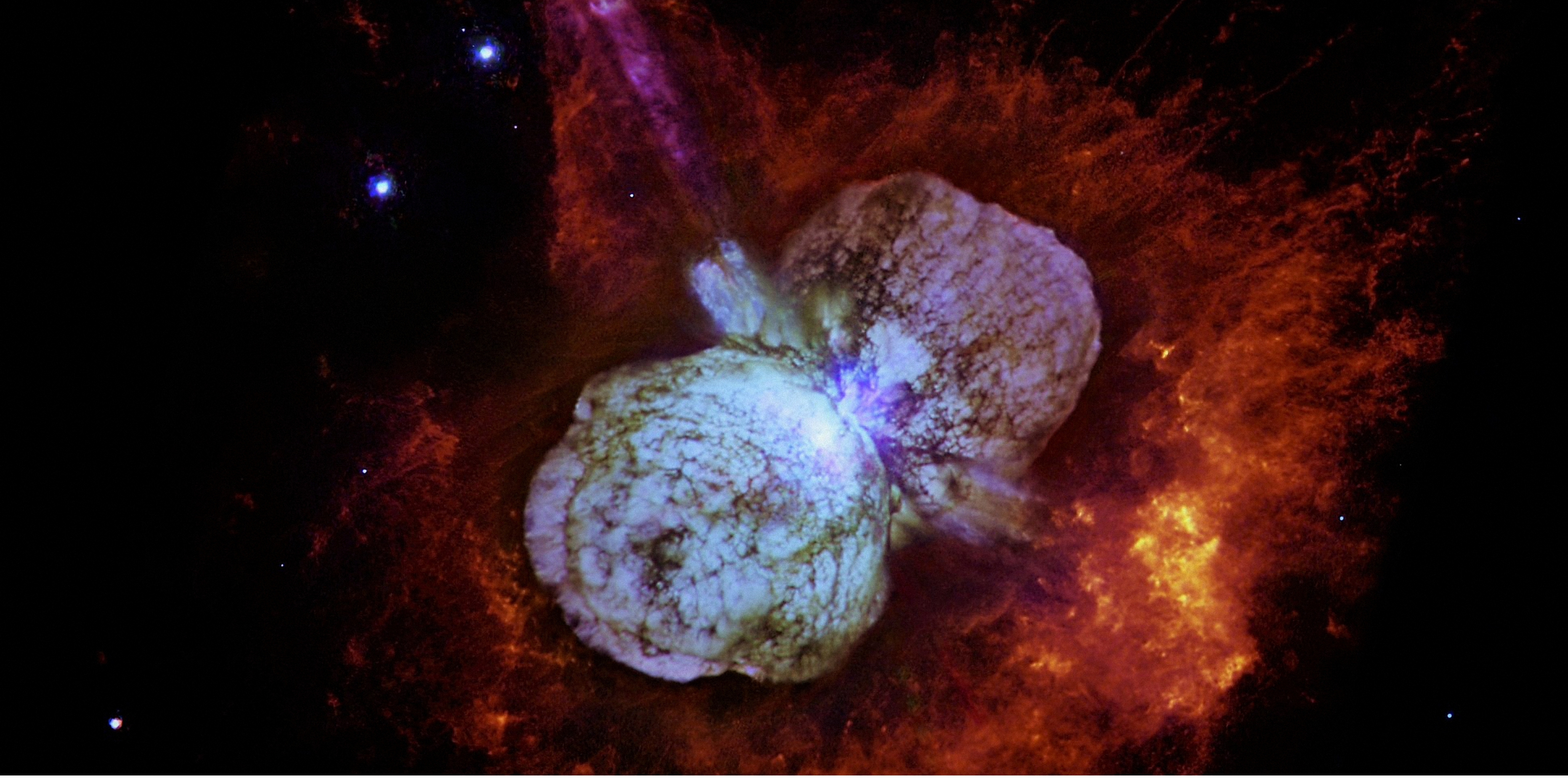


By Nathan Smith (University of California, Berkeley), and NASA (HST)

The Colliding-Wind Binary Eta Carinae as seen with the H.E.S.S. telescopes

H.E.S.S.

Eva Leser
for the H.E.S.S. Collaboration

TeVPA 2018 . Berlin

DESY.

