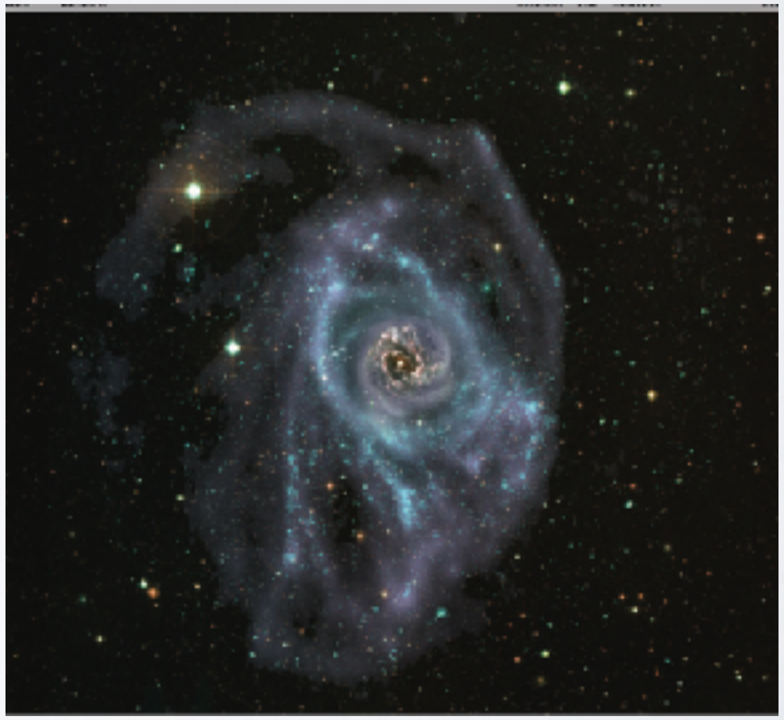
Overview of the HI SWG needs in the context of SRCs

Lourdes Verdes-Montenegro

Instituto de Astrofísica de Andalucía (CSIC)

Co-chair of the HISWG (together with Sarah Blyth)

History of gas in our universe through the study of atomic HI line emission and absorption



Blok et al 2015, Picture courtesy B. Koribalski

27th March 2018, AENEAS all-hands meeting (Nice)

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- …on behalf of the HI SWG
- …feedback of interest for AENEAS WPs

SKA1 Science Goals. HI Science

Science Goal	SWG	Objective	SWG Rank
1	CD/EoR	Physics of the early universe IGM - I. Imaging	1/3
2	CD/EoR	Physics of the early universe IGM - II. Power spectrum	2/3
3	CD/EoR	Physics of the early universe IGM - III. HI absorption line spectra (21cm forest)	3/3
4	Pulsars	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection	1/3
5	Pulsars	High precision timing for testing gravity and GW detection	1/3
6	Pulsars	Characterising the pulsar population	2/3
7	Pulsars	Finding and using (Millisecond) Pulsars in Globular Clusters and External Galaxies	2/3
8	Pulsars	Finding pulsars in the Galactic Centre	2/3
9	Pulsars	Astrometric measurements of pulsars to enable improved tests of GR	2/3
10	Pulsars	Mapping the pulsar beam	3/3
11	Pulsars	Understanding pulsars and their environments through their interactions	3/3
12	Pulsars	Mapping the Galactic Structure	3/3
13	HI	Resolved HI kinematics and morphology of ~10^10 M_sol mass galaxies out to z~0.8	1/5
14	HI	High spatial resolution studies of the ISM in the nearby Universe.	2/5
15	HI	Multi-resolution mapping studies of the ISM in our Galaxy	3/5
16	HI	HI absorption studies out to the highest redshifts.	4/5
17	HI	The gaseous interface and accretion physics between galaxies and the IGM	5/5
18	Transients	Solve missing baryon problem at z~2 and determine the Dark Energy Equation of State	=1/4
19	Transients	Accessing New Physics using Ultra-Luminous Cosmic Explosions	=1/4
20	Transients	Galaxy growth through measurements of Black Hole accretion, growth and feedback	3/4
21	Transients	Detect the Electromagnetic Counterparts to Gravitational Wave Events	4/4
22	Cradle of Life	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc	1/5
23	Cradle of Life	Characterise exo-planet magnetic fields and rotational periods	2/5
24	Cradle of Life	Survey all nearby (~100 pc) stars for radio emission from technological civilizations.	3/5
25	Cradle of Life	The detection of pre-biotic molecules in pre-stellar cores at distance of 100 pc.	4/5
26	Cradle of Life	Mapping of the sub-structure and dynamics of nearby clusters using maser emission.	5/5
27	Magnetism	The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields	1/5
28	Magnetism	Determine origin, maintenance and amplification of magnetic fields at high redshifts - I.	2/5
29	Magnetism	Detection of polarised emission in Cosmic Web filaments	3/5
30	Magnetism	Determine origin, maintenance and amplification of magnetic fields at high redshifts - II.	4/5
31	Magnetism	Intrinsic properties of polarised sources	5/5
32	Cosmology	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.	1/5
33	Cosmology	Angular correlation functions to probe non-Gaussianity and the matter dipole	2/5
34	Cosmology	Map the dark Universe with a completely new kind of weak lensing survey - in the radio.	3/5
35	Cosmology	Dark energy & GR via power spectrum, BAO, redshift-space distortions and topology.	4/5
36	Cosmology	Test dark energy & general relativity with fore-runner of the 'billion galaxy' survey.	5/5
37	Continuum	Measure the Star formation history of the Universe (SFHU) - I. Non-thermal processes	1/8
38	Continuum	Measure the Star formation history of the Universe (SFHU) - II. Thermal processes	2/8
39	Continuum	Probe the role of black holes in galaxy evolution - I.	3/8
40	Continuum	Probe the role of black holes in galaxy evolution - II.	4/8
41	Continuum	Probe cosmic rays and magnetic fields in ICM and cosmic filaments.	5/8
42	Continuum	Study the detailed astrophysics of star-formation and accretion processes - I.	6/8
43	Continuum	Probing dark matter and the high redshift Universe with strong gravitational lensing.	7/8
44	Continuum	Legacy/Serendipity/Rare.	8/8

Table 1. Collated list of science goals. Within each science area, the entries are ordered in the rank provided by the SWG Chairs. The eight different groups of SWG contributions are listed in the Table in an arbitrary sequence.

