ALMA summer school
: HOPS287

GROUP 1

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2019 ALMA Summer School

CONTENTS

01 INTRODUCTION

✓ **Herschel Orion Protostar Survey (HOPS)**

- Herschel Space Observatory program
- Protostar catalogue

✓ **Target : HOPS-287**

- Class I Young Stellar Object (YSO)
- Bipolar outflow observed (HST/WFC3)

✓ **ALMA Data**

- 12m + 7m data combine
- Synthesize beam : 1.06 arcsec
- Primary beam : 22 arcsec
- Velocity resolution : 20 m/s (70 m/s used)

✓ **Hubble Space Telescope (HST) Data**

- HST/WFC3
- Total mode (200 – 1700 nm)
- To find outflow direction

02 Method

✓ **Continuum**

- Image : Disk mass estimate

✓ **C18O**

- Position-Velocity (PV) diagram : **Disk** rotation check & **Systemic velocity**

✓ **12CO**

- PV diagram : **Jet** or **Outflow** check
- Outflow direction check using **HST/WFC3** images

✓ **13CO**

- PV diagram : **Outflow** & **disk**

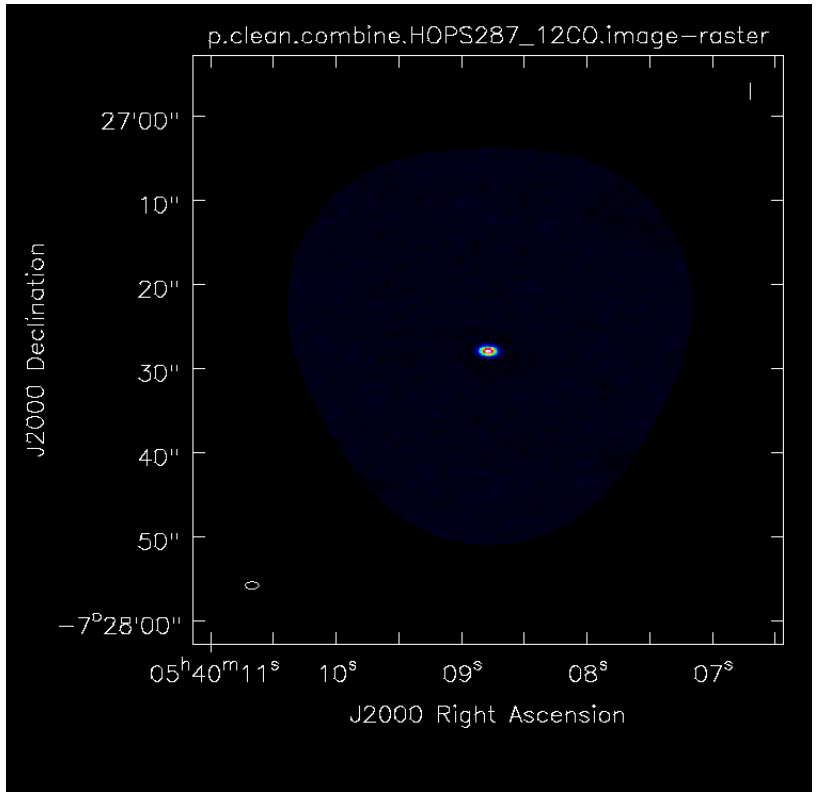
03 RESULT

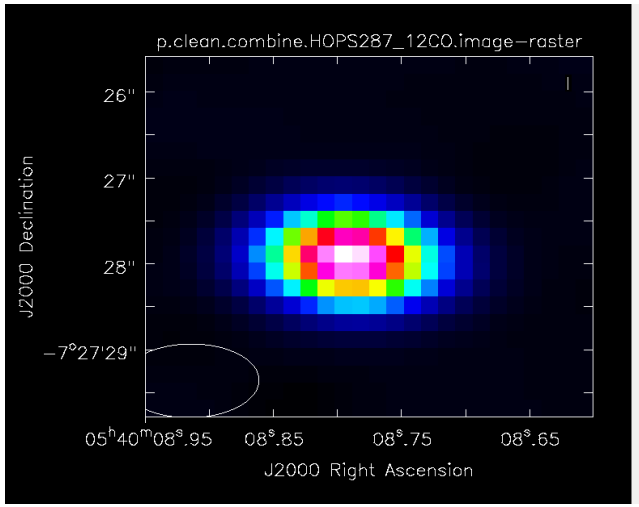
✓ Continuum

param	value	unit
Flux density	35.77	mJy/beam
Maximum	35.56	mJy/beam
RMS	7.155	mJy/beam
Distance	420	AU
Temperature	30	K
Opacity	0.01	cm^2/g
M_{disk}	0.0035	Solar mass

Thi et al. (2001)

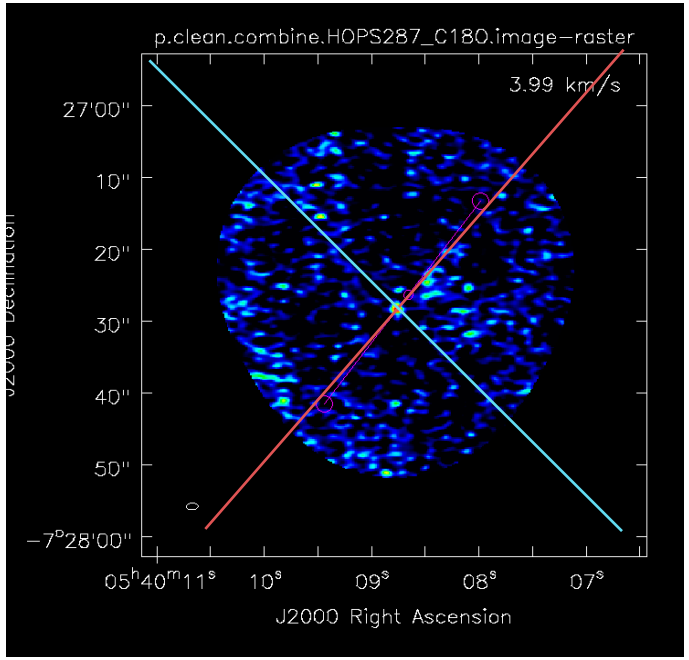
$$M_{\rm disk} = 0.06\ M_\odot \frac{F_\lambda}{1\ {\rm Jy}} \left(\frac{d}{100\ {\rm pc}}\right)^2 \frac{50\ {\rm K}}{\langle T \rangle} \frac{0.01\ {\rm cm^2\ g^{-1}}}{\kappa_{1.3\ {\rm mm}}}, \quad (6)$$

