CubeSats for Space Weather
Two examples of payloads at the CSUG

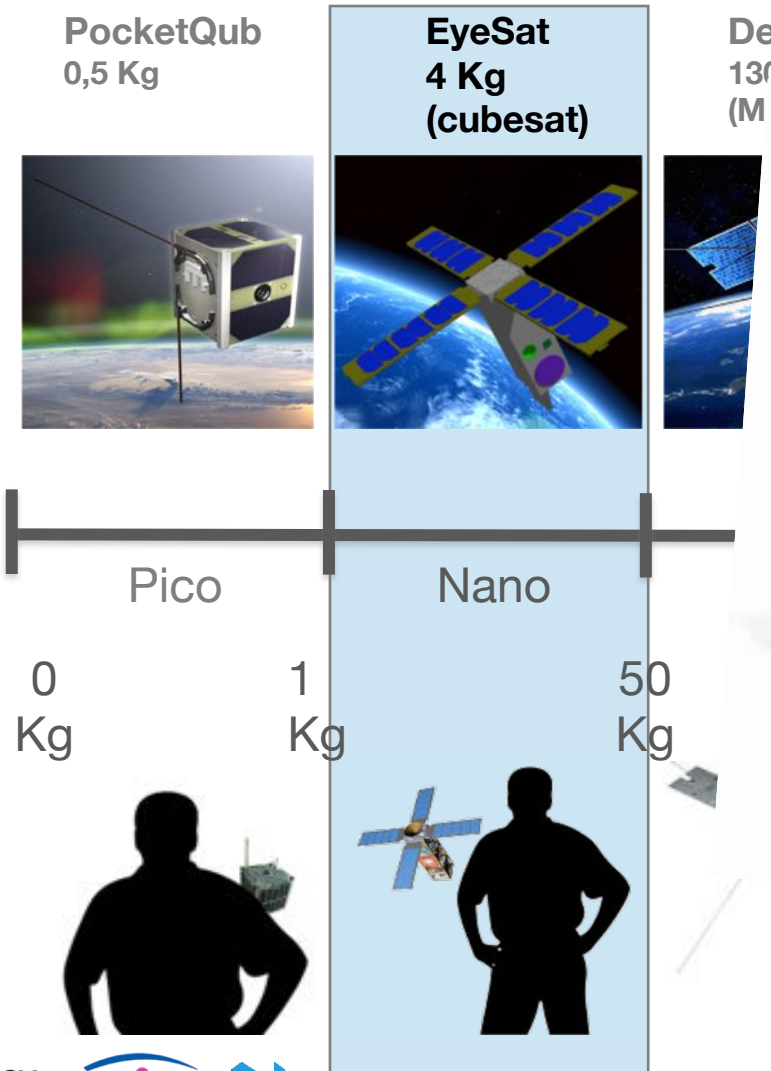
Barthelemy M (UGA-CSUG)

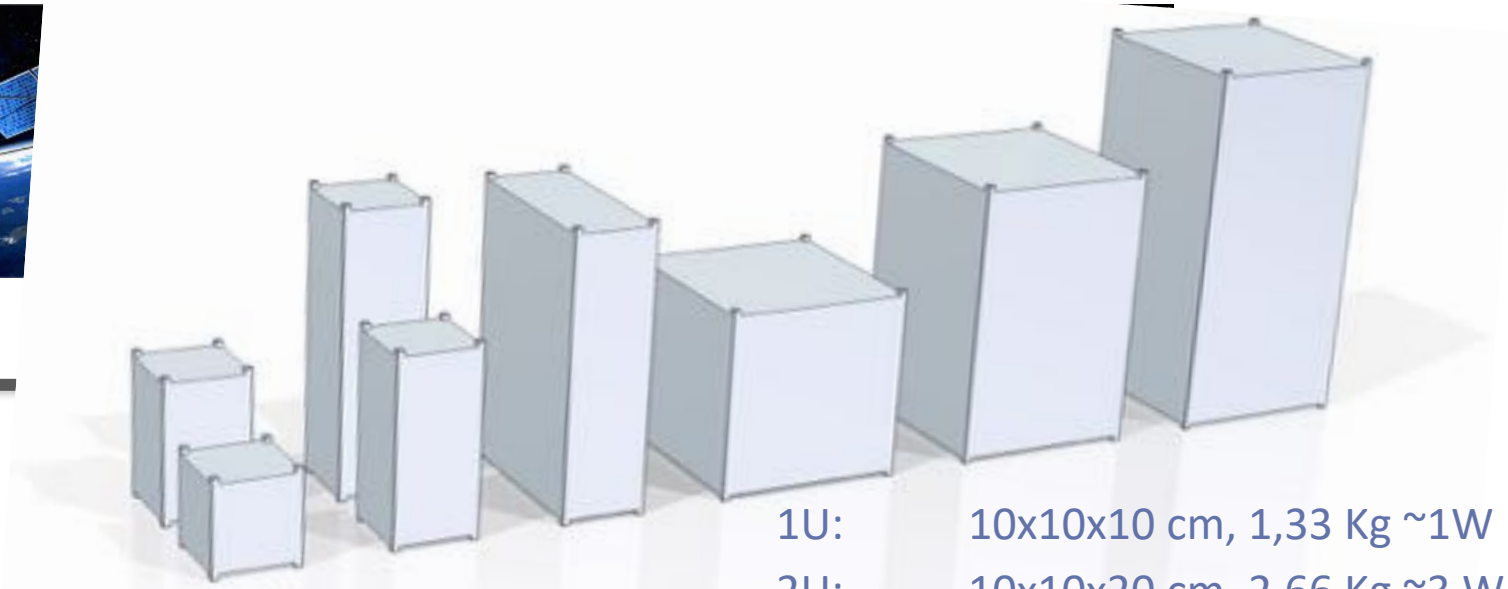
« From Miniaturized Space Instrumentation …

… to Space Data Exploitation! »


- The Newspace

What is a Cubesat (Nanosat)?

