Single Dish Radio Observation

Observing sequence and data reduction

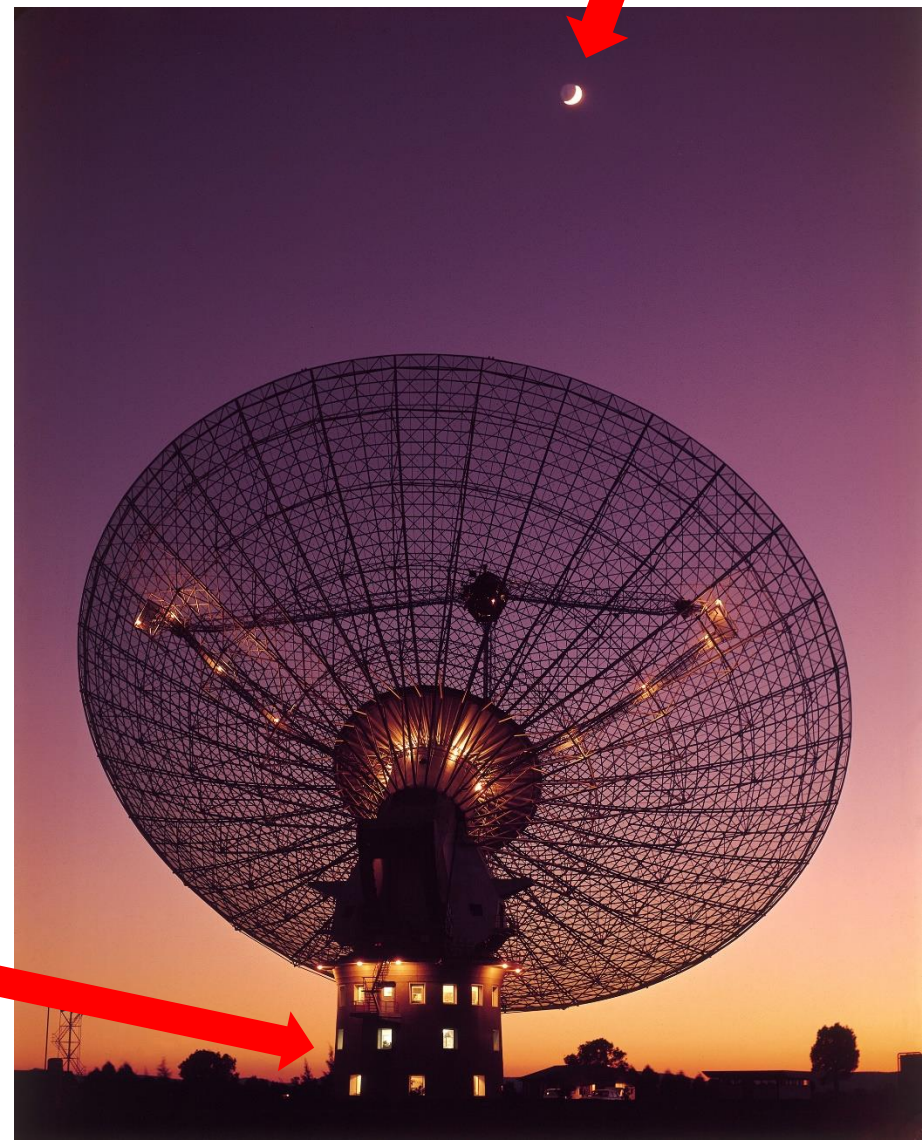
Hyeong-Sik Yun

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



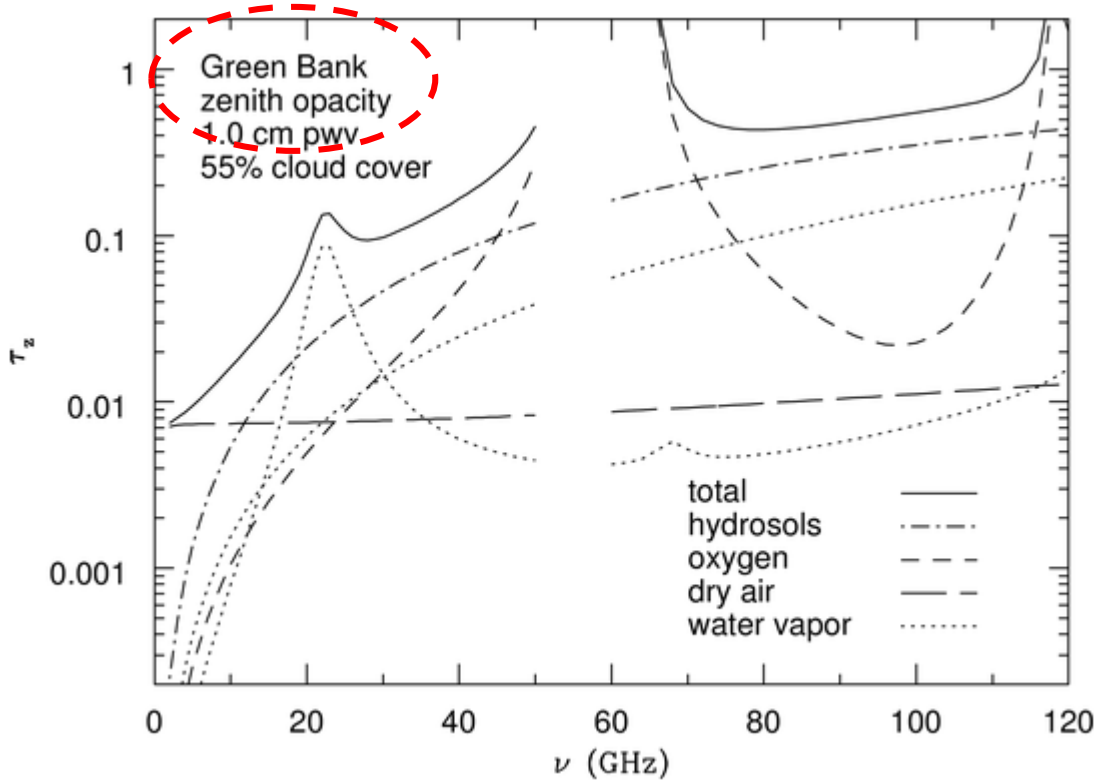
Sky changes depending on the observing frequency

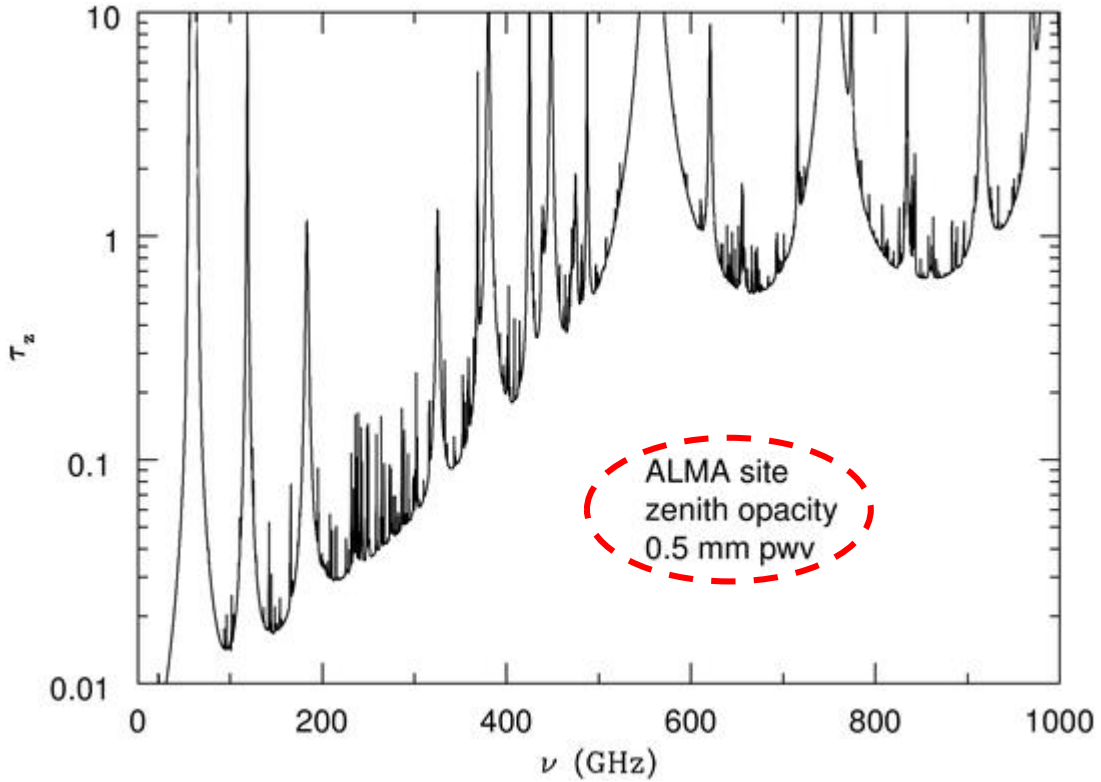
- Opacity: the measure of impenetrability to radiation.

