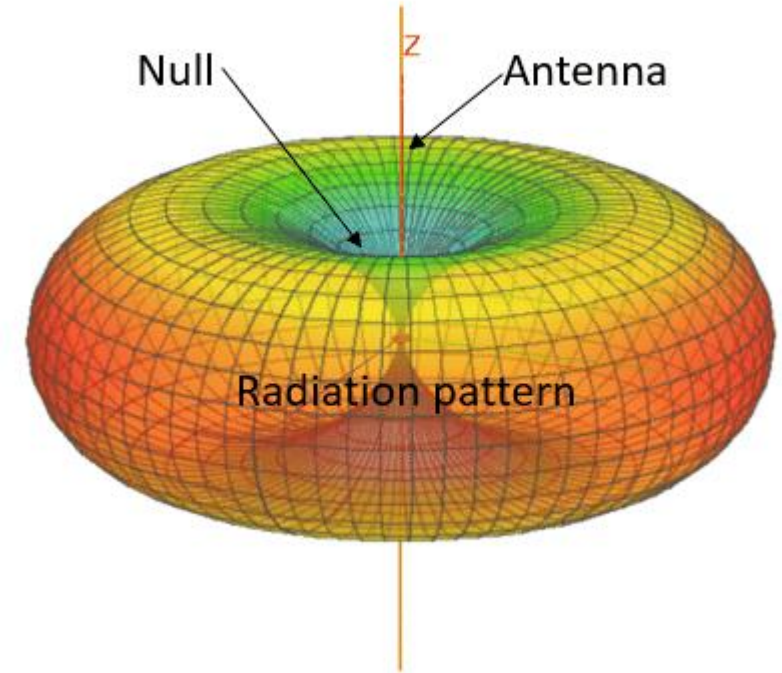
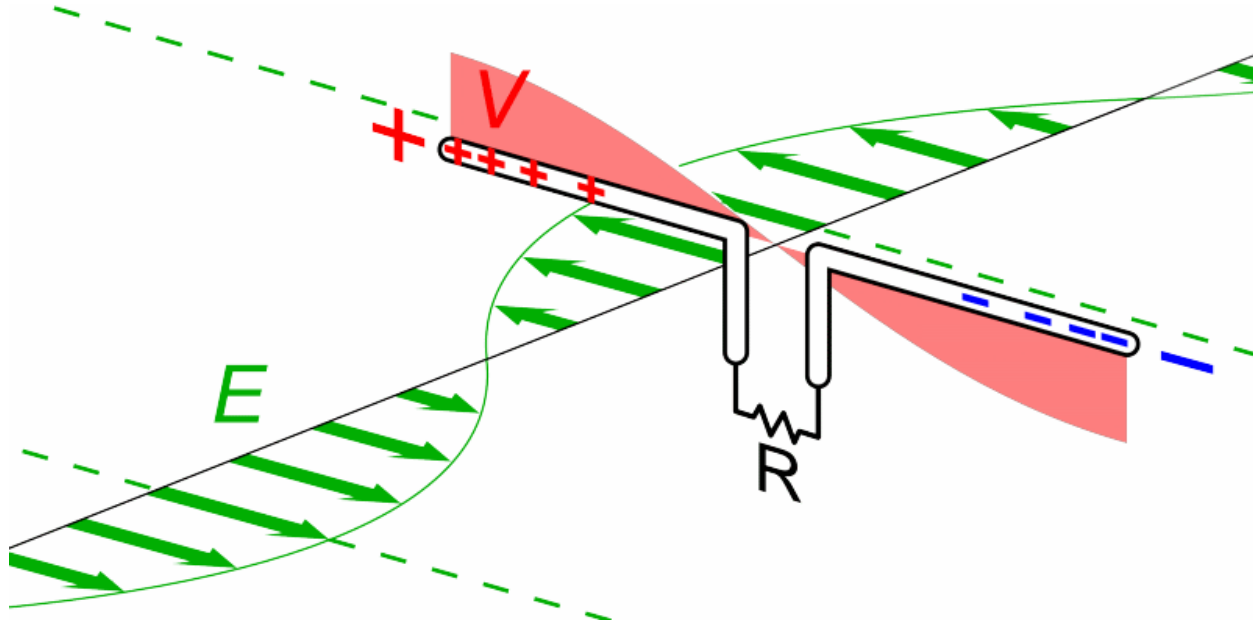


# Single Dish Radio Observation

Observation using single dish radio antenna and its output

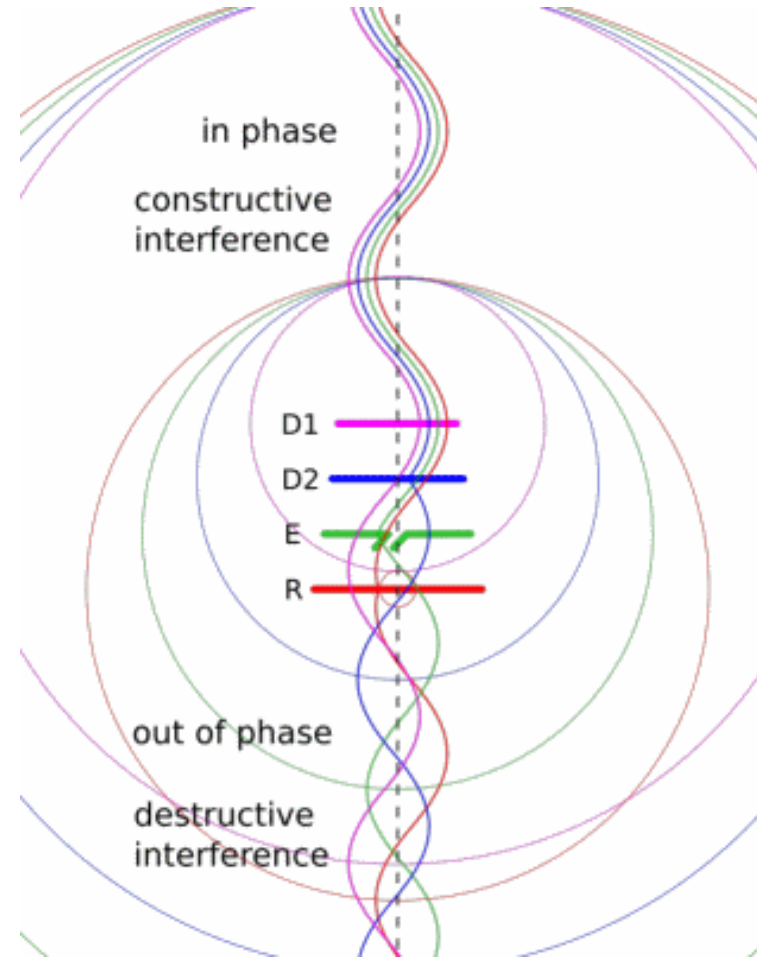
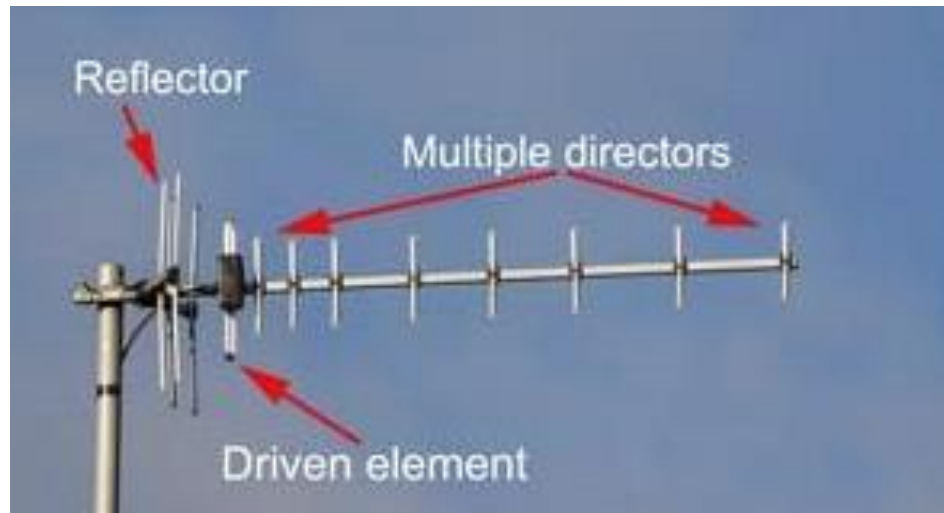
Hyeong-Sik Yun

