



# InfraRed Imaging of astronomical targets with a Stabilised Camera IRISC



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TEKNISKA  
UNIVERSITET

# Table of Contents

## ① IRISC: In a Nutshell

## ② System

- Construction
- Thermal
- Electrical Setup
- Ground Station
- OBSW
- Control System
- Cameras
- Telescope

## ③ Science

- Targets
- Expected Results
- Data Analysis

## ④ Project Management

- Schedule
- Outreach

## ⑤ Summary

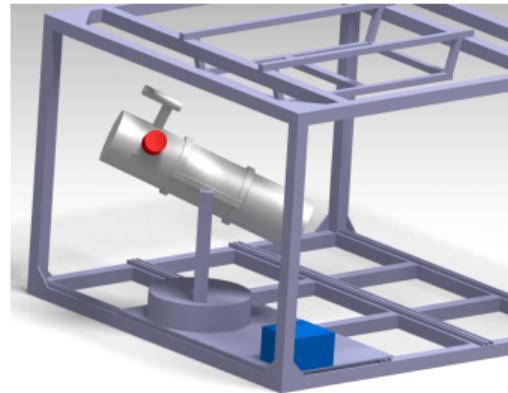
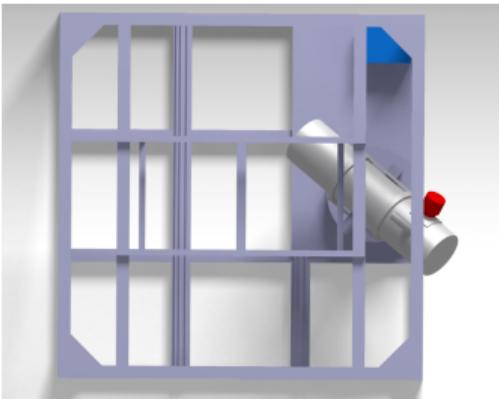
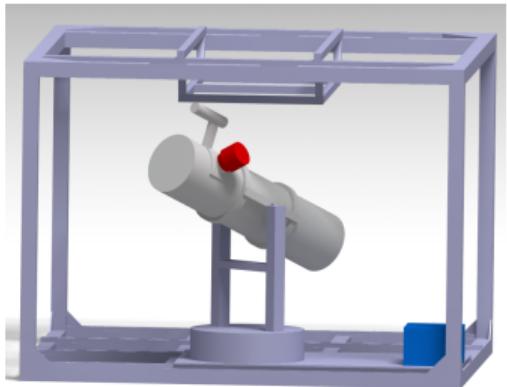
## ⑥ Questions

Our vision is to make astronomical research  
more accessible by developing a stabilised  
balloon-borne telescope

# Construction

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

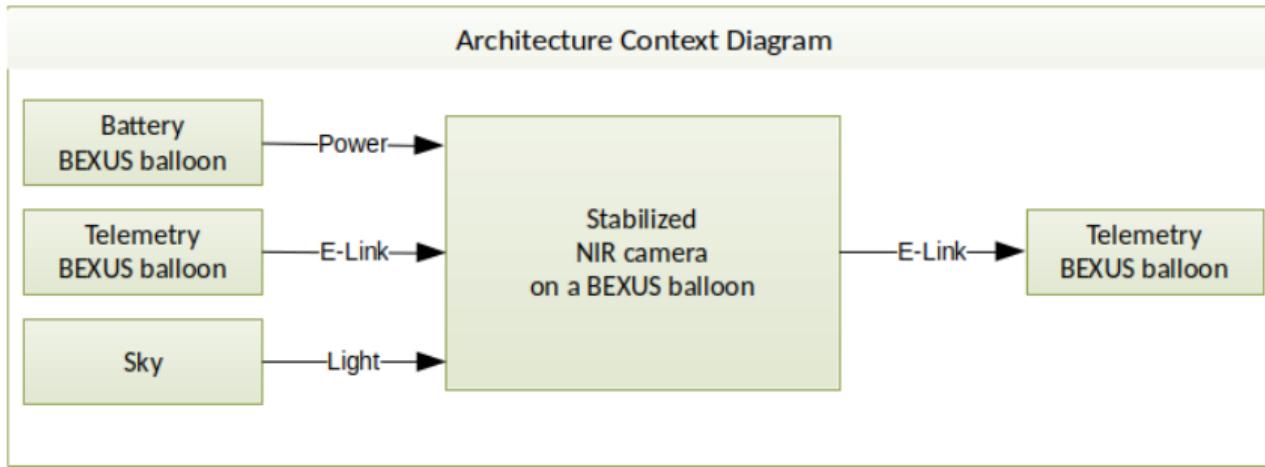


- Using a Newtonian telescope gives us the advantage of not needing an added baffle anymore since the primary mirror is situated on the rear part of the telescope, effectively using the telescope's structure as a baffle.
- For the electronics box, FEA analysis will be made in order to determine the heat produced by the components and therefore determine where heating or cooled will be required.

