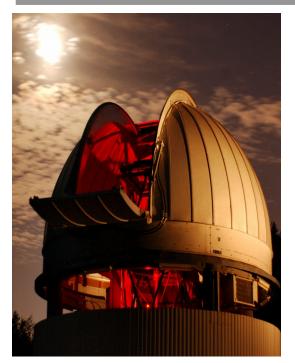


Data Format, Modeling, and Imaging



Gail Schaefer

The CHARA Array of Georgia State University

Mount Wilson, CA

With contributions from: Fabien Baron and Laurent Bourgès



















- CHARA staff and consortium members will support data reduction to OIFITS format
- Many users may find it informative to run reduction software and calibration themselves
- Data analysis, model fitting, image reconstruction performed by users



















- OIFITS: Data exchange standard for Optical Interferometry
- Target and instrument information tables:
 - OI_TARGET
 - OI_ARRAY
 - OI_WAVELENGTH
- Data tables:
 - OI_VIS2
 - OI_T3













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OI_VIS2 Table (OIFITS)

TARGET_ID	Target number		
TIME	UTC time of observation (s)		
MJD	Modified Julian Date		
INT_TIME	Integration time (s)		
VIS2DATA	Squared Visibility		
VIS2ERR	Error in Squared Visibility		
UCOORD	U coordinate of data (m)		
VCOORD	V coordinate of data (m)		
STA_INDEX	Station numbers		
FLAG	Flag		















OI_T3 Table (OIFITS)

	TARGET_ID	Target number			
	TIME	UTC time of observation (s)			
-	MJD	Modified Julian Date			
	INT_TIME	Integration time (s)			
	T3AMP	Triple Product Amplitude			
	T3AMPERR	Error in Triple Product Amplitude			
	ТЗРНІ	Triple Product Phase in degrees			
	T3PHIERR	Error in Triple Product Phase in degrees			
	U1COORD	U coordinate of baseline AB in triangle (m)			
	V1COORD	V coordinate of baseline AB in triangle (m)			
	U2COORD	U coordinate of baseline BC in triangle (m)			
-	V2COORD	V coordinate of baseline BC in triangle (m)			
	STA_INDEX	Station numbers			
	FLAG	Flag			
	Georgia <u>State</u> University 🐲 💭 l'Observatoire – LESIA 😥 net of a la contra d'Azur Exervatoire de Paris				

Software for Reading/Writing OIFITS Files

- OIFITSlib C Library
 - https://github.com/jsy1001/oifitslib
- IDL OIFITS Library by John Monnier
 - http://dept.astro.lsa.umich.edu/~monnier/oi_data/
- OIFITS Explorer by JMMC
 - http://www.jmmc.fr/oifitsexplorer_page.htm
- OITOOLS.jl in development by Fabien Baron
 - Data visualization and modeling (Julia)



