



DICOM and Slicer: A Tutorial

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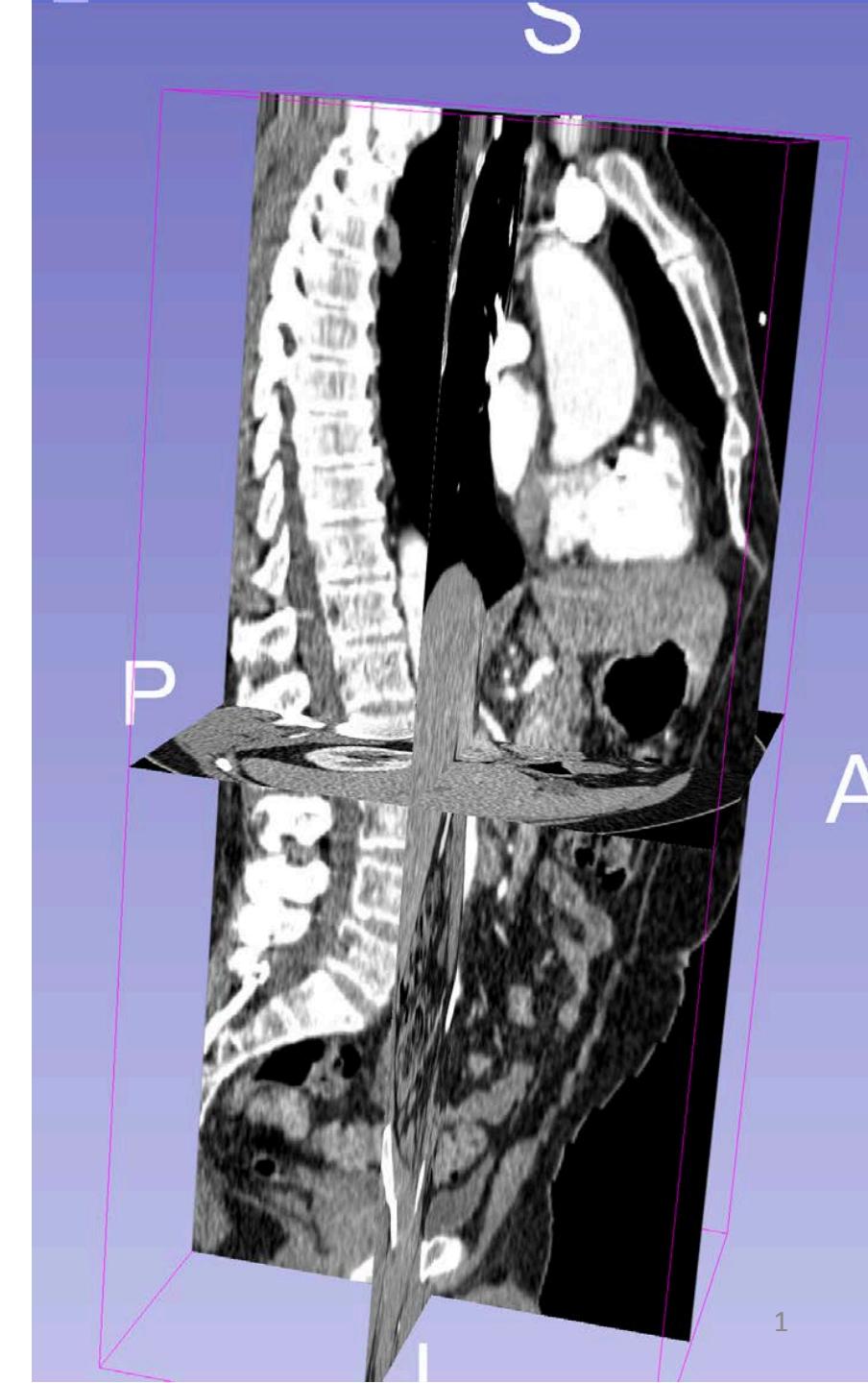
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Objective

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



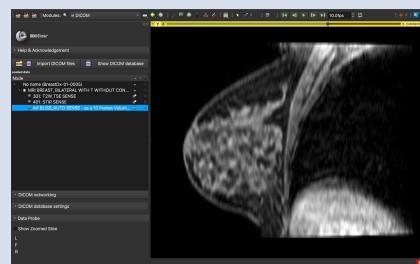
Tutorial Outline



Part 1: Introduction to DICOM



Part 2: DICOM and Slicer



Part 3: Loading and Visualizing DICOM data in Slicer

Tutorial material

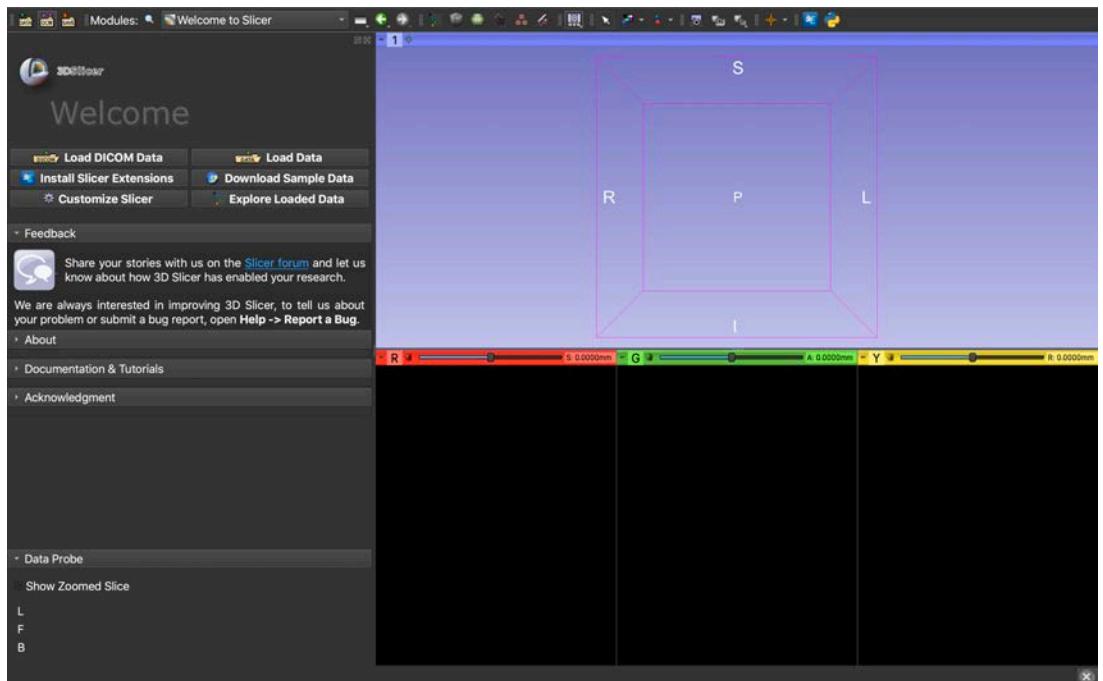
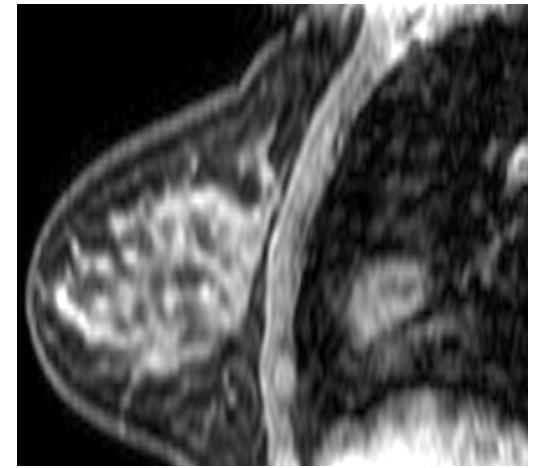
3D Slicer version 5.0

<https://download.slicer.org>

SlicerDICOMTutorialData

DICOM Torso CT

DICOM Breast MRI



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



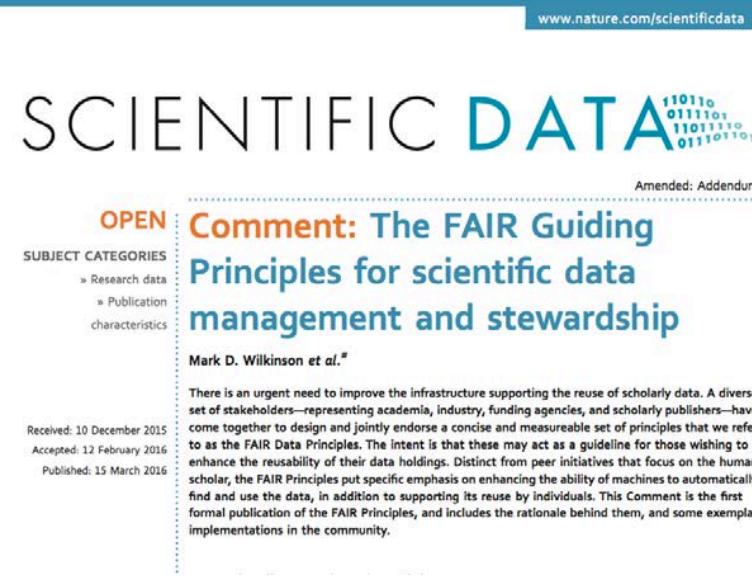
Part 1: Introduction to DICOM

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



F.A.I.R. Principles



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

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



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

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 by the DICOM Standard Committee to develop the Standard for a particular modality, clinical domain or technical area (e.g. WG-16 Magnetic Resonance) <http://dicomstandard.org>

FAIR Data and the DICOM Standard

www.nature.com/scientificdata

SCIENTIFIC DATA 1101110
0111101
11011110
011101101

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Amended: Addendum

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

Mark D. Wilkinson et al.*

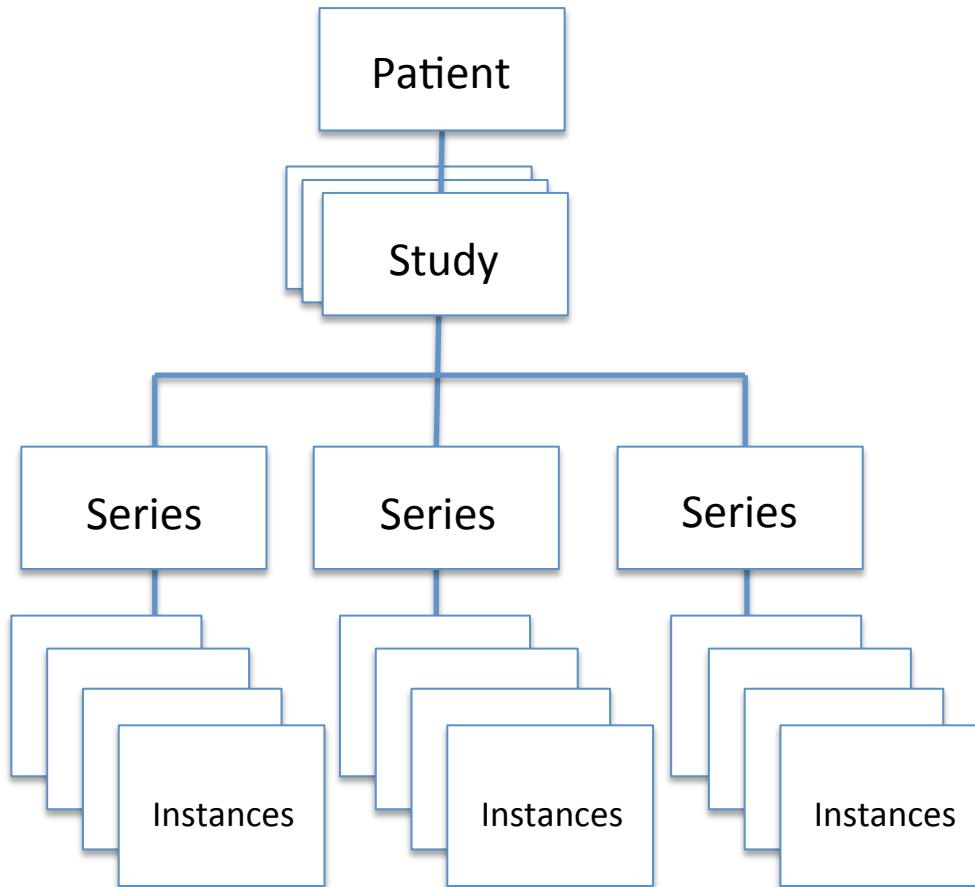
Received: 10 December 2015
Accepted: 12 February 2016
Published: 15 March 2016

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 measurable 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.



The DICOM Standard facilitates compliance of imaging data with FAIR principles

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**)

Example of DICOM instances: DICOM MRI Image data

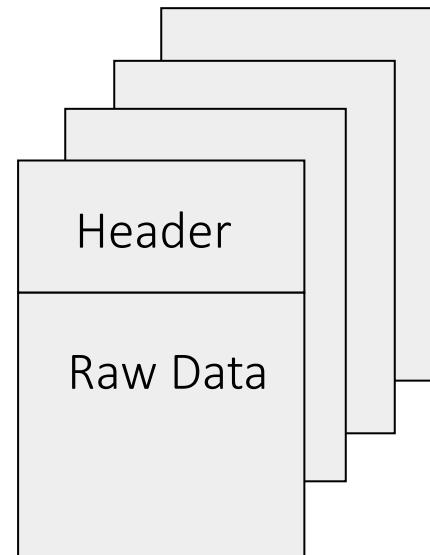
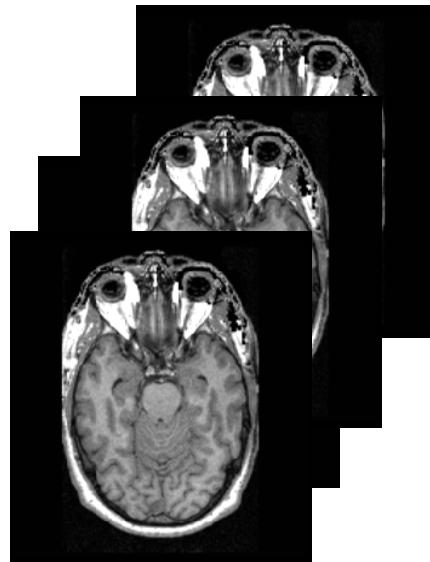


Image001.dcm

Image002.dcm

Image003.dcm

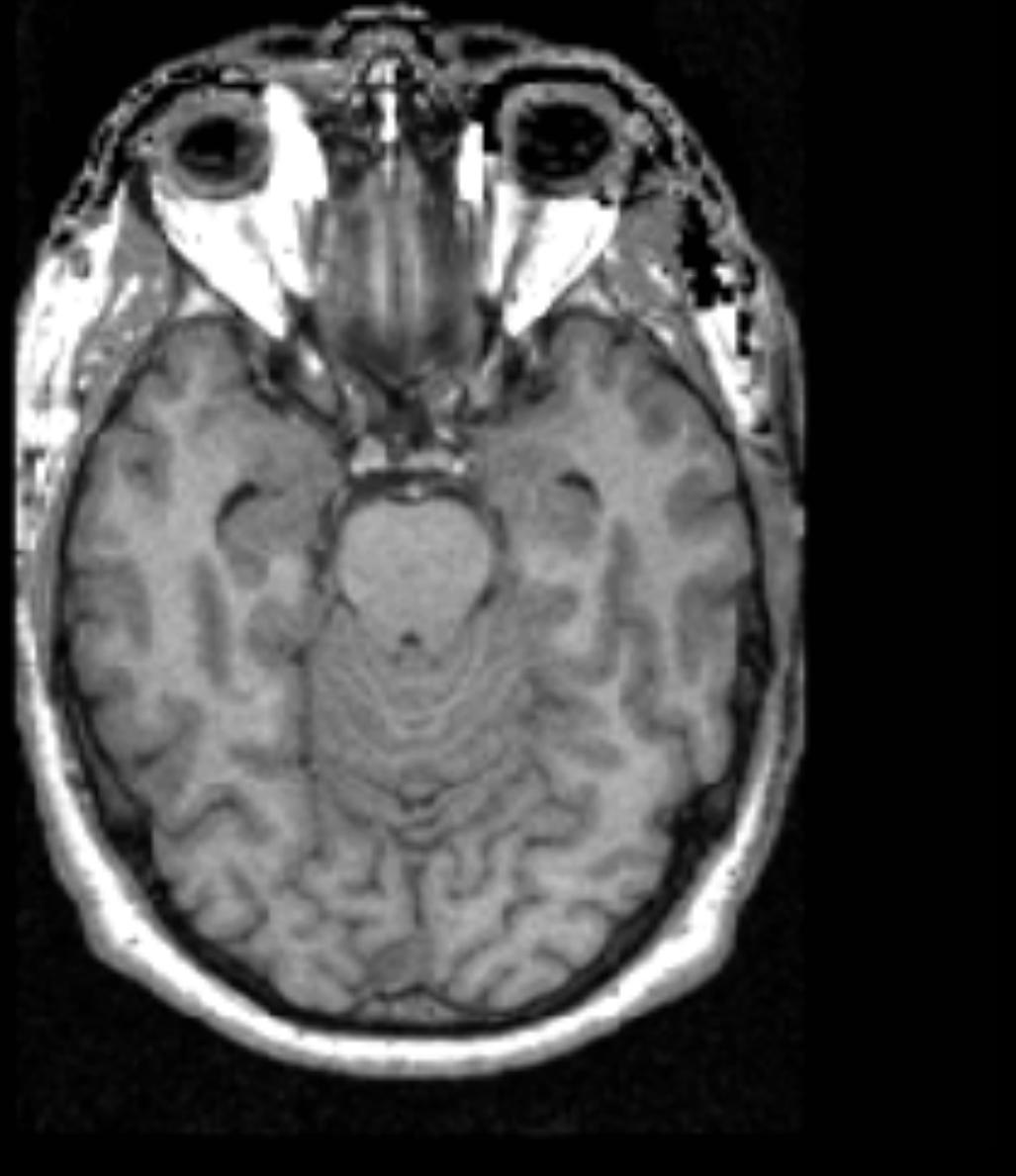
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An MRI image is an example of DICOM instance that consists of a DICOM header and an image dataset

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Example of DICOM header content

- The **DICOM header** contains metadata information on the patient, study and imaging data.
- 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



