The Cygnus Loop's Distance & Environmental Driven Morphology

Kathryn E. Weil[1], Robert A. Fesen[1], Ignacio Cisneros[1], William P. Blair[2], & John C. Raymond[3]

[1]Dartmouth College, [2]Johns Hopkins University, [3]Harvard-Smithsonian Center for Astrophysics

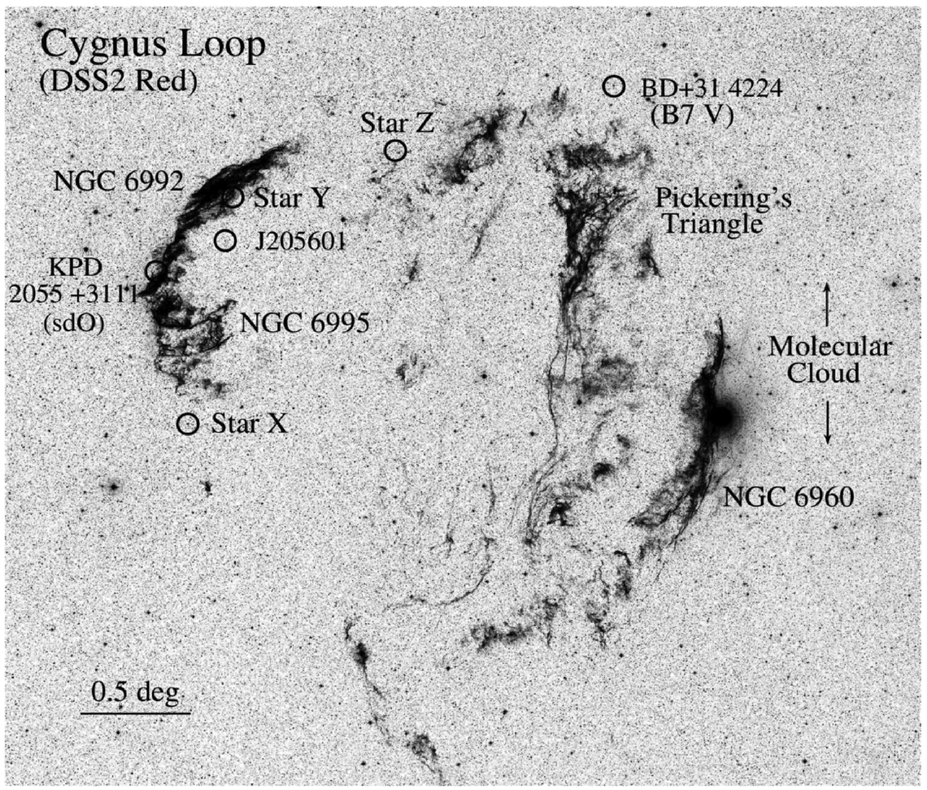
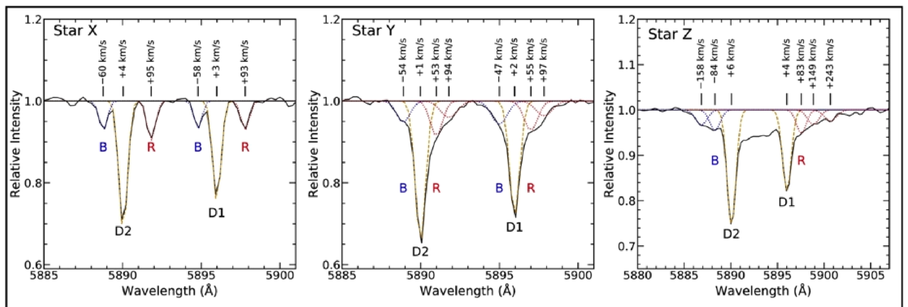


