Nobeyama 45-m CO survey for Cygnus-X: Possible evidence for formation of DR21 and W75N by cloud-cloud collision

NOBEYAMA FOREST

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Current understandings toward high-mass star formation (HMSF)

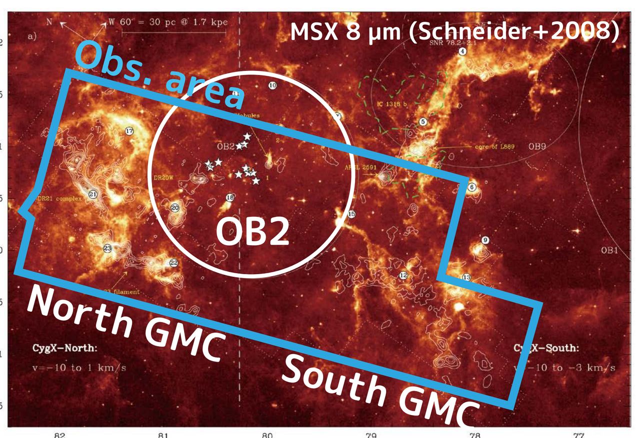
Theoretically, two models (core accretion; McKee&Tan 2003, and competitive accretion; Bonnel et al. 2001) have been proposed and widely investigated (reviewed in Tan et al. 2014). These models can create high-mass stars, however, they require extraordinary high-density for an initial condition of collapsing cores (e.g., Krumholz & McKee 2008). Therefore, the outstanding topic for high-mass star formation (HMSF) is now that the process of high-density core formation.

The idea that collision of clouds triggers HMSF have been considered to be qualitatively correct in the context of galactic dynamics e.g., galaxy interaction and spiral arm formation. Recently, start with a discovery of cloud collision in the Galactic superstar cluster (Furukawa et al. 2009), cloud collision evidence is found in all Galactic superstar cluster which is younger enough to be associated with natal cloud (Fukui et al. 2014, 2016, 2018).

Furthermore, cloud collision is found in most of famous HII region in the Sagitarius Arm (M8, M20, M16, M17, NGC6334; see the special issue of cloud collision published in Jan. 2018 from PASJ). Numerical simulations show that a high mass accretion rate providing a high-mass star (~10^{-3} Mo/yr) is achieved in the compressed shock layer of the collision where turbulence and magnetic field is enhanced (Inoue & Fukui 2013, Inoue et al. 2018).

Cygnus-X

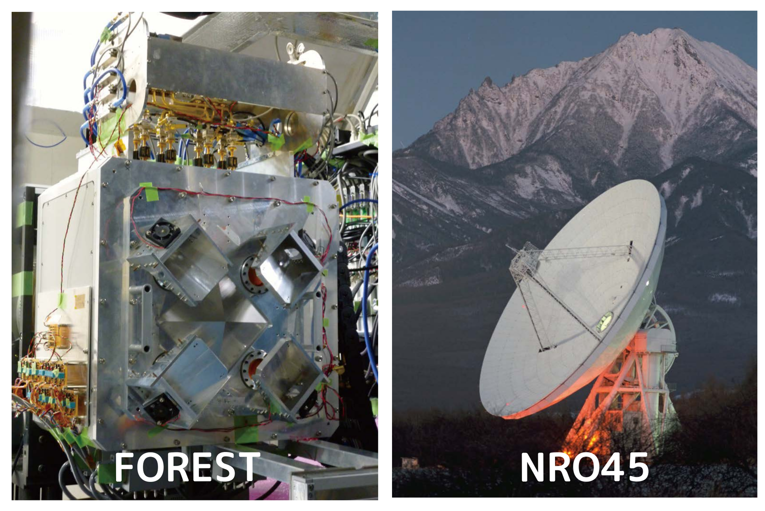
Cygnus-X is one of the most luminous region in the sky for most of wavelengths also knwon as very active high-mass star formation site at the distance of 1.4 kpc. Therefore, Cynus-X can be a template of HMSF. The region consists of 9 OB associations, GMCs with >40 massive protostars including famous DR21, W75N, S106R, and AFGL2591 regions.



