

Interface with Araucaria Project

N. Nardetto



SPICA Workshop, Nice, 01/06/23

The Araucaria Project



- PI: G. Pietrzynski and W. Gieren since early 2000

- ~ 40 researchers at the international level

<https://araucaria.camk.edu.pl/>

- Book : <https://arxiv.org/abs/2305.17247>

- **Goal:** « *The main goal of the Araucaria Project is to improve the calibration of the cosmic distance scale in the local Universe. We trace down environmental dependencies on the brightness of various standard candles by comparing distances to their host galaxies and clusters, obtained with different methods.* »



Fig. 3. Araucaria Meeting in Potsdam, Germany, 2010.



Fig. 5. Araucaria Meeting in the Royal Restaurant Wierzynek in Kraków, Poland, 2017.



Fig. 4. Araucaria Meeting in Nice, France, 2013.



Fig. 6. Araucaria Meeting in Concepción, Chile, 2019.



Fig. 7. Araucaria Meeting in Sopot, Poland, in 2021, twenty-one years after founding.

*Armazones Observatory ...
next to ELT*



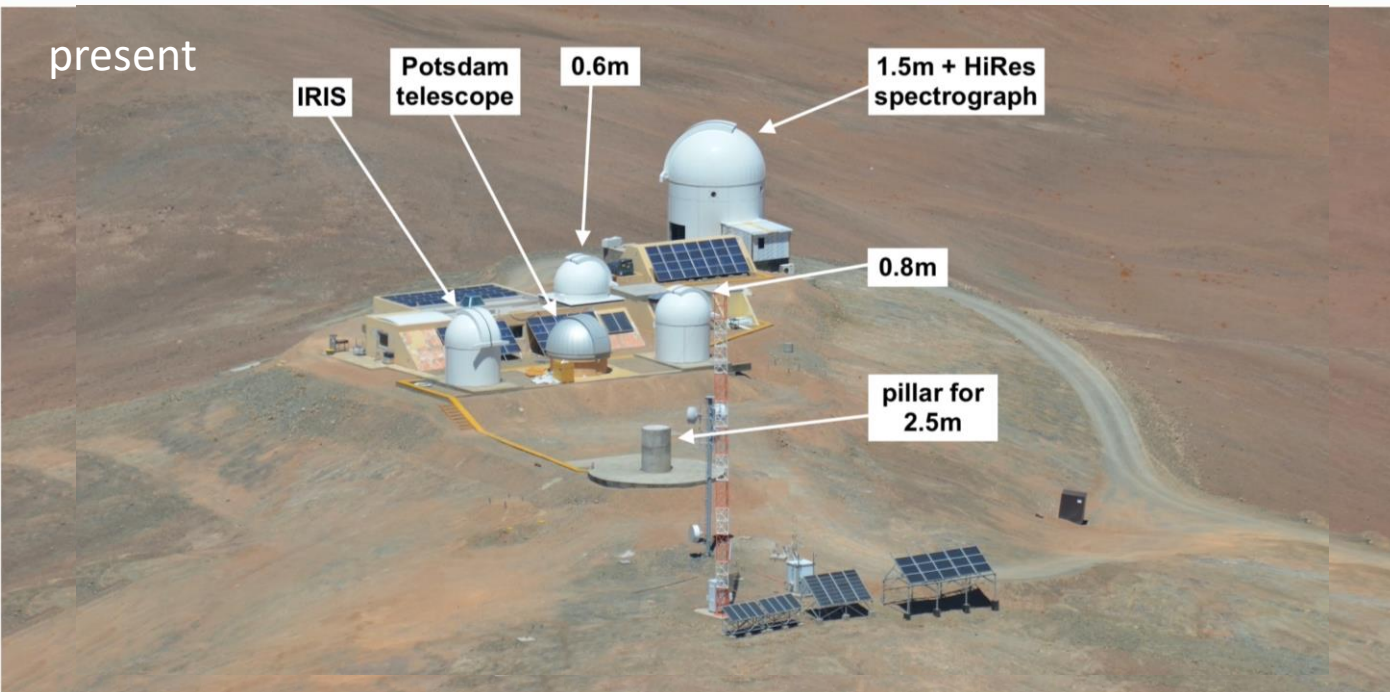
past



project



present



- *Present:*

- 3 completely new telescopes: 0.6m, 0.8m and 1.5m, constructed by ASA, and one old near-infrared telescope IRIS.

