# Gamma-ray Binaries in the Southern Hemisphere

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# Outline

Prototype of a γ Binary

Overview of Known Sources

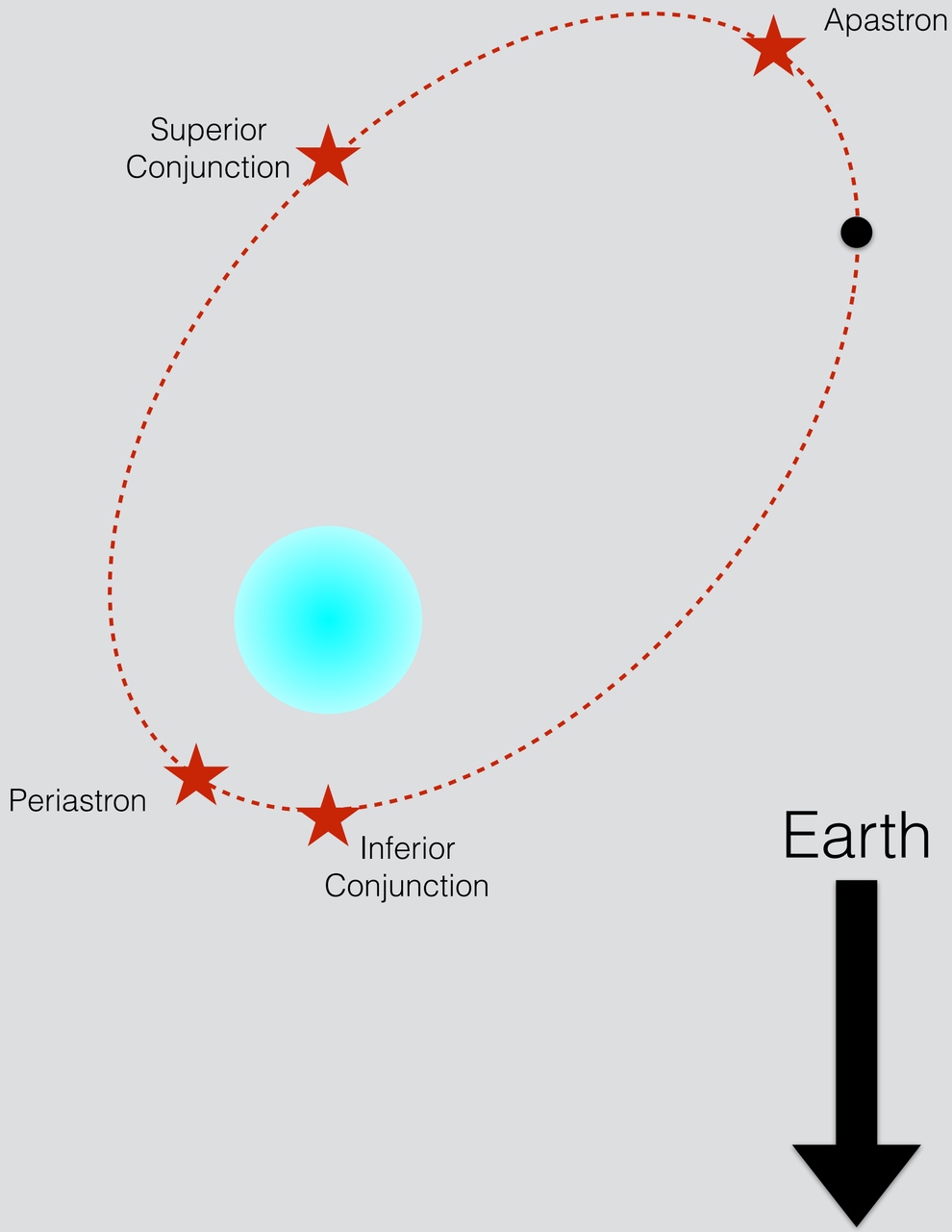
Emission Scenarios

Unresolved Questions

Detector things & Candidate sources

# What does a γ binary look like?

- O/B type star
- Compact Companion
- Emission highly dependent orbital position
- Emission at all energies
  - Radio → TeV
- Wide range of periods