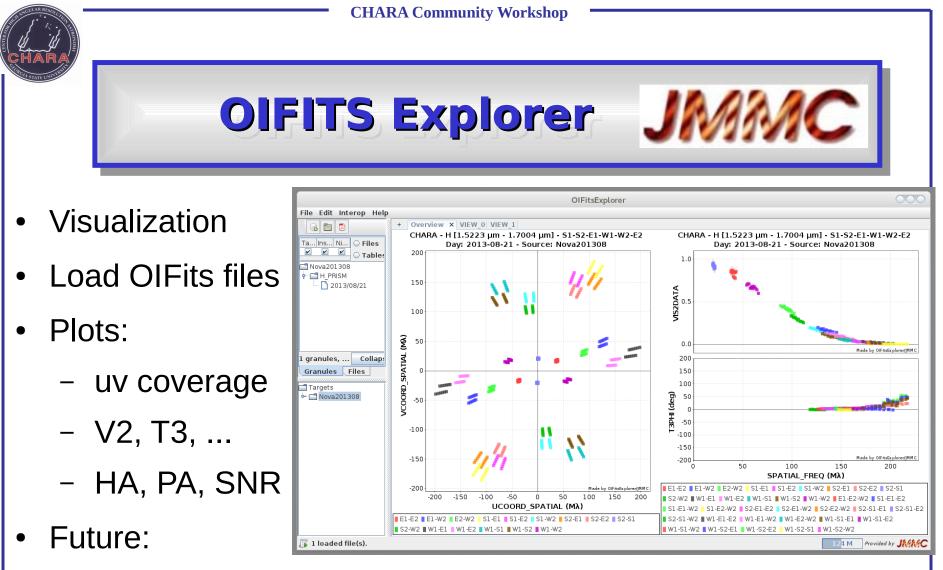












- Editor: flag and export merged OIFITS files

l'Observatoire

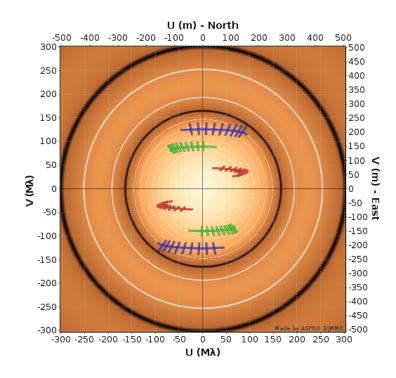
LESIA

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Better data selection graphically

GeorgiaStateUniversity

Data Analysis



- Interferometers measure the Fourier Transform of the brightness distribution
- Sparse sampling
- Geometric model fitting
- Physical models
- Image reconstruction







LESIA





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- Fit geometric and limb-darkened models
- Plots to visualize data, models, and results of fits
- Tools to find global minimum

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LITpr⇔



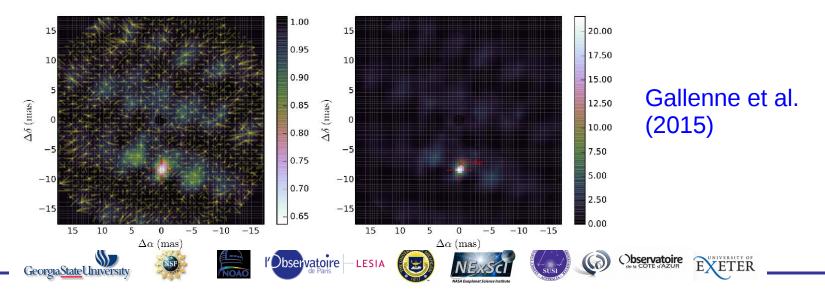








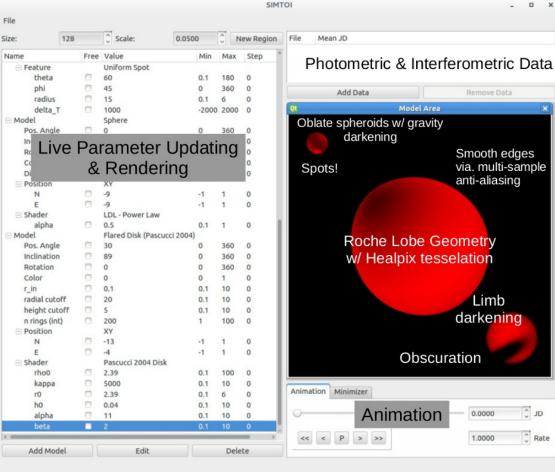
- Companion Analysis and Non-Detection in Interferometric Data
- Grid search for binary companions
- Estimate detection limits
- https://github.com/amerand/CANDID



Model Fitting: SIMTOI

- SIMTOI: SImulation and Modeling Tool for Optical Interferometry
- Written by Brian Kloppenborg
- GPU accelerated
- Photometry + interferometry
- Physical models
- Global optimization
- Keplerian orbits

https://github.com/bkloppenborg/simtoi













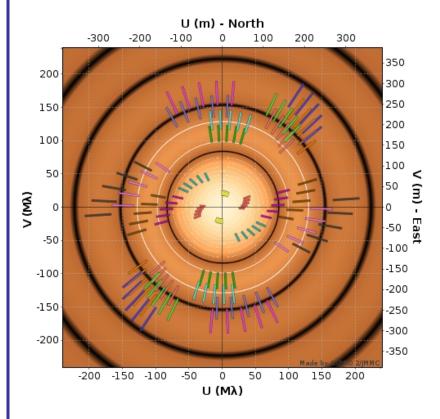


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bservatoire

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Image Reconstruction



- Sparse sampling of Fourier frequencies in plane of sky
- Inverse Fourier transform to obtain image
 - Compromise between:
 - Fitting available data
 - Keeping the image as regular (simple) as possible