# Electrical ACD

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System  
Science  
Project Management  
Summary  
Questions

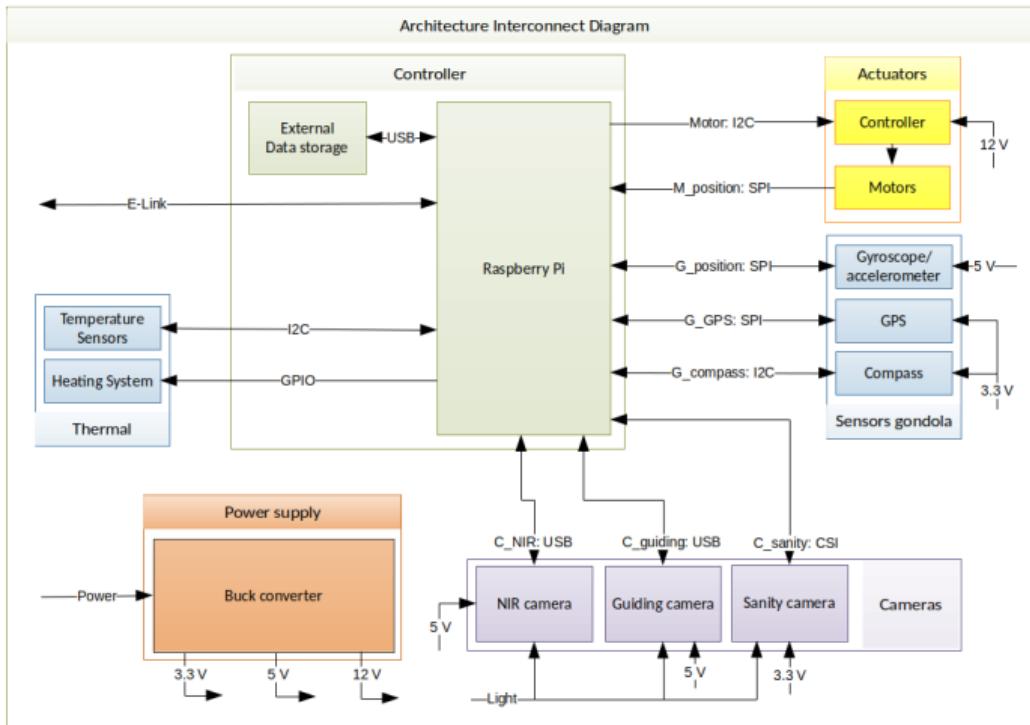
Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope



# Electrical AID

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope



# Power Consumption

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

	Power [W]	On-time [%]	Energy 4h [Wh]
NIR camera	1.5	100	6
Guiding camera	1.5	100	6
Controller	6.25	100	25
Sensors	1	100	4
Motors	$3 \times 4.2$	100	50.4
Heating system	10	20	8
Subtotal			99.4 Wh
Standby E (6h)			40 Wh
Total			139.4 Wh

# Bandwidth

Item	File size*	Downlink rate	Datarate
NIR camera	18 MB	60 sec	2.4 Mbits/sec**
Guiding camera	2 MB	60 sec***	0.27 Mbits/sec
Sanity camera	7 MB	On request	-
Sensors****	30 B	1 sec	240 bits/sec

\* File sizes reflect lossless compressing

\*\* Not planned to send all pictures down, thus will be reduced

\*\*\* Onboard save time is 15 sec

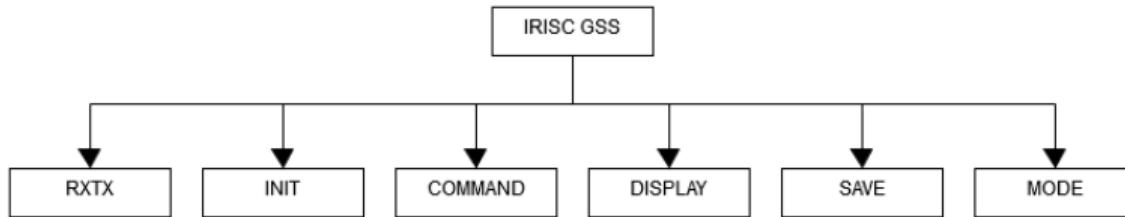
\*\*\*\* GPS; Compass; Gyroscope; Encoders; NIR temp sensor

# Ground Station

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System  
Science  
Project Management  
Summary  
Questions

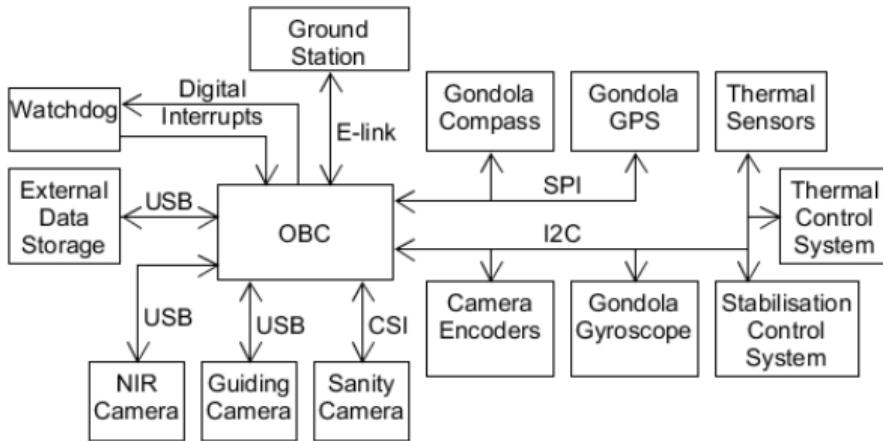
Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

- K.I.S.S.
- Written in C with GTK+



# On-board Software

- The glue between the systems
- C on a simple linux distro
- Compression and storage



# Control system

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

- Stabilisation of the gimbal: dynamic control system (e.g. PID)  
Sensor data: gyroscopes, accelerometer  
Includes mechanical model of gimbal, motors

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IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

- Stabilisation of the gimbal: dynamic control system (e.g. PID)  
Sensor data: gyroscopes, accelerometer  
Includes mechanical model of gimbal, motors
- Selection and tracking of targets:  
Sensor data: magnetometer, GPS, gyroscopes, encoders  
Includes model of movements of astronomical targets

