Memo: Kinematic Parameter Extraction for Wallaby

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ABSTRACT

This memo outlines the progress of a working sub-group that will define a strategy for extracting kinematic parameters from WALLABY detections. Our current focus is to characterize the kinematics of disk-dominated objects at intermediate inclinations throughout the WALLABY detection volume. In this context, we are testing the effectiveness of 3 popular approaches for extracting kinematic parameters: ROTCUR and DISKFIT, which operate on velocity fields, and TIRIFIC, which operates on datacubes. After revisiting our November 2011 milestones, we report on the three most significant developments since our last report: a) we have created an extensive suite of synthetic disk galaxies that span the expected WALLABY observing parameter space, b) we have developed a novel method for extracting velocity fields from datacubes using principal component and Bayesian analyses, and successfully tested it on the LMC, and c) we have scripted a TIRIFIC pipeline, and have fit preliminary models to WHISP, LVHIS, and simulated galaxies. We conclude with a conceptual pipeline for extracting reliable kinematics from WALLABY utilizing the three algorithms being tested.

1. Introduction

The Widefield ASKAP L-band Legacy All-sky Blind surveY[1] (WALLABY; Koribalski & Stavely-Smith 2009) is the top-ranked spectral line Survey Science Project that will be carried out with the Australian Square Kilometre Array[2] (ASKAP).

A significant number ($\sim 5,000$) disk galaxies out to 200 Mpc should be resolved by WALLABY (Duffy et al. 2012), which affords the possibility of deriving kinematic parameters

[1]http://www.atnf.csiro.au/research/WALLABY/

[2]http://www.atnf.csiro.au/projects/askap/

and rotation curves for statistically meaningful samples out to this distance. It is therefore desirable to include a suite of parameters in the WALLABY source catalog that reliably describe resolved source kinematics, as well as to consider releasing related data products such as velocity fields. Carrying out this task is the *raison d'être* for this working sub-group, whose scope was detailed in our last report (see §2 of Spekkens et al. 2011). Briefly, our main goals are:

1. to define a strategy for extracting kinematic parameters from WALLABY data products,
2. to implement this strategy as a pipeline, and
3. to determine which pipeline parameters, models or maps are suitable for inclusion in a WALLABY catalog and/or data product release.

As a means to achieve these goals, the working group has been exploring the potential of pipelining three existing algorithms: ROTCUR (Begeman 1987) and DISKFIT (formerly VELFIT; Spekkens & Sellwood 2007; Kuzio de Naray et al. 2012), that operate on 2D velocity fields generated from the reduced datacubes, and TIRIFIC (Józsa et al. 2007), that operates on the 3D datacube itself. While TIRIFIC uses all of the information in the cube, it is much slower to execute than velocity field methods; the latter are therefore preferred when they yield reliable results. It is expected that the WALLABY pipeline will constitute a combination of these three algorithms (c.f. §4).

This memo outlines the progress of our working group since our last annual report in June 2011 (Spekkens et al. 2011). We begin in §2 by reviewing progress towards accomplishing the milestones set out for this group in November 2011 (Koribalski & Stavely-Smith 2011), and then report on three areas of significant progress in the past year: we discuss the development of an extensive database of simulated galaxies that span the WALLABY detection volume in §3.1, we review a new technique for extracting velocity fields from datacubes using principal component analysis in §3.2, and describe our efforts to pipeline the TIRIFIC algorithm and model galaxies from the WHISP (van der Hulst et al. 2001) and LVHIS (Koribalski 2010) databases in §3.3. In §4 we discuss a conceptual pipeline for extracting kinematic parameters from resolved WALLABY detections, and briefly describe plans for future work in §5.

2. Review of 2011 Milestones

Of the 63 milestones identified by the WALLABY team in their 2011 review (Koribalski & Stavely-Smith 2011), 17 were specific to the kinematics sub-group. Progress on most of these milestones has been made, and areas in which significant work was carried out are described in detail in the following sections. Here, we briefly address the 2011-2012 milestones and their current status. Where applicable, the person(s) responsible for the milestone are named in italics.

The following two milestones were achieved; we do not anticipate further work in these areas at this time:

- The latest versions of TIRIFIC[3] (*Jozsa*) as well as the successor to VELFIT called DISKFIT[4] (Kuzio de Naray et al. 2012) (*Spekkens*) have both been documented and released to the public.

Significant work was carried out towards achieving the following milestones; work is ongoing, and is described in detail in later sections of this memo:

- There has been significant progress towards developing a database of synthetic galaxies that span the WALLABY parameter space in distance, sensitivity and inclination (*Elson, Oh*), and preliminary ROTCUR and DISKFIT models of these systems have been fitted. An overview of this work is presented in §3.1.
- A new algorithm for generating velocity fields using principal component and Bayesian analyses has been designed and tested on the Large Magellanic Cloud (LMC) (*Oh*). An overview of this work is presented in §3.2.
- The TIRIFIC algorithm has been scripted such that several galaxies can be analysed in an automated manner (*Kamphuis*). An overview of this work is presented in §3.3.
- We have developed a first conceptual pipeline for extracting kinematic parameters for resolved WALLABY detections (*Spekkens*), which is presented in §4.

Preliminary work on the following milestones was carried out in the past year, which will carry over into the next one. Accordingly, we defer a detailed report on this work for a future memo.

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[3] `www.astron.nl/~jozsa/tirific/`

[4] `www.physics.rutgers.edu/~spekkens/diskfit/`

- Limited progress was made on refining estimates for the number of resolved galaxies that WALLABY is expected to detect. After some discussion and manipulation of the numbers provided by Duffy et al. (2012), it was decided that the best approach would be a follow-on paper focussing on resolved galaxies.

- A preliminary investigation of the performance of TIRIFIC on high-inclination disks has been carried out. There seems be no change in performance of this algorithm as the disk inclination is increased, and a more thorough analysis of this issue is forthcoming. The range of inclinations where velocity field analyses (ROTCUR and DISKFIT) are adequate still needs to be quantified. Some warped and flared disks have been simulated, but most ROTCUR, DISKFIT and TIRIFIC models have insofar been limited to flat disks.

- There has been limited discussion of how to quantify the morphologies of the H I detections in addition to their kinematics.

Finally, two milestones related to estimating computing resources needed for the kinematic pipeline have been postponed indefinitely: a proposal for computing time is not required at this time.

