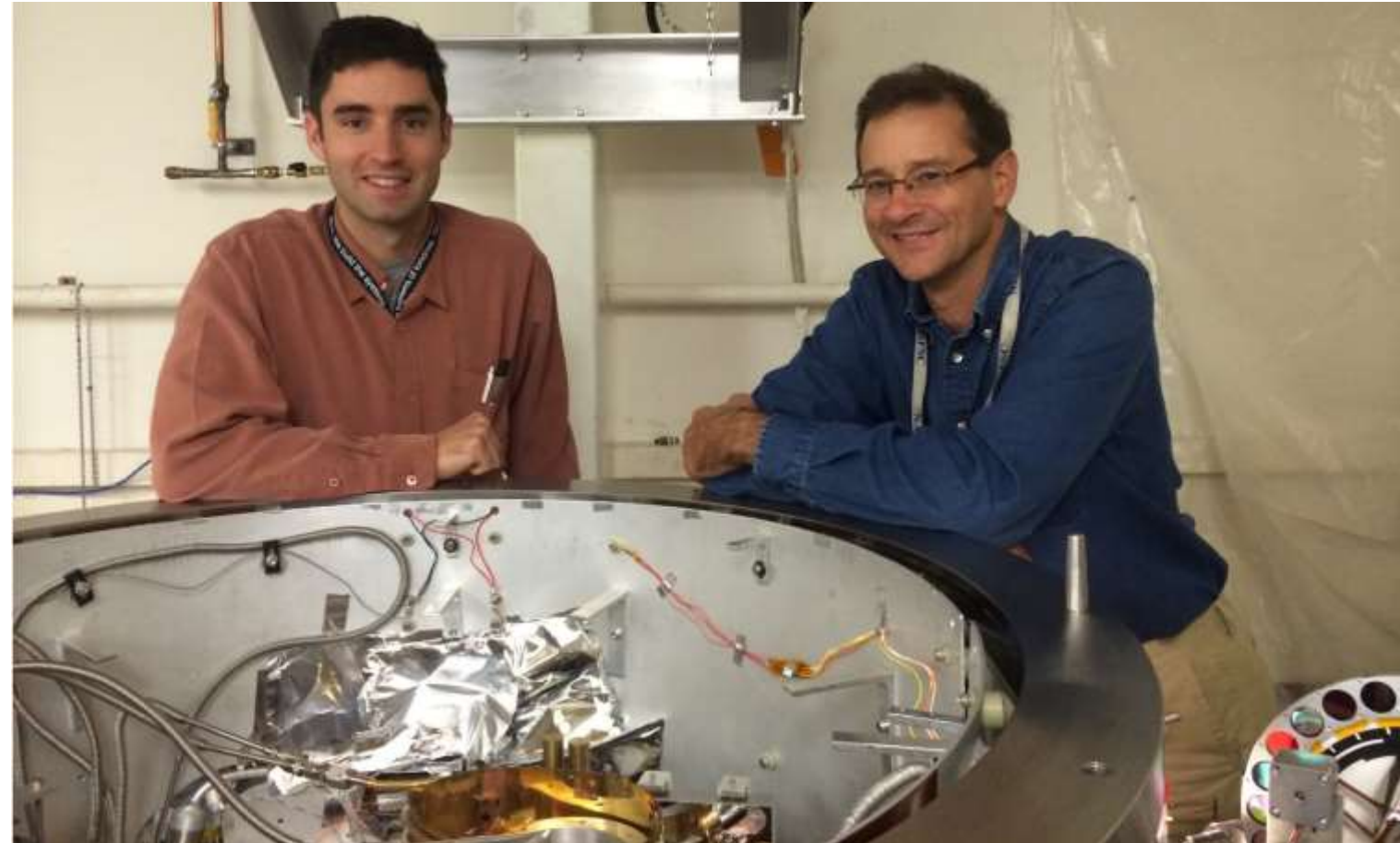


Cryogenic Refractive Indices of S-LAH55, S-LAH55V, S-LAH59, S-LAM3, S-NBM51, S-NPH2, S-PHM52, and S-TIH14 Glasses

Kevin H. Miller & Manuel A. Quijada / *NASA Goddard Space Flight Center, Greenbelt, MD*
Douglas B. Leviton / *Leviton Metrology Solutions, Inc., Boulder, CO*

K.H.M. and D.B.L. with the Cryogenic High Accuracy Refraction Measuring System (CHARMS) at NASA GSFC

