A first taste of Bbarolo:

a 3D-fitting software to model the kinematics of disc galaxies

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Tilted-ring model

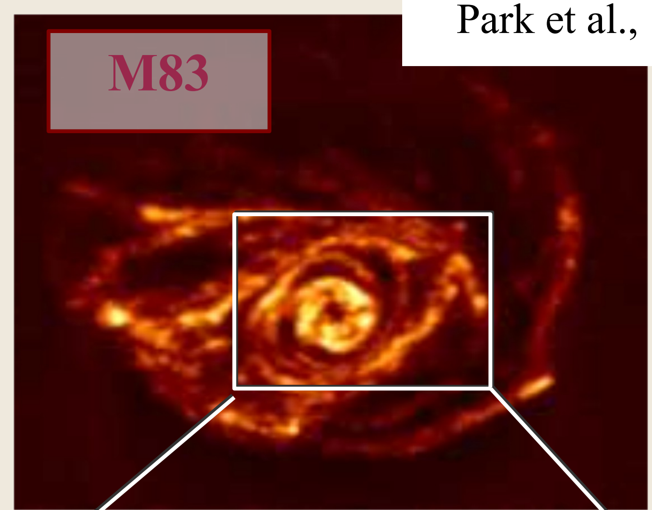
Tilted-Ring Model
(Rogstad et al. 1974):

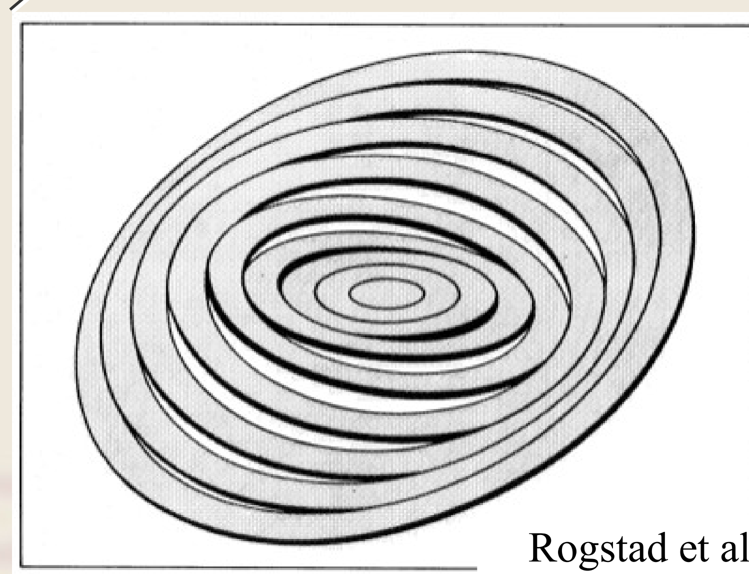
Decomposing a disc galaxy in thin rings

Rings at different radii described by:

- Center of the ring (x_0, y_0)
- Two geometrical parameters:
  - inclination i
  - position angle φ
- Two kinematic parameters:
  - systemic velocity v_{sys}
  - rotation velocity v_{rot}

Park et al., 2001



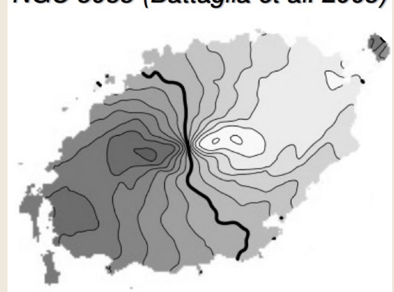


Rogstad et al., 1974

Tilted-ring model: fitting strategies

2-D

NGC 5055 (Battaglia et al. 2005)



- 2D velocity fields
  (e.g., Begeman 1987, Spekkens 2007)

- 6 free parameters

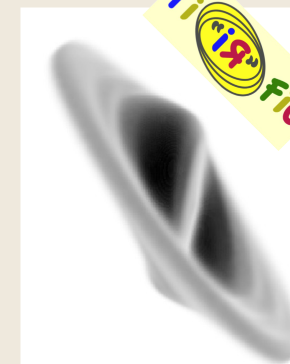
$$V_{\rm los}(x,y) = V_{\rm sys} + V_{\rm c}(R)\cos\theta\,\sin i$$

$$\cos\theta = \frac{-(x - x_0)\sin\varphi + (y - y_0)\cos\varphi}{R}$$

- *PROs*: computationally fast & good for high resolution

- *CONs*: beam smearing in low resolution data

3-D



Józsa+ 2007

- 3D datacubes
  (e.g., Corbelli & Schneider 1997, Józsa et al. 2007)

- 6 free parameters + 3 (Z_0, $\Sigma_{\rm gas}$ and σ)

- No analytical expression

- *PROs:* it takes into account the beam smearing

- *CONs:* slowness & larger set of parameters

A new 3D-fitting cube software

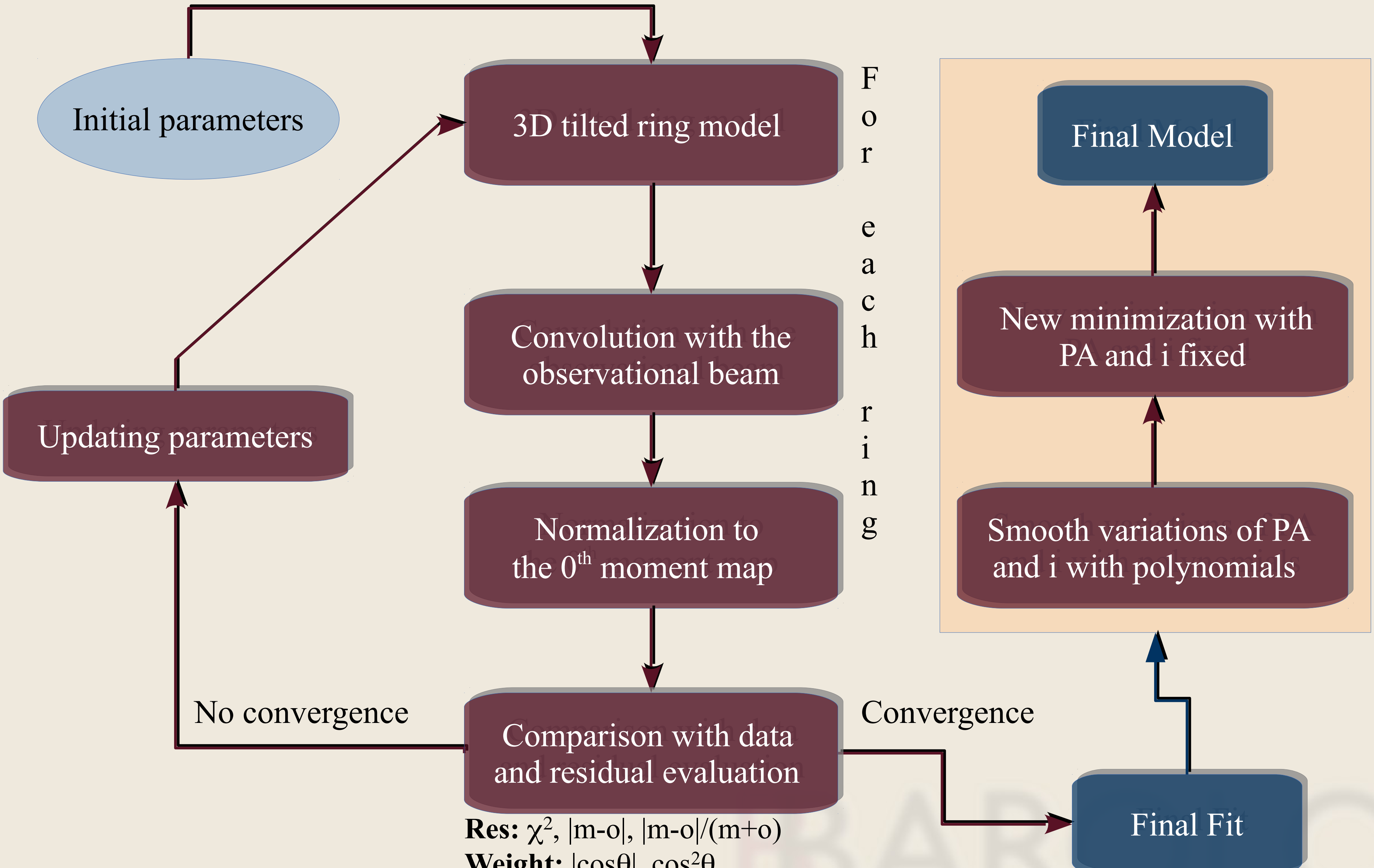
Bologna **B**est-fit **A**nalysis of **R**otating **O**bjects from **L**ine **O**bservations