3. Towards a Kinematic Pipeline: 2011-2012 Progress

Since our last report, we have made significant progress in three important areas. In this section, we summarize our efforts to create an extensive suite of synthetic disk galaxies (§3.1), to develop a new method for extracting velocity fields (§3.2), and to pipeline the TIRIFIC algorithm (§3.3).

3.1. A Synthetic Galaxy Database

The kinematics working sub-group has developed a sophisticated pipeline capable of generating synthetic H I data cubes which will be used to test the kinematic parameterisation routines. This work was spearheaded by E. Elson.

The properties of the synthetic galaxies are based on observations of real galaxies. By design, the kinematics of the galaxies are dominated by circular rotation but also contain large- and small-scale non-circular flows of varying magnitude. To make them more "WALLABY-like", the synthetic galaxies are artificially redshifted to various distances (Elson 2011) and are also made to contain varying amounts of Gaussian noise. As an example, Fig. 1 shows

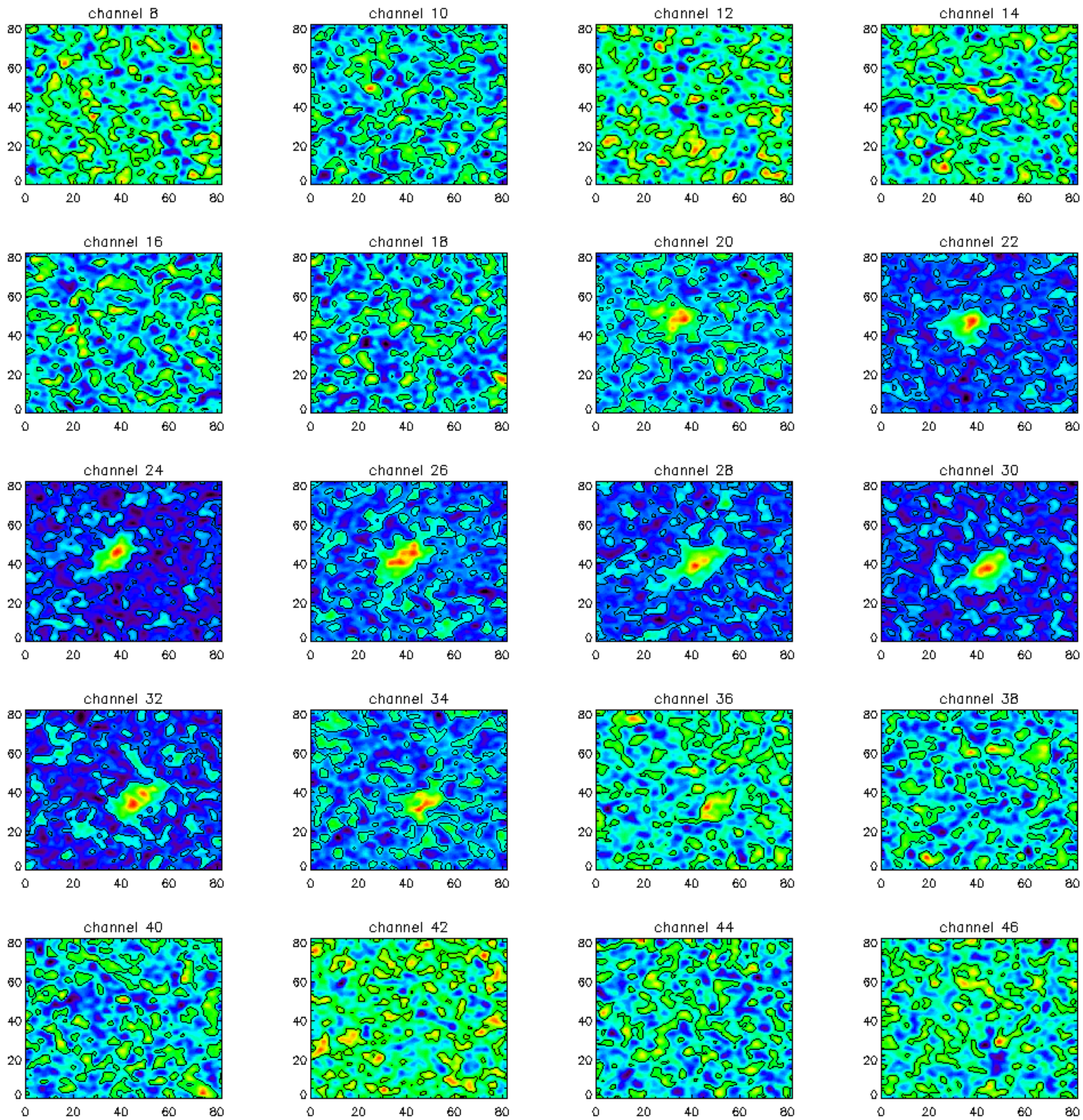

Fig. 1.— Channel maps for a synthetic late-type system developed as part of an extensive database described in §3.1. This particular system is at a distance of $\sim 5\,\mathrm{Mpc}$, and has an H I disk diameter of $\sim 20\,\mathrm{kpc}$. The channels are separated by $5\,\mathrm{km\,s^{-1}}$, and the intensity scaling in each channel is linear, with the colorscale spanning the range of synthetic intensities. The black contour in each channel corresponds to $S/N = 1$.

