Passive neutron sensing of martian subsurface from onboard rovers: results from MSL/DAN and expectations from ExoMars/Adron-RM

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2 units

DAN DE:

Based on two ^{3}He detectors. The main measuring functions include measuring of 16-channel spectra of thermal and epithermal neutrons in the energy range
up to 100 keV.

DAN PNG:

Based on the neutron generator which provides pulsing generation of neutrons with energy of 14 MeV with the frequency up to 10 Hz. Not less than 10^{7} neutrons emitted per one pulse.

1 unit

ADRON-RM:

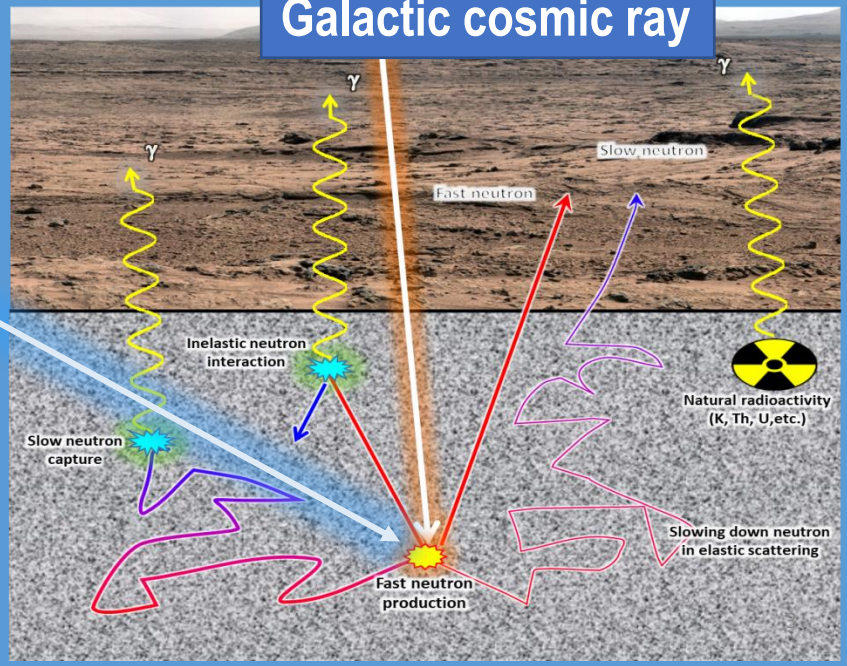
Based on two ^{3}He detectors. The main measuring functions include measuring of 32-channel spectra of thermal and epithermal neutrons in the energy range
up to 100 keV.

Active mode

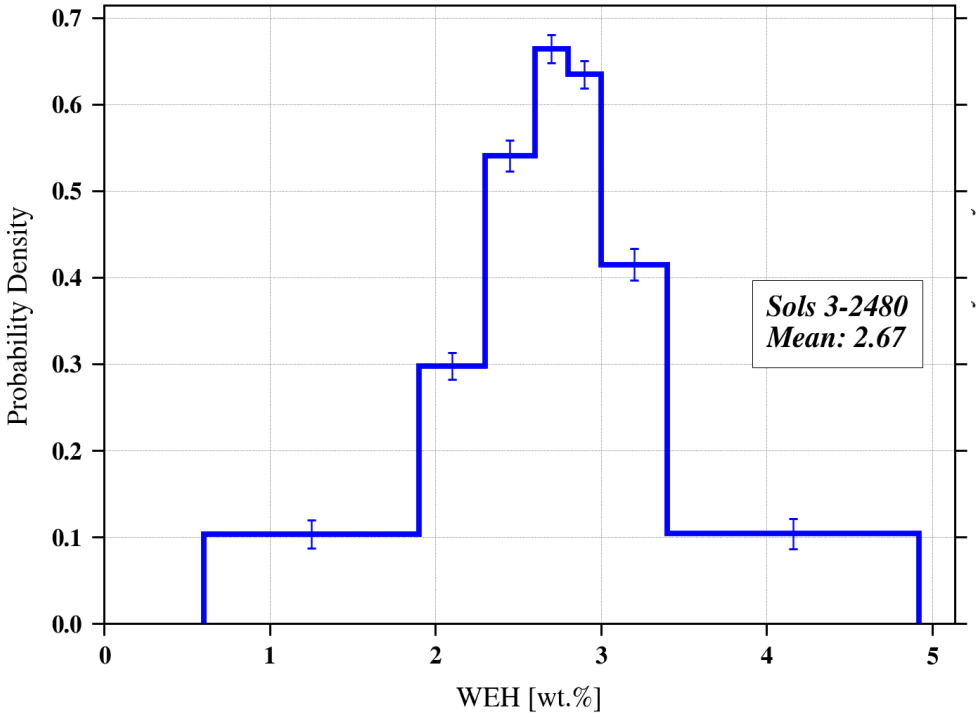
MMRTG (^{238}Pu)