- Generating 3D model through a stochastic function
- Nelder–Mead (downhill simplex) method for minimizing the model
- Built-in algorithm for source detection (from *Duchamp* code, [Whiting, 2012])
- Initial parameters estimate

Fully automated execution

Ideal for large up-coming HI surveys!!
(e.g., SKA Pathfinders)

Cube fitting flowchart



Res: χ^2, |m-o|, |m-o|/(m+o)
Weight: |cosθ|, $\cos^2\theta$

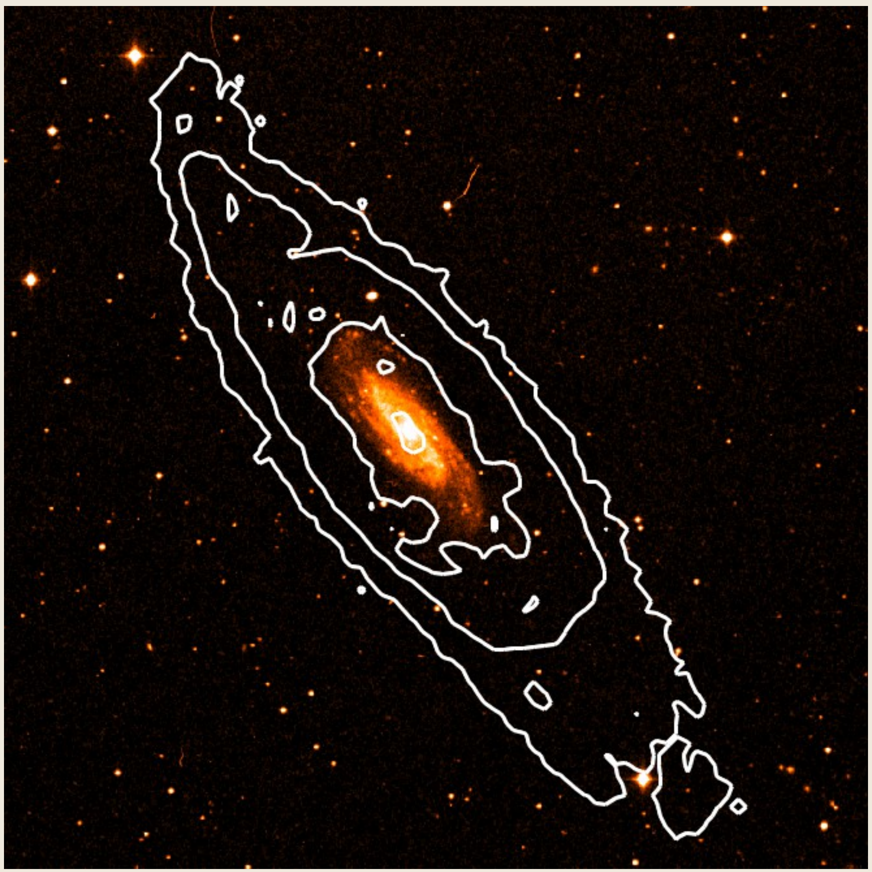
Applications

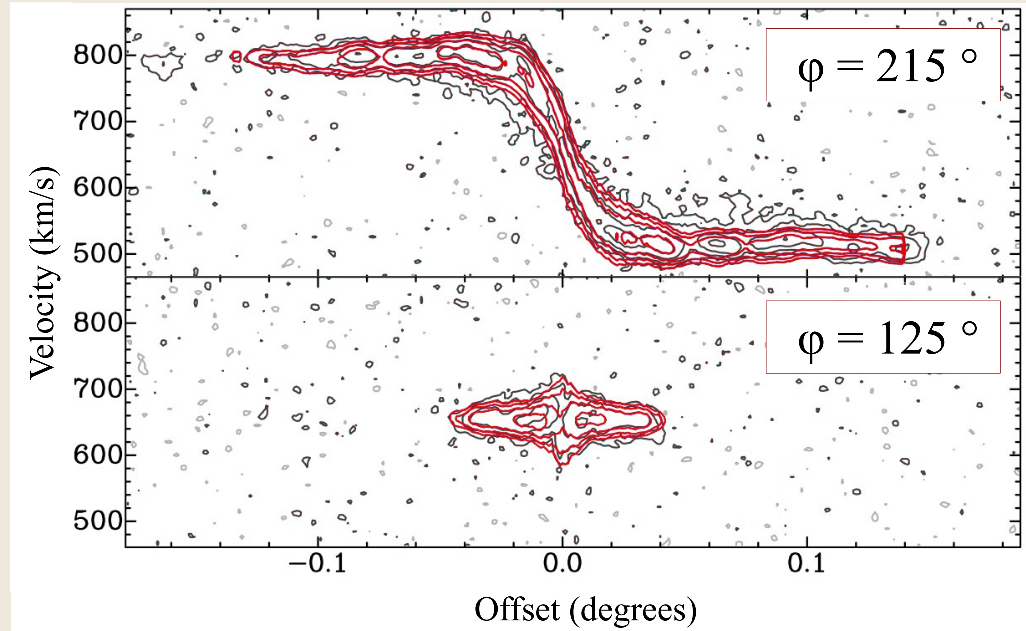
- High resolution data & automatic mode
- Galaxy sample at mid-low resolution
- 2D vs 3D in very low resolution data

