CubeSat and astrophysical polarimetry

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The idea of this report is to briefly use the achievements of various organizations and universities in the use of the CubeSat technology, which could solve various of astrophysical problems. Nowadays, this is one of perspective paths in the space research .

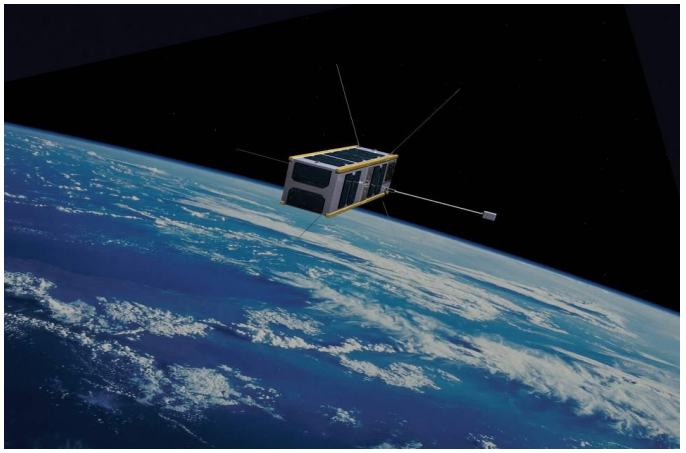
Introduction

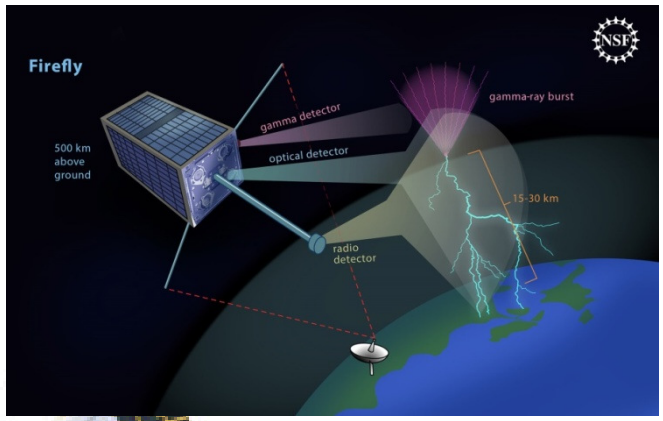
…why CubeSats?

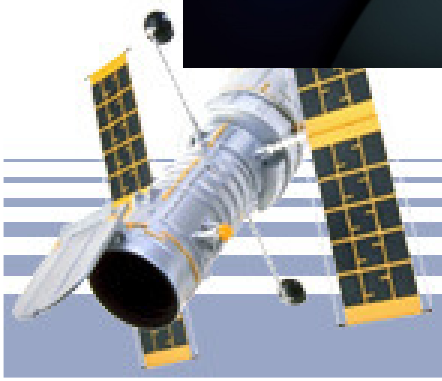
Advantages of nanosatellites:

- low-cost
- fast delivery
- easy for the educational purpose
- the possibility of independence in space
- contemporary trends in advances in electronic miniaturization

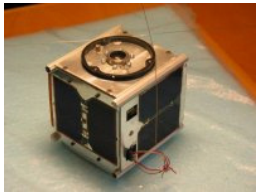
CubeSat

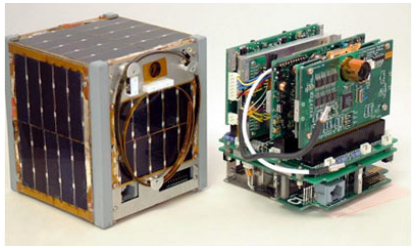



Firefly
NSF
gamma detector
optical detector
gamma-ray burst
500 km
above
ground
15-30 km
radio
detector

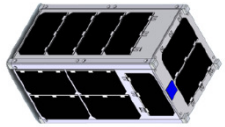


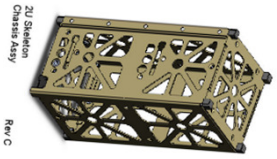
1U/2U/3U



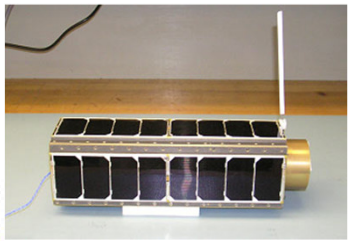


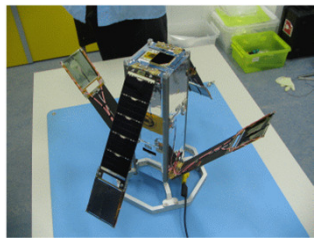
1U CubeSat: PicoSatellite ~ 1 kg in mass.
(CP1-X, XI-V, and many more)

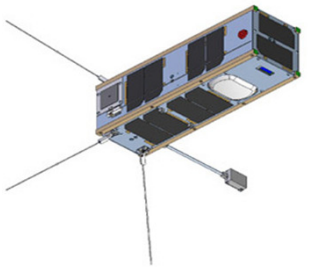


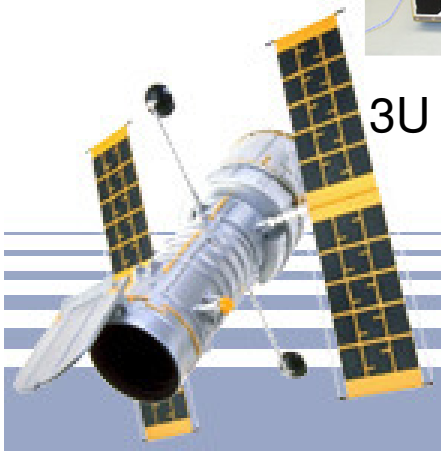


2U CubeSat: PicoSatellite ~ 2 kg in mass.