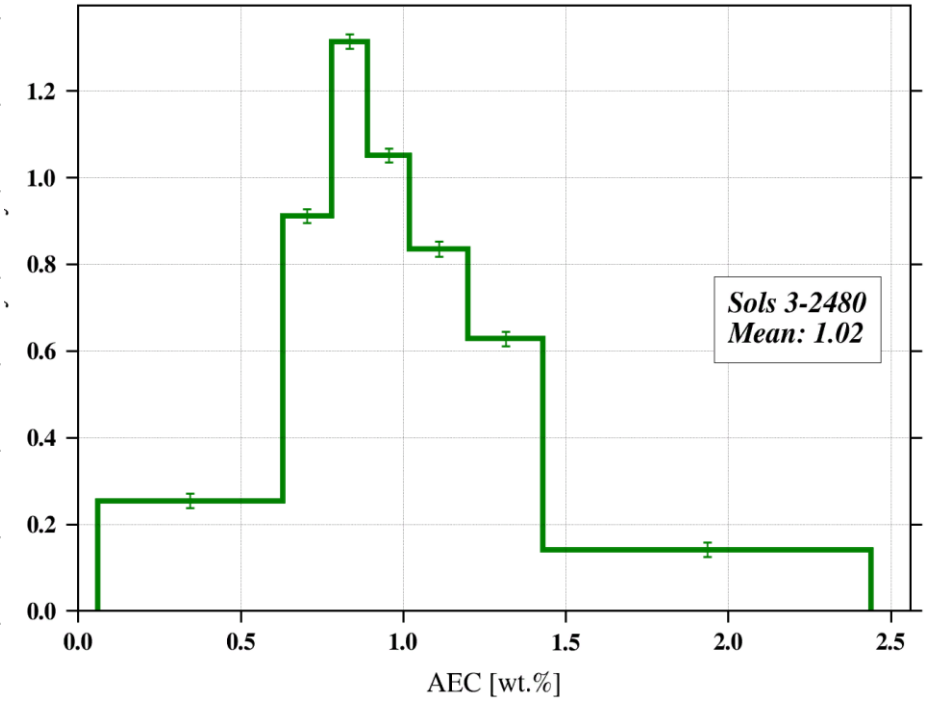
Passive mode

Galactic cosmic ray



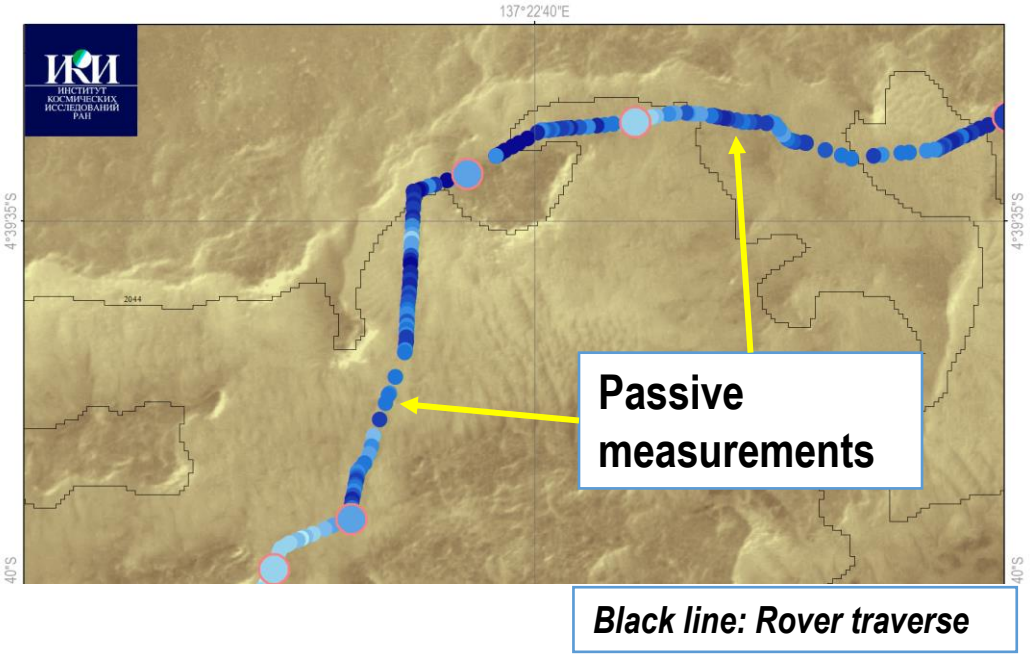
Active measurements. Measurements with the neutron generator.





Values of water equivalent hydrogen (WEH) and Absorption Equivalent Chlorine (AEC) for 500 tested spots consistent with homogeneous model

Why is it important to assess Passive measurements?



