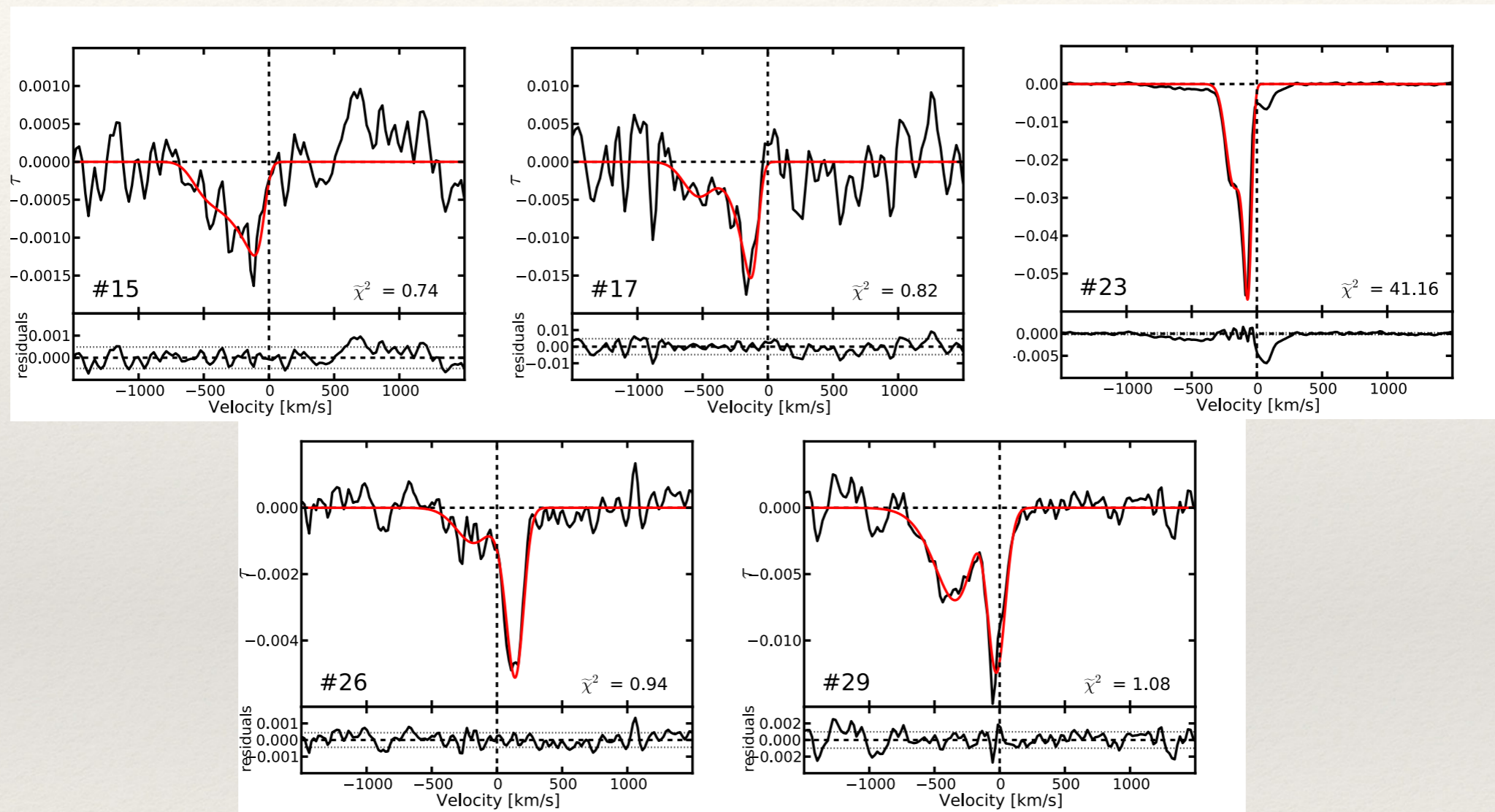# Understanding the distribution and the kinematics of neutral hydrogen from absorption lines


F. Maccagni; R. Morganti; T. Oosterloo; K. Geréb; E. Mahony; V. Moss; J. Allison; E. Sadler

A variety of profiles

- **Upcoming surveys searching for HI absorption** (FLASH, SHARP) will detect **hundreds of new HI absorption lines**

- Exploratory work: 66 detections of associated HI absorption out of 248 sources observed with the WSRT.

  - 3 main categories:

    - Narrow lines:

      FWHM < 100 km/s

    - Medium width lines:

      100 km/s < FWHM < 200 < km/s

    - Broad lines:

