Superb Astronomical Seeing at Dome A

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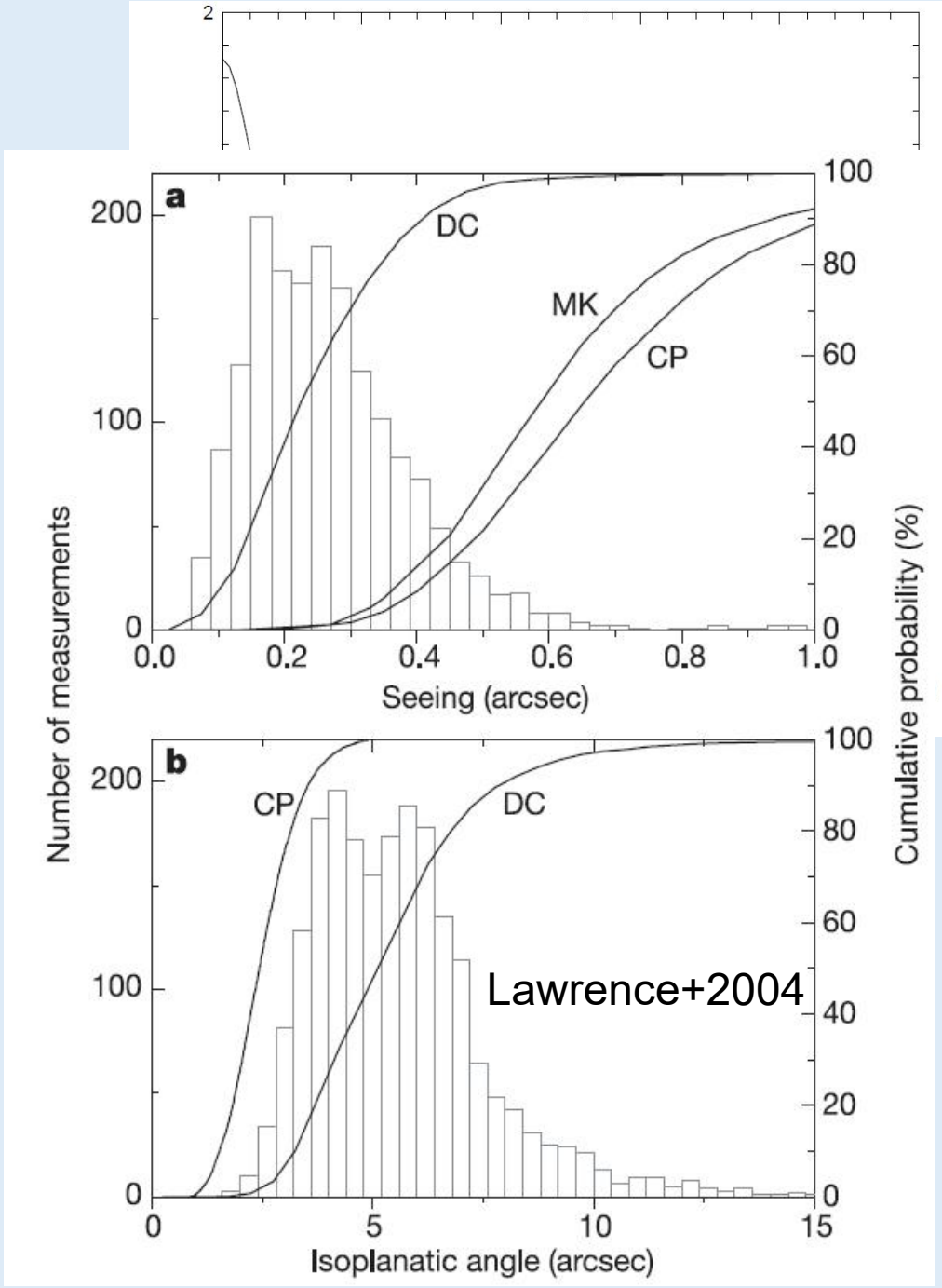
outline

- 1 Introduction
- 2 KL-DIMM for Dome A
- 3 seeing results from Dome A
- 4 Summary

1 Introduction

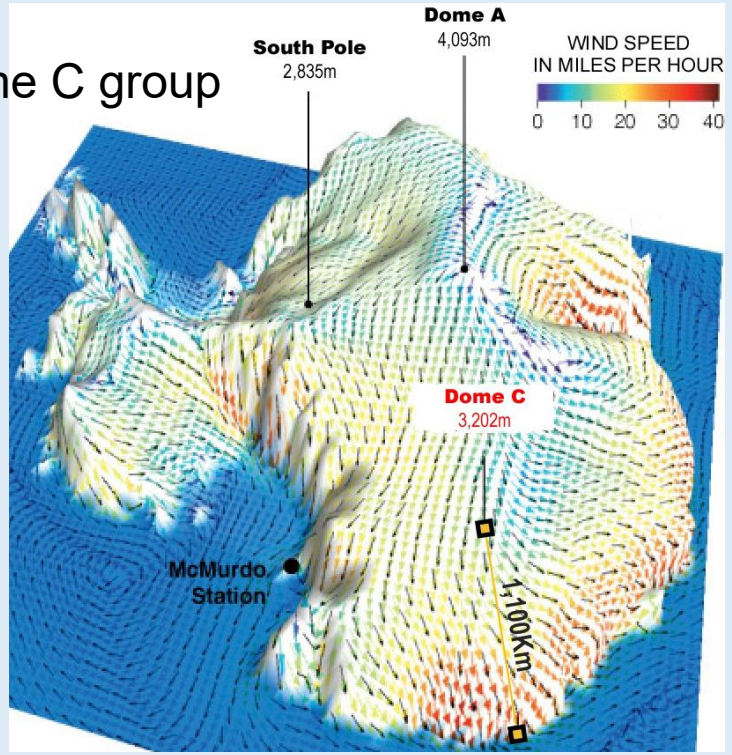
- Seeing at the best mid-latitude sites:
  ~ 0.6 – 0.8″
- Boundary layer in Antarctica:
  more turbulent but much thinner
  - ➢Free-atmosphere seeing is possible
- Dome C:
  - ➢Seeing ~ 0.3″ above BL (~30 m)
- Dome F:
  - ➢~ 0.3″ @ 11m was observed during daytime