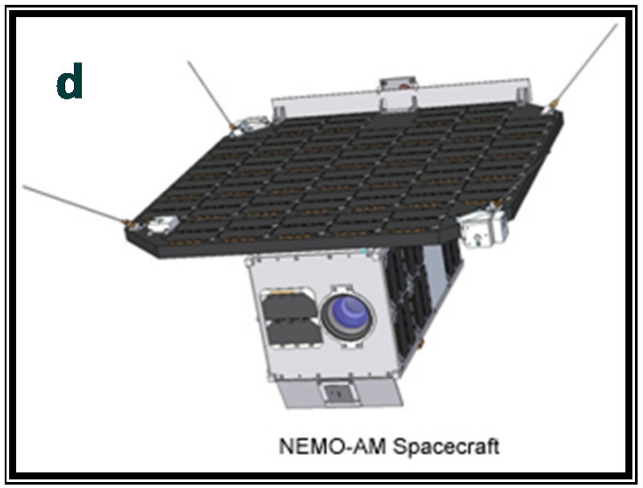


3U CubeSat : PicoSatellite ~ 3 kg in mass.
(GeneSat, Delfi-C3, CANX-2)

Introduction: History and realized scientific projects around the World

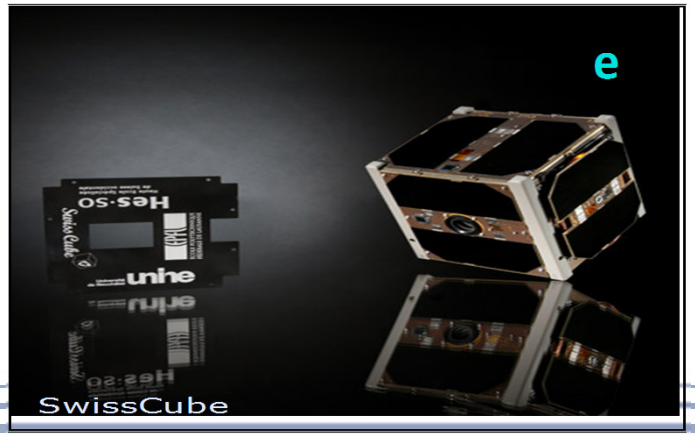
- Earth Monitoring and Observation – Aerosol Monitoring;

Satellite: NEMO-AM (Canada, India.) (d)



- Observation of the airglow phenomena;

Satellite: Swiss Cube (Switzerland, 2009) Size: 10x10x10 cm; Mass ~1kg. (e)



Introduction: History and realized scientific projects around the World

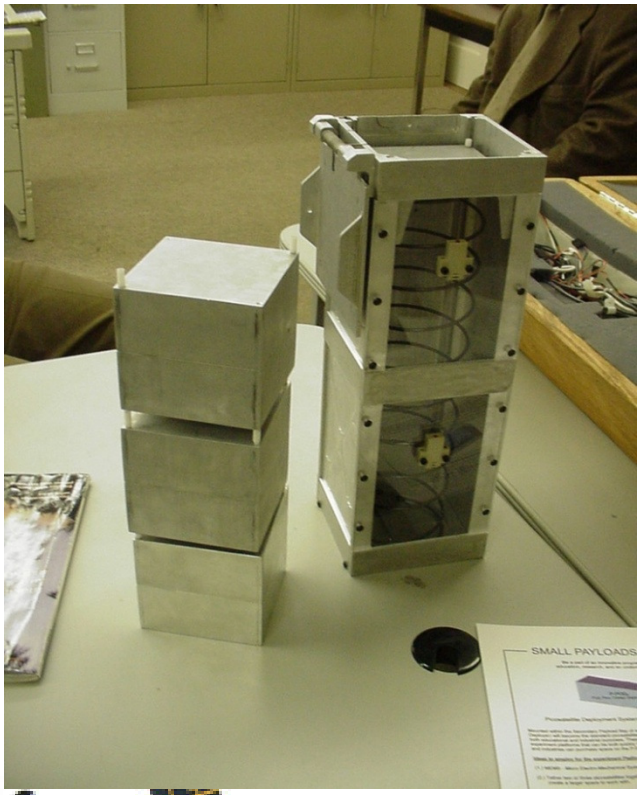
- investigation of impulsive electromagnetic signals generated by electrical discharges in terrestrial thunderstorms (lightning), blizzards, volcanic eruptions, earthquakes and dust devils;

Satellite: LiNSAT (Austria)
Size: 20 cm cube; Mass ~ 5 kg.

- tracking maritime assets, and the integration of space-based AIS (Automatic Identification System) data into a national maritime tracking information system.

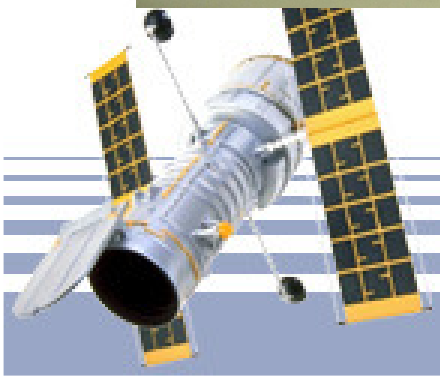
Satellite: AISSat-1 (Norway 2)
Size: 20x20x20cm; Mass: 6kg;

CubeSat



Specifications

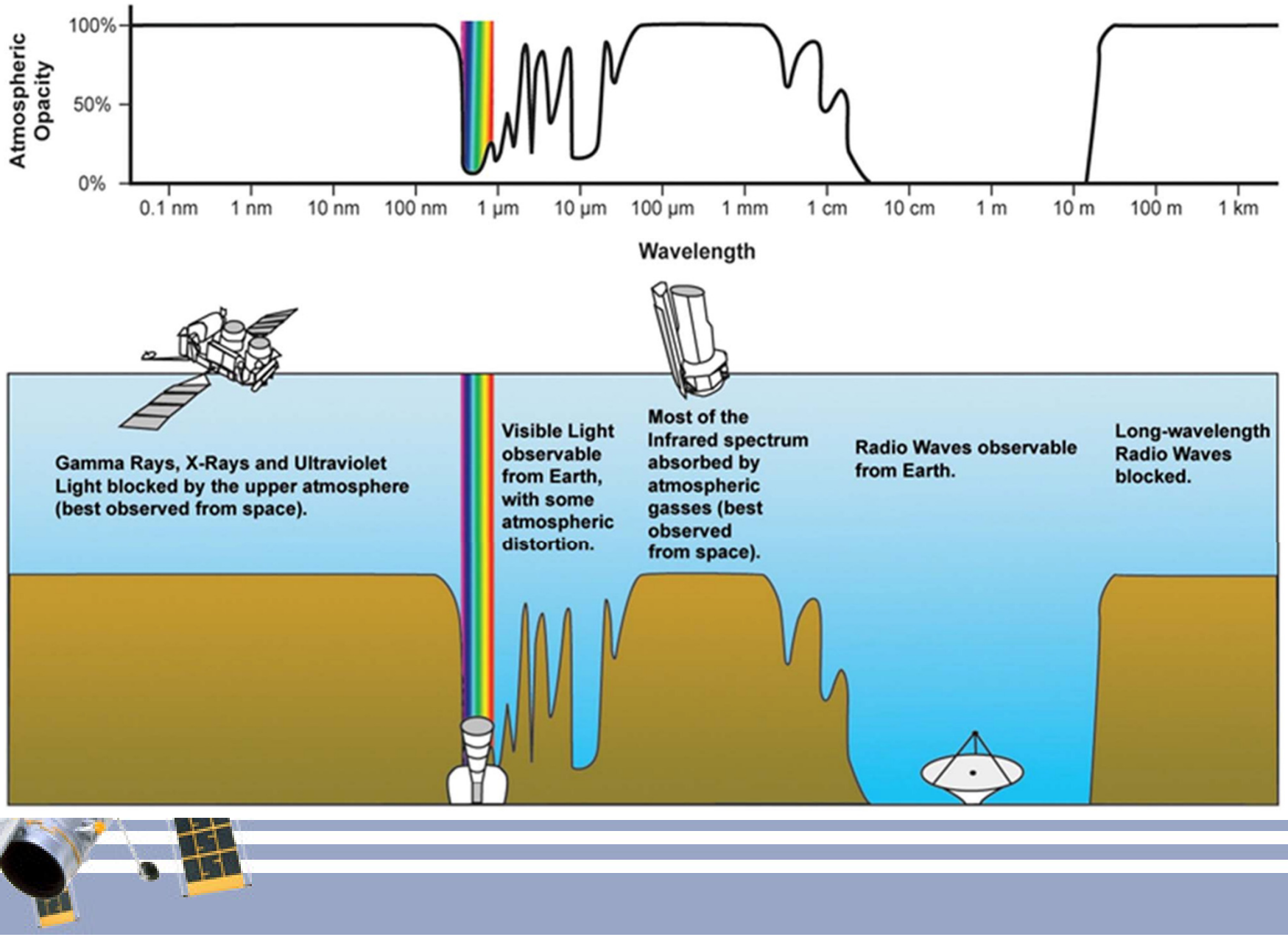
- **Size ~ 4 inch (10cm) cube**
- **Weight ~ 1kg**