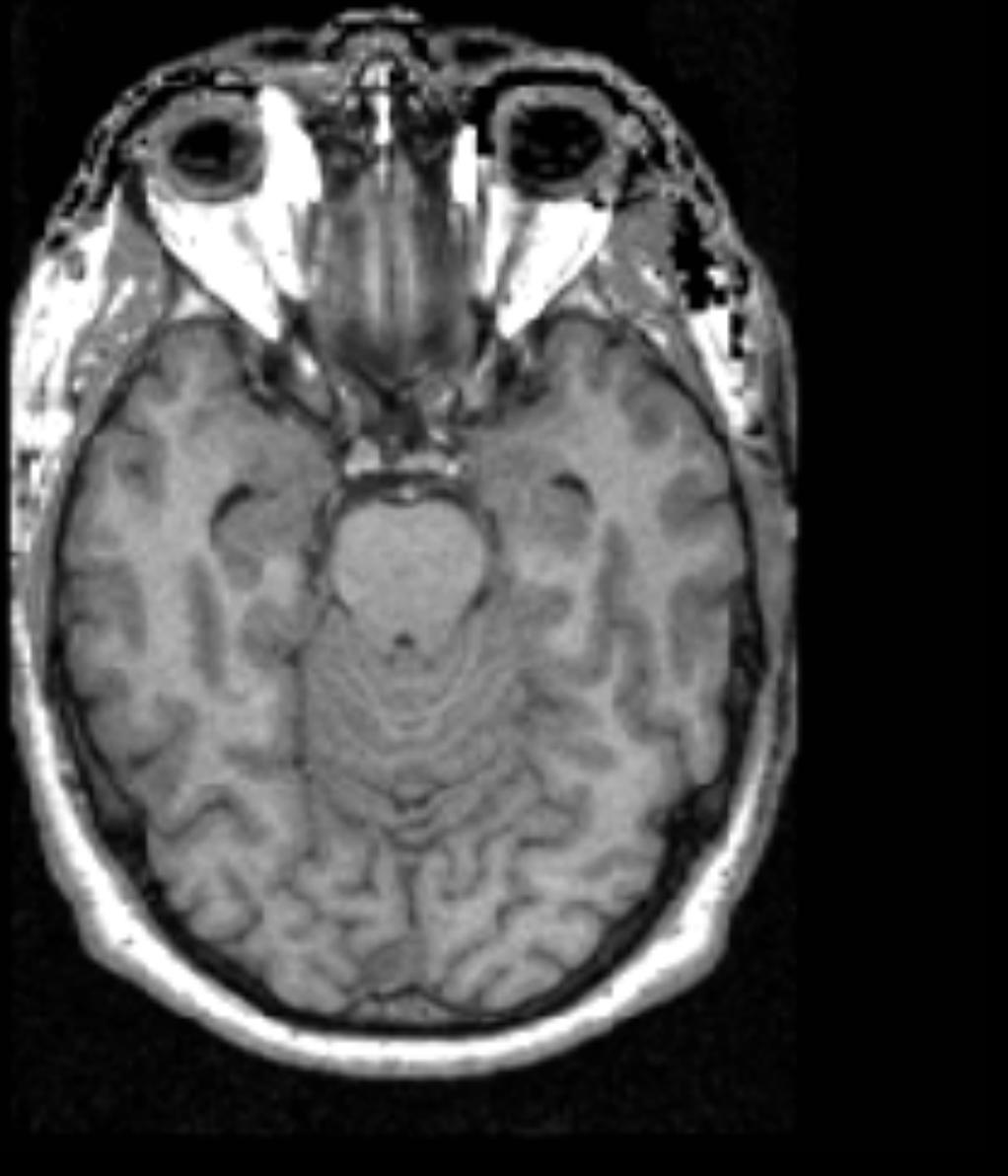
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HIPPA Patient privacy

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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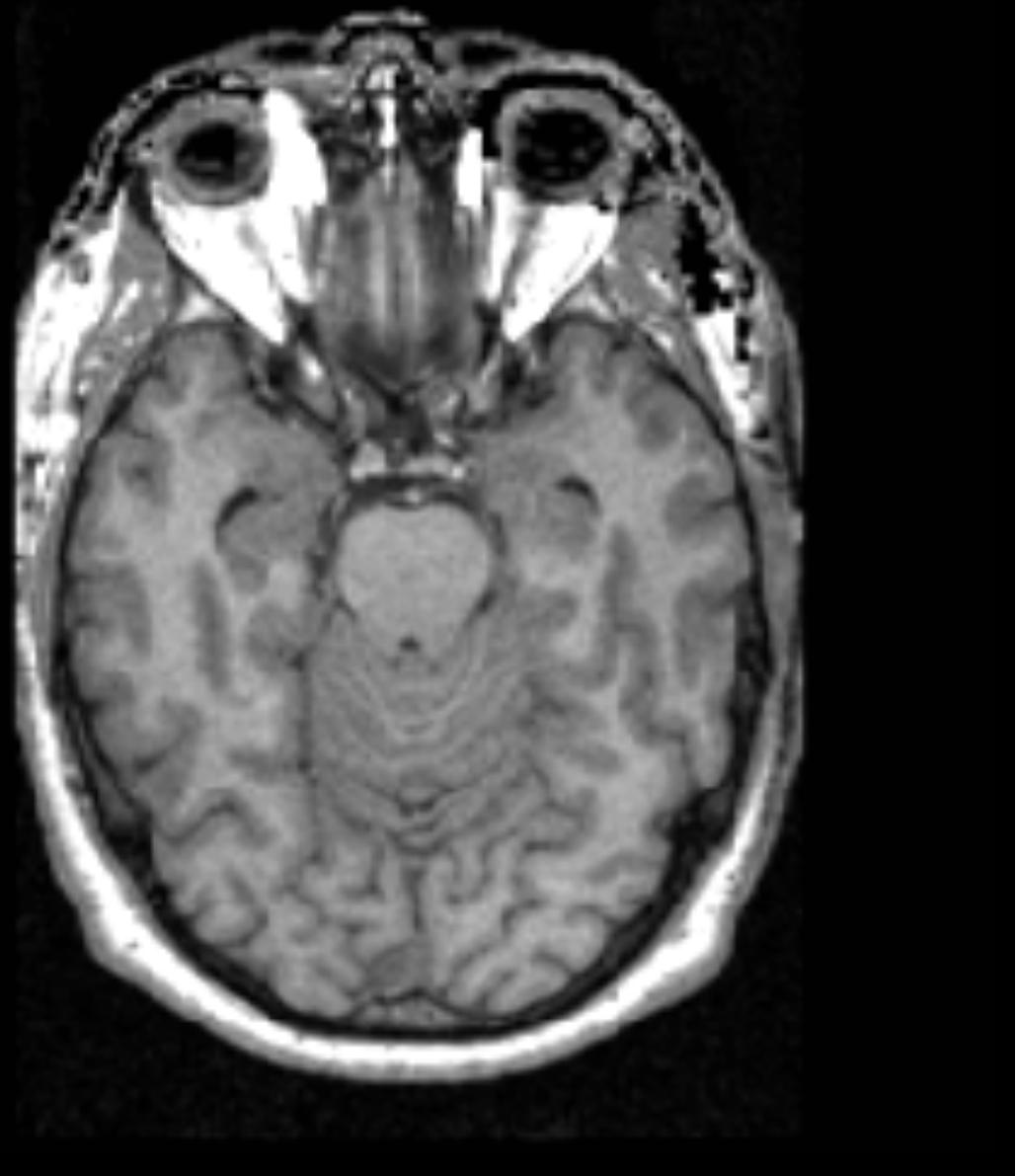
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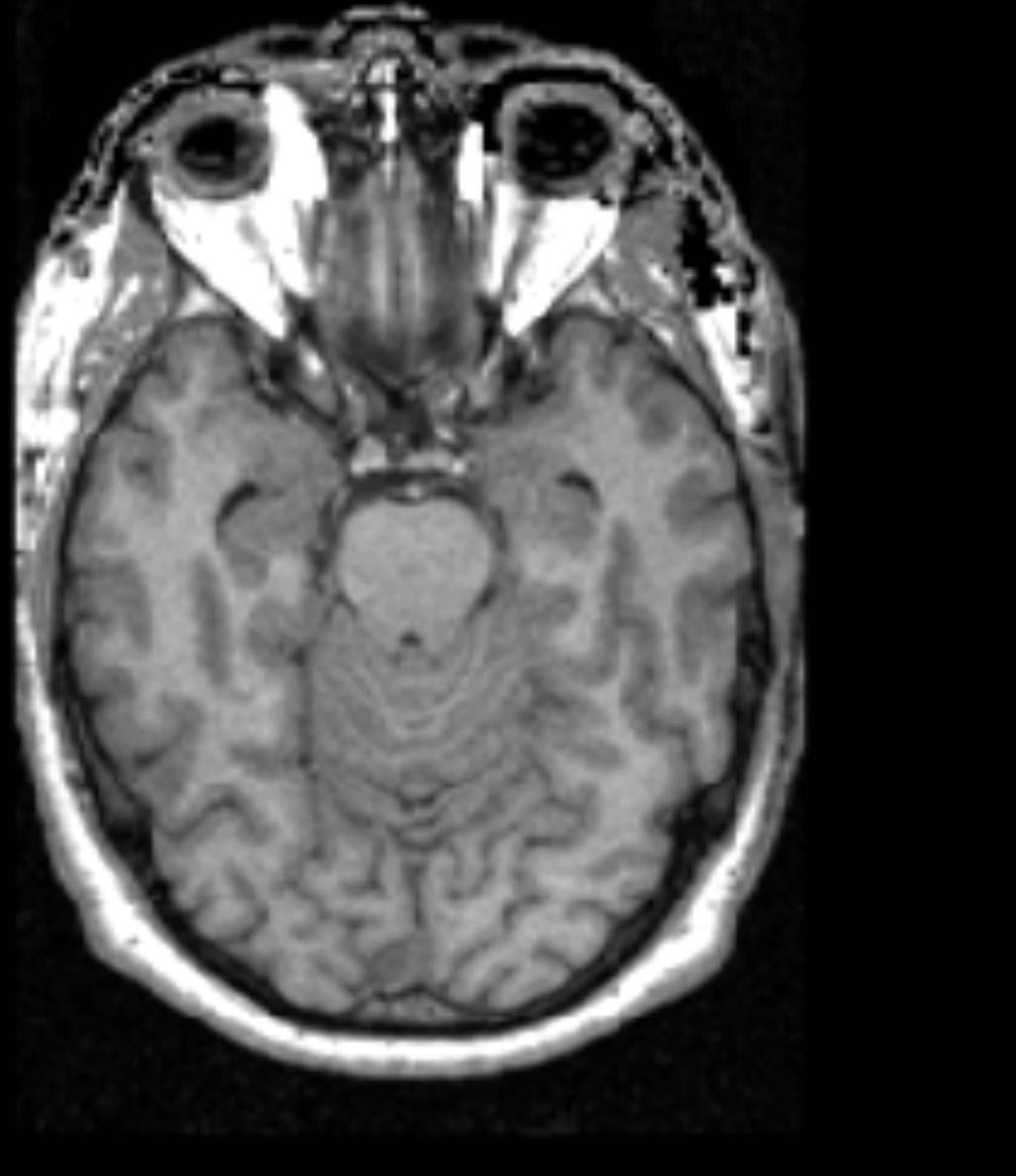


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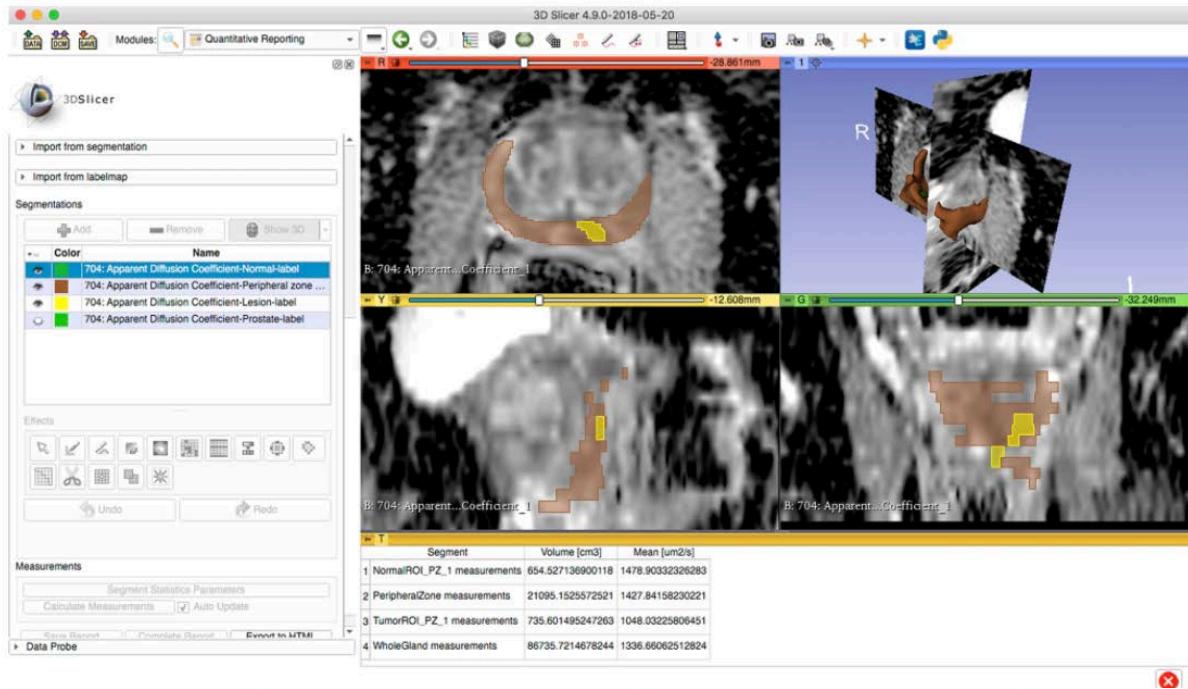
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0028,00FD,Pixel Pitch=1.000000
0028,00FE,Pixel Depth=8
0028,00FF,Pixel Representation=1
0028,0000,Pixel Data=131072

Pixel Data

Standard DICOM Instances

- **DICOM images** produced by imaging equipment: single DICOM MRI slice, DICOM CT volume, DICOM multi-frame object (e.g. fMRI experiment)
- **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



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-0100”, “SRT”, “Morphologically Altered Structure”)	(“M-0110”, “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”)

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”)

Examples of Standard DICOM Instances

DICOM Images

Prostate MRI Images

DICOM Segmented Structures

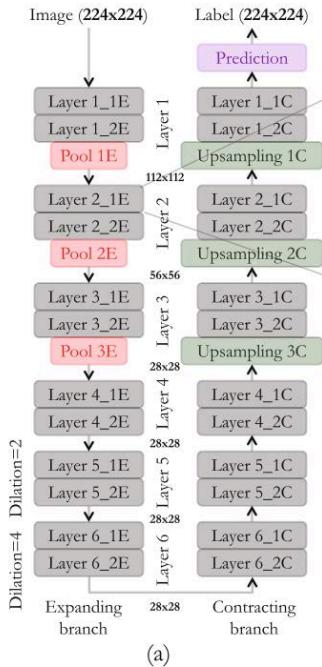
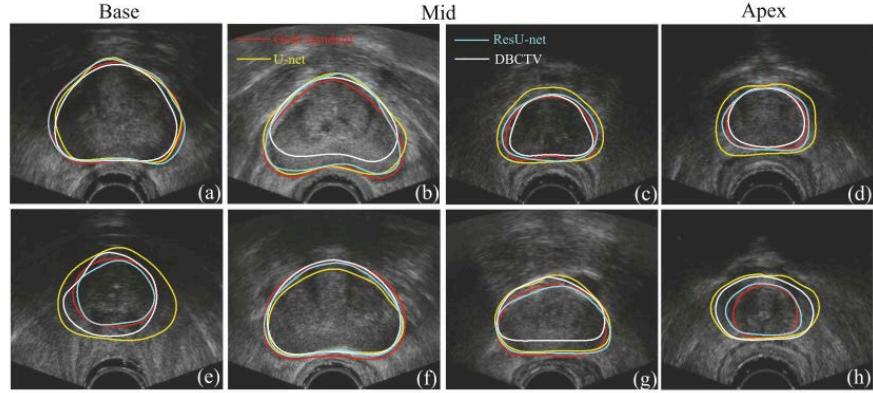
Prostate gland, peripheral zone, lesion, normal tissue

Measurements

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

DICOM Terminology

- DICOM provides support for annotation and segmentation objects
- 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



Anas et al. MICCAI 2017

DICOM for AI Studies

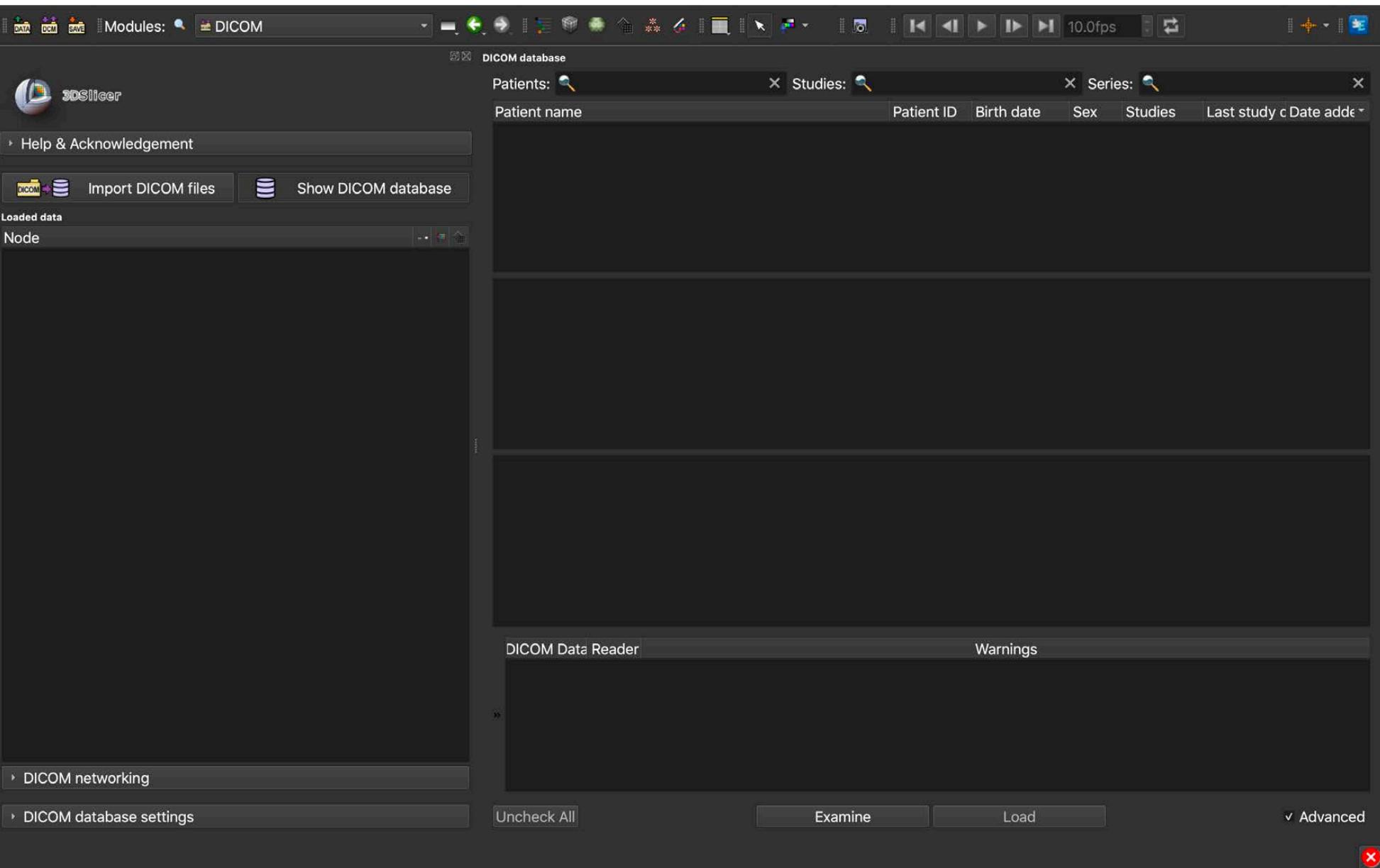
- DICOM defines **syntax rules** and **vocabularies** that enable easy extraction of knowledge from the data
- The DICOM framework for medical imaging data management enables the **automation of cohort formation** and maximizes the interoperability of the data for AI studies



Part 2: DICOM and Slicer

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.)