- Opacity of the atmosphere depending on the frequency.
  - Longer wavelength (higher 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

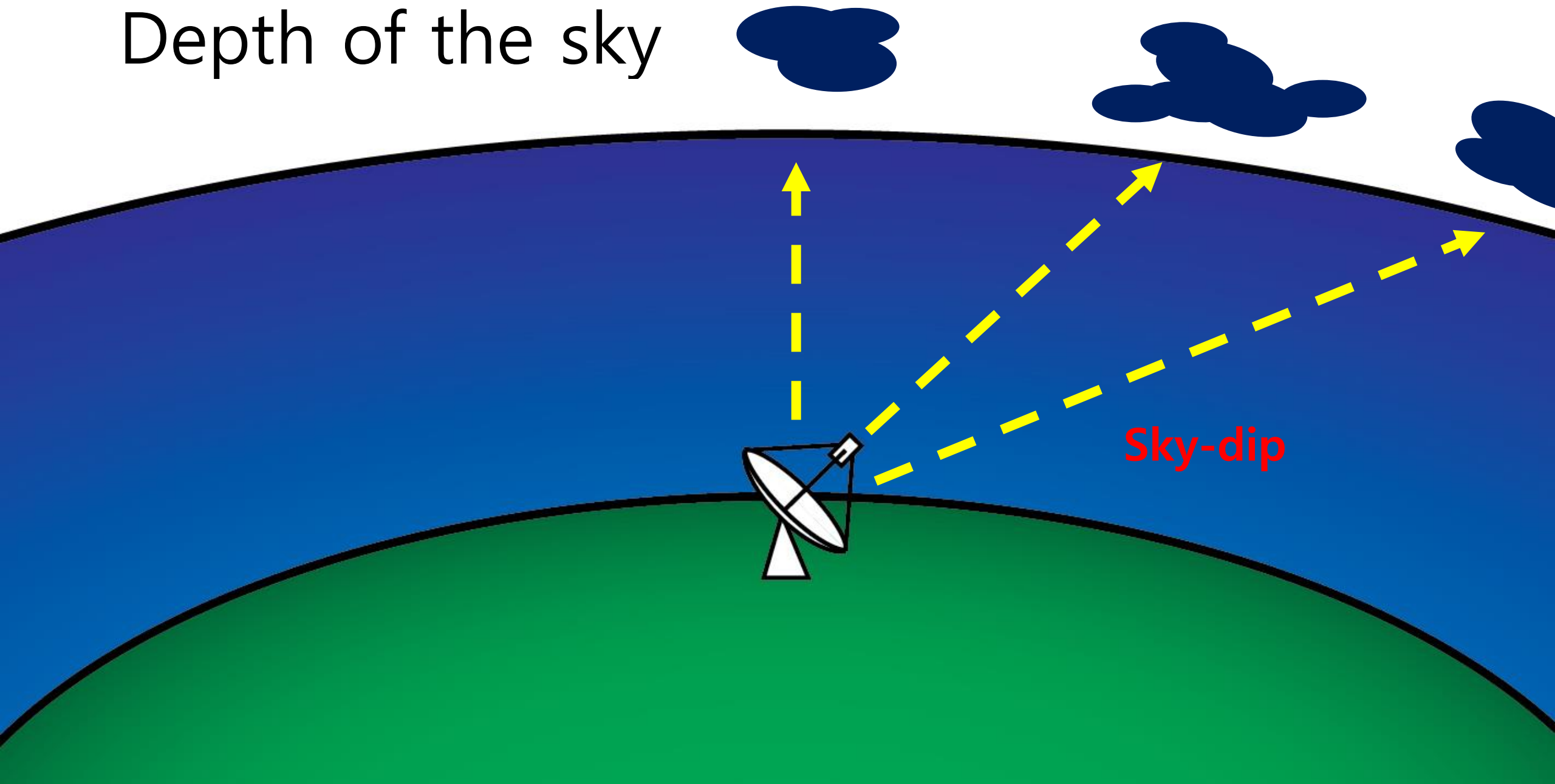
- Opacity: the measure of impenetrability to radiation.





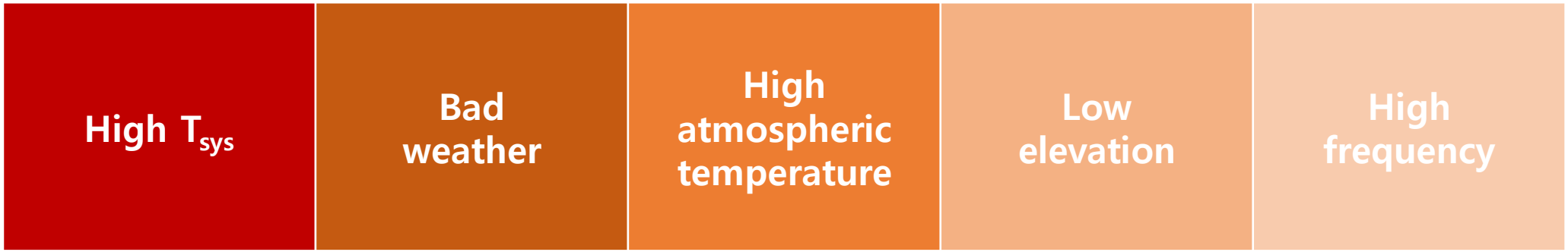
Reference: Essential Radio Astronomy
(https://www.cv.nrao.edu/~sransom/web/Ch1.html)

Depth of the sky



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**.

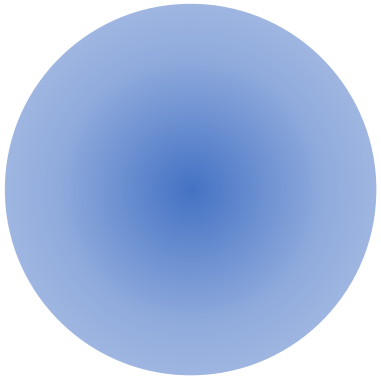


❖How to measure T_{sys}?
- Chopper wheel **calibration** method

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.