TABLE 1
STARS USED TO ESTIMATE THE DISTANCE TO THE CYGNUS LOOP

Star ID[a]	Catalog Number[b]	RA (J2000)	Dec (J2000)	Magnitude (v)	Gaia DR2 Parallax	Gaia DR2 Distance	Location to SNR
J205601	TYC 2688-1037-1	20:56:00.936	+31:31:29.75	11.57	0.6334 ± 0.0661 mas	1580 ± 180 pc	far behind
KPD 2055 +3111	UCAC2 42838052	20:57:26.889	+31:22:52.56	14.12	1.2610 ± 0.0413 mas	793 ± 30 pc	behind
BD+31 4224	TYC 2691-290-1	20:47:51.817	+32:14:11.33	9.58	1.3033 ± 0.0438 mas	767 ± 27 pc	inside
Star X	HD 335334	20:56:44.629	+30:41:14.33	9.51	1.3586 ± 0.0440 mas	736 ± 25 pc	just behind
Star Y	TYC 2688-365-1	20:55:51.948	+31:43:27.40	11.25	1.3598 ± 0.0449 mas	735 ± 25 pc	just behind
Star Z	TYC 2692-3378-1	20:52:27.557	+31:56:29.48	10.73	1.1581 ± 0.0390 mas	864 ± 30 pc	far behind

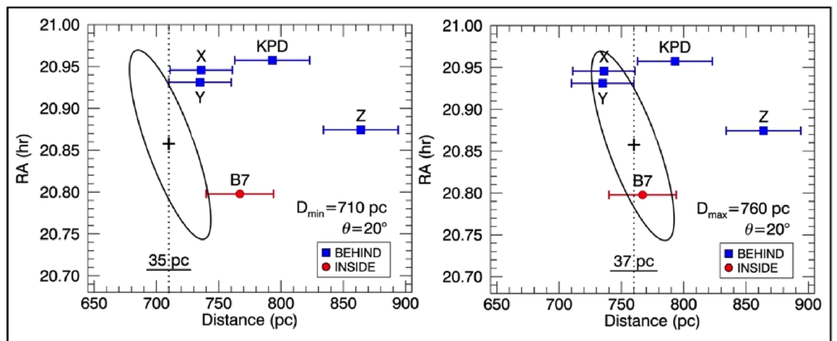
[a] References: J205601 & BD+31 4224: Fesen et al. (2018); KPD 2055 +3111: Blair et al. (2009); X, Y, Z: this work
[b] TYC: Høg et al. (2000); UCACA2: Zacharias et al. (2004); HD: Henry Draper Catalogue



Optical spectra of three stars behind the Cygnus Loop with Na I 5890, 5896 Å absorption due to the remnant's expanding shell.

TABLE 2
MEASURED INTERSTELLAR VELOCITY COMPONENTS AND EQUIVALENT WIDTHS

Star ID	Line	V_0 km s^{-1}	EW_0 Å	V_{B1} km s^{-1}	EW_{B1} Å	V_{B2} km s^{-1}	EW_{B2} Å	V_{R1} km s^{-1}	EW_{R1} Å	V_{R2} km s^{-1}	EW_{R2} Å	V_{R3} km s^{-1}	EW_{R3} Å
Star X	Na I D1	+3	0.17	−58	0.04	···	···	+93	0.05	···	···	···	···
	Na I D2	+4	0.22	−60	0.05	···	···	+95	0.07	···	···	···	···
	Ca II K	−2	0.13	−58	0.11	···	···	+88	0.29	···	···	···	···
Star Y	Na I D1	+2	0.23	−47	0.07	···	···	+55	0.08	+97	0.05	···	···
	Na I D2	+1	0.29	−54	0.06	···	···	+53	0.08	+94	0.05	···	···
Star Z	Na I D1	+4	0.21	···	···	···	···	+83	0.07	+149	0.05	+243	0.04
	Na I D2	+6	0.30	−84	0.06	−158	0.05	···	···	···	···	···	···



Gaia DR2 distances versus RA for the stars used to the determine the distance to the Cygnus Loop. The ellipse represents a slightly aspherical remnant, tilted remnant. The cross represents the location of the center of the remnant.

Left Panel: Minimum distance to the remnant such that the B7 star remains inside the remnant at its extrema distance while Stars X and Y are located behind the remnant.

Right Panel: Maximum distance to the remnant such that Stars X and Y lie behind the remnant at their extrema distances while the B7 star lies within the remnant.