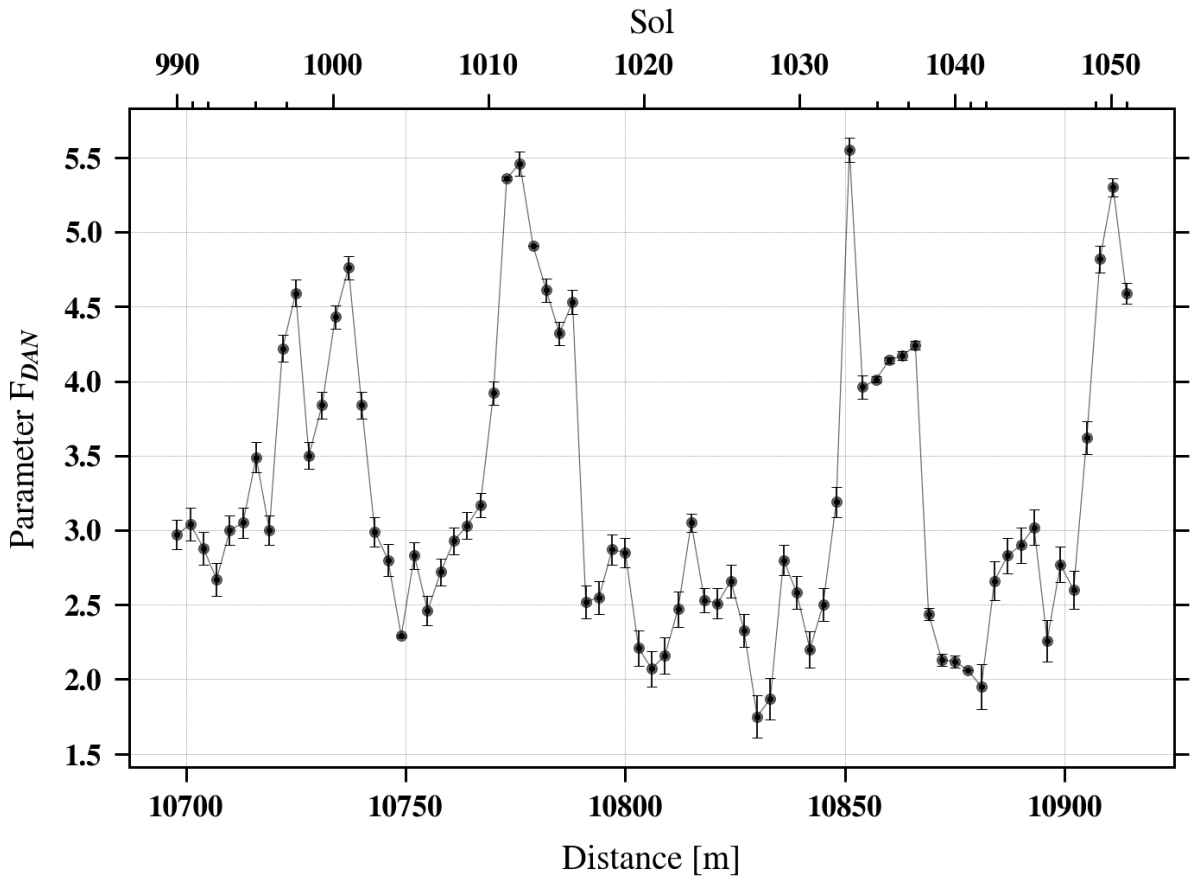
Black line: Rover traverse

- Active measurements is allowed only then Rover is stopped. During the drive DAN can use only Passive mode.
- There is no information on subsurface water during a traverse.
- Generator has a finite lifetime.

Here below, we propose the method for estimation of WEH along the traverse from the Passive data, when WEH and AEC from Active measurements are used as a reference values.

Observation parameter F_{DAN} for passive mode

$$\mathbf{F_{DAN}} = \frac{\boldsymbol{Count\ rate\ (CTN)}}{\boldsymbol{Count\ rate\ (CETN)}}$$

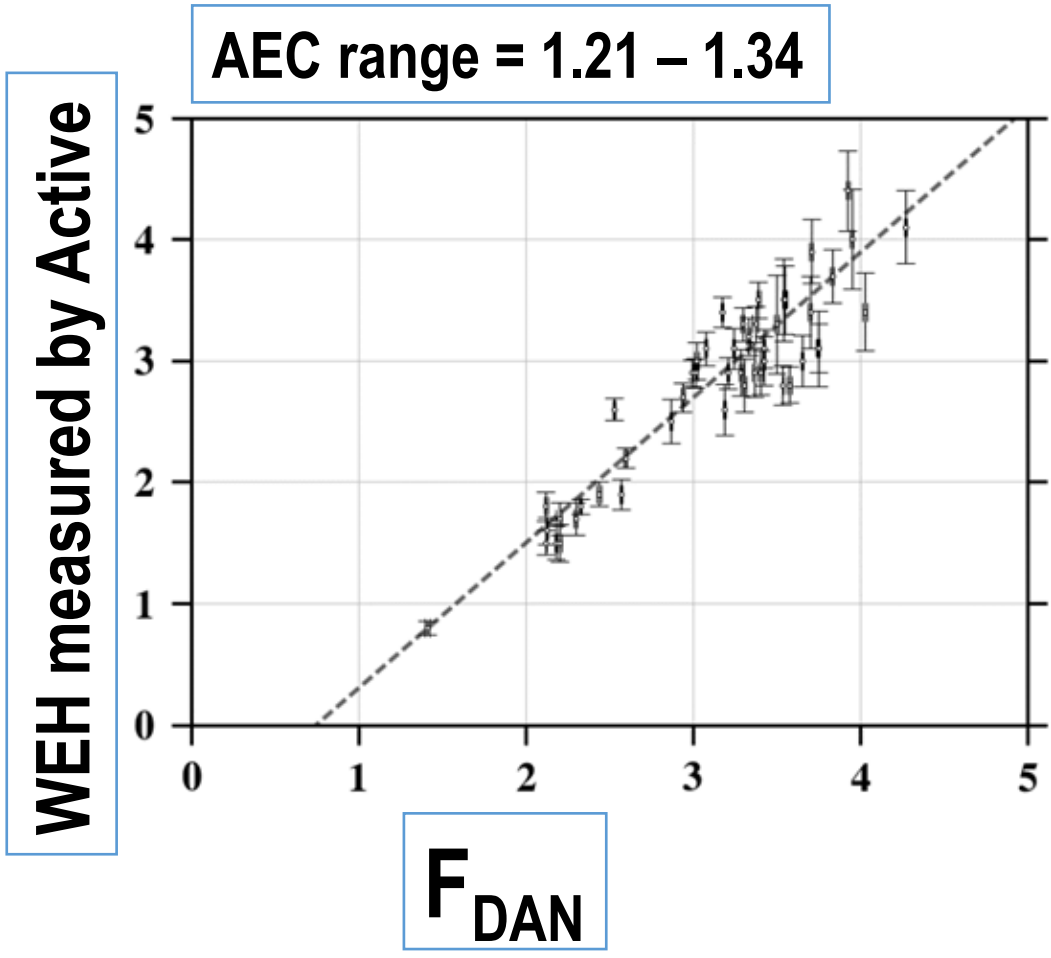


- The ratio of count rates of thermal and epithermal neutrons is suggested as a parameter $\mathbf{F_{DAN}}$ for Passive measurement.
- Such parameter allows to exclude variations of neutron count rate due to variable of GCR flux as well as effect due to distance changing between the rover and the surface.
- Variations of F_{DAN} are associated with WEH variation and less dependent to AEC value.

