L1448 IRS 3B

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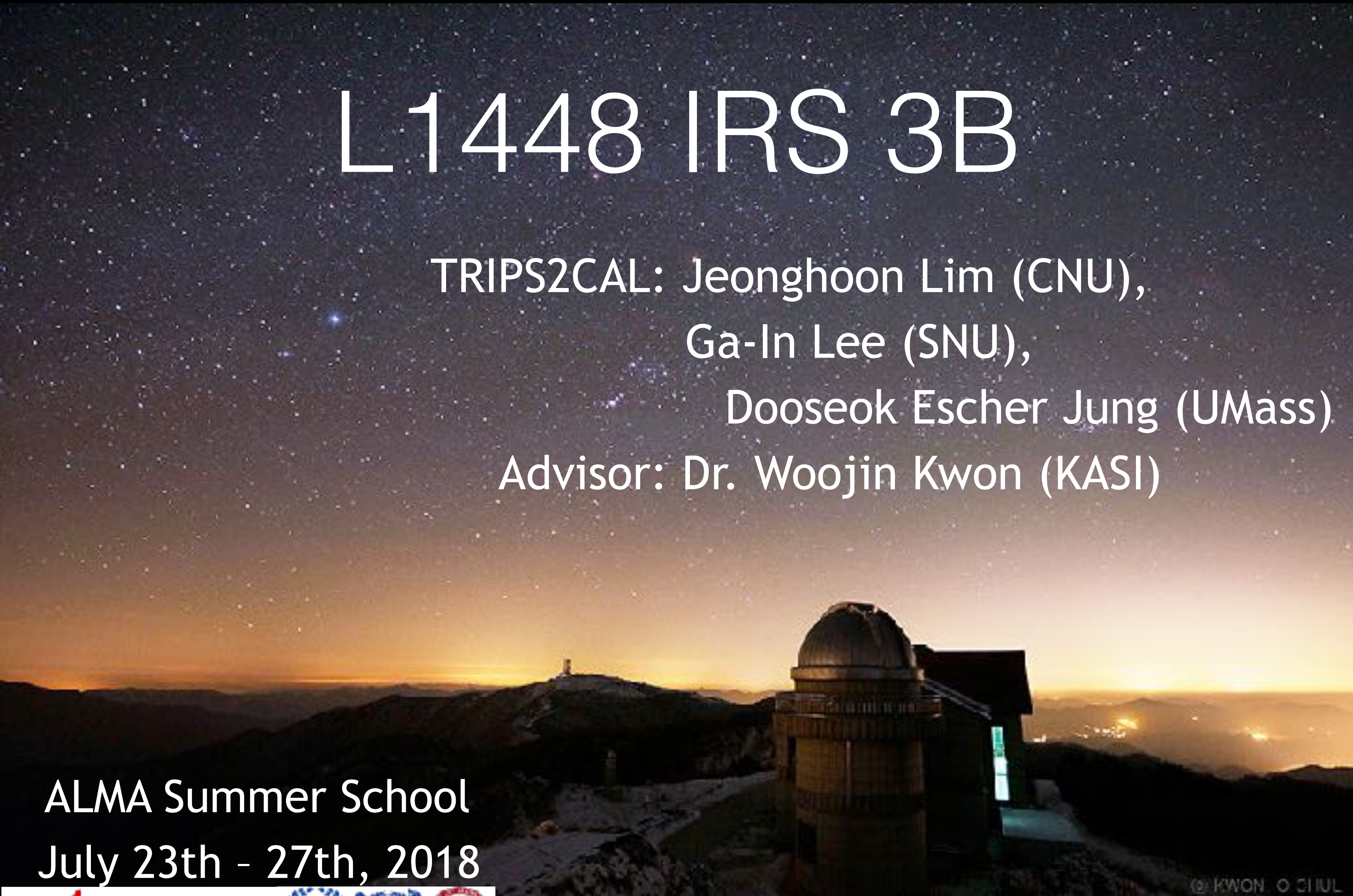


ALMA Summer School
July 23th – 27th, 2018

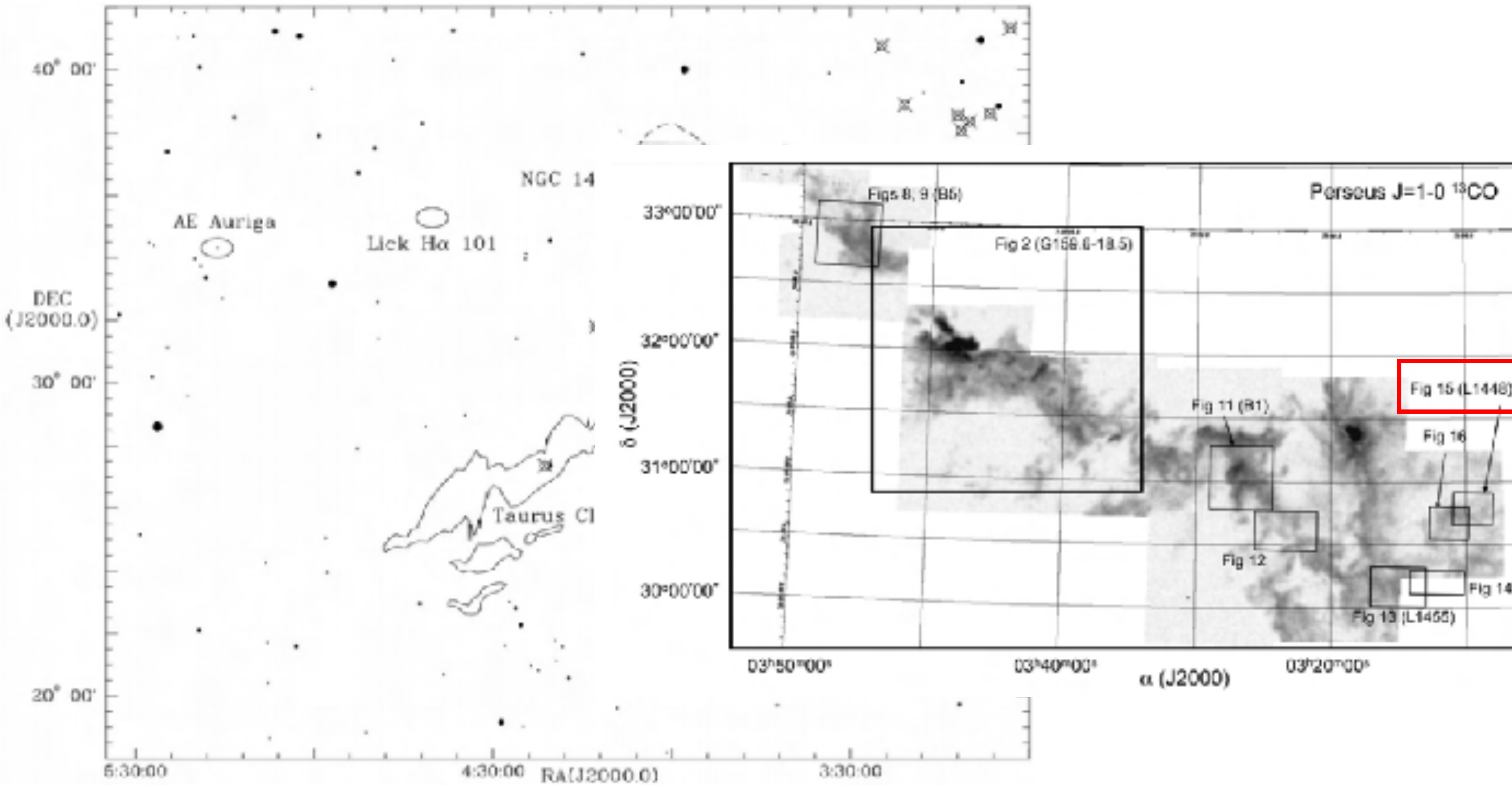
KASI 소백산천문대

TRIPS2CAL: Group 5’s Name

- Triple Protostar System Tuning to CASA, ALMA & “L1448 IRS 3B”
- ***TRI***ple ***P***rotostar ***S***ystem ***T***uning t***O*** ***C***ASA, ***A***LMA & “***L***1448 IRS 3B”
- TRIPS2CAL

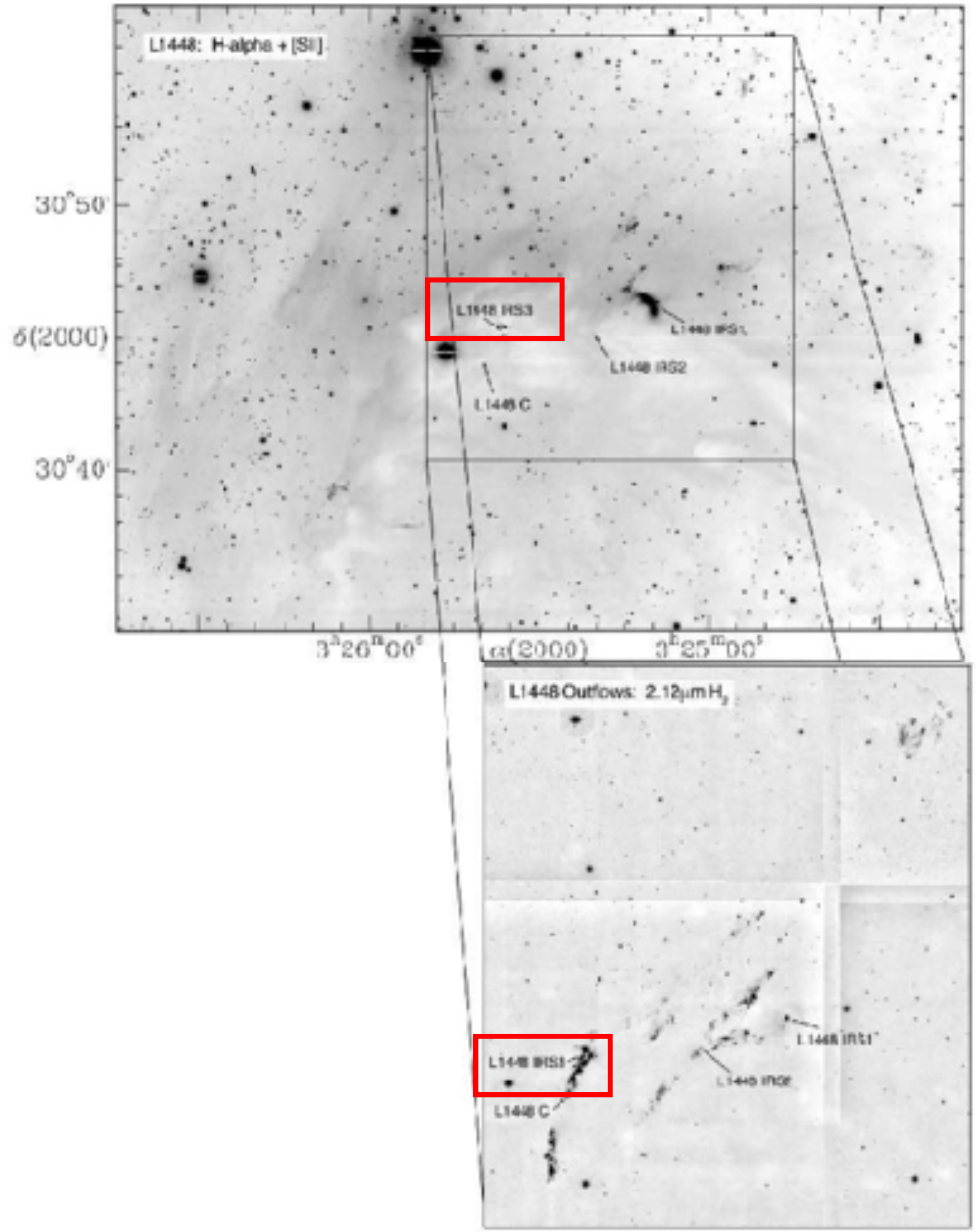
Where is it?

