DICOM and Slicer: A Tutorial

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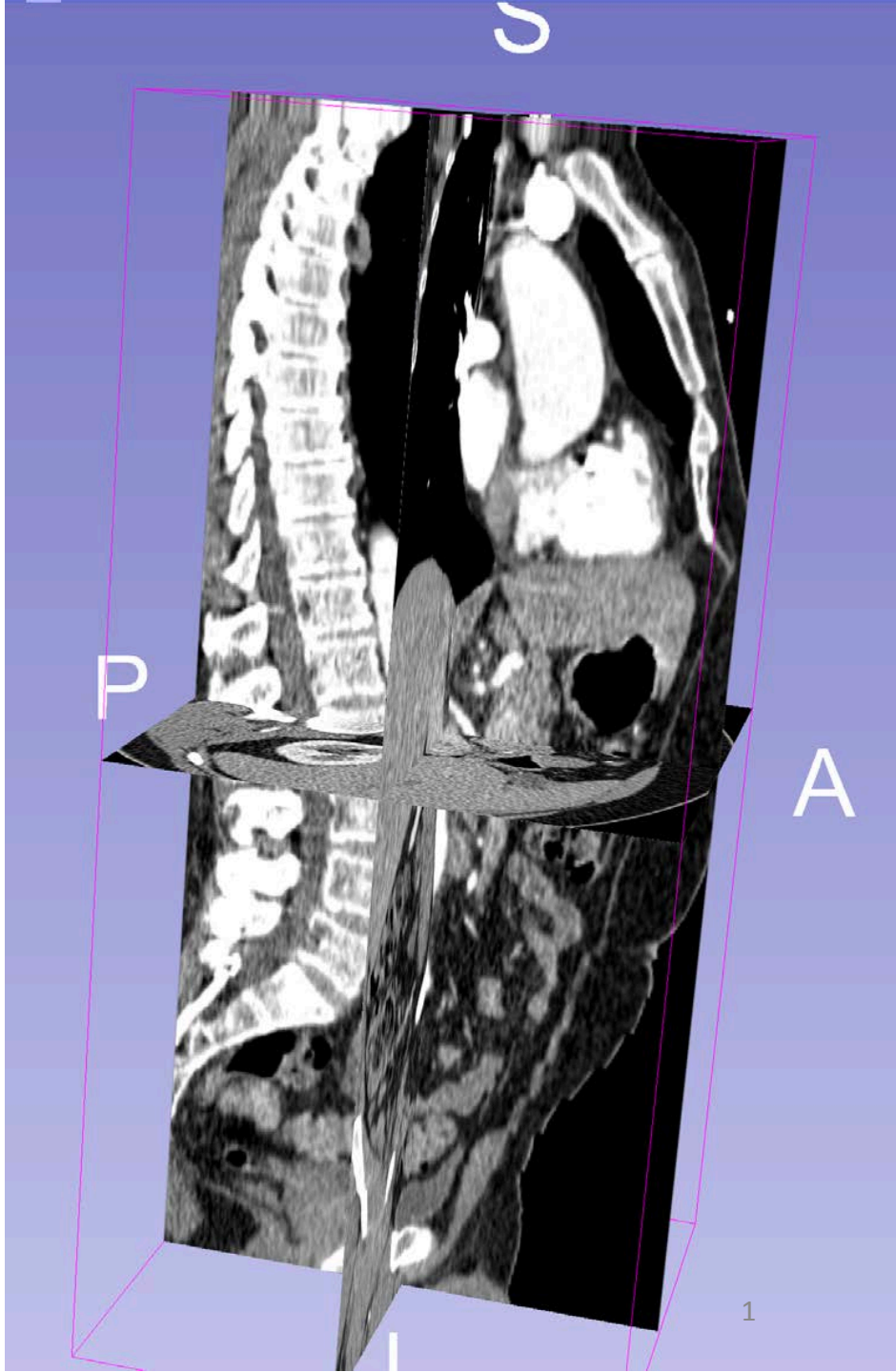

Objective

This tutorial provides a basic introduction to the DICOM standard, and shows how to visualize DICOM images in 3D Slicer version 5.0

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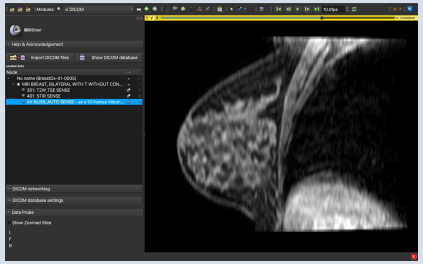
Tutorial Outline

Part 1: Introduction to DICOM

Part 2: DICOM and Slicer



Part 3: Loading and Visualizing DICOM data in Slicer

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Tutorial material

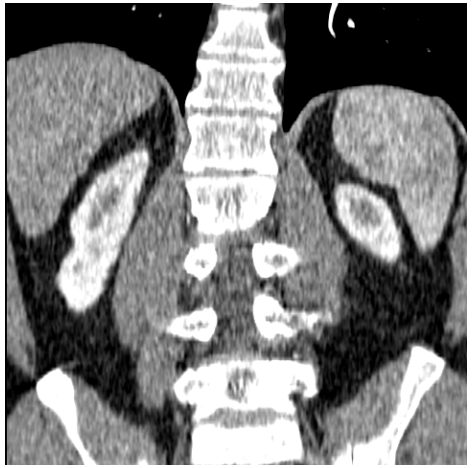
3D Slicer version 5.0

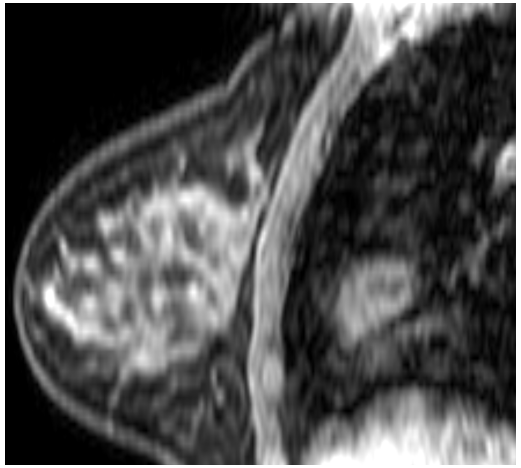
https://download.slicer.org

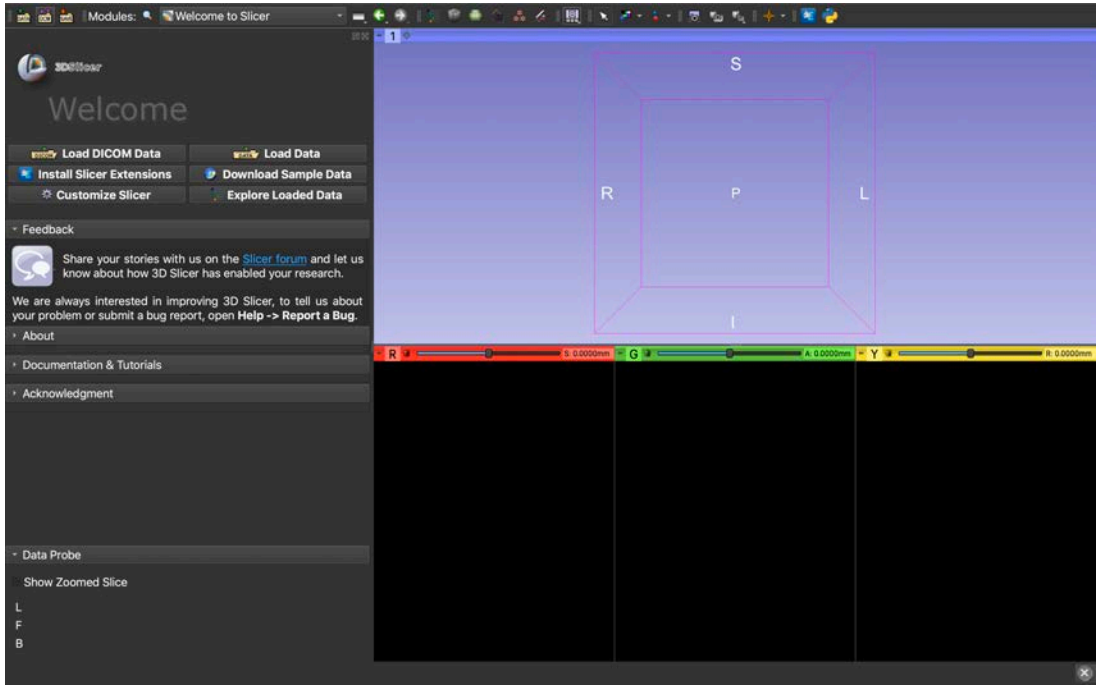
SlicerDICOMTutorialData

DICOM Torso CT

DICOM Breast MRI







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Disclaimer

- 3D Slicer is a free open source software application distributed under a BSD style license
- The software is not FDA approved or CE marked, and is for research use only

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Part 1: Introduction to DICOM

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Reproducible Science

- Reproducible science is critical to drive research and accelerate discoveries

- Open-source software tools such as 3D Slicer and data standards such as DICOM contribute to the reproducibility of scientific results in biomedical research

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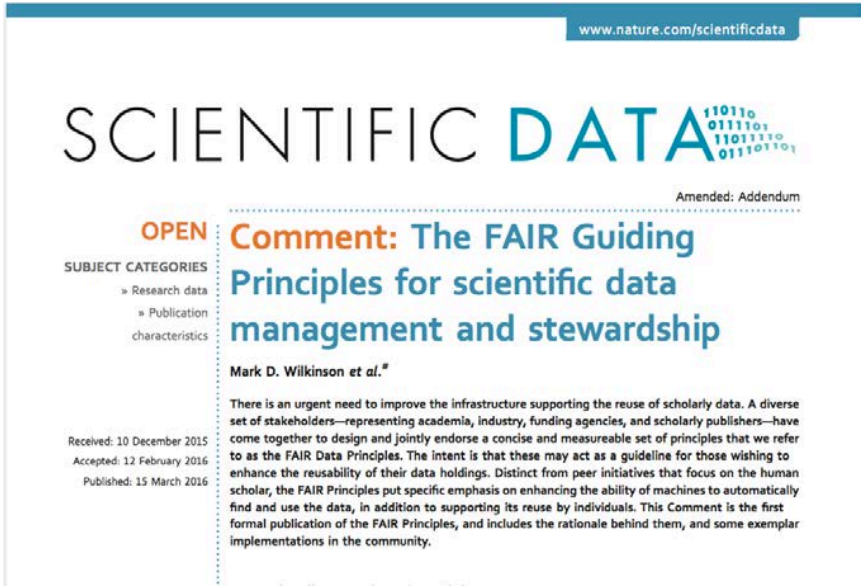
F.A.I.R. Principles



www.nature.com/scientificdata

SCIENTIFIC DATA

Amended: Addendum

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson *et al.*

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measureable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to enhance the reusability of their data holdings. Distinct from peer initiatives that focus on the human scholar, the FAIR Principles put specific emphasis on enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals. This Comment is the first formal publication of the FAIR Principles, and includes the rationale behind them, and some exemplar implementations in the community.

Received: 10 December 2015
Accepted: 12 February 2016
Published: 15 March 2016

The FAIR Guiding Principles for scientific data management and stewardship. Wilkinson et al. Sci. Data 2016
http://go-fair.org/fair-principles

- **Findable:** Data are easily findable
- **Accessible:** Users know how to access the data, including authentication and authorization
- **Interoperable:** Data can be integrated with other data and can interoperate with applications for storage and analysis
- **Reusable:** Data can be replicated or combined for new research

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The DICOM standard

- DICOM (Digital Imaging and Communications in Medicine) is the international standard for handling, storing, printing and transmitting medical imaging data

- Clinical imaging equipment (CT scanners, MR scanners, X-Ray and ultrasound machines) generate DICOM files

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DICOM History

- 1982: The American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) initiate standards for the interconnection of medical imaging devices
- 1985: Publication of the ACR-NEMA Digital Imaging and Communications Standards version 1.0
- 1988: Publication of the ACR-NEMA Digital Imaging and Communications Standards version 2.0
- 1993: Publication of the ACR-NEMA Standards version 3.0 also referred to as the Digital Imaging and Communications in Medicine (DICOM) standard

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DICOM Today

- The DICOM standard is continuously being refined to address new community needs through multiple releases every year
- As of 2020/07/06, the DICOM standard is DICOM PS3 2020c and contains 4,000 pages
- DICOM Working Groups are established to expand the capabilities of the standard given the continuous evolution of imaging modalities

(e.g. WG-16 Magnetic Resonance)
https://www.dicomstandard.org/wgs

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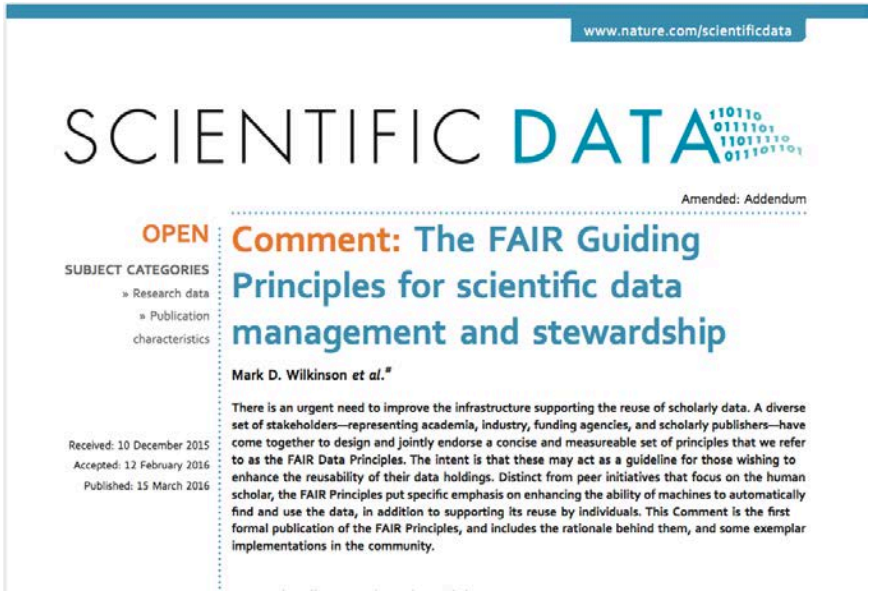
FAIR Data and the DICOM Standard



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DICOM®

Digital Imaging and Communications in Medicine

The DICOM Standard facilitates compliance of imaging data with FAIR principles

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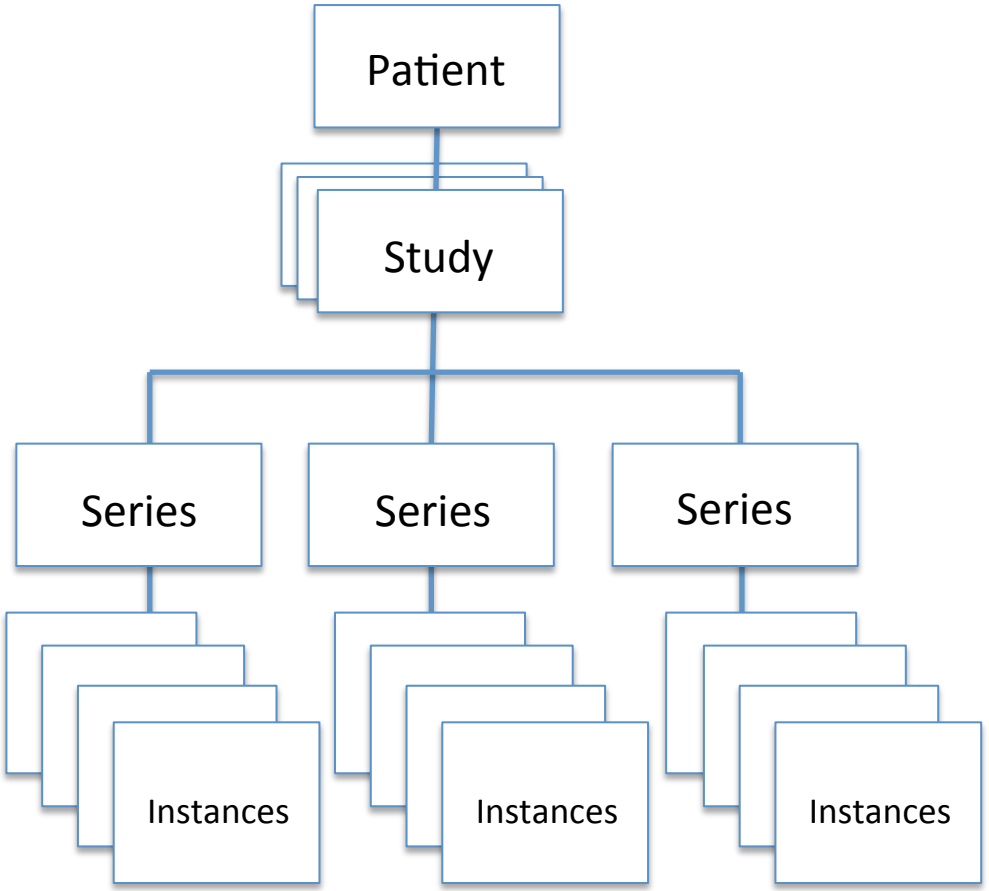
DICOM Data Model



- In the DICOM data model, a **DICOM Study** consists of several **DICOM Series**, and each DICOM Series contains **DICOM Instances**

- Each of the DICOM Studies, Series and Instances are assigned a Unique Identifier (UID)

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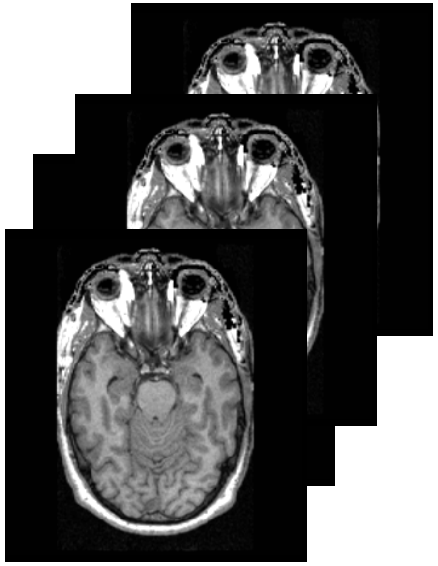
Example of DICOM instances: DICOM MRI Image data



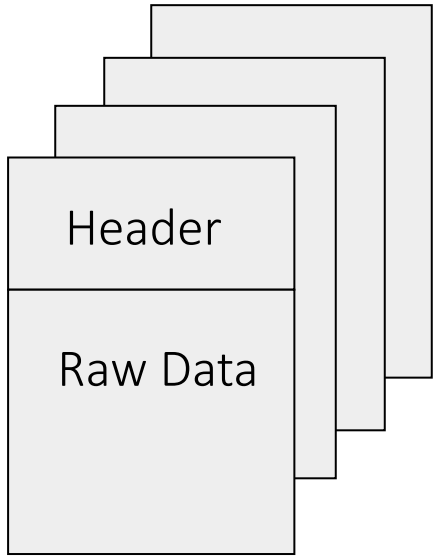


Image001.dcm

Image002.dcm

Image003.dcm

....

An MRI image is an example of DICOM instance that consists of a DICOM header and an image dataset

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Example of DICOM header content

- The **DICOM header** contains metadata which include information on the patient, study and imaging data.
- DICOM provides a standardized way to present metadata which makes it searchable
- The metadata information is accessible through **DICOM tags**
- DICOM tags uniquely identify DICOM attributes
- Original data from the scanner tell users important elements about the acquisition

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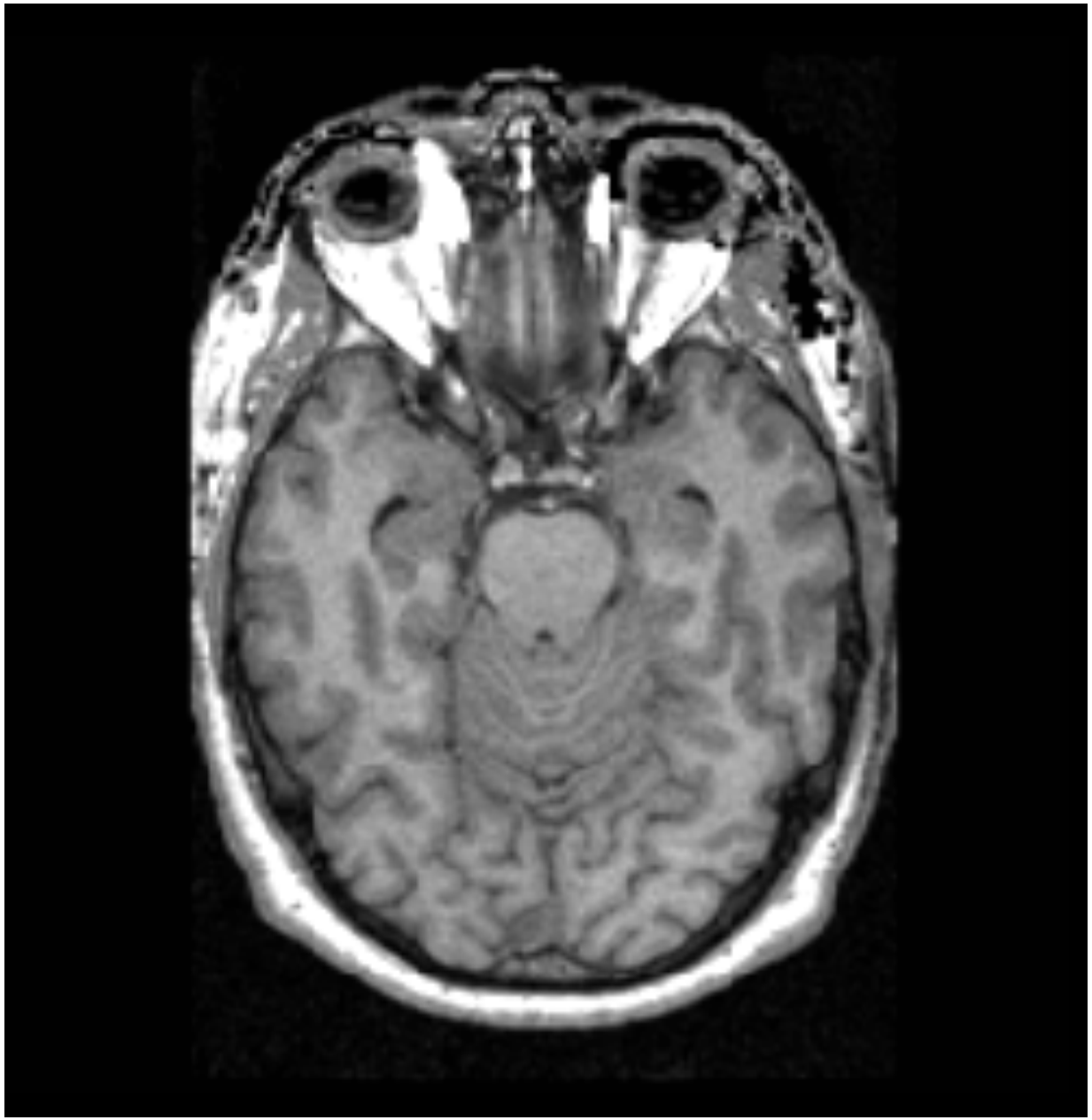

Physician and Study Information

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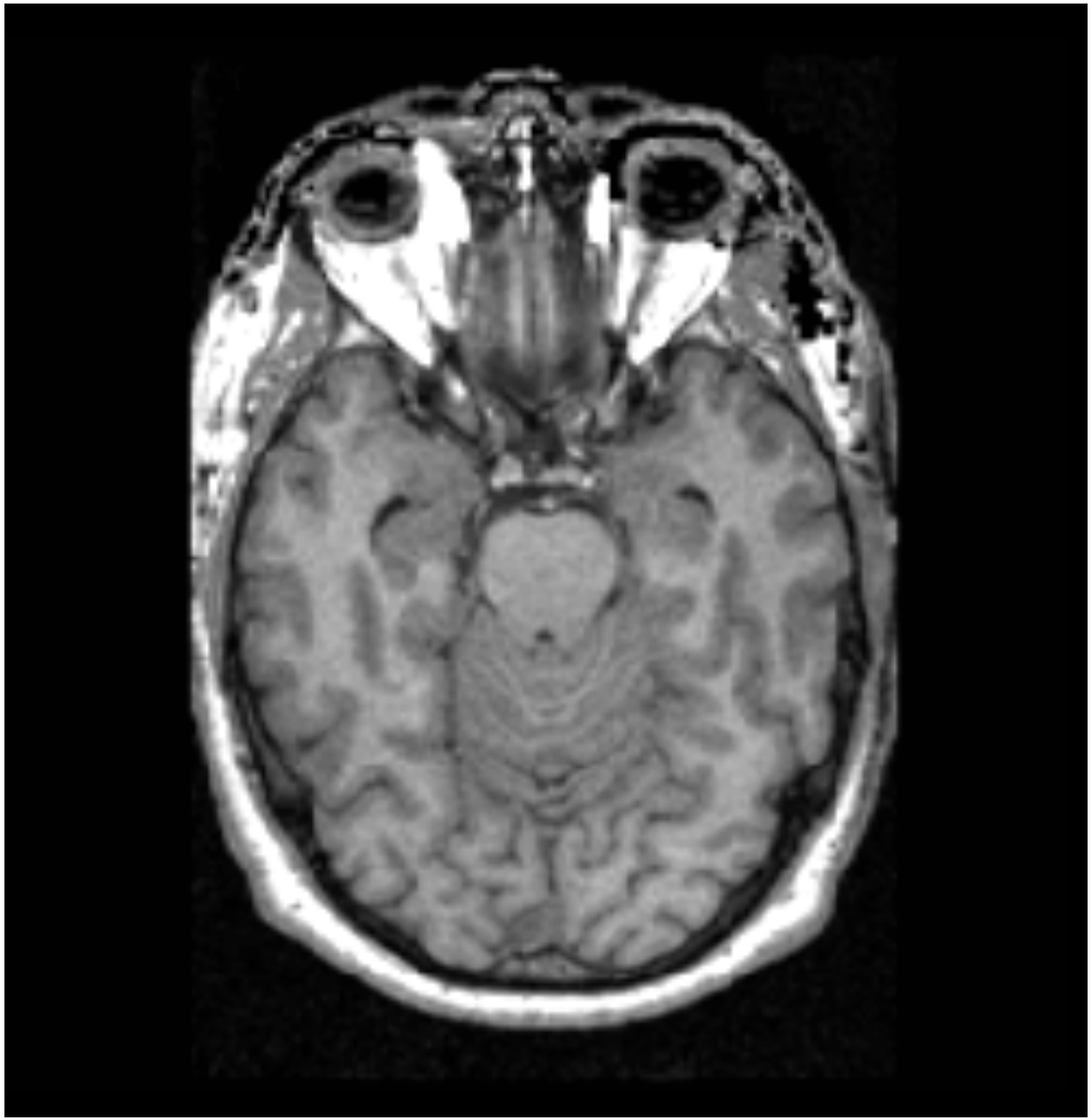