- **0.6m:** Strömgen (u b v y), H β wide, H β narrow, Johnson-Cousins (B V Ic)
- **0.8m:** Sloan filters (u g r i z) and Johnson-Cousins filters (B V Ic)
- **1.5m:** Strömgen (u b v y), H α wide, H α narrow, H β wide, H β narrow, Sloan (u g r i z), and Johnson-Cousins (B V Ic). It also supports a high-resolution spectrograph (wavelength range = 3700Å–8600Å, resolution $\lambda/\Delta\lambda = 48000$).
- **0.8m (IRIS)** alt-azimuth telescope with two Nasmyth foci that can be reached via a computer-controlled movable third mirror. IRIS is equipped with a 1k x 1k infrared camera optimized for the NIR region; there are various broad and narrow band filters between 1.1 and 2.5 μ . The optical system provides a resolution of 0.74"/pixel and a field-of-view of 13' x 13'; the limiting magnitude is about K \sim 16. Thus, IRIS exceeds the capabilities of 2MASS.

- Start of observations with the new ASA telescopes. Calibration images. Start of scientific programs within 2-3 months: bright objects (eclipsing binaries, Cepheids, ...)

- *Project:*

- Within 2 years, a **2.5 meters telescope**. High-resolution spectrograph (R \sim 80.000).

The distance to LMC: a major achievement of Araucaria Project



20 eclipsing binaries in LMC
+
Use of a Surface Brightness Color
Relation

SBCR

=

Distance to LMC at 1%

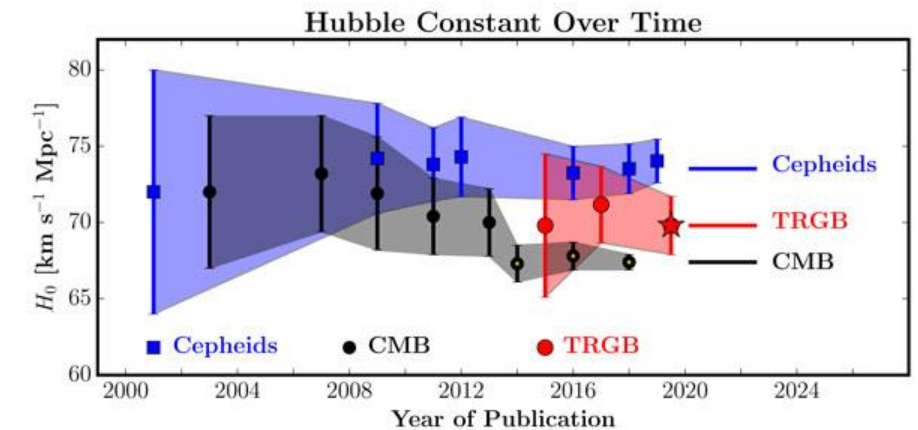
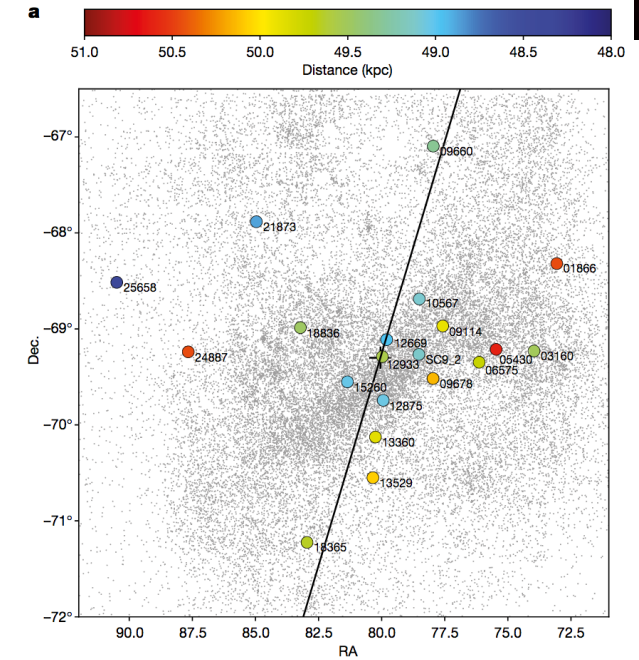
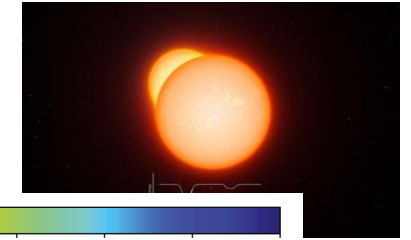
Pietrzynski et al. 2013, Nature, 495, 76
Pietrzynski et al. 2019, Nature, 567, 200



Hubble Constant at 1.4%

[Project SHOES, Riess+21]

