# Star forming Regions

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# Potential sources

## Detection of gamma-ray emission from SFRs

| | | |
|---|---|---|
| **1.** | **Cygnus Cocoon** | **Ackermann et al, Sci, 334, 2011** |
| **2.** | **Westerlund 1** | **Abramowski et al, A&A, 537, 2012, Ohm et al, MNRAS, 434, 2013** |
| **3.** | **Westerlund 2** | **Yang et al, A&A, 611, 2018** |
| **4.** | **NGC 3603** | **Saha, L. et al, ApJ, 897, 2020, Yang et al, A&A, 611, 2018** |
| **5.** | **W 43** | **R. Yang and Y. Wang, A&A, 640, 2020** |
| **6.** | **G25.0+0.0 Region** | **Katsuta et al, ApJ, 839, 2017** |
| 7. | BDS 2003 | Albert et al 2021 ApJL 907 |
| 8. | W 40 | Sun et al 2020, A&A, 639 |
| 9. | RSGC 1 | Sun et al 2020, MNRAS, 494 |
| 10. | MC 20 | Abdalla et al. 2018, A&A, 612, Sun et al 2021, A&A, 659 |
| 11. | NGC 6618 | Liu et al, MNRAS, 513, 2022 |
| 12. | 30 Dor (LMC)/NGC 2070/RCM | HESS coll et al, Science, 347, 406 |

## Recently several massive star clusters have been associated with gamma-ray sources

| Name | log M/M$_{sun}$ | $r_c$/pc | D/kpc | age/Myr | $L_w$/ $10^{38}$ erg s$^{-1}$ | Reference |
|---|---|---|---|---|---|---|
| Westerlund 1 | 4.6 ± 0.045 | 1.5 | 4 | 4-6 | 10 | Abramowski A., et al., 2012, A&A, 537, A114 |
| Westerlund 2 | 4.56 ±0.035 | 1.1 | 2.8 ± 0.4 | 1.5 - 2.5 | 2 | Yang, de Oña Wilhelmi, Aharonian, 2018, A&A, 611, A77 |
| Cyg. OB2 | 4.7±0.3 | 5.2 | 1.4 | 3 - 6 | 2 | Ackermann M., et al. 2011, Science, 334, 1103 |
| NGC 3603 | 4.1 ± 0.10 | 1.1 | 6.9 | 2 - 3 | ? | Saha, L. et al 2020, ApJ, 897, 131 |
| BDS 2003 | 4.39 | 0.2 | 4 | 1 | ? | Albert A., et al., 2020, arXiv:2012.15275 |
| W40 | 2.5 | 0.44 | 0.44 | 1.5 | ? | Sun, X.-N. et al. 2020, A&A 639 |
| RSGC 1 | 4.48 | 1.5 | 6.6 | 10 - 14 | ? | Sun et al. 2020, MNRAS 494 |
| MC 20 | ~3 | 1.3 | 3.8 - 5.1 | 3 - 8 | ~4 | Sun et al. 2021, A&A 659 |
| NGC 6618 | | 3.3 | ~2 | < 3 | ? | Liu et al. 2022, MNRAS 513 |
| 30 Dor (LMC)<br>NGC 2070/RCM | 4.8-5.7<br>4.34-5 | multip<br>le sub- | 50 | 1<br>5 | ? | H. E. S. S. Collaboration et al., 2015, Science, 347, 406 |

