

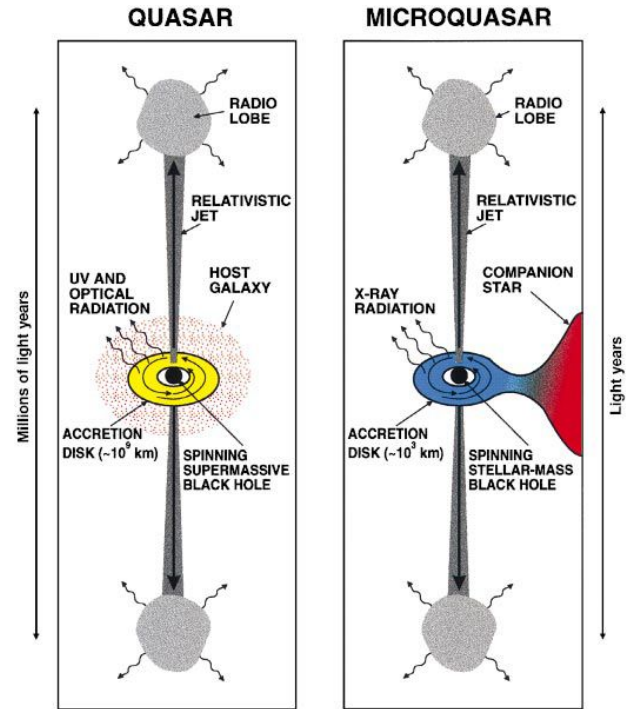
Multimessenger Analysis of Microquasars

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Transient Circle Meeting
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What are microquasars?

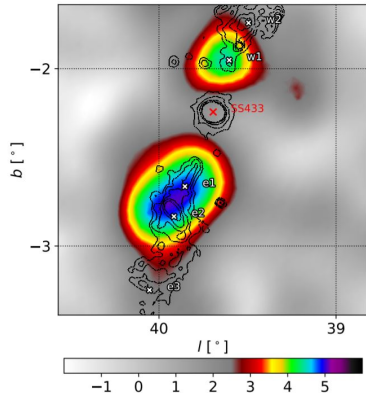
- Binary systems with a compact object (Black Hole or Neutron Star) and a companion star
- Matter transfer from the companion to the compact object
- Process of Accretion - Ejection:
 - Accretion through a **disk**
 - Ejection of matter through a **jet** (which can be relativistic)
- Emit mostly in X-Ray $\Rightarrow$ XRB
- 2 Types:
 - LMXB - Low Mass companion: mass transfer via Roche Lobe overflow
 - HMXB - High Mass companion (type O and B): Mass transfer via winds
- Transient with periods of **outburst**



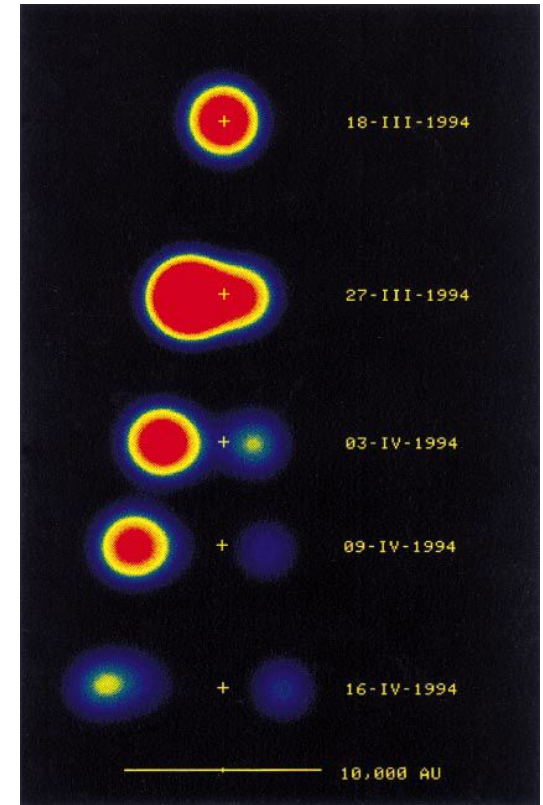
Observations: Overview

High energy processes in microquasars:

- **Radio** : Ejection of plasma clouds that can have an apparent superluminal speed. This indicates relativistic bulk speed.
- **Radio and X-Rays** : Distribution compatible with synchrotron from a non-thermal population of electrons. Indicates particle acceleration
- **Gamma HE**: 4 detections (Fermi): Cyg X-1, Cyg X-3, SS433 (High Masses) and V404 Cyg (Low Mass).
- **Gamma VHE**: interaction region between SS433 jet and surrounding nebula W50 detected by HAWC. Photons up to 25 TeV.



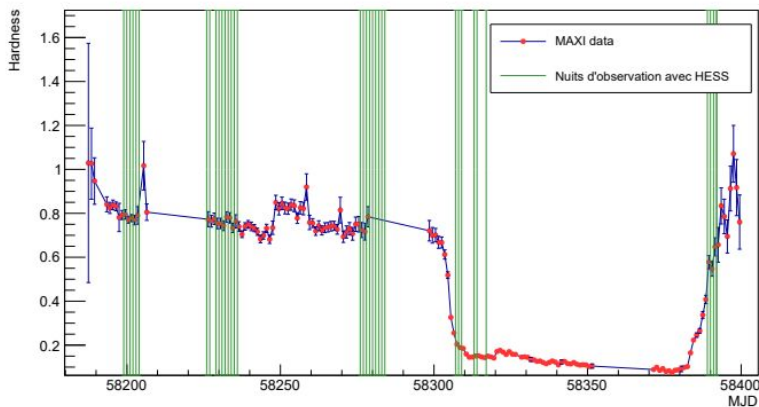
HAWC significance map around SS433



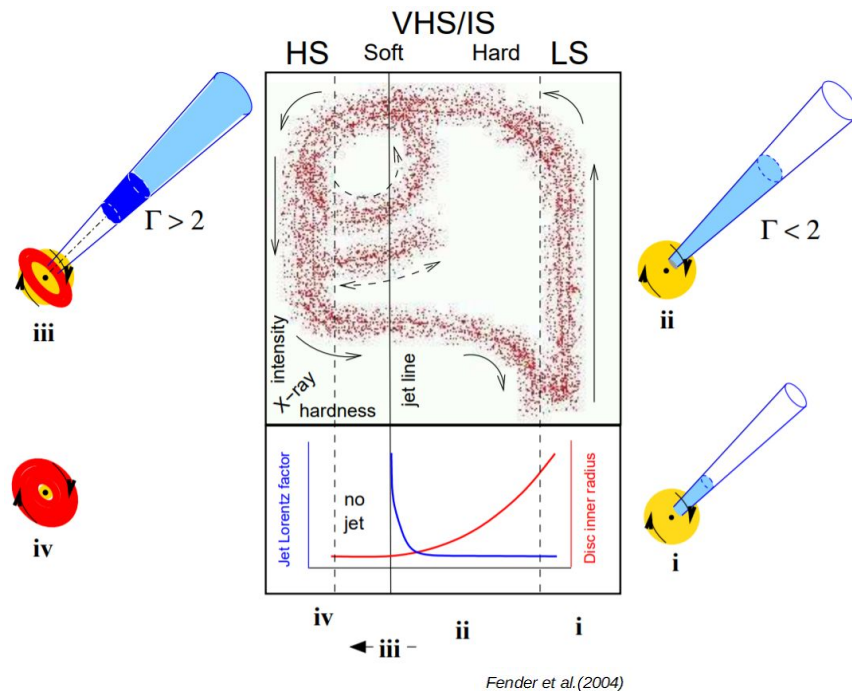
“Superluminal” plasma clouds from GRS1915+105, associated with an outburst.
Bulk velocity $\sim 0.92 c$
Mirabel & Rodriguez (1998)

Phenomenology

- **X-Ray spectra:** soft, thermal component + hard, non-thermal component
- A typical outburst go through a sequence of **states**
- Matter is ejected at relativistic speed **during transitions** between the “hard” and “soft” states
- Collision with slower matter could create **shocks**
- Could lead to particle acceleration to **very high energy**