# How many γ ray binaries are there?

PSR B1259-63

LS 5039

LS I 61° 303

HESS J0632+57

1FGL J1018.6-5856

LMC P3

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~~LS I 61° 303~~

~~HESS J0632+57~~

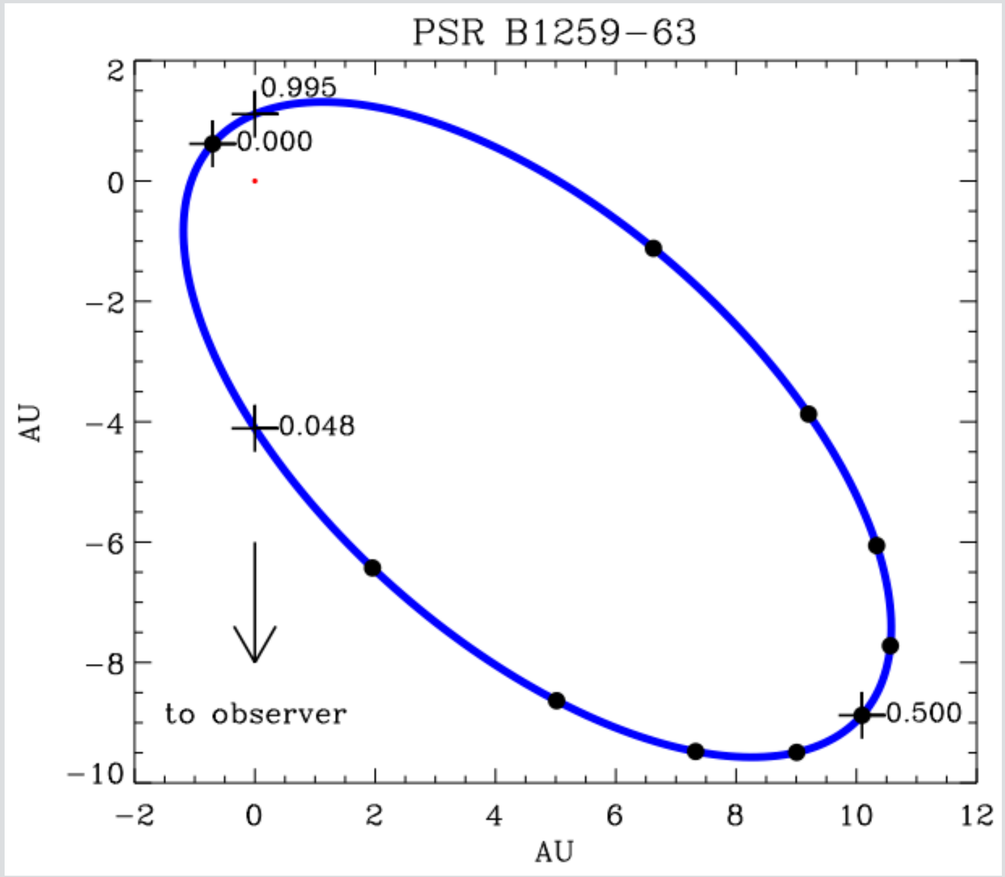
1FGL J1018.6-5856

LMC P3

Not in Southern Hemisphere

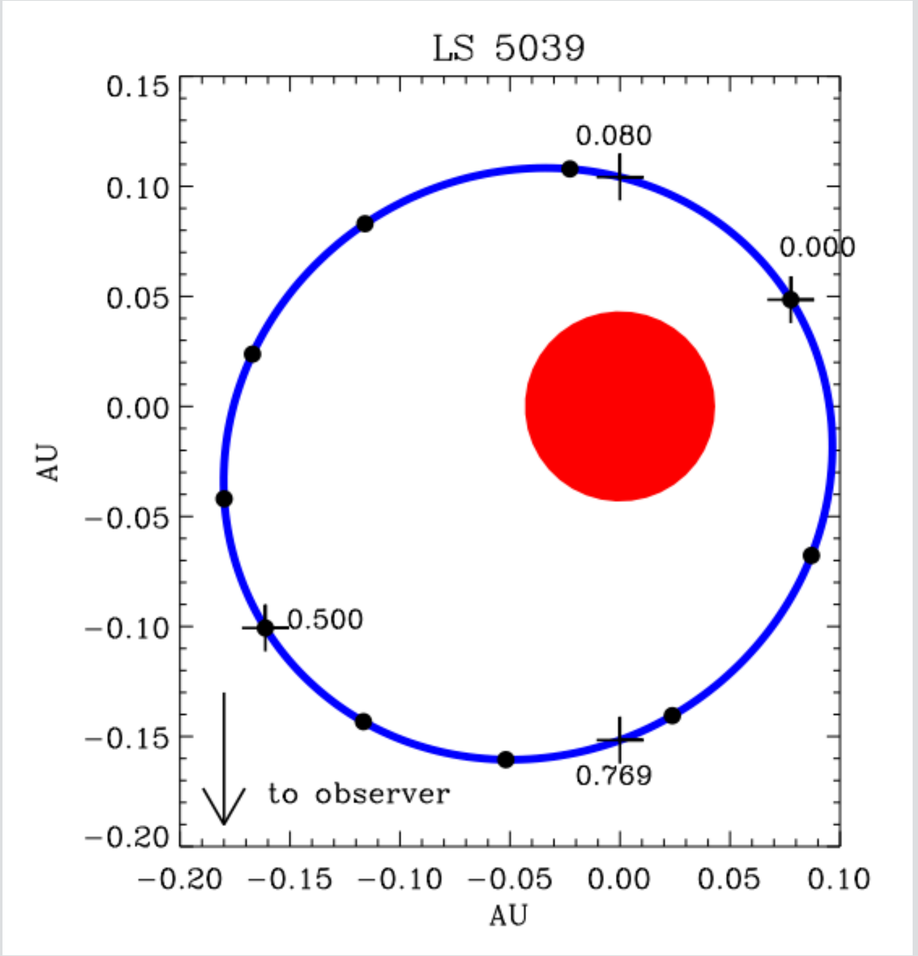
# Overview of PSR B1259-63

- Only system with known compact companion
- Type O9.5Ve star, 31 M⊙
- Period: 1236.7 Julian days



