A Molecular Jet and Arc toward Westerlund 2

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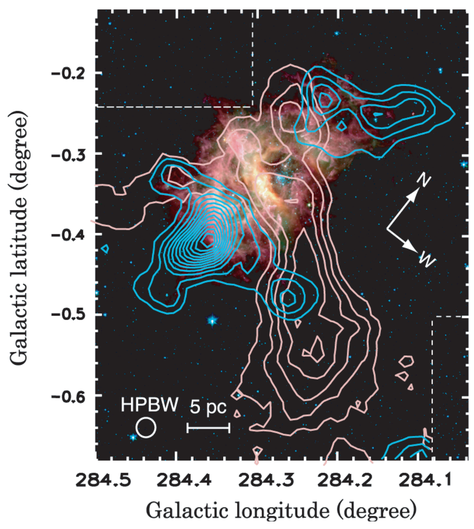
Abstract

We discovered molecular jet and arc associated with TeV & GeV γ-ray source [1]. We present higher resolution CO(J=1-0, 2-1) data as well as distrivutions of temperature and density. We discuss that an anisotropic supernova explosion or a microquasar jet is a possible candidate for driving and heating of the jet.

Introduction

- Parent Molecular Clouds of Westerlund 2 -



Spitzer IRAC GLIMPSE 3 color image of RCW49 overlaid with 12CO(J=2-1) contours.

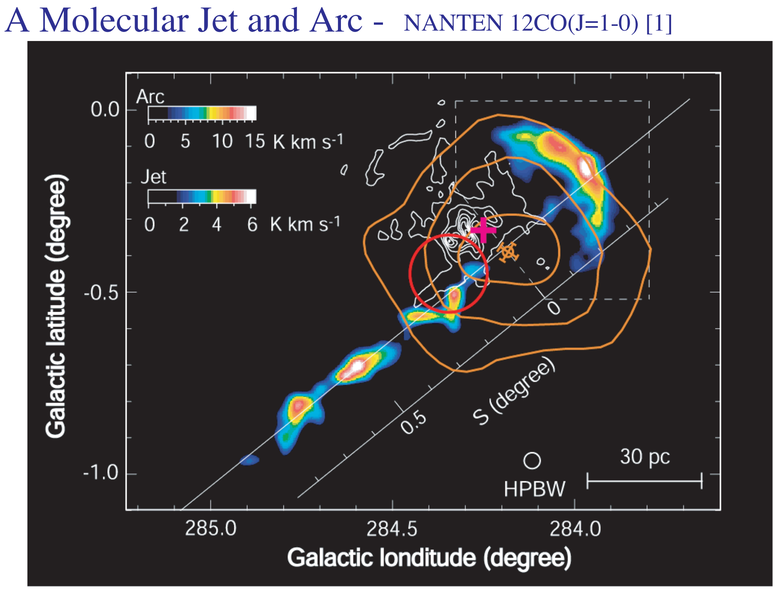
Westerlund 2
-Position:(l, b)=(284.27, -0.33)
-$_{J2000}$(R.A., Dec.)=(10h23m58s,-57°45' 49")
-Mass of stars:4500 Mo [7]
-Age of cluster:2-3 Myr [8]
-O stars: 12 [7]
-Wolf-Rayet: 2 [7]
-Distance: $5.4^{+1.1}_{-1.4}$ kpc [2]

Parent molecular clouds

	Red contour	Blue contour
Vel. range:	11 - 21 km/s	1 - 9 km/s
Mass:	9.1±4.1x10^4 Msun	8.1±3.7x10^4 Msun

Main Points
- Two molecular clouds show remarkably good spatial correlations with HII region.[2]
- The triggered formation of the Wd2 cluster via cloud-cloud collision. [2]
- Revealing the temperature and density distribution of two molecular clouds.[3]

- A Molecular Jet and Arc - NANTEN 12CO(J=1-0) [1]



- The distribution of the 12CO(1-0) emission integrated over a velocity range from 24 - 28 km/s (the arc in the dashes region) and from 28 -30 km/s(the jet)
- The orange contours are the TeV gamma ray source, HESS J1023-575[4].
- The red circle is the MeV/ GeV gamma-ray excess with Fermi [5].
- The white contours are the radio coninuum [6].
- The cross indicates the position of Wd2.