      FWHM > 200 km/s

[Geréb, Maccagni, et al., 2015]
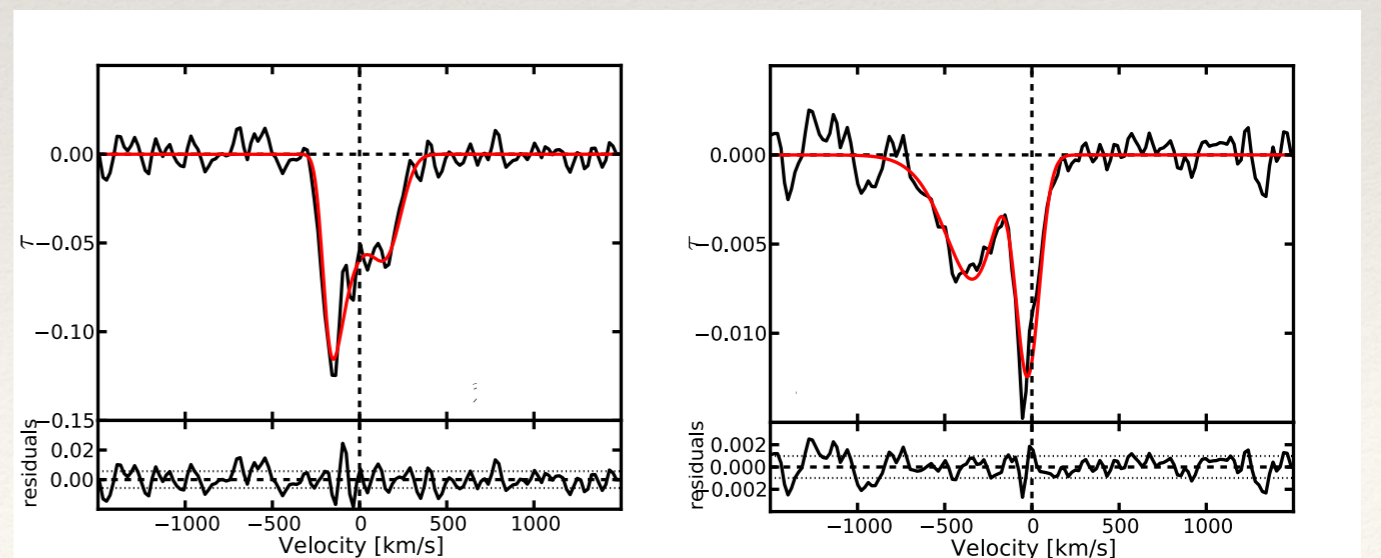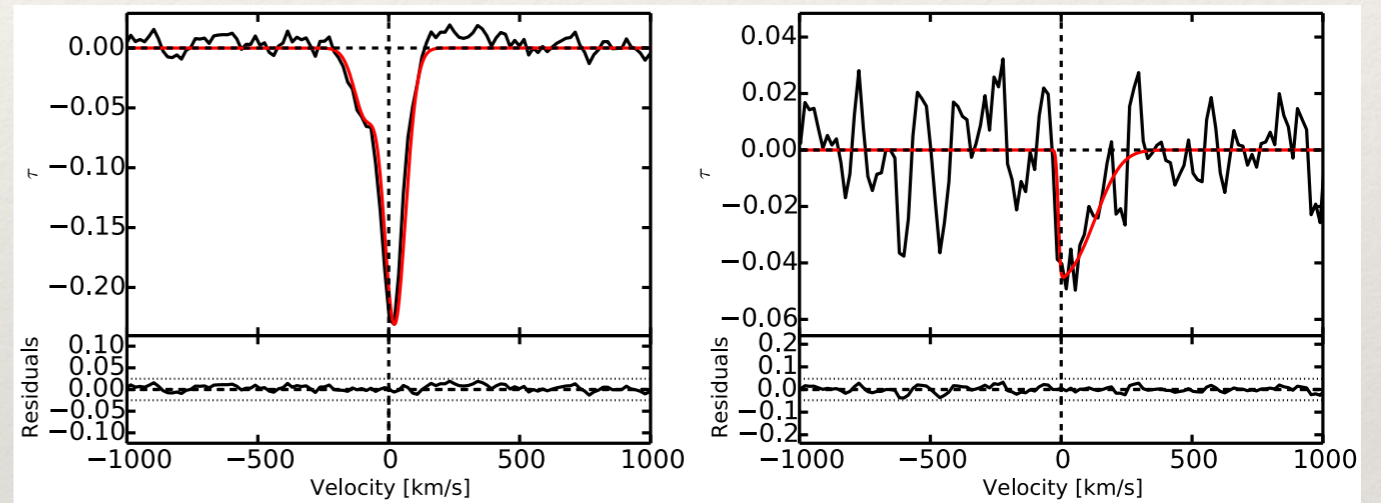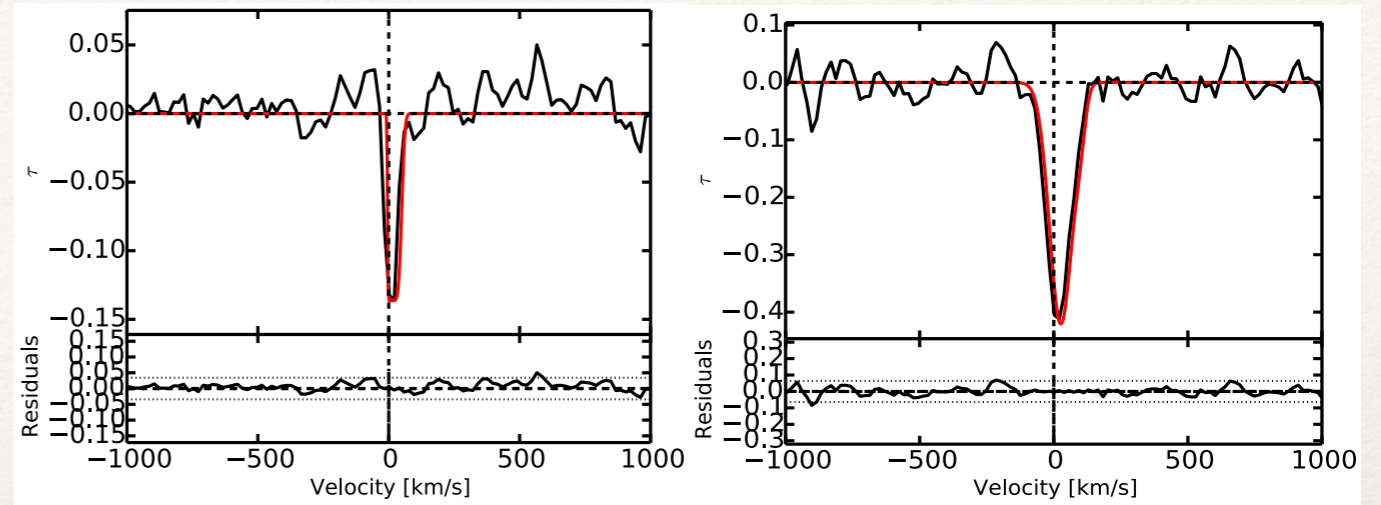
What's behind the shape and width of absorption lines:
