

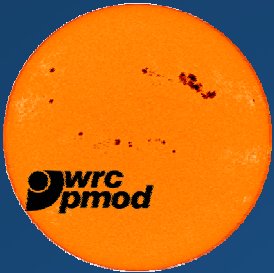
# Relation of the World Radiometric Reference to SI from Laboratory comparisons

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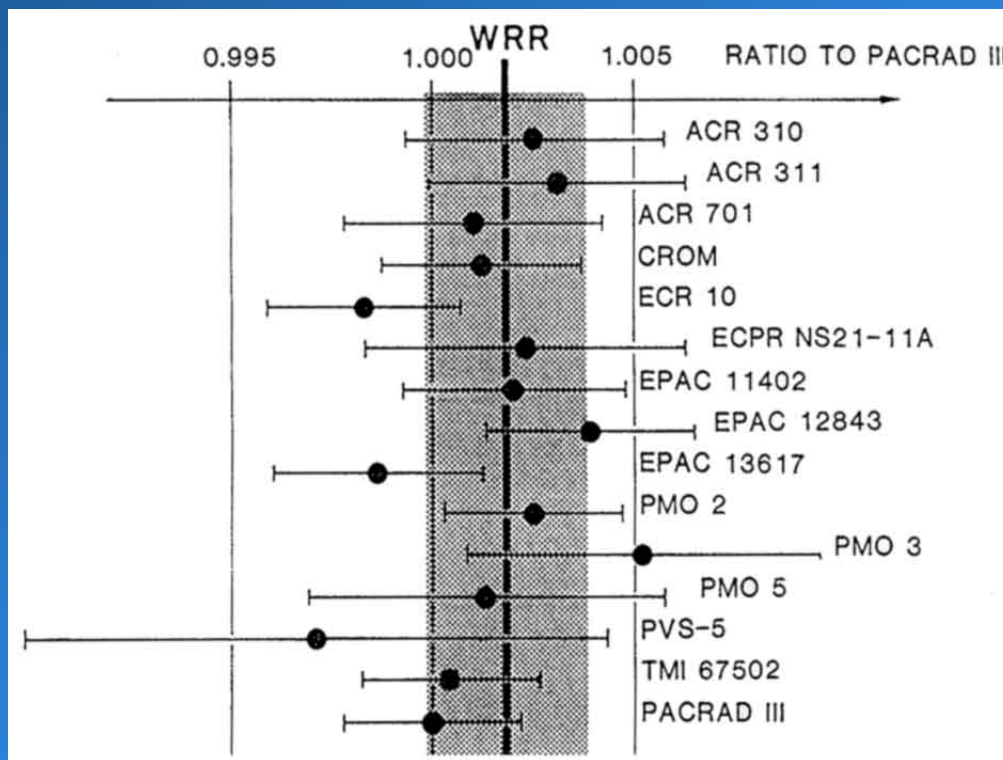
eMail: [cfrohlich@pmodwrc.ch](mailto:cfrohlich@pmodwrc.ch); <http://www.pmodwrc.ch>

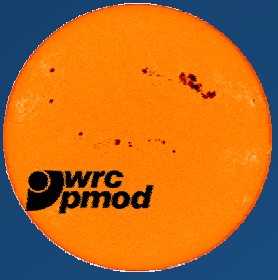
With contributions from Isabelle Rüedi and Wolfgang Finsterle



# World Radiometric Reference and SI

- From a thorough discussion of the results of comparison of many ECRs with the sun as source at PMOD/WRC the World Radiometric Reference has been defined and adopted by WMO in 1975. A group of radiometers, the World Standard Group, have been identified to materialize it. The WWR is what is called in metrology a **conventional reference** as it has a much higher repeatability than its estimated SI uncertainty of 0.3%.



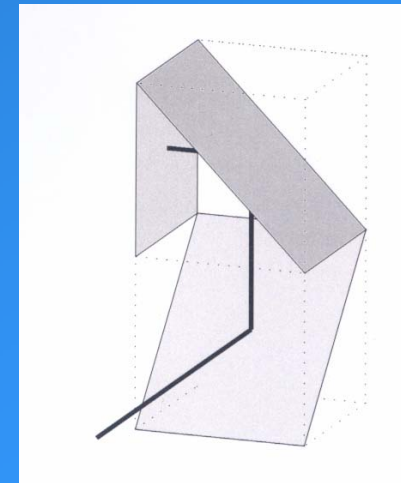


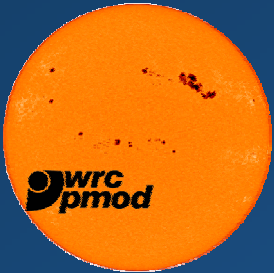
# Transfer from a Cryogenic Radiometer to Trap Detector

