# Single Dish Radio Observation

Observing sequence and data reduction

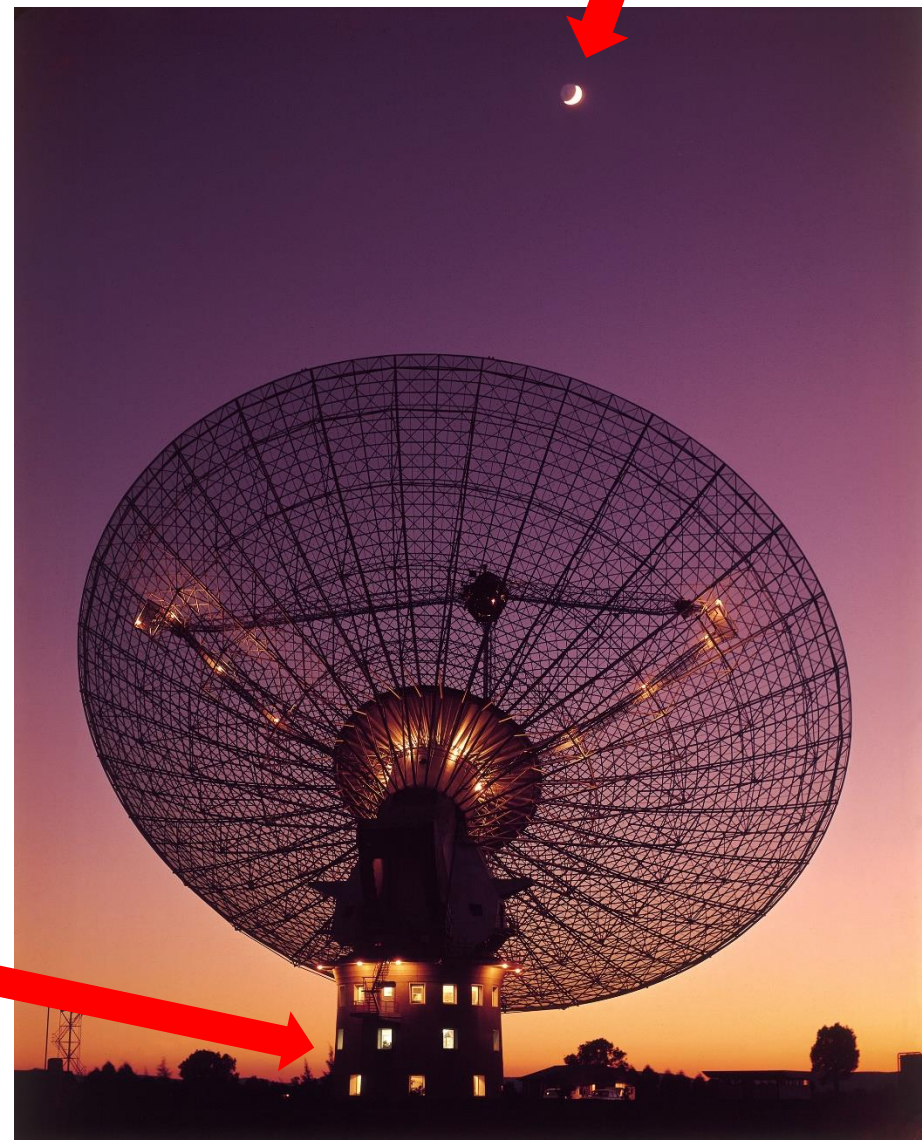
Hyeong-Sik Yun

# Observing astronomical object

- During the observation, we **investigate various data** to obtain the spectrum, which is solely originated from observing target (Calibration).

The things that we should consider during the observation.

1. Atmosphere
2. Focus and pointing of the telescope
3. Error signal from the system



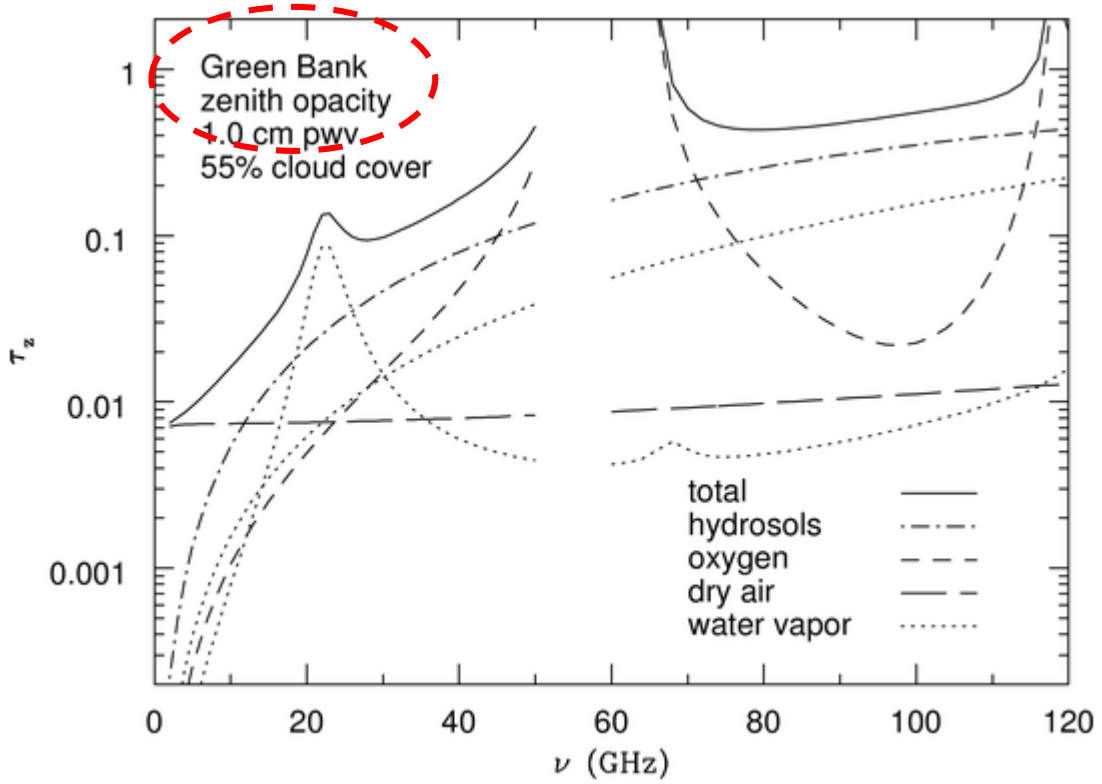
# Sky changes depending on the observing frequency

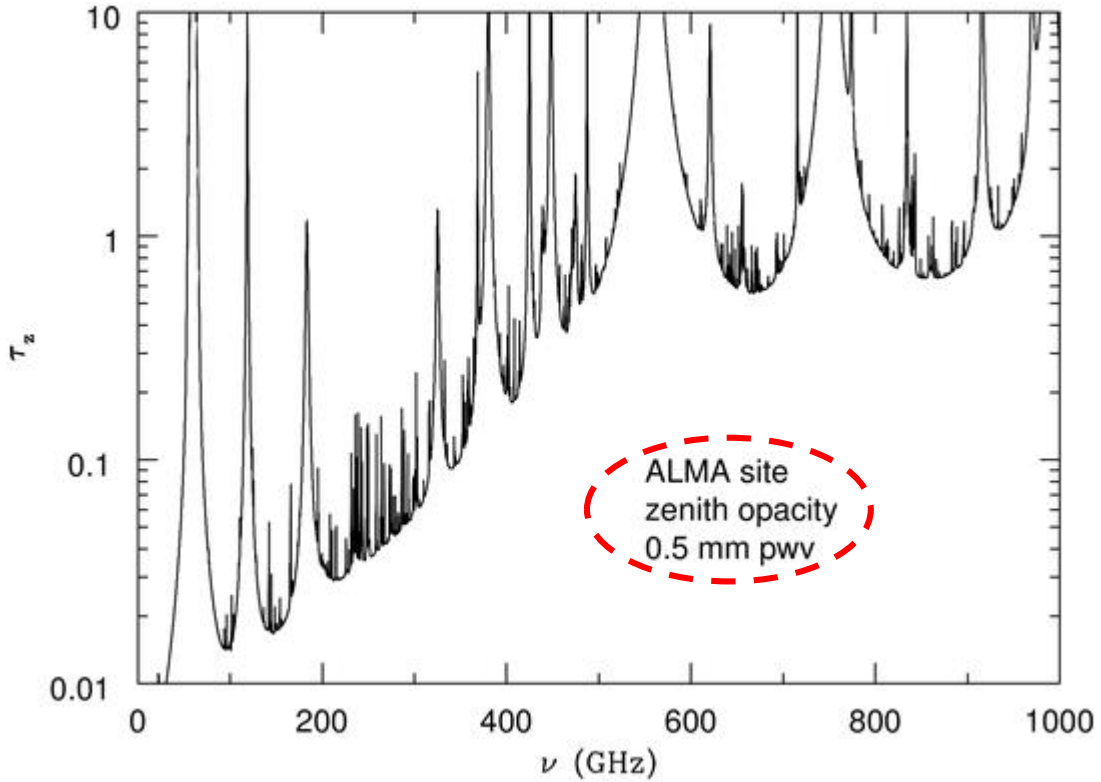
- Opacity: the measure of impenetrability to radiation.


- Opacity of the atmosphere depending on the frequency.
  - Longer wavelength (low frequency) -> less opaque
  - The frequency that its energy is consistent to the energy gab of a certain molecule.

