Science with the Polish BRITE satellites

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image credit: Fajna Sztuka (http://fajnasztuka.org/)

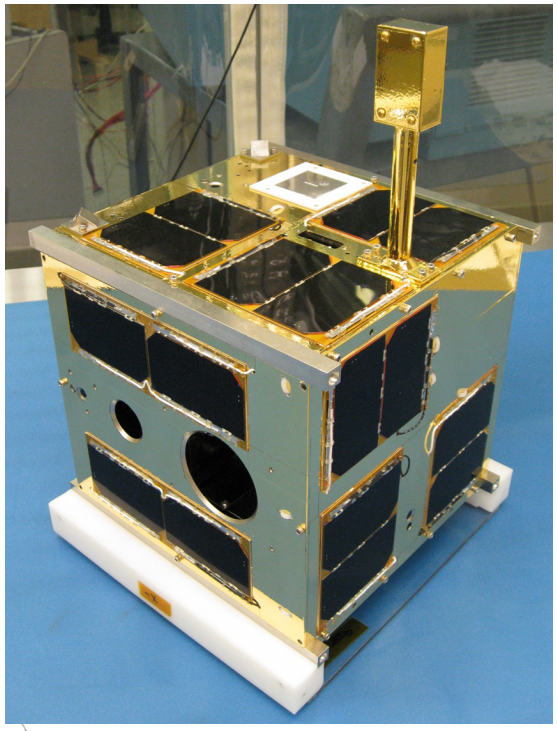
BRITE-PL

CBK PAN TM

Polish Academy of Sciences
Nicolaus Copernicus
Astronomical Center

BRITE

- **BRI**ght **T**arget **E**xplorer
- 6 kg, $20 \times 20 \times 20$ cm cube satellite
- three axis stabilisation with 1' pointing accuracy
- 3 cm telescope with $\sim 24^\circ$ filed of view
- CCD (4008×2672 pixels)
- either red or blue filter



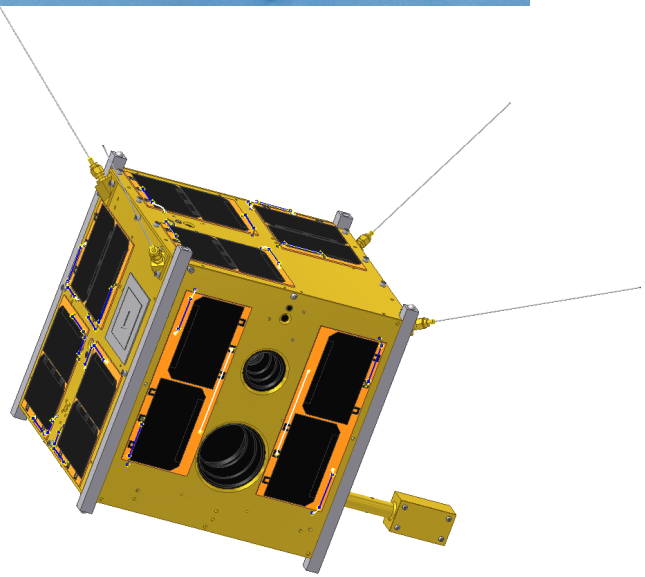


image credit: UTIAS/SFL, CBK

BRITE Constellation

- Austria (UniBRITE, BRITE-Austria)

  launched 02.2013

  blue + red

- Poland (Lem, Heweliusz)

  Lem launched (21.11.2013)

  blue (Lem) + red

- Canada

  launch planned for 2014

  blue + red

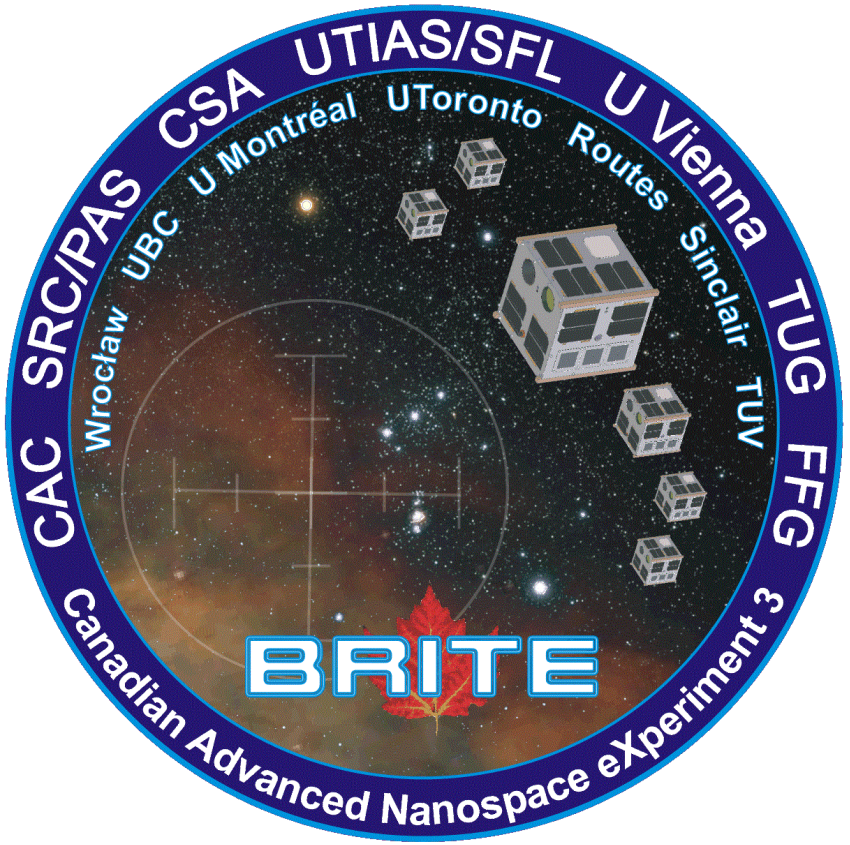


image credit: UTIAS/SFL

BRITE – scheme

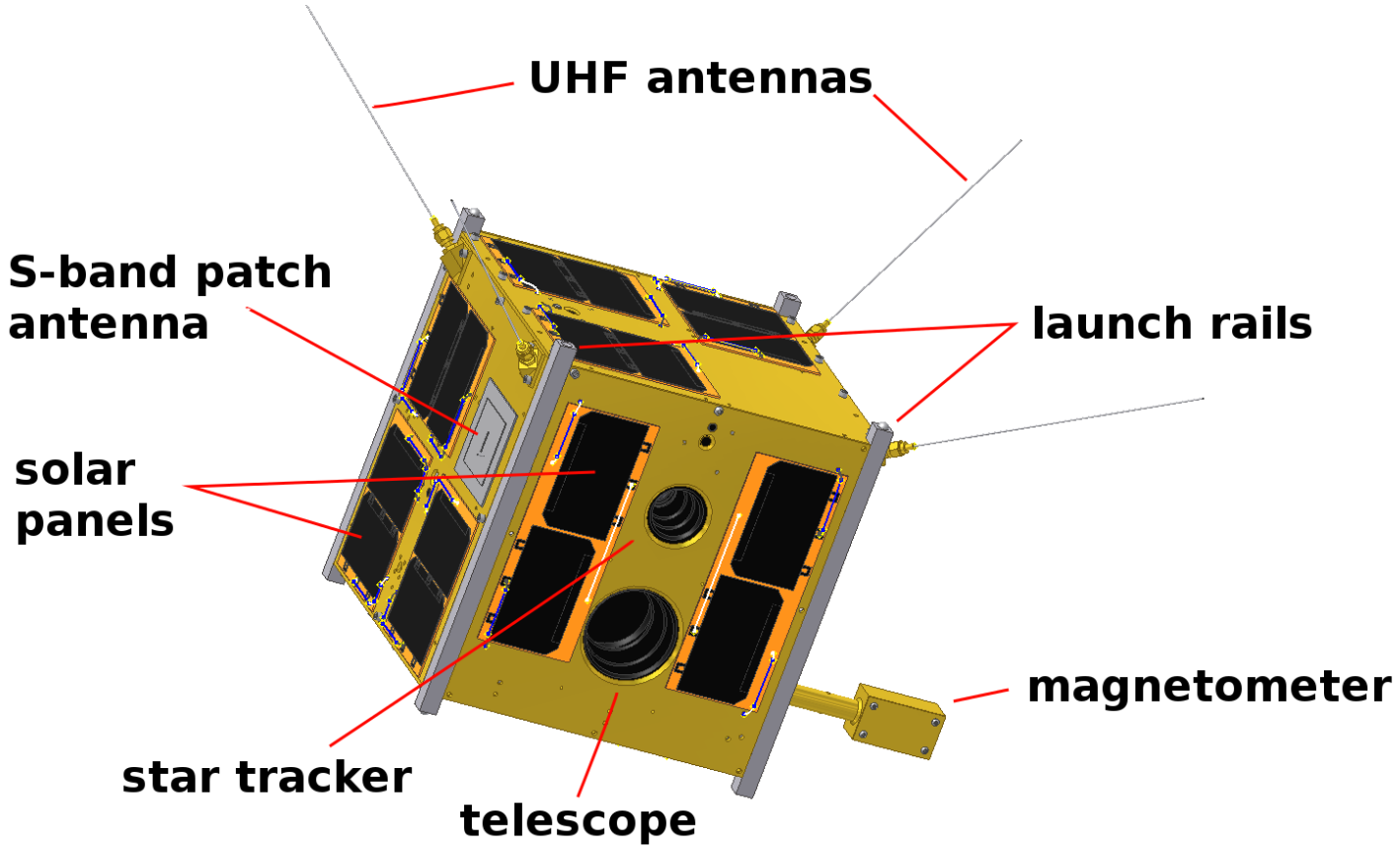
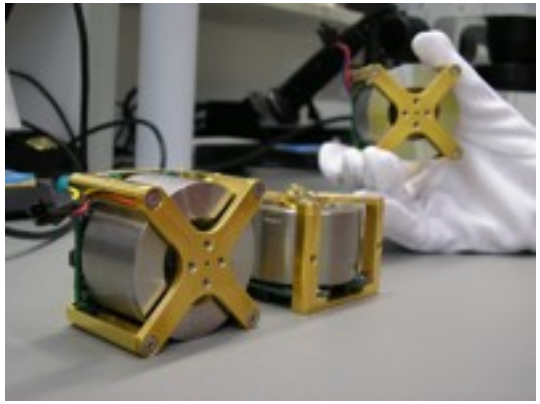


image credit: CBK

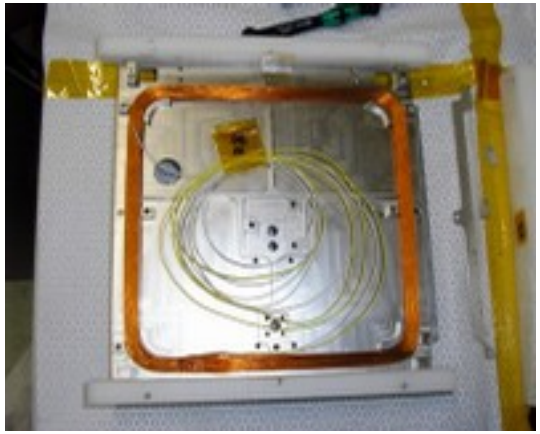
BRITE – attitude control

- ⋆ sensors
  - ▸ magnetometer
  - ▸ Sun sensors
  - ▸ star tracker
- ⋆ actuators
  - ▸ reaction wheels
  - ▸ magnetorquer coils

star tracker RT-16



reaction wheel

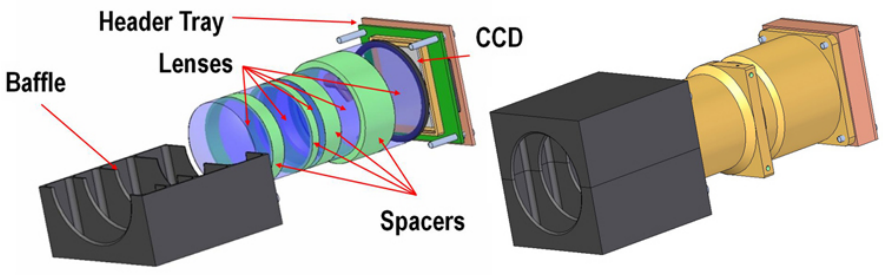


magnetorquer coil

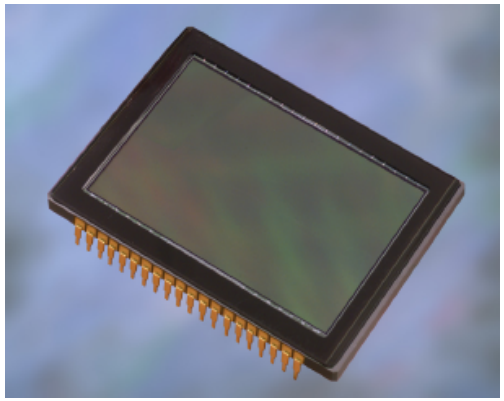
image credits: Sinclair Interplanetary/TU Graz

BRITE – optics

⋆ telescope



⋆ CCD (KODAK KA11002)