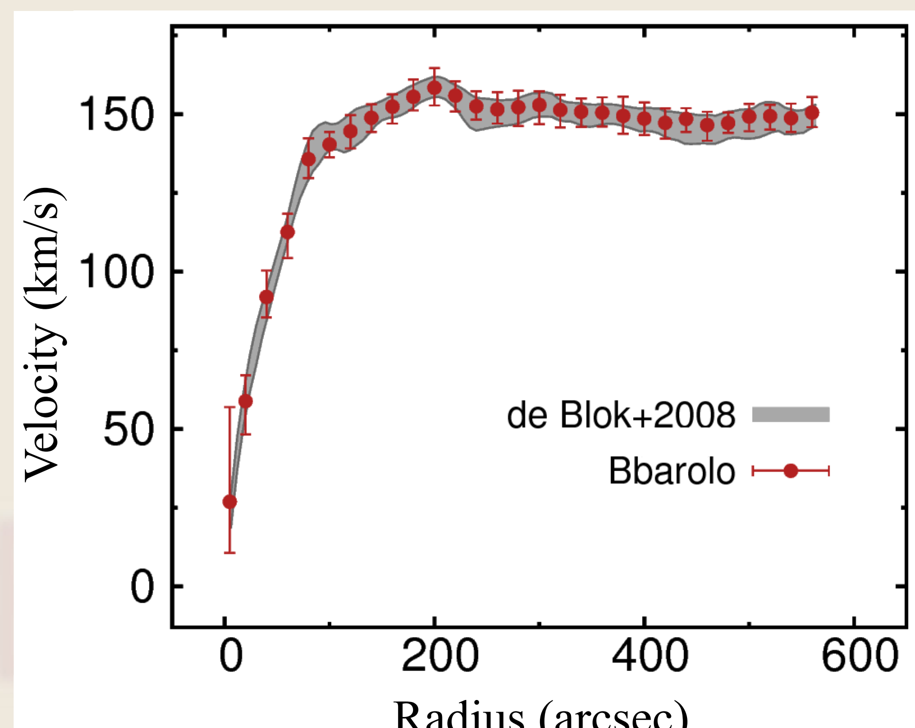
Example I: High resolution rotation curve

```
$ ./Bbarolo -f ngc3198_fullres.fits
```

NGC 3198







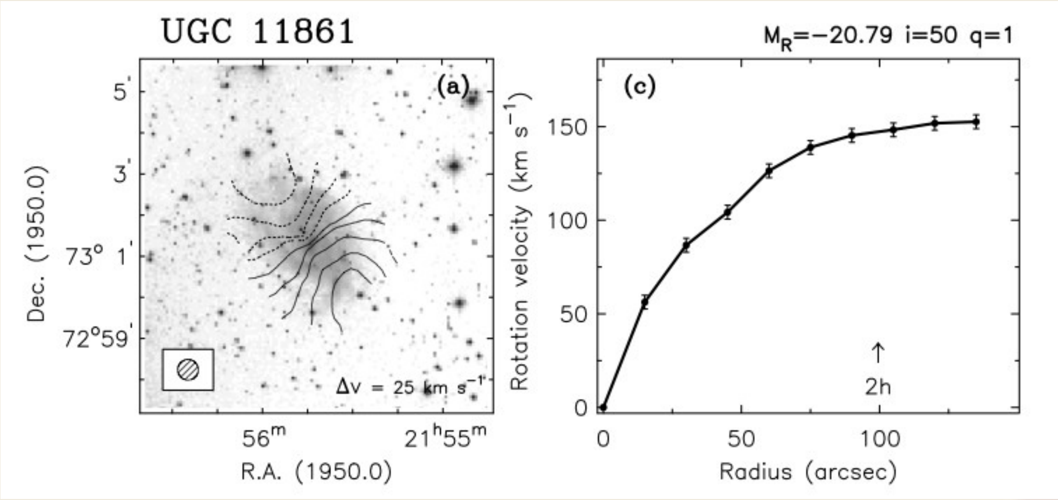
Model

Data

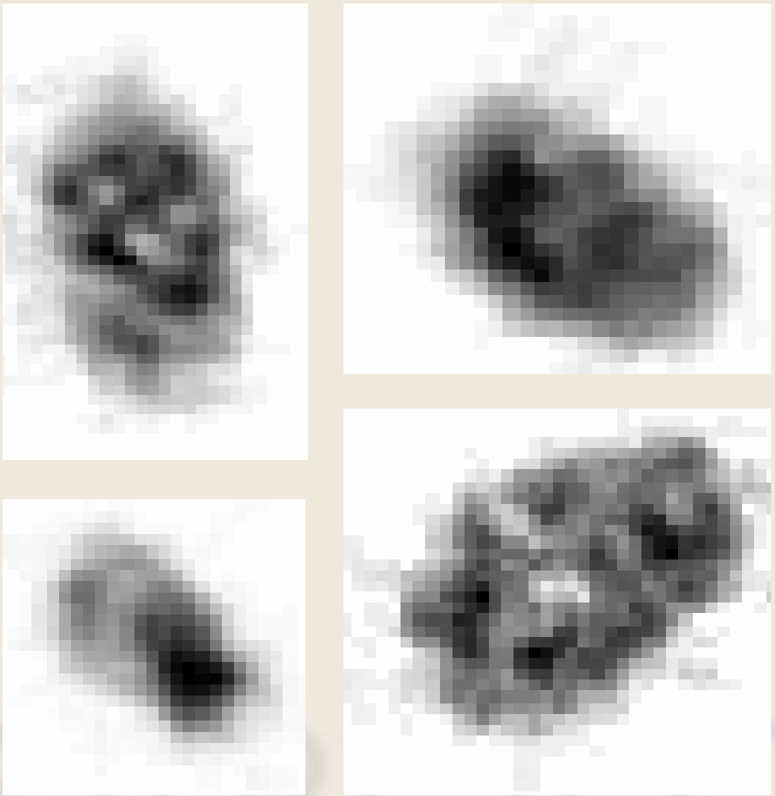
Example II: *Mid-low resolution rotation curves*

Model spiral galaxies at low resolution (WHISP sample)