# Sky changes depending on the observing frequency

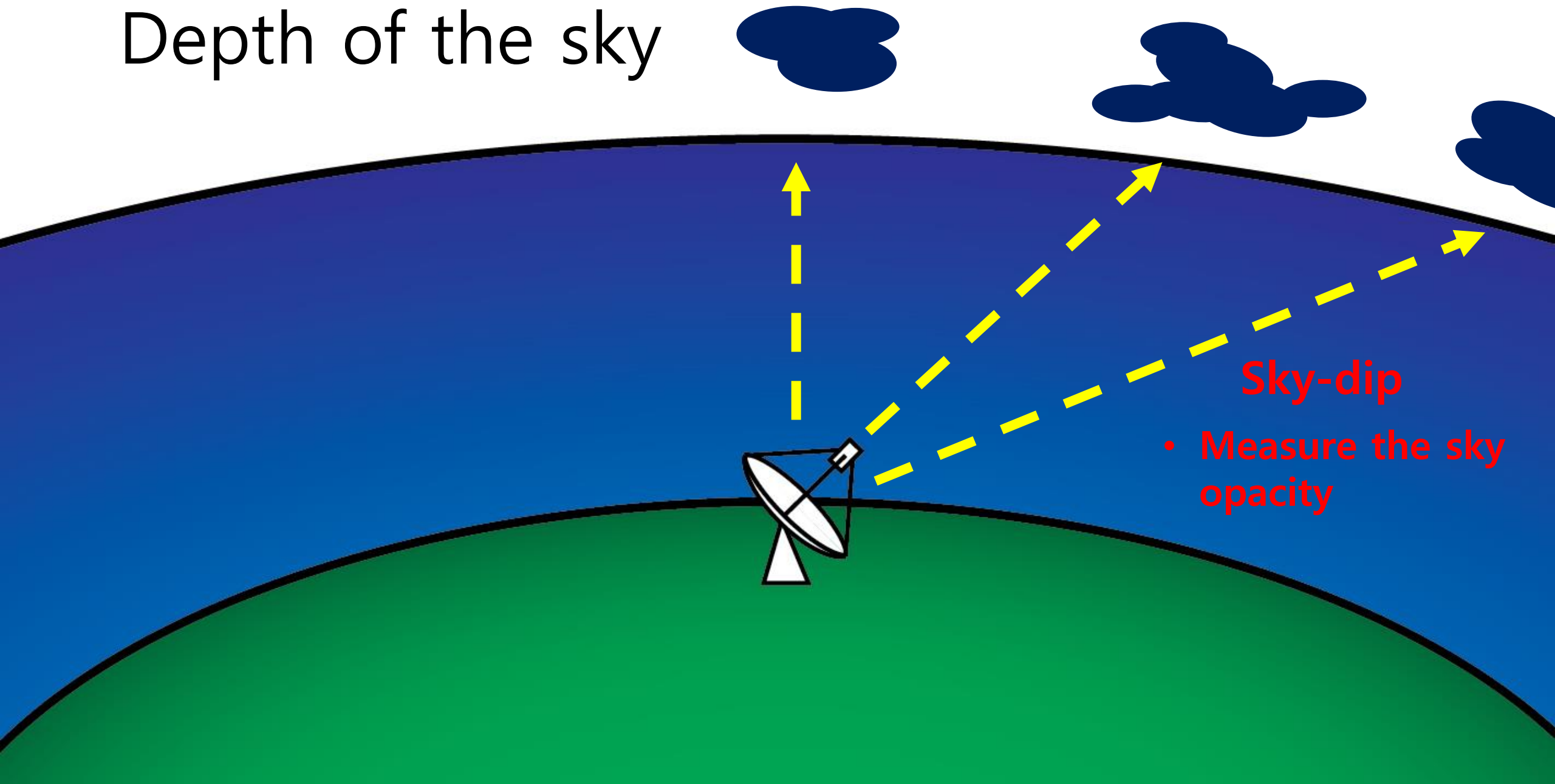
- Opacity: the measure of impenetrability to radiation.




Reference: Essential Radio Astronomy
(https://www.cv.nrao.edu/~sransom/web/Ch1.html)

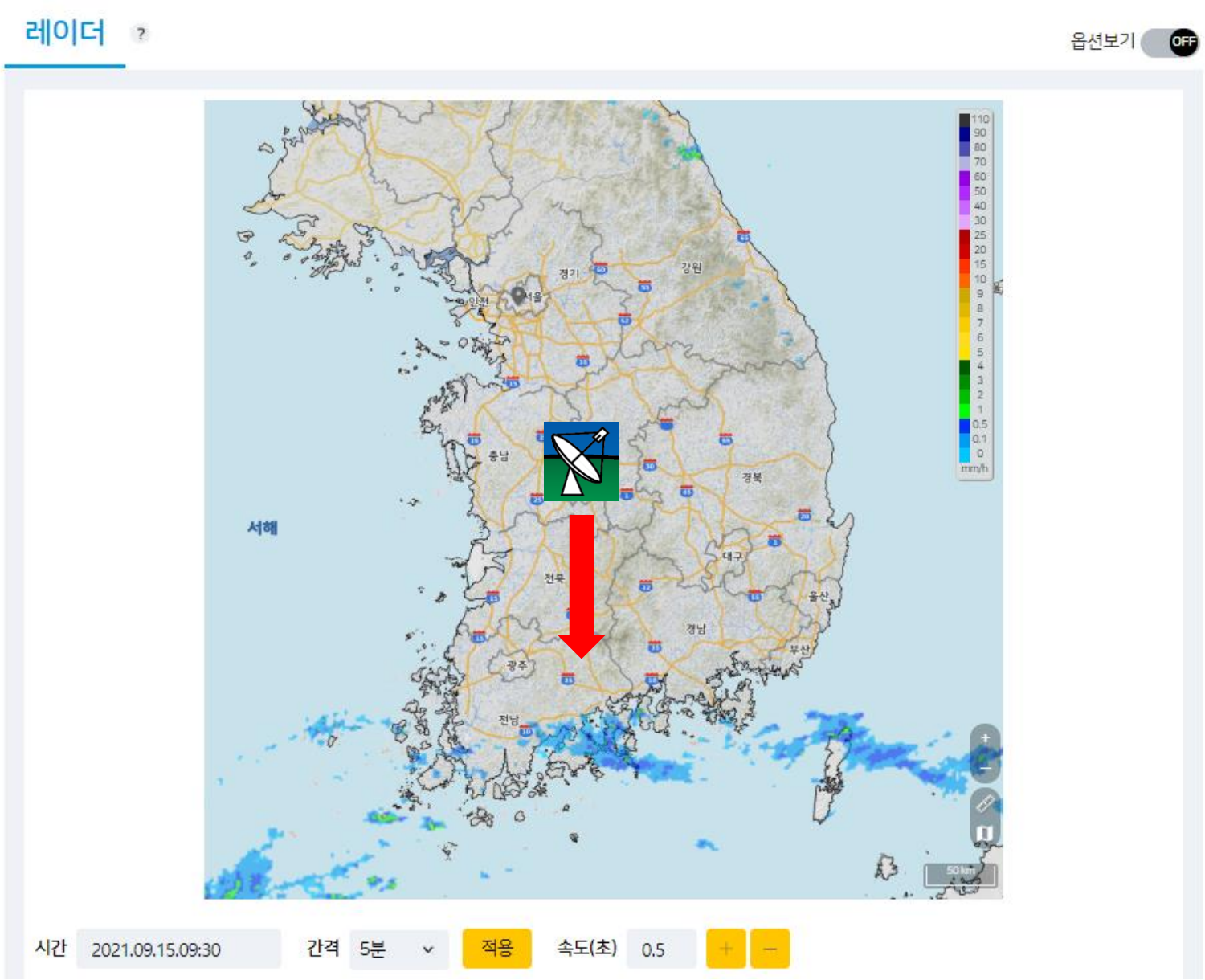
# Depth of the sky



# Weather

- Air temperature
- Humidity
- Cloud and rain
- Sun light

❖Water (Rain) significantly increase the noise temperature.



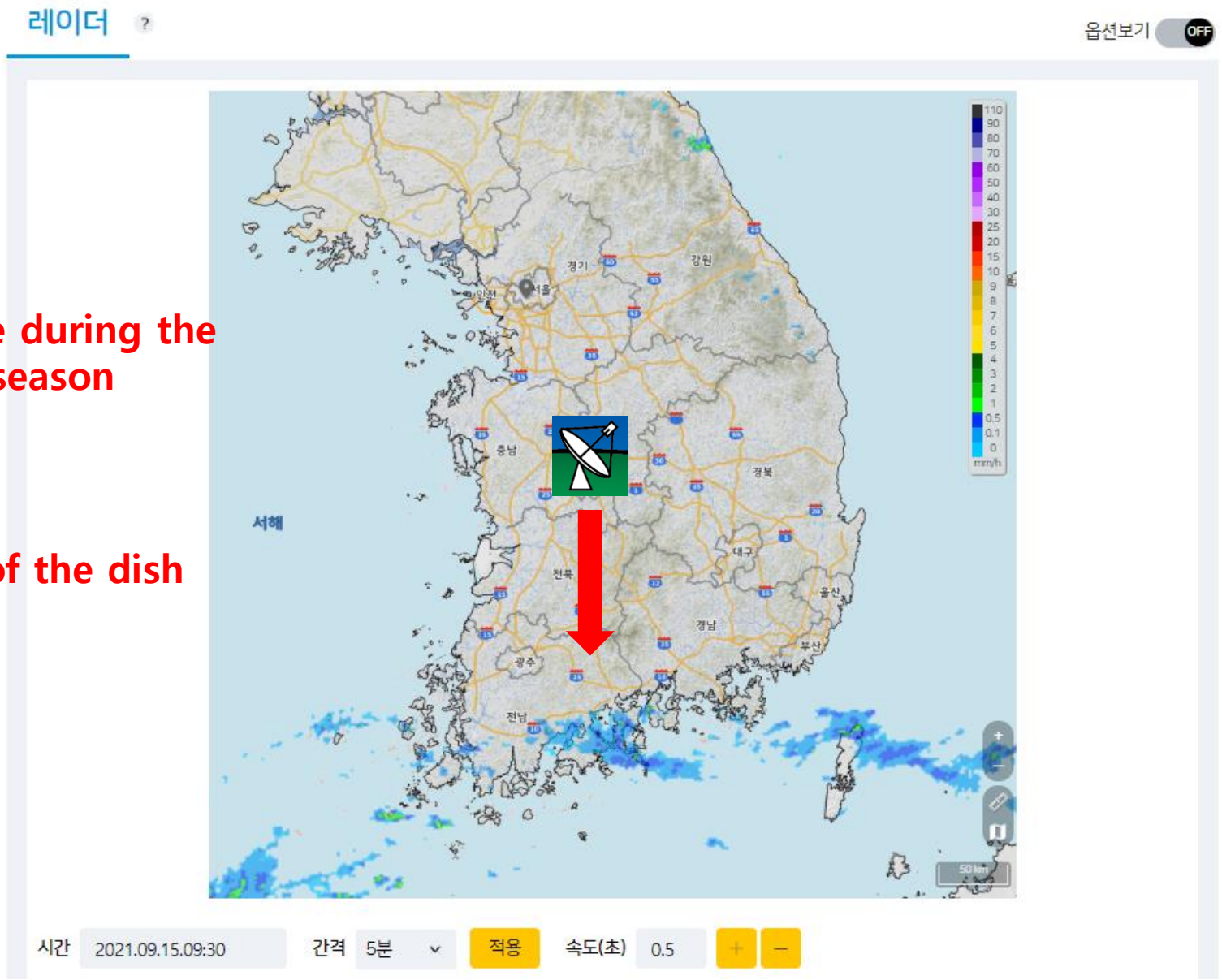

- 기상청 날씨누리 – 레이더 (실시간 비구름 분포 확인)