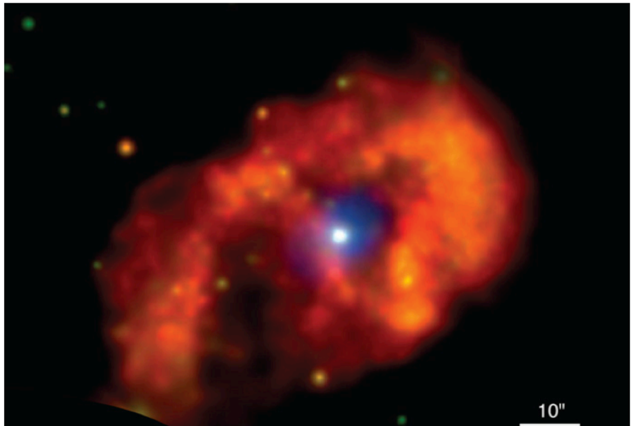
Universität Potsdam

Eta Carinae

- Binary stellar system
- Properties:
  - Distance 2.3 kpc
  - Period of 5.54 yr
  - Last periastron May 2014
  - Eccentricity e ~ 0.9
  - Semi-major axis 16.64 AU (1.66 AU at periastron)

Primary: LBV type	Companion: O- or B-type
$M \sim 120\ M_\odot$	$M \sim 30\ M_\odot$
$\dot{M} \sim 5 \times 10^{-4}\ M_\odot/yr$	$\dot{M} \sim 10^{-5}\ M_\odot/yr$
$v_{w,\infty} \sim 500$ km/s	$v_{w,\infty} \sim 3000$ km/s

- Particle acceleration in shock regions
- Non-thermal emission predicted:
  - Radio and X-rays: Synchrotron radiation
  - Gamma-rays: from electrons via inverse Compton scattering, from protons via π^0 decay



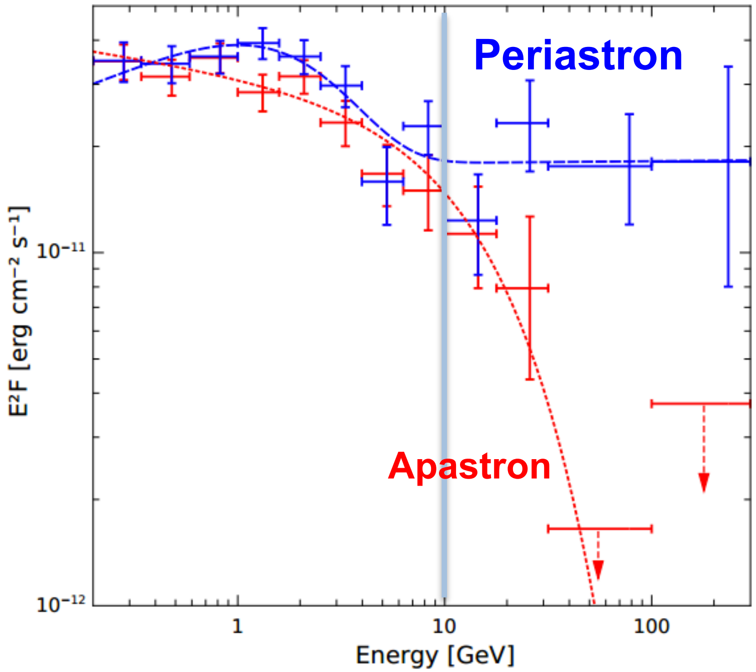
Chandra (Hamaguchi et al. 2014)

Eta Carinae in gamma-rays

- First detection by **AGILE** (Tavani et al. 2009)
- **Fermi-LAT**:
  - low- energy (0.2 – 10 GeV) & high-energy (10 – 300 GeV) components
  - Spectral variability in both components

- <u>**Search for VHE gamma-ray emission close to periastron**</u>

Spectral energy distribution (Fermi-LAT) covering 500 days of observations



Reitberger et al. (2015)

The High Energy Stereoscopic System: H.E.S.S.

- IACT in Southern hemisphere (Khomas Highland, Namibia)
- 4 telescopes with 12 m diameter (CT1-4), one 28 m diameter telescope (CT5)
- Energy range: 10s of GeV - 10s of TeV
- Camera Field of view: CT5 3.5°/ CT1-4 5° diameter
- Allows for single or multiple telescope observation modes