# Control system

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

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Includes mechanical model of gimbal, motors
- Selection and tracking of targets:  
Sensor data: magnetometer, GPS, gyroscopes, encoders  
Includes model of movements of astronomical targets
- Feedback loop, measured states: utilisation of a Kalman filter to determine exact position & orientation

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IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

Minor objectives of the control system:

- Avoid looking directly into the Sun
- Thermal control of the camera sensor and electronics
- Motor control

# NIR Camera

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

- CMOS Sensor: ZWO ASI183MM (mono-colour)  
resolution: 20.18 MP, sensor size: 13.2x8.8 mm
- NIR-conversion with 720 nm NIR filter
- Sensitivity: 720 nm to 1150 nm
- Rolling shutter: no mechanical shutter, no moving parts



Credits: ZWO ASI183MM (mono)

# Guiding Camera

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Construction  
Thermal  
Electrical Setup  
Ground Station  
OBSW  
Control System  
Cameras  
Telescope

- For verification of the field of view
- Support of ground-based re-calibration of sensors (e.g. magnetometer, gyroscopes)
- Imaging sensor with a high sensitivity, resulting in shorter exposure times (compared to NIR camera)
- Imaging in visible wavelengths



Credits: Guiding camera by ZWO



SkyWatcher BKP 130DS (with eyepiece in place of the camera)

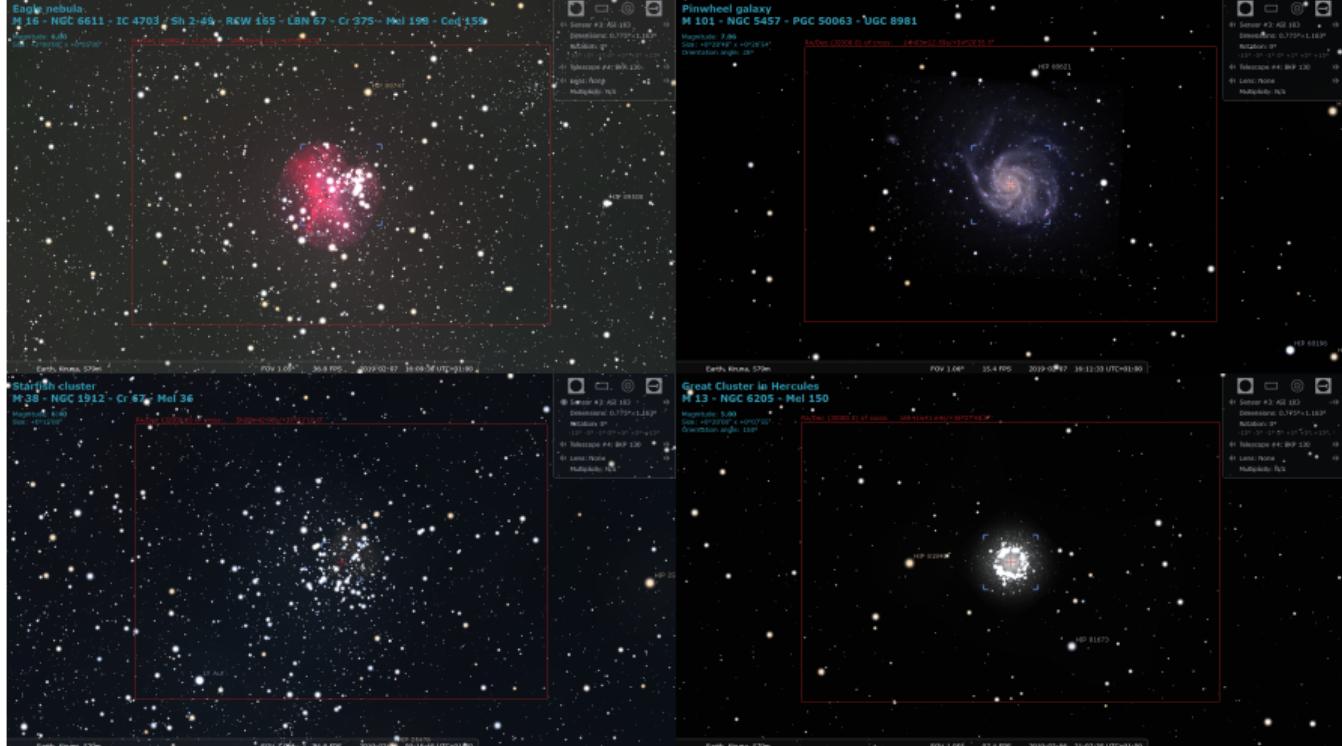
## SkyWatcher BKP 130DS

- Newtonian telescope
- Focal length: 650 mm
- Aperture: 130 mm
- FOV: 1.16 deg by 0.78 deg
- Diffraction-limited-resolution: 1.94 arcsec
- Pixel size: 0.76 arcsec (in combination with the camera)

# Targets

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Targets  
Expected Results  
Data Analysis



# Signal to Noise Ratio

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Targets  
Expected Results  
Data Analysis

