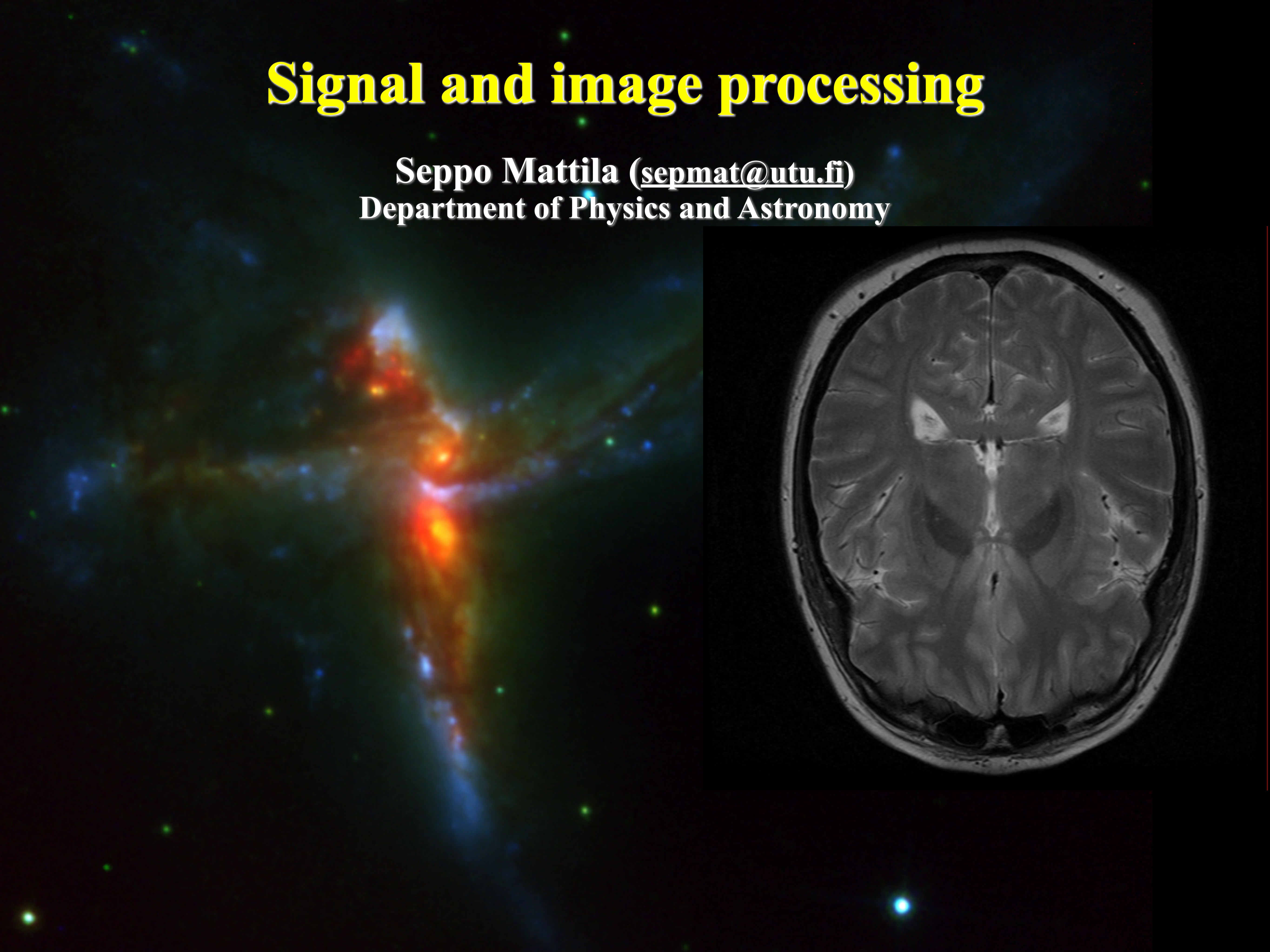
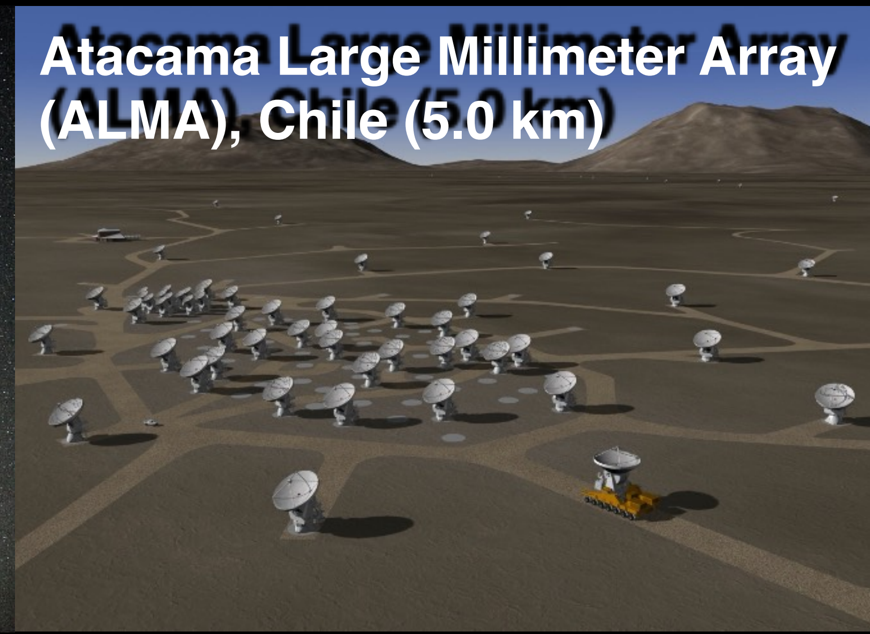
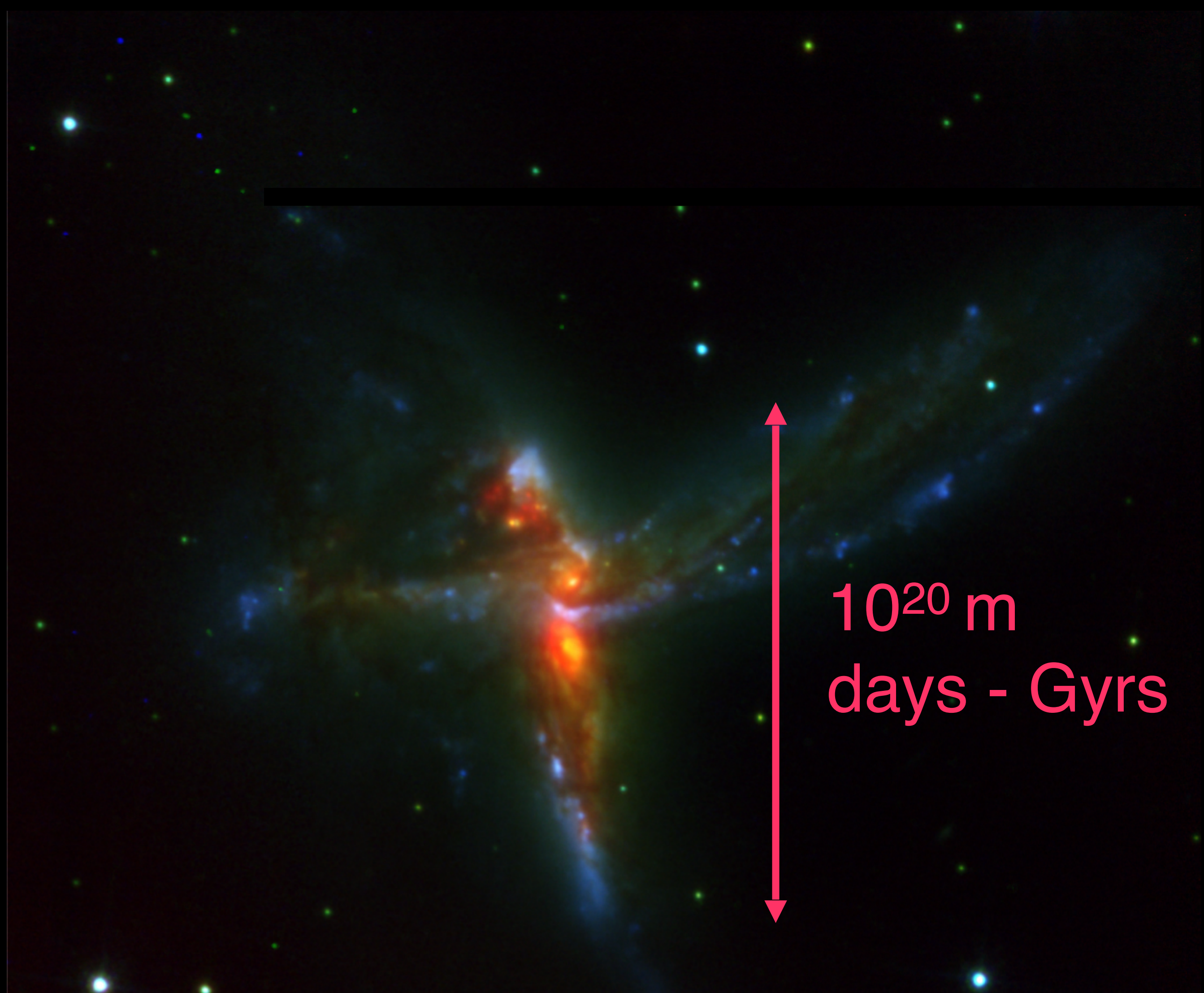
Signal and image processing