**Thanks to Giovanni for the list**

| Source | Mass ($10^4$ $M_\odot$) | Age (Myr) | Diameter (pc) | Stellar wind power ($10^{38}$ erg $s^{-1}$) | Distance (kpc) |
|---|---|---|---|---|---|
| Cygnus cocoon | ~3 | 1-7 | 100 | 2-3 | 1.4 |
| Westerlund 1 | 10 | 4-6 | 160 | 10 | 4 |
| Westerlund 2 | 3.6 | 2.5-3.5 | 210 | 2 | 2.8 |
| NGC 3603 | 1.2 | 2-3 | 130 | 8.5 | ~ 7 |
| G25.0+0.0 | ~1 | <3 | 180 | 1 | 3-6 |
| W 43 | - | 0.1 | 60 | 0.3 | 6 |
| W 40 | 0.03 | 1.5 | 3.5 | - | 0.44 |
| BDS 2003 | 2.4 | 1 | 13 | - | 4 |
| RSGC 1 | 3.0 | 10-14 | 3.4 | - | 6.6 |
| MC 20 | 0.1 | 3-8 | 100 | ~4 | 3.8-5.1 |
| NGC 6618 | 3 | <3 | 25 | - | ~2 |
| 30 Dor C | 6.3-50 | 1-5 | 47 | - | 50 |

Needs further update

# Some details on these sources

**Westerlund 1**: The origin of observer gamma rays and their possible association with counterparts at other wavelengths remain poorly understood. A recent study of Westerlund 1 shows a resemblance of the source's characteristics to those of the Cygnus cocoon indication CR acceleration by the compact stellar clusters (Aharonian et al, 2019).

**Westerlund 2:** Diffuse extended gamma-ray emission at MeV-GeV energies was found from the direction of the young massive cluster Westerlund 2 (Yang et al 2018), although its association with the stellar cluster is not conclusive.

**NGC 3603**: Both diffuse and point-like gamma-ray emission at MeV--GeV energies were found from the direction of young massive cluster NGC 3603 (Saha et al 2020, Yang et al 2018). No firm evidence of association with other classes of gamma-ray emitters is found. The gamma-ray luminosity of the source is ~0.2% of the total mechanical power of the winds. Hence it appears to be a potential case of gamma-ray emitting SFR.

**G25.0+0.0 region:** A detailed study of this region likewise shows many similarities of the gamma-ray emission between G25.0+0.0 and Cygnus cocoon. However, OB associations are firmly established.

**W 43:** Diffuse extended gamma rays at MeV-GeV energies are detected from the direction of of young star forming region W43. However, its association with the stellar cluster is not conclusive.

# Some details on these sources

**BDS 2003:** Very high energy gamma-ray emission above 200 TeV detected from a source HWC J1825-134 close proximity of young star cluster BDS 2003 ( Albert et al 2021 ApJL 907). A definitive association to the young star cluster is still to be clarified.

**W 40:** Diffuse extended gamma rays at MeV-GeV energies are detected from the direction of of young star forming region W 40 (Sun et al 2020, A&A, 639). However, its association with the stellar cluster is not conclusive.

**RSGC 1**: Diffuse extended gamma rays at MeV-GeV energies are detected from the direction of of young star forming region RSGC 1 (Sun et al 2020, MNRAS, 494). However, its association with the stellar cluster is not conclusive.

**MC 20:** Observed gamma-ray emission at GeV–TeV energies from HESS J1912+101 (Abdalla et al. 2018, A&A, 612). More likely associated with supernova remnant. Although association with MC 20 argued, it is not conclusive.

**NGC 6618:** Gamma-ray observed towards the young massive star cluster NGC 6618 (Liu et al, MNRAS, 513, 2022). No conclusive evidence for association with the SFR.

**30 Dor C (LMC)/NGC 2070**: Observed GeV–TeV emission from the direction of 30 Dor C. Although some associations are argued, no conclusive evidence is not present yet.

# Compelling cases & OB associations

The only compelling cases of emission from the SFR are **Cygnus X** and **Westerlund 1**.

The others are simply detections of gamma-ray emission from a SFR. No firm OB associations are made for all other case.

# Proposal

→ Add simulations for **Cygnus cocoon and Westerlund 1** as representatives of this class.

→ Add 2/3 more sources like **NGC 3603, Westerlund 2** and **W 43** or **G25.0+0.0 Region as prospects for CTA.**