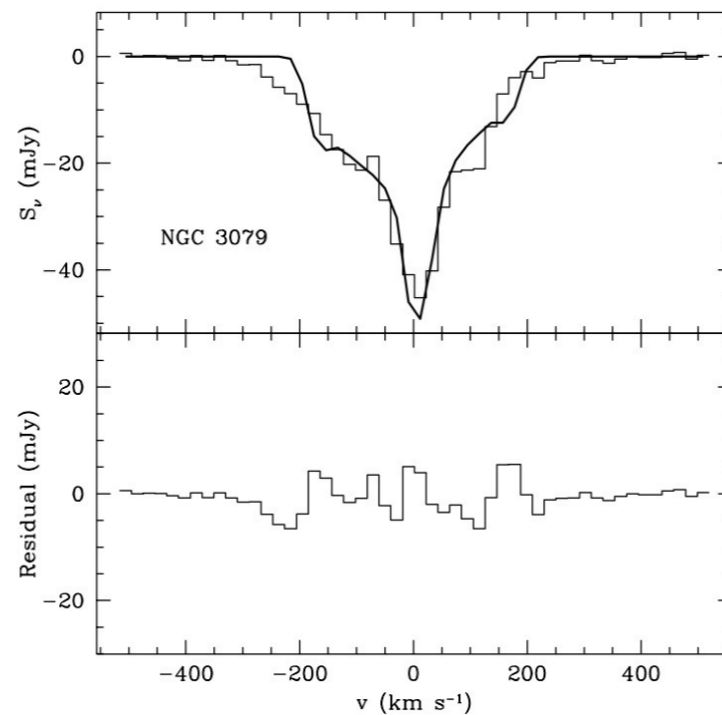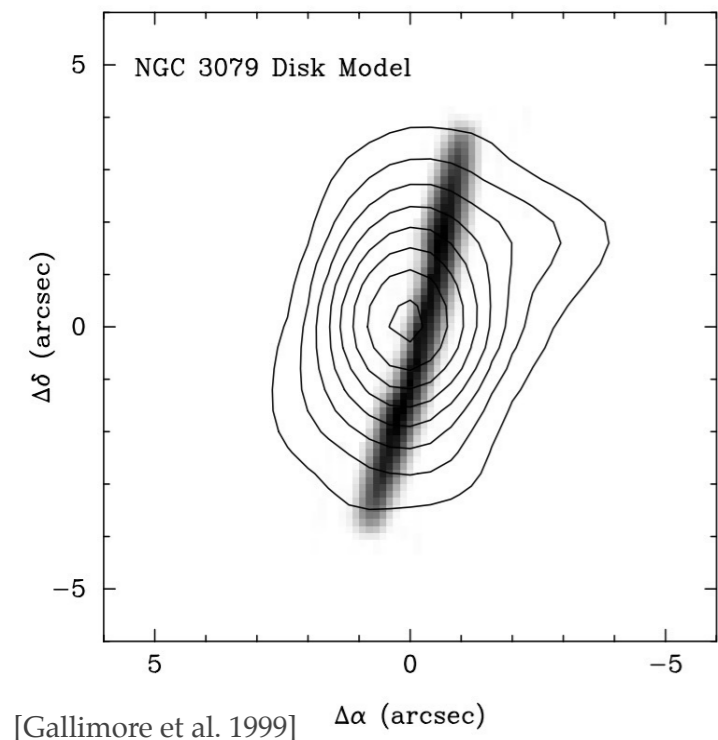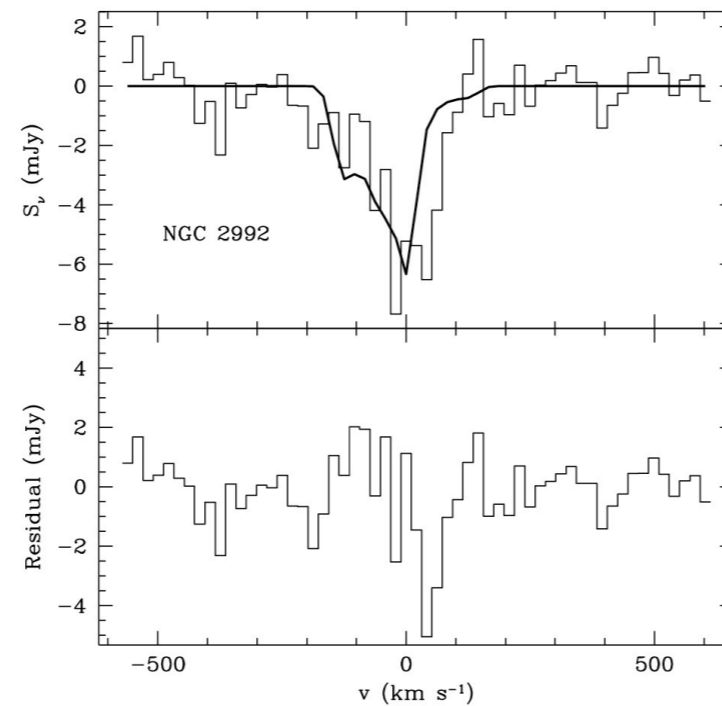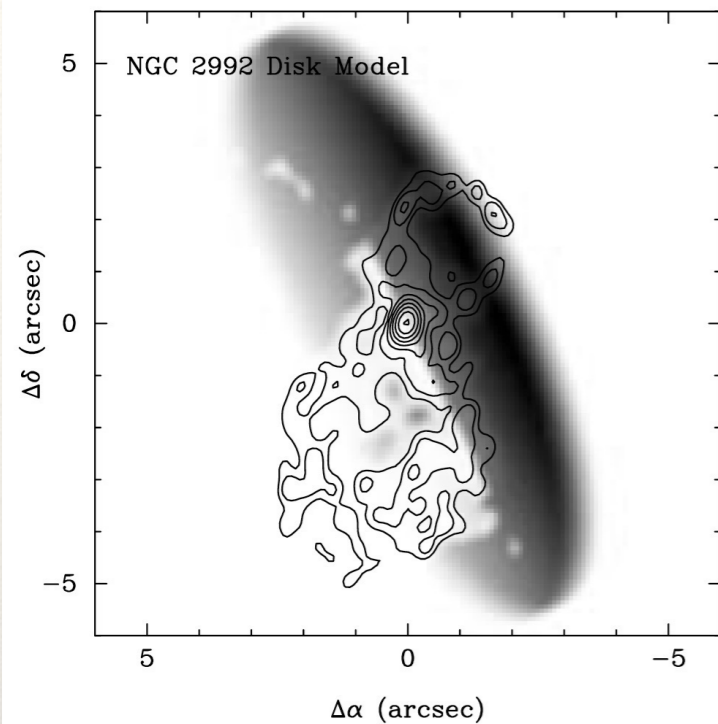
[Gallimore et al. 1999]