# Antenna and Beam pattern



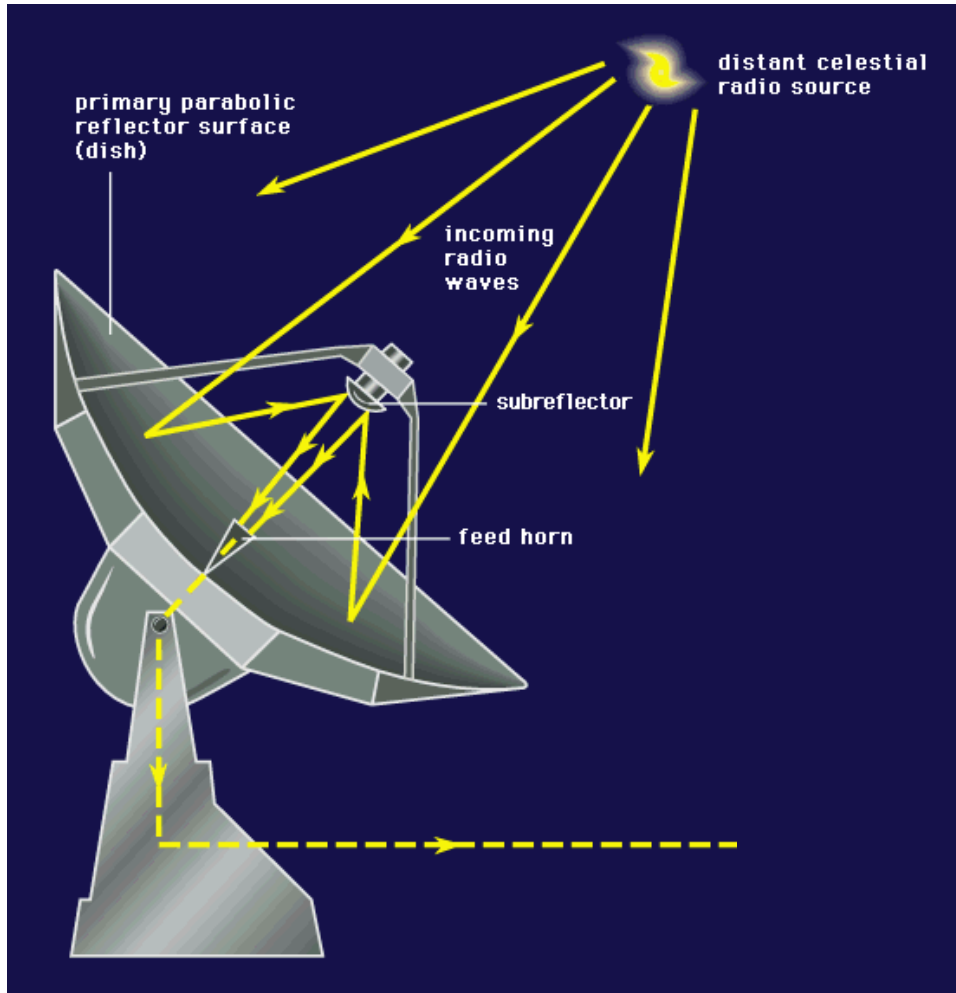
Dipole and monopole antenna

# Antenna and Beam pattern

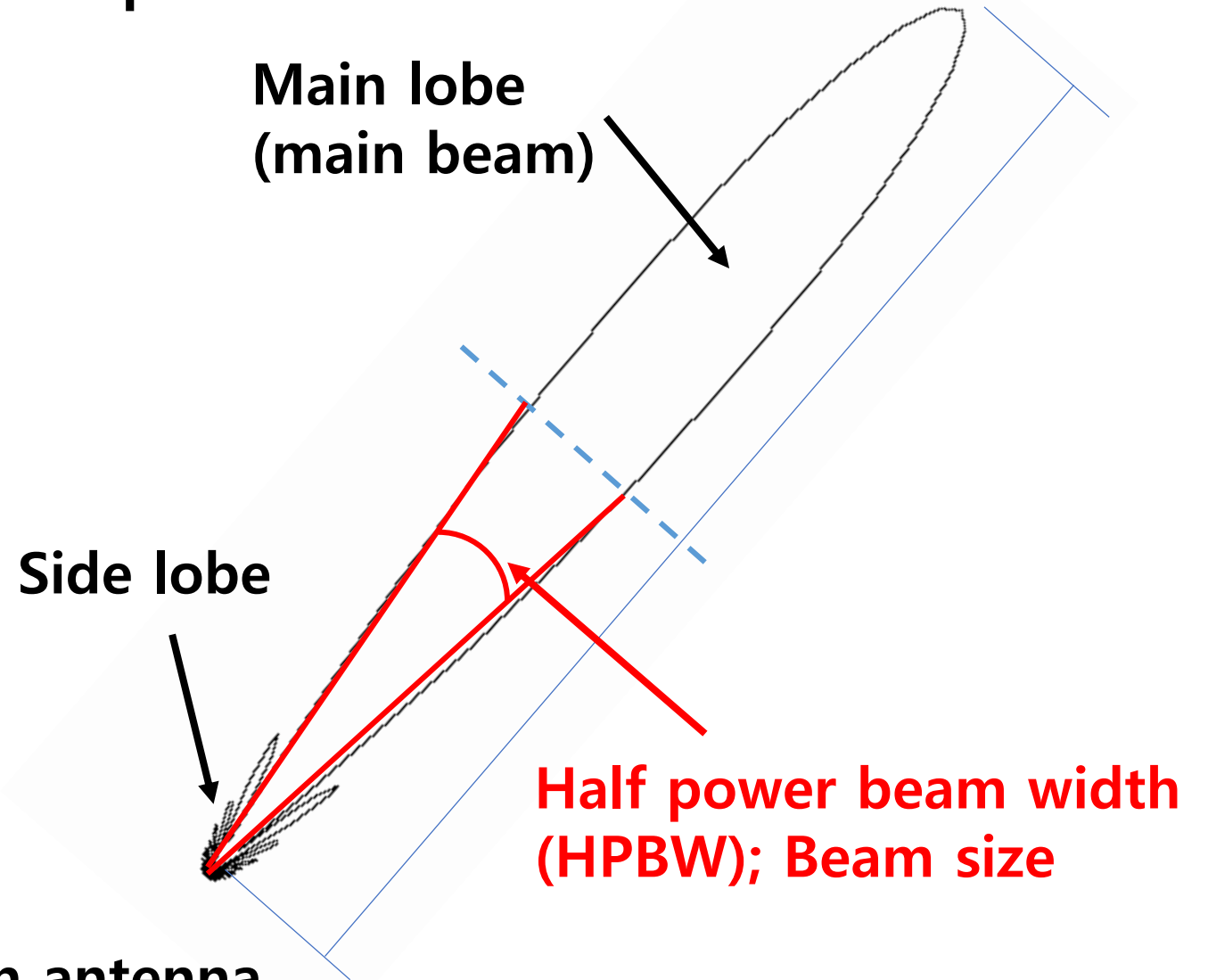


**Yagi-Uda antenna**

# Antenna and Beam pattern



Dish antenna



# Dish radio antennae

**Taeduk Radio Astronomy  
Observatory (TRAO)**



**Korean VLBI Network  
(KVN)**



# Single dish observation

- Observation of radio waves using a dish antenna.
- The radio signals received through the beam pattern are measured at the same time
  - Large beam size -> Low spatial resolution
  - Observed data contains the average signal within the main beam.
- Basically, single dish observation can investigate **a single-point data**.



# Investigate multi-point data (Maps)

- **Grid mapping**
- Multi-beam receiver
- On-The-Fly (OTF) mapping

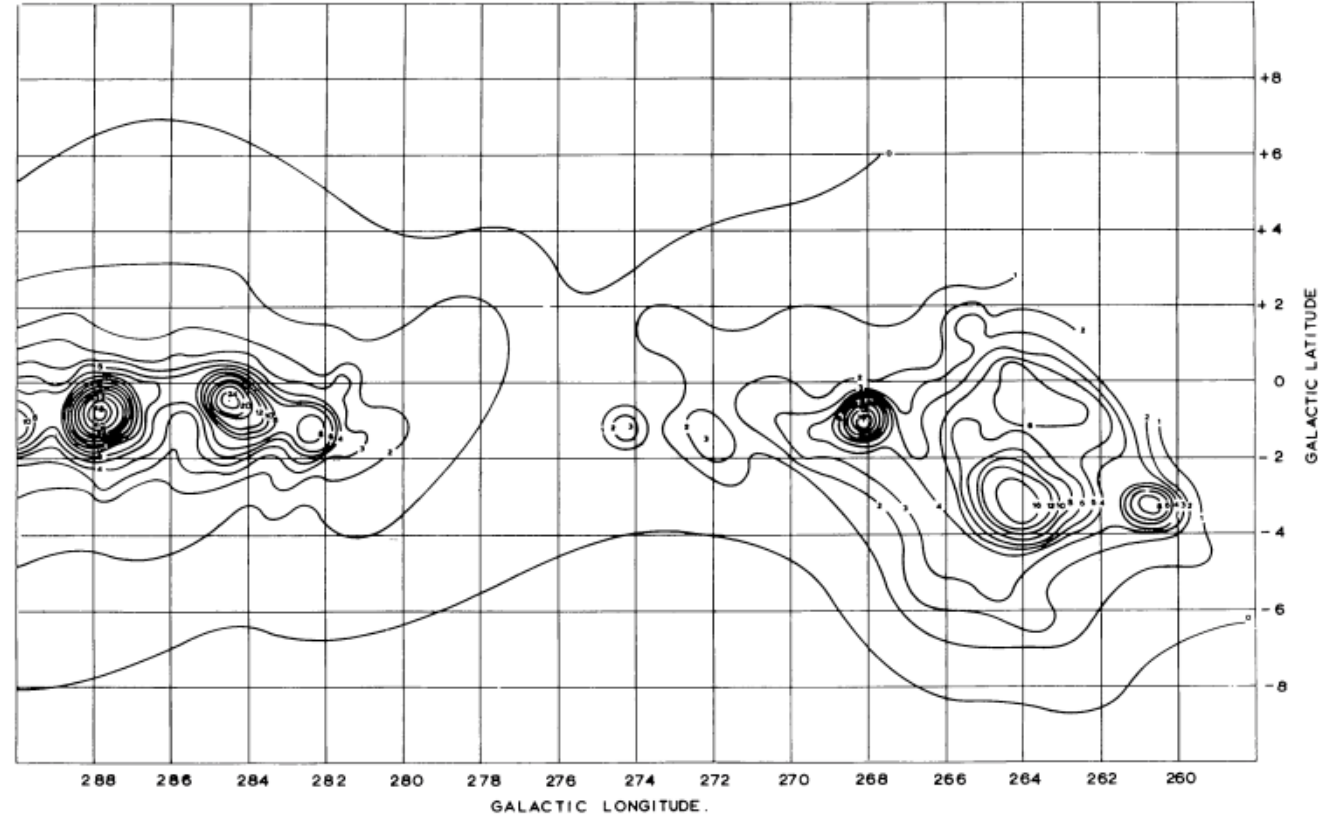
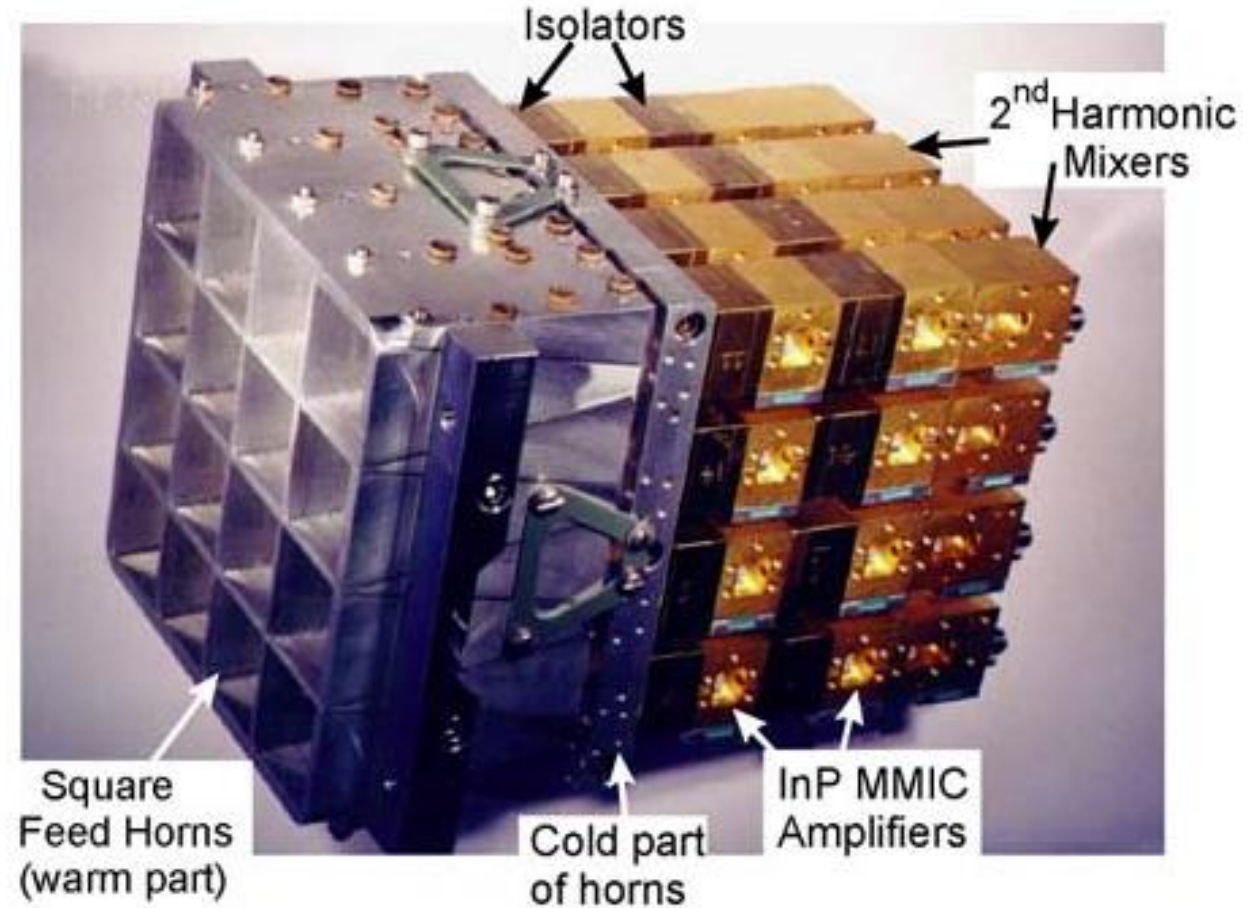


FIG. 2.—Galactic radiation at 960 Mc/s;  $l = 260^\circ$ – $290^\circ$ .