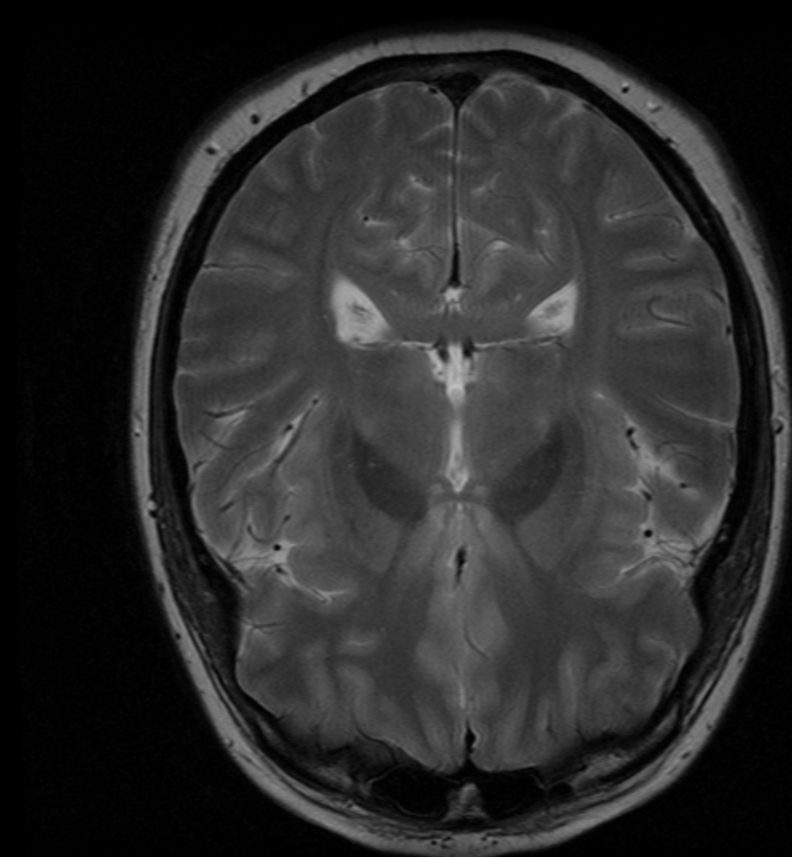
Seppo Mattila (sepmat@utu.fi)
Department of Physics and Astronomy





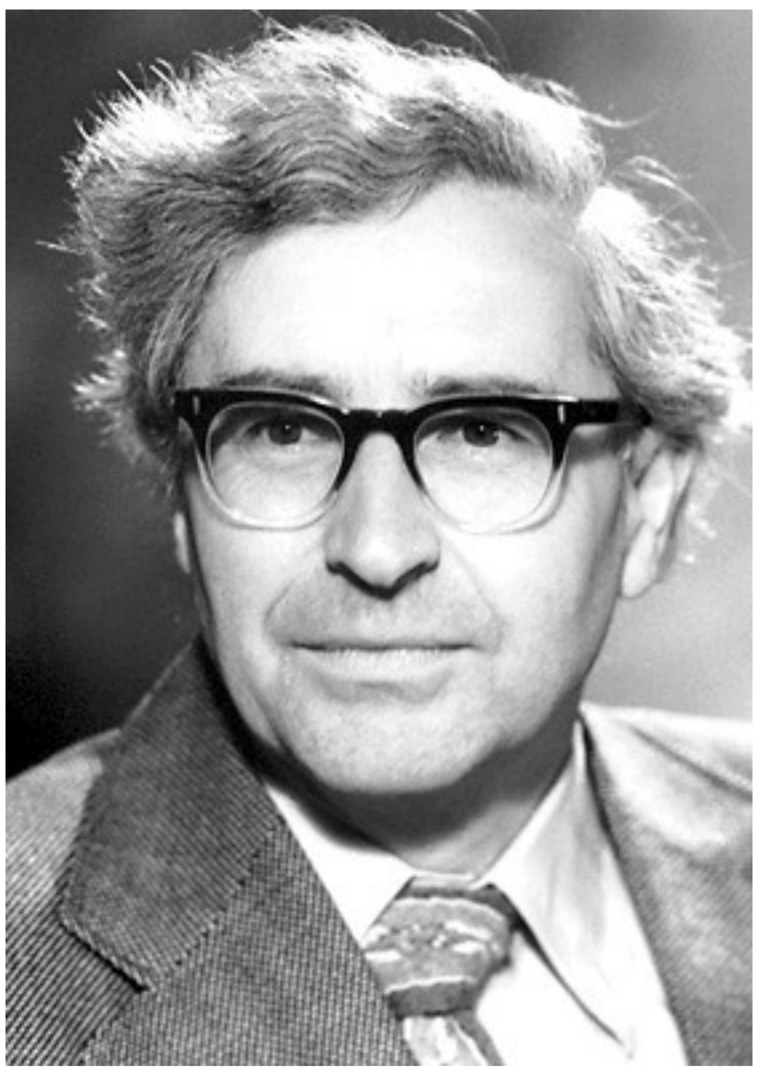


ESO VLT; NASA/ESA HST

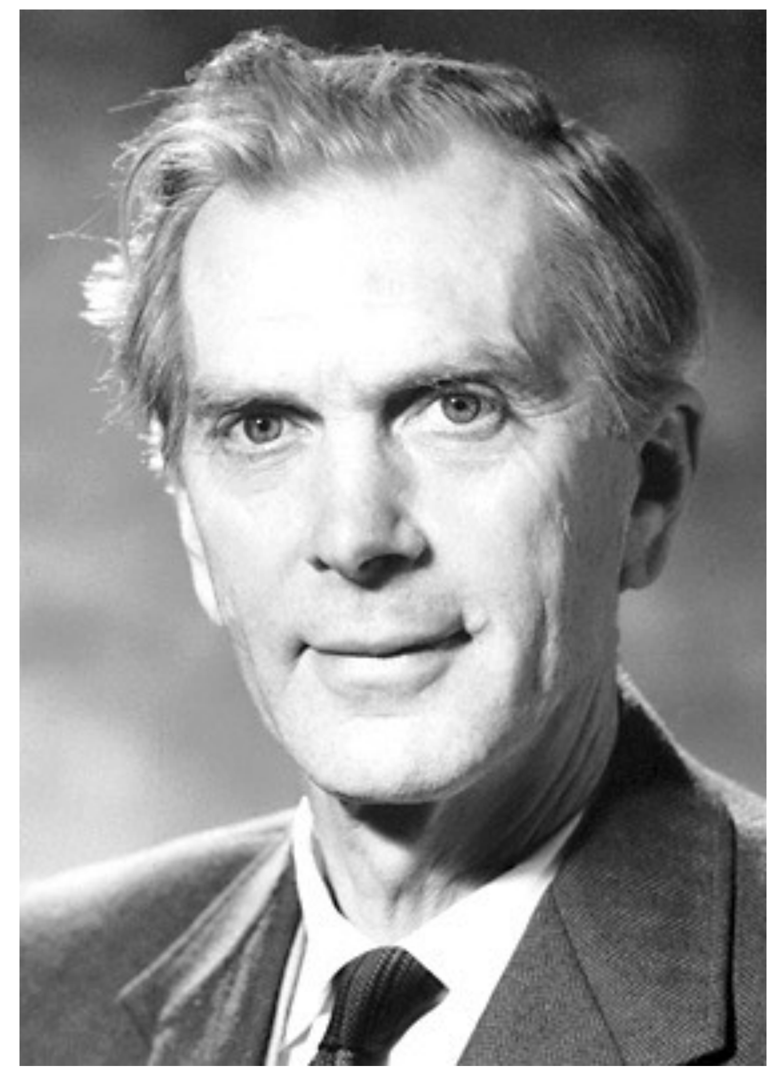


3T MRI (AMI Centre, Aalto University)

The Nobel prize in Physics 1974 was awarded “for their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars”