# Weather

- Air temperature
- Humidity
- Cloud and rain
- Sun light **Change the shape of the dish**

**Operate during the winter season**

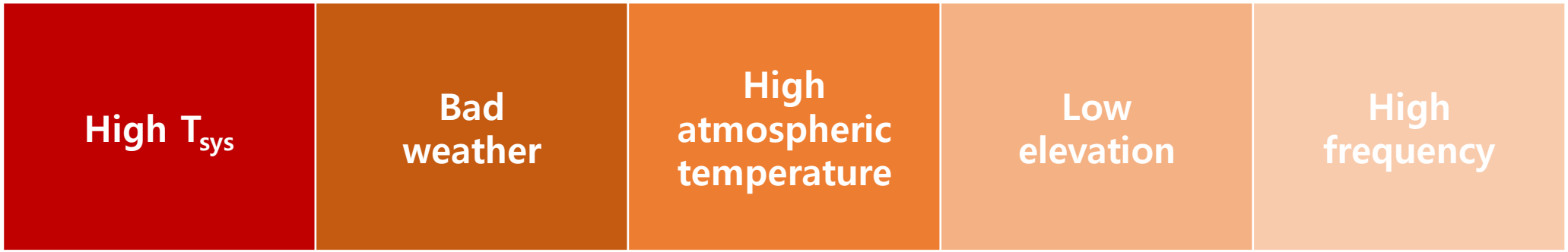
❖**Water (Rain)**
significantly increase the noise temperature.




- 기상청 날씨누리 – 레이더 (실시간 비구름 분포 확인)

# The system temperature ($T_{sys}$)

- Total noise power: the sum of many contributors to the antenna temperature.
  ex) CMB, background emission, radiation from ground, and **noise generated by the telescope itself**.

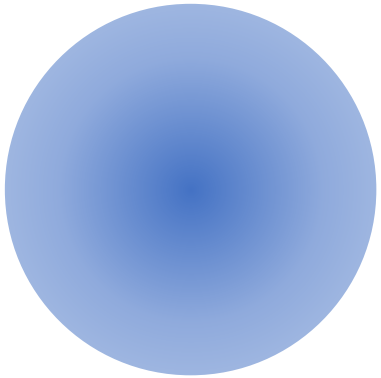



❖How to measure $T_{sys}$?
- Chopper wheel **calibration** method

**Related reference:** Atmospheric phase correction at the IRAM instruments Radiometer Workshop at the Universität BW, Neubiberg July 26, 2005

# Focus and Pointing

- **Five-point** observation.



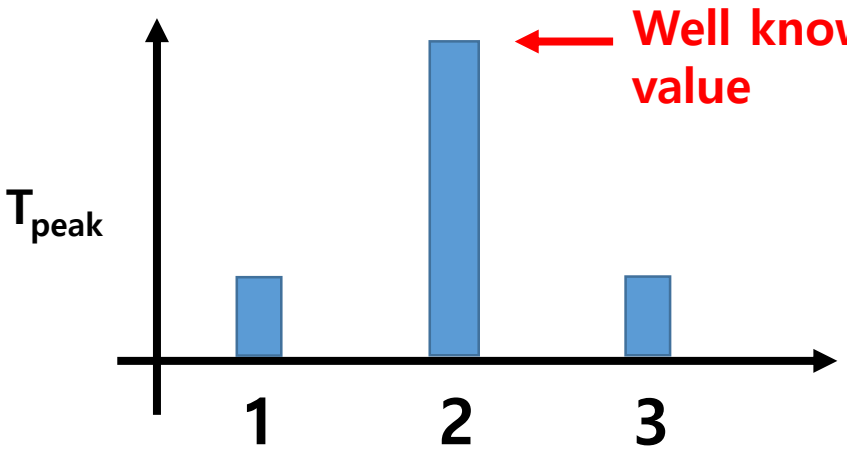
**Main beam projected on the sky plane**

**Well-known point-like radio source**

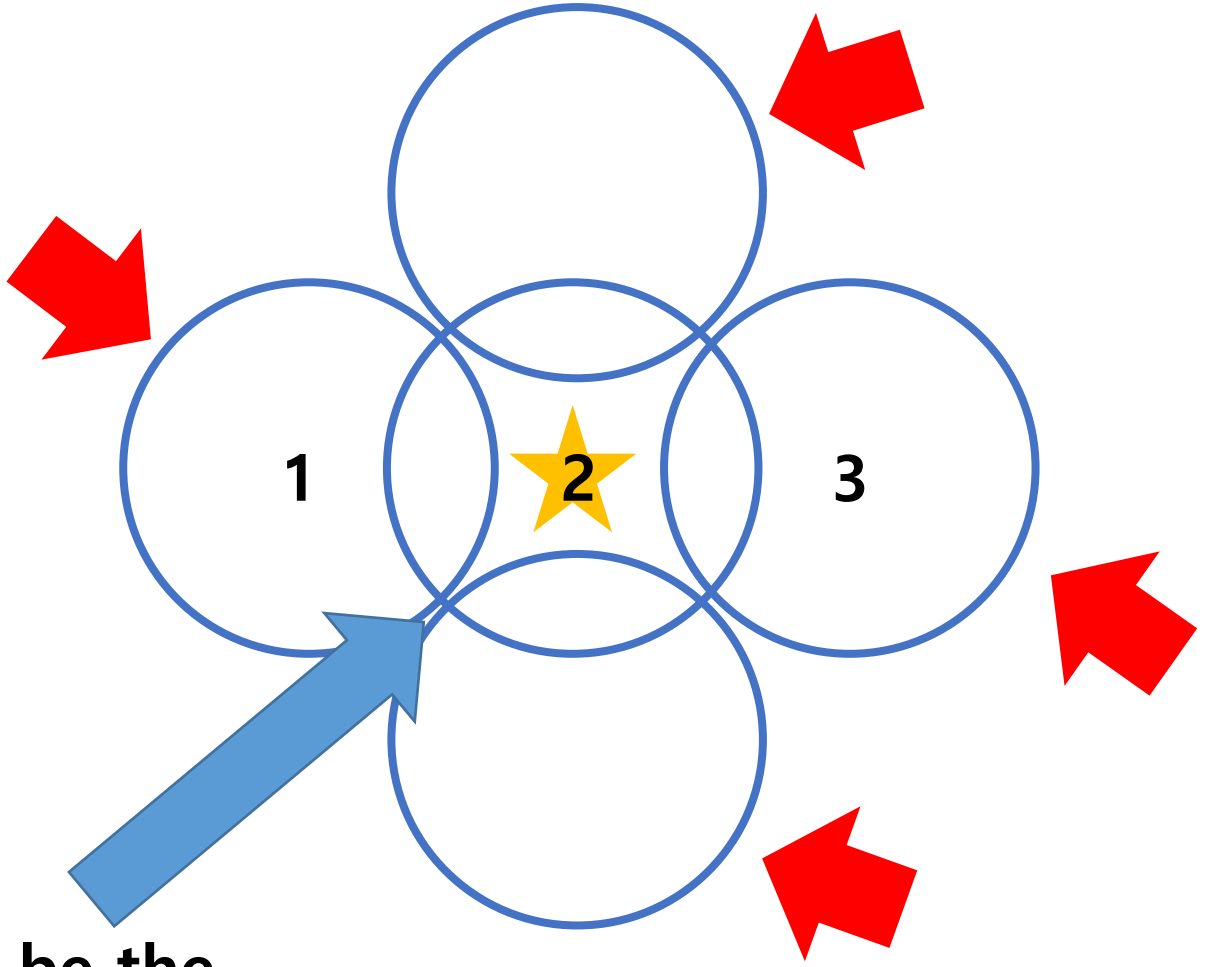
- The best focus
  the smallest beam size
- Not on the best focus
  the beam size becomes larger

# Focus and Pointing

- **Five-point** observation with the best focus and the best pointing



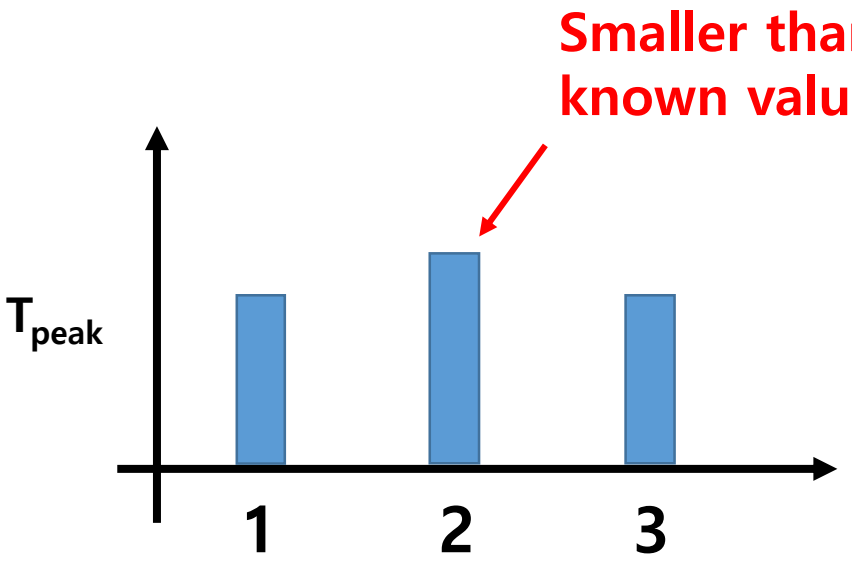

The other pixels would detect smaller and similar line emissions.