The Perseus Cloud → L1448



소백산천문대

L1448 IRS
→ L1448 IRS 3
→ L1448 IRS3B ?



Research History

L1448 IRS "3"

THE ASTROPHYSICAL JOURNAL, 653:1358–1368, 2006 December 20

TWO BIPOLAR OUTFLOWS AND MAGNETIC FIELDS IN THE MULTIPLE PROTOSTAR SYSTEM L1448 IRS 3

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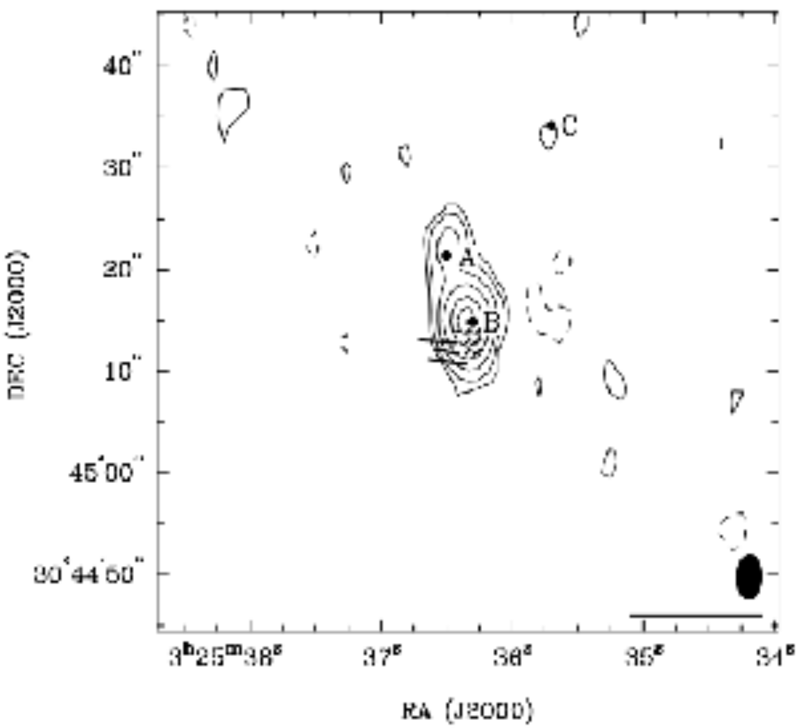
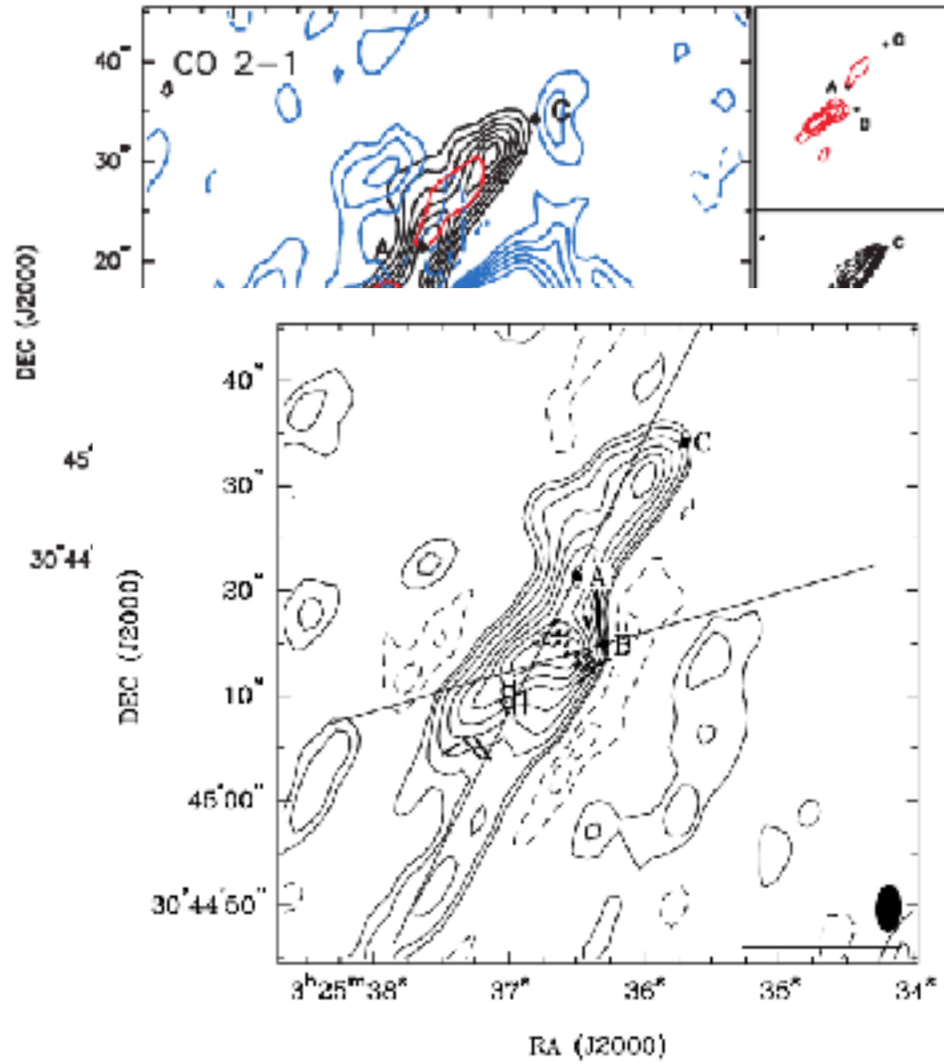
ABSTRACT

We present spectral line observations of CO $J = 2 \rightarrow 1$, ^{13}CO $J = 1 \rightarrow 0$, and C^{18}O $J = 1 \rightarrow 0$ and polarimetric observations in the $\lambda = 1.3$ mm continuum and in CO $J = 2 \rightarrow 1$ toward the multiple protostar system L1448 IRS 3, using the BIMA array. In the $\lambda = 1.3$ mm continuum, two sources (IRS 3A and 3B) were clearly detected with estimated envelope masses of 0.21 and 1.15 $M_{\odot}$, and one source (IRS 3C) was marginally detected with an upper mass limit of 0.03 $M_{\odot}$. In CO $J = 2 \rightarrow 1$, we revealed two outflows originating from IRS 3A and 3B. The masses, mean number densities, momentums, and kinetic energies of outflow lobes were estimated. Based on those estimates and outflow features, we conclude that the two outflows are interacting and that the IRS 3A outflow is nearly perpendicular to the line of sight. In addition, we estimate the velocity, inclination, and opening of the IRS 3B outflow using Bayesian statistics. Linear polarization was detected in both the $\lambda = 1.3$ mm continuum and CO $J = 2 \rightarrow 1$. The linear polarization in the continuum shows a magnetic field at the central source (IRS 3B) perpendicular to the outflow direction, and the linear polarization in the CO $J = 2 \rightarrow 1$ was detected in the outflow regions either parallel or perpendicular to the outflow direction. Moreover, we comprehensively discuss whether the binary system of IRS 3A and 3B is gravitationally bound, based on the velocity differences detected in ^{13}CO $J = 1 \rightarrow 0$ and C^{18}O $J = 1 \rightarrow 0$ observations and

L1448 IRS 3A, 3B & 3C





L1448 IRS “3B”

LETTER

doi:10.1038/nature20094

A triple protostar system formed via fragmentation of a gravitationally unstable d

John J. Tobin[1,2], Kaitlin M. Kratter[3], Magnus V. Persson[2,4], Leslie W. Loo
Zhi-Yun Li[7], Claire J. Chandler[8], Sarah I. Sadavoy[9], Robert J. Harris[5], C

Binary and multiple star systems are a frequent outcome of the star formation process[1,2] and as a result almost half of all stars with masses similar to that of the Sun have at least one companion star[3]. Theoretical studies indicate that there are two main pathways that can operate concurrently to form binary/multiple star systems: large-scale fragmentation of turbulent gas cores and filaments[4,5] or smaller-scale fragmentation of a massive protostellar disk due to gravitational instability[6,7]. Observational evidence for turbulent fragmentation on scales of more than 1,000 astronomical units has recently emerged[8,9]. Previous evidence for disk fragmentation was limited to inferences based on the separations of more-evolved pre-main sequence and protostellar multiple systems[10–13]. The triple protostar system L1448 IRS3B is an ideal system with which

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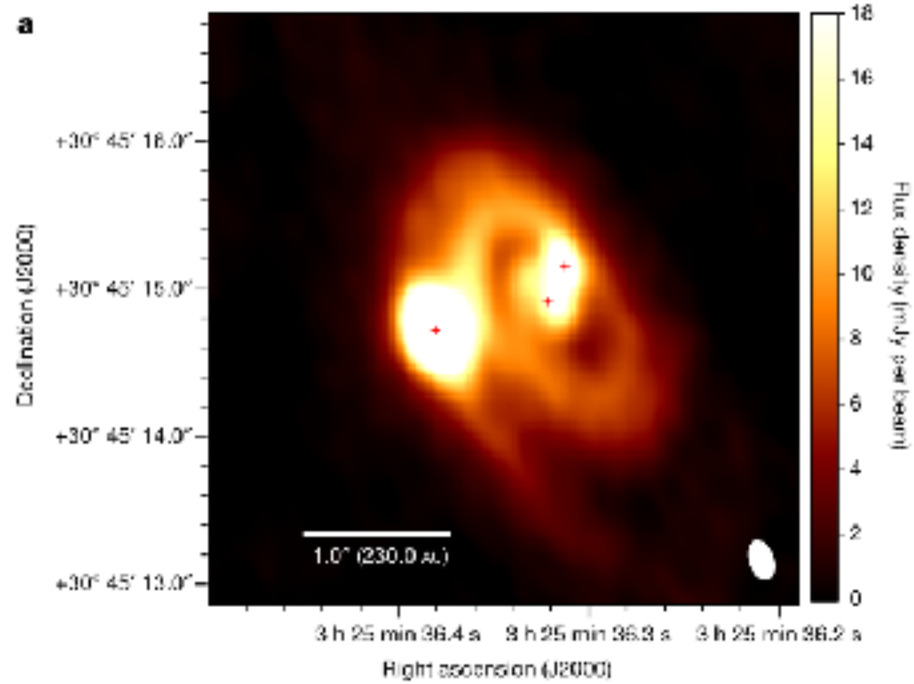

Wait…What's happening?