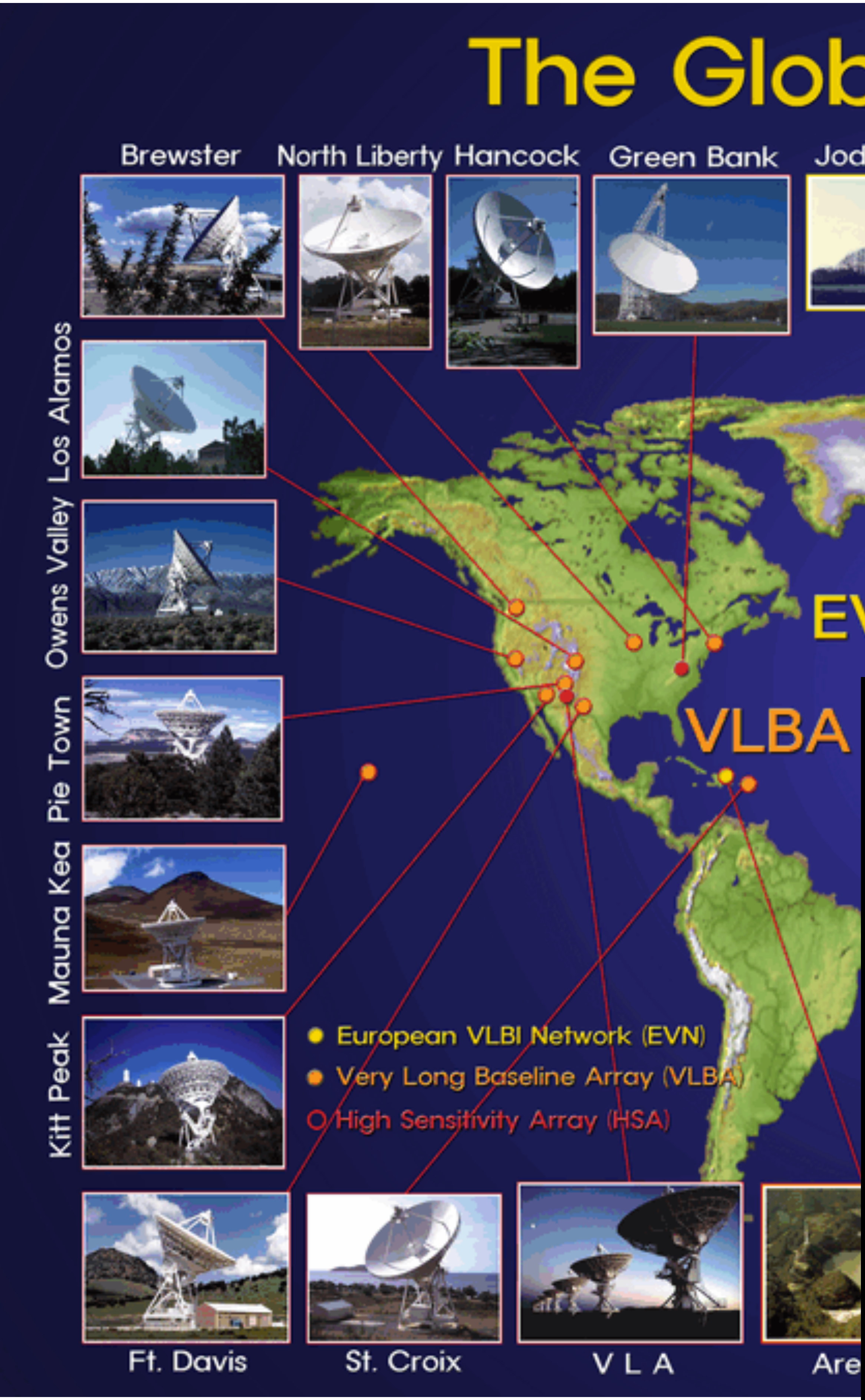


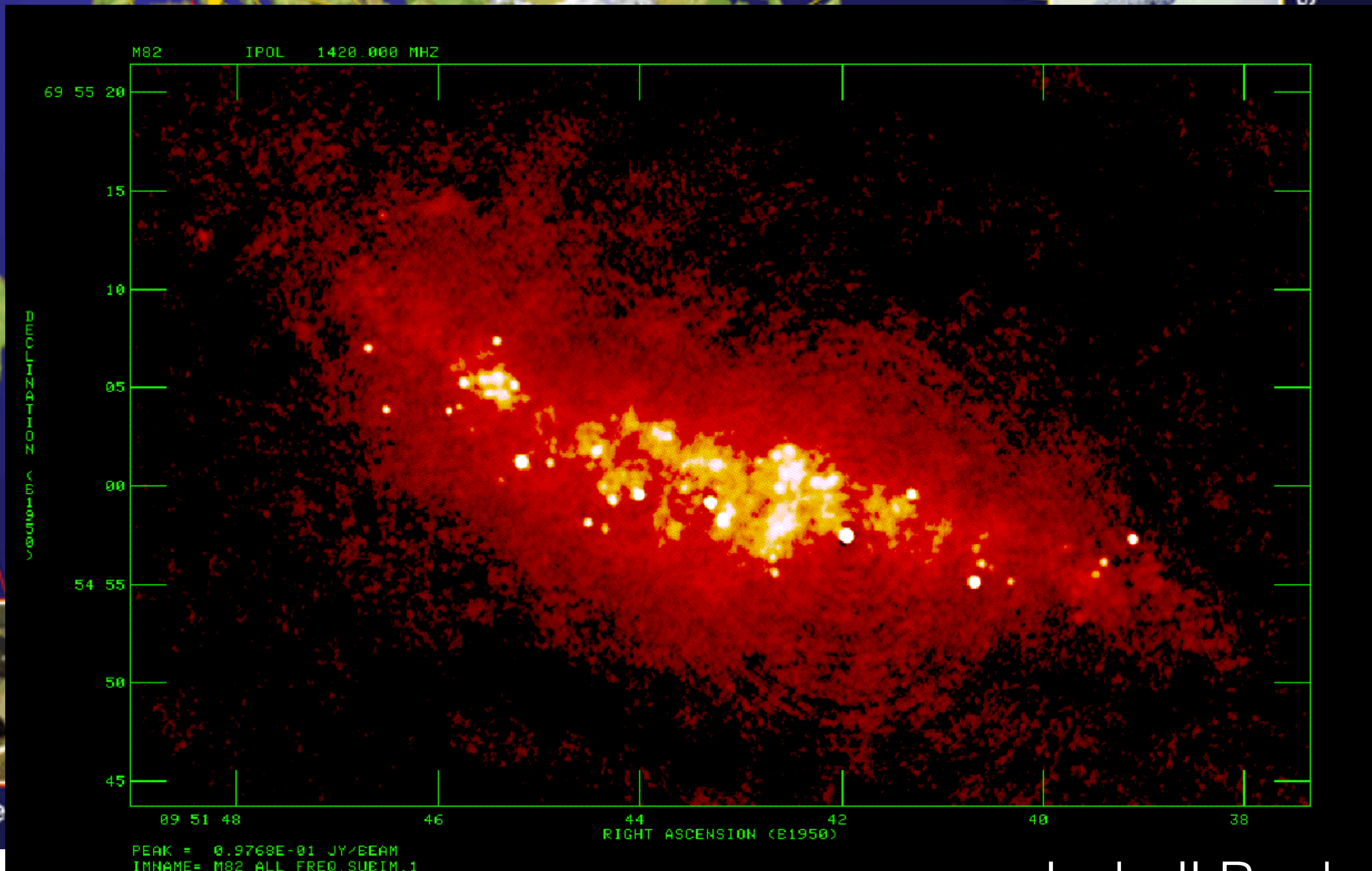
Antony Hewish (Cambridge)



Sir Martin Ryle (Cambridge)


The Global VLBI - Array
Brewster
North Liberty
Hancock
Green Bank
Jodrell Lovell
Jodrell Mk2
Cambridge
Onsala 25m and 20m
Metsähovi
Los Alamos
Owens Valley
Pie Town
Mauna Kea
Kitt Peak
Urumqi
Shanghai
Westerbork
Medicina
Noto
EVN
VLBA
European VLBI Network (EVN)
Very Long Baseline Array (VLBA)
High Sensitivity Array (HSA)
Ft. Davis
St. Croix
V L A
Arecibo
Effelsberg
Yebes
Wettzell
Torun
Hartebeesthoek