- In Seyfert galaxies: very different lines can be reproduced by a rotating disk in front of the radio continuum. [Gallimore et al. 1999]

- High resolution observations sometimes show that part of the absorption line is tracing an outflow of gas pushed by the radio jet [Morganti et al. 2005]

⇒ Which lines trace outflows ?
⇒ Can we find a systematic way to interpret absorption lines?

Modeling the HI absorber

- Understand the overall distribution of the HI traced by the absorption line
  - **Which lines trace galactic disks? which ones circum-nuclear? which ones outflows?**
    - Ideal solution: trace the HI absorption against the radio jets (VLA, VLBI, EVN)
    - Help of a <u>kinematical model</u>:
      - Model the rotating HI disk in front of the radio continuum:

3C 305   Observation ⟶   Model

[Jackson et al., 2003]
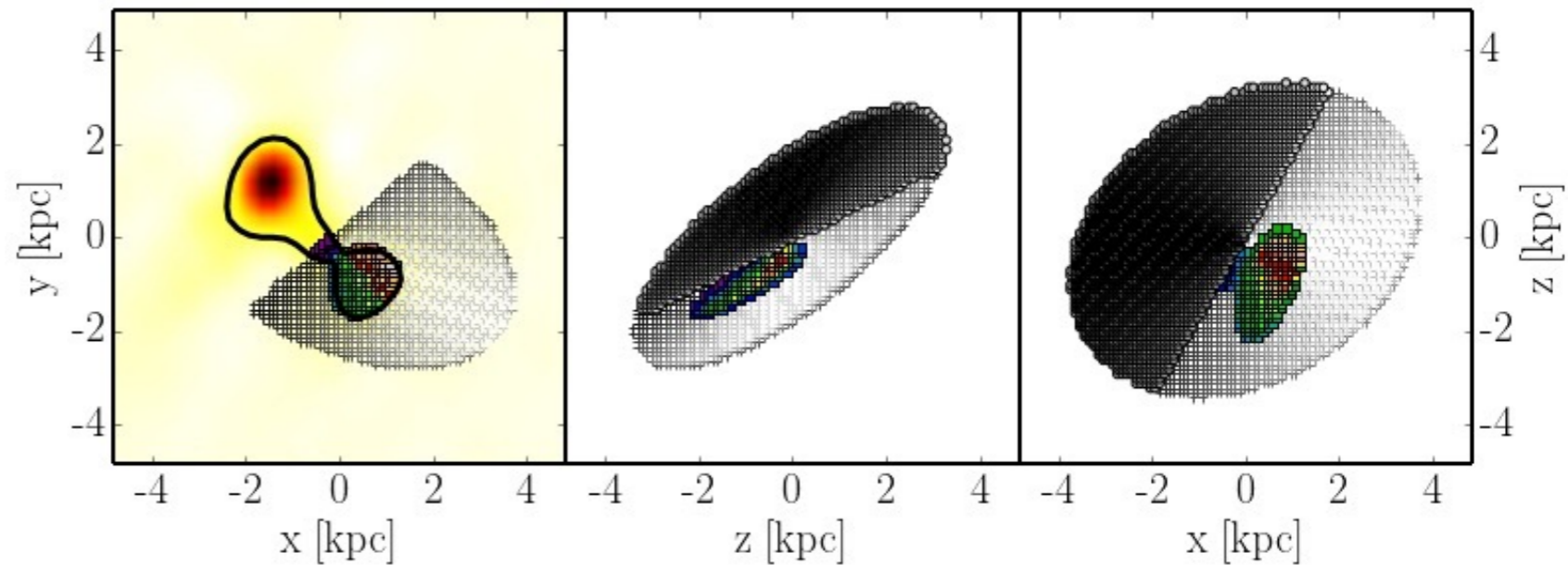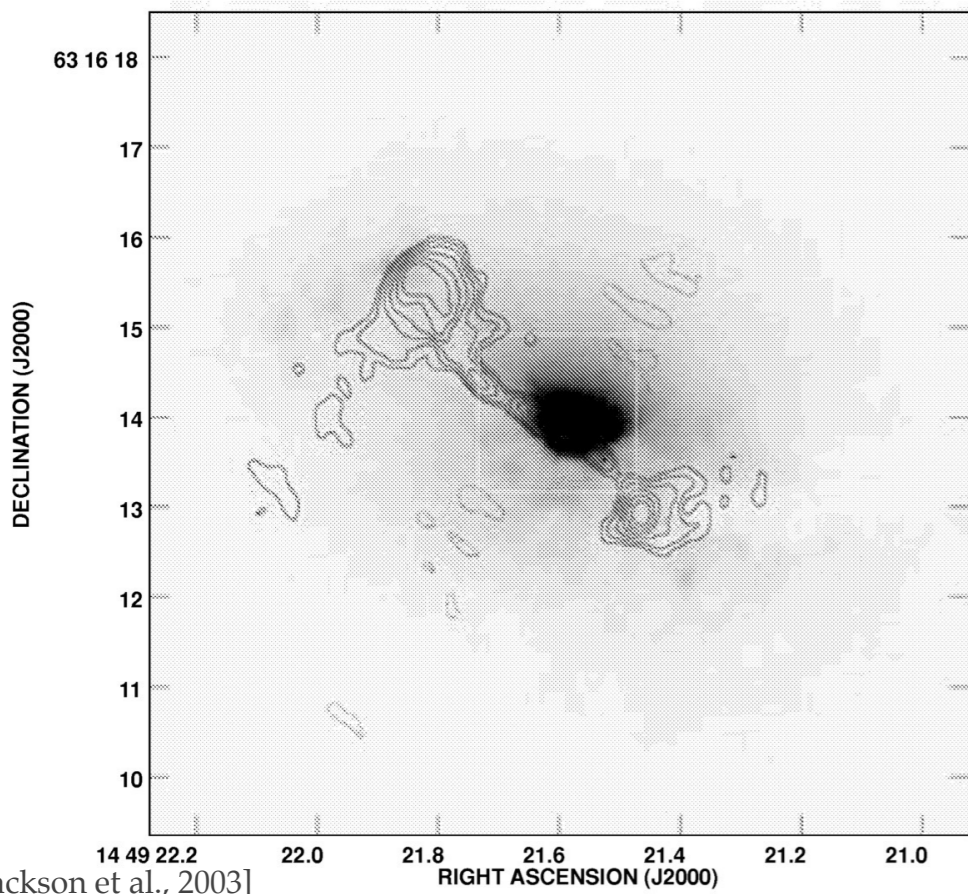
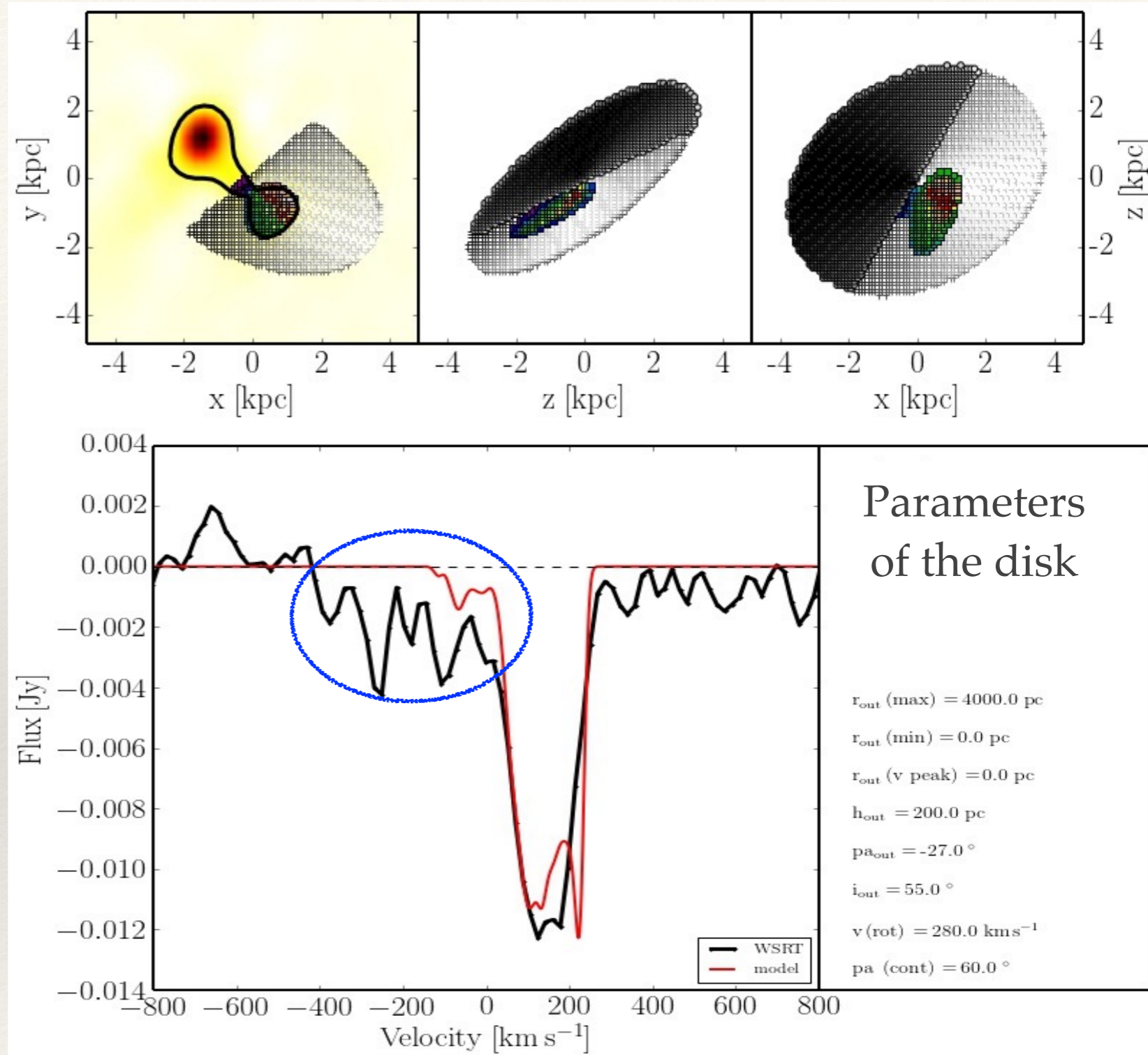Plane of the sky : x,y   Side view: z,y   From above: x,z