⋆ filters

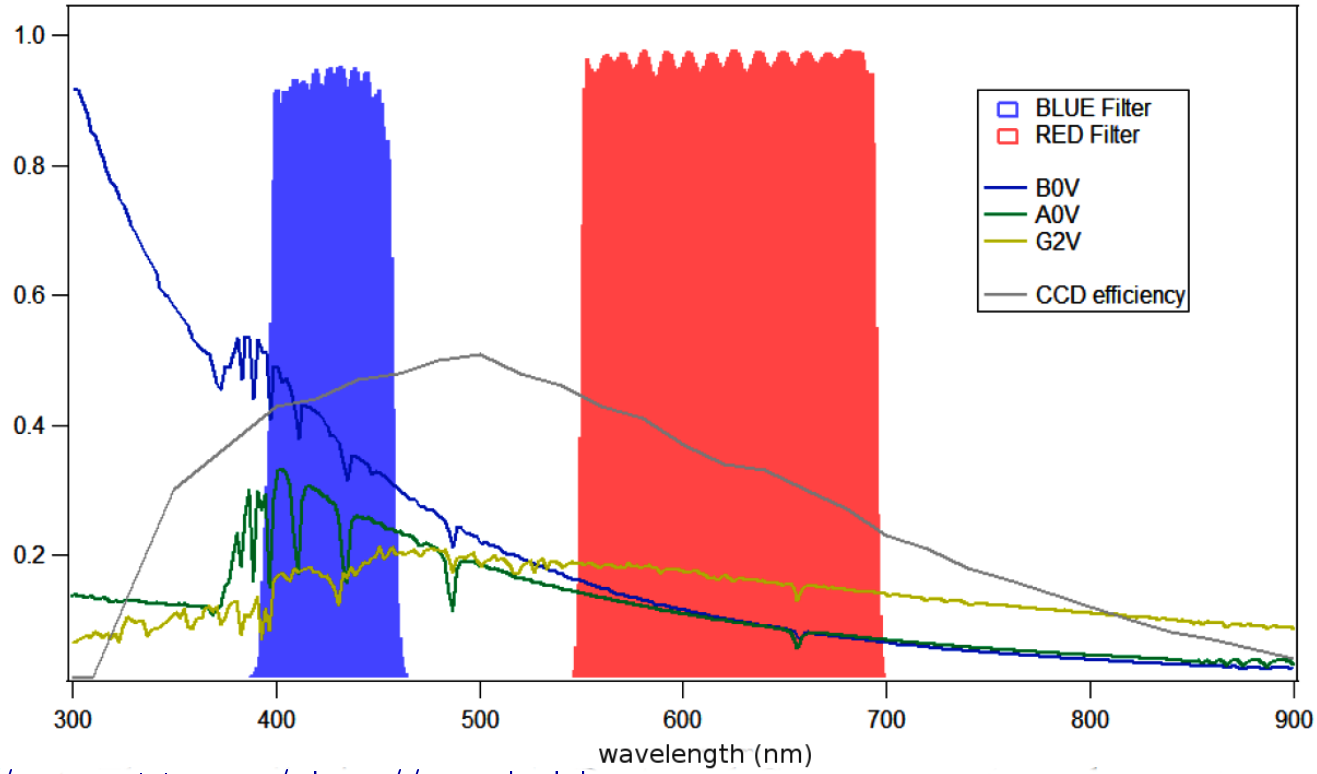


image credits: http://www.univie.ac.at/, http://www.kodak.com

Science with BRITE

⋆ BRITE will observe the brightest stars in the sky

- ▸ close stars
- ▸ **intrinsically most luminous (and most massive) stars**

⋆ Why these stars are important?

- ▸ primordial nucleosynthesis: $\approx 75\%$ H, $\approx 25\%$ He
- ▸ heavier elements are produced in stars

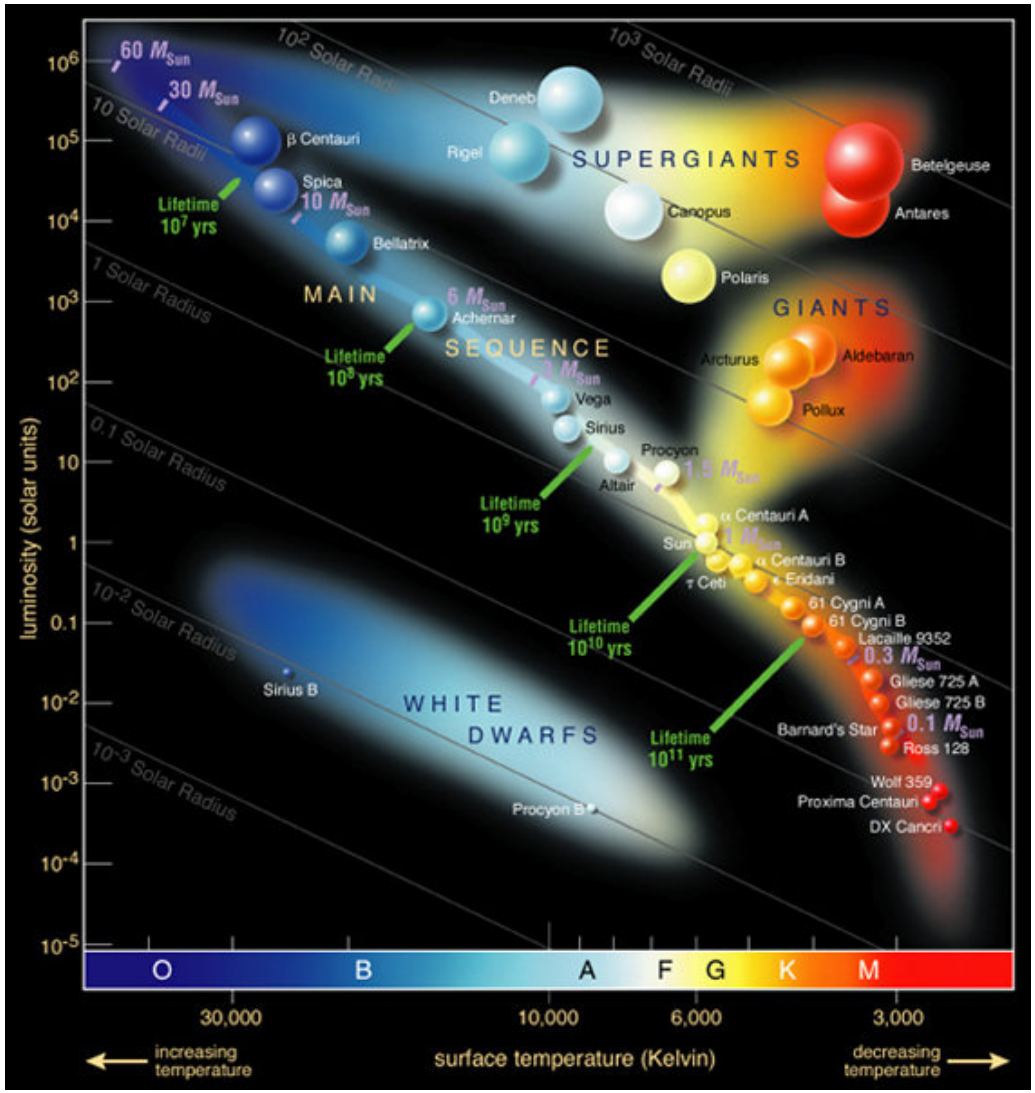


image credit: http://commons.wikimedia.org

Science with BRITE

- ⋆ least massive stars will only burn hydrogen
- ⋆ medium mass stars will burn helium and produce neutron rich isotopes during AGB phase
  - ▸ stellar wind
  - ▸ planetary nebulae
- ⋆ most massive stars will also explode as supernovae
- ⋆ more massive the star, shorter it lives → **massive stars dominate the ecology of the Universe**

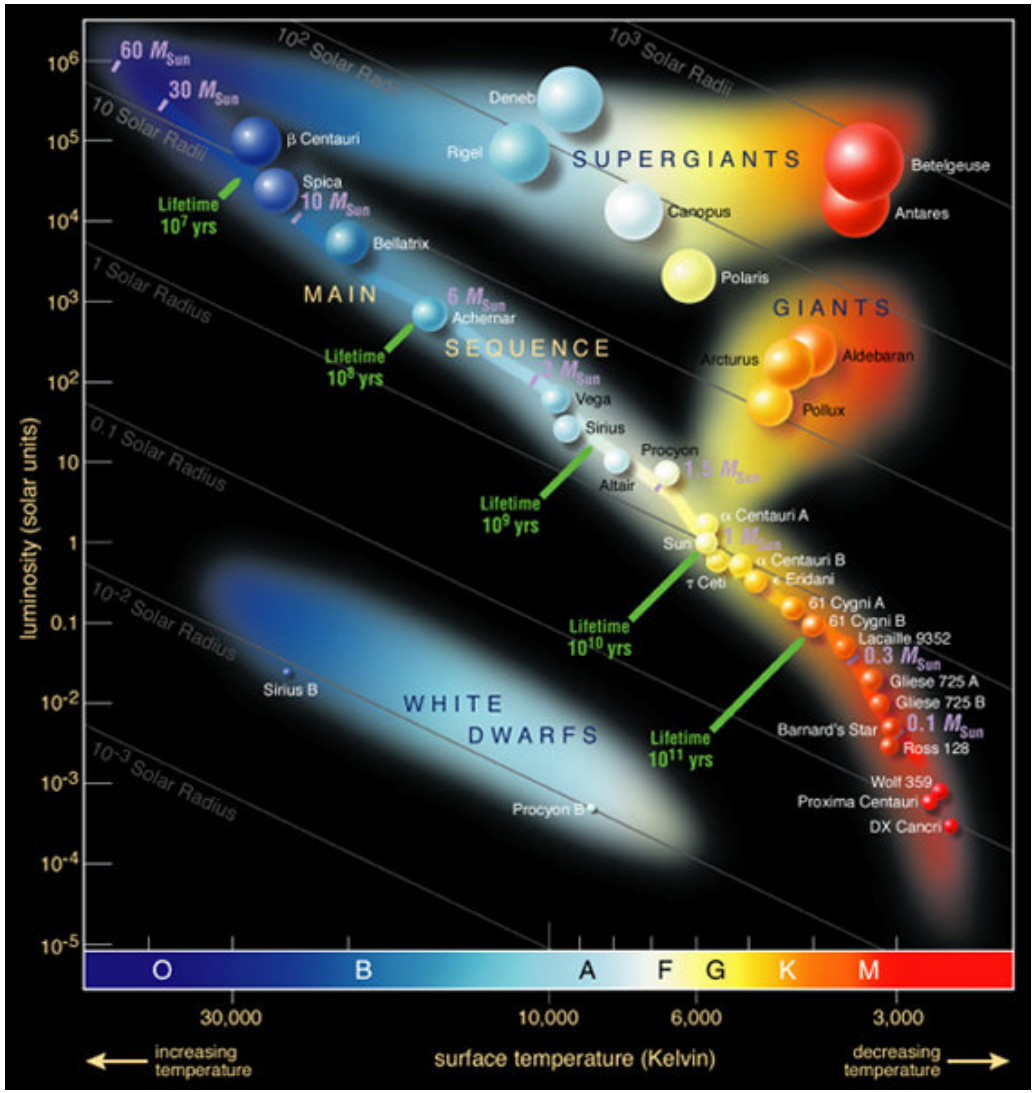


image credit: http://commons.wikimedia.org

Science with BRITE

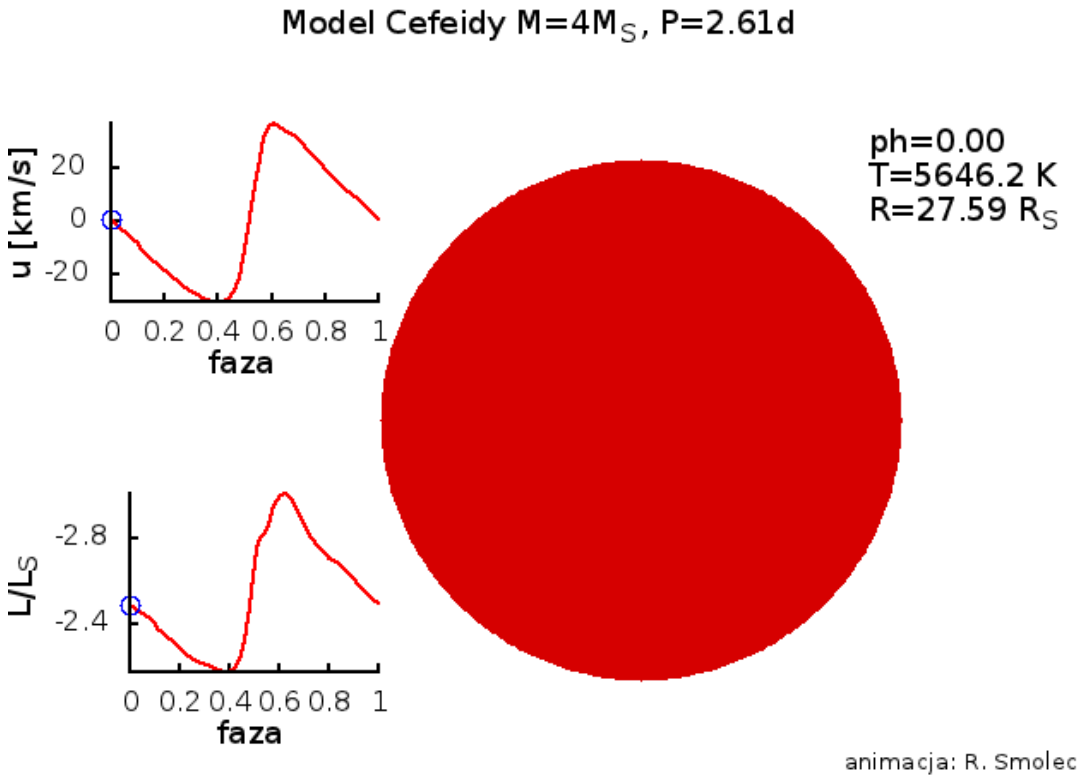
image credit: Hubble: NASA, ESA, N. Smith (Univ. of California, Berkeley), and The Hubble Heritage Team (STScI/AURA); CTIO:N. Smith (Univ. of California, Berkeley) and NOAO/AURA/NSF;