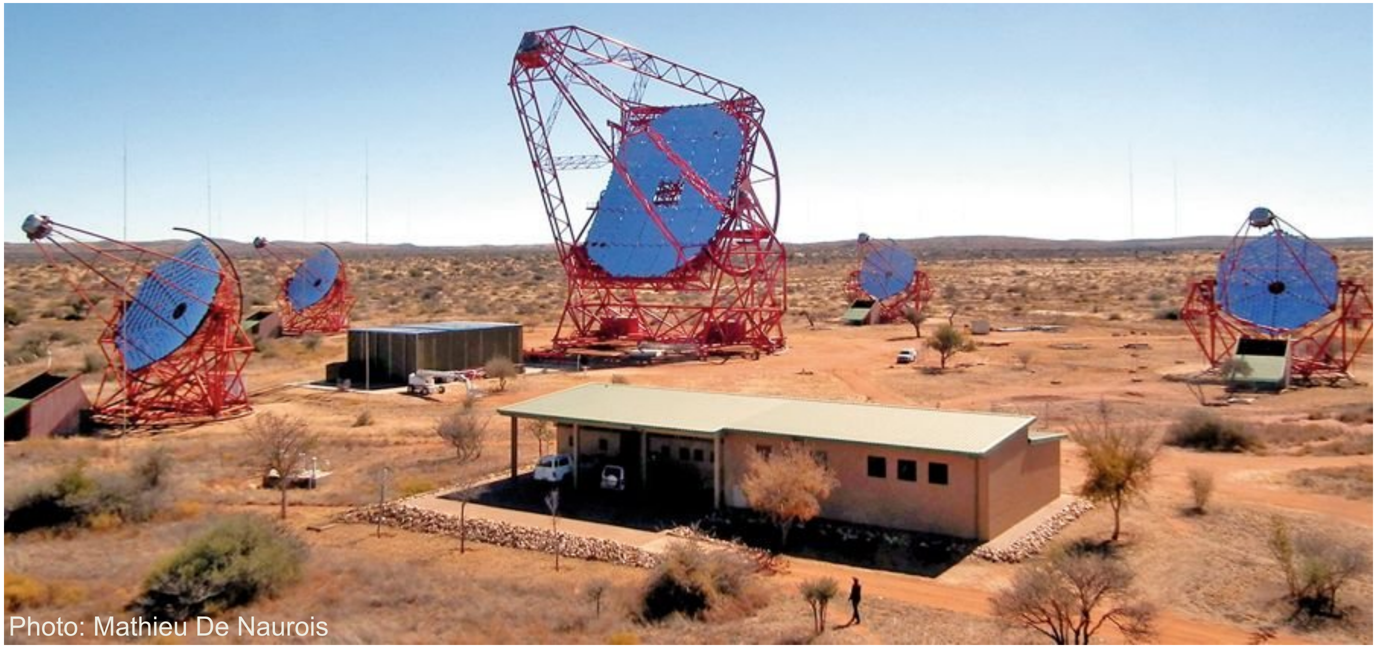


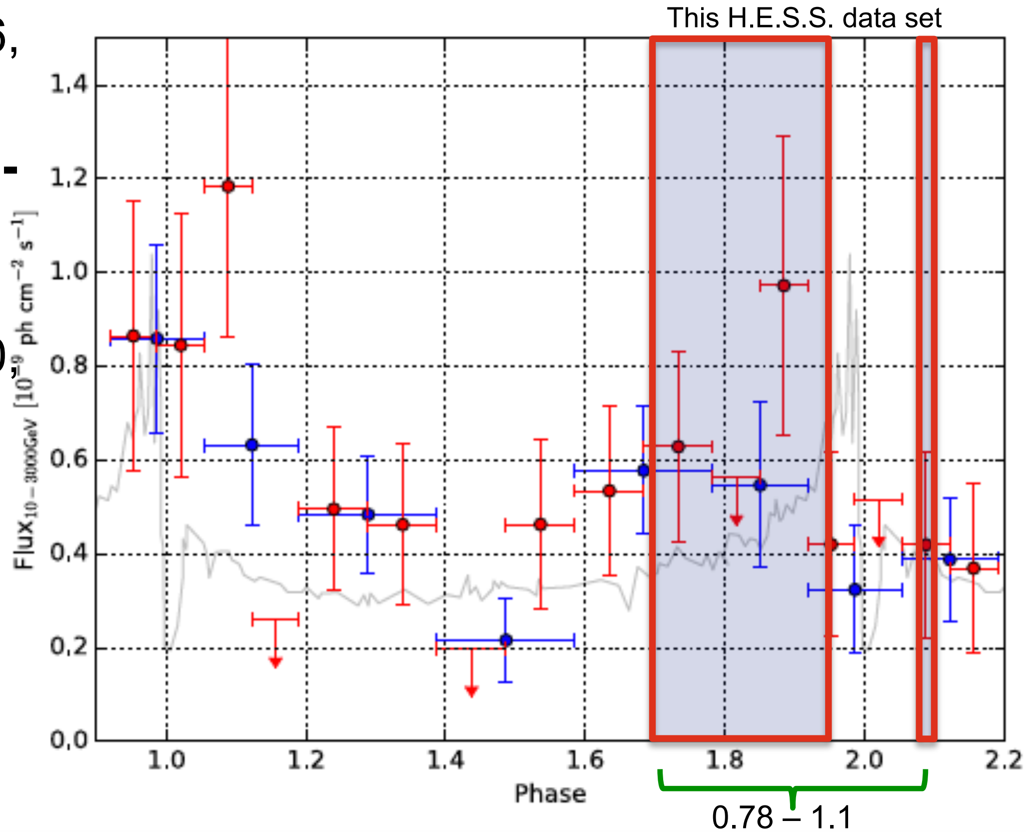
Photo: Mathieu De Naurois

The H.E.S.S. data set of 2014/2015

- (1 orbit = 5.54 yr)
- Coverage around periastron
- In total: 25.4 h
  - 12.1 h at phases 0.78 – 0.96, 68 % at phase 0.93
  - all five telescopes: **mono- and stereoscopic reconstruction**
  - 13.3 h at phases 0.96 – 1.10, 54 % at phase 1.09
  - 28 m diameter telescope only: only **monoscopic reconstruction** possible