TWO BIPOLAR OUTFLOWS AND MAGNETIC FIELDS IN THE MULTIPLE PROTOSTAR SYSTEM L1448 IRS 3

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Received 2006 April 19; accepted 2006 September 4

ABSTRACT

We present spectral line observations of CO $J = 2 \rightarrow 1$, ^{13}CO $J = 1 \rightarrow 0$, and C^{18}O $J = 1 \rightarrow 0$ and polarimetric observations in the $\lambda = 1.3$ mm continuum and in CO $J = 2 \rightarrow 1$ toward the multiple protostar system L1448 IRS 3, using the BIMA array. In the $\lambda = 1.3$ mm continuum, two sources (IRS 3A and 3B) were clearly detected with es-

A triple protostar system formed via fragmentation of a gravitationally unstable disk

John J. Tobin[1,2], Kaitlin M. Kratter[3], Magnus V. Persson[2,4], Leslie W. Looney[5], Michael M. Dunham[6], Dominique Segura-Cox[5], Zhi-Yun Li[7], Claire J. Chandler[8], Sarah I. Sadavoy[9], Robert J. Harris[5], Carl Melis[10] & Laura M. Pérez[11]

Binary and multiple star systems are a frequent outcome of the star formation process[1,2] and as a result almost half of all stars with masses similar to that of the Sun have at least one companion star[3]. Theoretical studies indicate that there are two main pathways that can operate concurrently to form binary/multiple star systems: large-scale fragmentation of turbulent gas cores and filaments[4,5] or smaller-scale fragmentation of a massive protostellar disk due to gravitational instability[6,7]. Observational evidence for turbulent fragmentation on scales of more than 1,000 astronomical units has

The ALMA 1.3 mm image of L1448 IRS3B is shown in Fig. 1, revealing dust emission towards each of the three distinct protostars, which were identified in previous Karl G. Jansky Very Large Array (VLA) observations[13]. The ALMA images also reveal a disk with substructure surrounding the entire system, extending to a radius of around 400 AU. The disk appears to have a dominant one- or two-armed spiral that links IRS3B-a and IRS3B-b with the more widely separated IRS3B-c, which is embedded in the outermost arm. The disk geometry and rotation profile (see below) place the centre of mass of the system near the

Upgrading Resolution during 10 years

5. CO $J = 2 \rightarrow 1$ OBSERVATION

5.1. *Bipolar Outflows*

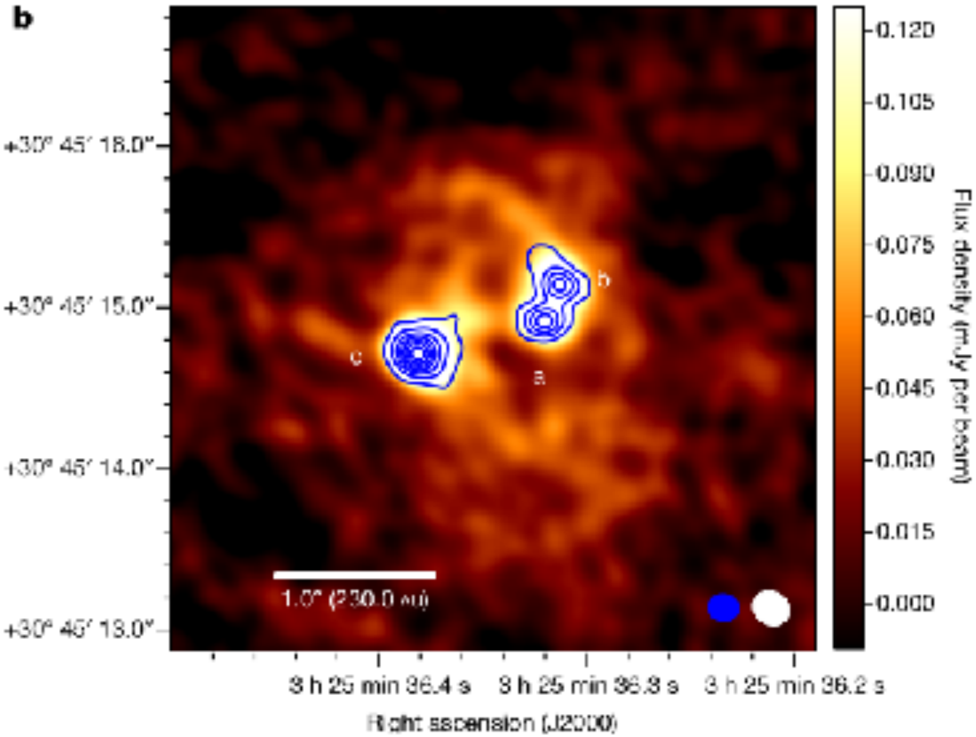
As introduced in § 1, one, two, or up to three outflows have been suggested for this region. Bachiller et al. (1990) proposed that an outflow in the east-west direction originates from IRS 3, based on a redshifted component that was detected in the region of the blueshifted lobe of the L1448-mm outflow. Recently Wolf-Chase et al. (2000) suggested outflows of position angle 150° and 129° from IRS 3A and 3B, respectively, using their large-scale CO $J = 1 \rightarrow 0$ observation as well as previous studies of H_2 observations and Herbig-Haro objects. In addition, Girart & Acord (2001) presented a redshifted SiO component along a line of position angle 110° from IRS 3B. However, to date there were no observations with enough angular resolution to clearly identify outflows with sources. Here we present high angular resolution BIMA observations to illustrate outflows in IRS 3. We reveal two outflows from IRS 3A and 3B, but no outflow from IRS 3C, based on channel maps and integrated intensity maps.

VS

L1448 IRS3B is located in the Perseus molecular cloud at a distance of around 230 pc (ref. 15) and contains three protostars out of the six that collectively make up L1448 IRS3[13,14], which spans a region that is 0.05 pc wide. L1448 IRS3B is a Class 0 protostar system[16], which represents an early phase of the star formation process when the protostars are deeply enshrouded in an envelope of accreting material[17]. The three protostars in L1448 IRS3B (denoted -a, -b, and -c) have a hierarchical configuration; the central protostar, IRS3B-a, has projected separations from IRS3B-b and IRS3B-c of 61 AU and 183 AU, respectively[13]. The new observations of L1448 IRS3B conducted with the Atacama Large Millimeter/submillimeter Array (ALMA) at a resolution of 0.27″ × 0.16″ (62 AU × 37 AU) provide images of the dust and gas emission surrounding the three protostars at 1.3 mm with a sensitivity that is ten times higher and a resolution that is two times higher than previous studies.

Beam Size	Kwon et al. 2006	Tobin et al. 2016
λ = 1.3mm	4”.6 X 2”.6	0.27” X 0.16”
CO(J = 2 → 1)	4”.5 X 2”.5	0.36” X 0.25”