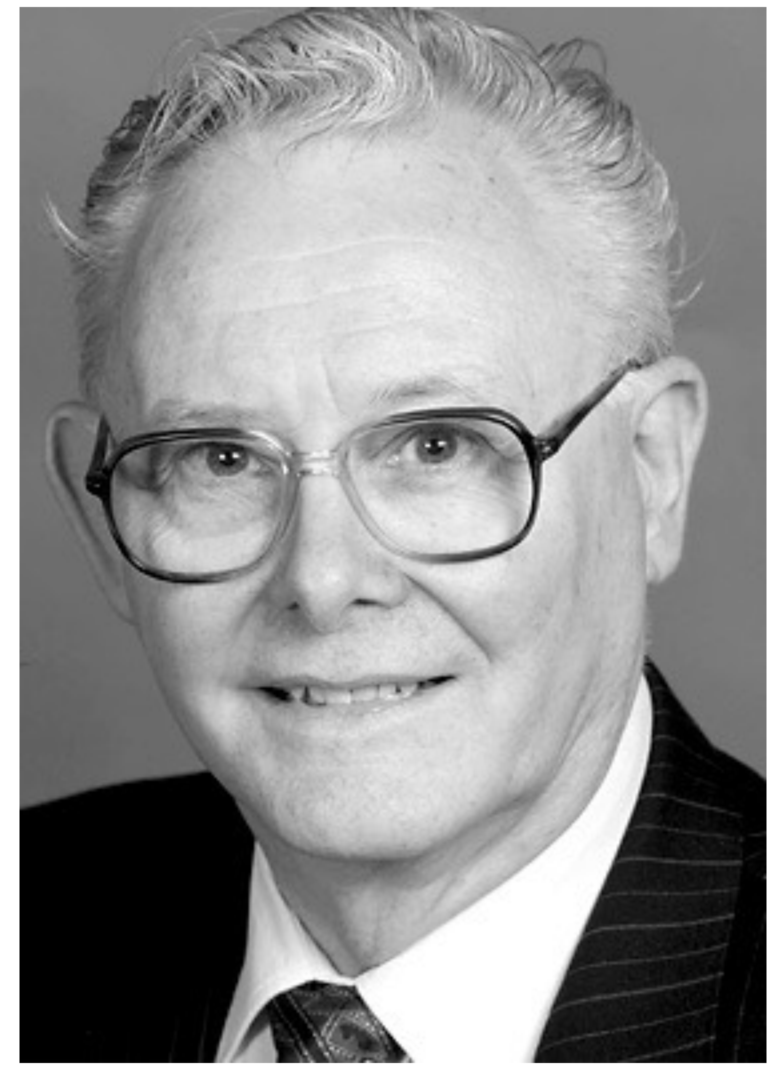




Jodrell Bank

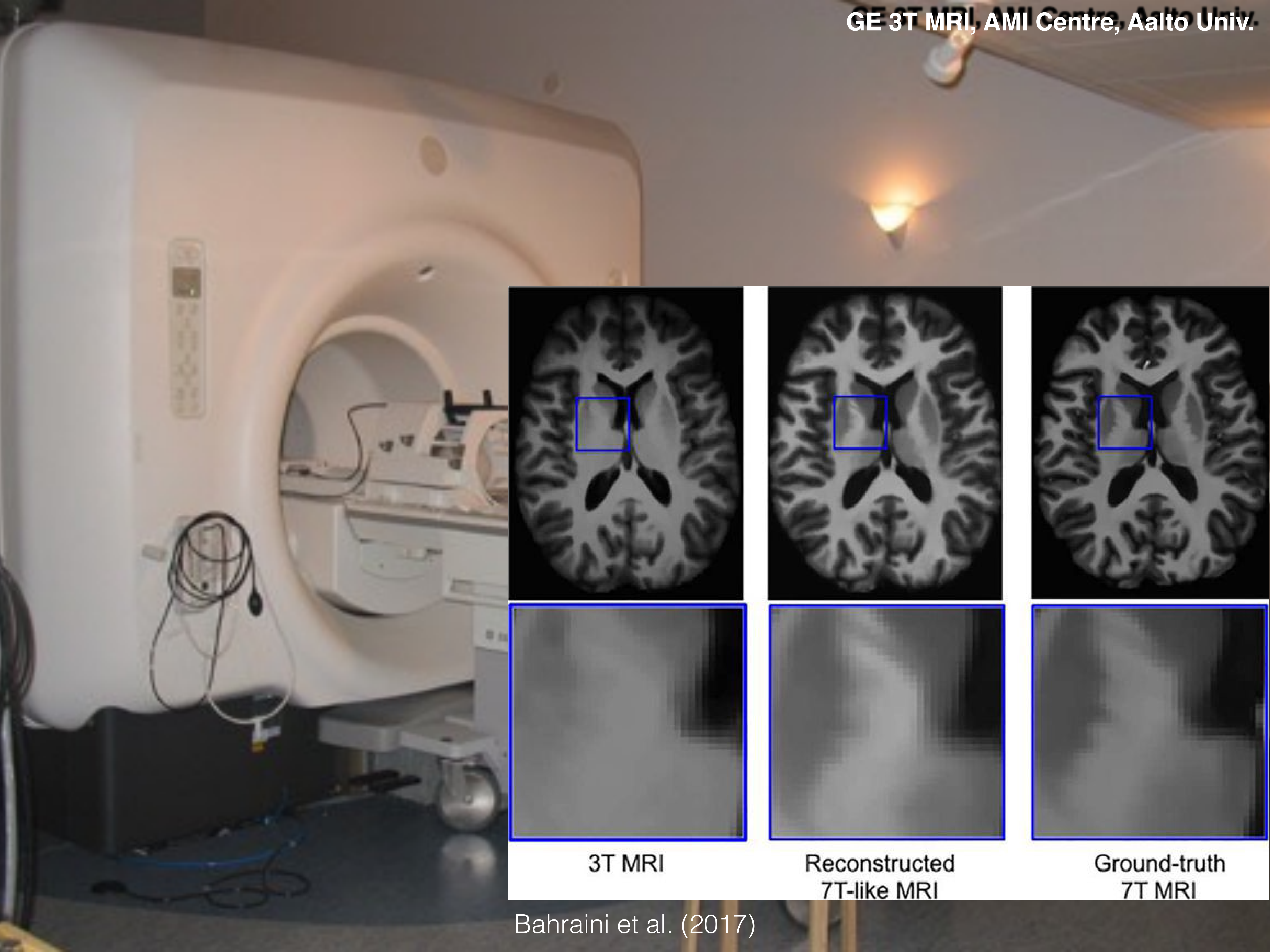
The Nobel prize in Physiology and Medicine 2003 was awarded “for their discoveries concerning magnetic resonance imaging”

Paul Lauterbur (Illinois)



Sir Peter Mansfield (Nottingham)

GE 3T MRI, AMI Centre, Aalto Univ.



Bahraini et al. (2017)

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Signal and image processing 2022

https://opas.peppi.utu.fi/en/course/FFYS7086/6135?period=2020-2022

- Programme
- Computing and software
- Exercises
- Practical information
- List of participants
- Material downloads

contact: Seppo Mattila (sepmat@utu.fi)

tube.utu.fi/courses

Learning outcomes

After completing the course the students should be able to:

(1) Describe the principles behind some advanced astronomical imaging techniques and identify suitable topics in astrophysics that can be studies with them;

(2) Understand the physics behind some of the most important medical imaging modalities and describe their value in clinical applications;

(3) Identify and discuss the differences and similarities in the challenges faced when analyzing data in these two different disciplines;

(4) Describe the theoretical basis and suitability of several image/signal processing and analysis methods commonly used in astronomy and medical imaging;

(5) Identify suitable algorithms and apply them to astronomical and/or medical imaging datasets to enhance their scientific and/or clinical value;

(6) Produce a written course report

Lecturers & supervisors

Hidehiro Iida (PET Centre)
Riku Klén (PET Centre)
Kalle Koskensalo (Institute of Biomedicine)
Timo Kravtson (Tuorla Observatory, Department of Physics and Astronomy)
Seppo Mattila (Tuorla Observatory, Department of Physics and Astronomy)
Harri Merisaari (Department of Clinical Medicine)
Lauri Nummenmaa (PET Centre)
Janika Paavola (Institute of Biomedicine)
Venkatessh Ramakrishnan (Finnish Centre for Astronomy with ESO, FINCA)
Jani Saunavaara (Terveystalo)
Tuomas Savolainen (Department of Electronics and Nanoengineering, Aalto Univ.)
Kerttu Seppälä (PET Centre)
Mika Teräs (Institute of Biomedicine)
Jarmo Teuho (PET Centre)
Kaj Wiik (Tuorla Observatory, Department of Physics and Astronomy)

Course programme

Monday 9.5. (online)
9:00-9:45 Introduction and motivation for the course (Seppo Mattila)
10:00-11:45 Radio interferometry in astronomy (Kaj Wiik)
12:00-12:45 Radio interferometric imaging in astronomy (Tuomas Savolainen)
Wednesday 11.5. (online)
9:00-10:45 Basics of optical/infrared observations and data processing in astronomy (Mattila)
11:00-11:45 Astronomical imaging (Seppo Mattila)
12:00-12:15 How to access the software for the course (Kaj Wiik)
Thursday 12.5. (online)
11:00-11:45 Positron emission tomography (PET) basics (Mika Teräs)
11:45-12:30 lunch
12:30-13:15 PET data Acquisition (Riku Klén)
13:15-14:00 PET data reconstruction (Jarmo Teuho)
14:15-15:00 PET modelling (Hidehiro Iida)
Monday 16.5. Practical work on radio interferometry (Quantum room 109)
9:00–10:00 Tutorial on radio interferometric imaging (Venkatessh Ramakrishnan, K. Wiik)
10:00–13:00 Practical work: Getting everything running (Venkatessh Ramakrishnan, K. Wiik)
Wednesday 18.5. (online)
16:30-17:00 Medical imaging basics (Jani Saunavaara)
17:00-19:00 MRI data acquisition (Jani Saunavaara)

Course programme

Thursday 19.5 (online)
09:00-10:45 MRI data processing (Harri Merisaari)
11:00-11:45 MRI / PET applications (Lauri Nummenmaa)
Monday 23.5. Practical work on MRI signal modelling and processing (Quantum 109)
13:00–14:00 Tutorial on basic MRI image processing: Basic image processing steps for T1W and DTI; (Harri Merisaari + Kalle Koskensalo)
14:00–17:00 Practical work: Getting everything running) (Harri Merisaari + Kalle Koskensalo)
Wednesday 1.6. Practical work on astronomical imaging and spectroscopy (Quantum)
09:00-09:45 Astronomical spectroscopy (Seppo Mattila)
09:45-10:30 Tutorial on astronomical imaging and spectroscopy (Seppo Mattila, Timo Kravtsov)
10:30–13:00 Practical work: Getting everything running (Seppo Mattila, Timo Kravtsov)
Thursday 2.6. (online)
9:00-9:45 Basics of EEG (Janika Paavola)
10:00-10:45 Basics of EEG analysis (Janika Paavola)
11:30-12:15 Time-domain data in astronomy (Seppo Mattila)
Friday 10.6. Practical work on PET reconstruction and modeling (Quantum room 109)
9:00-10:00 Tutorial on PET reconstruction and modeling (Jarmo Teuho, Kerttu Seppälä)
10:00–13:00 Practical work: Getting everything running (Jarmo Teuho, Kerttu Seppälä)

Practical sessions

- All the four sessions are compulsory to attend in oder to pass the course + you need to report the practical work you have done in a course report

☆ Practical work on radio interferometry
☆ Practical work on MRI signal modelling and processing
☆ Practical work on astronomical imaging and spectroscopy
☆ Practical work on PET reconstruction and modelling

Sessions will take place in Quantum room 109 + IT class room next door. Bring your own laptop!

Course report

- The minimum length is 9 pages (12 pt font) of text (2 pages based on each of the four practical sessions + 0.5 page introduction + 0.5 page summary) + figures, tables, references
- For reporting the work done in each of the sessions please follow the advice of the teachers
- Keep in mind the learning outcomes (slide 10) when preparing your report
- For writing the report you can use any word processing software that you are familiar with. Please, save the report as PDF
- Please, hand-in to sepmat@utu.fi by 1st of August

Astronomical and medical imaging
opportunities for interdisciplinary exchange of know-how ?