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Continuum	Star formation history of the Universe (SFHU) – I+II. Non-thermal + Thermal processes

SKA1 SCIENCE PRIORITY OUTCOMES

Document number SKA-TEL-SKO-0000122
Context .... SCI-REQ-RE
Revision 1
Author .... R. Braun, T. Bourke, J. Green, J. Wagg
Date 2014-09-25
Document Classification .... FOR PROJECT USE ONLY
Status .... Released

2014/09/25

PREVIOUS RELATED DISCUSSIONS

- In November 2015 there was an SDP/science working group meeting in which the HISWG was represented by Attila Popping
- A document was circulated on "Science Data Processor: anticipated data products"
- The HISWG gave comments/requests to the SDP
- This feedback was gathered by the SDP with no particular agreement reached but the plan was
  - this to be the beginning of further discussions on what could be realistic,
  - Post processing by SWGs will have to be done by computing nodes or centres outside the central processor

Note that:

- This meeting was previous to the decision by the Board (April 2016) confirming its preference for a regional network model for provision of science data
- So now **the feedback should have as a starting point the boundary between the SDP and the SRCs**

BASED ON

- Update from Rosie Bolton March 2018 on the SDP/SRCs boundaries (from SDP Architecture) == Talk yesterday
- What should I ask that can be useful…?

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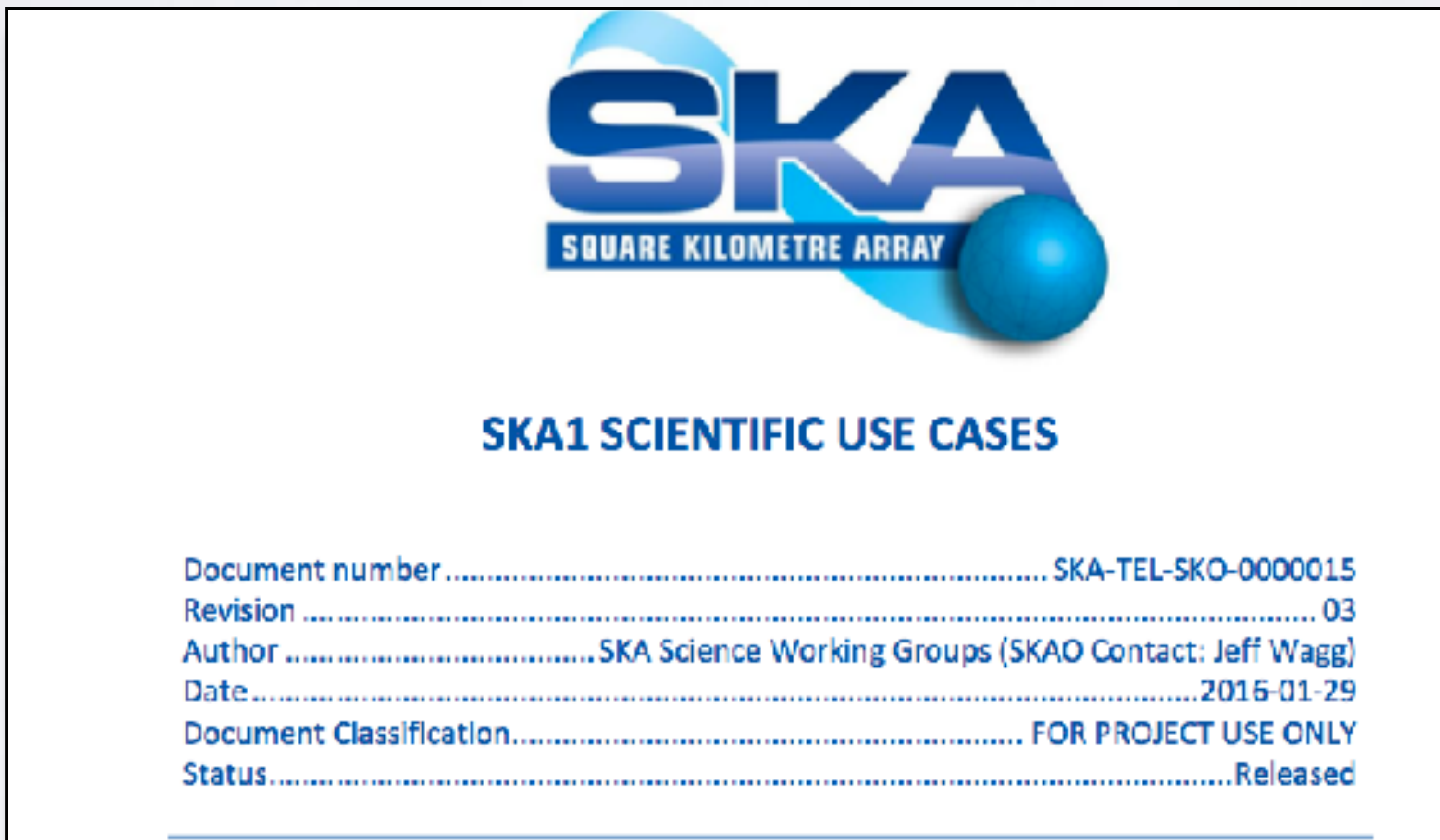

SKA
SQUARE KILOMETRE ARRAY

SKA1 SCIENTIFIC USE CASES

Document number SKA-TEL-SKO-0000015
Revision 03
Author .... SKA Science Working Groups (SKAO Contact: Jeff Wagg)
Date 2016-01-29
Document Classification .... FOR PROJECT USE ONLY
Status .... Released

SKA1 SCIENTIFIC USE CASES** (2016-01-29)

- Initial set of requirements extracted from the sample use cases scenarios indicated below (that intended to serve to guide requirements for SKA1 design)

TABLE OF CONTENTS

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SKA1 SCIENTIFIC USE CASES (2016-01-29)

3.4 SKA1 All-Sky HI Survey

PROJECT DETAILS	
Title	**SKA1 All-Sky HI Survey**
Principal Investigator	**Oort**
Co-Authors	**HI-Galaxy SWG**
Time Request	**10,000 hrs**
FACILITY	**Preconditions**
SKA1-LOW	
□ SKA1-MID	

RECEIVER(S) REQUIRED		Time (hrs)
	SKA1-LOW	
	SKA1-MID Band 1	
□	SKA1-MID Band 2	10,000
	SKA1-MID Band 3	
	SKA1-MID Band 4	
	SKA1-MID Band 5	

OPERATIONAL MODE (as defined in Concept-of-Operations)		Details
□	Normal	Mosaic observations
	Fixed schedule (give cadence)	
	Time-critical override	
	Custom Experiment	
□	Commensal	Continuum, polarisation, co
	Collaborative & Coordinated	
	Sub-arrays required	

DATA ANALYSIS	
Procedures required	RFI mitigation, flagging, calibration, continuum subtraction, widefield imaging, mosaicing, source-finding and source parameterisation
Processing considerations	Likely processing issues: • Large data volumes • Widefield images with non-coplanar baselines • Accurate primary beam for mosaicing • Flagging of RFI • Requirement to search cubes multiple times (source detection). • Requirement to stack at a given set of coordinates
Data products	Stokes I data cubes; image cut-outs; spectra; minicubes; catalogues
Pipeline	• Collect visibilities on multiple days • Apply barycentric correction • Apply flagging • Calibrate visibilities • Peel strong continuum sources • Subtract remaining continuum sources using global sky model • Make daily cubes at multiple resolutions for each pointing • Combine cubes (and beams) for individual pointings in the image domain • Residual polynomial continuum subtraction in image domain • Linear mosaicking of multiple fields, followed by cutouts in RA, Dec, Freq • Multiscale deconvolution of strongest sources
Quality assessment plan & cadence	• Inspect RFI occupancy plots • Examine rms and histogram of pixel values in daily cubes. • Compare flux densities of known sources in daily cubes.
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Last midnight