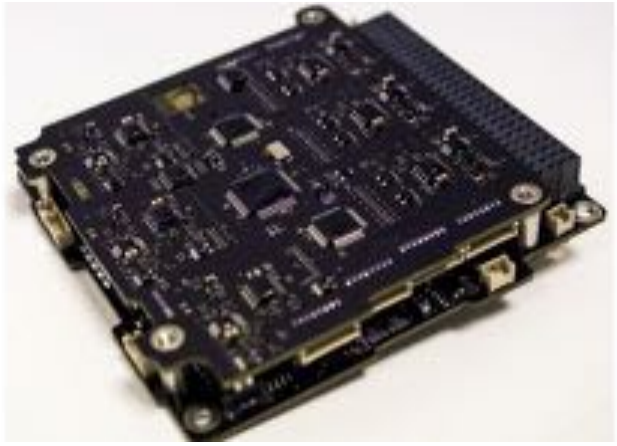




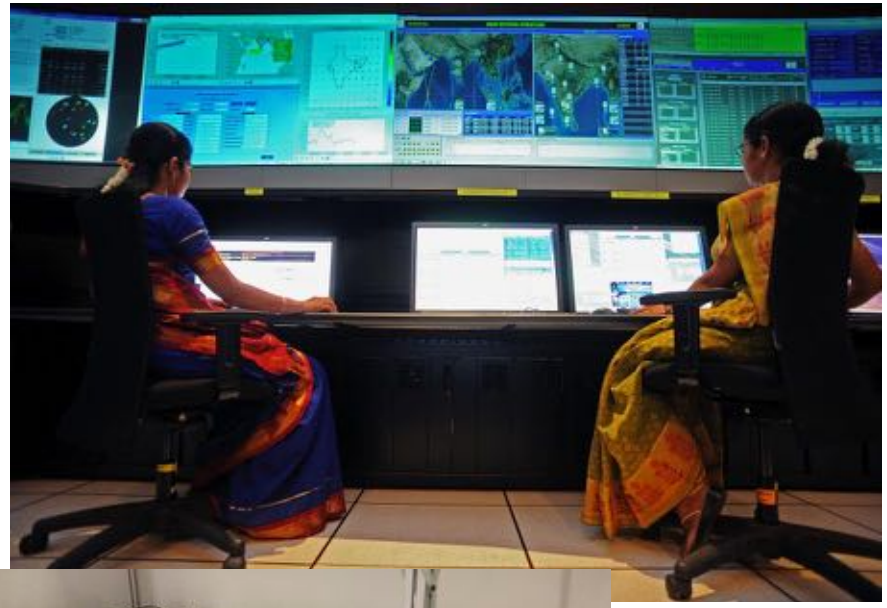
1U: 10x10x10 cm, 1,33 Kg ~1W
2U: 10x10x20 cm, 2,66 Kg ~3 W
3U: 10x10x30 cm, 3,99 Kg ~6 W
6U: 10x20x30 cm, 8 kg, ~10 W
12U: 20x20x30 cm, 24 kg ~25 W
27U: 30x30x30 cm, 40 kg, ~40 W

Interest of cubesats ?

- **Standardisation** of components
- Development time reduction
- Cost reduction



Transformation of space sector?



Easier access to space, innovation, costs : new actors…

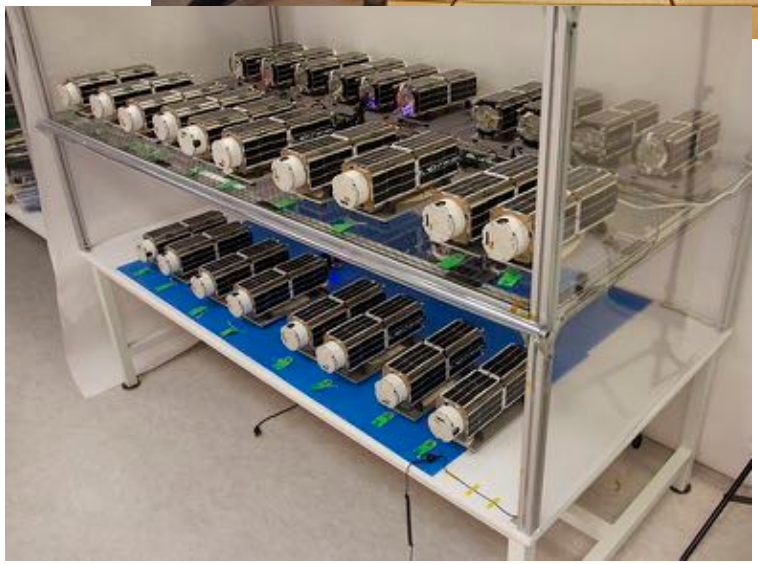
⟹ Countries without space history, Univrsities, SMEs

Risk vs fiability

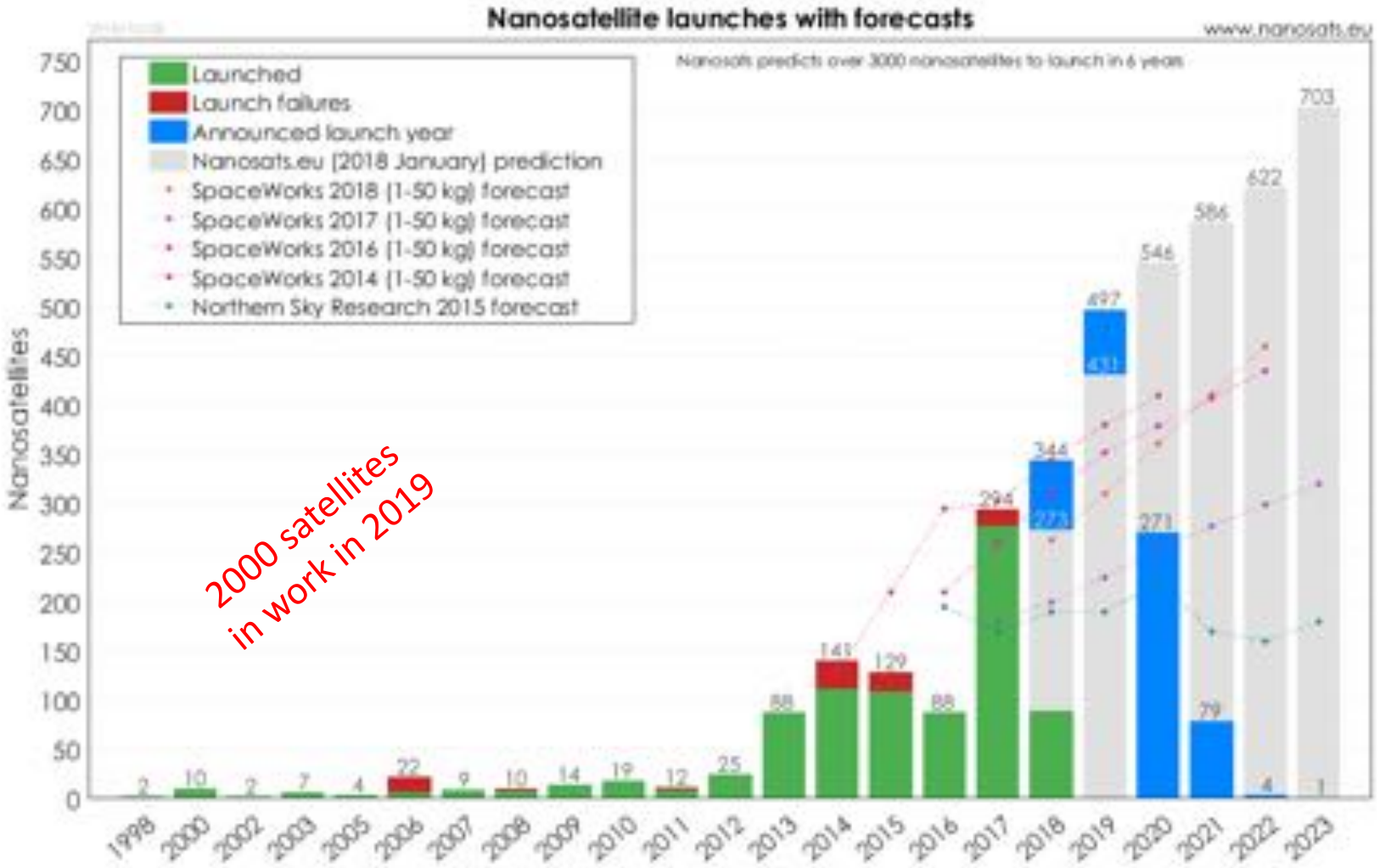
Innovation but competition

Industrial production

Constellations…



Newspace : launch forecast



Cost order of magnitudes:

*500k€ for 1U up to 3-5 M€ for a 12U

*100 less than classical space…

www.nanosats.eu


- CSUG – Open up the space of possibilities

From payload to uses

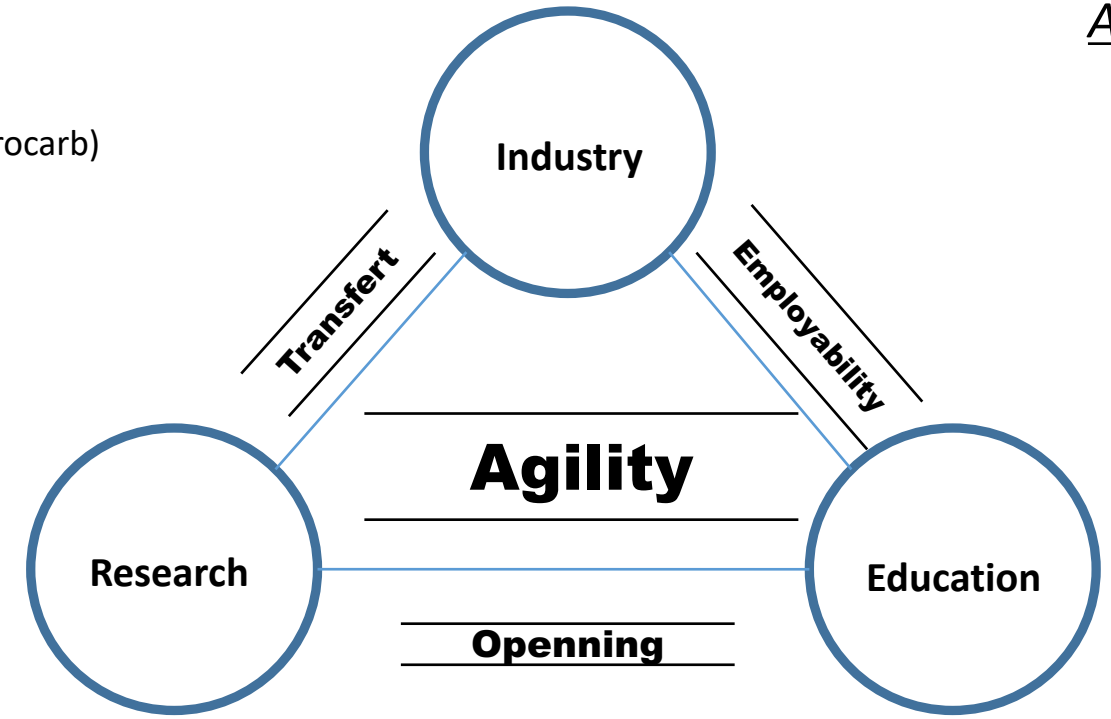
Booster CENTAuRA

Projects

7 projects in development(ATISE, AMICal, NanoBob, NanoCarb, WFAI, ThingSat, hydrocarb)

Prospectives 2020

8 additional projects in discussion



Everything is possible

Application domain

Earth Observation
Space weather
QKD
IOD/IOV
Communications LORA/Sigfox
IA
Exobiology

ATISE and AMICal Sat: Two example of CubeSat missions for Space weather

Lomonosov Moscow State University

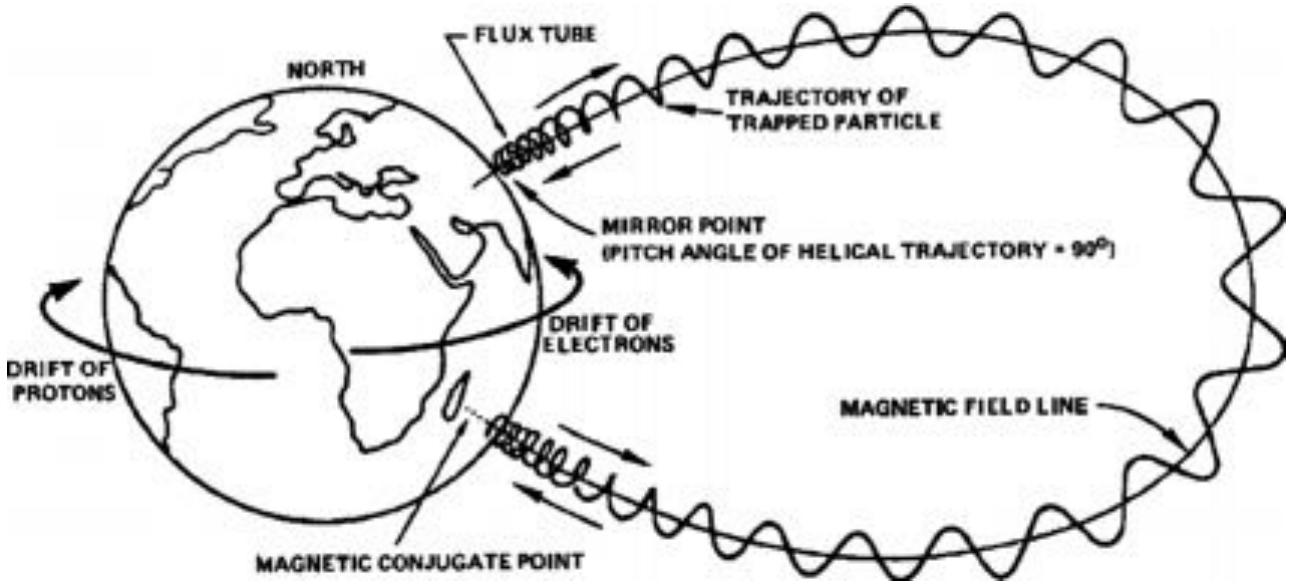
Maquette de ATISE lors de la PDR de Juin 2018.

AMICal Sat flight model payload.

TELEDYNE e2v Everywhereyoulook™ SOFRADIR Sensing your future NICOMATIC Air Liquide creative oxygen GORGY TIMING LA MARQUE DU TEMPS cnrs cnes UNIVERSITÉ Grenoble Alpes Grenoble INP FONDATION UNIVERSITÉ Grenoble Alpes

ATISE-AMICal Scientific objectives

- Main questions:
  - Interface between upper atmosphere and magnetosphere
  - Particle fluxes at the top of the atmosphere
    - Energy, total flux, distribution shape
  - Depisition into the atmosphere
    - Especially eV and KeV range
    - Altitude of the emissions
      - Between 90 and 300 km



