Evaluation of light pollution sources over Pistoia area with an autonomous payload for sounding balloons.

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Abstract:

The MINLU ("Misurazione dell' INquinamento LUminoso") payload was successfully launched on July 7th 2021 with a sounding balloon from Tuscany, achieving continuous observation of sky brightness and ground light sources from ground to maximum stratospheric altitude near to 34 km. The operation was the result of a joint effort by the Department of Industrial Engineering (DII) and the Center of Studies and Activities for Space "G. Colombo" of University of Padova which realized the scientific gondola in collaboration with the Space Systems Lab from University of Pisa, which provided its UniPiHAB04 flight platform to carry the system to stratospheric altitude and safely back to ground.

MINLU autonomous payload has been designed and tested to provide complete and detailed aerial observations of Light Pollution and Sky brightness, with the capability to be integrated either on stratospheric balloons or drones. The implemented architecture includes three cameras with dedicated filters (one monochromatic camera working as raw spectrometer, one as luminance meter and a colour camera for overall ground illumination reconstruction) and two commercial Sky Quality Meter (SQM-L) units, controlled a Raspberry based Central Data Management Unit performing sensor conditioning, data acquisition, compression and storage; inertial position and attitude information are acquired by on board GPS and IMU systems and automatically linked to scientific data.

The work will briefly present the calibration activity of the luminance camera and the raw spectrometer conducted in the laboratories of university of Padova and then describe the balloon flight trajectory and attitude reconstruction focusing on the elaboration of camera's inertial pointing used for the calculation of ground illuminating sources based on luminance data.

Light polluting sources in the Pistoia area will be analysed from 34km altitude highlighting the entity and reconstructed type of emission sources and comparing elaborated stratospheric measurements with the available radiance values from satellite imaging (based on VIIRS instrument data)

Keywords: light pollution monitoring; autonomous payload for sounding balloon; trajectory and pointing reconstruction.

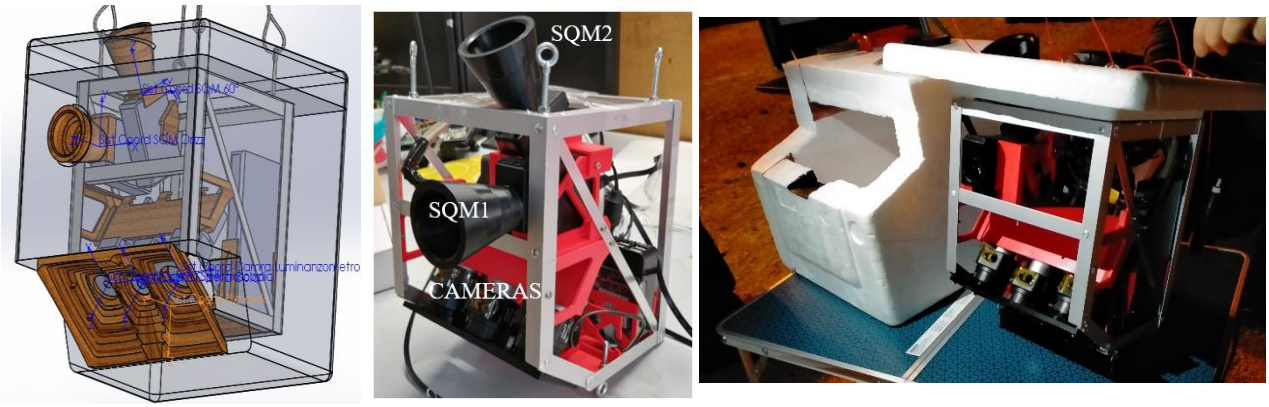
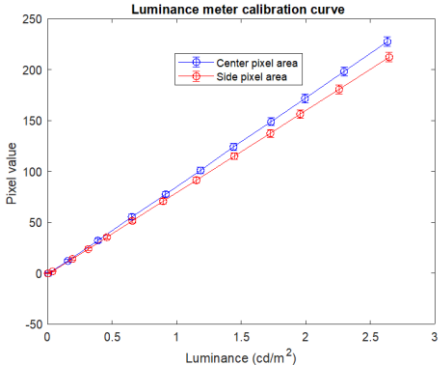
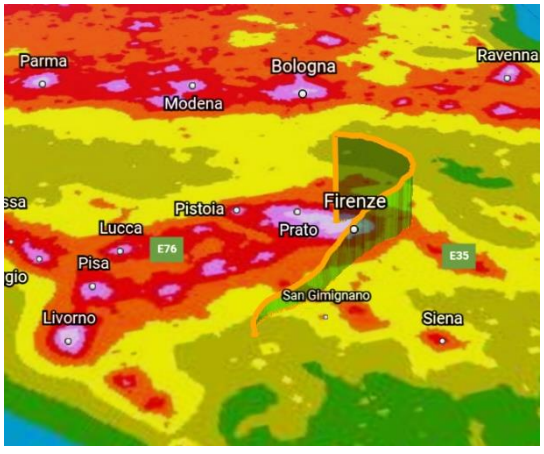


Fig 1. 3D impression (left) and flight unit (centre and right) of MINLU autonomous payload for sounding balloon