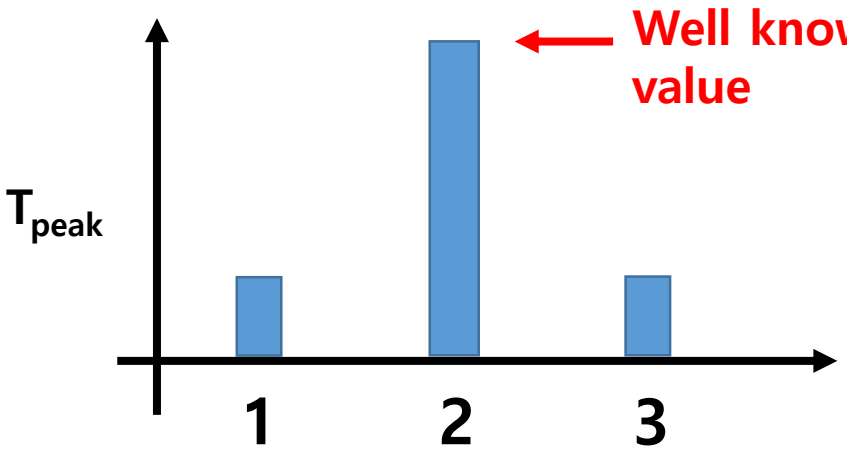
Main beam projected on the sky plane

Well-known point-like radio source

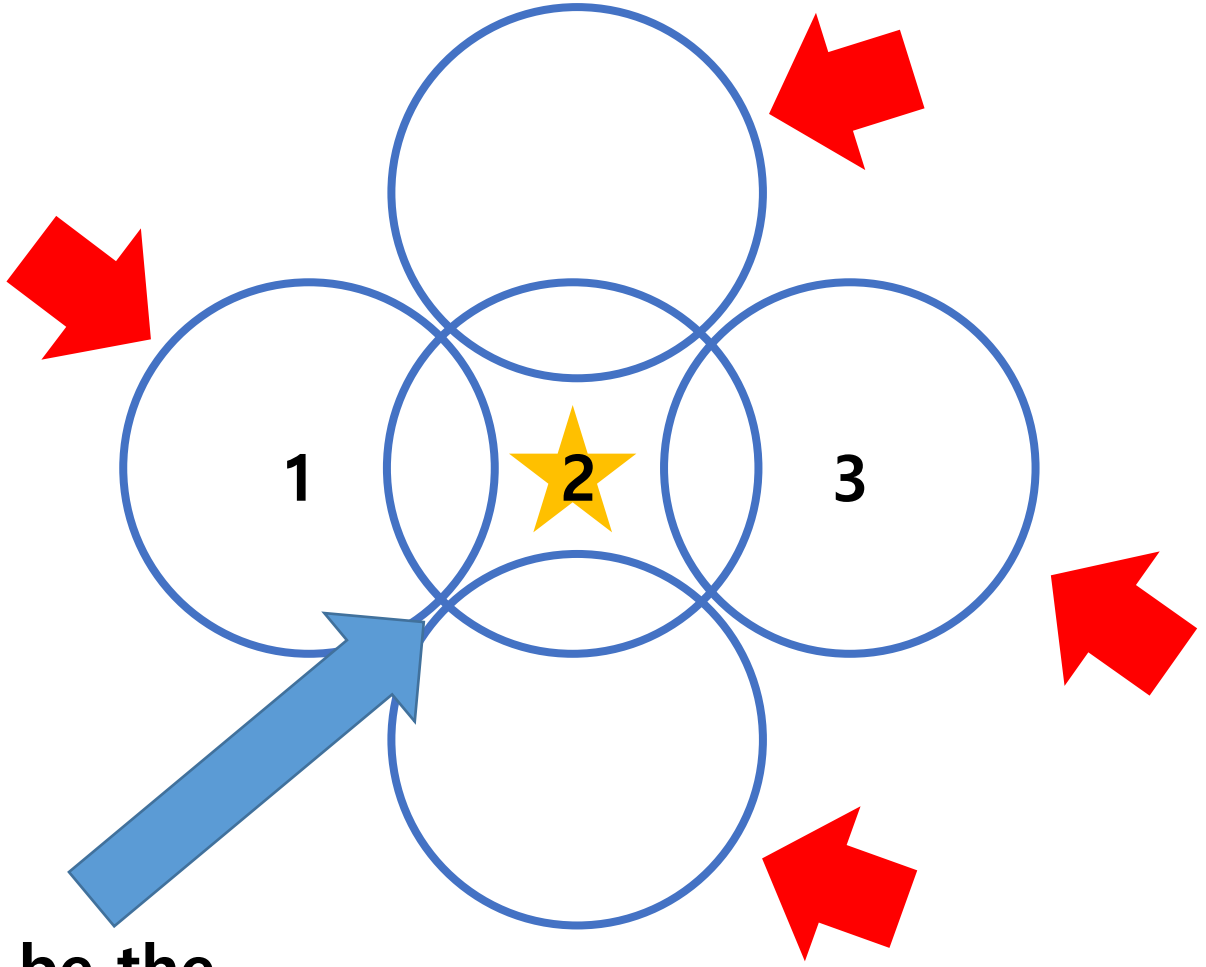
- The best focus
  the smallest beam size
- Not on the best focus
  the beam size becomes larger

Focus and Pointing

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



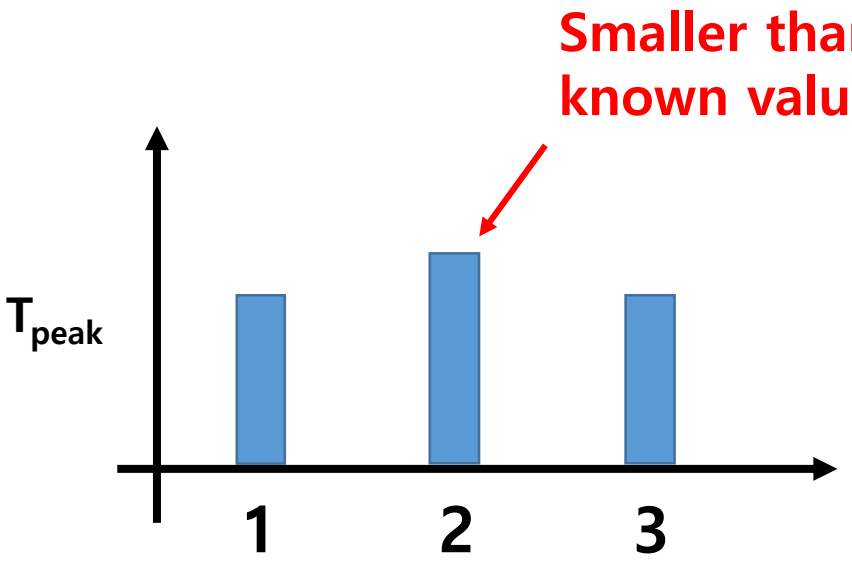
The other pixels would detect smaller and similar line emissions.



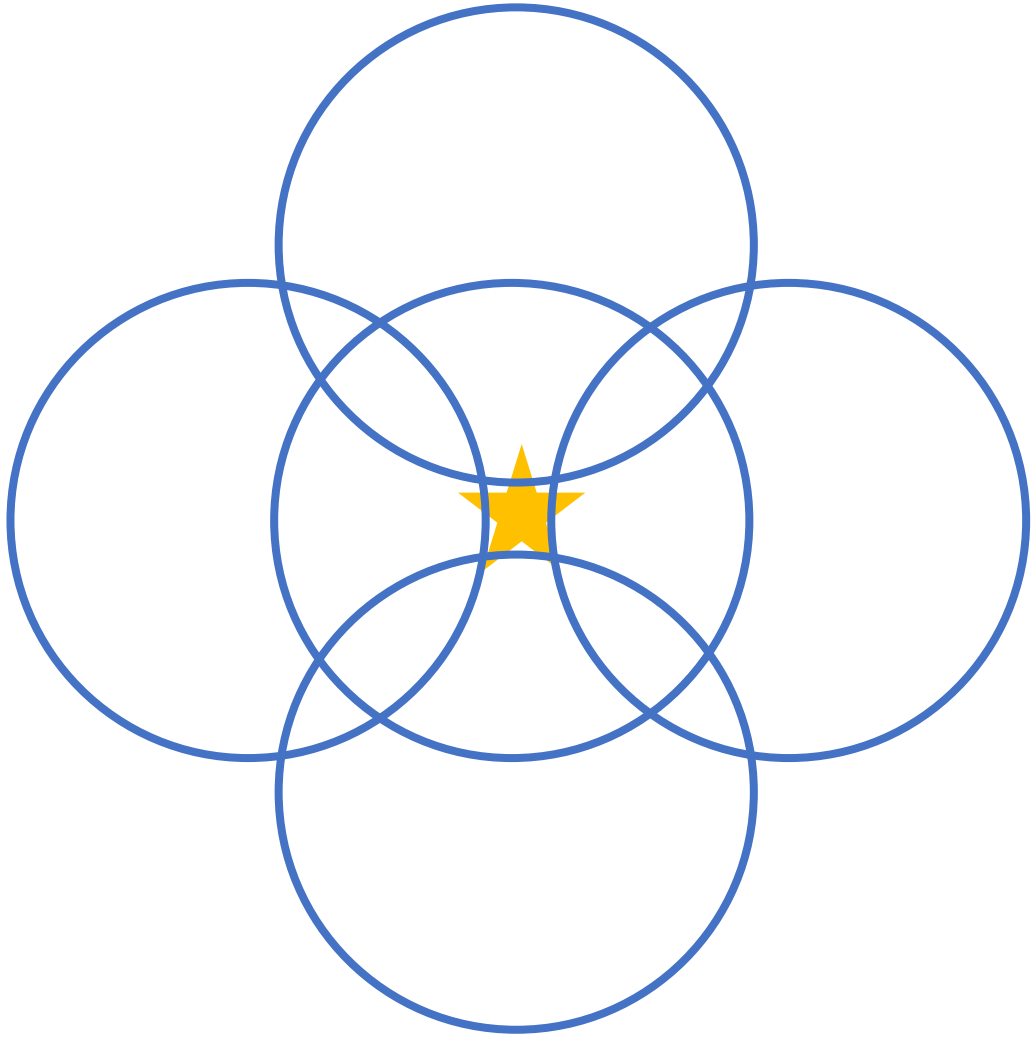
The line would be the strongest in the center