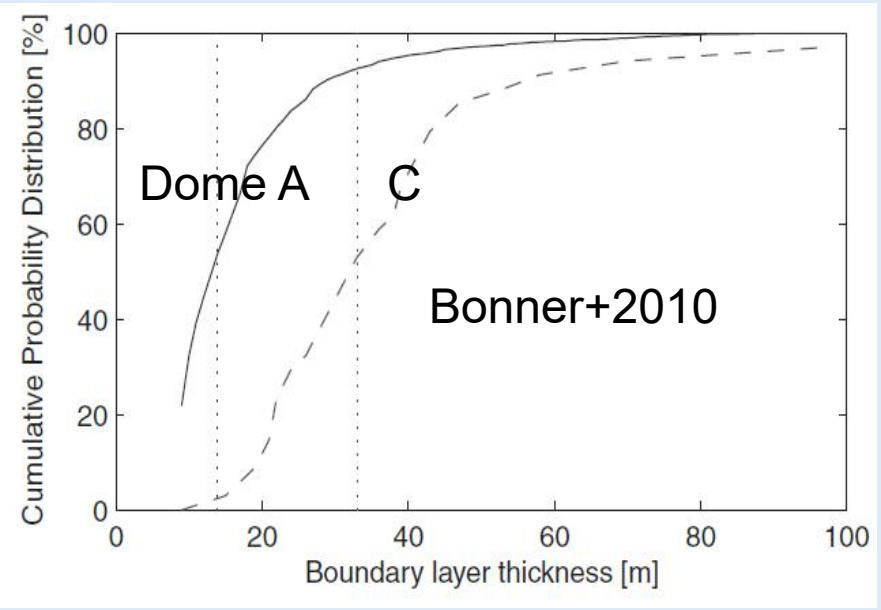
Dome A (Kunlun Station)

- the highest point (4093 m) in Antarctic plateau
  - ➢BL thickness ~ 14 m by Snodar
  - ➢yet only daytime seeing: median 0.8″ @ 3 m by DIMM (Differential Image Motion Monitor)

credit: Dome C group

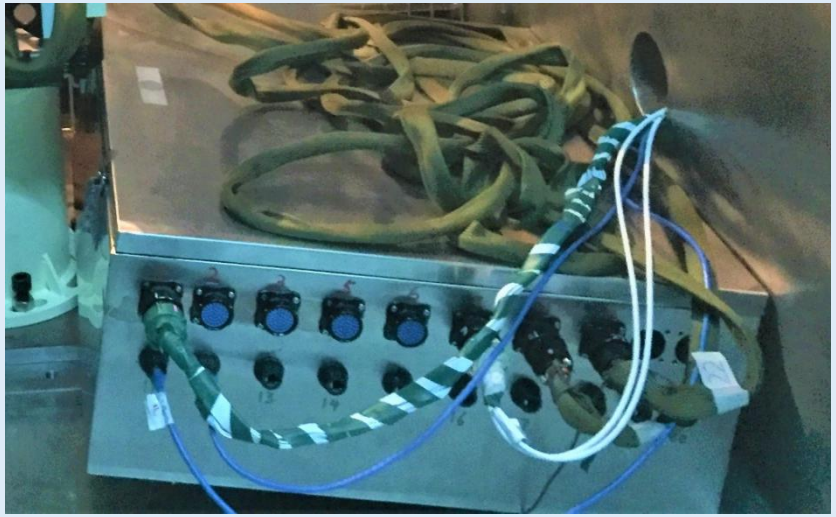


Pei+2013

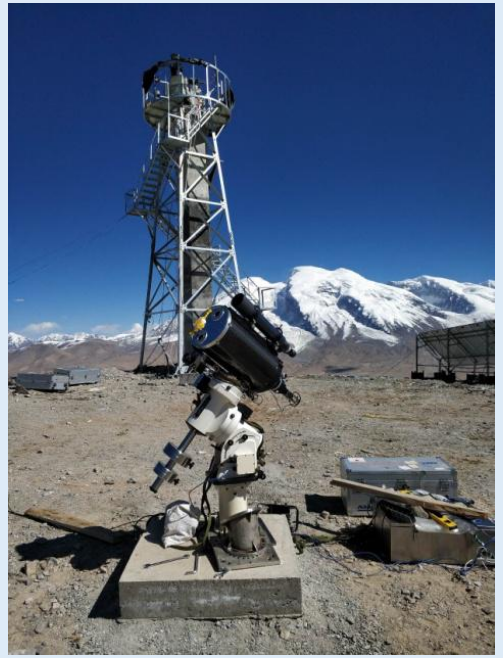


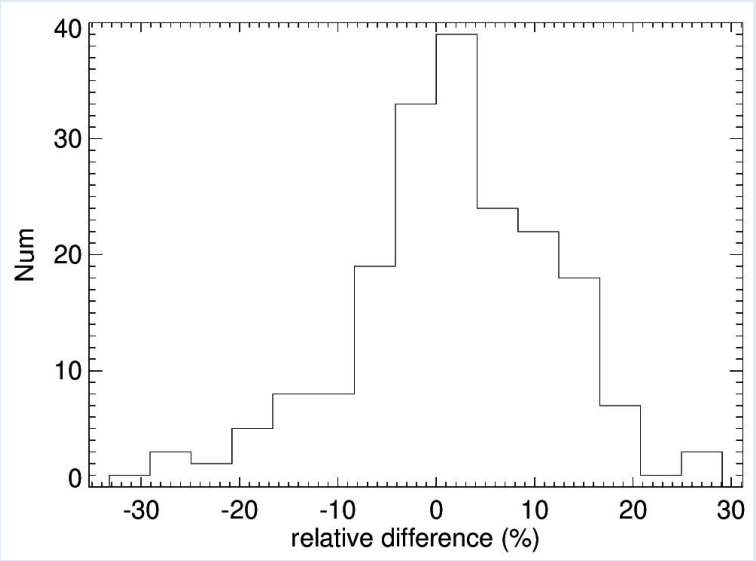
2 KL-DIMM for Dome A

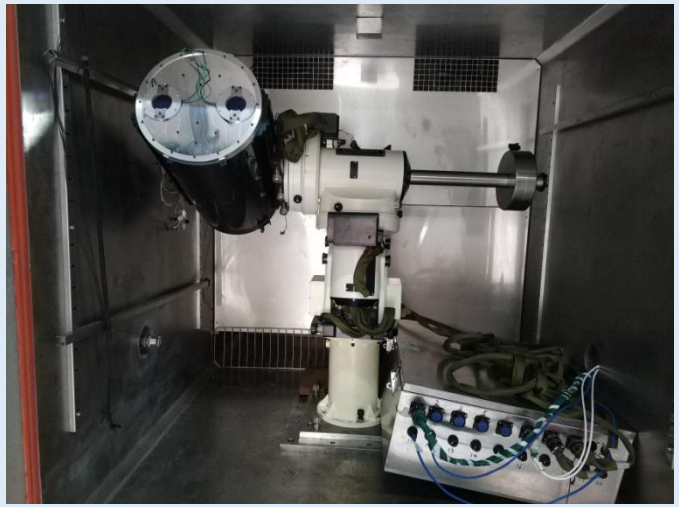
- the automatic DIMM
  for KunLun station (ambient -80℃)
  - ➢Active thermal control for electronics
  - ➢Mechanical improvement
  - ➢two KL-DIMMs for redundancy
- Tower: 8 m
  - ➢Logistical limit
  - ➢BL < 9 m for 25% time