Slicer DICOM module



3DSlicer

Help & Acknowledgement

Import DICOM files Show DICOM database

Loaded data

Node

DICOM data loaded into Slicer

DICOM networking

DICOM database settings

DICOM database

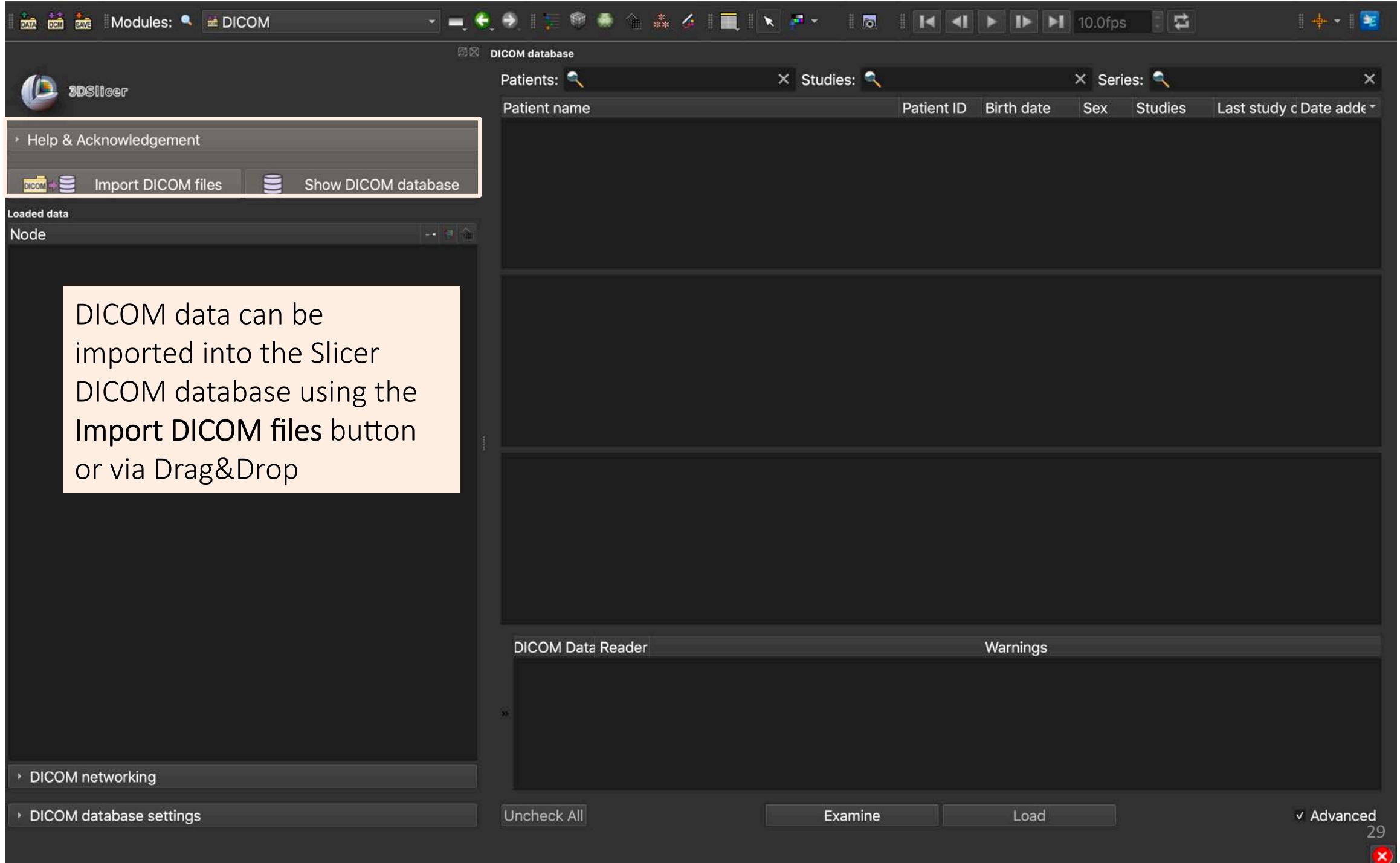
Patients: Studies: Series:

Patient name Patient ID Birth date Sex Studies Last study c Date add...

DICOM database

DICOM Data Reader Warnings

Uncheck All Examine Load Advanced 28



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

DICOM database

Patients: Studies: Series:

Patient name Patient ID Birth date Sex Studies Last study c Date add e

Patients

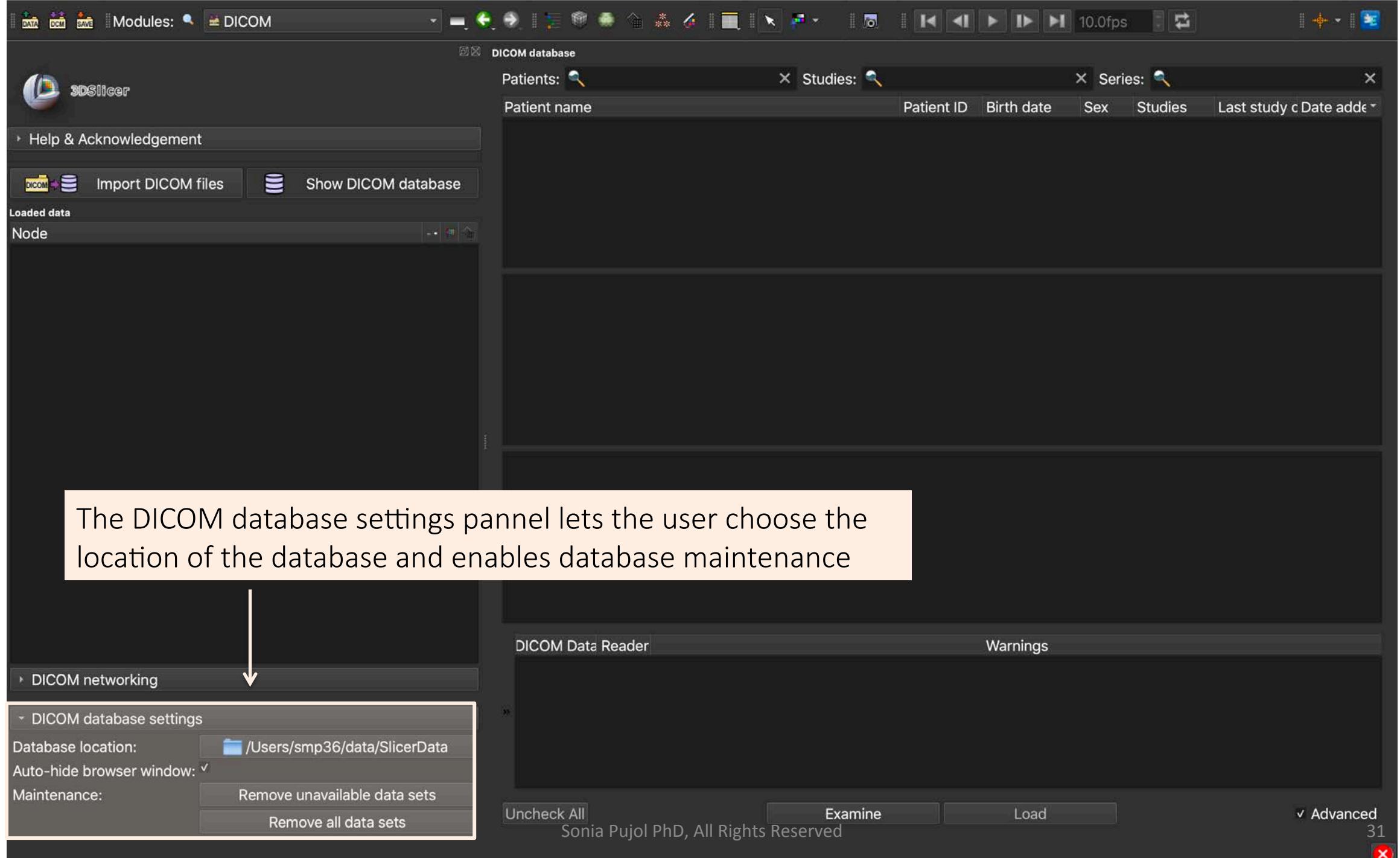
Studies

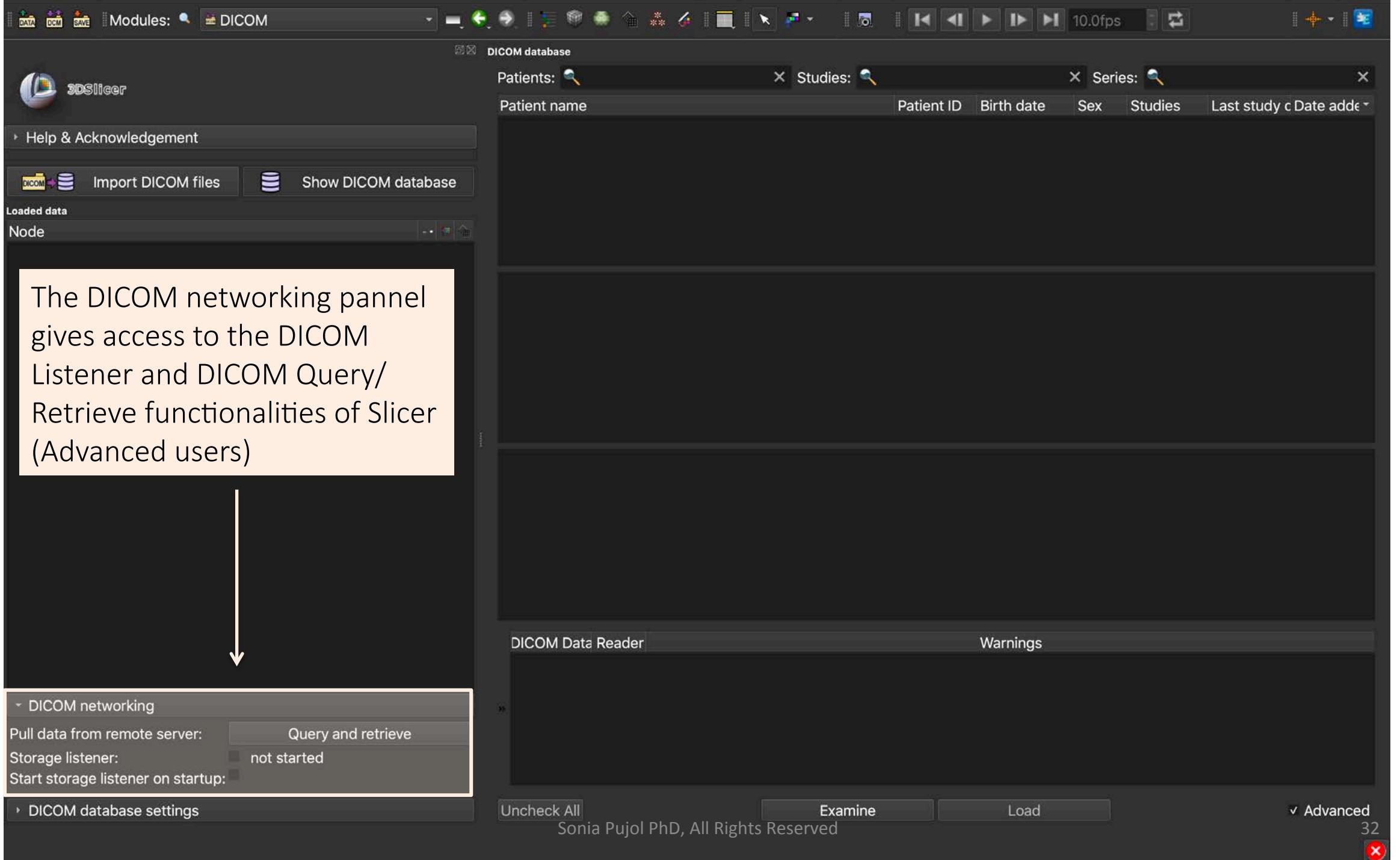
Series

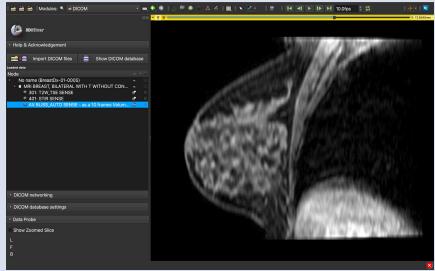
DICOM Data Reader Warnings

Uncheck All Examine Load Advanced

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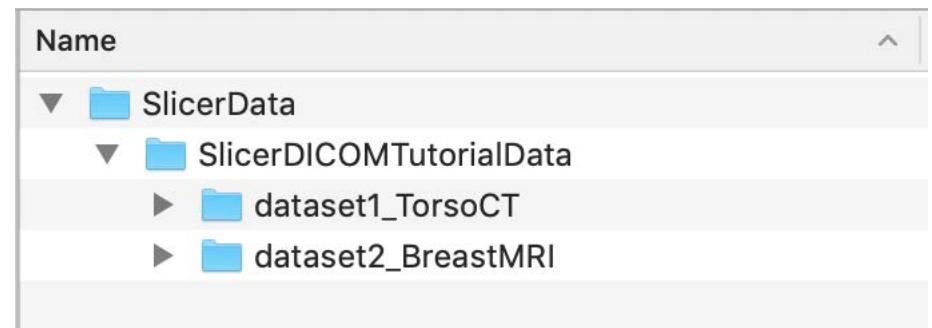


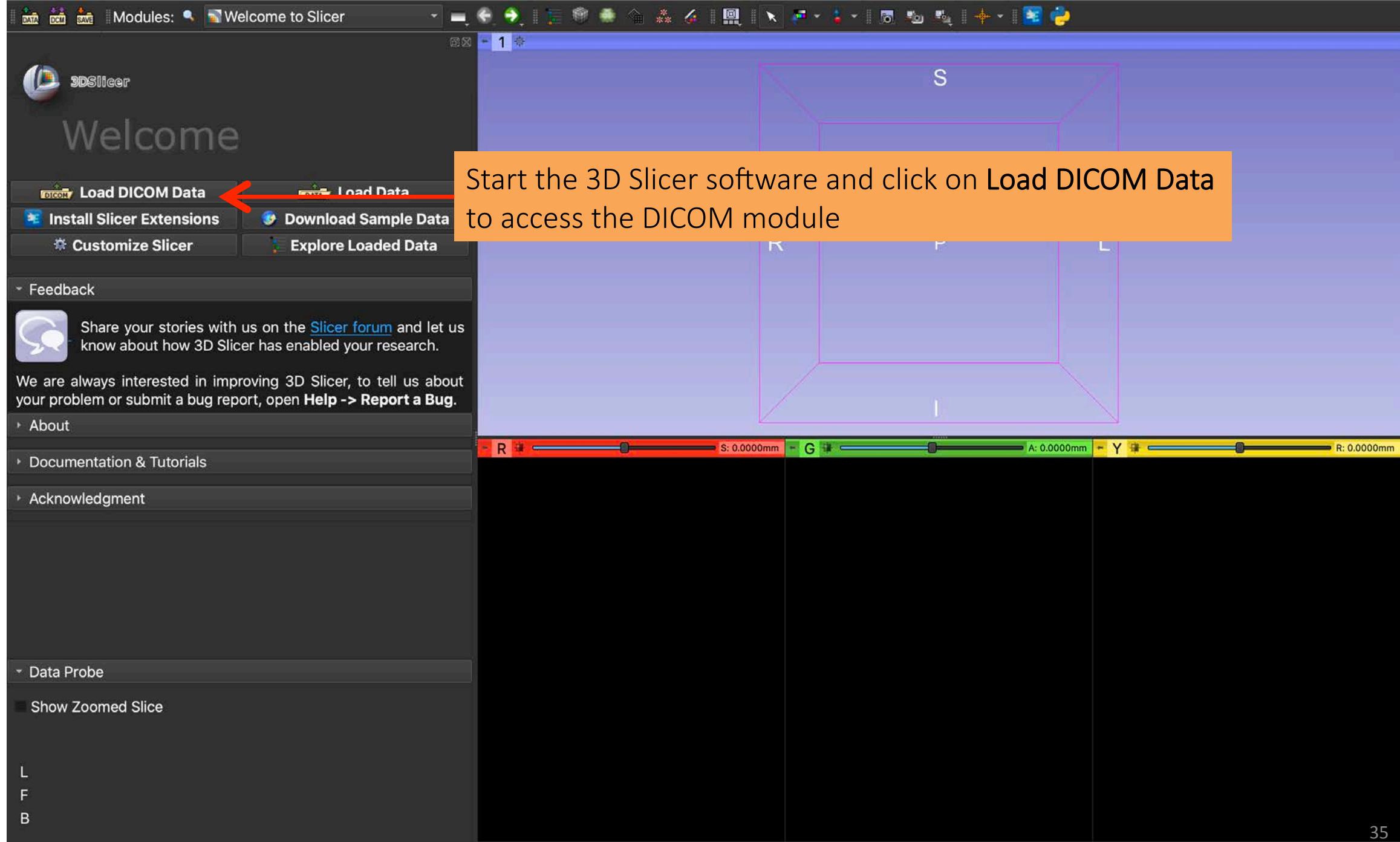


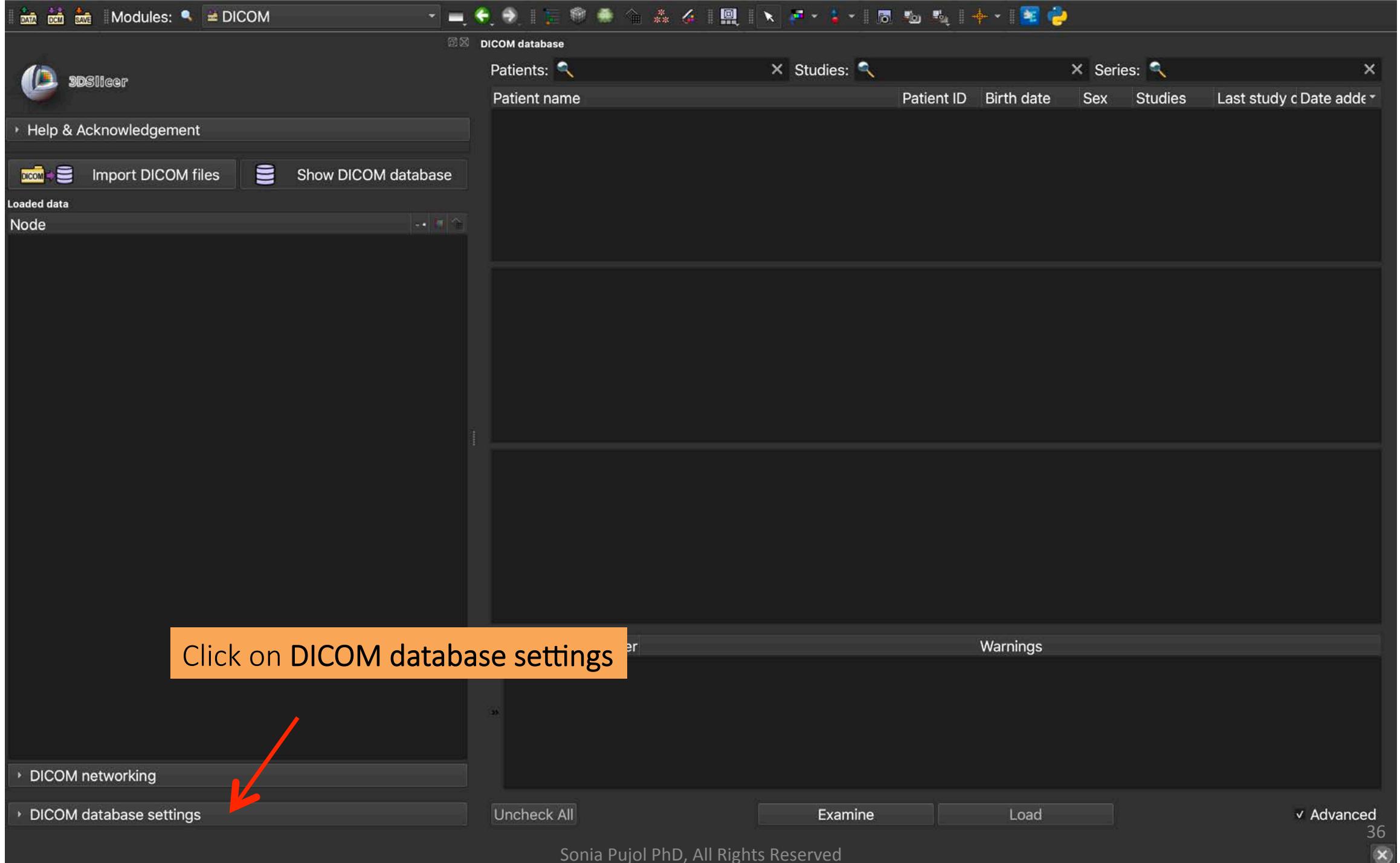
Part 3: Loading and Visualizing DICOM data in Slicer