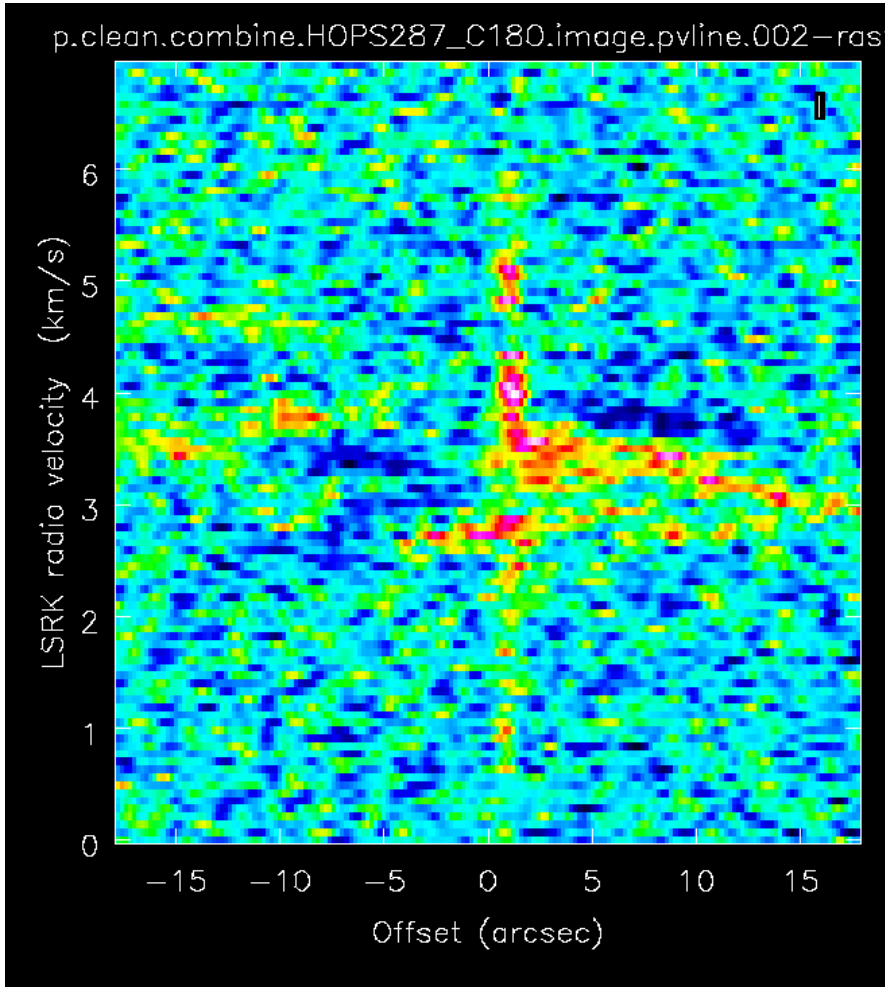


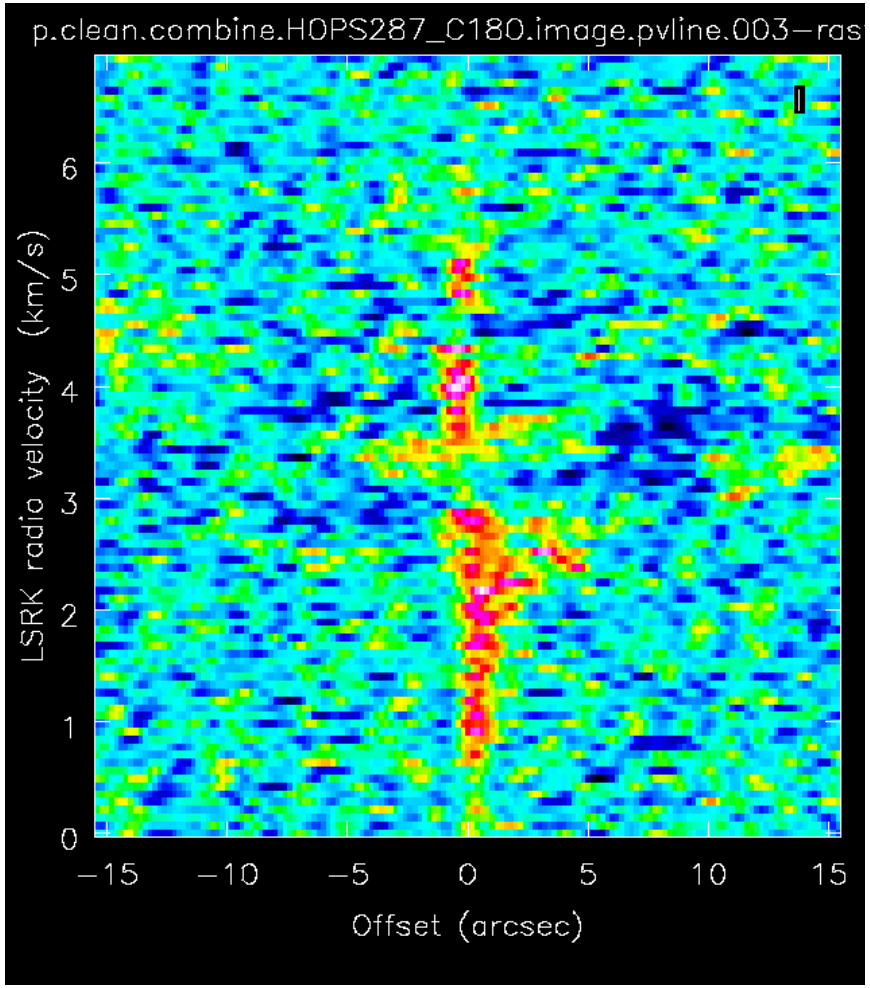


03 RESULT

✓ C18O