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PIPELINES

16	HI	HI absorption studies out to the highest redshifts.

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50 unique pointings x 100 h
3.7 An all-sky absorption survey at z~1 - 3
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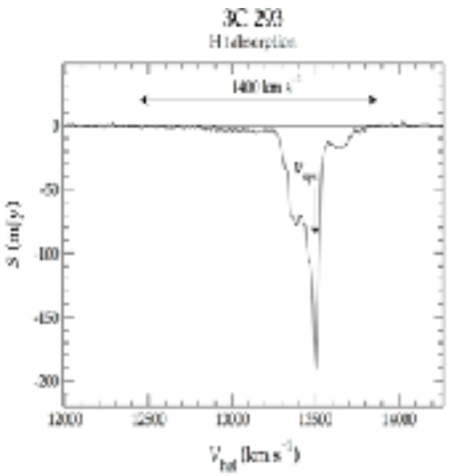

Morganti et al 2015

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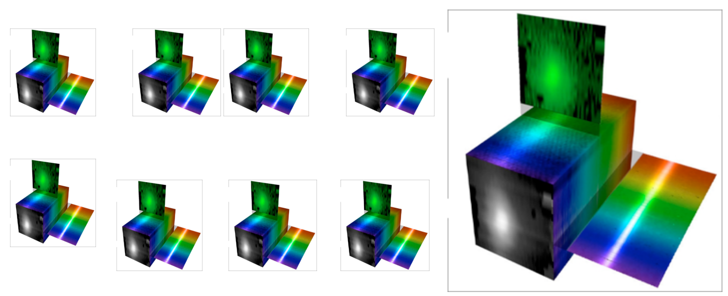

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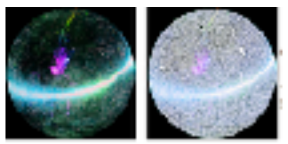
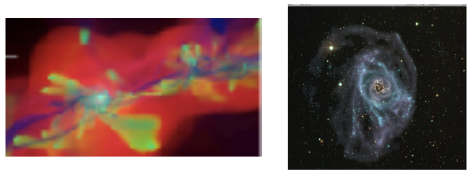


McClure-Griffiths et al 2015



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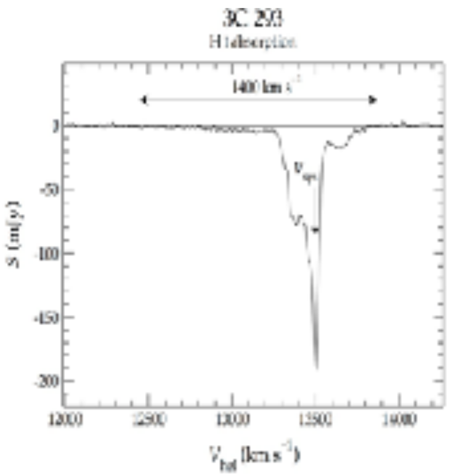

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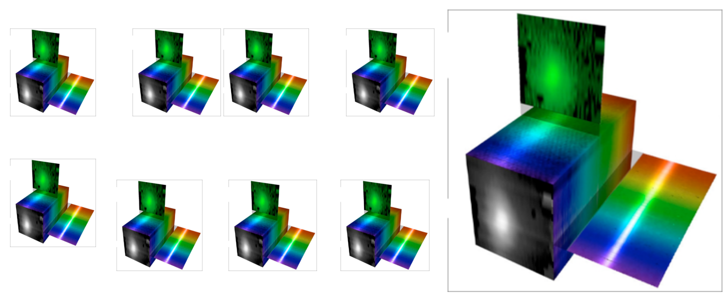

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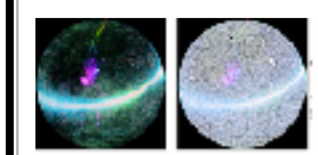

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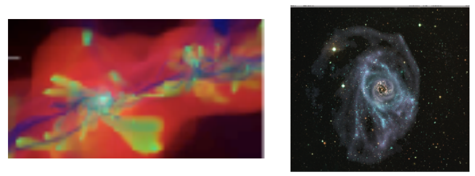

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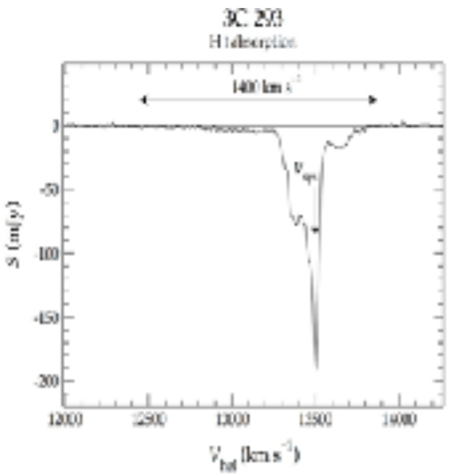

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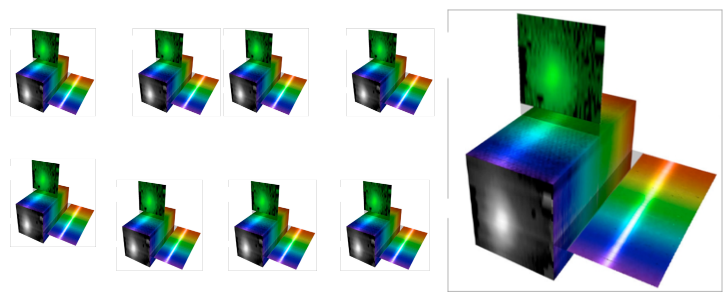

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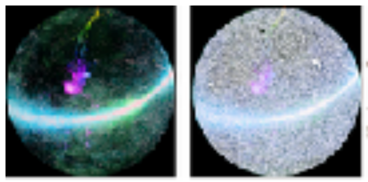

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- Gridding the UV data so that new data can be combined in this grid as it is observed.