Properties of L1448 IRS3B



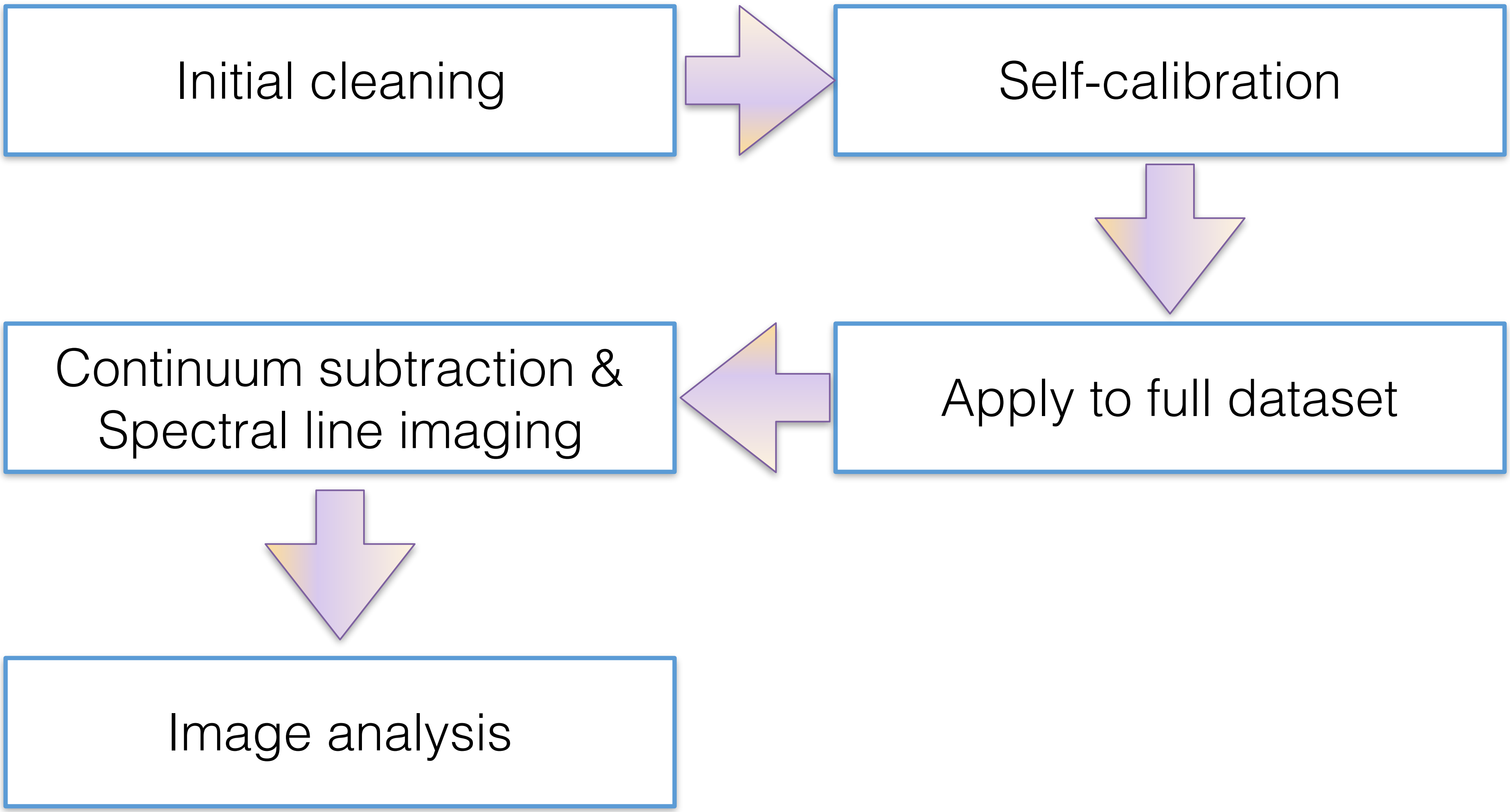
- Class 0 Protostar system
- Inclination of the system: 45.4 degree
- Radius of entire system : 400 AU
- M_disk = 0.30M_solar
- M_outer disk of IRS3B-c : 0.085 M_solar
- Combined Mass of IRS3B-a & b : 1 M_solar
- Spiral Arm Structure by Gravitational Instability

Let's TRIP 2 CAL… IBRATION!!

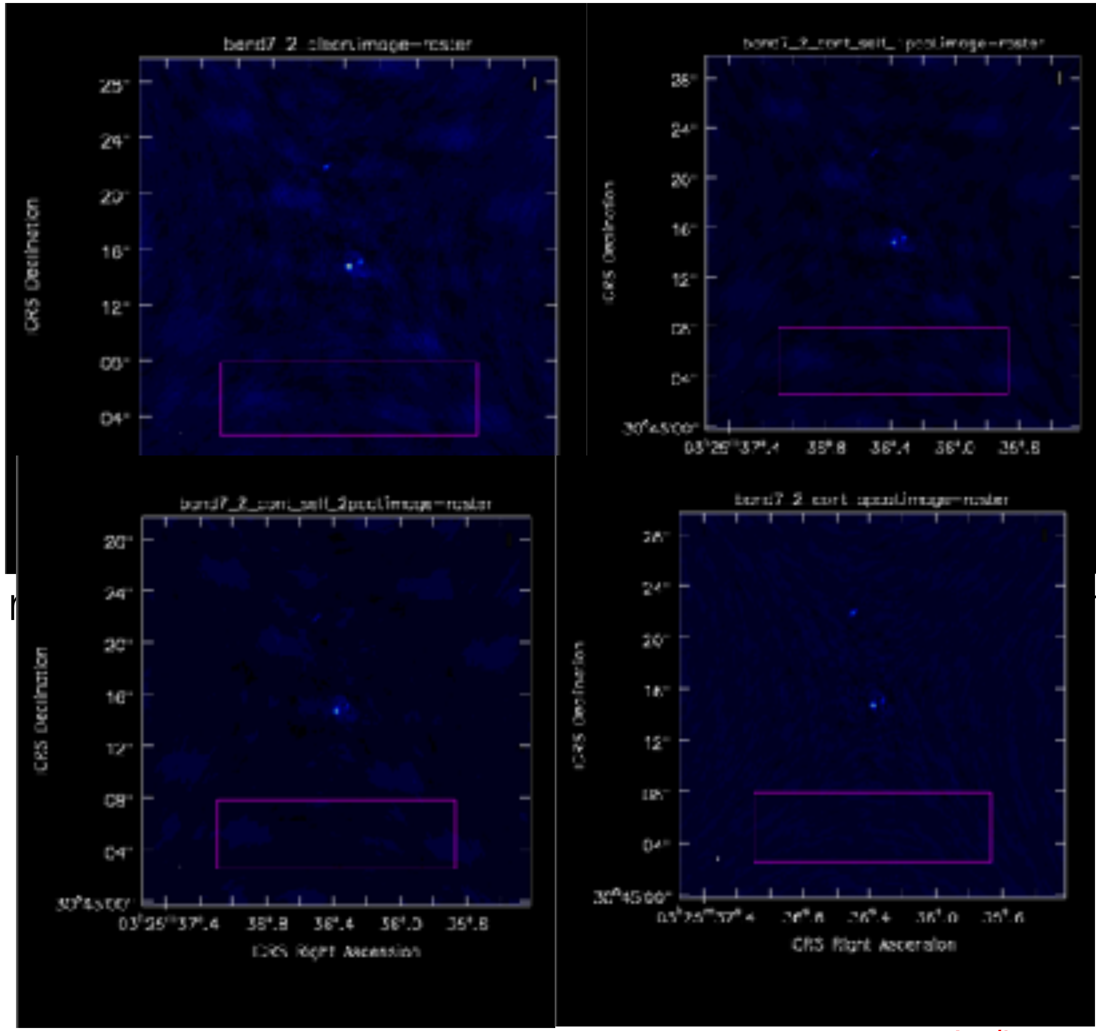
Data for imaging

	Band7_A	Band7_B
Resolution	0.08(high)	0.5(low)
FOV	15 arcsec	
Data set	$C^{17}O$ continuum	CO(3-2) $C^{17}O$ continuum