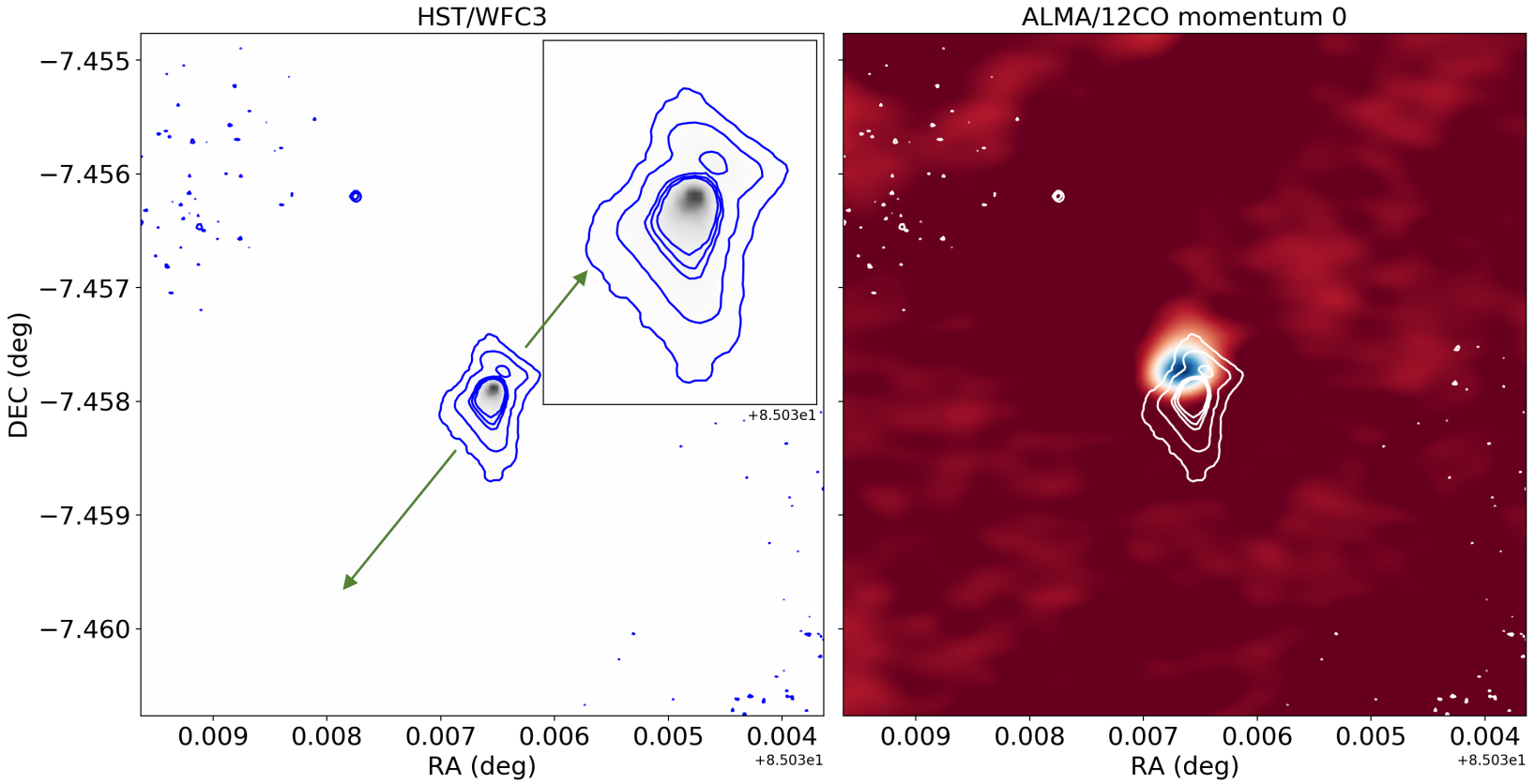




- Outflow signal in PV
- No disk motion
- Systemic velocity ~ 3 km/s
- Shows 1 – 6 km/s velocity

