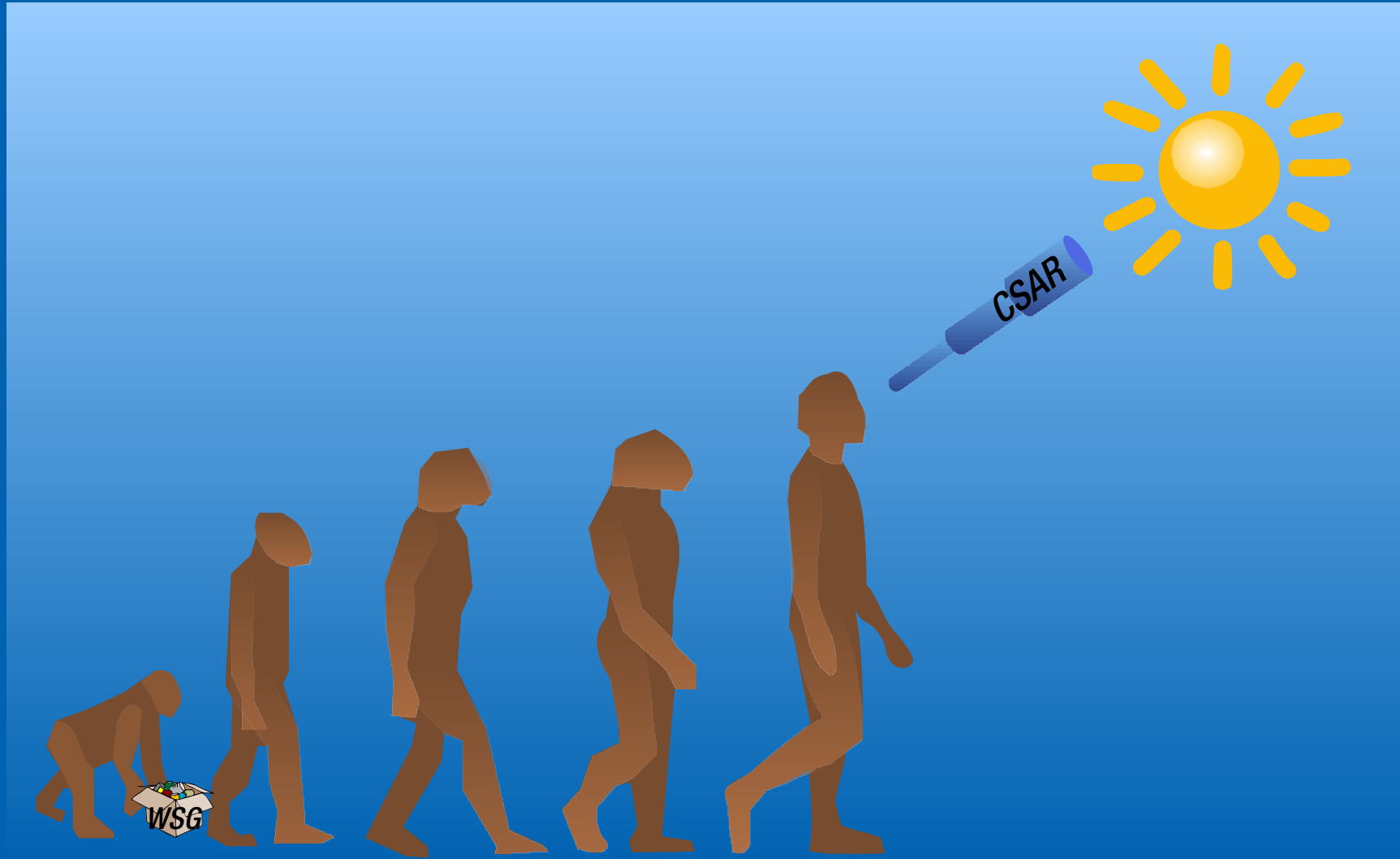


# Cryogenic Radiometer for Total Solar Irradiance

NEWRAD 2011  
Wolfgang Finsterle

# How it all began...



**NEWRAD 2008**

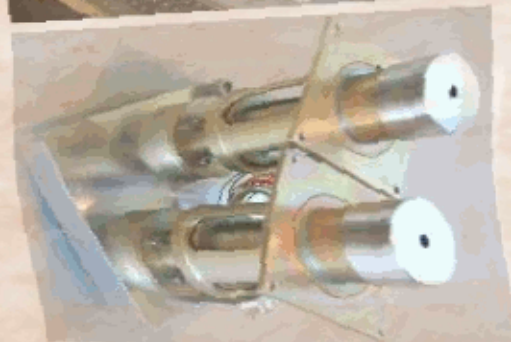
# The Cryogenic Solar Absolute Radiometer (CSAR) Project



Cryogenic radiometer (see session *Scale Realization*: Poster P\_22 by Rainer Winkler et al.)



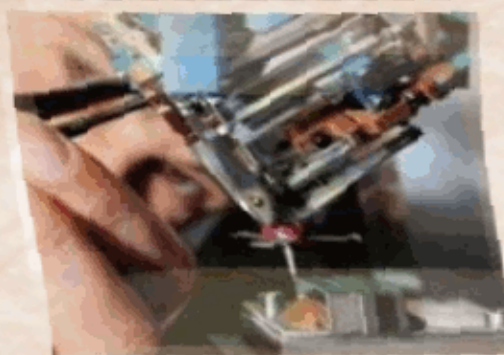
Ambient temperature transmission monitor (see session *Absolute Radiometry*: Poster P\_26 by André Fehlmann et al.)



