Strap on your Boötes: The Journey to Achieve Widefield Sub-arcsecond Resolution with LOFAR

Emmy Escott
emily.l.escott@durham.ac.uk
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Durham University

LOFAR

LOw Frequency ARray

Central frequency: 144MHz

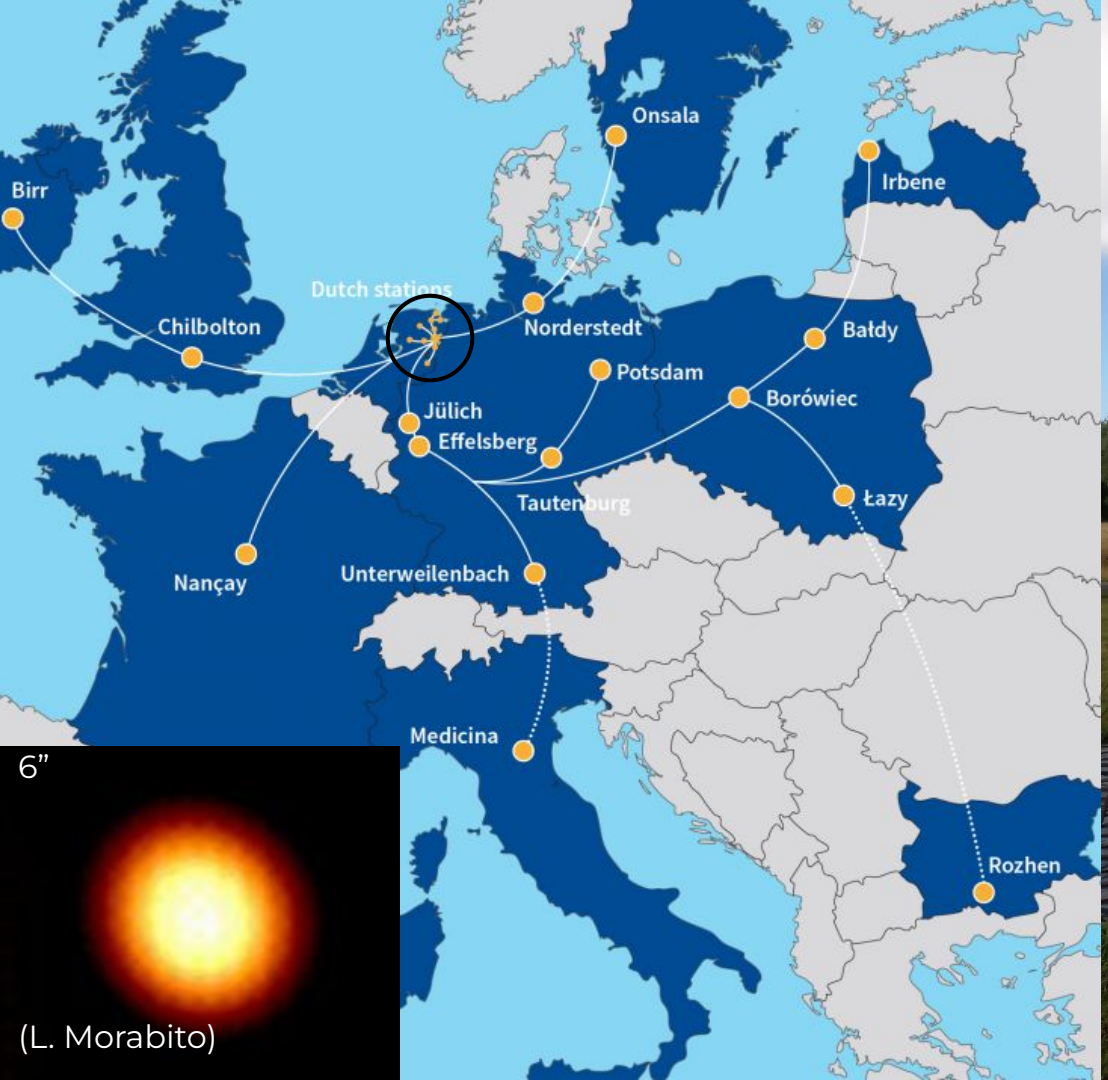
52 stations across Europe

38 “dutch” stations

14 International stations

Emmy Escott


Onsala
Birr
Irbene
Dutch stations
Chilbolton
Norderstedt
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Nançay
Unterweilenbach
Medicina
Rozhen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Medicina
Rozhen

6”
(L. Morabito)