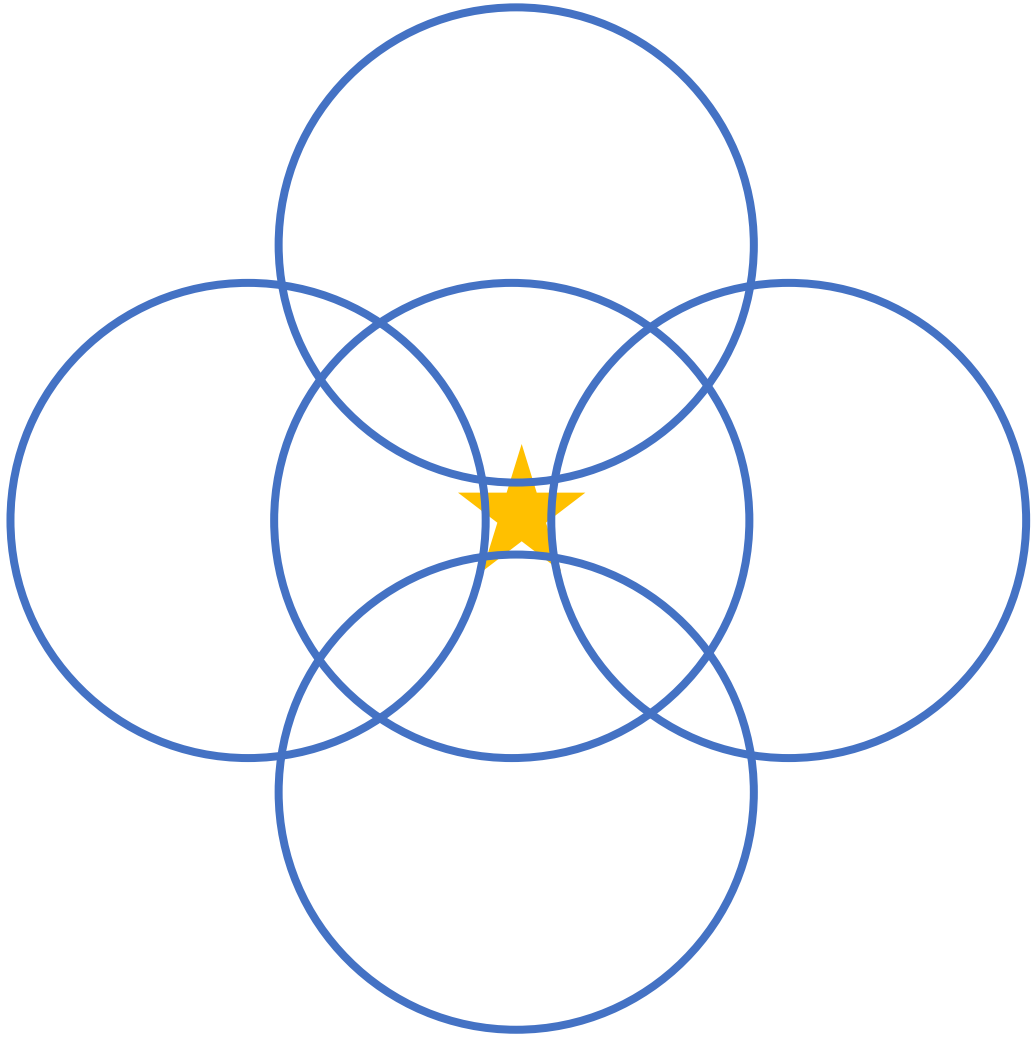

**The line would be the strongest in the center**

# Focus and Pointing

- **Five-point** observation without the best focus

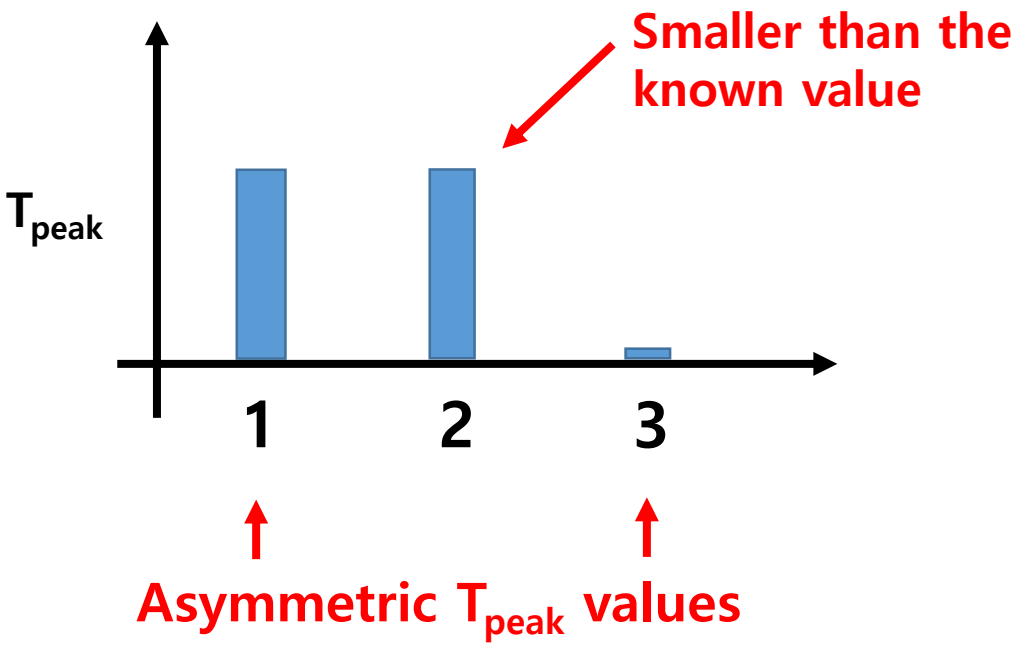


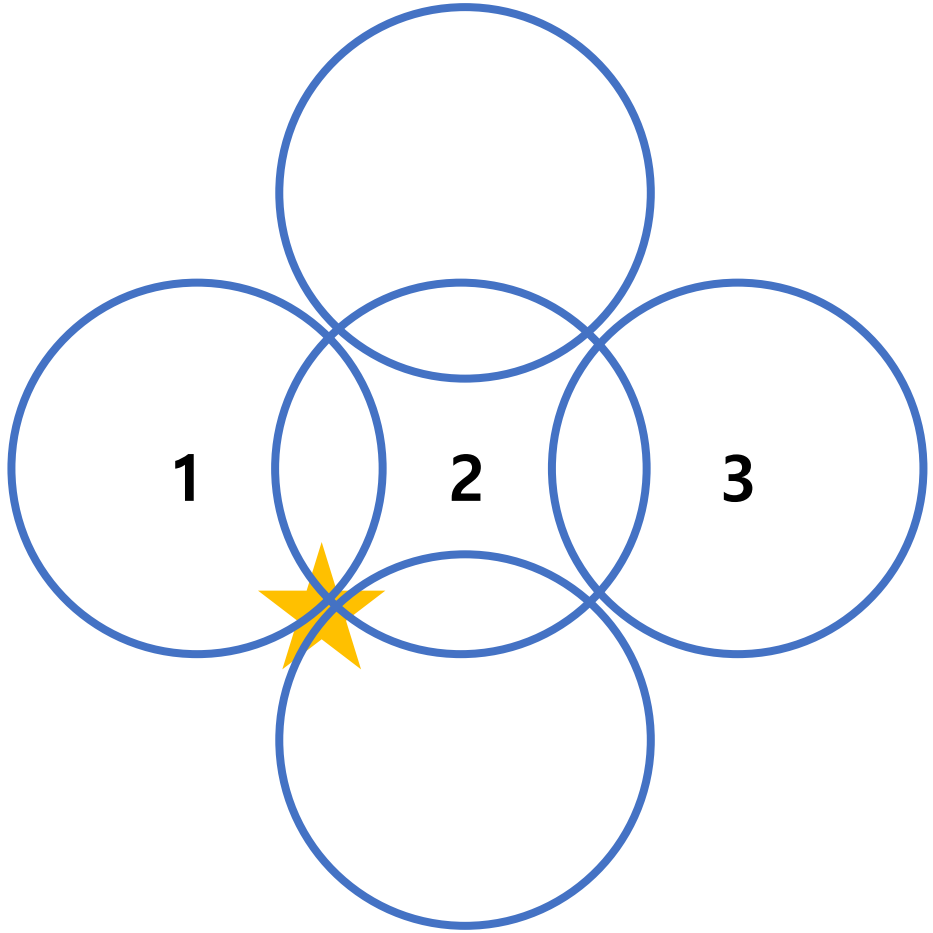

**The peak temperature is not concentrated to the center**



# Focus and Pointing

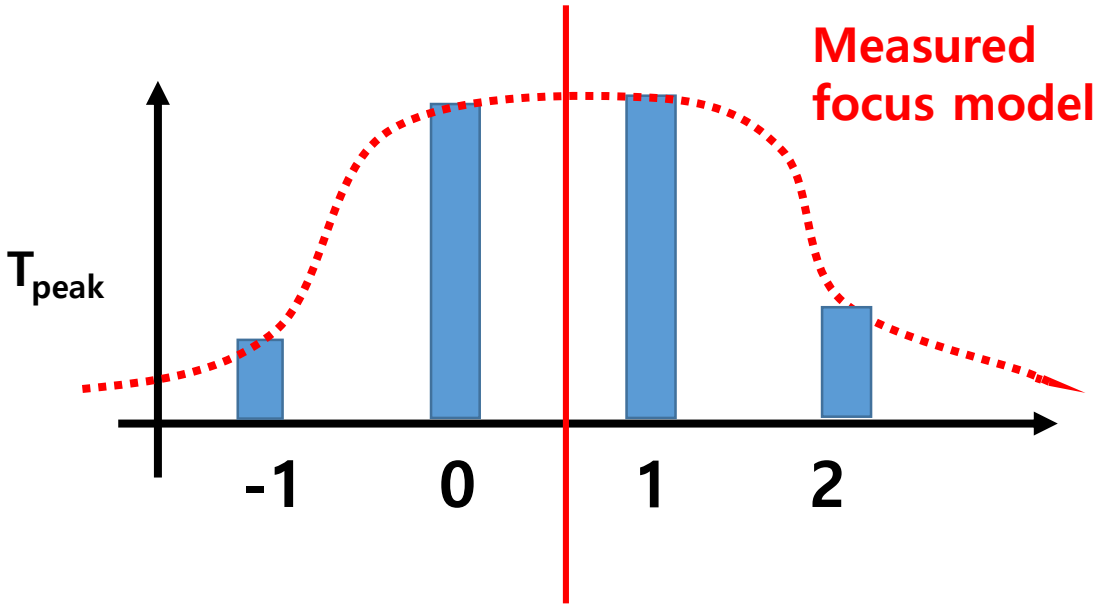
- **Five-point** observation with an wrong pointing

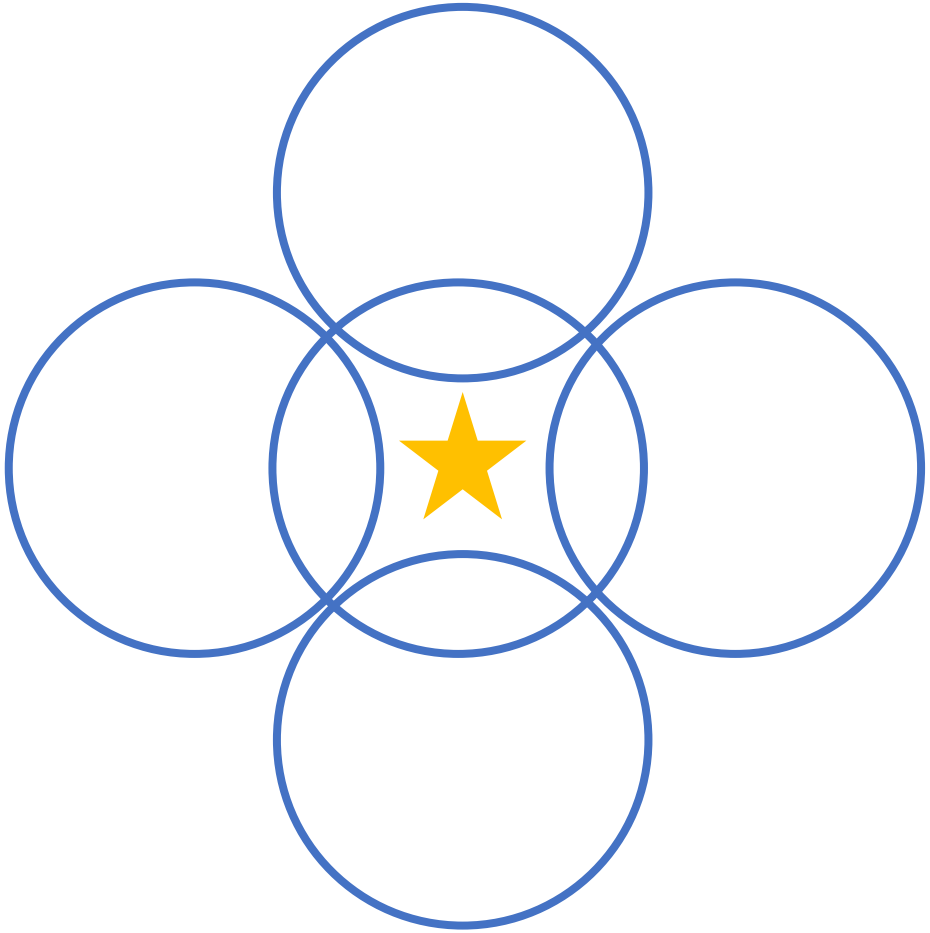


# Focus and Pointing

- Repeat fallowing processes