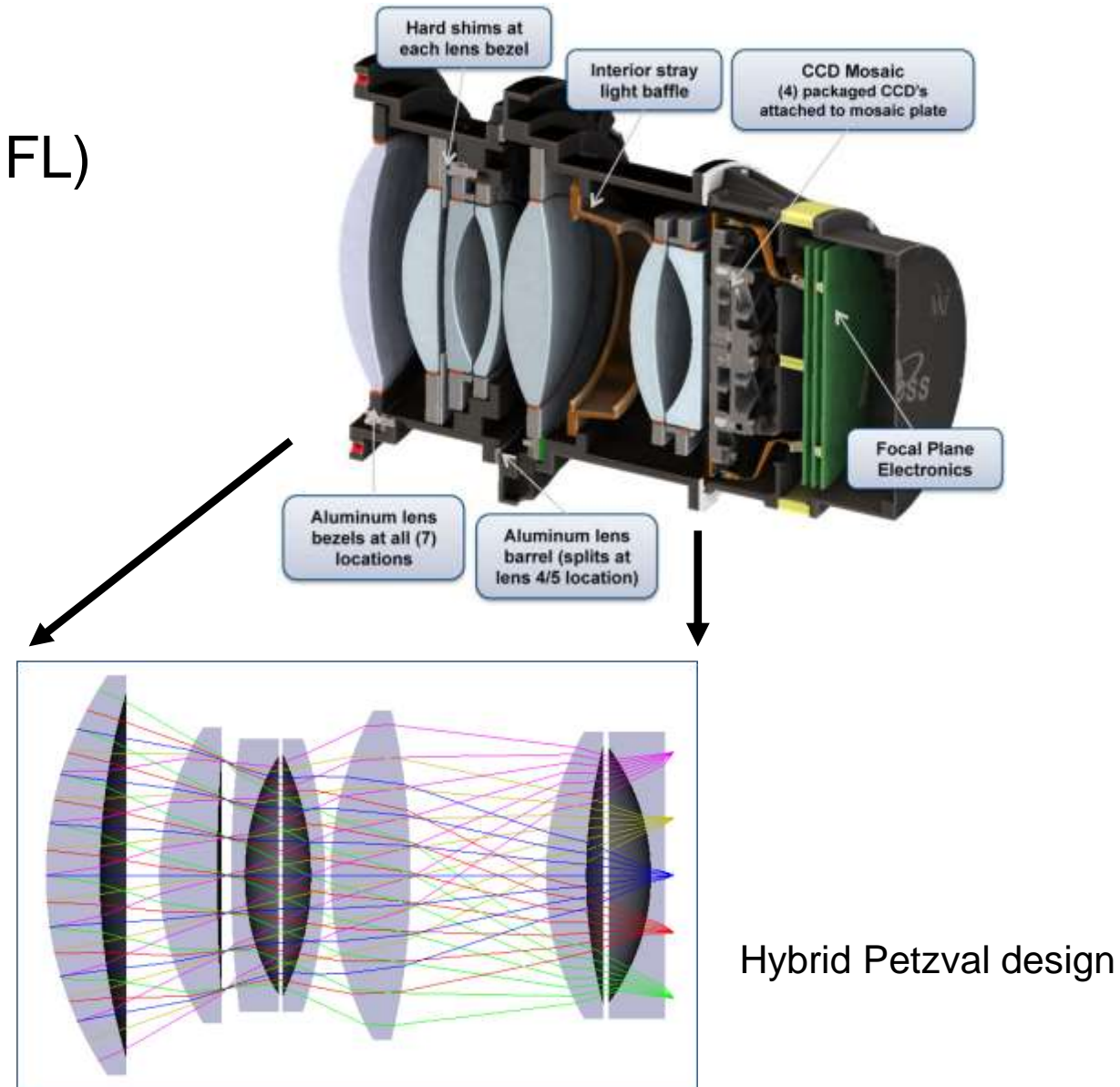
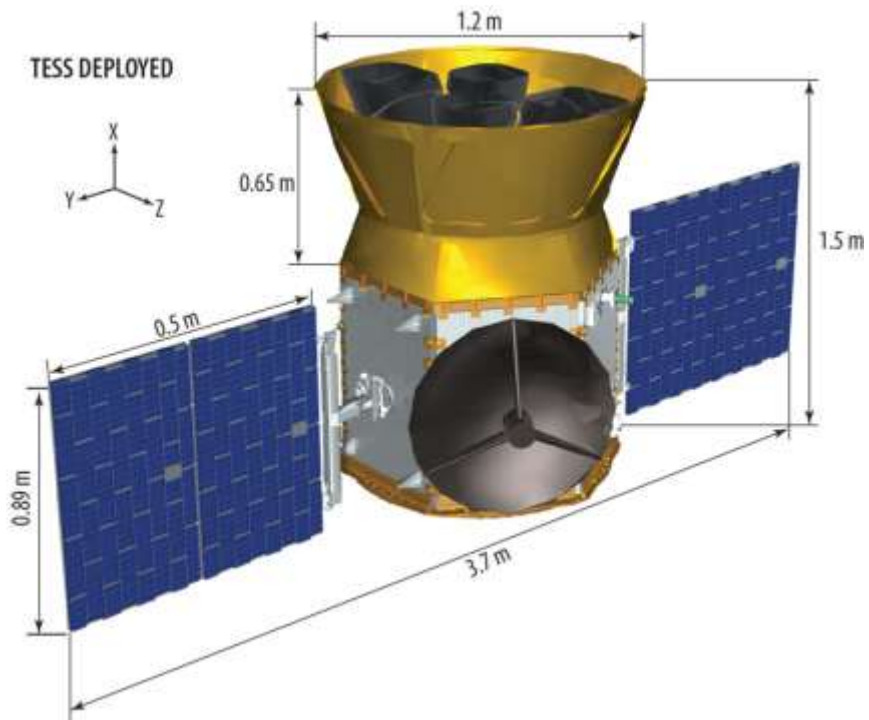


Outline of Slides

- Motivation for measurements (TESS mission)
- CHARMS: operation and capabilities
- CHARMS: cryogenic capabilities
- Ohara glass map and nomenclature
- First evidence of intra-melt variability in S-LAH55V
- Optical properties of “high” index prisms
- Optical properties of “middle” index prisms
- CHARMS measurements compared to literature values

Motivation: Transiting Exoplanet Survey Satellite (TESS)

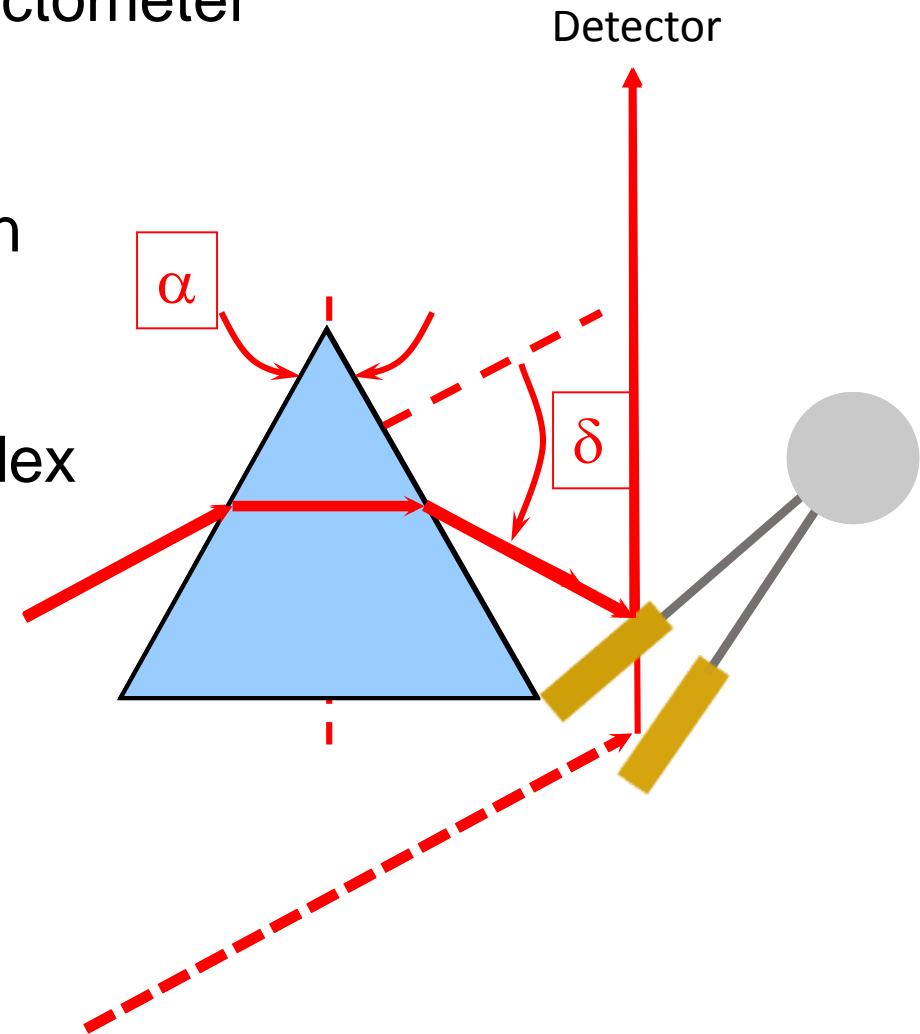
- Planet finder
- 2017 Launch date (Cape Canaveral, FL)
- Highly Elliptical Earth Orbit
- 4 identical cameras 90° X 90° FOV
- 600 – 1000 nm bandpass