*pmod* wrc

**METAS**

Radiometric aperture  
Spectral characterisation



*pmod* wrc

# History of the World Radiometric Reference (WRR)

**NEW RAD 2008**

1977

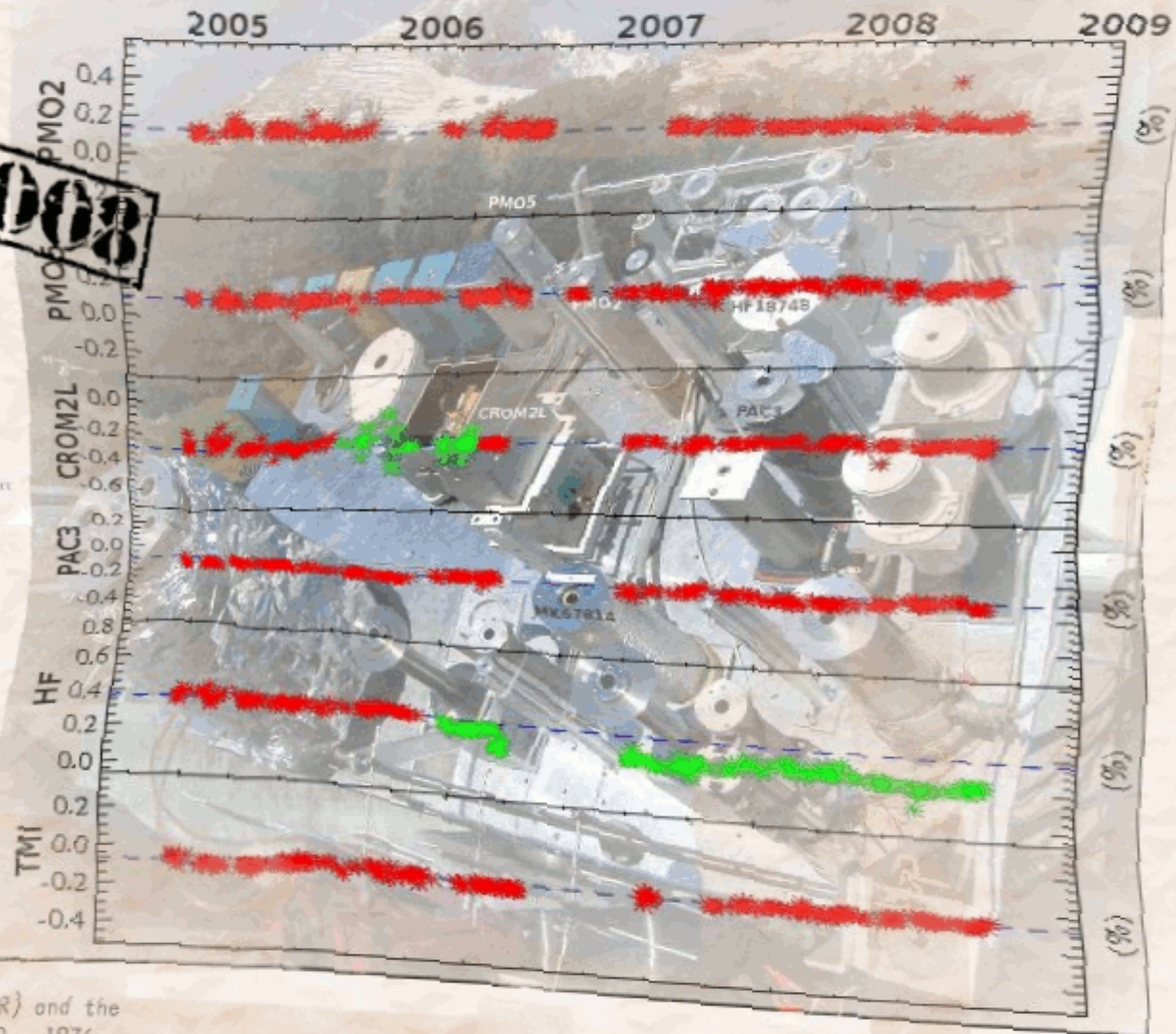
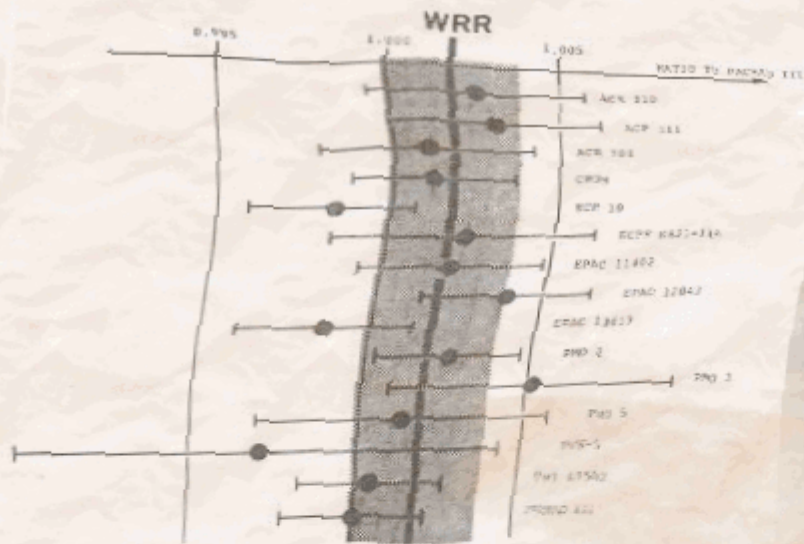
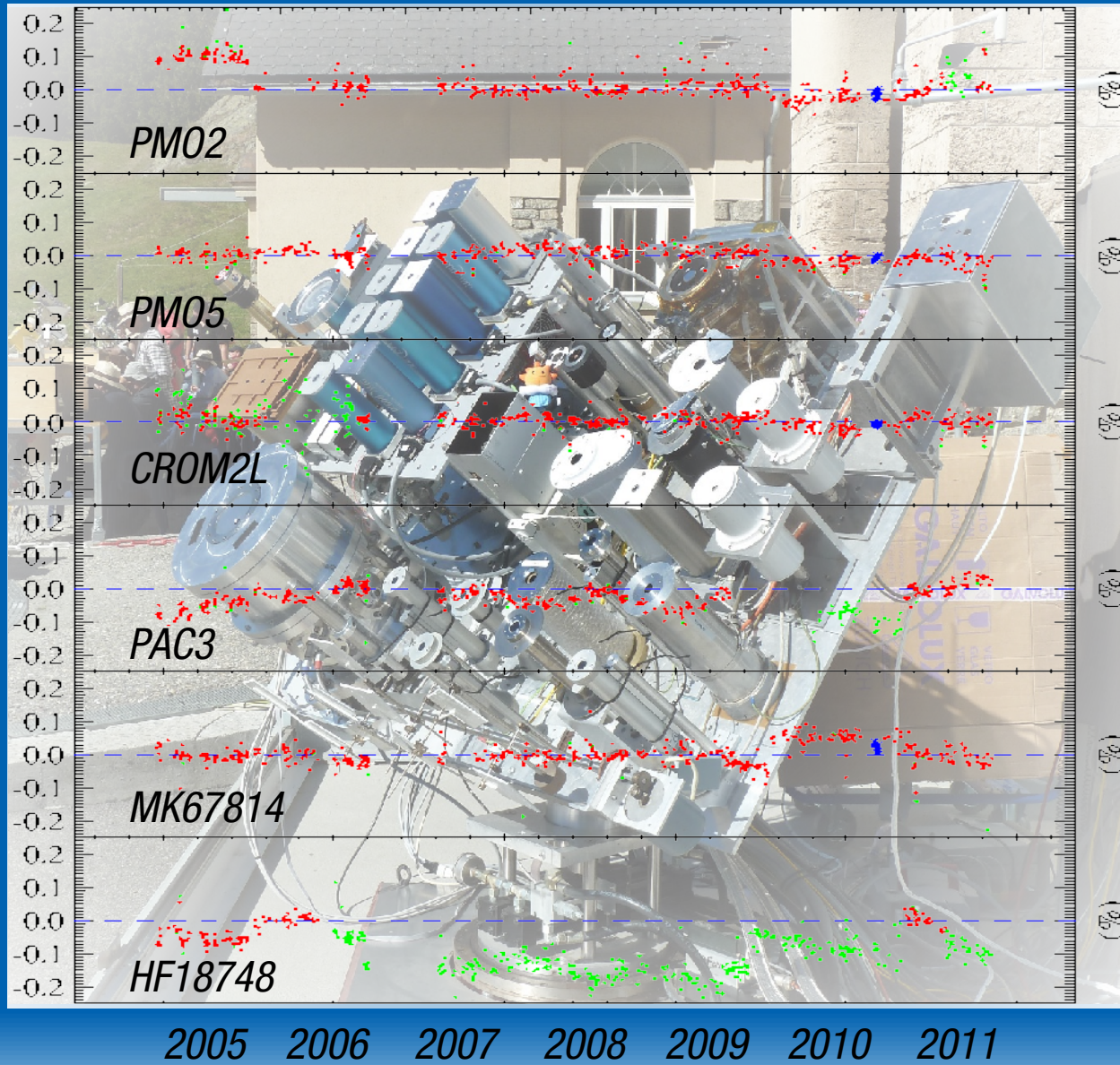
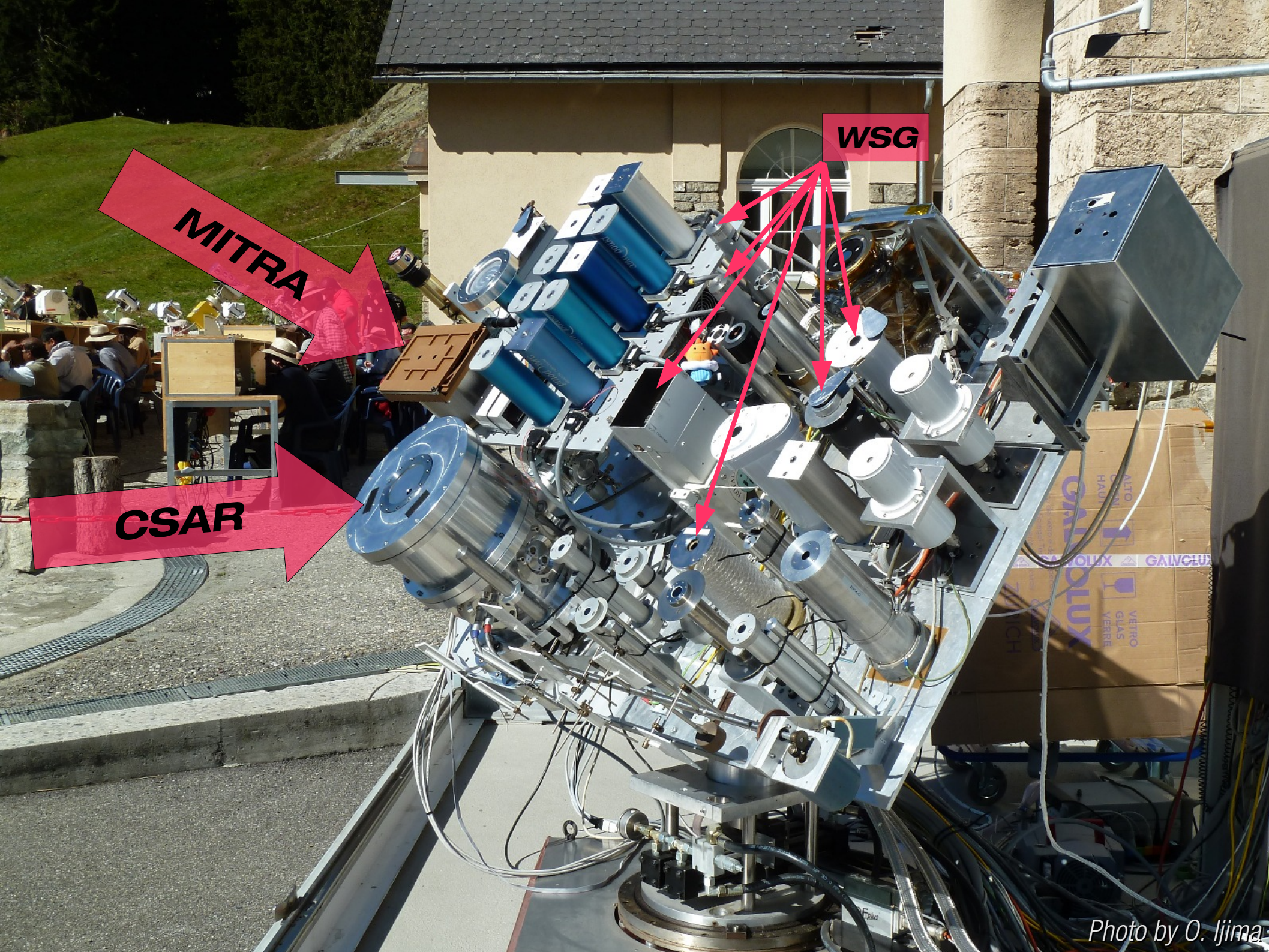