- cold tests: single-part/whole system
  - working/rebooting correctly at -70C
  - ~100W including heaters
- test obs @ Muztagh Ata: seeing precision ~ 10%





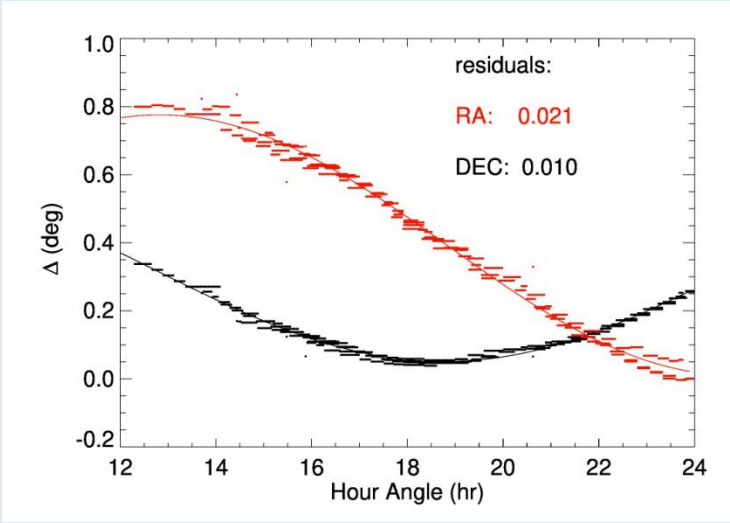


low temperature chamber @ NIAOT

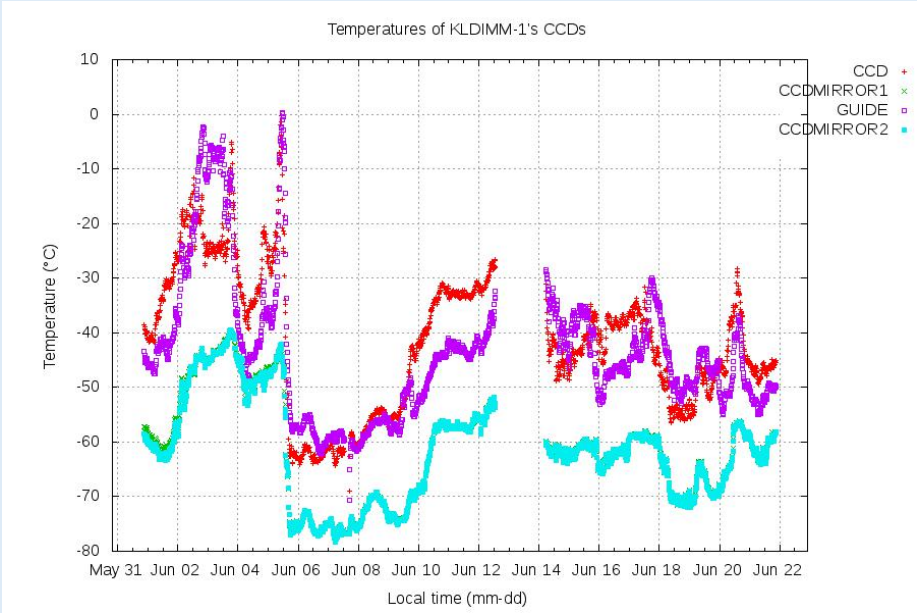
- 2 KL-DIMMs were installed at Dome A in 2019
- 2 members from NAOC + help from
  another 2 astronomers
  + the traverse team
- supported by PLATO-A

operations

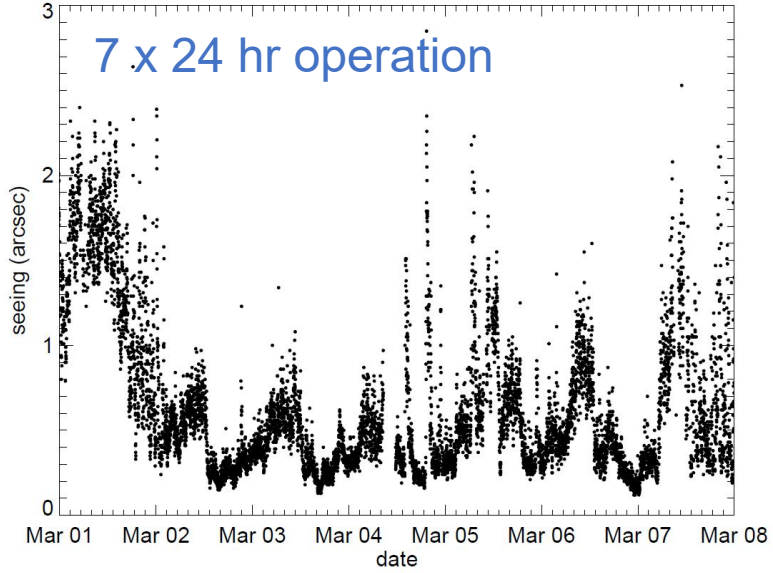
- fully automatic observation
- data processing in real-time
- seeing results were sent back every 30 min, and shown in website