Focus and Pointing

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

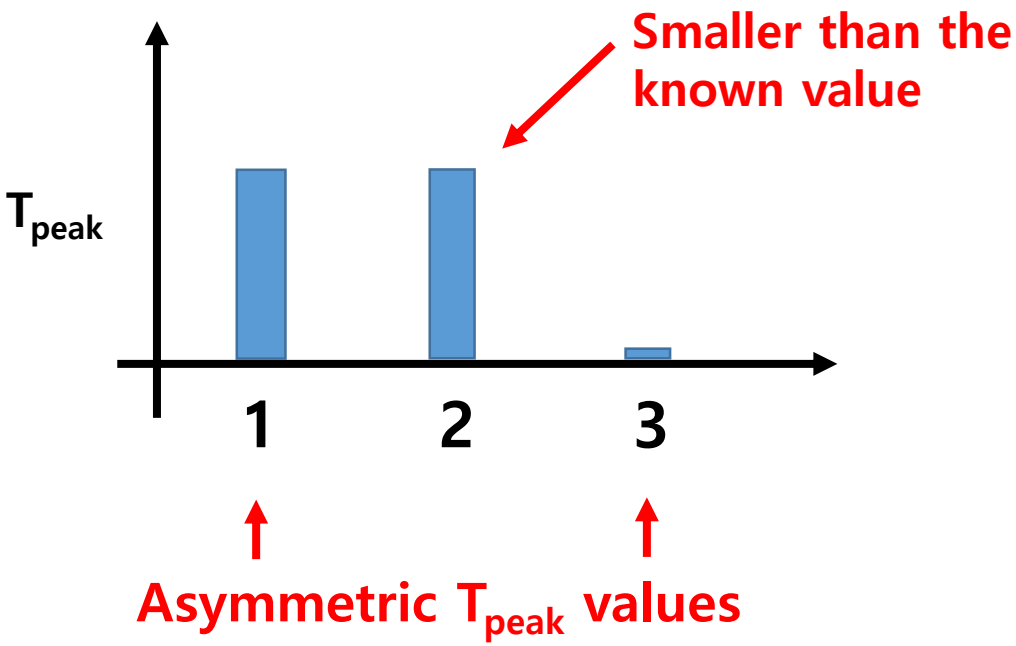


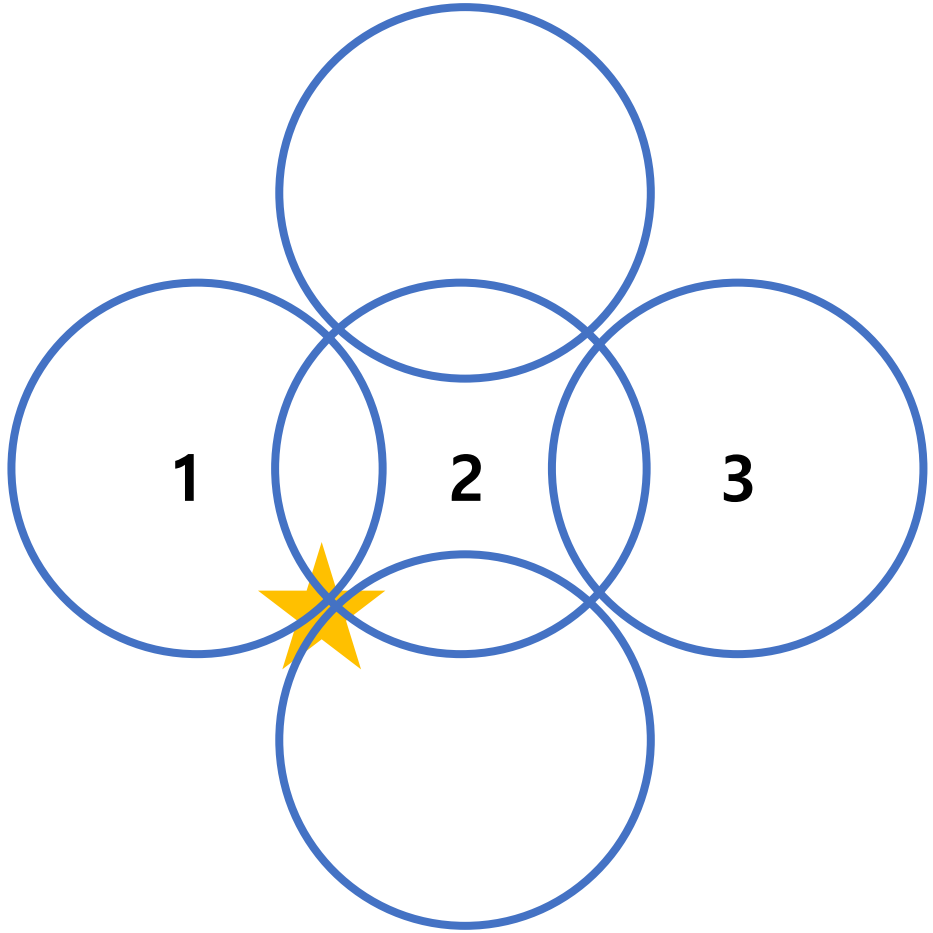
The peak temperature is not concentrated to the center



Focus and Pointing

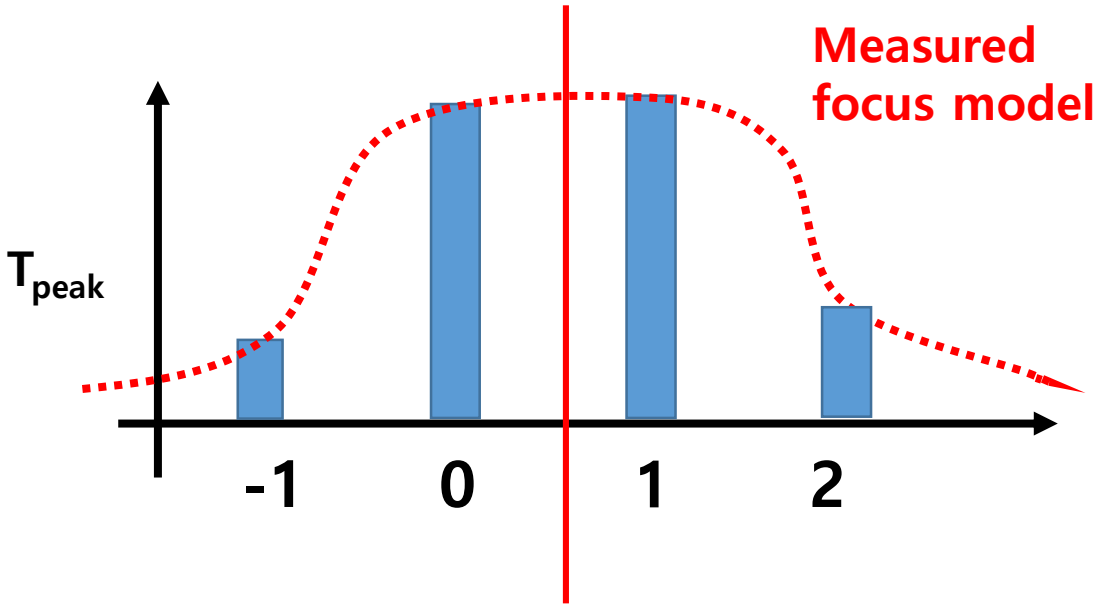
- **Five-point** observation with an wrong pointing