3.3 A blind HI 21-cm absorption line survey at 3<z<6
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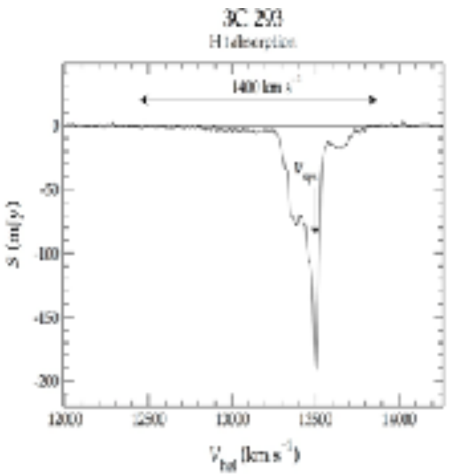
50 unique pointings x 100 h
3.7 An all-sky absorption survey at z~1 - 3
Mid- Band 1, 1,000 h, Individual pointings



Morganti et al 2015

- RFI mitigation and flagging
- Gain calibration
- Generate continuum visibility dataset
- Generate continuum image
- Apply the self-calibration solutions and direction-dependent corrections to the spectral line visibility dataset
- Subtract continuum from the line dataset
- Doppler correct (CVEL) line dataset
- Generate stokes-I spectral-line cube for full FoV at 4.6 kHz resolution
- Deconvolve channels with line detections, if needed.

Calibrated continuum and spectral line visibilities to be **combined with the data from other observing runs** to generate `final' stokes-I spectral-line cube(s).

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3.6 Medium-Deep HI Imaging Survey
3.9 Deep HI Imaging Survey
3.10 Medium-Wide HI Imaging Survey
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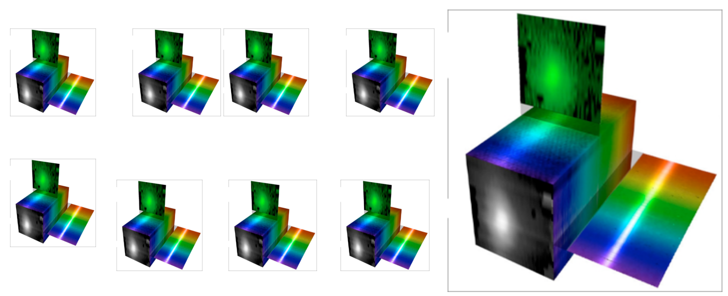
Mosaic observations,
20,000 targets, One deep field, Single pointing



- Collect visibilities on multiple days
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- Subtract remaining continuum sources using global sky model / Polynomial continuum subtraction

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- Daily cubes at **multiple resolutions** for each pointing (will SDP produce the required number?)
- **Combine cubes** (and beams) for individual pointings in the image domain
- Residual cont. subtraction in image domain
- **Multiscale deconv.** of strongest sources
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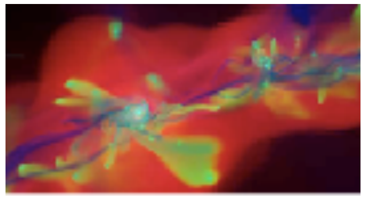

Agertz, Teyssier, Moore 2009

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14	*HI*	High spatial resolution studies of the ISM in the nearby Universe.

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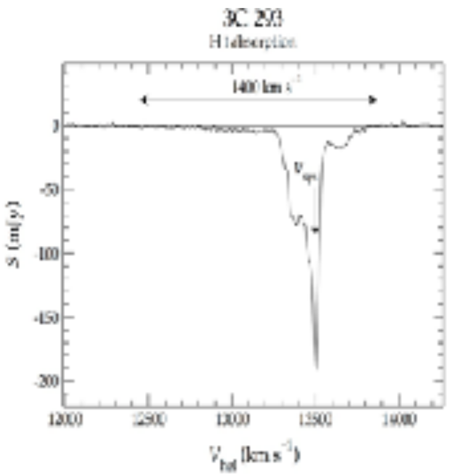

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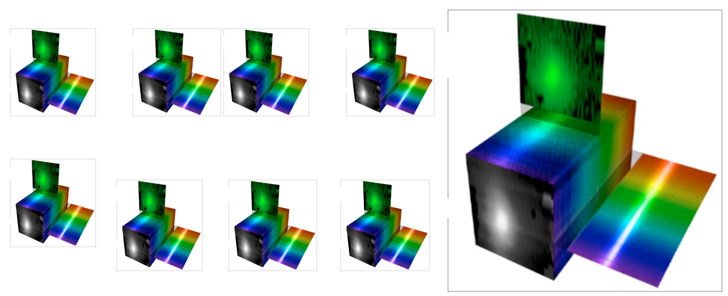

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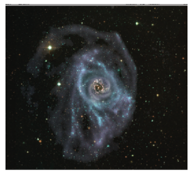

Blok et al 2015, Picture courtesy B. Koribalski

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Procedures required

Processing considerations

Data products

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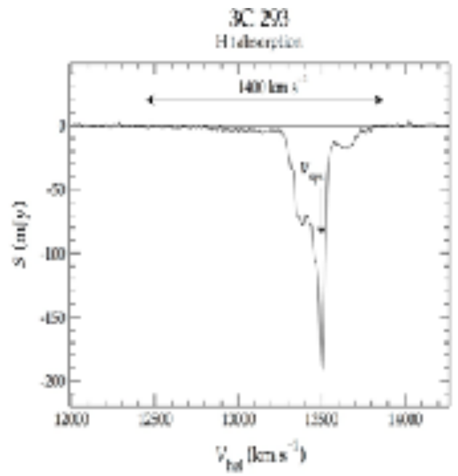

Morganti et al 2015

Procedures required, not in the SDP

—

Processing considerations

Reprocessing of calibrated visibilities

Data products

- Stokes I continuum visibility datasets and images at 225, 275 and 325 MHz
- Stokes I spectral-line cube over 200 – 350 MHz with 4 kHz resolution
- Cubelets and spectra towards all the sources brighter than 10 mJy in the FoV along with the RFI flags applied to the data. ?

——-

Continuum source and spectral line catalogs
Continuum image with 30% bandwidth centered at 600 MHz. This will be used to check the total flux density of the background source which should further be **logged in a public database for future sky-model** reference

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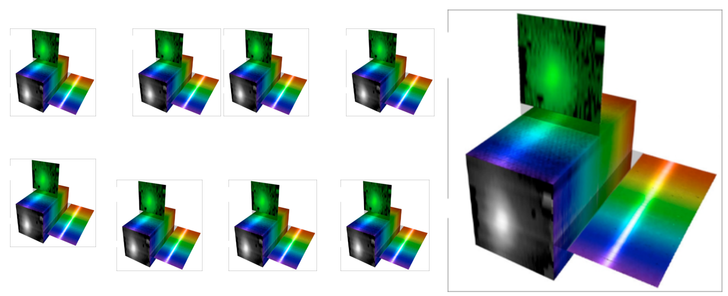

Procedures required, not in the SDP

- source-finding and source parameterisation
- data combination to created integrated deep cube (uv and image domain)

Processing considerations

Large data volumes, search cube multiple times (source detection), stacking

Data products

- Stokes I data cubes
- Calibrated, imaged, continuum subtracted datacubes

————

- image cut-outs
- spectra
- minicubes
- catalogues
- moment maps
- **masks used to make moment maps**
- **signal-to-noise maps**

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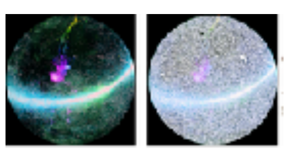
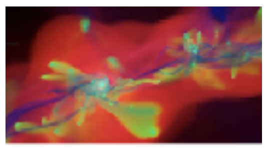
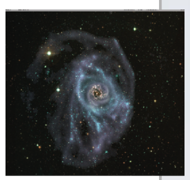


McClure-Griffiths et al 2015





Agertz, Teyssier, Moore 2009

Procedures required, not in the SDP

—

- Image cubes at multiple resolutions (will SDP produce the required number?).
- Addition of single dish data for imaging.
- joint deconvolution of mosaic;
- Multi-scale deconvolution;
- Addition of single-dish data for imaging ?