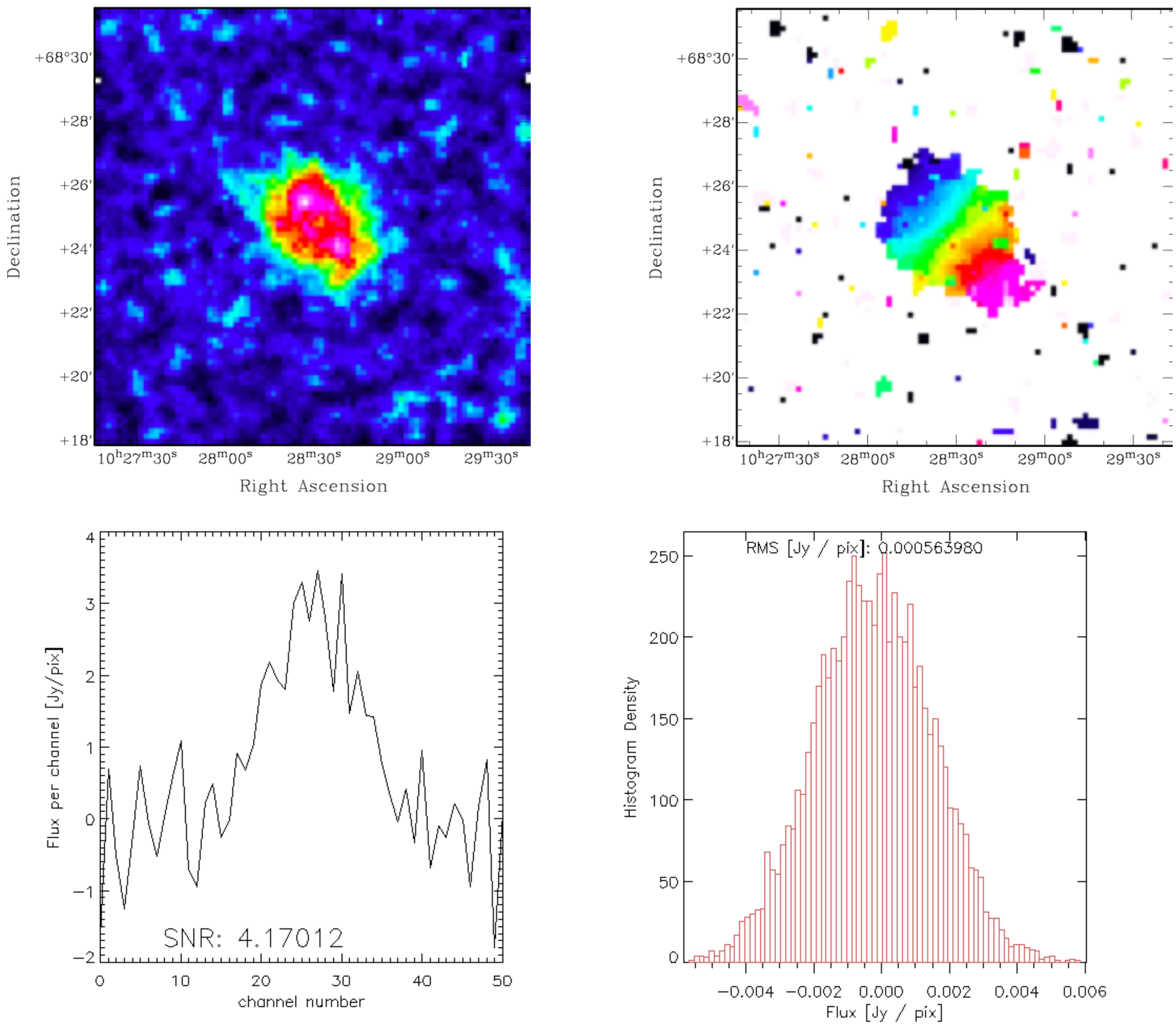

Fig. 2.— Properties of the synthetic system shown in Fig. 1. *Top left:* zeroth velocity moment map. *Top right:* first velocity moment map. *Bottom left:* total flux in each channel. *Bottom right:* distribution of noise in a line-free channel.

the channel maps for a (synthetic) late-type system at a distance of $\sim 5\,\mathrm{Mpc}$, having a disk diameter of $\sim 20\,\mathrm{kpc}$. The zeroth velocity moment and first velocity moment maps extracted from the cube are shown in the top-left and top-right panels of Fig. 2. The bottom-left panel of Fig. 2 shows the total flux in each channel, while the bottom-right panel shows the distribution of noise in a line-free channel. Each synthetic galaxy is shifted to a range of distances. This shifting procedure has been fully automated - our scripts are capable of producing many hundreds of shifted versions of a particular synthetic galaxy, with varying noise levels for each shift. We are ready to use our scripts to produce a very large database of thousands of synthetic galaxies spanning a large range of distances and noise levels. These data sets will later be made freely available to the community.

The synthetic galaxies allow for unambiguous assessments of the performance of various parametrisation routines, and tests using the velocity-field routines ROTCUR (Begeman 1987) and DISKFIT (Spekkens & Sellwood 2007; Kuzio de Naray et al. 2012) have been carried out. Initial results suggest ROTCUR and DISKFIT to be capable of accurately modelling intermediate-inclination galaxies with as few as three $30''$ ASKAP beams across their semi-major axes. In addition to reliably extracting rotation curves for the galaxies, the routines also produce accurate estimates of the orientation parameters, systemic velocities and the dynamical centres. These are the parameters that will ultimately be used to generate a WALLABY catalog of galaxy parameters.

Given the large number of synthetic galaxies that have been generated, the implementation of the parameterisation routines has been fully automated. These scripts will potentially serve as a starting point for the development of a fully-automated WALLABY parameterisation pipeline in the near future (§4).

3.2. Extracting Velocity Fields Using Principal Component Analysis

The kinematics sub-group has been developing a novel method to disentangle random and small-scale non-circular motions in disk galaxies from their underlying "bulk motions", which represent their physical structure and mass distribution. This work was spearheaded by S.-H. Oh.

The WALLABY kinematic parameterisation pipeline will build on existing routines such as ROTCUR and DISKFIT, which operate on 2D velocity fields, and TIRIFIC, which operates on 3D datacubes (§4). For the first two routines, the extraction of reliable velocity fields which represent the bulk motions of galaxies is essential for accurate kinematic parameterisation.

There are several ways to extract a 2D velocity field from a 3D datacube, including