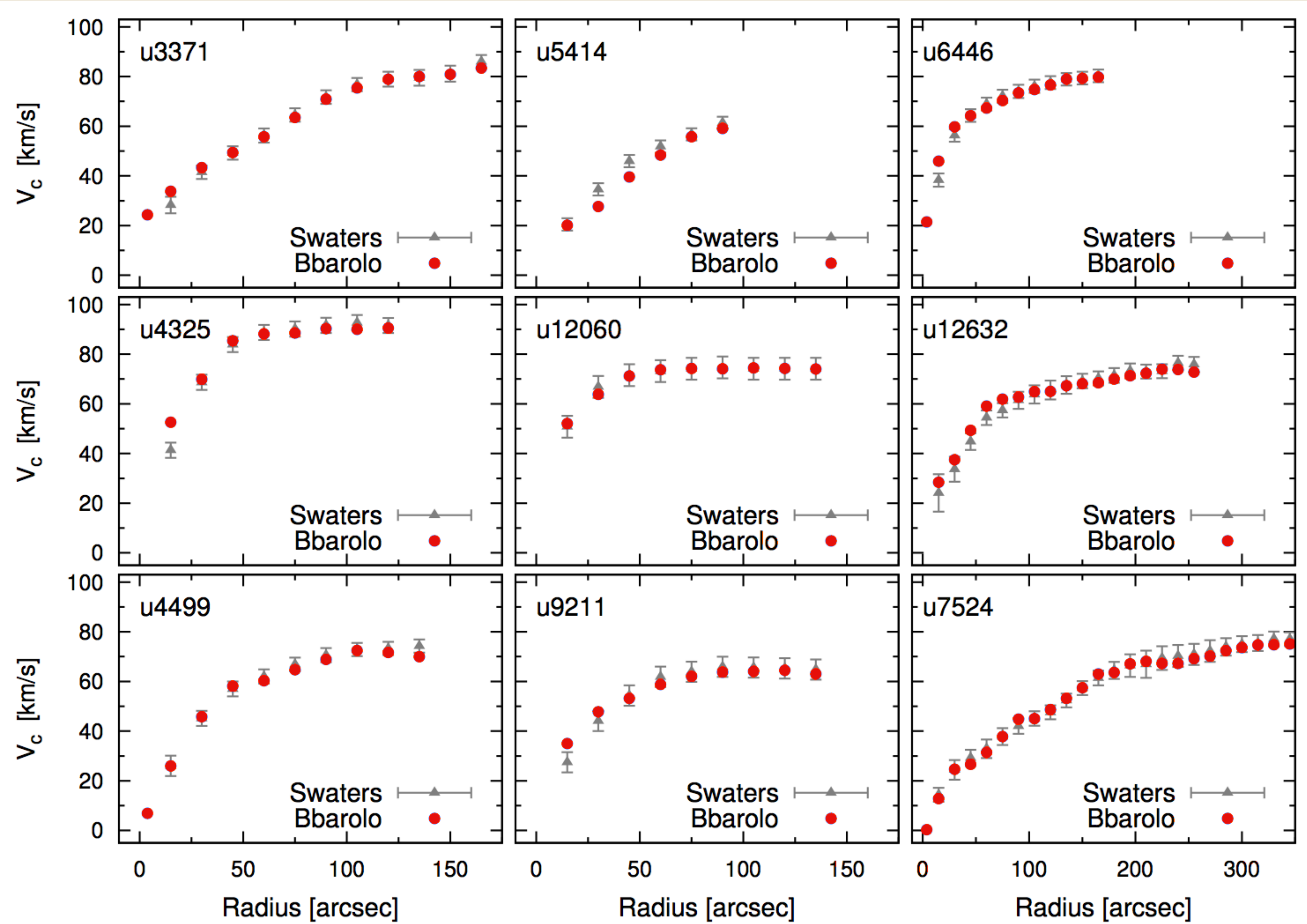
Comparison with rotation curves by Swaters 2002 (*2D tilted-ring + beam smearing correction*)



Beam area



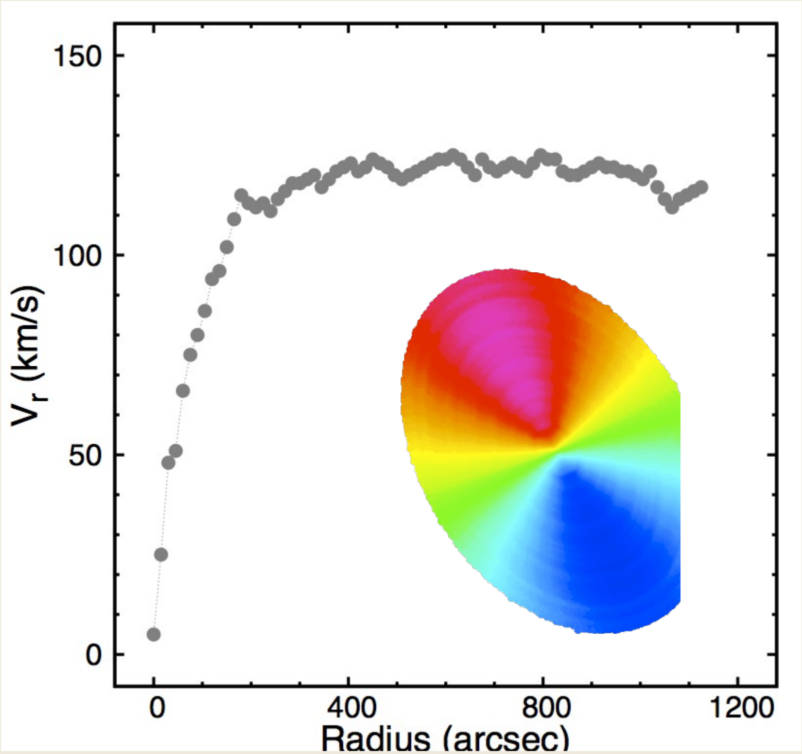
Example II: Mid-low resolution rotation curves



Example III: 2D vs Bbarolo *at very low resolution*

Artificial galaxy with:

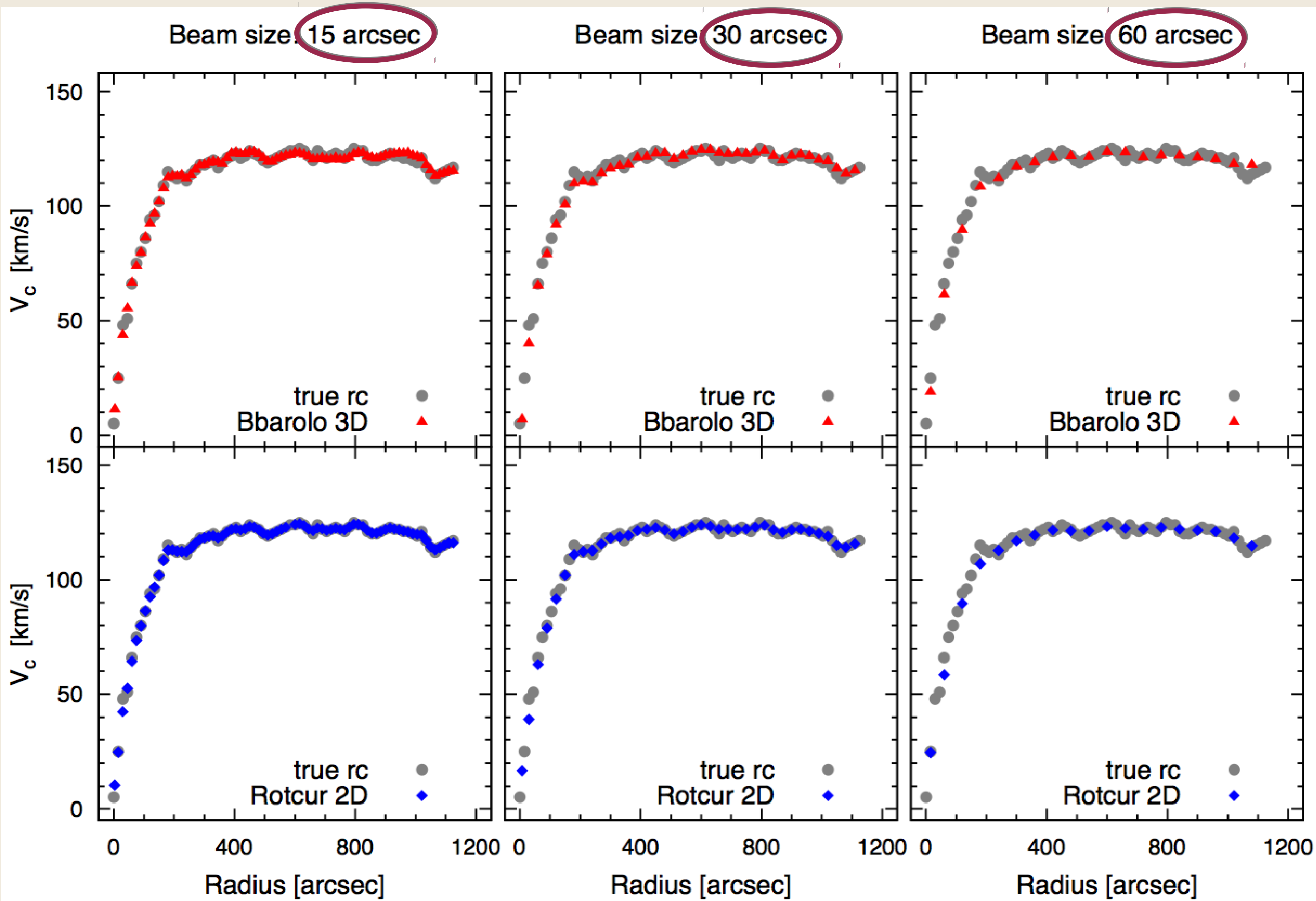
- Spatial resolution: **15''** (beam = 16 pixel)
- Fixed center, i, P.A, V_{sys} , Z_0
- Fixed velocity dispersion: **12 km/s**
- Quickly rising rotation curve