Astronomical vs. medical imaging instrumentation

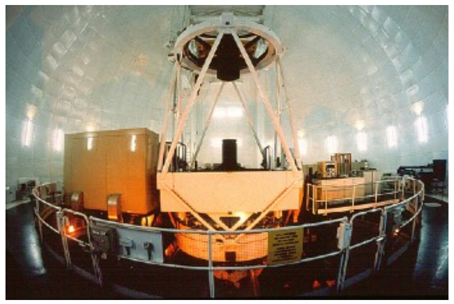
Astronomy

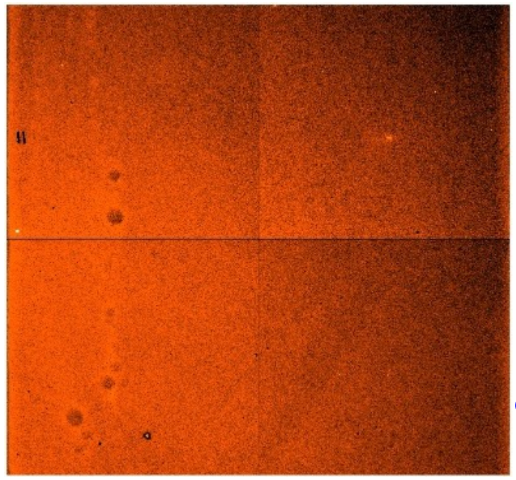
- Expensive one-off instruments using state-of-the-art technology
- Large international projects funded together by several countries
- For example the European Southern Observatory (ESO)
- Heavy competition for telescope time - time allocation committees rank proposals
- Determine which science will be done
- Most data are publicly available after 1 year from observation

Medicine

- Usually commercial instruments
- State-of-the-art instruments at more ‘affordable’ cost (from ~100-500 kEur for 1.5T MRI scanners to >5 MEur for 7T MRI scanners)
- Individual institutes/hospitals own their own instruments
- Freedom to decide which science will be done
- ‘Observer’ owns the data but data archives are in development !

Data reduction in astronomical imaging studies





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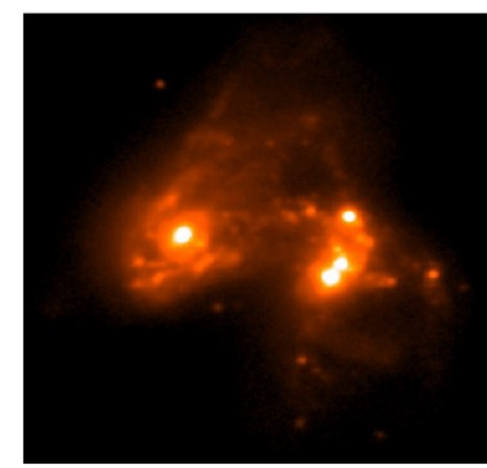
Sky subtraction & flat fielding

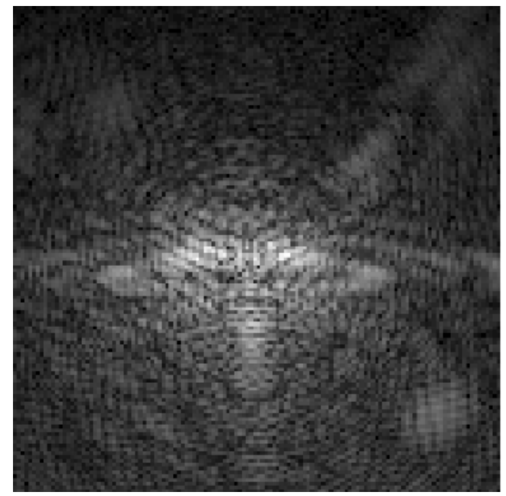
Aline & combine



- Use public and free packages (often python based)
- Use pipelines (self-written or provided by the observatory)
- Reductions usually described in detail in the paper
  - Possible to exactly repeat
  - Calibration using stars available in the images

Data reduction in medical imaging studies

raw (k-space) MR image



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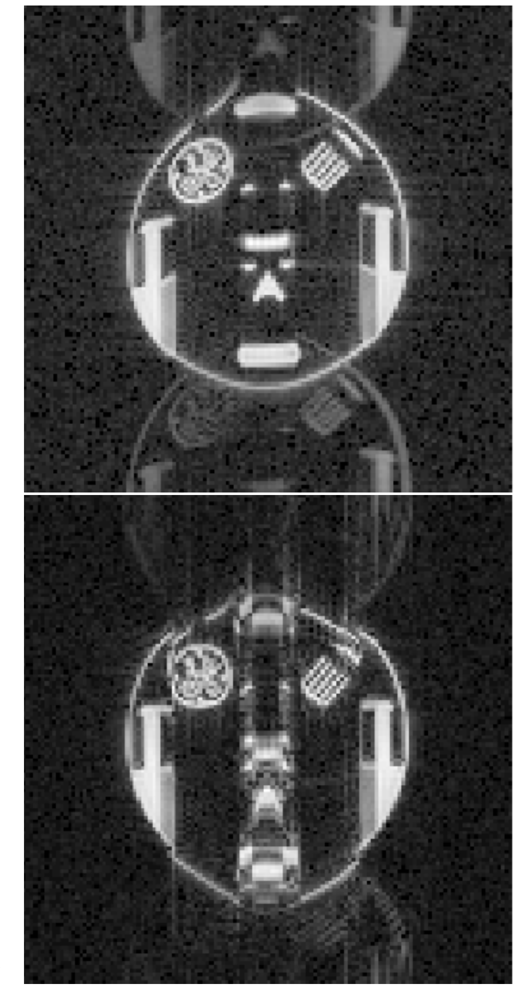
IFT

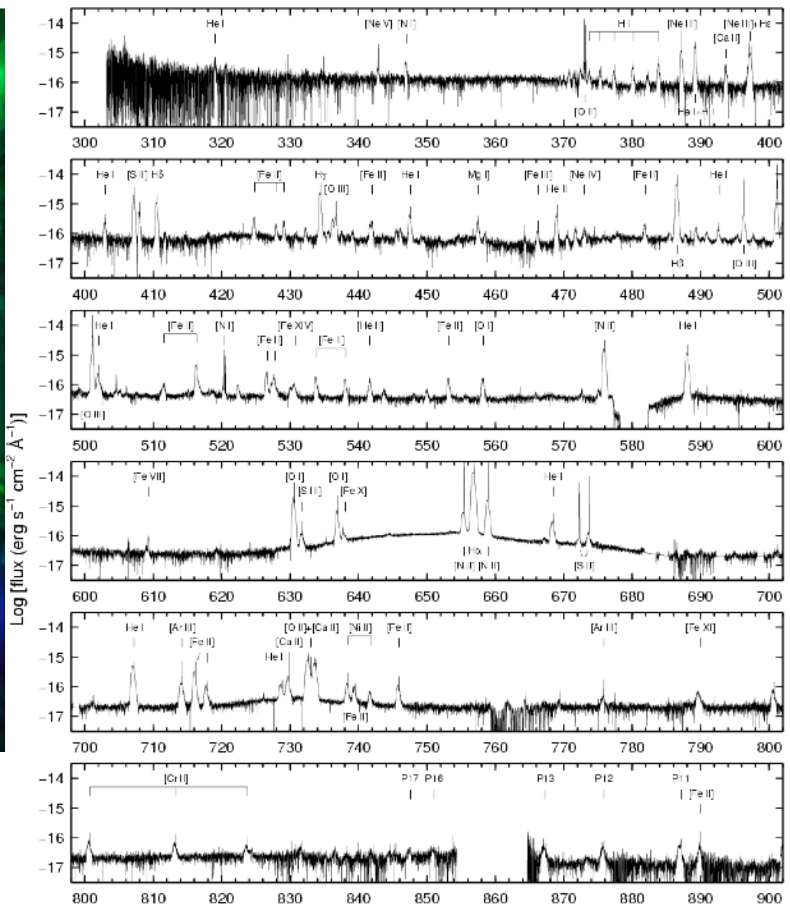
After reconstruction

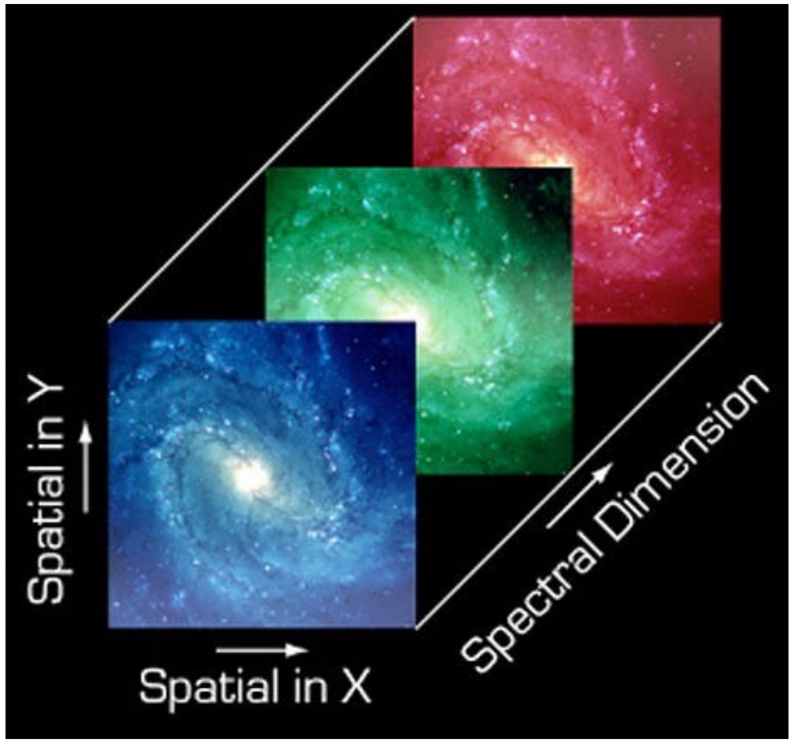


- Automatic but often 'hidden' data processing pipelines (required for the clinical use of the scanners)
- All details not always available to report in a paper, e.g., depend on the manufacturer of the imaging device
- Might be difficult to exactly repeat the data processing steps
- Quality controls for medical imaging data using phantoms

Archiving data: astronomical and medical imaging

- International observatories responsible for storing and distributing the raw data (and more advanced data products), e.g., the ESO and HST Science Archives
- Astronomical data become available for the whole international research community typically one year from the date of observation
- Data archives open completely new opportunities for research (examples from astronomy!) - virtual observatories the digital future for astronomy !