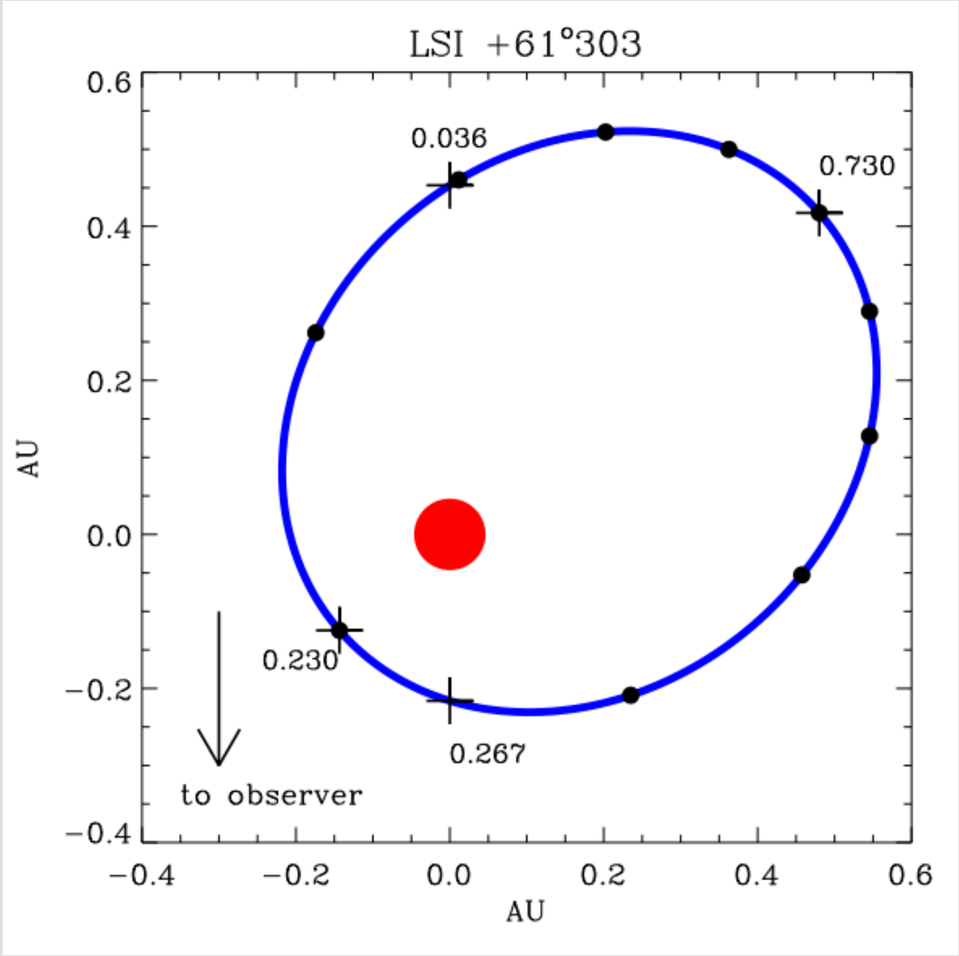
# Overview of LS 5039

- High Mass X-ray Binary
- Type O6.5V star, 23M⊙
- Period: 3.9 Julian days



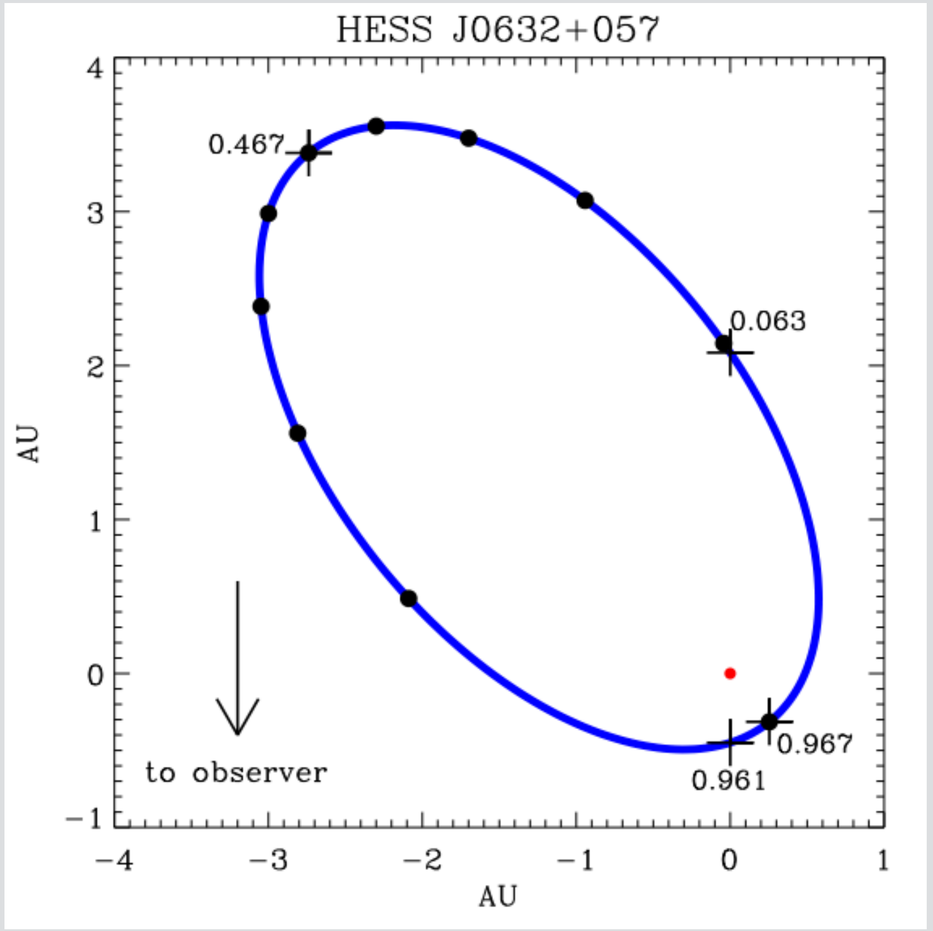
# Overview of LS I 61° 303

- Discovered in γ rays
- Type B0Ve star, 12M⊙
- Period: 26.5*Julian days
  - 1667 day period supraorbital period



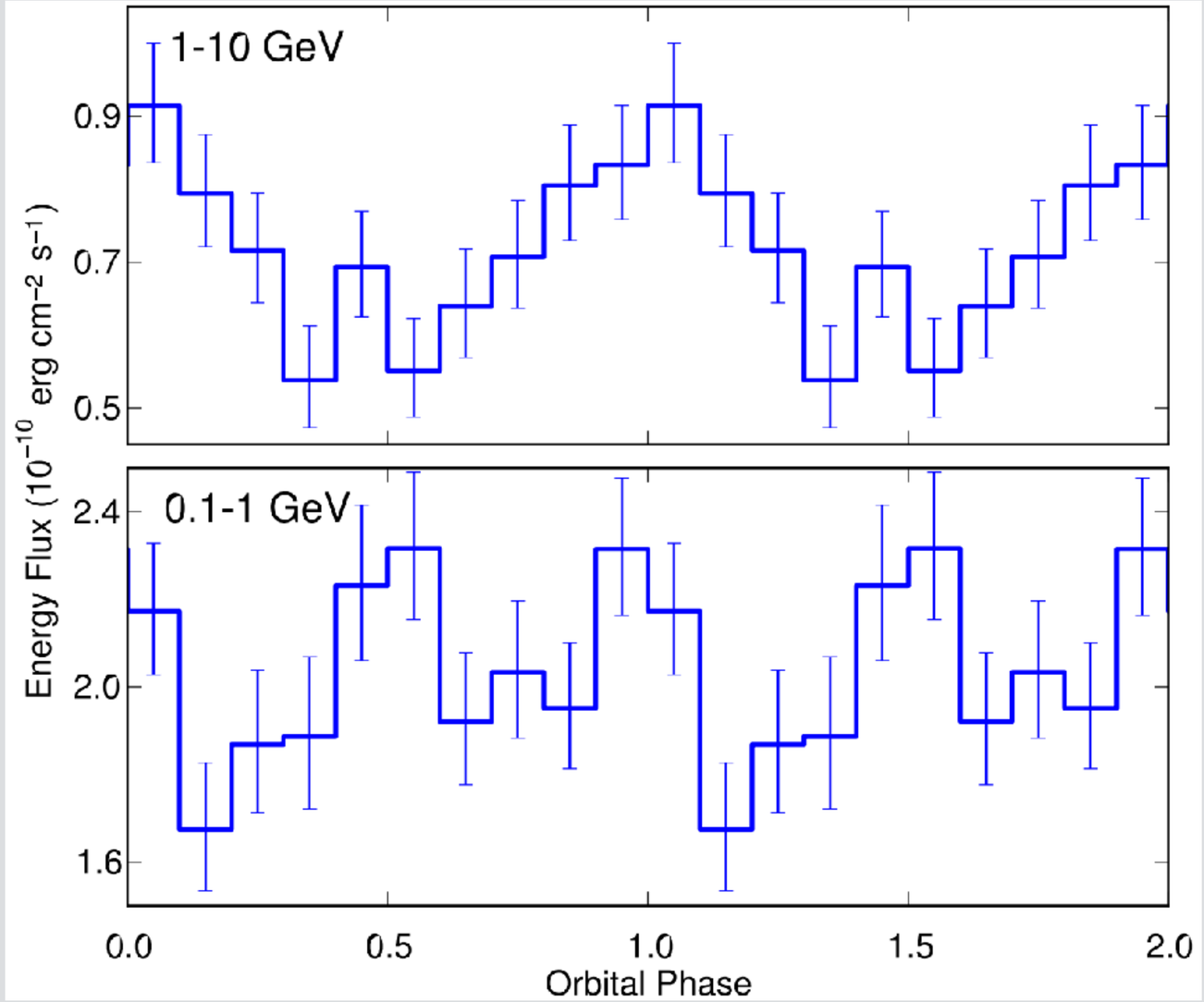
# Overview of HESS J0632+57

- Discovered in γ rays
- Type B0Ve star, 16M⊙
- Period: 315 Julian days



# Overview of 1FGL J1018.6-5856

- Associated with HESS J1018-589
- Type O6V star, 31M⊙
- Period: 16.6 Julian days