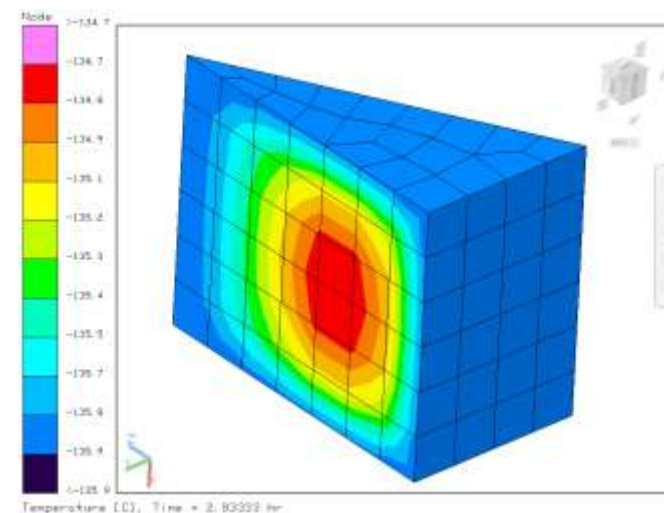
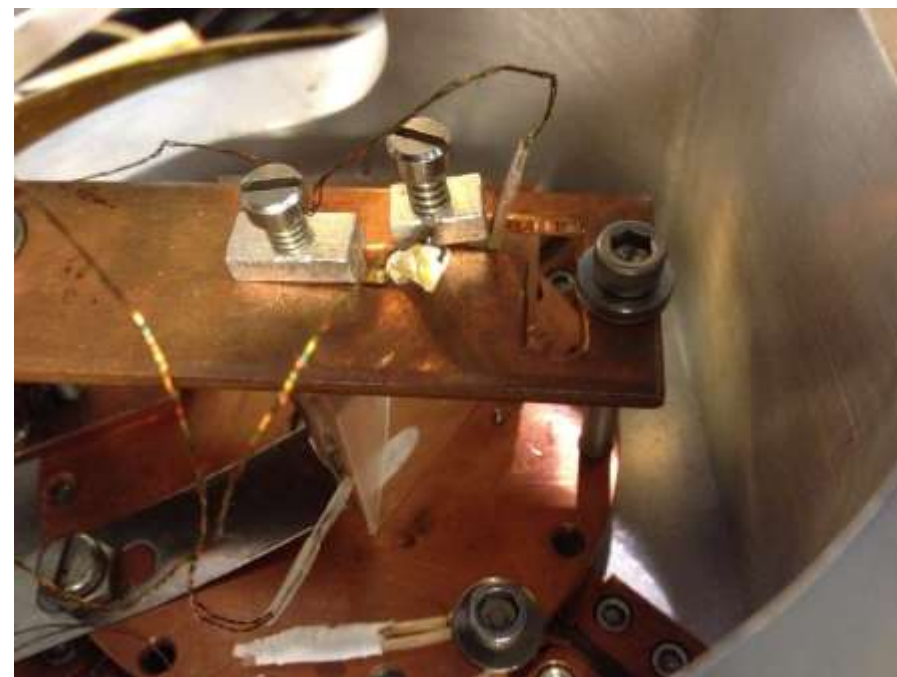
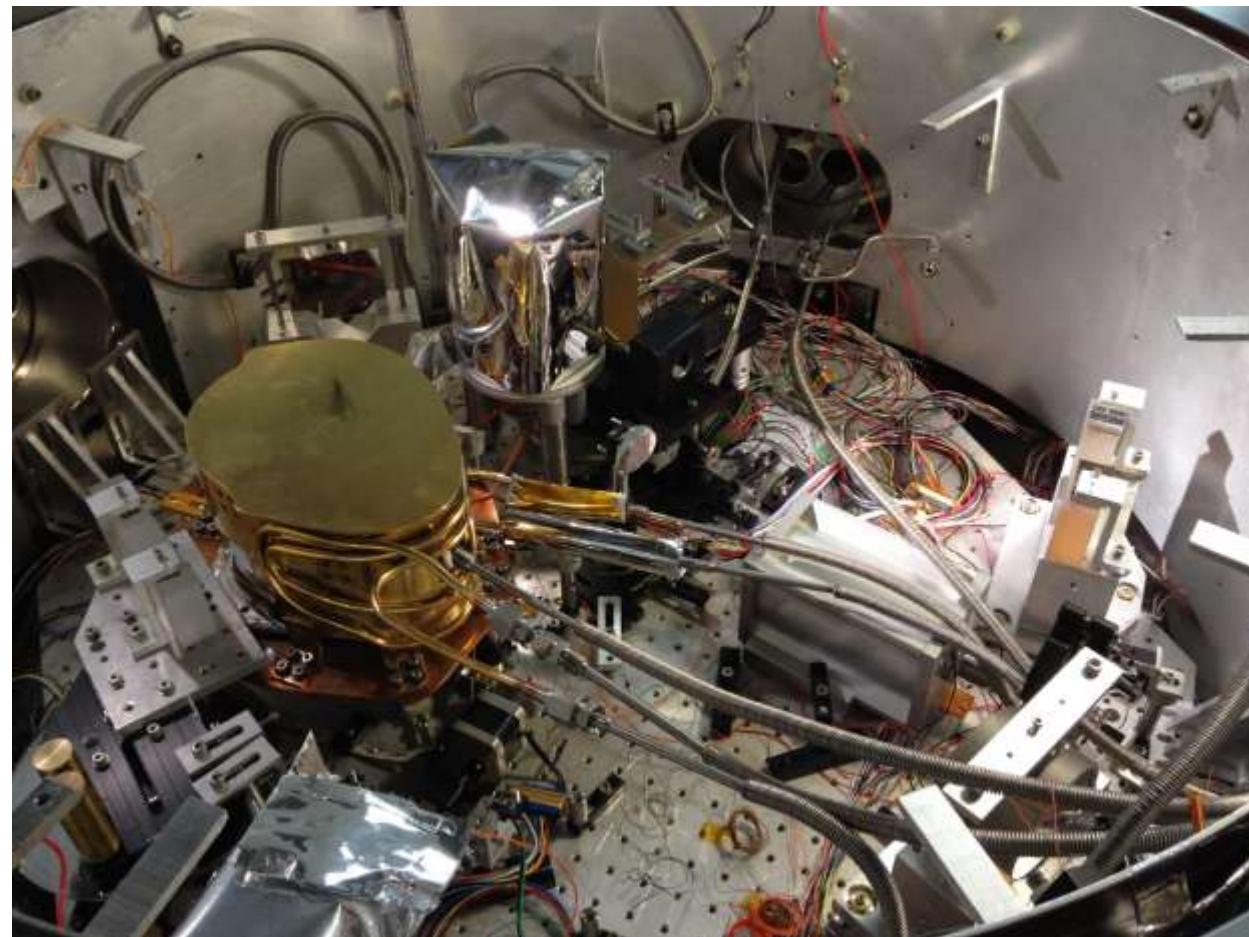
CHARMS: Operation and Capabilities

- CHARMS is a minimum deviation refractometer
- Five simple steps:
 1. Measure the apex angle of the prism
 2. Establish the condition of min deviation
 3. Measure angle of undeviated beam
 4. Measure angle of deviated beam
 5. Compute deviation angle; compute index

$$n = \frac{\sin\left(\frac{\alpha + \delta}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)}$$