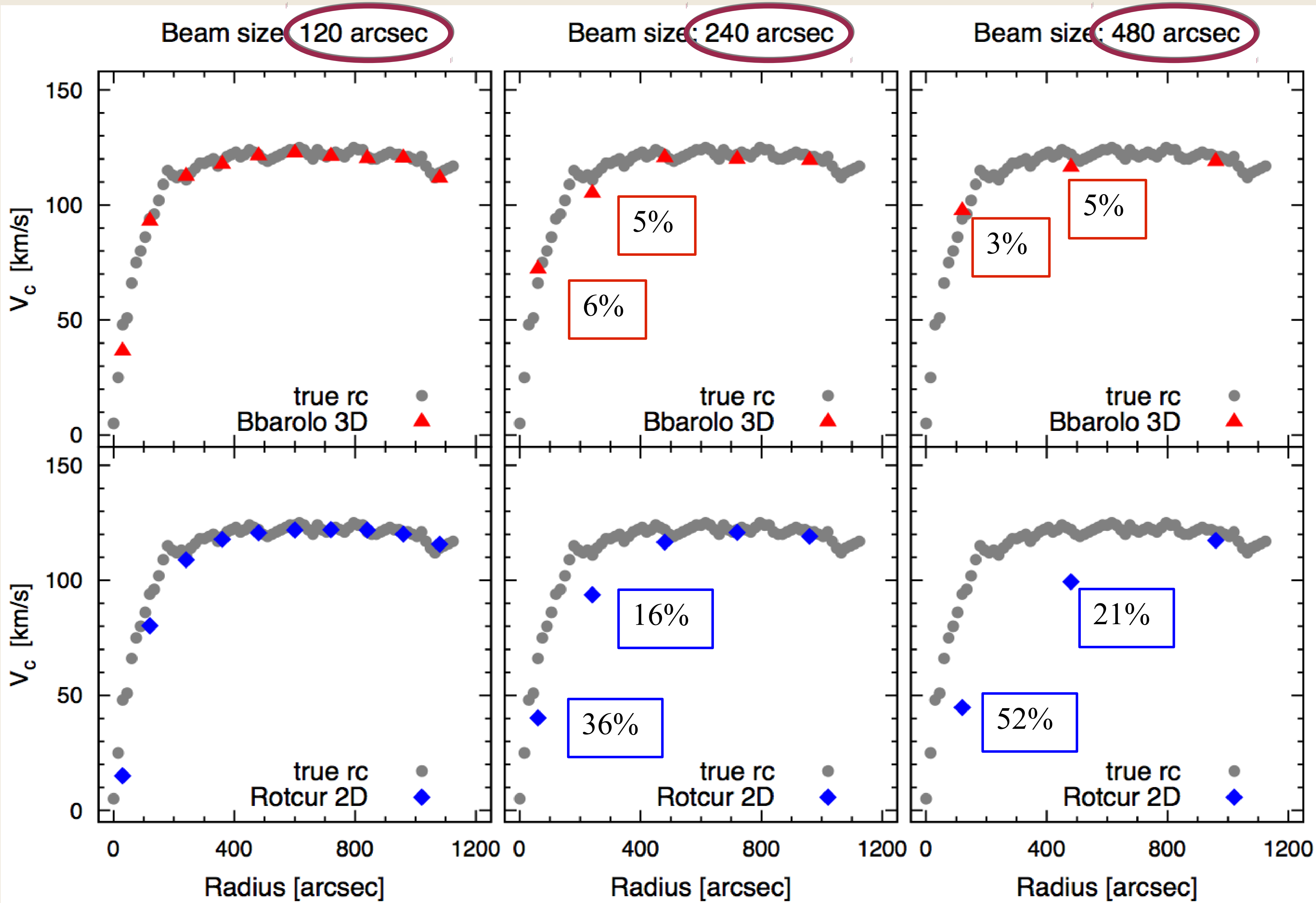
2D		***3D***
Rotcur (GIPSY) Free parameter: v_{rot}	VS	***Bbarolo*** Free parameters: v_{rot}, σ_d, pa, inc

- Repeating the analysis on datacubes smoothed at 30'', 60'', 120'', 240'', 480''