Imaging process



Self Calibration

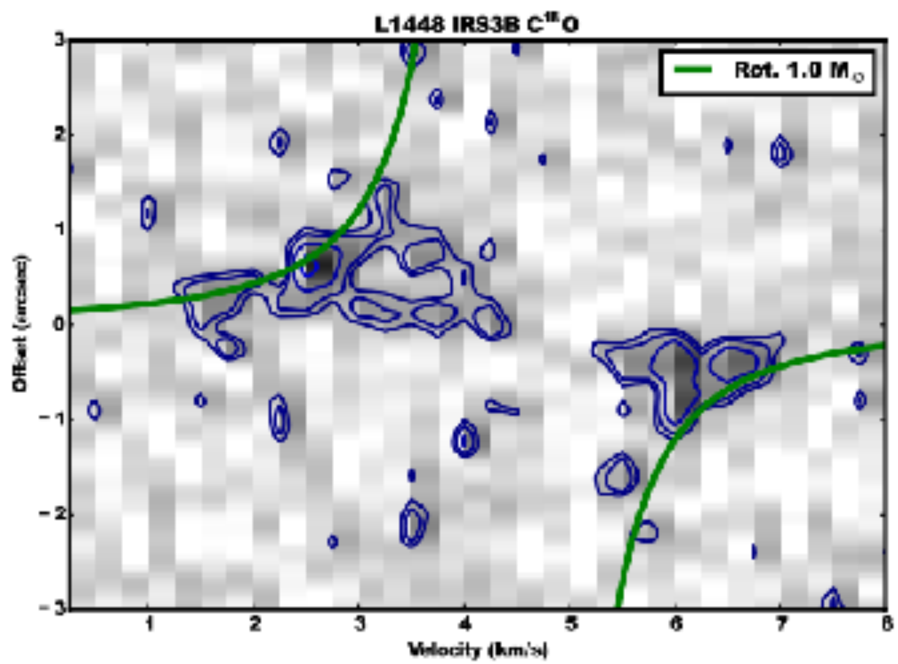


rms ~0.67903 mJy/beam rms ~0.37913 mJy/beam

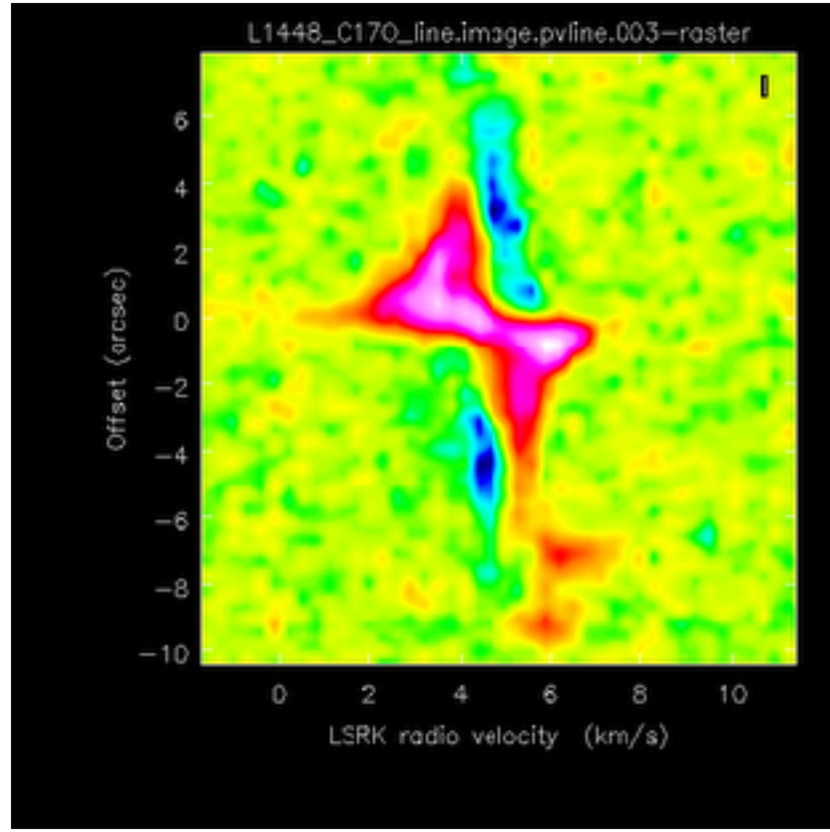
Image analysis using spectral line data

1. PV diagram and channel maps

(1) C17O

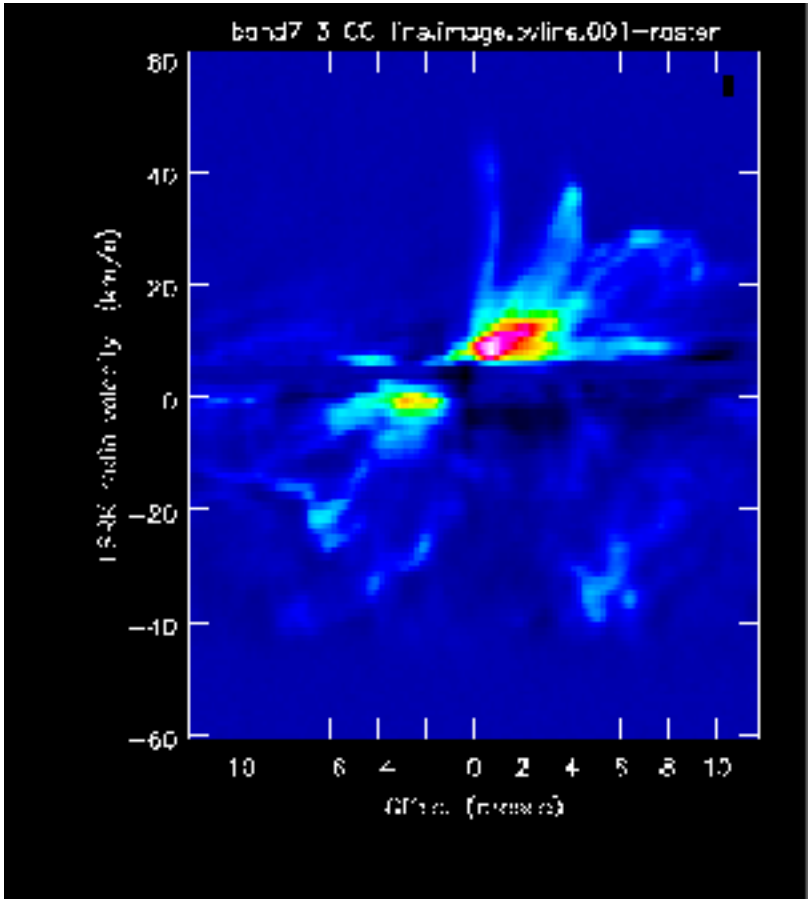


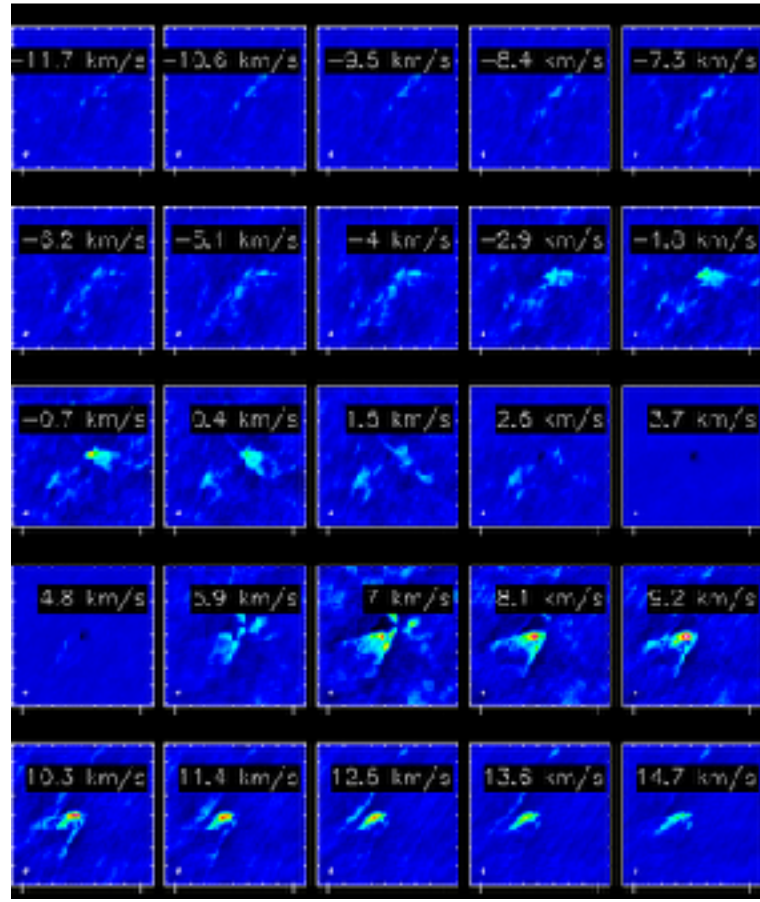
Extended Data Figure 5 | Position–velocity diagrams of L1448 IRS3B and a model disk showing the rotation profile. A position–velocity (*PV*) cut is taken along the major axis of the disk (analogous to a long slit spectrum), across the position of IRS3B-a and IRS3B-b (left). The solid



Indication for Keplerian motions

(2) CO(3-2)





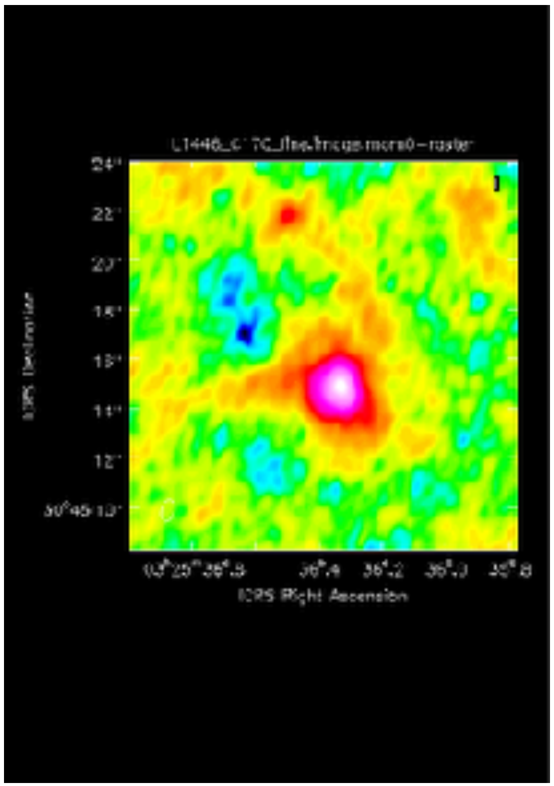
Strong red shift, weak blue shift

Image analysis using spectral line data

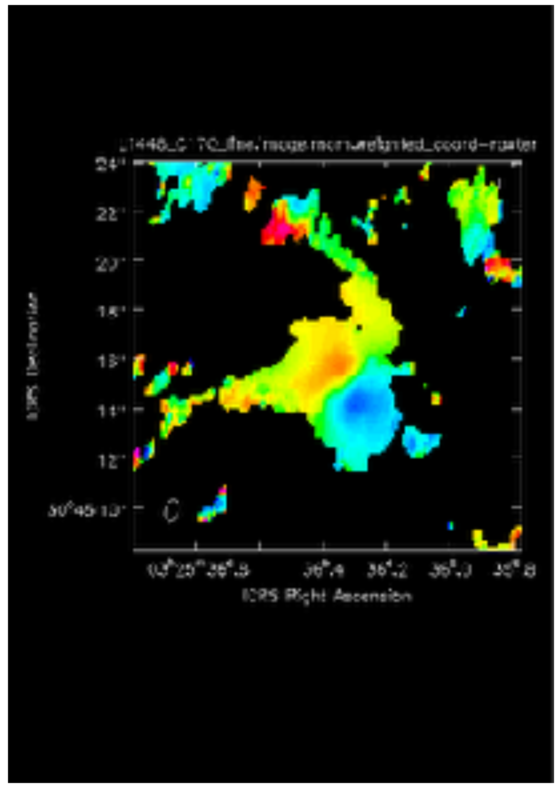
2. Moment maps

(1) Band7_B Moment Maps($C_{17}O$)