Figure 1: The definition of World Radiometric Reference (WRR) and the results of the Absolute Radiometer Comparisons 1970 - 1976. The shaded area represents a  $\pm 0.2\%$  range around WRR

*...three years later*





**MITRA**

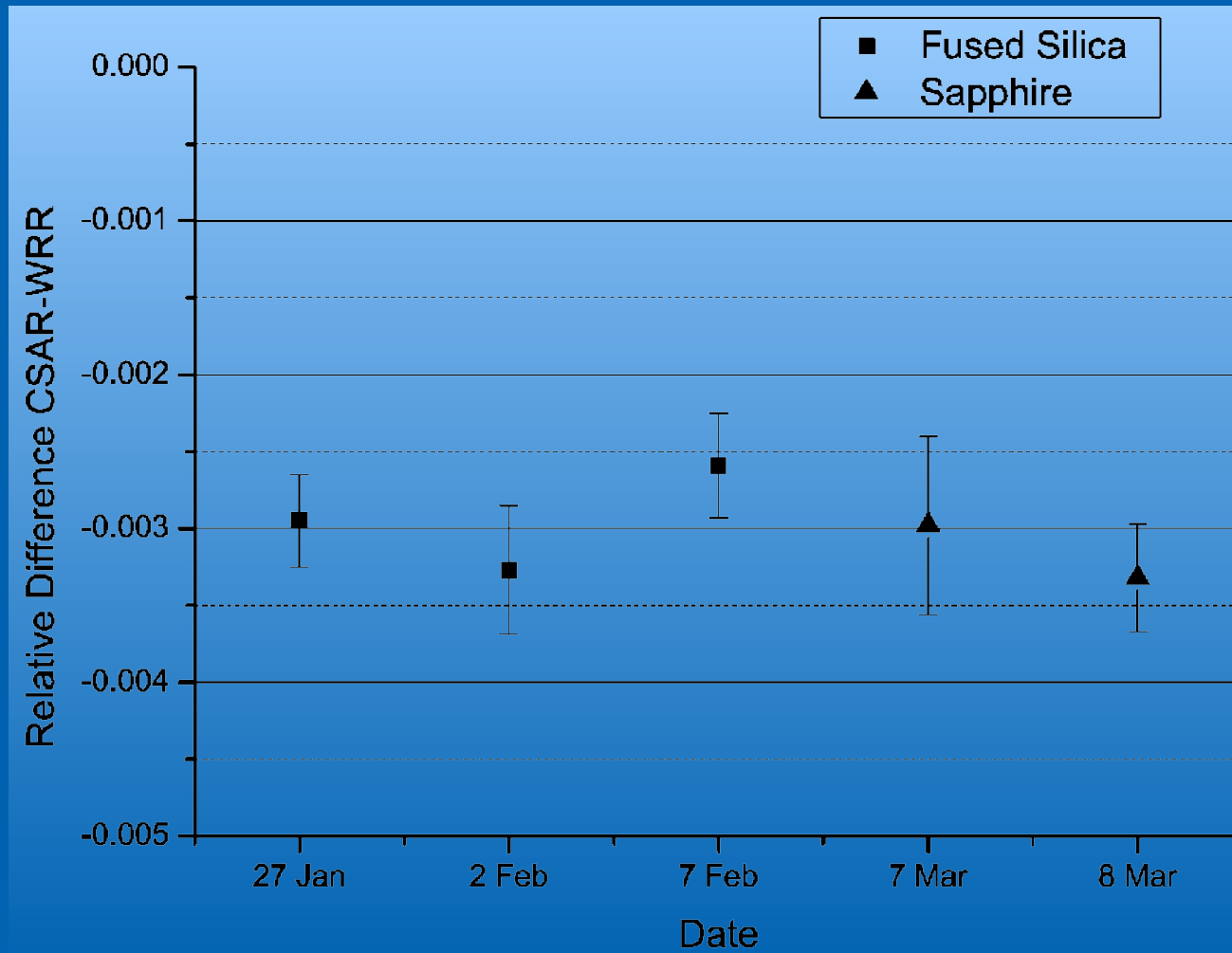
**CSAR**

**WSG**

## *CSAR Concept*

- Cryogenic radiometer measures solar irradiance (CSAR)
- Ambient temperature differential radiometer monitors window transmittance (Monitor for Integrated Transmittance, MITRA)

# CSAR-to-WRR Ratio



Graphics by R. Winkler

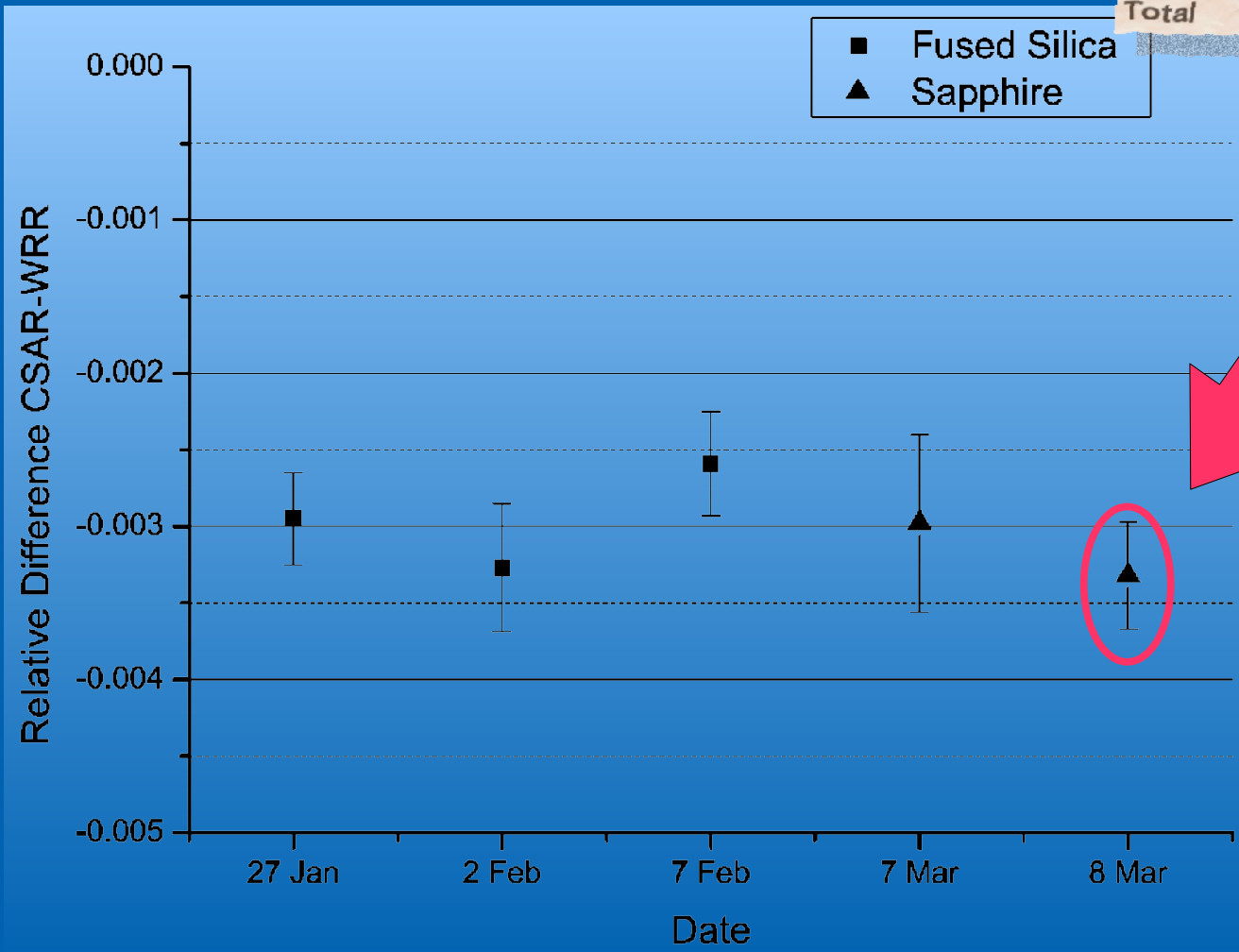


# CSAR-to-WRR Ratio

Tentative uncertainty budget of the CSAR (k=2)

Source of uncertainty	parts per million (ppm)
cryogenic radiometer	50
entrance window	100
radiometric aperture	50
<b>Total</b>	<b>122</b>