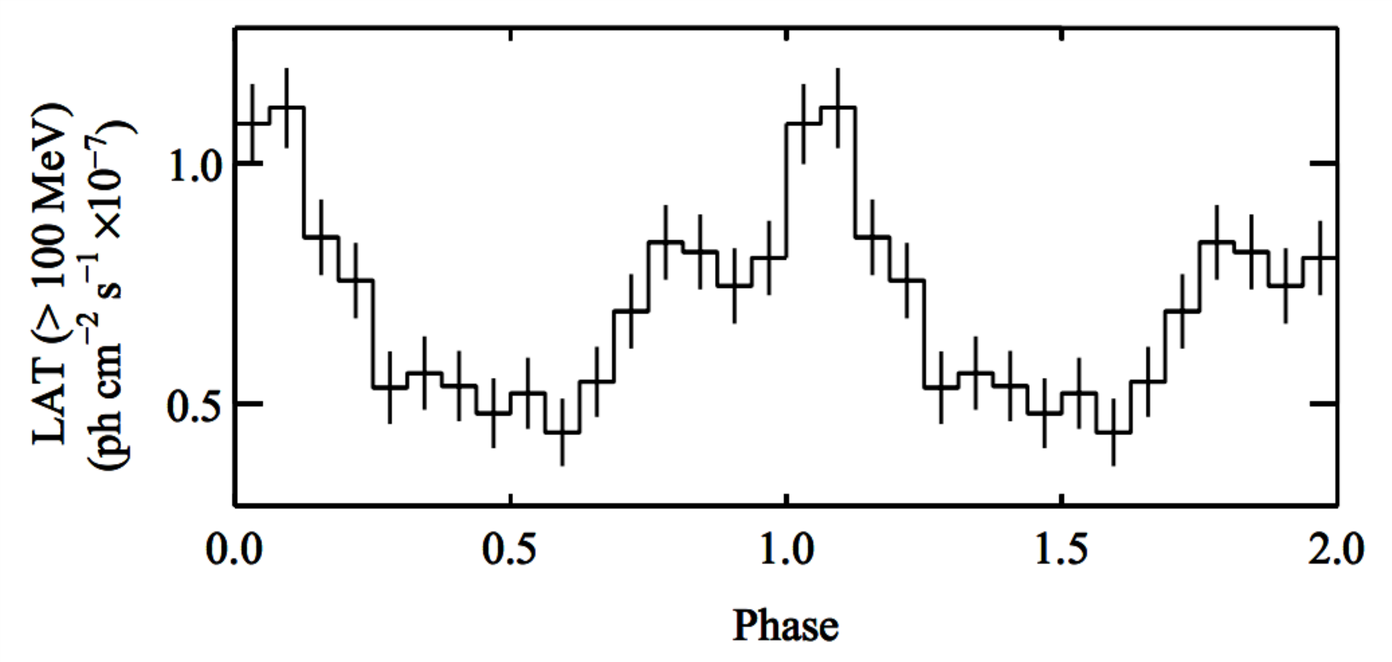



https://arxiv.org/pdf/1202.3164v1.pdf

# Overview of LMC P3

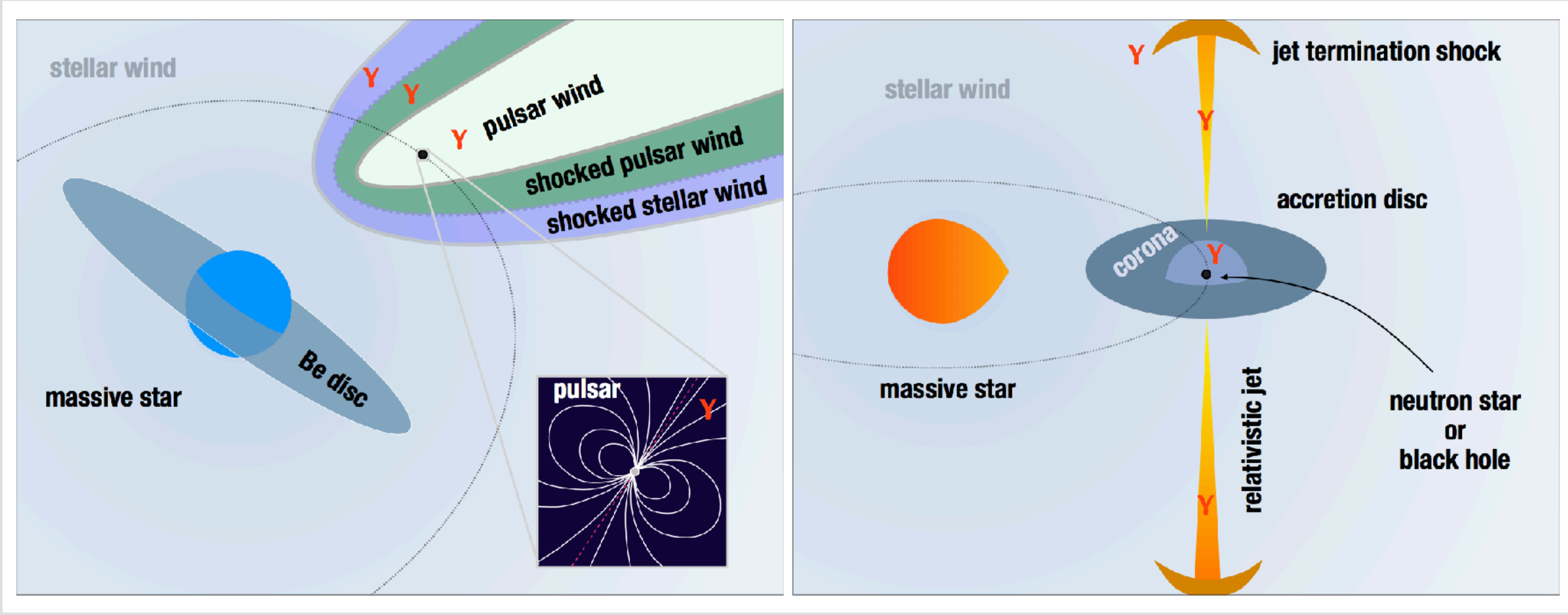
**Discovered August 2016**

- Extragalactic!
- Type O5III star, 42-24M⊙
- Period: 10.3 days




A LUMINOUS GAMMA-RAY BINARY IN THE LARGE MAGELLANIC CLOUD - http://dx.doi.org/10.3847/0004-637X/829/2/105

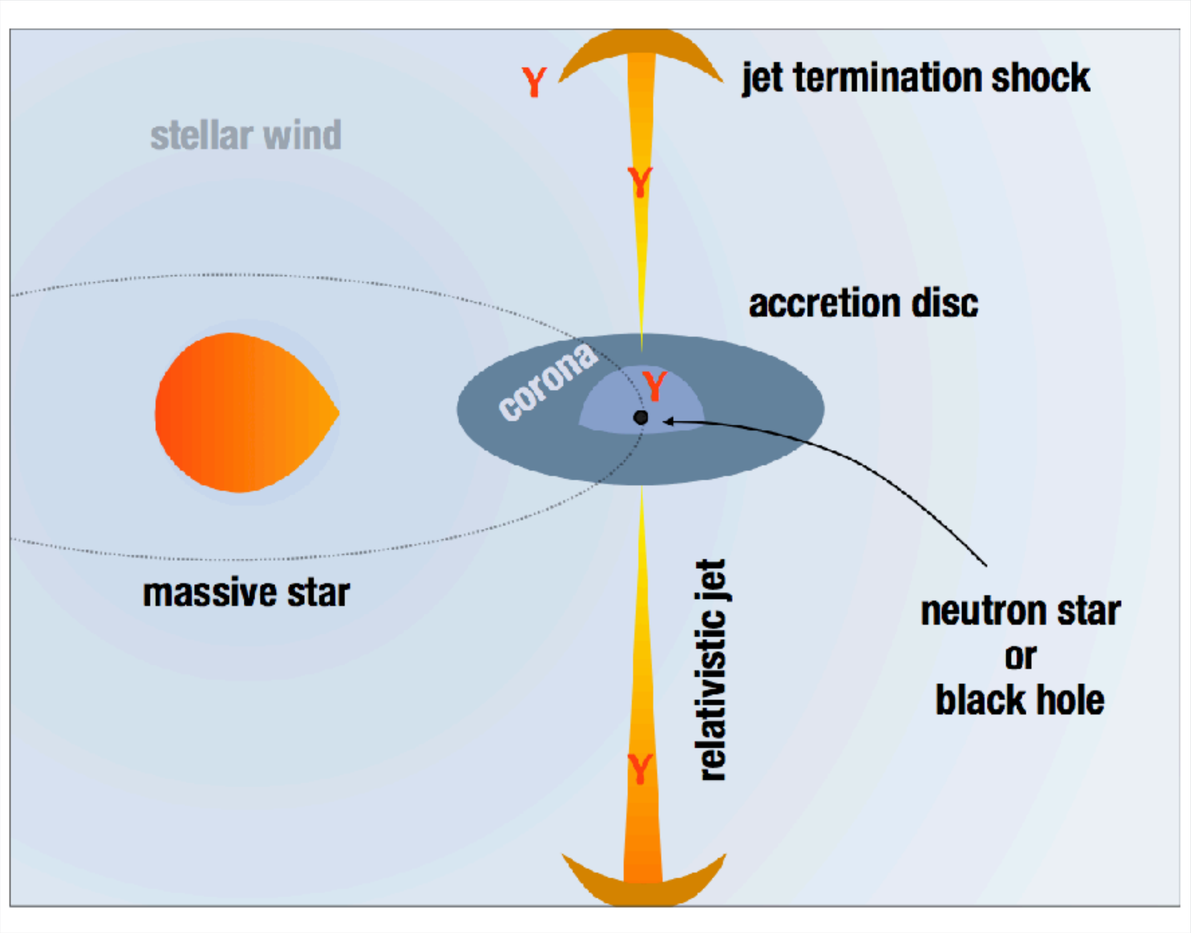