CHARMS: Cryogenic Capabilities



Courtesy of
S. Scola

CHARMS: data reduction and presentation style

$$n^2(\lambda, T) - 1 = \sum_{i=1}^3 \frac{S_i(T) \cdot \lambda^2}{\lambda^2 - \lambda_i^2(T)}$$

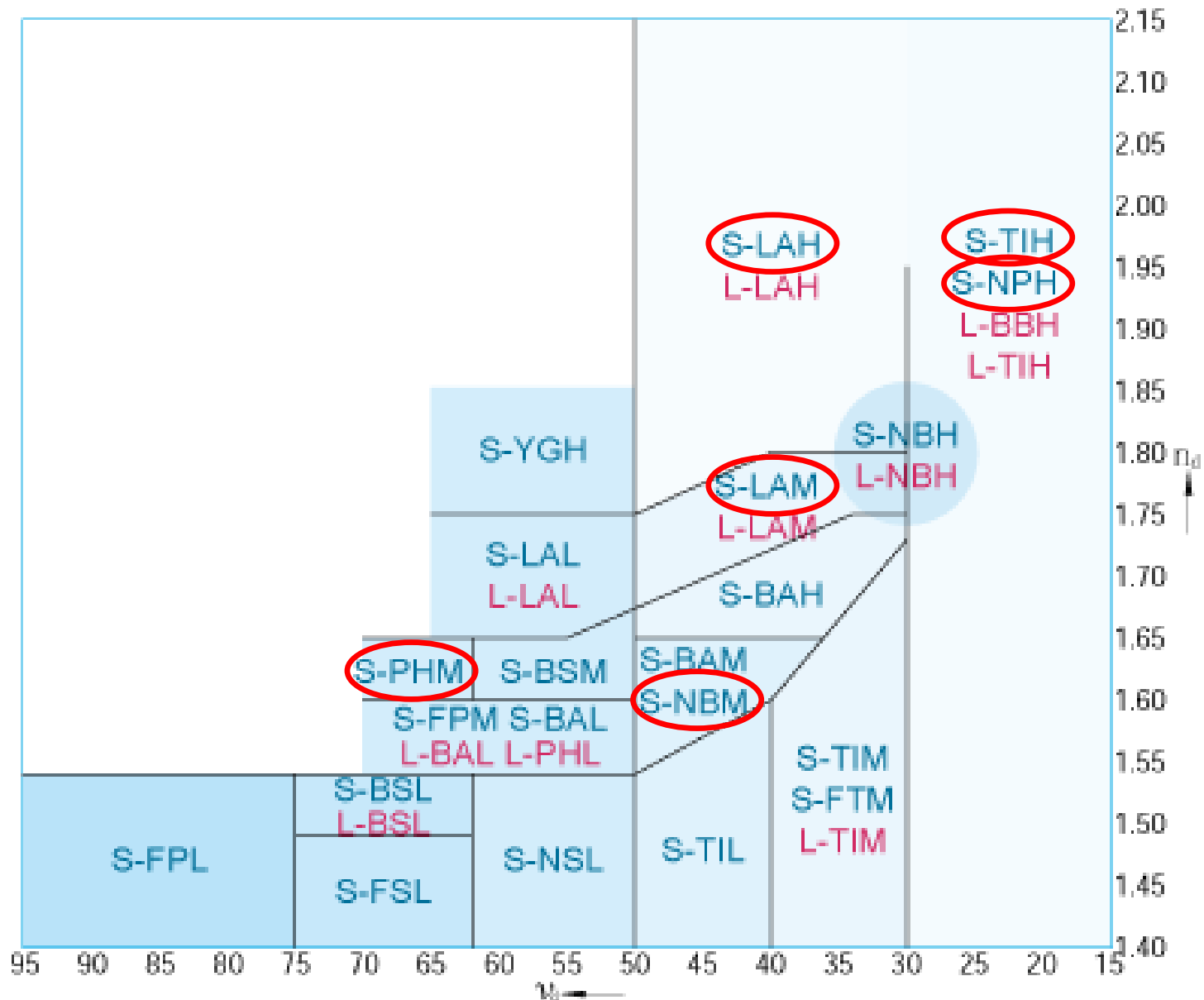
$$S_i(T) = \sum_{j=0}^3 S_{ij} \cdot T^j$$

$$\lambda_i(T) = \sum_{j=0}^3 \lambda_{ij} \cdot T^j$$

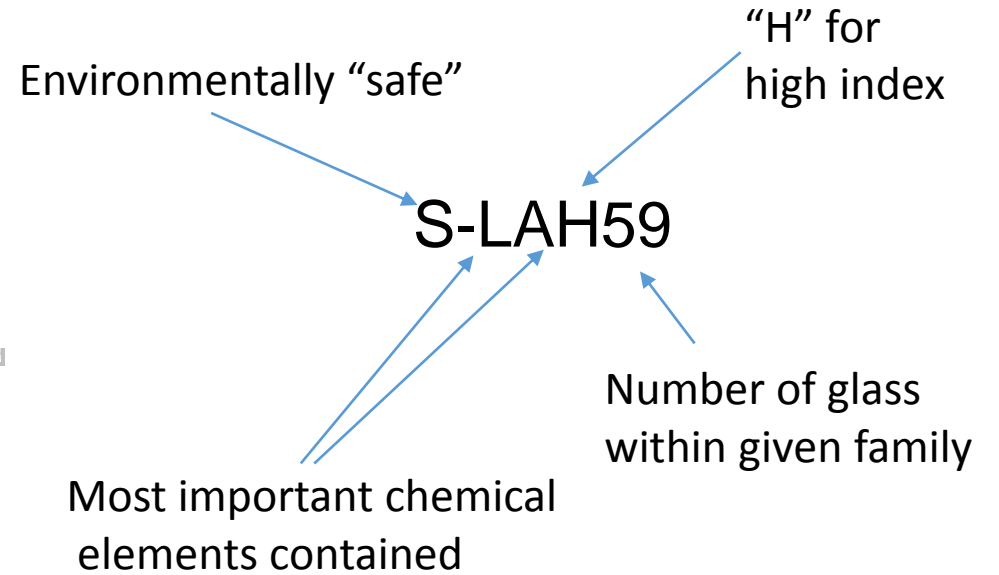
$$AAR = \frac{\sum_{k=1}^n |index_{measured} - index_{fit}|}{n}$$

Prism ID	average absolute residual
S-LAH55	4.4E-6
S-LAH55V-1	3.7E-6
S-LAH55V-2	3.6E-6
S-LAH59	3.6E-6
S-TIH14	5.2E-6
S-NPH2	7.1E-6
S-LAM3	3.7E-6
S-NBM51	2.6E-6
S-PHM52	3.5E-6