5 sigma of tension



The objectives at the interface of
ISSP & Araucaria projects

ISSP/S04: Calibration of **Surface Brightness Color Relations (SBCR)**

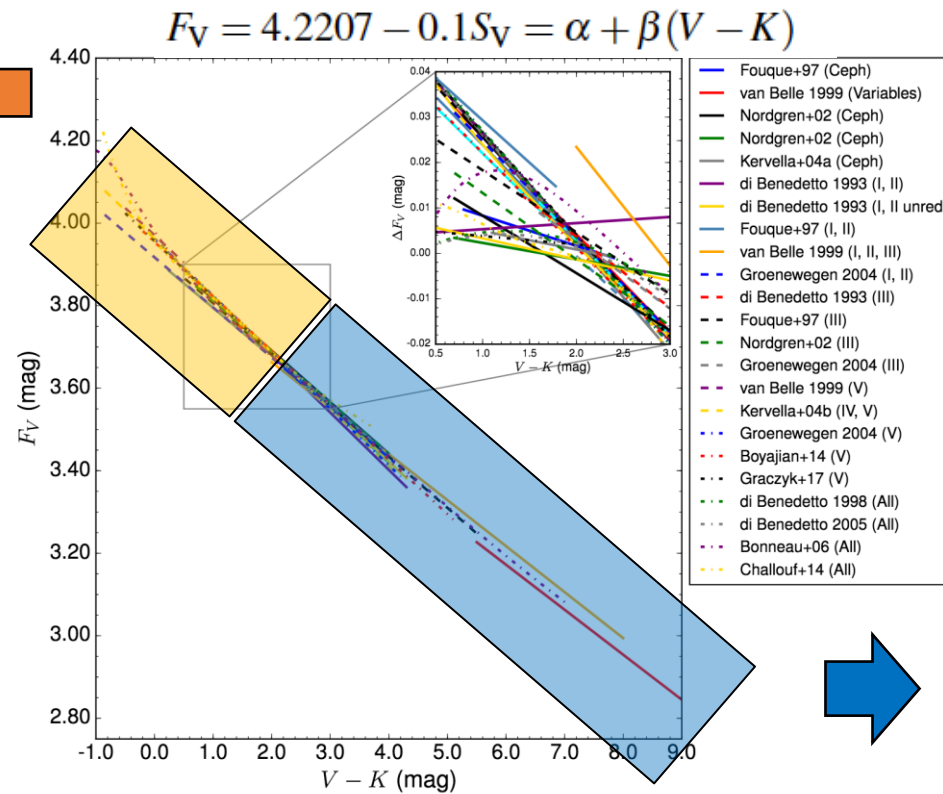
- Calibration of the SBCR all over the HR diagram with ~ 2 stars per sub-spectral channel in [B0, M3] & classes V/IV/>III (324 targets)
- Control of systematics due to stellar activity (rotation, binarity, wind, ...) when calibrating/using SBCR on the interferometric & photometric points of view

Early-type stars

- **ISSP**
SBCR at 2% for early type stars (B IV/V)
[SBCR for early-type stars based on CHARA/VEGA (Salsi+20)]
- **Araucaria:**
Distance to M31/M33 at 2%
(new way to H_0)

All over HR diagram

The underlying physics
[Theoretical study (Salsi+21)]