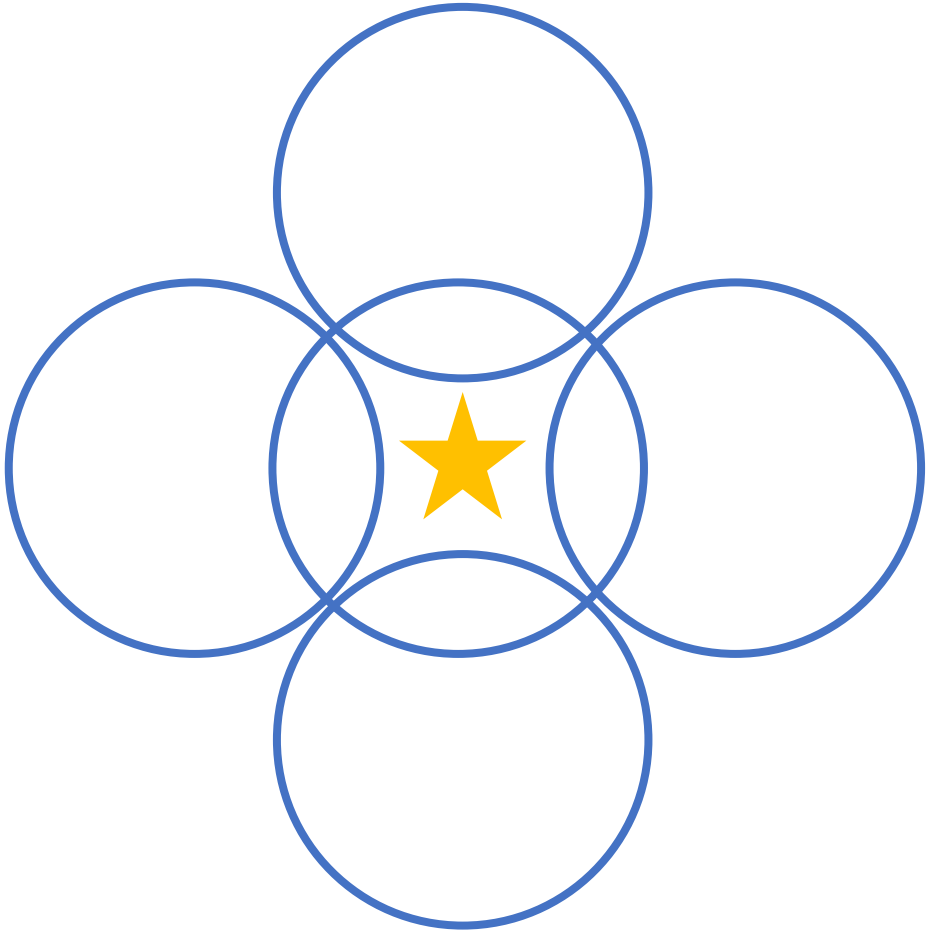




Focus and Pointing

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



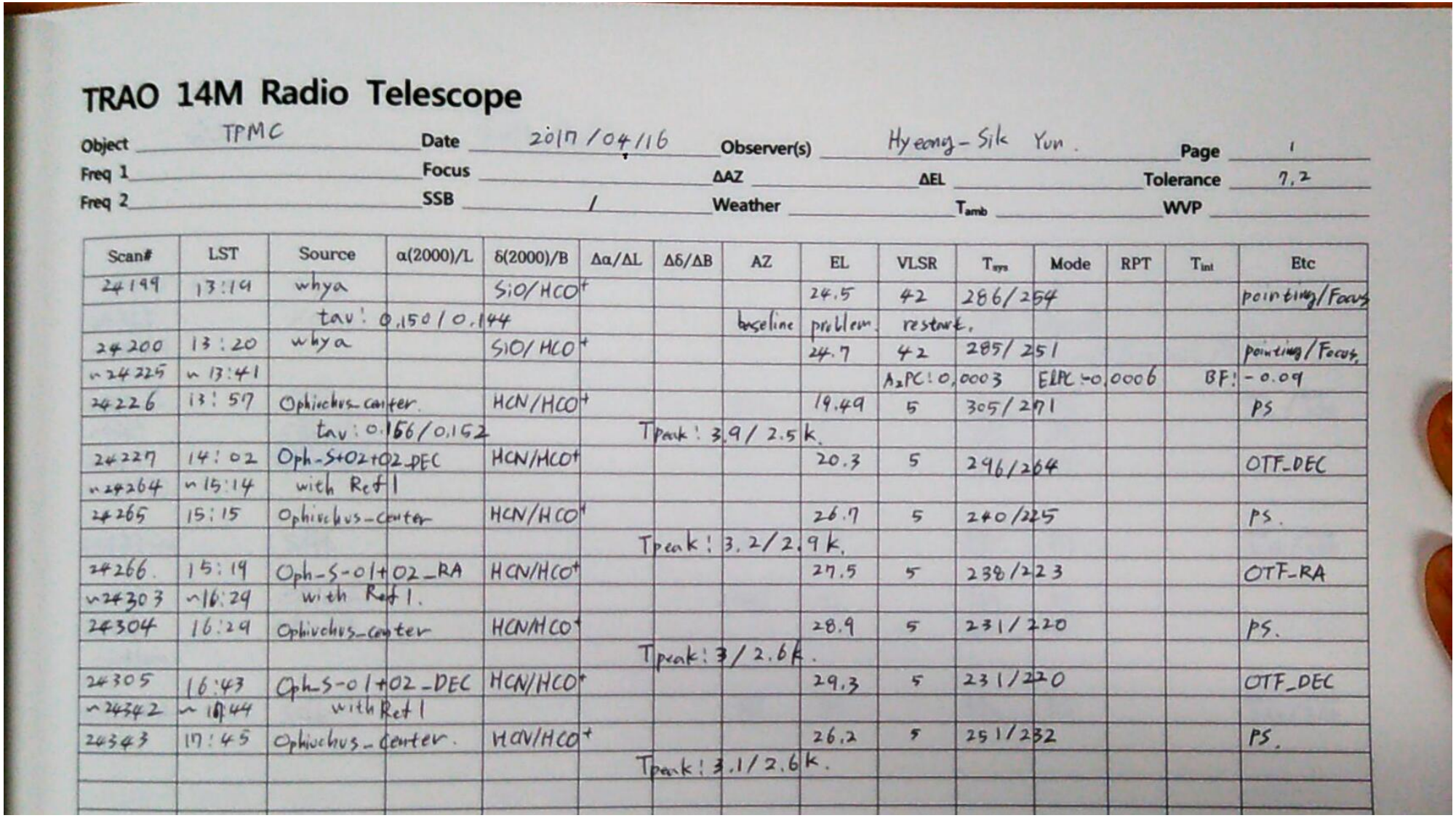


The best-focus position → Find pointing → Start observation

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

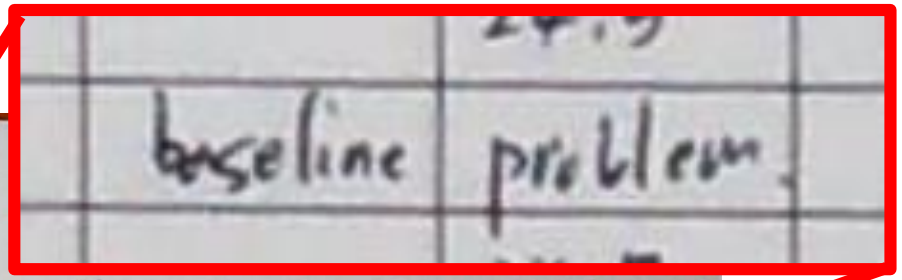
Freq 1 Focus ΔAZ ΔEL Tolerance 7.2

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_2PC: 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