Ohara Glasses

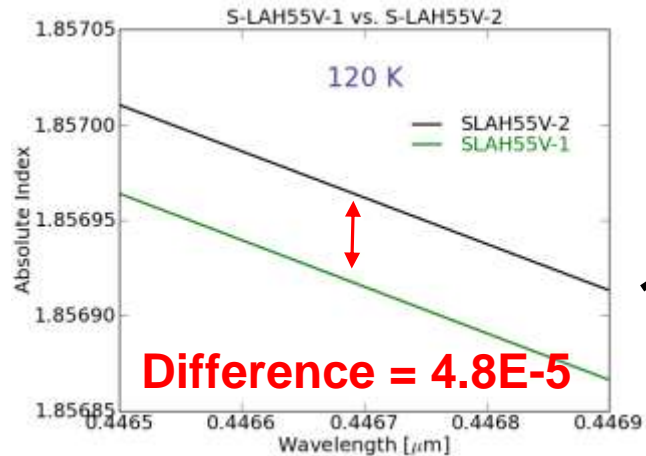
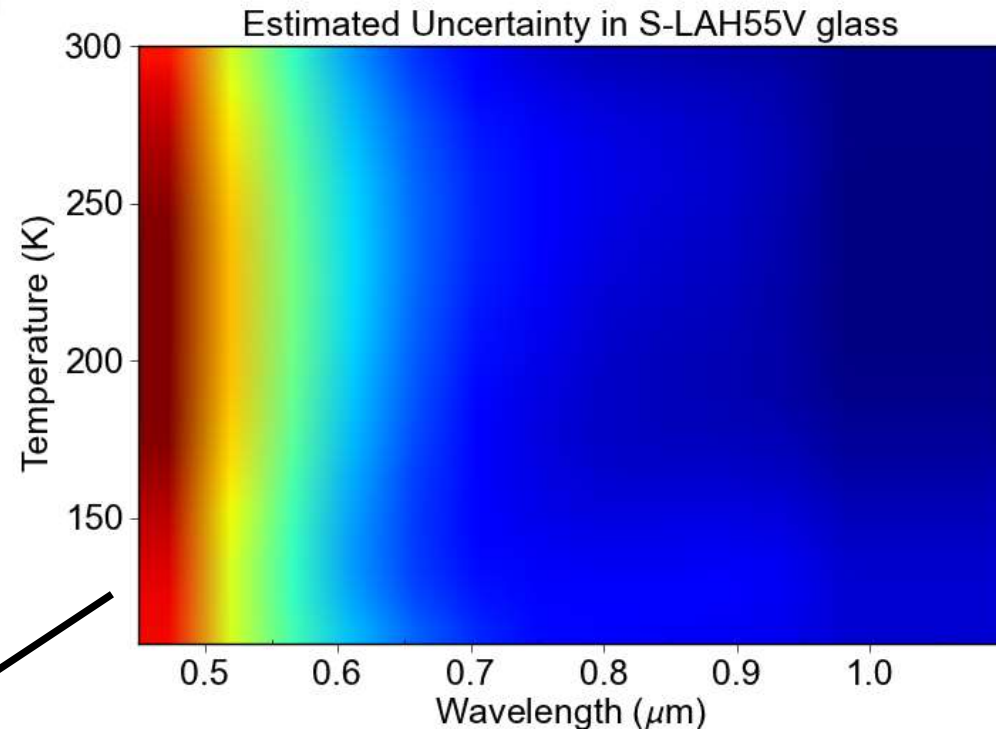
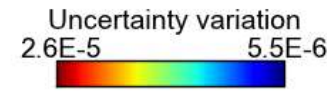
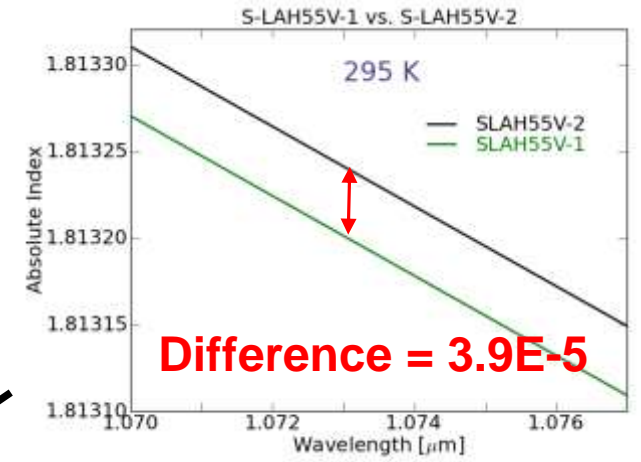
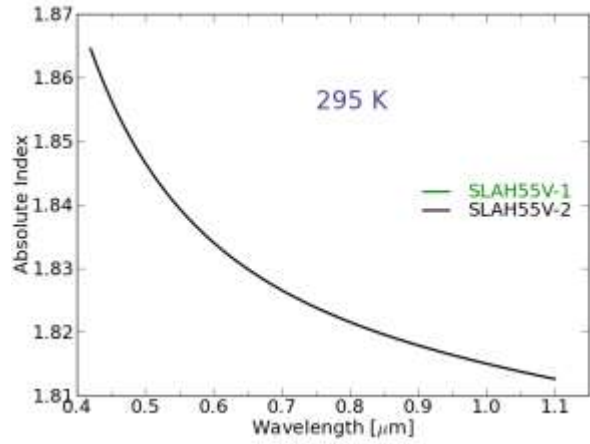


Ohara nomenclature example:

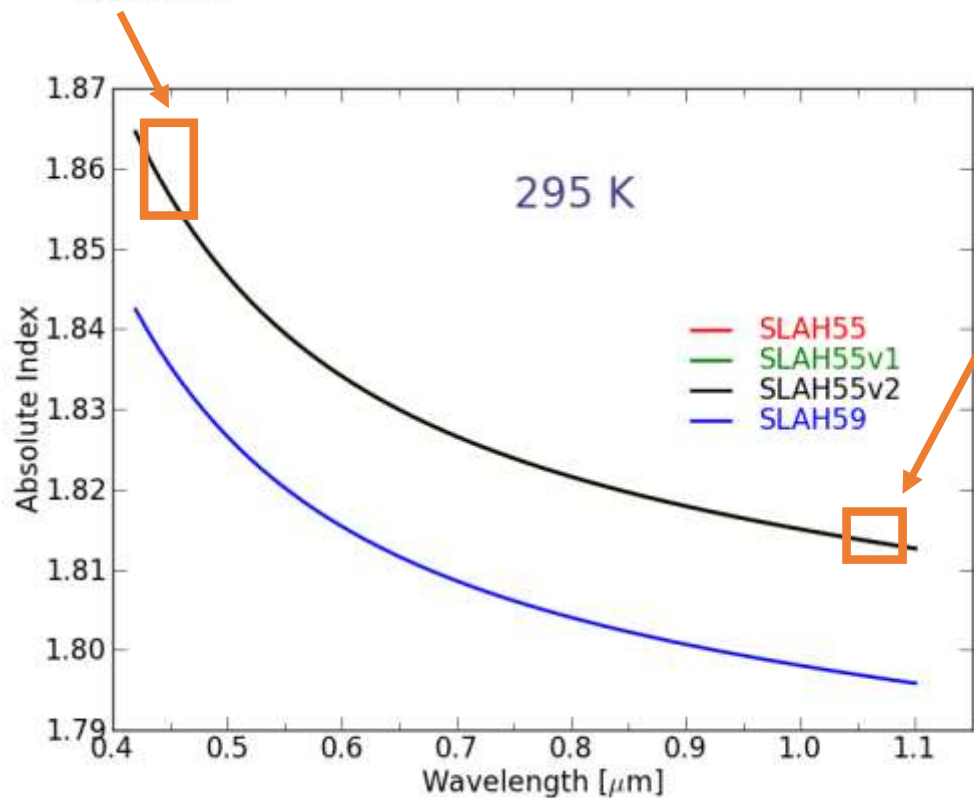
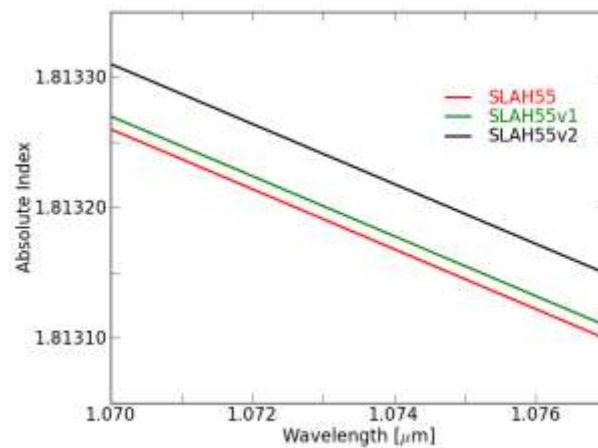
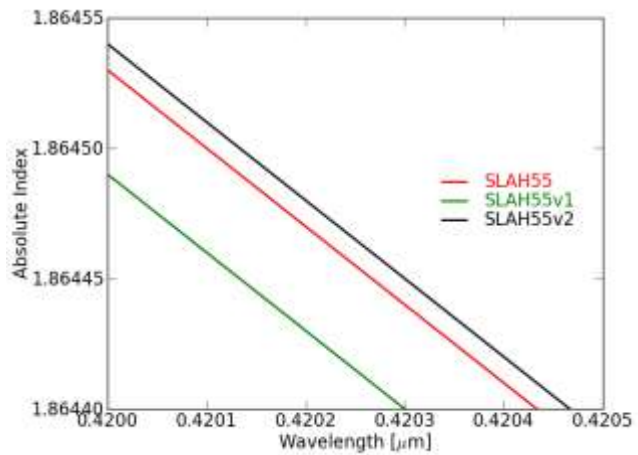