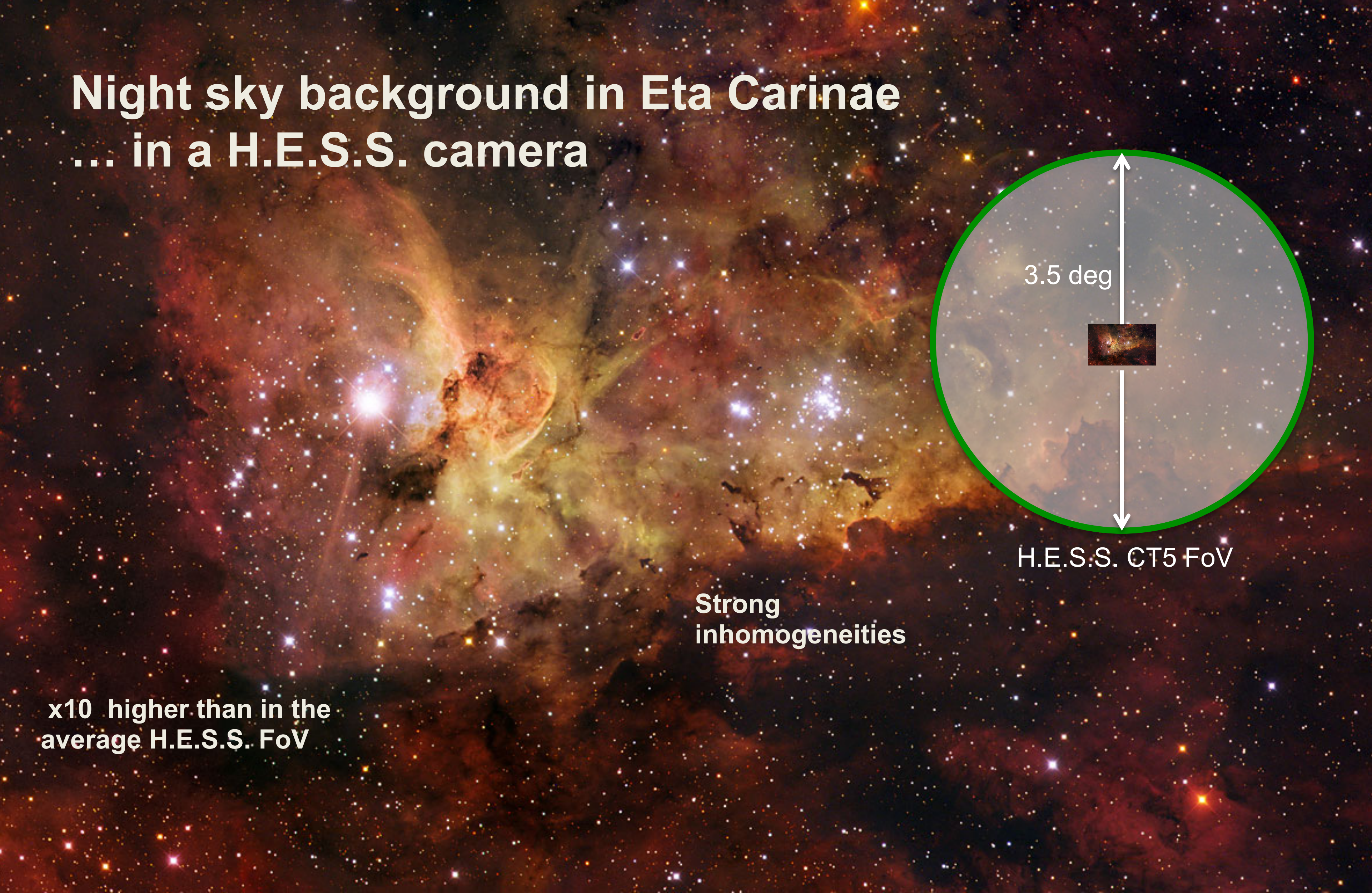
=> Monoscopic reconstruction

Phase-binned flux 30 – 300 GeV by Fermi-LAT



Balbo & Walter (2017)