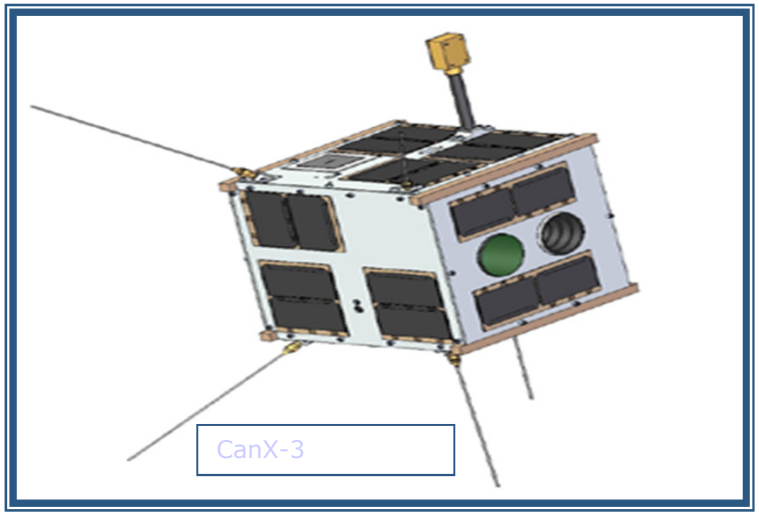
CubeSat Launch Costs

Universities	$40,000/CubeSat
Amateur Radio/ Private	$40,000/CubeSat
Government/ Industry	$40,000/CubeSat

Above the Atmosphere



Applications in astronomy



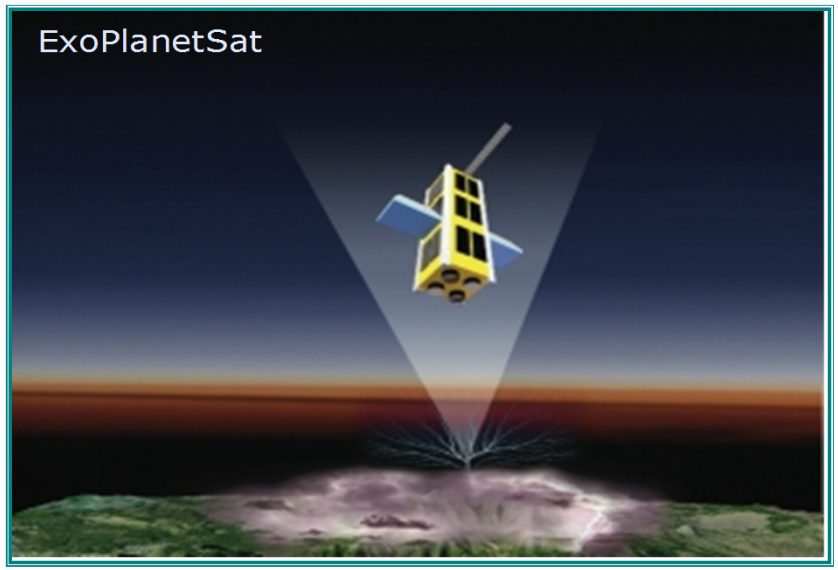
Investigation of massive luminous stars

- photometric observations of some of the brightest stars in the sky in order to examine these stars for their variability.

Satellite: **CanX-3 - BRITE Mission (Canada, 2009),** 20cm cube.

our suggestion: applying the polarimetry methods on the photometric data, received from the instruments on board.

Applications in astronomy



Discovery of transiting exoplanets around the nearest and brightest Sun-like stars