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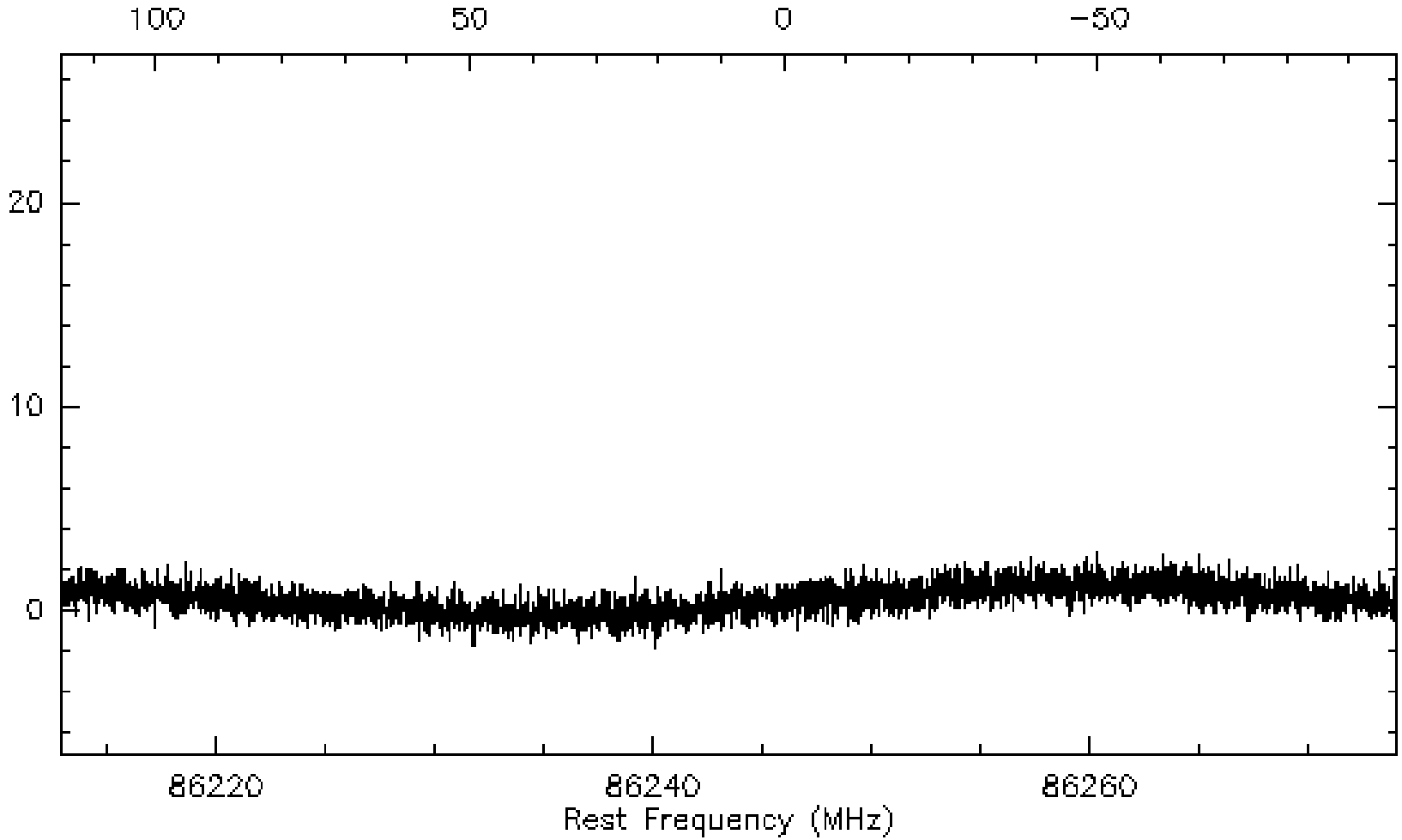
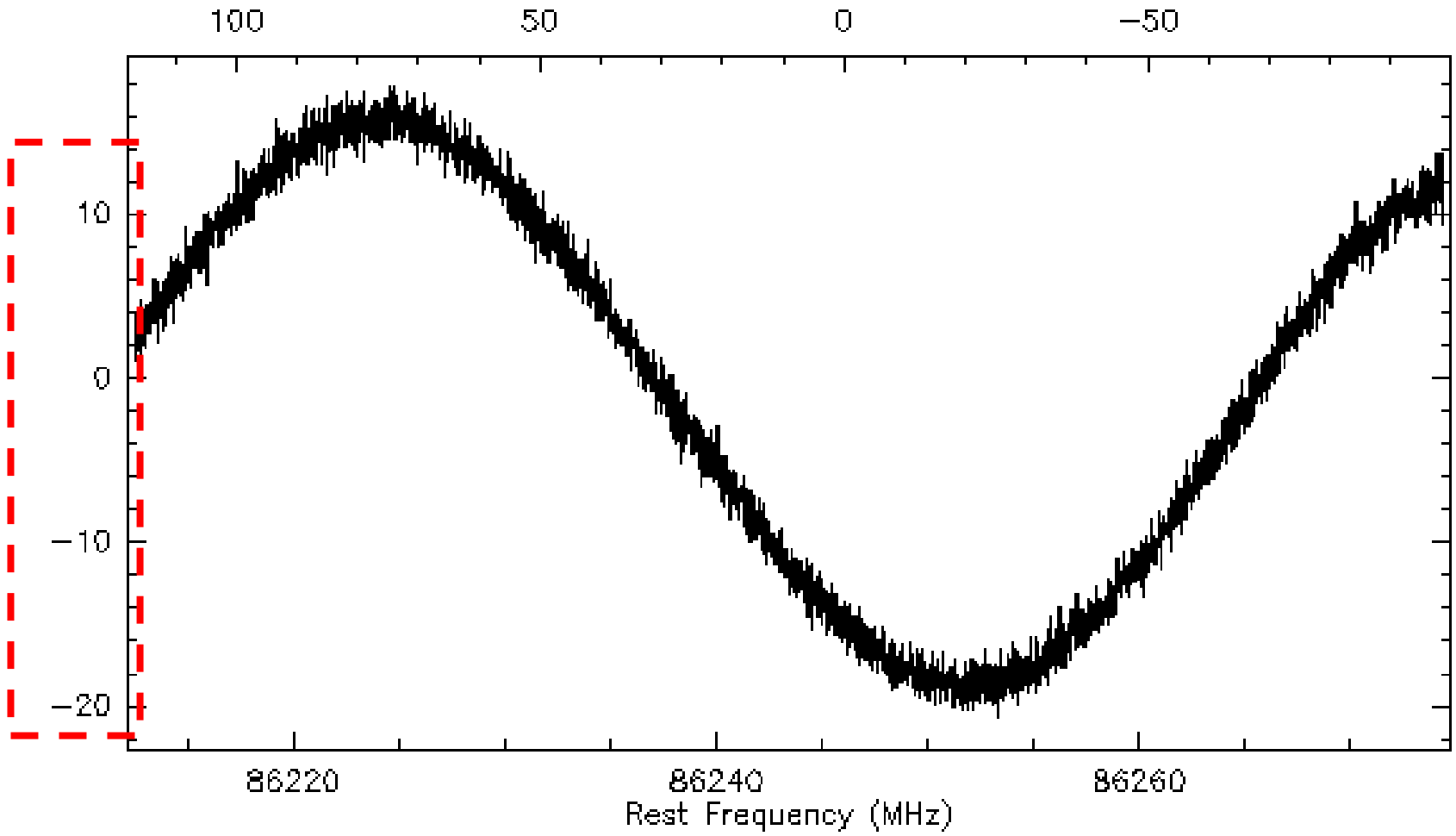
Freq 1 Focus ΔAZ ΔEL Tolerance 7.2
Freq 2 SSB / Weather Tamb WVP

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.							