Processing considerations

Large data volumes due to full spectral resolution?

Data products

- Fully calibrated I, Q, U and V cubes at full spectral resolution
- Image cubes, moment maps, images of the PS
- Data cubes, Total HI image, velocity field, velocity dispersion map. At various resol.
- **masks used to make moment maps**
- **signal-to-noise maps**

MAIN CHARACTERISTICS OF THE DATA PRODUCTS

- **Volumes:**
  - SKA1MID, Band 2: Discovery cube size 2.6Pbytes. HI science a fraction down to 1/10 of the max. Extracted data products at least 10 times smaller (moment maps, pos.vel cuts, spectra)
  - continuum data products or spectral postage stamp cubes would be orders of magnitude smaller than the discovery cube

- **Formats:**
  - ongoing work by ICRAR-IT on the jp2 and jpx formats could feed perfectly into the requirements of efficiently extracting sub-cubes of various resolutions from a huge master cube.
  - …
- **Metadata:**
  - E.g. for spectra, description of the parameters that went into making them, like the size of the extraction region.

POTENTIAL SOFTWARE TO INTEGRATE IN THE SRCs SCIENCE PLATFORM

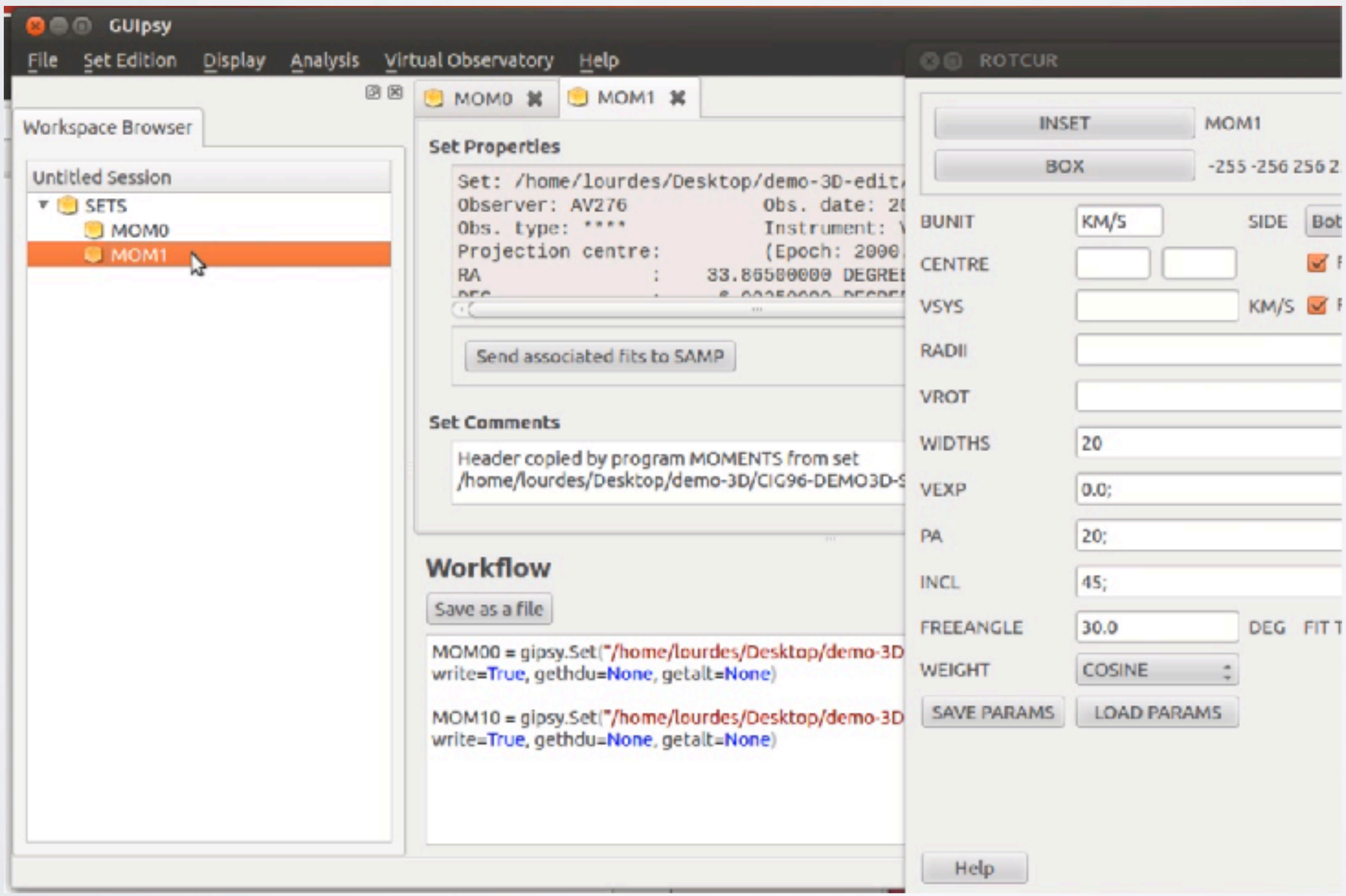
- Potential candidates:
    - Developed by SWGs, KSPs, precursors/pathfinders:
        - **Analysis**, e.g. SoFiA, TiRiFiC, GalAPAGOS, GIPSY/GuiPSY, 2DBAT, FAT, MAGMO,Barolo, GBKFit, CASA, etc (TBD)
        - **Visualization**: e.g SlicerAstro, VISIONS, X3D
    - Interaction/connection with the VO (e.g. in order to request complementary data or input data for modeling; e.g GuIPSY is connected with Topcat and Aladin)

-

CONNECTION BETWEEN VO TOOLS AND RADIO TOOLS

E.g.:
GUIPSY: Graphical User Interface for Groningen Image Processing Package

GUIpsy a VO compliant tool for the kinematical modelling of HI datacubes
Sánchez-Exposito, S.; Ruiz, J.E.; Vogelaar, M.G.R; Terlouw, J.P.; Verdes-Montenegro, L.; Santander-Vela, J.D.; van der Hulst, J.M; Garrido, J.
3GC4: HI Fidelity, 28th October, 2016. Port Alfred, South Africa