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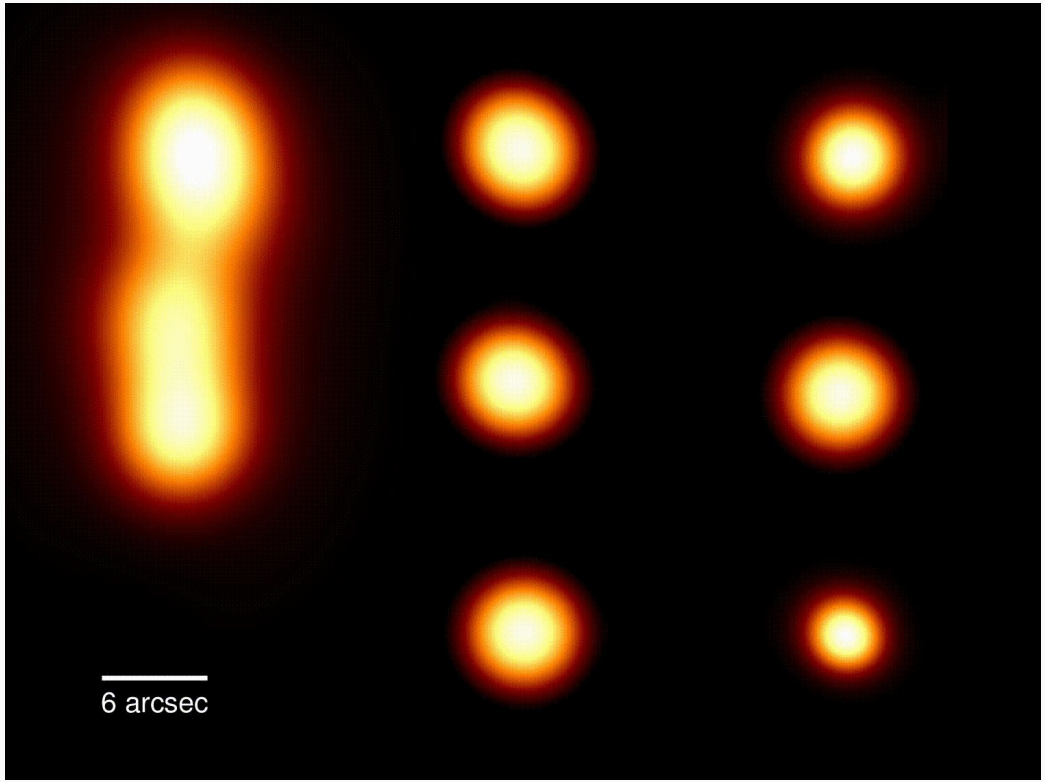
0.3”
(L. Morabito)

LOFAR VLBI



(L. Morabito)

Widefield LOFAR-VLBI

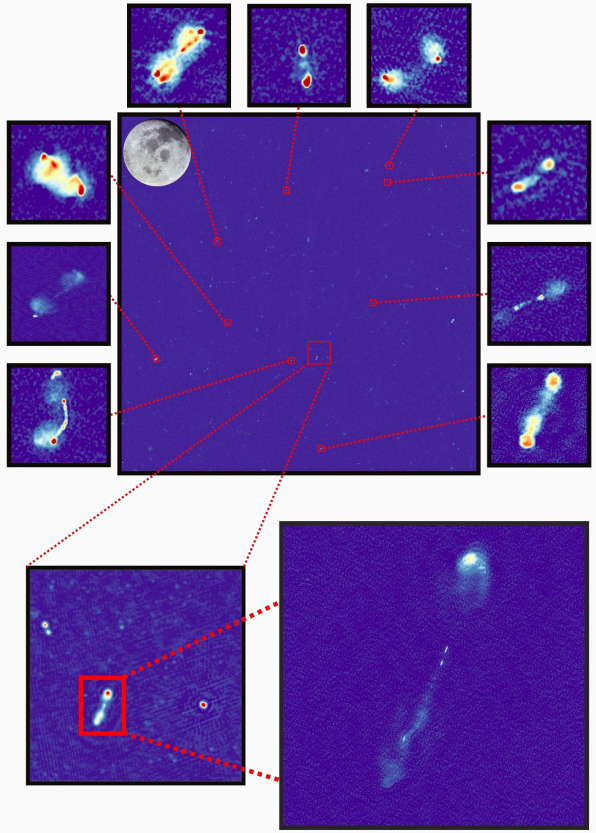
Sub-arcsecond image of Lockman Hole (Sweijen et al 2022)

Produced by incorporating the international stations via VLBI techniques

~7 billion pixel, >6^2 degrees

~250,000 CPU hours

~2,500 sources



(Sweijen et al. 2022)