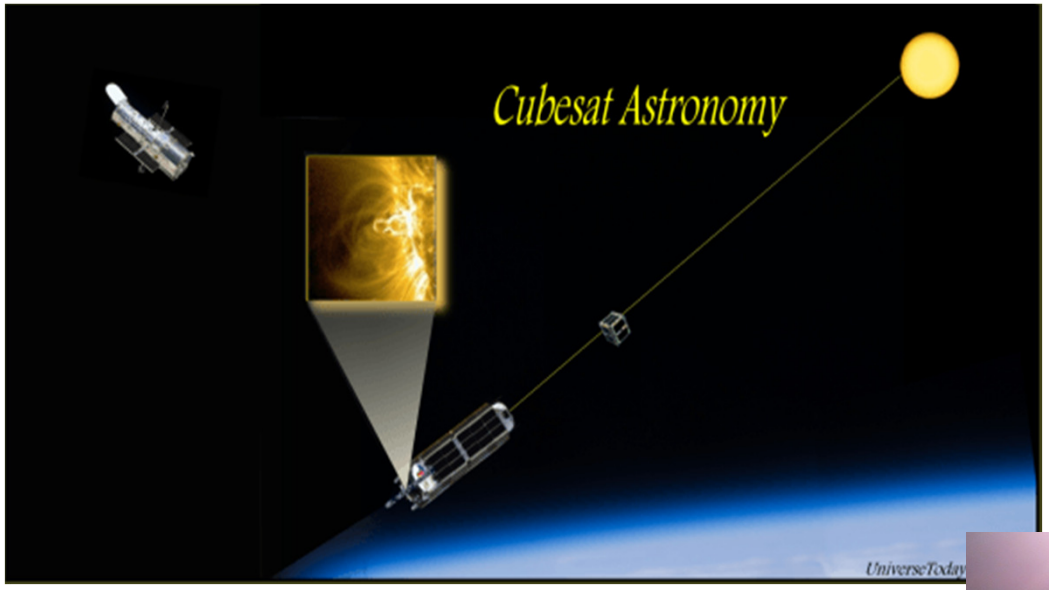
- analysis based on the blurring of the stars when in orbit to pass companion; Satellite: **ExoPlanetSat (USA, 2012**). Size: 10x10x34cm), mass: ~4 kg.

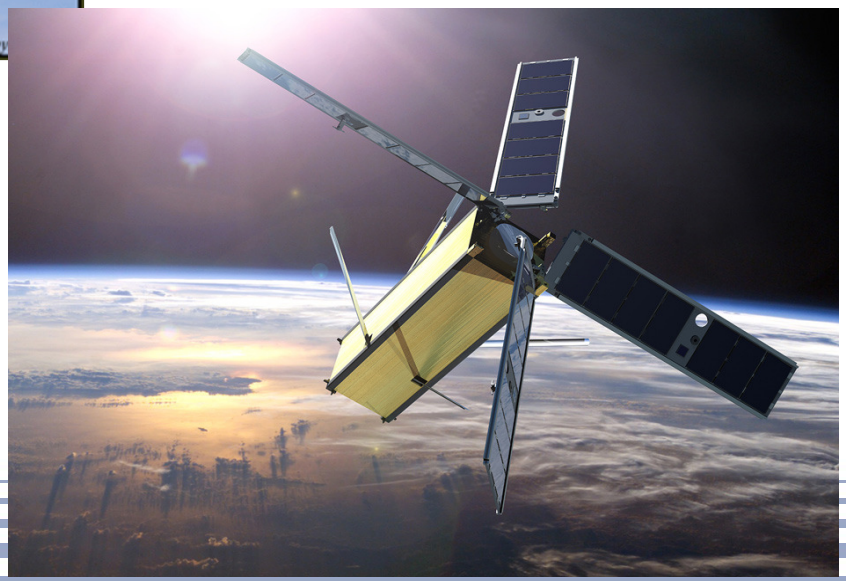
Applications in astronomy

Advantages of CubeSats for astronomy:

- observation of stars without interference by earth atmosphere
- training of students
- hands-on experience in conducting of a challenging space project and synergies between several scientific fields.

CubeSat in Astronomy and Astrophysics





CubeSat in Astronomy and Astrophysics

- The use of different kind of apparatus, such like telescopes or satellites for monitoring the astrophysical objects, gives always rise to the following requirements :
  - Precision targeting and the ability to continuously monitoring;
  - Sensitivity and efficiency of the apparatus;
  - Flow of data and processing.