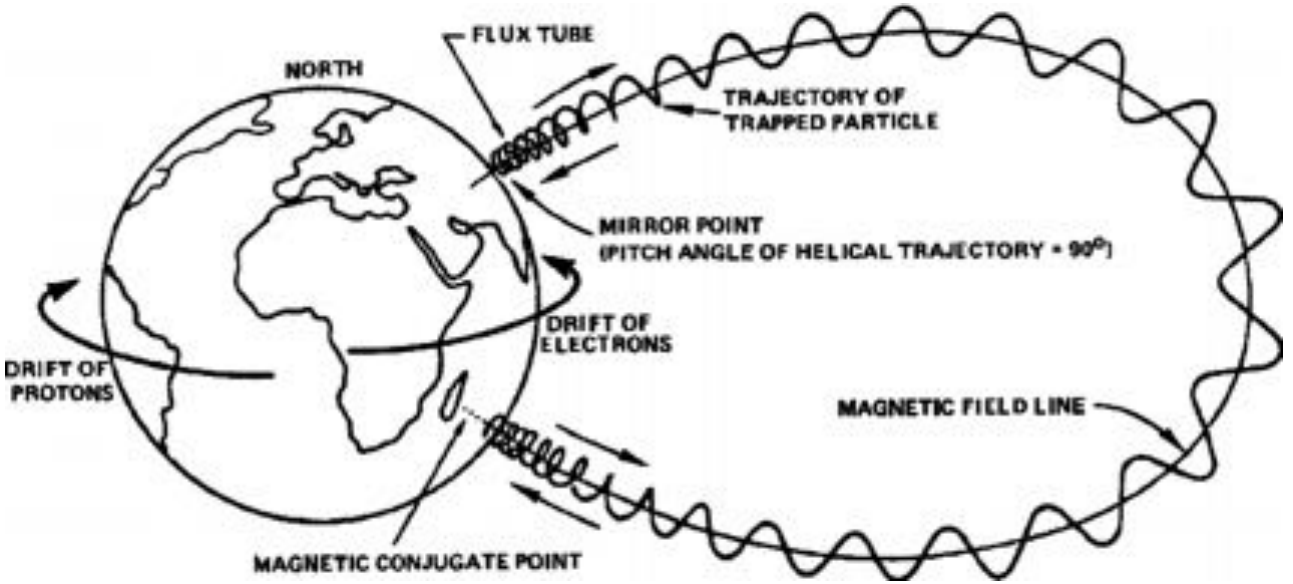
ATISE-AMICal Scientific objectives

- Main questions:
  - Oval extension
  - Small scale structure

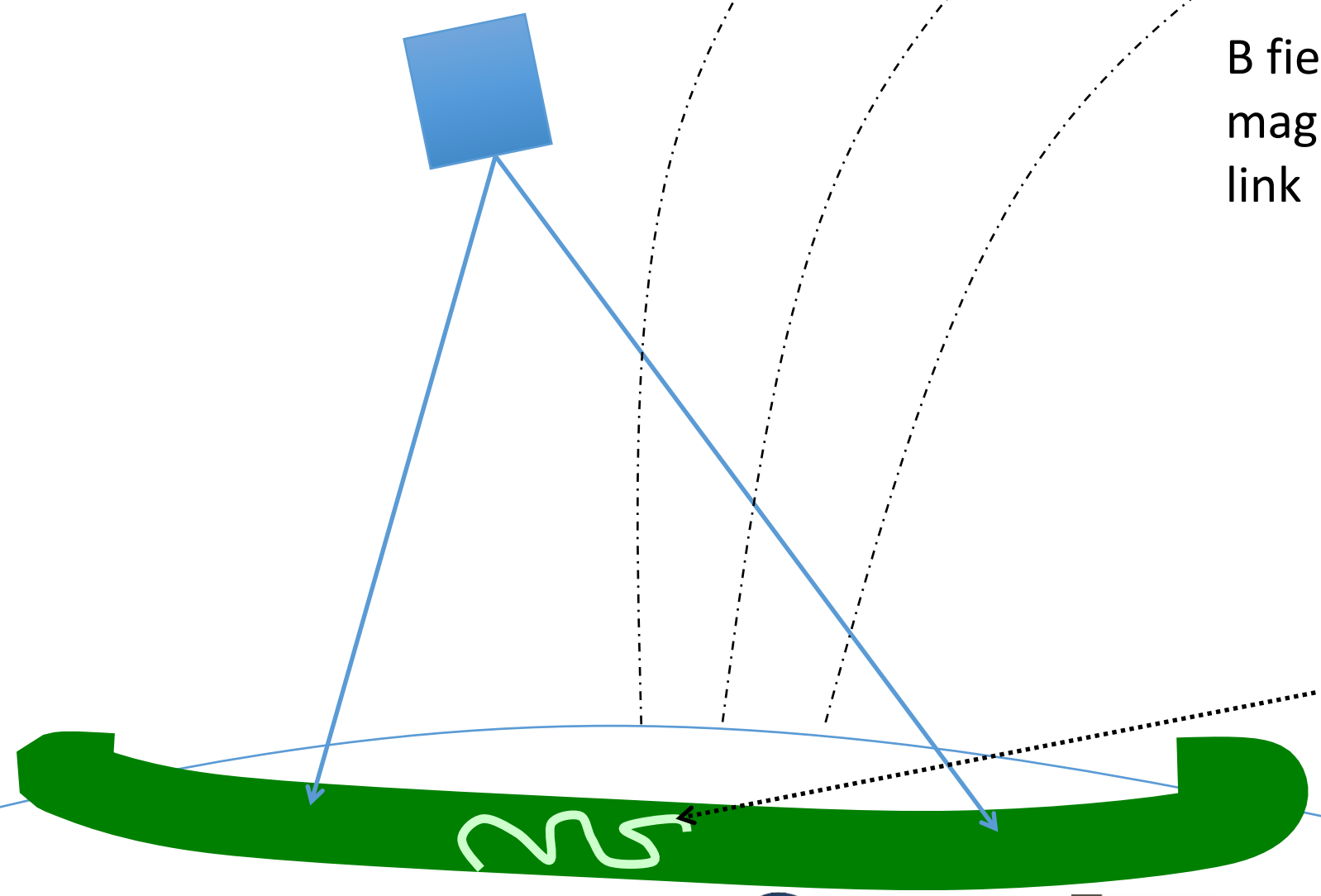
→ Aurora as a « tracer » of magnetospheric processes