  1. Move sub-reflector
  2. Find pointing
  3. Measure Focus



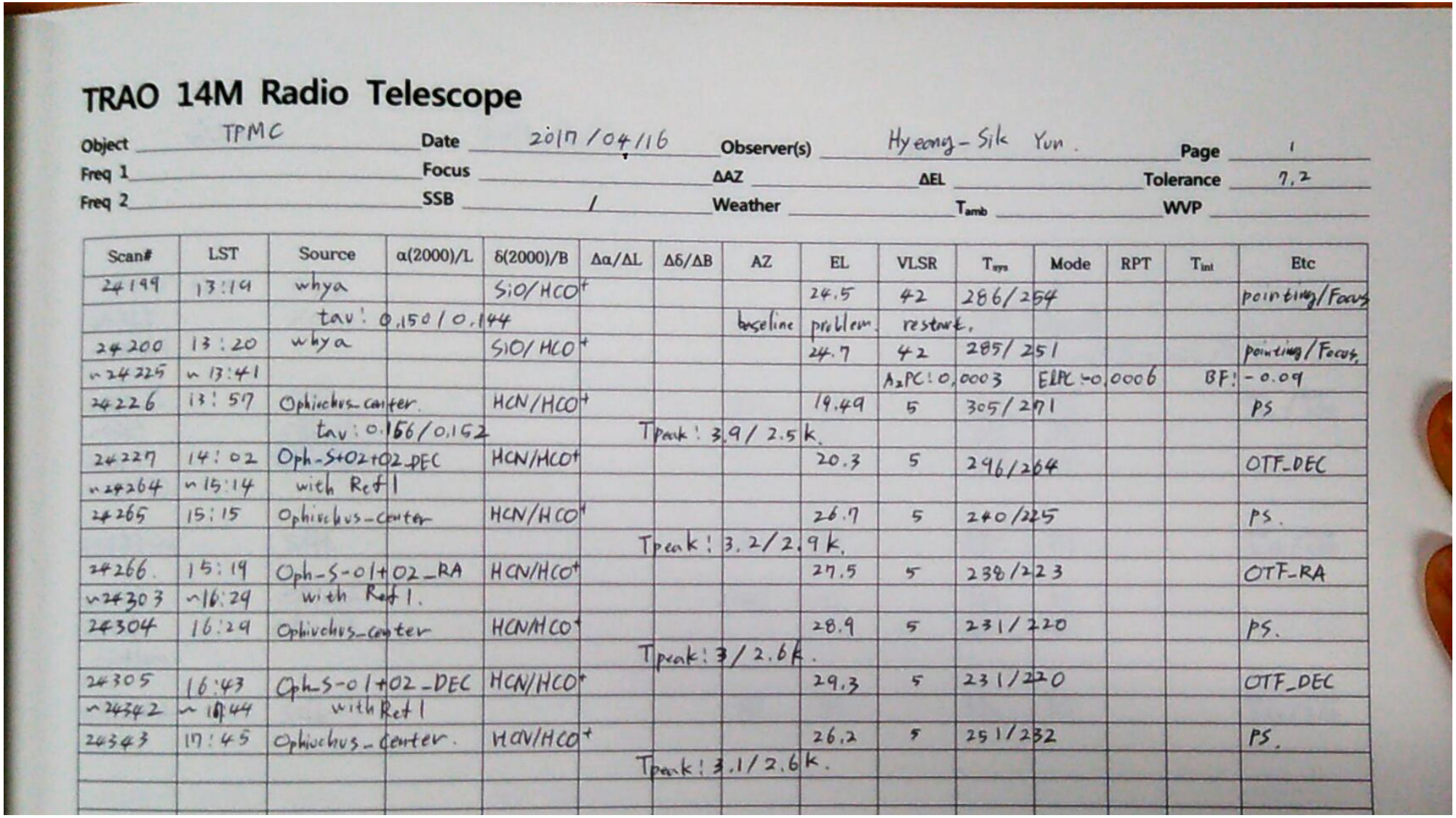



The best-focus position → Find pointing → Start observation

# The typical observation sequence

1. Tuning (change frequency; for pointing)
2. Calibration
3. Sky-dip (measure sky opacity; for pointing)
4. Calibration
5. 5-point observation (Find focus & pointing)
6. Calibration
7. Tuning (change frequency; for observation)
8. Calibration
9. Sky-dip (measure sky opacity; for observation)
10. Calibration
11. Observation start!!