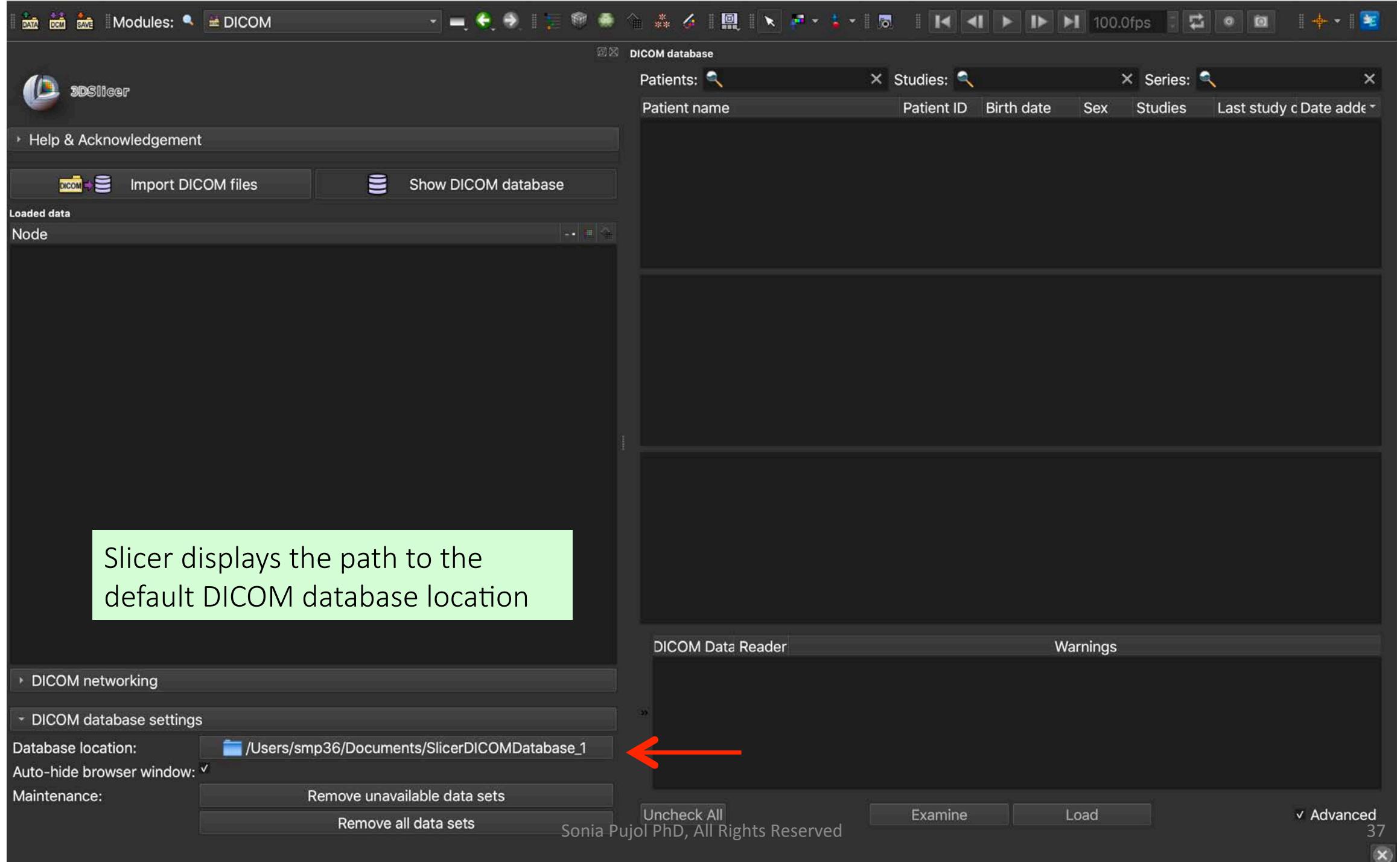
Tutorial Dataset

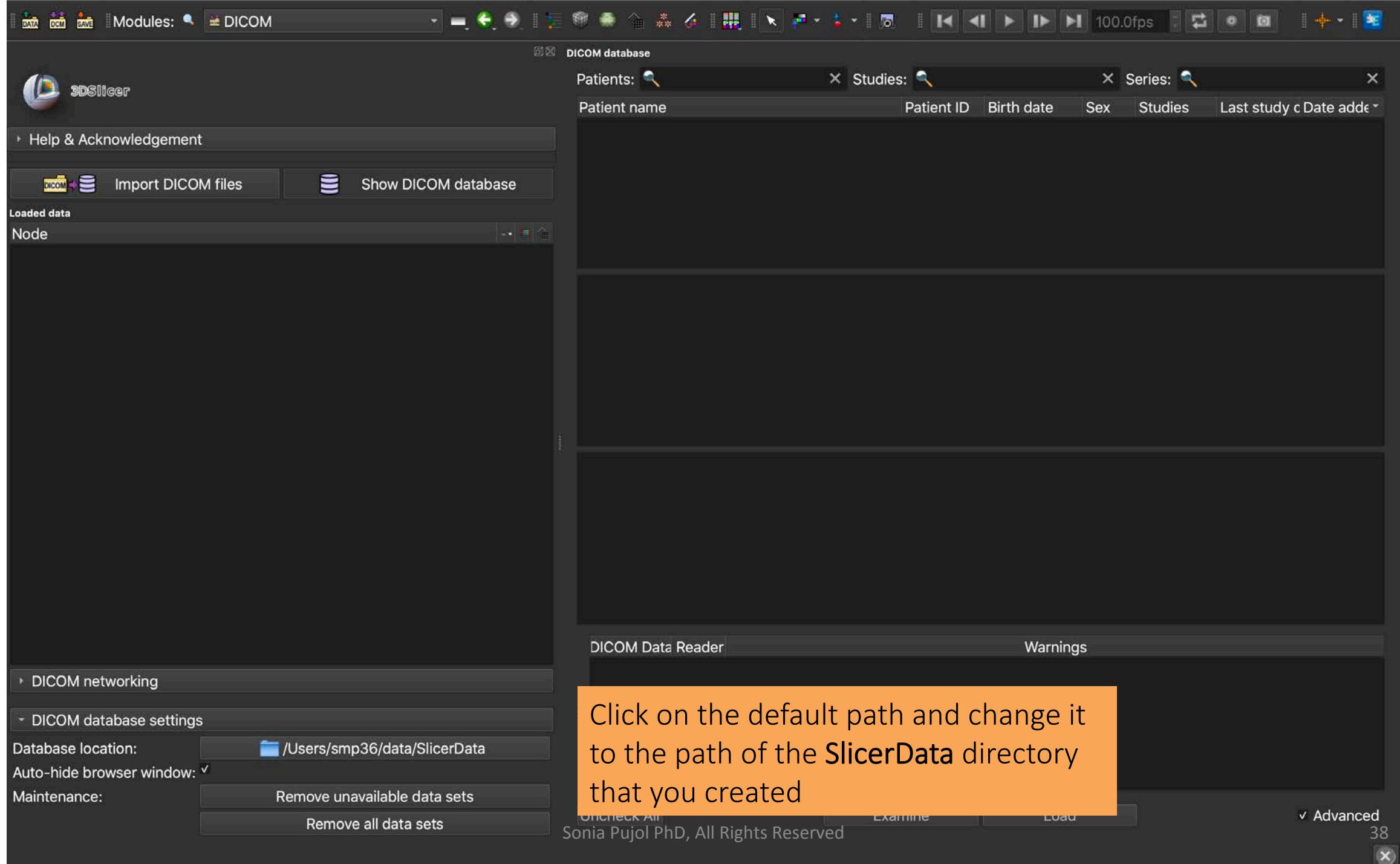
- Download the **SlicerDICOMTutorialData.zip** file to your computer
- Create a **SlicerData** folder on your computer and move the **SlicerDICOMTutorialData.zip** file to the **SlicerData** folder
- Unzip the **SlicerDICOMTutorialData.zip**









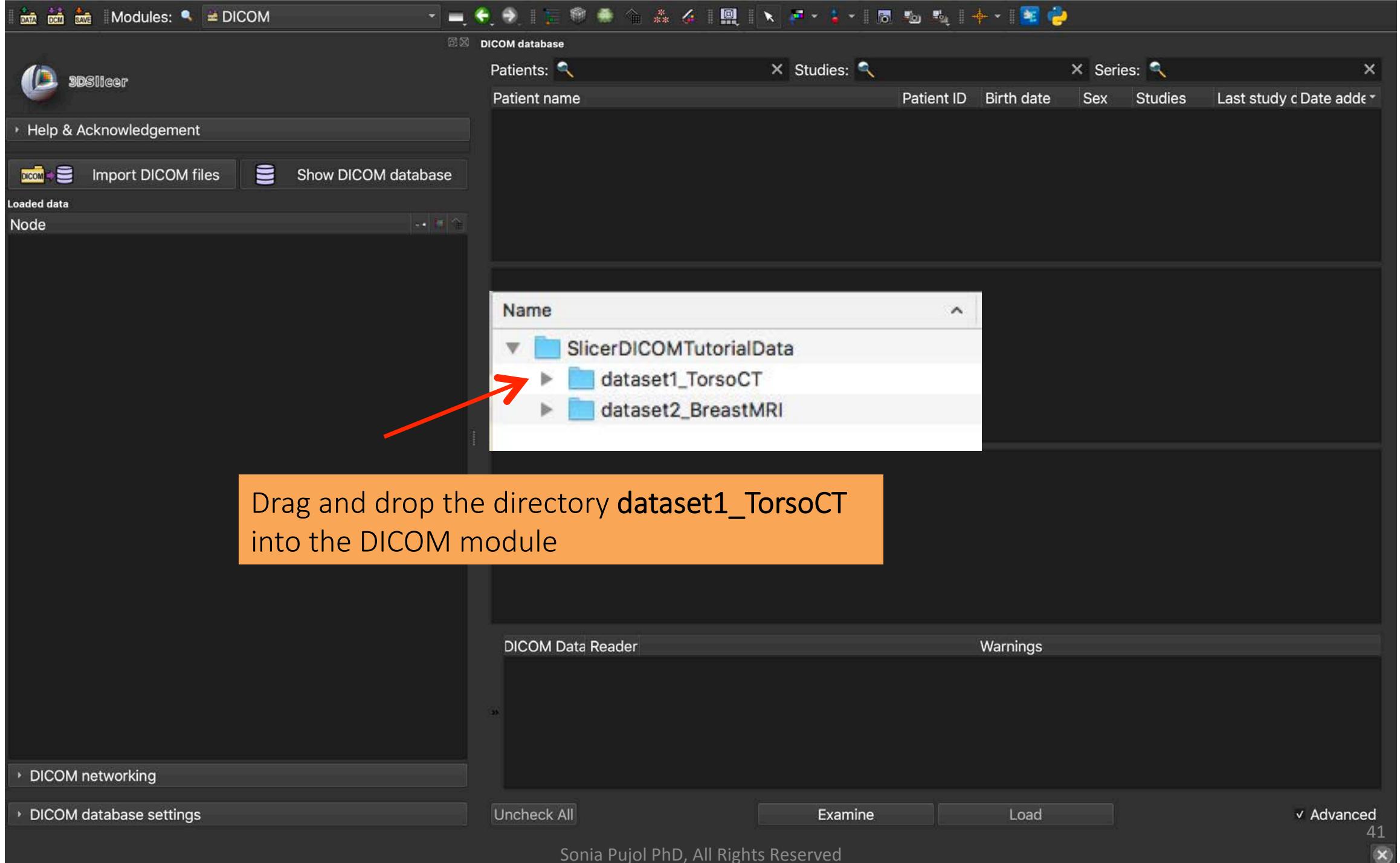




Dataset #1

Torso CT

Loading a DICOM dataset in Slicer



The screenshot shows the 3DSlicer interface with the DICOM module open. The top menu bar includes 'DATA', 'DCM', 'SAVE', 'Modules:', and 'DICOM'. The 'DICOM' tab is selected, showing the 'DICOM database' panel.

DICOM database:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
patient1	patient1_ID			1	Wed Jun 1 2005	2020...842

Loaded data:

Node

Slicer displays the corresponding study and series

Study date | Study ID | Study description | Series | Date added
20050601 | 6936864 | CT Thorax Abdomen | 1 | 202...843

Series # | Series description | Modality | Size | Count | Date added
6 | CT_Thorax_Abdomen | CT | 512x512 | 291 | 202...843

DICOM Data Reader Warnings
6: ... Scalar Volume

Uncheck All Examine Load Advanced

Annotations:

- An orange callout box with the text "Click on patient1 in the list of patients" points to the "patient1" row in the Patient list table.
- A green callout box with the text "Slicer displays the corresponding study and series" points to the "Study description" and "Series description" tables.

3DSlicer DICOM Modules: DICOM

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
patient1	patient1_ID			1	Wed Jun 1 2005	2020...842

Import DICOM files Show DICOM database

Loaded data Node

Study date Study ID Study description Series Date added

20050601	6936864	CT Thorax Abdomen	1	202...843
----------	---------	-------------------	---	-----------

Series # Series description Modality Size Count Date added

6	CT_Thorax_Abdomen	CT	512x512	291	202...843
---	-------------------	----	---------	-----	-----------

DICOM Data Reader Warnings

✓ 6: ... Scalar Volume

Click on Examine

Uncheck All Examine Load Advanced

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3DSlicer DICOM Modules: DICOM

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
patient1	patient1_ID			1	Wed Jun 1 2005	2020...842

Import DICOM files Show DICOM database

Loaded data Node

Study date Study ID Study description Series Date added

20050601	6936864	CT Thorax Abdomen	1	202...843
----------	---------	-------------------	---	-----------