Nicolson (1965); the first radio astronomy paper

# Investigate multi-point data (Maps)

- Grid mapping
- **Multi-beam receiver**
- On-The-Fly (OTF) mapping



SEQUOIA-TRAO receiver system (TRAO)



# Investigate multi-point data (Maps)

- Multi-beam receiver
- Grid mapping
- **On-The-Fly (OTF) mapping**

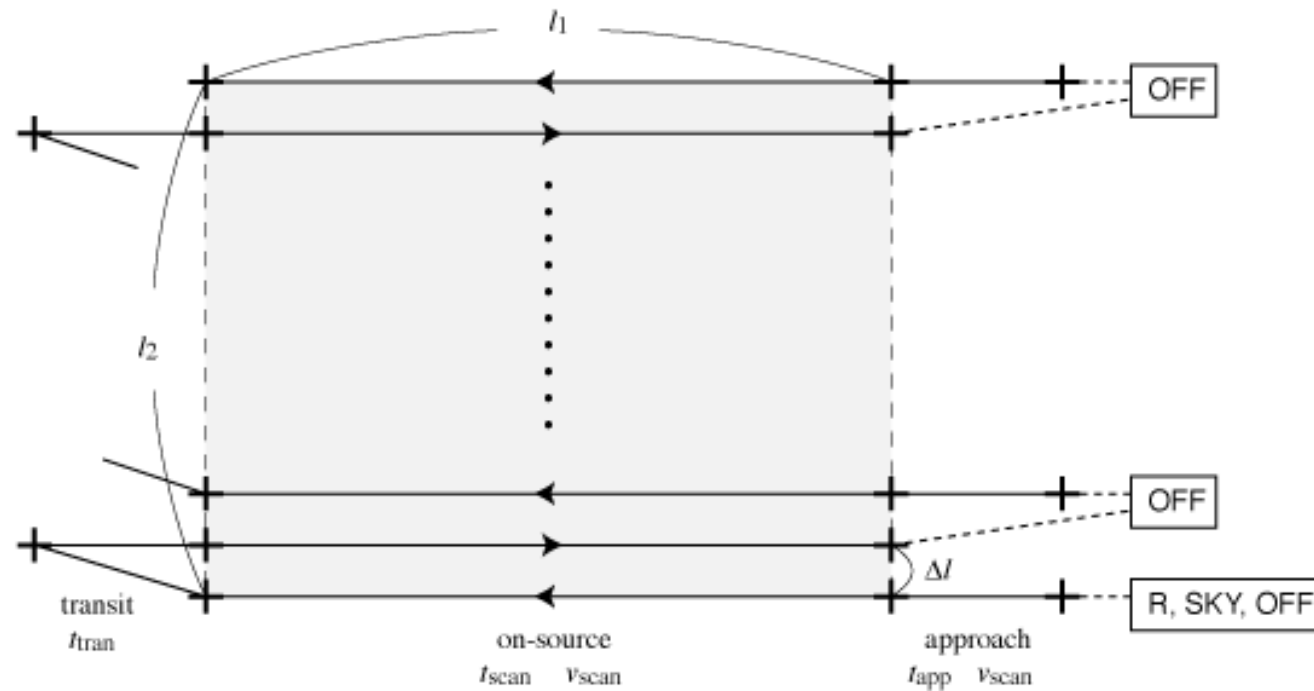


Figure. Schematic illustration of an OTF scan pattern (NRO)

# Investigate multi-point data (Maps)

- Multi-beam receiver
- Grid mapping
- **On-The-Fly (OTF) mapping**

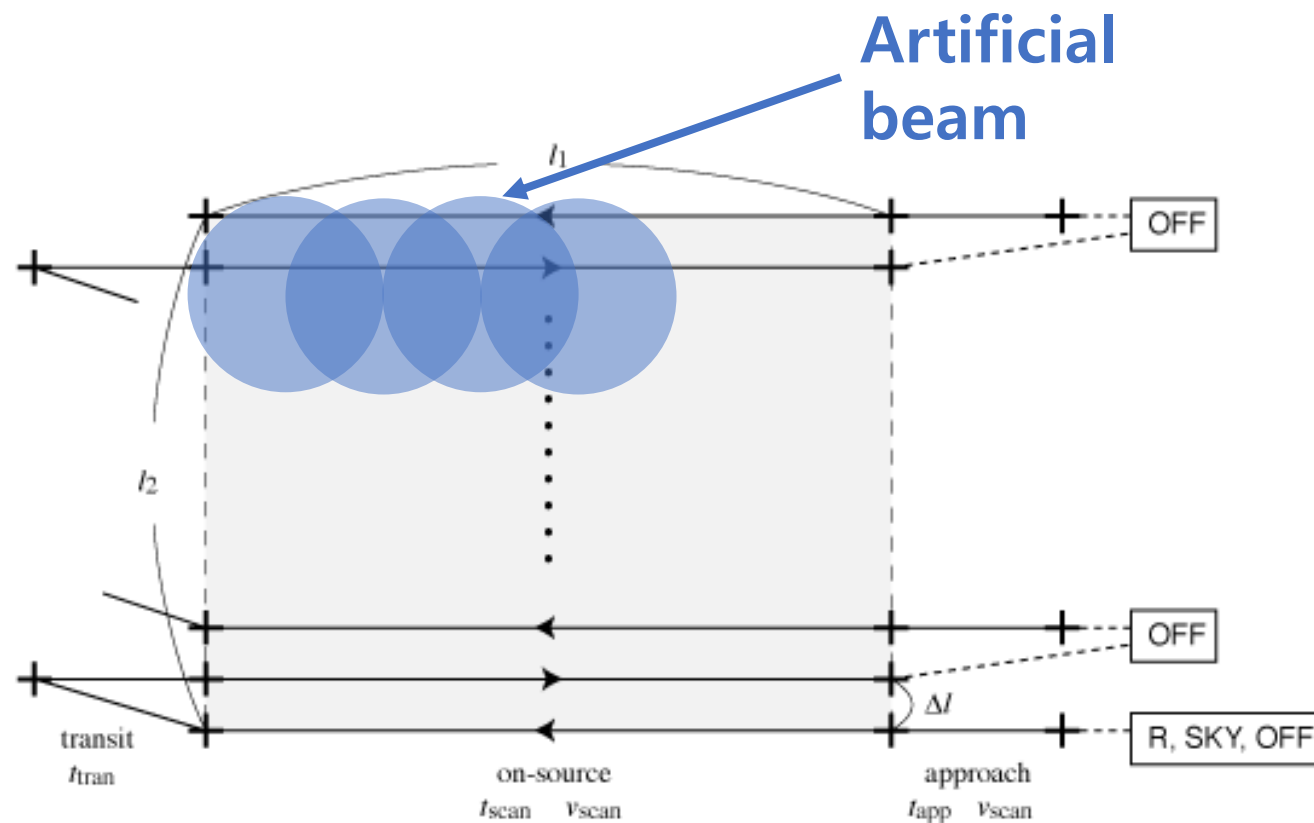


Figure. Schematic illustration of an OTF scan pattern (NRO)

# Investigate multi-point data (Maps)

- Multi-beam receiver
- Grid mapping
- **On-The-Fly (OTF) mapping**

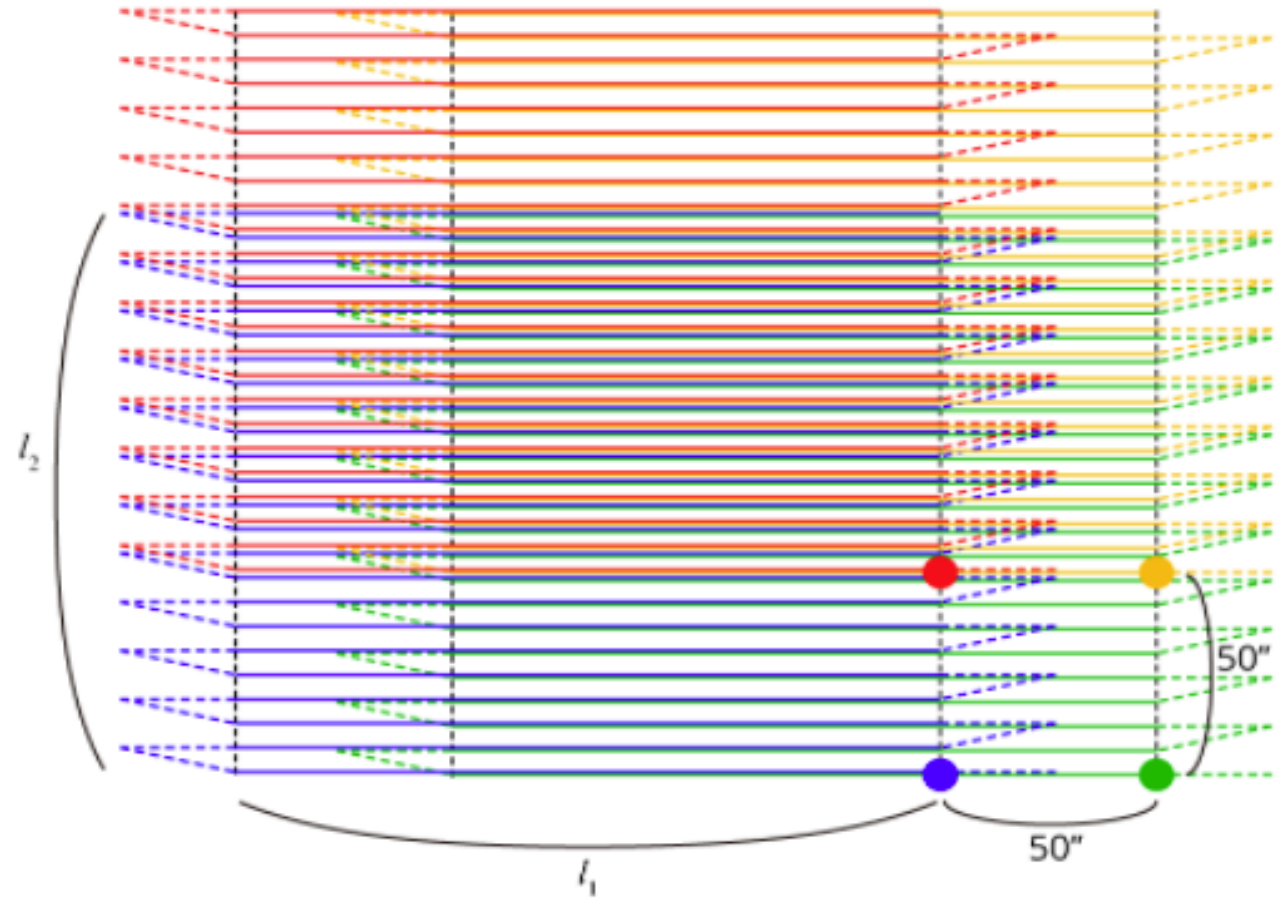


Figure. Schematic illustration of an OTF scan pattern with FOREST 4-beams receiver (NRO)