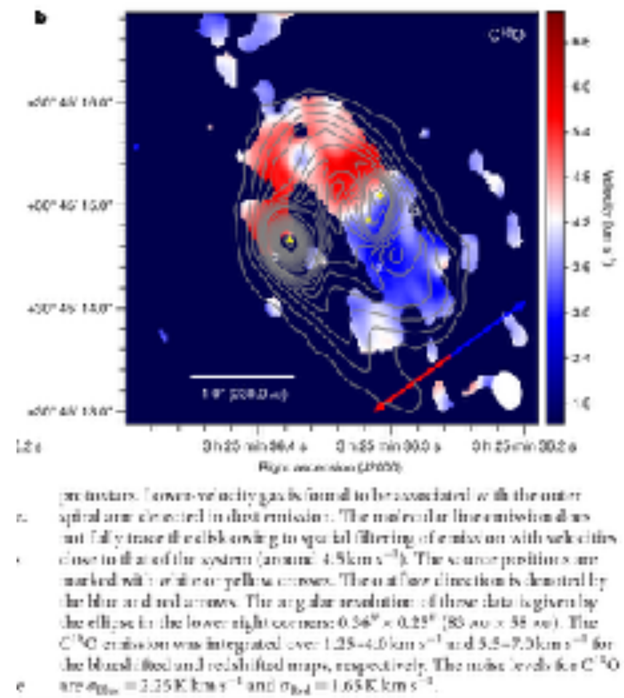
Moment 0



Moment 1



Reference

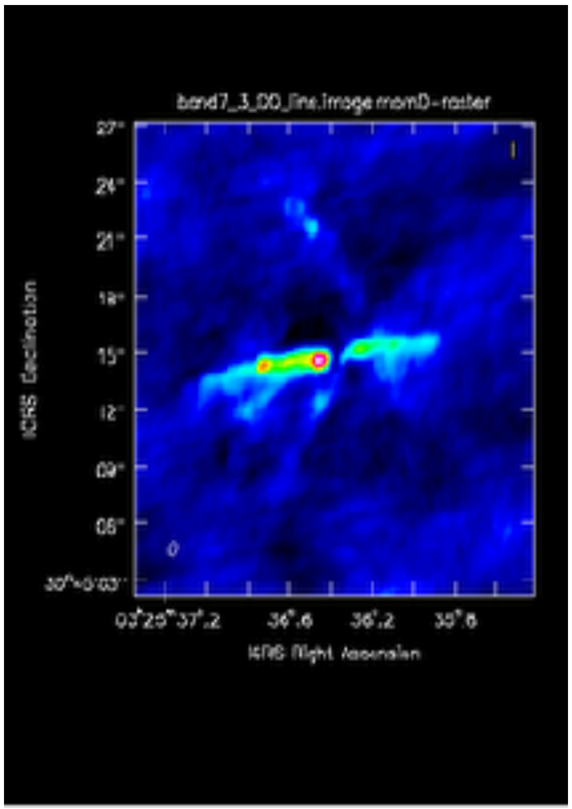


Tobin et al. 2016

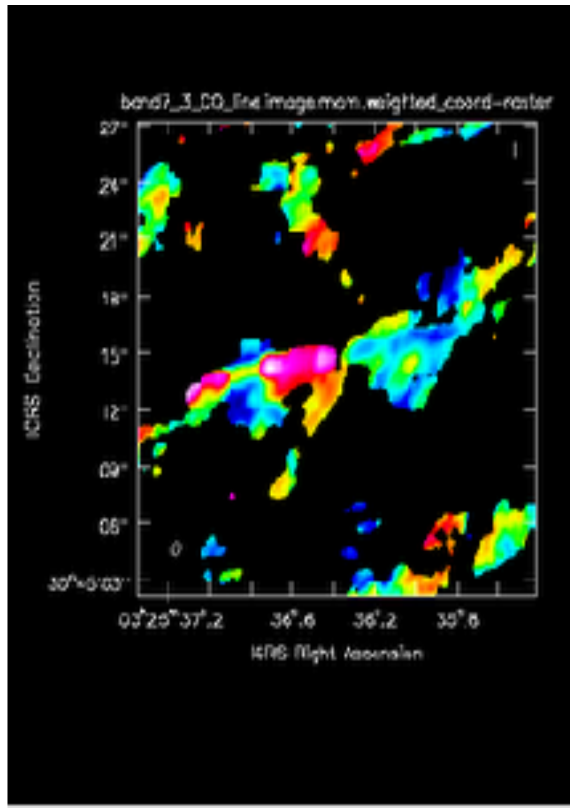
Envelope tracer!!

(2) Band7_B Moment Maps(CO 3-2)

Moment 0

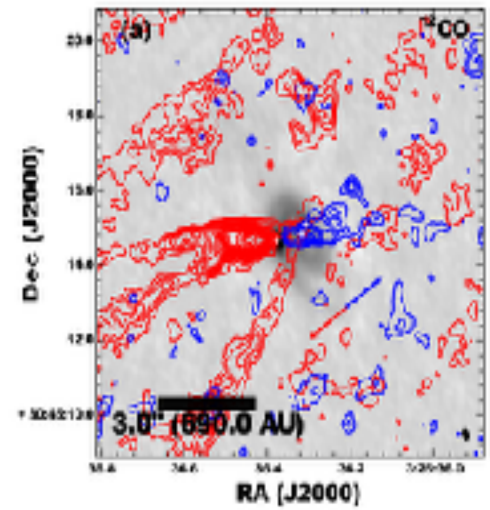


Moment 1



Outflow tracer!!