Usage of Active data for Passive data analysis

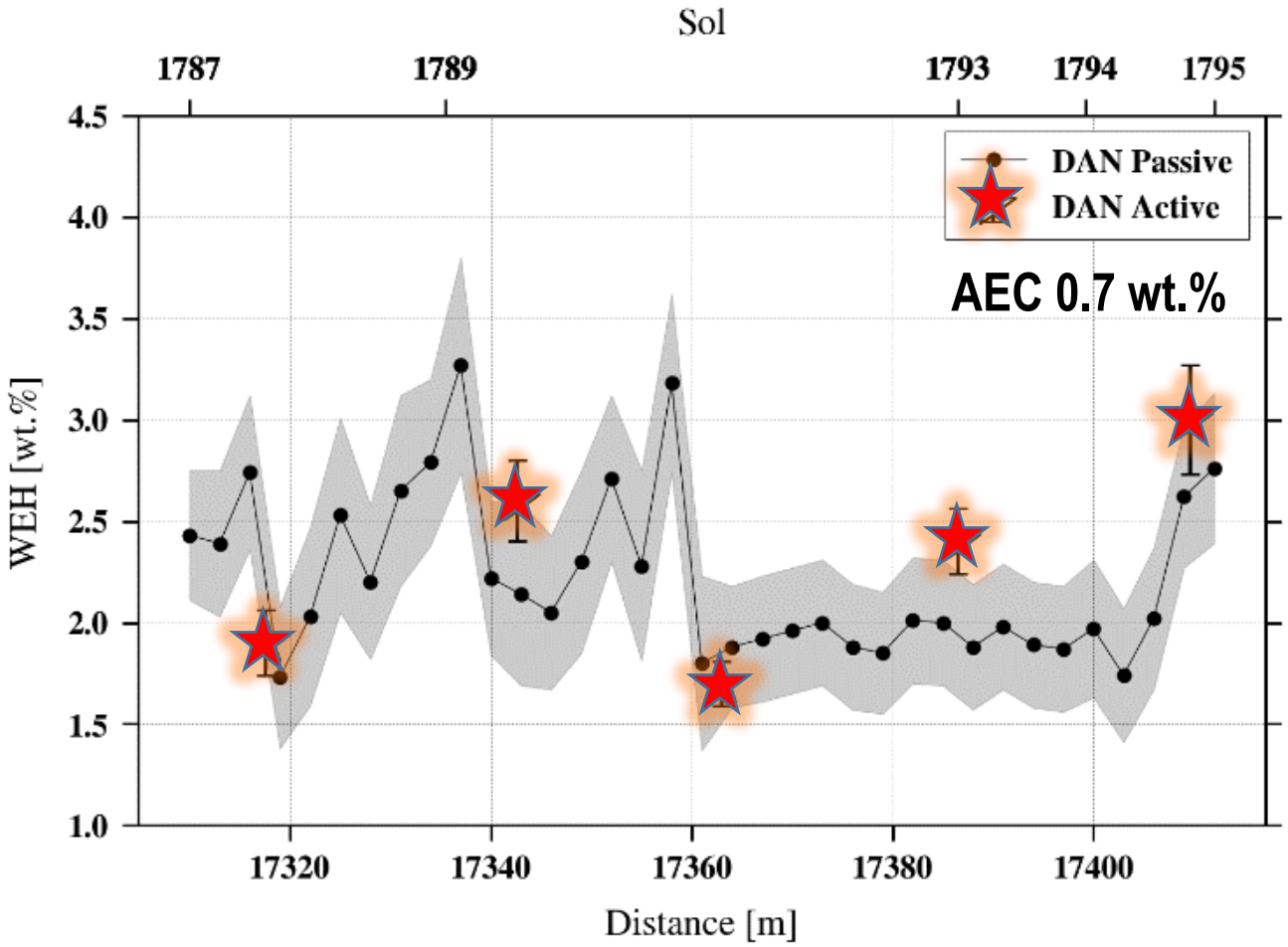
For each range of **AEC_{Active}** the empirical dependence **WEH_{Active} - F_{DAN}** was described by a linear regression function.

- The Active data was distributed into 10 groups with AEC_{Active} to provide statistically close number of values (table is available in backup)
- AEC values from 0.35 up to 2.5 %.
- Measurements only with *homogenous model* were used.
- Active data was used from sol 3 up to sol 2218.



AEC assessment. Long range variation.

- AEC content is known from Active measurements
- AEC variations are within the bounds of uncertainty
- To assess traverse data: AEC values are interpolated between stop measurements