  - Emission vertical profile

→ Aurora as a « tracer » of energy deposition



AMICal Sat Nadir configuration

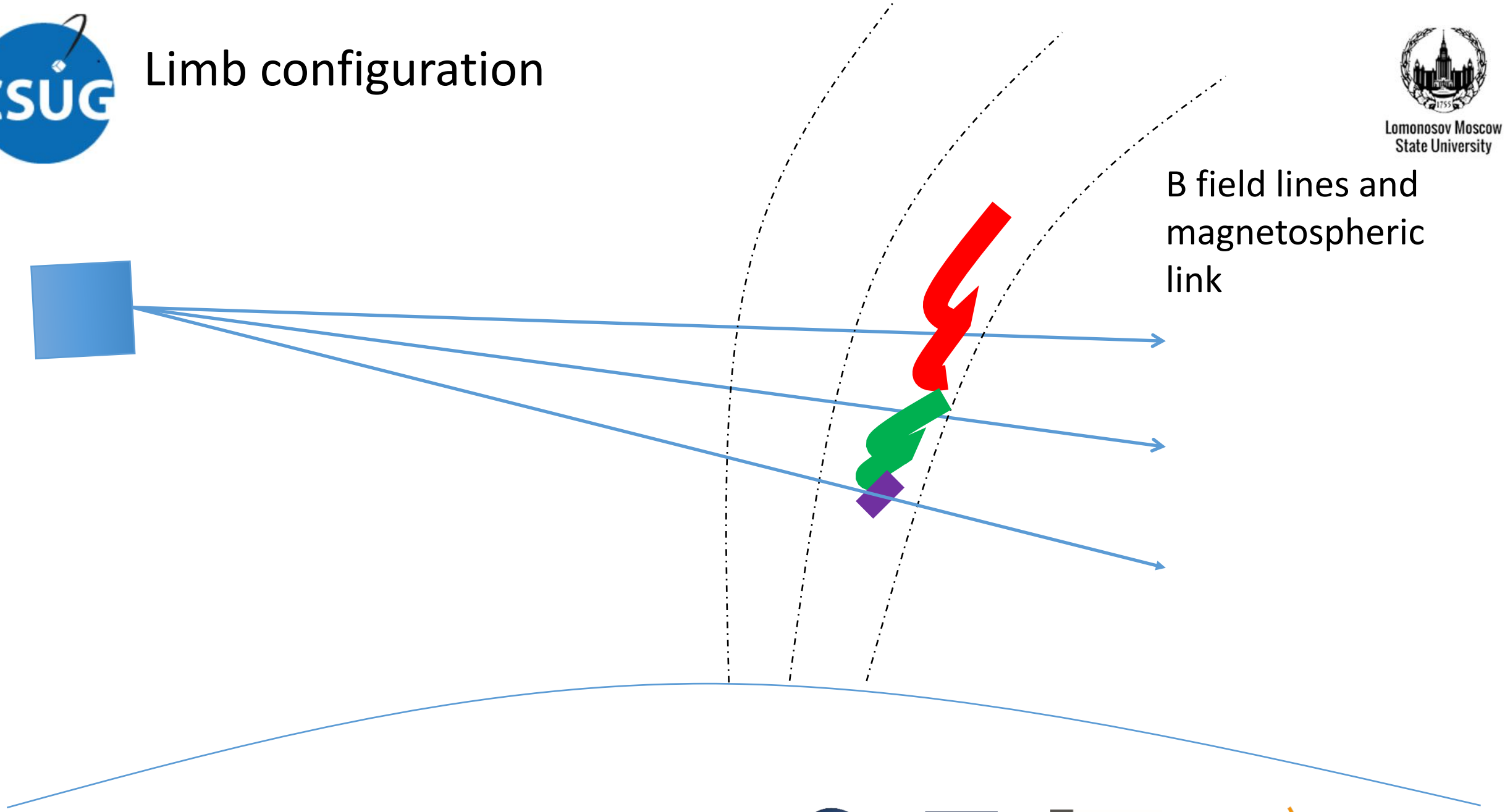


B field lines and magnetospheric link

Oval global structure

Small scale structure

Limb configuration



B field lines and magnetospheric link

Possible coordinated experiment

With both

AMICal and ATISE

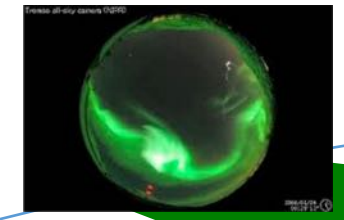
Other satellites

Particle detectors

Waves (ULF for example)

All Sky camera network

EISCAT



AMICal Sat: a 2U cubesat for SW on a short time schedule

- ATISE Imager tests
  - NADIR(Auroral Mapping)
  - LIMB Images (Vertical Profile)
    - Sensitivity: 500R
    - Exp time: 1s
- **Orbit**

SSO, Local times: 11h-23h

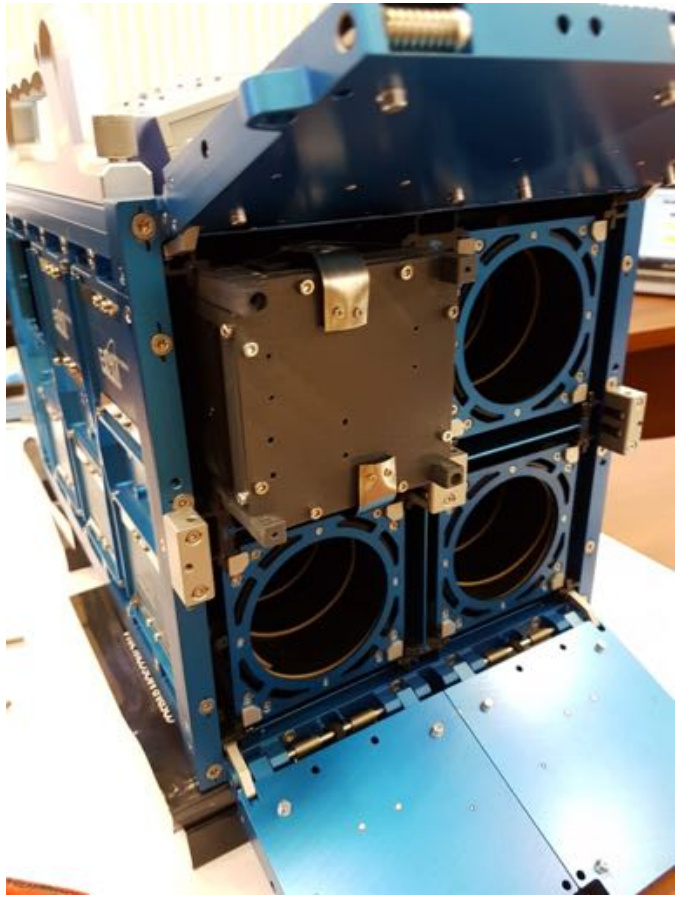
Altitude : 550km

AMICal Sat Launch: Launch schedule.
March 2019 (if non delayed)
Soyuz, Vostotchny.

Lifespan: 1 year (extensible to 3 years)

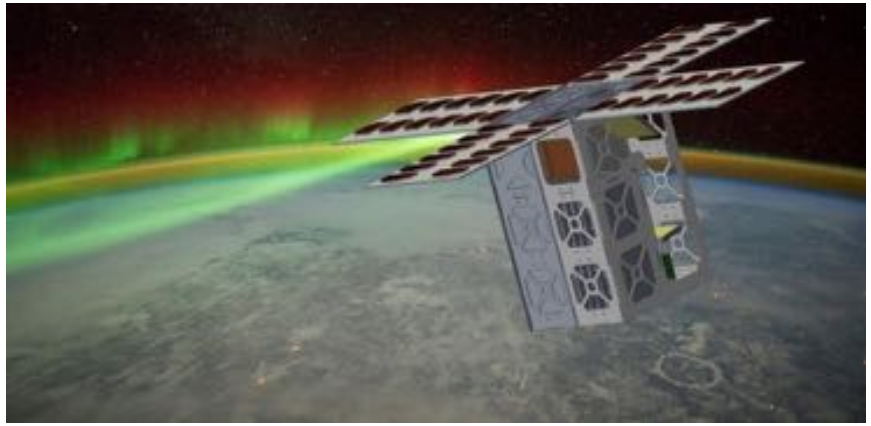
© Gabriel Dubreuil

AMICal Sat: 2U plateform provided by Satrevolution (Brought through a public trend)