The Life Cycle of Medical Imaging Data - Sonia Pujol, Ph.D.
Functional Magnetic Resonance Imaging: Data Acquisition and Analysis
Harvard-MIT Health Sciences and Technology (HST.583)

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Patient Information

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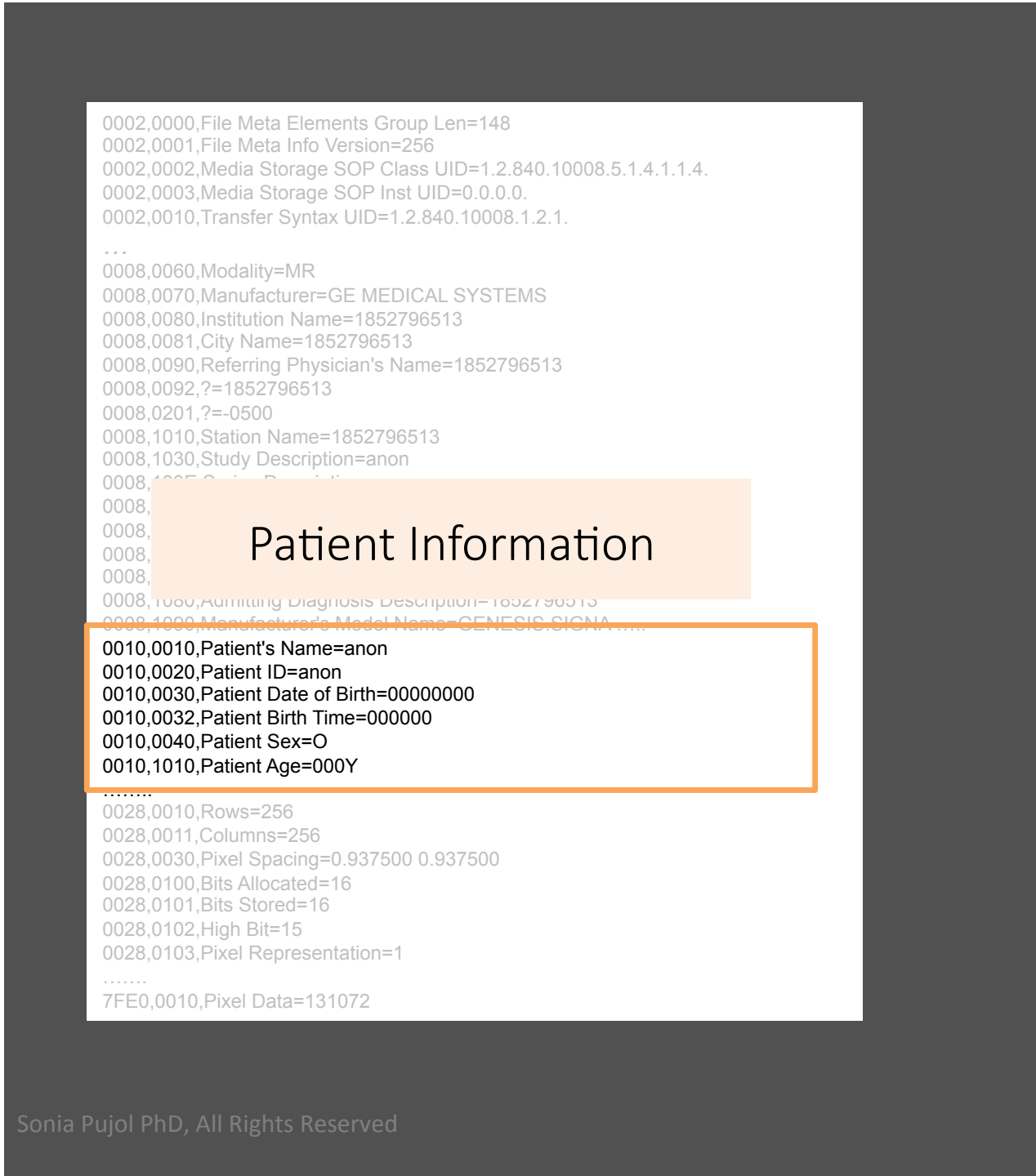
HIPPA Patient privacy

The Health Insurance Portability and Accountability Act of 1996 (HIPAA) protects the privacy and security of certain health information

http://www.hhs.gov/hipaa/index.html



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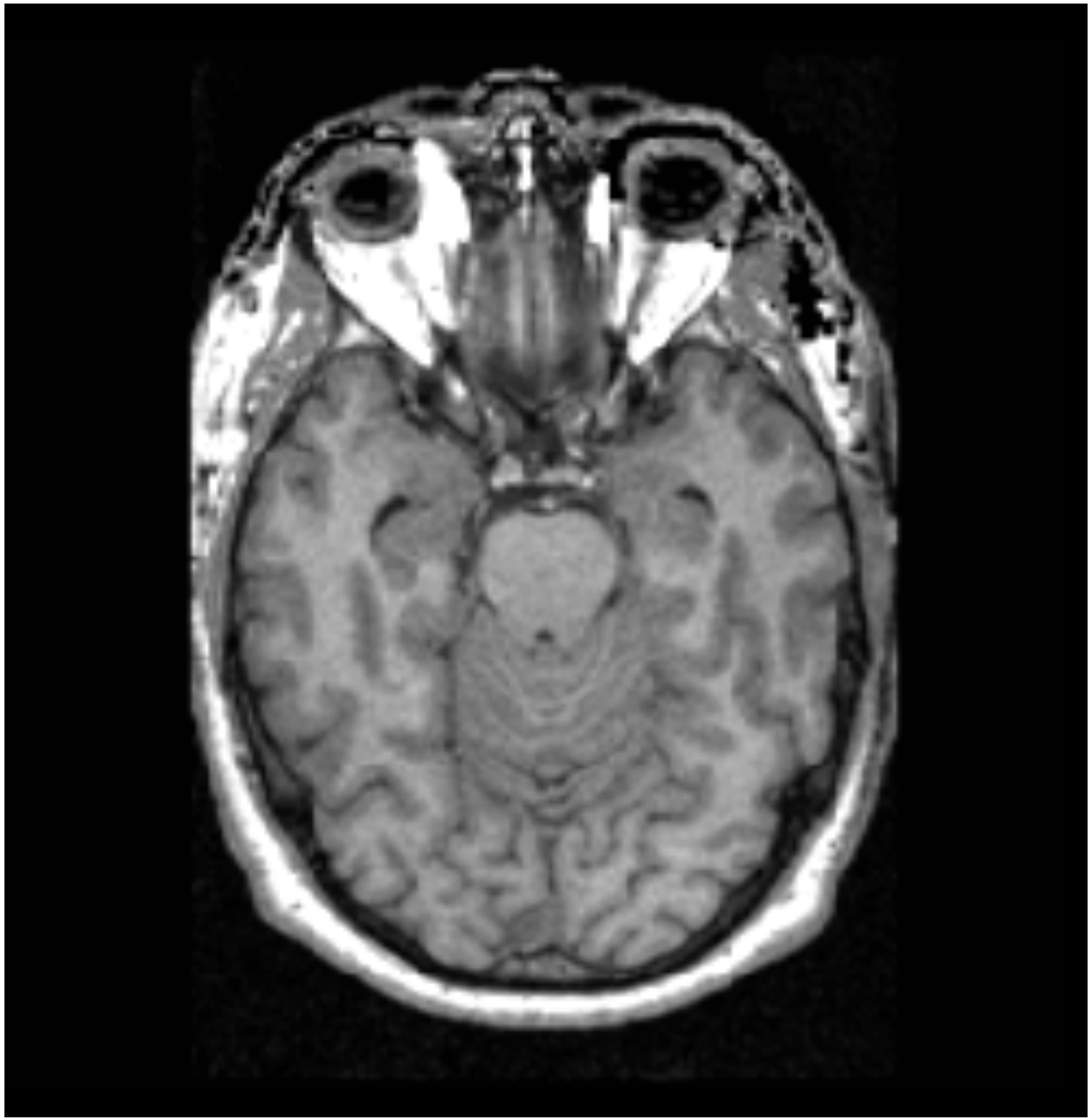

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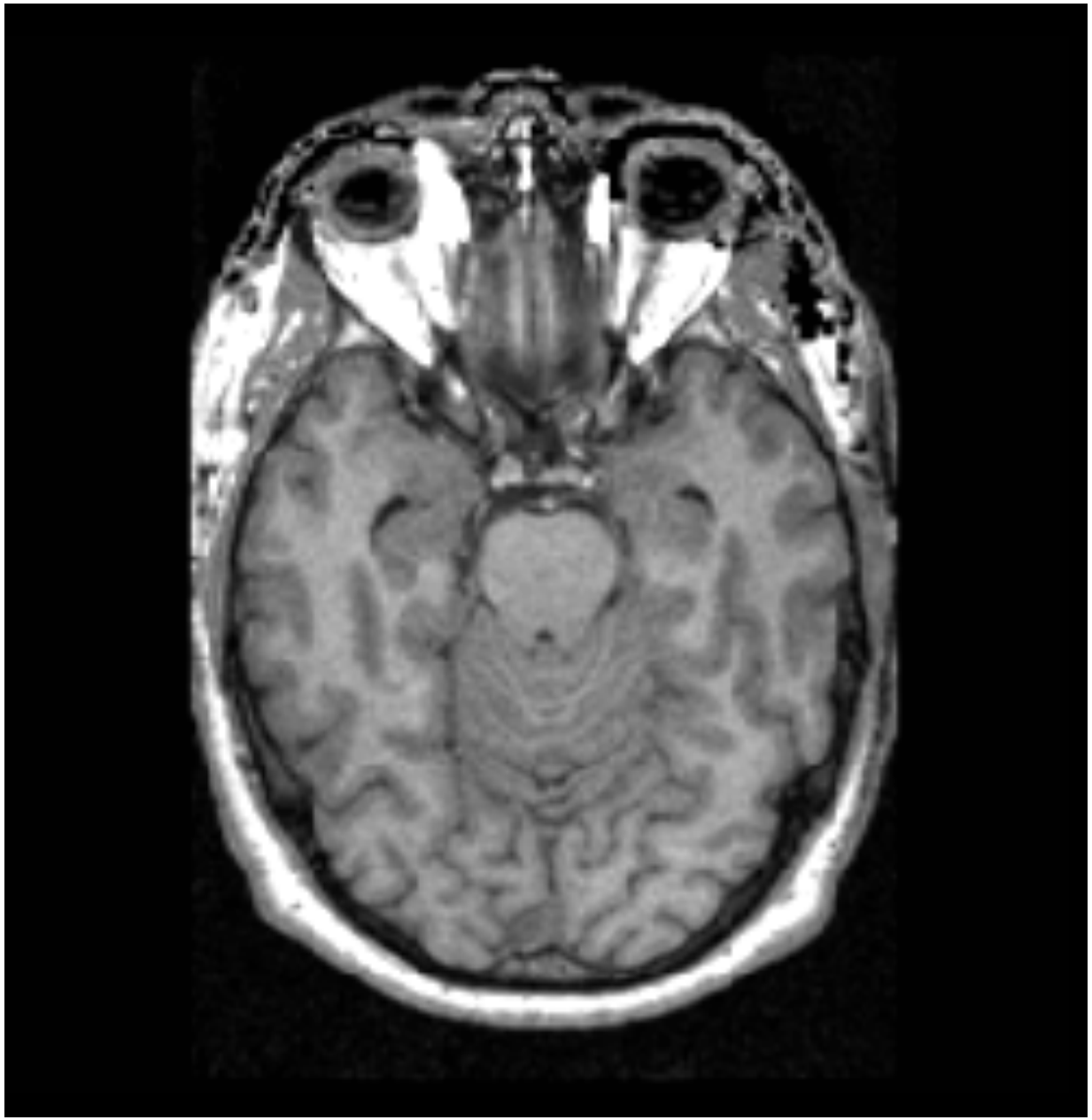

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Pixel Data

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Examples of Standard DICOM Instances

- **DICOM images** produced by imaging equipment: single X-Ray slice , DICOM CT or DICOM MR volume, DICOM multi-frame object (e.g. fMRI experiment, diffusion MRI, DCE)
- **DICOM Segmentation Object (SEG)**: voxels labelled in regions of interest (ROIs)
- **DICOM Structured Report (SR):** clinical information (e.g. diagnosis, pathology, surgery, etc.), measurements computed from segmented ROIs

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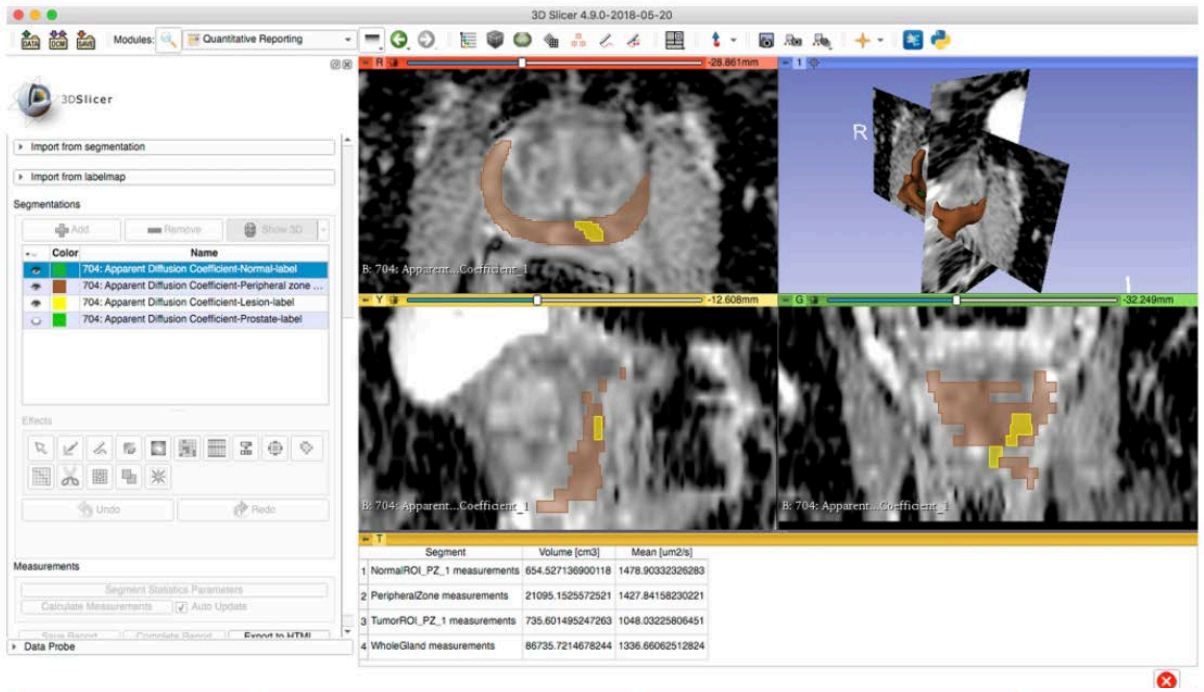
Examples of Standard DICOM Instances



DICOM Images

Prostate MRI Images

Segmented structure	SegmentedPropertyCategoryCodeSequence	SegmentedPropertyTypeCodeSequence	AnatomicRegionSequence
Prostate gland	("T-D000A", "SRT, "Anatomical Structure")	("T-9200B", "SRT", "Prostate")	NA
Peripheral zone of the prostate gland	("T-D000A", "SRT, "Anatomical Structure")	("T-D05E4", "SRT", "Peripheral zone of the prostate")	NA
Lesion in the peripheral zone of the prostate gland	("M-01000", "SRT", "Morphologically Altered Structure")	("M-01100", "SRT", "Lesion")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Normal tissue in the peripheral zone of the prostate gland	("T-D0050", "SRT, "Tissue")	("G-A460", "SRT", "Normal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")

DICOM Segmented Structures

Prostate gland, peripheral zone, lesion, normal tissue

Measured structure	Finding	Finding Site
*Prostate gland **	(T-F6078, SRT, "Entire Gland")	("T-9200B", "SRT", "Prostate")
Peripheral zone of the prostate gland	(R-404A4, SRT, "Entire")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Lesion in the peripheral zone of the prostate gland	(R-42037, SRT, "Abnormal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Normal tissue of peripheral zone of the prostate gland	("G-A460", "SRT", "Normal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")

Measurements

Volumes of prostate gland, peripheral zone, lesion, normal tissue

Fedorov et al. Data Descriptor: An annotated test-retest collection of multiparametric MRI. Sci. Data. 2016

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DICOM Terminology

- DICOM provides support for segmentation objects and annotations
- DICOM Structured Reports enable provenance tracking
- DICOM derived data can be stored on a DICOM server or on other archive (e.g. TCIA) with permission, and is compliant with FAIR principles

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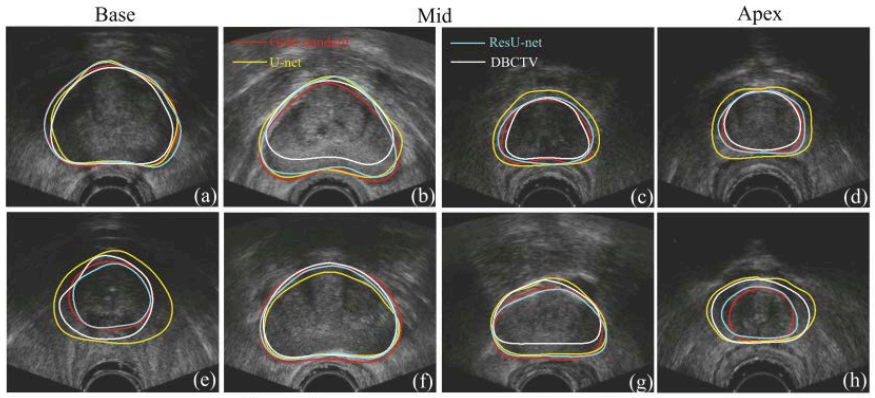

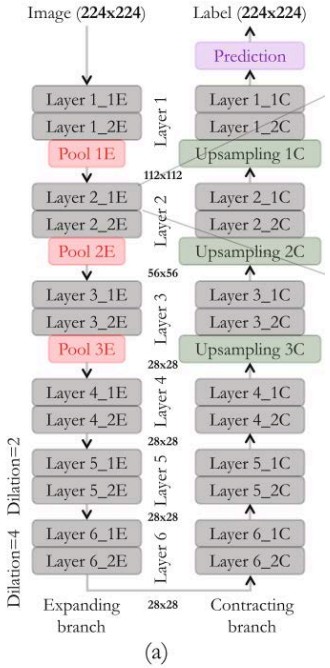

Anas et al. MICCAI 2017

DICOM for Artificial Intelligence Studies

- DICOM defines **syntax rules** and **vocabularies** that enable easy extraction of knowledge from the data

- The DICOM framework for medical imaging data management enables the **automation of cohort formation** and maximizes the **interoperability of the data for AI studies**

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Part 2: DICOM and Slicer

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Slicer DICOM module

- The **Slicer DICOM module** provides the infrastructure for storing, loading and exporting DICOM data
- Slicer supports CT, MRI, PET, X-Ray and ultrasound DICOM data
- Dedicated **Slicer Extensions** can be added to Slicer for importing additional DICOM instances (e.g. DICOM RT Dose, DICOM Segmentation Object, Diffusion Weighted MRI, etc.)

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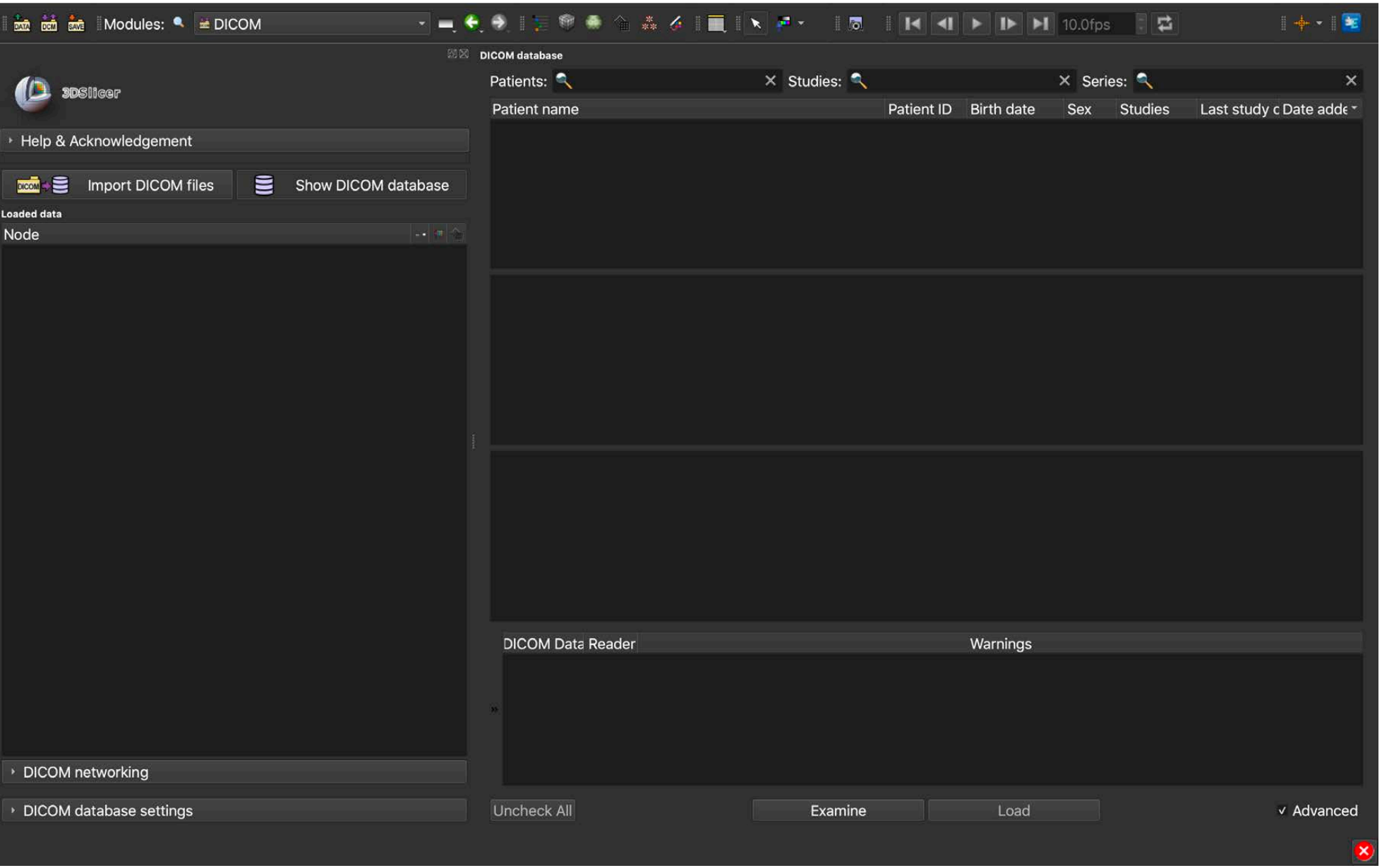