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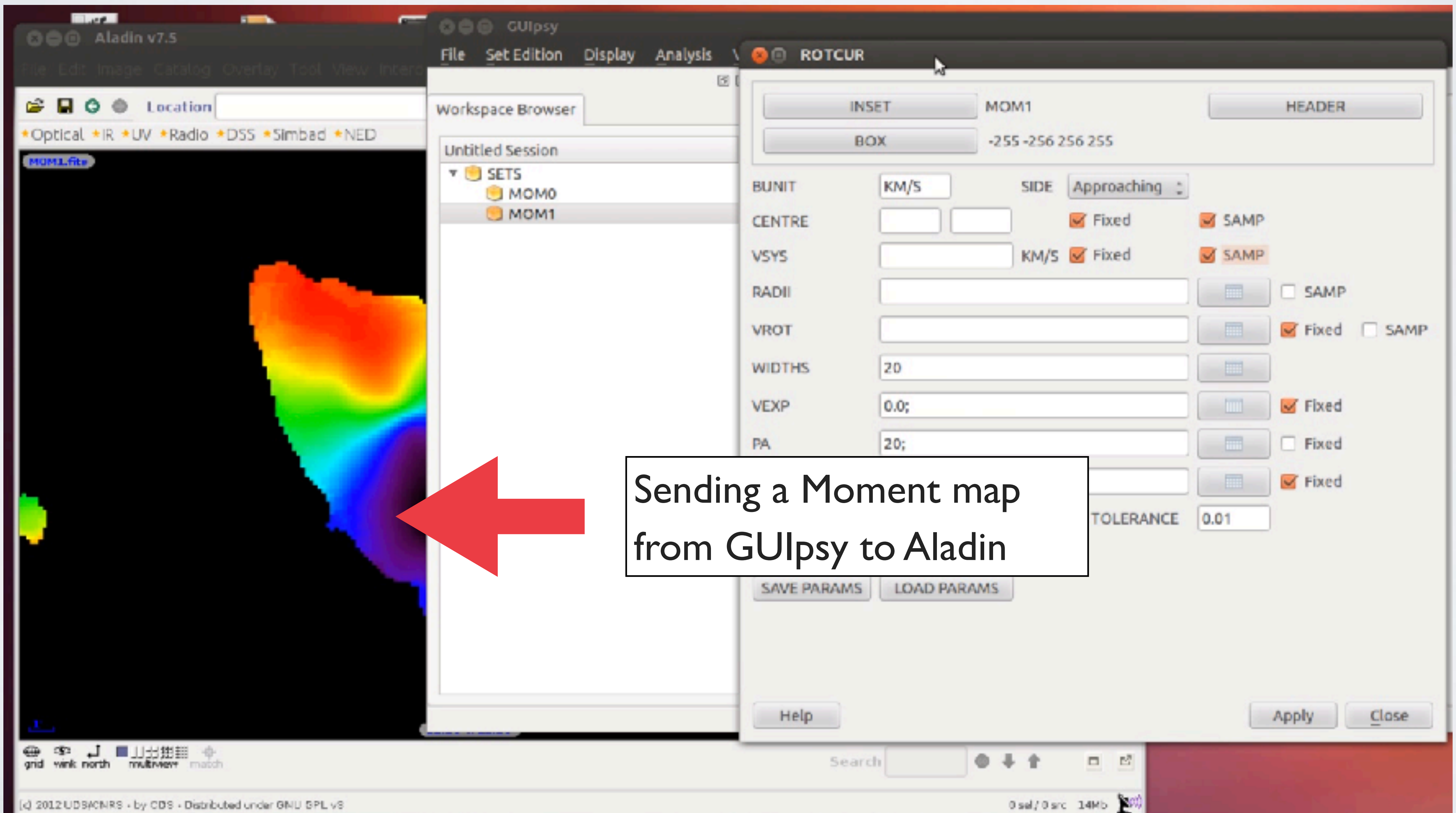

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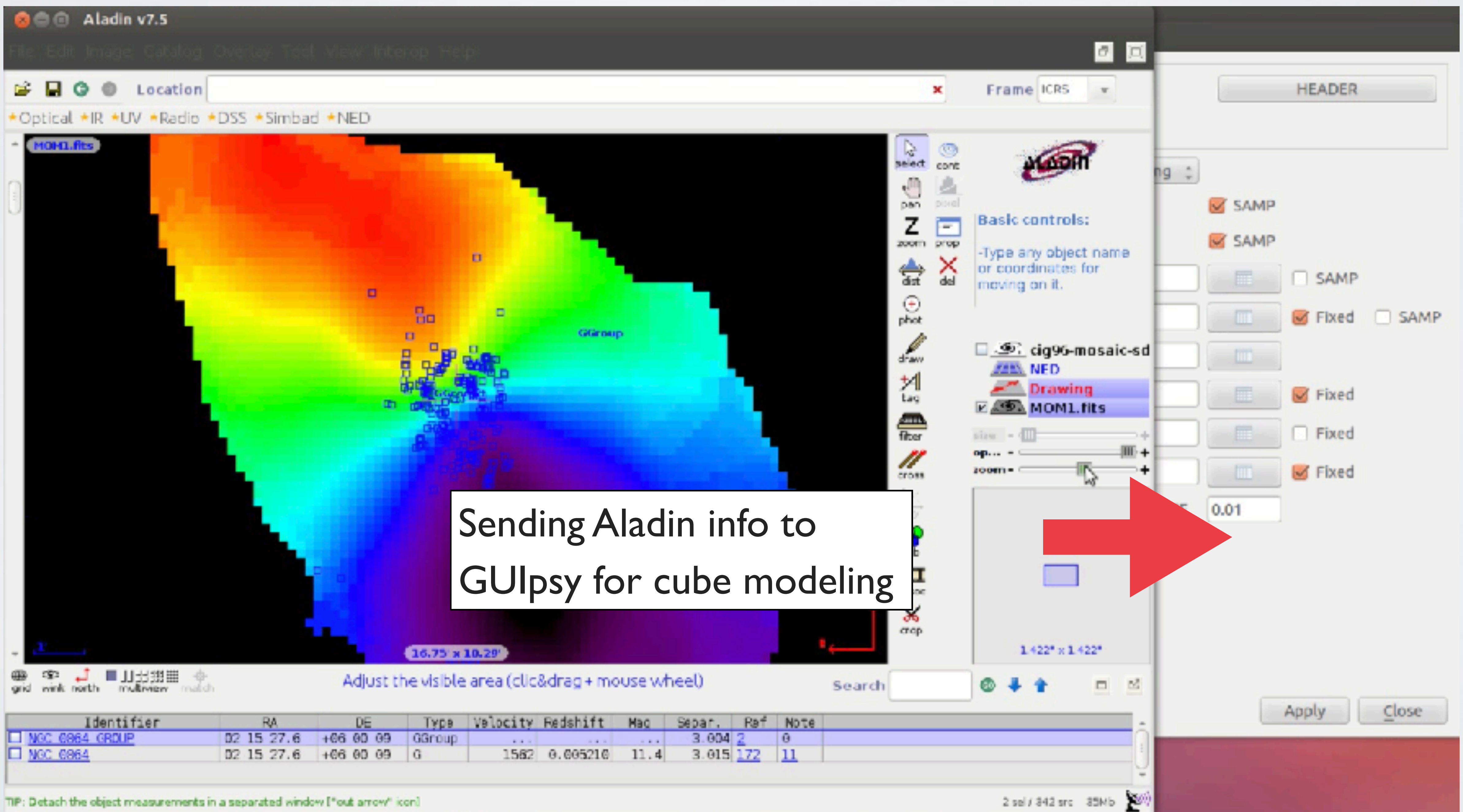