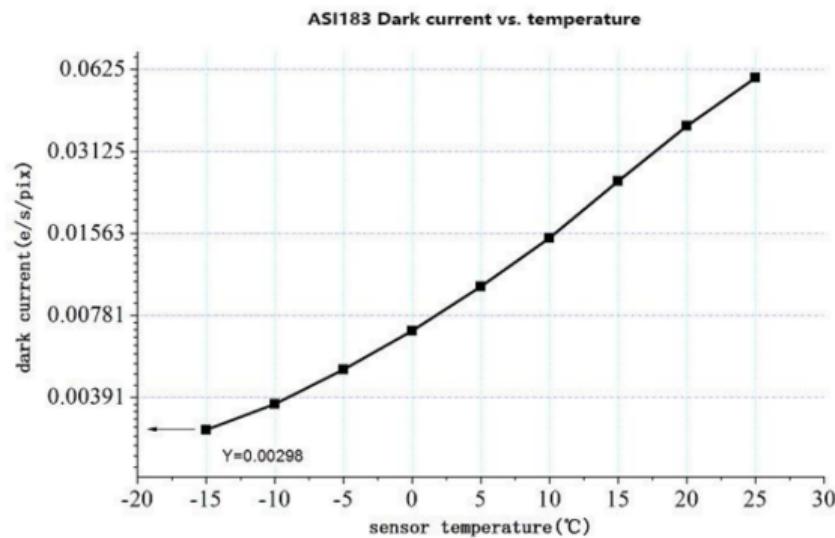
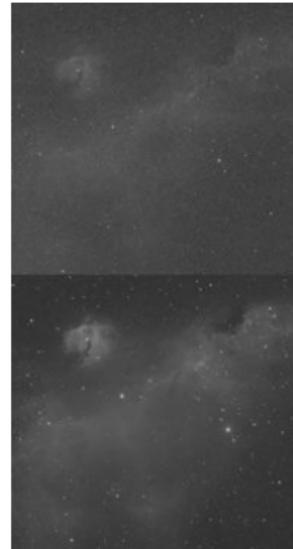


Figure: Dark current vs. temperature as given in the camera manual



Credit: Richard S.  
Wright Jr.,  
SkyandTelescope.com

# Data Analysis

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Targets  
Expected Results  
Data Analysis

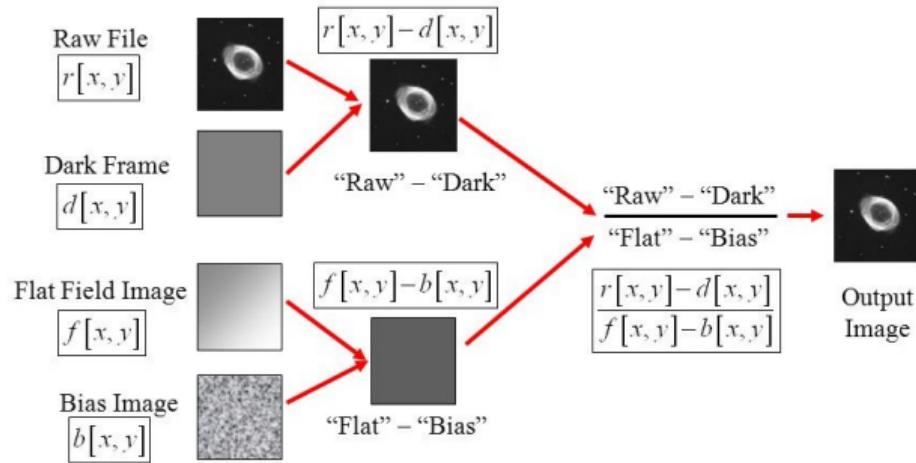
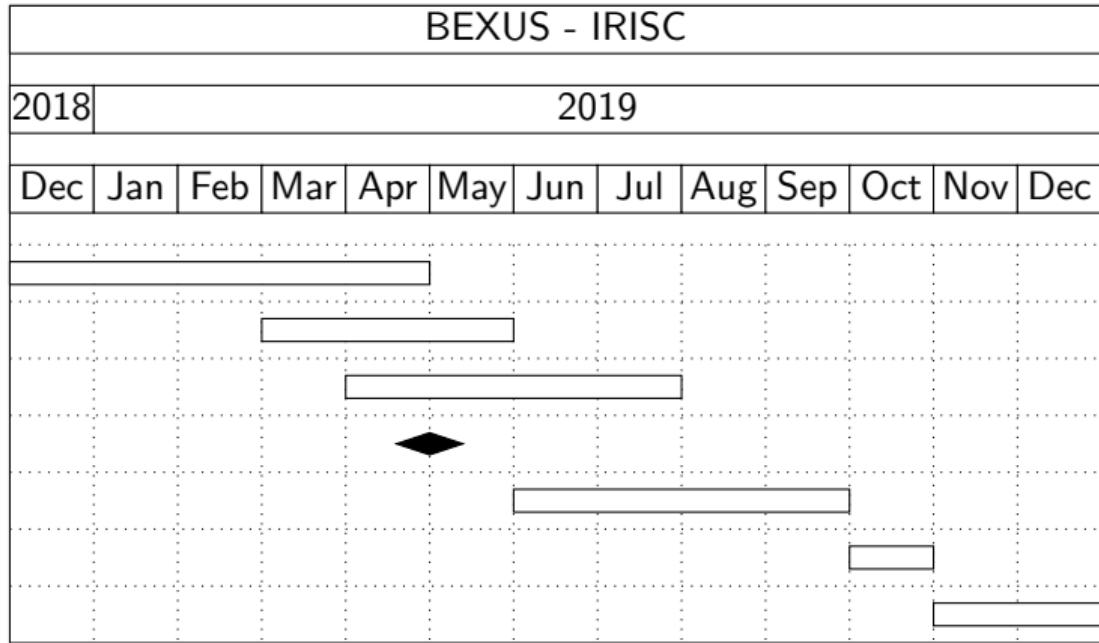


Figure: Standard astrophotography image calibration pipeline

- **Light Frames:** image of the target itself
- **Dark Frames:** aperture blocked of light
- **Flat Frames:** brightness balance of the sensor
- **Bias Frames:** readout noise due to the sensor

# Schedule

Design Phase  
Unit testing  
Manufacturing Phase  
*First Prototype*  
Complete System Testing  
Launch Campaign  
Data Analysis Phase



## Website and Social media

- Facebook
- Twitter
- Instagram

# Summary

- Proof of concept of a stabilised balloon-borne telescope with an NIR camera
- Empowered by the BEXUS project
- To achieve a higher degree of accessible and affordable astronomical research



# Thank you for your attention

Let us explore the NIR universe with a BEXUS balloon together!