Night sky background in Eta Carinae
… in a H.E.S.S. camera



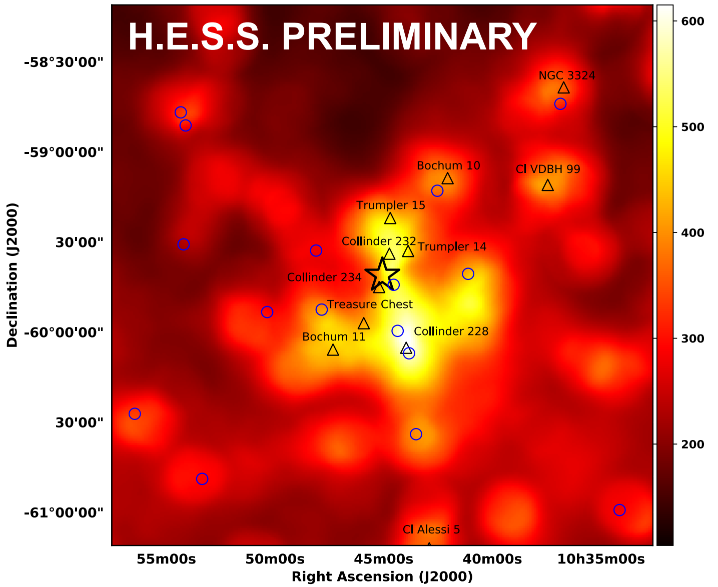
ESO/IDA/Danish 1.5m/R. Gendler, J.-E. Ovaldsen, C. Thöne, C. Feron

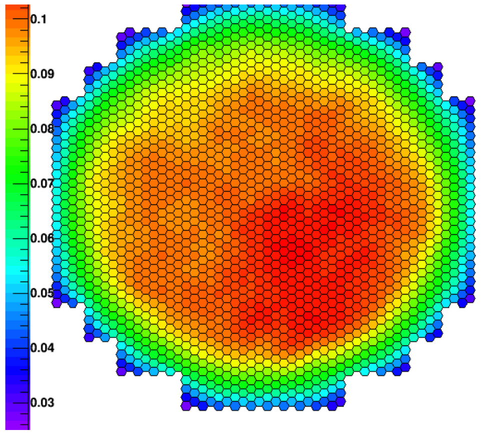
Handling the night sky background

- Hardware: increase pixel trigger threshold of Cherenkov camera
- Low-level data analysis: Increasing the shower image cleaning level
- Remaining noise is treated via:
  - Run-wise MC simulations for observations (correct NSB, turned-off pixels etc.)
  - Checks with different analysis methods and in-field high-NSB regions

=> Extensive tests demonstrate that NSB is under control

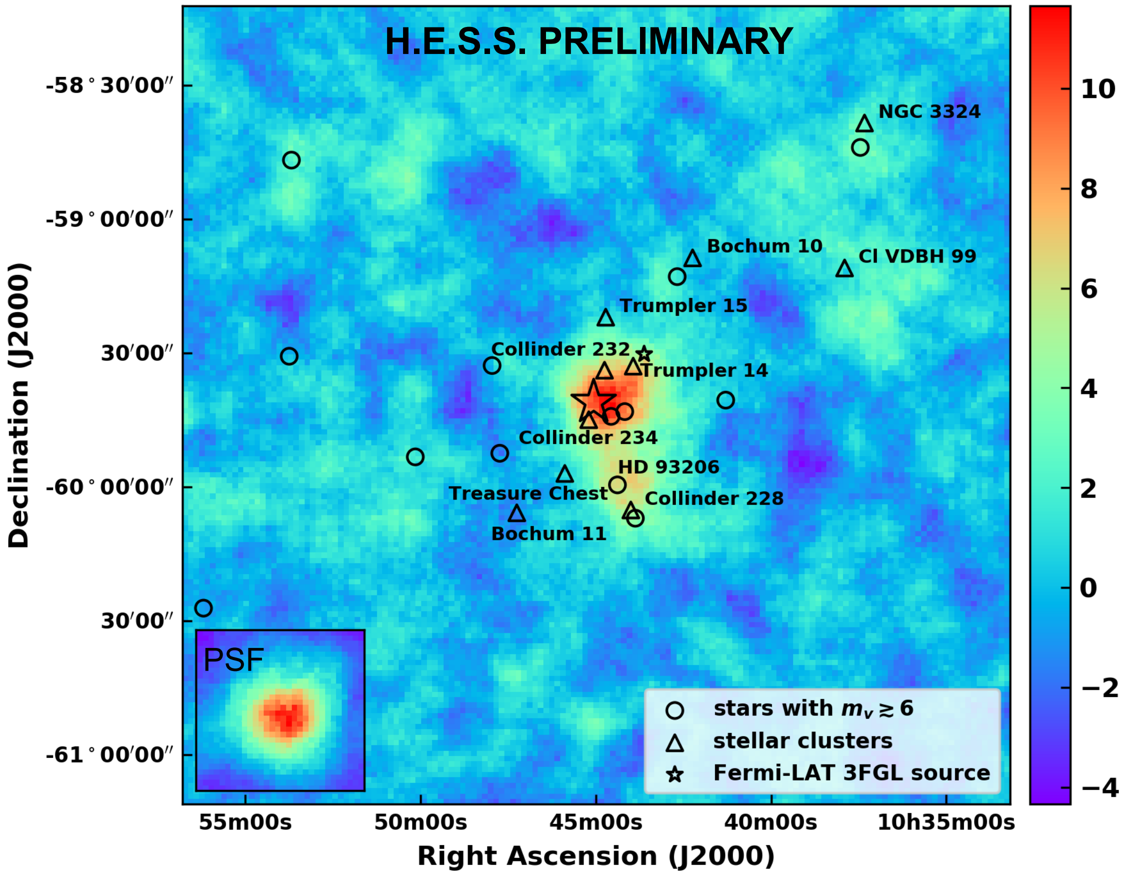
Night sky background in H.E.S.S. FoV in MHz





Detection of Eta Carinae with H.E.S.S.