# Emission Scenarios




Gamma Ray Binaries and Related Systems - Guillaume Dubus - https://arxiv.org/pdf/1307.7083v2.pdf

# Accretion

- Massive Star accretes onto compact object
- Relativistic Jets give rise to TeV emission
- Possible for Pulsars **or** Black Holes

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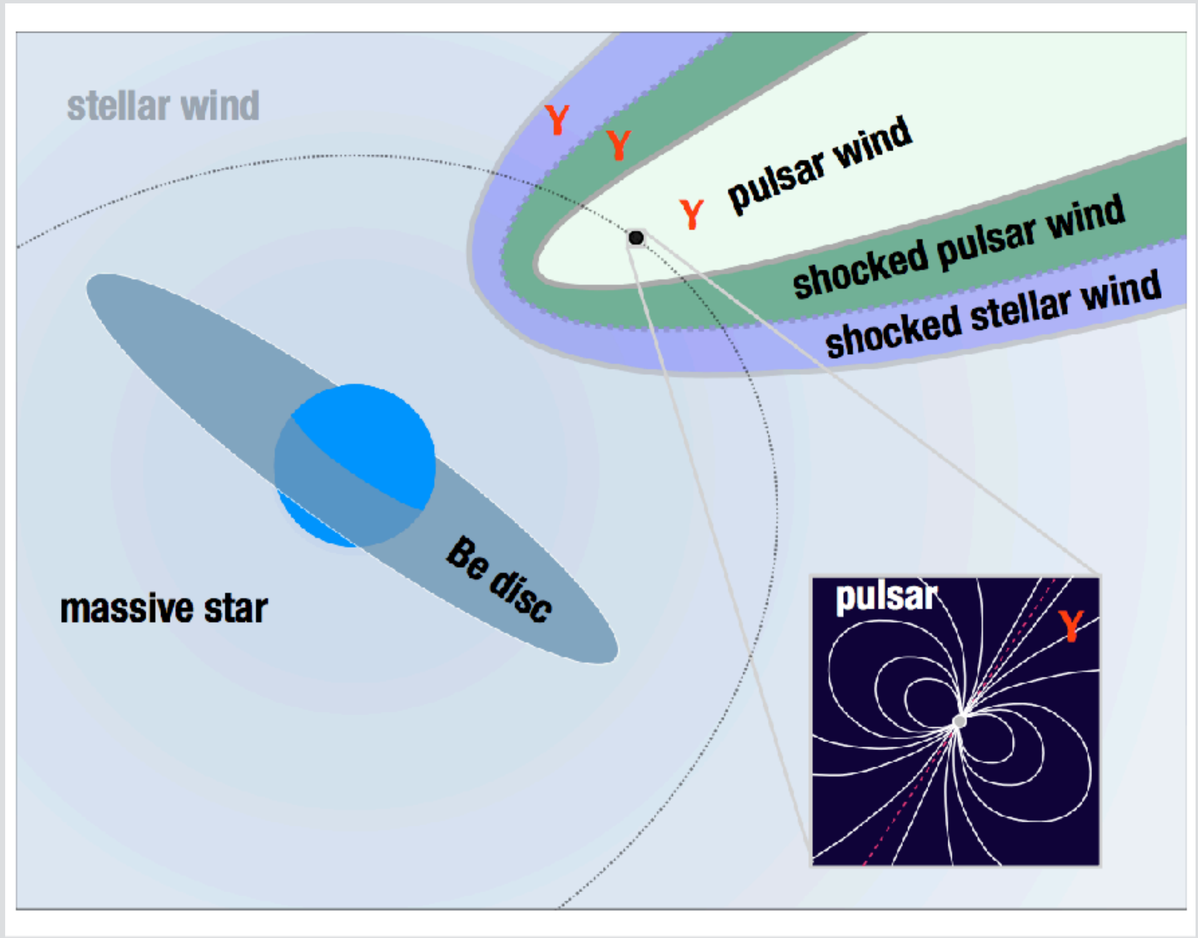
# Pulsar Wind