Observations / Data

NRO internal observation time (PI. Nishimura)
Receiver : FOREST/SAM45
Obs. date : 2016 Jan 13 - May 08 (observed 77 hours)
Target lines : ^{12}CO(1-0), ^{13}CO(1-0), C^{18}O(1-0) and CN(1-0)
Resolution : 30.52 kHz (0.08 km/s), Polarization : single
Scanmode : FUGIN wide scan mode

Mapped area : 9 deg^2
Typical noise level : 0.5 K (dv=0.5km/s)
Data open policy :
FITS data cubes will be available via our web site after publishment of corresponding papers



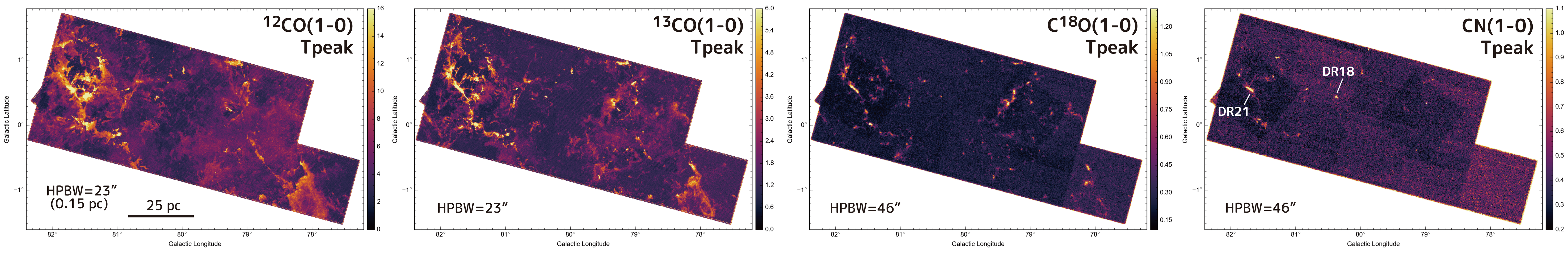


Fig. 1 : Peak temperature images of observed lines.

Results

Large scale distribution

We find two velocity components have absolutely different spatial distributions for entire Cygnus-X region each other (Fig. 2).

	North GMC	OB2	South GMC
Blue-shifted (-7 -- 0 km/s)	main ridge (incl. DR21, W75N) clear boundary	has emission clear boundary	diffuse emission unclear boundary
Red-shifted (6 -- 15 km/s)	shell like surrounding main ridge clear boundary	no emission	diffuse emission unclear boundary