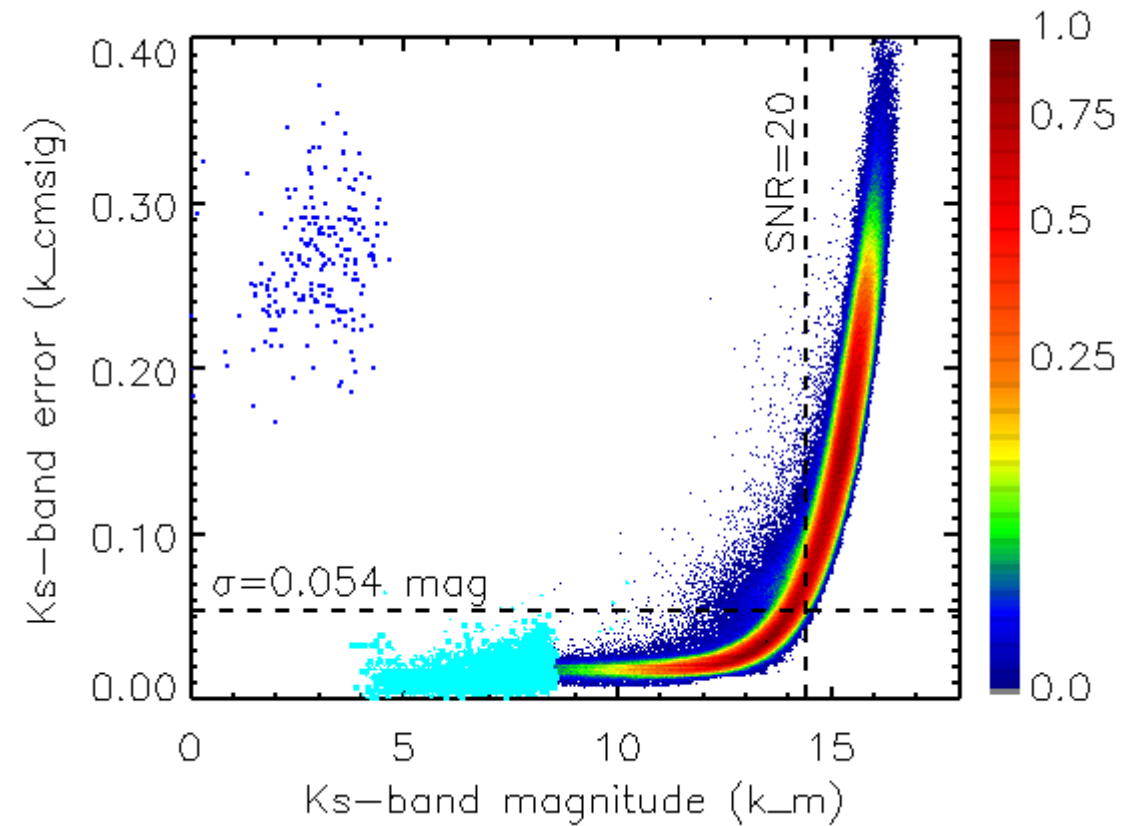
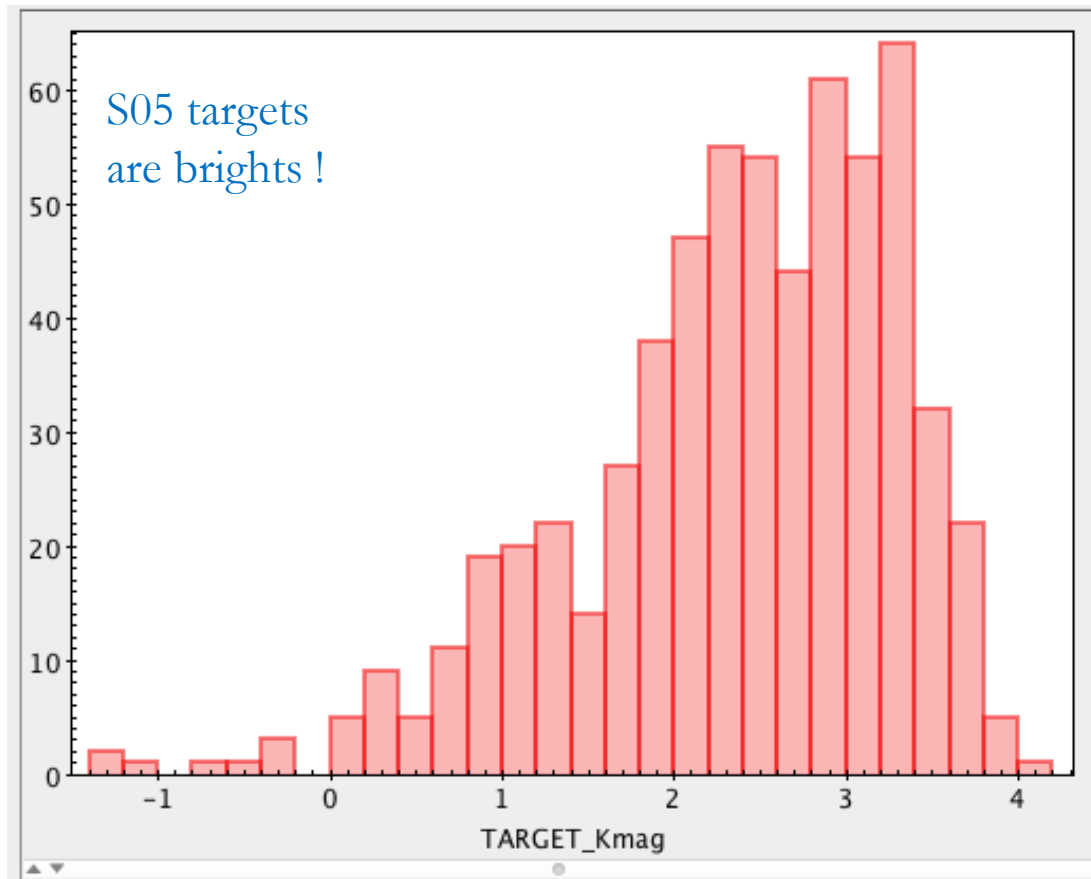