# Investigate multi-point data (Maps)

- Multi-beam receiver
- Grid mapping
- **On-The-Fly (OTF) mapping**

**High sensitivity can be achieved**

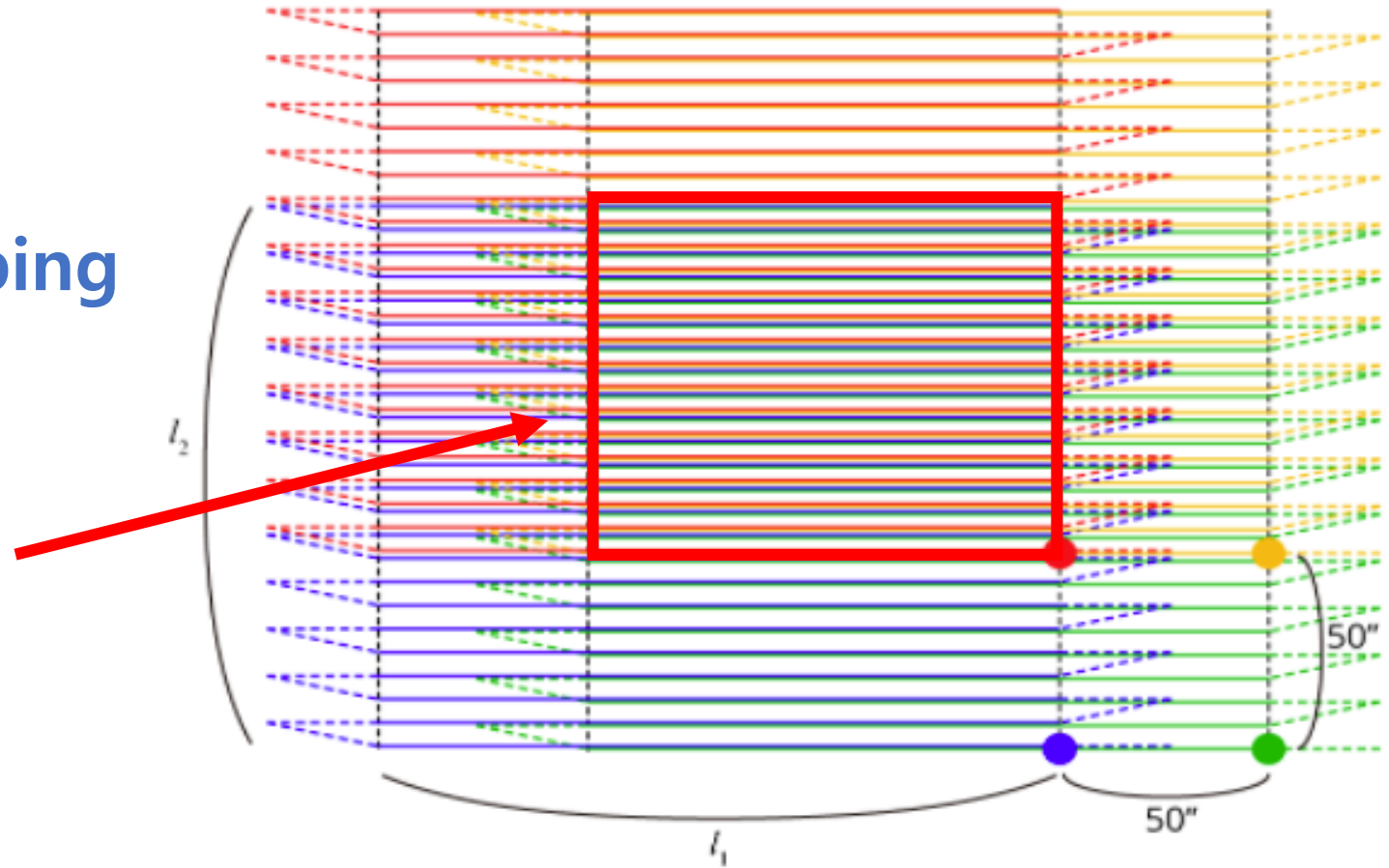
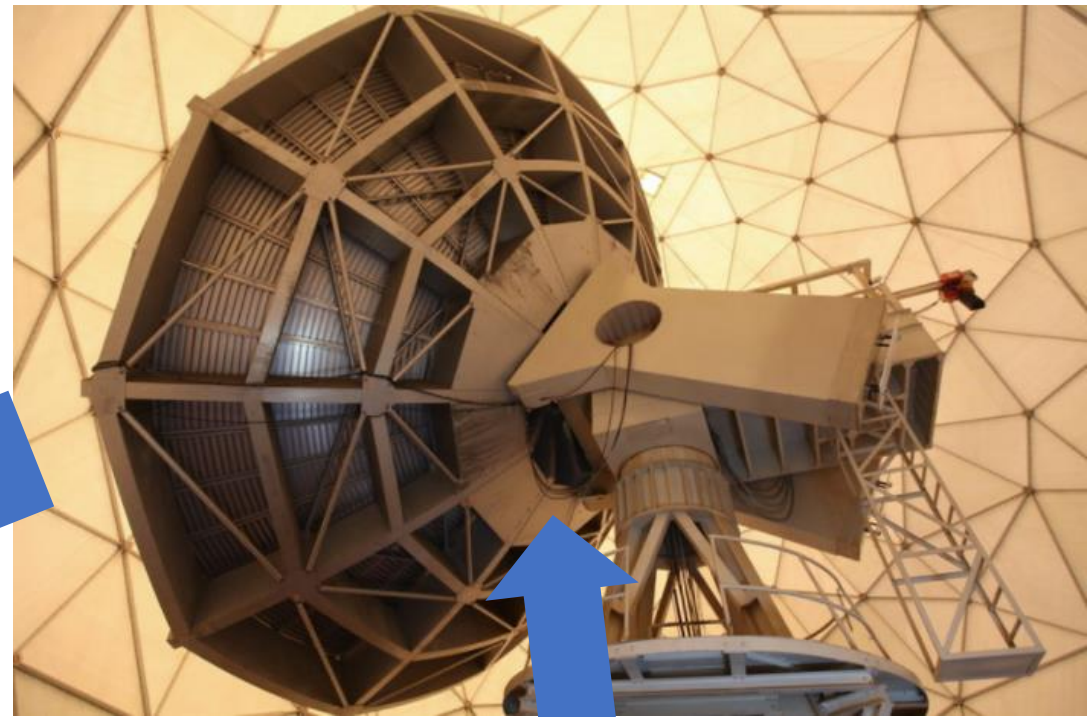


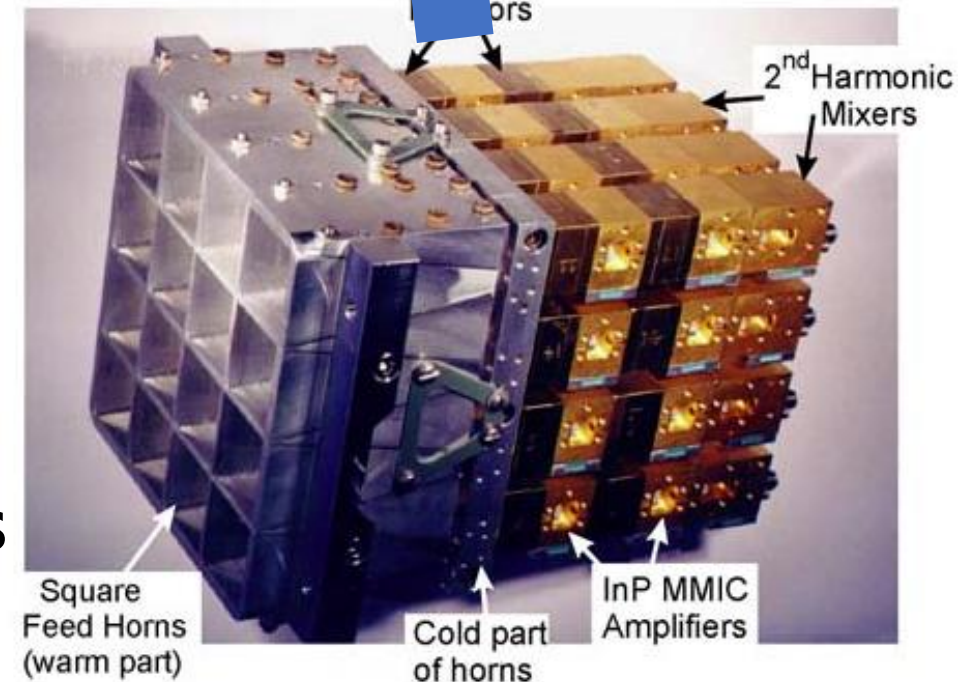
Figure. Schematic illustration of an OTF scan pattern (NRO)

# TRAO 14-m telescope

Radome



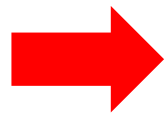
4x4 pixels receiver





# TRAO 14-m telescope

- Receiver with **16 pixels** arranged 4x4 array
- **OTF** observing mode
- Simultaneous observation of **two lines**