03 RESULT

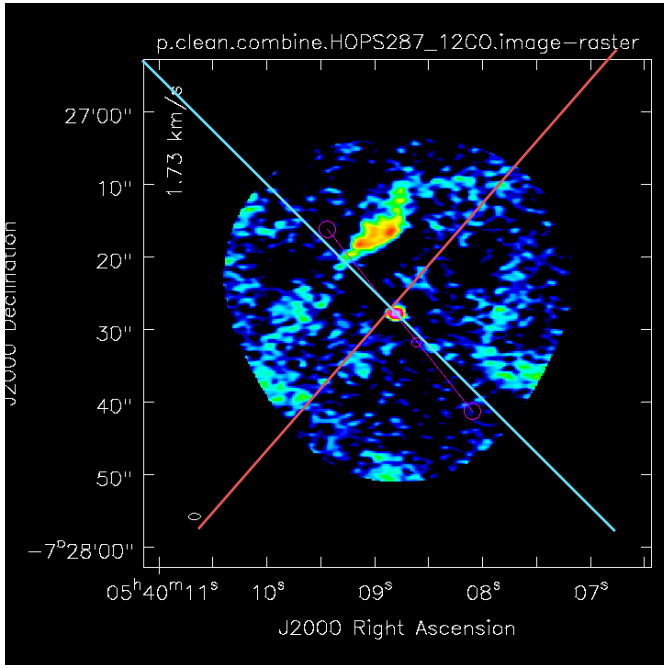
✓ HST vs ALMA

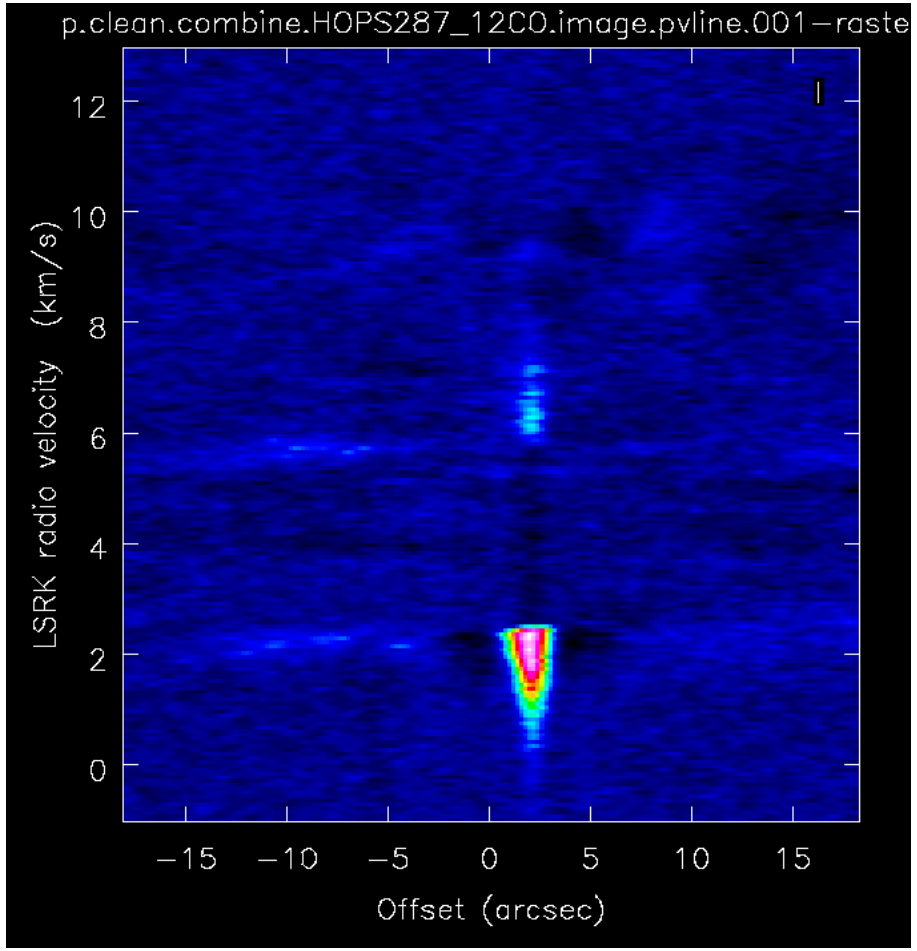


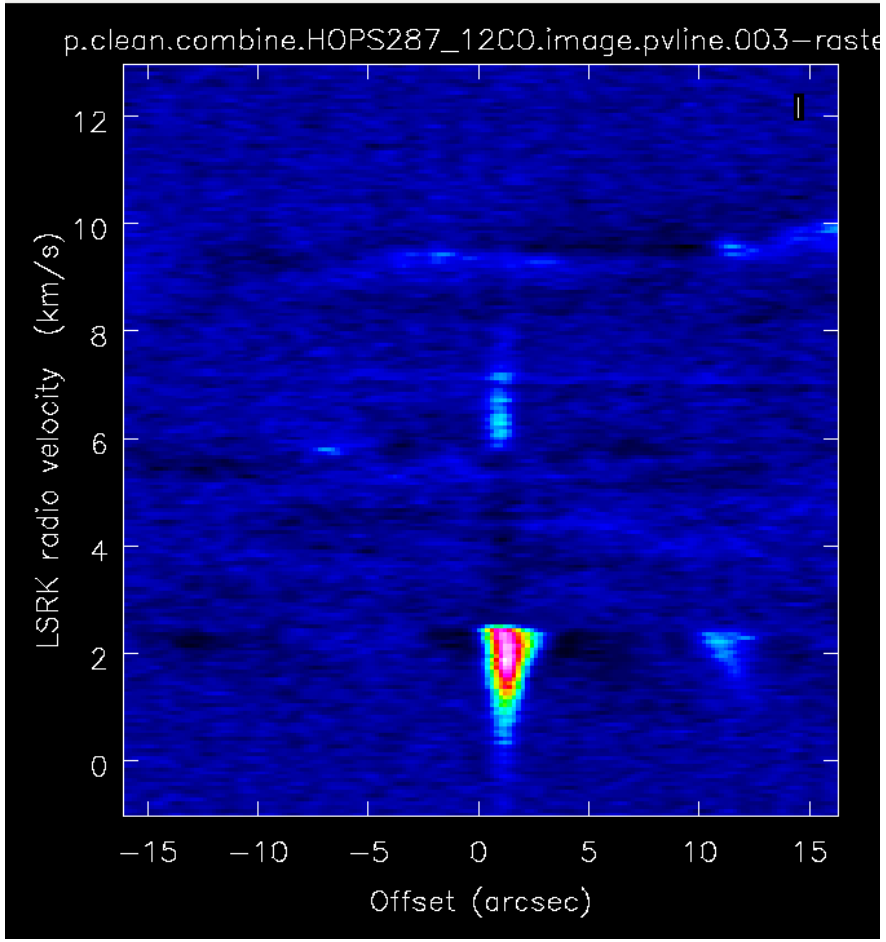
- HST/WFC3 total combine
- ALMA/12CO momentum 0
- Contour = HST [3, 5, 7, 9 sigma]
- Offset & size difference exist
- Outflow direction estimated
- In HST image, high contrast part is seems to outflow launching point.