A. Möslinger, K. Steele, D. Talavera, N. Ulfvarson, and E.F.M. Weterings  
and the rest of the IRISC team



# Cooling electrical systems in space

The only way to get rid of thermal energy, outside the lower atmosphere, is radiation.  
Passive solutions are:

- Highly efficient components.
- Passive cooler with fluid (convection).
- Solid thermal conducting material connected to the heat sources (conduction).

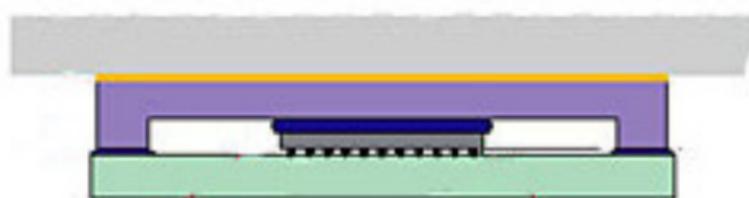
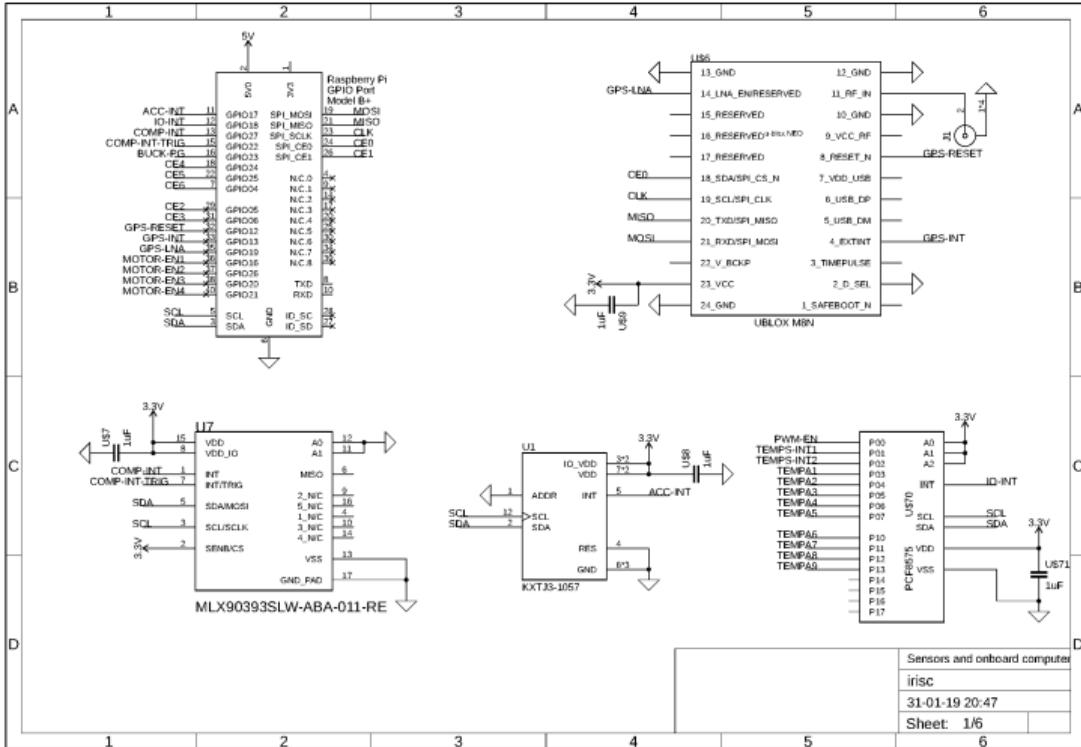
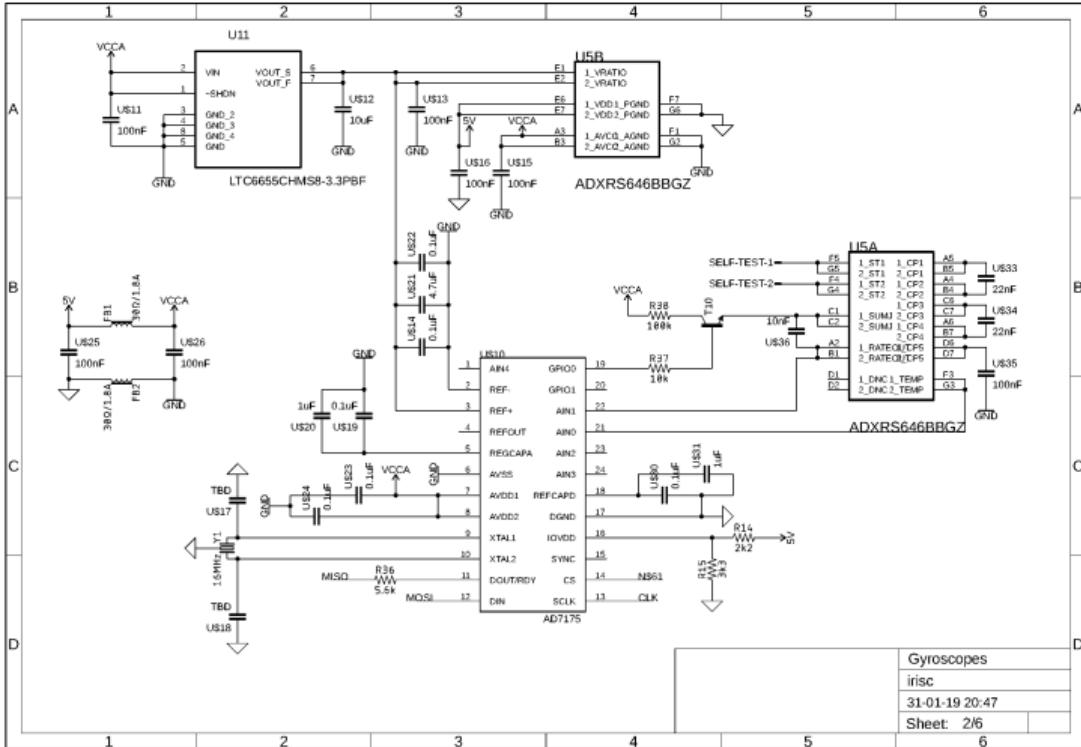