Series # Series description Modality Size Count Date added

6	CT_Thorax_Abdomen	CT	512x512	291	202...843
---	-------------------	----	---------	-----	-----------

DICOM Data Reader Warnings

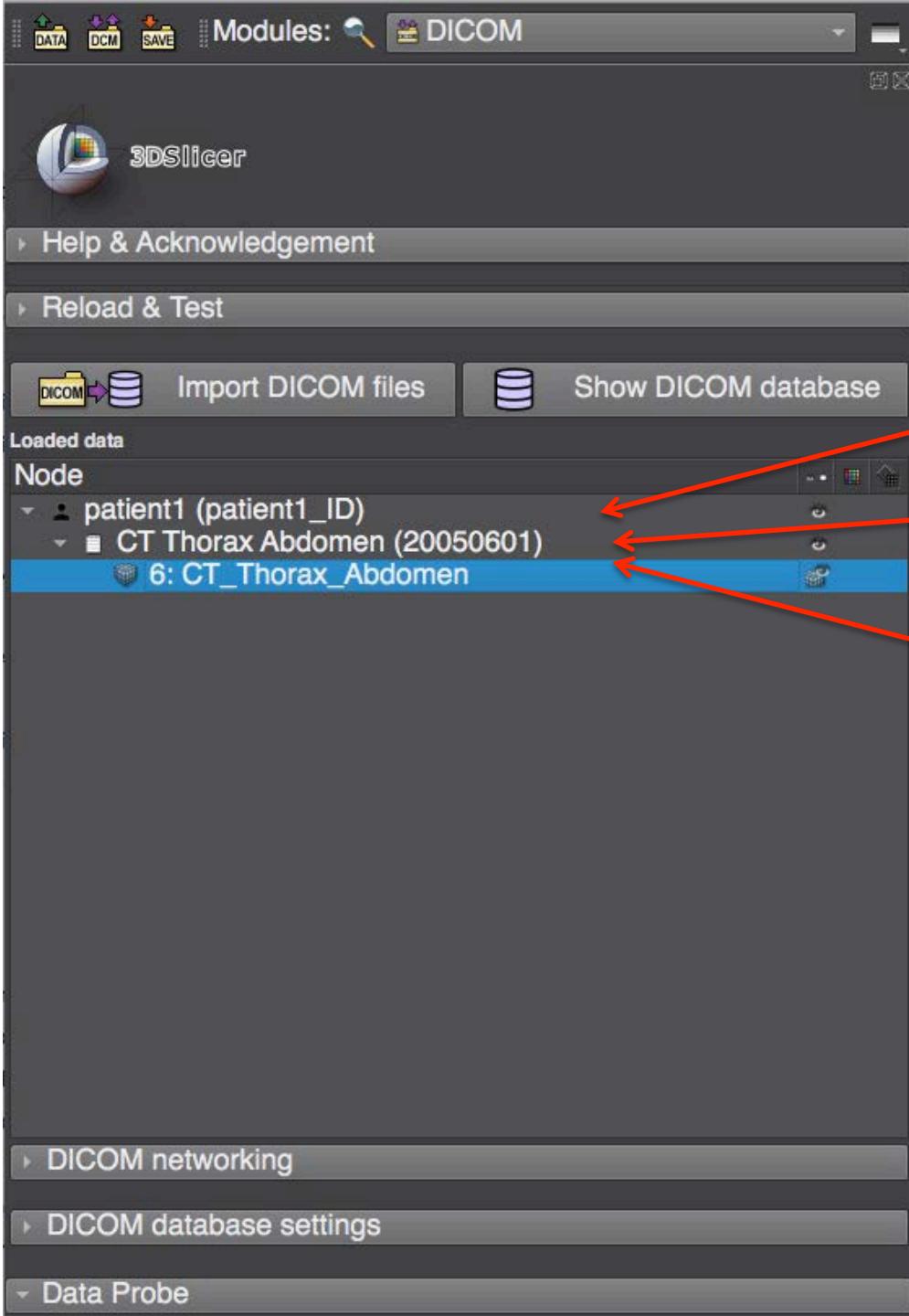
6: ... Scalar Volume

Click on Load

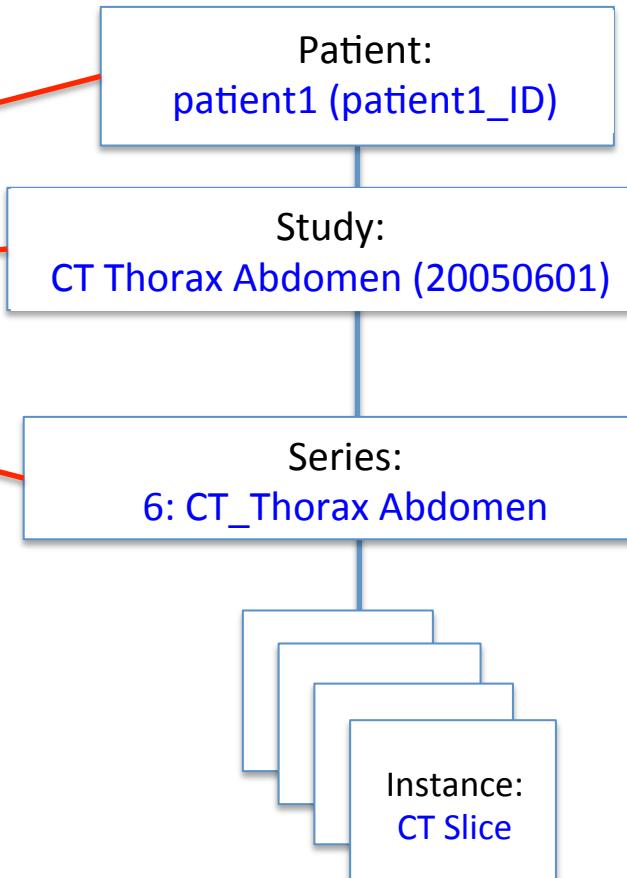
Uncheck All Examine Load Advanced

DICOM networking DICOM database settings

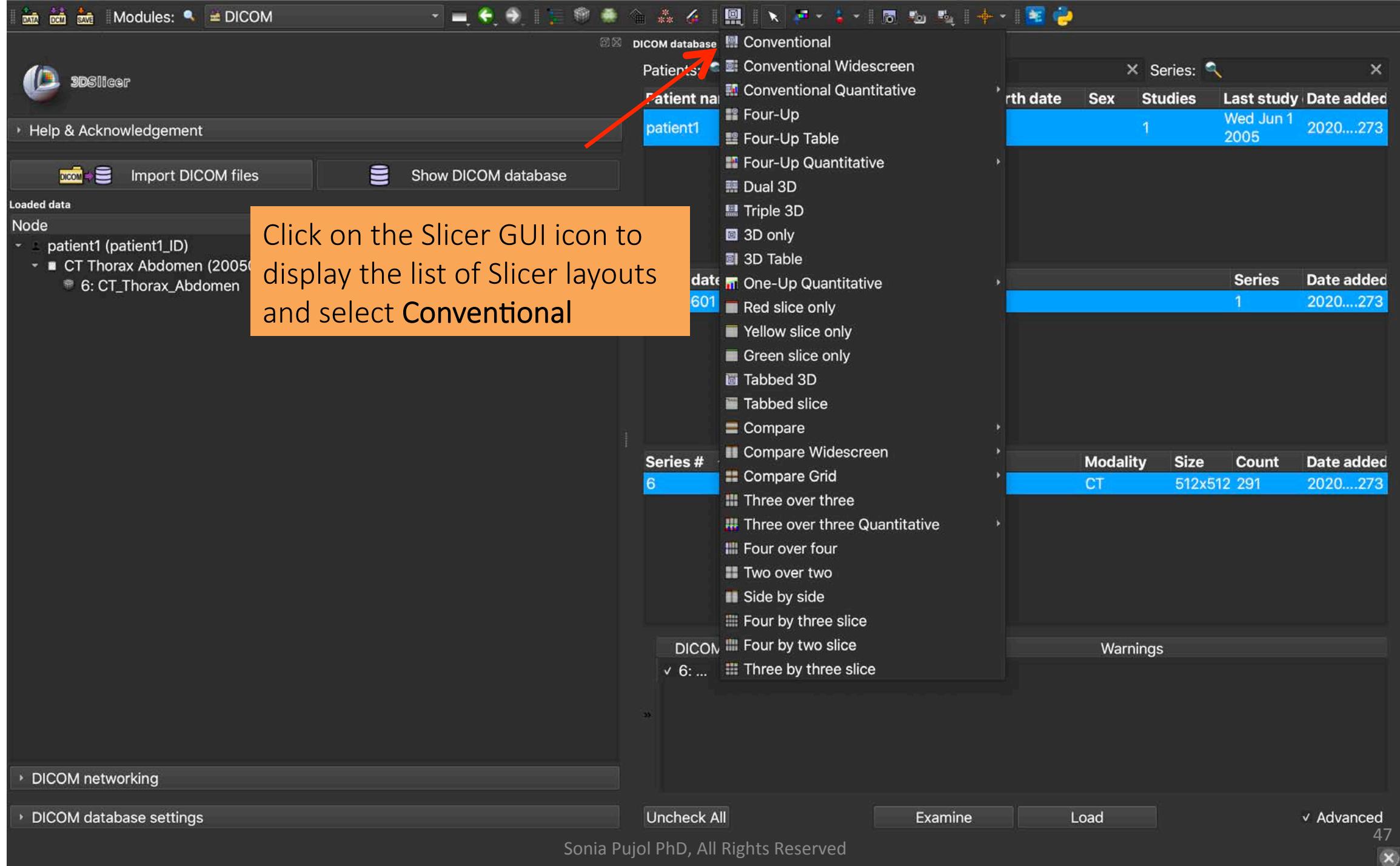
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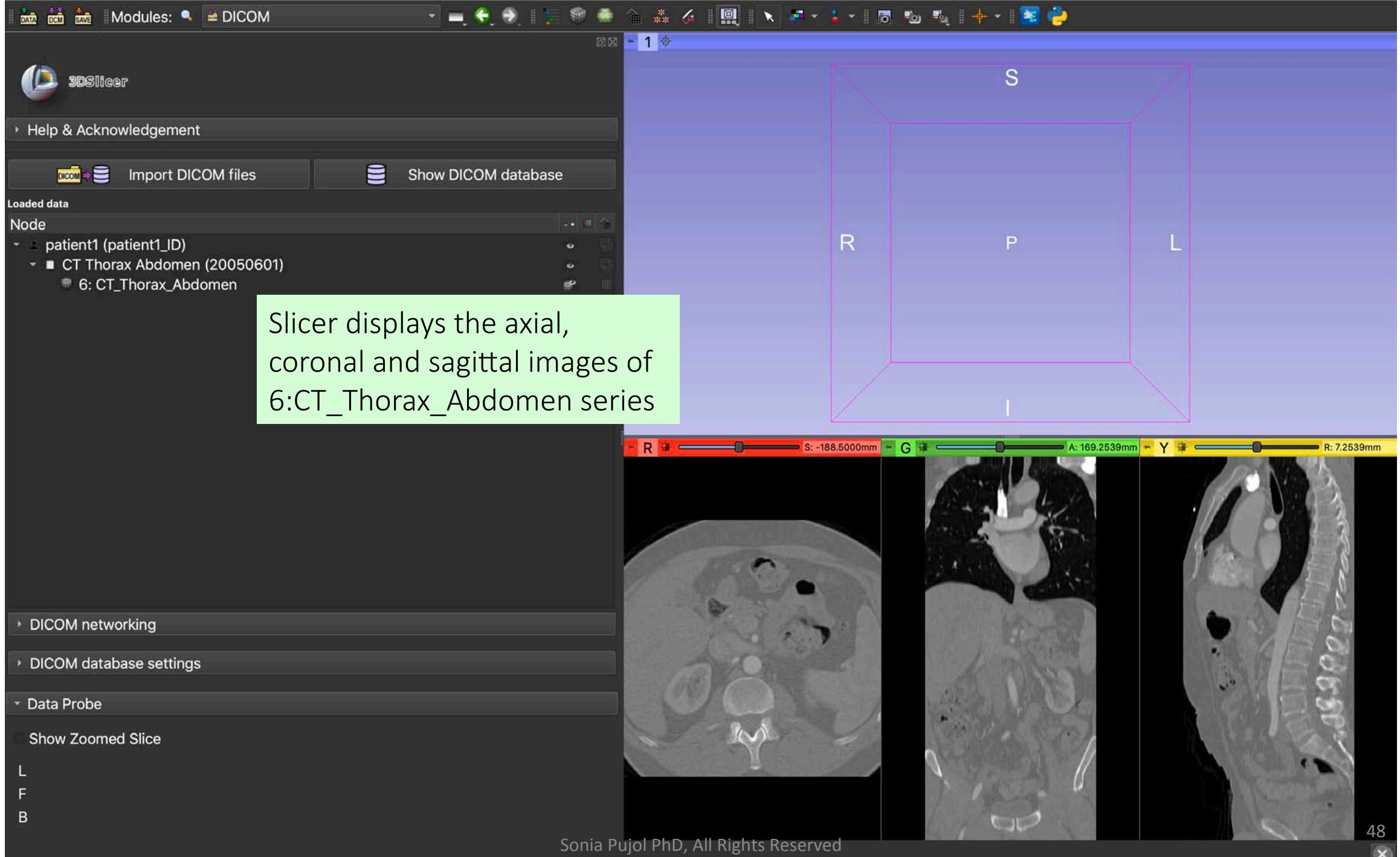


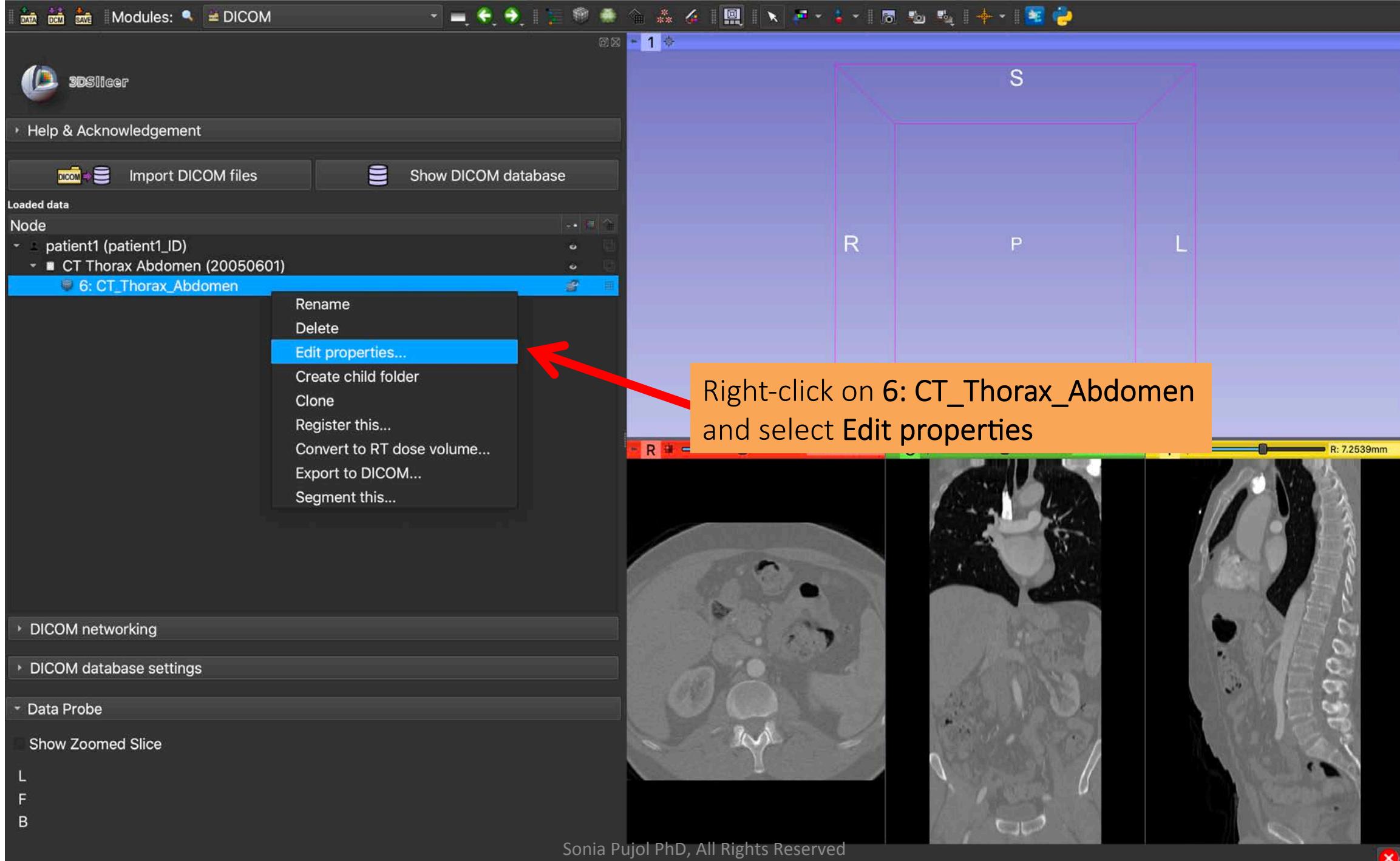
The DICOM dataset is loaded into Slicer as a patient-study-series DICOM hierarchy