S-LAH55 vs. S-LAH55V

S-LAH55V: Intra-melt Variability



S-LAH55, S-LAH55V, S-LAH59



Constituent % by weight	S-LAH55	S-LAH59
La ₂ O ₃	40-50 %	20-30 %
Gd ₂ O ₃	2-20 %	30-40%

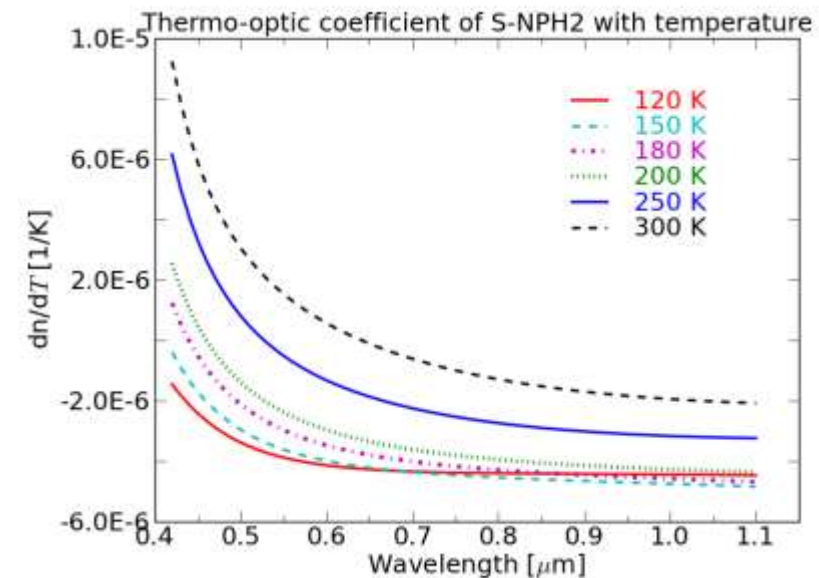
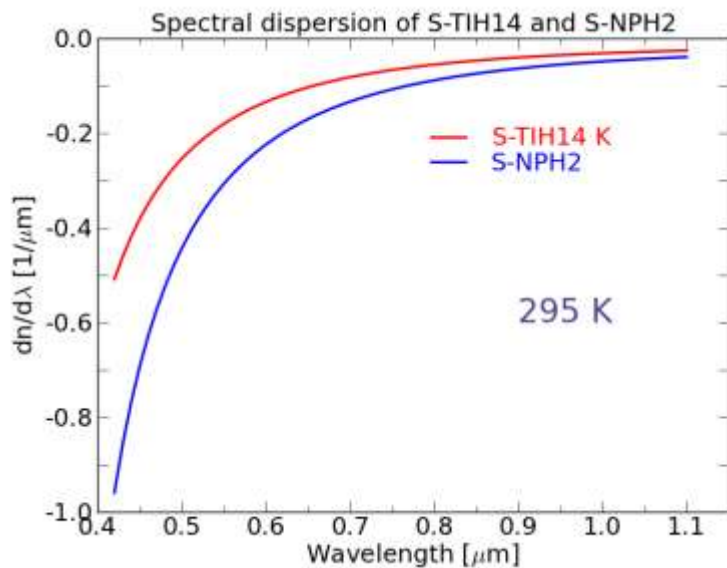
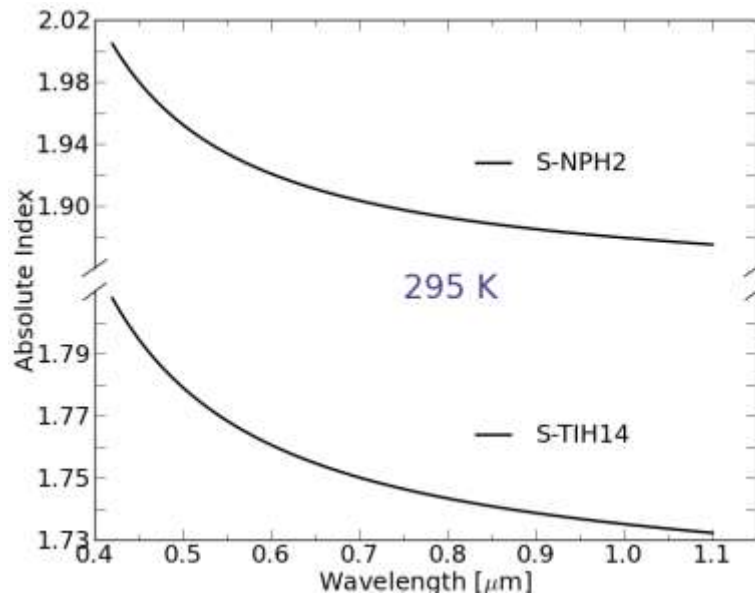
S-TIH14 & S-NPH2