Figure: Clemens J. M. Lasance, cooling electronics

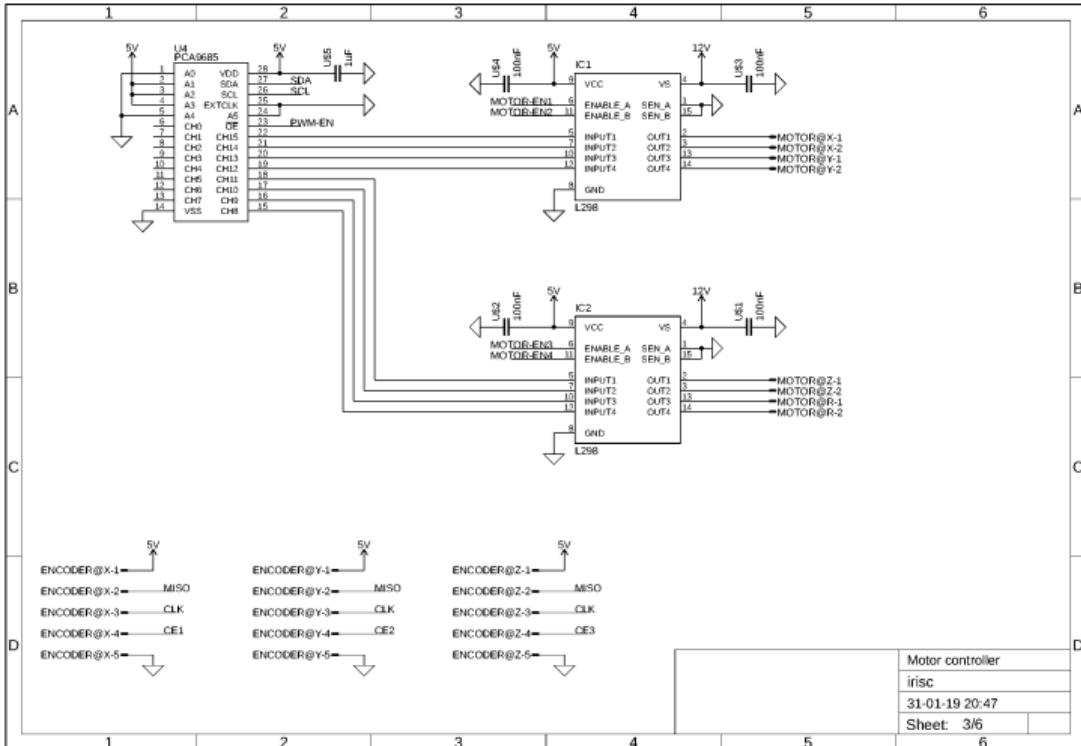
# Schematic: Sensors & onboard computer



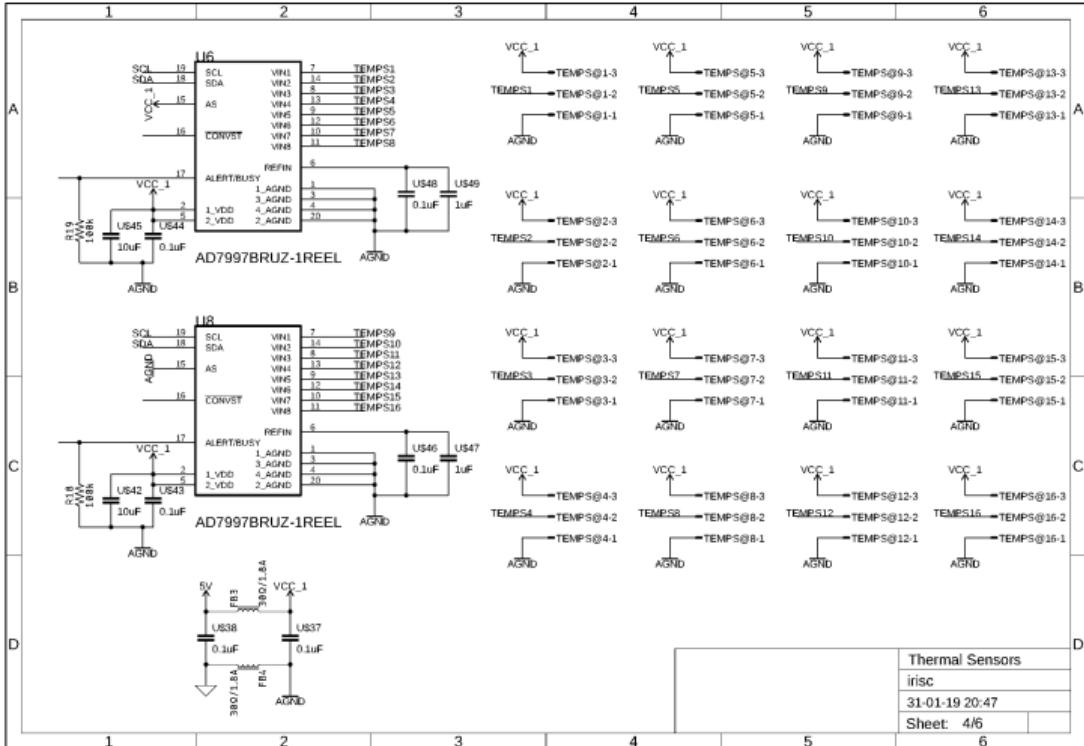
# Schematic: Gyroscopes



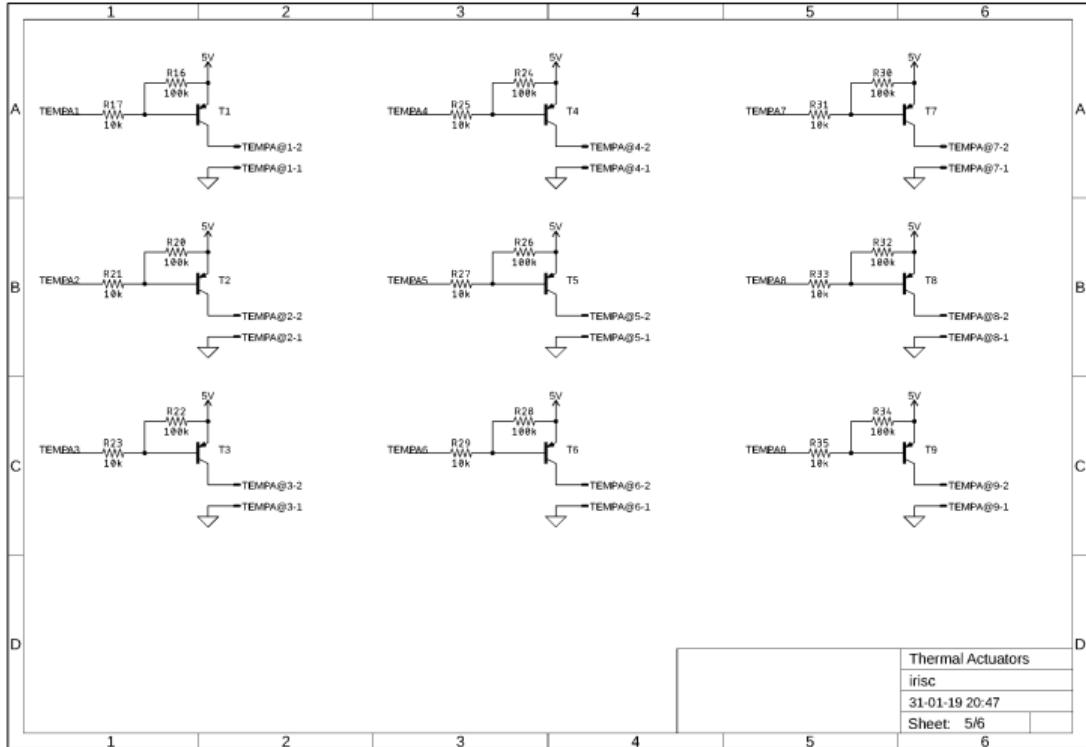
# Schematic: Motor Controller



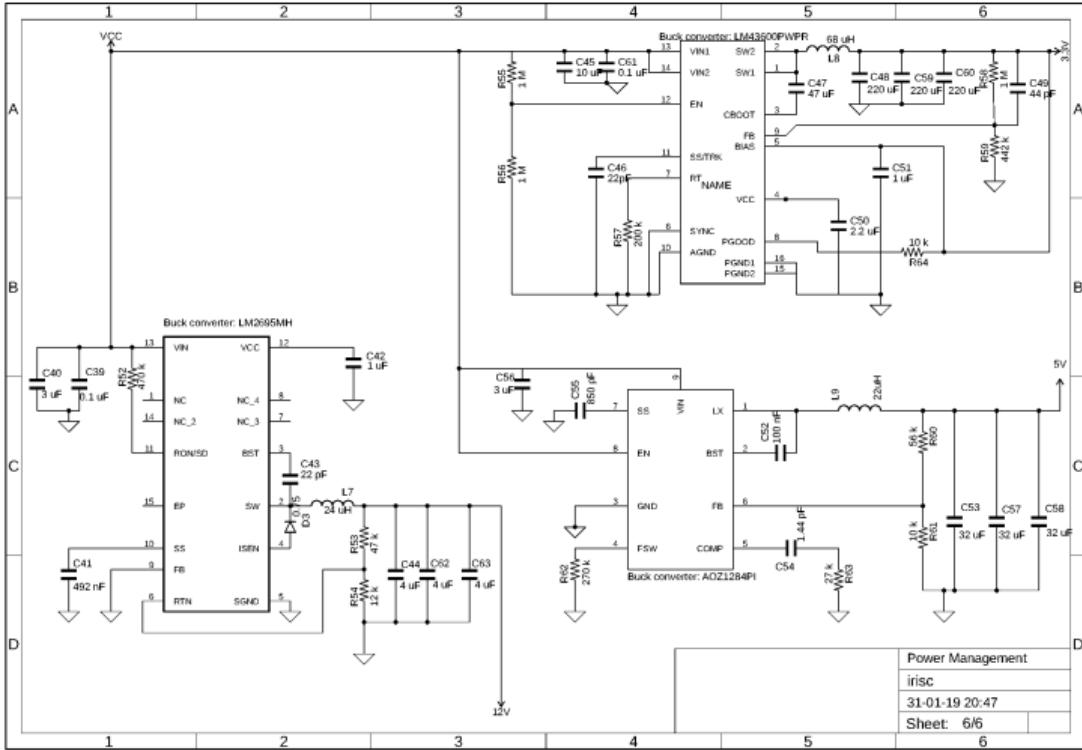
# Schematic: Thermal Sensors



# Schematic: Heating System



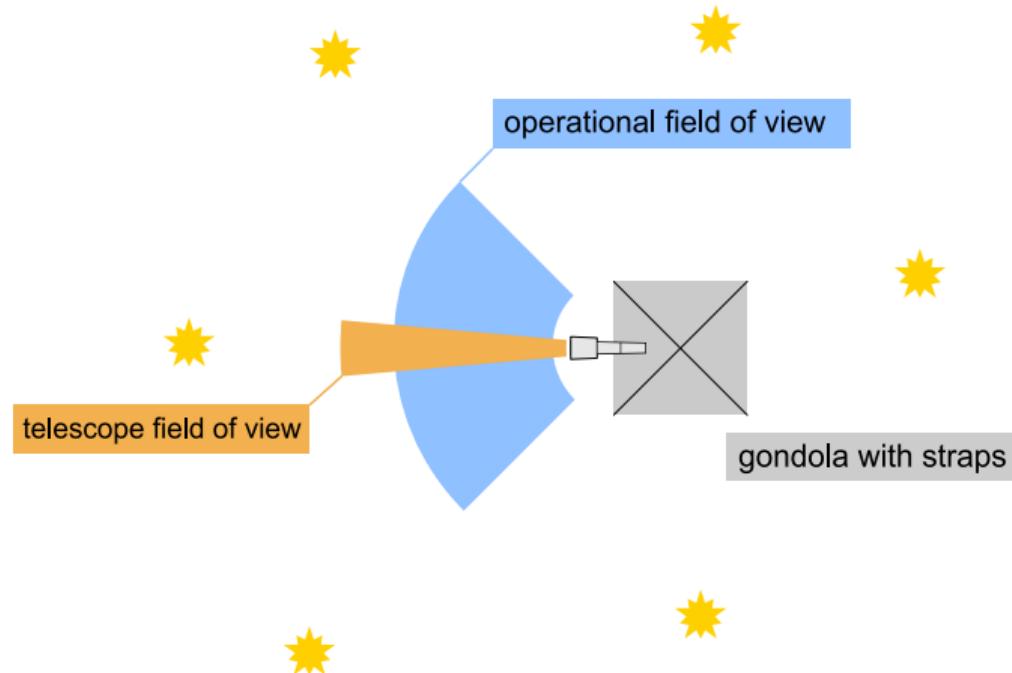
# Schematic: Power Management



# Control System

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Electrical  
Control System  
Science  
Budget





SkyWatcher BK MAK127 OTAW (with eyepiece in place of the camera)

## SkyWatcher BK MAK127 OTAW

- Cassegrain telescope