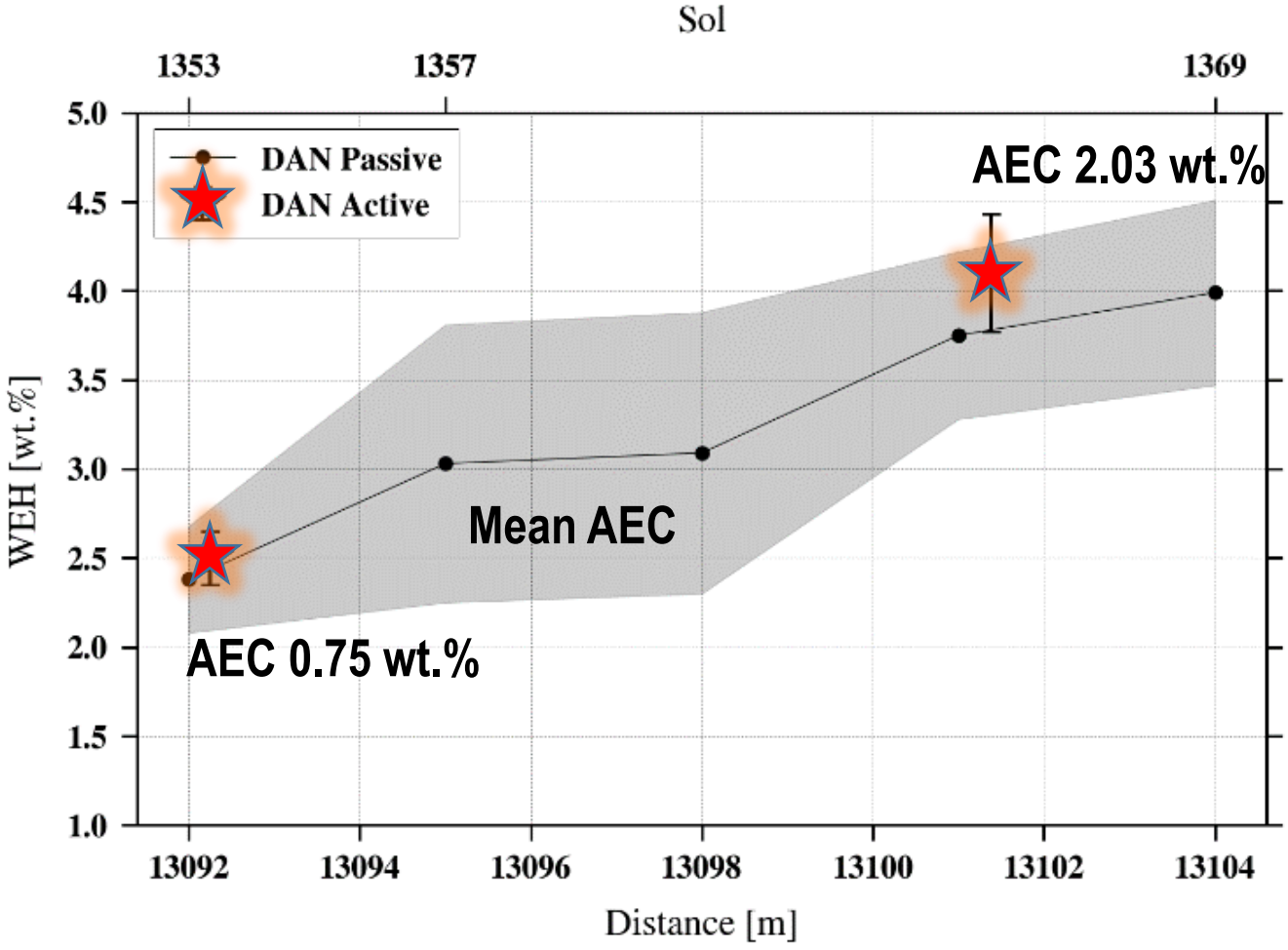


Example: five active measurements were taken along the 92 meters long path between the odometry marks of 17 317 meters and 17 412 meters.

AEC content are corresponds to **(0.7 ± 0.1)** wt.%.

AEC assessment. Short range variation.

- AEC content is known from Active measurements
- AEC variations are at a scale of several meters
- To assess traverse data: Active measurement mean AEC value is used

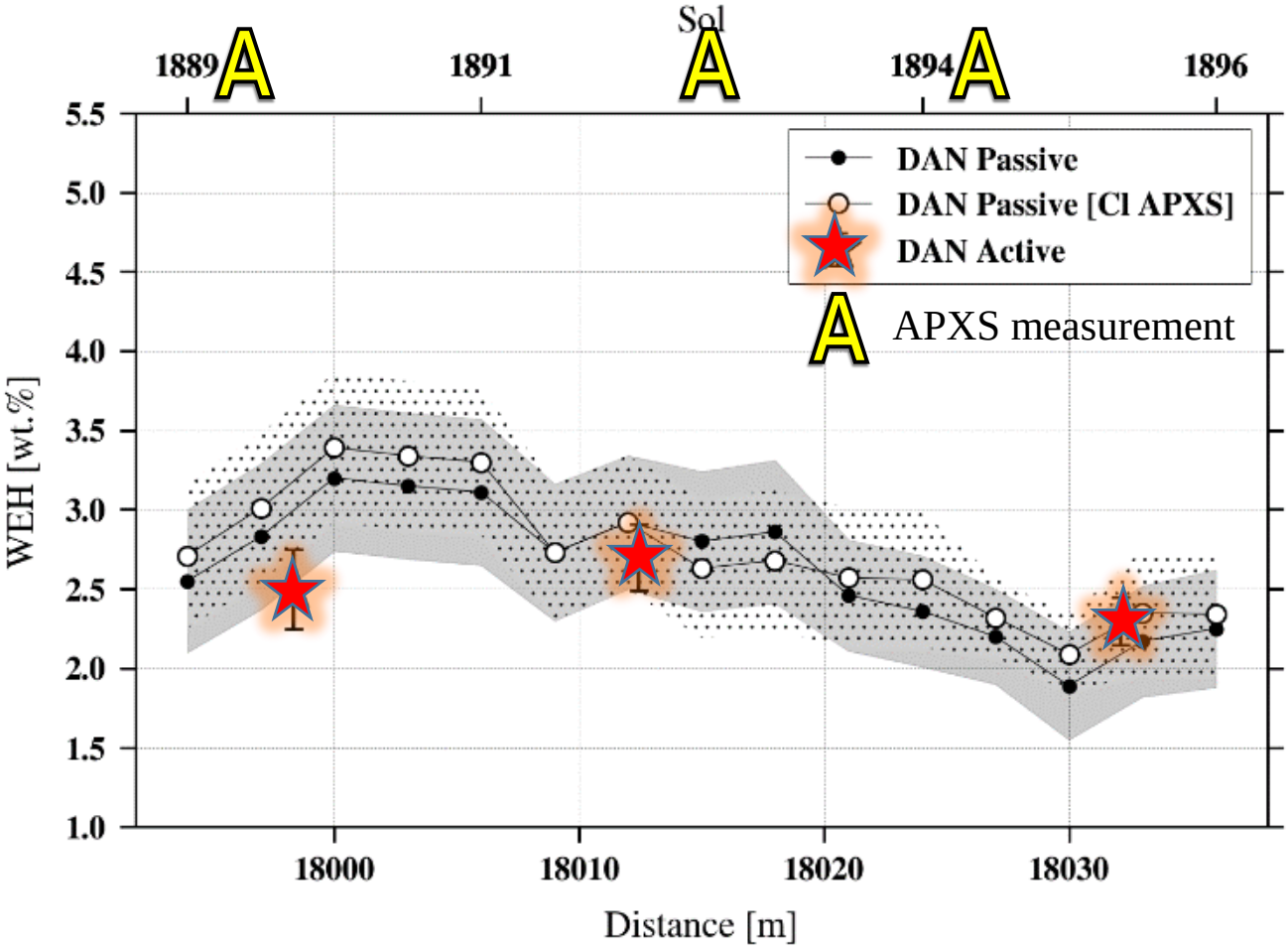


Example: at two spots at 13 092 meters and at 13 101 meters, the AEC content are **(0.75 ± 0.08)** wt.% and **(2.03 ± 0.19)** wt.%, respectively.