Astronomy and Astrophysics

- **CubeSat Opportunities and Limitations**

Some Limitations -> Technology Development

Early universe
Galactic evolution
Stellar evolution
Extrasolar planets

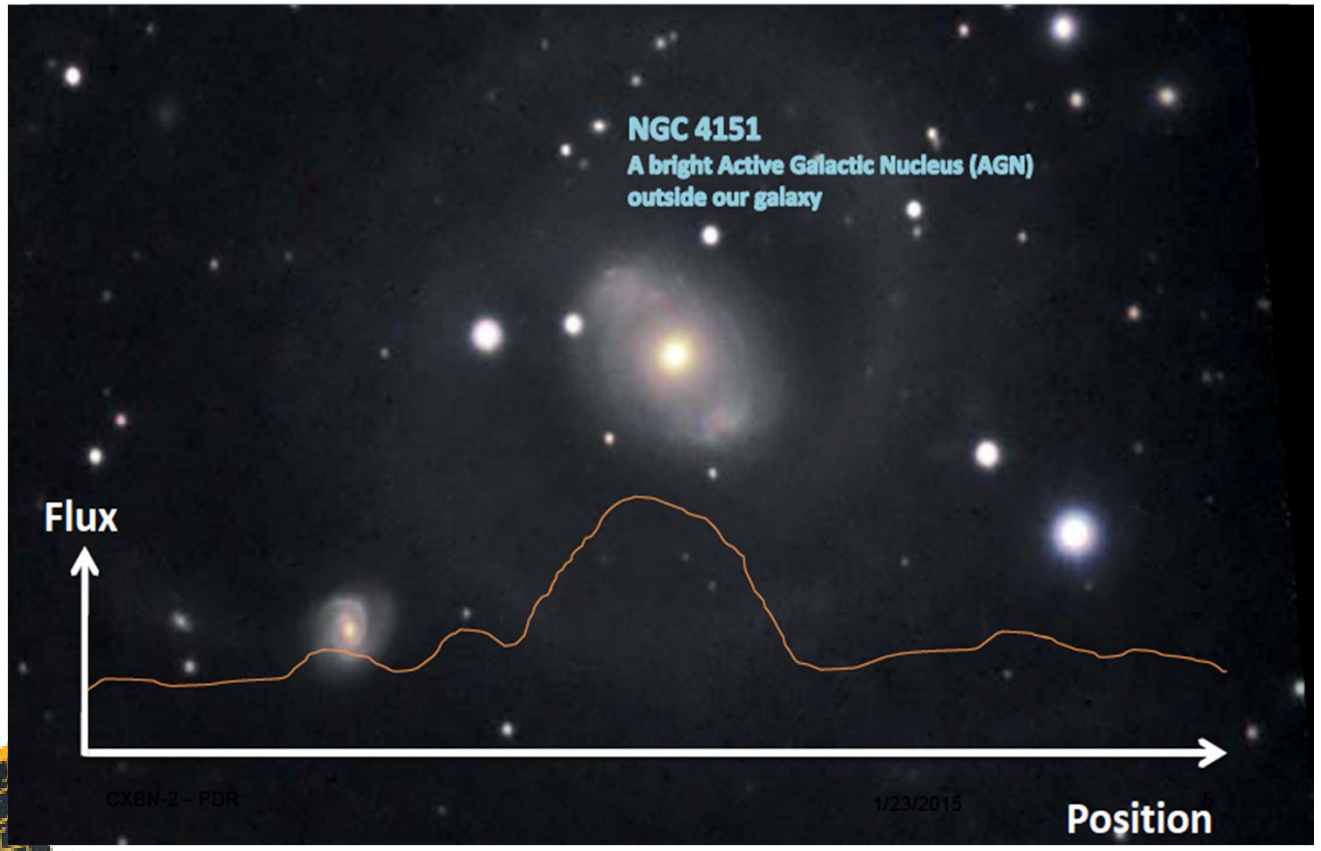
Technology Development

CubeSat Opportunities and Limitations

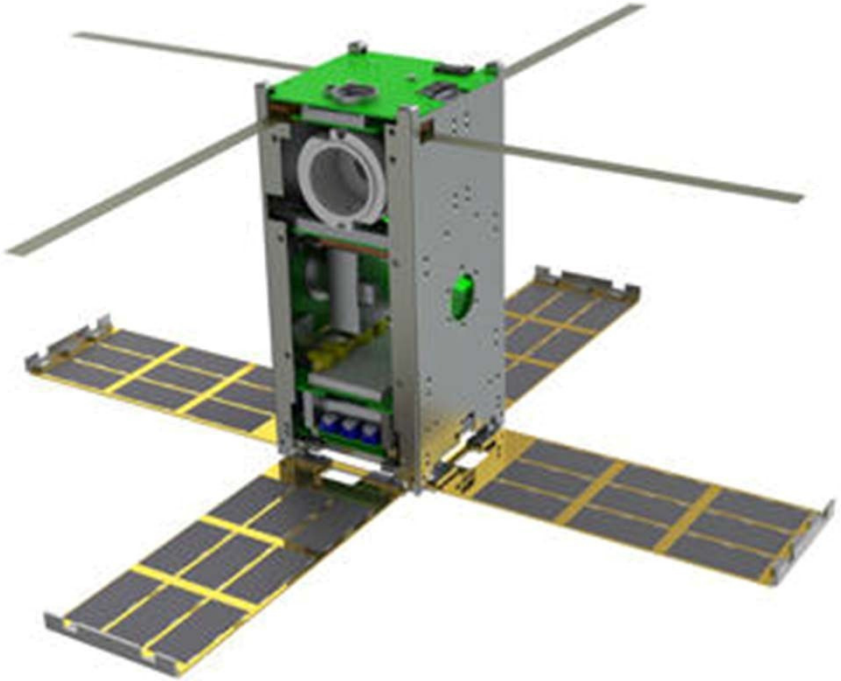
- **Opportunities**
  - Above the atmosphere
  - Can sit and stare at targets (assuming pointing is good enough)
  - More launch opportunities
  - Lower cost*
- **Limitations**
  - Aperture
    - Deployables
    - Distributed apertures
  - Pointing
  - Navigation
  - Limited downlink data rates
  - Limited power
  - Orbits determined by host

**hardware costs may be lower, however, still have personnel, and carry higher risk*

Diffuse X-ray background

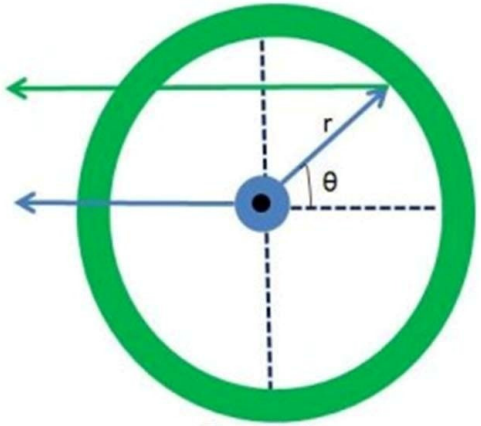


Diffuse X-ray background

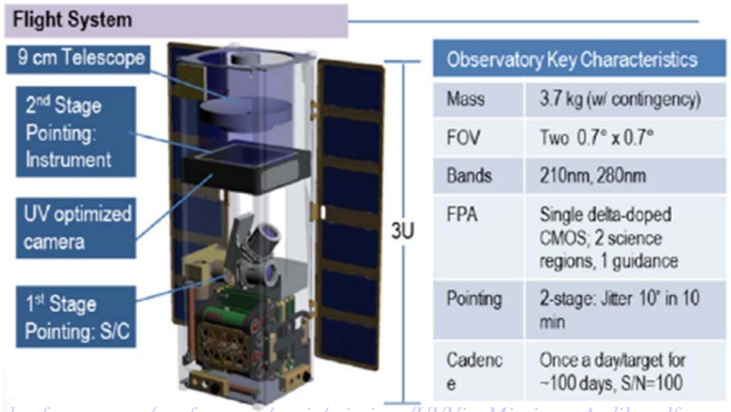


Galactic Evolution: Black hole mass

- Broad Line Region emissions are "reprocessed" from central continuum source;
- Need to stare at AGN continuum source and record variability and events;
- Radius of BLR ~ few light days
- Continuously observe to correlate source events with BLR emission
- Can put UV detector on Cubesats to do this;
- E.g. Space Explorer for Accretion and Reverberation (SpEAR)



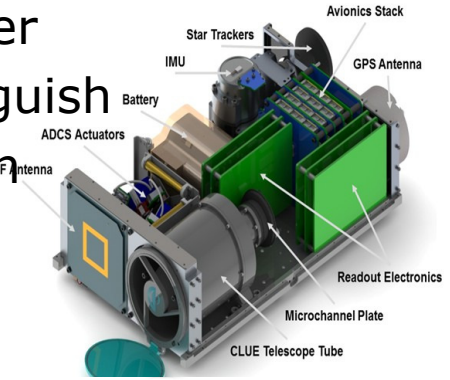
http://astrobites.org/2012/03/14/measuring-the-black-hole-mass-in-markarian-6-using-reverberation-mapping/



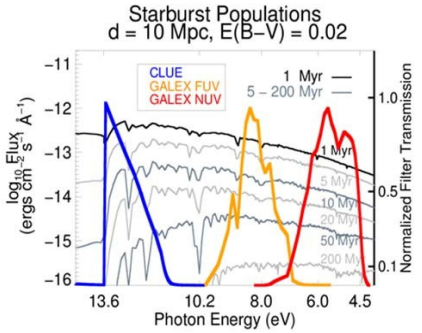
http://asd.gsfc.nasa.gov/conferences/uvvis/missions/UVVis_Missions_Ardila.pdf