- Pulsar Wind shocked by strong stellar wind
- PWN highly anisotropic
- Lifetime limited to spin down time of the Pulsar

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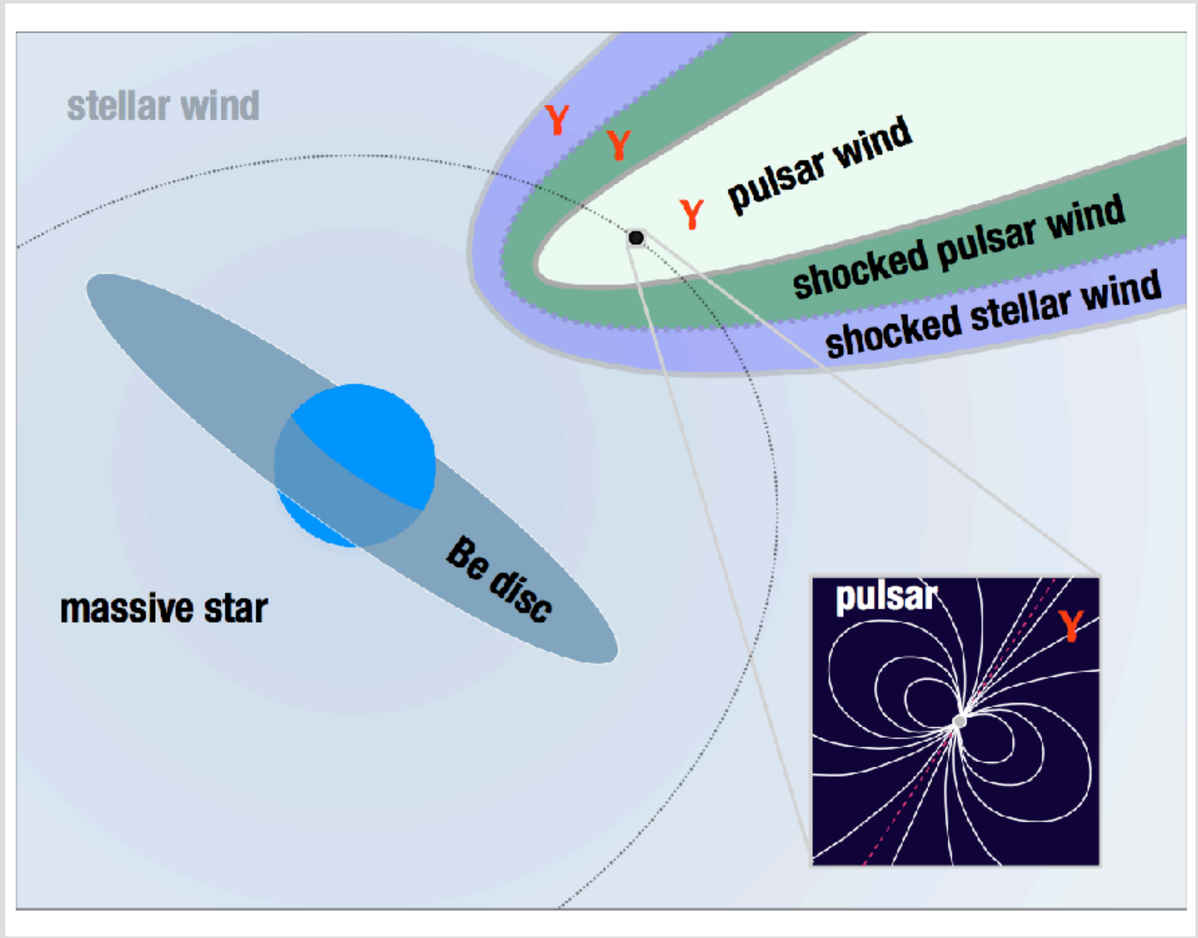
# Pulsar Wind

- TeV spectrum dominated by inverse compton emission
- Anisotropy in pulsar wind simply explains orbital dependence