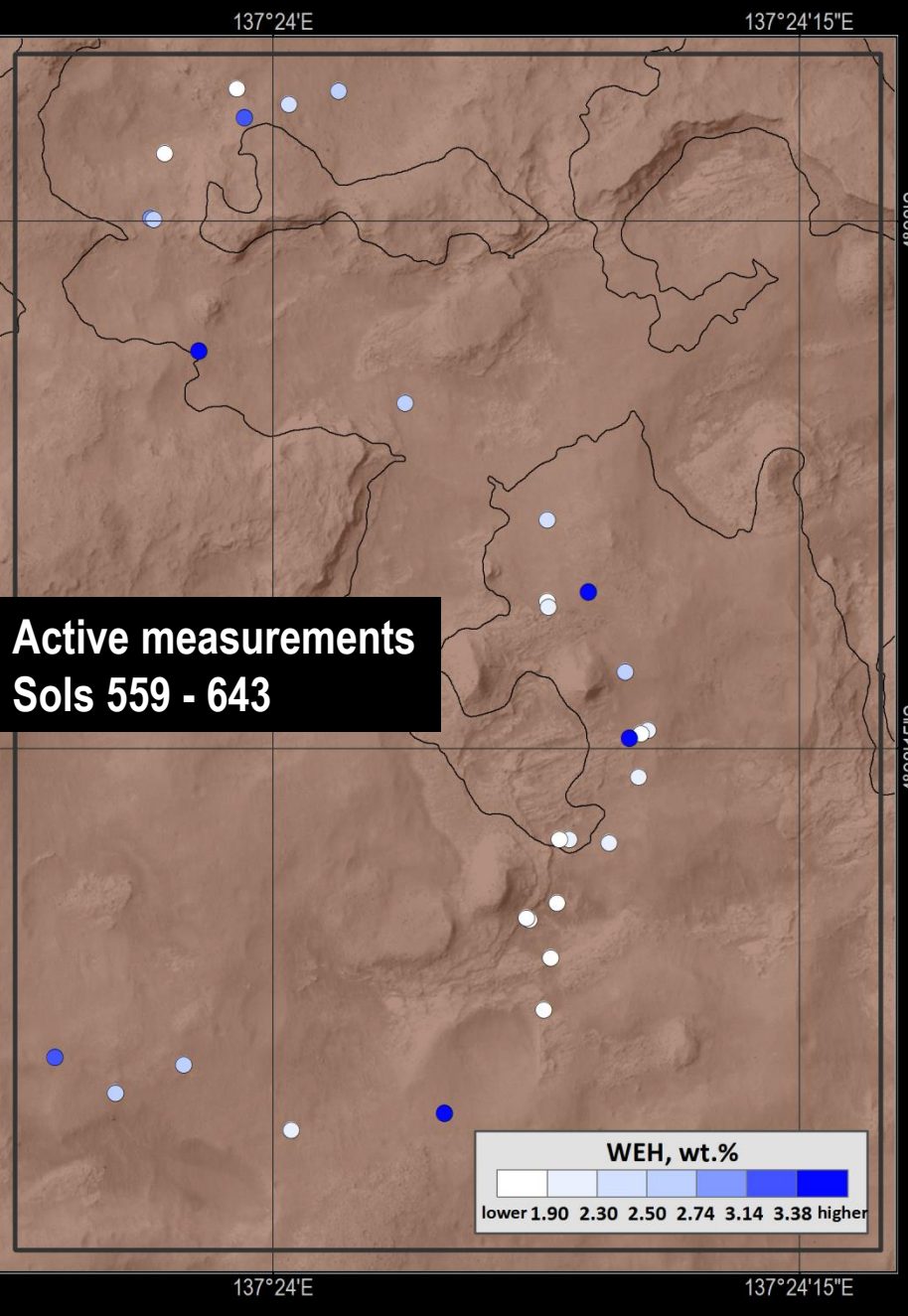
AEC mean value = 1.02 wt.%

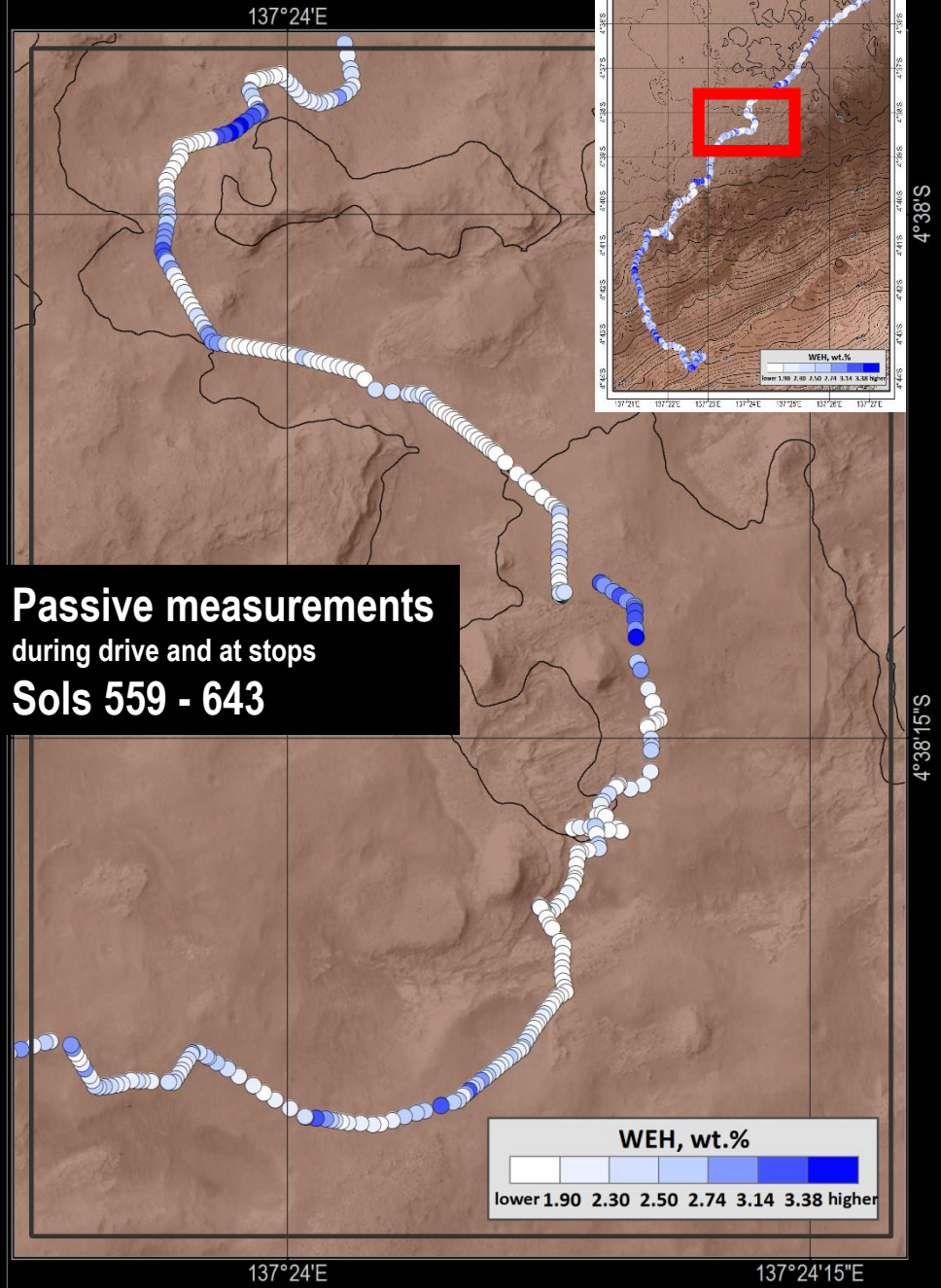
AEC assessment. Assessment by other instruments.

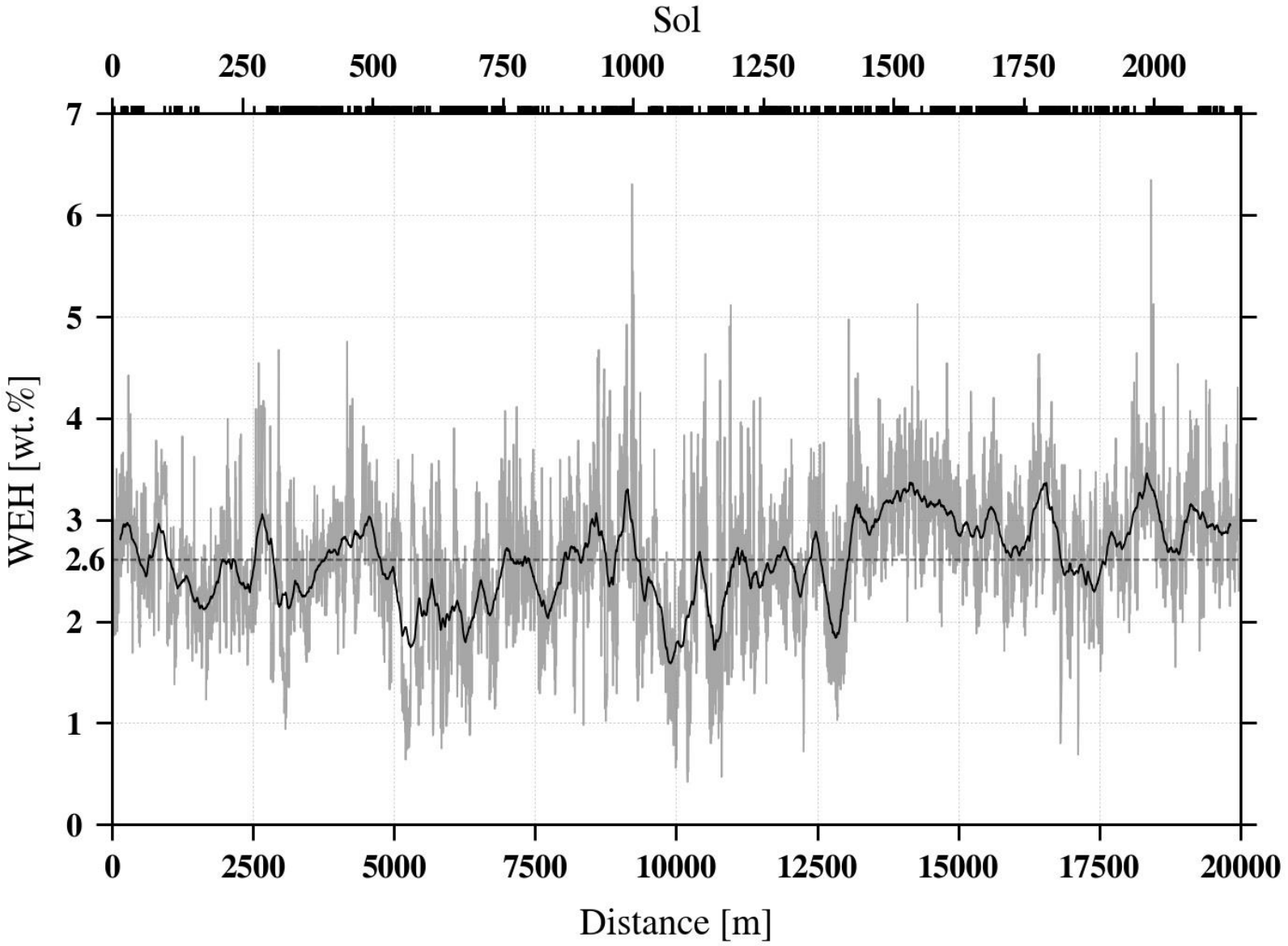
- Active measurements are not available
- AEC content is known from other instruments



Example: the interval between 17 994 and 18 040 meters.
The APXS and DAN measurements showed close average values of AEC.