Slicer DICOM module

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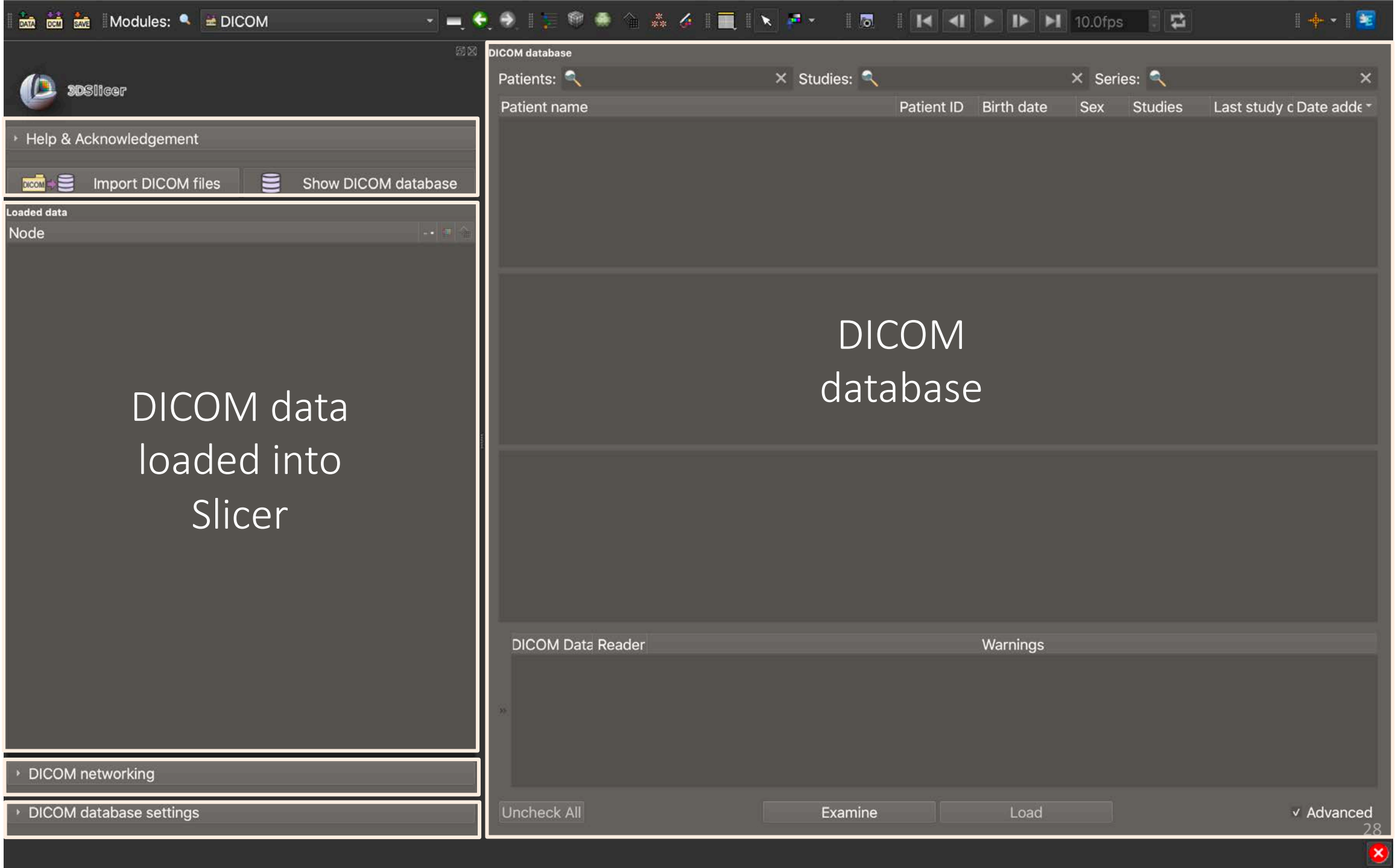
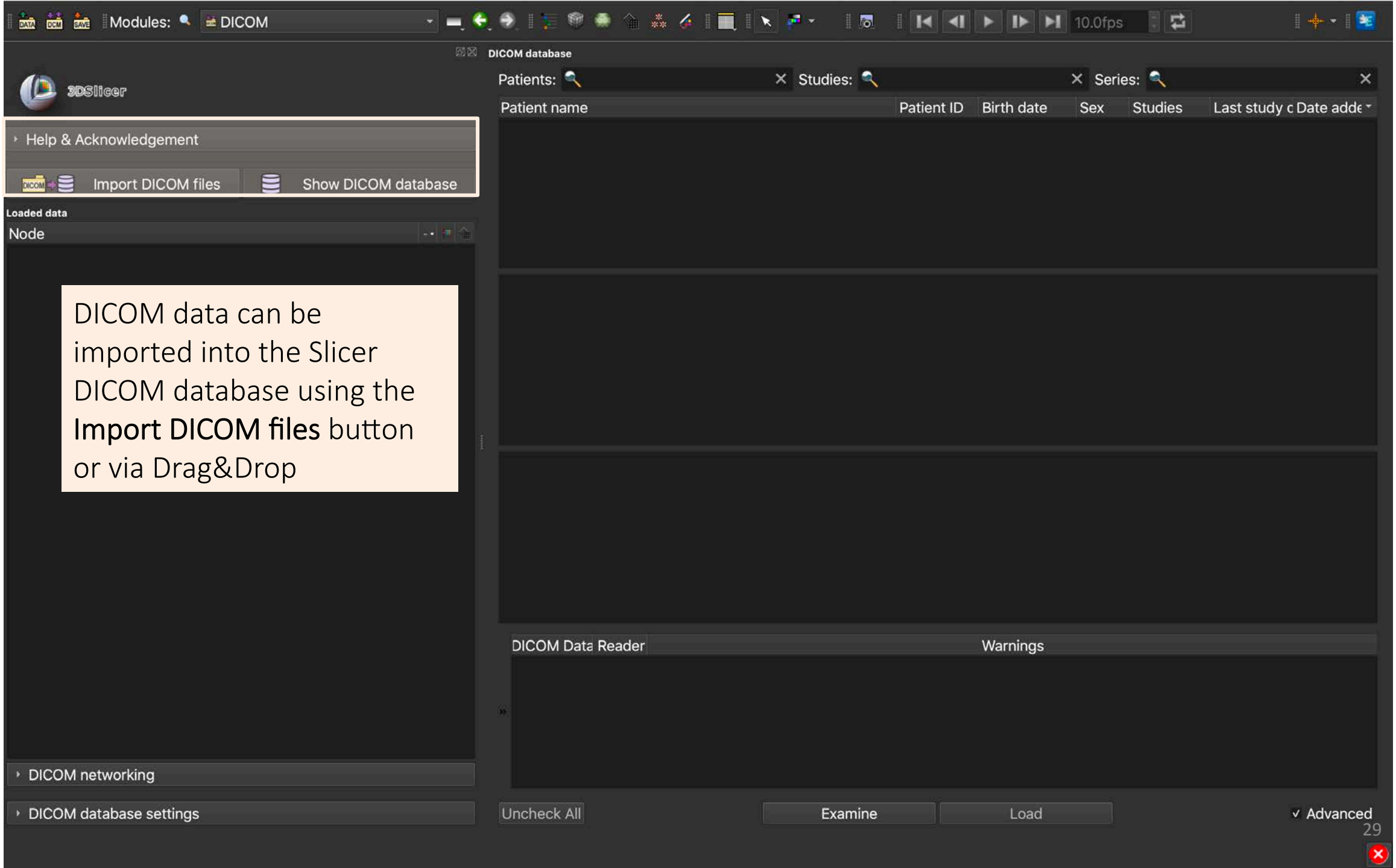
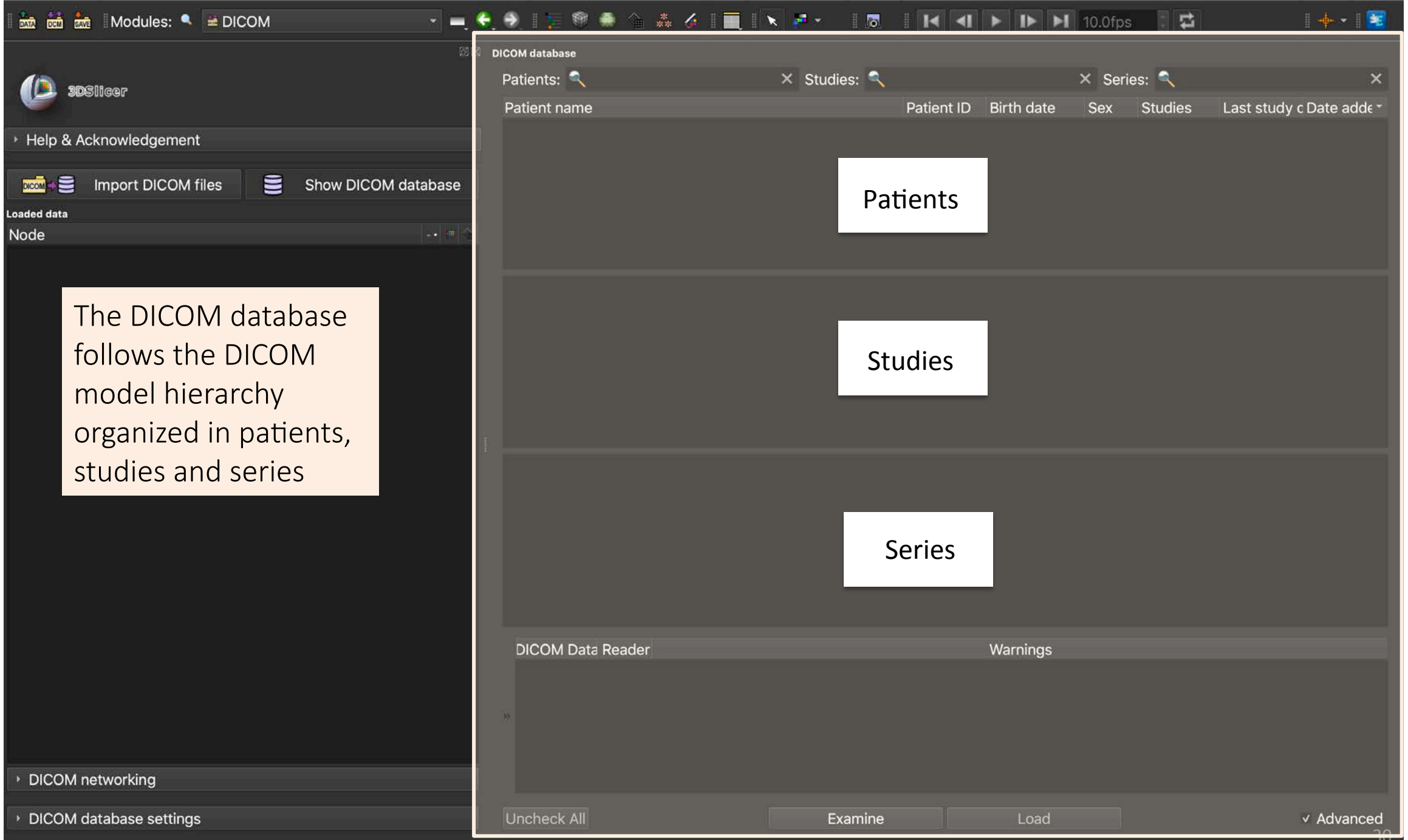

Modules: DICOM
10.0fps
3DSlicer
Help & Acknowledgement
Import DICOM files
Show DICOM database
Loaded data
Node
DICOM data loaded into Slicer
DICOM networking
DICOM database settings
DICOM database
Patients:
Studies:
Series:
Patient name
Patient ID
Birth date
Sex
Studies
Last study c
Date adde
DICOM database
DICOM Data Reader
Warnings
Uncheck All
Examine
Load
Advanced


Modules:
DICOM
10.0fps
DICOM database
3DSlicer
Patients:
Studies:
Series:
Patient name
Patient ID
Birth date
Sex
Studies
Last study c
Date adde
Help & Acknowledgement
Import DICOM files
Show DICOM database
Loaded data
Node
DICOM data can be imported into the Slicer DICOM database using the Import DICOM files button or via Drag&Drop
DICOM Data Reader
Warnings
DICOM networking
DICOM database settings
Uncheck All
Examine
Load
Advanced



The DICOM database follows the DICOM model hierarchy organized in patients, studies and series

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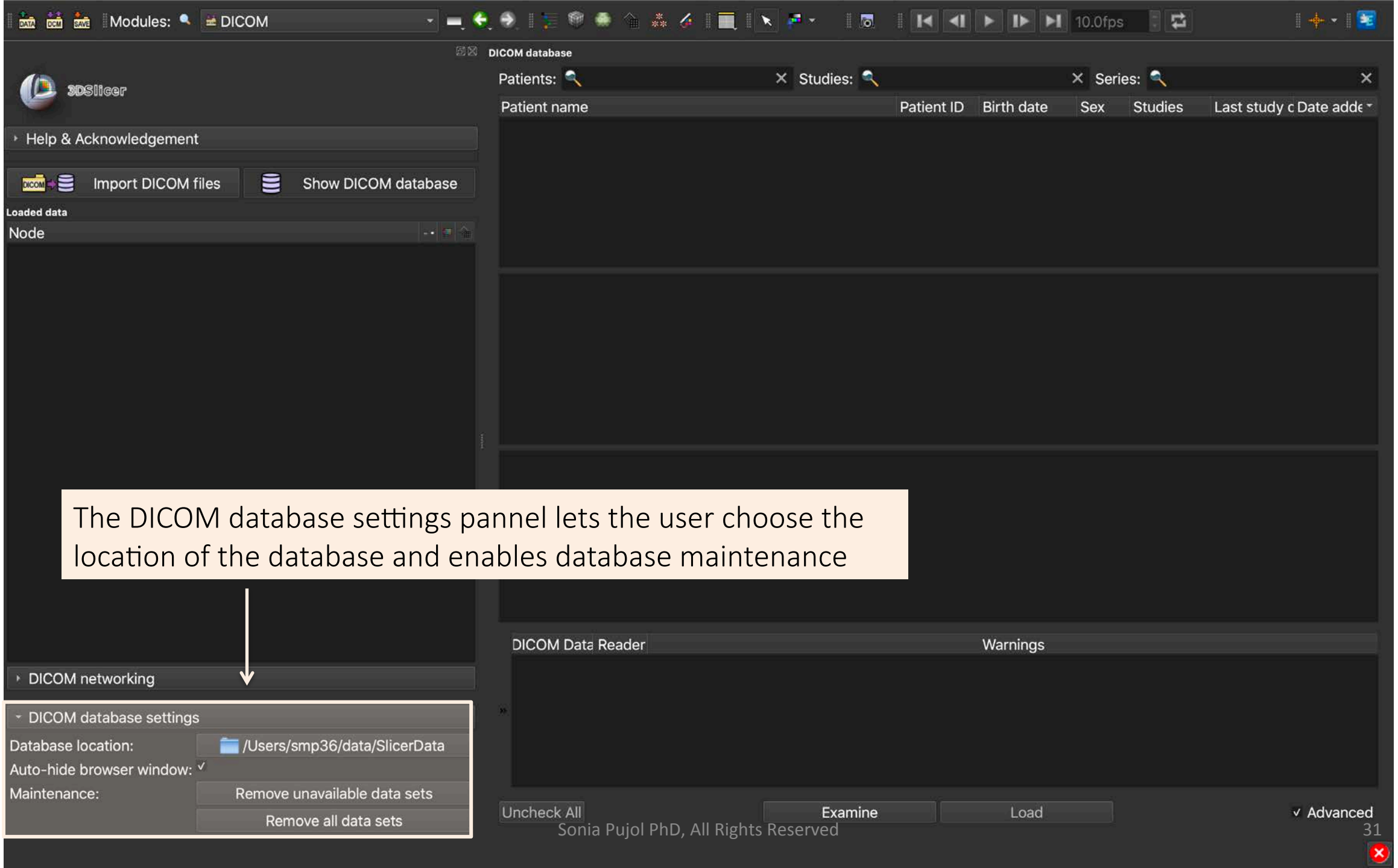

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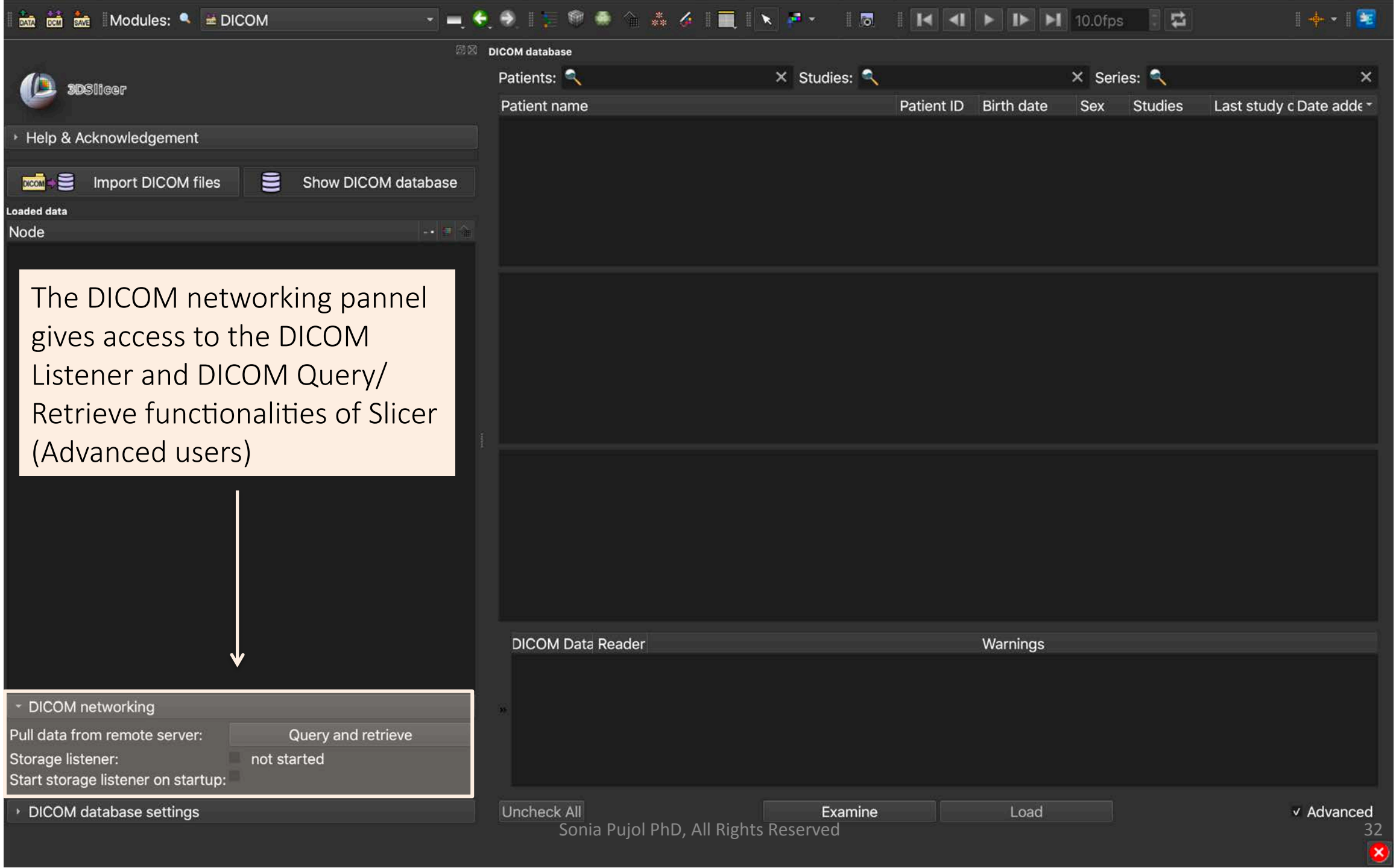

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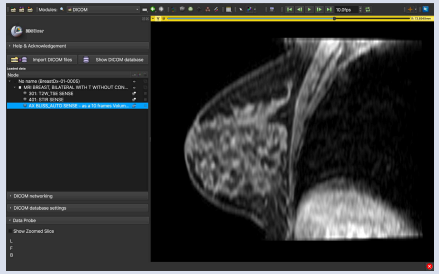

Part 3: Loading and Visualizing DICOM data in Slicer

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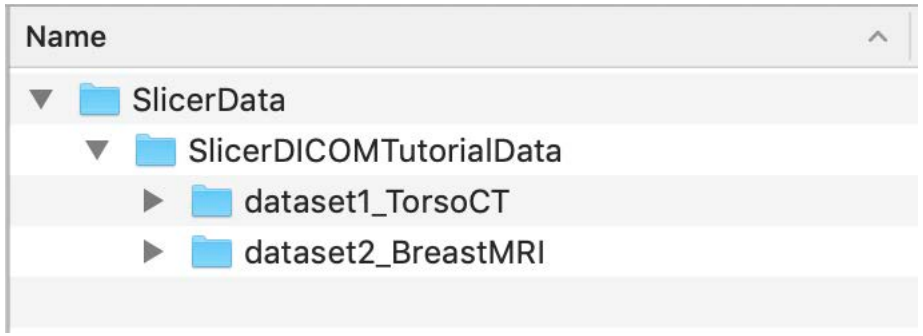
Tutorial Dataset

- Download the **SlicerDICOMTutorialData.zip** file to your computer
- Create a **SlicerData** folder on your computer and move the SlicerDICOMTutorialData.zip file to the SlicerData folder
- Unzip the SlicerDICOMTutorialData.zip



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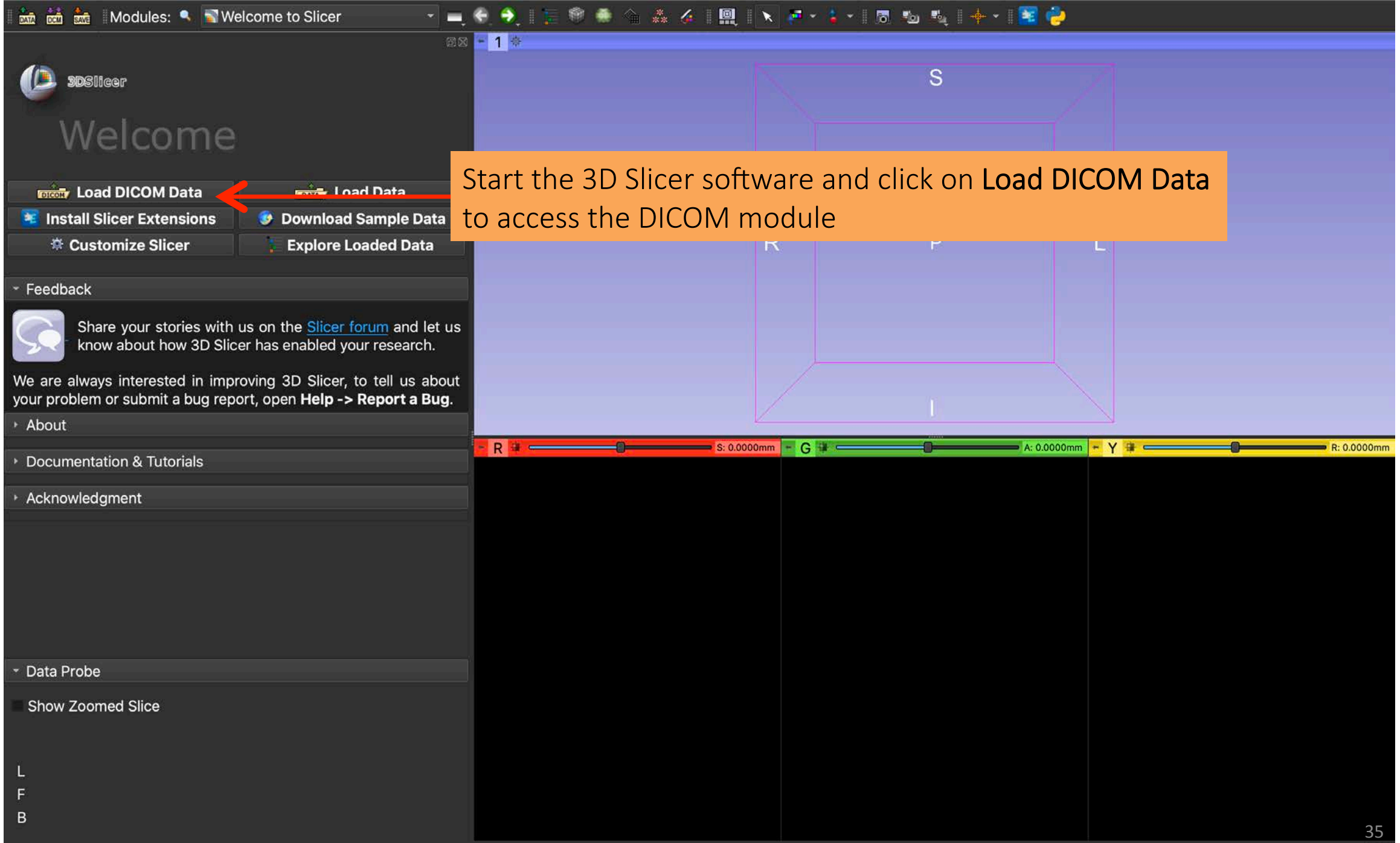

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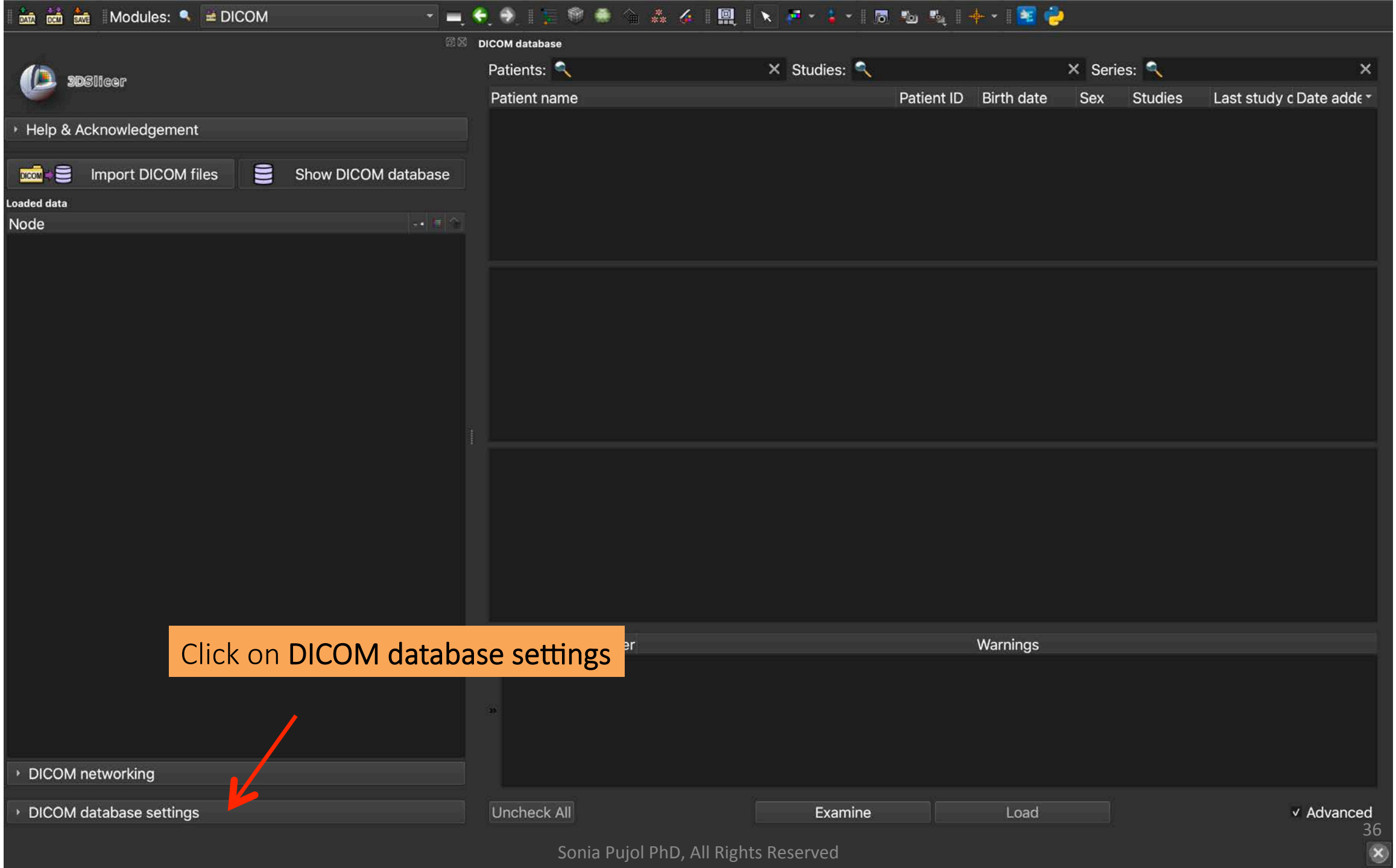