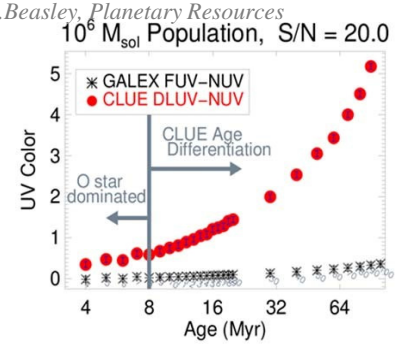
Galactic Evolution: Stellar Populations

- Compact Lyman Ultraviolet Explorer (CLUE). UV observations help distinguish young, massive stellar populations in star-forming galaxies.
  - Lyman alpha, 912-1100 angstroms
- Also energetic radiation from the hot upper atmospheres of low-mass exoplanet host stars.
- Supernova remnants.
- Modest pointing requirements
  - 15 arcsecond resolution
  - 2.66 degree field of view
- Long integration times help counter small aperture.

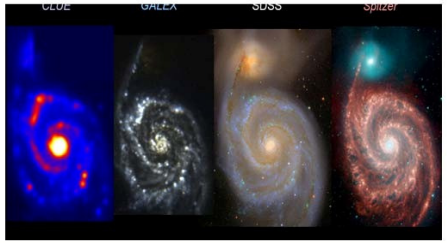


M.Beasley, Planetary Resources





Leitherer et al. 1999; 2010; age in Myr shown



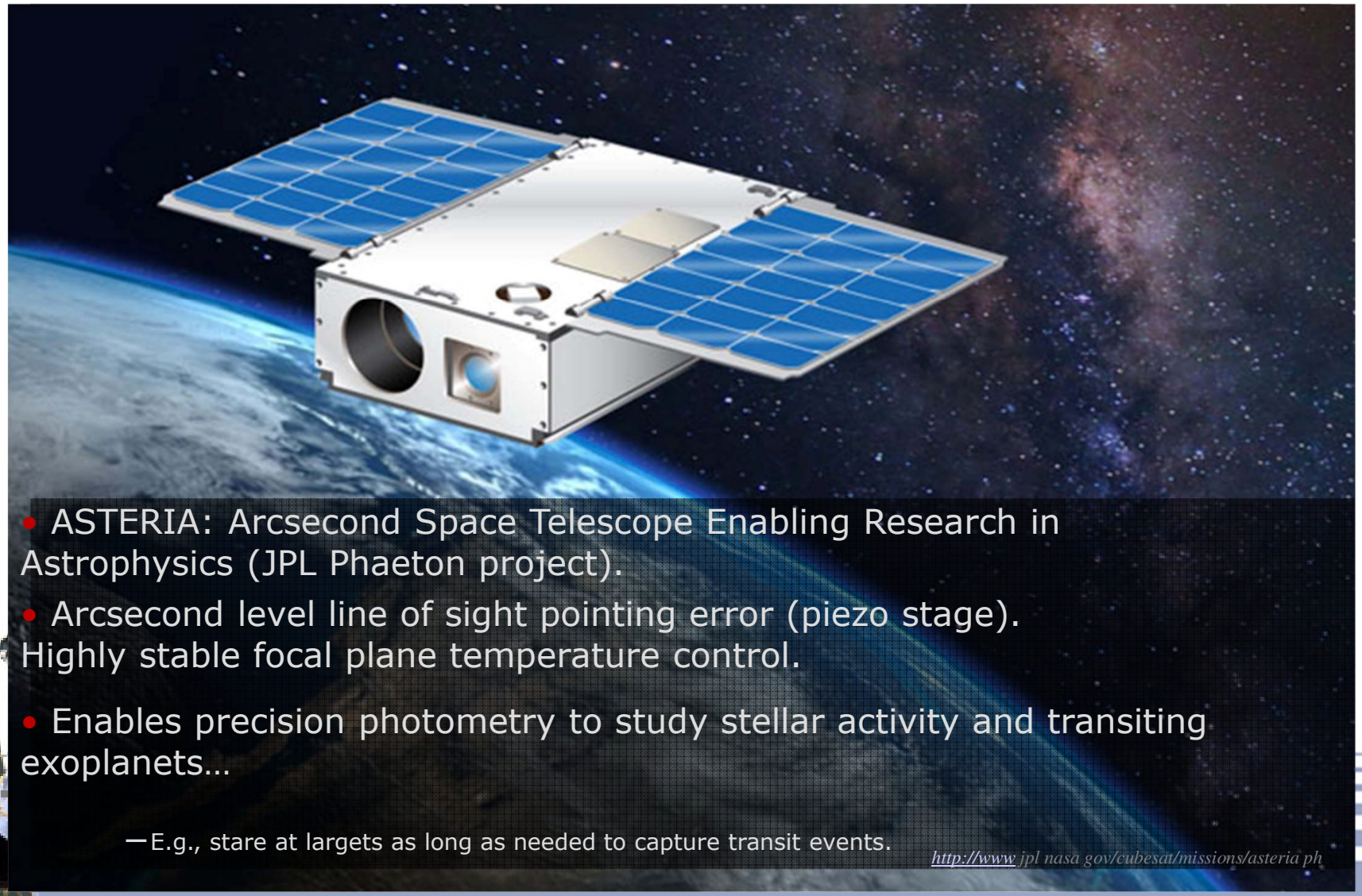
Stellar Evolution: X-ray polarimetry

Neutron stars have the highest magnetic fields known in the universe

Quantum electrodynamics predicts they should be highly polarized.

Use of X-ray detectors and reflective multilayer optic.