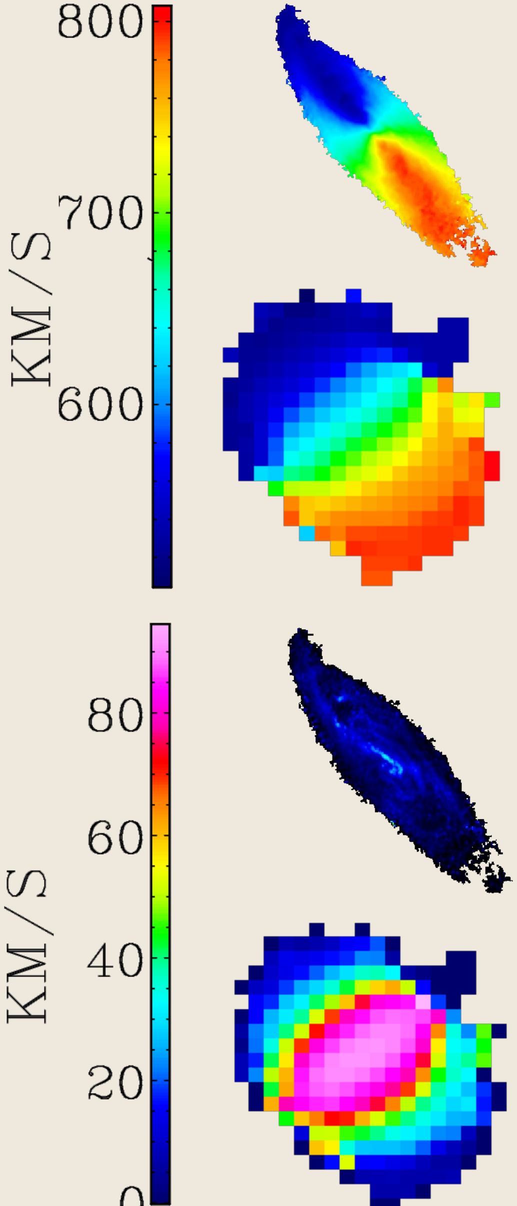
Example III: resolution effects

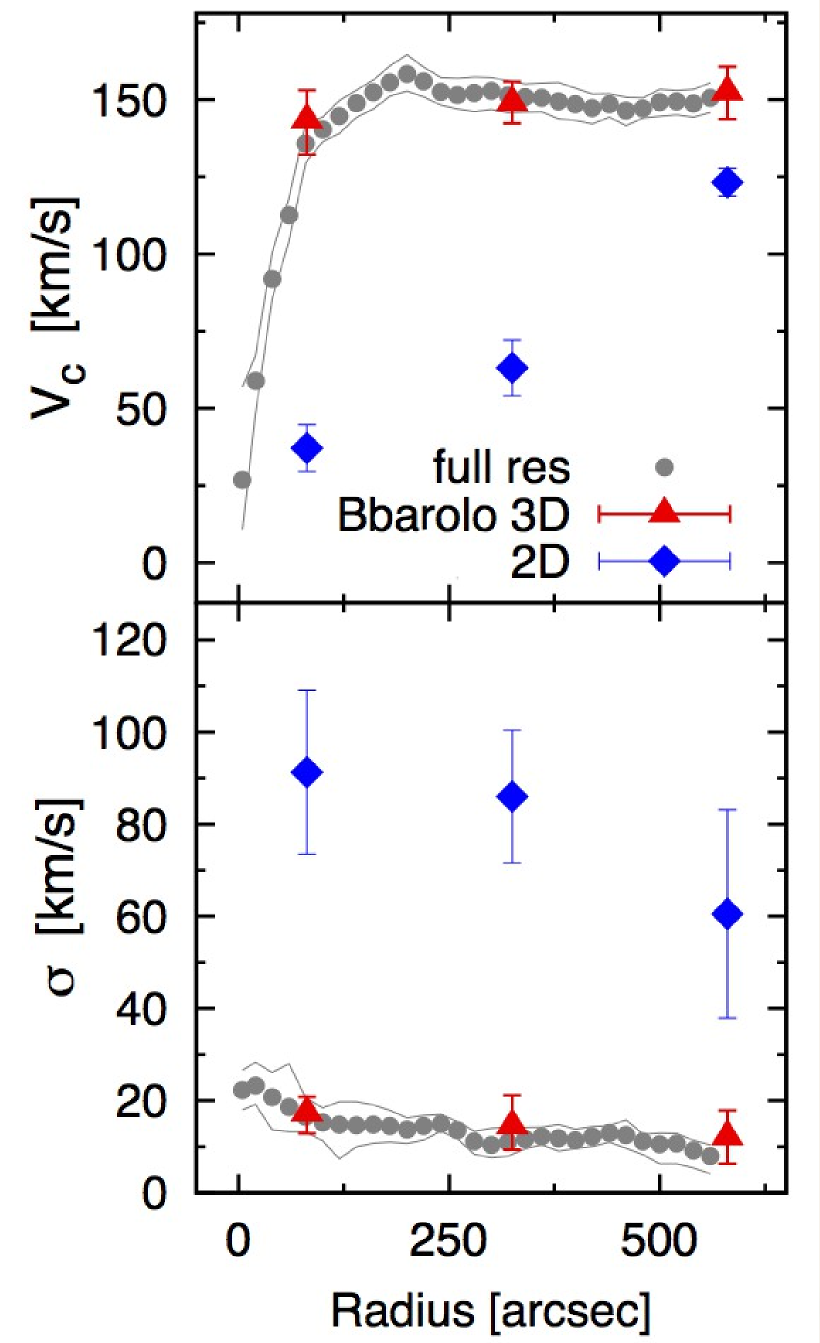


Example III: resolution effects



Example III: Real life (NGC3198 single-dish)