# Observing log



**TRAO 14M Radio Telescope**

Object TPMC Date 2017/04/16 Observer(s) Hyeong-Sik Yun. Page 1

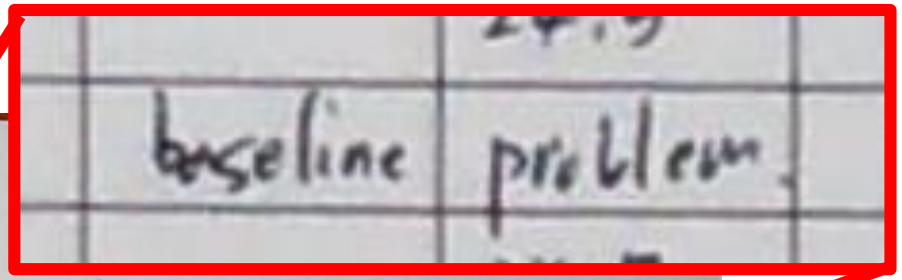
Freq 1 Focus ΔAZ ΔEL Tolerance 7.2

Freq 2 SSB / Weather $T_{amb}$ WVP

| Scan# | LST | Source | α(2000)/L | δ(2000)/B | Δα/ΔL | Δδ/ΔB | AZ | EL | VLSR | $T_{sys}$ | Mode | RPT | $T_{int}$ | Etc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24199 | 13:14 | whya | | SiO/HCO+ | | | | 24.5 | 42 | 286/254 | | | | pointing/Focus |
| | | tau: 0.150/0.144 | | | | | baseline | problem. | restart. | | | | | |
| 24200 | 13:20 | whya | | SiO/HCO+ | | | | 24.7 | 42 | 285/251 | | | | pointing/Focus |
| ~24225 | ~13:41 | | | | | | | | $A_2$PC: 0.0003 | | ELPC -0.0006 | | BF: -0.09 | |
| 24226 | 13:57 | Ophiuchus_center. | | HCN/HCO+ | | | | 19.49 | 5 | 305/271 | | | | PS |
| | | tau: 0.166/0.162 | | | | Tpeak: 3.9/2.5 k. | | | | | | | | |
| 24227 | 14:02 | Oph-S+02+02_DEC | | HCN/HCO+ | | | | 20.3 | 5 | 296/264 | | | | OTF_DEC |
| ~24264 | ~15:14 | with Ref1 | | | | | | | | | | | | |
| 24265 | 15:15 | Ophiuchus-center | | HCN/HCO+ | | | | 26.7 | 5 | 240/225 | | | | PS. |
| | | | | | | Tpeak: 3.2/2.9 k. | | | | | | | | |
| 24266. | 15:19 | Oph-S-01+02_RA | | HCN/HCO+ | | | | 27.5 | 5 | 238/223 | | | | OTF-RA |
| ~24303 | ~16:29 | with Ref1. | | | | | | | | | | | | |
| 24304 | 16:29 | Ophiuchus_center | | HCN/HCO+ | | | | 28.9 | 5 | 231/220 | | | | PS. |
| | | | | | | Tpeak: 3/2.6 k. | | | | | | | | |
| 24305 | 16:43 | Oph-S-01+02_DEC | | HCN/HCO+ | | | | 29.3 | 5 | 231/220 | | | | OTF_DEC |
| ~24342 | ~17:44 | with Ref1 | | | | | | | | | | | | |
| 24343 | 17:45 | Ophiuchus_center. | | HCN/HCO+ | | | | 26.2 | 5 | 251/232 | | | | PS. |
| | | | | | | Tpeak: 3.1/2.6 k. | | | | | | | | |

# Observing log

**Baseline problem.**

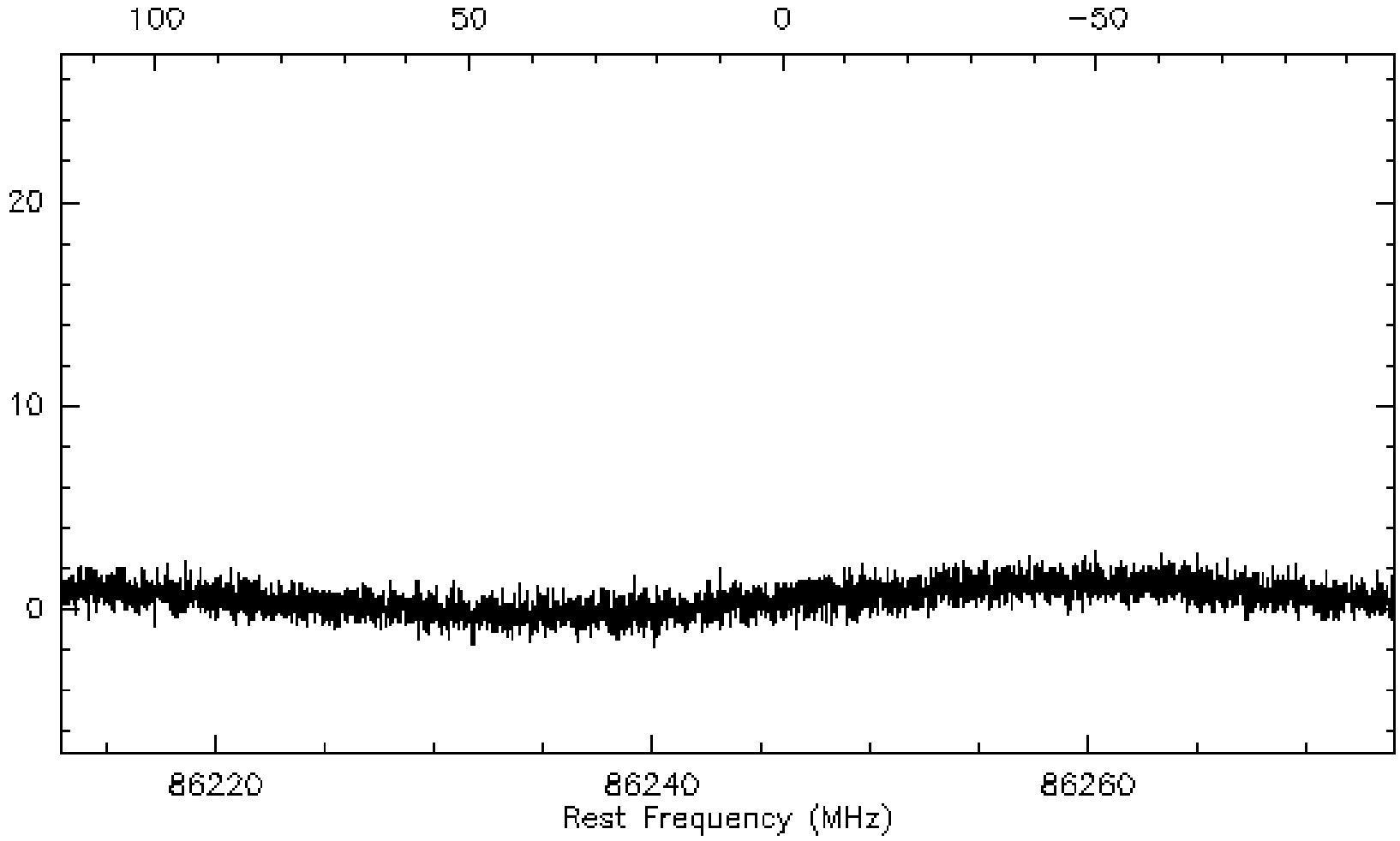



## TRAO 14M Radio Telescope

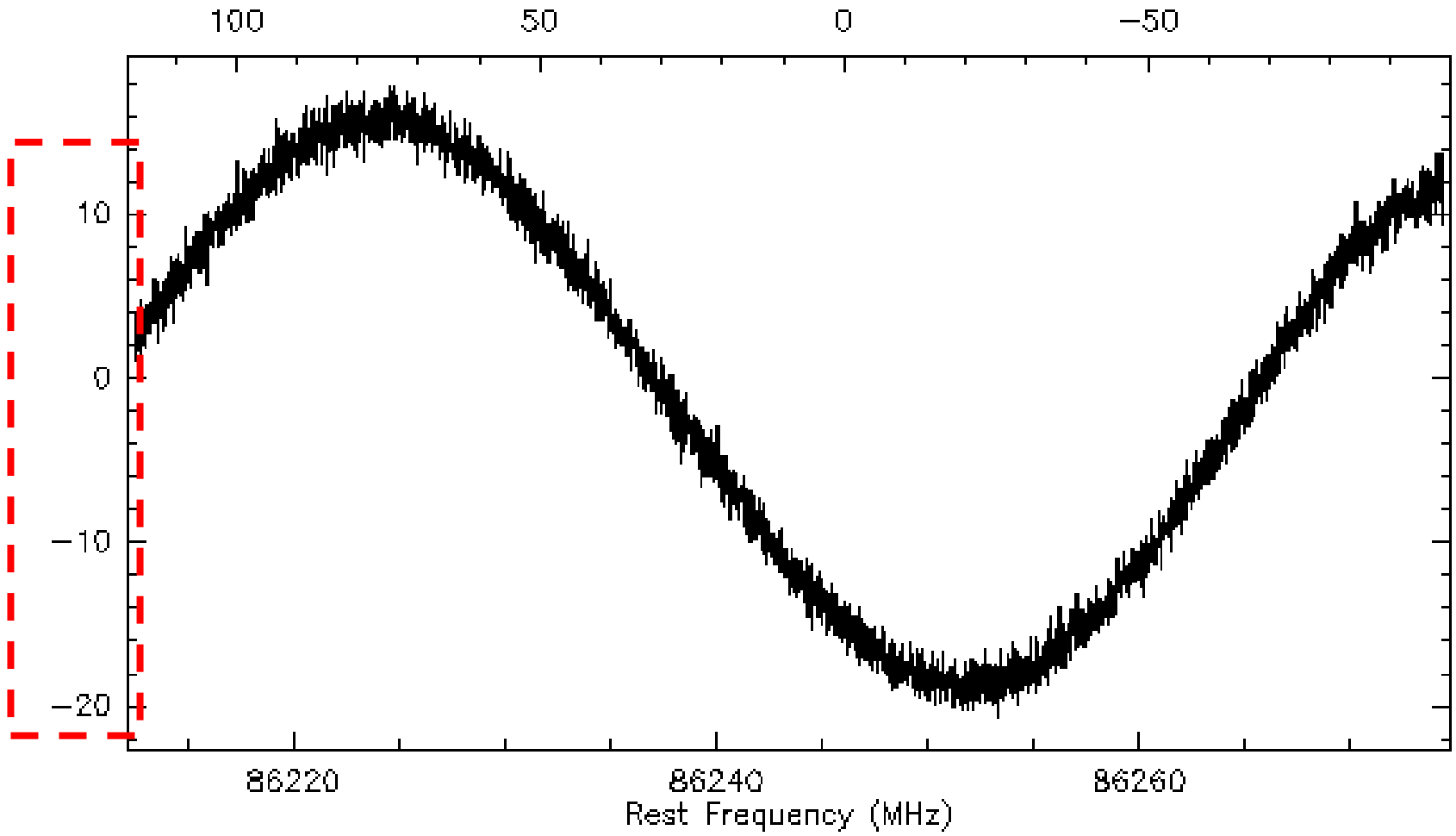
Object TPMC Date 2017/04/16 Observer(s) Hyeong-Sik Yun. Page 1
Freq 1 Focus ΔAZ ΔEL Tolerance 7.2
Freq 2 SSB / Weather Tamb WVP