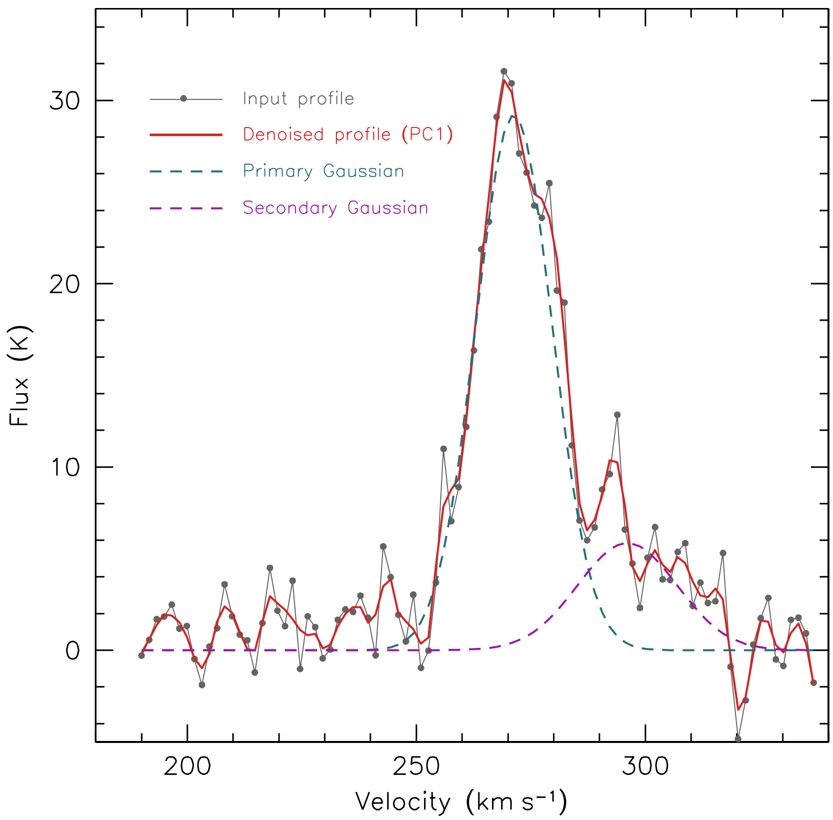

Fig. 3.— Example of profile denoising and modelling using PCA and Bayesian statistics described in §3.2. The input velocity profile is shown by the black points, and the first principal component of that profile is shown in red. The denoised (red) profile is then modelled with two Gaussians, shown by the cyan and magenta dashed lines. The Bayes factor of this model indicates that it is superior to single or multiple Gaussian models.

first velocity moment (c.f. top-right panel of Fig. 1, and top-left panel of Fig. 4), single Gaussian, and hermite polynomial fits as well as peak velocity fields which work well for single, symmetrical velocity profiles. However, these often fail to properly account for the presence of multiple velocity components (Oh et al. 2011). Moreover, this becomes more worse for velocity profiles with low signal-to-noise S/N, making it difficult to estimate their central velocities. This is particularly relevant for blind surveys such as WALLABY, where the number of detections increases steeply with decreasing S/N (Duffy et al. 2012). To improve on this situation, we propose an alternative Gaussian decomposition method based on principal component analysis (PCA) and Bayesian analysis which denoises velocity profiles and decomposes them into small-scale and bulk velocity components more reliably.

Firstly, we find the principal components of a velocity profile using PCA, and approximate the input profile using the 1st principal component which explains most of the variation therein. As shown in Fig. 3, the noise level is significantly reduced in this "denoised" velocity profile relative to the input profile, while dominant features are conserved. Secondly, we decompose the denoised profile into either single or multiple Gaussian components according to its "Bayes factor", which evaluates the statistical benefit of adding additional free parameters to the fit. For example, the Bayes factor for the denoised profile in Fig. 3 indicates that it is best described by a double Gaussian, whose two components are shown as magenta and cyan dashed lines. Lastly, we assess whether the decomposed velocity components are representative of the underlying bulk motions of the galaxy by comparing them with an artificial velocity field derived by fitting a standard galaxy disk model using standard techniques. From this, we can minimise the effects of localised non-circular motions such as those caused by star formation, and extract undisturbed bulk motions.

We have developed a python program based on the algorithm and as a test case, applied it to the LMC. As shown in its first moment velocity field extracted from ATCA H I observations (Kim et al. 1998) in the left panel of Fig. 4, the kinematics are significantly disturbed due to the presence of multiple velocity components in the galaxy. In the right panel of Fig. 4, we show the bulk velocity field of the LMC extracted using our new algorithm. Compared to the first moment velocity field, the bulk velocity field shows better aligned iso-contours, which indirectly implies that it properly extracts the underlying bulk motion of the LMC. We will further test and optimise the algorithm using other galaxies, and ultimately include it as a computational component which feed into the WALLABY kinematics pipeline (§4).

3.3. Pipelining the TIRIFIC algorithm

In order to investigate the reliable extraction of kinematical parameters from WALLABY we have scripted an IDL wrapper for the χ^2 minimization code TIRIFIC (Józsa et al. 2007). This work was spearheaded by P. Kamphuis.

The IDL wrapper tries to eliminate the need for human interaction in TIRIFIC. Since TIRIFIC fits the full 3D information in the datacube instead of merely the velocity field as with ROTCUR and DISKFIT, the expectation is that this code can be more successful in fitting data of lesser quality, e.g. lower S/N, marginally resolved systems, or systems with extreme inclinations. Since the majority of the resolved systems in WALLABY will be at higher inclinations (Duffy et al. 2012), especially for the latter TIRIFIC might prove crucial to WALLABY. An additional advantage is that due to the direct fitting of the cube more parameters, such as the radial surface brightness distribution μ_{HI} and scale height z_0, can be extracted from the data. A downside is that the 3D fitting is computationally more expensive and therefore a careful analysis of multiple fitting methods is required.

Despite the extensive capabilities of TIRIFIC[5] the pipeline here is restricted to fit the main disk parameters as well as for rotation. This is done in order to ensure the reliability of the extracted parameters. The fitting is in principle a three step process. The first step concerns the initial estimates which can currently be provided to the code in the form of an ASCII table or can be extracted from the cube through the use of the GIPSY programs ELLINT and ROTCUR. From these initial estimates TIRIFIC tries to fit a flat disk to the data. This means that in this step one value is determined for each of the following parameters: z_0, the position angle PA, the inclination i, the rotational velocities $V_{rot}(r)$, and the central coordinates V_{sys} and (x_c, y_c). For μ_{HI} the GIPSY results or an exponentially declining distribution is assumed which can then be scaled by TIRIFIC. In this step the main goal is to determine $[V_{sys}, (x_c, y_c)]$ correctly as it is crucial in determining the other parameters. At the end of each TIRIFIC run the parameters are automatically evaluated and compared to the initial parameters and/or to the previous step. Once convergence is reached on the central coordinates the pipeline progresses to next step. In the third and final step the pipeline takes the parameters from the flat disk and tries to fit $[PA(r), i(r), V_{rot}(r), \mu_{HI}(r)]$ on a ring by ring basis, where the radii of the rings are separated by one beam. In this step regularization of the parameters is enforced by assuring that the variance in a parameter remains limited.