Science with BRITE

Science objectives of BRITE:

- ⋆ understanding of luminous stars and the life-cycle of matter
  - ▸ stellar winds
  - ▸ convection and mixing
  - ▸ effects of rotation and magnetic fields
- ⋆ understanding variability and structure of the most luminous stars
  - ▸ asteroseismic study of internal structure of stars

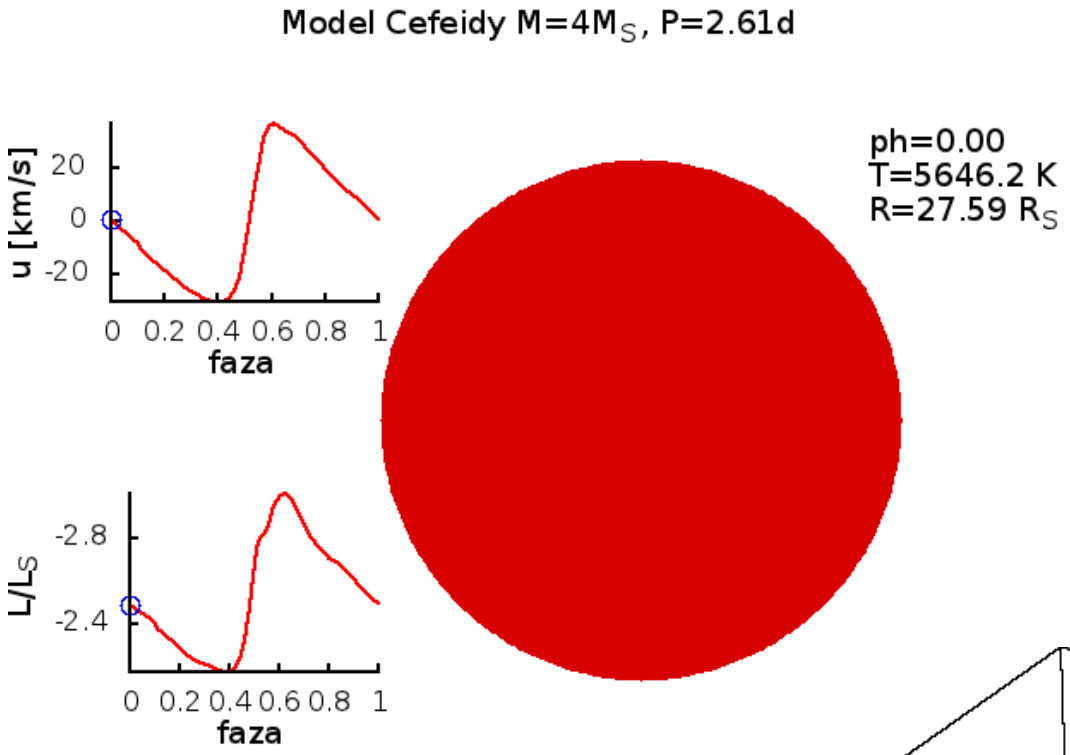
Science with BRITE – stellar pulsations



radial modes

n – radial order, fundamental mode, first overtone, 2O,...

Science with BRITE – stellar pulsations



radial modes

n – radial order, fundamental mode, first overtone, 2O,...

non-radial modes

ℓ – mode degree

m – mode order, $|m| < \ell$

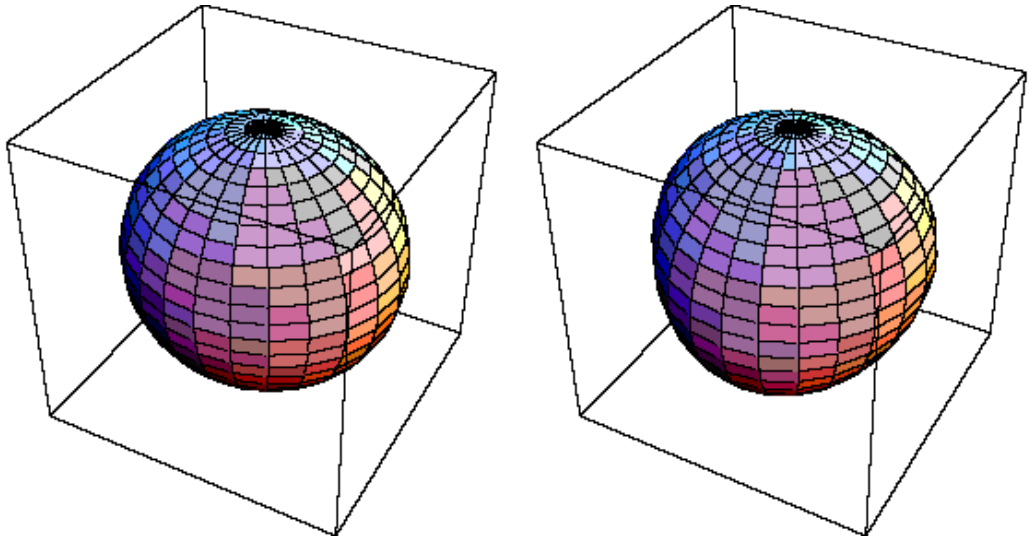
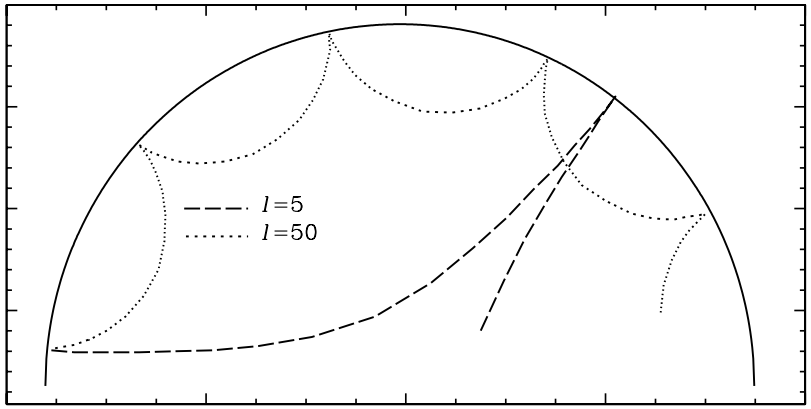


image credits: R. Smolec (Cepheid animation), A. Chambers, D. Baker (U. Sydney) (non-radial modes)

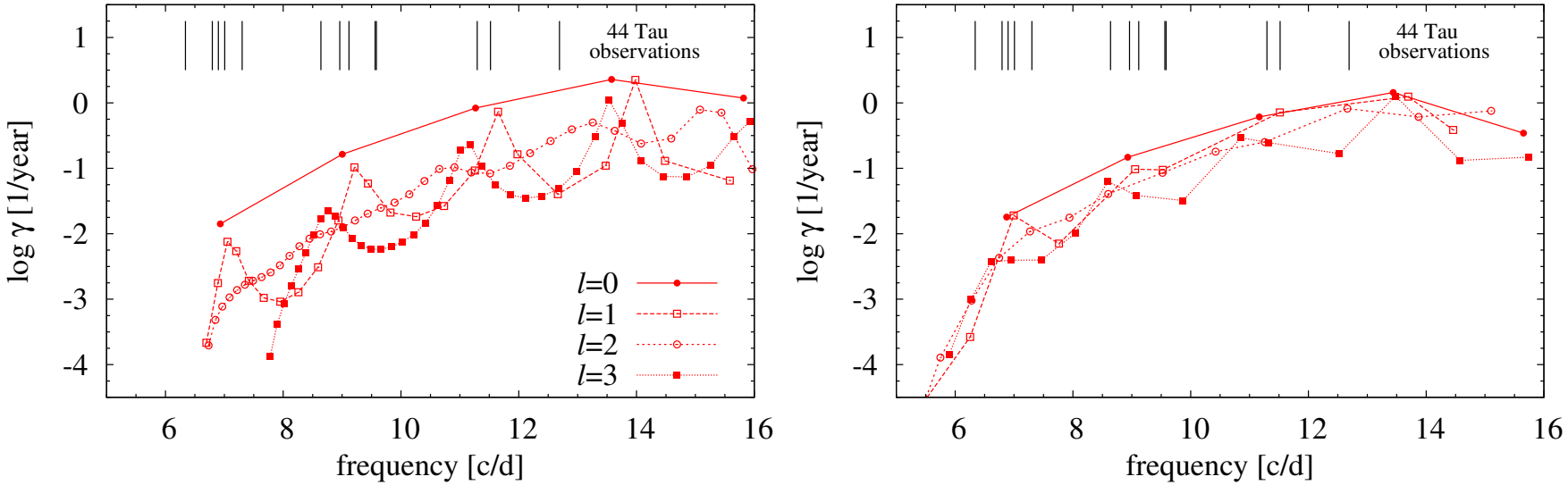
Science with BRITE – stellar pulsations

- ⋆ pulsation mode: standing sound wave, frequency depends on sound speed profile along propagation path
- ⋆ propagation path depends on mode geometry: smaller the ℓ deeper into the star the mode penetrates
- ⋆ spherical, non-rotating, non-magnetic star: frequency does not depend on m
- ⋆ rotation breaks the degeneracy

  $\rightarrow$ sounding internal rotation



Science with BRITE – stellar pulsations

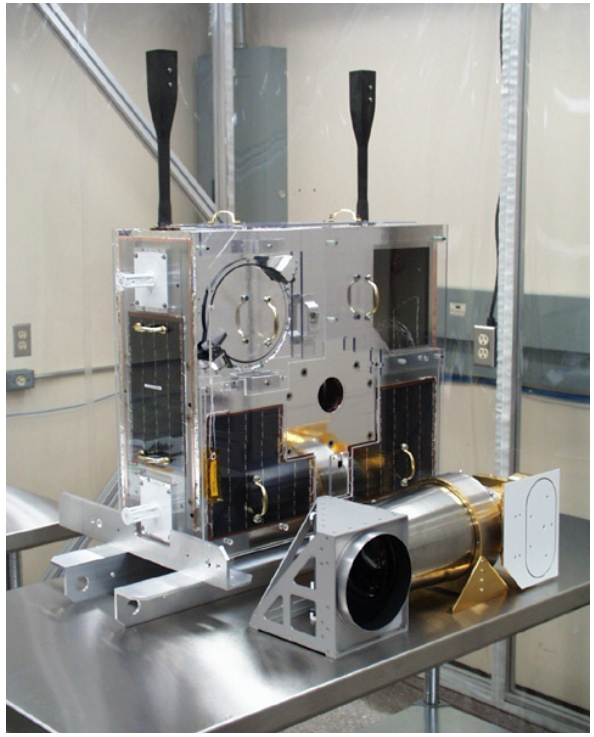


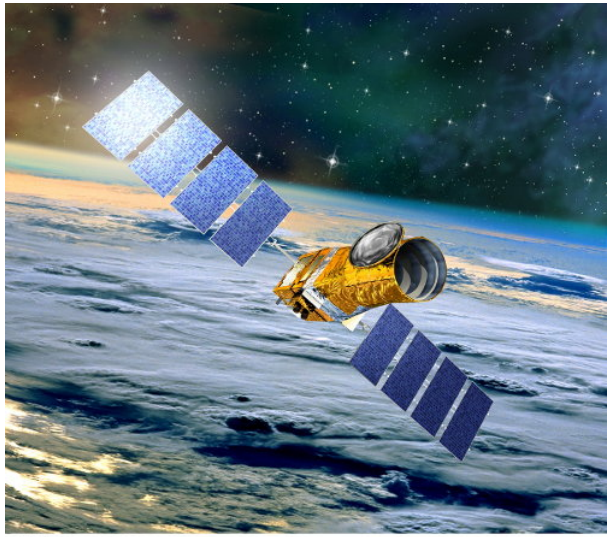
⋆ asteroseismic modelling in practice: δ Sct star – 44 Tau