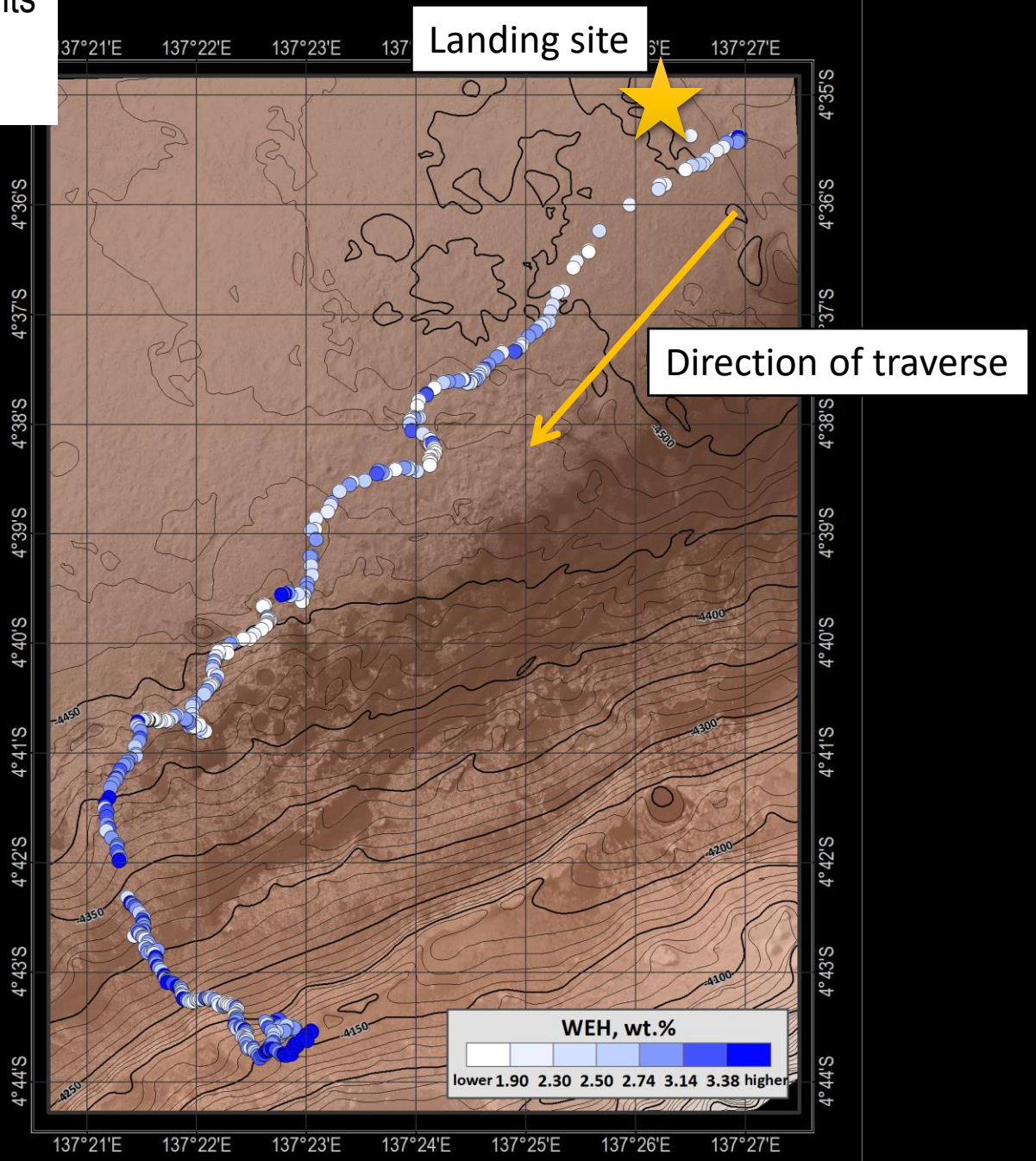

137°24'E
137°24'15"E
4°38'S
4°38'15"S
Active measurements
Sols 559 - 643
WEH, wt.%
lower 1.90 2.30 2.50 2.74 3.14 3.38 higher


137°24'E
137°24'15"E
4°38'S
4°38'15"S
Passive measurements
during drive and at stops
Sols 559 - 643
WEH, wt.%
lower 1.90 2.30 2.50 2.74 3.14 3.38 higher



WEH content profile based on DAN Passive measurements along the traverse (3-meter footprint, including stop and drive) from the MSL landing site up to Sol 2218. Mean WEH is (2.6 ± 0.7) wt.% (dotted grey line)

Passive measurements
at rover stops
Sols 3 - 2218



Conclusions

- **The method for WEH analysis was proposed for DAN Passive measurements. This method is described in Nikiforov et al., Icarus 346C (2020) 113818 https://doi.org/10.1016/j.icarus.2020.113818**
- **The method provides data analysis during the MSL rover stops and drive, and gives possibility for local subsurface studies during the rover in drive.**
- **It is expected to use this method as a basis for data processing with the Adron-RM instrument in ExoMars 2022.**
- **Average WEH in Gale crater measured by DAN / MSL by sol 2218: (2.6 ± 0.7) wt%**
- **Expected average WEH by Adron-RM / ExoMars in Oxia Planum: (2.1 ± 0.5) wt%**