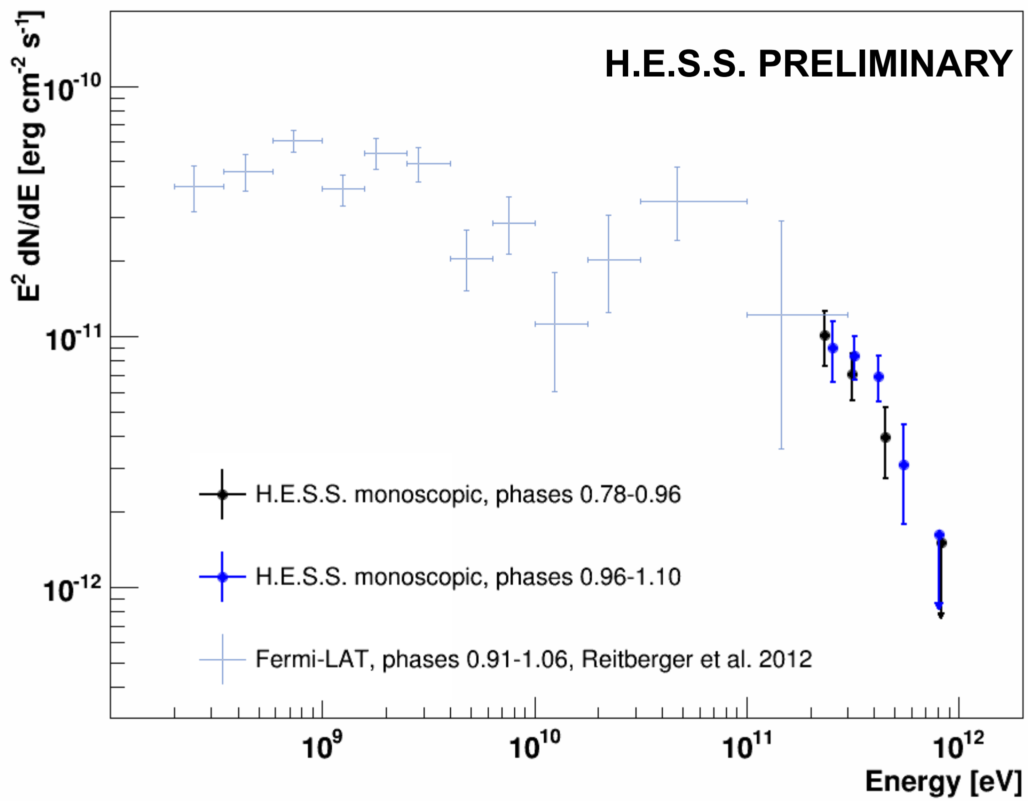
- CT5-mono data
  Orbital phases:
  - 0.78 – 0.96
  - 0.96 – 1.10
- **Combined: 13.6 σ**
- 1070 γ in 25.4 h
- Energy threshold: 190 GeV
- VHE gamma-ray emission consistent with being point-like