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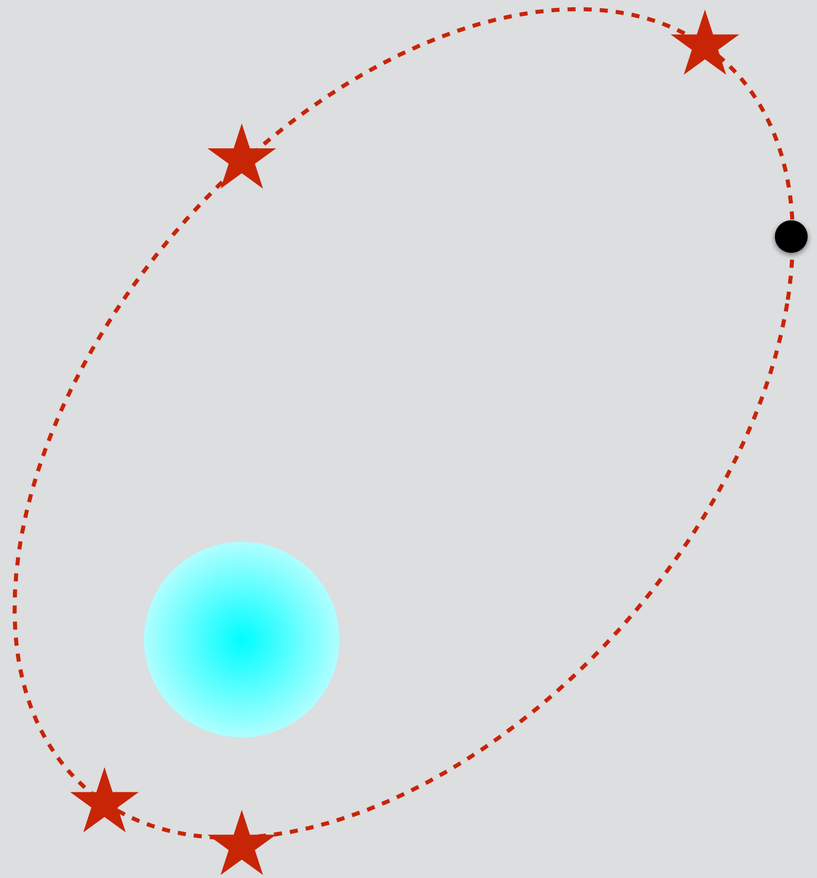
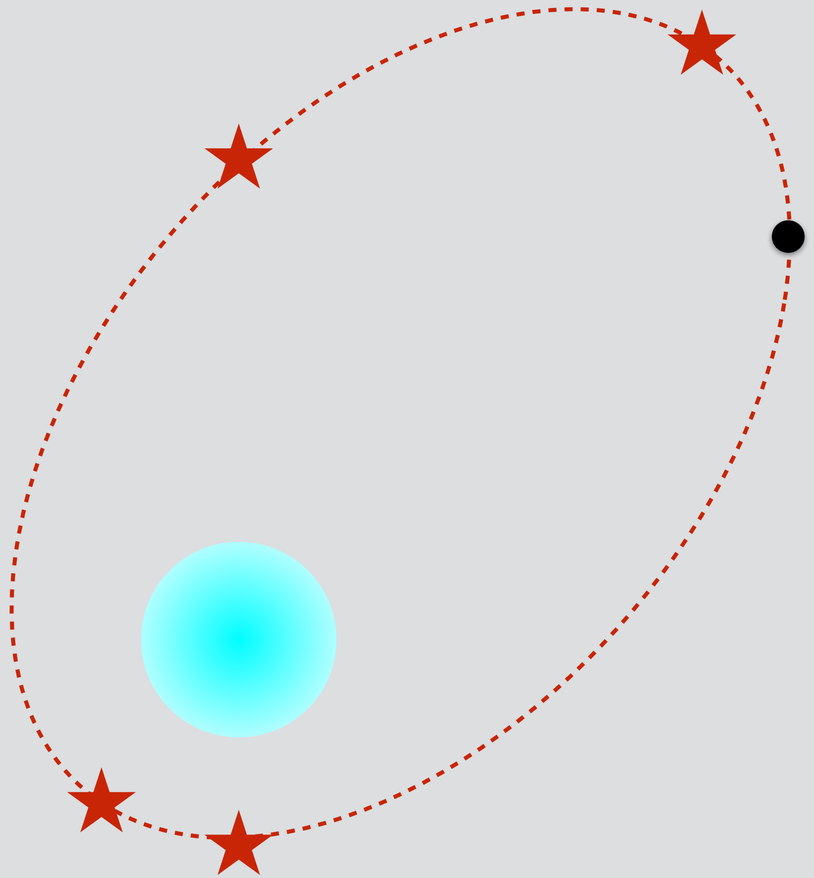
# Outstanding Questions

- Where does the TeV emission occur?
  - (Un)Shocked Pulsar wind?
  - Jet?
  - Near or far from compact object?
  - For HAWC, point-like? or extended?
- Does the location change with phase?
- Where do micro-quasars/Colliding Wind binaries fit into the picture?



# Outstanding Questions

- How common are these systems?
  - We know of five ~few kpc away
  - Estimate of ~30-100 in galaxy
  - 114 HMXB in Catalog from 2005
- One possible system in SMC
- Lifetime == Spindown Time of Pulsar
- May be progenitors of Transient Gravitational wave sources?



# Opportunities & Requirements for Southern Observatory

# Candidate γ Binaries

Pulsars with Massive companions!

| | PSR B1259-63 | PSR J1740-3052$^{\star}$ | PSR J1638-4725$^{\circ}$ | PSR J0045-7319$^{\dagger}$ |
|---|---|---|---|---|
| $M_{\star}$ ($M_{\odot}$) | 31 (> 3) | >11 | > 6 | > 4 |
| spectral type | O9.5Ve | B?V | ? | B1V |
| $P_{orb}$ (days) | 1237 | 231 | 1941 | 51$^{\ddagger}$ |
| $P_{pulse}$ (s) | 0.048 | 0.570 | 0.764 | 0.926 |
| $\dot{E}$ ($10^{34}$ erg s$^{-1}$) | 80 | 0.5 | 0.04 | 0.02 |
| $\tau_{sd}$ ($10^5$ yr) | 3.3 | 3.5 | 52.8 | 32.9 |
| $e$ | 0.87 | 0.58 | 0.96 | 0.81 |
| $d$ (kpc) | 2.3 | 11 | (6-7)$^{\oplus}$ | 61 (SMC) |
| $d_{periastron}$ (AU) | 0.9 | 0.7 | 0.2 | 0.1 |
| $d_{apastron}$ (AU) | 13 | 2.7 | 11.6 | 0.9 |