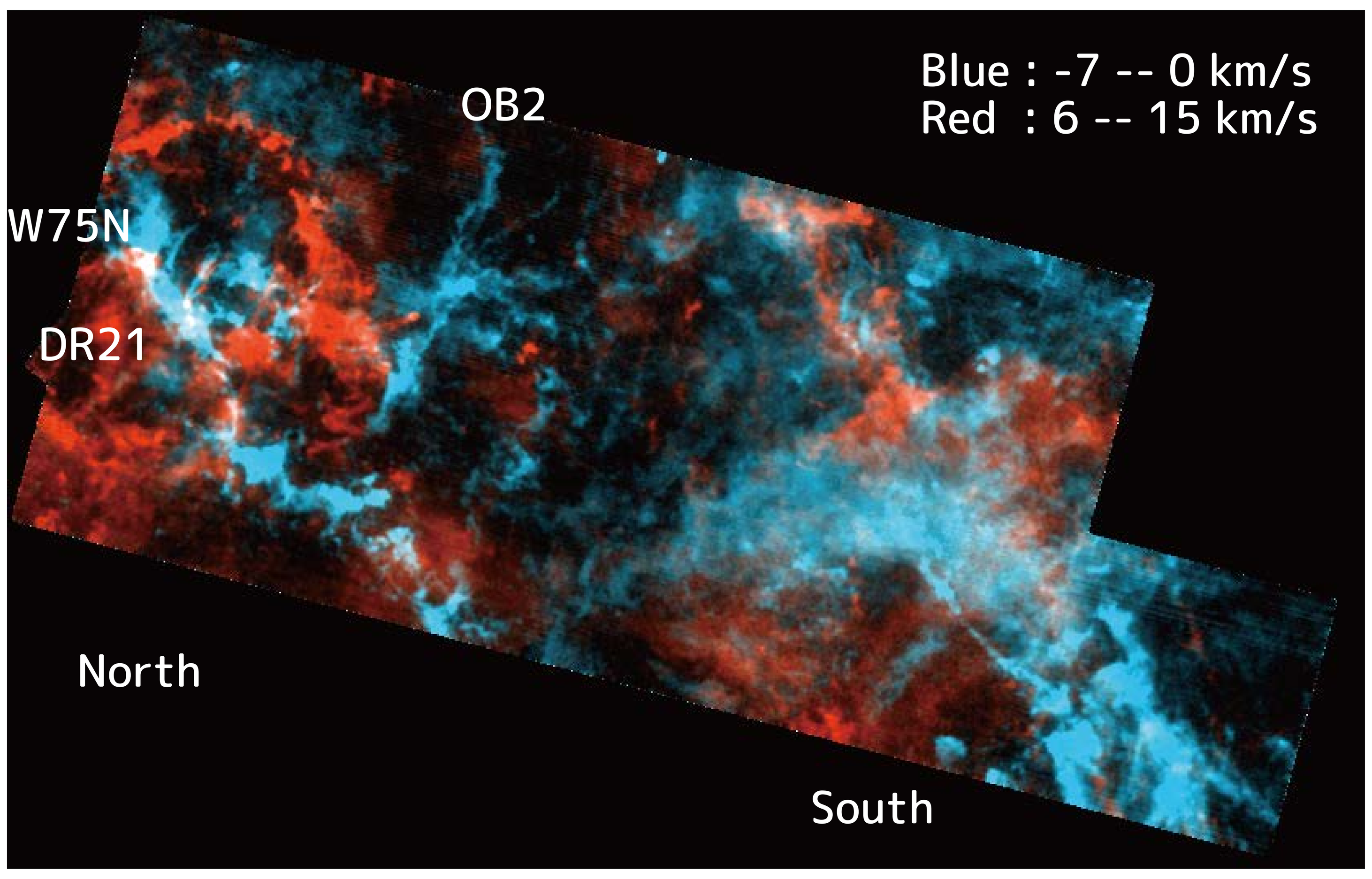


Fig. 2 : Large scale comparison of blue- and red-shifted components.

CO distribution in main ridge of north GMC

Two velocity (blue- and red-shifted) components show complementary distribution in the main ridge of north GMC (Fig. 3). Complementary distribution can be seen in colling clouds if clouds have different size and different density structure (e.g., Takahira et al. 2014, Matsumoto et al. 2015). Therefore, two components are likely colliding. Similar velocity structure is also found in other HMSF sites (M16: Nishimura et al. 2018b, M17: Nishimura et al. 2018a, M42: Fukui et al. 2017).