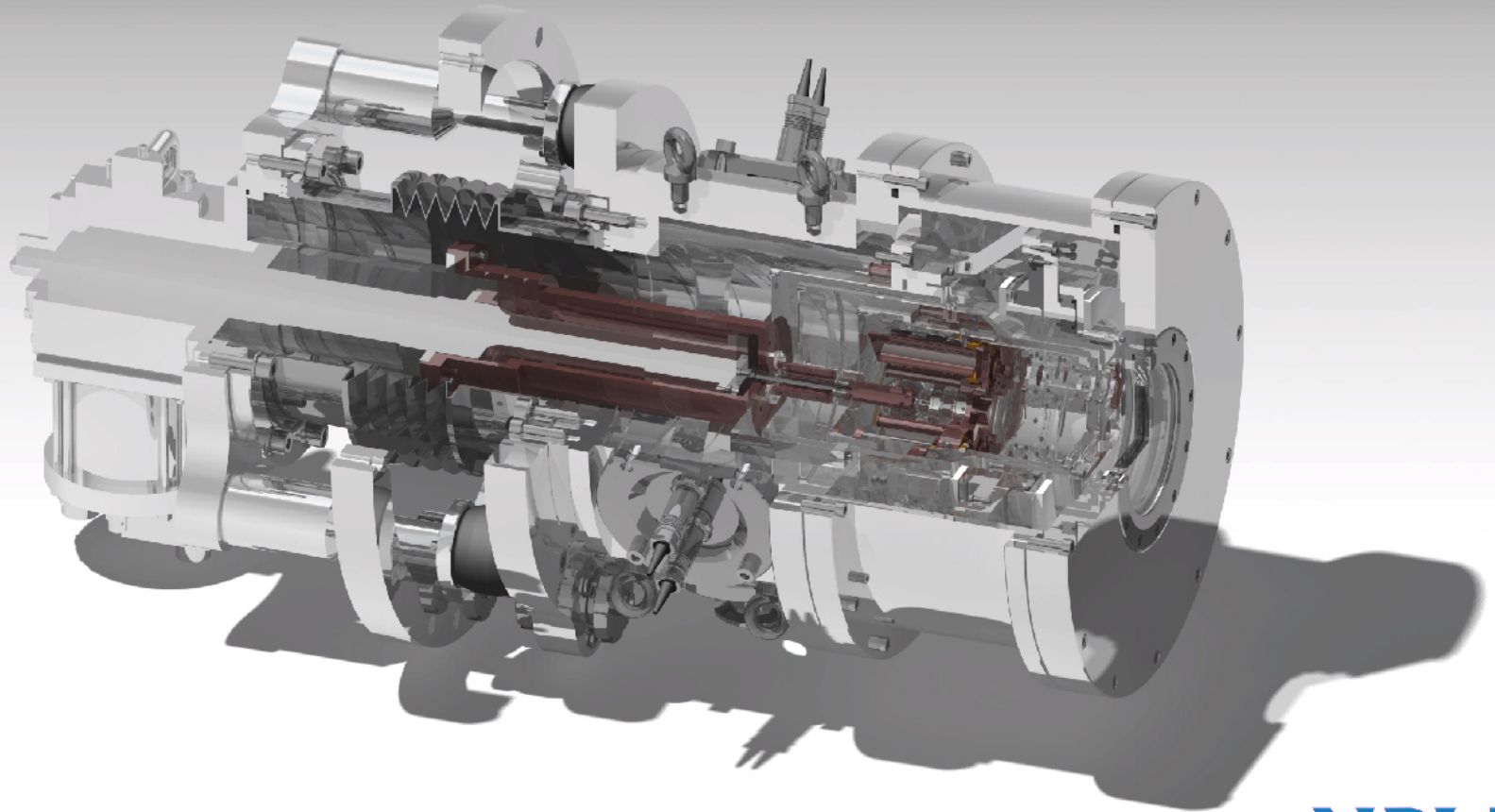
*NEWRAD 2008*



**almost!**

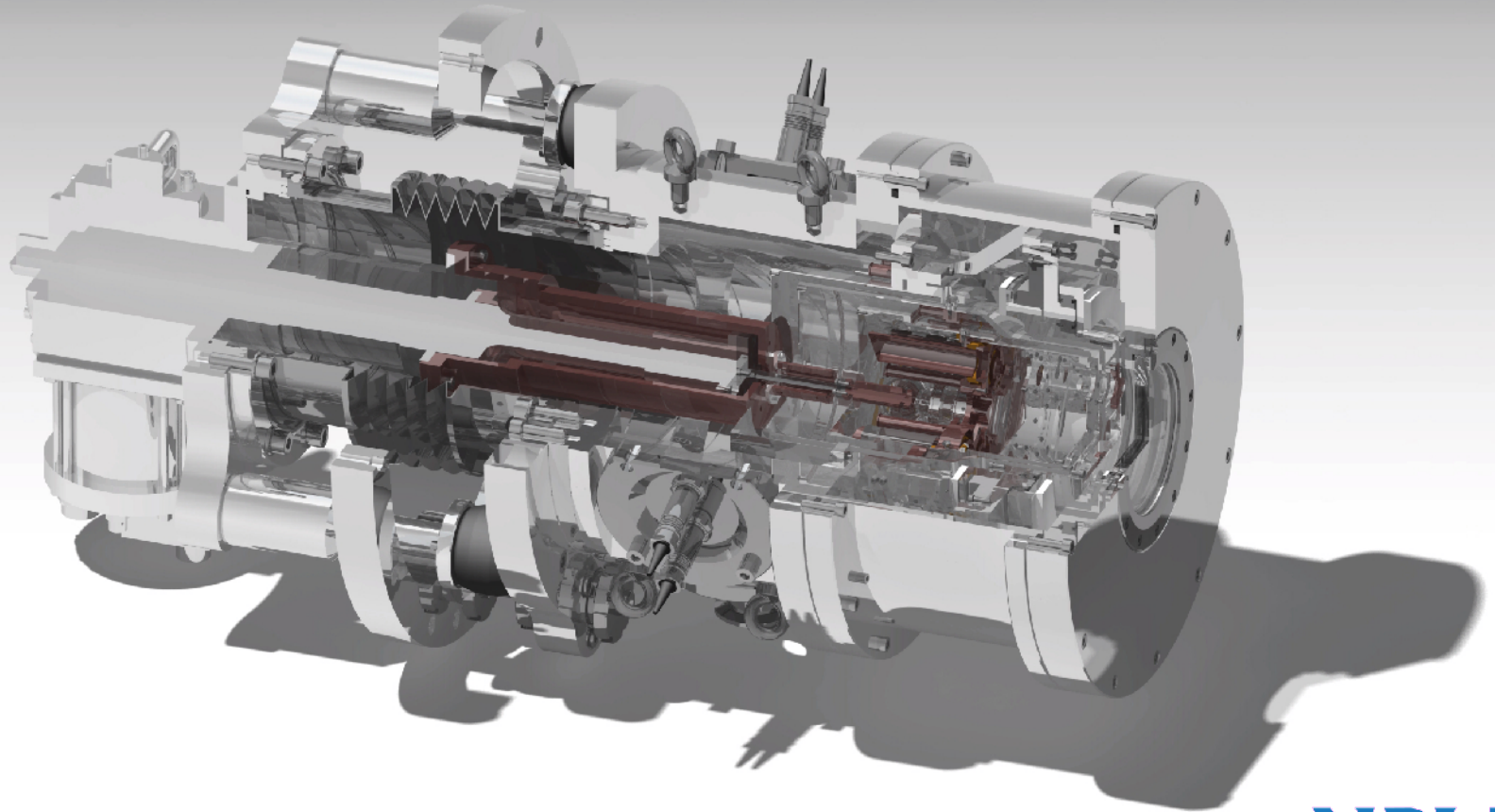
Graphics by R. Winkler

# CSAR Measurement Principle



*The cryogenic stage measures irradiance below window cut-off*

# CSAR Measurement Principle



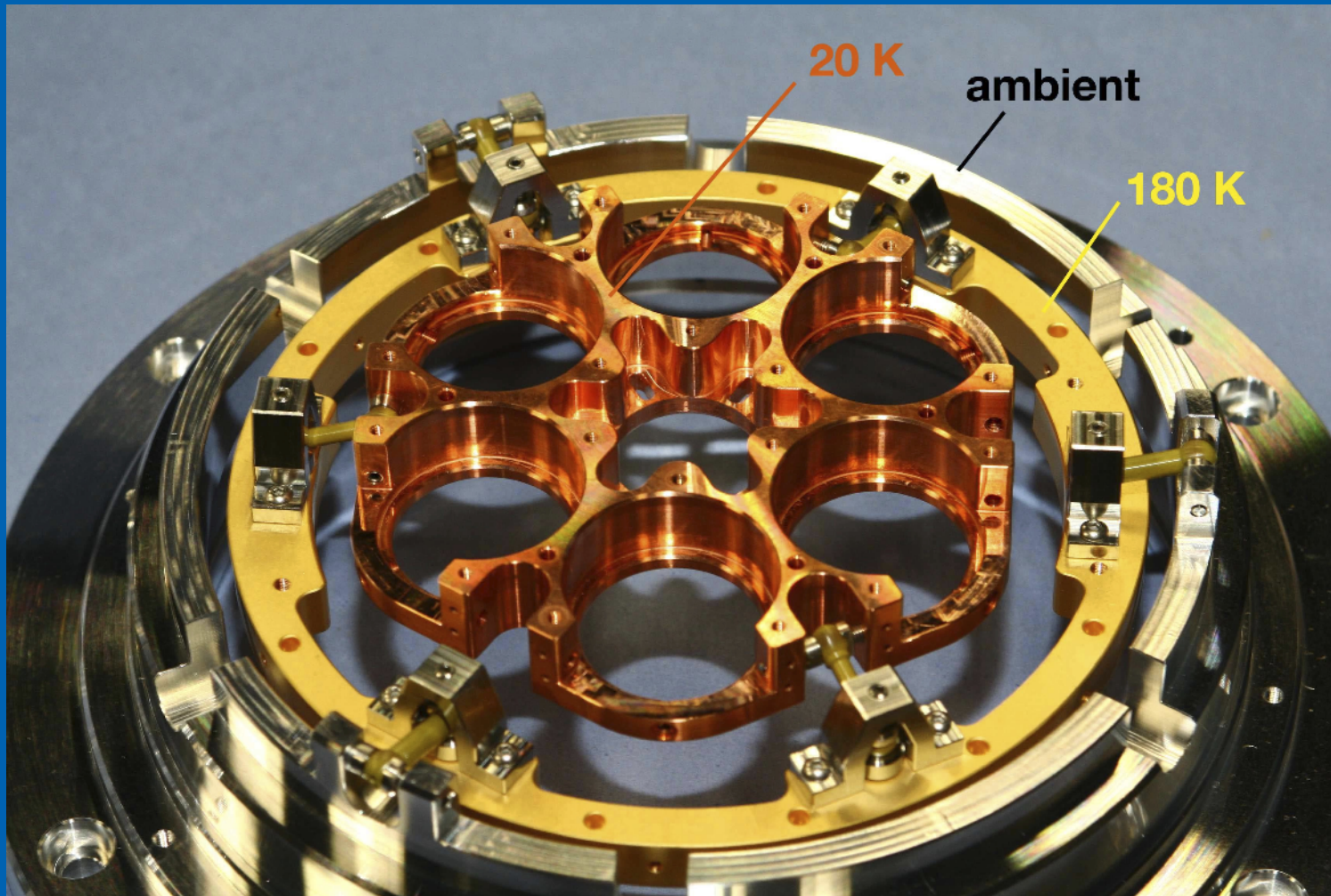
*The cryogenic stage measures irradiance below window cut-off*