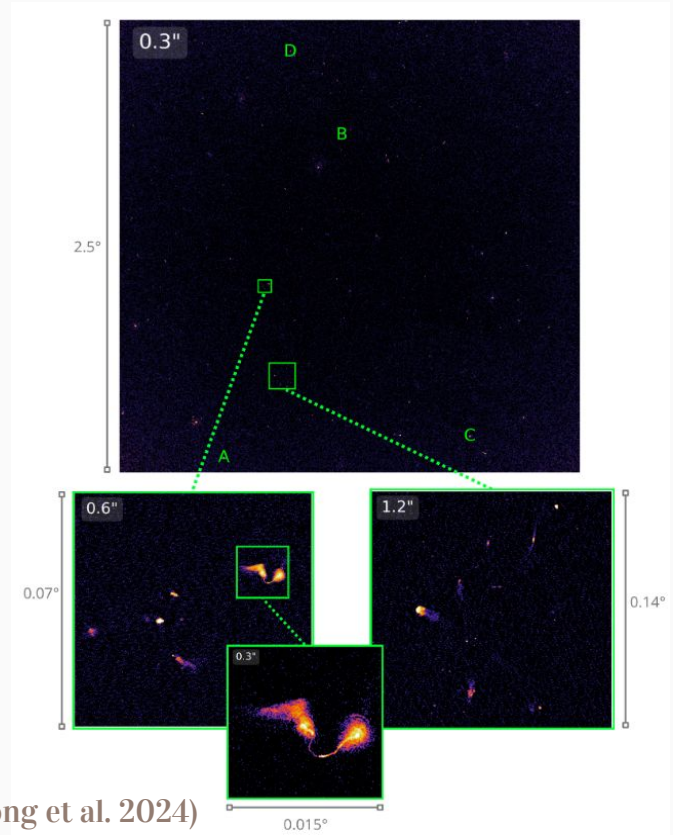
Widefield LOFAR-VLBI

Sub-arcsecond image of ELAIS-N1 (de Jong et al. 2024)

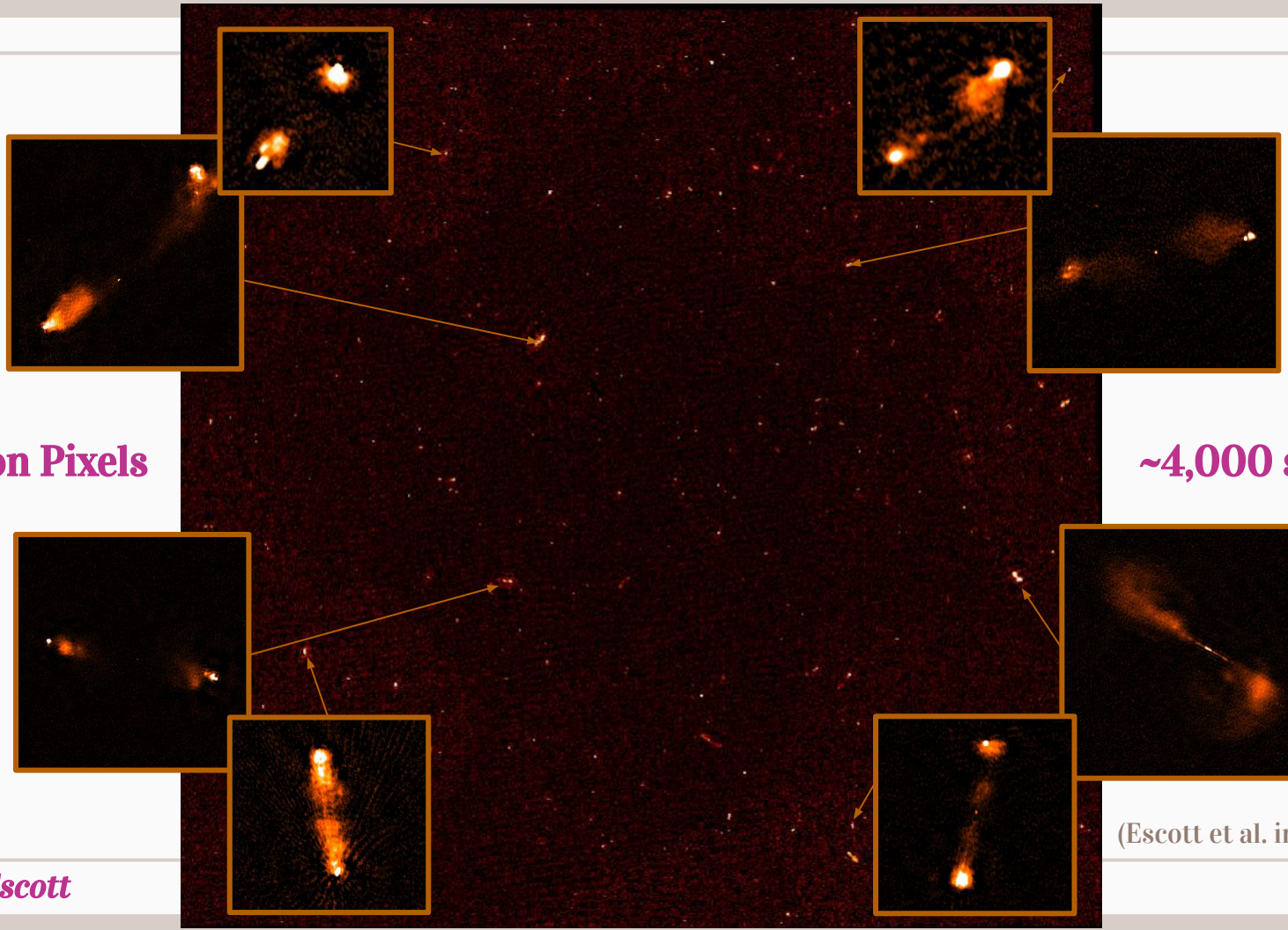
Produced by incorporating the international stations via VLBI techniques