The current version of the pipeline is being evaluated and improved by fitting four different samples of galaxies, two synthetic and two real data samples. Initially the most

[5]See http://www.astron.nl/∼jozsa/tirific/ for its full capabilities

important set is a set of 6 synthetic galaxies that are randomly created with TIRIFIC (and thus differ from those in §3.1). To these models white noise is added. In principle this means that the noise statistics are slightly different from real data but it is assumed that these differences are negligible. The galaxies in this set randomly vary in size, rotation, warp and scale height. However, the parameters in a single galaxy are loosely correlated according to our current understanding of galaxy structure. The models do not contain any non-circular flows, however they do contain a flare (change in scale height) which the pipeline does not attempt to fit. An example of such a galaxy, and its fit, is given in Fig. 5. Here the black and blue lines represent the input values of the synthetic model corresponding to two separate halves of the model – cut in the frame of the galaxy such that the disks connect at the line of nodes – and the red and yellow lines represent the fit of the pipeline to both halves. Due to the small size of the galaxy ($\sim$ 6 beams across the major axis) regularization or the exact cutoff are no problem in this fit.

Fig. 6 shows how the pipeline currently performs on a set of such synthetic galaxies. The S/N in the top-left panel was calculated by assuming that the noise is the variance in the first channel. The signal in the data cube is calculated by taking the mean of all values above 2σ in one channel and subsequently taking the mean of these values in all channels where it is above 3σ. This way we obtain a value for the average S/N in the cube that can also be directly calculated from a real dataset. Fig. 6 shows that, with the exception of Sample Galaxy 0, the pipeline returns good results. It is also immediately obvious that Galaxy 0 is the case where we have the lowest S/N, barely above 3. A closer look at this specific galaxy shows that its inclination ($i = 45°$), low S/N and high rotational velocity ($V_{rot} \sim 275\,\mathrm{km\,s^{-1}}$) conspire to produce a central flux that is below the noise in several channels around V_{sys}. This in turn causes V_{sys} to be misfitted and, subsequently, i and V_{rot}. Besides this obviously incorrect fit a detailed analysis of the fitted galaxies shows that regularization also remains a problem. Currently we are looking at ways to solve these problems in the pipeline and get a more quantitative error analysis. However, based on these galaxies we estimate that 70-80% of these galaxies are fitted to within acceptable errors.

In order to compare this pipeline to others we also test it on the WHISP (van der Hulst et al. 2001) database, and a subset of regular galaxies in the LVHIS (Koribalski 2010) referred to as LVHIS-26. A subset of the synthetic galaxies described in §3.1 have been fitted with the pipeline; at the moment, the success rates are very low. However, no clear trends can be found and even large galaxies without random motions are ill-fitted from time to time. It is therefore necessary to look at a subset of individual fits carefully in order to determine the source of the error. For the databases of real data the second step is run and an initial inspection of the fits shows a fairly high success rate. Since the true values for these galaxies are unknown a careful analysis of the results is required before continuing.

4. A Conceptual WALLABY Kinematics Pipeline

Our performance tests of the three algorithms ROTCUR, DISKFIT and TIRIFIC afford the development of a conceptual pipeline for extracting kinematic parameters from resolved WALLABY detections. We present a schematic overview of this pipeline in Fig. 7. In Fig 7, magenta circles represent pipeline inputs, green squares represent the computational elements of the pipeline, and purple diamonds represent decision points. Please note that Fig. 7 represents the decision tree for the operation of the pipeline, but the numbers therein are for illustrative purposes only: for example, the precise ranges of angular sizes, S/N, and i that will drive the pipeline have yet to be established.

The primary inputs to the pipeline are a datacube that contains the detection, a zeroth velocity moment of that datacube, a velocity field derived from that datacube (§3.2), and any ancillary data available such as an optical image or HIPASS detection parameters. Note that in pipeline concept of Fig. 7, only the velocity field (for ROTCUR and DISKFIT) or the datacube itself (for TIRIFIC) are actually used in the estimating kinematic parameters, while the zeroth velocity moment and the ancillary data are merely used to generate model inputs.

The pipeline uses the input datasets to generate a set of input parameters to the model fitting algorithms, some of which will determine whether the 2D velocity field (ROTCUR, DISKFIT) or the 3D datacube (TIRIFIC) will be used. The required input parameters are the disk geometry (V_{sys}, (x_c, y_c), i, PA) as well as the basic properties of the velocity field derived from the datacube: the angular size of the detection, as well as its S/N. Exactly how these initial parameters are computed has yet to be determined, but this should be relatively straightforward. For example, V_{sys} can be estimated from a global profile computed from the datacube, while (x_c, y_c) and PA could be estimated from the zeroth velocity moment. The parameter i may be more difficult to estimate from WALLABY data products alone, because beam smearing is likely to significantly distort the minor axis of the zeroth velocity moment for a large fraction of detections. Adopting i determined from isophotal fits to optical counterparts may therefore be desirable.

In the current pipeline concept, the values of three computed input parameters determine whether 2D or 3D fits will be carried out: the angular size of the detection velocity field, the S/N of the detection velocity field, and the disk inclination (accordingly, this parameter space is well-sampled by the synthetic galaxy database of §3.1). Detections that are too small will be excluded from the pipeline altogether (this filter may also be applied "upstream"). In order for a 2D analysis to be carried out, detections have to be 1) relatively large, 2) relatively bright, and 3) have intermediate inclinations. If any of these criteria are not met, a 3D analysis is performed. Recall that the numbers in Fig. 7 are for illustrative purposes only, but are nonetheless representative of the choices for each decision point. Note that the angular size numbers in Fig. 7 implicitly refer to the number of beams across the semi-major axis, but this has yet to be decided: the resolution about the minor axis is also important.

If the angular size, S/N and inclination criteria are all satisfied, then a velocity field analysis is attempted. It is envisioned that elements from both ROTCUR and DISKFIT will be used in the fit, but this remains to be established. The estimated disk geometry (V_{sys}, (x_c, y_c), i, PA) is used as an input to the fit, which is performed on the computed velocity field. Ideally, all of the disk geometry parameters are allowed to vary during the fit: in this case, the basic output parameters are the best fitting disk geometry (V_{sys}, (x_c, y_c), i, PA) as well as the rotation curve $V_{rot}(r)$, but this is likely not feasible for all detections. For example, there may be a class of detections for which reliable fits can be obtained only if i is held fixed to the value determined by fitting optical isophotes. It may be desirable to search for a disk warp (at which ROTCUR excels) or non-circular flows (at which DISKFIT excels) in addition to fitting for these basic properties, but it is unlikely that the angular size and S/N of the average WALLABY detection will afford this. It is imperative that reliable uncertainties on each output parameter be determined.