→ Poster SSR\_OR\_005 by Rainer Winkler

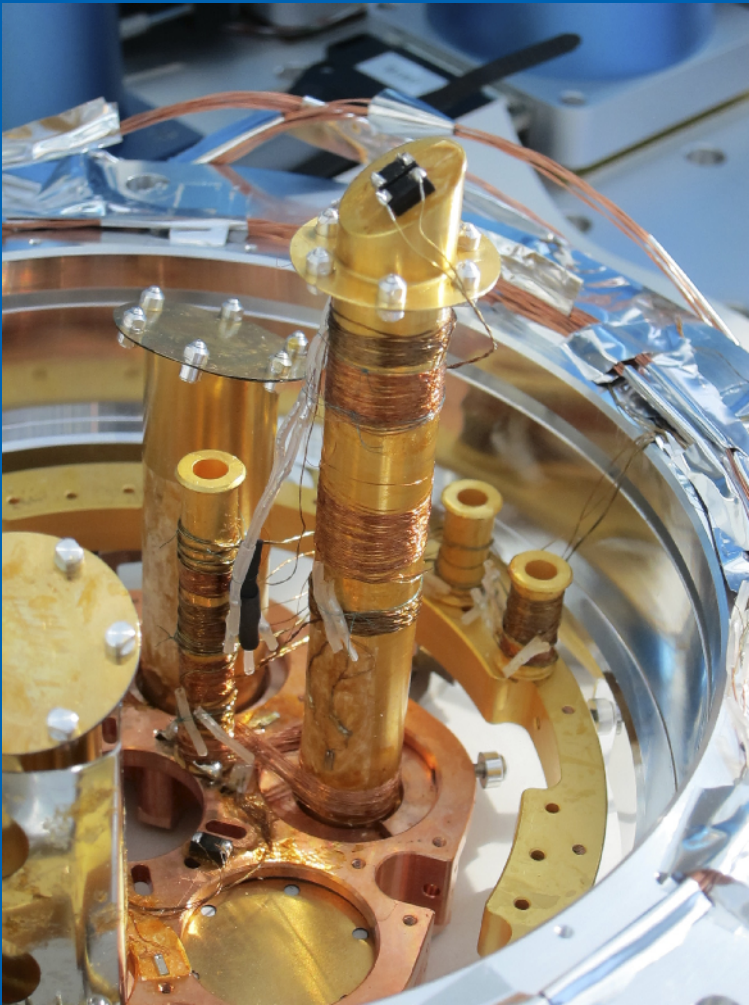
## *CSAR – Design Features*

- Mechanical cooling system
  - Sensor stage: ~25 K (0.4 W)
  - Thermal shield: ~100 K
  - Entrance window and aperture: ambient
- 5 mm entrance aperture (aluminum)
- Temperature-stabilized reference block
- Sapphire or Quartz entrance window
- External shutter