32-hour deeper multiple resolution images (1.2”, 0.6”, 0.3”) - 14 μJy/beam at 0.3”

~9,000 sources



(de Jong et al. 2024)



~9 Billion Pixels

~4,000 sources

(Escott et al. in prep)

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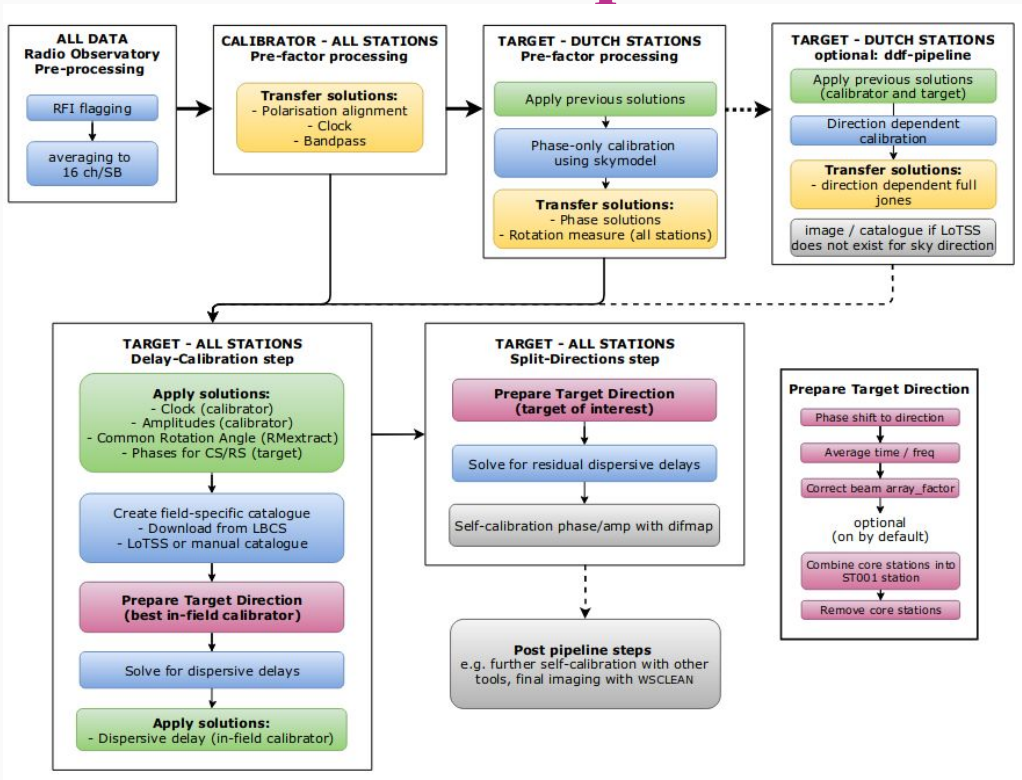
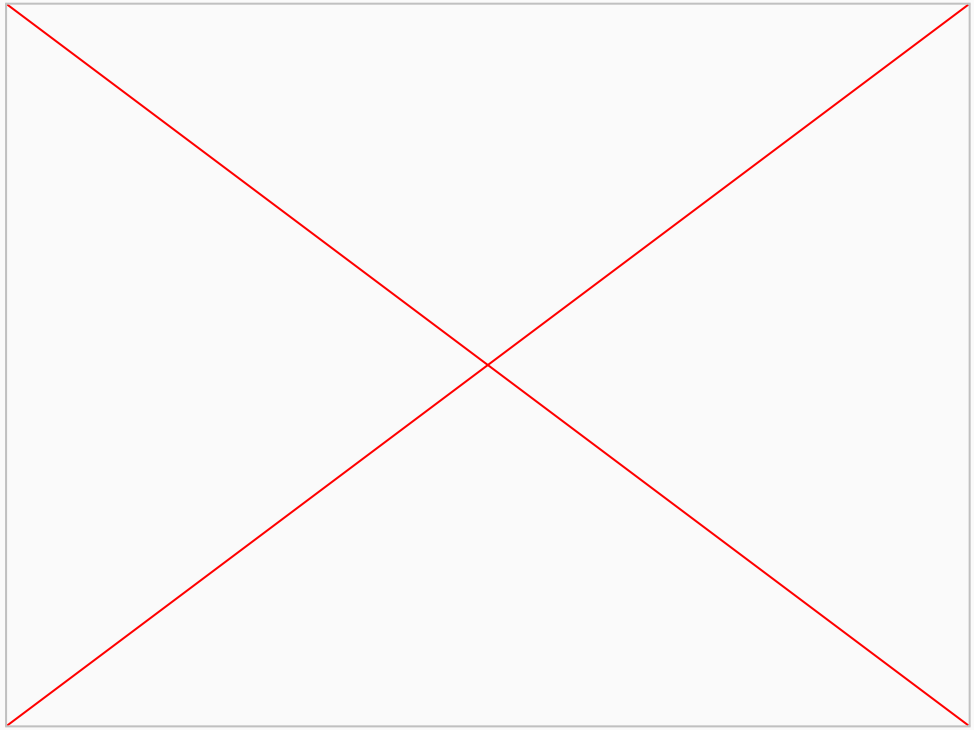
Widefield Pipeline