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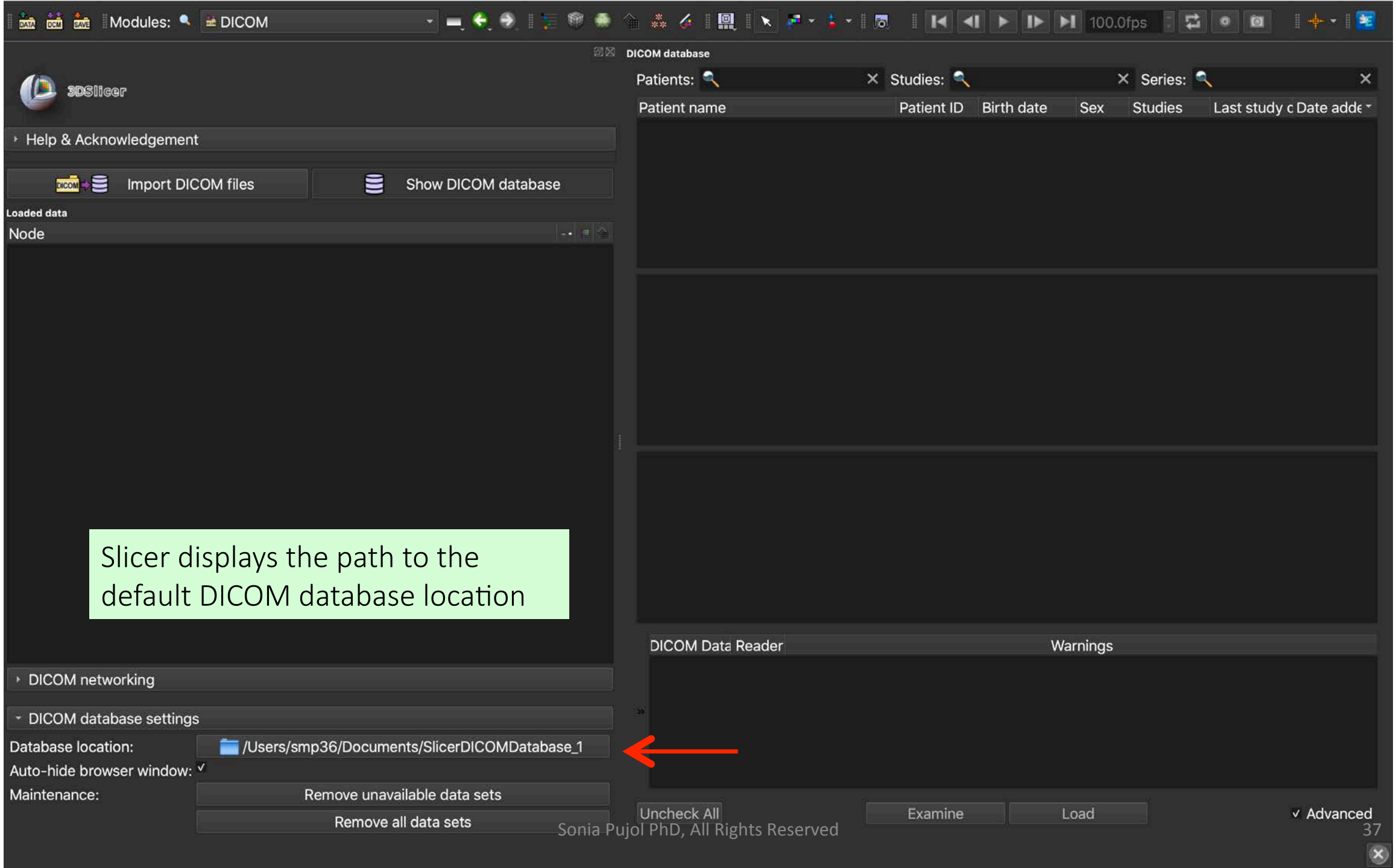

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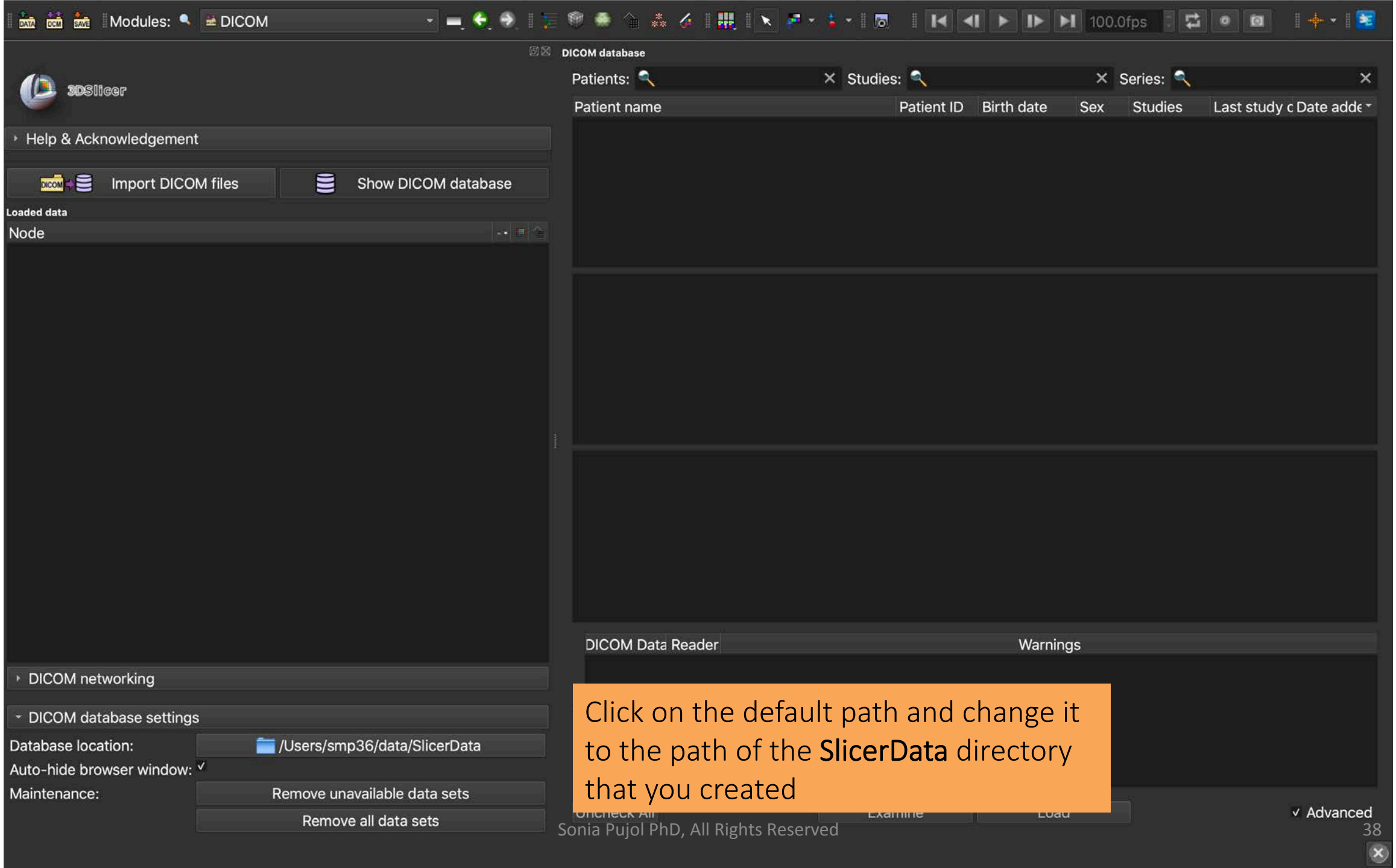

Click on the default path and change it to the path of the **SlicerData** directory that you created

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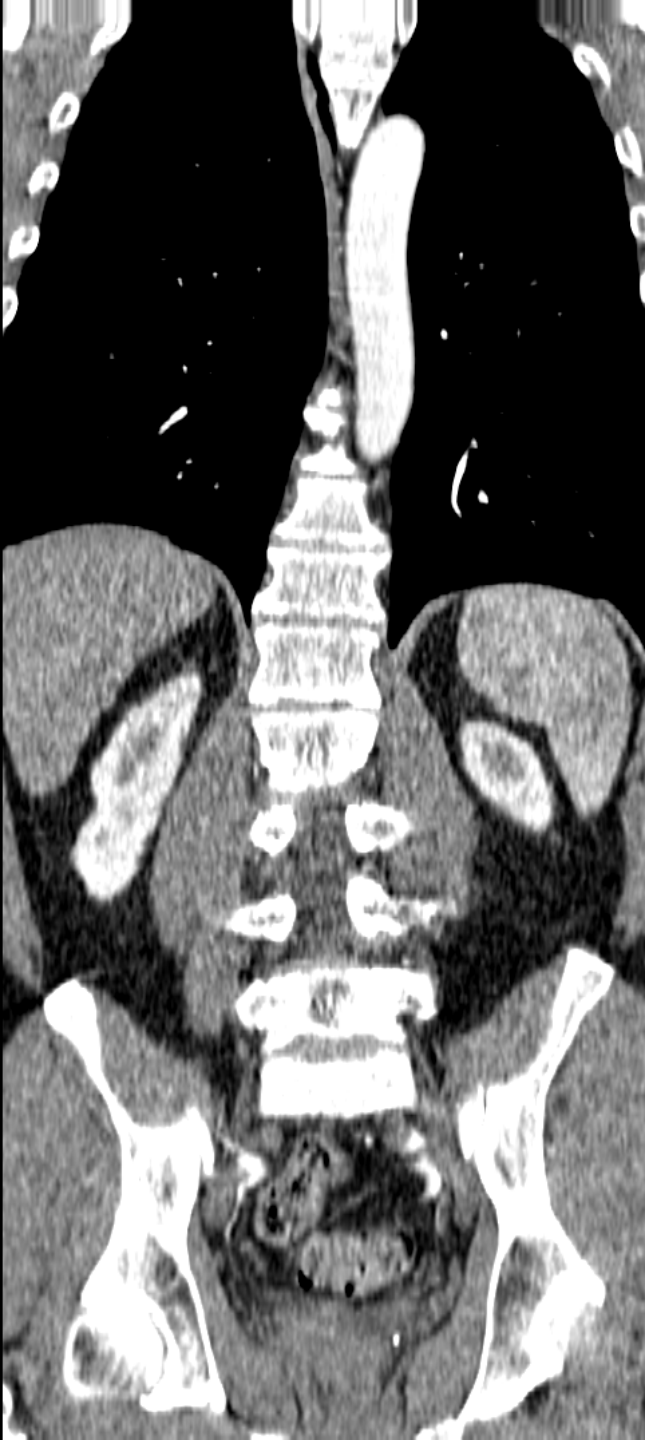

Dataset #1
Torso CT

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Loading a DICOM dataset in Slicer

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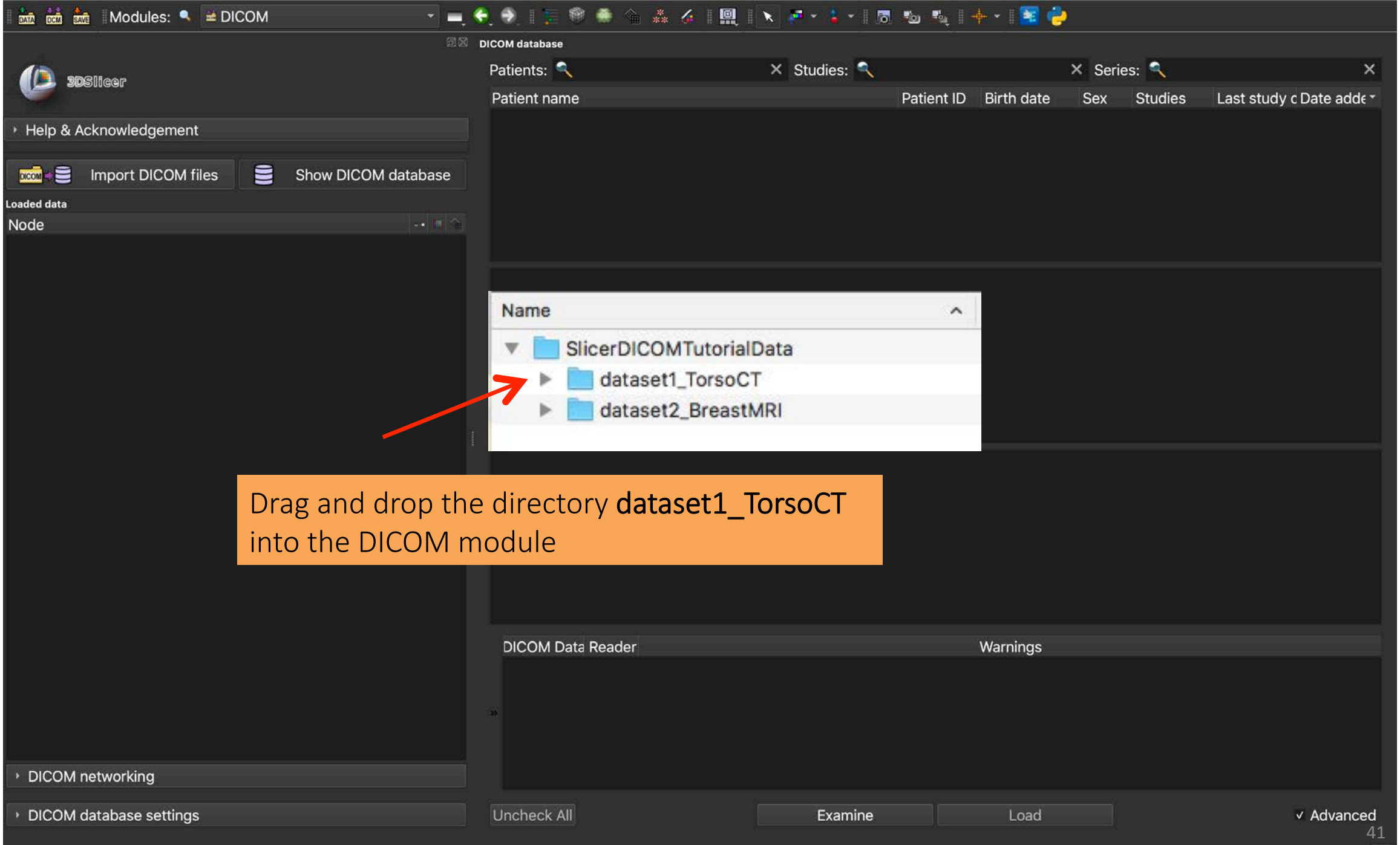

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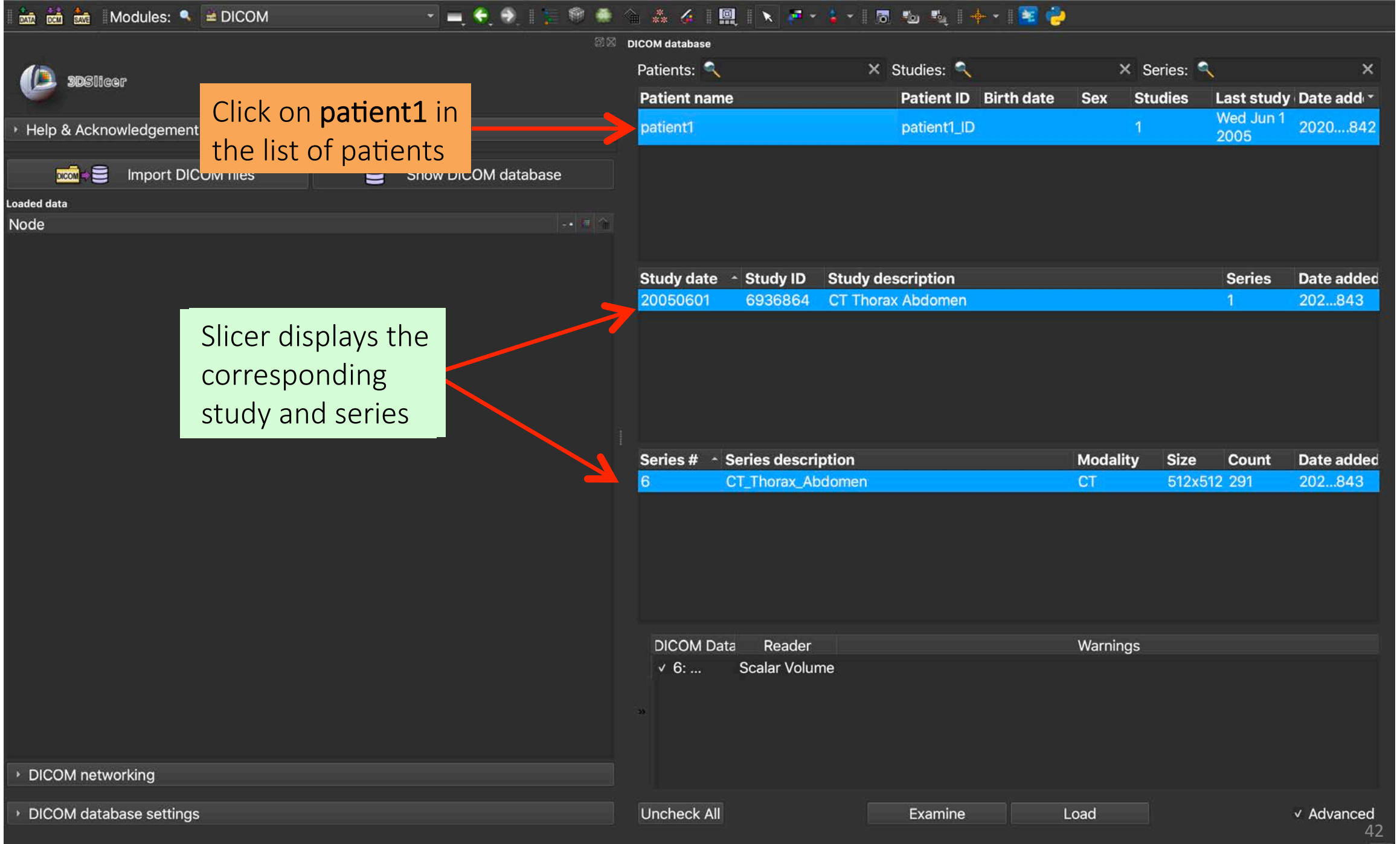

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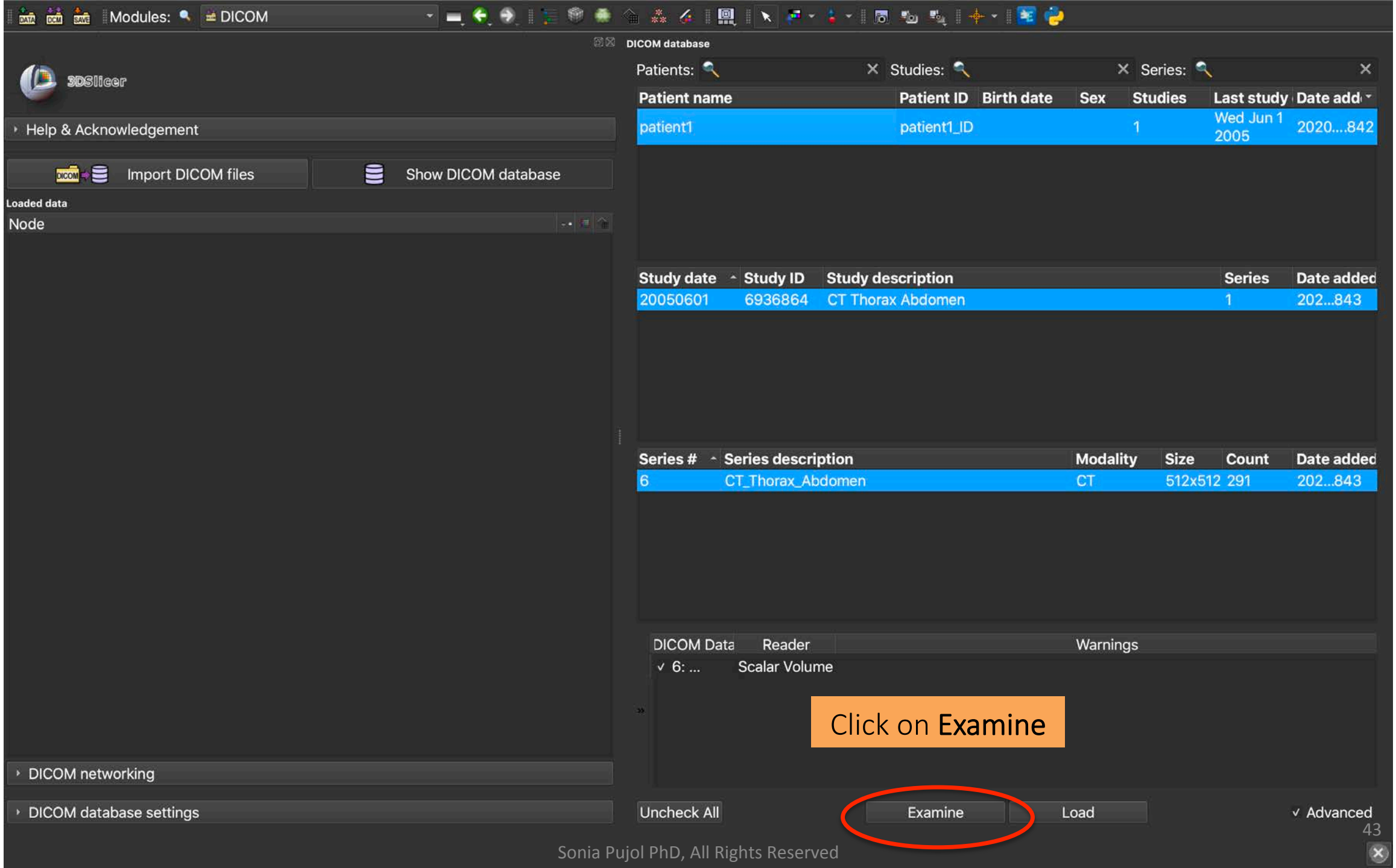

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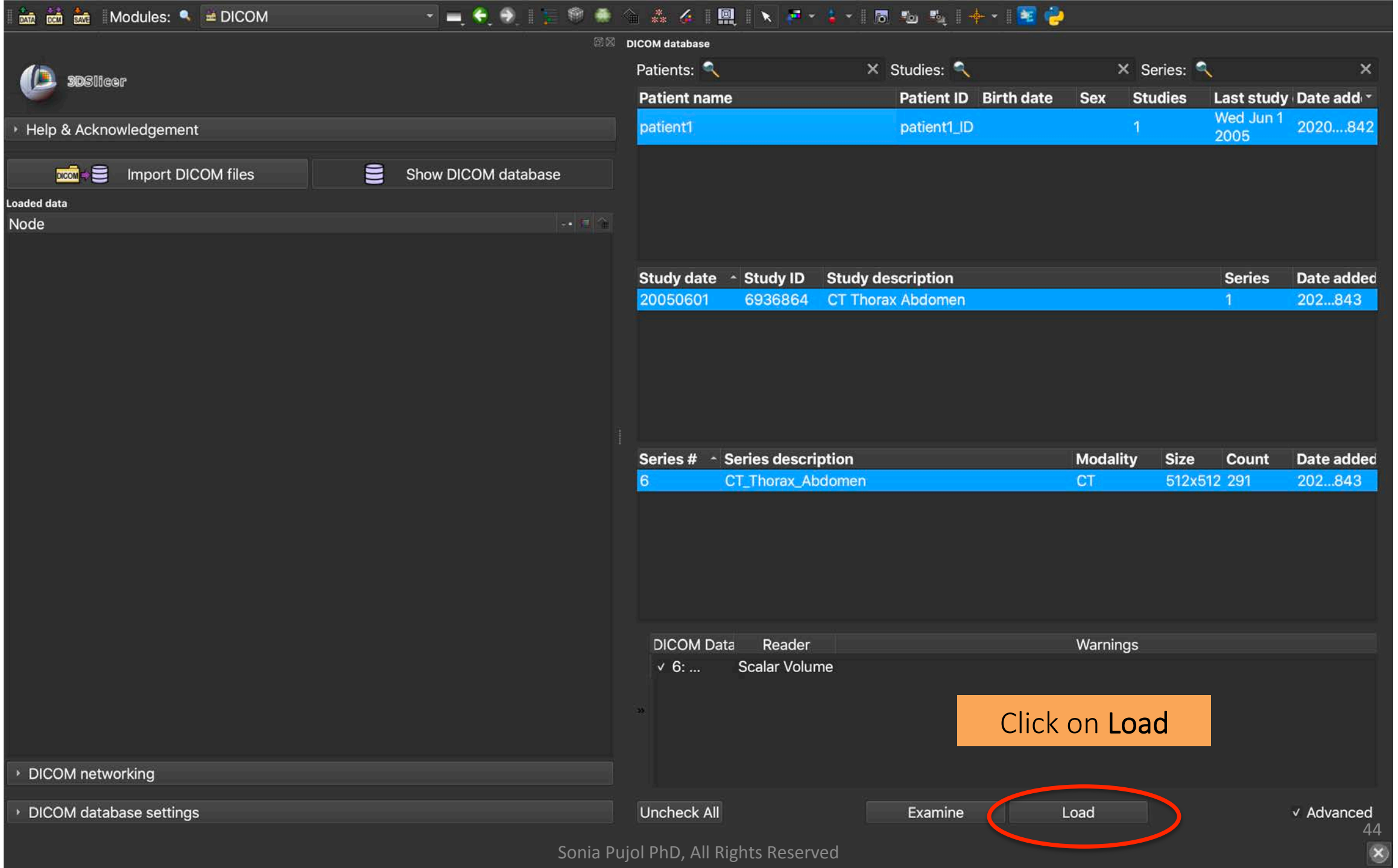