3C 305

- We fix the parameters of the disk from available information on the galaxy:

    - Optical Image: i, PA
    - Radio continuum image
    - Tully Fisher -> V_{flat}
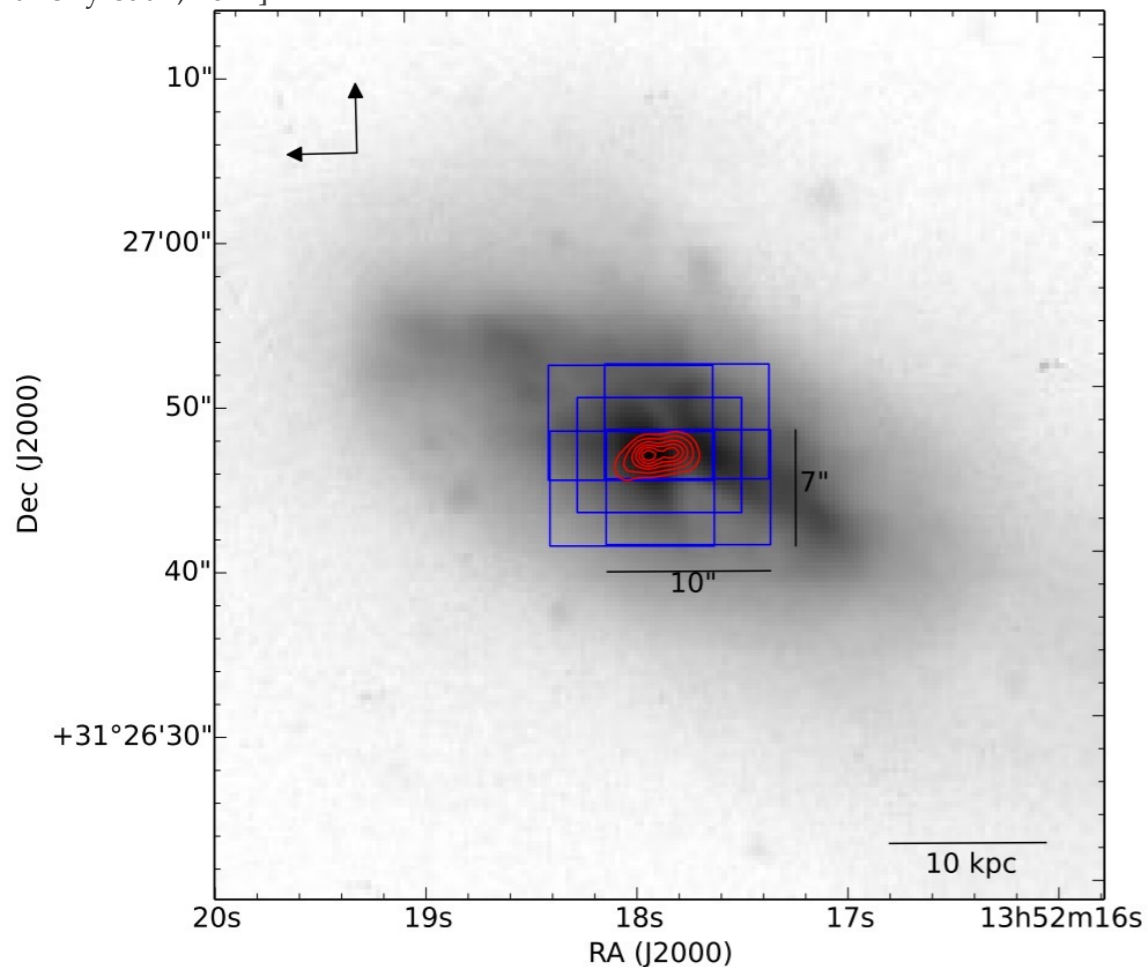   - Flat rotation curve

- Does the model reproduce the observed line?

    - The bulk of the absorption is well reproduced by a rotating disk
    - Blue-shifted wing not reproduced by the model

Parameters of the disk

$r_{out} (max) = 4000.0 \, pc$

$r_{out} (min) = 0.0 \, pc$

$r_{out} (v \, peak) = 0.0 \, pc$

$h_{out} = 200.0 \, pc$

$pa_{out} = -27.0°$

$i_{out} = 55.0°$

$v (rot) = 280.0 \, km \, s^{-1}$

$pa (cont) = 60.0°$

WSRT
model

3C 293

Test the model on a more complex case:
- 3C 293

  - Radio jets expanding in the plane of the galaxy
  - Central dust lanes misaligned with the optical disk
  - The galaxy may have an inner thick disk and outer thin disk aligned edge-on