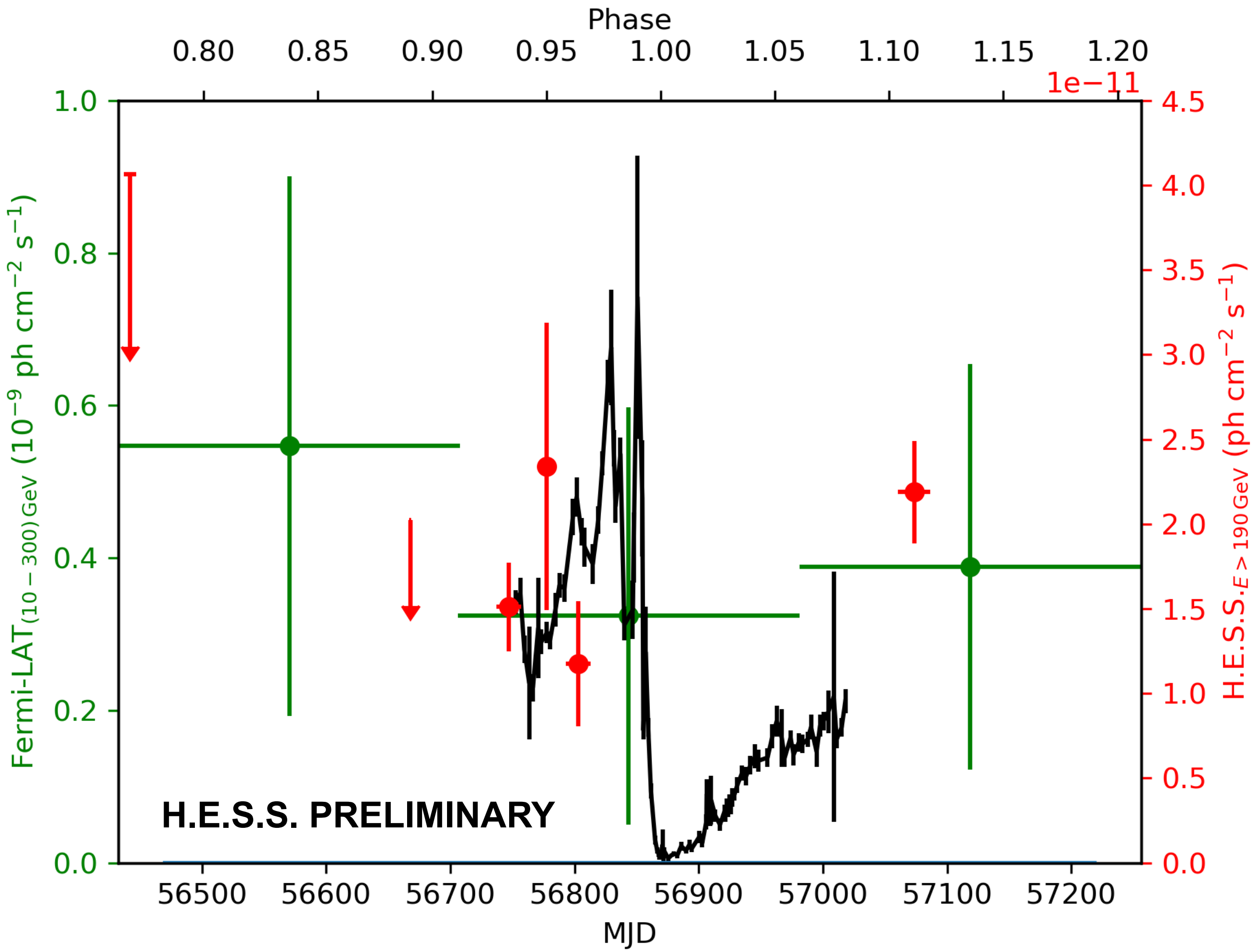
Spectral Energy Distribution

Phases	0.78 - 0.96	0.96 - 1.10
Power-law index Γ	$3.94 \pm 0.35_{stat} \pm 0.96_{syst}$	$3.49 \pm 0.23_{stat} \pm 0.36_{syst}$
Threshold energy E_{th} [TeV]	0.19	0.22
Photon flux ($E > E_{th}$) [cm^{-2} s^{-1}]	$(1.76 \pm 0.19)\,10^{-11}$	$(1.56 \pm 0.13)\,10^{-11}$

- H.E.S.S. spectra before and after periastron agree within statistic uncertainties



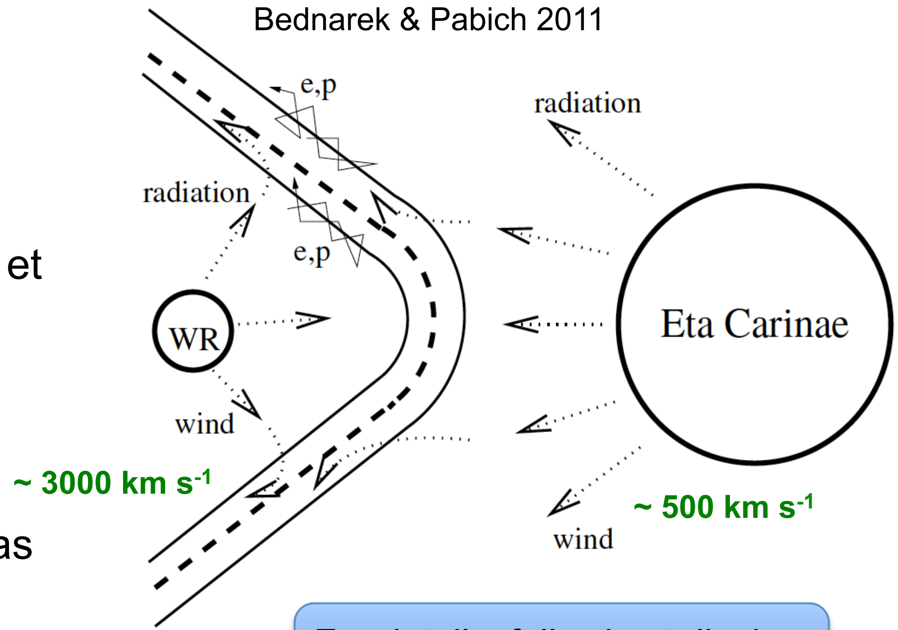
Lightcurve from X-rays to VHE gamma rays