03 RESULT

✓ 12CO



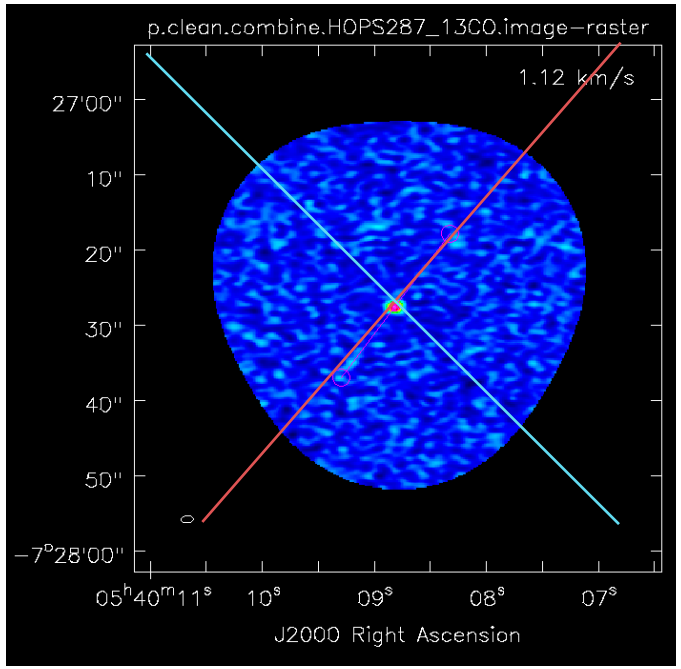


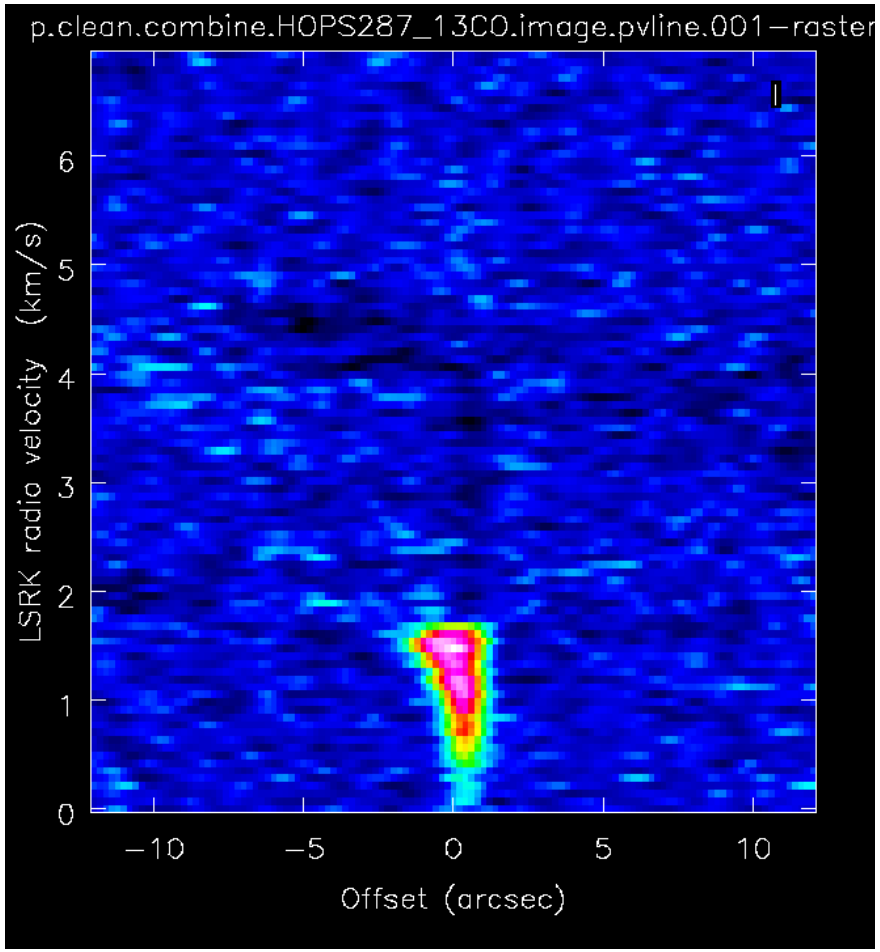


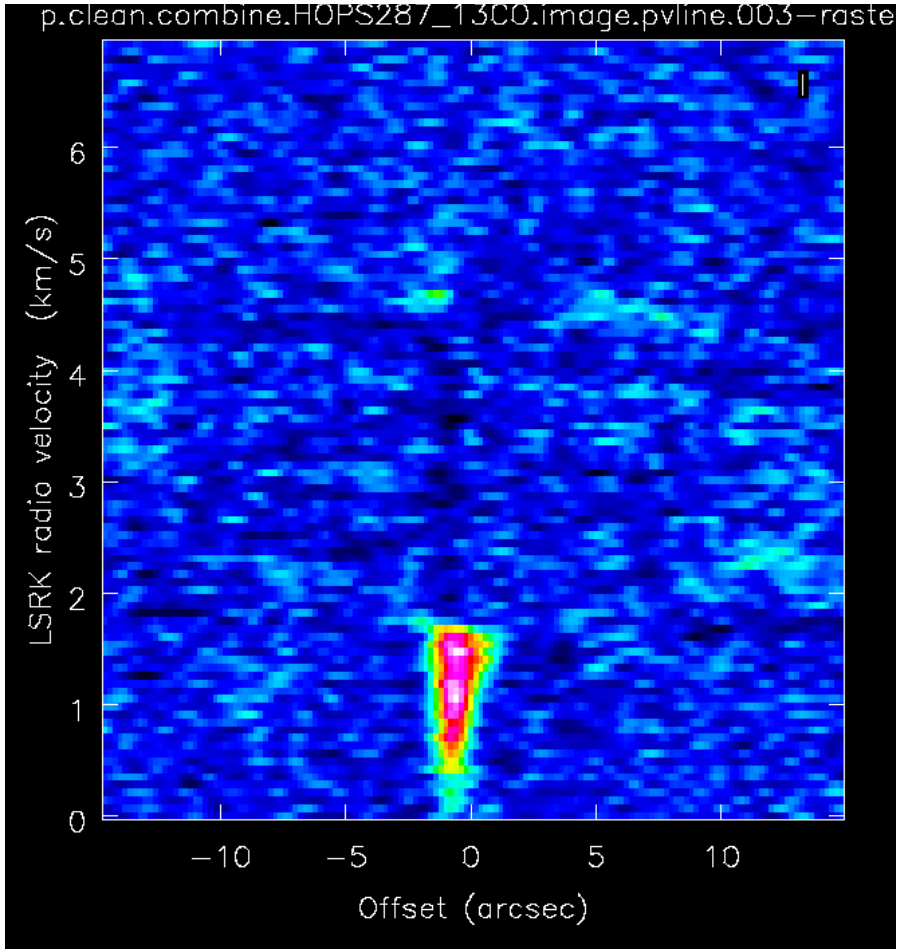
- Outflow signal in PV
- No disk motion
- Systemic velocity ~ 3 km/s
- Velocity : 0 – 2.3 km/s

03 RESULT

✓ 13CO







- Outflow signal in PV
- No disk motion
- Systemic velocity ~ 3 km/s
- Velocity : 0 – 1.7 km/s

04 SUMMARY & DISCUSSION

✓ Outflow

- The direction of outflow is estimated from HST/WFC3 image.
- 12CO, C18O PV diagram shows bipolar outflows. This is consistent with HST observation.

Param	C18O	12CO	13CO	Unit
Outflow velocity (blue)	0 - 2	1 -3	1.3 - 3	**Km/s**
Outflow velocity (red)	2 – 2.5	3 - 5		**Km/s**
Disk structure	None	None	None	

- HST image shows outflow launching point
- 12CO & C18O shows faint red shifted outflow velocity in PV diagram.

04 SUMMARY & DISCUSSION

- It seems that outflowed gas is already mixed with ambient molecular cloud.

  because the target shows (respectively) compact source and very low outflow velocity.

✓ **Disk**

- The disk is not resolved, because this observation's synthesize beam is about 1 arcsec, and the distance to HOPS287 is about 420 pc. Thus, the resolve limit is about 420 AU. This is bigger than typical disk size, about 200 AU.

THANK YOU FOR YOUR ATTENTION