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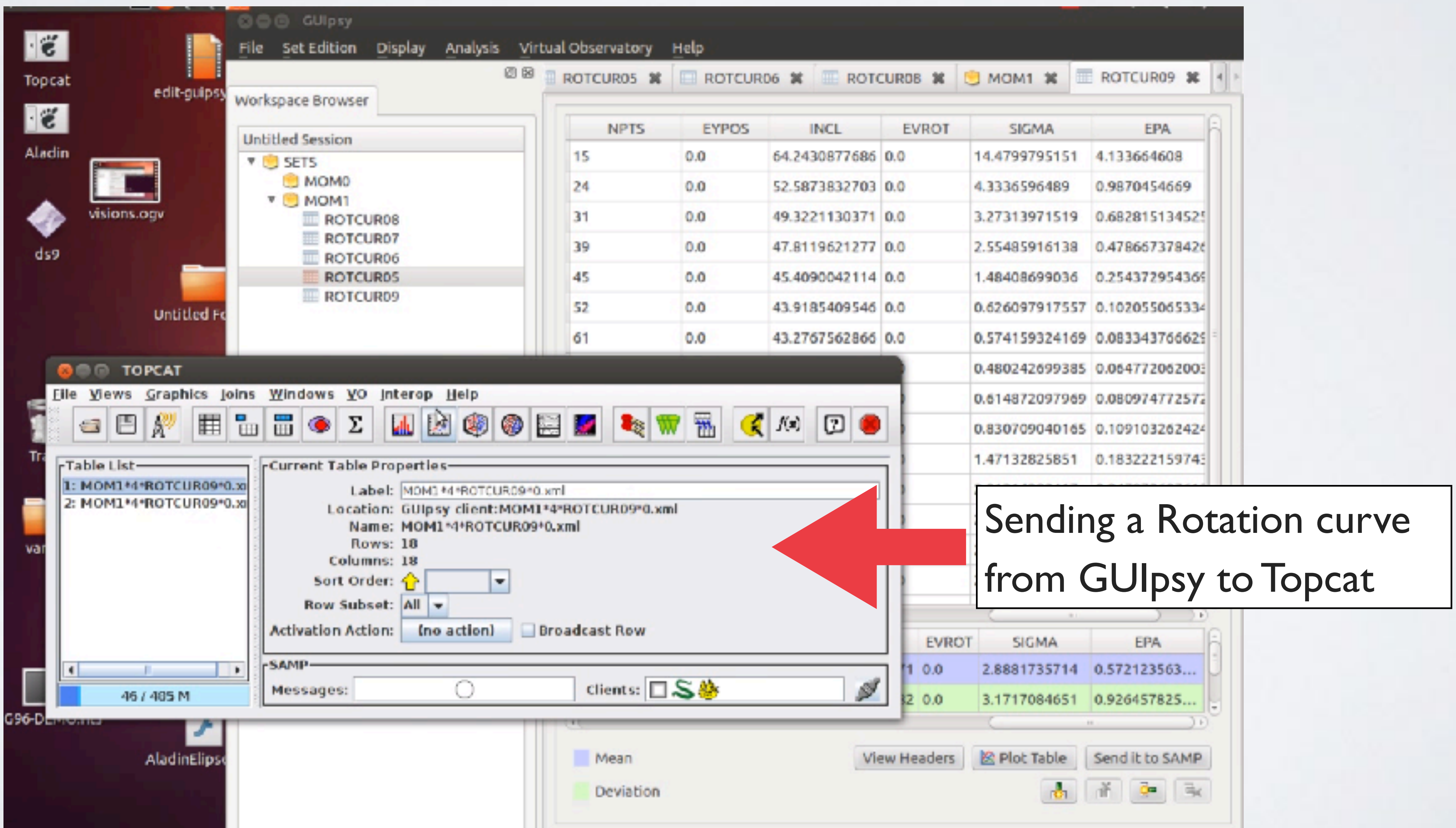

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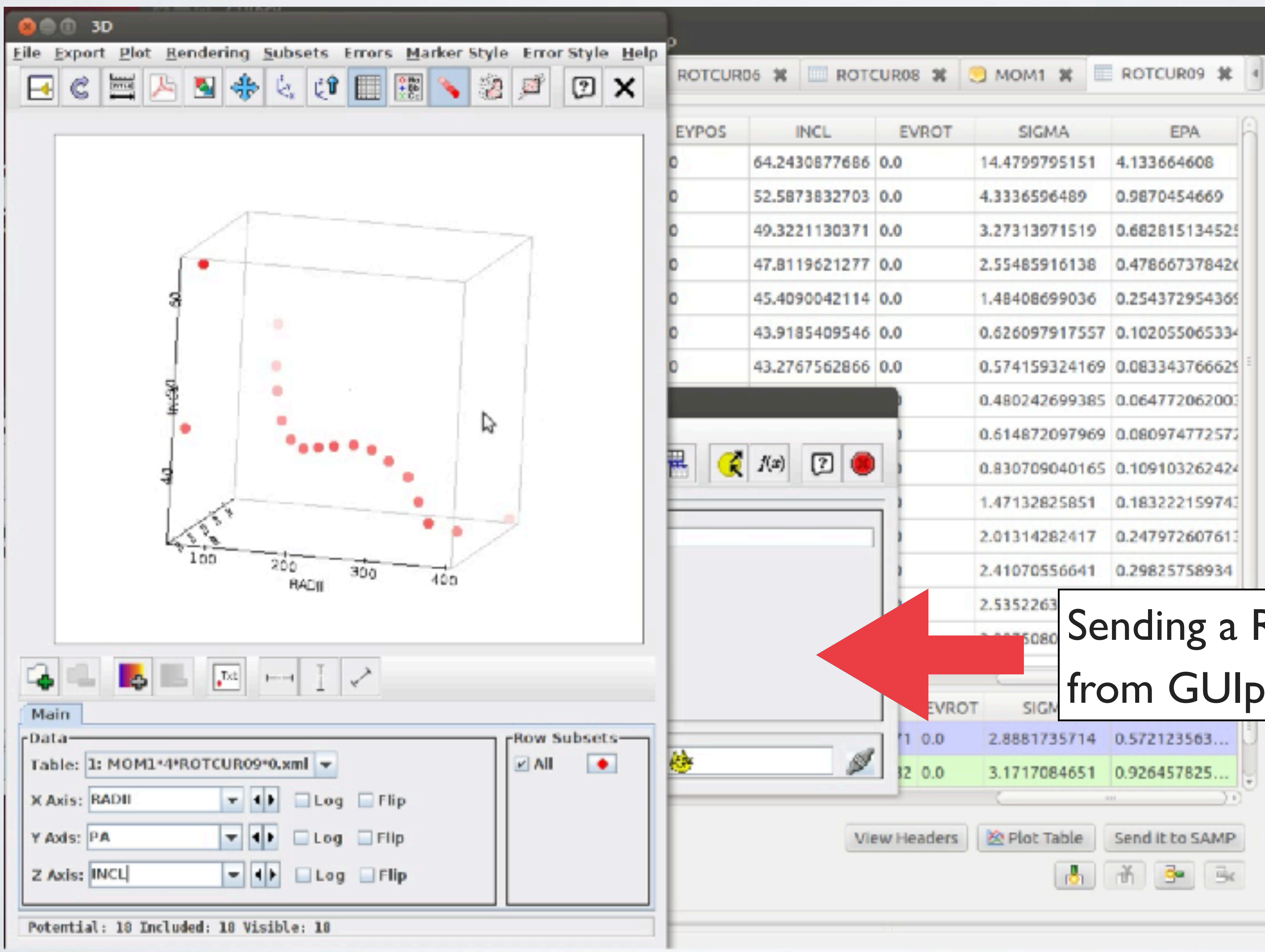