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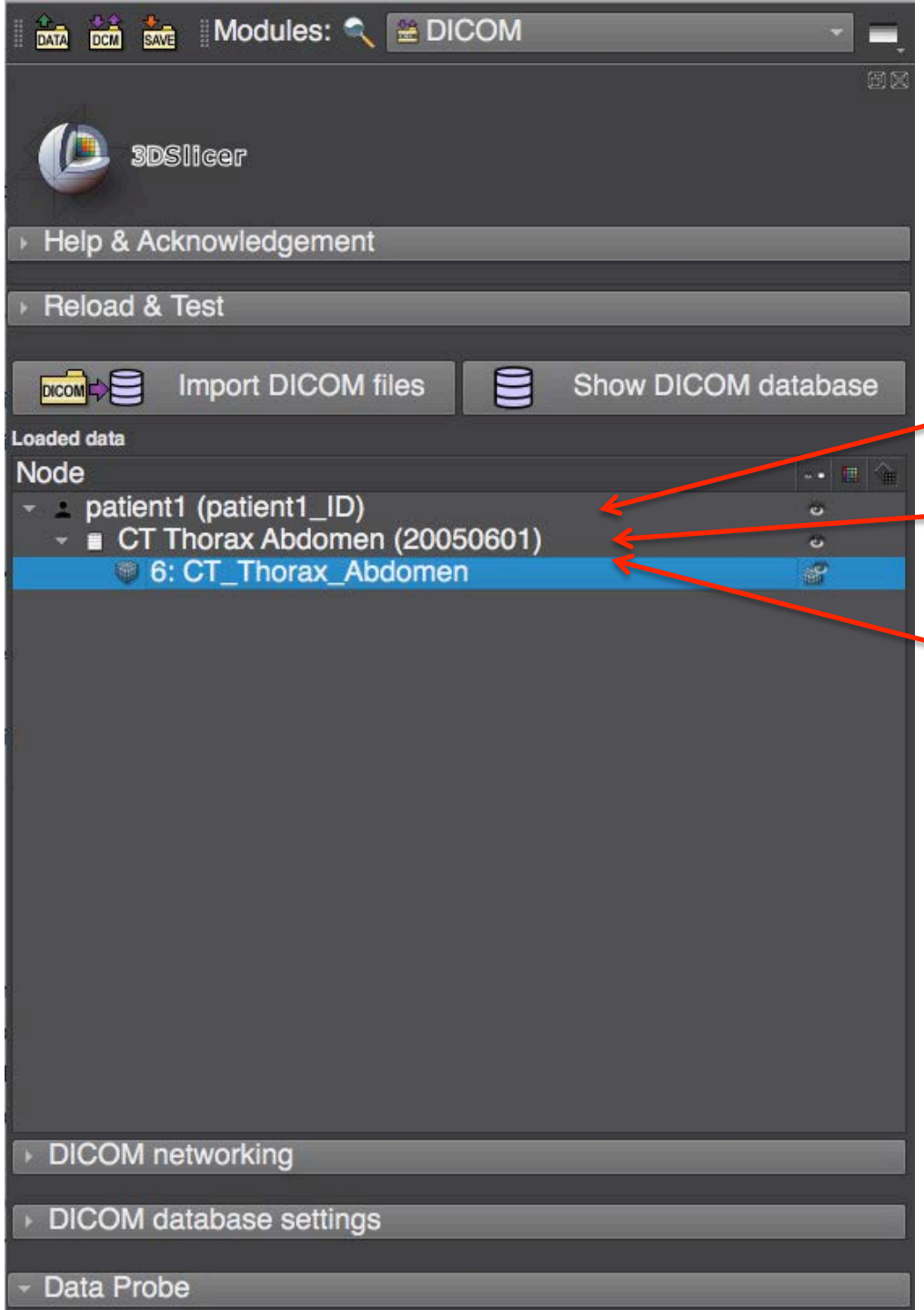
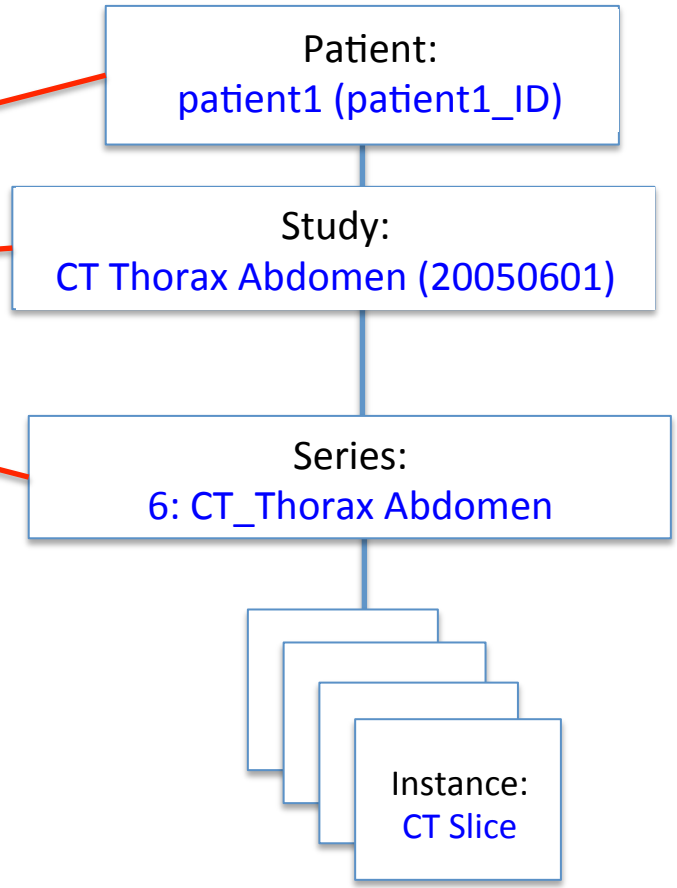
The DICOM dataset is loaded into Slicer as a patient-study-series DICOM hierarchy





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Visualizing a DICOM dataset in Slicer

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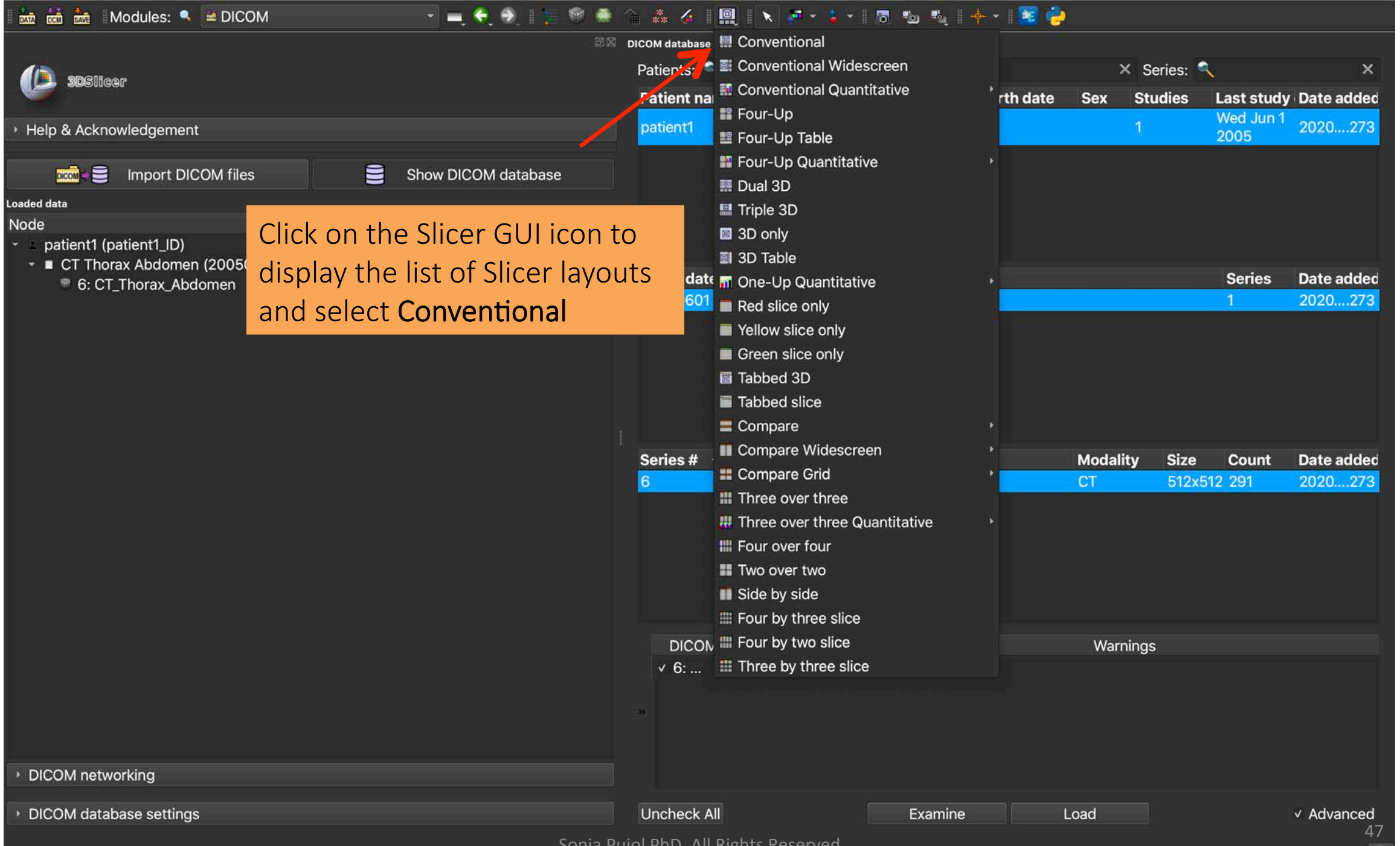

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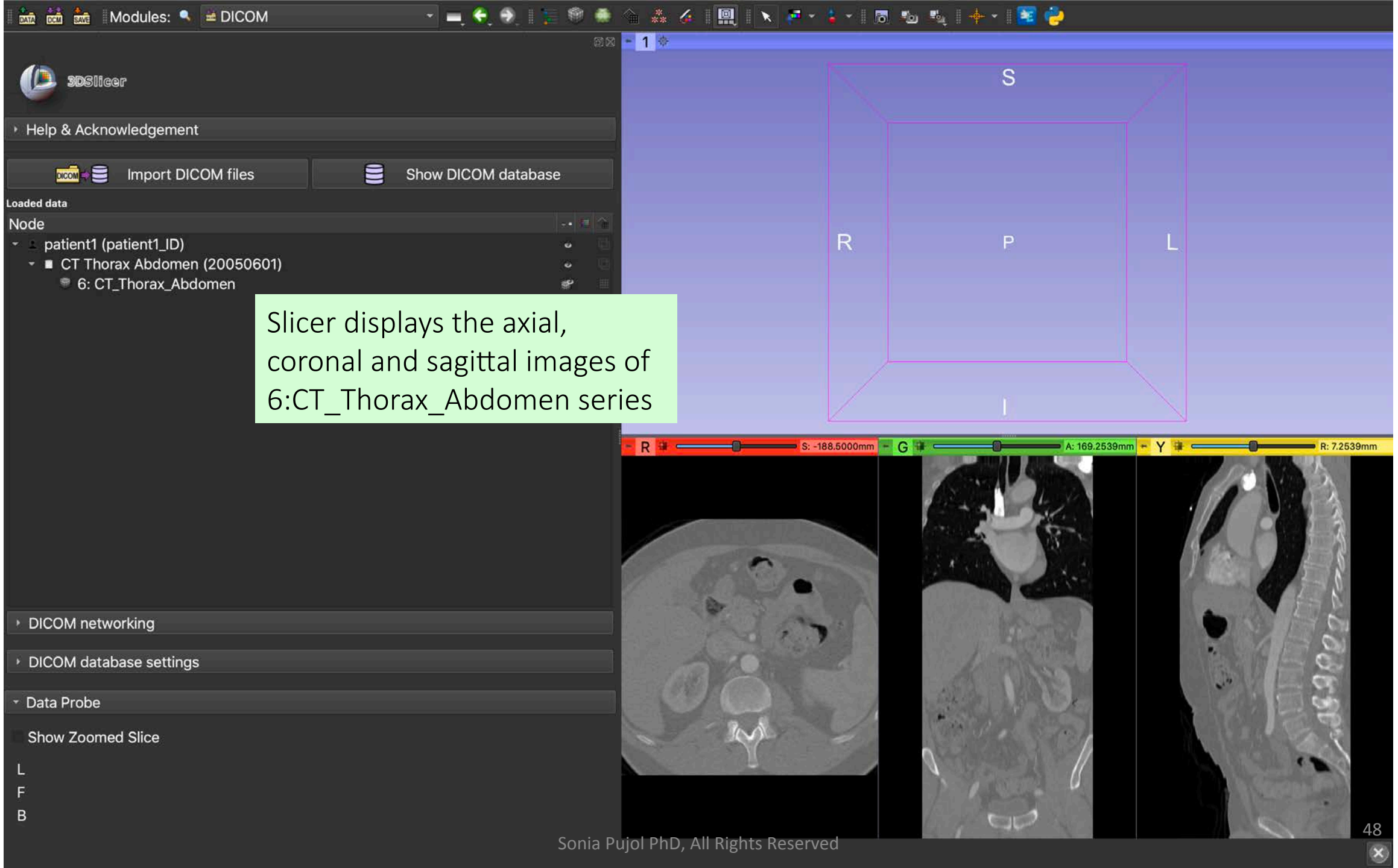

Slicer displays the axial, coronal and sagittal images of 6:CT_Thorax_Abdomen series

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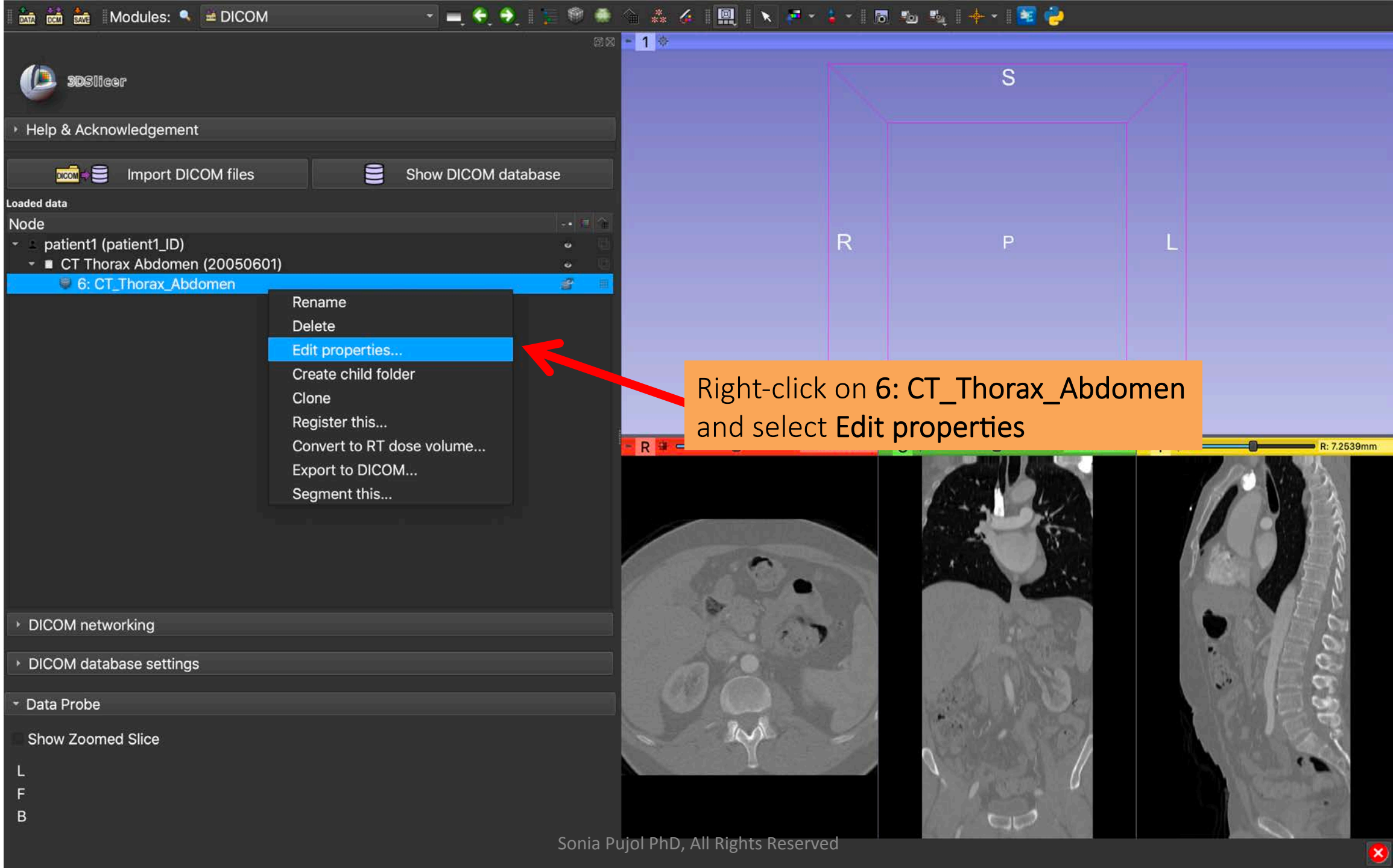

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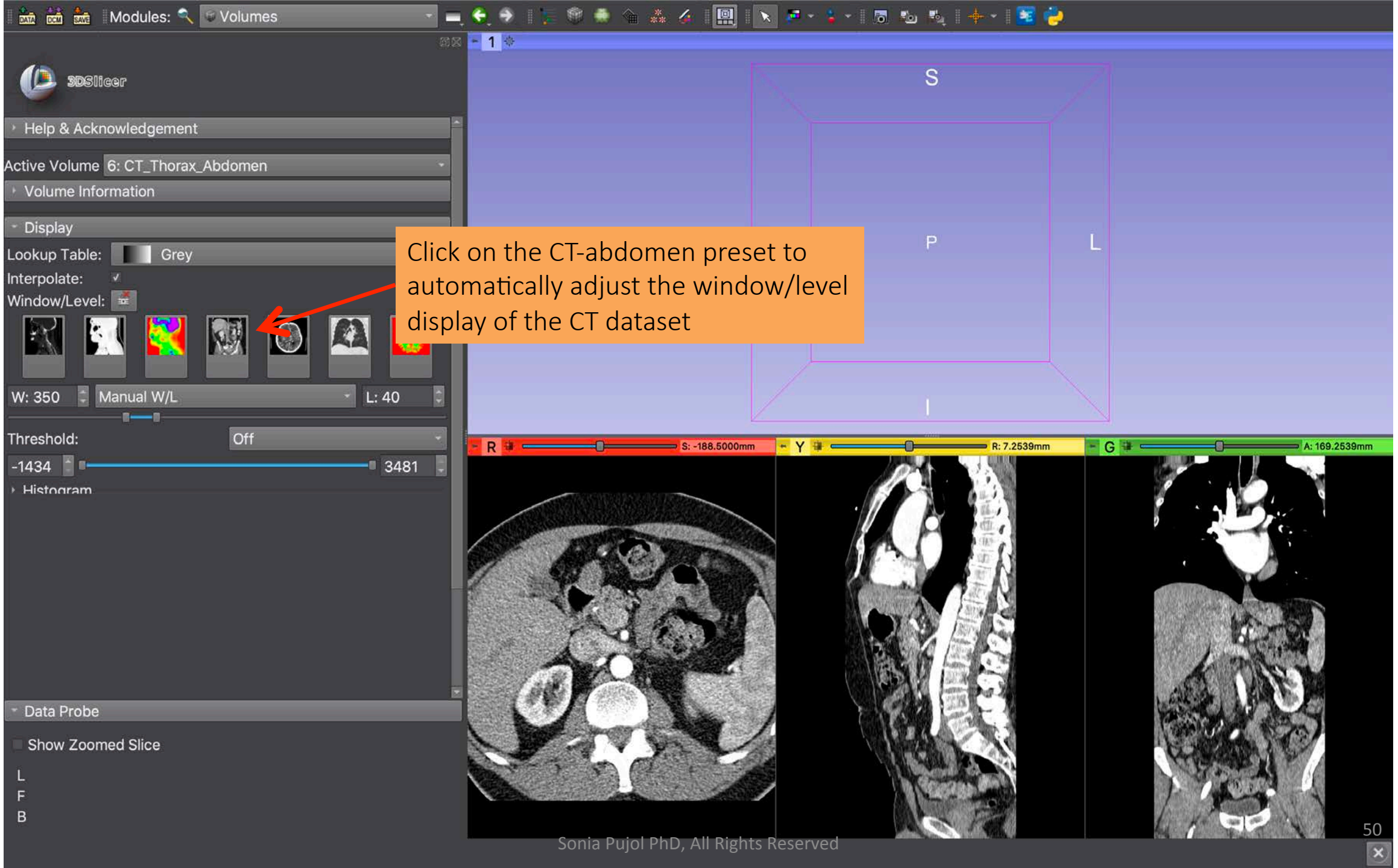

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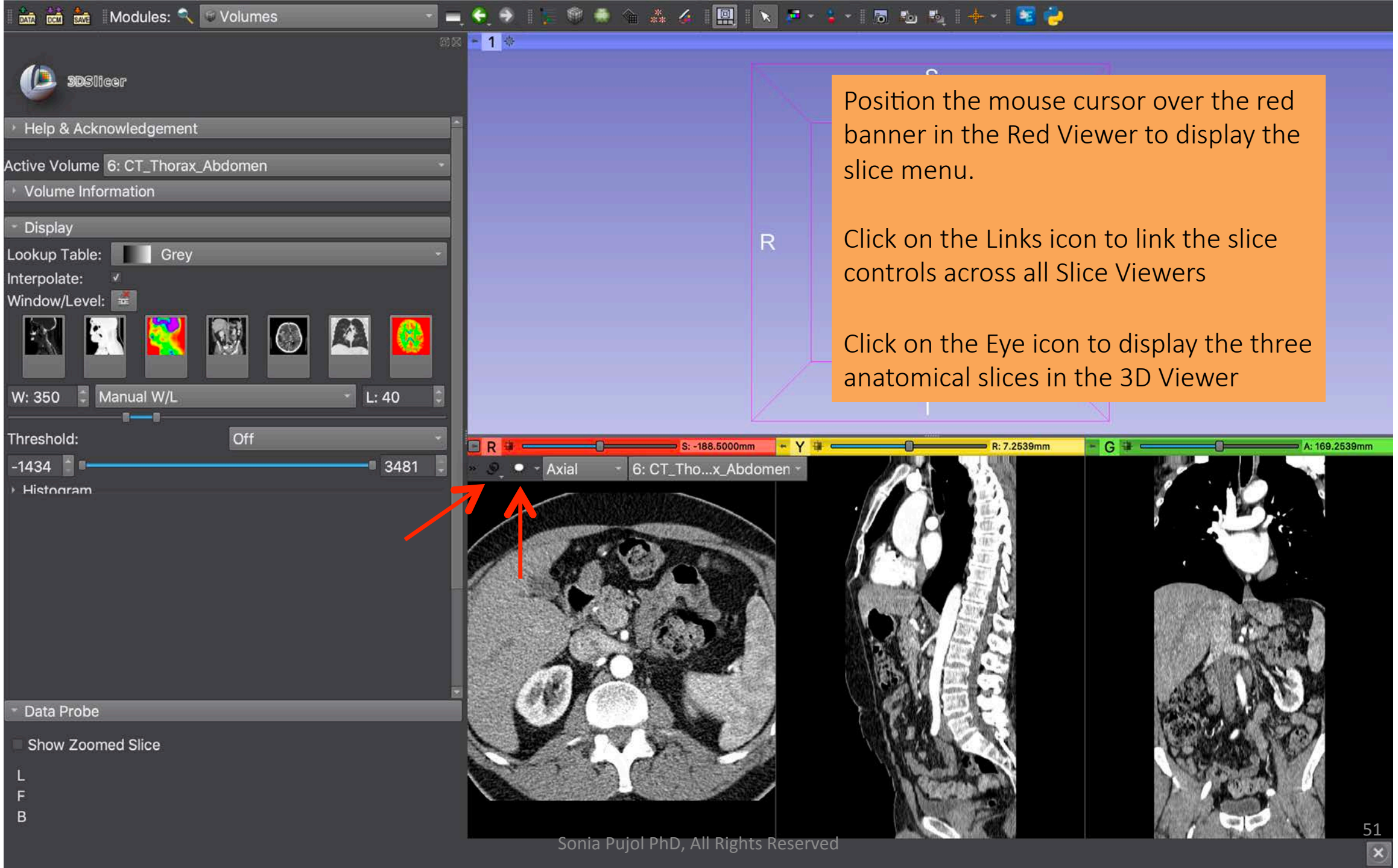

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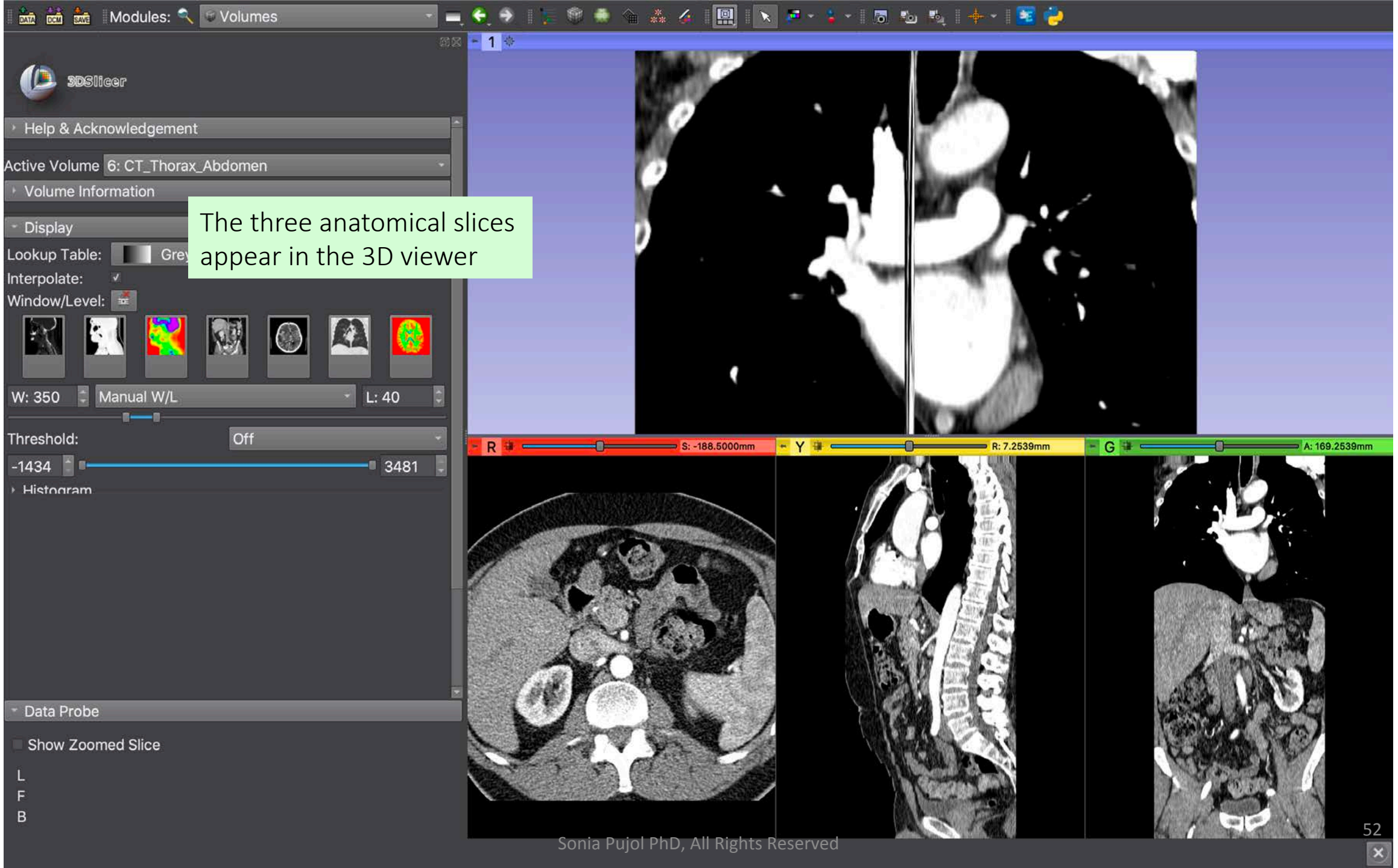