**Very efficient to map the large area in multiple lines.**

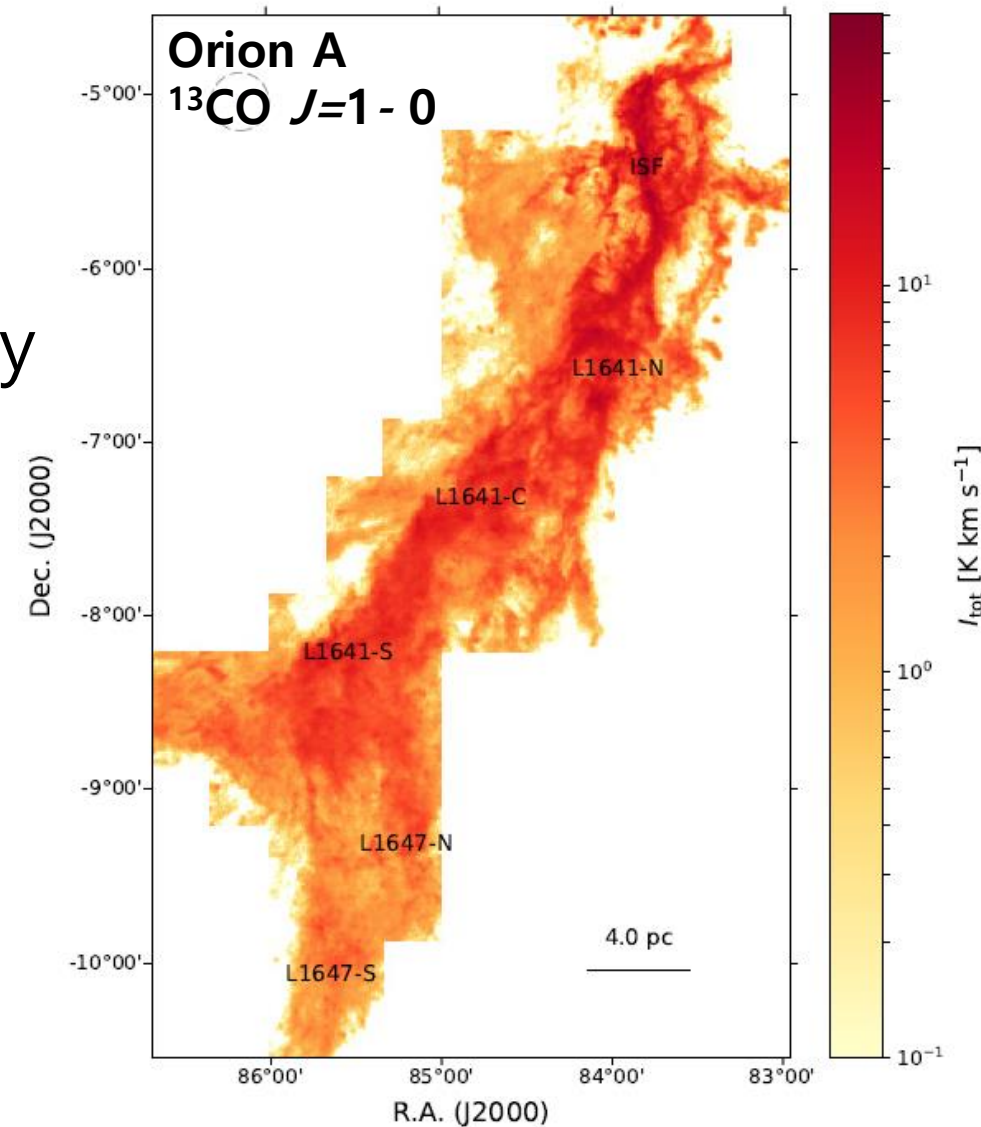
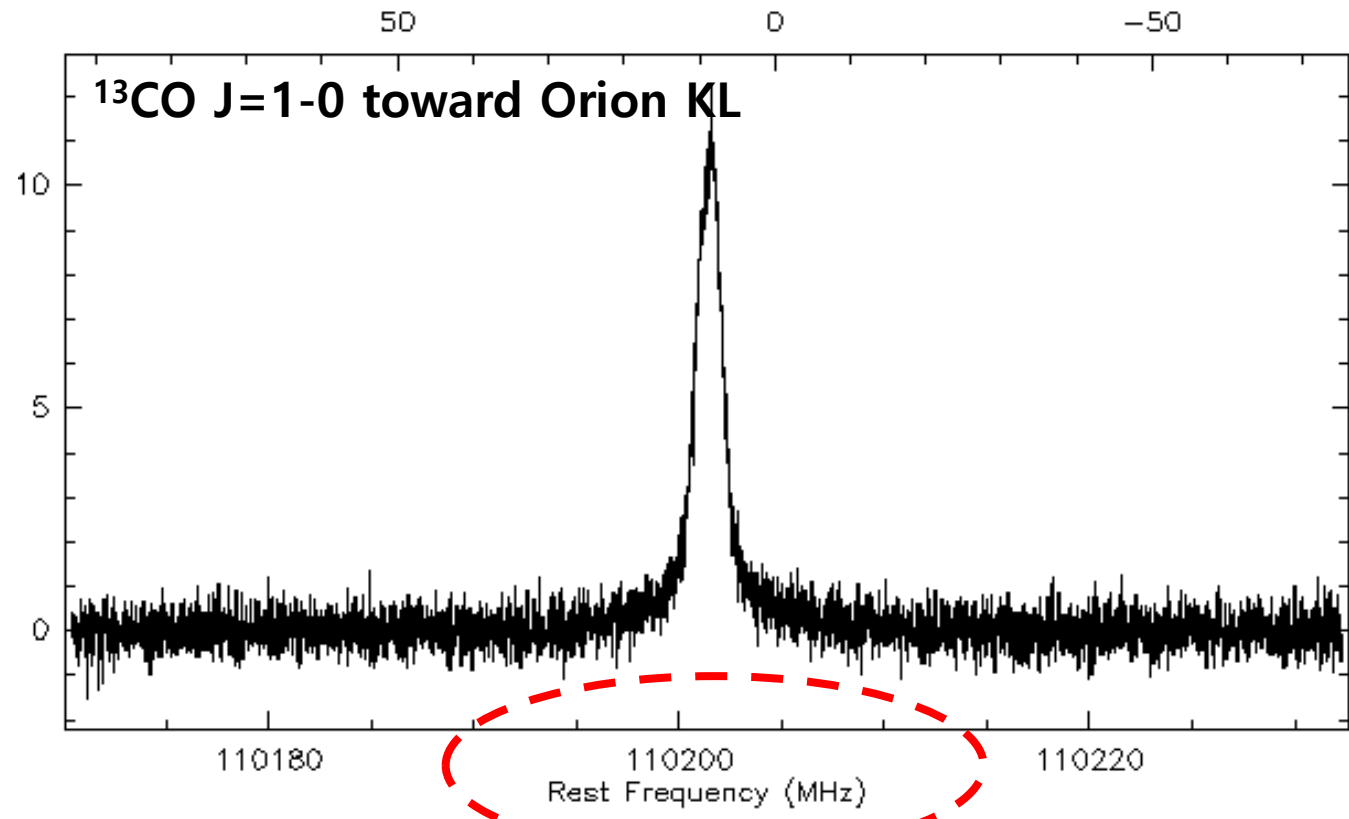
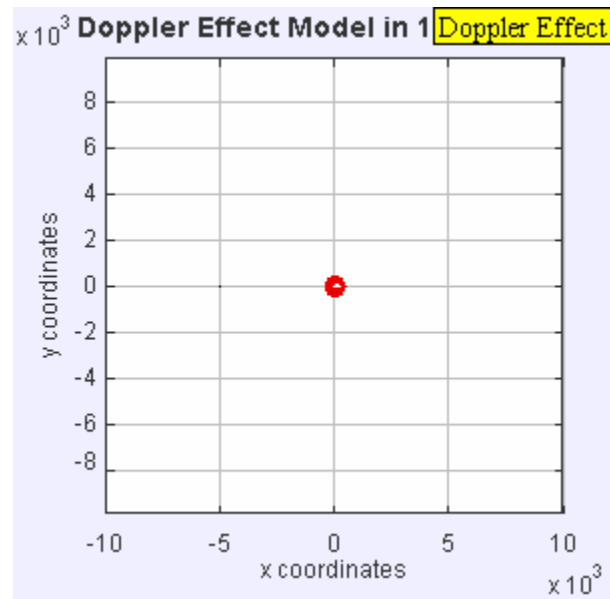


Figure. The integrated intensity map of the Orion A cloud obtained using TRAO (Yun et al. in press).



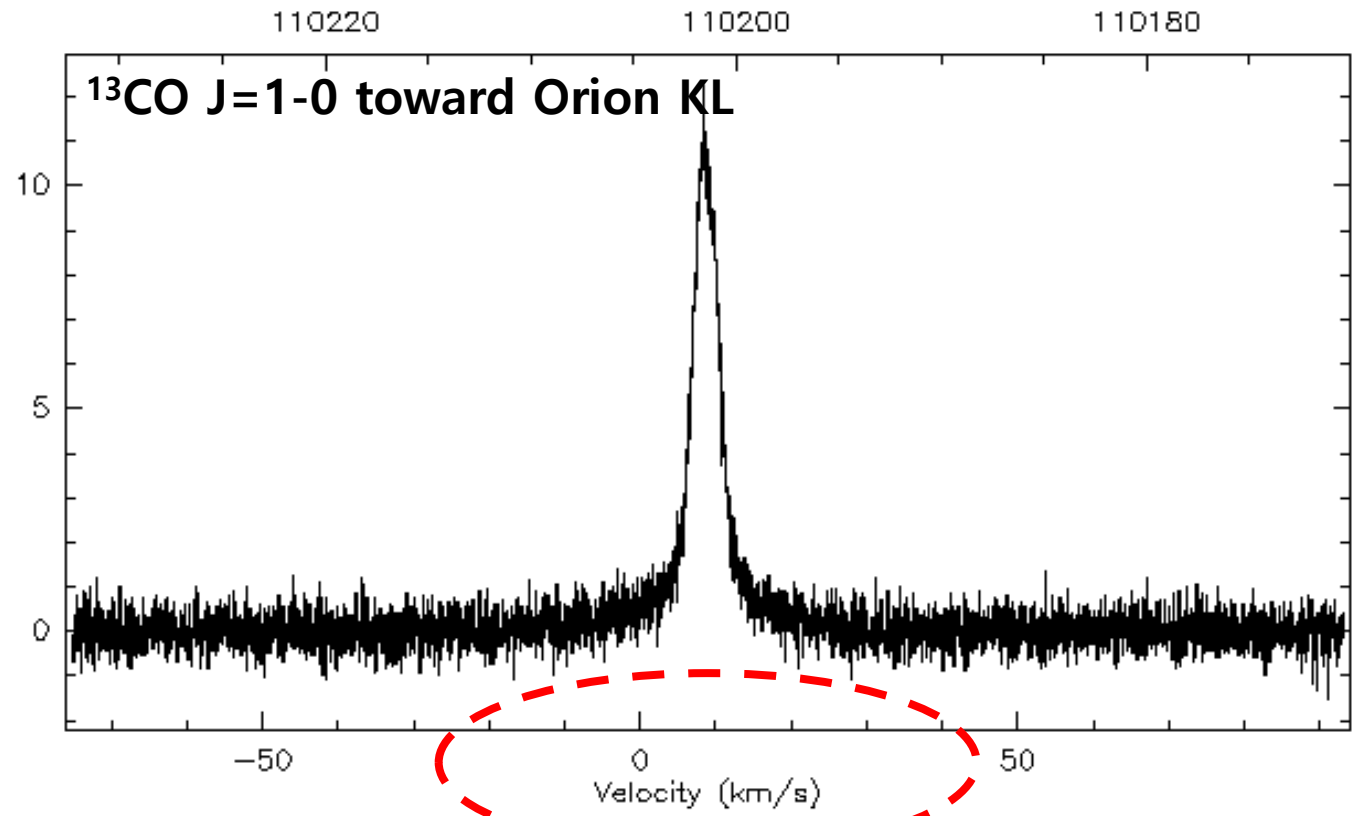
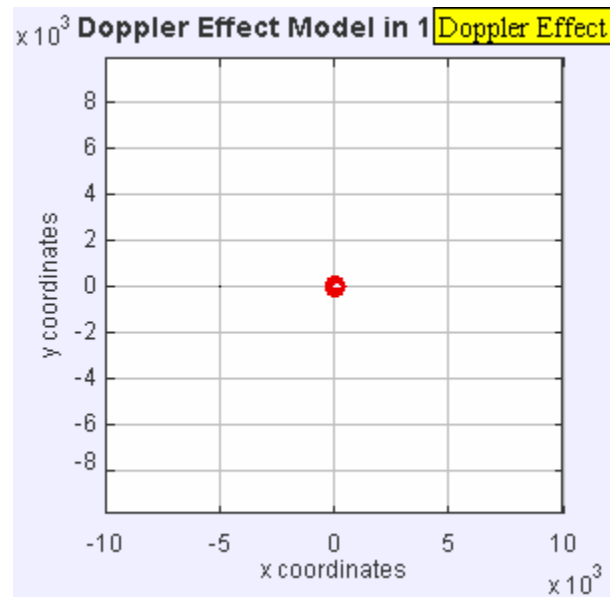
# Spectroscopic observation

- Spectrum: Intensity on the wavelength (or **frequency**) space
- Spectral mapping: the maps in various frequencies
- Doppler effect



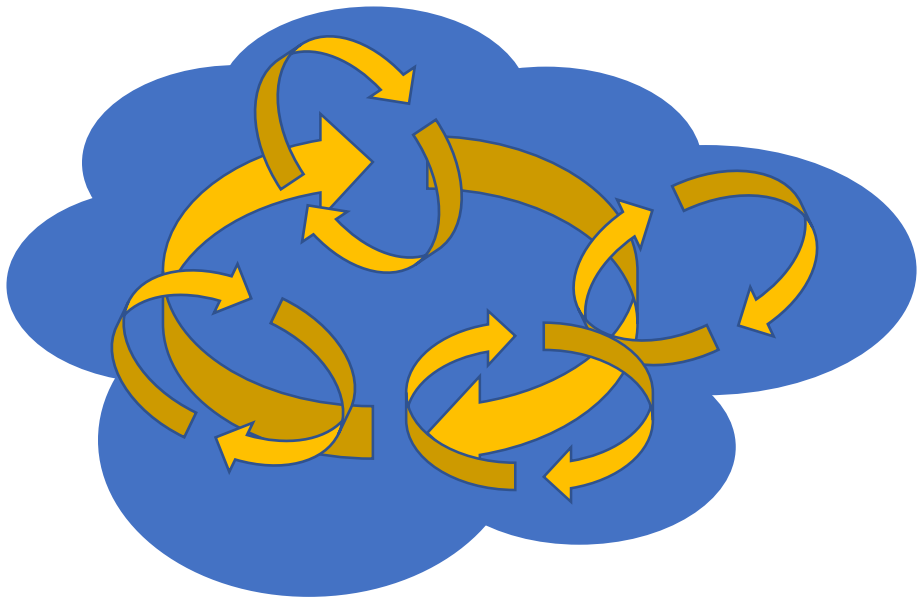
# Spectroscopic observation

- Spectrum: Intensity on the wavelength (or **frequency**) space
- Spectral mapping: the maps in various frequencies
- Doppler effect



# Turbulent star-forming molecular cloud

- All molecular clouds are turbulent.