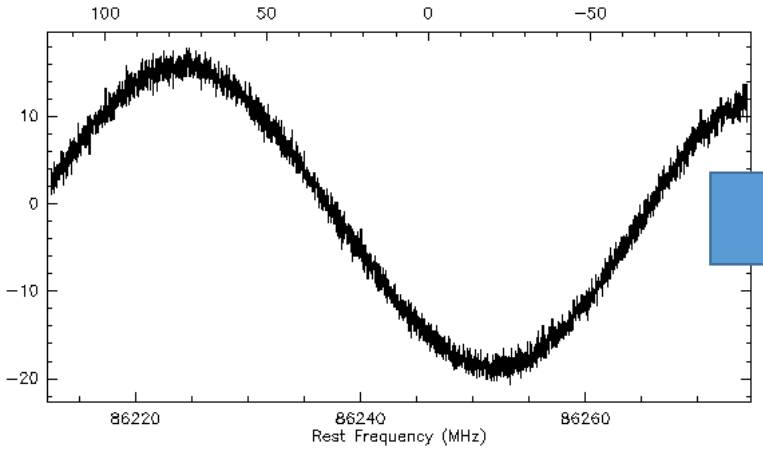
Example: Baseline fluctuation (example1)

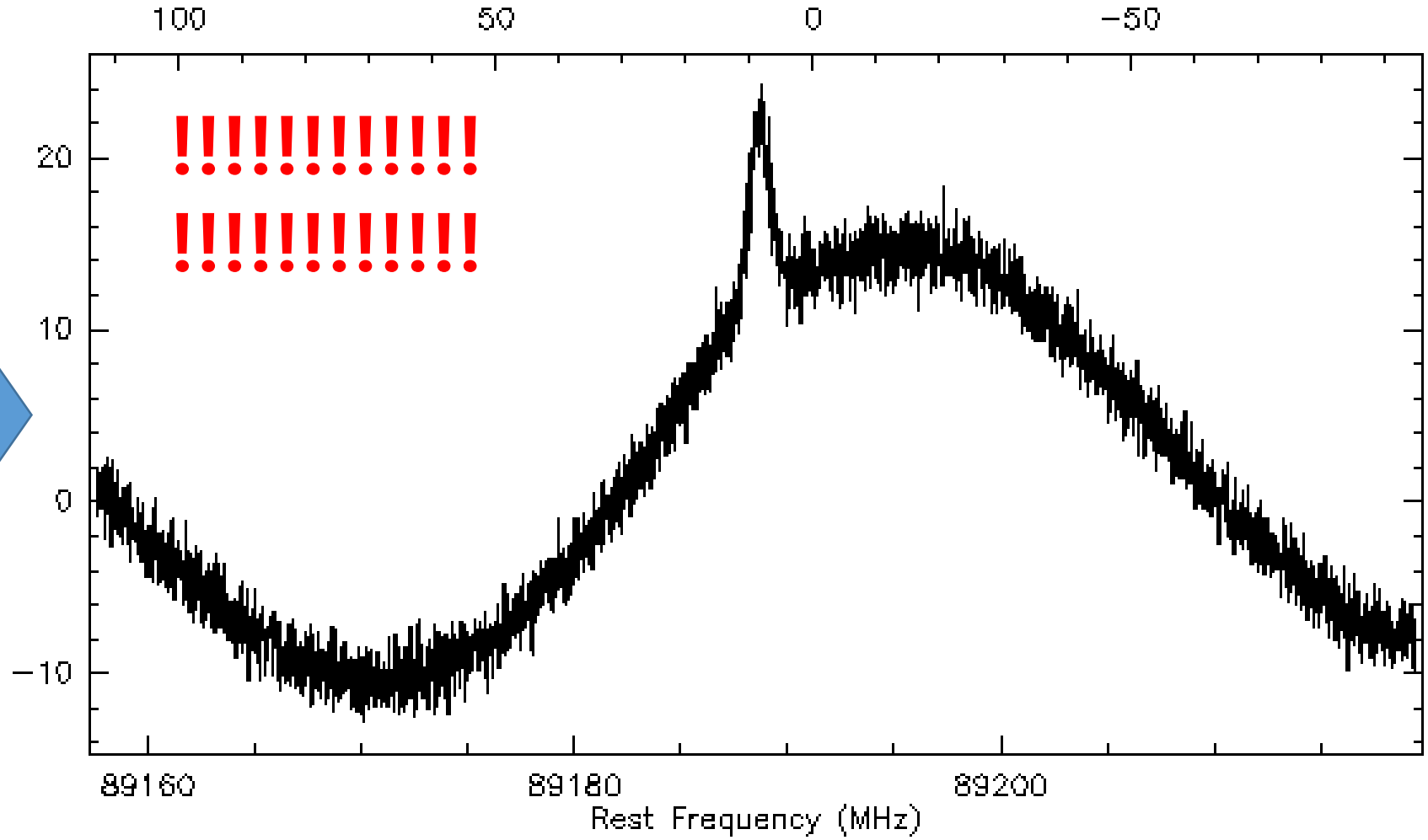


Example: Baseline fluctuation (example2)