Lamp	Ref. (cd m^{-2})	Camera (cd m^{-2})	Diff. (%)	Std (%)
Fluorescent 2600K	13.1	12.5	-5.6	1.3
Fluorescent 3750K	12.9	12.8	0.5	0.7
Fluorescent 5800K	12.5	12.4	-0.8	1.0
Mercury vapor	54.5	57.0	4.4	0.12
HP Sodium	82.1	82.1	0.02	1.0
HP Sodium calibration	61.0	61.0	0.00	0.15

Fig 2. Calibration test for luminance camera of imaging subsystem



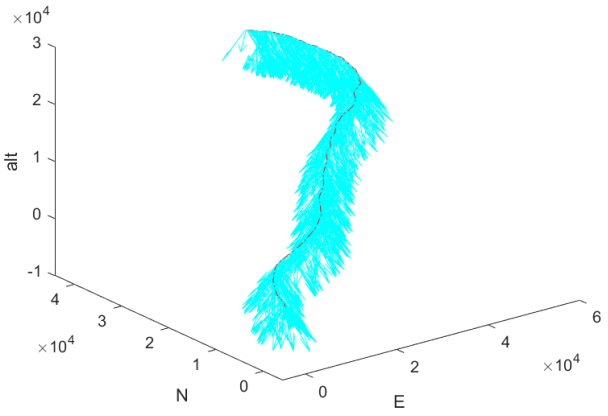


Fig 3. Sounding balloon ascent trajectory over light pollution world atlas of Sky brightness based on VIIRS data (left) and camera inertial pointing reconstruction along trajectory in NED reference centred at launch site during ascent phase (right)

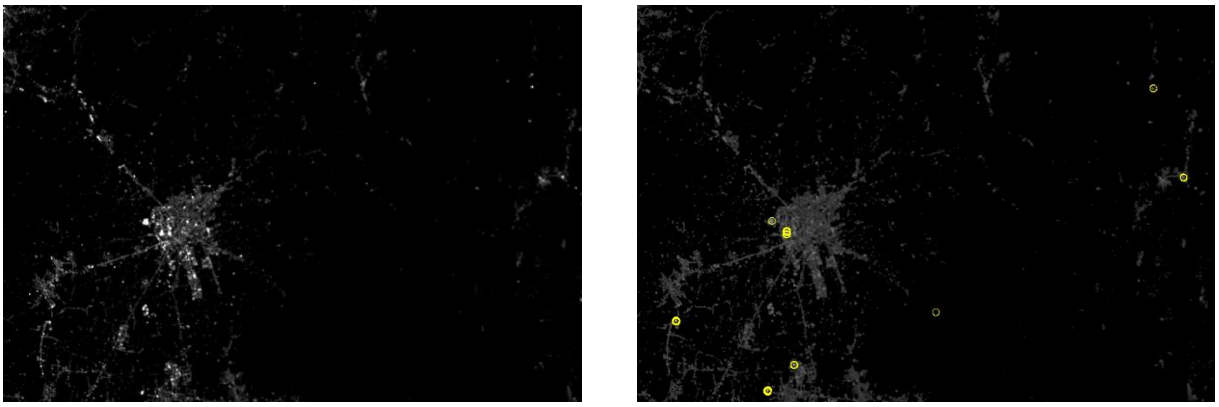


Fig 4. Luminance camera image of the Pistoia area from 34 km altitude (left), illumination sources with reconstructed intensity above 150 lumen (right)

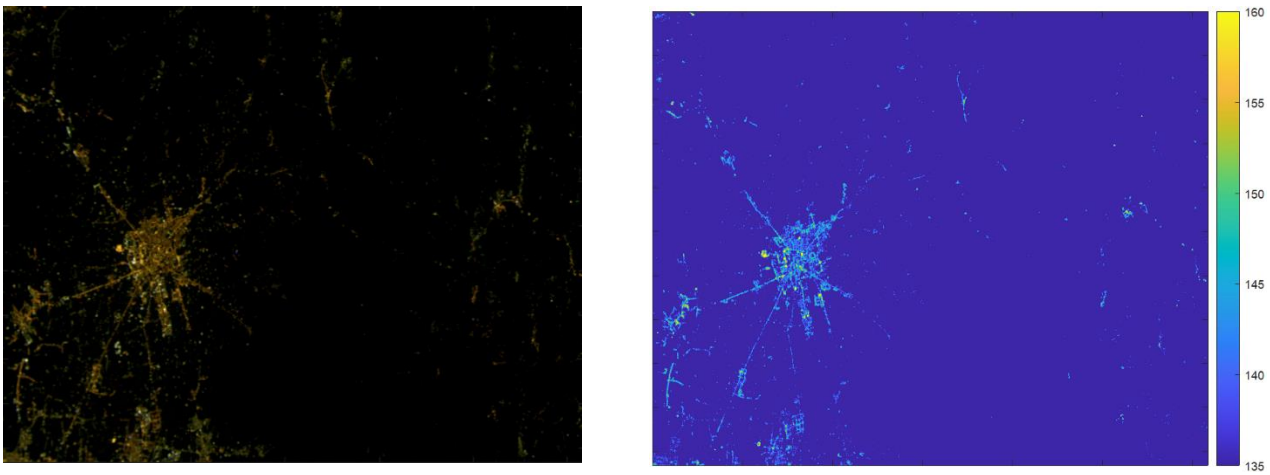


Fig 5. Colour camera image of the Pistoia area from 34 km altitude (left), and map of illuminating sources type based on emission in red colour (right)