- Physical length:
- Focal length: 1500 mm
- Aperture: 127 mm
- FOV: 0.5 deg by 0.34 deg
- Diffraction-limited-resolution: 2.01 arcsec
- Pixel size: 0.33 arcsec (in combination with the camera)

## Targets (brightness-ordered)

Name	Designation	RA	DEC	Mag	Dim x (arcsec)	Dim y (arcsec)
Andromeda Galaxy	M31	0.70	41.27	3.44	190	60
Open Star Cluster	M52	23.40	61.58	5	13	13
Reflection Nebula	NGC 1333	3.48	31.35	5.6	6	3
Triangulum galaxy	M33	1.55	30.65	5.72	70.8	41.7
Hercules Globular	M13	16.68	36.45	5.8	20	20
Eagle Nebula	M16	18.30	-12.18	6	7	7
Iris Nebula	NGC 7023	21.02	68.17	6.8	18	18
Veil Nebula	NGC 6992	20.75	30.70	7	180	180
The Wizard Nebula	NGC 7380	22.78	58.10	7.2	25	25
Pacman Nebula	NGC 281	0.87	56.62	7.4	20	30
Starfish Open Cluster	M38	5.47	35.85	7.4	21	21
Crescent Nebula	NGC 6888	20.20	38.35	7.4	18	12
Dumbbell Nebula	M27	19.98	22.72	7.5	8	5.6
Pinwheel galaxy	M101	14.05	54.33	7.8	28.8	26.9
Whirlpool Galaxy	M51	13.48	47.18	8.4	11.2	6.9
Cigar Galaxy	M82	9.92	69.67	8.41	11.2	4.3
Intergalactic Tramp	NGC 2419	7.63	38.87	9.06	6	6
Sunflower galaxy	M63	13.25	42.02	9.3	12.6	7.2
Bubble Nebula	NGC 7635	23.33	61.20	10	15	8

# Budget

IRISC: In a Nutshell  
System  
Science  
Project Management  
Summary  
Questions

Electrical  
Control System  
Science  
Budget

- LTU Project funds
- Trusts and foundations
- Crowdfunding