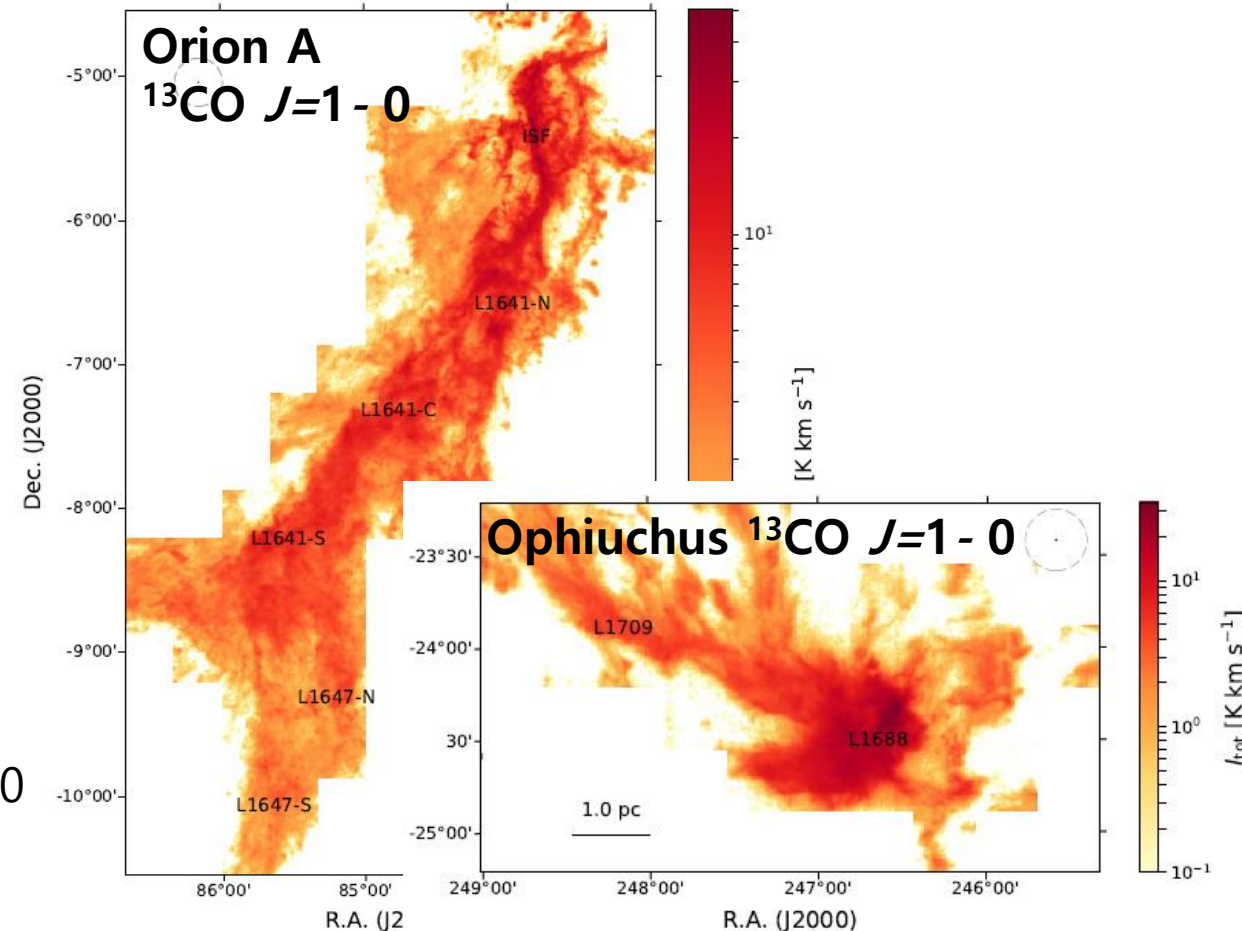


- High velocity turbulent motions in large-scales
  - ➡ Produce **high-density regions** via shocks
- Low velocity turbulent motions in small-scales
  - ➡ Produce non-thermal pressure  
Act against the **gravity**

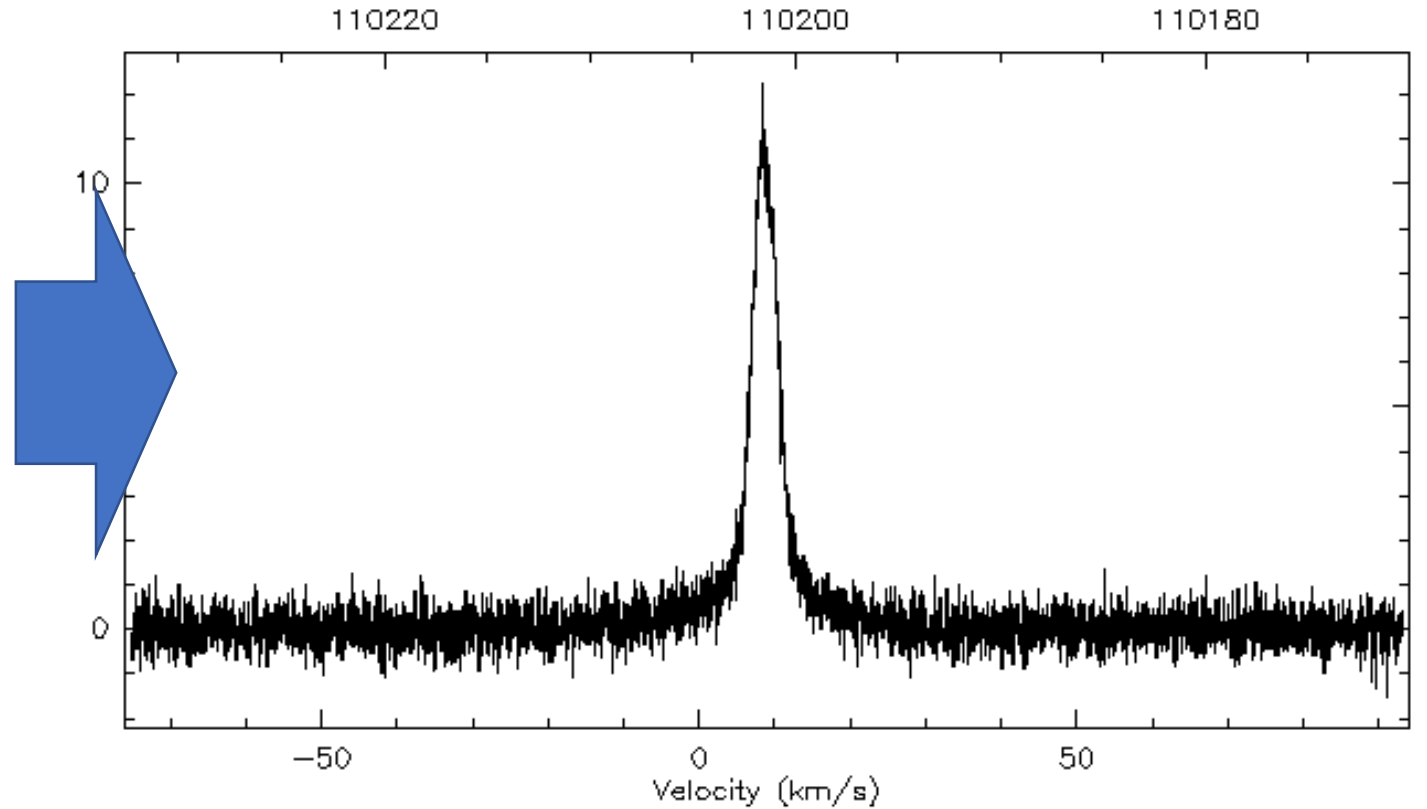
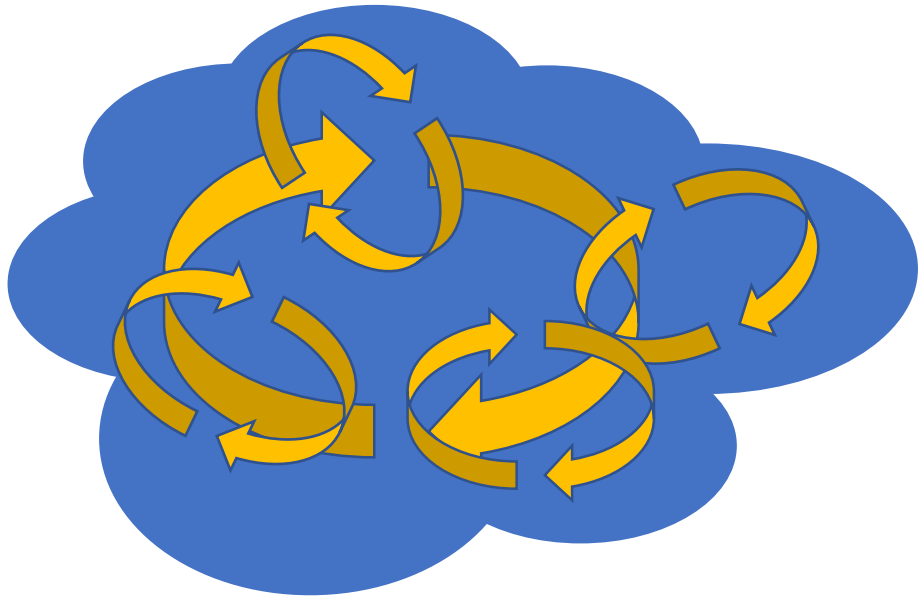
# TRAO-KSP: **TIMES**

“mapping **T**urbulent properties **I**n star-forming **M**olecular clouds down to the **S**onic scale” (**TIMES**)

- Target clouds: Orion A (8.7 deg<sup>2</sup>) and Ophiuchus (3.9 deg<sup>2</sup>)
- Lines:  $^{13}\text{CO } J=1-0$ ,  $\text{C}^{18}\text{O } J=1-0$ ,  $\text{HCN } J=1-0$ ,  $\text{HCO}^+ J=1-0$ ,  $\text{N}_2\text{H}^+ J=1-0$ ,  $\text{CS } J=2-1$
- Observed time: 2016/01 – 2019/04 (1673 hours)
  - ❖ Integrated intensity maps for  $^{13}\text{CO } J=1-0$  (Yun et al. in press)