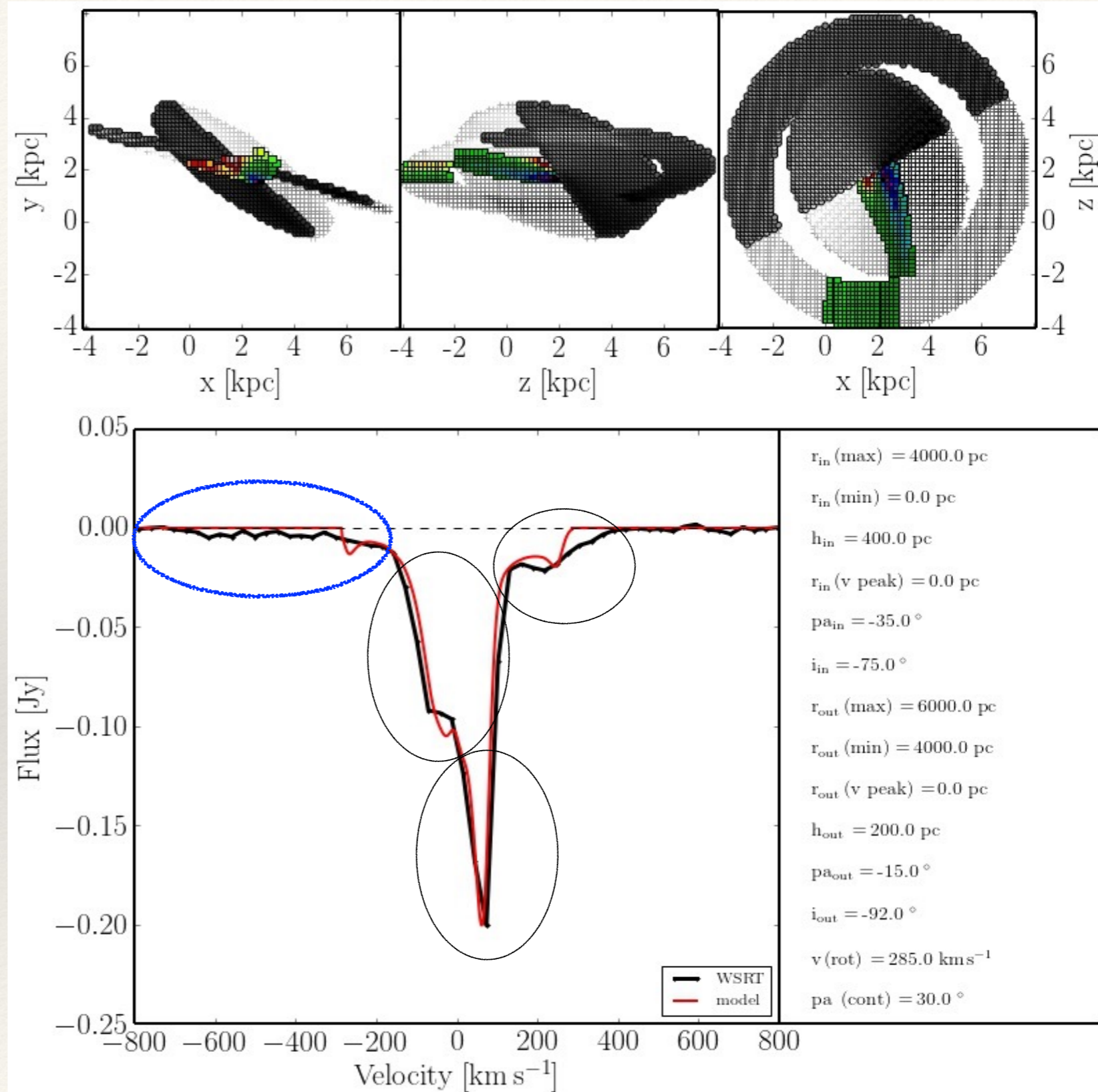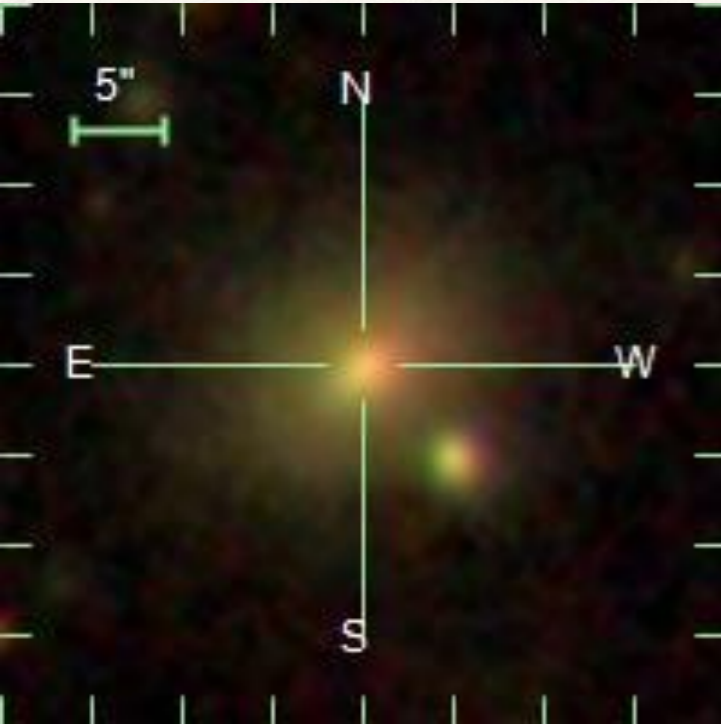[Beswick et al. 2002, 2004; Mahony 2014]
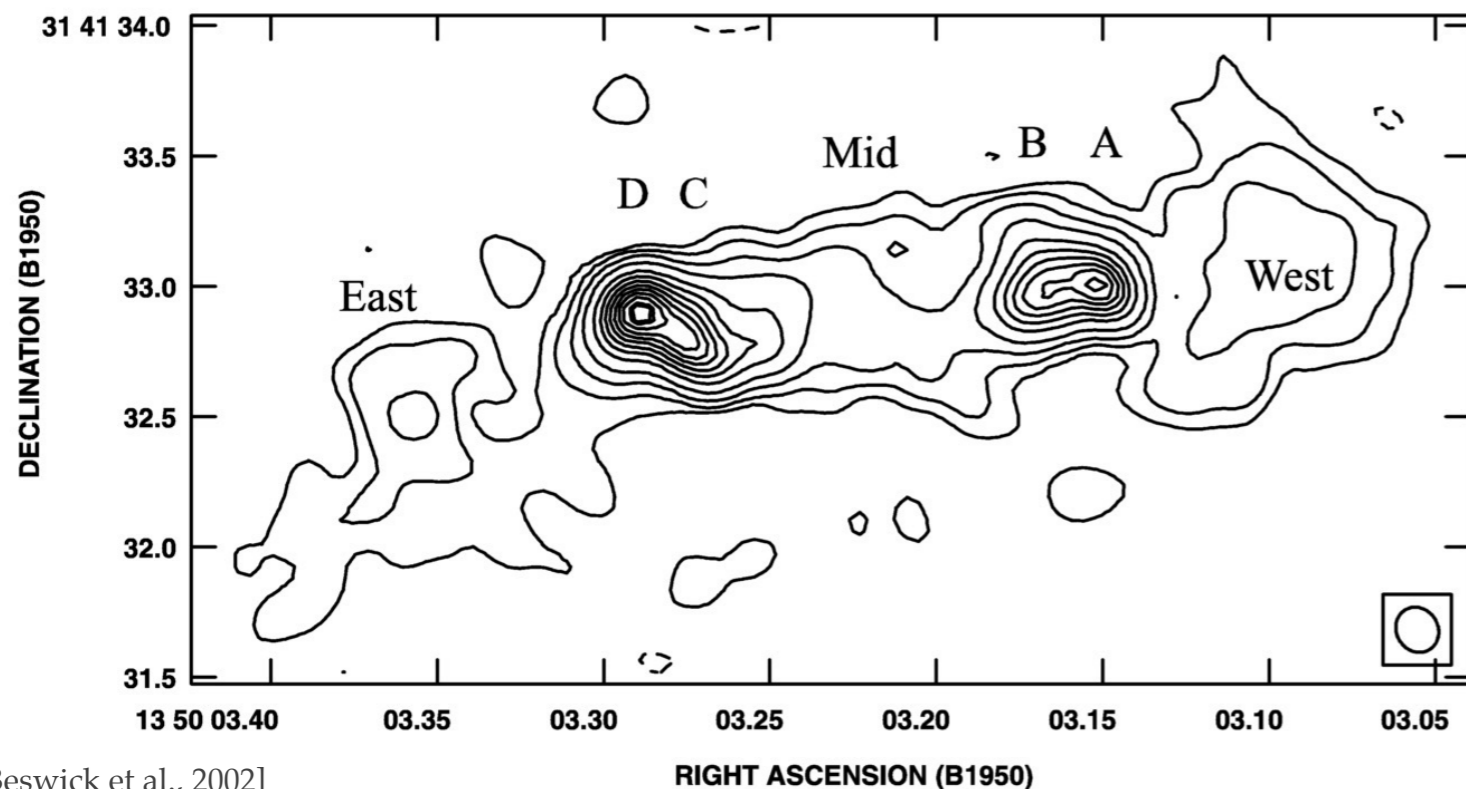
3C 293