| Scan# | LST | Source | α(2000)/L | δ(2000)/B | Δα/ΔL | Δδ/ΔB | AZ | EL | VLSR | $T_{sys}$ | Mode | RBE | $T_{int}$ | Etc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24199 | 13:14 | whya | | SiO/HCO+ | | | | | | 286/25 | | | | pointing/Focus |
| | | tau: 0.150/0.144 | | | | | baseline | problem. | restore | | | | | |
| 24200 | 13:20 | whya | | SiO/HCO+ | | | | | | 285/251 | | | | pointing/Focus |
| ~24225 | ~13:41 | | | | | | | | A2PC: 0.0003 | | ELPC: -0.0006 | | BF: -0.09 | |
| 24226 | 13:57 | Ophiuchus_center | | HCN/HCO+ | | | | 19.49 | 5 | 305/271 | | | | PS |
| | | tau: 0.166/0.162 | | | | | Tpeak: 3.9/2.5 k. | | | | | | | |
| 24227 | 14:02 | Oph-S+02+02_DEC | | HCN/HCO+ | | | | 20.3 | 5 | 296/264 | | | | OTF_DEC |
| ~24264 | ~15:14 | with Ref1 | | | | | | | | | | | | |
| 24265 | 15:15 | Ophiuchus-center | | HCN/HCO+ | | | | 26.7 | 5 | 240/225 | | | | PS. |
| | | | | | | | Tpeak: 3.2/2.9 k. | | | | | | | |
| 24266. | 15:19 | Oph-S-01+02_RA | | HCN/HCO+ | | | | 27.5 | 5 | 238/223 | | | | OTF_RA |
| ~24303 | ~16:29 | with Ref1. | | | | | | | | | | | | |
| 24304 | 16:29 | Ophiuchus_center | | HCN/HCO+ | | | | 28.9 | 5 | 231/220 | | | | PS. |
| | | | | | | | Tpeak: 3/2.6 k. | | | | | | | |
| 24305 | 16:43 | Oph-S-01+02_DEC | | HCN/HCO+ | | | | 29.3 | 5 | 231/220 | | | | OTF_DEC |
| ~24342 | ~17:44 | with Ref1 | | | | | | | | | | | | |
| 24343 | 17:45 | Ophiuchus_center. | | HCN/HCO+ | | | | 26.2 | 5 | 251/232 | | | | PS. |
| | | | | | | | Tpeak: 3.1/2.6 k. | | | | | | | |

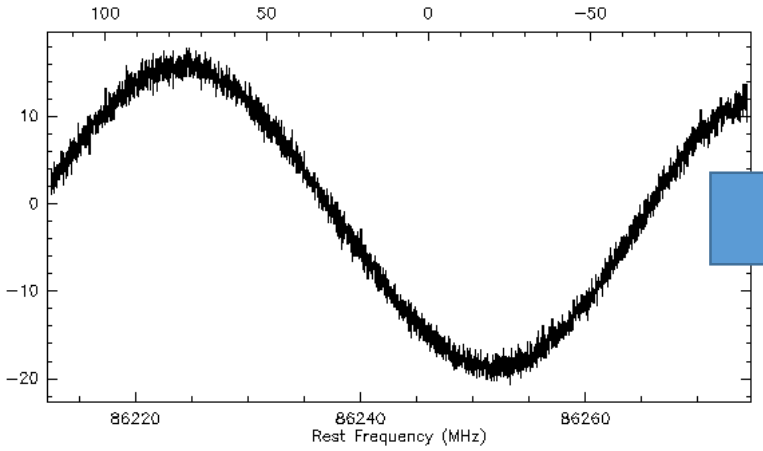
# Example: Baseline fluctuation (example1)

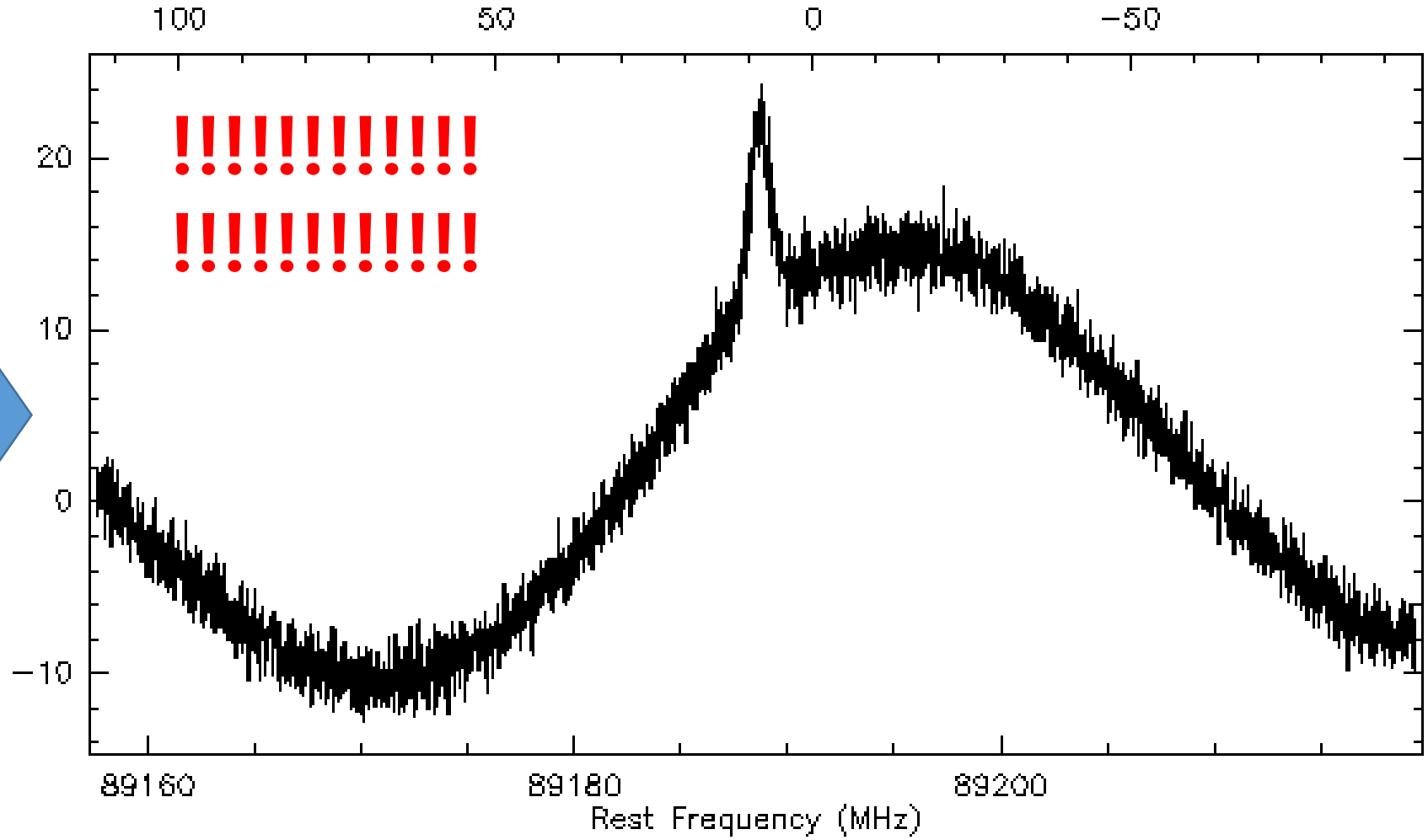


# Example: Baseline fluctuation (example2)



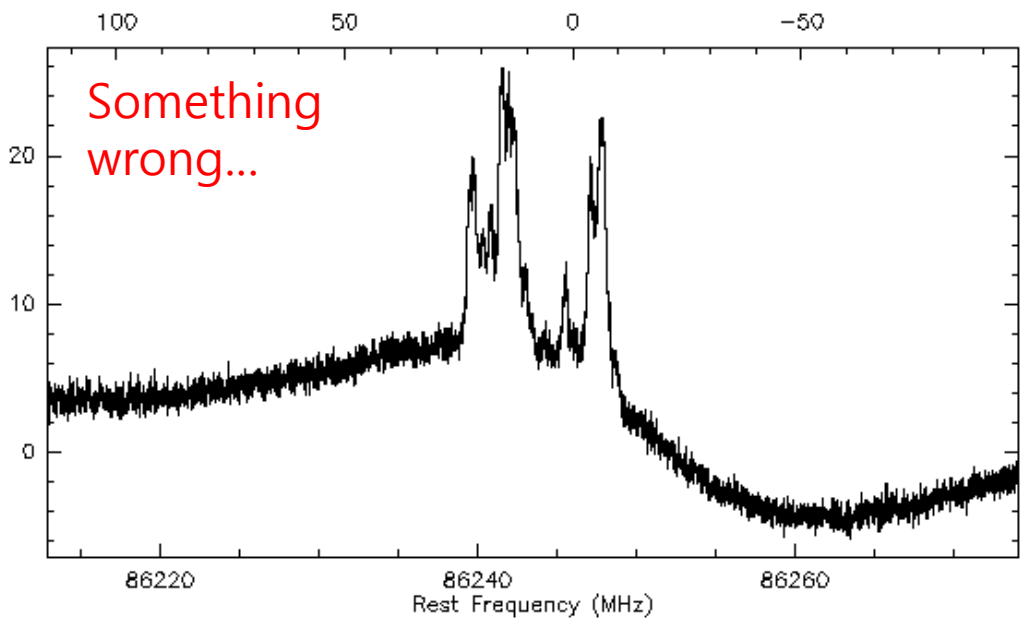
# Example: Baseline fluctuation with line