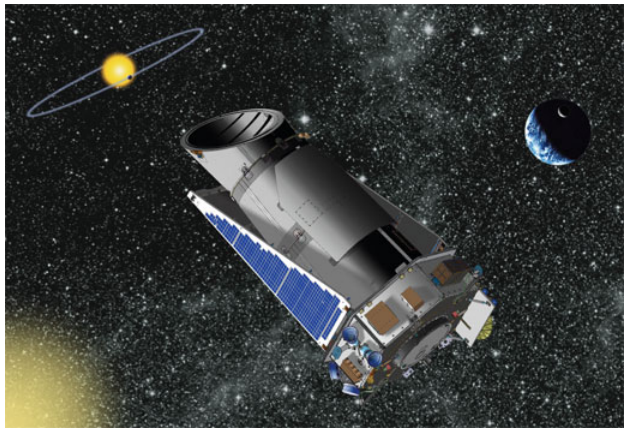
- coupled stellar evolution and stellar pulsation code are used to compute the evolutionary track and variation of frequency spectrum along it
- mode identification is crucial
- additional constraints (e.g. $T_{\rm eff}$ or Z) are very important

image credit: P. Lenz

Space observations of pulsating stars







MOST (Canada)

- 65x65x30 cm, 54 kg
- launch 3.2003
- still observing

CoRoT (CNES+ESA)

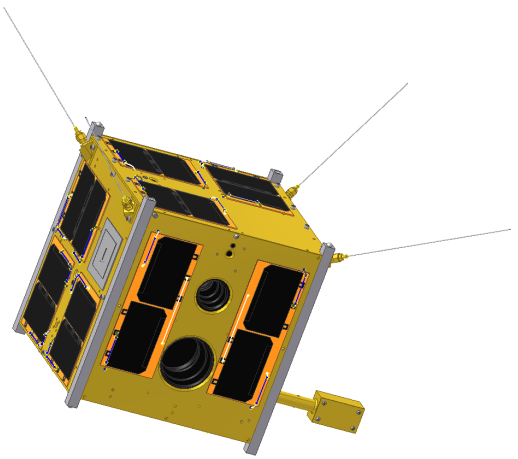
- 4.10x1.98 m, 630 kg
- launch 12.2006
- defunct

Kepler (NASA)

- 4.7x2.7 m, 1054 kg
- launch 3.2009
- stand-by mode

image credits: http://www.astro.ubc.ca/MOST/ http://smsc.cnes.fr/COROT/ http://www.kepler.nasa.gov

BRITE – small is powerful



- project is very cheap
- all sky is accessible
- two band observation (red and blue filters)
- simultaneous observations by up to six satellites
- bright stars accessible
- ground-based spectroscopic follow-up feasible with 3-m class telescopes

images credit: CBK

BRITE sky – H-R diagram, $V < 4\,mag$

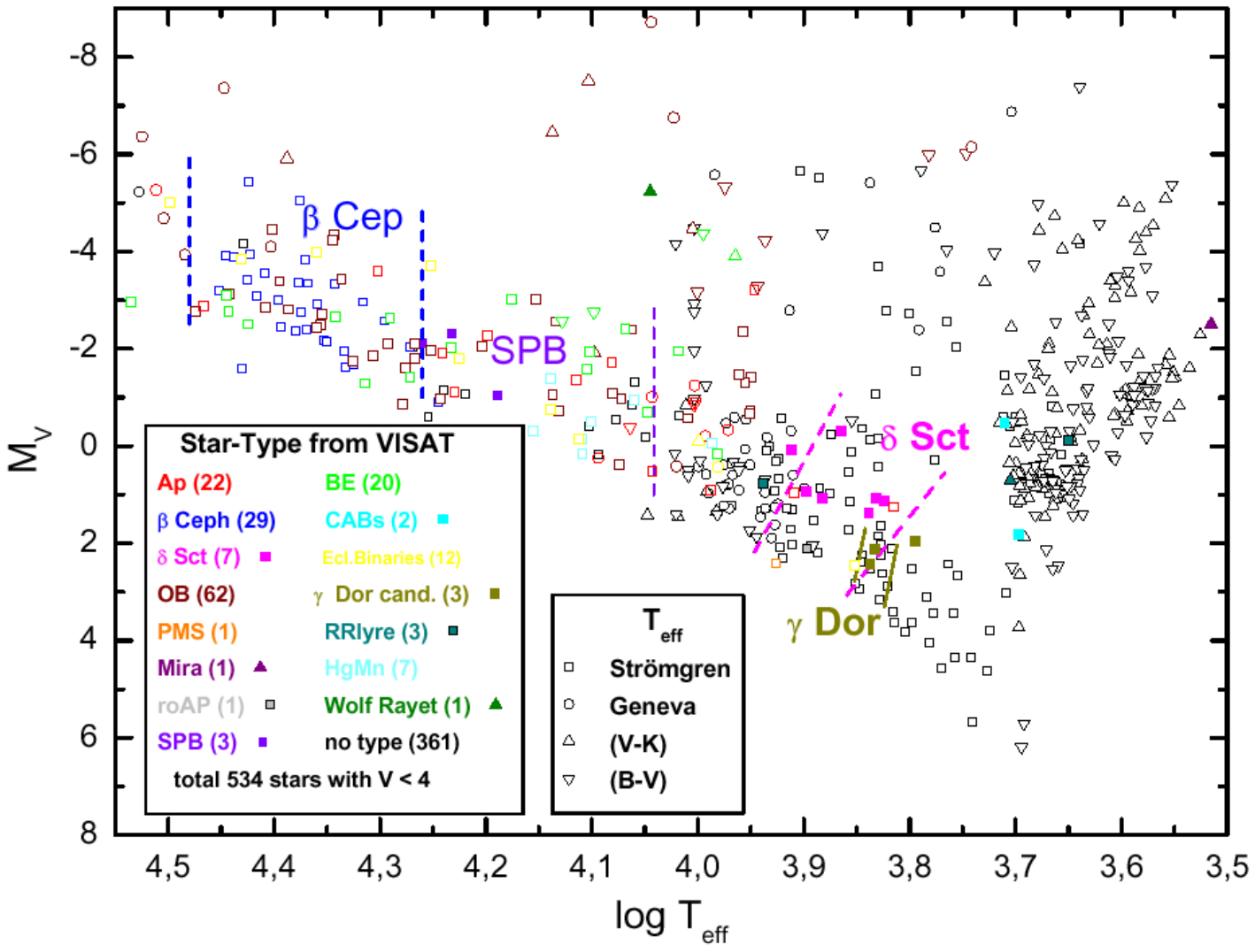


image credit: W. Weiss

BRITE sky – H-R diagram, $V < 6\,mag$

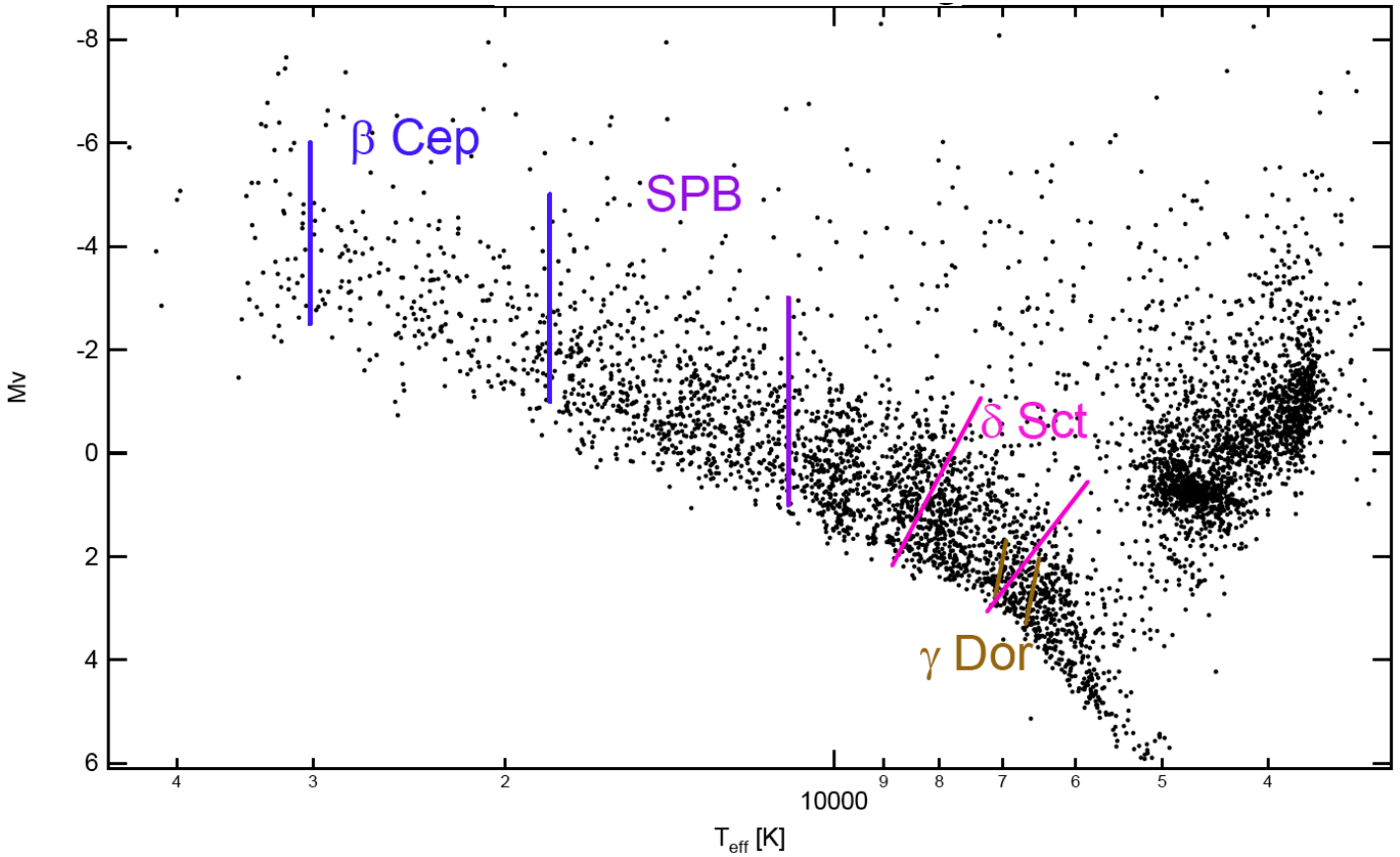
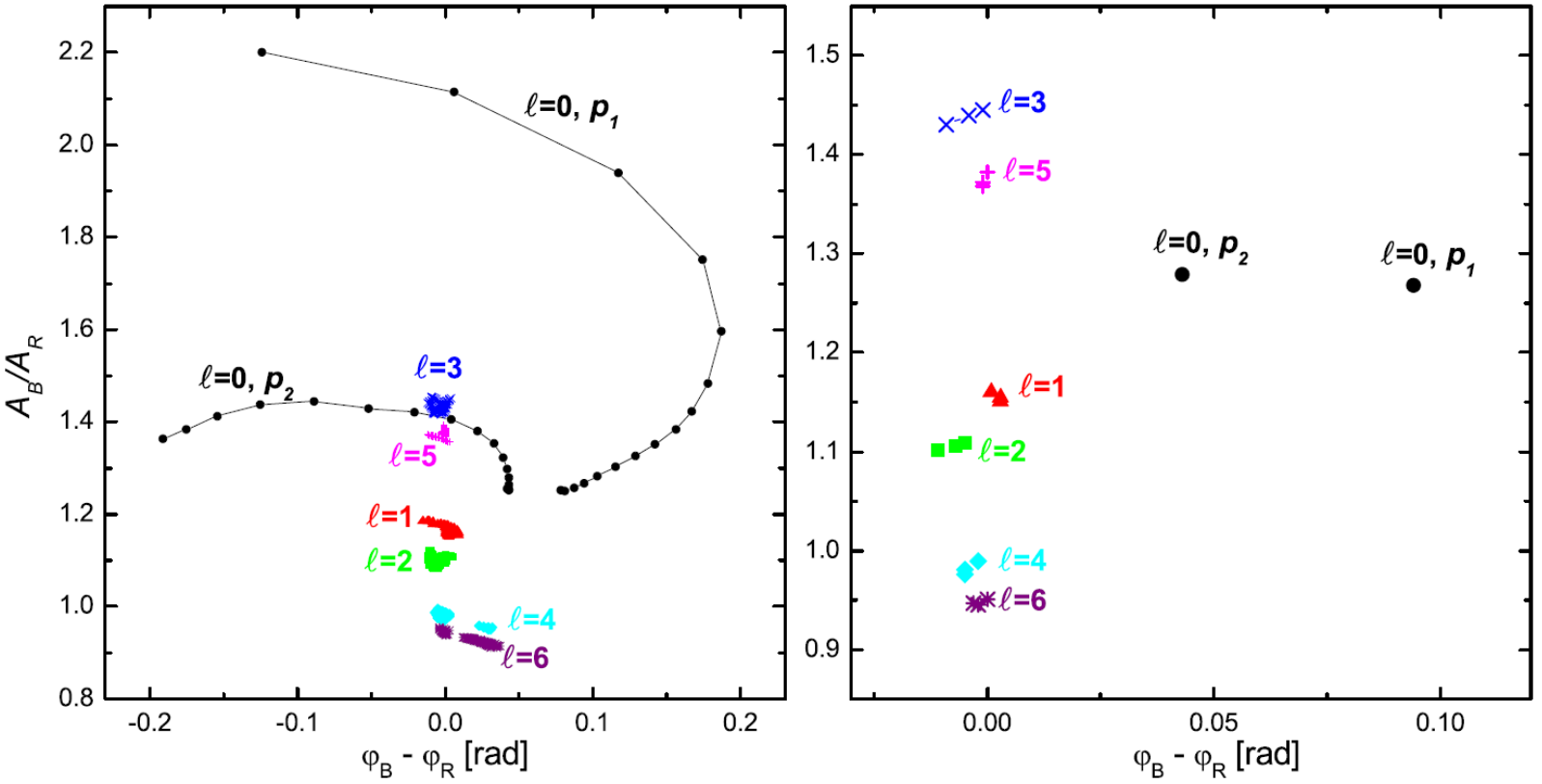


image credit: W. Weiss

BRITE sky – mode identification with two band photometry



$\star$ β Cep models ($12M_\odot$, left: MS evolution, right: one model at $\log T_{\rm eff} = 4.4$)

image credit: J. Daszyńska-Daszkiewicz

BRITE sky

Our (Warsaw group) objectives include

- ⋆ main sequence stars
  - ▸ asteroseismic modelling: constraints on basic stellar parameters
  - ▸ testing rotation and mixing scenarios
  - ▸ testing microphysics data (opacities)
- ⋆ Cepheids
  - ▸ long-term stability of light curves
  - ▸ additional low-amplitude modes