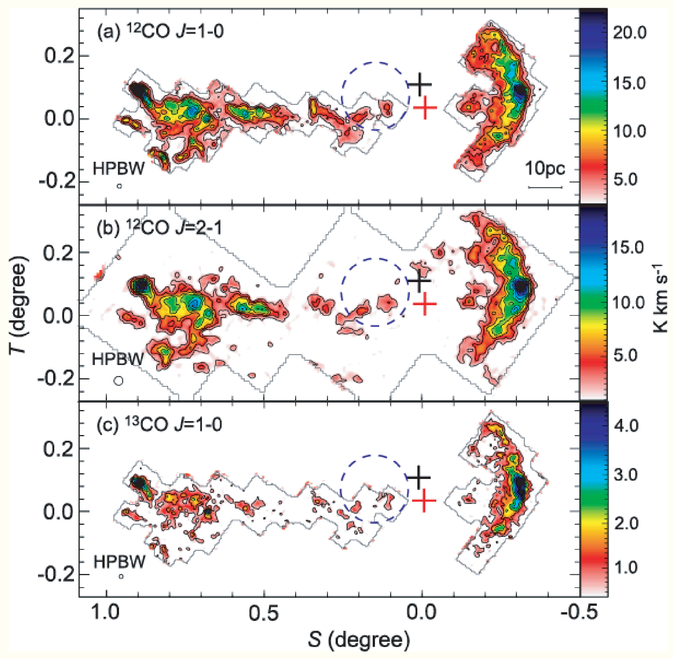
Observations

Telescope: Mopra 22 m telescope
Targets: 12,13CO(J=1-0):115,110GHz
Beam size: 33" @ 115 GHz
Obs mode: On The Fly
Vel. coverage: 356 km/s
Vel. resolution: 0.087 km/s
T r.m.s.: 0.7 K/ch(12CO),0.3 K/ch(13CO)

Telescope: NANTEN 2 4 m telescope
Targets: 12,13CO(J=2-1):230,220GHz
Beam size: 90" @ 230 GHz
Obs mode: On The Fly
Vel. coverage: 385 km/s
Vel. resolution: 0.38 km/s
T r.m.s.: 0.4 K/ch(12CO),0.05 K/ch(13CO)

Telescope: NANTEN 4 m telescope
Targets: 12CO(J=1-0): 115GHz
Beam size: 2.6' @ 115 GHz
Obs mode: Position switch
Vel. coverage: 56 km/s
Vel. resolution: 0.6 km/s
T r.m.s.: 1.0 K/ch(12CO)

- CO(J=1-0,2-1) Distributions -

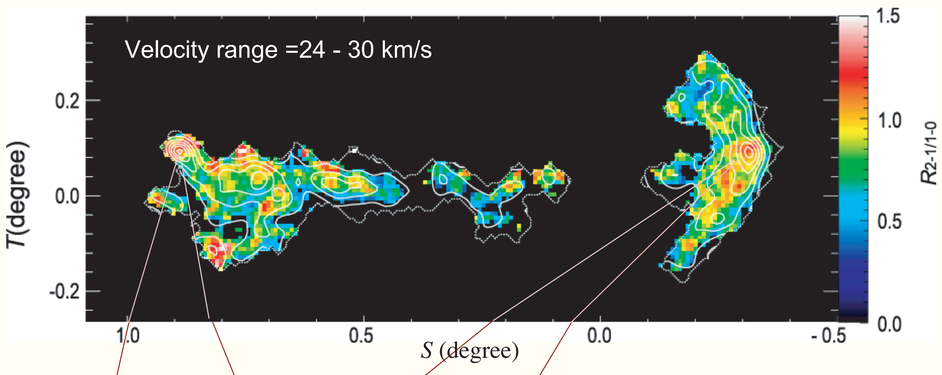


The black cross is the position of Westerlund 2 cluster.
The red cross is the center of TeV gamma ray HESS J1023-575
The blrack circle is distribution of Fermi source
- High resolution observations reveal detailed structures in the jet and arc molecular cloud.
- Mass:The jet like molecular cloud is 1.0-2.7 x 10^4 Msun
The arc like molecilar cloud is 2.0-5.2 x 10^4 Msun
X factor = N(H2)/Wco = 2.0x10^{20} [cm^{-2} (K km s^{-1})-1] [9]

- Molecular cloud in 12CO(J=1-0) emission shows a helical structure.
- Shape of the arc molecular cloud is crescent.

- 12CO(J=2-1) intensity in the jet molecular cloud is the strongest in position (S,T=0.9, 0.1).
- The arc molecular cloud is detected 13CO(J=2-1) emission.