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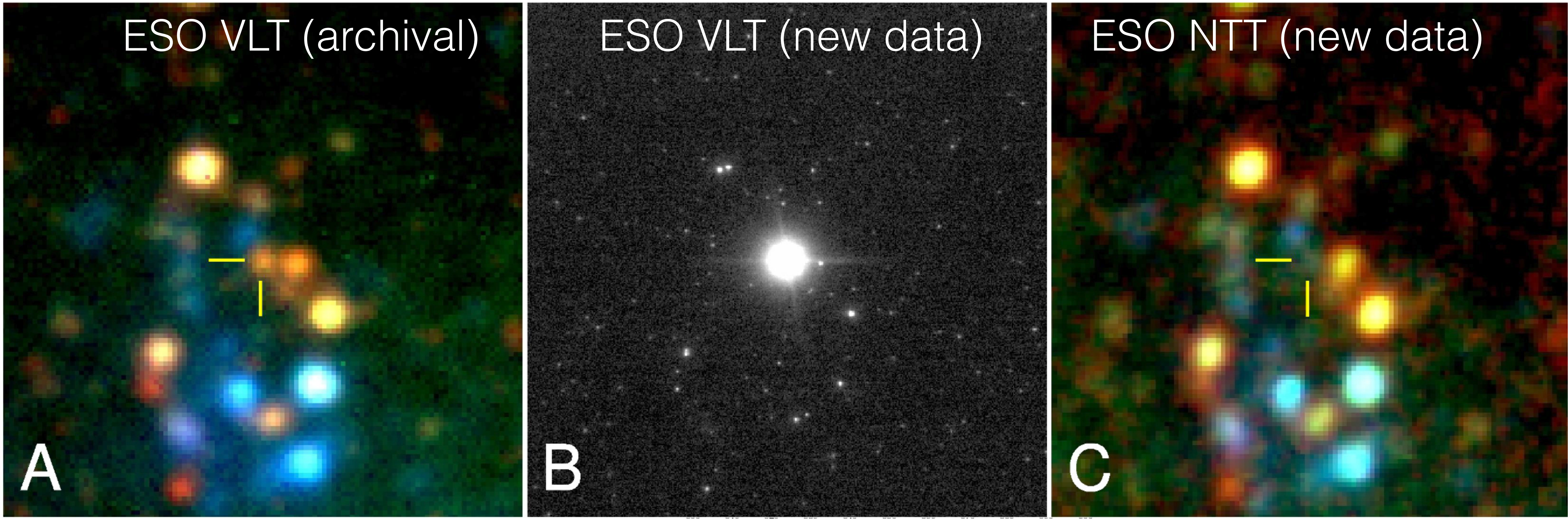
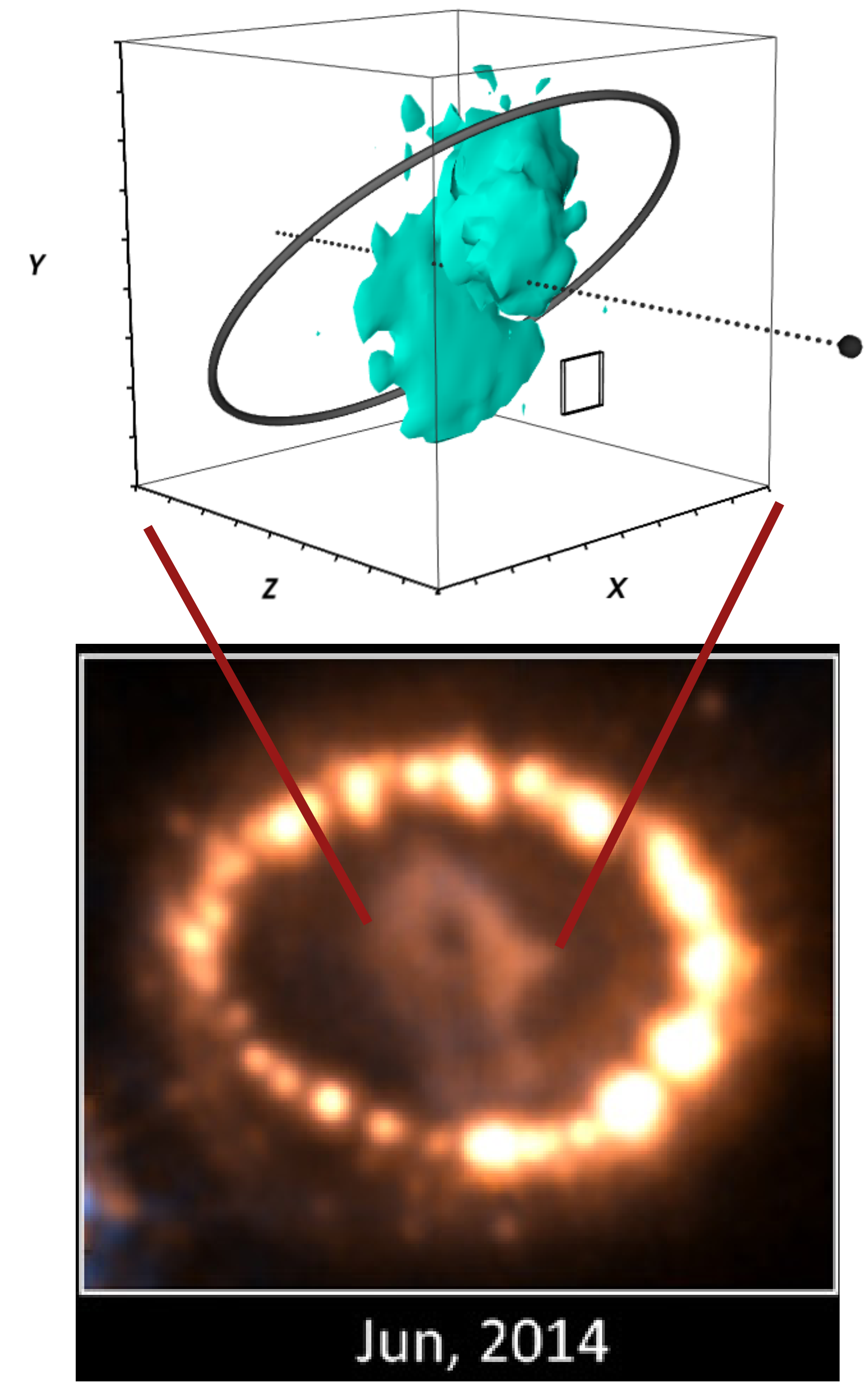
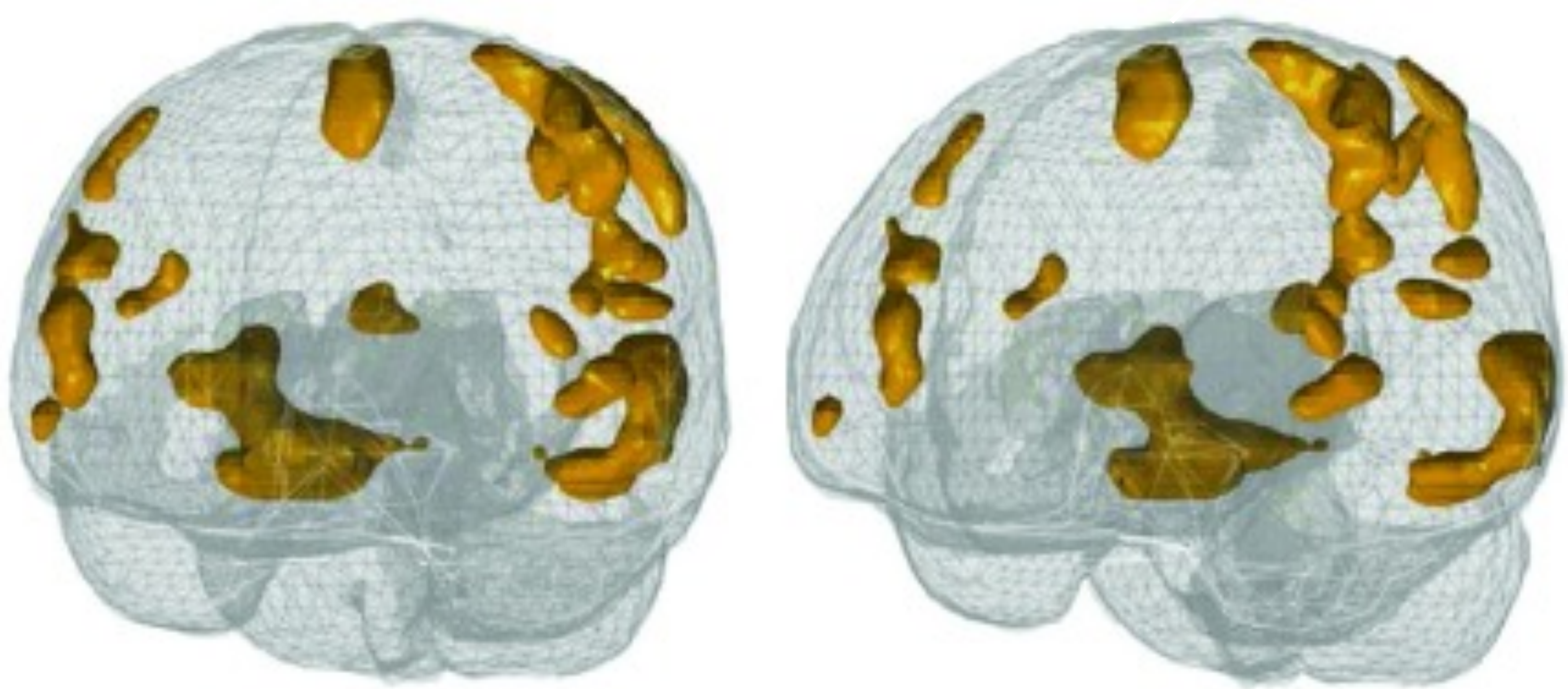