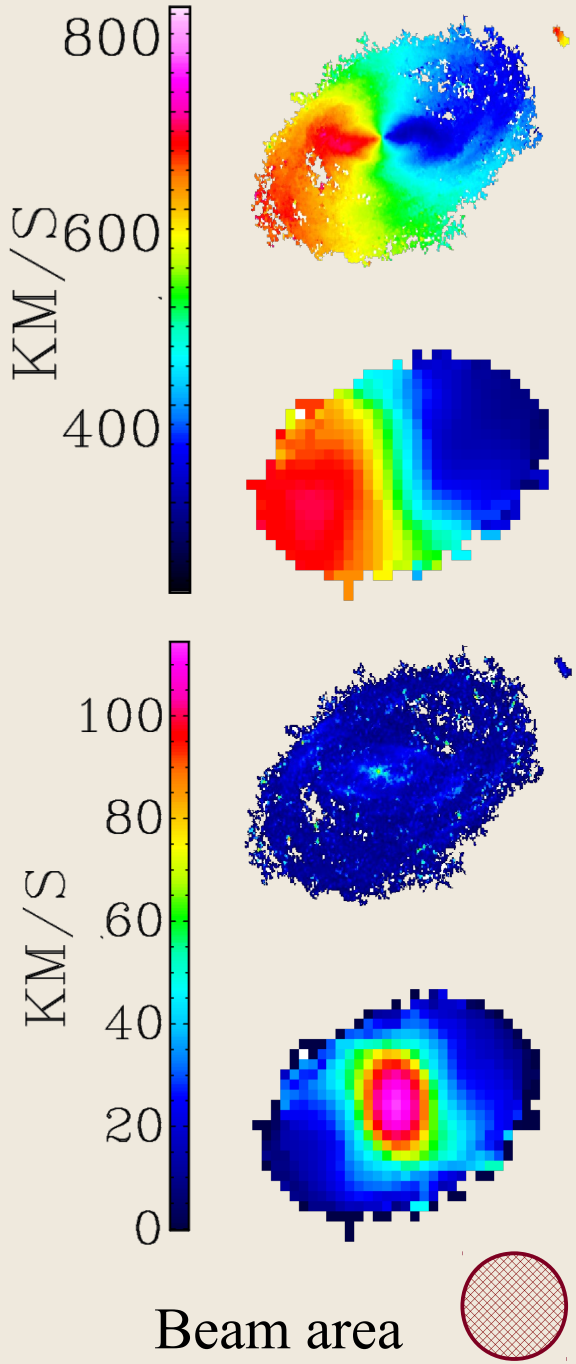
Beam area

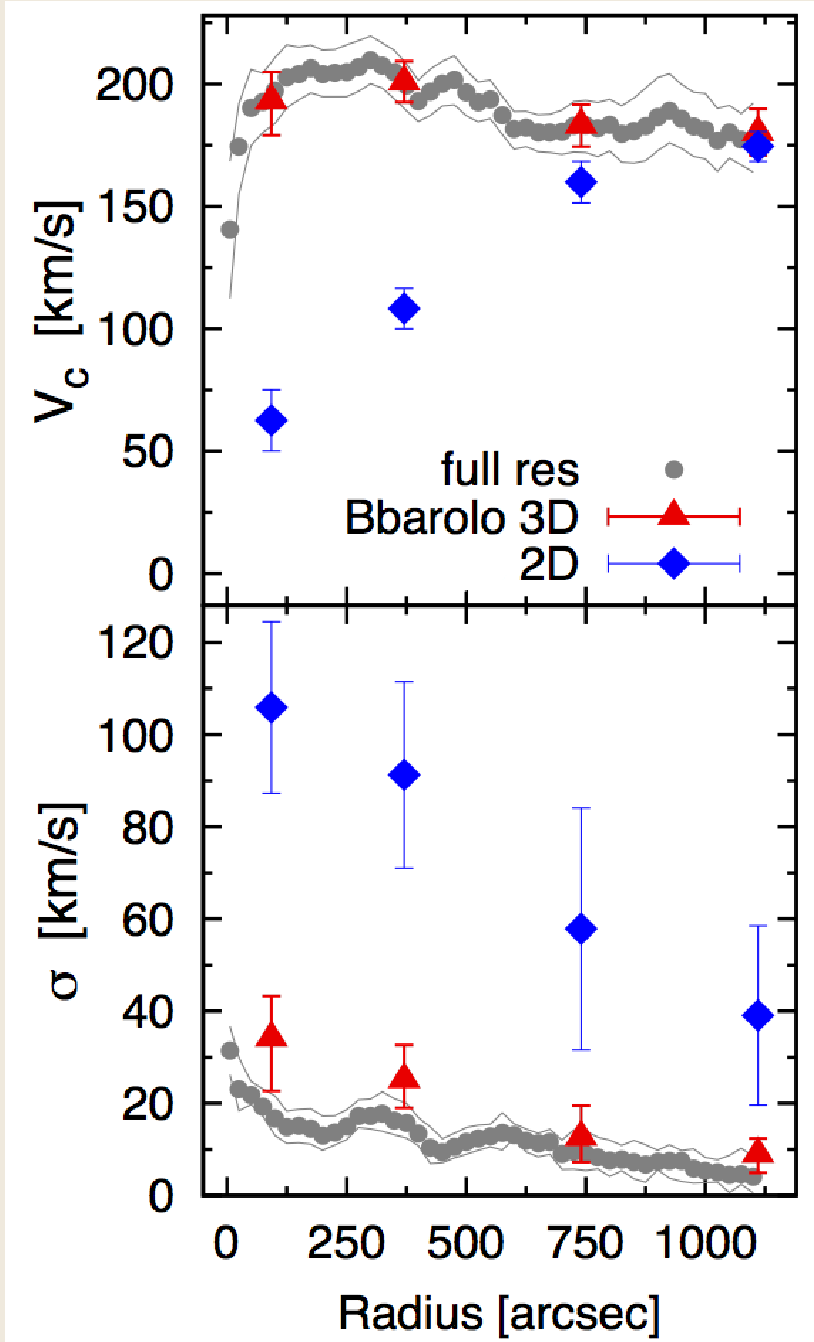
NGC 3198
(Effelsberg)

Model

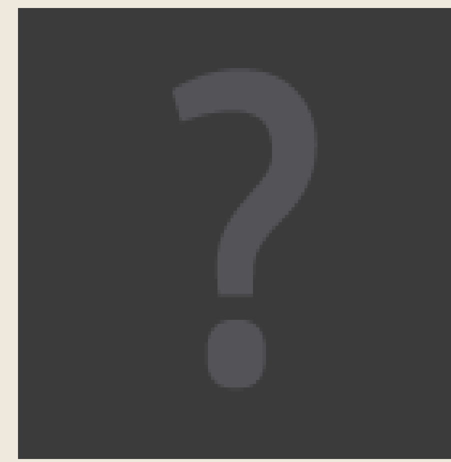
Data

Example III: Real life (NGC5055 single dish)





NGC 5055
(Effelsberg)



Model

Data

Conclusions and future prospects

- Bbarolo is a code for fitting simple tilted-ring models to data-cubes

- Applications range from high-resolution to very low resolution data

Forthcoming steps:

- Improvements in the fitting algorithm and full code parallelization

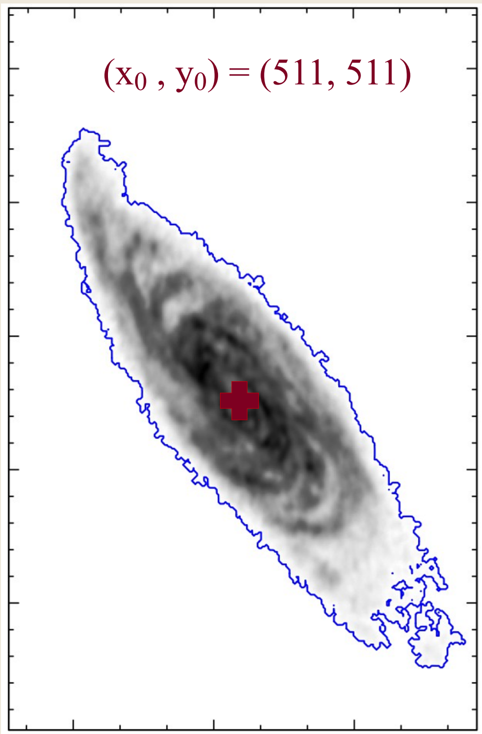
- Running Bbarolo on emission-line data of high-redshift galaxies (e.g. ESO/VLT SINFONI & MUSE, ALMA)

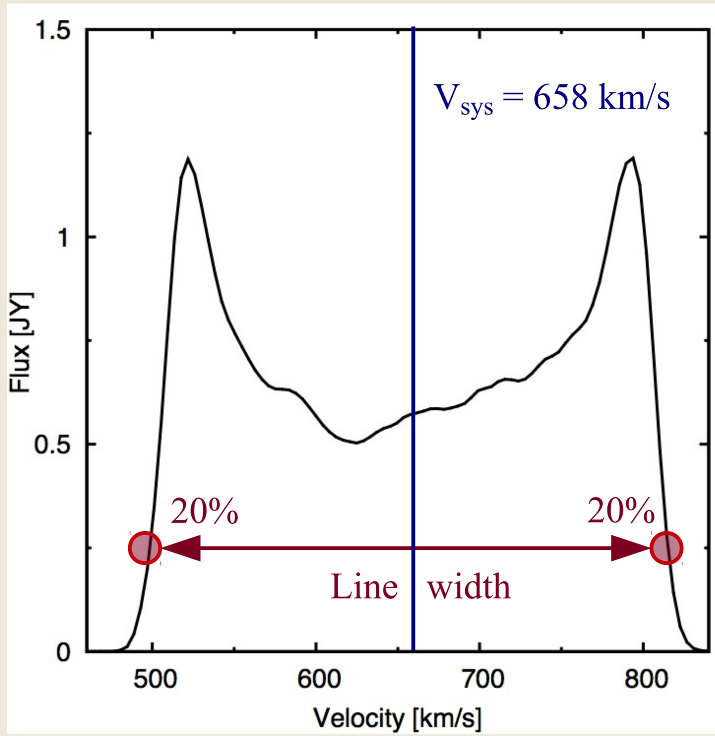
- Application on next-coming large HI surveys