Late-type stars

- **ISSP:**
SBCR at 1% for K III
[Calibration of the SBCR with VLT/PIONIER in H band (Gallenne+18)]
- **Araucaria:**
Confirmation/improvement of LMC/SMC distances in the visible domain

Take Home Messages

1. Araucaria will do his best to provide complementary data for ISSP SBCR targets (*at least*). It means S04 targets, but also S05 in order to enlarge the SBCR sample.
2. The SBCR of SPICA will be used to derive the distance of eclipsing binaries in SMC/LMC/M31/M33 and in other galaxies.
3. A grant application will be deposited this year on the Polish side to secure
 - complementary data for the SBCR ISSP calibration
 - complementary data for the application of the SBCR to distant eclipsing binaries
 - complementary data for the open time CHARA/SPICA program on Cepheids.



Need good K magnitude for bright stars in order to include S05 stars (with limb-darkening measurements) into SBCR calibration (i.e. S04)

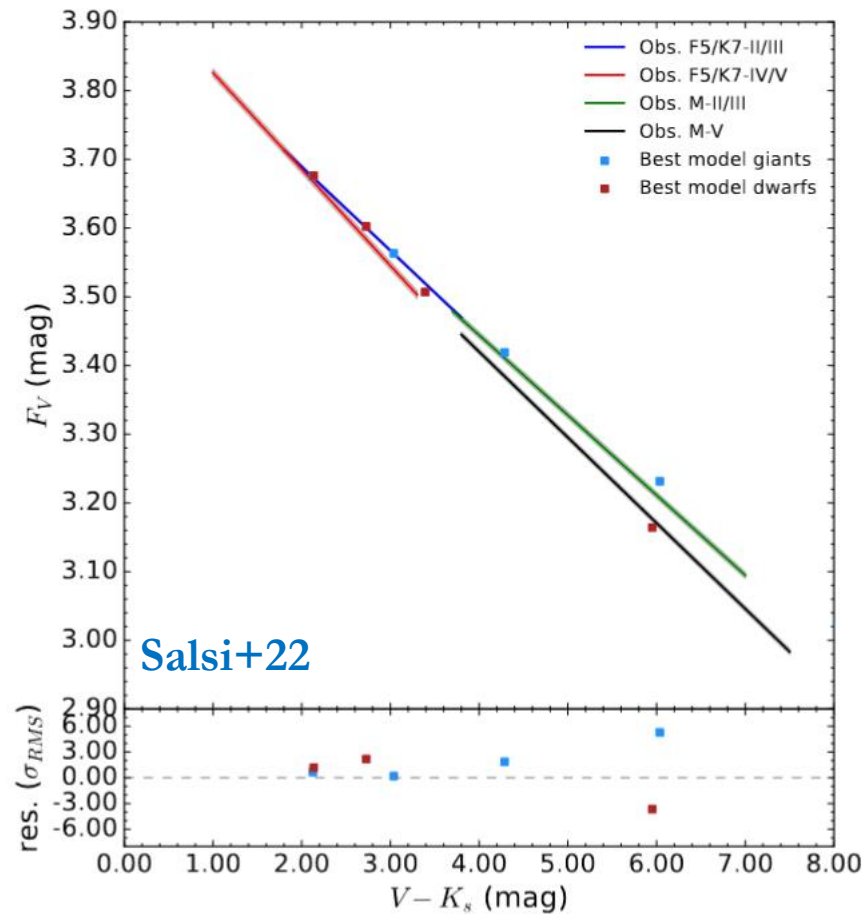


Fig. 5. Comparison between 2MASS- K_s SBCRs from Paper II and theoretical surface brightnesses calculated from stellar MARCS atmosphere models defined in Table 1, i.e. with a $\log g$ varying with the effective temperature. The metallicity is considered to be solar. The shaded grey area corresponds to the 1σ confidence interval of the empirical SBCRs (corresponding in some cases to the thickness of the line). The lower panel shows the difference between the models and the corresponding SBCR (giants or dwarfs, respectively) in a fraction of the RMS of the empirical SBCR.

The difference of SBCR between classes is due to a difference in $\log g$ but most probably also to a difference in limb-darkening. Important synergies between S04 and S05 should be investigated. Idea of “preliminary” study: use MARCS models (like in Salsi+22) to analyse LD all over HR diagram.