If either the angular size or S/N of the velocity field is too small or if the disk is not at intermediate inclination, then a 3D analysis is carried out. As described in §3.3, it is anticipated that a streamlined version of TIRIFIC will be adopted. The estimated disk geometry (V_{sys}, (x_c, y_c), i, PA) is used as an input to the fit, which is performed on the datacube. Additional input parameters are also required: the scale-height z_0 and H I surface brightness μ_{HI} of the disk. How these are estimated from the pipeline inputs has yet to be determined (but see §3.3 for one possibility), as does the sensitivity of a typical fit to these input parameters. Ideally, all of the disk geometry parameters are allowed to vary during the fit: in this case, the basic output parameters are the best fitting disk geometry (V_{sys}, (x_c, y_c), i, PA) as well as the rotation curve $V_{rot}(r)$, but as with the 2D approach this is likely not feasible for all detections. It may be desirable to search for a disk warp, non-circular flows, a disk flare or variations from the input μ_{HI} in addition to fitting for these basic properties, but it is unlikely that the angular size and S/N of the average WALLABY detection will afford this. It is imperative that reliable uncertainties on each output parameter be determined.

Upon completion of either the 2D or 3D analysis, the best fitting model must be deemed either successful or not. The criteria that will govern this decision have yet to be determined, but it will likely involve examining the relative uncertainties on best fitting parameters as well as the parameter values themselves. If a 2D analysis is deemed unsuccessful, then an attempt at fitting the datacube is made. If a 3D analysis fails, then the detection is rejected from the final catalog by the pipeline.

Once a successful kinematic fit has been obtained, then the parameters of that fit need to be homogenized for input into a catalog of properties of resolved WALLABY detections. This computational element is the most nebulous of those depicted in Fig. 7, but its basic function is to ensure that the parameters and uncertainties ultimately reported are not biased by the branch of the pipeline that generated them. It may also be desirable to check that the best fitting i satisfies the criteria for the branch of the pipeline used; if not, then the detection in question would be reprocessed at this step (this is not depicted in Fig 7).

The final step of the pipeline is to enter the homogenised kinematic parameters and their uncertainties into a catalog of resolved WALLABY detections, as well as a flag indicating which branch of the pipeline was used. It is also desirable to record a series of intermediate pipeline products for internal consumption, such that the steps that generated all publicly released quantities can be exactly reproduced. Finally, the enhanced data products used as pipeline inputs – the datacube, velocity field and zeroth velocity moment at the top of Fig. 7 – should also be released where appropriate.

5. Conclusions and Future Work

In this memo we have detailed the annual progress of the WALLABY kinematics subgroup working towards developing a pipeline to produce reliable kinematic parameters for the $\sim$ 5000 resolved detections that the survey should produce. We have achieved a large fraction of our 2011-2012 milestones (§2), and have made significant progress in three areas: developing a synthetic galaxy database (§3.1), developing a PCA+Bayesian velocity field derivation algorithm (§3.2), and pipelining the TIRIFIC code (§3.3). We used the knowledge gained from this work to develop a conceptual WALLABY kinematics pipeline (§4).

The future goals of this group will be detailed in a set of 2012-2013 milestones that will be the focus of a separate document. However, it has become clear that the work in §3 is of relevance not only to WALLABY, but also to the broader community of researchers working on large kinematic surveys. A major goal for the next year is therefore to publish the results of this research as a series of PASA or MNRAS papers. Also, we will further develop the conceptual pipeline by quantifying some of the numbers in Fig. 7, in particular by fully evaluating ROTCUR, DISKFIT and TIRIFIC at high and low galaxy inclinations. We will hold regular telecoms ($\sim$once every one or two months) to help reach these goals, to keep group members abreast of recent developments as well as to share ideas and expertise. This group will provide another progress report in the fall of 2013.

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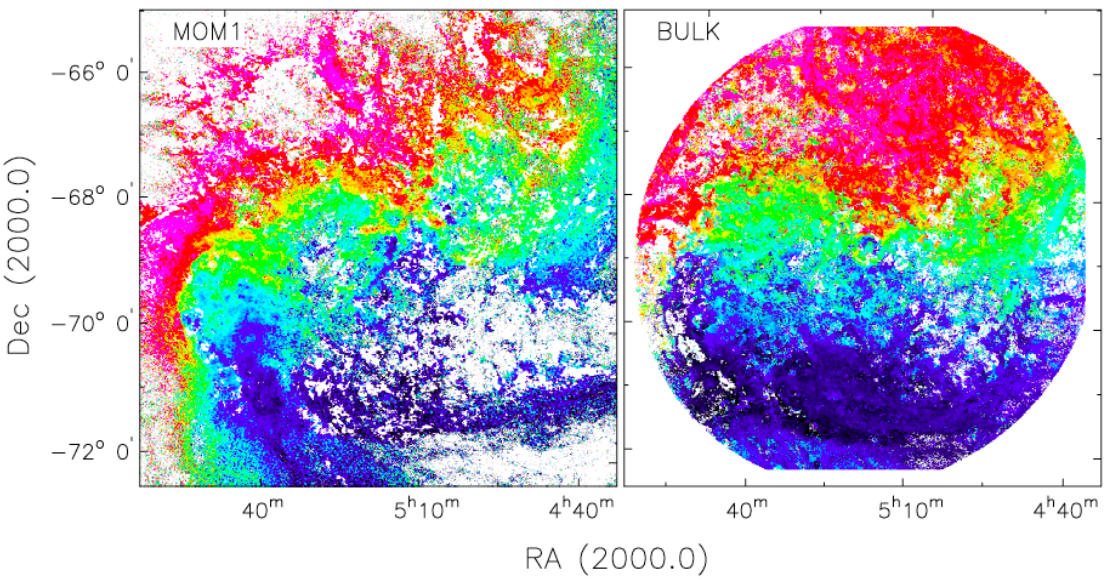

Fig. 4.— Application of the velocity field extraction algorithm described in §3.2 to the LMC. *Left panel:* First velocity moment map of the LMC, from Kim et al. (1998). *Right panel:* Bulk velocity field of the LMC extracted using the algorithm described in §3.2.