polar misalignment:
<0.3 deg in left-right
<0.1 deg vertically

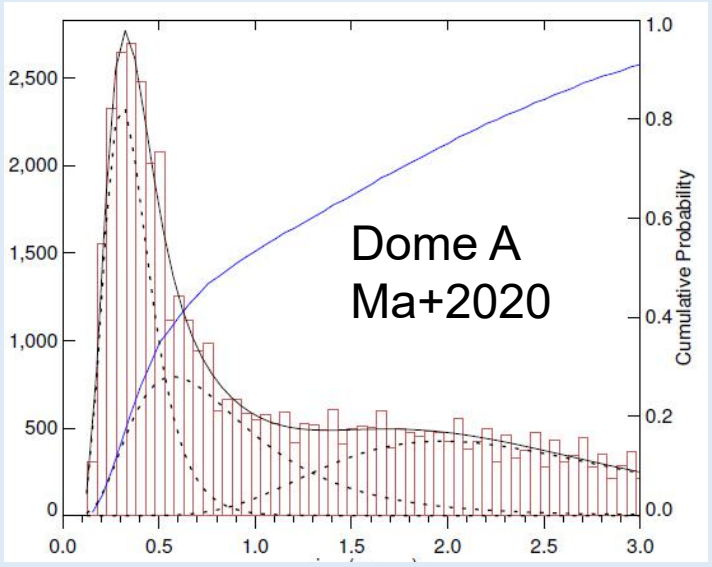


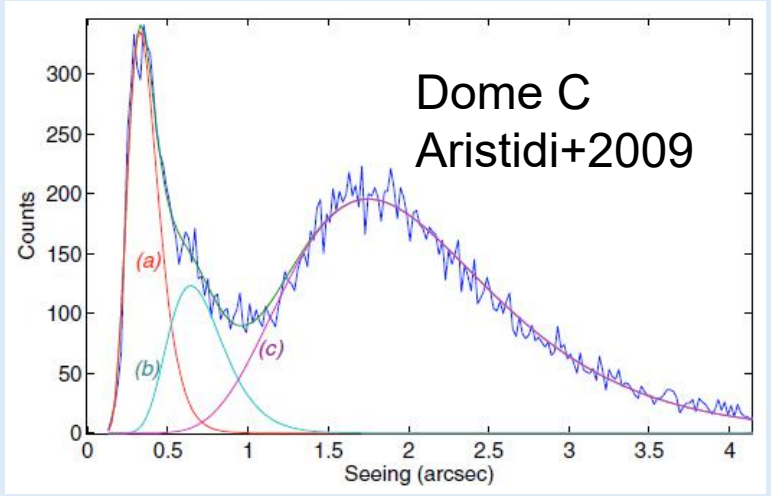
working well even t < -75℃

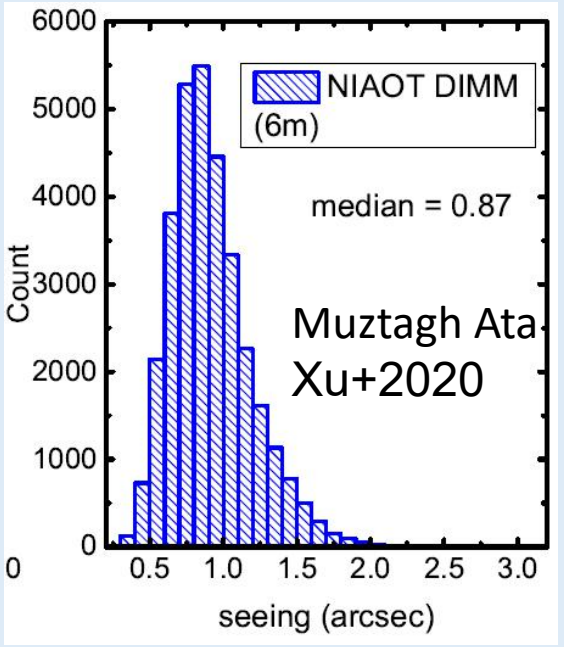


3 seeing results from Dome A

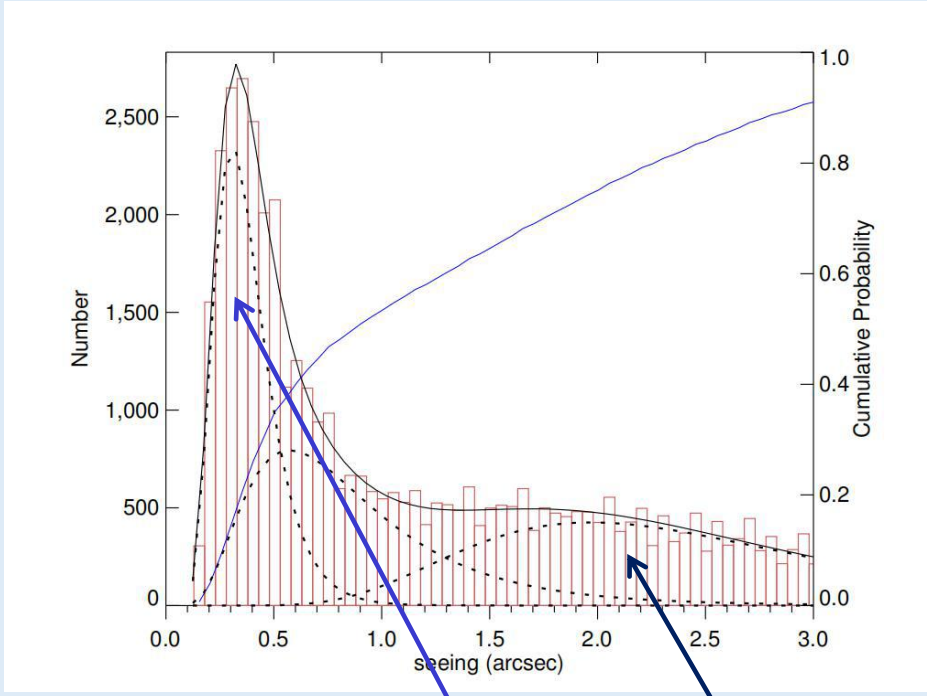
- April - Aug 2019
- histogram of night-time seeing:
  a sharp peak (<0.5″) + a long tail (up to >3″)
- log-normal distribution in mid-latitude sites
- 2 or 3 log-normal components in Antarctica

