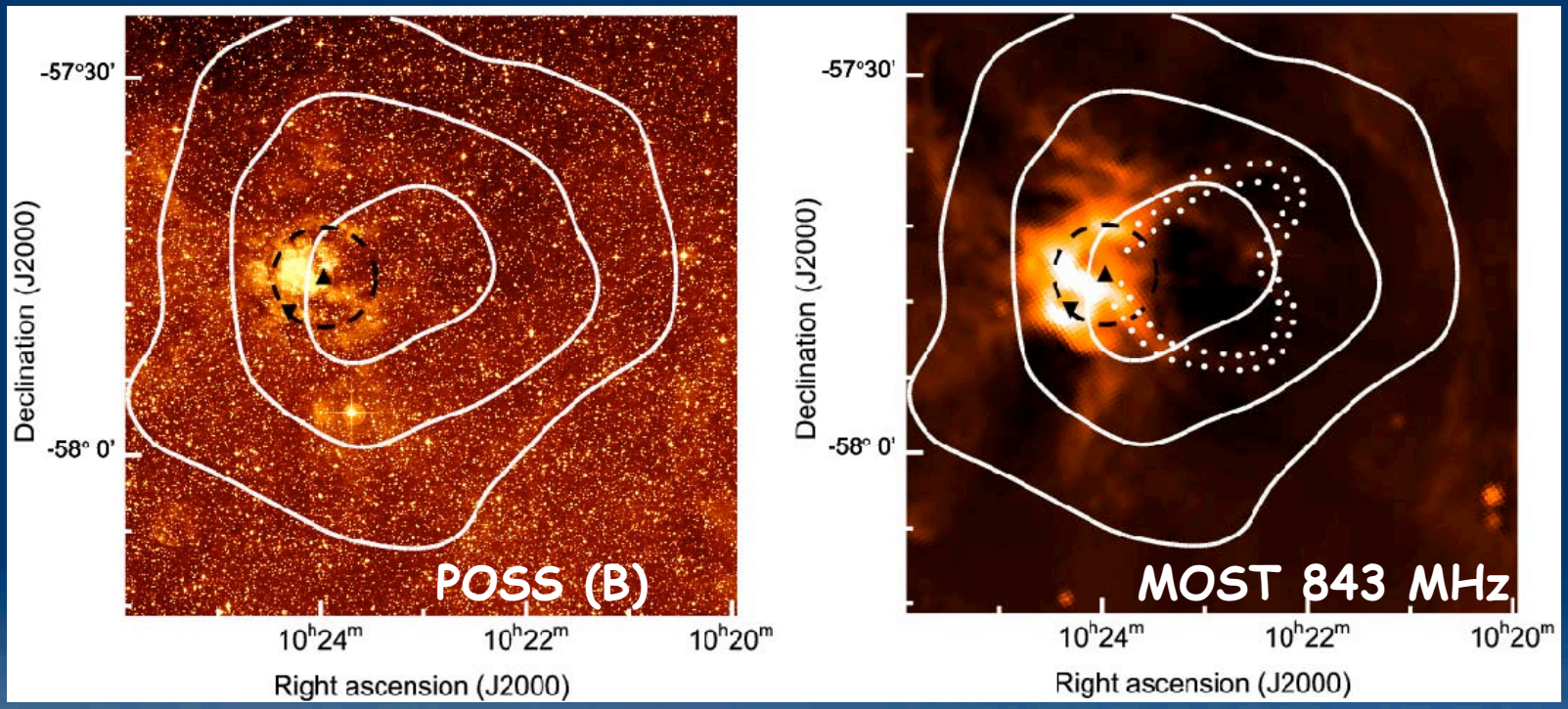
diffusive shock acceleration by encountering multiple shocks [Klepach et al. 2000]
neutral pion decay photons produced through inelastic pp interactions [Domingo & Torres 06]

MHD particle acceleration

Magnetized plasma produced by supersonic flows, which then penetrate into a dense medium (-> bubbles), usually known in context with SNR [e.g. Bykov & Toptygin 87 … Bykov 01]

The "blister" (Whiteoak & Uchida 1997):

indicative for rapid expansion into a ambient low-density medium (superbubble?)



Shock acceleration at the boundaries of the blister

Analogy with SN-driven expansions (Völk 1983 .. Bykov 2001) with expanding stellar winds.

Outbreak phenomenon from winds of hot and massive star ensembles (Tenario-Tagle 1979, Völk & Forman 1982, Cesarsky & Montmerle 1983) ?

Contribution to Cosmic Rays (Cassé & Paul 1980)?

Energetics ok here?

- size of emission region at the distance of stellar cluster (8kpc according to Rauw et al. 2007 now) matches theoretical predictions for bubbles blown into the interstellar medium (H.E.S.S. source extension -> r_{8kpc} ~ 28 pc)

- luminosity ~1 x 10^{35} erg/s -> 0.5% of total E_{kin} available in WR20a, other hot massive stars take their share, too

- M: few x 10^{-5} M_{sol}... 10^{-6} M_{sol} (smooth winds, clumping)
  -> ~2% luminosity in the winds (below γ-ray prod. eff. constr. -
  - either π^0 or IC)

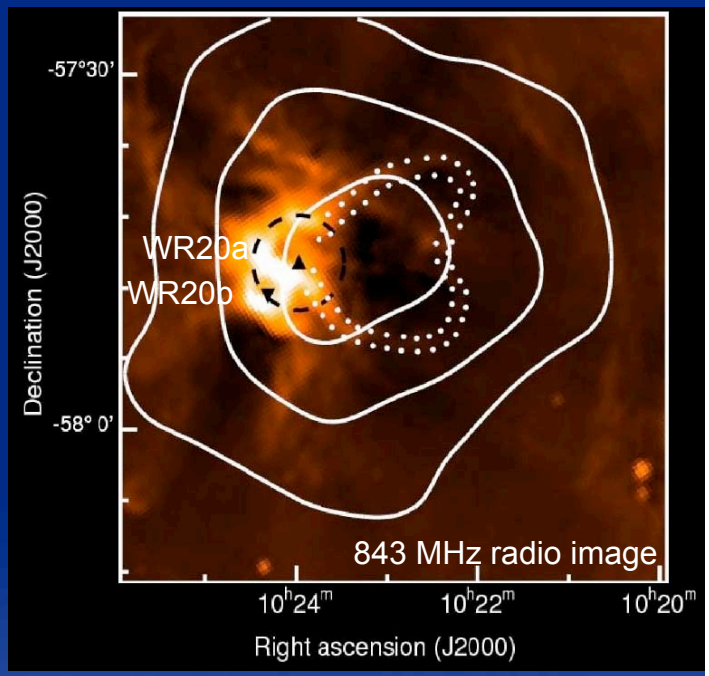
- -> particle acceleration probably related to stellar winds, but not close to WR20a

-> shocks and turbulent motion inside a bubble can efficiently transfer energy to cosmic ray particles

Implications of the H.E.S.S. findings:

- intriguing new type of VHE gamma-ray source
- archetypal for other young massive clusters ?

- if this association is confirmed and further stellar clusters will be detected in γ-rays (by ground-based γ-telescopes, or GLAST)



-> consider a new class of extreme particle accelerators in our Galaxy
-> consequences for CRs