# Site Candidates from MSU

- Cerro Chajnantor — 5640m
- Cerro Tocco — 5200m
- Chorillos — 4800m

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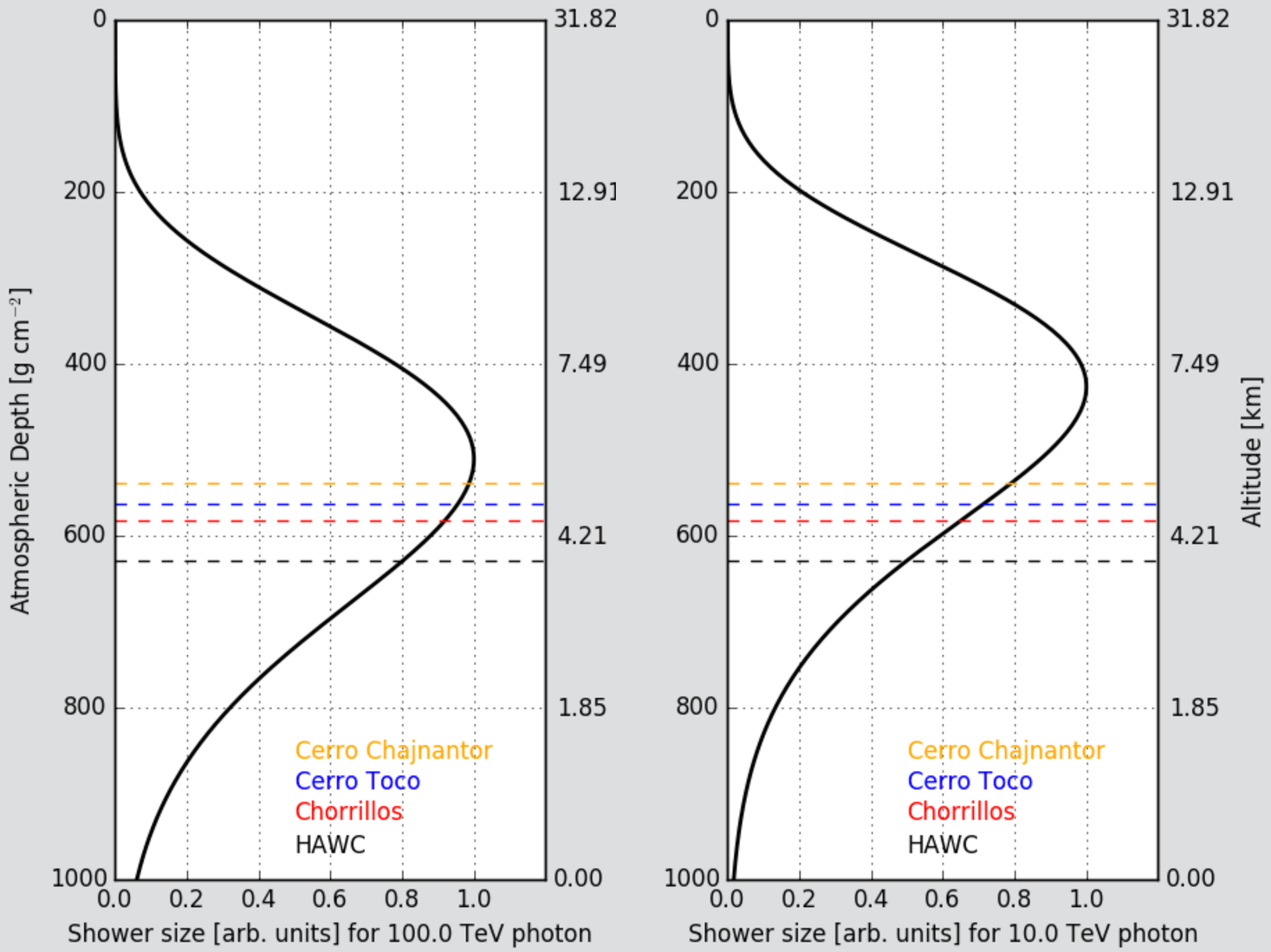
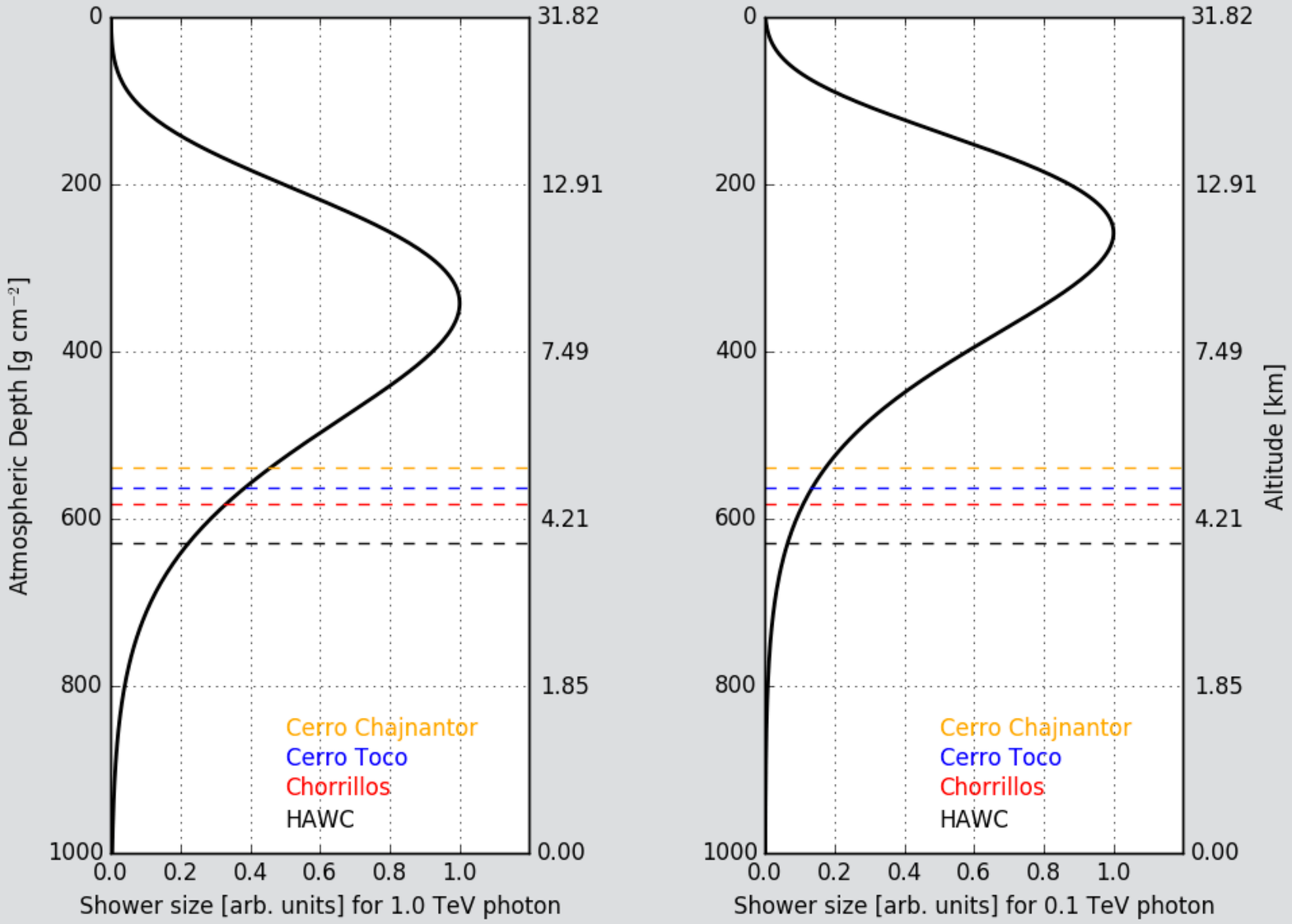
Reducing our atmospheric depth gets us sensitivity to lower energy showers

# High Energy Shower Size



# Low Energy Shower Size



# Low Energy Shower Size

**Double shower sizes at Higher Altitudes for <1.0TeV**