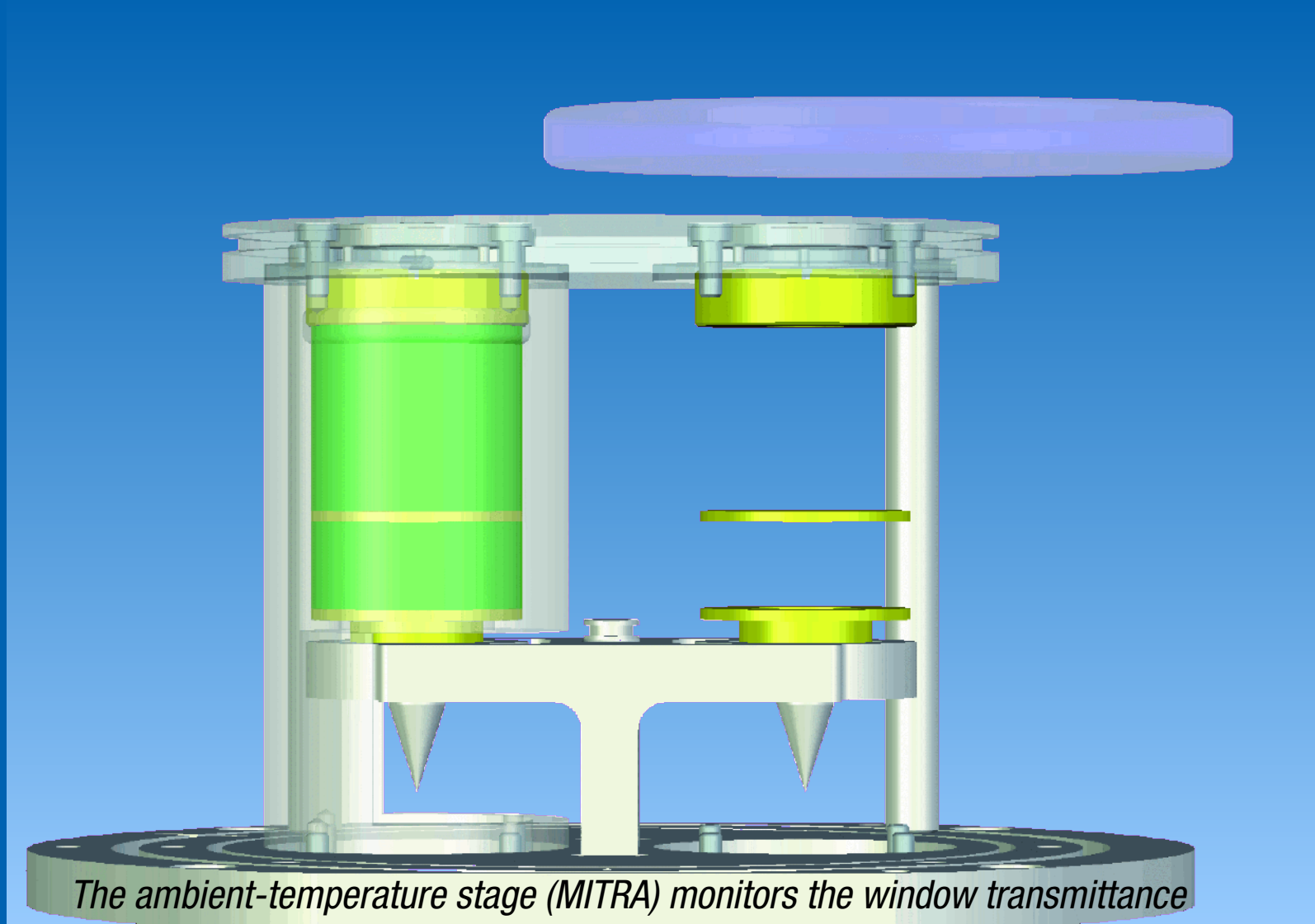
# CSAR Reference Block



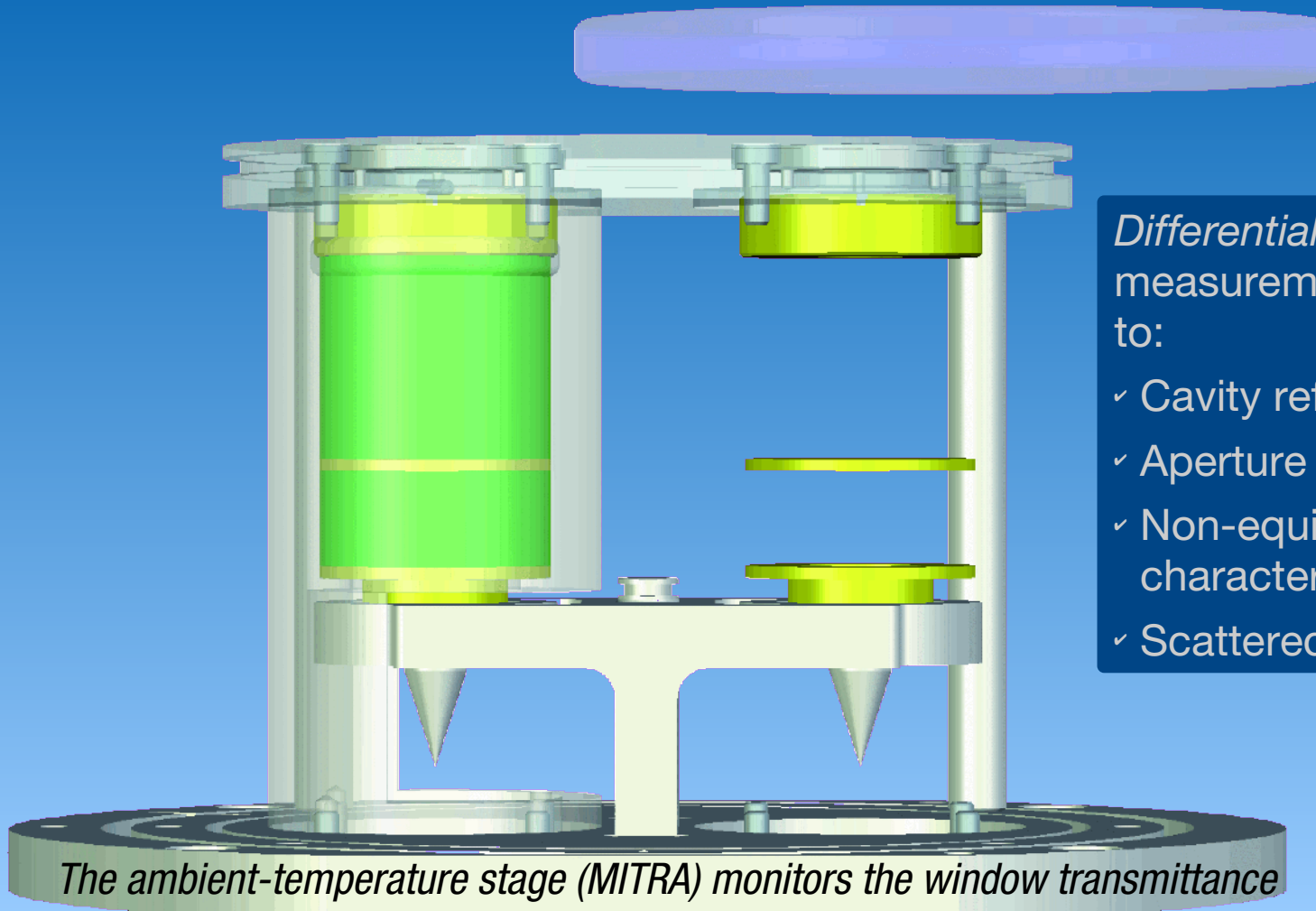
# CSAR Cavities and Heat Link



## *MITRA Measurement Principle*



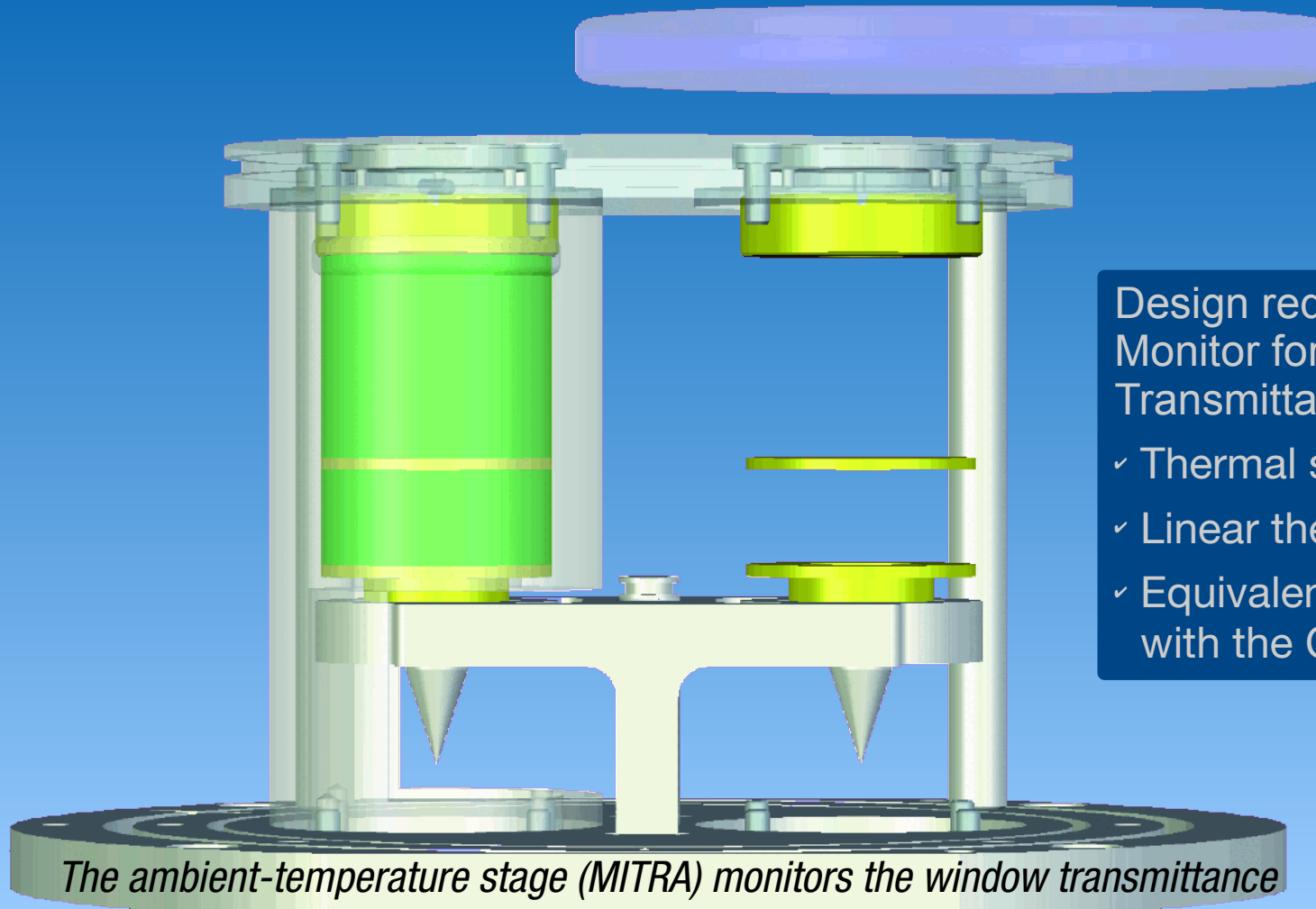
# MITRA Measurement Principle



- Differential and passive* measurements are insensitive to:
- ✓ Cavity reflectance
  - ✓ Aperture area
  - ✓ Non-equivalence and characteristics of control loop
  - ✓ Scattered light and diffraction