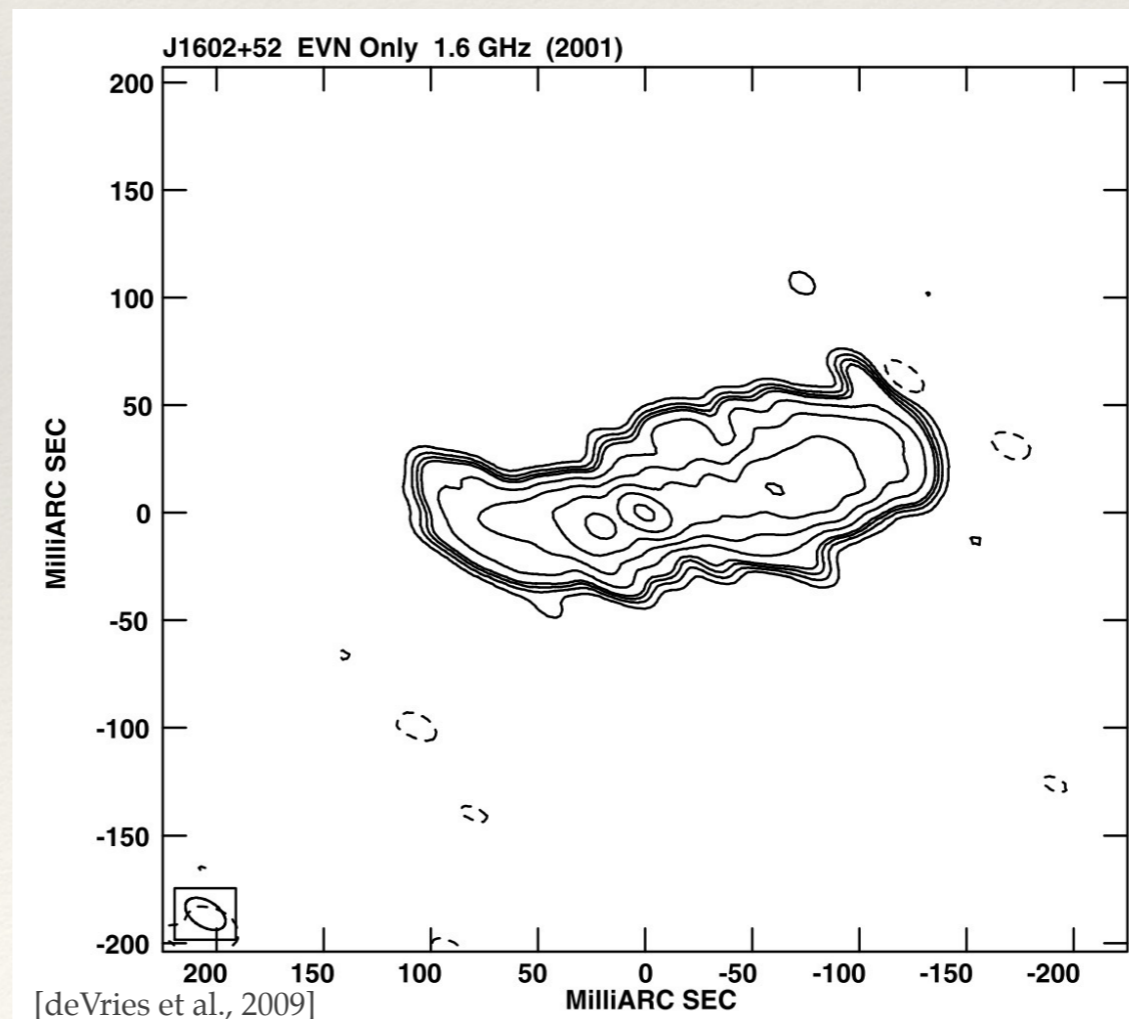Outer thin disk

+

Inner thick disk

=

- Reproduce the main features of the line
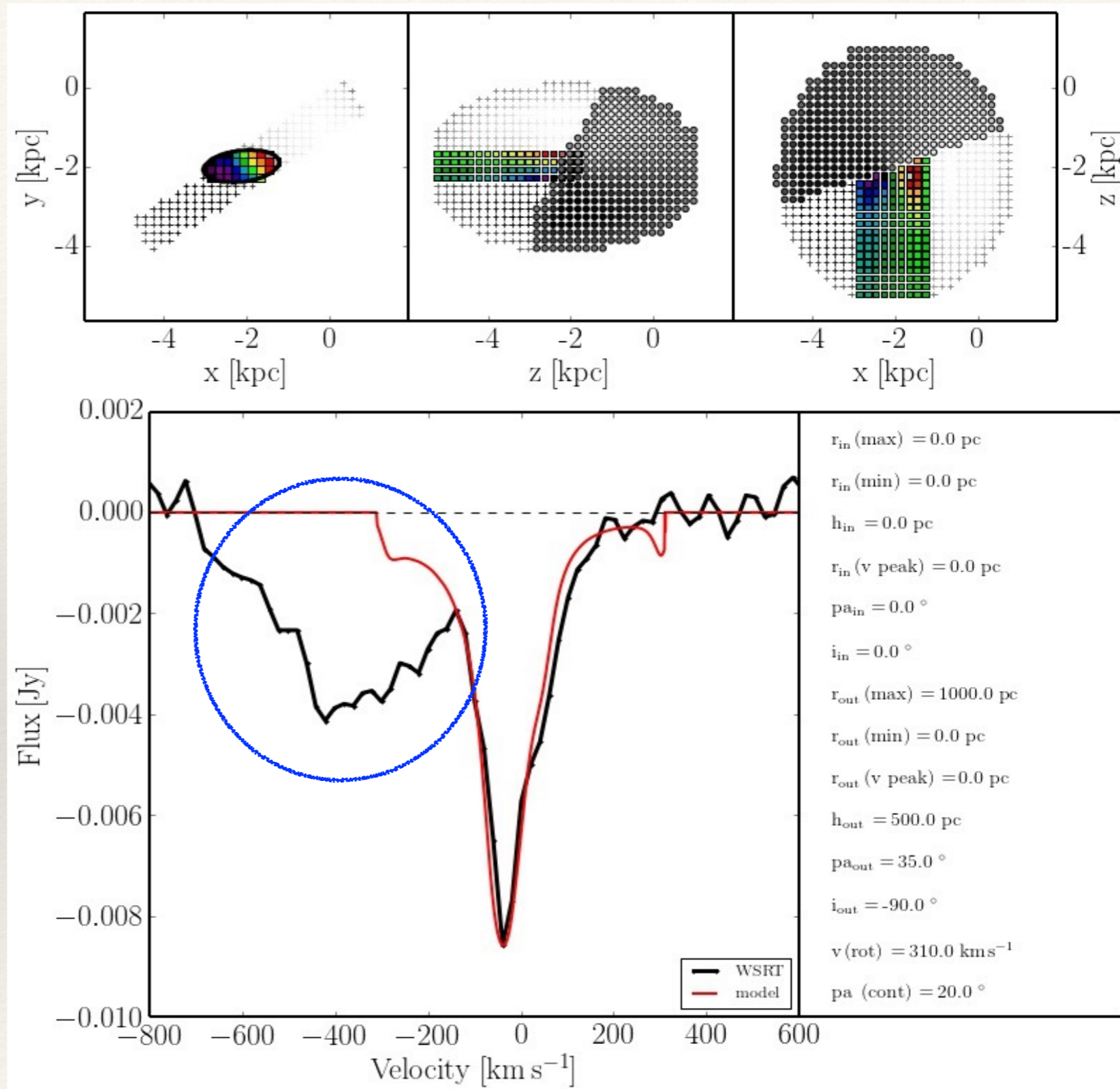- Blue-shifted wing not reproduced by the model