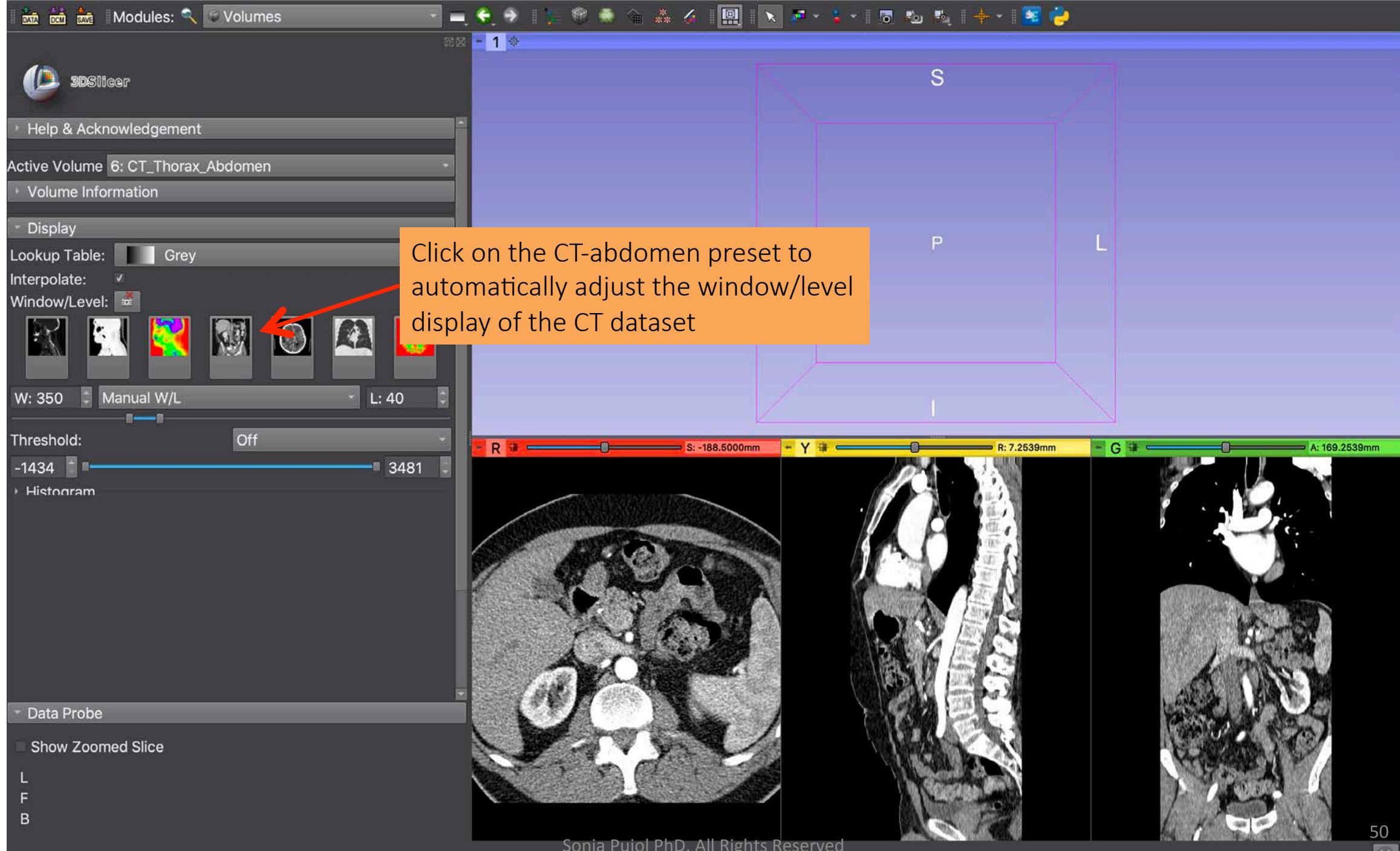


Visualizing a DICOM dataset in Slicer



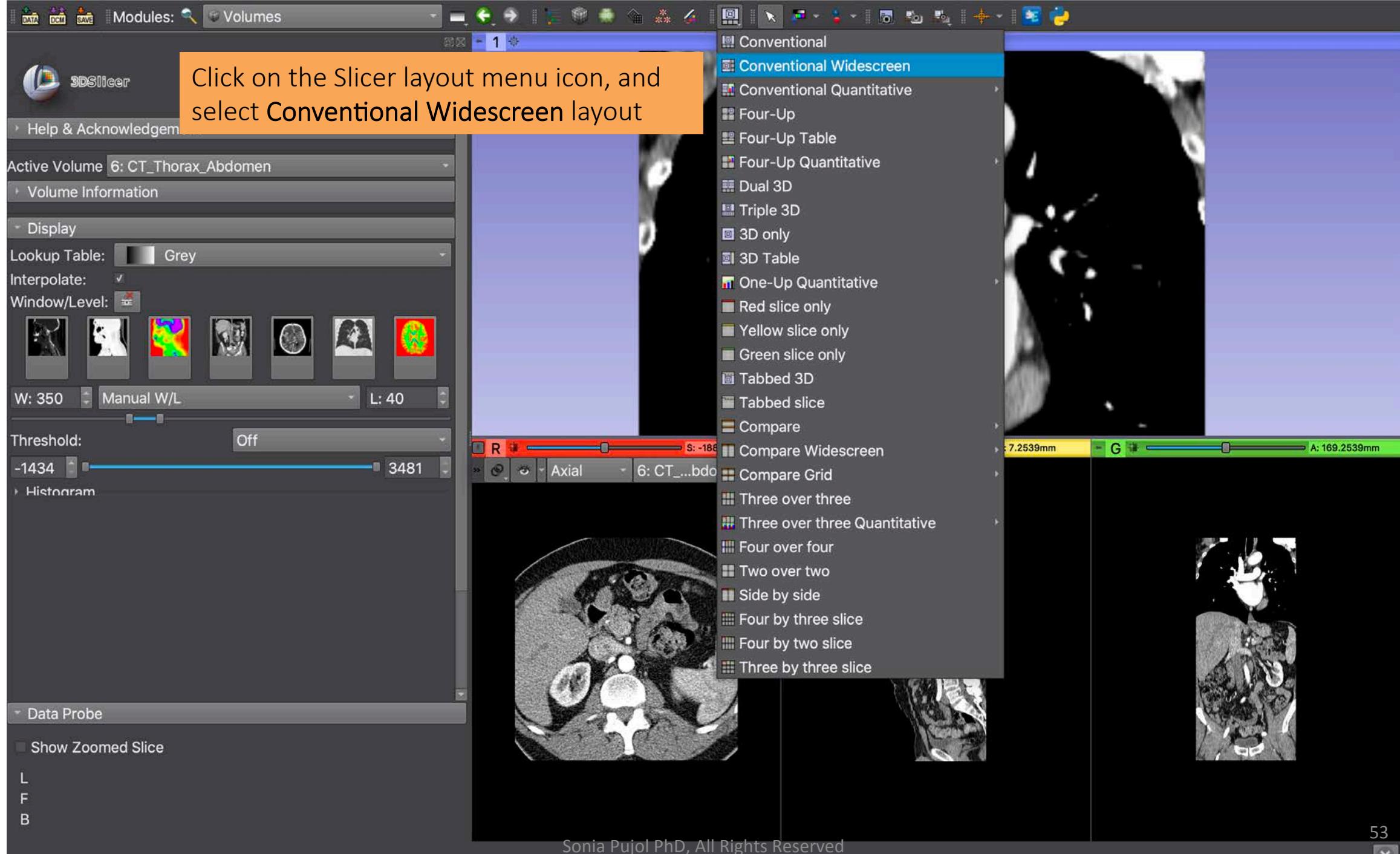


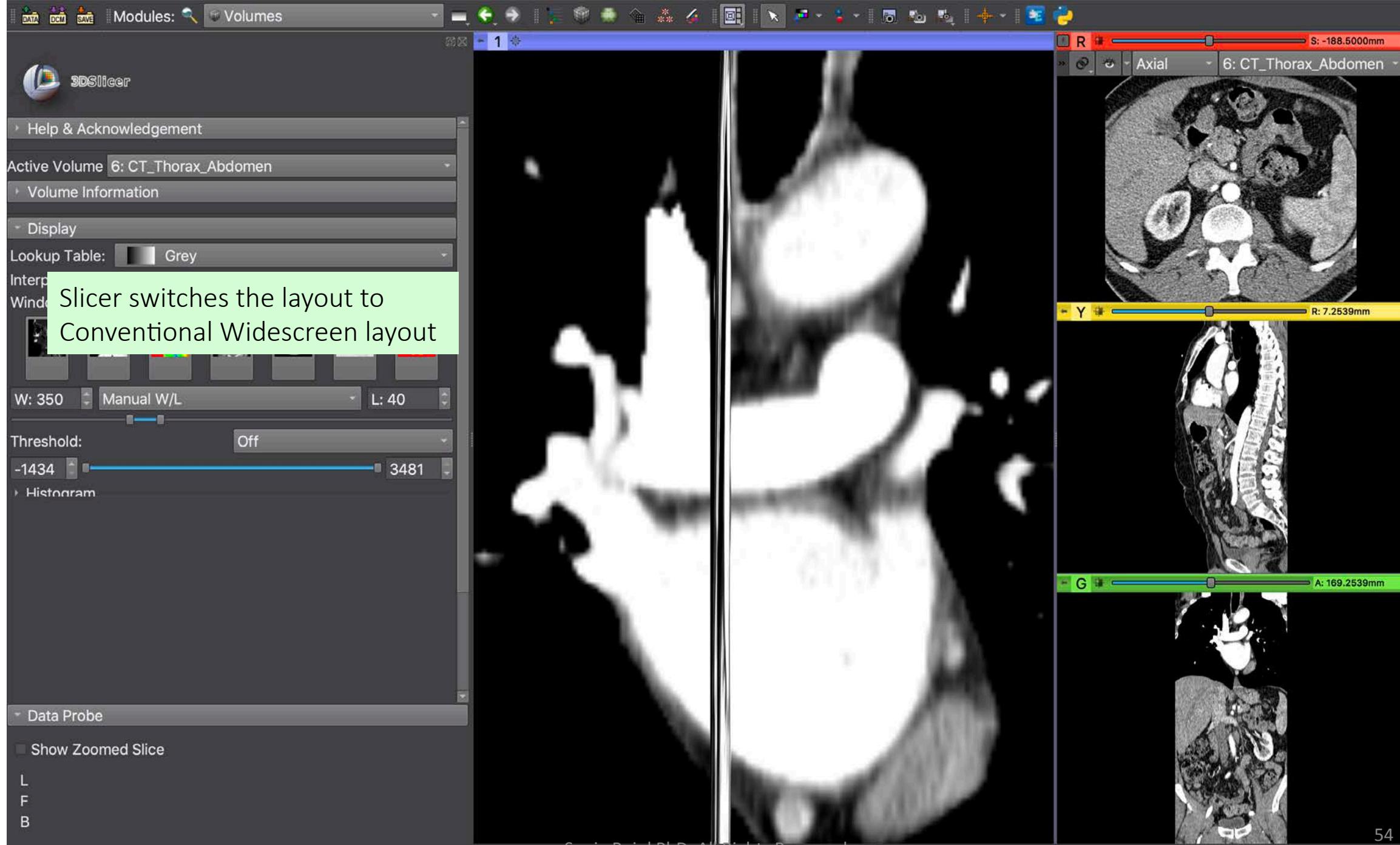


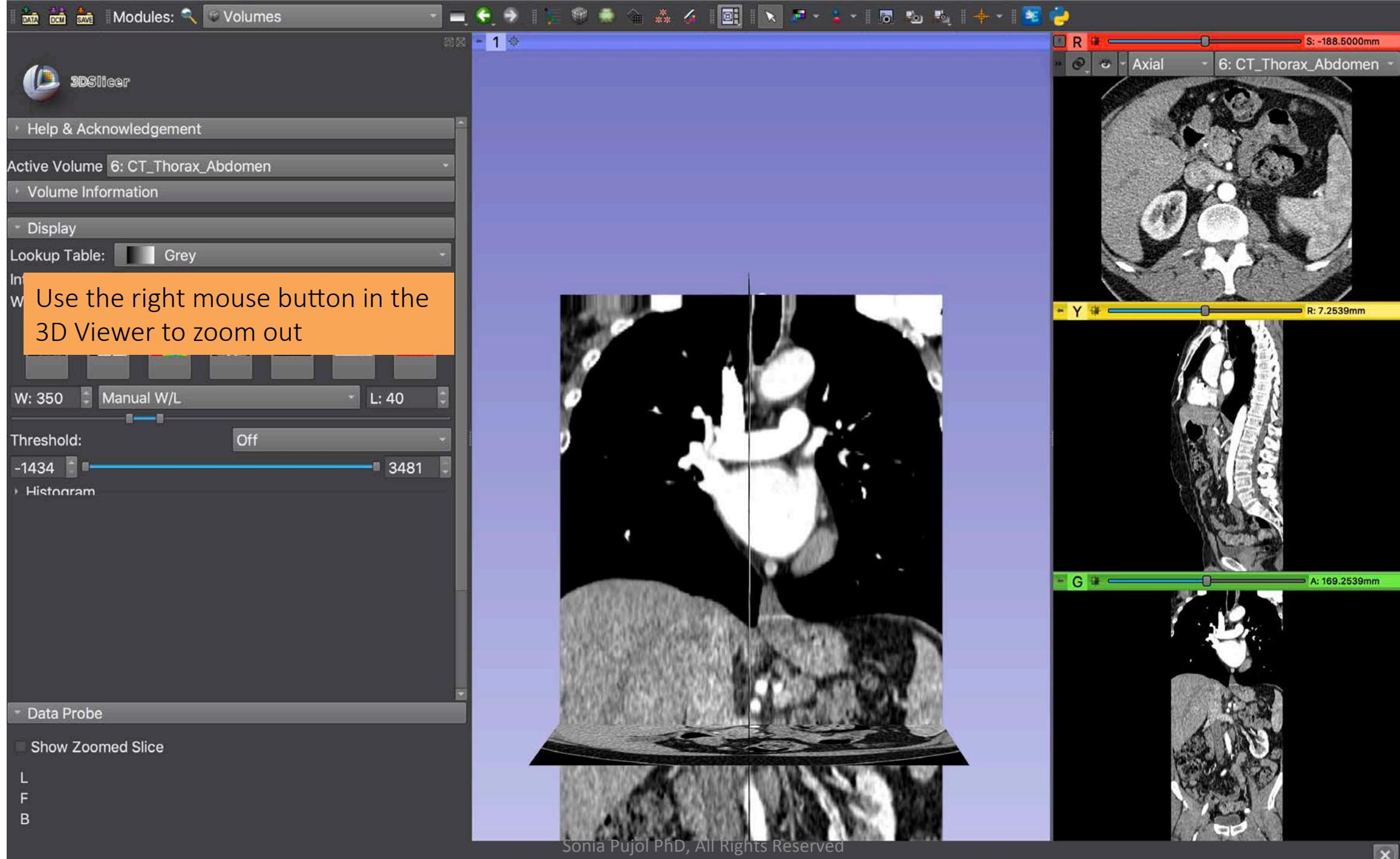


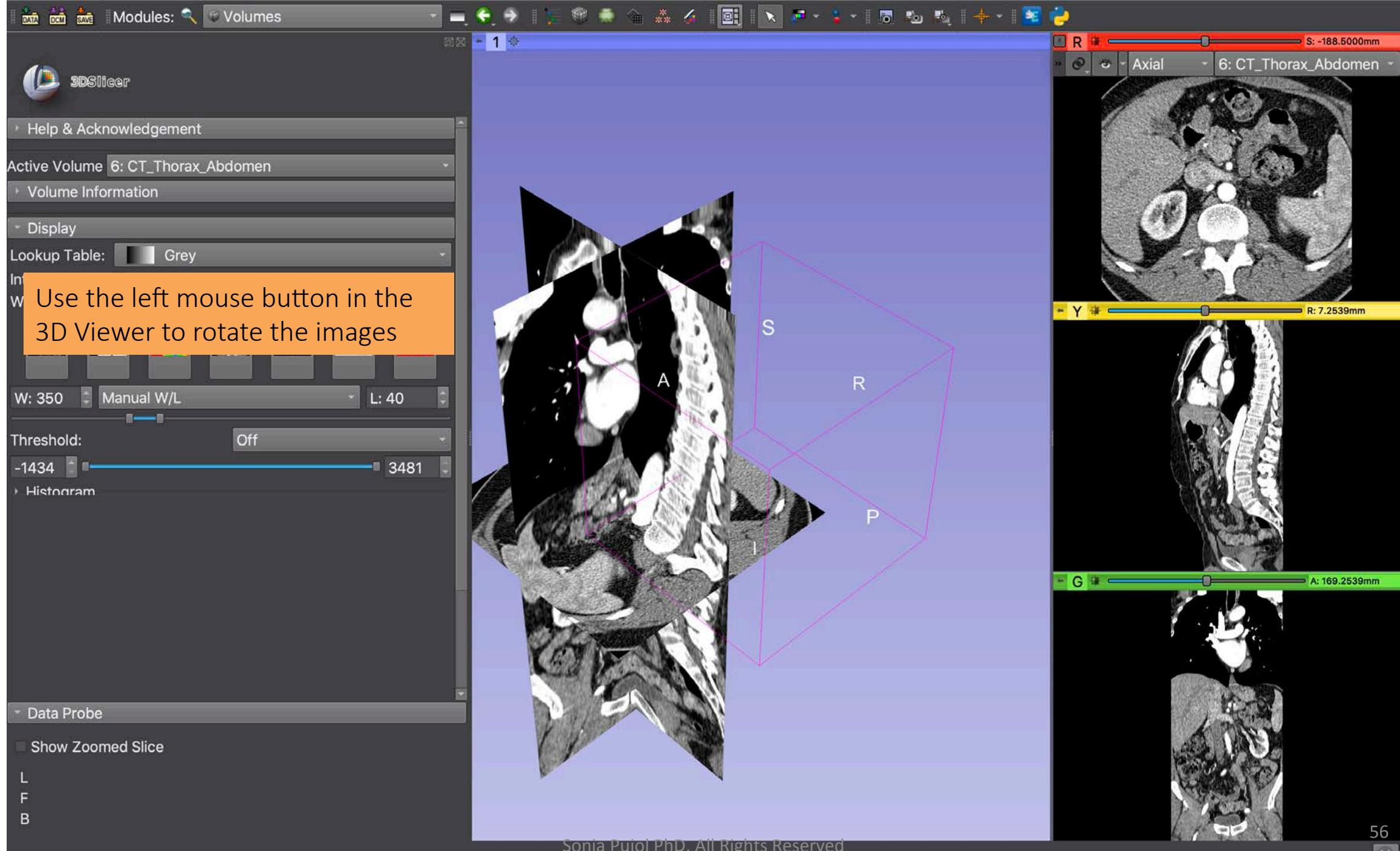


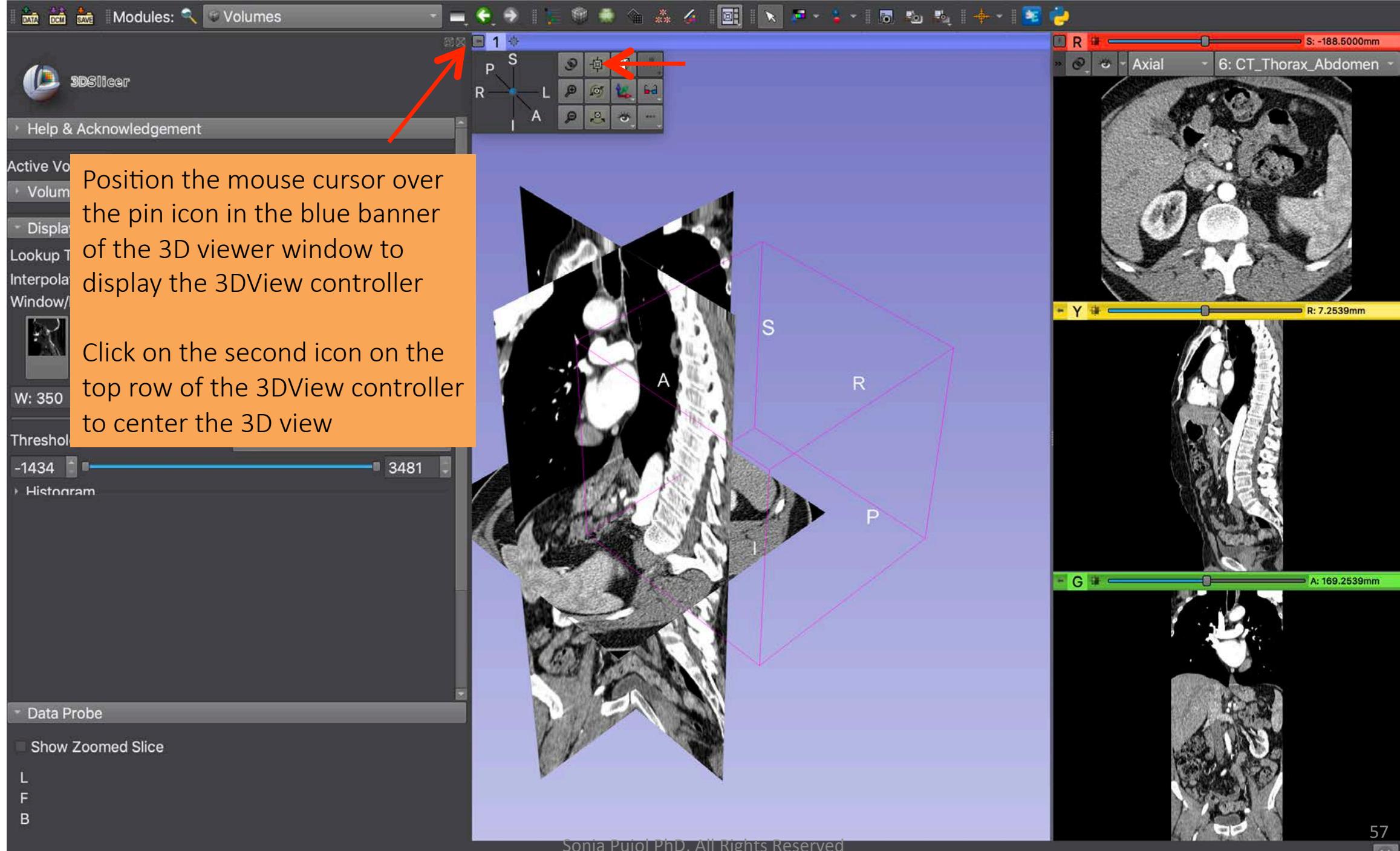


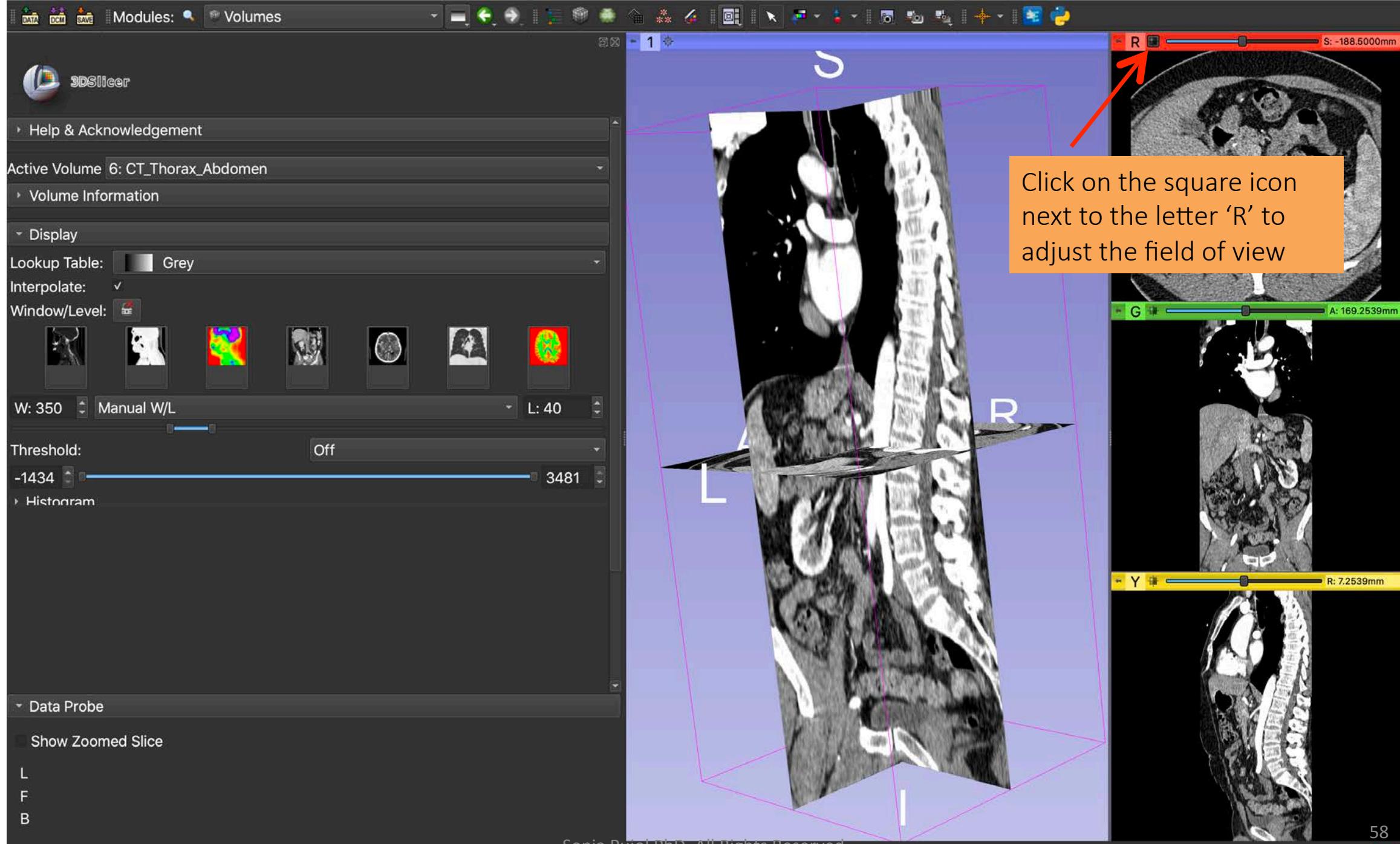


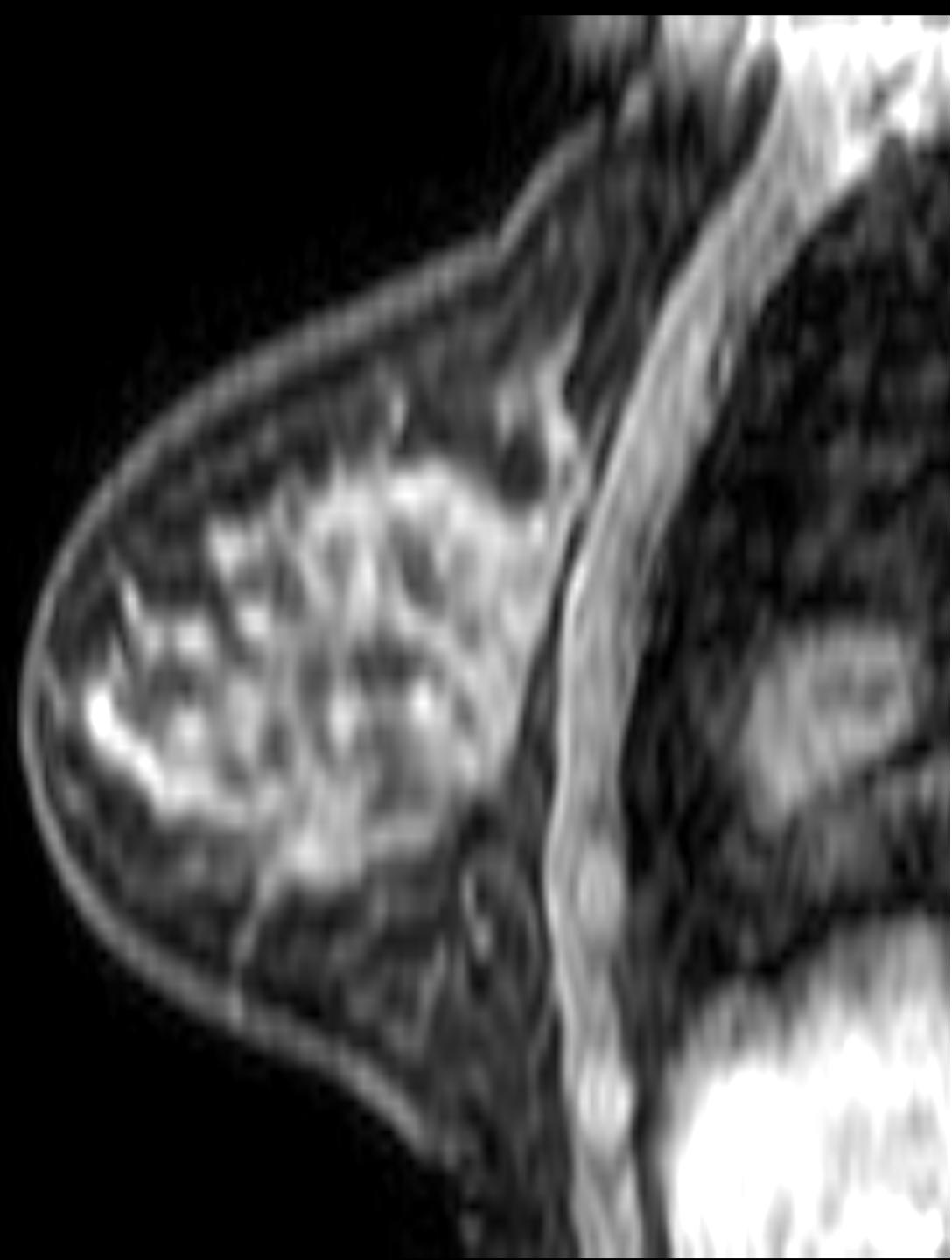












Dataset #2

Breast MRI

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>

DICOM database

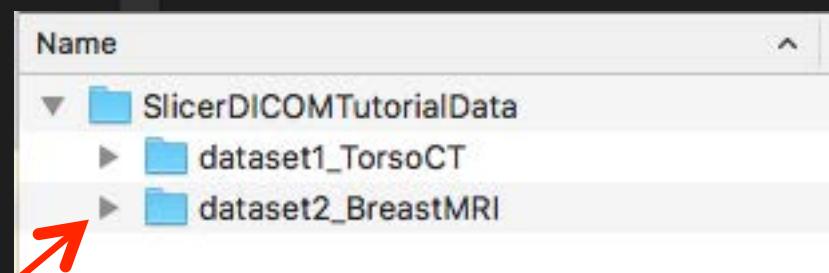
Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study c Date added
patient1	patient1_ID			1	Wed Jun 1 2005 2020...858

Help & Acknowledgement

Import DICOM files Show DICOM database

Loaded data Node



Drag and drop the directory
dataset2_BreastMRI into the DICOM module

DICOM Data Reader

Warnings

DICOM networking

DICOM database settings

Uncheck All

Examine

Load

Advanced

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DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study c Date added
Bre...005			F	1	Tue Nov 11 2008 2020...622
patient1	patient1_ID			1	Wed Jun 1 2005 2020...858

Import DICOM files Show DICOM database

Loaded data
Node

Slicer imports the dataset2_BreastMRI directory into the DICOM database

The directory contains 1 patient, 1 study and 3 series



Import completed: added 1 patients, 1 studies, 3 series, 1008 instances.

OK

DICOM Data Reader

Warnings

DICOM networking

DICOM database settings

Uncheck All

Examine

Load

Advanced

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Click on the PatientID
BreastDx-01-0005 to display
the study and the three
T2W, STIR and BLISS series

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
	BreastDx-01-0005		F	1	Tue Nov 11 2008	2020...583
patient1	patient1_ID			1	Wed Jun 1 2005	2020...273

Study date Study ID Study description Series Date added

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020...583

Series # Series description Modality Size Count Date added

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020...583
401	STIR SENSE	MR	528x528	84	2020...221
801	AX BLISS_AUTO SENSE	MR	528x528	840	202...646

DICOM Data Reader Warnings

DICOM networking

DICOM database settings

Uncheck All Examine Load Advanced

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The list of DICOM plugins appear