Polish BRITE – route to space: flat sat

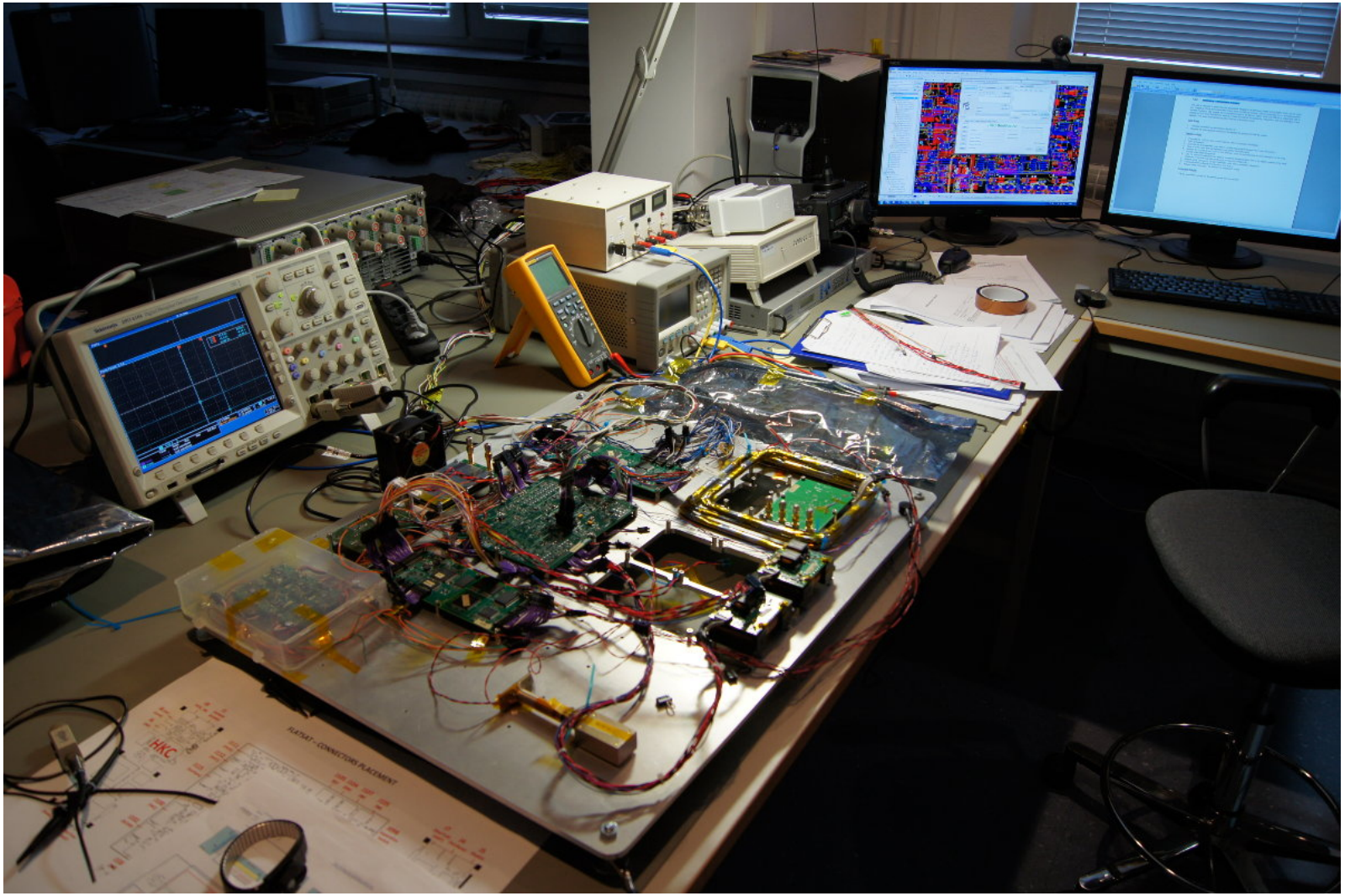


image credit: CBK

Polish BRITE – route to space: Lem integration

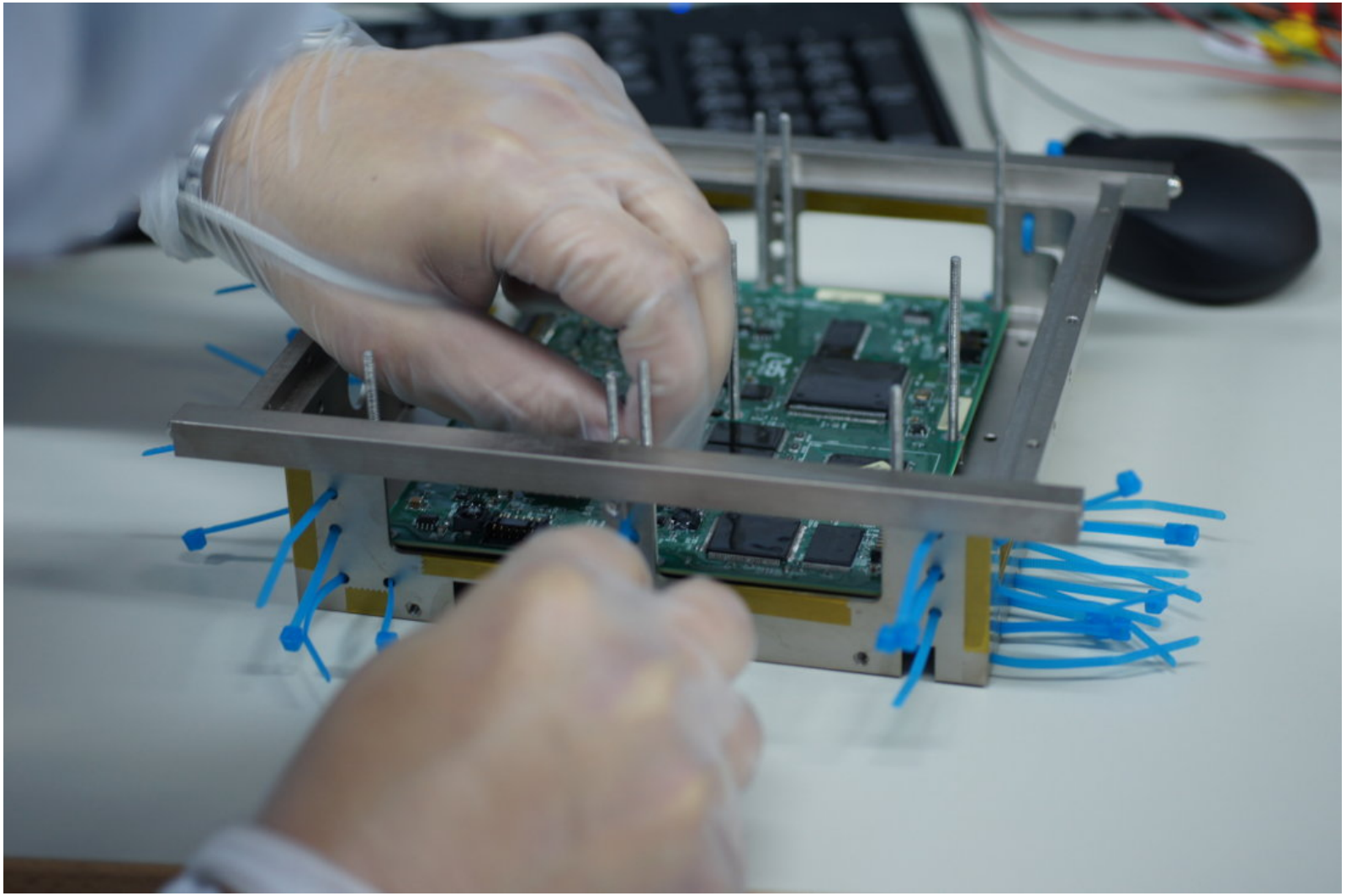


image credit: CBK

Polish BRITE – route to space: Lem integration

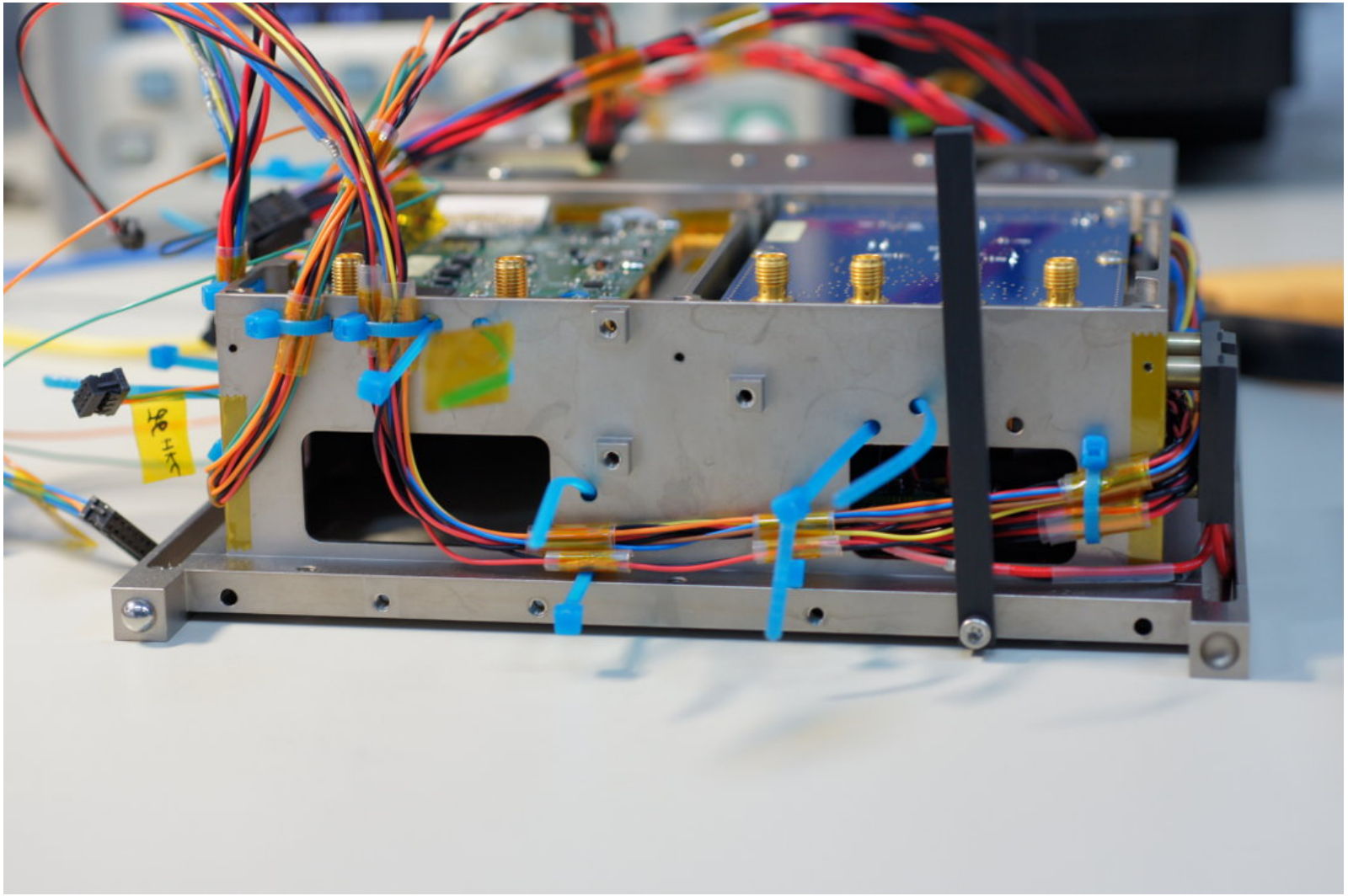


image credit: CBK

Polish BRITE – route to space: Lem integration

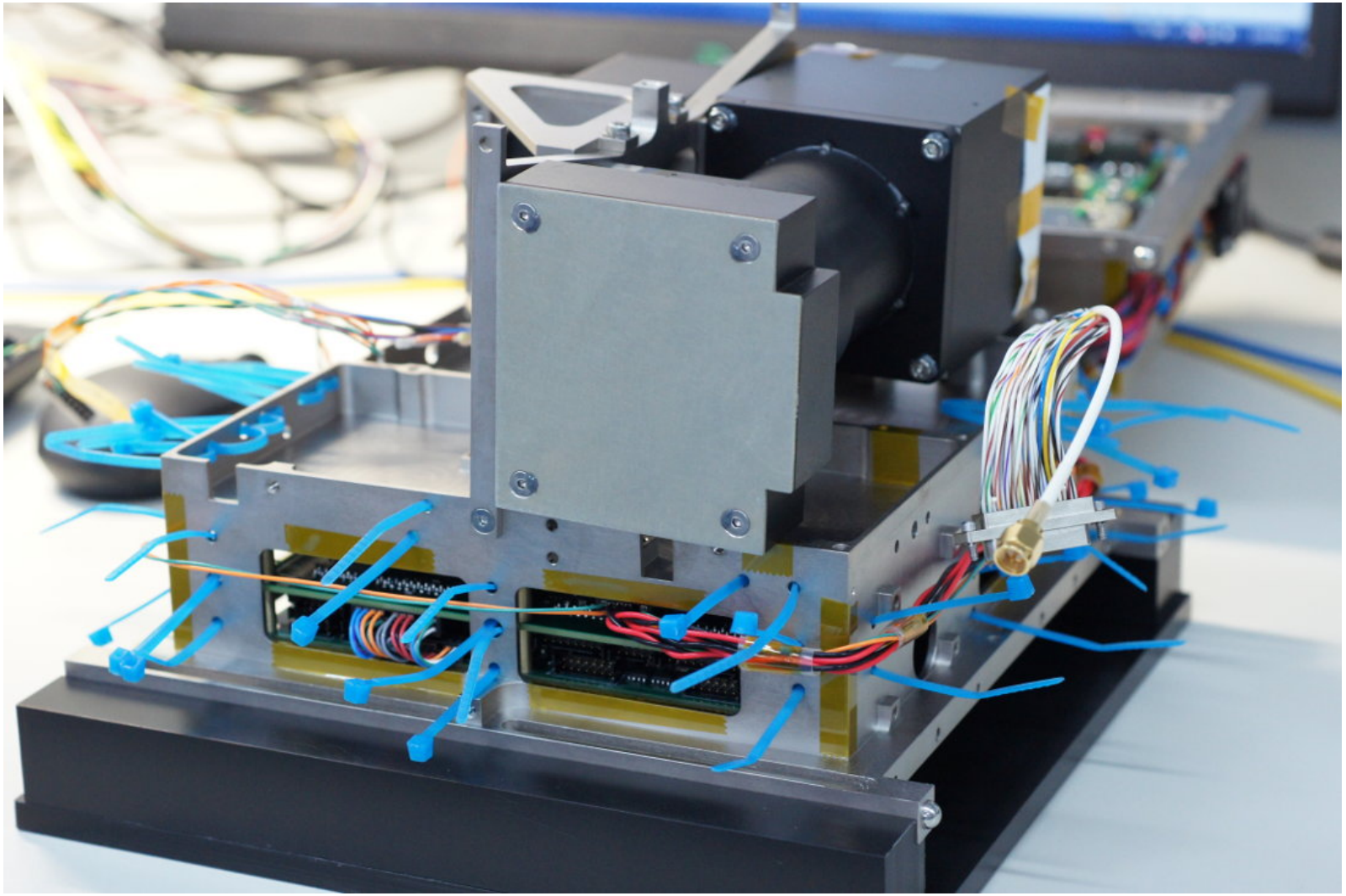


image credit: CBK

Polish BRITE – route to space: Lem integration

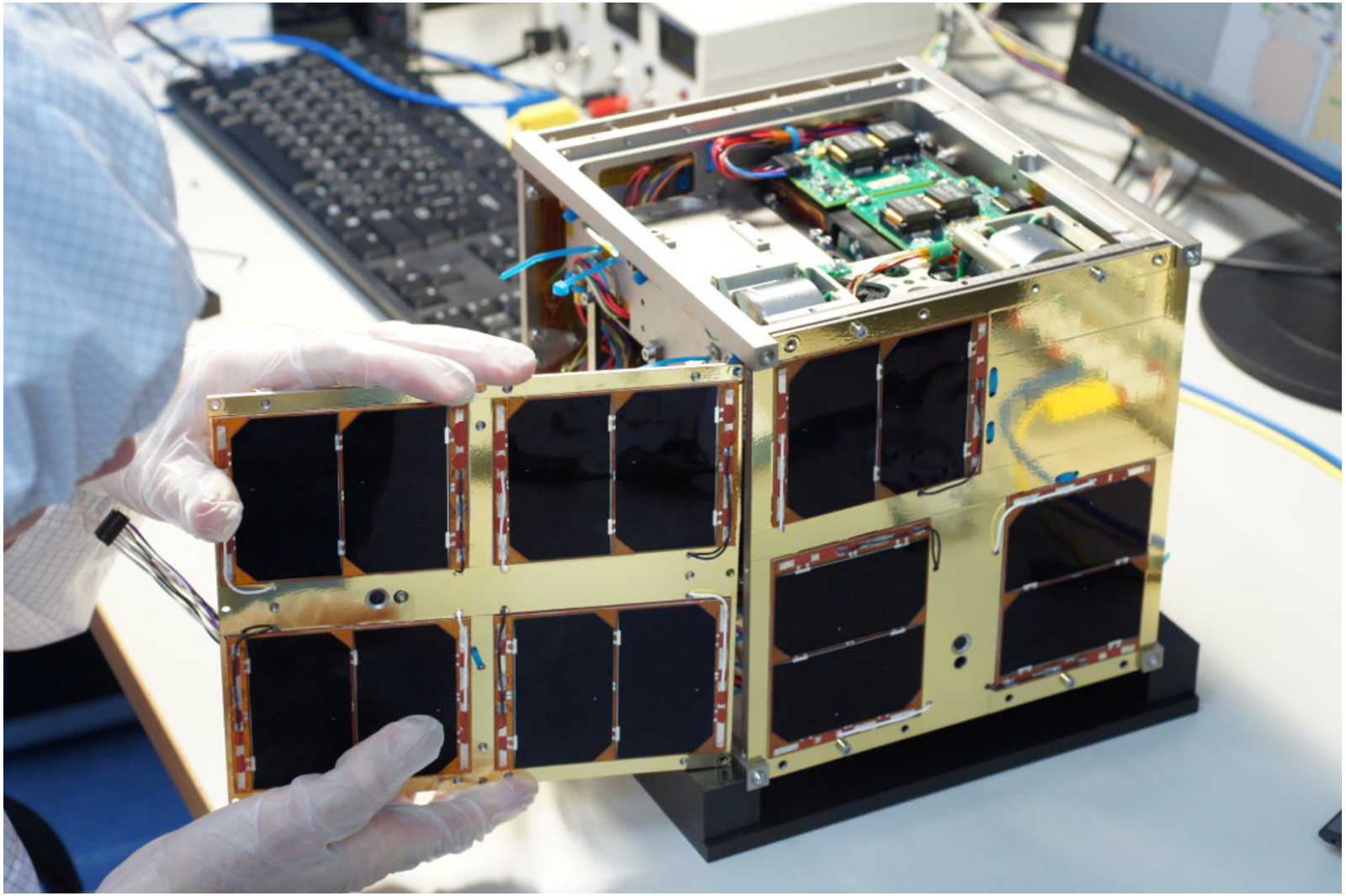


image credit: CBK

Polish BRITE – route to space: Lem integration

image credit: CBK