Trap detector

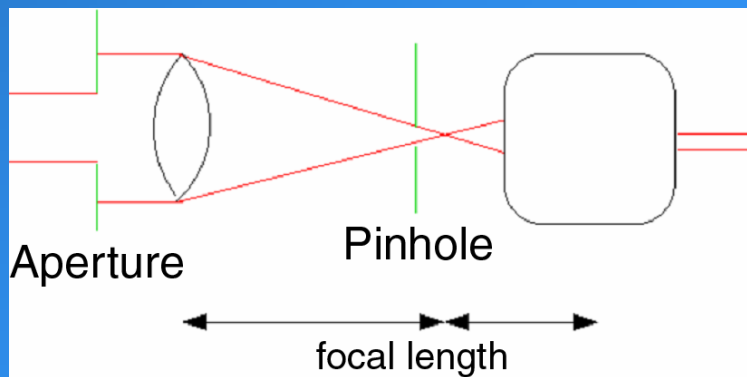
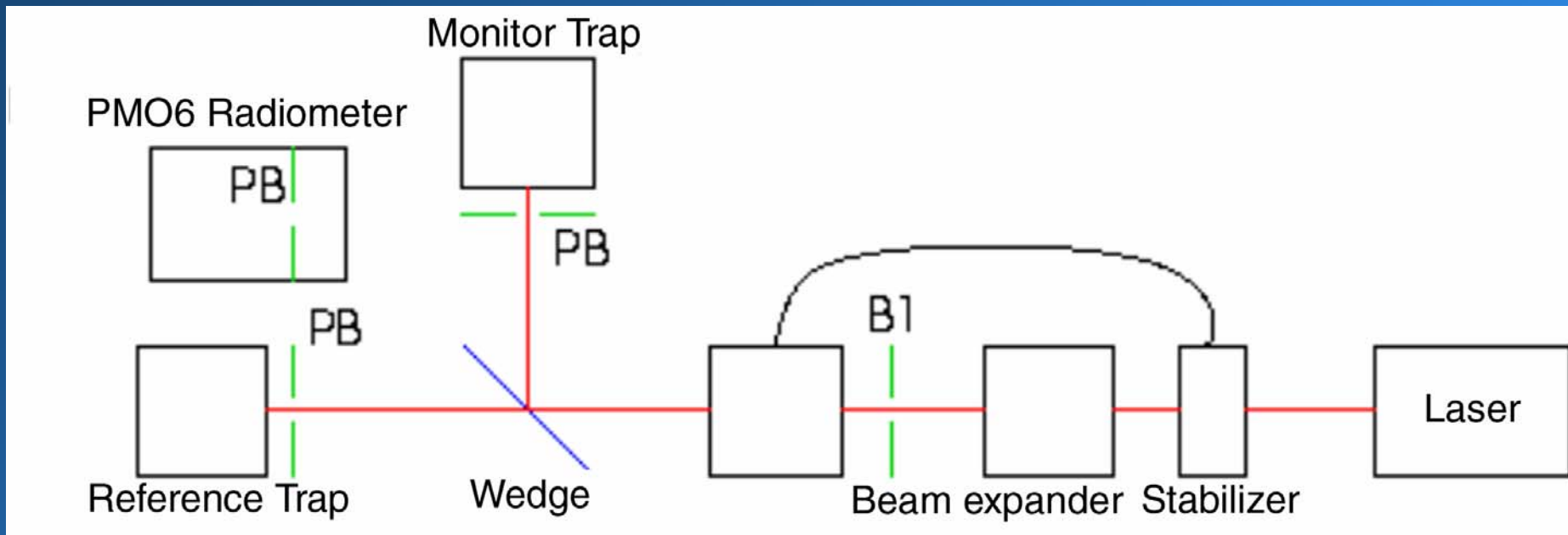