Extrasolar Planets: Technology

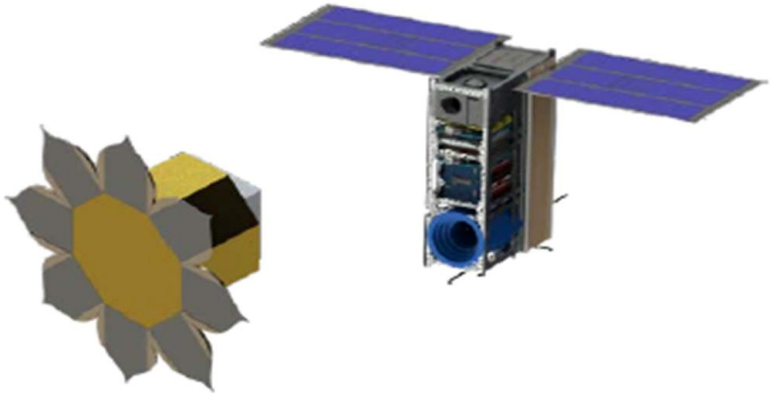


- ASTERIA: Arcsecond Space Telescope Enabling Research in Astrophysics (JPL Phaeton project).
- Arcsecond level line of sight pointing error (piezo stage). Highly stable focal plane temperature control.
- Enables precision photometry to study stellar activity and transiting exoplanets…
  - —E.g., stare at largets as long as needed to capture transit events.

http://www.jpl.nasa.gov/cubesat/missions/asteria.php

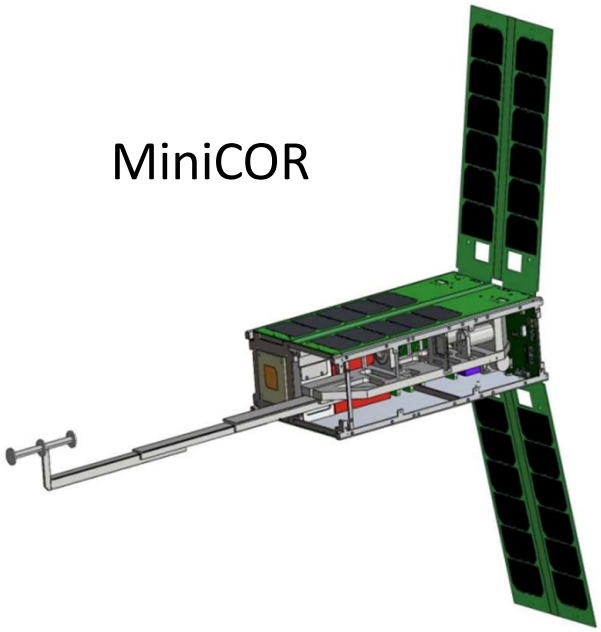
Extrasolar Planets: Technology

- Miniature "Exo-S" and "Exo-C Exoplanet-Starshade and Exoplanet-Coronagraph
- Direct imaging of exozodiacal dust and exoplanets
- Miniaturized Distributed Occulter/Telescope (mDOT)

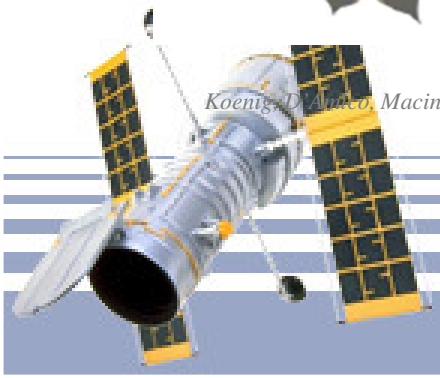


Koenig, D'Amico, Macintosh, Titus SPIE 2015

MiniCOR



Korendyke et al., SmallSat 2015



ExoplanetSat: Detecting transiting exoplanets using a low-cost CubeSat platform

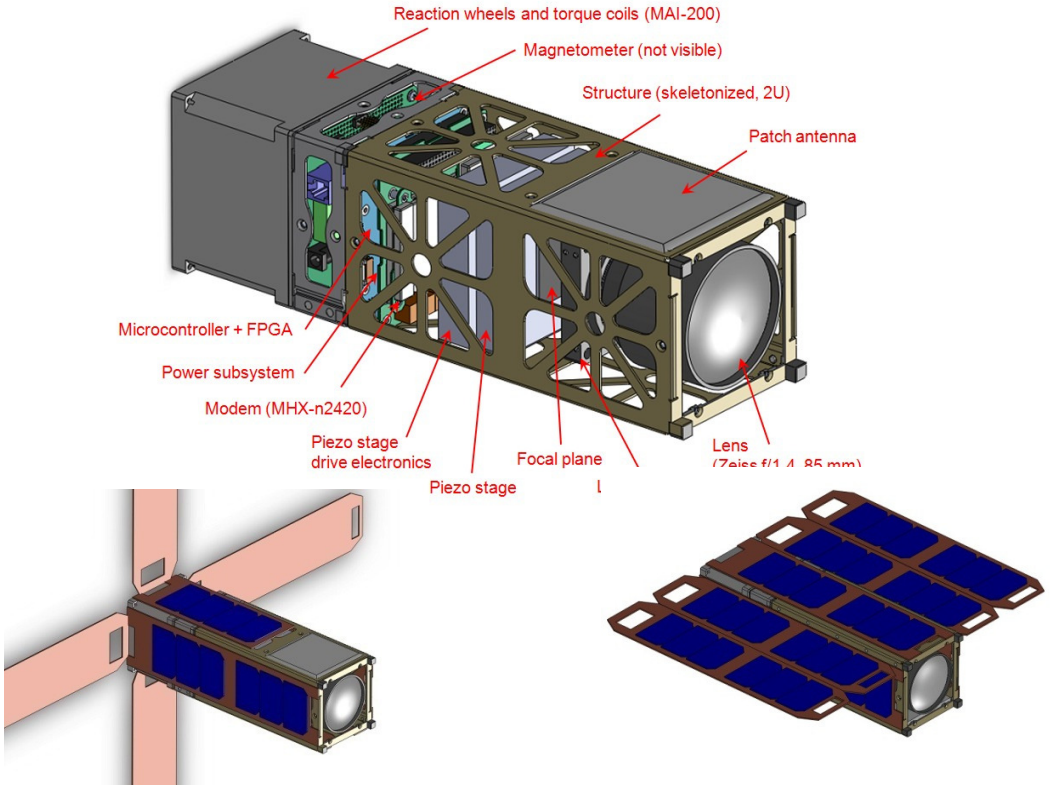
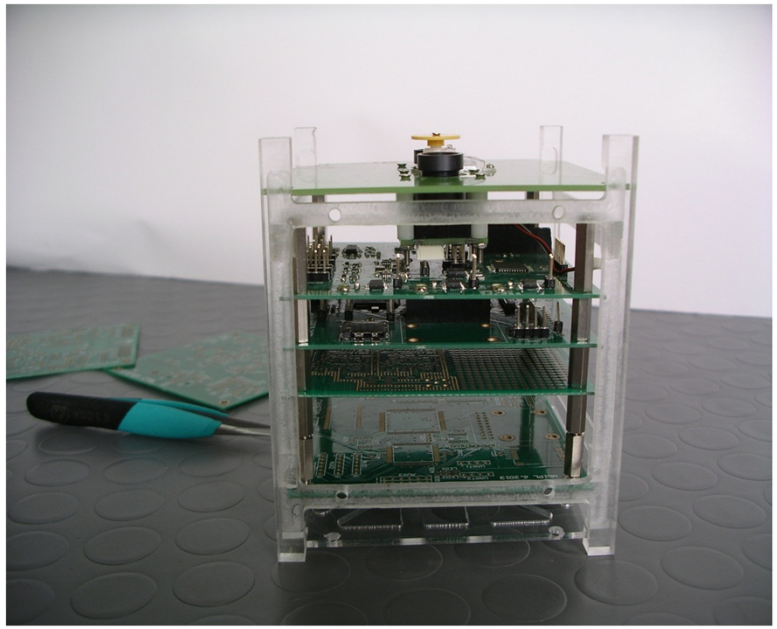