Polish BRITE – route to space: vibration testing

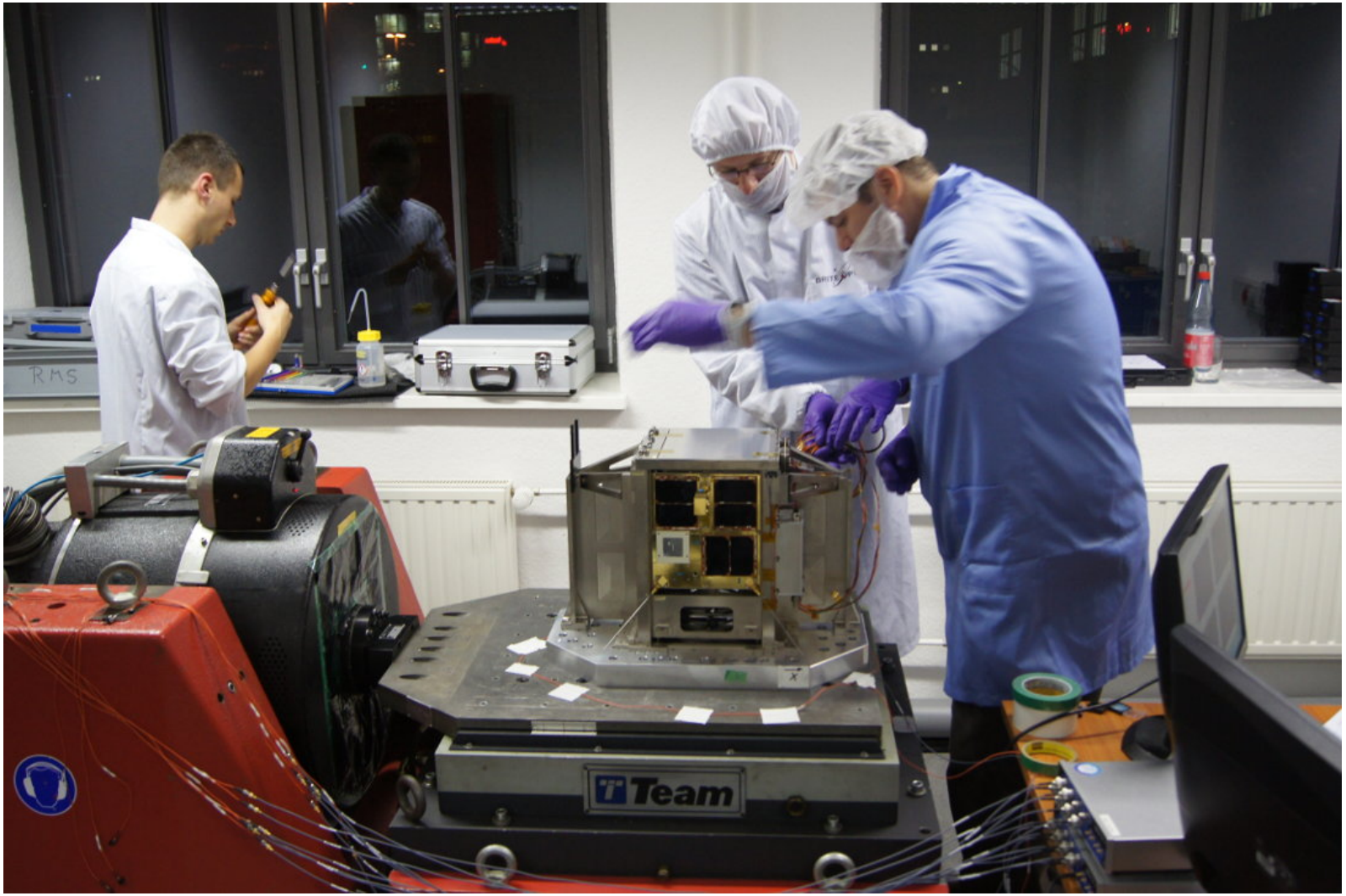


image credit: CBK

Polish BRITE – route to space: open field testing

image credit: CBK

Polish BRITE – route to space: assembly with XPOD

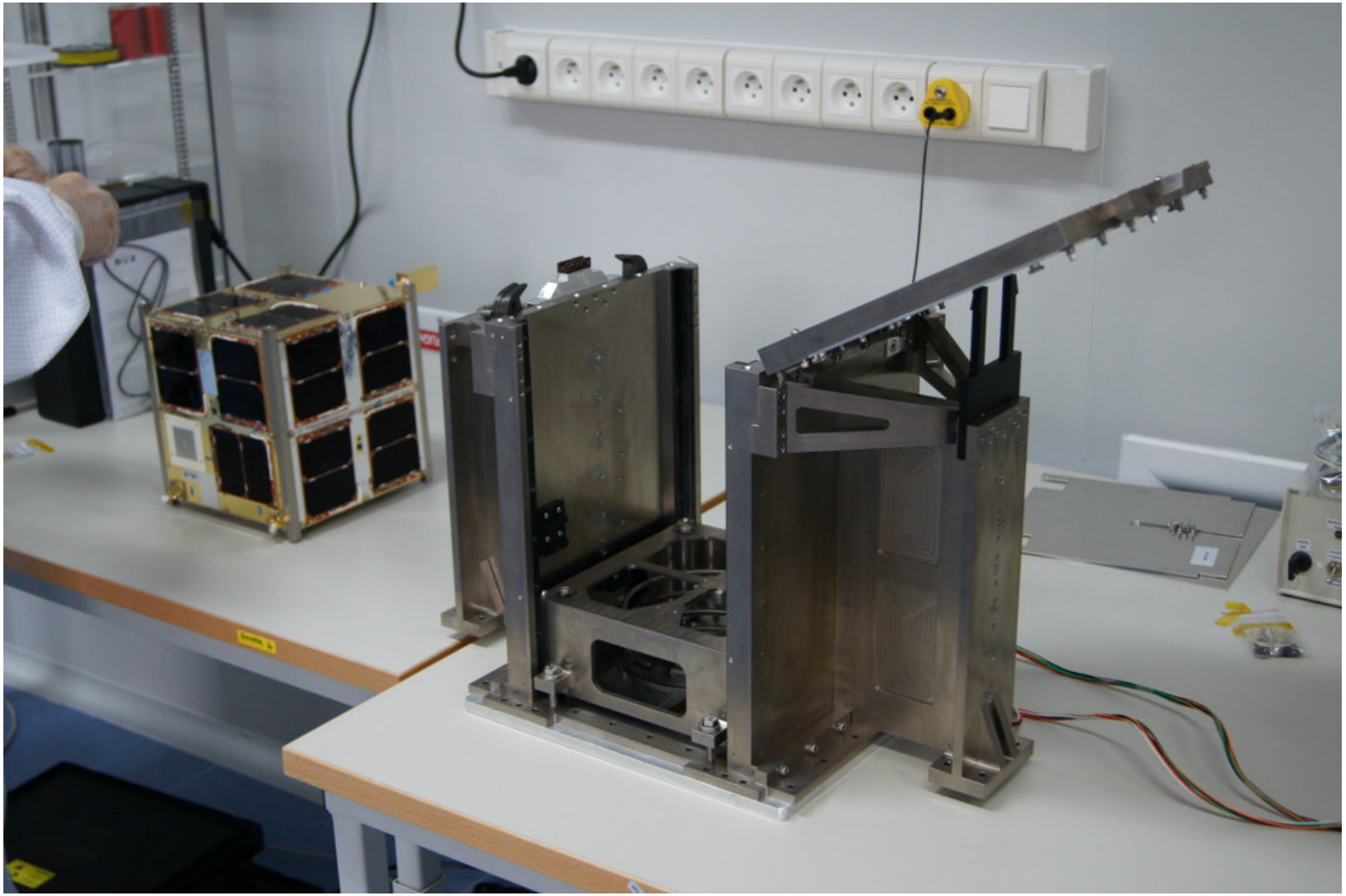


image credit: CBK

Polish BRITE – route to space: assembly with XPOD

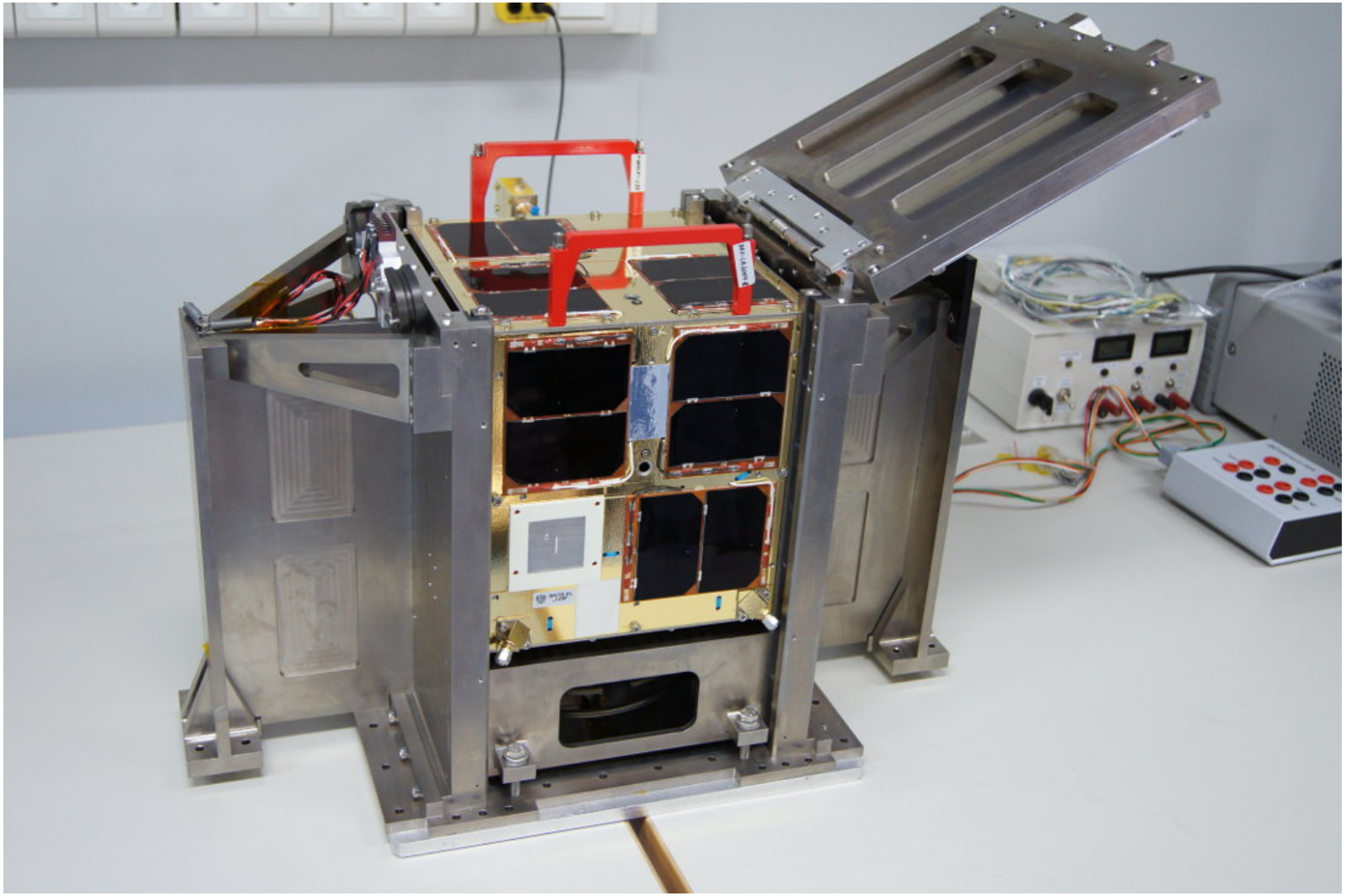


image credit: CBK

Polish BRITE – route to space: ready for travel to Yasny

image credit: CBK

Polish BRITE – route to space: integration with Dnepr

image credit: KOSMOTRAS