- Origin of emission inside wind-collision region -> variability along orbit expected
- No indication for variability in H.E.S.S. data with currently available statistics

H.E.S.S.
Fermi-LAT 10 – 300 GeV, Balbo & Walter (2017)
Swift 2 – 10 keV, Corcoran et al (2015)

Proposed scenarios for gamma-ray emission from Eta Carinae



For details: following talks by M. Balbo & K. Reitberger

- Likely origin of gamma-ray emission
  - In the colliding wind region
  - Two shocks on both sides of the contact discontinuity (e.g. Bednarek et al. 2011)
- Leptonic scenarios:
  - Inverse Compton emission, two Fermi-LAT components interpreted as gamma/gamma absorption feature (Reitberger et al. 2012)
- Mixed scenarios
  - Low-energy component interpreted in leptonic (Farnier et al. 2011, Reitberger et al. 2015, Balbo & Walter 2017) and hadronic scenarios (Ohm et al. 2015)
  - High-energy component often interpreted as hadronic in origin (Farnier et al. 2011, Reitberger et al. 2015, Ohm et al. 2015, Balbo & Walter 2017)

Ingredients for particle acceleration

- Last 2 σ spectral point in H.E.S.S. starts at 700 GeV
- Implications for parent particles?

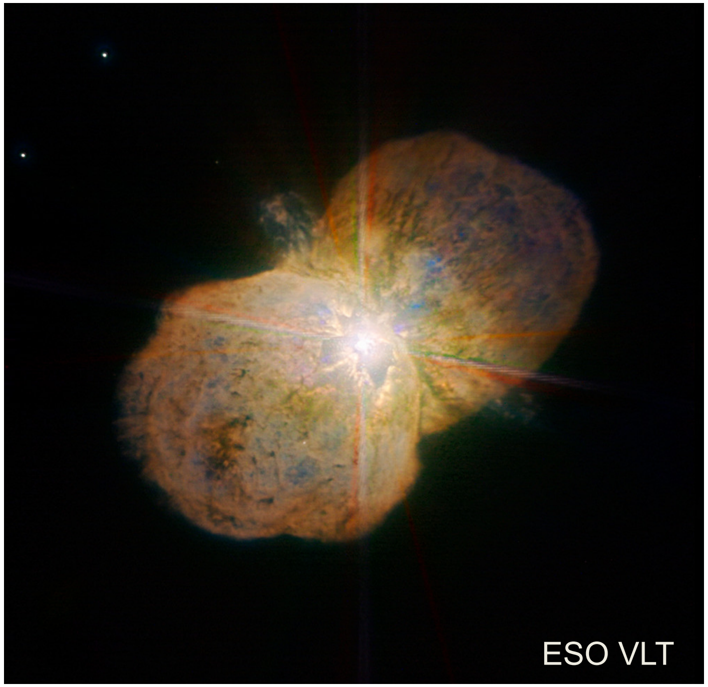
- Electrons
  - Minimum required E_e ~ **700 GeV** (Klein Nishina)
  - Balance between acceleration and synchrotron losses
  - $B < 0.2$ G required, , $t_{acc,e} \sim 5.4$ h

- Protons
  - Minimum required E_p ~ **7 TeV**
  - In $B = 0.2$ G field, $t_{acc,p} \sim 2\,¼$ days

- Gamma-ray luminosity > 190 GeV implies:
  - 6% of primary kinetic wind power in CWR into interacting CRs
  - 1% of companion kinetic wind power in CWR into interacting CRs

Summary and outlook

- VHE gamma-ray source coincident with Eta Carinae
- Careful investigation of NSB from the beginning, including detailed tailored simulations
- Maximum energy in gamma-rays 700 GeV
- Requires e^- with E_e > 700 GeV or p with E_{pp} > 7 TeV



- Further H.E.S.S. data available: Eta Carinae frequently observed since 2014
- Next periastron passage in December 2020 – full orbit of H.E.S.S. observations 🎉
- Paper in preparation

Backup – Discussion

- Last 2σ spectral point in H.E.S.S. starts at 700 GeV
- Implications for parent particles?

- For acceleration, assume
  - Diffusive shock acceleration (DSA) in strong shock (Bohm)
  - Shock velocity = companion wind velocity
  - Strong magnetic field

$$\tau_{\rm acc} = 5 \times 10^4 \; s \, v_{\rm sh,10^3\,km\,s^{-1}}^{-2} \frac{E_{\rm TeV}}{B_G}$$

- Electron acceleration limited by synchrotron losses at >~100 GeV
- For **electrons**: minimum required E_e ~ **700 GeV** (Klein Nishina)

➔ B < 0.2 G required (in synchrotron cooling limit)

➔ acceleration time to reach required E_e: $t_{acc,e}$ ~ 5.4 hr