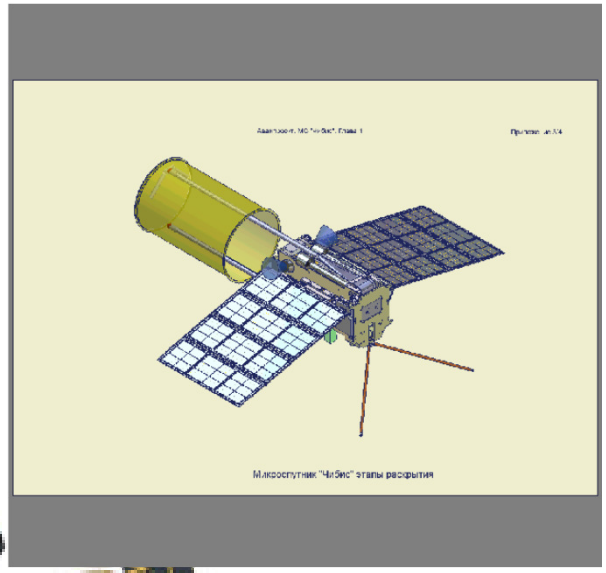
Figure 3. Possible deployable solar array configurations: (a) "cross" configuration (solar cells on the deployed panels are facing away) and (b) "table" configuration. In both cases body-mounted panels are used for tumbling scenarios.

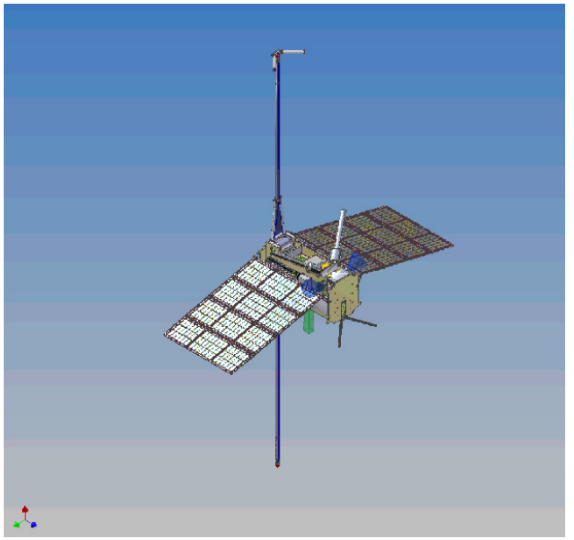
Our unrealized project Bulcube

The aim of the project: polarimetric measurements of Zodiacal light by using CubeSat on sunsynchronous low-earth orbit.

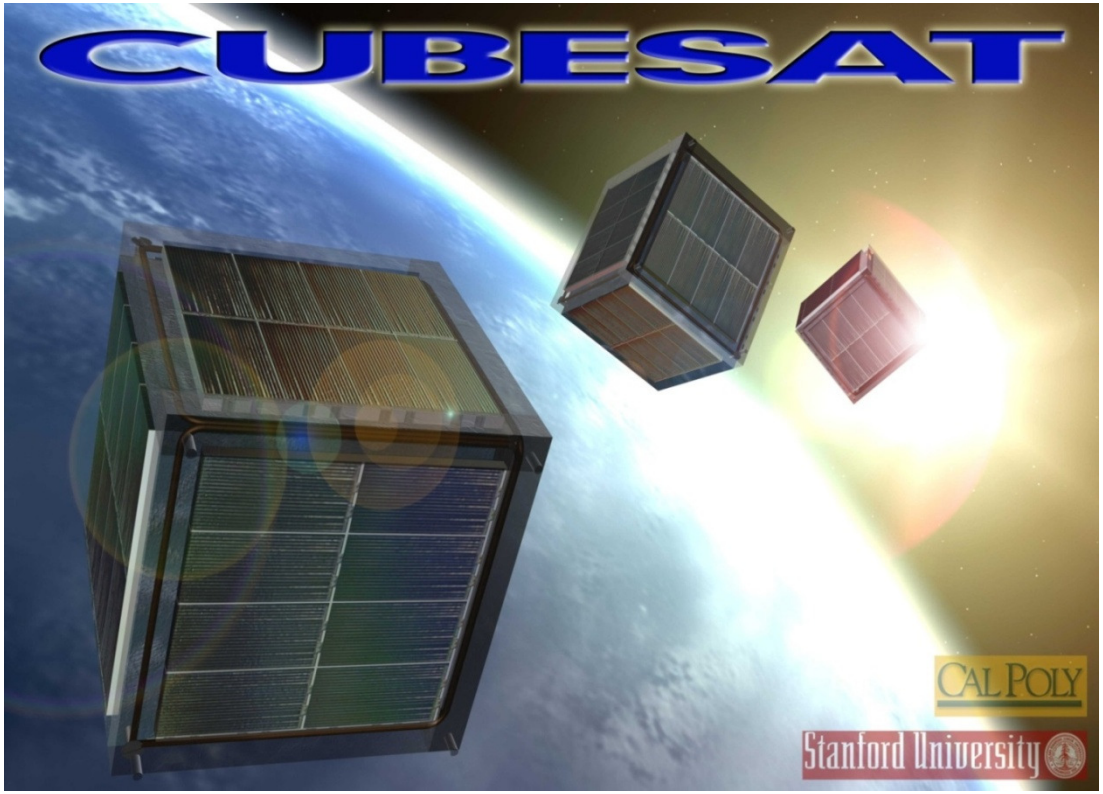


- **to take colour panorama pictures of the space**
- **3 nanosatellite's cameras**
- **to measure Stokes parameters for every zone in the field of view**


Микроспутник "Чибис" этапы раскрытия



CubeSat – The Next Generation of Space exploration



Thank you for your attention!

Thank COST action 1104 and especially Dr. Herve Lamy