The three anatomical slices appear in the 3D viewer

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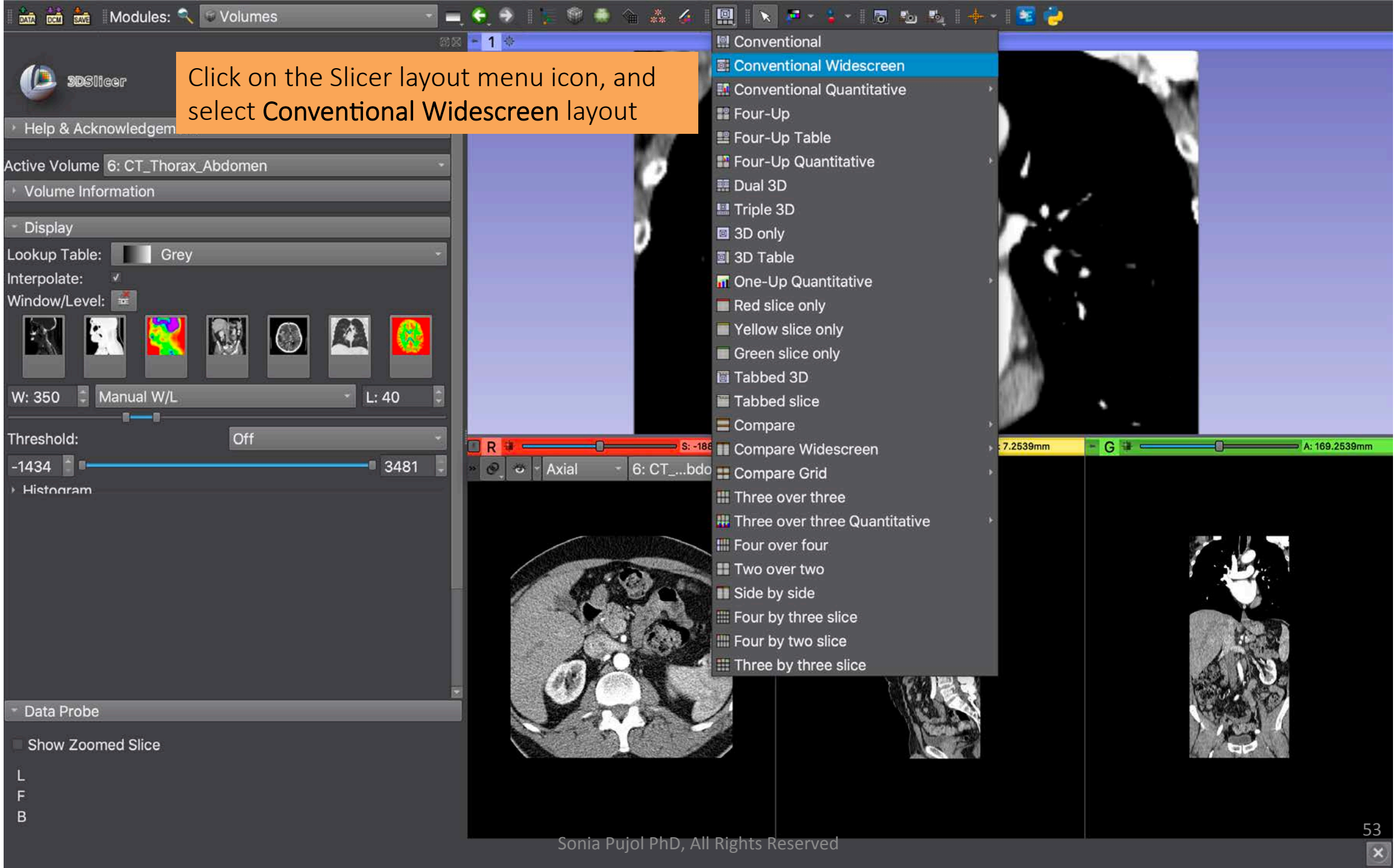

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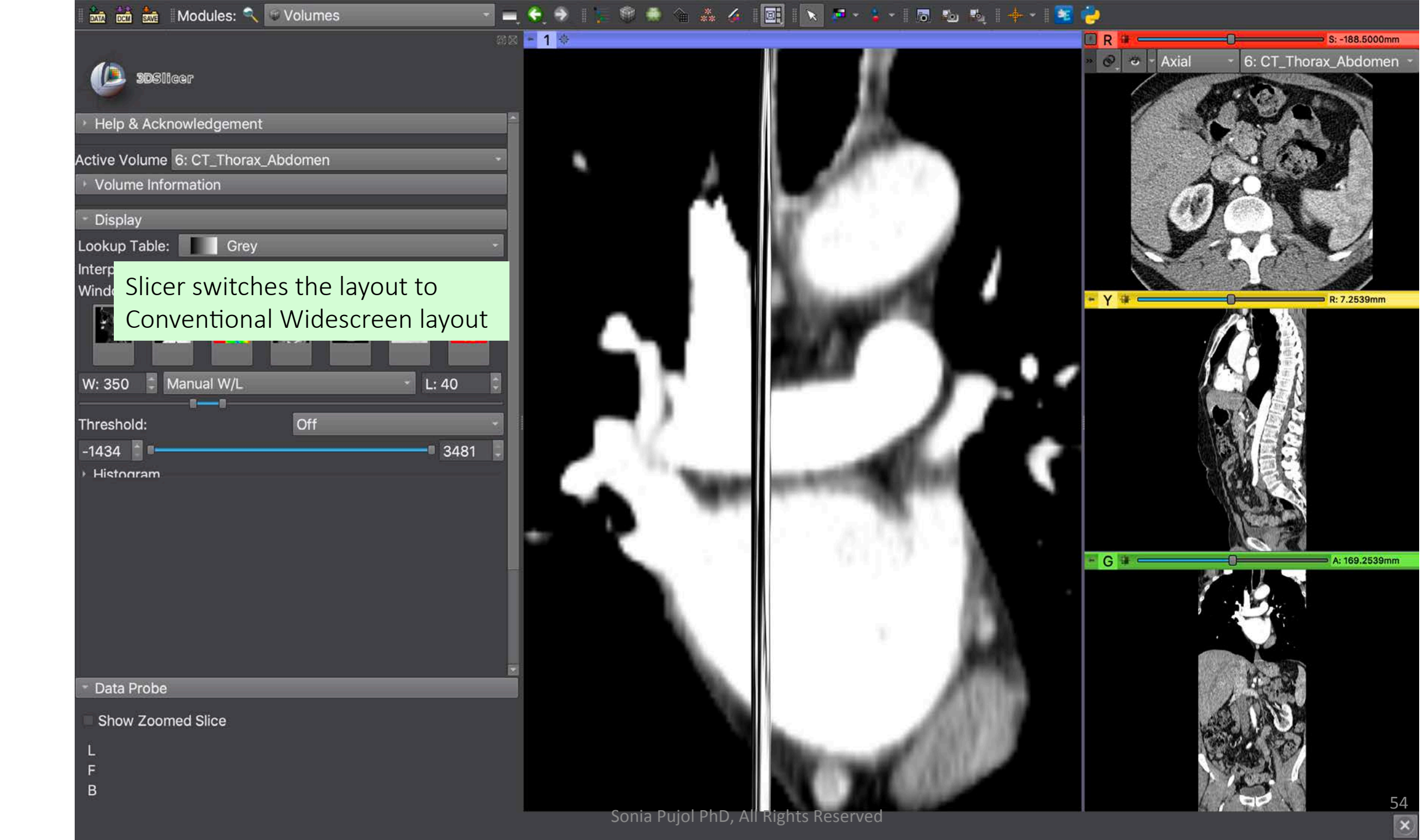

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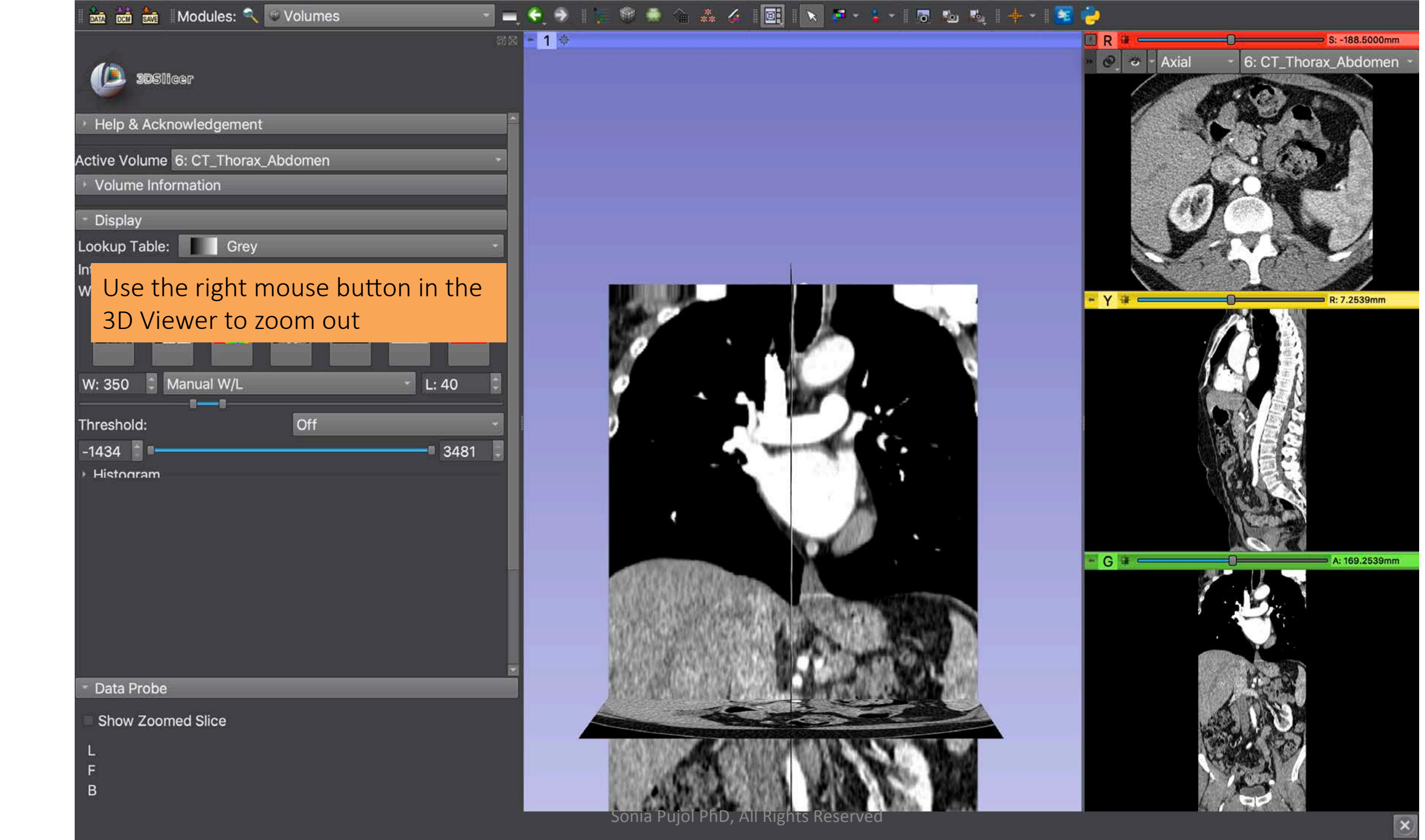

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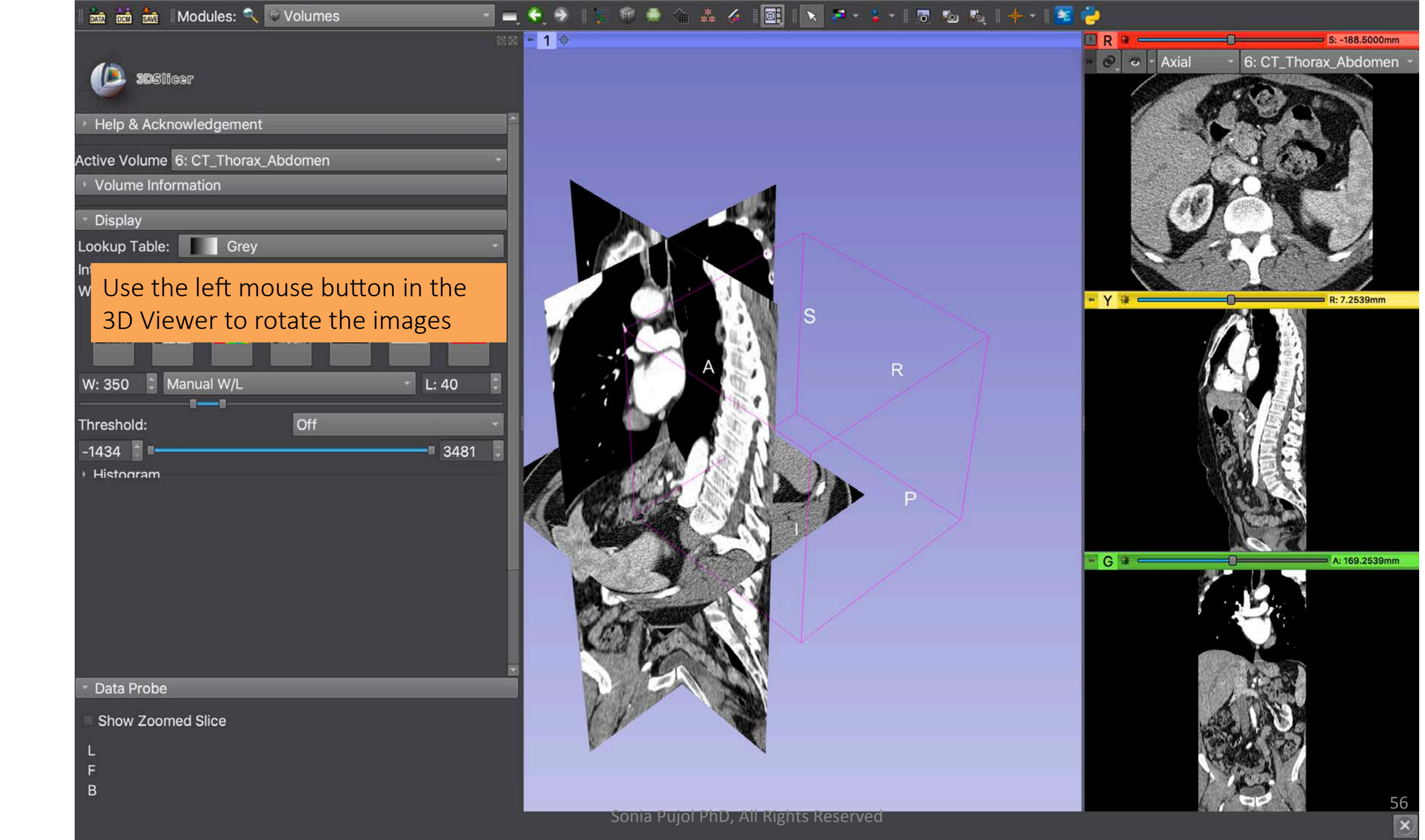

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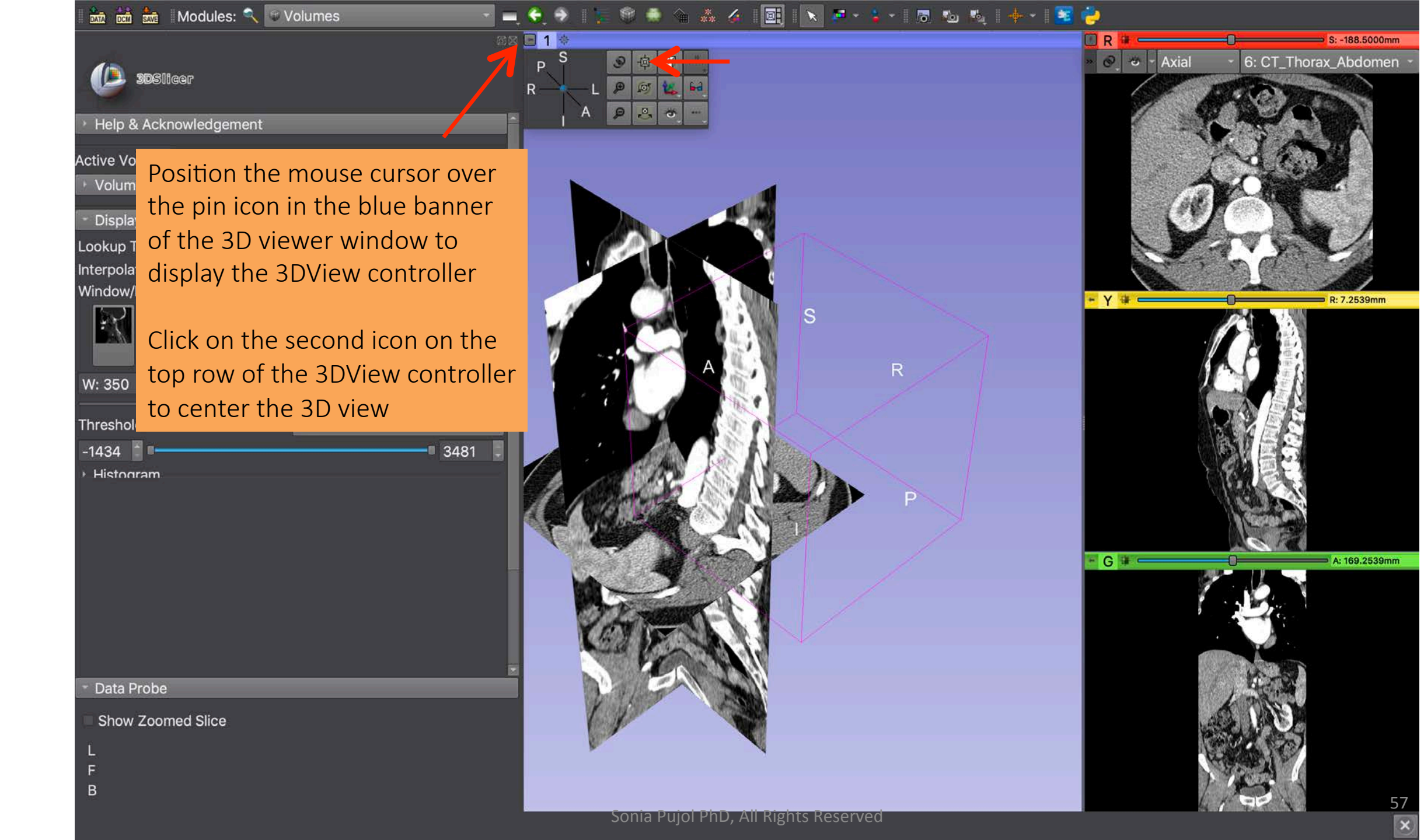

Position the mouse cursor over the pin icon in the blue banner of the 3D viewer window to display the 3DView controller

Click on the second icon on the top row of the 3DView controller to center the 3D view

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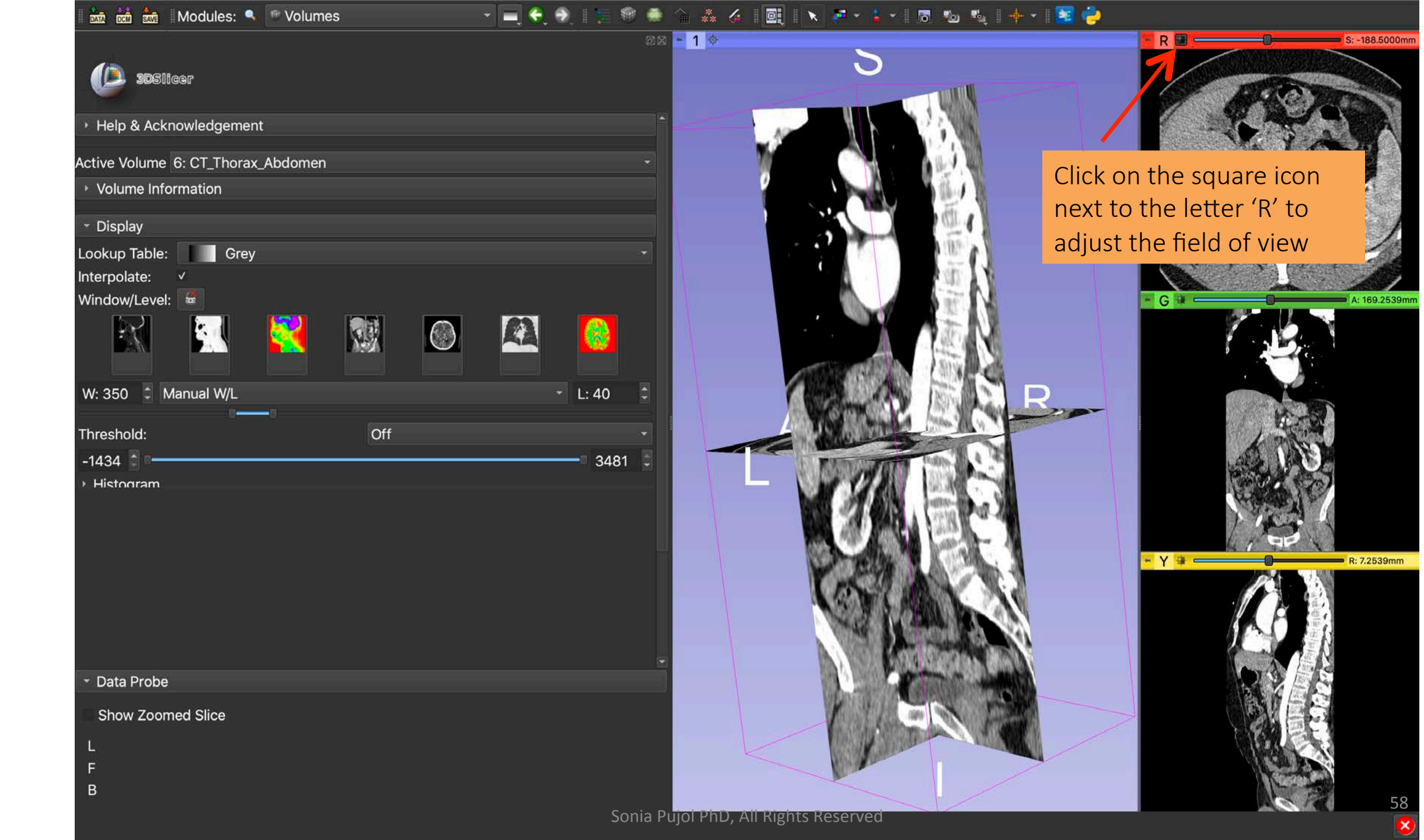

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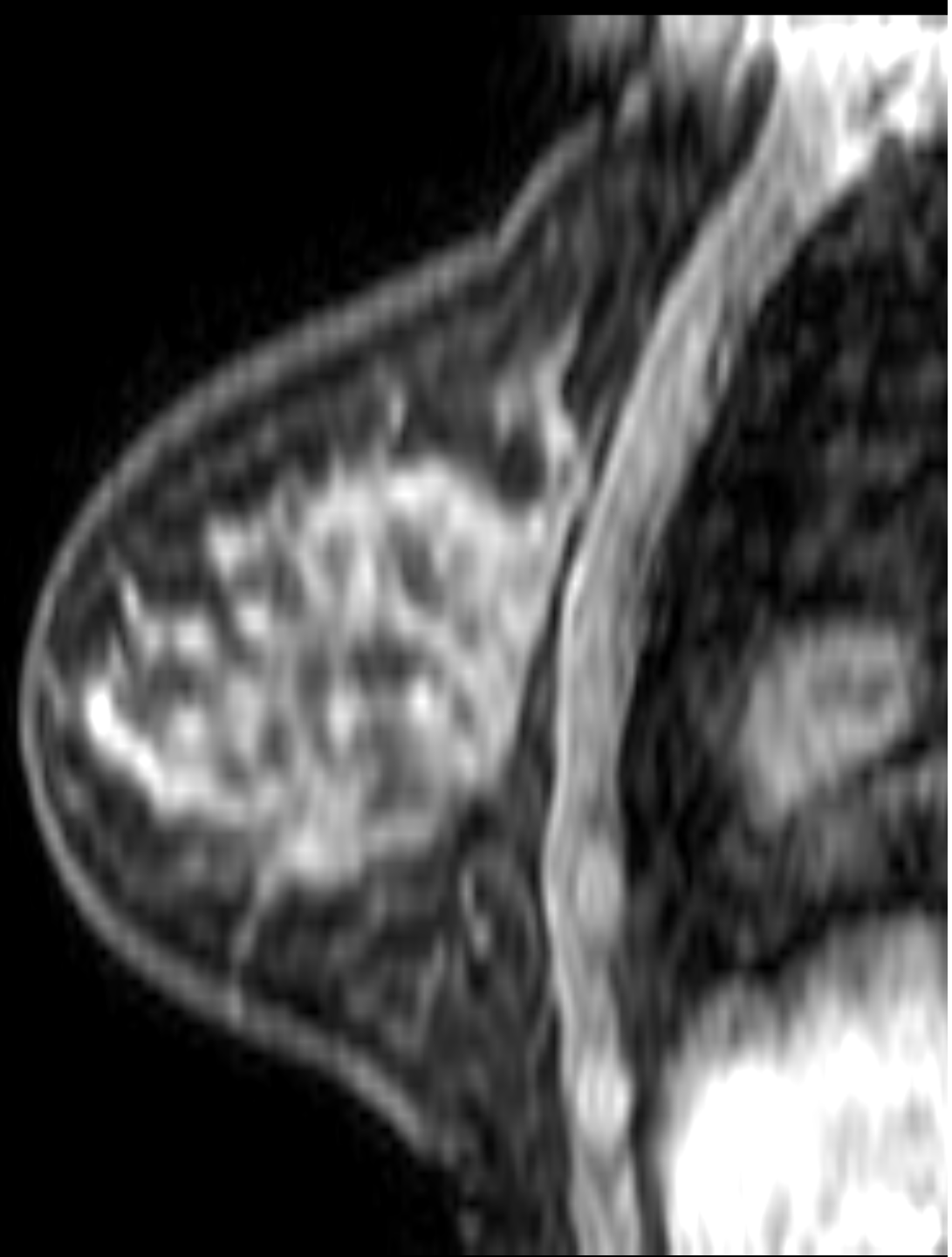

Dataset #2
Breast MRI

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Breast MRI Dataset

- The Breast MRI dataset is part of the BREAST-DIAGNOSIS collection of The Cancer Imaging Archive (TCIA) of the National Cancer Institute
- The dataset was acquired on patient with right breast infiltrating ductal carcinoma
- The DICOM images consist of one study and three series: T2, STIR and BLISS
- BLISS is an MRI sequence for breast MRI studies. BLISS provides the measurement of two bilateral volumes in a single acquisition.