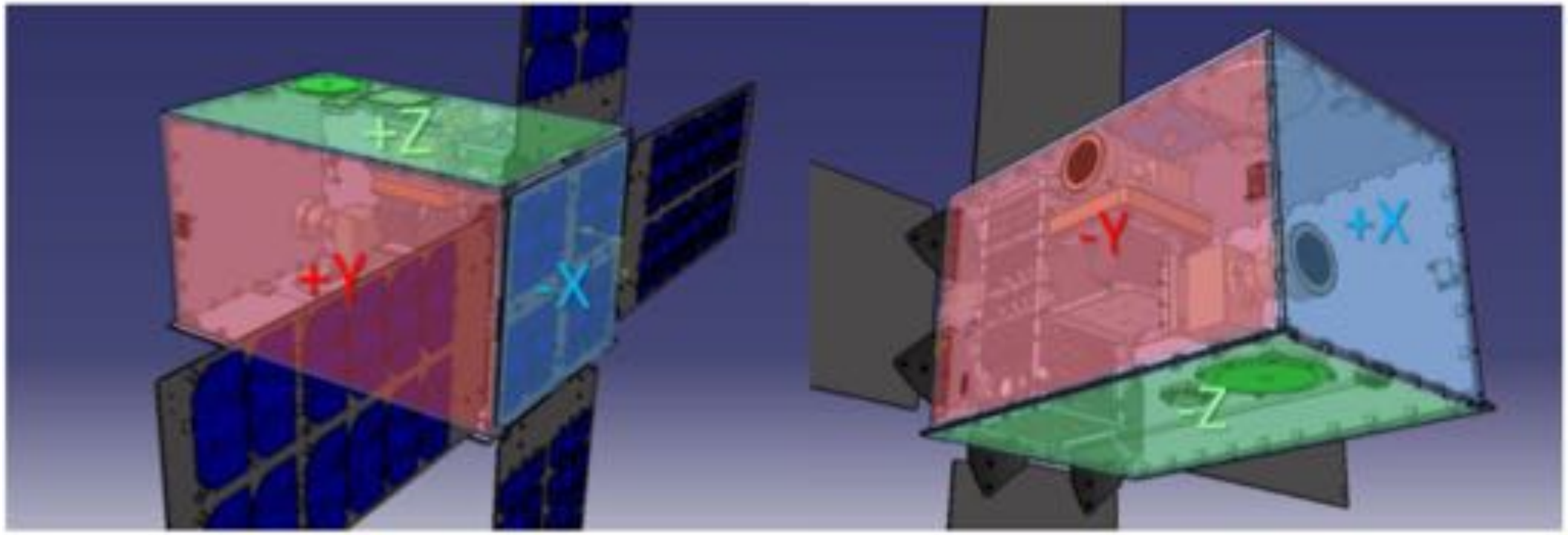


ATISE Mission profile

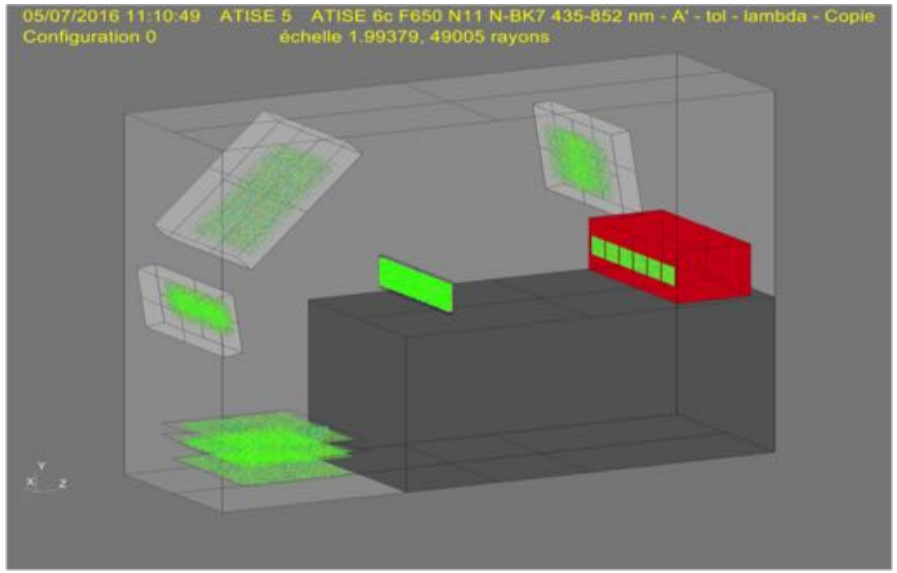
- 2 y nominal (ext 5y)
- Aurora (and Airglow)
- Orbital best choice : 70°, 600km
  - Shift in Local hours
- Visible (360-900nm). R~500 to 1000; ~1nm
- Vertical profiles of the emissions (6 lines of sight)
  - Limb sighting
  - between 100 and 350 km altitudes. 1°x1.5° for each.
- 1s exposure time (20 s in Airglow)
- Detection threshold : 5R. Sensitivity: 1R.
- Absolute Photometric precision ~5%(In flight Calibration)

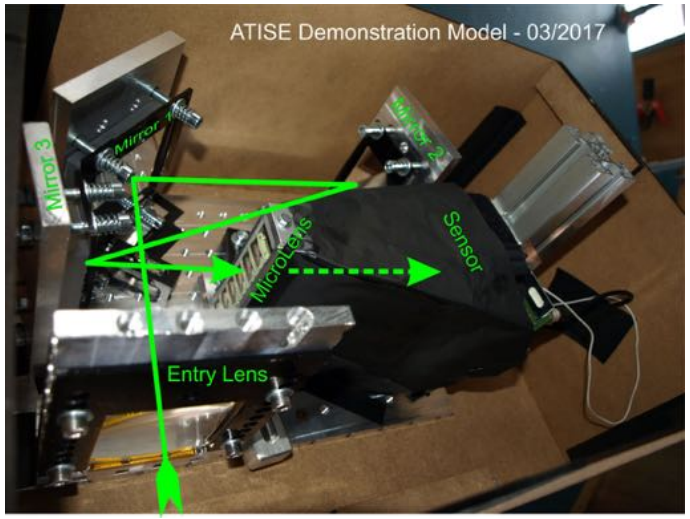


ATISE: Platform: 12U Mona from CSUT (ISAE)