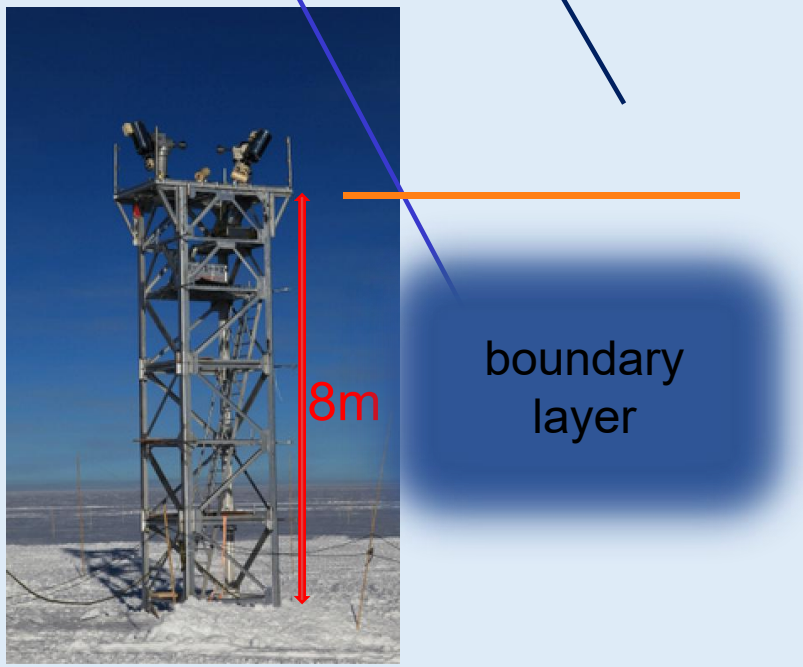






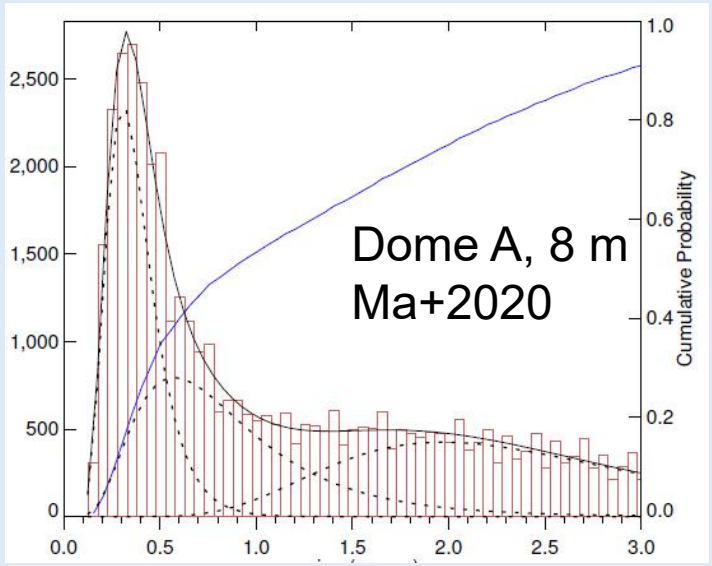
- the 3 components in the histogram: FA, BL & intermediate seeing
- caused by the variation of BL thickness
- at just 8 m, FA seeing was obtained for 31% of the time, when the median was 0.31″
- Snodar: BL < 9 m for 25% time

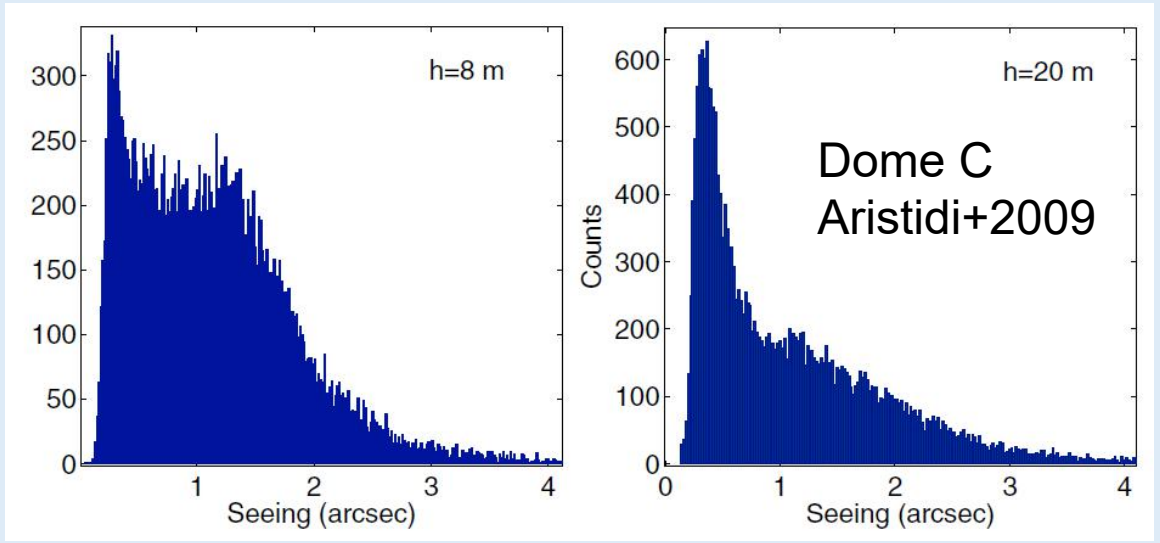




Note: the measured seeing values were overestimated by up to 10-20% due to the ice on the sub-apertures

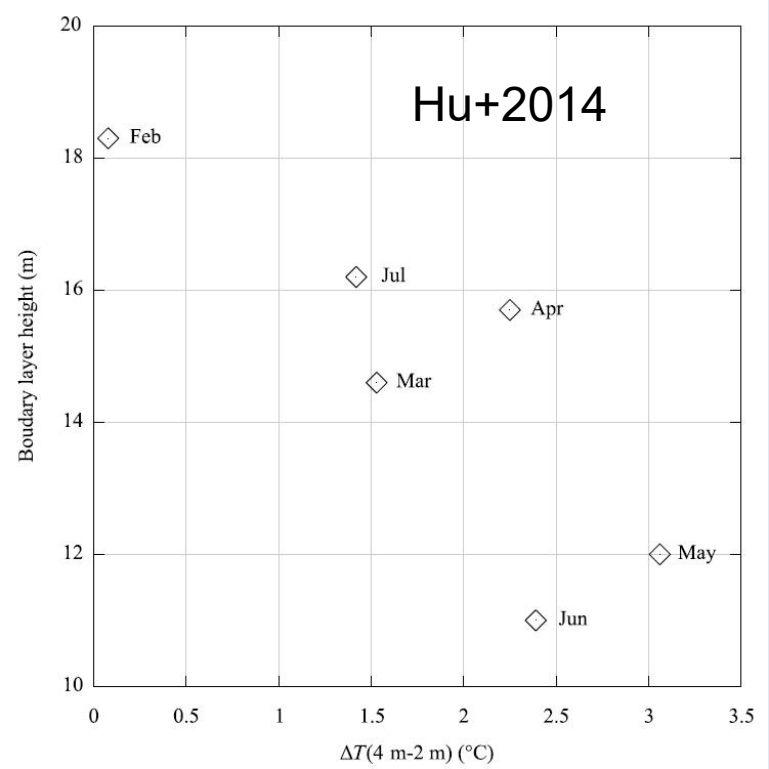
Site	DIMM tower height (m)	25% (arcsec)	50% (arcsec)	75% (arcsec)	ε_{FA} (arcsec)	ε_{IN} (arcsec)	ε_{BL} (arcsec)	f_{FA} (%)	f_{IN} (%)	f_{BL} (%)
Dome A	8	0.41	0.89	2.02	0.31	0.57	1.97	31.0	30.1	38.9
Dome C	8	0.83	1.65	2.32	0.33	0.54	1.73	16.2	14.4	69.4
Dome C	20	0.43	0.84	1.55	0.30	0.42	1.17	15.7	29.3	55.0
Mauna Kea	7	0.57	0.75	1.03						
Armazones	7	0.50	0.64	0.86						
La Palma	5	0.62	0.80	1.06						