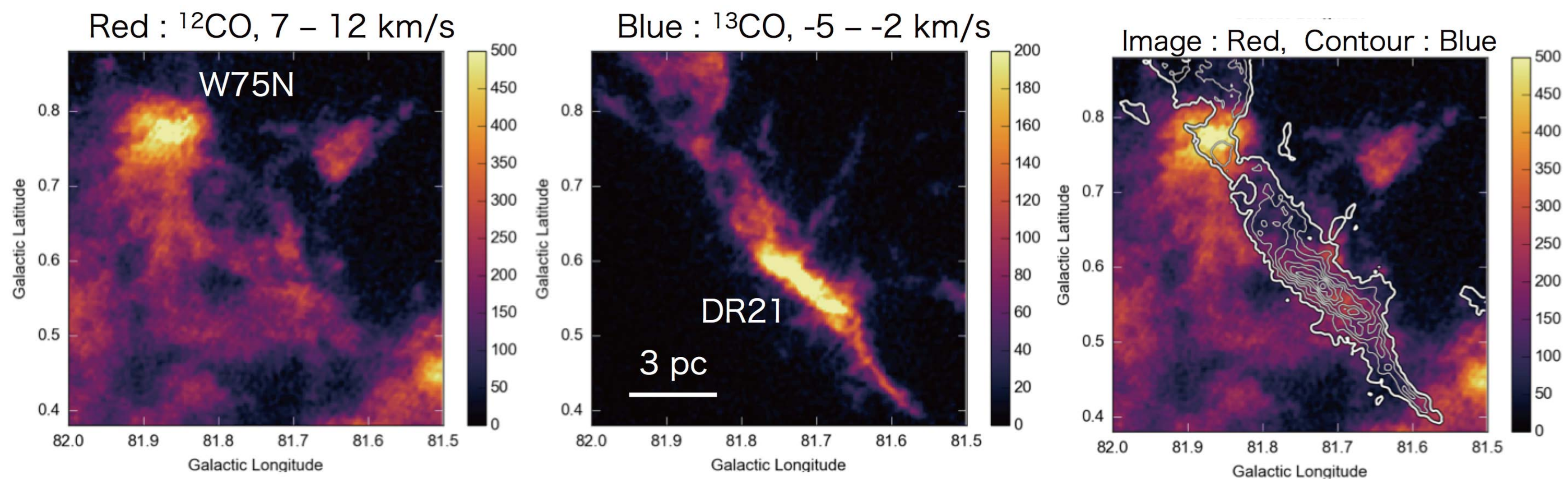


Fig. 3 : Complementary distribution between blue- and red-shifted components.

Bridge feature

Bridge feature is a diffuse velocity structure between two velocity components observed in colliding cloud (Torii et al. 2015, 2017, Haworth et al. 2015). Generally, outflows have bipolar structure, while bridges have emission between two velocities. Bridge feature is detected toward DR21 and W75N regions, where are on-going active star formation sites. This results support collision scenario.