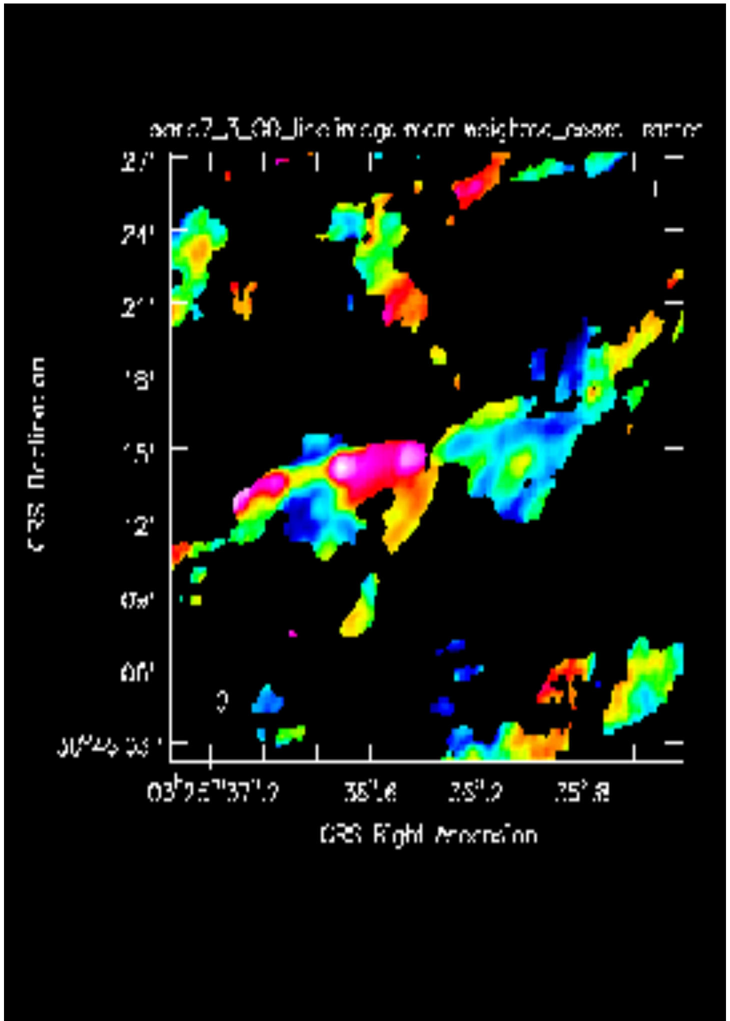
Reference



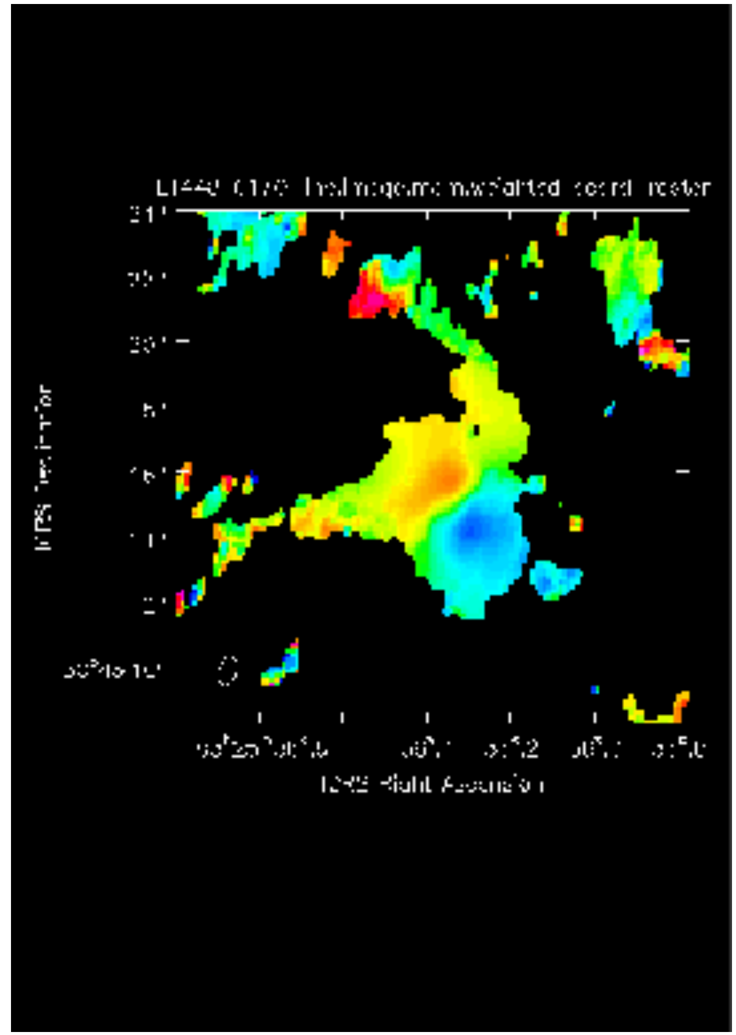
Tobin et al. 2016

CO vs C17O

CO



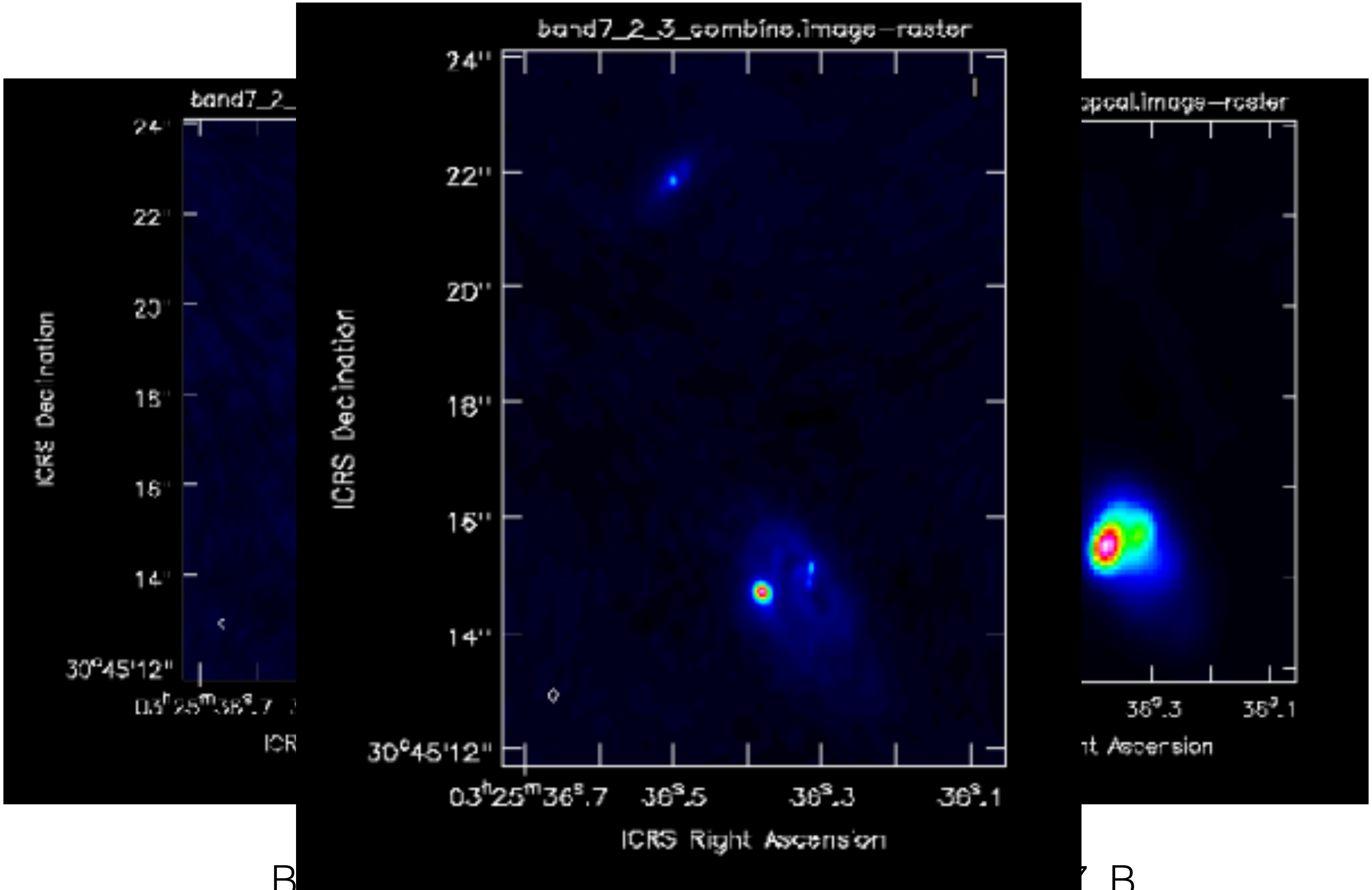
C17O



Combined images

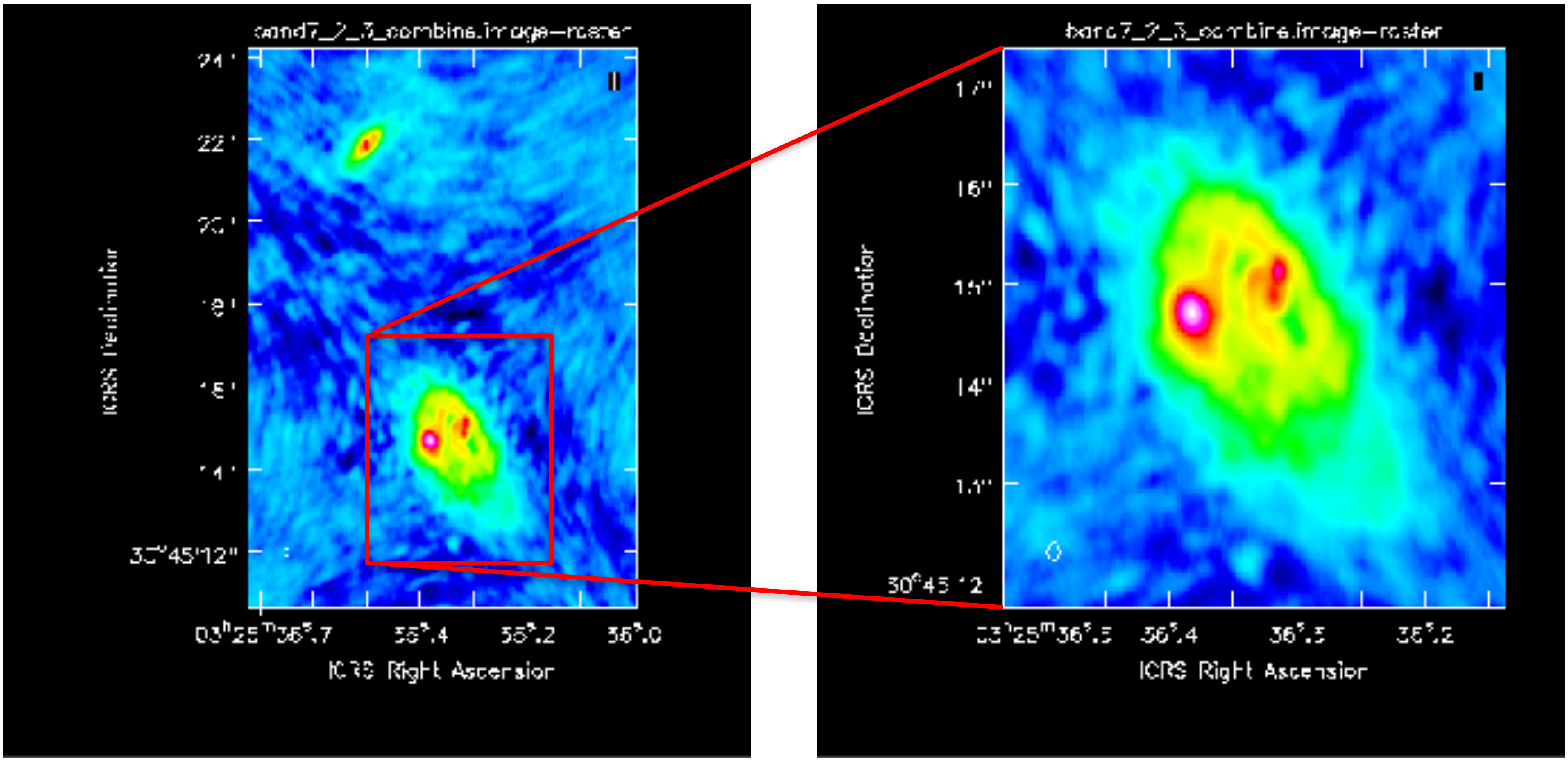
1. Continuum images

Continuum Combined Image



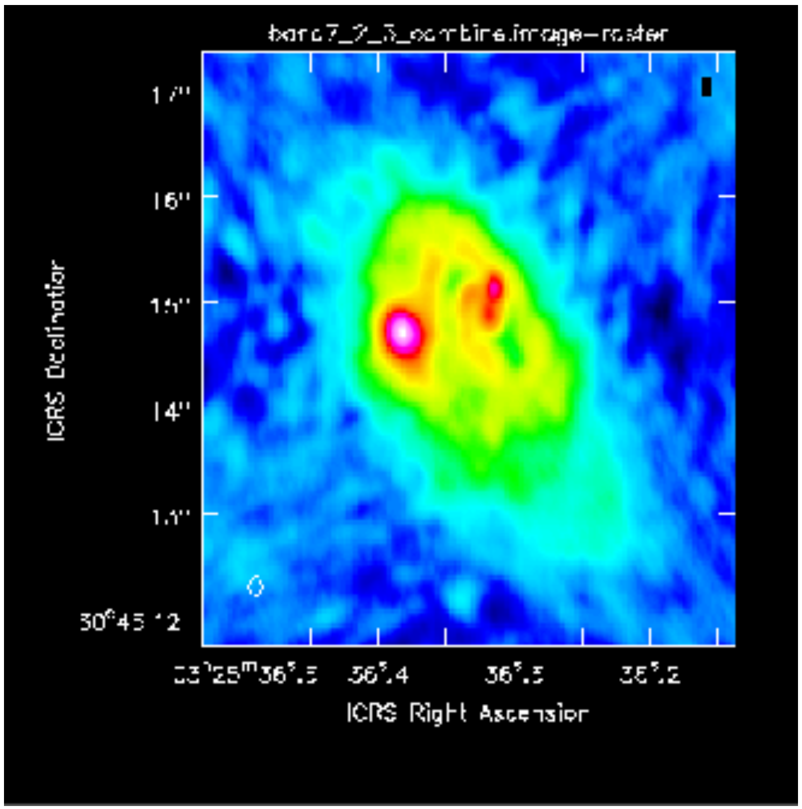
Band7_A + Band7_B

Continuum Combined Image

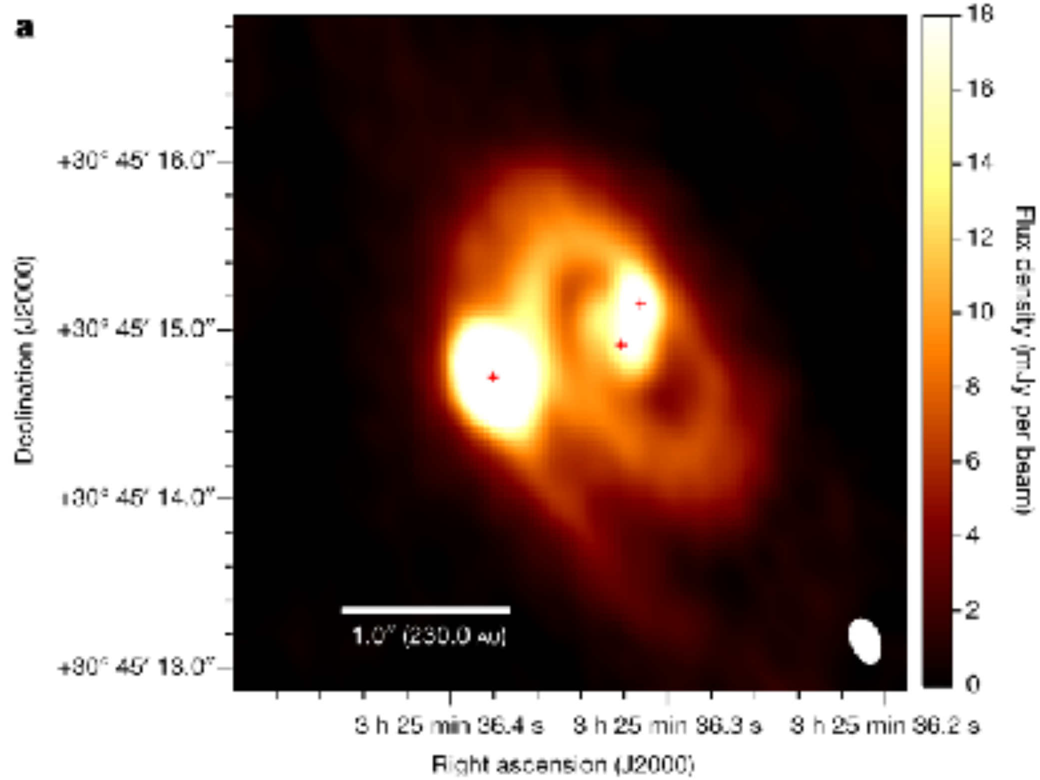


Comparison

TRIPS2CAL



Tobin et al. 2016

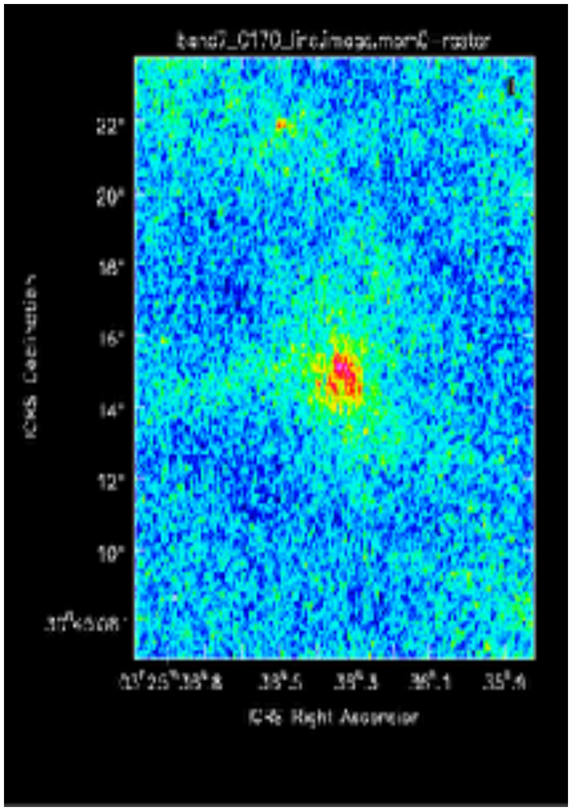


Combined images

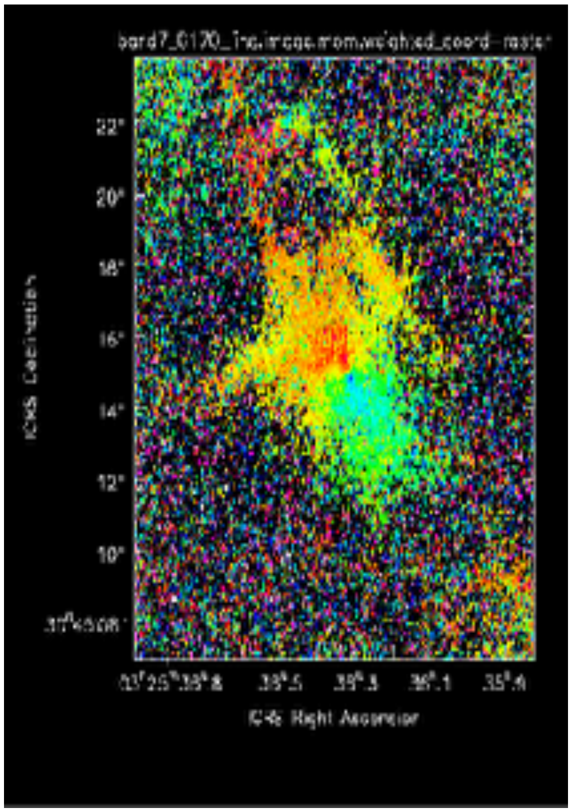
2. Moment maps

(1) $C^{17}O$ Line Combined Image