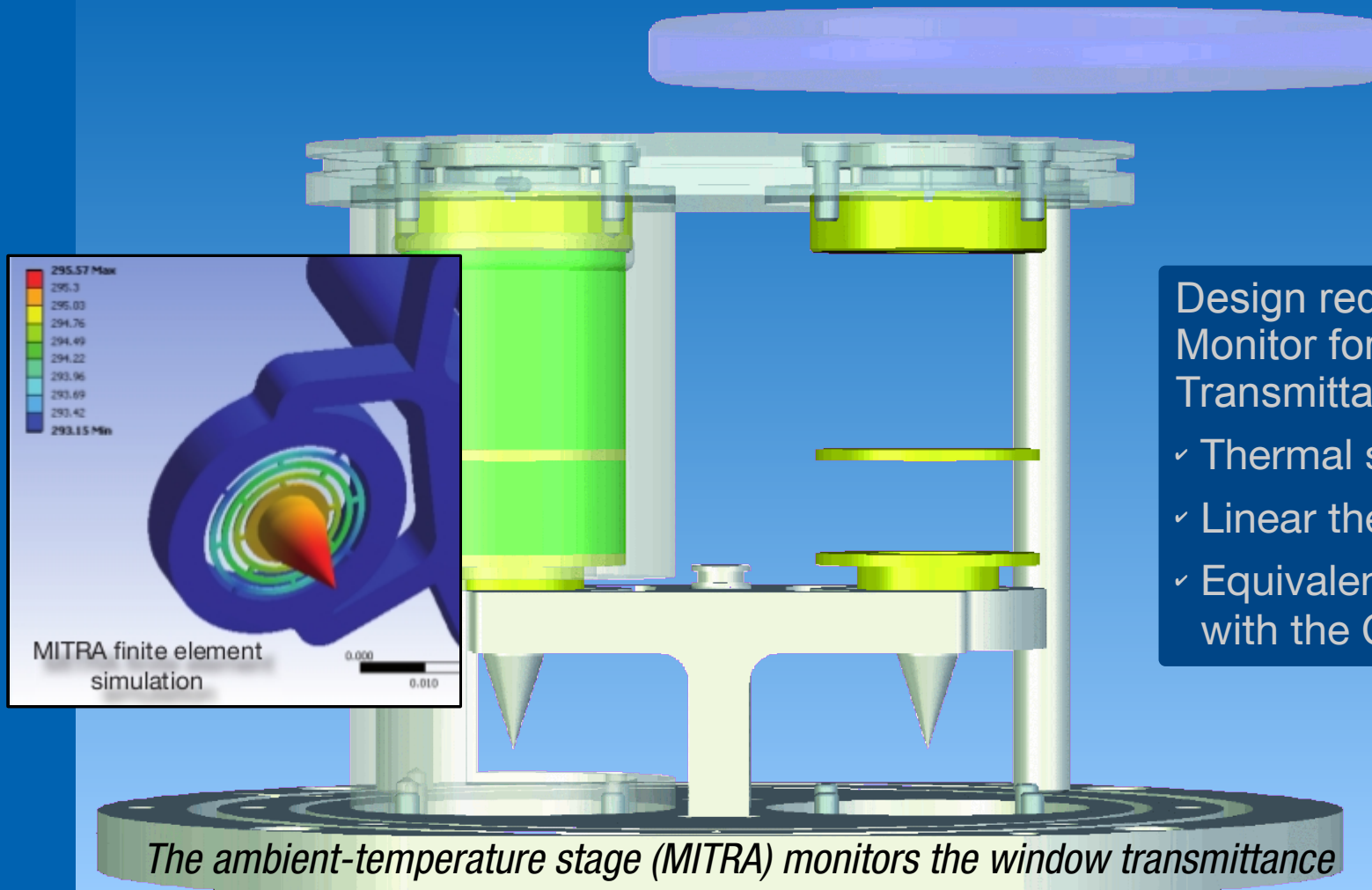
# MITRA Measurement Principle



- Design requirements for the Monitor for Integrated Transmittance (MITRA):
- ✓ Thermal symmetry
  - ✓ Linear thermometers
  - ✓ Equivalent window material with the CSAR

*The ambient-temperature stage (MITRA) monitors the window transmittance*

# MITRA Measurement Principle

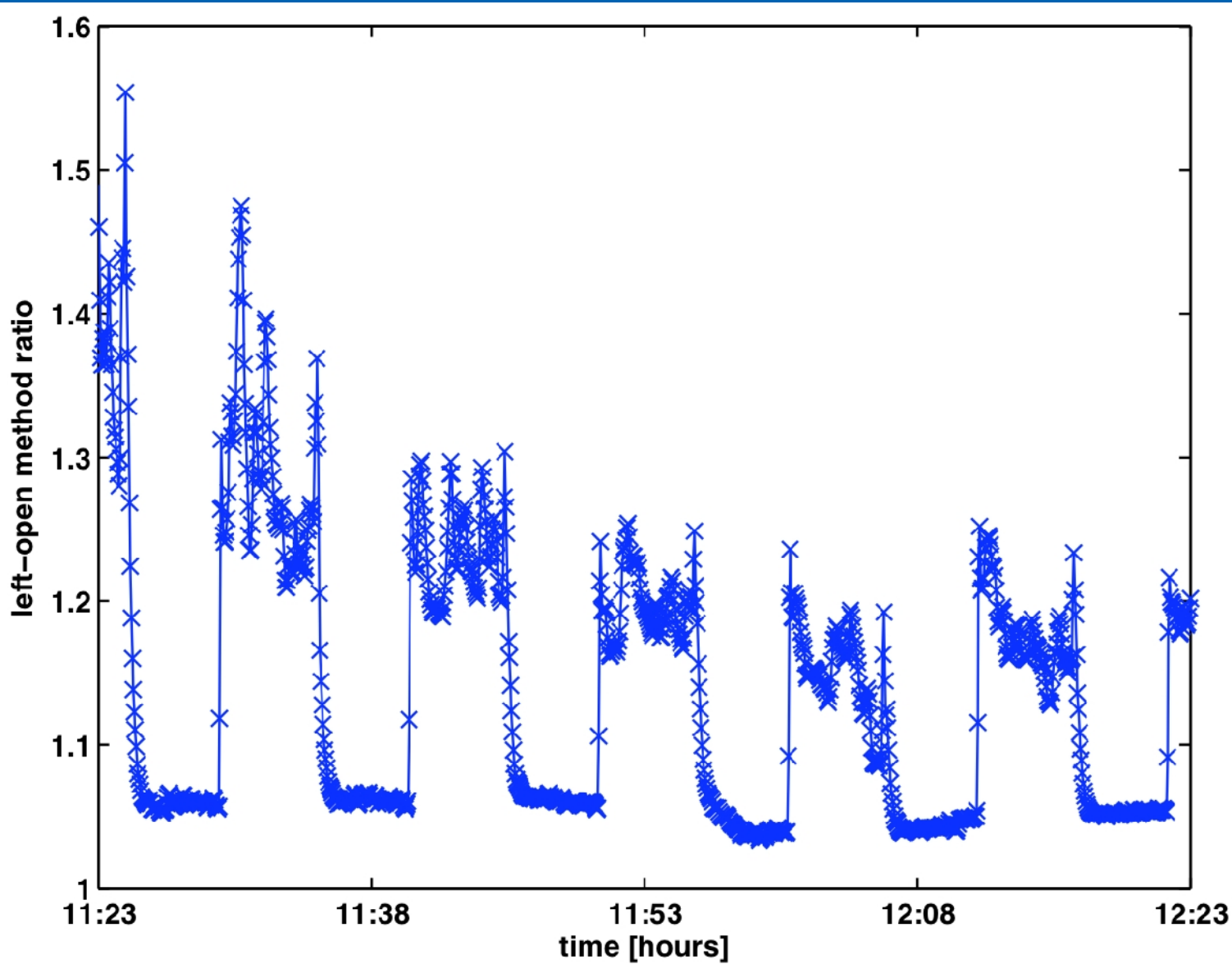


Design requirements for the Monitor for Integrated Transmittance (MITRA):

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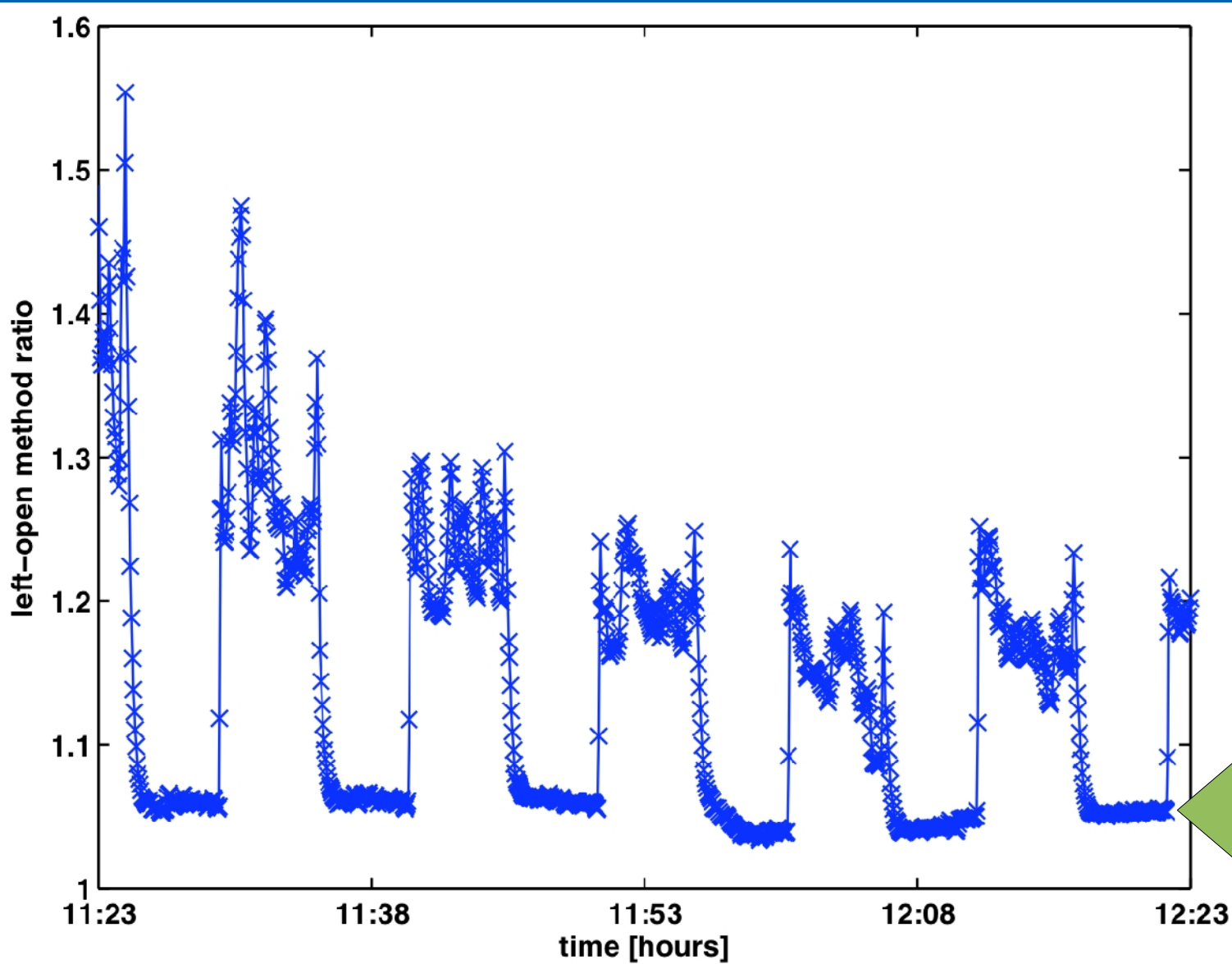
→ Poster SSR\_OR\_010 by André Fehlmann