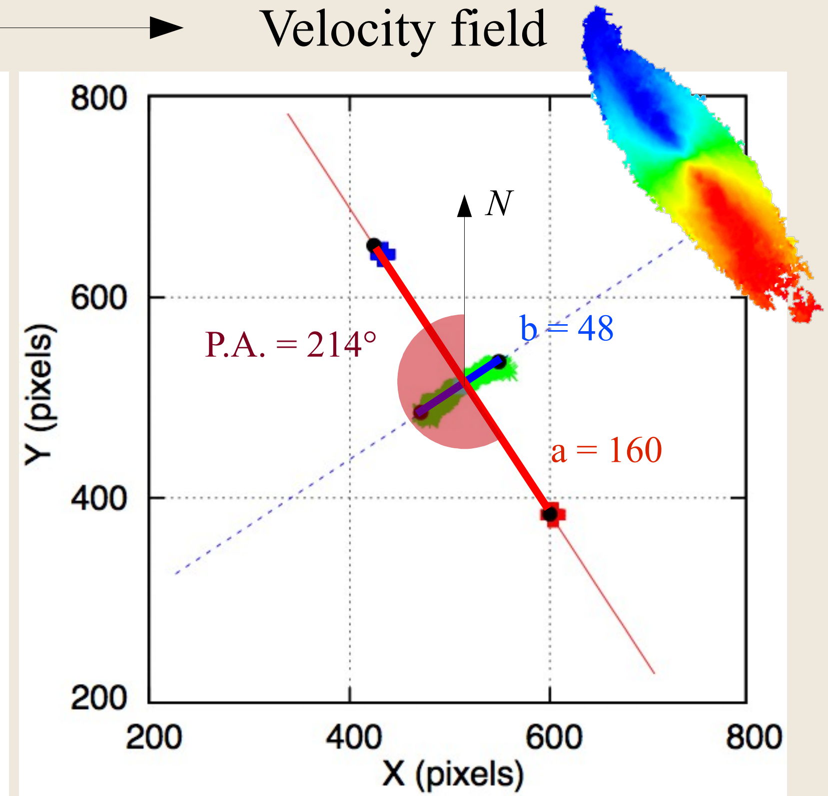
Thank you for your kind attention

NGC 3198: Initial parameter estimate

Source detection → Global line profile → Velocity field







X_0 = 511.3

Y_0 = 510.9

V_{sys} = 658.9 km/s

P.A. = 214.6 °

W_{20} = 305 km/s

a = 160
b = 48

i = acos(b/a) = **= 72.5°**

+

σ = 8 km/s

Z_0 = 150 pc

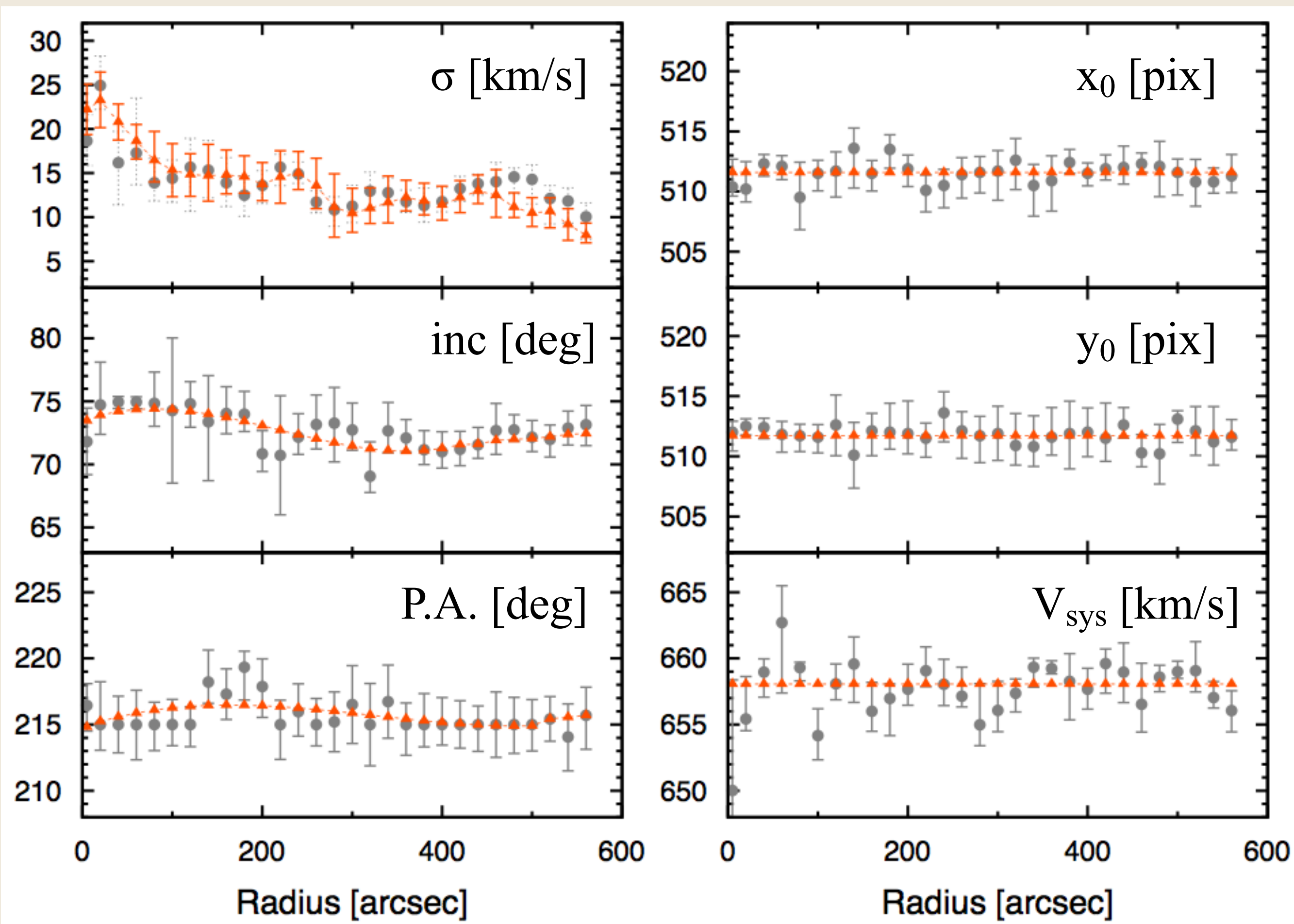
V_{rot} = 0.5*W_{20} / sin i = **160 km/s**

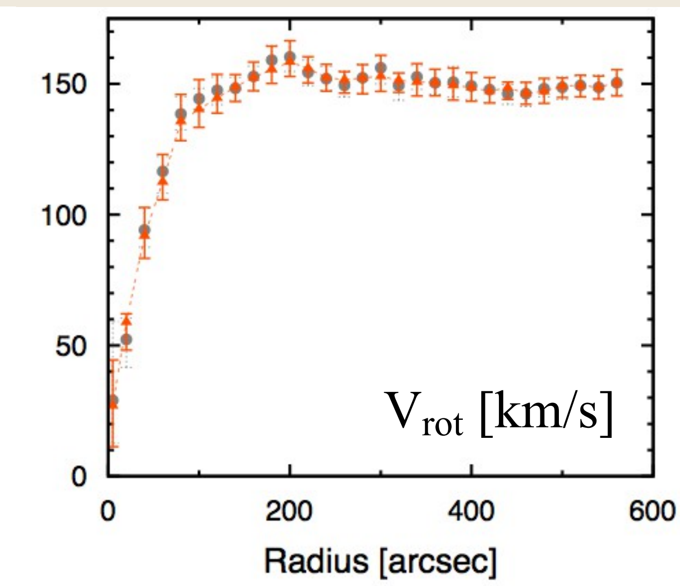
NGC 3198: Fitting the model

First fitting step:
All parameters free!

Fixing parameters:
PA & inc as 3rd degree polyn.
Others constant

Second fitting step:
Only V_{rot} and σ free





Errors in Bbarolo

Best model → **Random variation of parameters** → **Fit with a 3rd deg. polynomial** → **Errors within 5%**