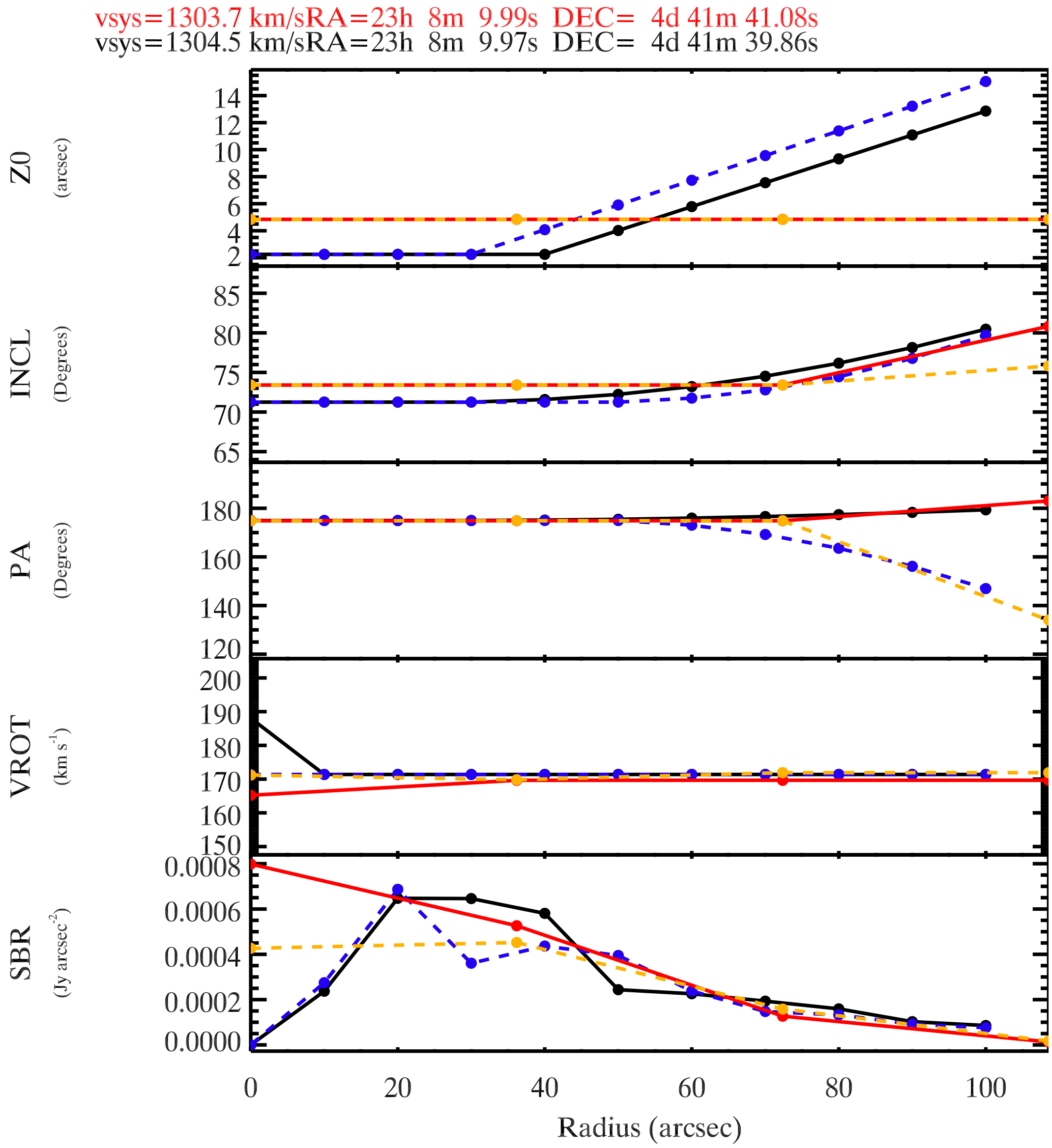

Fig. 5.— Example of input parameters for the synthetic TIRIFIC Galaxy 4. The black and blue lines are the input parameters where the dots on the lines indicate the center of a ring. The red and yellow lin indicate the pipeline fits to this example galaxy. On top the central input coordinates are given for the input (black) and fitted (red) model.