Hardness of MAXIJ1820+070 vs time
MAXI telescope



High Energy Phenomena

Particles accelerated during outbursts and phase transitions could produce, up to TeV range:

- Gamma
- Neutrinos (if matter has a hadronic component)

Leptonic process:

$$\textit{Inverse Compton} : e_{\text{accelerated}}^{-} + \gamma_{LE} \rightarrow e^{-} + \gamma_{HE}$$

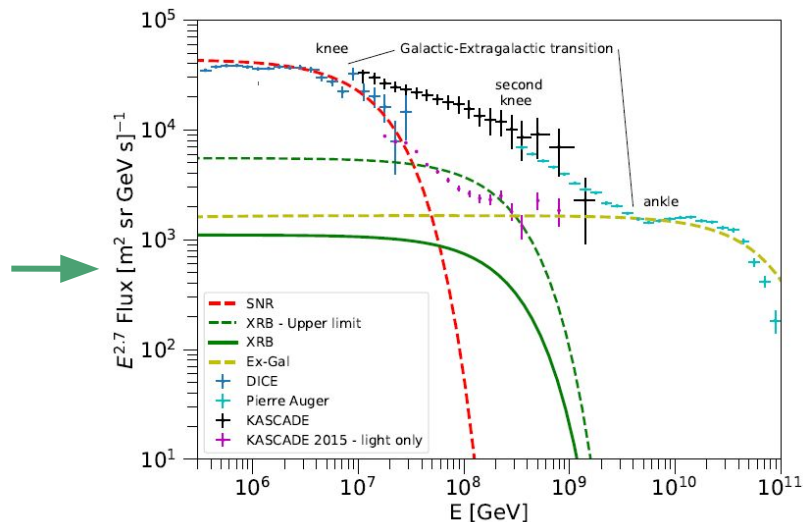
Hadronic process:

$$\left. \begin{aligned} p_{\text{accelerated}} + p &\longrightarrow X + \{\pi^0, \pi^-, \pi^+\} \\ p_{\text{accelerated}} + \gamma_{LE} &\rightarrow \Delta^+ \rightarrow p\pi^0 \text{ or } n\pi^+ \end{aligned} \right| \rightsquigarrow \gamma_{HE} \text{ or } \nu$$

Particular interest to observe during outbursts and transitions $\Rightarrow$ Multiwavelength and Multimessenger astronomy

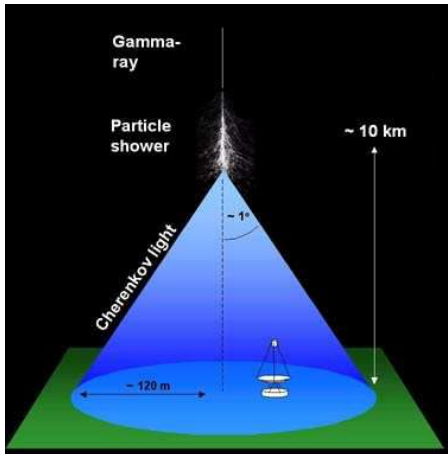
What can we learn?

- **Jet composition** : Hadronic or leptonic fractions
- **Mechanism of jet formation** : Jets powered by BH rotational energy are expected to contain electrons via pair production (Blandford & Znajek, 1977). A high leptonic fraction could indicate this mechanism.
- **Origin of intermediate energy cosmic rays** : If we have protons, we can explore the possibility of microquasars as candidates for origins of cosmic rays (Cooper et al, 2020)
- **Location of particle acceleration** : As they are not absorbed, detecting neutrinos without gamma photons could indicate absorption. This would mean that particle acceleration is taking place in the inner parts of the system with higher density.