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study c Date added
Bre...005	F	1	Tue Nov 11 2008	2020....622	
patient1	patient1_ID	1	Wed Jun 1 2005	2020....858	

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020....622

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020....622
401	STIR SENSE	MR	528x528	84	2020....126
801	AX BLISS_AUTO SENSE	MR	528x528	840	2020....672

DICOM Data Reader Warnings

- ✓ DICOMScalarVolumePlugin
- ✓ DICOMSlicerDataBundlePlugin
- ✓ DICOMVolumeSequencePlugin
- ✓ MultiVolumeImporterPlugin

Uncheck All Examine Load Advanced

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Slicer DICOM Plugins

- ✓ DICOMScalarVolumePlugin
- ✓ DICOMSlicerDataBundlePlugin
- ✓ DICOMVolumeSequencePlugin
- ✓ MultiVolumeImporterPlugin

- 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

3DSlicer

Help & Acknowledgement

DICOM Import DICOM files Show DICOM database

Loaded data Node

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study c Date added
Bre...005			F	1	Tue Nov 11 2008 2020...622
patient1	patient1_ID			1	Wed Jun 1 2005 2020...858

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020...622

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020...622
401	STIR SENSE	MR	528x528	84	2020...126
801	AX BLISS_AUTO SENSE	MR	528x528	840	2020...672

✓ DICOMScalarVolumePlugin
✓ DICOMSlicerDataBundlePlugin
✓ DICOMVolumeSequencePlugin
✓ MultiVolumeImporterPlugin

DICOM Data Reader Warnings

Uncheck All Examine Click on Examine Advanced 66

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3DSlicer

Help & Acknowledgement

DICOM Import DICOM files Show DICOM database

Loaded data Node

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study c Date added
Bre...005			F	1	Tue Nov 11 2008 2020...622
patient1	patient1_ID			1	Wed Jun 1 2005 2020...858

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020...622

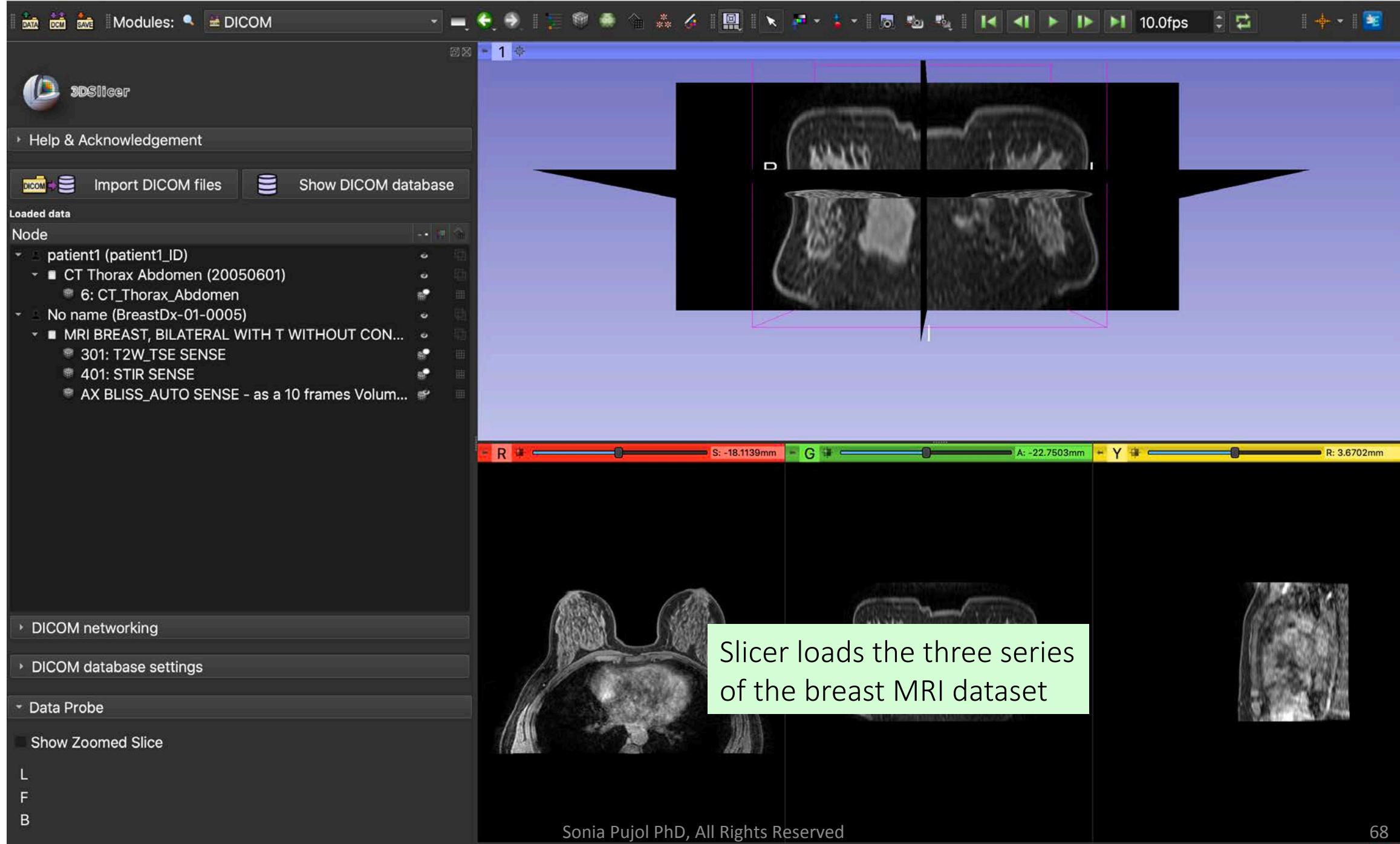
Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020...622
401	STIR SENSE	MR	528x528	84	2020...126
801	AX BLISS_AUTO SENSE	MR	528x528	840	2020...672

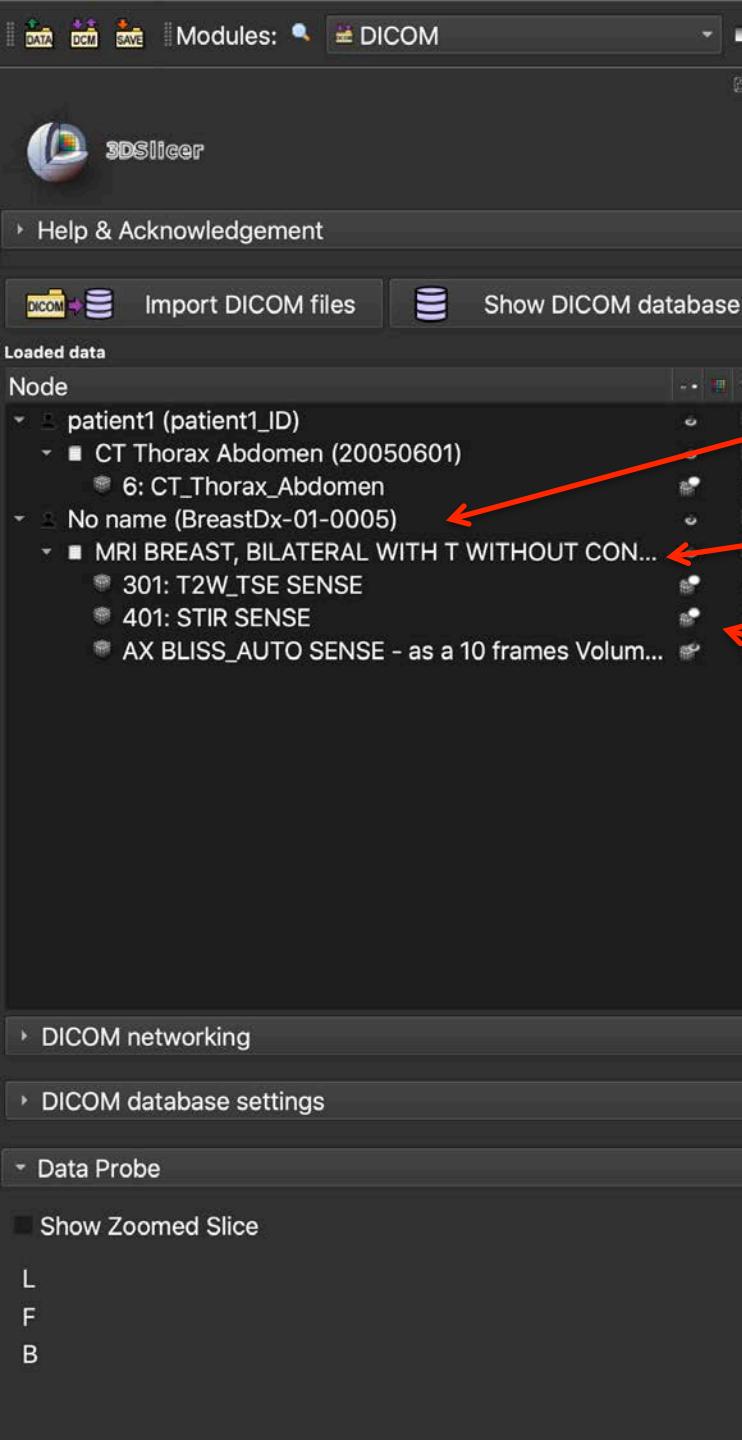
✓ DICOMScalarVolumePlugin ✓ DICOMData Reader
✓ DICOMSlicerDataBundlePlugin ✓ 301: ... Scalar Volume
✓ DICOMVolumeSequencePlugin ✓ 401: ... Scalar Volume
✓ MultiVolumeImporterPlugin ✓ AX ... MultiVolume
801: A... Scalar Volume Images are not equally spaced (a difference of 2 v...
AX ... MultiVolume