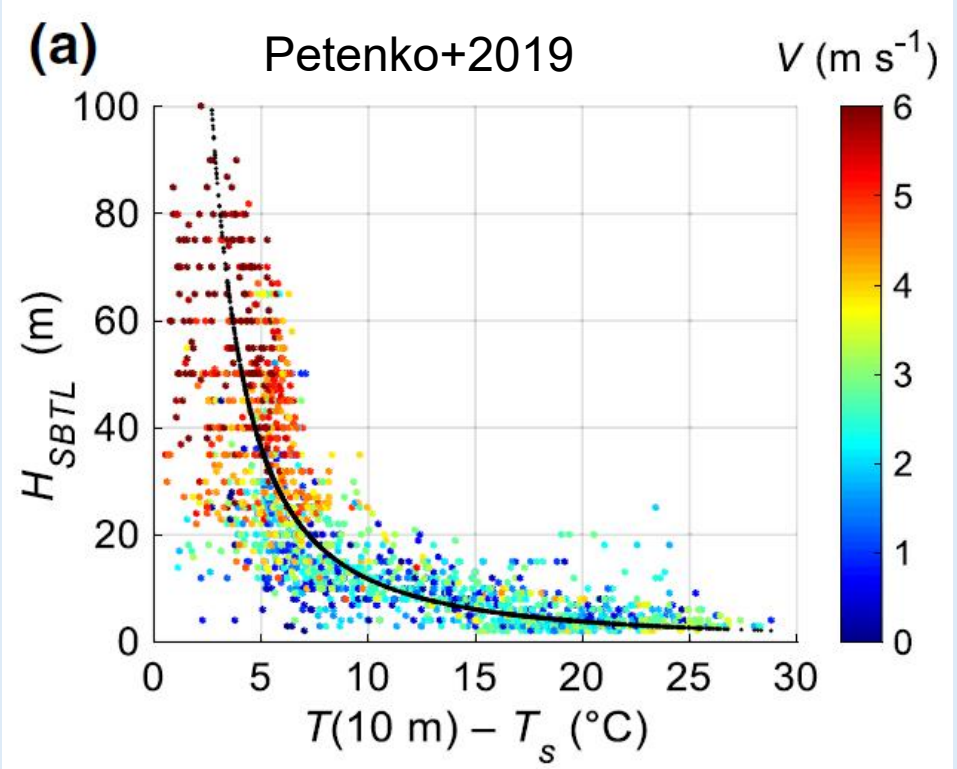




- the seeing could be improved on a higher tower:
  more FA seeing, less and smaller BL seeing