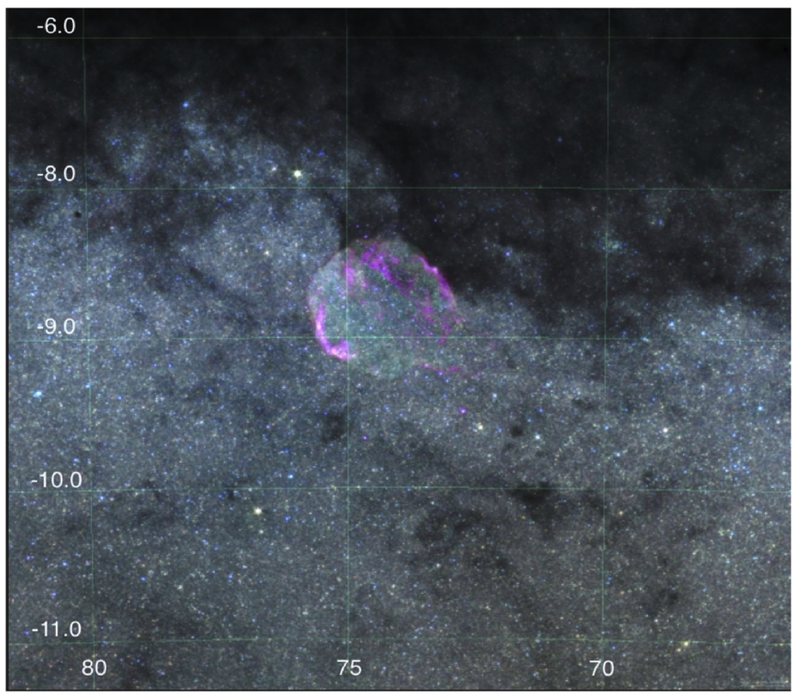
MAIN RESULTS

Optical spectra of three stars (X, Y, Z) with projected locations toward the remnant revealed Na I 5890, 5896 Å and Ca II 3934 Å absorption features associated with the remnant's expanding shell, with velocities ranging from −160 to +240 km/s.

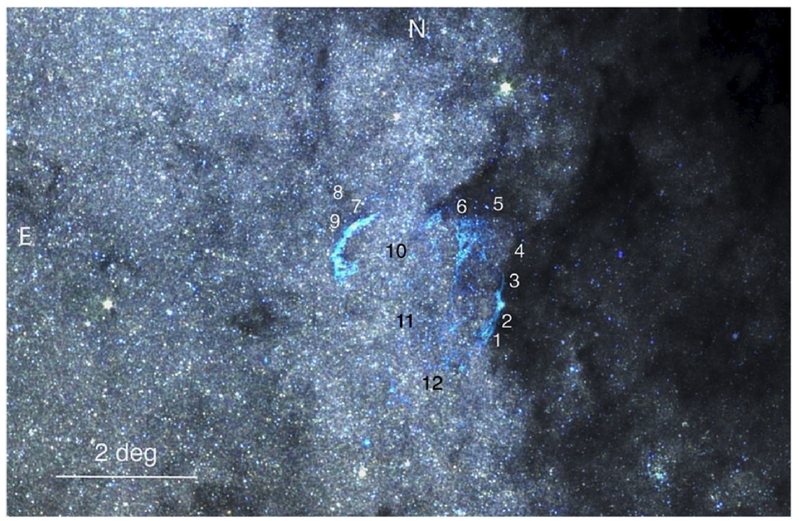
Combining Gaia DR2 parallax measurements for these stars with other recent observations, **we find the distance to the Cygnus Loop's center is 735 ± 25 pc,** only a bit less than the 770 pc value proposed by Minkowski some 60 yr ago. Using this new distance, we discuss the remnant's physical properties including size, SN explosion energy, and shock velocities.

Multi-wavelength emission maps reveal that, instead of being located in a progenitor wind-driven cavity as has long been assumed, the Cygnus Loop lies in an extended, low-density ISM region. **Rather than wind-driven cavity walls, these images reveal in unprecedented clarity the sizes and locations of local interstellar clouds with which the remnant is interacting, giving rise to its large-scale morphology.**

For more details see: Fesen et al. 2018 MNRAS 481 1786F



Composite image made from optical Mellinger RGB, Planck infrared (gray), GALEX (pink), & X-ray (white) images of the Milky Way region around the Cygnus Loop in Galactic Coordinates. The remnant's brightest optical & X-ray emission features appear immediately adjacent to local dust clouds.



Composite image made from optical Mellinger RGB images (white), Planck infrared (grey), and GALEX UV (blue) data. Marked are 12 ISM dust regions where cumulative dust reddening measurements were made using Pan-STARRS and 2MASS data.

We find a large increase in E(B-V) values for estimated distances greater than 650 pc for regions 1 thru 9, but virtually no change in values for regions 10 – 12.