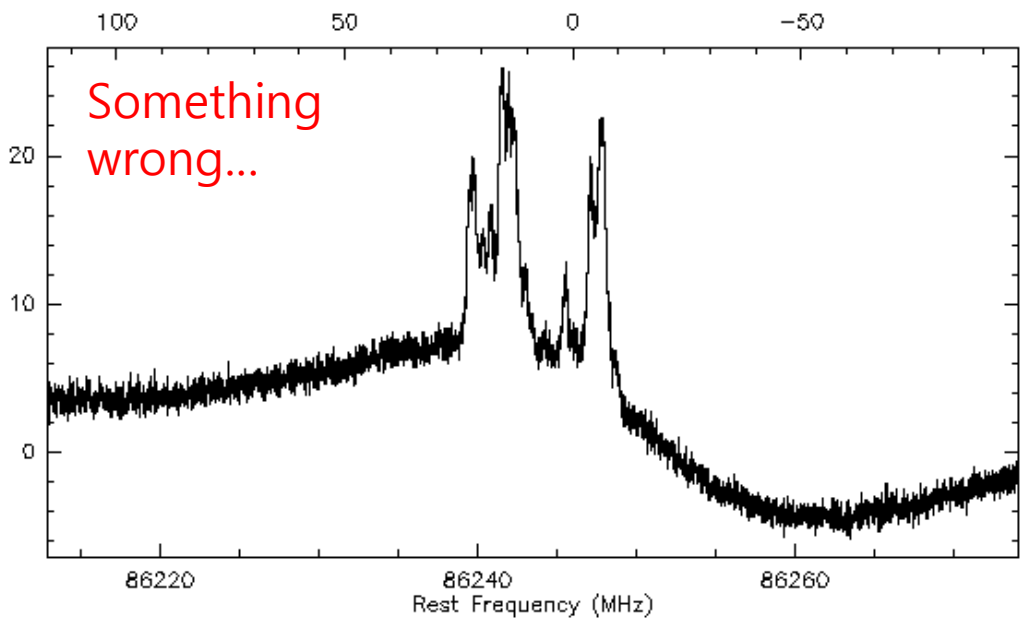
Example: Baseline fluctuation with line

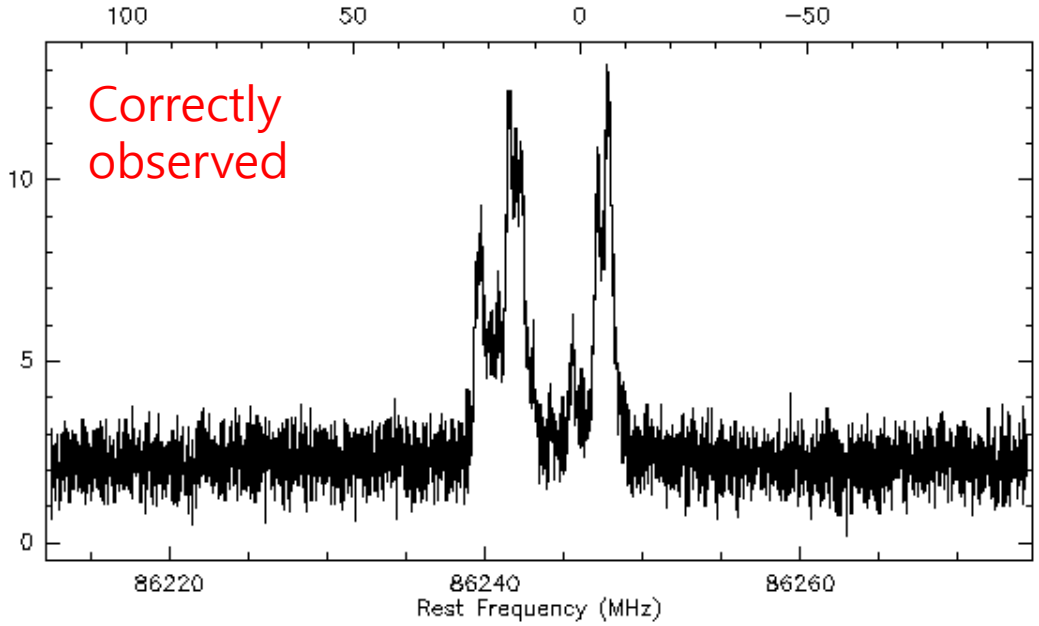




Baseline

- 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.

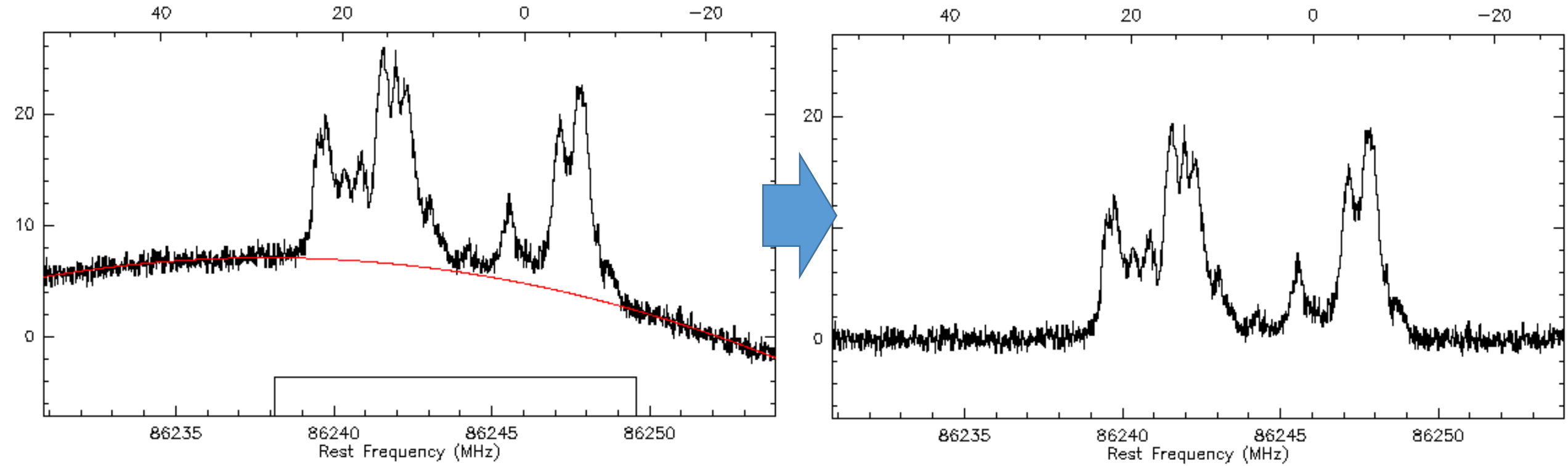




Useful reference: [Baseline | COSMOS (swin.edu.au)]

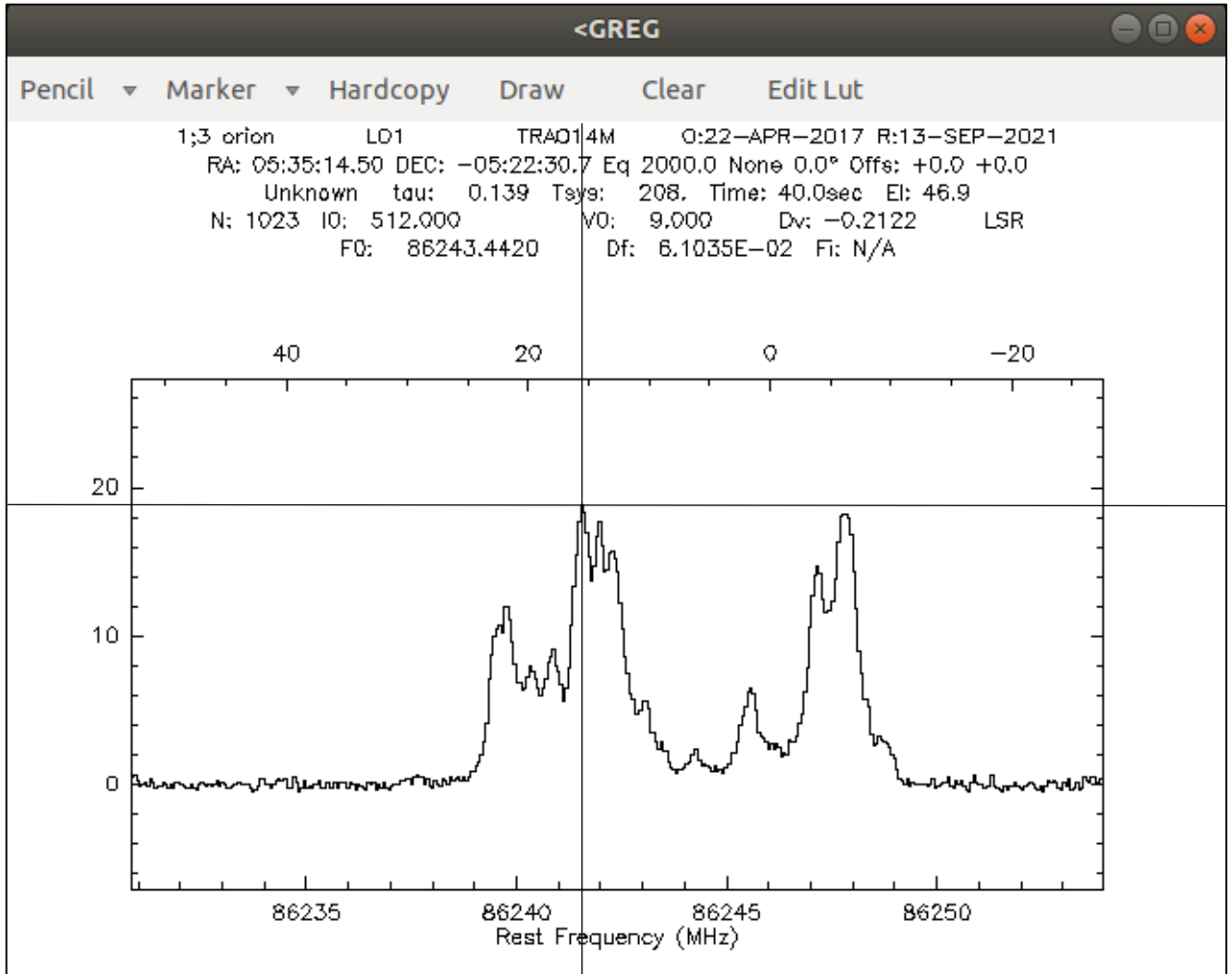
Baseline

- 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?