# MITRA Stability Issue



Graphics by A. Fehlmann

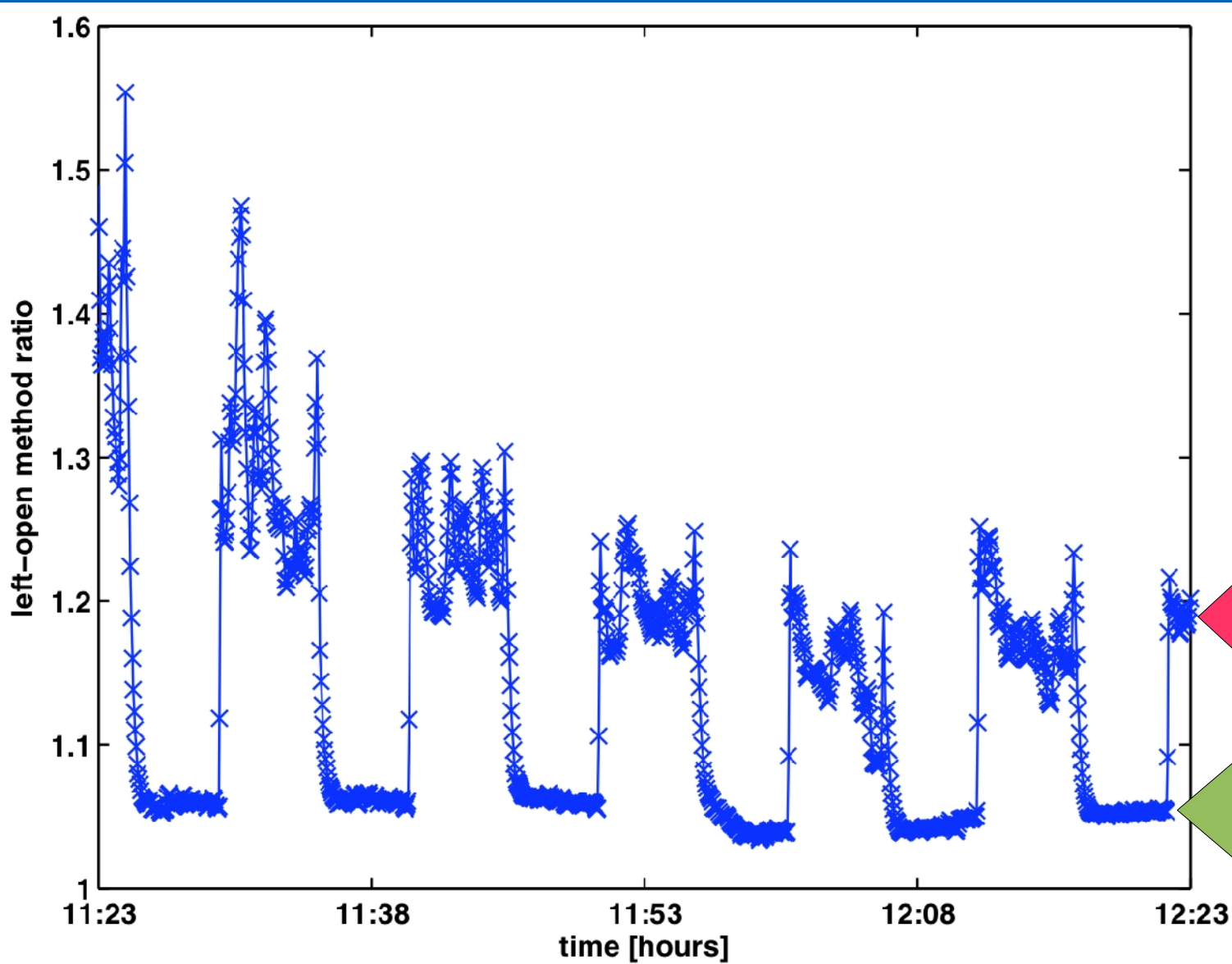
# MITRA Stability Issue



≈ 100 ppm when irradiated symmetrically

Graphics by A. Fehlmann

# MITRA Stability Issue



*noisy when one cavity is windowed*

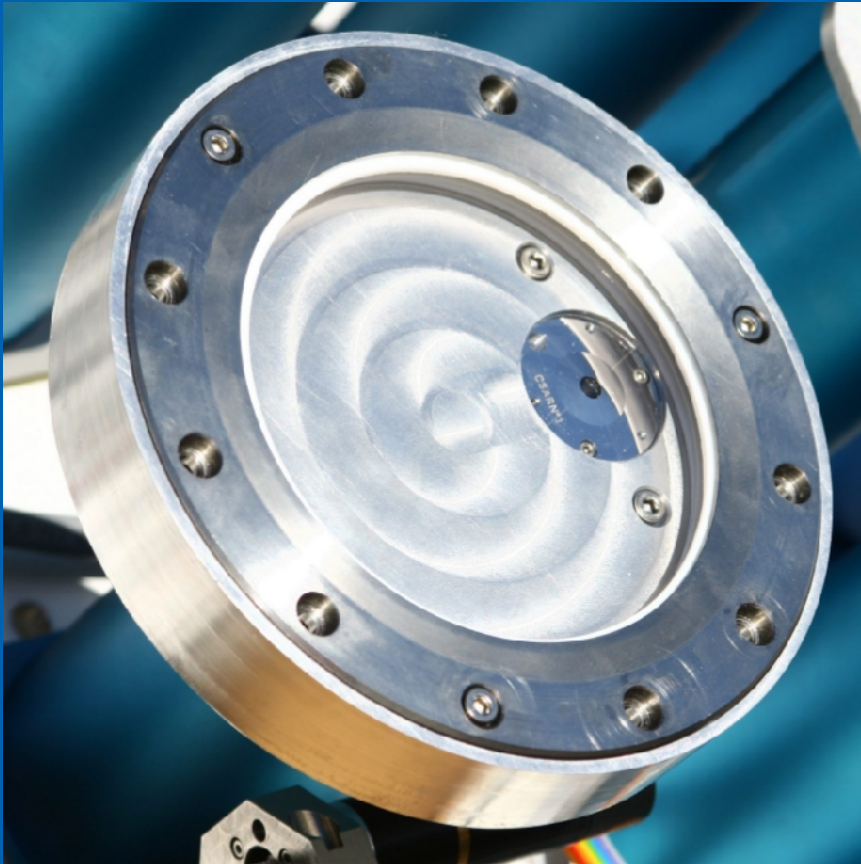
*≈ 100 ppm when irradiated symmetrically*

Graphics by A. Fehlmann

## *MITRA Stability Issue – Potential Causes*

- 😊 No issue when both cavities are irradiated symmetrically
  - 😊 *MITRA performs to specs, thus validating the design principle*
- 😞 High noise level when one cavity is windowed
  - 🤔 *Asymmetric heat loss to environment?*
  - 🤔 *Influence of wind?*
  - 🤔 *Irregular scattering?*

# Surrogate Transmittance Monitor



- Modified cavity radiometer (PMO6)
- Absolute irradiance measurements!
  - Need to average over a day to boost accuracy
  - Only reasonable on days with stable conditions

## *Discussion and Conclusions*

- The CSAR can measure daily-averaged total solar irradiance with an absolute uncertainty of ~500ppm
  - Target uncertainty of ~100ppm not yet reached
- The WRR scale is ~0.3% too high
  - Independently confirmed by a (monochromatic) irradiance source in the laboratory (TRF, LASP, cf. Presentation SSR\_OR\_009 by André Fehlmann)



## *Current Limitations of the CSAR/MITRA and Future Steps Towards a New Primary Standard*

- MITRA: stability issue when behind window
  - Transmittance only for daily averages
  - Identify the cause and solve the issue!
- CSAR: slow heater control loop
  - No differential measurements
  - Design and build dedicated heater controller
- Propose the CSAR/MITRA to WMO/CIMO

## *Additional Information*

- 1) Poster Session A, SSR\_OR\_005: Rainer Winkler,  
*Design Features and Test of the Cryogenic Solar Absolute Radiometer*
- 2) Poster Session A, SSR\_PO\_010: André Fehlmann,  
*Monitor to measure the Integrated Transmittance (MITRA) of Windows*
- 3) Oral Session 2a, SSR\_OR\_009: André Fehlmann,  
*Fourth World Radiometric Reference to  
Srradiometric scale comparison and implications to  
on-orbit measurements of the total solar irradiance*