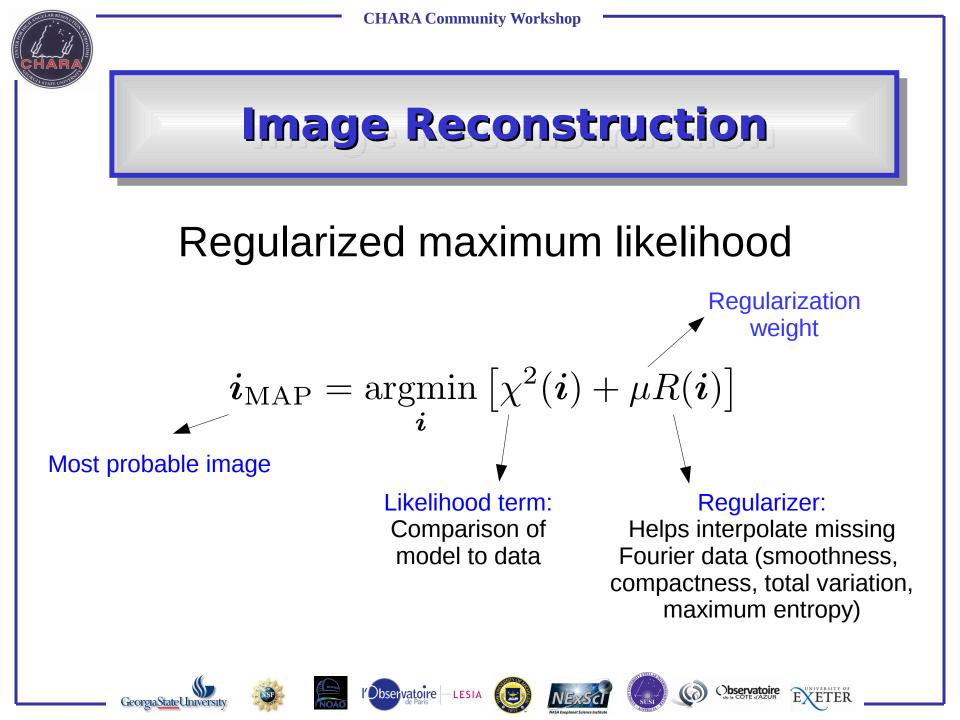




Image Reconstruction Software

Software	Optimization	Regularizer	Multi- Spectral	Simultaneous Model Fitting
BSMEM	Trust region gradient	Maximum Entropy Method	No	No
MACIM	Simulated annealing	Maximum Entropy Method, Darkness	No	Yes
MiRA	Variable Metric Limited Memory with bound constraints	Many	No	Yes
SQUEEZE	Parallel Tempering	Many	Yes	Yes
PAINTER	Alternating Direction Method of Minimizers	Many	Yes	No











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Imaging Tutorial



Principles of image reconstruction in optical interferometry: tutorial

ÉRIC THIÉBAUT^{1,*} AND JOHN YOUNG²

¹University of Lyon, University Lyon 1, ENS de Lyon, CNRS, Centre de Recherche Astrophysique de Lyon UMR5574, F-69230, Saint-Genis-Laval, France ²University of Cambridge, Cavendish Laboratory, JJ Thomson Avenue, Cambridge CB3 0HE, UK *Corresponding author: eric.thiebaut@univ-lyon1.fr

> JMMC is developing a common interface for "classic" image reconstruction software http://www.jmmc.fr/oimaging.htm