Polish BRITE – route to space: integration with Dnepr

image credit: KOSMOTRAS

Launch of LEM – 21 Nov 2013

- ⋆ Dnepr rocket
  - ▸ SS-18 Satan (R36M) → START-1 → Dnepr
  - ▸ 3-stages, UDMH+N_2O_4
- ⋆ launch
  - ▸ from silo at Dombarovsky (Yasny) base
  - ▸ 21.11.2013, 8:10:11 (CET)
- ⋆ BRITE orbit
  - ▸ orbital period 99.55 min
  - ▸ mean altitude 736.8 km
  - ▸ eccentricity 0.0207
  - ▸ inclination 97.78°

image credit: Kosmotras

Communication: ground station at CAMK

image credit: A. Pamyatnykh

Communication: ground station at CAMK

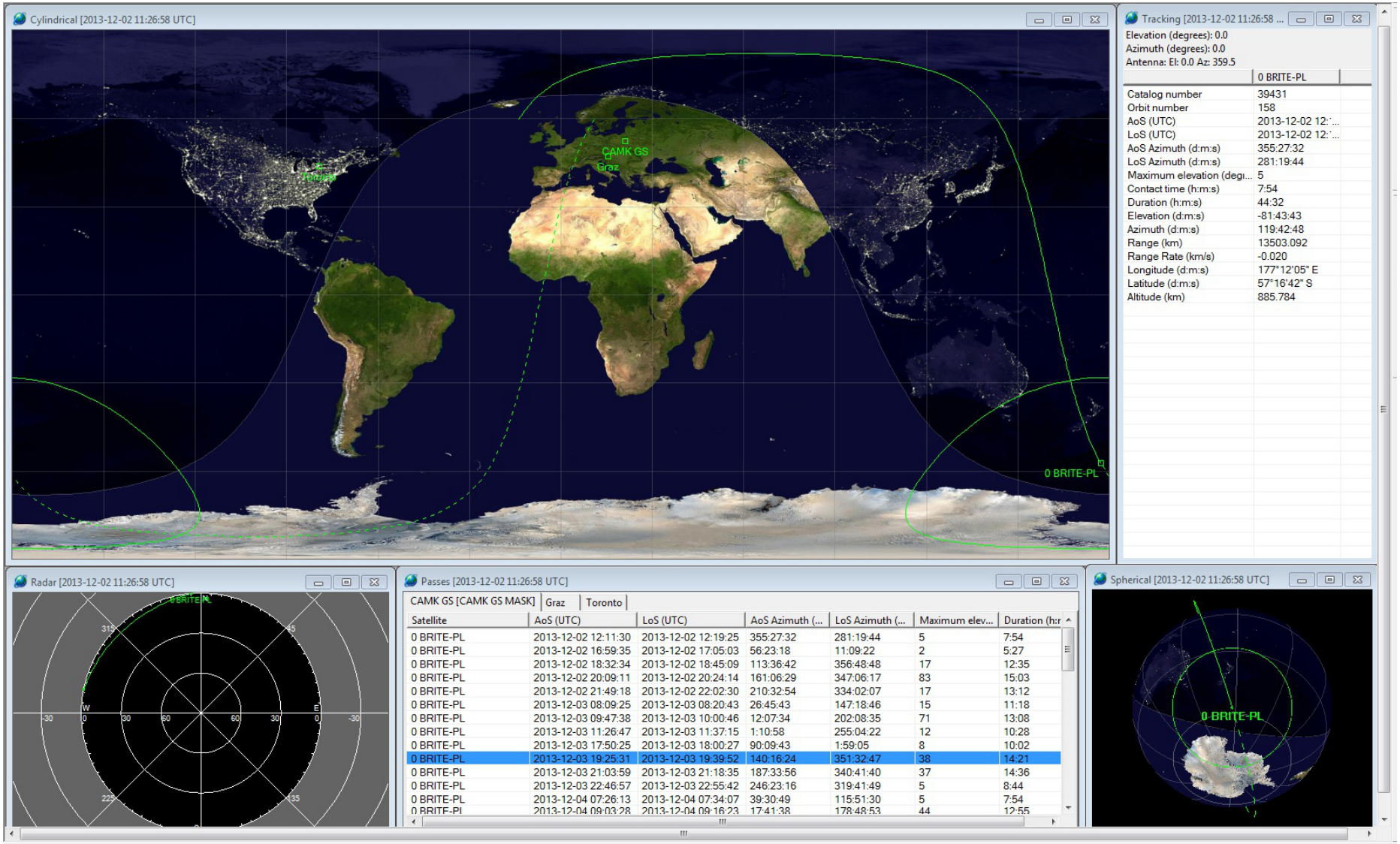
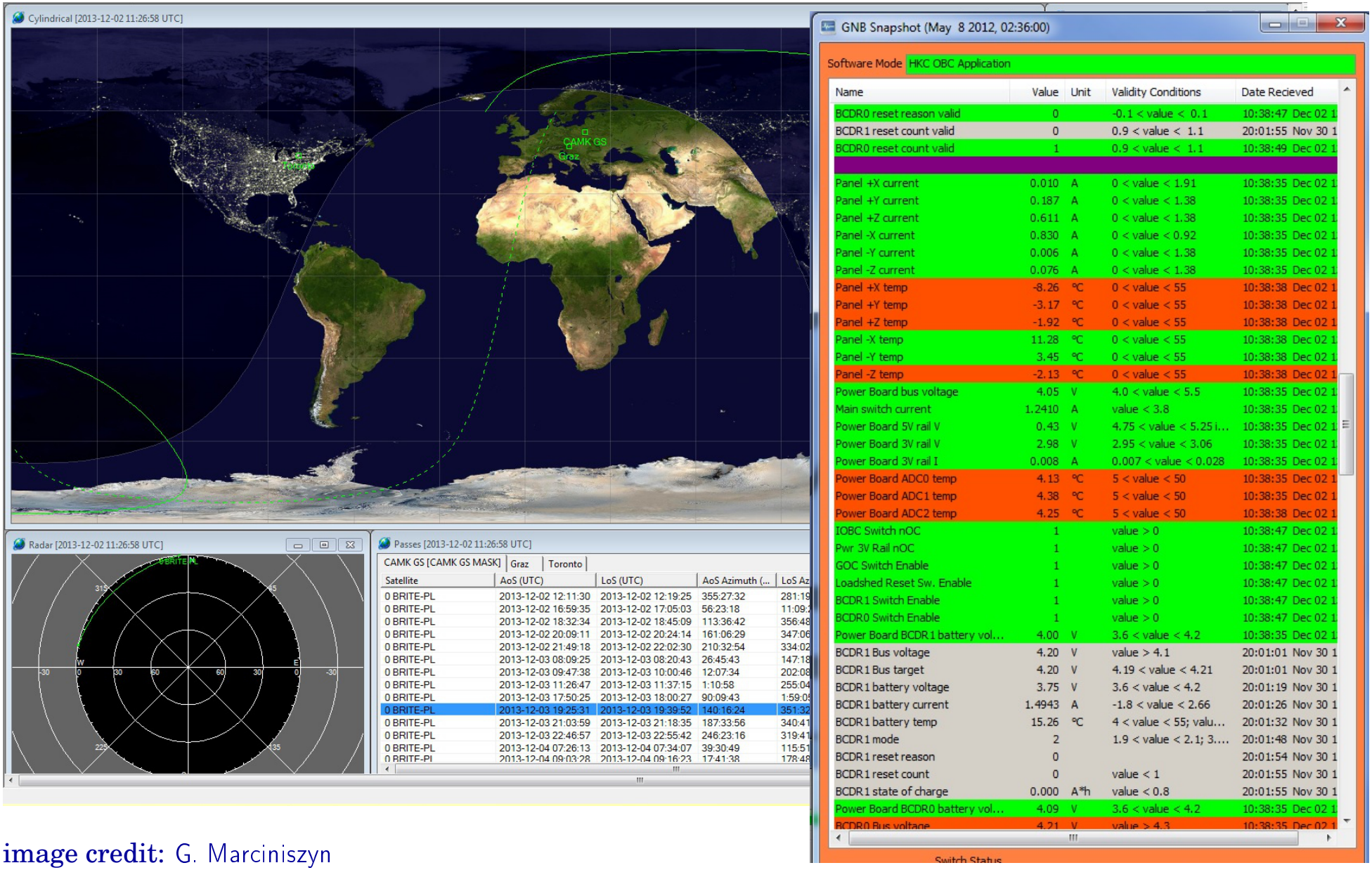