Project overview

- Neutrinos with ANTARES/KM3NeT (see Feifei's presentation)
- Gamma with HESS :
 - Array of IACT (Imaging Atmospheric Cherenkov Telescopes)
 - Very High Energy Gamma Ray (few 100s GeV $\rightarrow$ 100 TeV)
 - Inaugurated in 2004



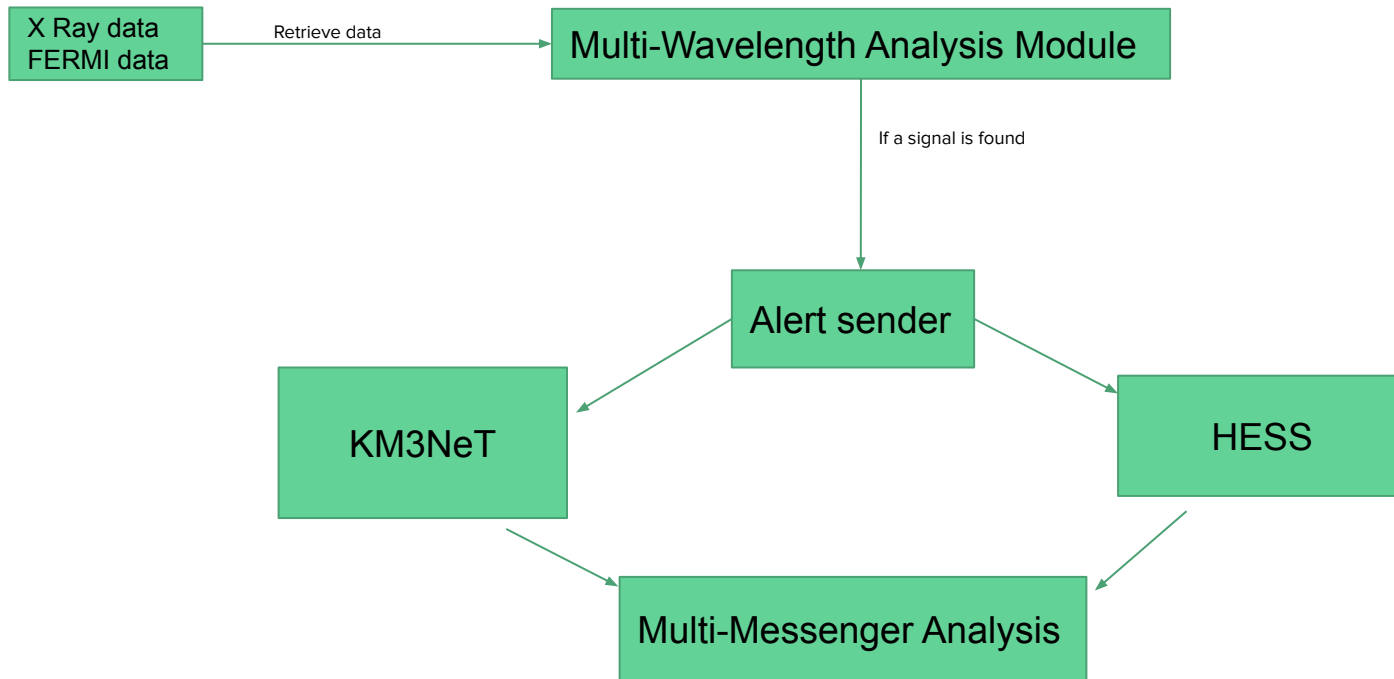
Sketch of Detection of a VHE Gamma-Ray



HESS Observatory

Project overview

Goal: To have a multi-messenger and time-dependent picture of microquasars at HE/VHE & confront it to existing models