Sending a Rotation curve from GUIpsy to Topcat

OTHERS

- Other items/feedback:
  - Should discuss within the SWG if interested in reuse of SDP pipelines in the SRCs (e.g imaging with different parameters)
  - Commensality?
  - Will need flexibility to adapt the processing strategy once the precursors/ pathfinders are underway
  - Where to find some details of the computing systems already envisaged at this stage?

(MY) CONCLUSIONS

In order to allow mutual feedback between astronomers/SWGs and SRCs designers there is something we should avoid:

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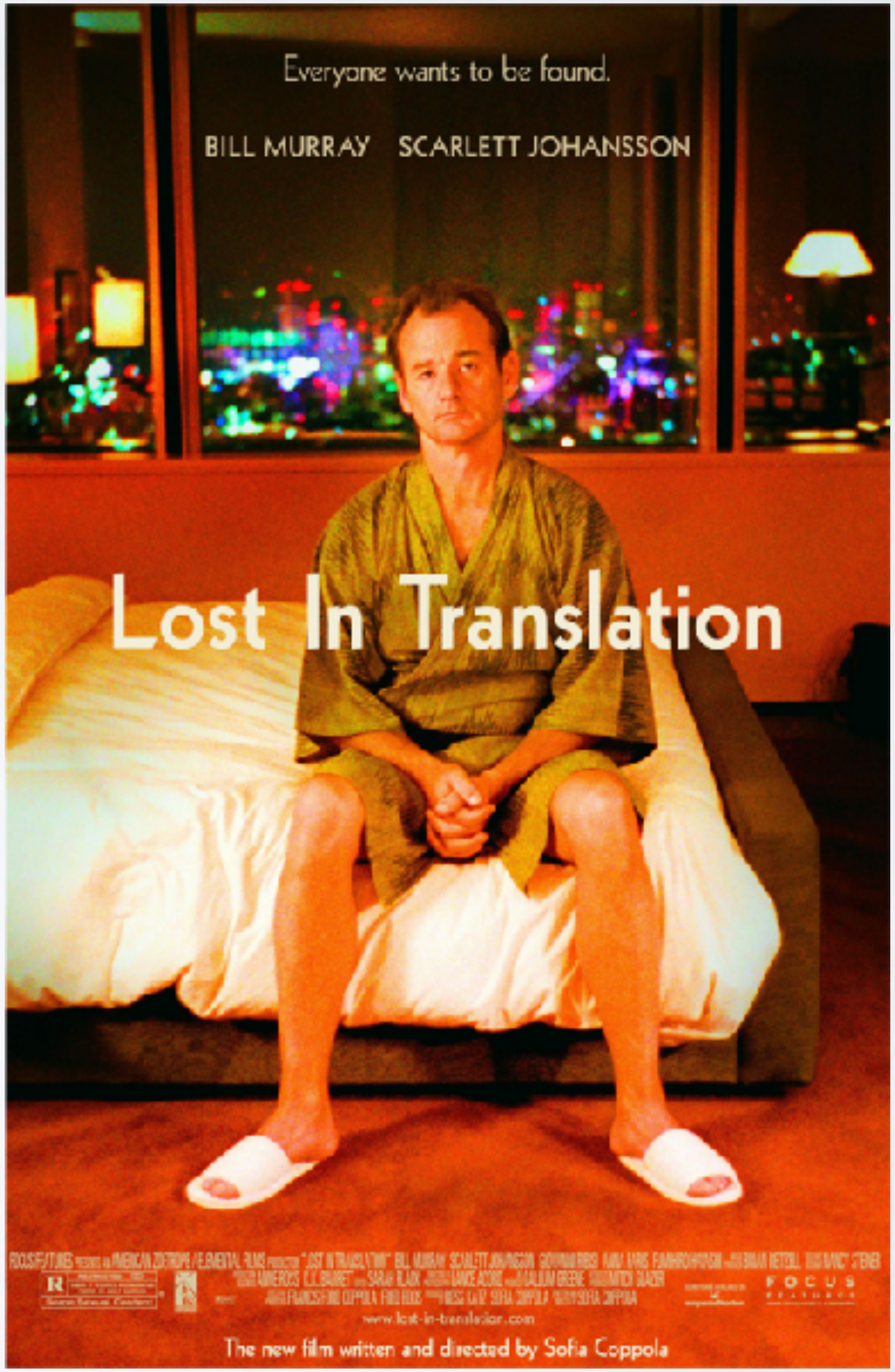

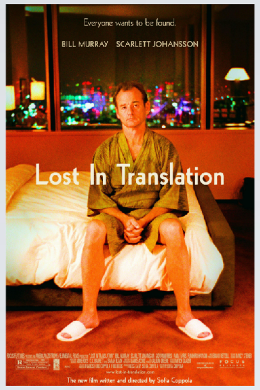

My action

Proposed a Session for the next SKA Science meeting **(Q1 2019) on mutual knowledge of the overlapping areas between these perspectives:**

- **Science teams working on KSP preparation**, summarizing the kind of tools they are considering, in many cases building on top of on-going works with precursors/pathfinders.
- **SDP,** on what pipelines are being considered, and how the interaction with the scientific teams is taking place, and what will be the products that the SDP will deliver
- **SRCCG**, on how the requirements are being defined and how those are expected to fulfill the needs of the community
- **Initiatives to prepare for the SRCs**: AENEAS, ERIDANUS, IDIA, Canada, India, etc
- **SKA data challenges**, that will be of much interest also for the algorithm and pipeline development
- And **how do PI projects fit in** and in what measure is needed - and possible - to plan ahead for those