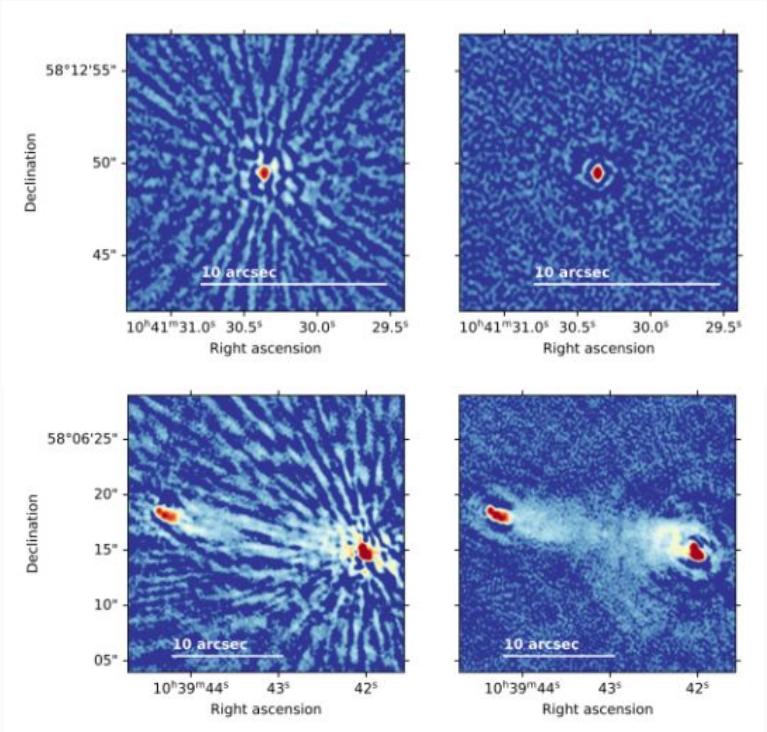
(Morabito et al. 2022)

Ionosphere



(Ger de Bruyn)