Multiwavelength analysis

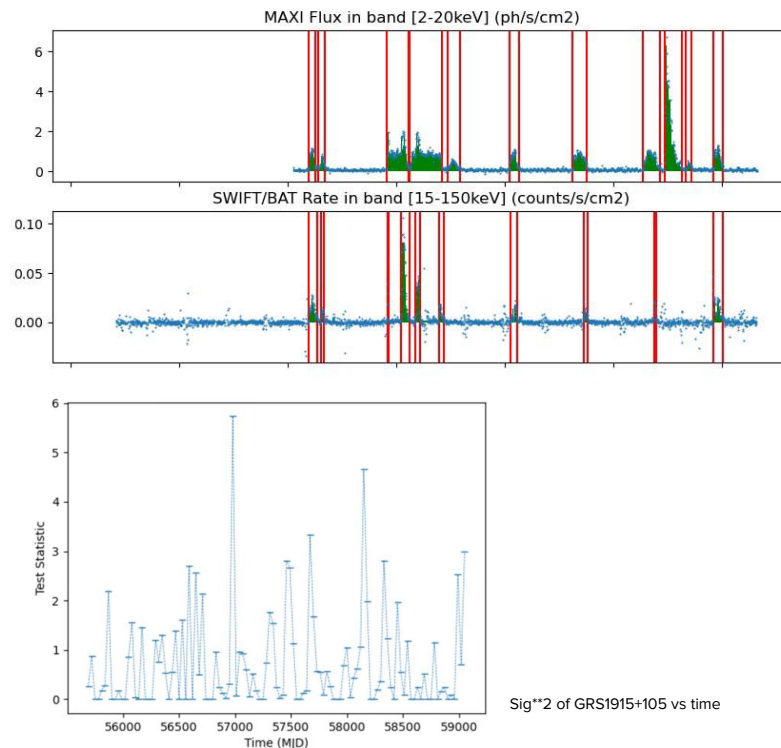
Goal: find favourable periods for high energy emissions

- Microquasars mostly bright in X Rays $\Rightarrow$ preferred energy band
- Publicly available data collected from multiple telescopes (NICER, MAXI, RXTE, INTEGRAL, SWIFT/BAT/XRT)
- Module for identification of activity periods from lightcurves

FERMI/LAT Gamma ray telescope (100MeV-100GeV):

- No microquasar in catalogue
- No lightcurve publicly available
- $\Rightarrow$ Pipeline for non-catalogued source search

These tools will be improved to work automatically for real-time analysis and observation triggers with HESS



Archive / Offline Analyses

Goal: Search for a signal in previous observations or compute upper limits

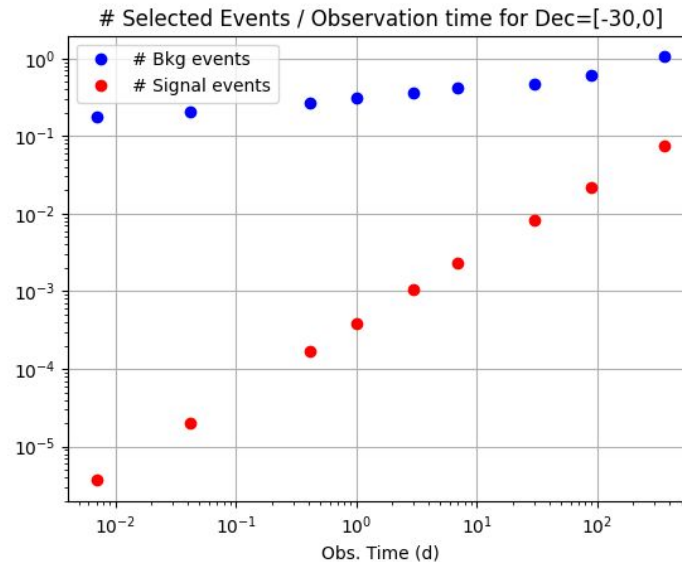
In HESS:

- Preliminary analysis of dedicated and fortuitous (object in FoV of other observations)
 - Determination of observations coinciding with a period of X-Ray activity
 - **No significant signal found**
-
- **Next:**
 - ANTARES analysis of microquasar over whole detector lifetime
 - Joint HESS/ANTARES analysis over concurrent periods
 - Comparison with models

KM3NeT Analysis

As part of the construction of KM3NeT/ORCA:

- Development of a tool for transient analysis:
 - Events selection
 - Significance computations
 - Upper limits derivations
- Quick online data analysis following alerts
- Initially for microquasar analysis but will also work for other sources



Summary

- Multiwavelength and Multimessenger analysis of a class of transient sources, Microquasars
- Search for VHE Gamma and neutrinos
- Preliminary archival analysis
- Preparation for future Real-Time analyses
- Next:
 - Automatize and Implement analysis tools
 - Gather all results and compare them to models
 - Hope for new outbursts!

Thank you for your
attention!