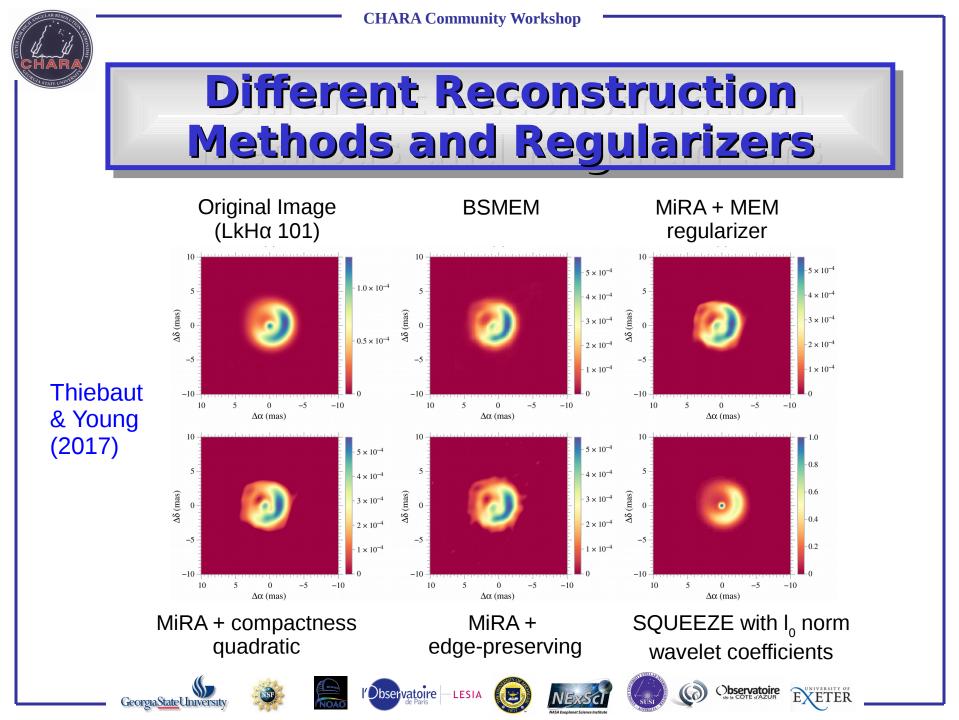










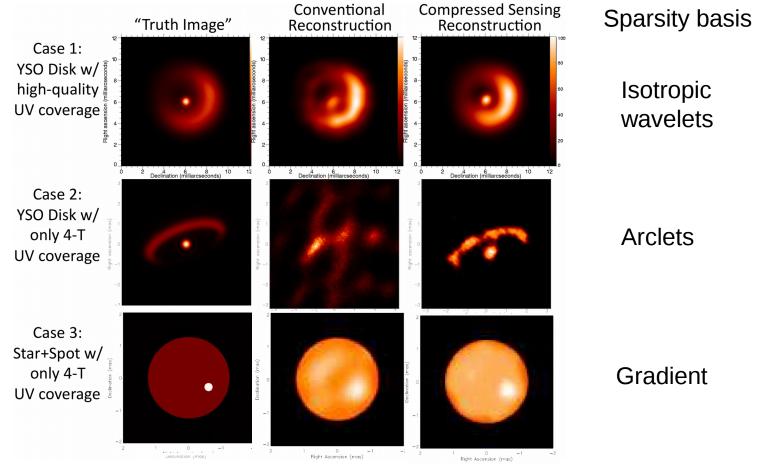


High Fidelity Imaging of Complex Targets is Difficult

Millour & Vannier (BSMEM) Rengaswamy (unamed method) Elias (CASA) AZ Cyg 2012 IAU Interferometry **Beauty Contest** Baron et al. 2012 -2 (1.5 million (mos)) (1.5 million (mos)) A 2 (2) Appl Appendix (max) Dicht Astension (mar) Young (BSMEM) Thiébaut & Soulez (MiRA) Monnier (MACIM) Bet Fak Model 64 Center = 12 00 0.0000, 00 00 0.000 J2000.0 4 Truth/Model \sim Y (mas) 4 2 3 2 Disto Assession (max) a 2 (2) and a state of (max). Mary & Vannier (MIROIRS) Millour & Vannier (MiRA) Hofmann, Schertl & Weigelt (IRS) \sim 4 γŤ 4 0 -2 $^{-4}$ Right Ascension (mas) l'Observatoire - LESIA Observatoire EXETER GeorgiaStateUniversity