Bloch, B. Nicolas, Jain, Ashali, & Jaffe, C. Carl. (2015). Data From BREAST-DIAGNOSIS. The Cancer Imaging Archive. http://doi.org/10.7937/K9/TCIA.2015.SDNRQXXR

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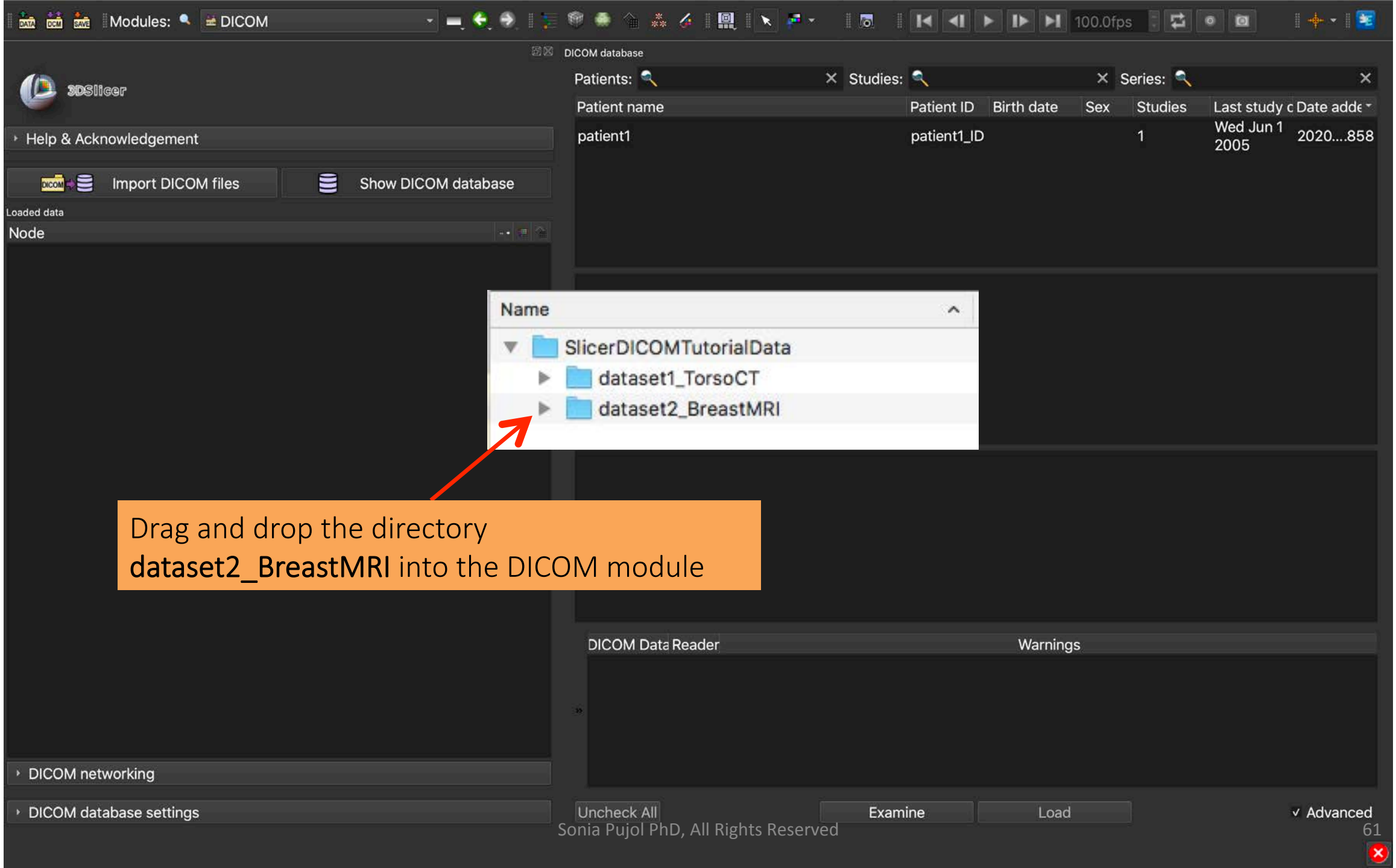

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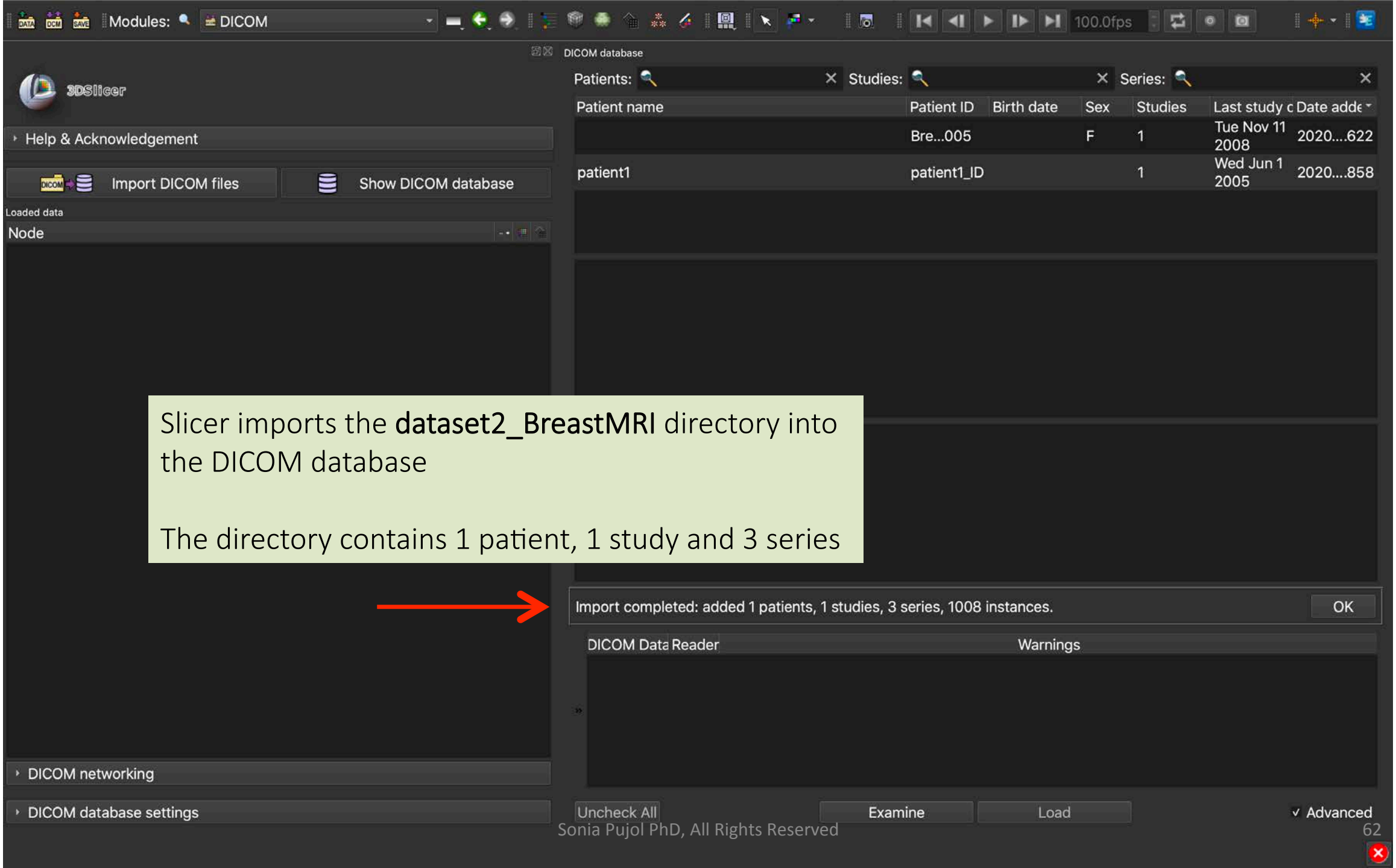

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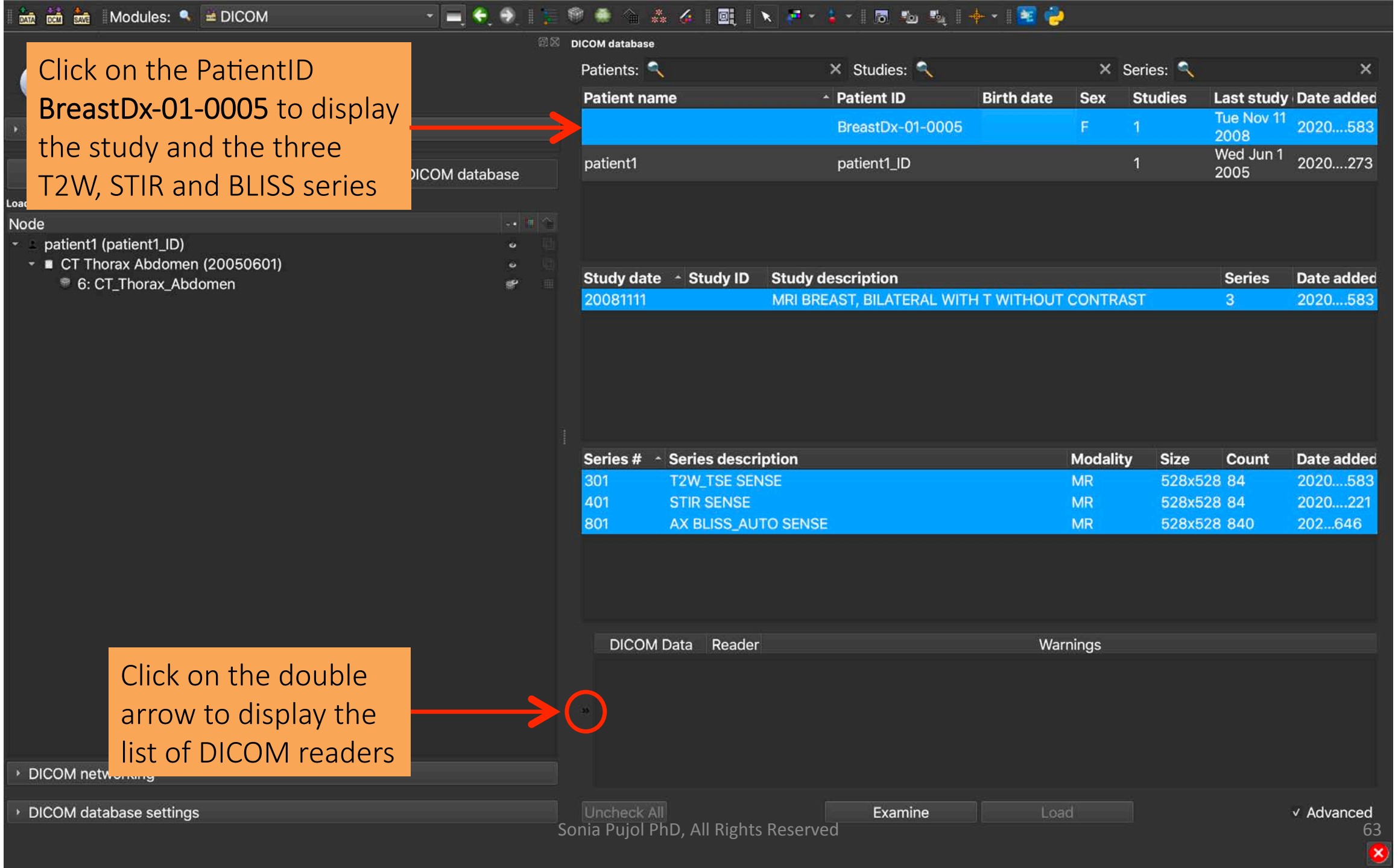

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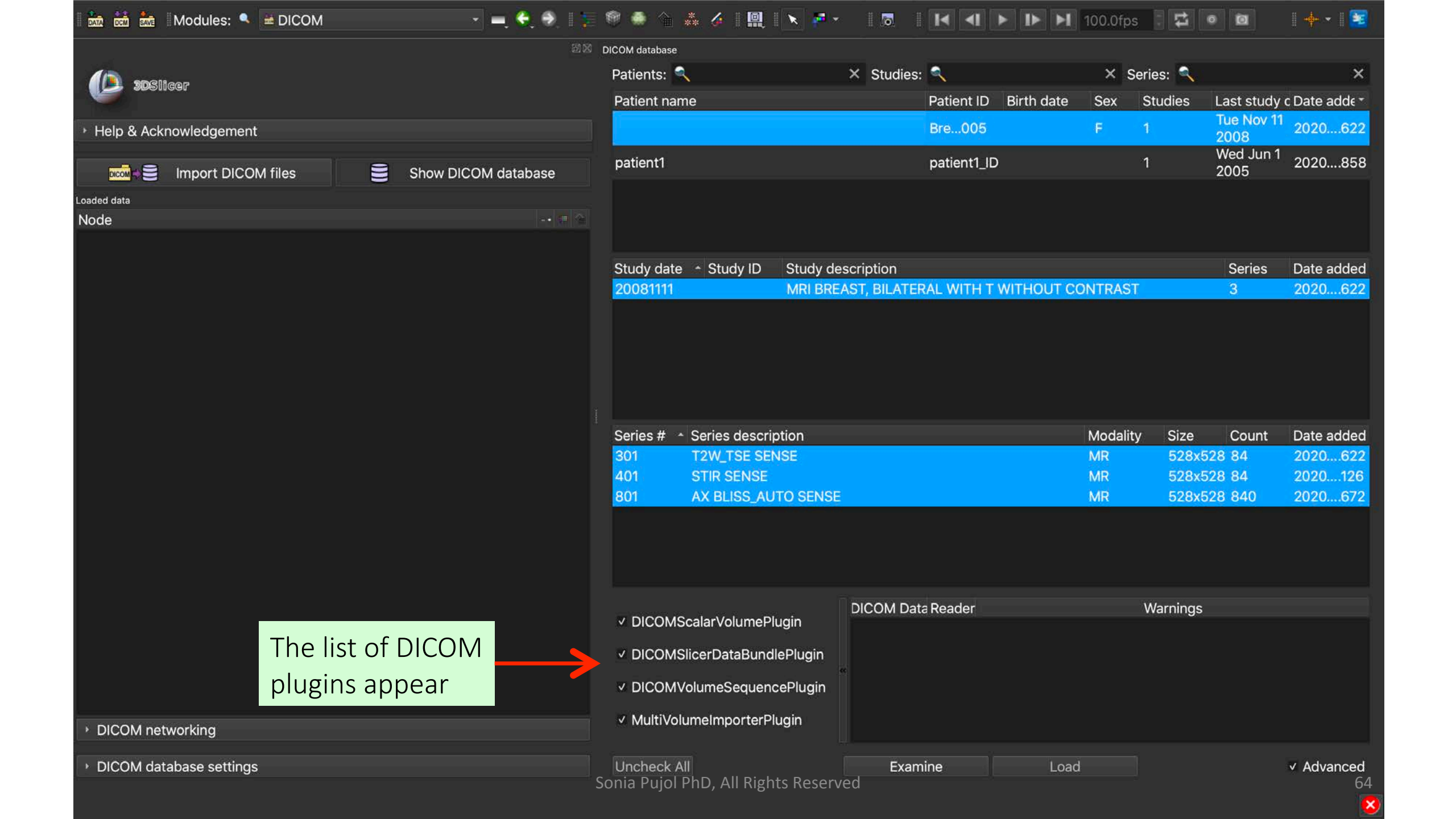

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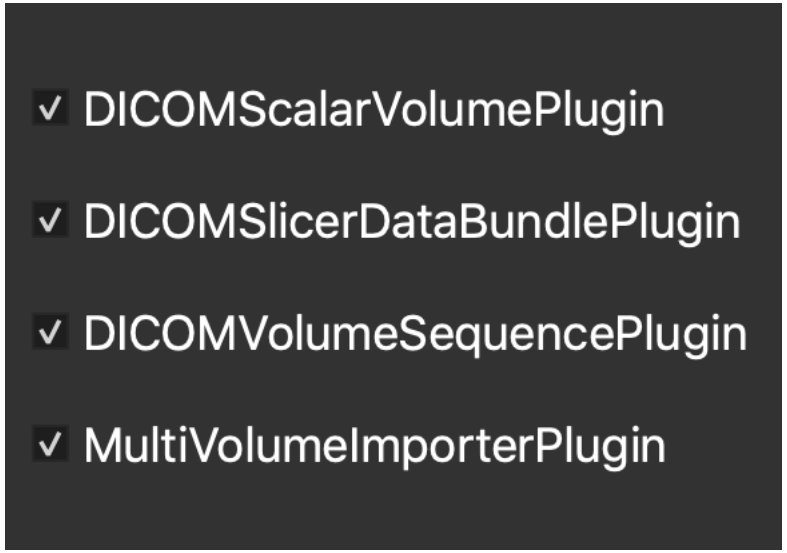
Slicer DICOM Plugins



- Slicer implements a list of DICOM plugins to handle a diverse set of DICOM data objects

- These plugins need to be enabled in order to read specific DICOM data objects such DICOM RT data or DICOM DWI data

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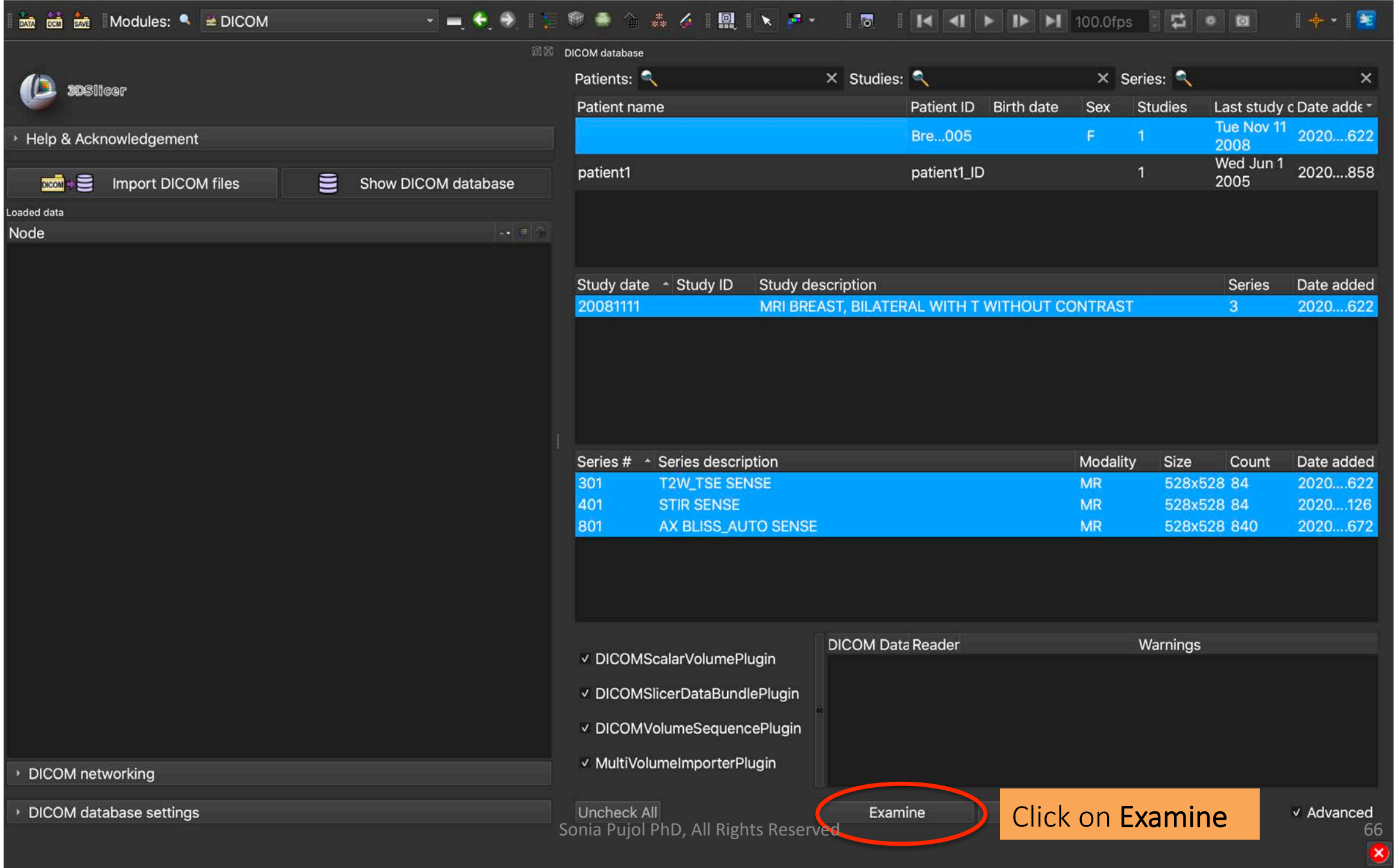

Click on **Examine**

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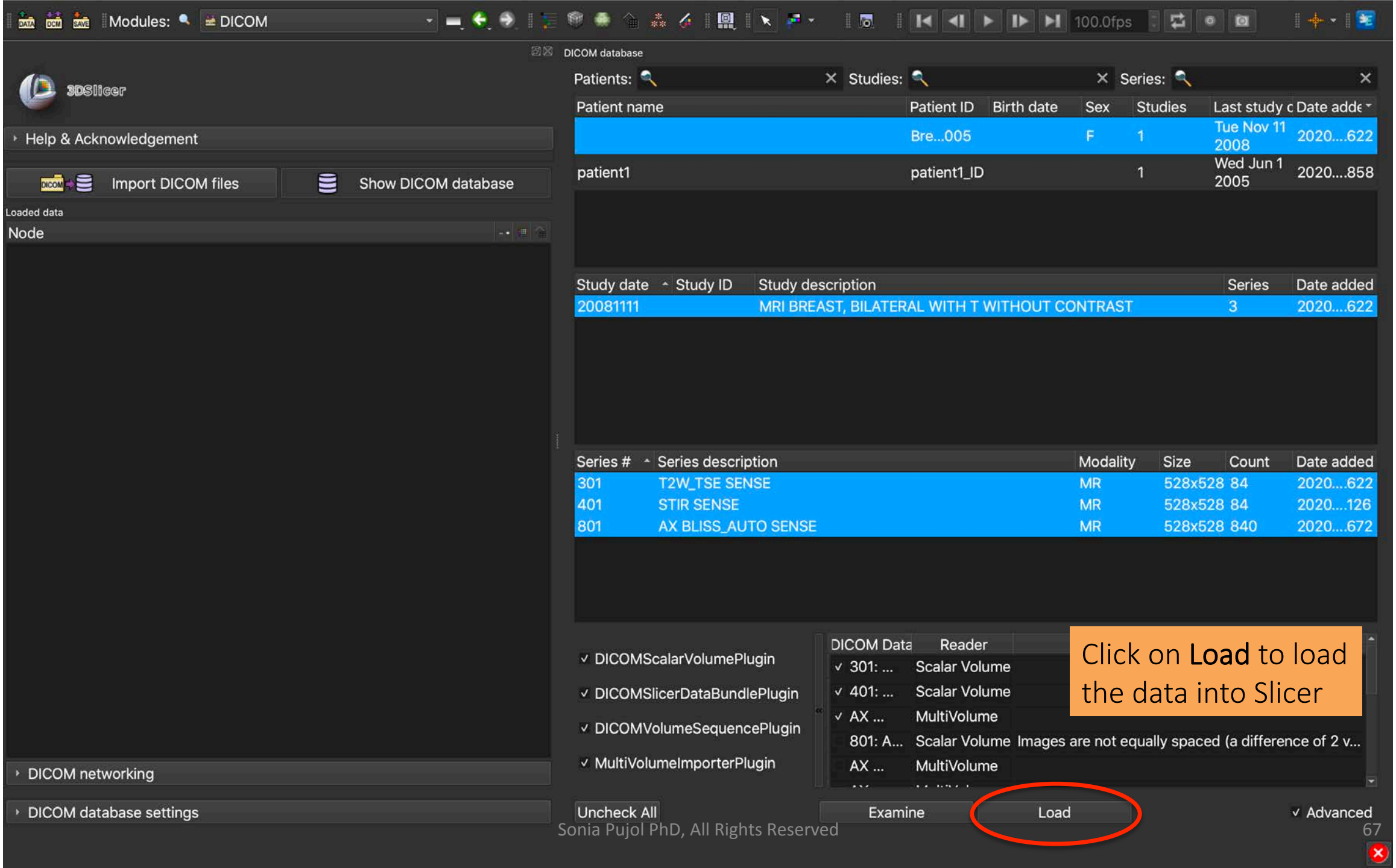

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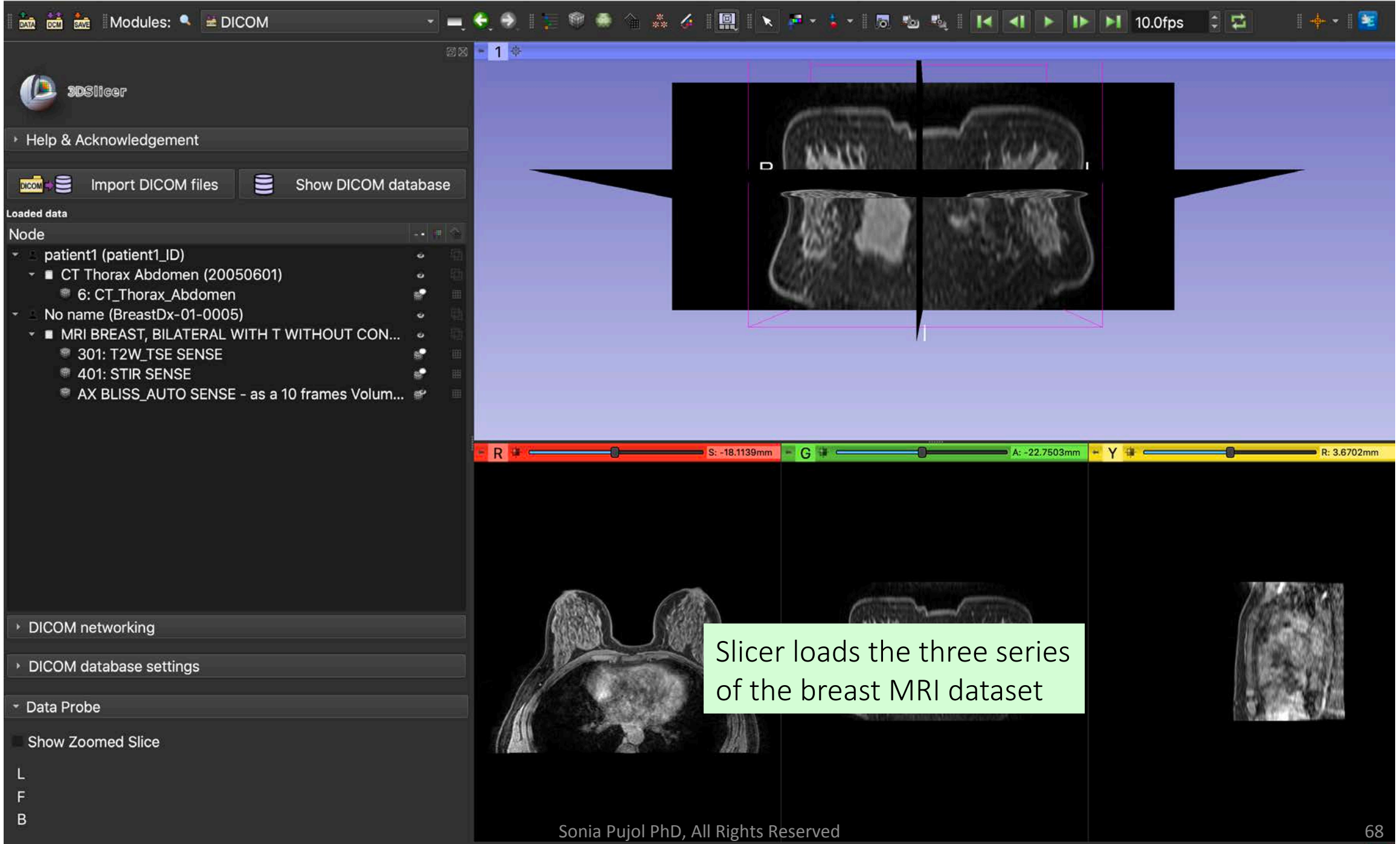