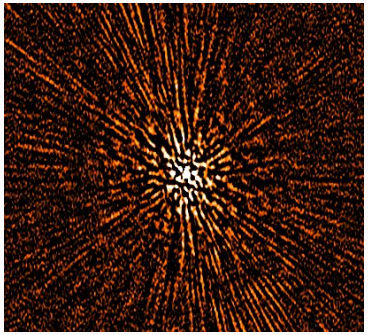
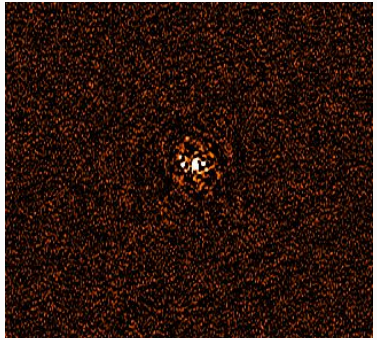
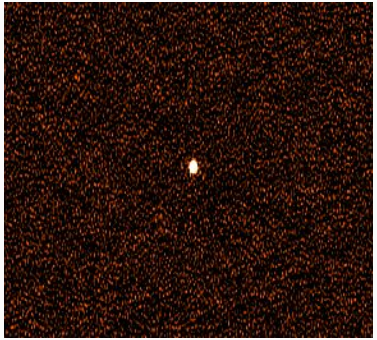
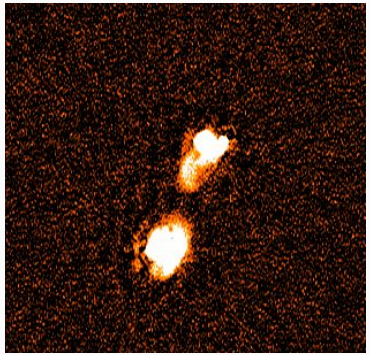
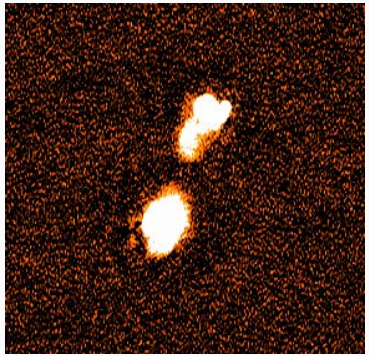
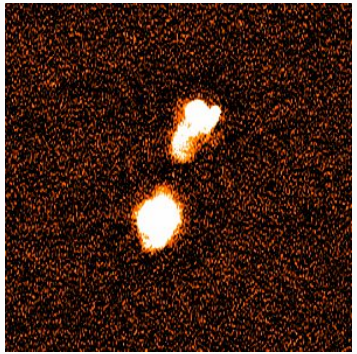
Ionosphere



(Sweijen et al. 2022)

- Ionospheric is a thin layer of charged particles in the Earth's atmosphere
- Faraday rotation has a $1/U^2$ dependence
- Ionospheric effect varies across the FoV - a major issue in widefield imaging with LOFAR
- Direction Dependent (DD) calibration effects are very important to consider in widefield imaging
- We find calibrator sources for each section of the sky and separate the image into facets which we calibrate separately