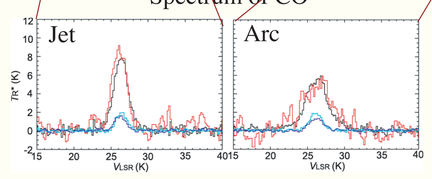
- Ratio CO J=2-1/1-0 Distributions -



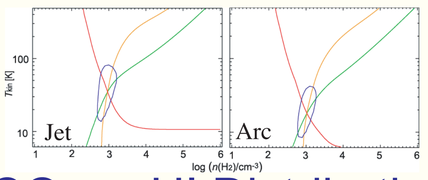
- Typical R2-1/1-0, 12CO(J=2-1)/12CO(J=1-0) ratio in molecular jet and arc is 0.7 - 1.2.
- There are two high R2-1/1-0 lines in the jet looking like helical structure.
- R2-1/1-0 of the arc moleuclar is high in the center.

- Temperature and Density; LVG Analysis -

Spectrum of CO



Temp. and density by LVG analysis



Black: 12CO(1-0)
Light blue: 13CO(1-0)
Red: 12CO(2-1)
Blue: 13CO(2-1)

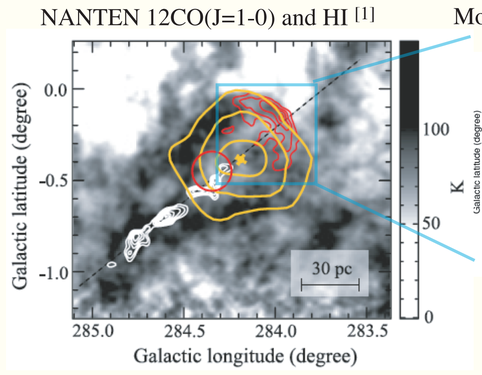
colors: Ratio
Red: 13CO(2-1)/13CO(1-0)
Orange:13CO(2-1)/12CO(2-1)
Green: 13CO(1-0)/12CO(2-1)
Error of caliblation is 20%

- We employ LVG (Large Velocity Gradient) analysis [10] to estimate temperature and density of the molecular gas in jet and arc.
- We use line intensity ratios in the analysis for two points that were observed in 12CO(J=1-0) and 13CO (J=1-0) by using the Mopra telescope, 12CO(J=2-1) by NANTEN 2.

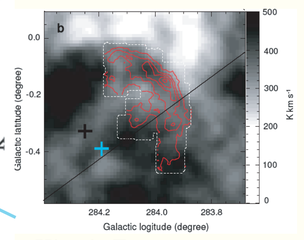
- The jet molecular
Temperature is ~35 K. Density is ~ 10^3 /cm3.
- The arc molecular
Temperature is ~18 K. Density is ~ 10^3 /cm3.

- CO vs. HI Distributions -

NANTEN 12CO(J=1-0) and HI [1]



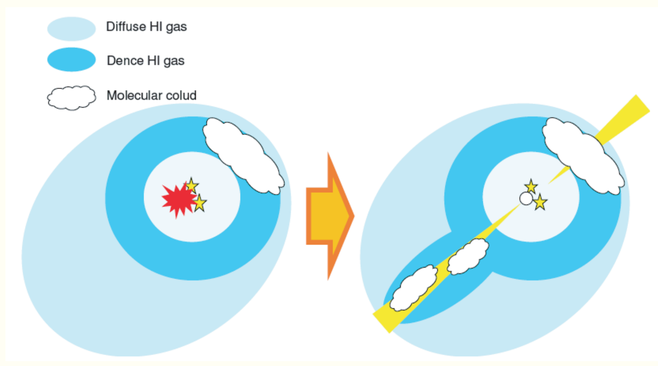
Mopra 12CO(J=1-0) and HI [1]



Kinetic Energy
Arc:1 x 10^{48} ergs
Jet: 1 x 10^{49} ergs

- The HI shows a clear sign of a hole toward Wd2 and HESS J1023-575.
- The HI shell exhibits an intensity depression in its norther part, coincident with the arc moleculur.
- The molecular arc and HI shell are physically related.
- This HI intensity depression is likely due to the conversion of HI into H_2.
-The jet is coincident with an elongated spur of HI extended to the east over ~1°, from l ~ 284°.3 to 285°.0.

- Scenario of the Molecular Jet & Arc - [11]



Two Scenarios to form the jet and arc molecular.
(i) a highly anisotropic supernova explosion
(ii)a high-energy accretion-powered jet from a compact object such as in a microquasar.

1. Jet from the high density object passes through the intersterllar matter.
2.The intersterlar matter is compressed in center of the jet axis by the jet.
3. The HI gas is converted to H_2 by the compression.

References

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