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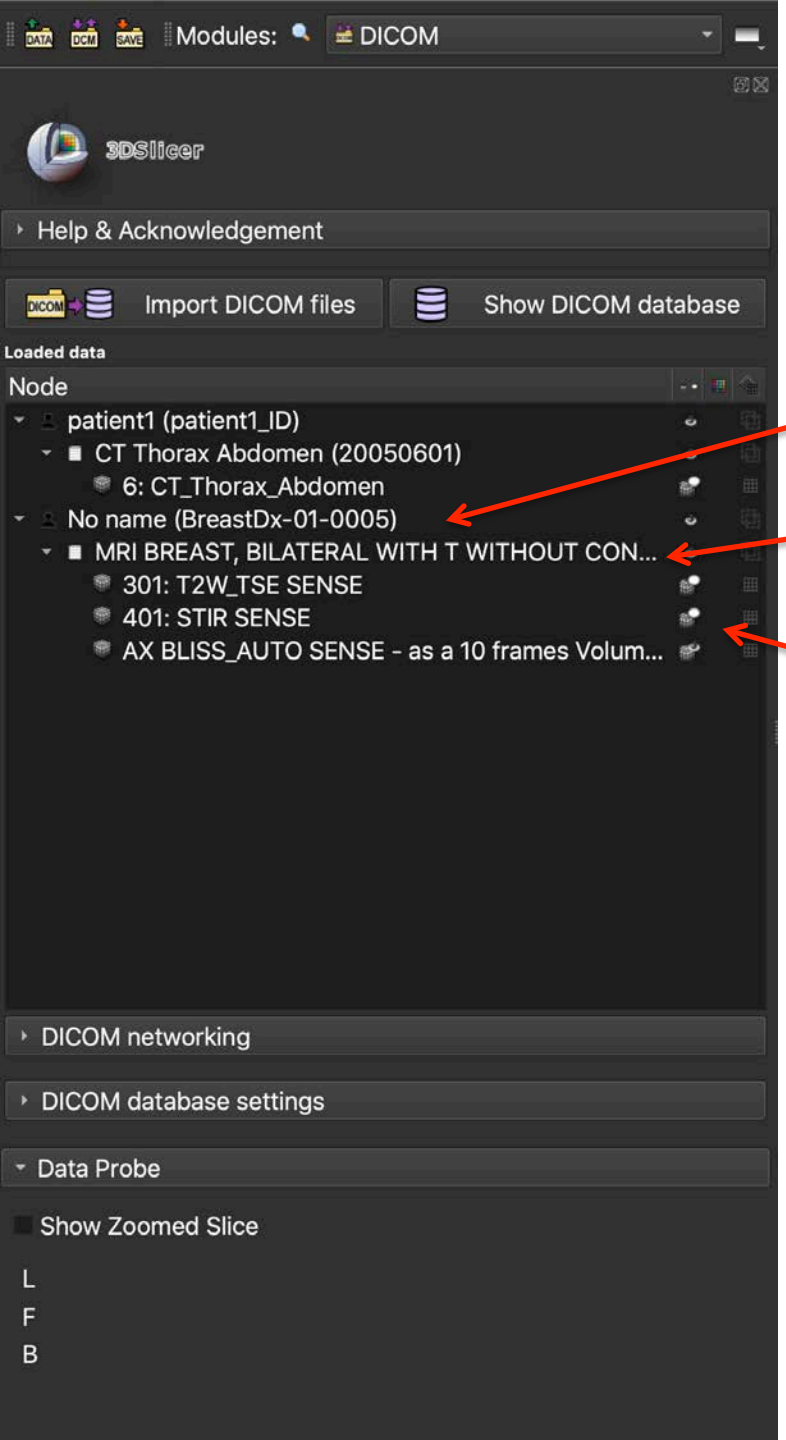
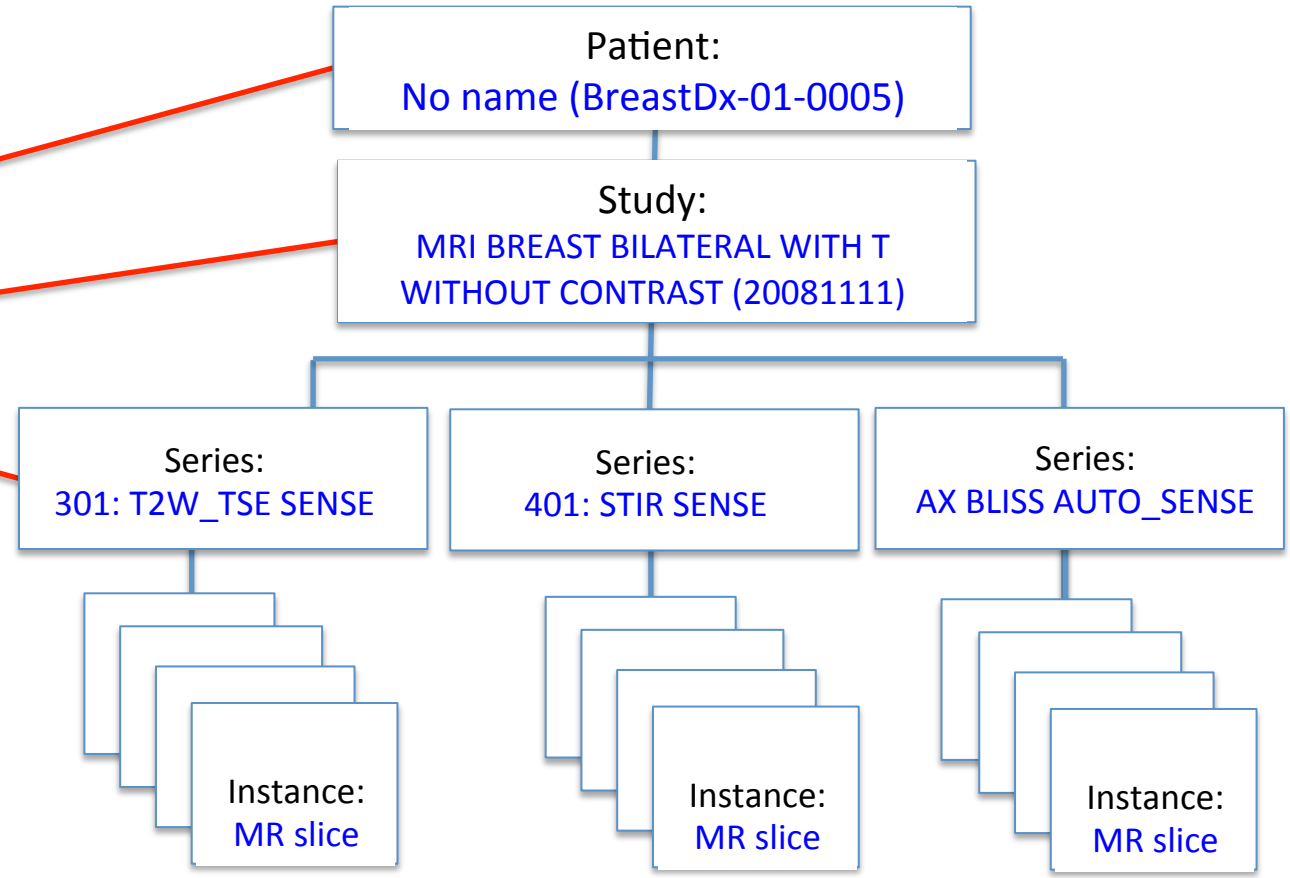
DICOM data are loaded into Slicer as a patient-study-series hierarchy





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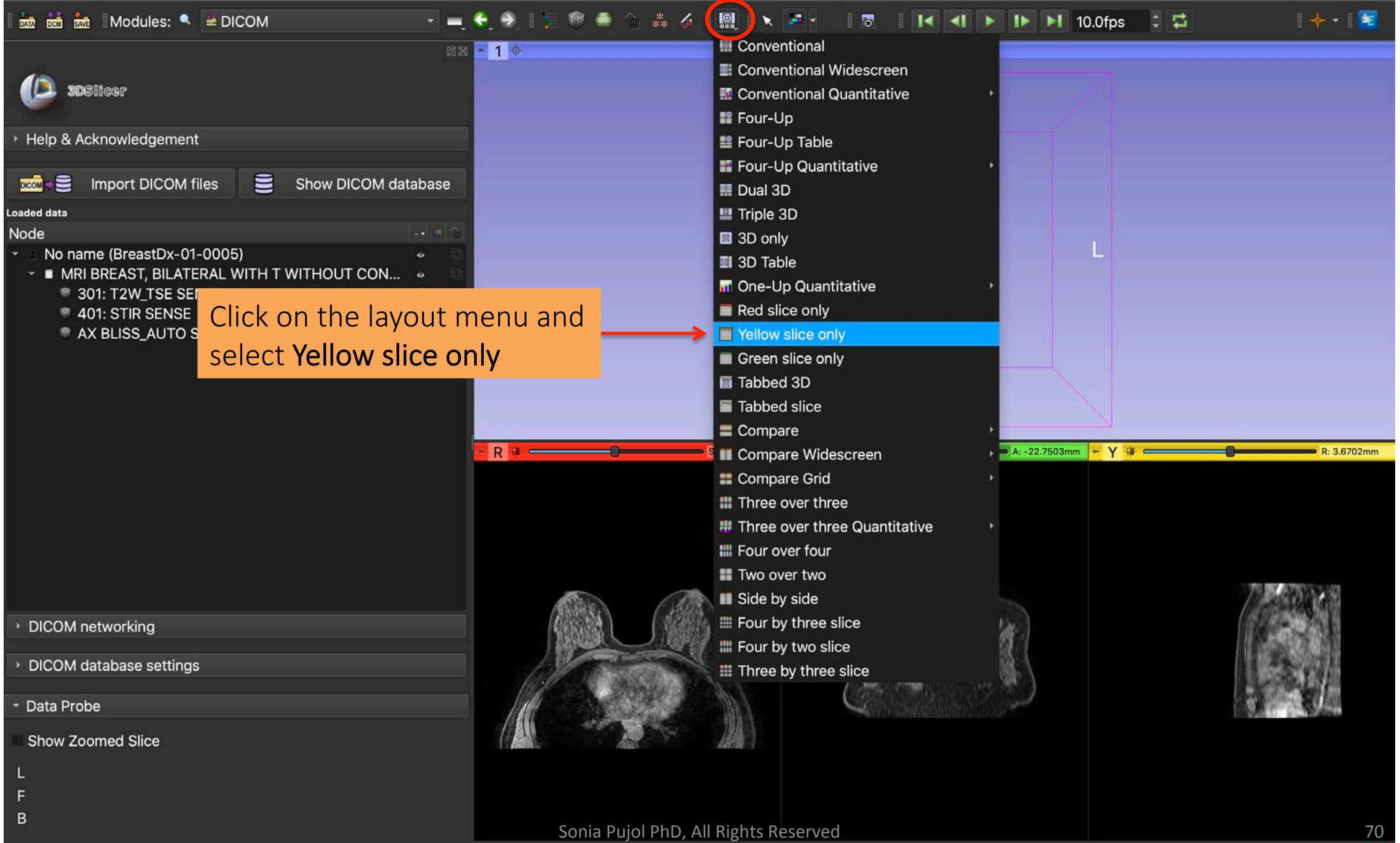

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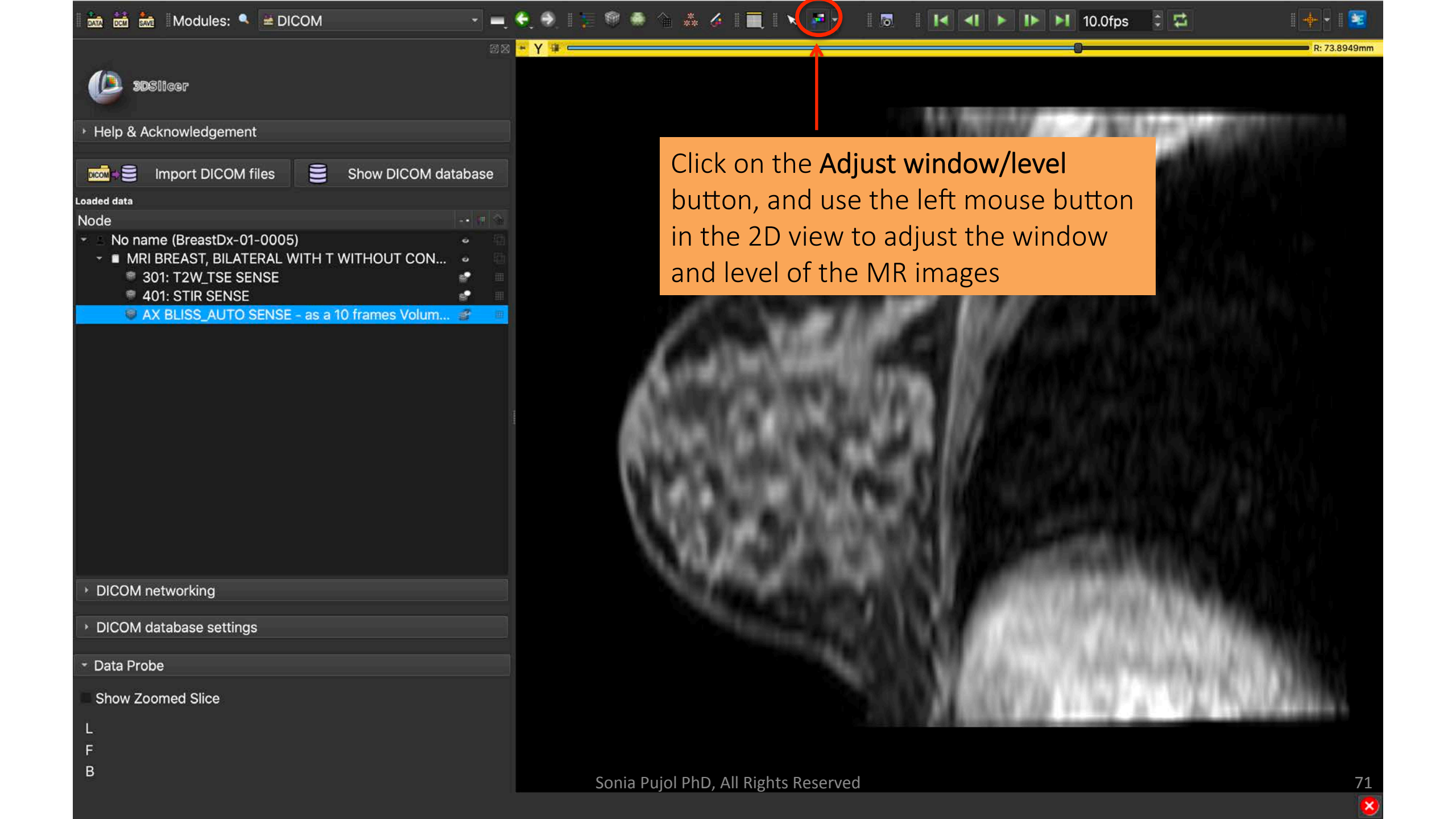

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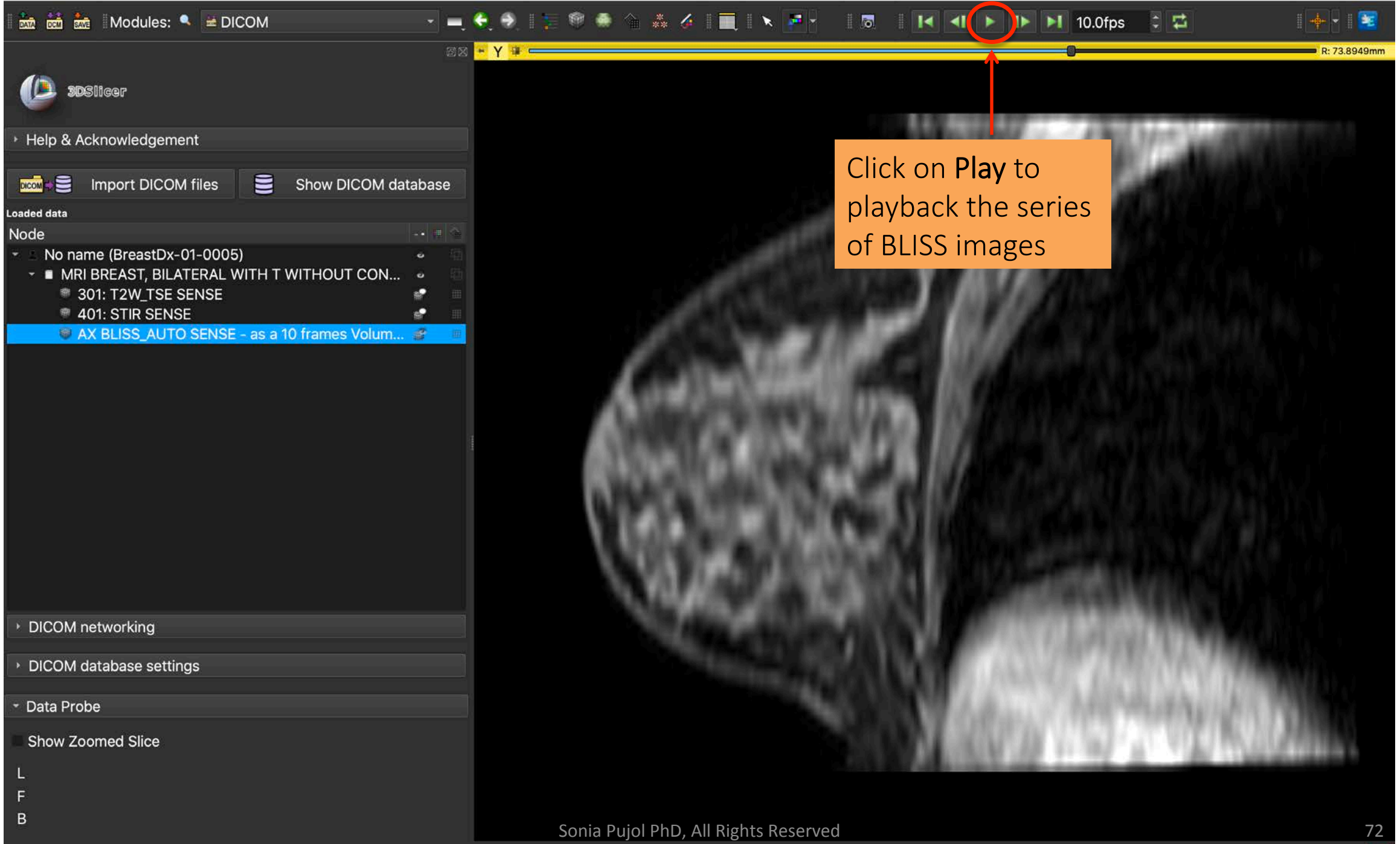

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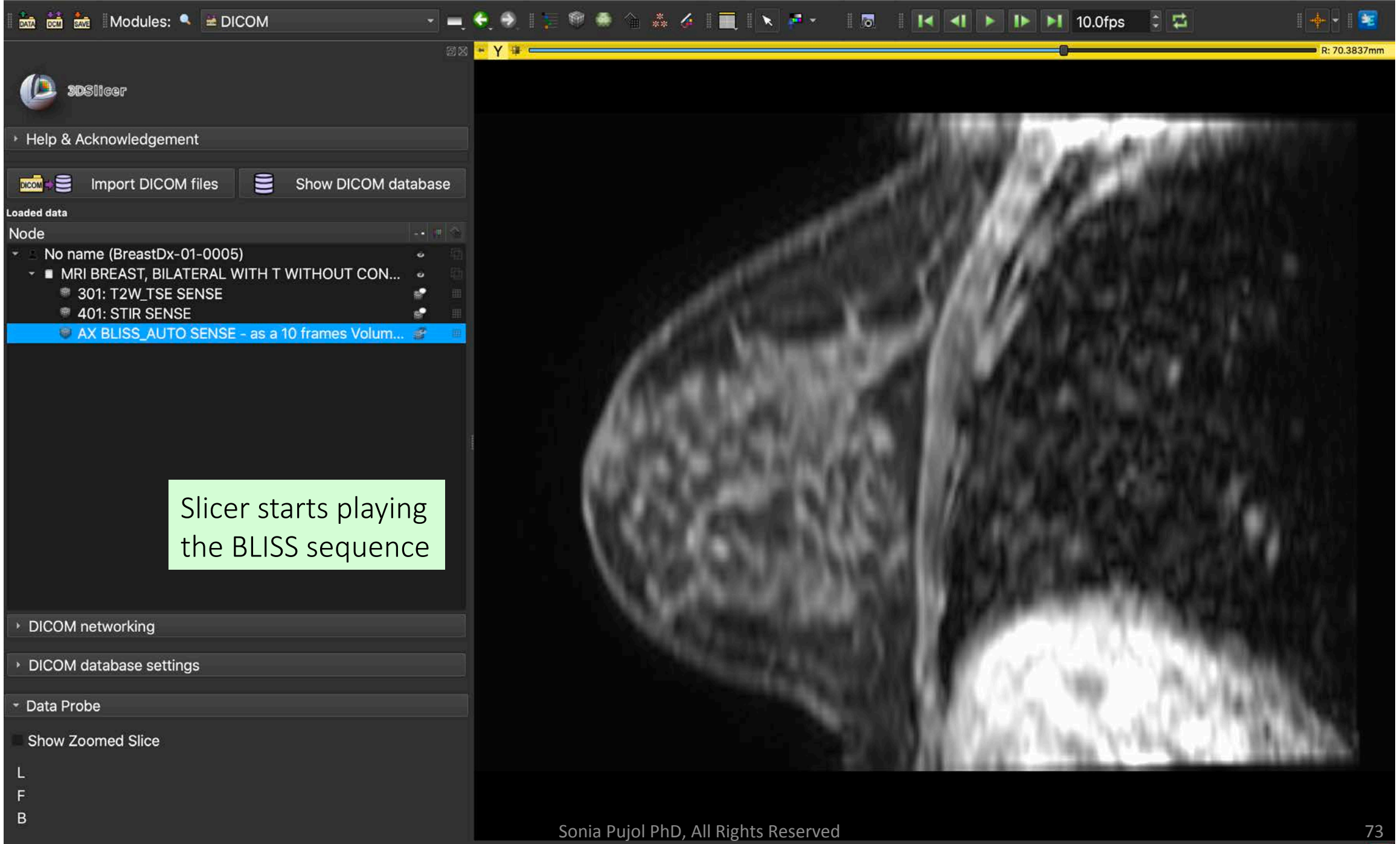

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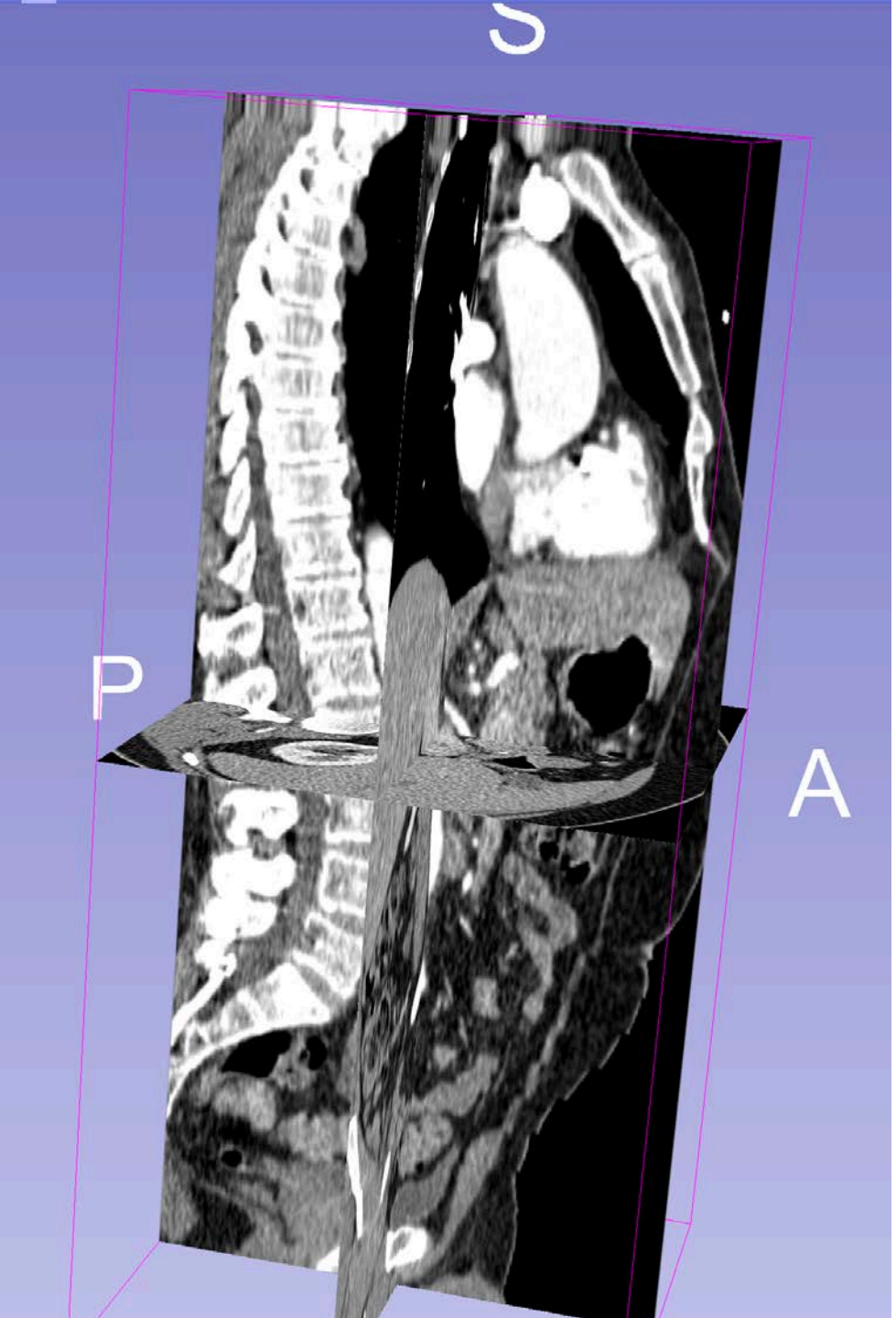

Conclusion

- This tutorial introduced the DICOM standard and showed how to load and visualize DICOM CT and MR images in Slicer
- 3D Slicer and the DICOM standard enable compliance with the FAIR principles for biomedical research
- By enabling interoperability between research and clinical environments, 3D Slicer and the DICOM standard lower the inherent barriers to the translation of research advances to patient care

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Acknowledgments

Neuroimaging Analysis Center
(NIBIB P41 EB015902)