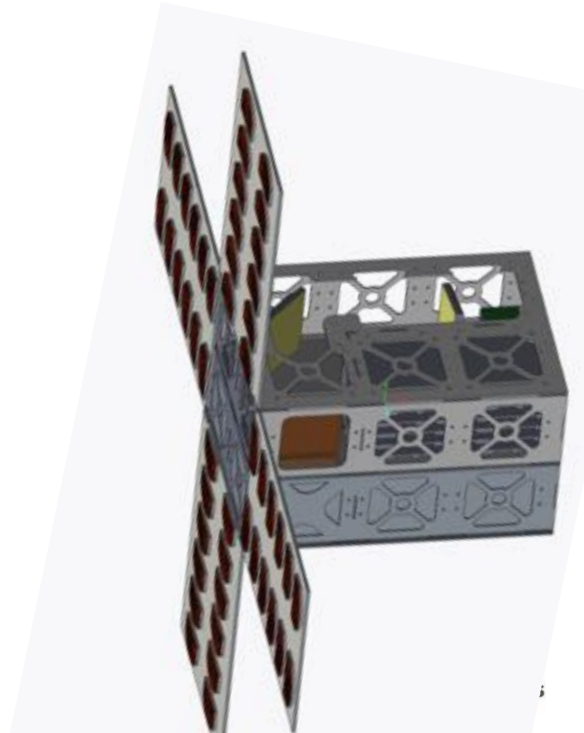


Instrumentation ATISE: Spectrometer

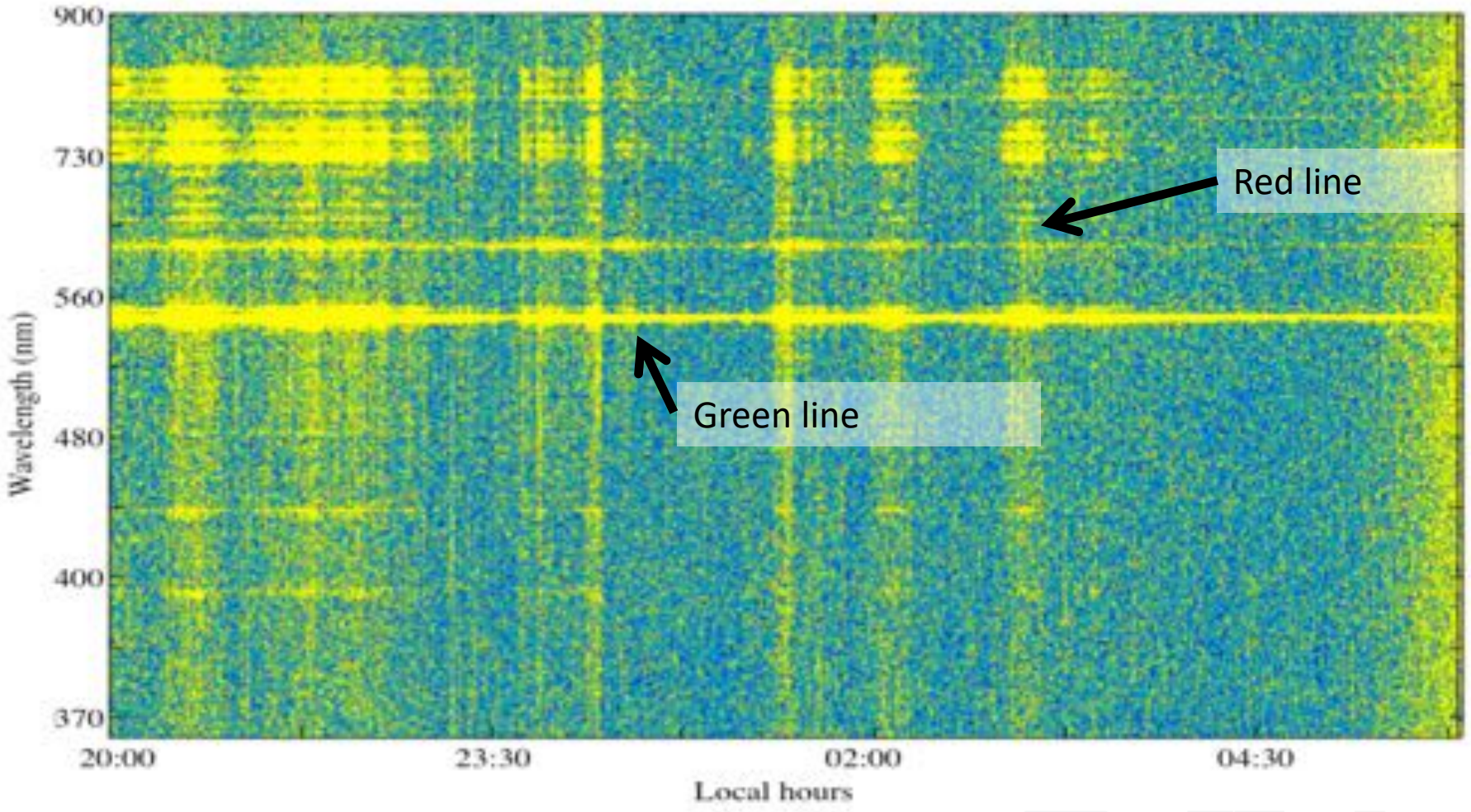




Based on the µSPOC concept:
Fizeau interferometer directly glued on the detector



Ground based demonstration (March 2017, Skibotn, Norway)



Around 18000 spectra

But

Still problems in line intensity conservation

Barthelemy et al. 2018

Imager (ATISE and ATISE)

- Wide field of view
  - 40°
- Important to Interpret the data.
- Need to know which structure is aimed.
- cross check of total intensity.

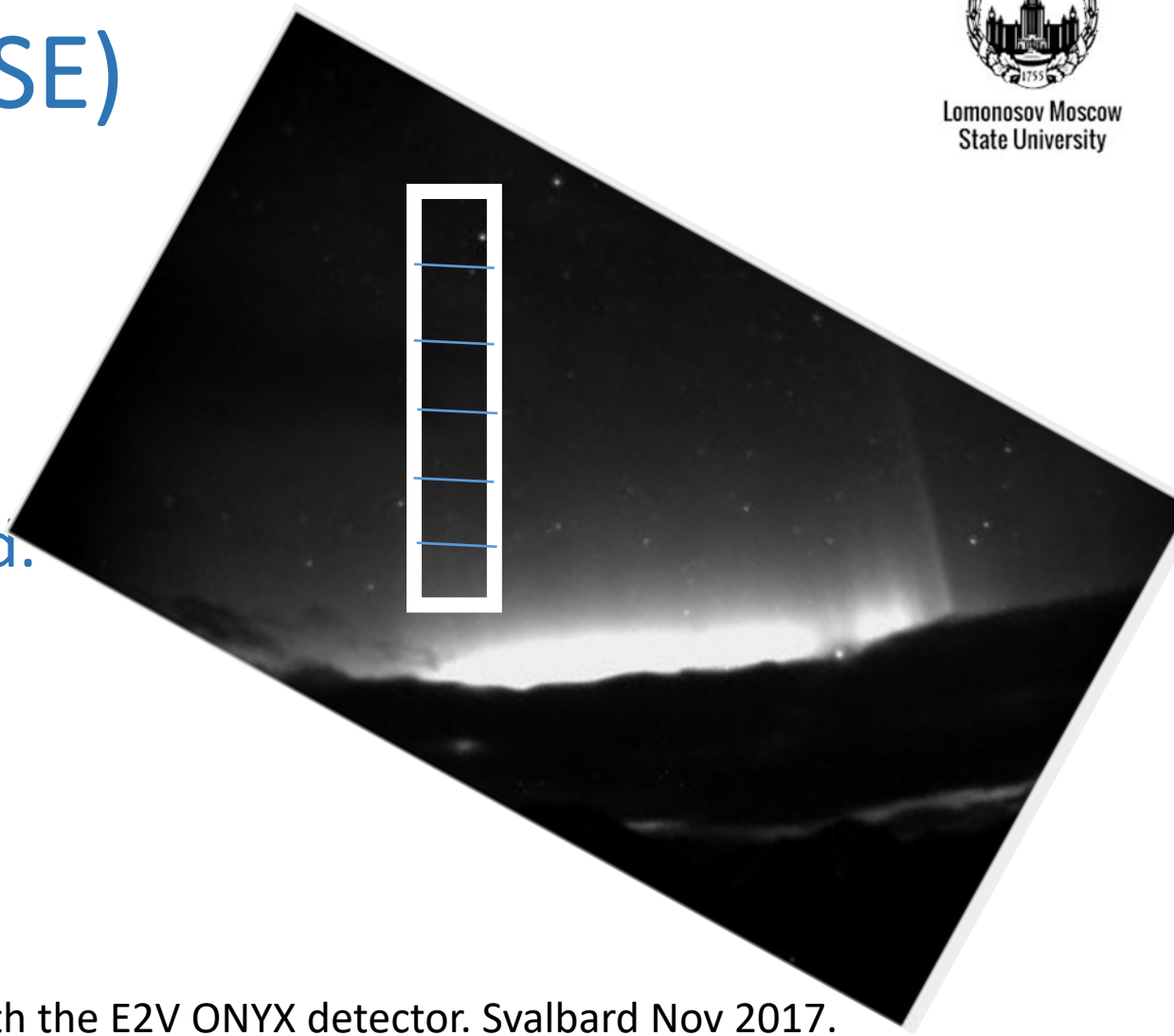


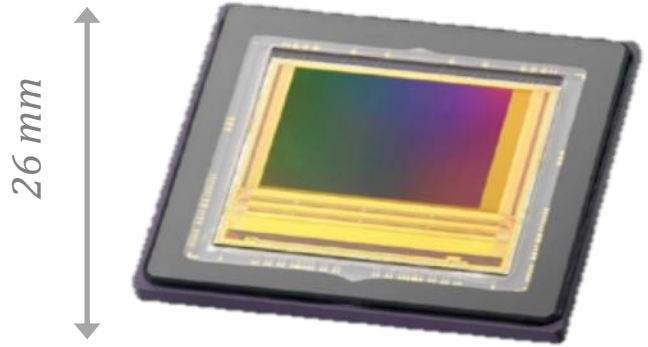
Image taken with the E2V ONYX detector. Svalbard Nov 2017.
A potential FoV of the 6 spectral LoS is added