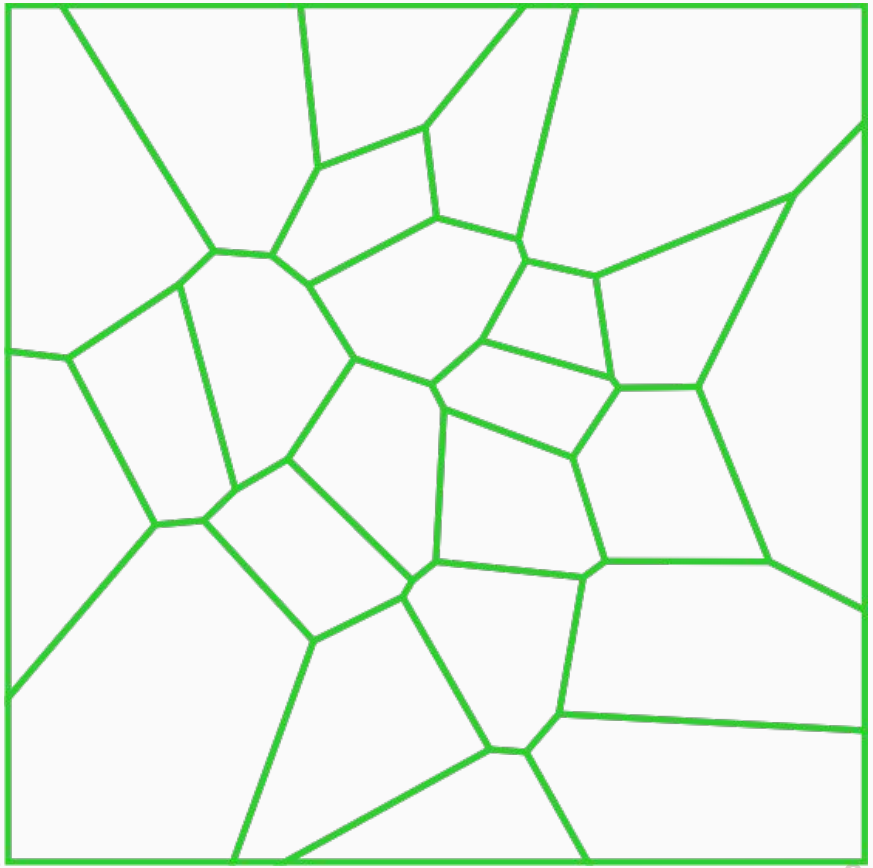
DD Calibration

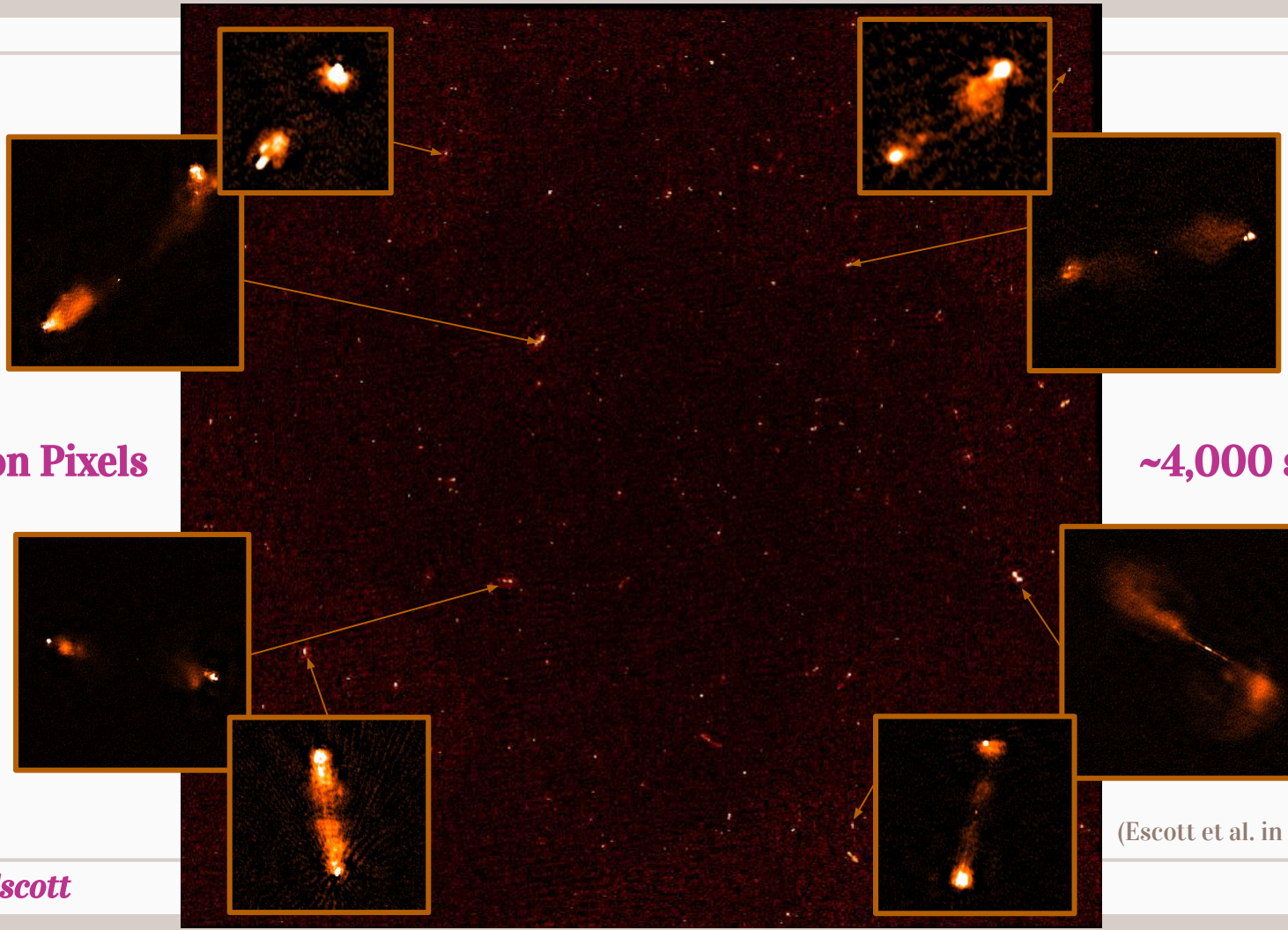







Widefield Imaging

Divide up the field into facets via Voronoi tessellation

Each facet contains one direction dependent calibrator





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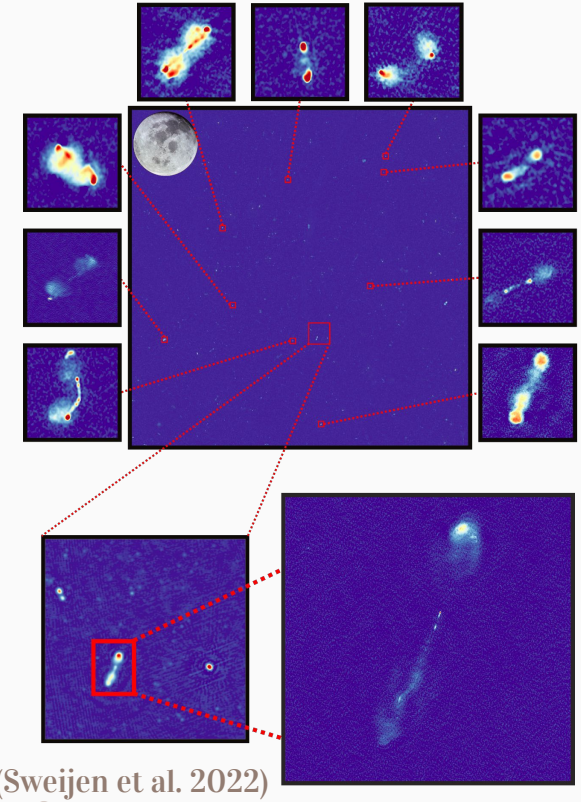
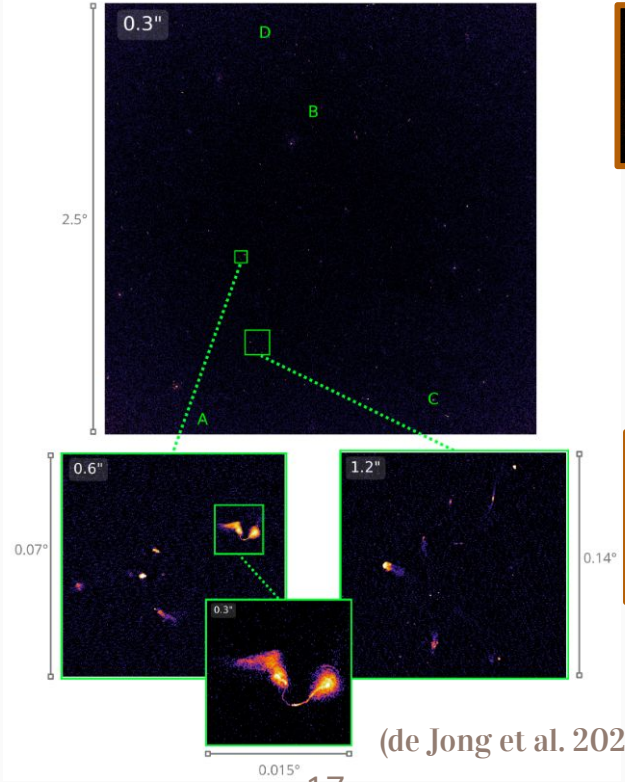
Lockman Hole



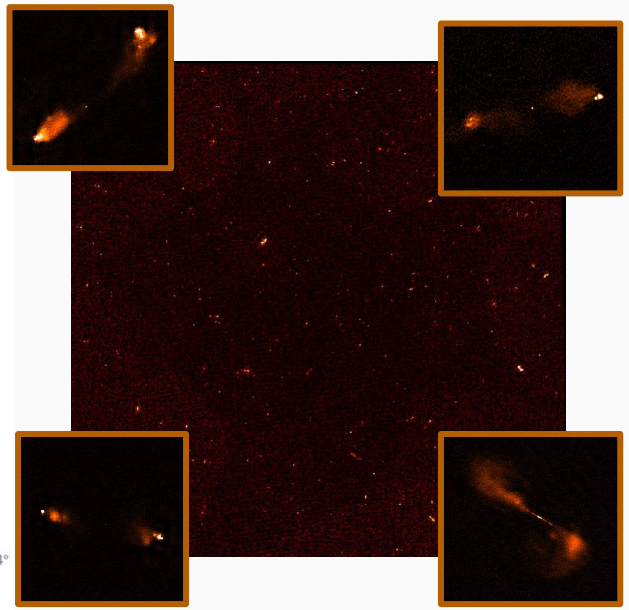
(Sweijen et al. 2022)

ELAIS-N1



(de Jong et al. 2024)

Boötes



(Escott et al. in prep)

Summary

- LOw Frequency ARray is a radio interferometer with 52 stations across Europe
- Introduced LOFAR-VLBI to obtain sub-arcsecond resolution
- Thanks to LOFAR's wide FoV we can make widefield images
- Final sub-arcsecond resolution image of Boötes
- Discussed how we calibrate ionospheric effects
- Demonstrated exciting science which can be conducted using these widefield images
- These calibration techniques will be essential for producing high resolution images for SKAO