3D visualisation: astronomical and medical imaging

- In medical imaging 3 dimensional information (x, y, z) often available and sophisticated tools already exist for the analysis and visualisation of data cubes
- In astronomical imaging instruments with integral field units provide data also in 3D (x, y, λ) and new tools are being developed

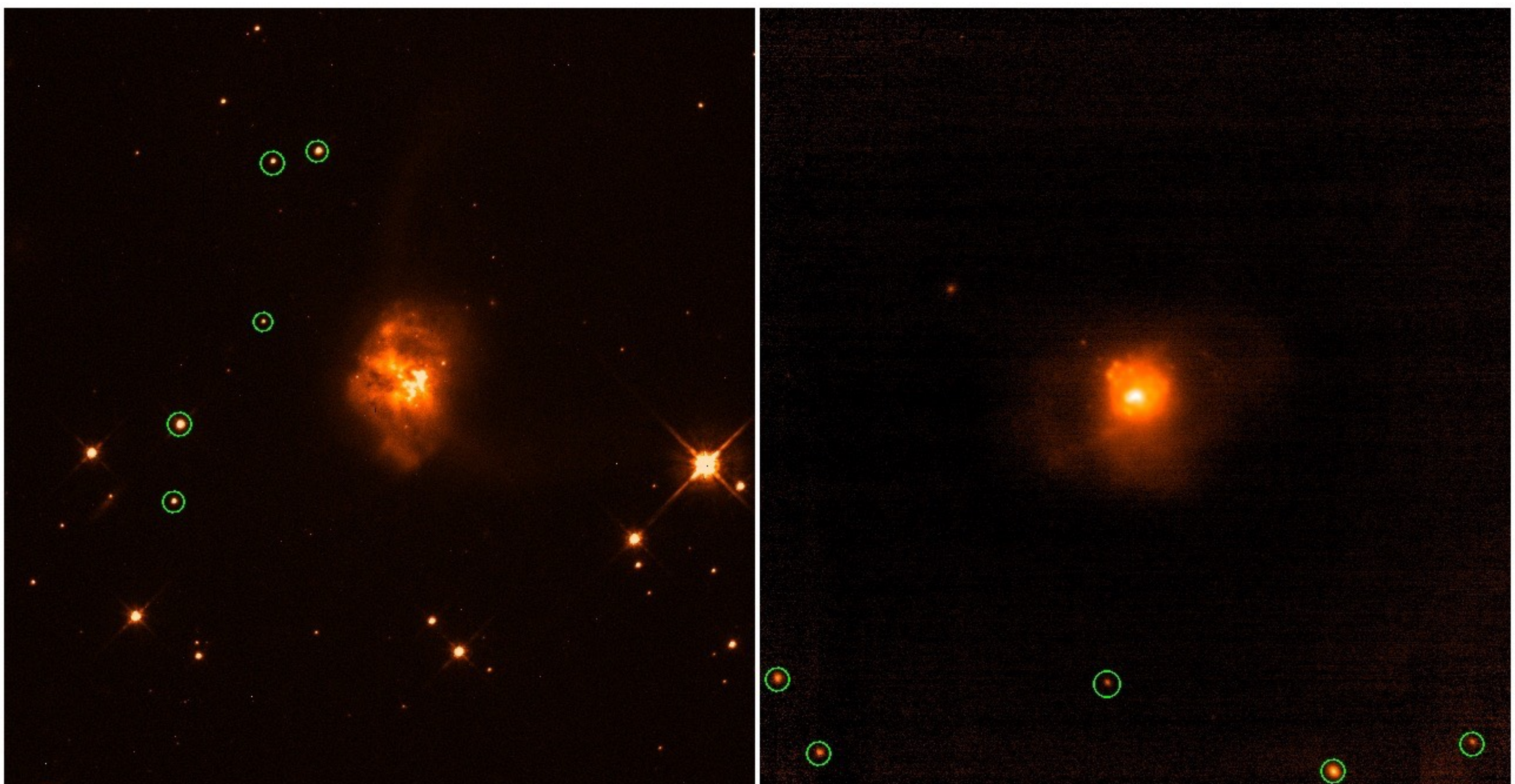




Functional magnetic resonance imaging (fMRI)

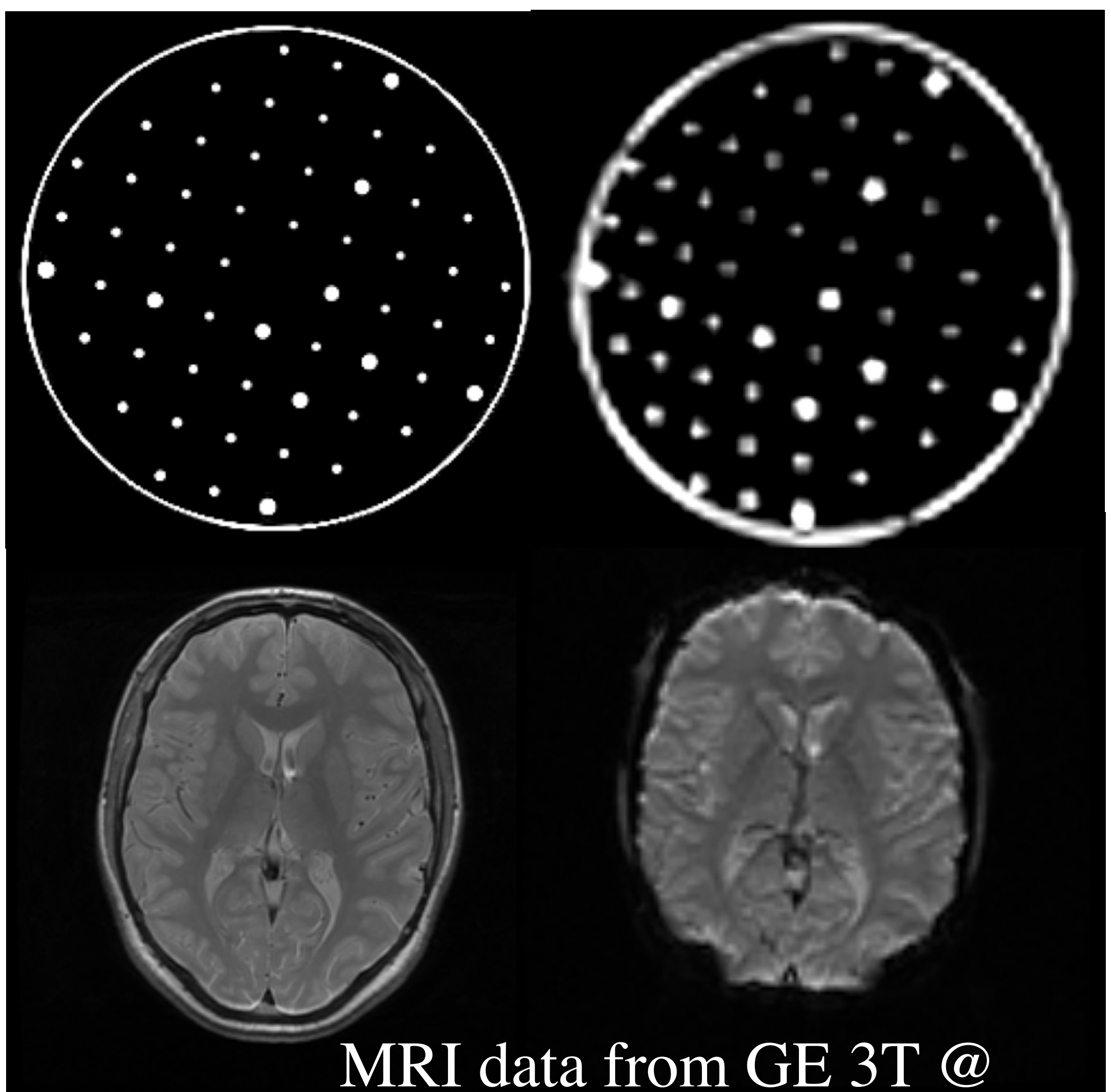
Data quality control: astronomical and medical imaging