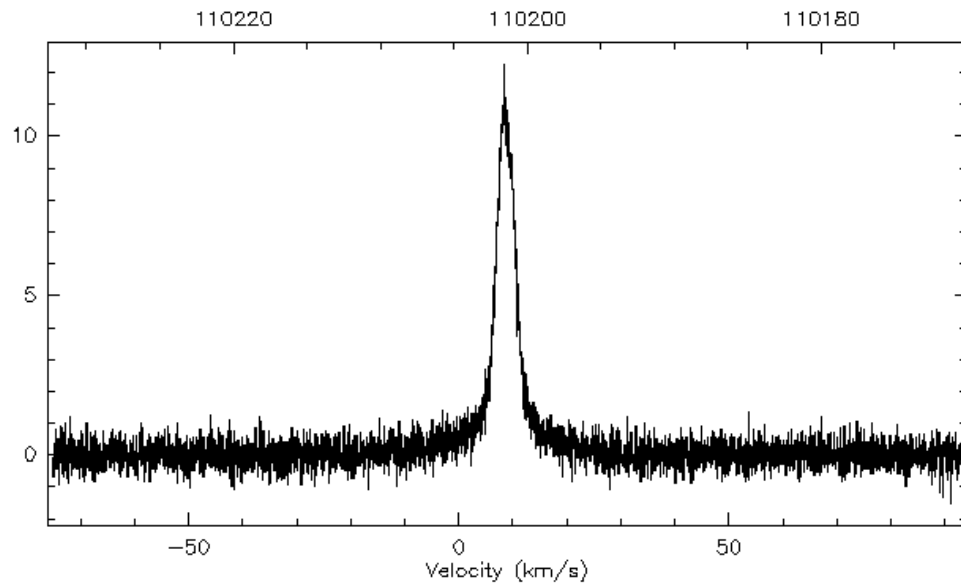
# Turbulence from the observed spectra



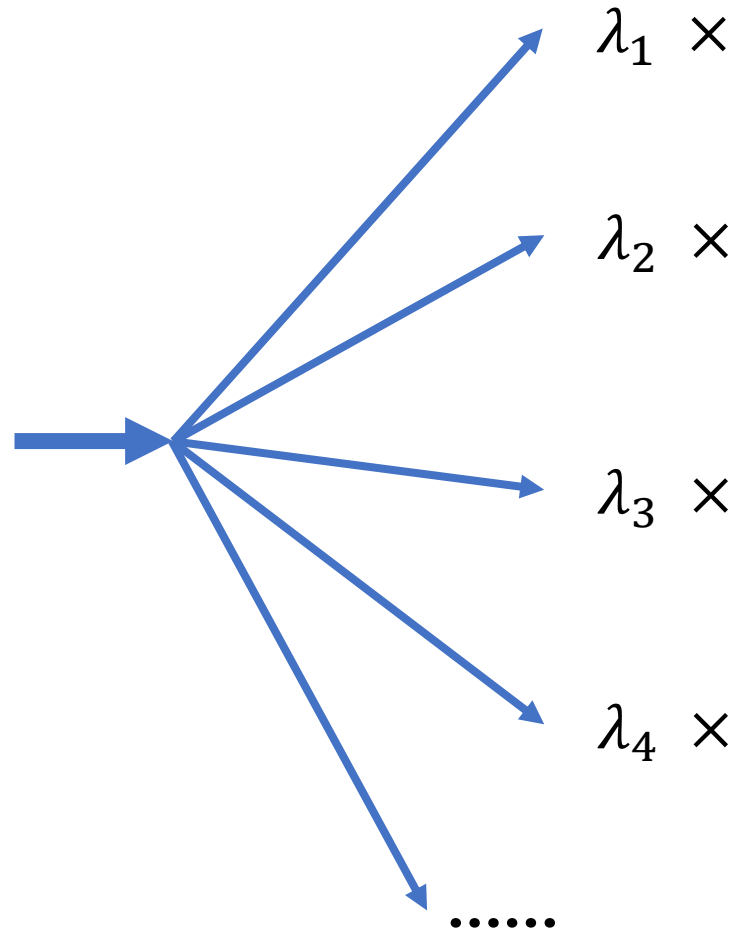
- How can we obtain the motion of turbulence from the observed spectrum?

# Turbulence from the observed spectra

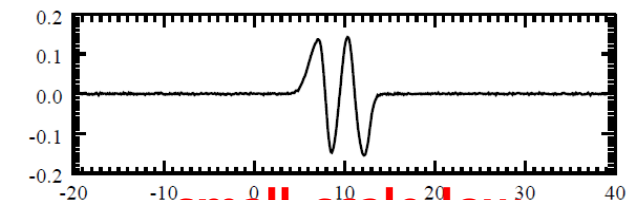
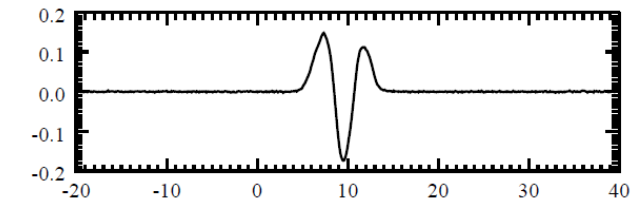
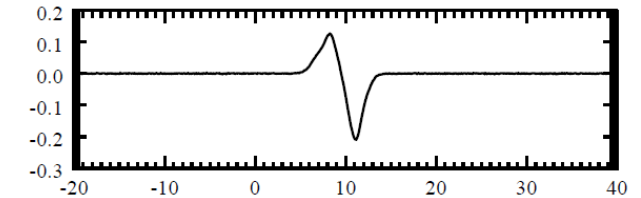
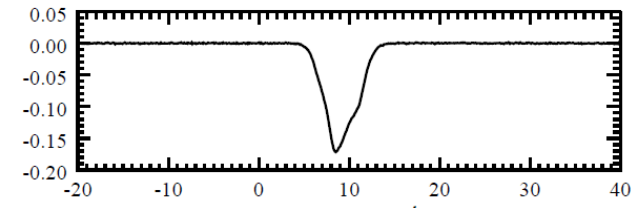
- The Principal Component Analysis (PCA)



Decompose the obtained spectrum!



Large-scale high  
velocity motions

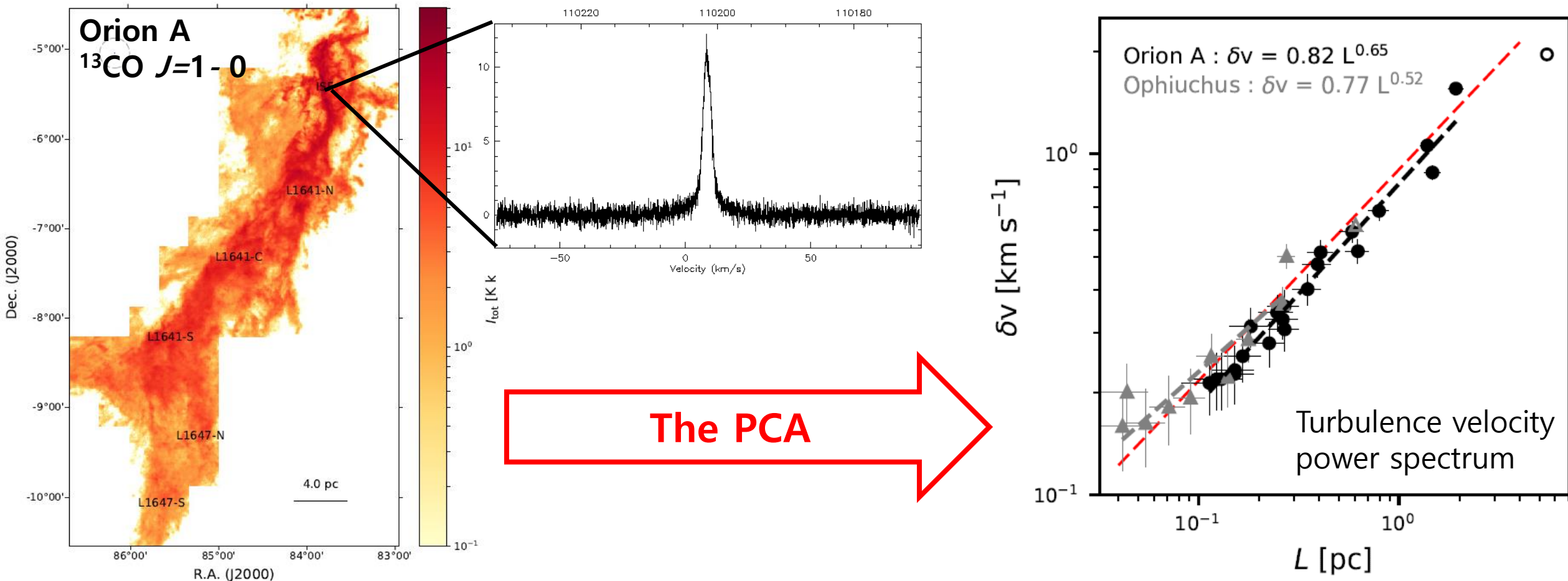


small-scale low  
velocity motions

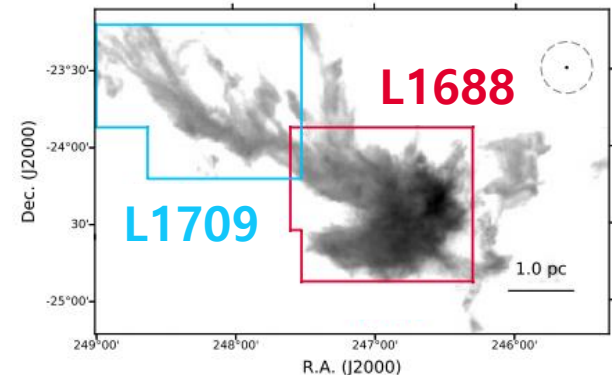
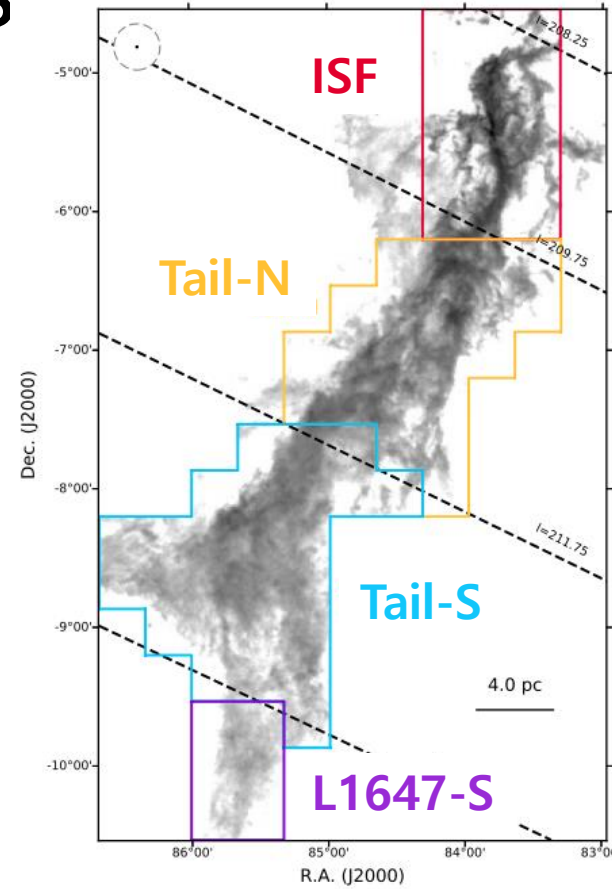
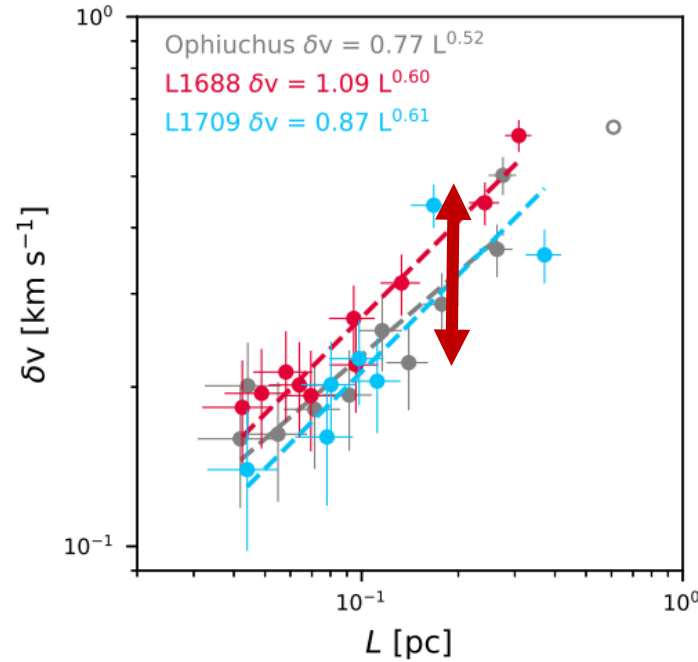
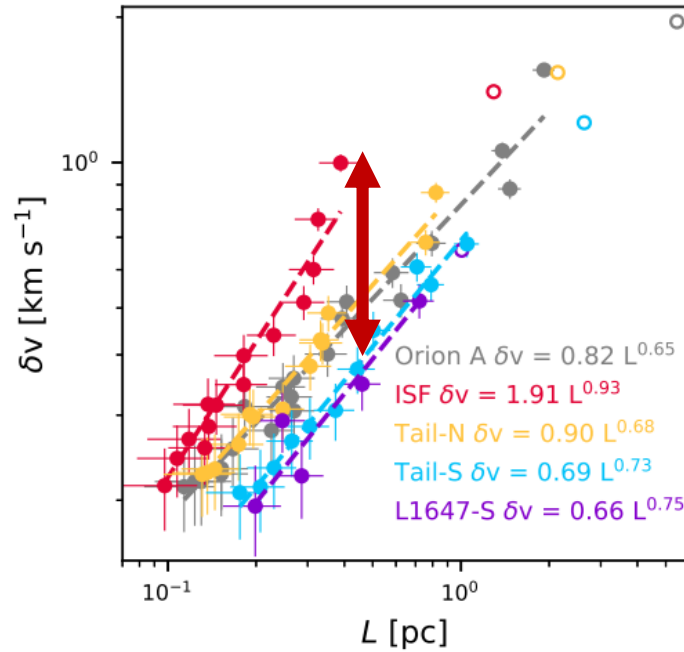