Ongoing Research on Better Regularization



Baron et al., in prep







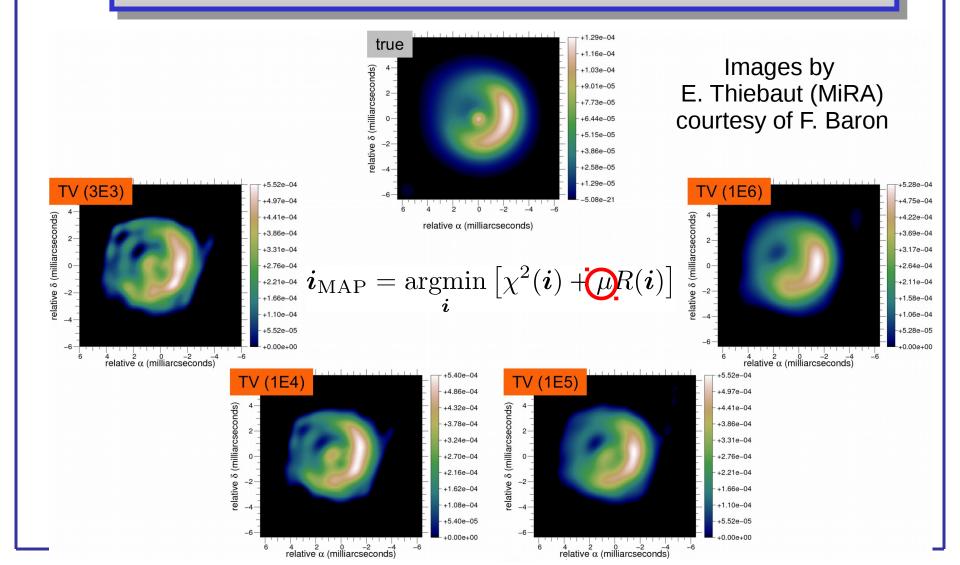


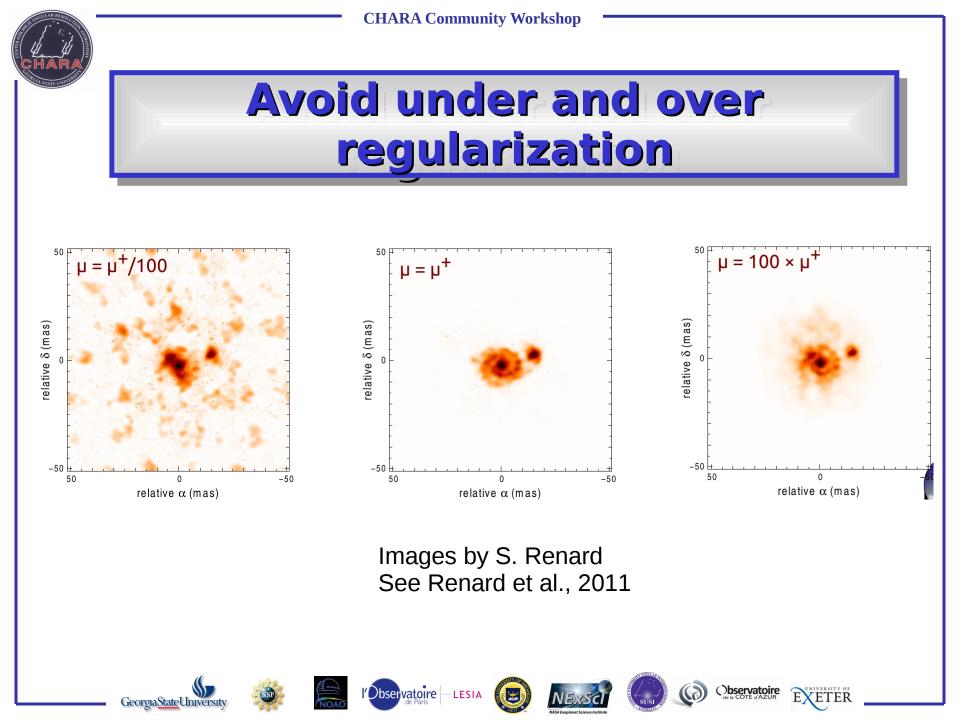






Regularization Weight







Artifact Detection

Use two control sets:

- model image of object with complexity (e.g., spotted star)
- much simpler model image with no features (e.g. limb-darkened disk)
- Simulate observations copy Fourier coverage and signal to noise from original data
- Reconstruct images for two control • data sets and check fidelity of reconstuctions
- Were spurious features introduced in • simple model?
- Were feature correctly recovered in • the complex model?









-1.0

-0.5



0.5

0.0

Right Ascension (mas)



1.0





Right Ascension (mas)

0.5

1.0

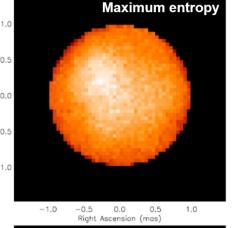
This method will help identify the best regularization

-1.0

0.0

-0.5 -0.5 -1.0 1.0 1.0 -0.5 0.5 Right Ascension (mas) Right Ascension (mas) Uniform disc regularizer **Total variation** 1.0 1.0 0.5

Model



Fabien Baron