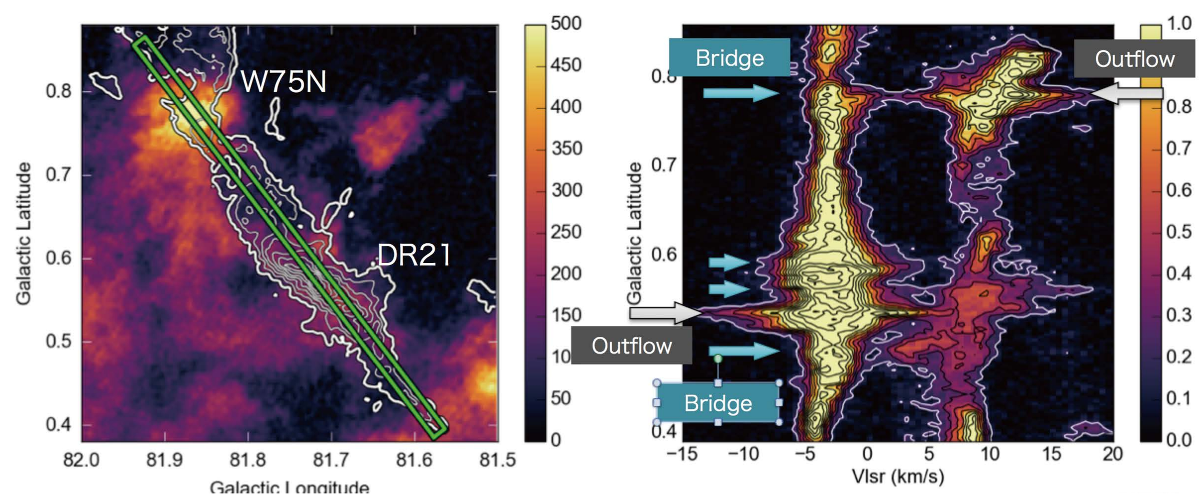


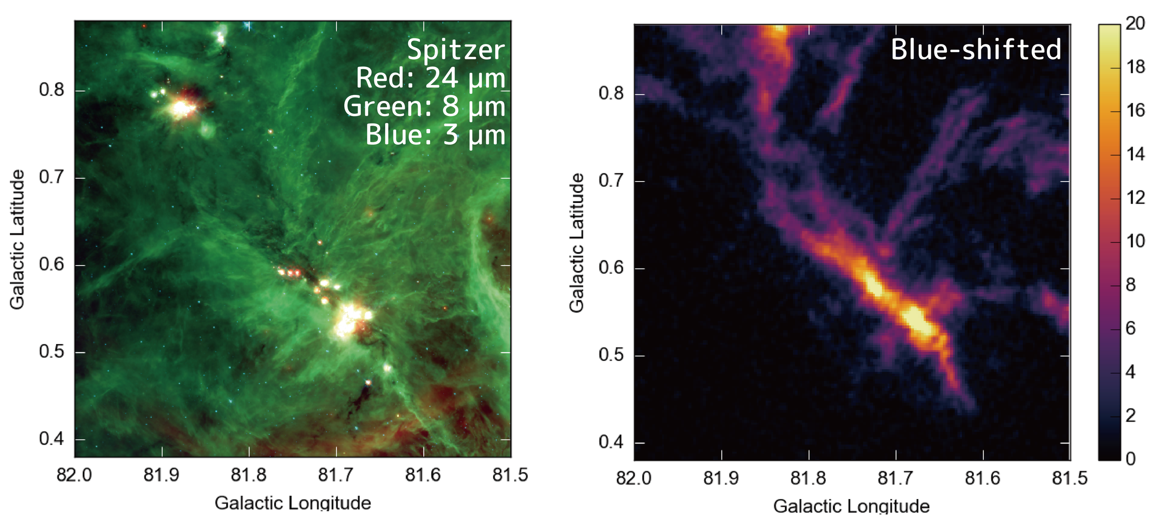
Fig. 4 : Bridging velocity structure at the DR21/W75N.

Comparison with IR image

DR21
- 7 OB cluster candidates (Schneider et al. 2006)
- Outflow DR21(OH) : timescale ~10^3 yr (Zapata et al. 2012)

W75N
- 2 OB cluster candidates (Schneider et al. 2006)

Blue-shifted component is corresponding to IR dark lane , that indicates the blue-shifted component is located at fore ground toward the star formation site. This geometry is in agreement with collision scenario.



Discussion

Collision timescale

Typicall collision timescale is estimated by:
colliding (small) cloud size / colliding velocity = 1pc / 13 km/s ~ 8 × 10^4 yr

Triggered cluster formation

Fukui et al. (2016) pointed out that if one of the colliding cloud has column density of >10^{23} cm^{-2}, the colliding event results with cluster formation.

	DR21	W75N
-2 km/s cloud	9 × 10^{22} cm^{-2}	3 × 10^{22} cm^{-2}
8 km/s cloud	3 × 10^{22} cm^{-2}	5 × 10^{22} cm^{-2}

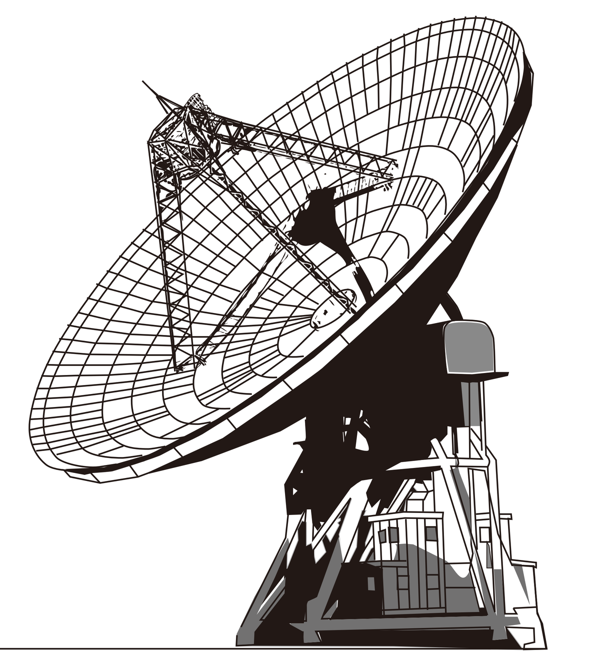
Our results suggests DR21 has a potential to form clusters, while W75N is smaller scale than DR21.

Comparison with previous studies

Schneider et al. (2006) observed entire region of the Cygnus-X by CO(3-2) line and pointed out that Cyg OB2 might formed with cloud collision.

Summary

We observed Cygnus-X HMSF region using NRO45m telescope with FOREST multibeam receiver. We found possible evidence of cloud-cloud collision (complementary distribution, bridge feature). Collision scenario can explain the formation of high-mass star clusters in DR21 and W75N.



NINS National Institutes of Natural Sciences 自然科学研究機構

国立天文台 NAOJ National Astronomical Observatory of Japan

Nobeyama Radio Observatory