# Turbulence from the observed spectra

- The Principal Component Analysis (PCA)



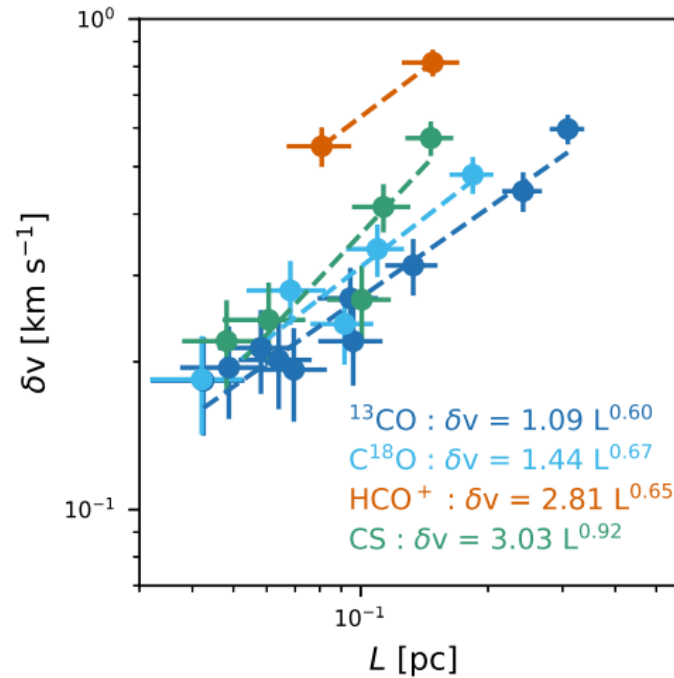
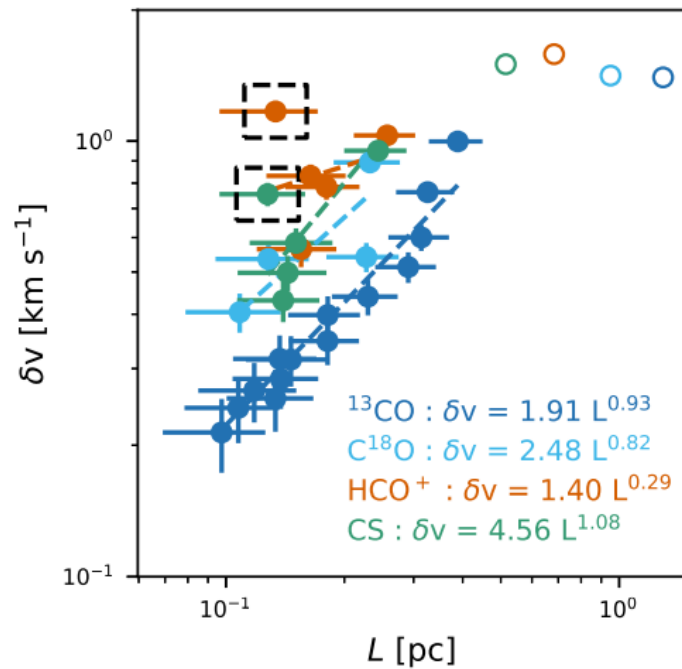
# Turbulence in different sub-regions



- The velocity dispersion ( $\delta v$ ) for a given spatial size ( $L$ ) is generally **higher in sub-regions that are more actively star-forming** (Furlan et al. 2016; Megeath et al. 2012; Dunham et al., 2015).

Yun et al. (in press)

# Turbulence in different density environments



Lines:

$^{13}\text{CO} \ J=1-0$

$\text{C}^{18}\text{O} \ J=1-0$

$\text{HCO}^+ \ J=1-0$

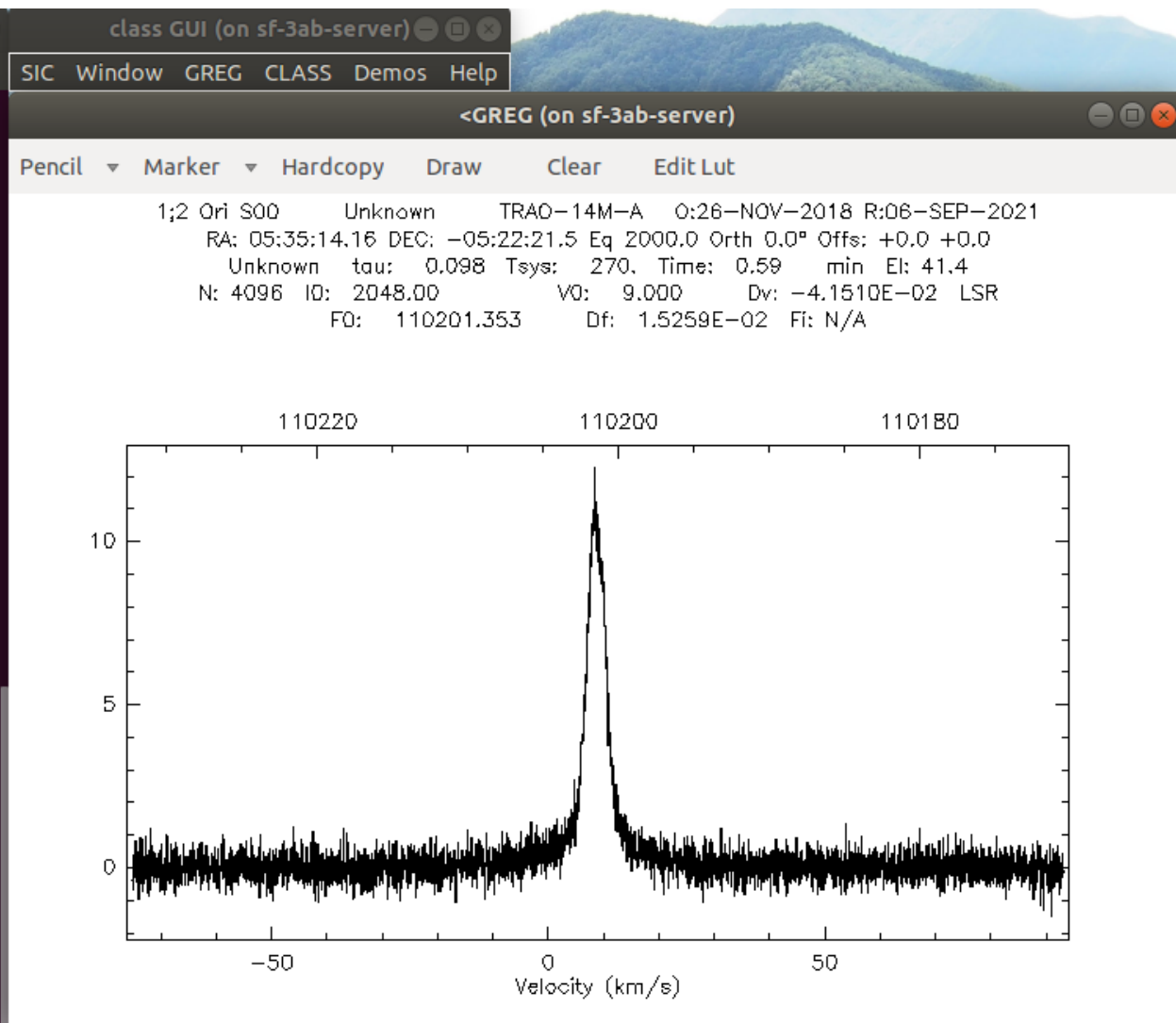
$\text{CS} \ J=2-1$

Yun et al. (in press)

- In the ISF and L1688, the  $\delta v$  of  $\text{C}^{18}\text{O}$ ,  $\text{HCO}^+$ , and  $\text{CS}$  are generally higher than that of  $^{13}\text{CO}$ .
- **The dense gas is more turbulent** than the diffuse gas in these regions.

# Useful program: GILDAS/CLASS

```
hs-yun@sf-3ab-server: ~/build_map/Ori_data
File Edit View Search Terminal Help
* Welcome to CLASS
* Loaded modules
  atm
  sic (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
  greg (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
  ephem (J.Boissier, F.Gueth, J.Pety)
  class (S.Bardeau, J.Pety, P.Hily-Blant, S.Guilloteau)
* Loaded extensions
  weeds (S.Maret, P.Hily-Blant, J.Pety, S.Bardeau, E.Reynier)
* In charge:      J.Pety, S.Bardeau
Active developers: S.Guilloteau
Main past contributors: T.Forveille, P.Hily-Blant, R.Lucas
* For more information, look at the HELP menu of the CLASS widget
* Questions? Comments? Bug reports? Mail to: gildas@iram.fr
* For help, type HELP and/or INPUT at the CLASS prompt
LAS> file in OrionKL_13CO_spectrum.class
I-CONVERT, File is [Native]
I-INPUT, OrionKL_13CO_spectrum.class successfully opened
LAS> find
I-FIND, 1 observation found
LAS> get first
I-GET, Observation 1; Vers 2 Scan 9099
LAS> pl
LAS> set unit v f
LAS> pl
LAS>
```



# Installation guide (the GILDAS package)

- Search 'GILDAS IRAM' on Google.
  - Go to webpage (<https://www.iram.fr/IRAMFR/GILDAS/>)
  - Move to 'Download – download area'
  - See 'gildas.README'
  - We will try to install 'the GILDAS package' and run 'CLASS'
- [https://github.com/HyeongSikYun/Singledish\\_class1](https://github.com/HyeongSikYun/Singledish_class1)