TiO₂ : 20—40 %

SiO₂ : 30—50 %

Nb₂O₅ : 40—50 %

P₂O₅ : 20—30 %



S-LAM3, S-NBM51, S-PHM52

La_2O_3 : 10—20 %

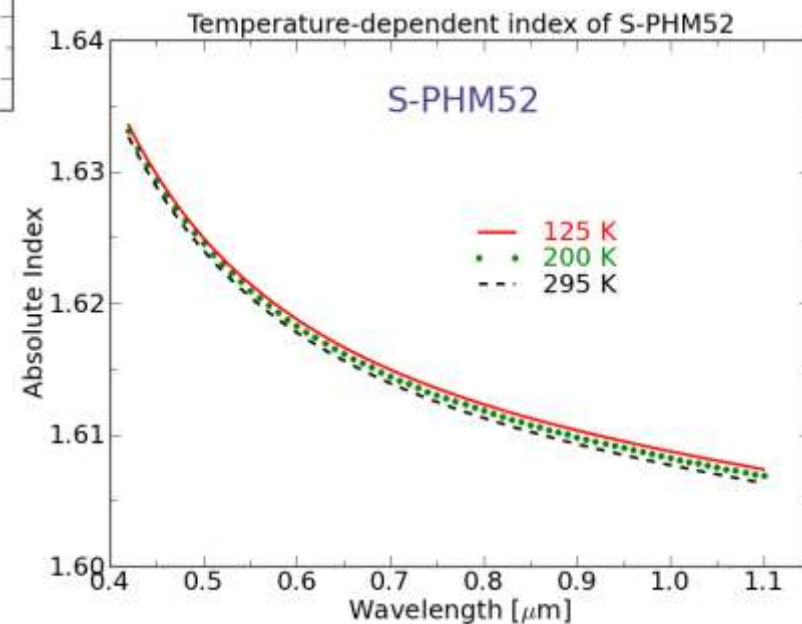
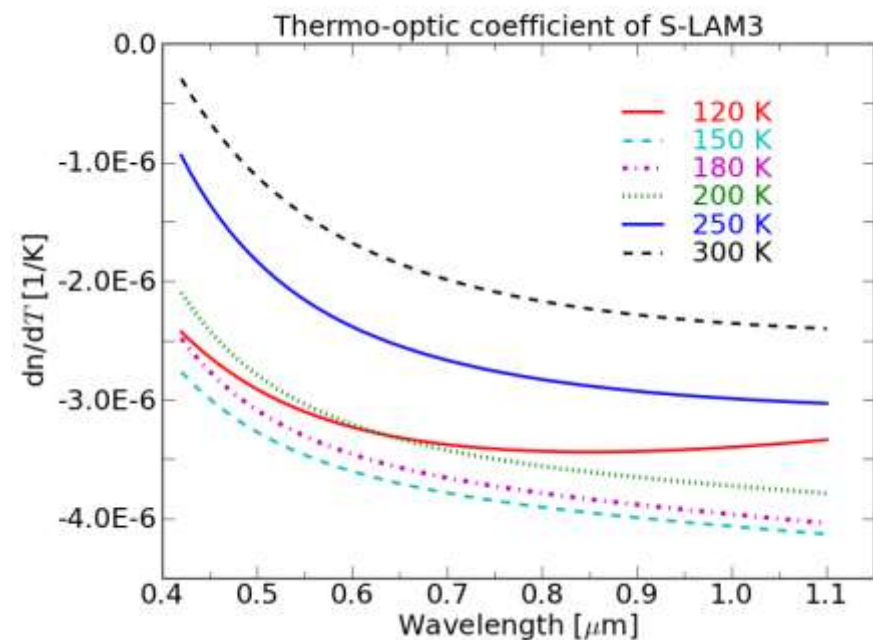
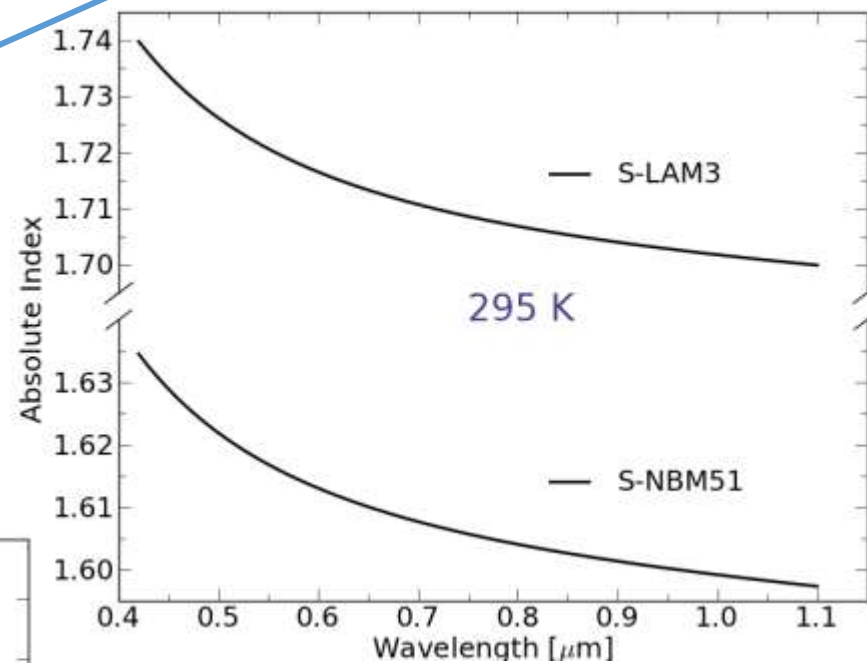
BaO : 40—50 %