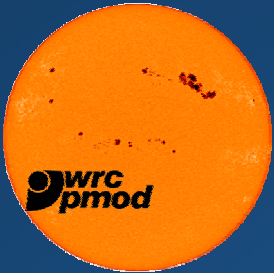
Cryogenic Radiometer





# Optical Setup





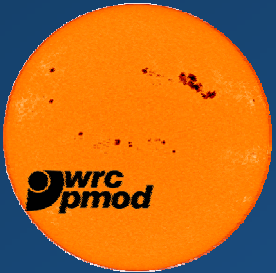
# Beam-Splitter Ratio and Beam Power

$$STV = \frac{\frac{S_{RT} - \overline{S_{RT0}}}{G_{RT}}}{\frac{S_{MT} - \overline{S_{MT0}}}{G_{MT}}}$$

- $STV$  beam-splitter ratio
- $S_{RT,MT}$  signal reference, monitor trap
- $S_{RT0,MT0}$  dark reference, monitor trap
- $G_{RT,MT}$  gain reference, monitor trap
- $P_{RT}$  power
- $P_{rad}$  power measured by radiometer
- $C_{rad}$  Correction factor
- $C_{WRR}$  WRR factor

$$P_{RT} = \frac{\overline{S_{MT} - \overline{S_{MT0}}} \cdot STV}{R_{RT} \cdot G_{MT}}$$

$$\frac{WRR}{SI} = \frac{P_{PMO6} \cdot C_R \cdot C_{WRR}}{P_{RT}}$$



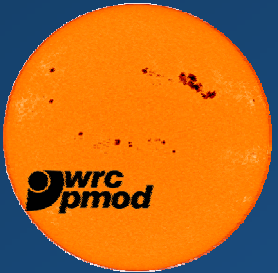
# Radiometric Constants to be used

## Solar Measurements: $C_I$

- Aperture area
- Reflectivity
- Diffraction
- Stray light
- Lead heating
- NE over-filled

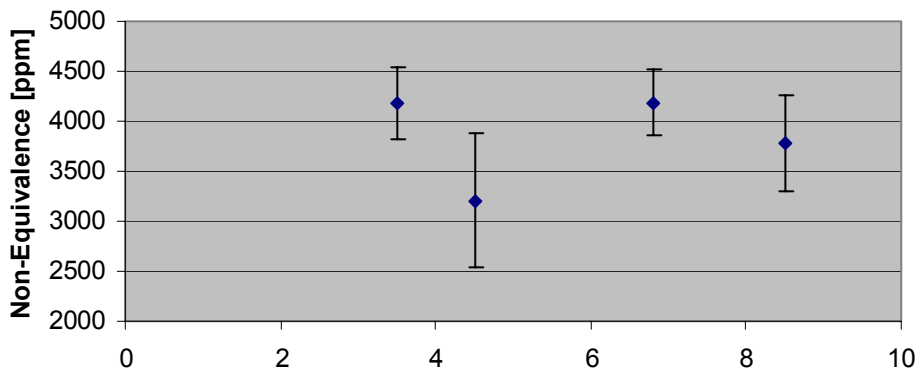
## SI Comparison: $C_R$

- 
- Reflectivity
- 
- 
- Lead heating
- NE under-filled



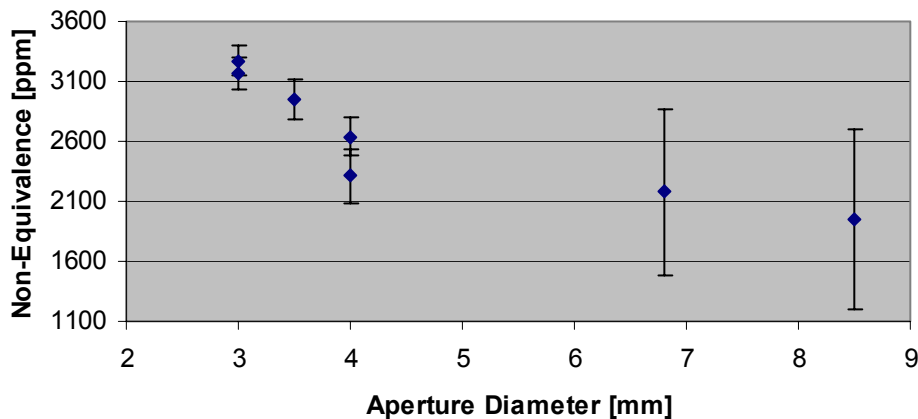
# Non-Equivalence

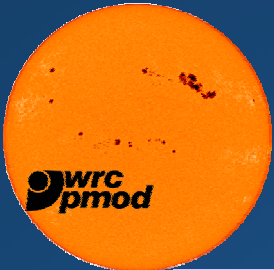
Non-Equivalence PMO6\_09



The difference between the under-filled and over-filled aperture (8.5mm) is  $0 \pm 820$  ppm for 6-9 and  $545 \pm 770$  ppm for 6-11.