Payload– Imager

Lomonosov Moscow State University

- **Commercial detector (ONYX teledyne E2V)**
  - **Large pixels : 10µm**
  - **Sparse RGB matrix: high sensitivity**

- **Objective: Designed at IPAG. f =23mm, f/1.4**



Onyx, 2Mpx, e2v

Calibration procedure (AMICal and ATISE):

- Detector photometric calibration on the Moon
  - Extended Source
  - Photometricaly stable (~10-8/y)

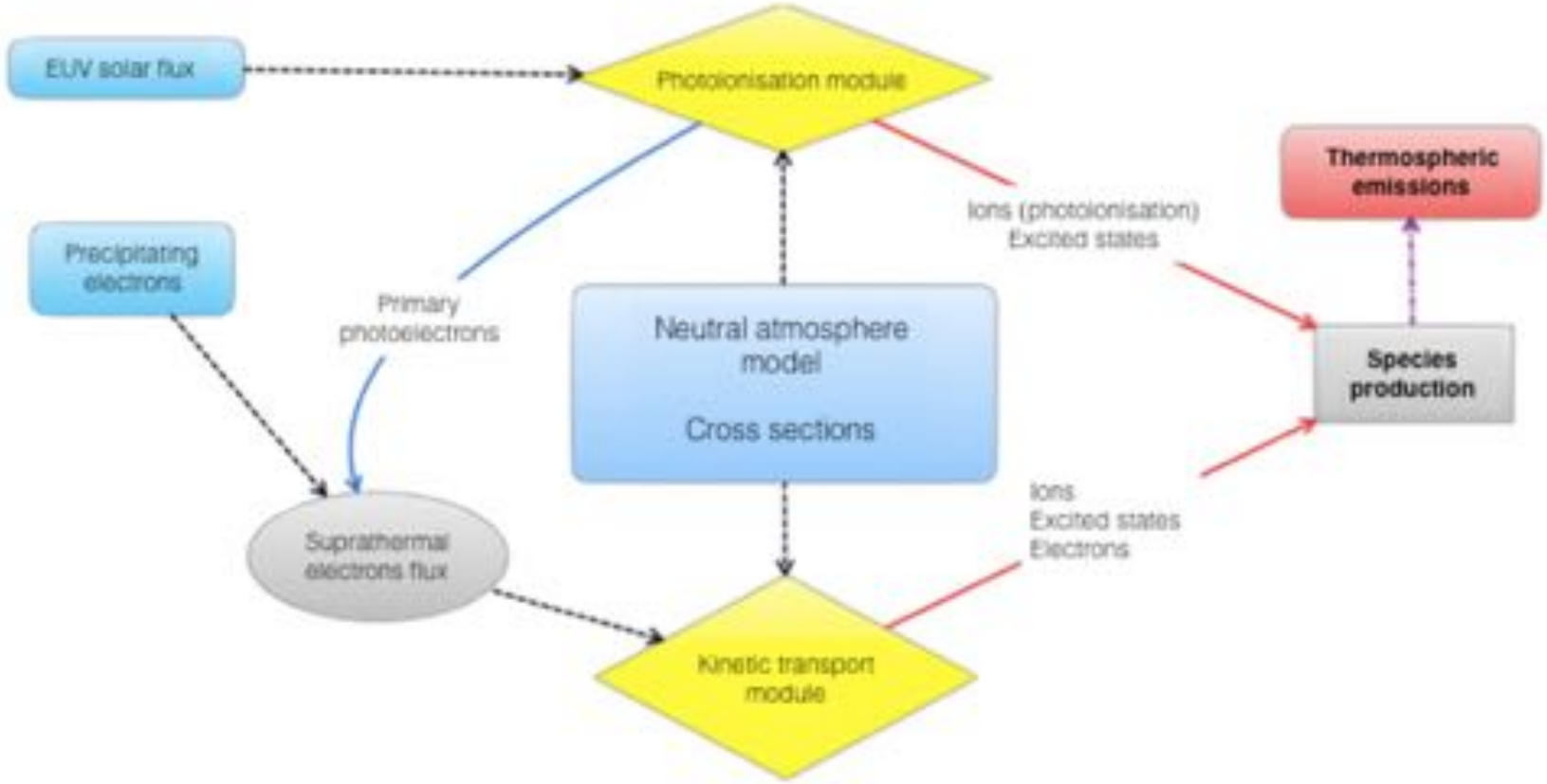
-Both Imager and spectrometer

-Use of ROLO and POLO codes for photometric simulation of the moon (Accuracy 2% to 5% in absolute photometry, 1% in relative)

© Wonderfl

Interpretation methods: the trans code

- Through the Transolo code



Fitted parameters

E tot

E moy for the distribution

If possible: ΔE

Considering the possibilities of several distributions (Need for enough information ie enough emission lines

AMICal Sat & ATISE SCHEDULE

- AMICal Sat
  - Payload delivery to system provider: Next week
  - Integration and tests satellite: Dec-Jan
  - Delivery to Launch authorities for last tests: End Jan 2019
  - Launch: March-Apr

- ATISE
  - Now in Phase C (PDR June 2018)
  - LAUNCH SCHEDULE Mid 2021.

The space of possibilities is very large

- See nanosats.eu

and

- **Workshop on Smallsats for Space Weather Research and Forecasting**

Examples of missions described in 2017 workshop:

- Observations of the Radiation Belts by the FIREBIRD-II Dual Cubesats

- The CubeSat Imaging X-ray Solar Spectrometer (CubIXSS) Mission Concep

- NASA Near Earth Network (NEN) Support for Lunar and L1/L2 CubeSats

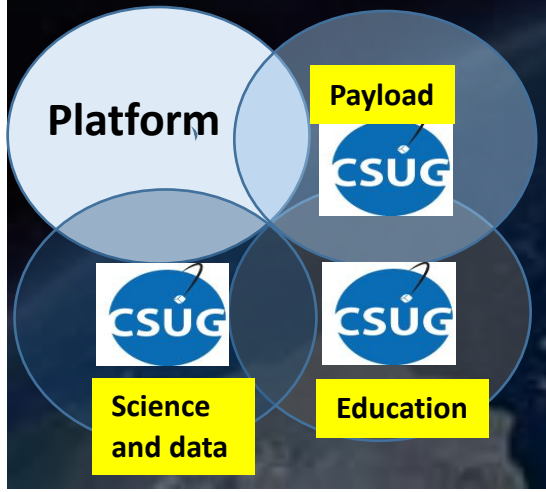
- Small satellite enabled new heliophysics science and prospects for improving our space weather capabilities.

Thank you for your attention

Lomonosov Moscow State University

Take home messages:

- High level payloads are possible in the cubesat standard (including optical ones)
- Need for a very pragmatic view: Is it faster, easier, cheaper?
- Need for common calibration procedures to allow intercalibration between different satellites



Open up the space of possibilities

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- Save the date
Grenoble NewSpace week
From payload ▷ to uses
May 14 to 17, 2019
Grenoble, France
Industrial & tech day // Scientific workshops
Student workshop // Public conference //
https://gnsw.sciencesconf.org
or
https://www.csug.fr/main-menu/newspace-week-2019/program-abstracts/