Uncheck All Examine Load Advanced

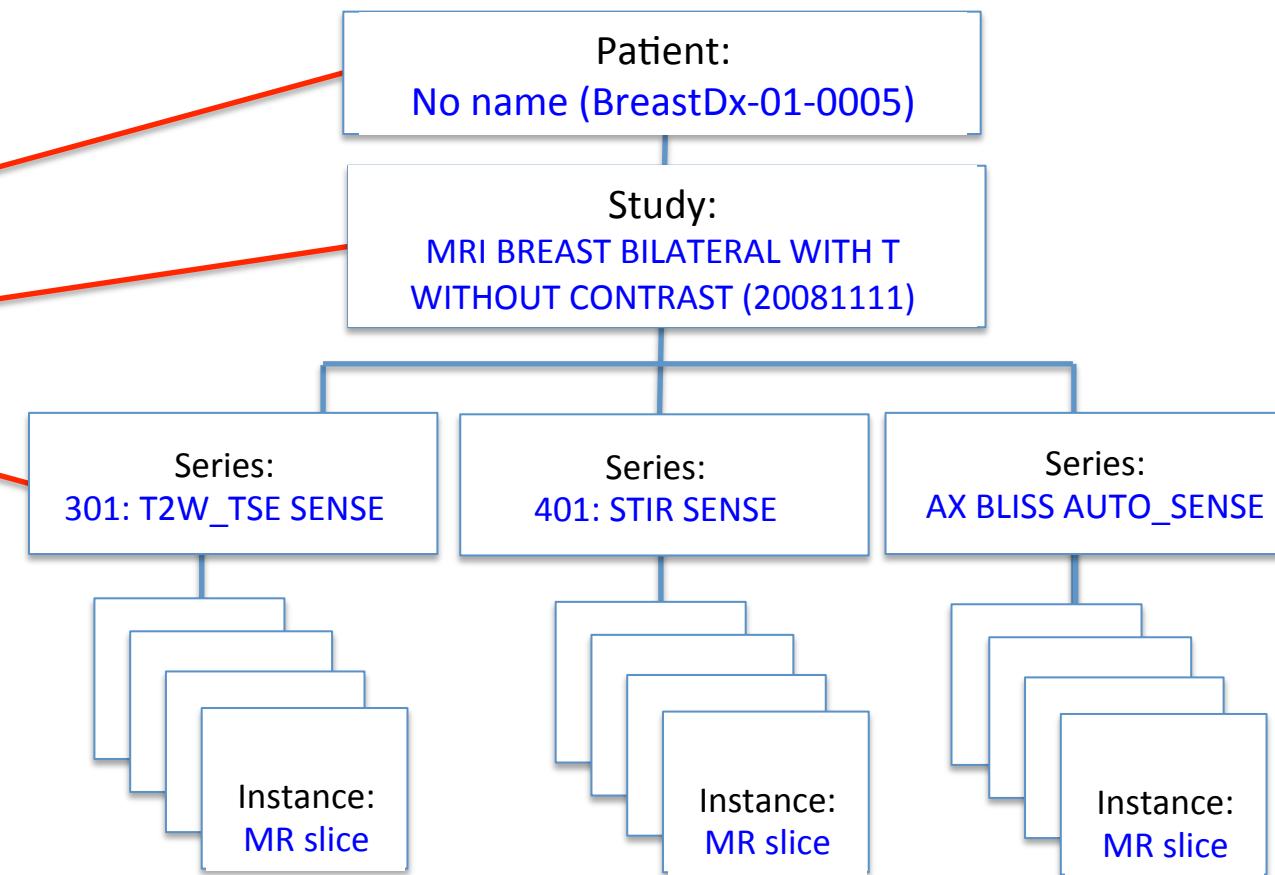
Sonia Pujol PhD, All Rights Reserved

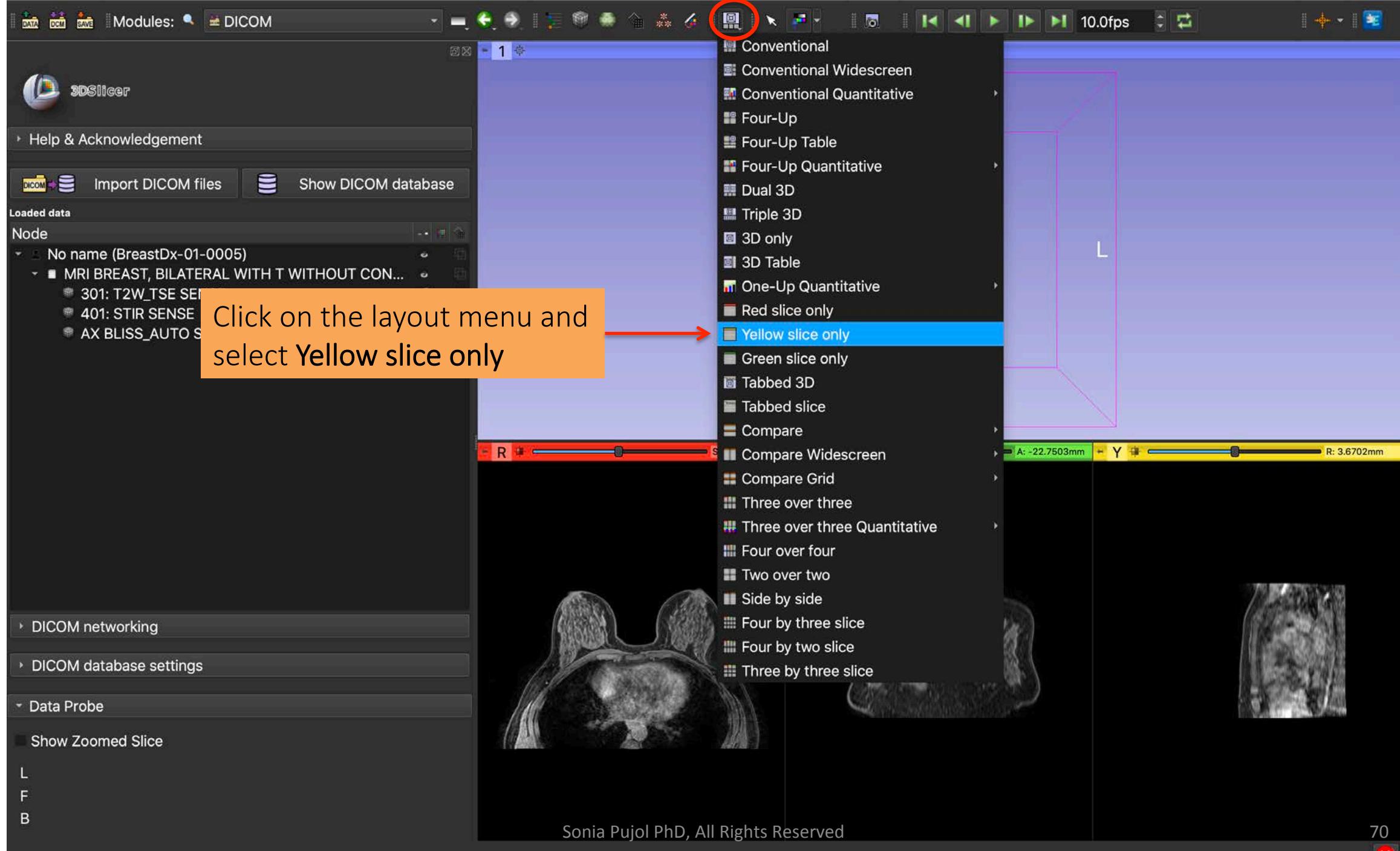
Click on Load to load the data into Slicer

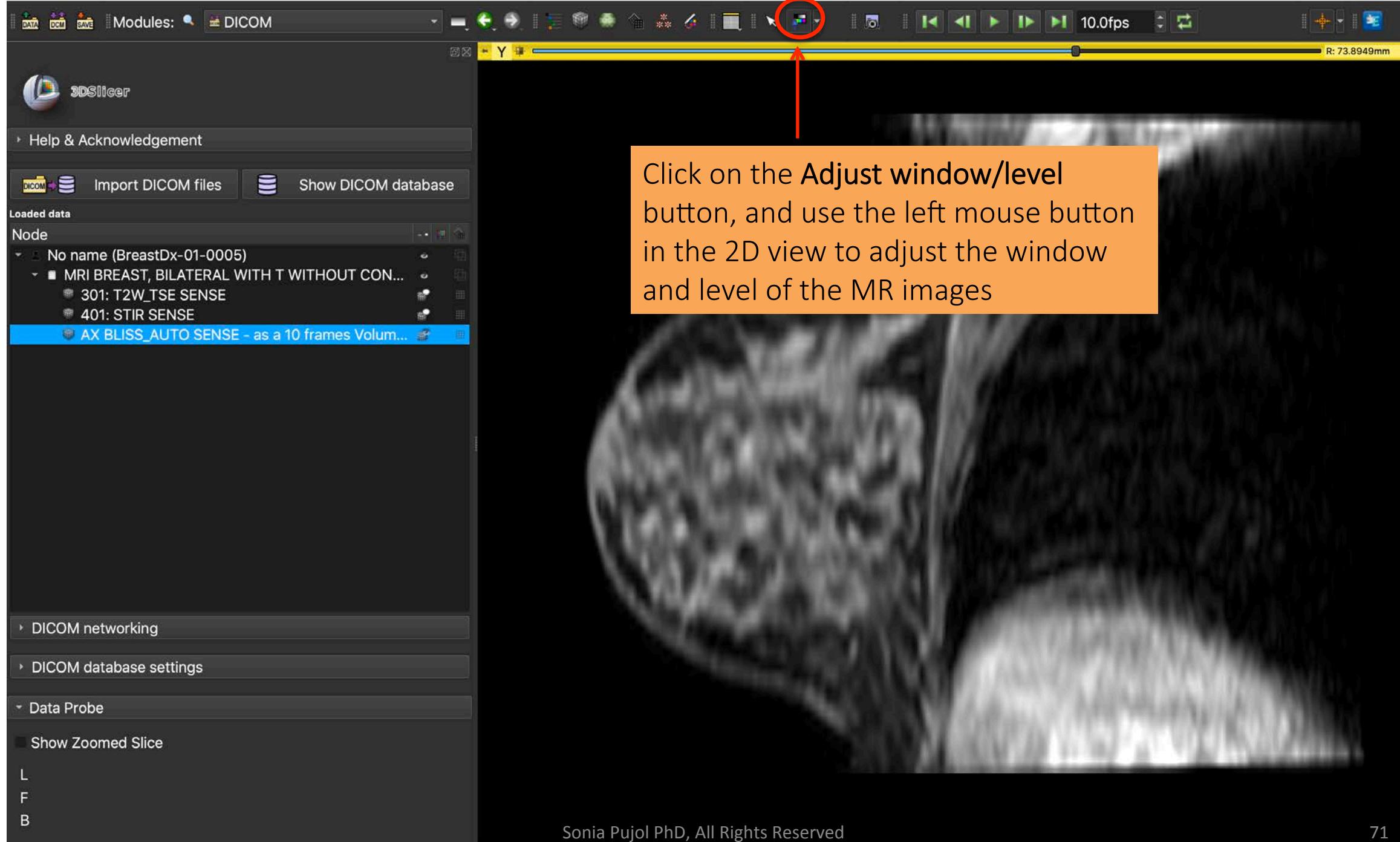


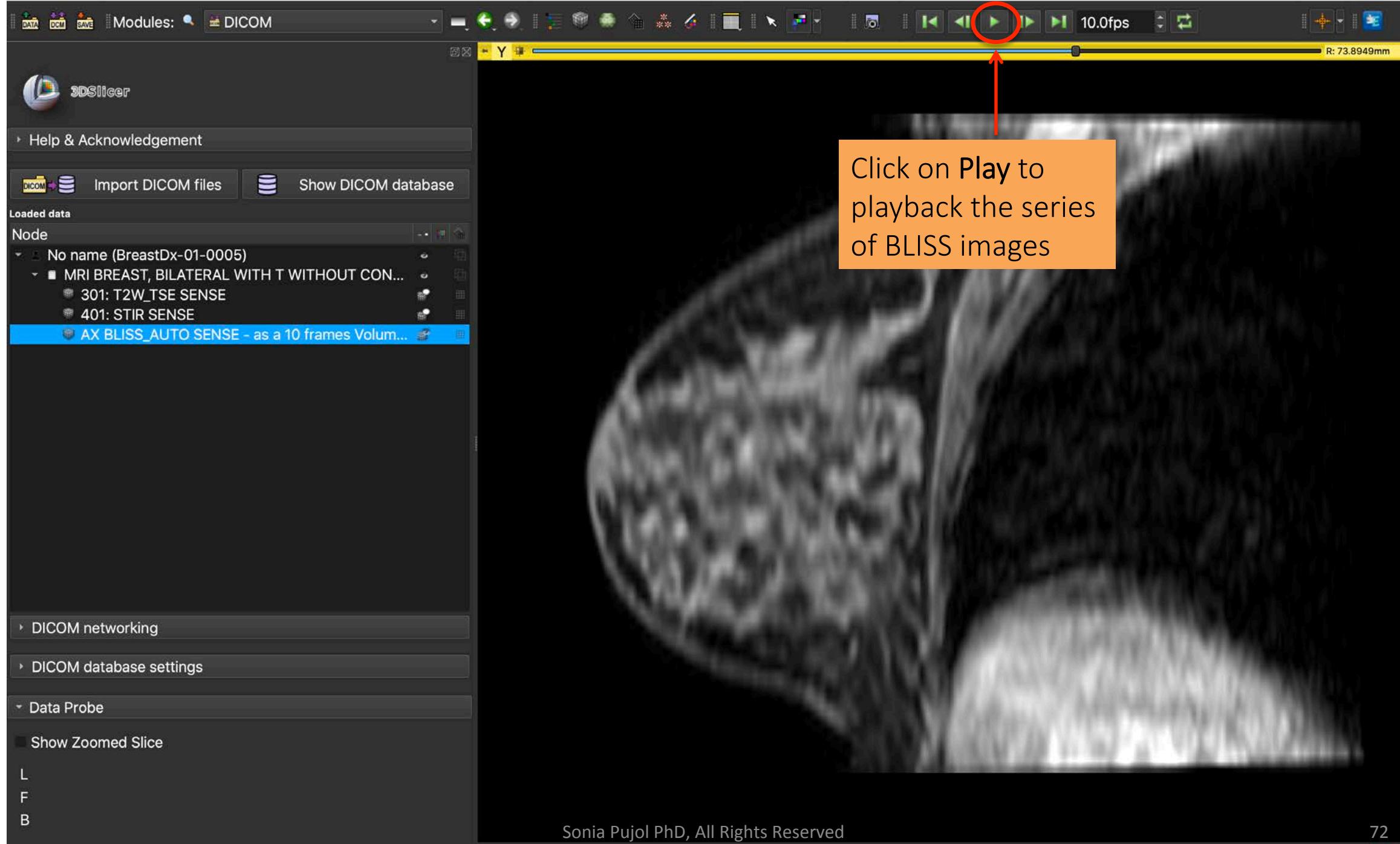


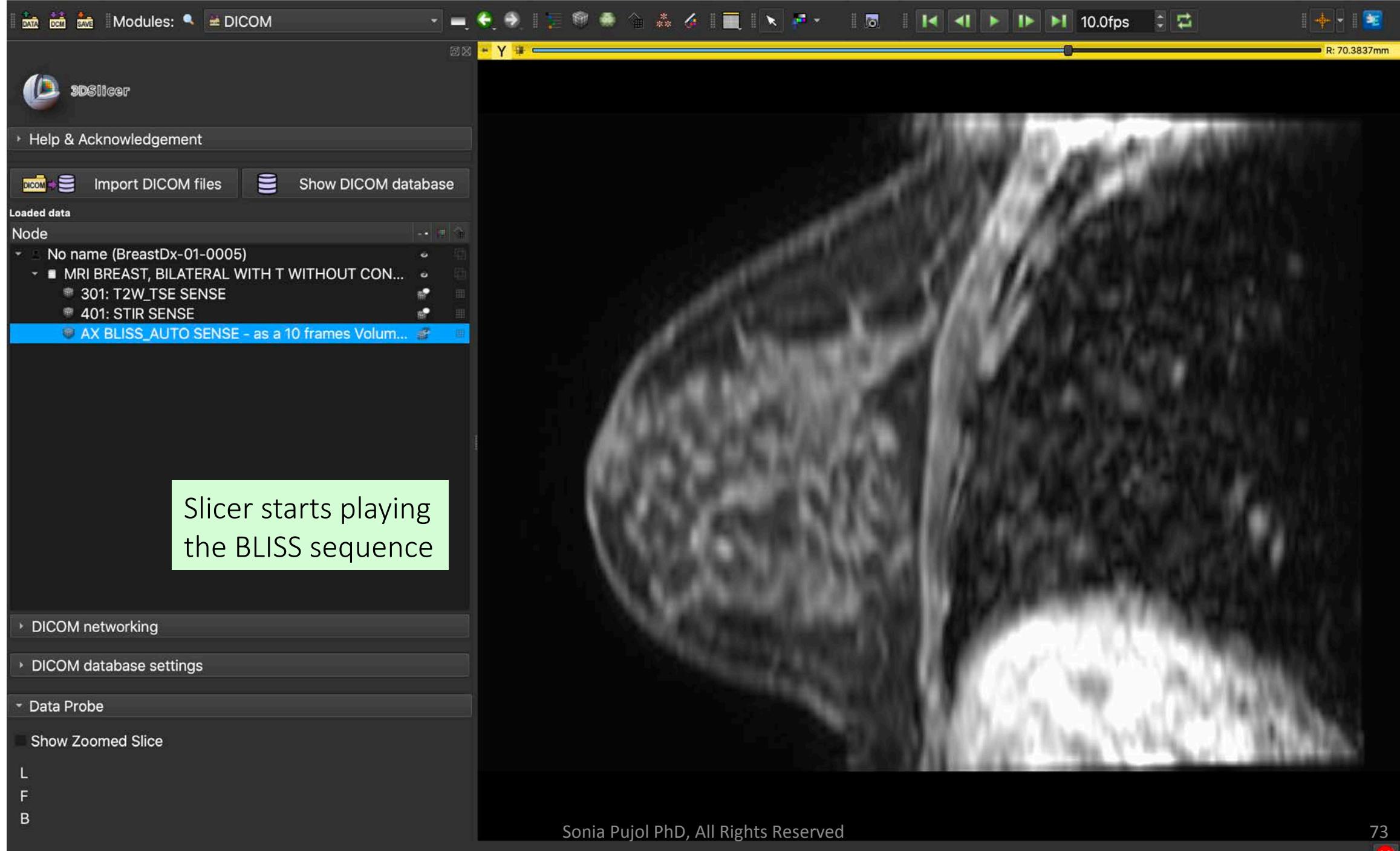
DICOM data are loaded into Slicer as a patient-study-series hierarchy

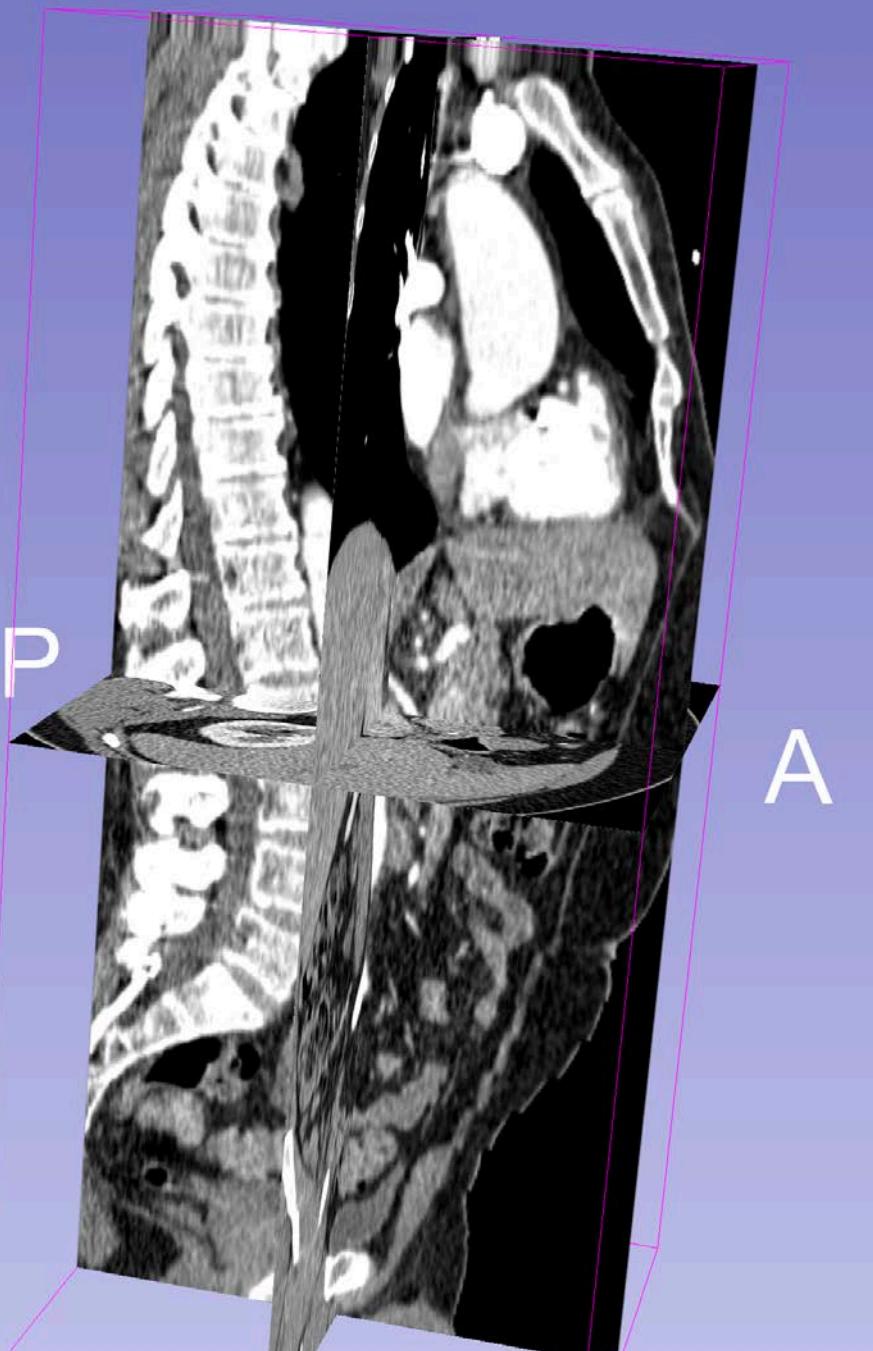












Conclusion

- 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



Acknowledgments

Neuroimaging Analysis Center
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