Science with the Polish BRITE satellites Radosław Smolec Centrum Astronomiczne im. M. Kopernika PAN

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







Polish Academy of Sciences NICOLAUS COPERNICUS ASTRONOMICAL CENTER

BRITE Science with the Polish BRITE satellites

BRITE

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



BRITE Science with the Polish BRITE satellites

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



BRITE – scheme



BRITE – attitude control

- \star sensors
 - ▶ magnetometer
 - ► Sun sensors
 - \blacktriangleright star tracker
- \star actuators
 - ▶ reaction wheels
 - ▶ magnetorquer coils



star tracker RT-16



reaction wheel



magnetorquer coil

image credits: Sinclair Interplanetary/TU Graz

BRITE – optics \star CCD (KODAK KA11002) \star telescope Header Tray CCD Lenses Baffle mmmmm Spacers 1.0 -BLUE Filter RED Filter * filters 0.8 B0V A0V G2V 0.6 CCD efficiency 0.4 -0.2 -300 400 500 600 700 800 900 wavelength (nm)

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

BRITE Science with the Polish BRITE satellites

Science with BRITE

- * BRITE will observe the brightest stars in the sky
 - \blacktriangleright close stars

▶ intrinsically most luminous (and most massive) stars

- \star Why these stars are important?
 - ▶ primordial nucleosynthesis: $\approx 75\%$ H, $\approx 25\%$ He
 - ► heavier elements are produced in stars



BRITE Science with the Polish BRITE satellites

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
- \star more massive the star, shorter it lives \rightarrow massive stars dominate the ecology of the Universe



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:

- \star understanding of luminous stars and the life-cycle of matter
 - ▶ stellar winds
 - ▶ convection and mixing
 - ▶ effects of rotation and magnetic fields
- \star 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, 20,... BRITE Science with the Polish BRITE satellites

Science with BRITE – stellar pulsations



Model Cefeidy M=4M_S, P=2.61d

radial modes

n – radial order, fundamental mode, first overtone, 20,...

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)

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Science with BRITE – stellar pulsations

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



Science with BRITE – stellar pulsations



 \star 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
- \blacktriangleright 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
- \bullet ground-based spectroscopic follow-up feasible with 3-m class telescopes



BRITE sky – H-R diagram, V < 4 mag



BRITE sky – H-R diagram, V < 6 mag



BRITE sky – mode identification with two band photometry



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

BRITE sky

Our (Warsaw group) objectives include

- \star main sequence stars
 - ▶ asteroseismic modelling: constraints on basic stellar parameters
 - ▶ testing rotation and mixing scenarios
 - ► testing microphysics data (opacities)
- \star 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: vibration testing



Polish BRITE – route to space: open field testing



Polish BRITE – route to space: assembly with XPOD



Polish BRITE – route to space: assembly with XPOD



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



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

- \star Dnepr rocket
 - ▶ SS-18 Satan (R36M) \rightarrow

 $START\text{-}1 \rightarrow Dnepr$

▶ 3-stages, UDMH+ N_2O_4

\star launch

▶ from silo at Dombarovsky (Yasny)

base

▶ 21.11.2013, 8:10:11 (CET)

 \star 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

Orion Constellation, UniBRITE, 2013-09-24



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

Orion as seen by UniBRITE

Orion Constellation, UniBRITE, 2013-09-24



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



Orion as seen by UniBRITE

Orion's Belt, many stars visible



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