Nb_2O_5 : 10—20 %

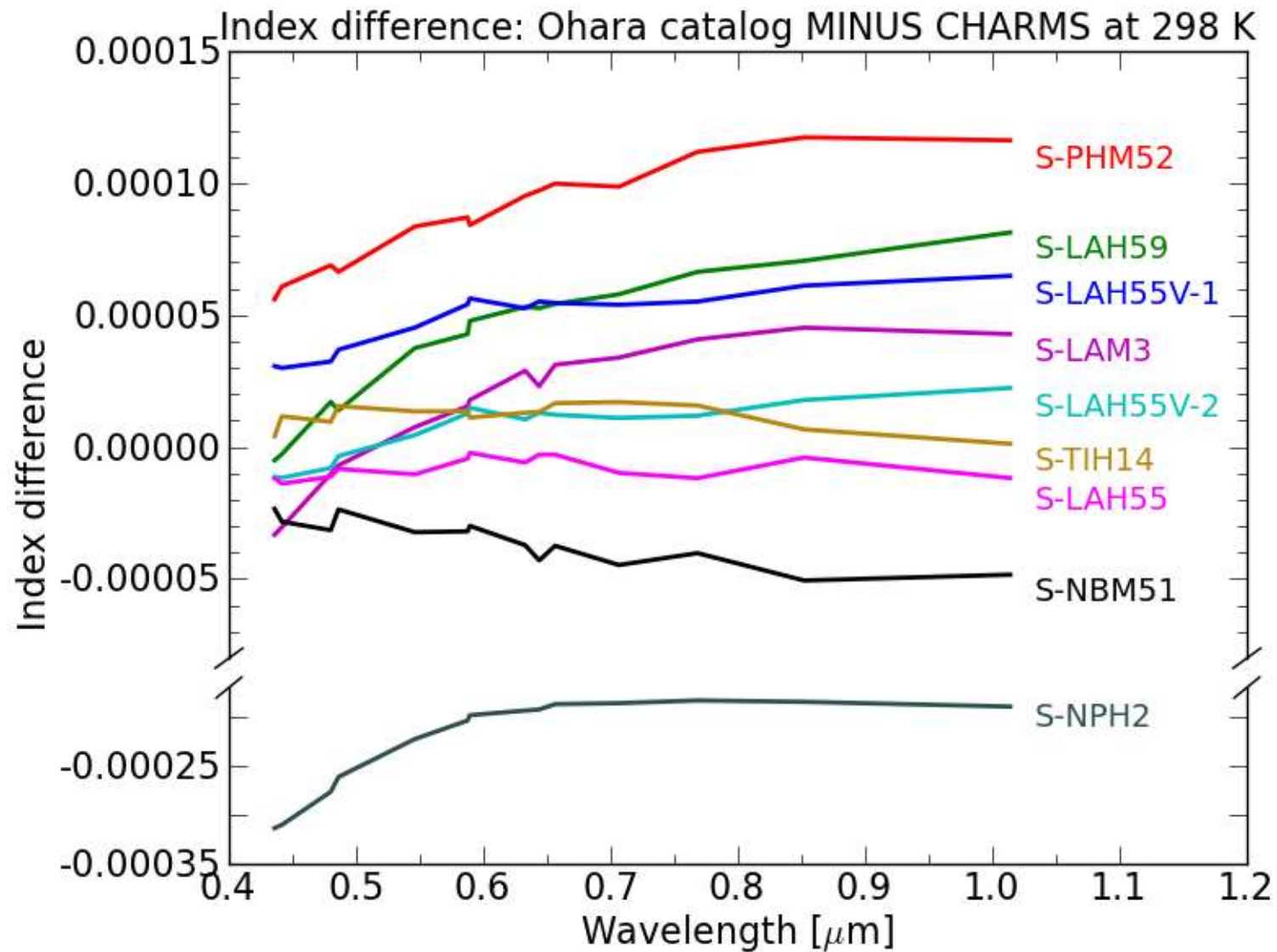
SiO_2 : 30—40 %

P_2O_5 : 40—50 %

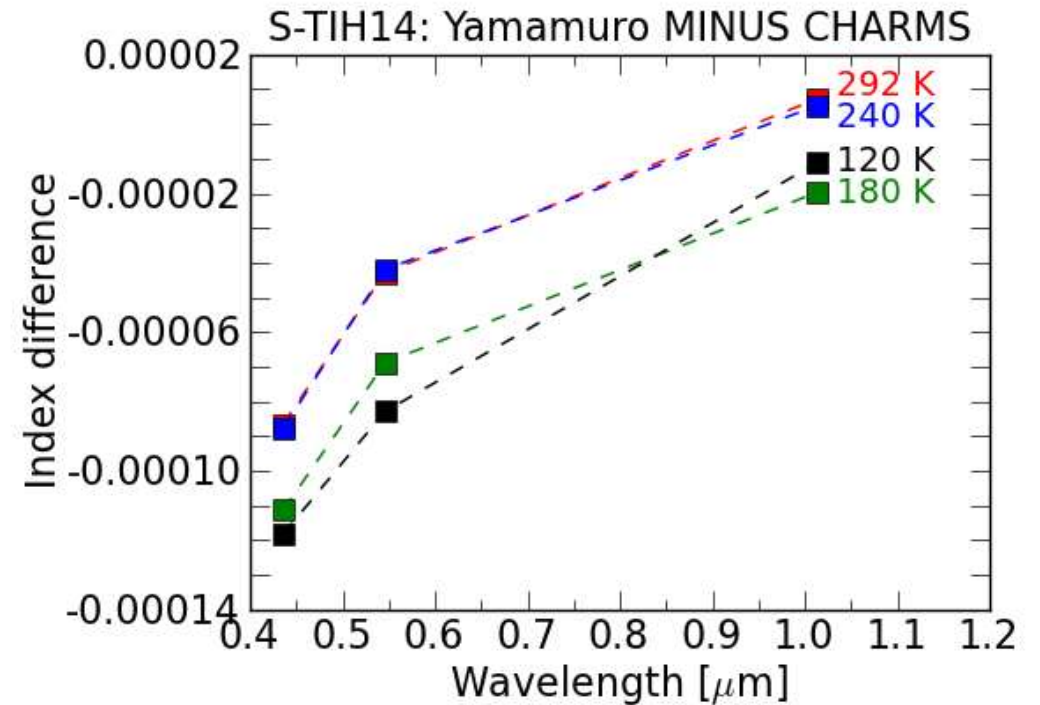
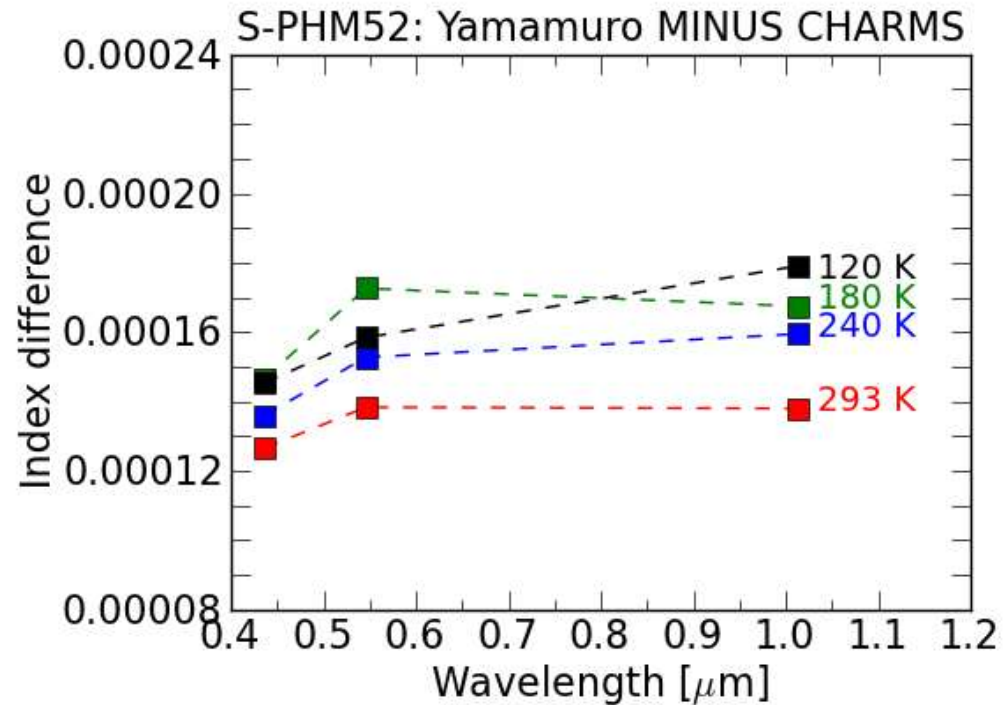
BaO : 30—40 %



Index Comparison: Ohara MINUS CHARMS



Cryogenic Index Comparison: Yamamuro MINUS CHARMS



Conclusions