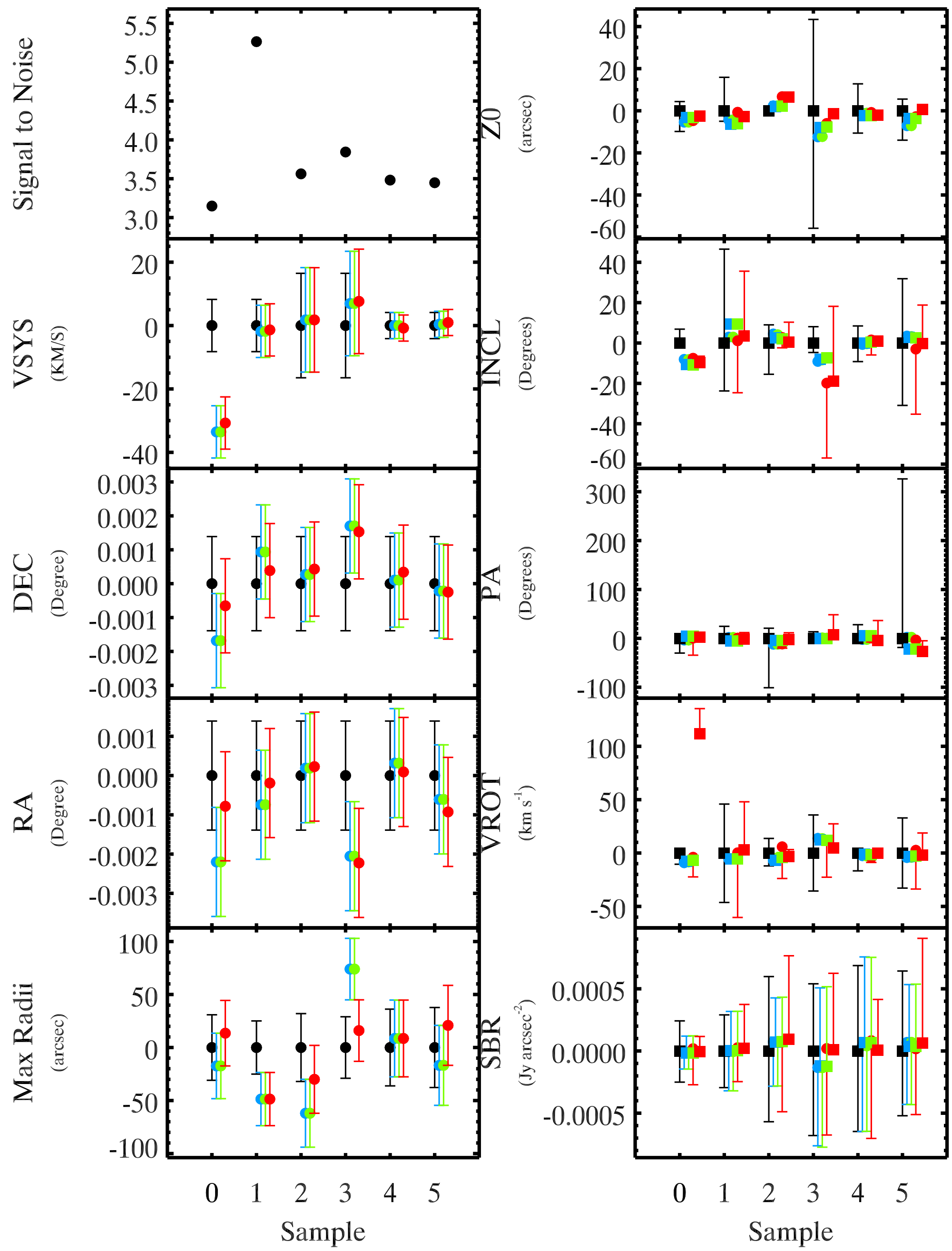

Fig. 6.— TIRIFIC pipeline results on 6 randomly created galaxies (x-axis). Error bars indicate pixel size for the central coordinates, beam size in case of the maximum radius and variation of the parameters, i.e. the maximum difference between the central value and the values in the other rings, in the parameters on the right. The circles and squares represent different halves of the galaxy where black is the input, blue the first fit to local minima, green the first fit to global minima (step 2) and red the second fit (step 3). The zero point is set to the central value of the input model.

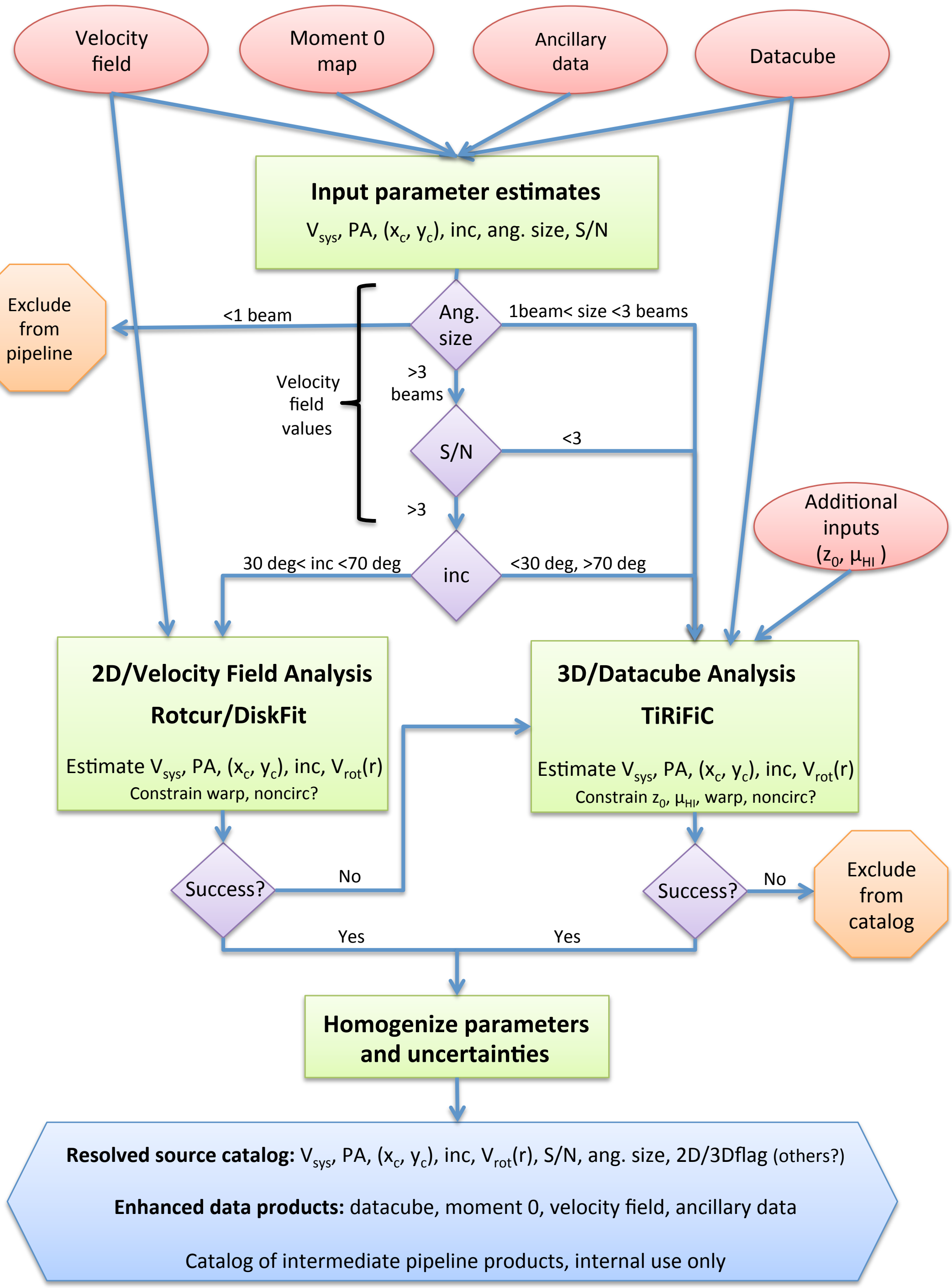

Fig. 7.— Conceptual pipeline for derivation of kinematic parameters for resolved WALLABY detections. Note that all numbers in the figure are for illustrative purposes only, and have yet to be refined. See text for details.