Non - Equivalence PMO6\_11



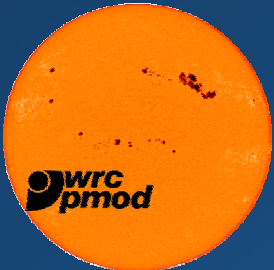


# Radiometer Uncertainty

## PMO6-9 Characterization for Flux @ 1000W/m2

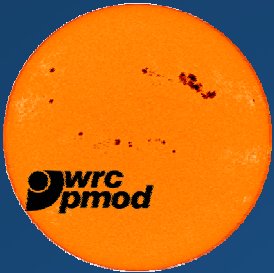
Component	Value	u	c	(u*c)^2	
Area	n/a		7.0452E-10	5.00E+07	
Pclosed	40 mW		0.000004	5.00E+04	0.04
Popen	20 mW		0.000002	5.00E+04	0.01
CNE		1	5.00E-04	1.00E+03	0.25
CR		1	7.00E-05	1.00E+03	0.0049
CSt	n/a		1.00E-04	1.00E+03	0
CLH		1	3.00E-05	1.00E+03	0.0009
CApH	n/a		5.00E-04	1.00E+03	
Cdiff	n/a		1.00E-04	1.00E+03	0
					0.3058
		Uncertainty abs			0.5530 W/m2
		Uncertainty rel			553.0 ppm
<i>Flux</i>		95% Uncertainty			1106.0 ppm
<i>Irradiance</i>		95% Uncertainty			1519.3 ppm





# Uncertainty of the comparison at NPL

Variable	Messwert	$u_i$	$c_i$	$(u_i c_i^2)$
$P_{PMO6}$ [W]	$1.67 \cdot 10^{-2}$	$5.77 \cdot 10^{-6}$	59.92	$1.20 \cdot 10^{-7}$
$C_R \cdot C_{WRR}$	1.01	$8.01 \cdot 10^{-4}$	$9.94 \cdot 10^{-1}$	$6.45 \cdot 10^{-7}$
$S_{MT}$ [V]	0.43	$7.51 \cdot 10^{-7}$	-2.30	$2.98 \cdot 10^{-12}$
$\overline{S_{MT0}}$ [V]	$-1.22 \cdot 10^{-4}$ V	$2.89 \cdot 10^{-7}$	2.30	$4.40 \cdot 10^{-13}$
$\overline{S_{MT0}}$ [V]	W	$1.66 \cdot 10^{-7}$ V	2.30	$1.46 \cdot 10^{-13}$
$S_{MT} - \overline{S_{MT0}}$ [V]	W	$2.10 \cdot 10^{-5}$	2.30	$2.32 \cdot 10^{-9}$
$STV$	20.07	$1.14 \cdot 10^{-3}$	$-4.98 \cdot 10^{-2}$	$3.24 \cdot 10^{-9}$
$STV$	W	$1.04 \cdot 10^{-3}$	$-4.98 \cdot 10^{-2}$	$2.70 \cdot 10^{-9}$
$R_{RT}$ [ $\frac{A}{W}$ ]	0.52	$6.00 \cdot 10^{-5}$	1.92	$1.33 \cdot 10^{-8}$
$G_{MT}$ [ $\frac{V}{A}$ ]	$1.00 \cdot 10^2$	$2.89 \cdot 10^{-2}$	$1.00 \cdot 10^{-3}$	$8.33 \cdot 10^{-7}$
<b>95% Uncertainty: 0.178 %</b>			$u_c^2$	$7.84 \cdot 10^{-7}$
			$u_c$	$8.86 \cdot 10^{-4}$



# Results of WRR to SI Ratio

1991:  $1.000557 \pm 0.001974$   
1996:  $0.999757 \pm 0.000948$   
2005:  $0.999828 \pm 0.000809$

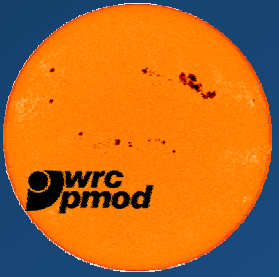
weighted average:

$0.999937 \pm 0.000808$

including aperture heating:

$0.999832 \pm 0.000808$

**95% uncertainty:  $\pm 0.001780$**



**END**