Moment 0

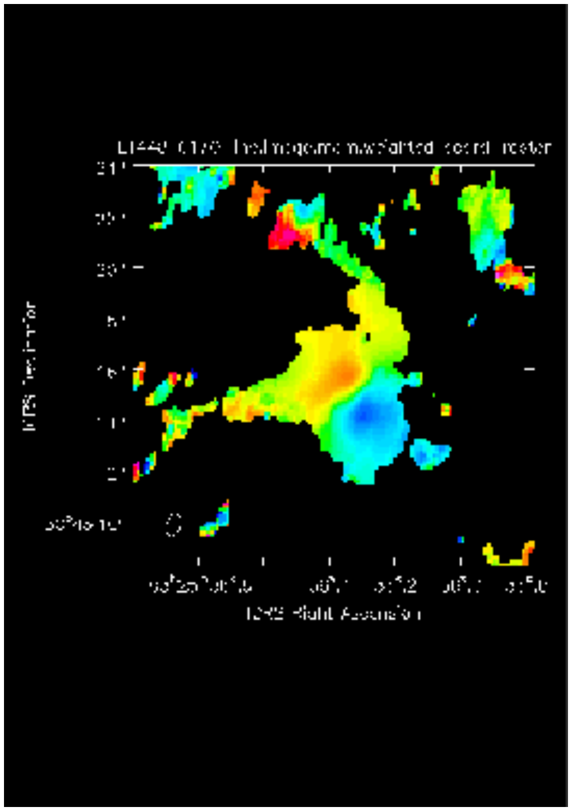


Moment 1



Band7_A + Band7_B

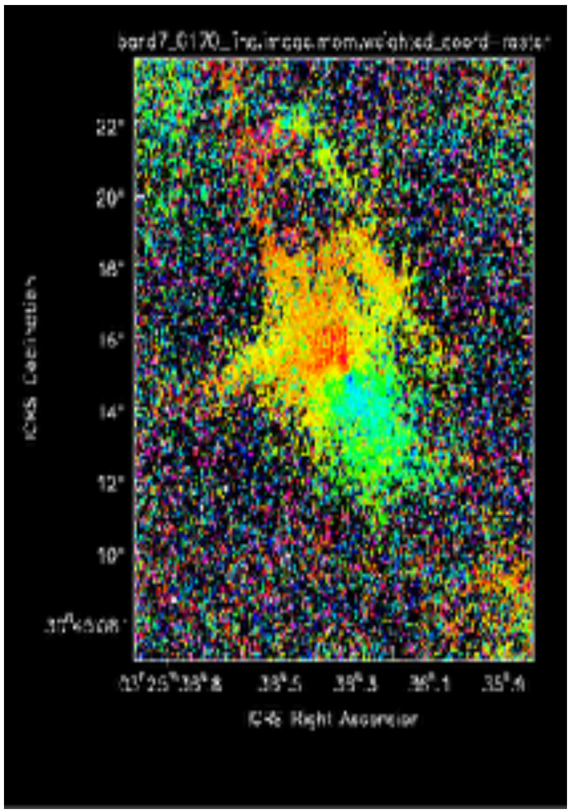
Moment 1



Band7_B

Art? Science?
What is the difference?

Moment 1



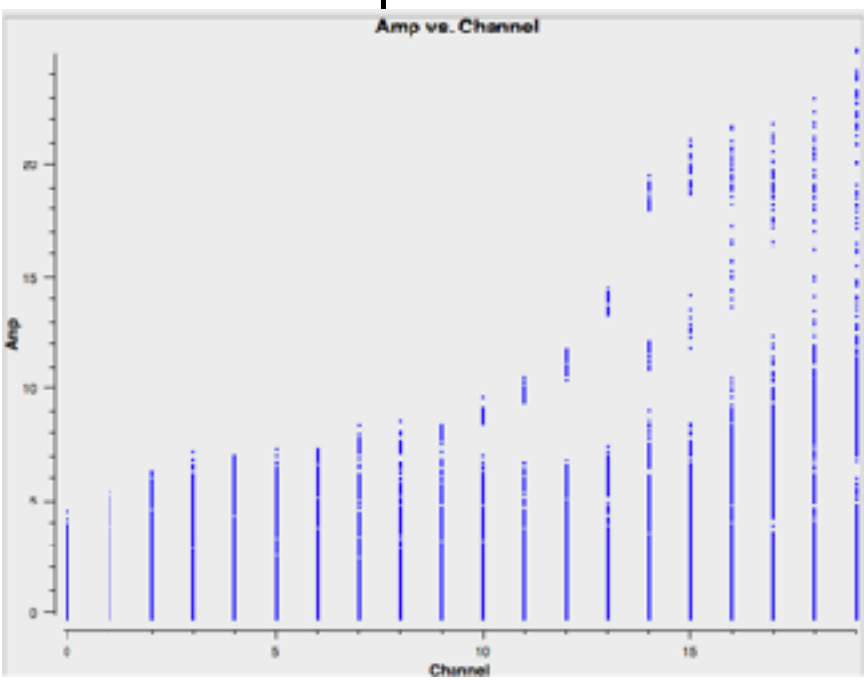
Band7_A + Band7_B

Galaxy by Morrill (Pointillism)

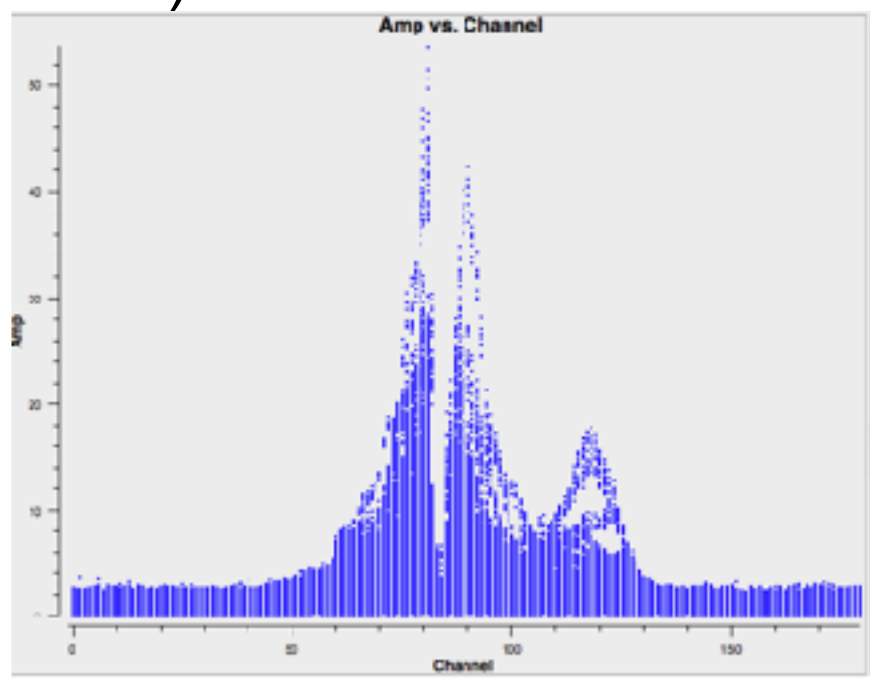
(2) CO (J=3-2) Line Combine Image

- Combining CO (J=3-2) line was problematic.
- The field of band7_A was not enough to encompass the CO (J=3-2) line.

Band7_A



Band7_B



Is it a pleasant TRIPS 2 CAL?

Thank You!

ALMA Summer School

July 23th – 27th, 2018

KASI 소백산천문대