Seeing vs. Weather





Dome A
Weather data in 2011
BL height in 2010

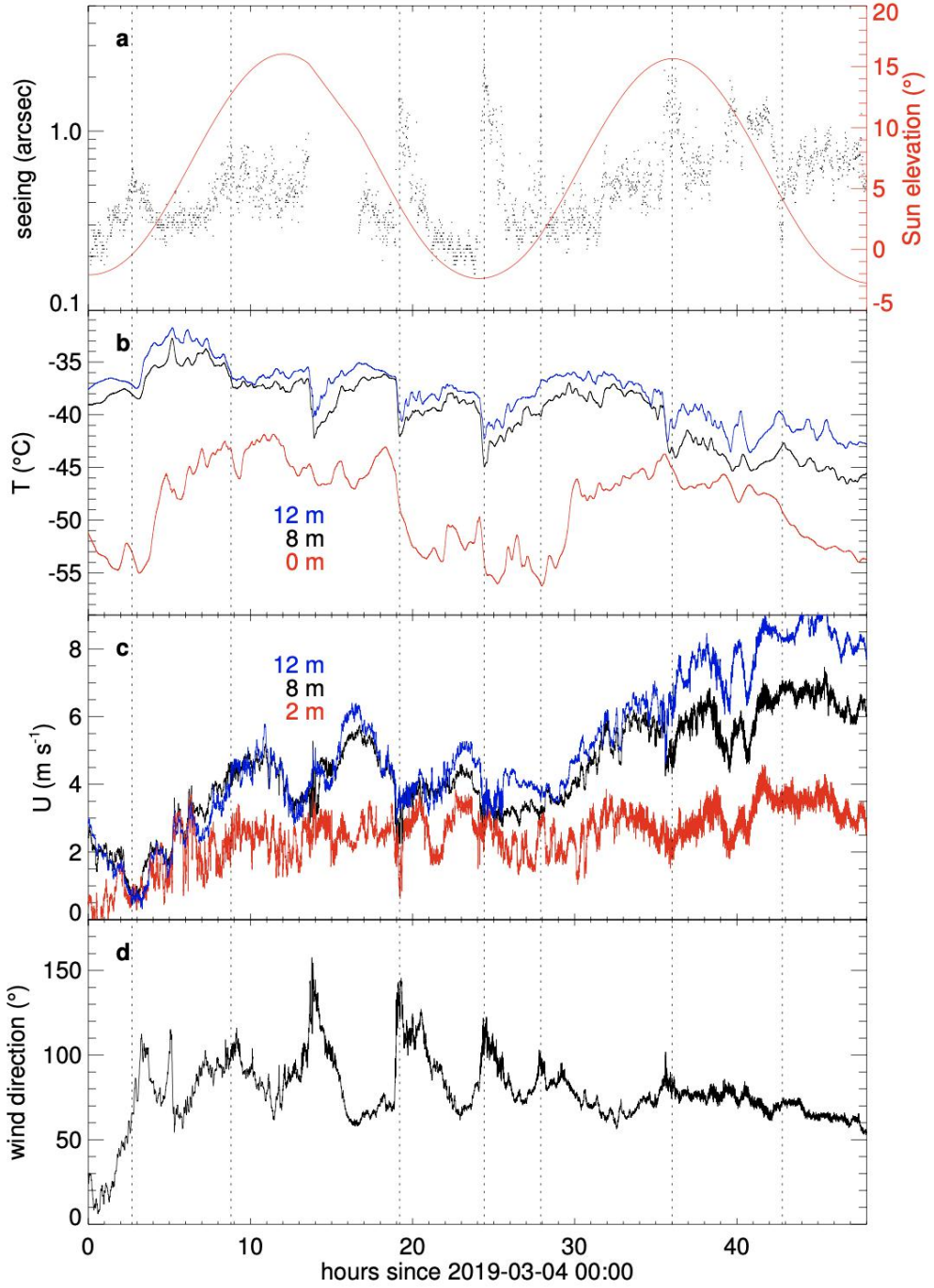
Dome C

Seeing vs. Weather

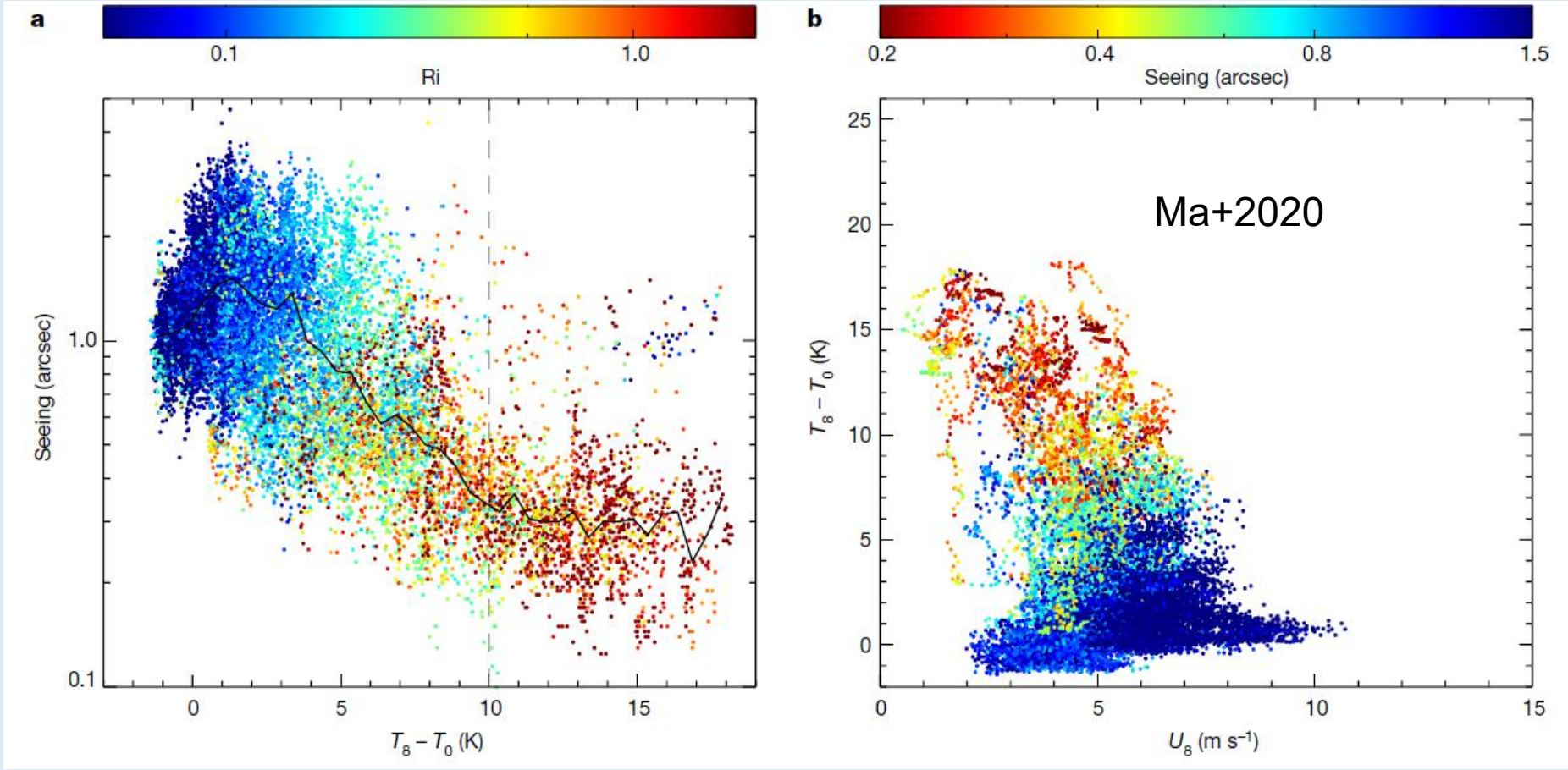
- KLAWS: weather data on multi-heights between 0 - 14 m
- simultaneous operations: Jan - March

Seeing changes with:

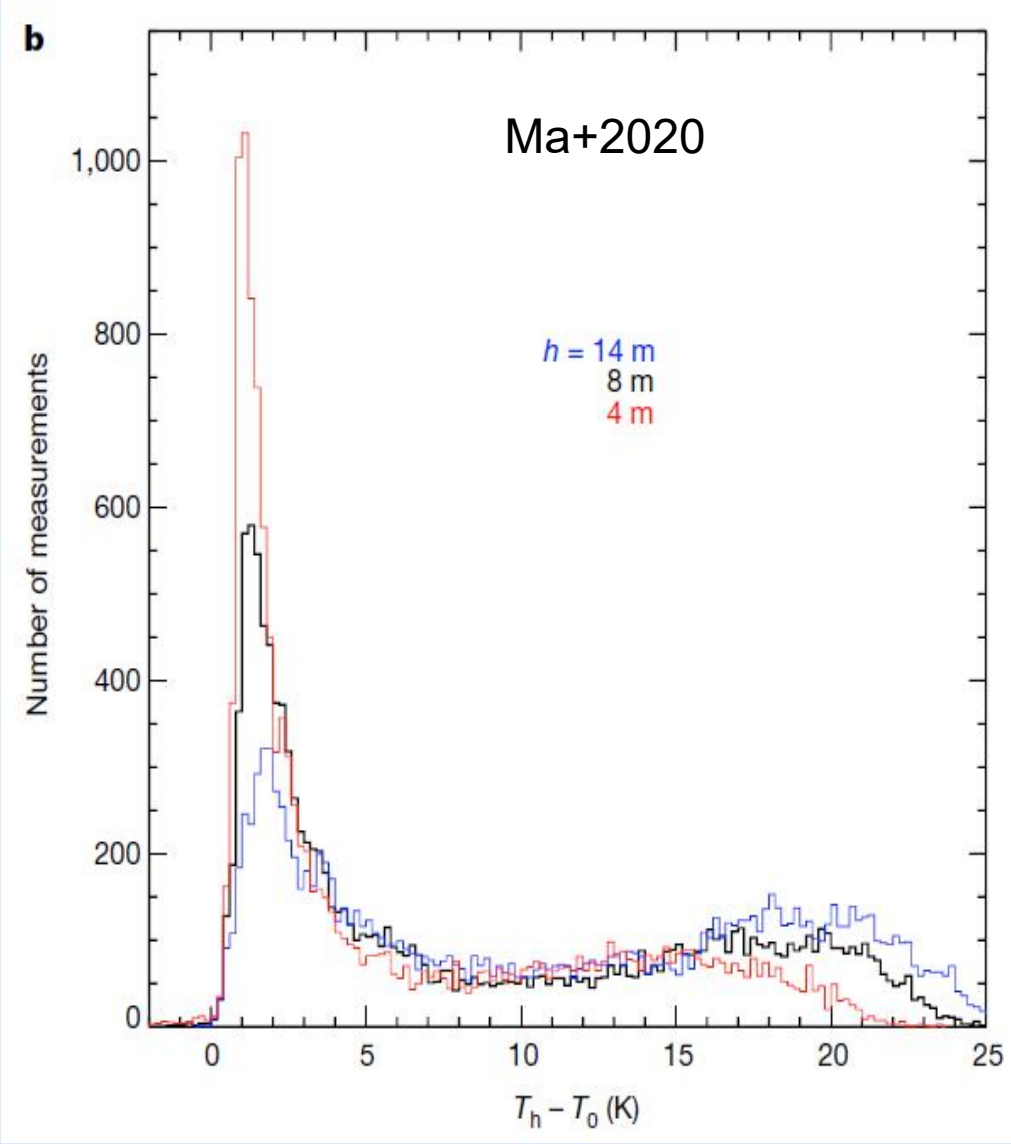
- Temperature gradient
- Wind speed
- Wind direction



- seeing vs weather
  - temp gradient
  - wind speed
- T_8-T_0~ 10 K indicates h_{BL} ~ 8 m

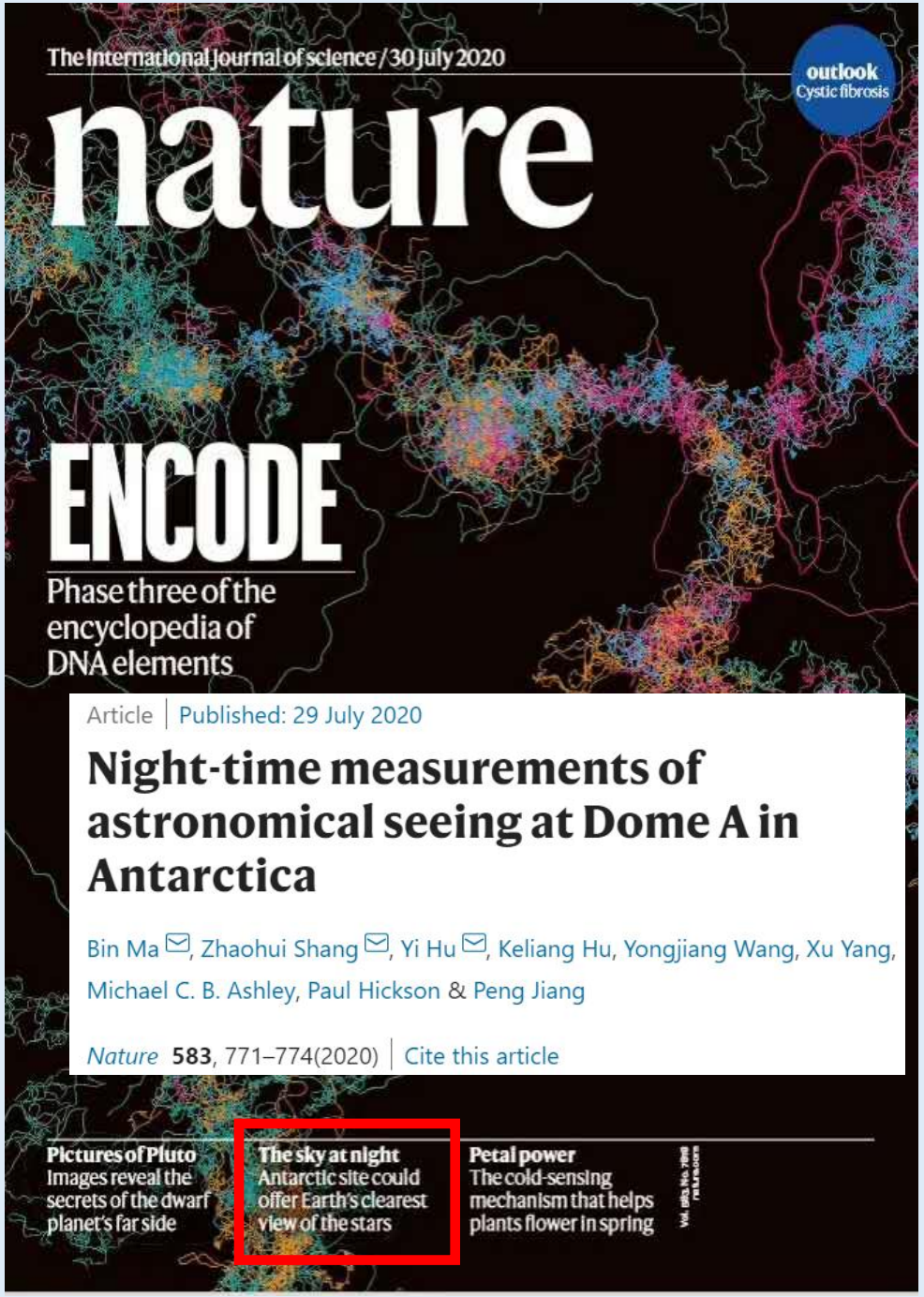


- larger temp gradient => thinner BL
- T_h-T_0 indicates if h_{BL} < h
- winter data in 2015:
  50% time when h_{BL}<14 m,
  consistent with Snodar results



4 Summary

- KL-DIMM: successful operations @ Dome A
- direct measurements prove the seeing @ Dome A is the best on the ground
- Future work
  - to improve de-icing of KL-DIMM
  - KL-DIMM + KLAWS in the winter
  - to measure $C_n^2(h)$: the optimized height for large telescopes?



Thank you!

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