image credit: G. Marciniszyn

Communication: ground station at CAMK



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Orion as seen by UniBRITE

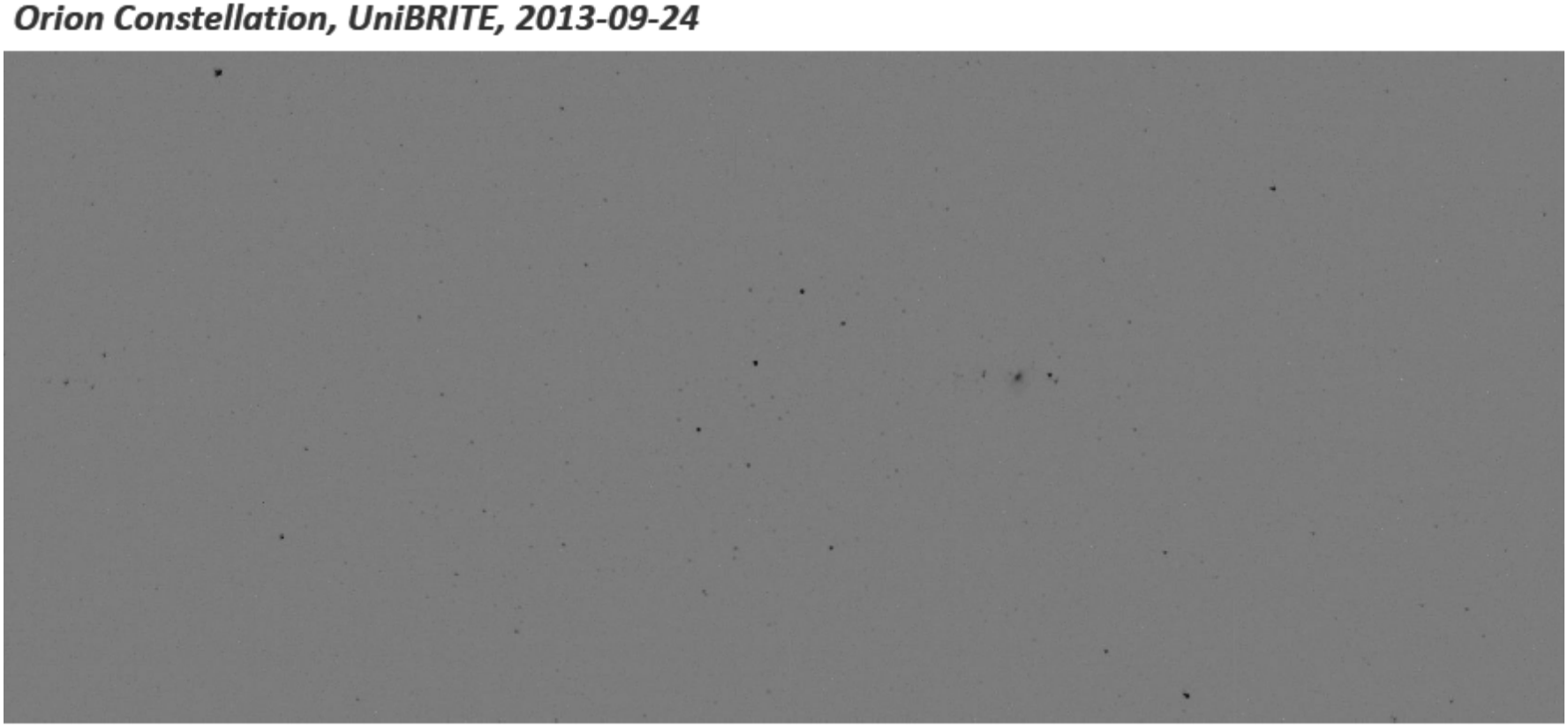
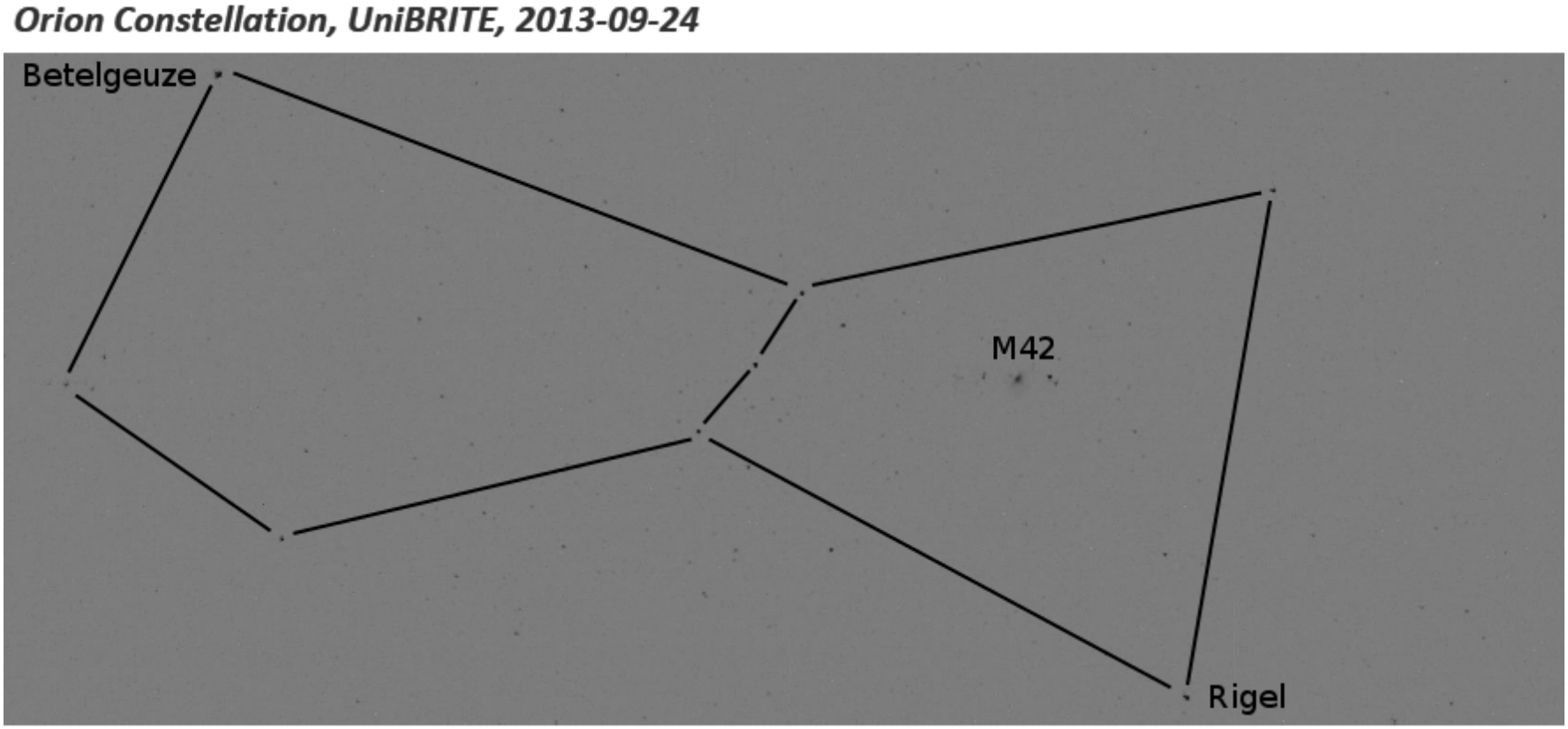


image: UniBrite/W. Weiss and BRITE-AT team

Orion as seen by UniBRITE



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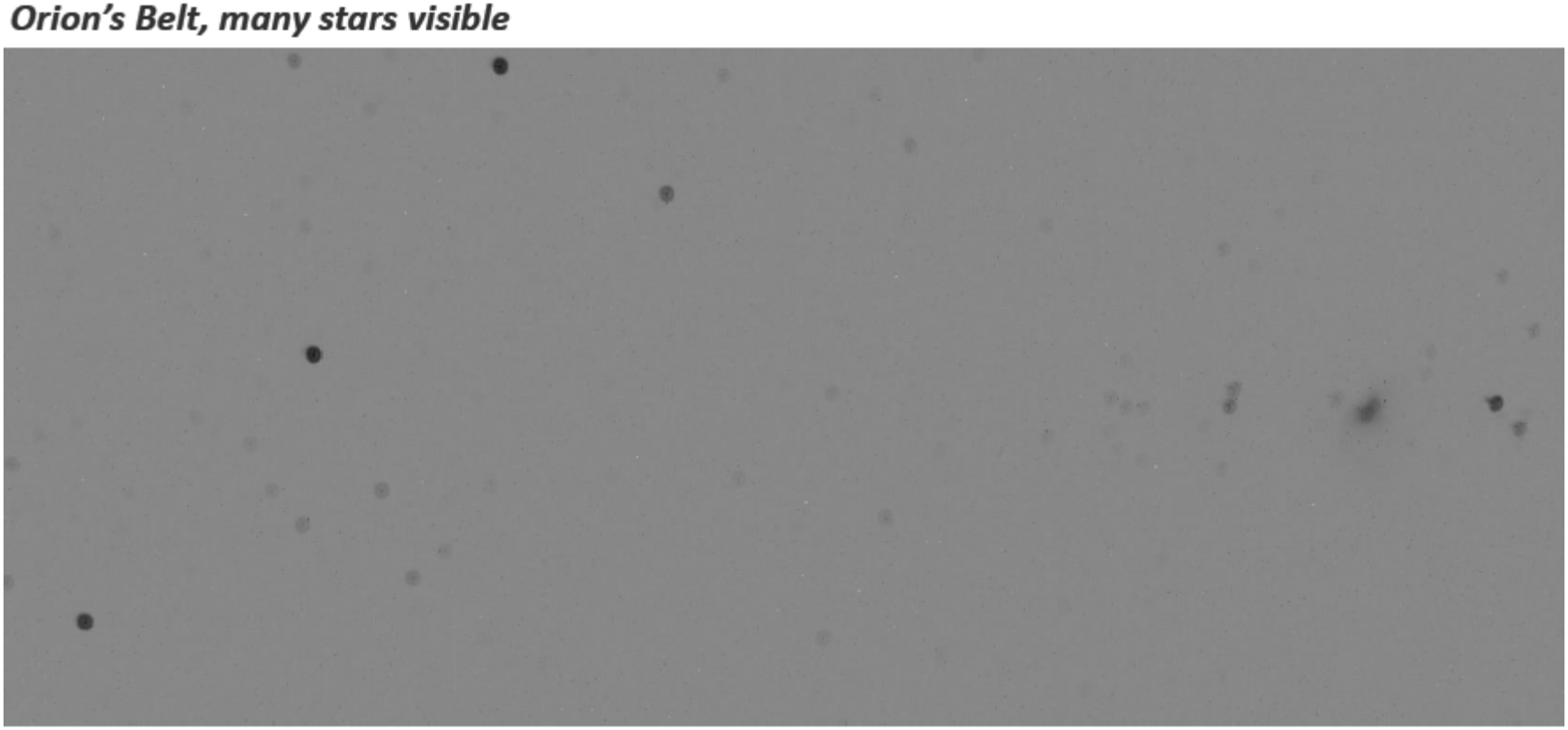

image: UniBrite/W. Weiss and BRITE-AT team