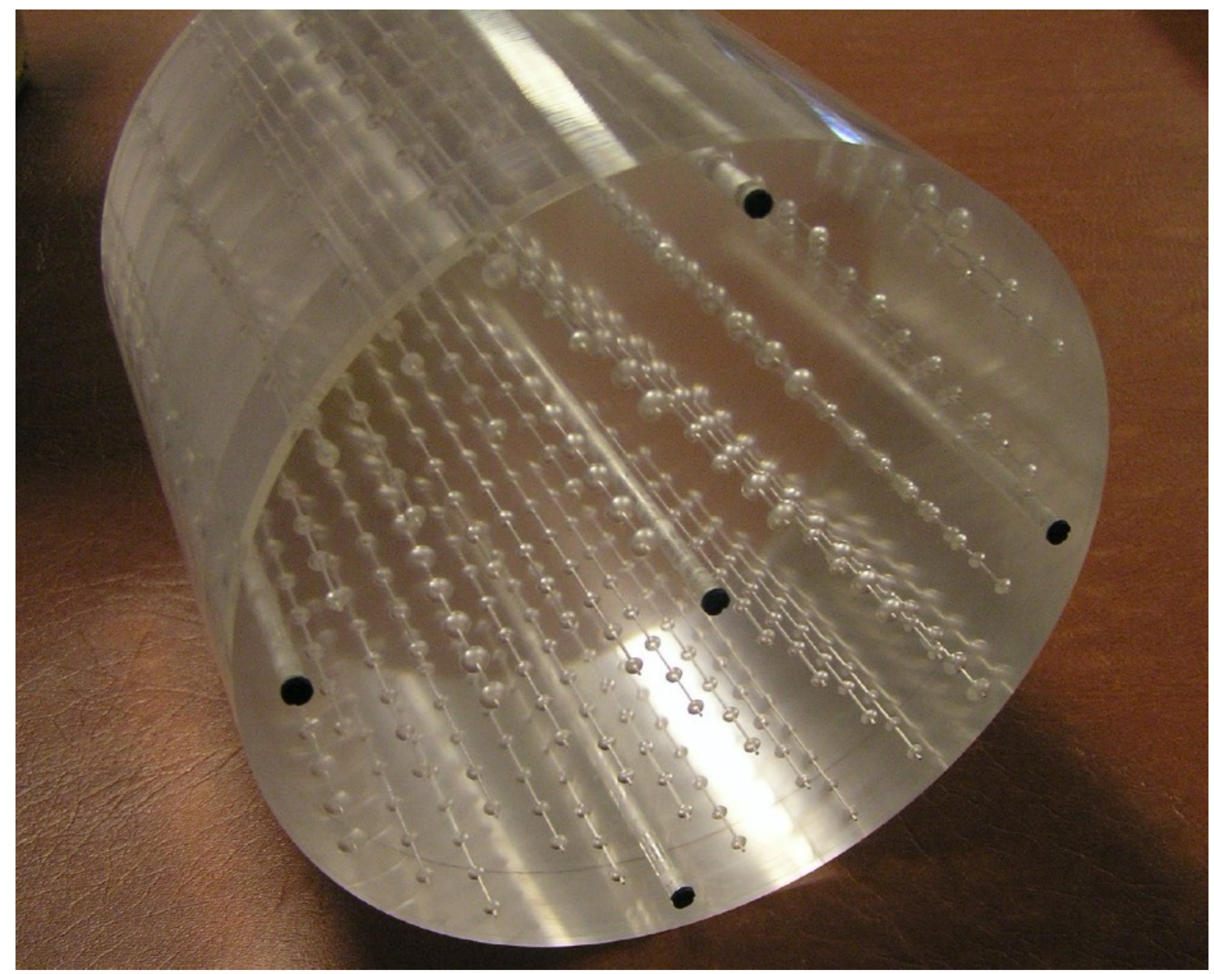
- In astronomy can usually identify several point sources (stars) common to the images
- Can derive precise geometric transformations, match point spread functions and signal levels between the images - importance for calibration and data quality control



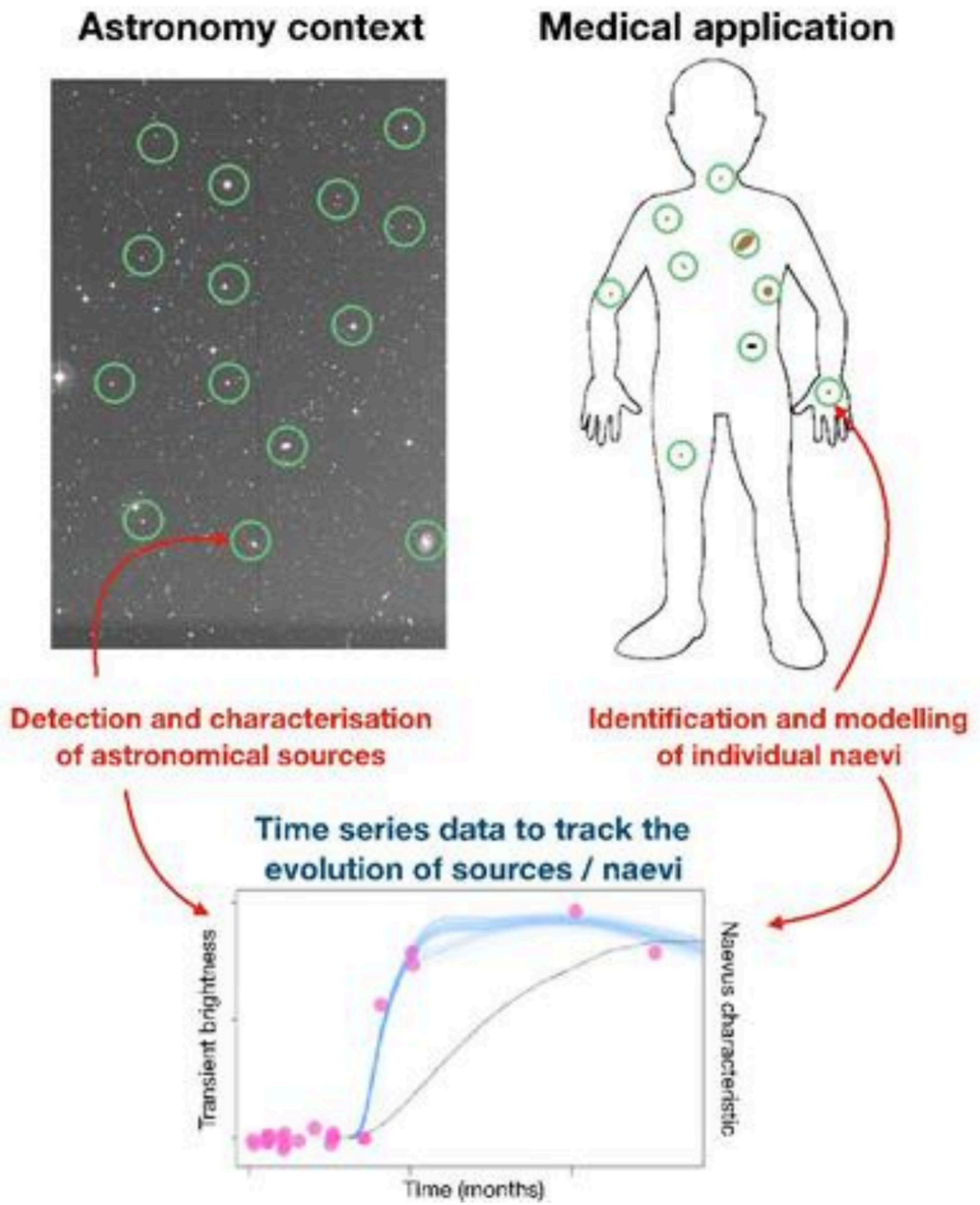
Data quality control: astronomical and medical imaging

- In astronomy can usually identify several point sources (stars) common to the images
- Can derive precise geometric transformations, match point spread functions and signal levels between the images - importance for calibration and data quality control
- In medical imaging can use test objects (phantoms) to provide reference structures (similar to stars in astronomy) in the imaging volume to allow precise mapping of geometric distortions, uniformity and stability of the signal





Mattila et al. 2007, MRM



The proposed methodology for MoleGazer in Total Body Photography

https://www.southampton.ac.uk/news/2020/01/molegazer.page

From Cells to Galaxies

Exploring the Synergies between Radio Astronomy and Medical Imaging

Speaker Series — September 2021 - March 2022

In-Person Meeting — June 22-24, 2022

Event Overview

Computing power, data acquisition rates and storage capabilities have increased roughly a million fold in the last 20 years. This rapidly changing landscape gives rise to new opportunities for **breaking down barriers** that have inhibited imaging research from meaningful inter-disciplinary research and development.

Through this speaker series and subsequent meeting, we seek to **bring together researchers** from the fields of Radio Astronomy Imaging and Radiological Imaging to **share ideas** and **stimulate discussions about joint research** that can **benefit both communities** through collaborative development projects**.**

The human imagination, powered by ingenuity, has led to the visualization of the furthest, largest structures in a dynamic universe while, at the same time, probing deep into our human physiology, to image the inner works of body and mind. Imaging, in all its forms, has impacted all areas of human endeavor, particularly in scientific and medical research.

In-Person Meeting

June 22-24, 2022 | St. Paul, Minnesota