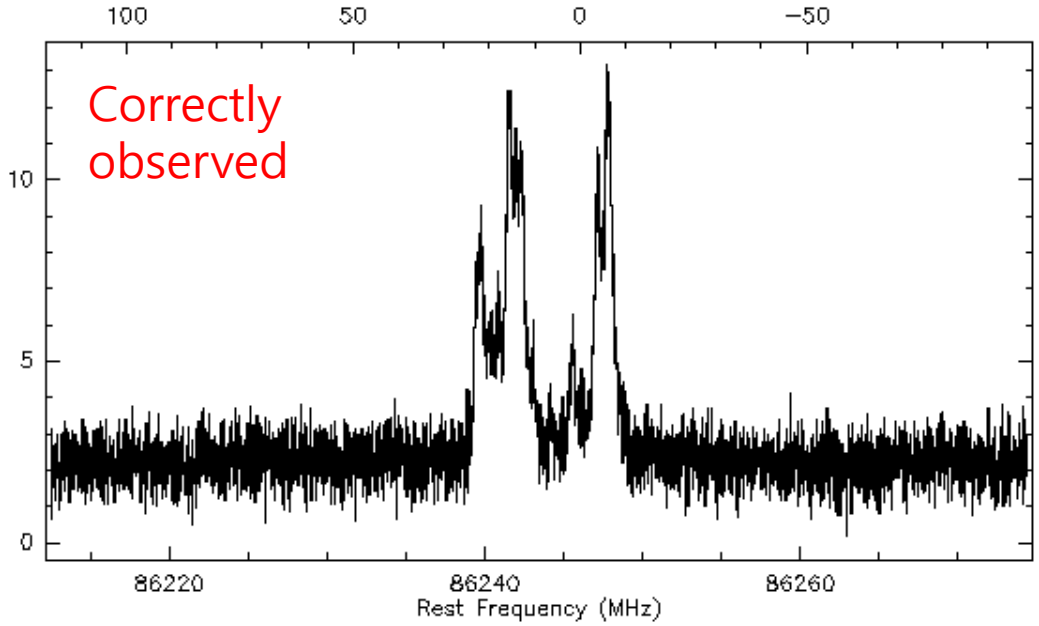


# Baseline

- Reference point for the measured intensity
- The baseline can be artificially changed.
- To estimate the true intensity of emission lines, the baseline should be removed.

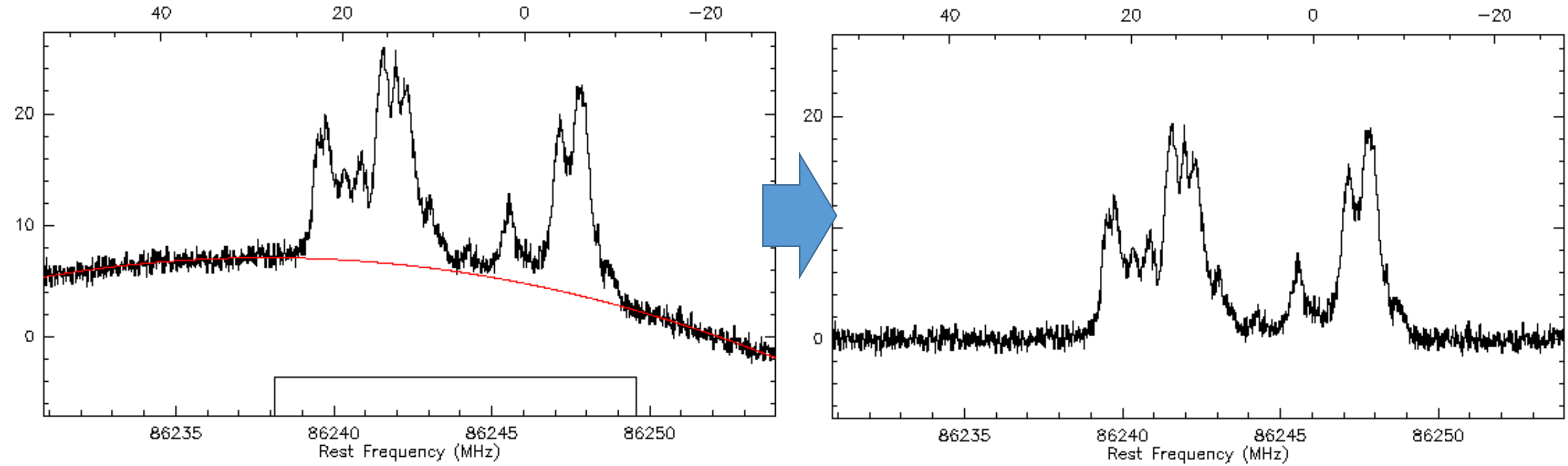



Useful reference: [Baseline | COSMOS (swin.edu.au)]

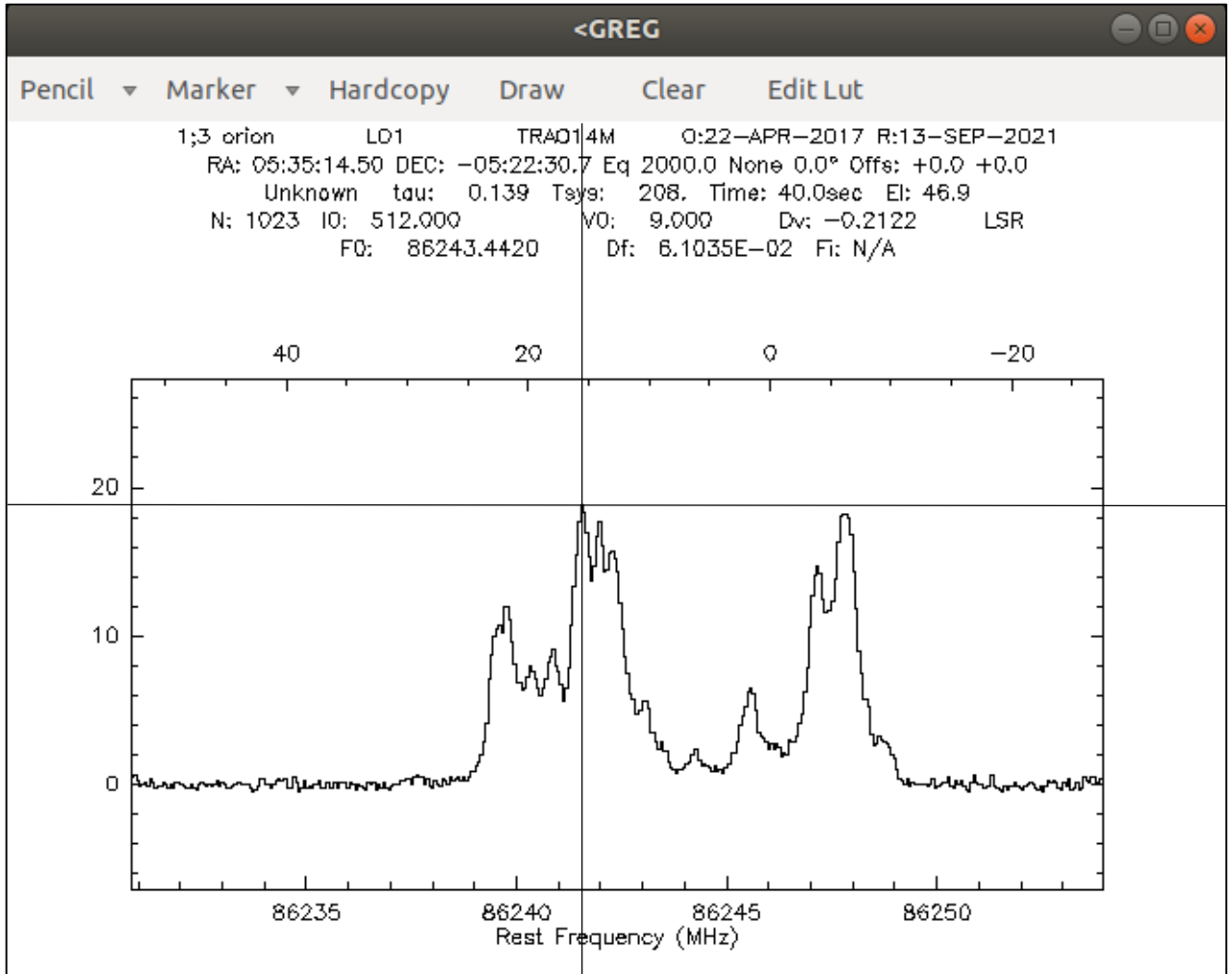
# Baseline

- Baseline can be removed by fitting a polynomial to the baseline spectrum in the data.



# Peak temperature

- The maximum temperature of the observed line.




- Smooth the spectrum
- Measure the peak temperature

- Output:

```
LAS> draw
    Channel number       : 481.56
    Velocity             :   15.459      km/s
    Rest Frequency       :   86241.5842768      MHz
    Image Frequency      : N/A
    Offset Frequency     :  -1.8577      MHz
    Antenna Temperature  :   18.817      K
LAS>
```

# Practice!

- Access the Github repository

  HyeongSikYun/Singledish_class2 (github.com)

- bad_baseline_#.class : the spectra with a fluctuating baseline
- good_baseline_#.class: the spectra with a stable baseline
- GILDAS_advance_useage_of_Class.txt: Guideline to use the Class program

- Final goal:

  Try to measure the peak temperature of the line from ‘bad_baseline_#.class’, and compare it with that from the ‘good_baseline_#.class’.

# How to export the spectrum?