4C +52.37

- Let's apply the model to a galaxy for which we have less information:
  - 4C +52.37
    - SDSS data give hints on PA, i
    - Radio continuum morphology
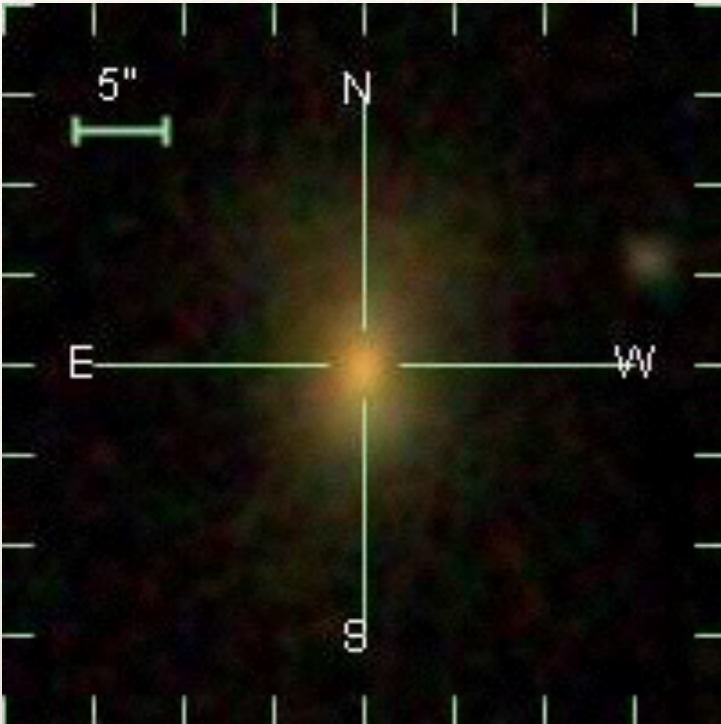   - Flat rotation curve + TF


J1602+52 EVN Only 1.6 GHz (2001)

[deVries et al., 2009]

4C +52.37

- The bulk of the absorption is well reproduced by a rotating edge-on disk
- Blue-shifted wing not reproduced by the model

$r_{in} (max) = 0.0$ pc
$r_{in} (min) = 0.0$ pc
$h_{in} = 0.0$ pc
$r_{in} (v\ peak) = 0.0$ pc
$pa_{in} = 0.0\,°$
$i_{in} = 0.0\,°$
$r_{out} (max) = 1000.0$ pc
$r_{out} (min) = 0.0$ pc
$r_{out} (v\ peak) = 0.0$ pc
$h_{out} = 500.0$ pc
$pa_{out} = 35.0\,°$
$i_{out} = -90.0\,°$
$v (rot) = 310.0\ \mathrm{km\,s^{-1}}$
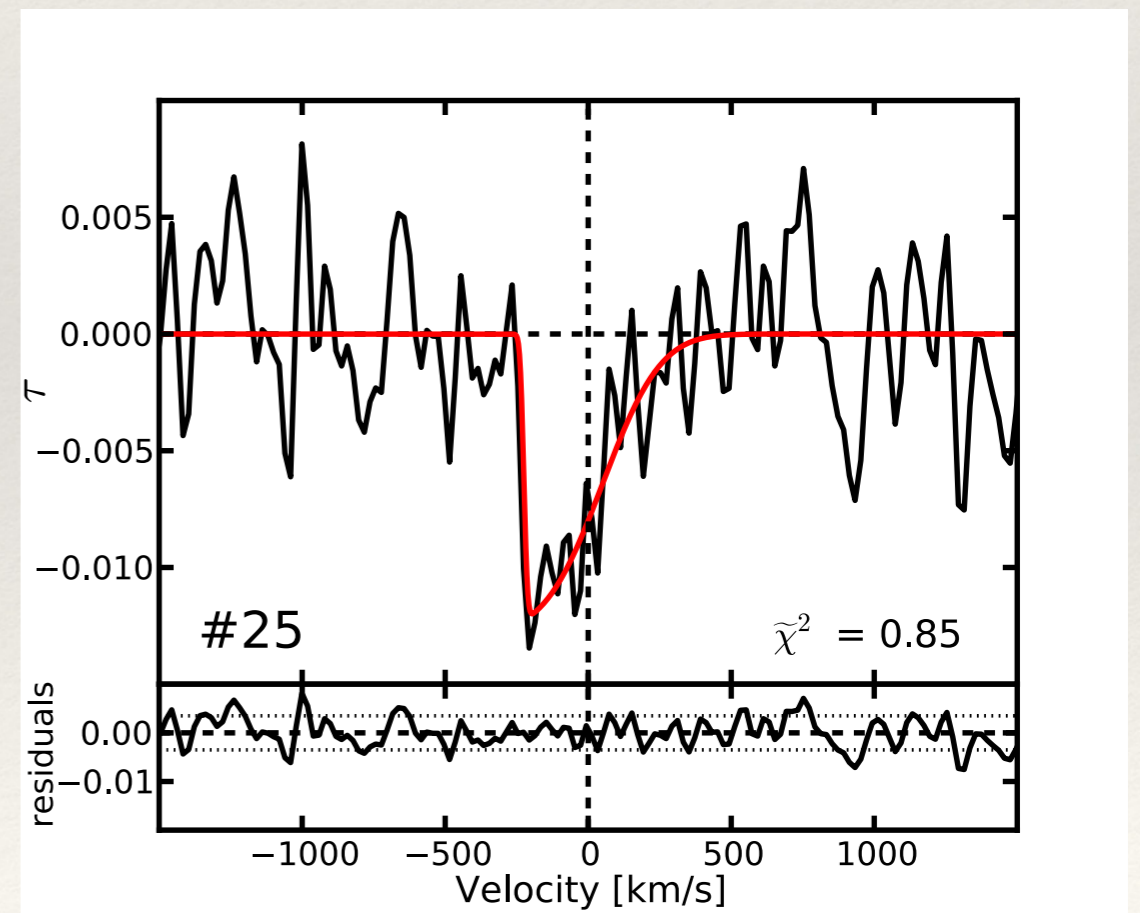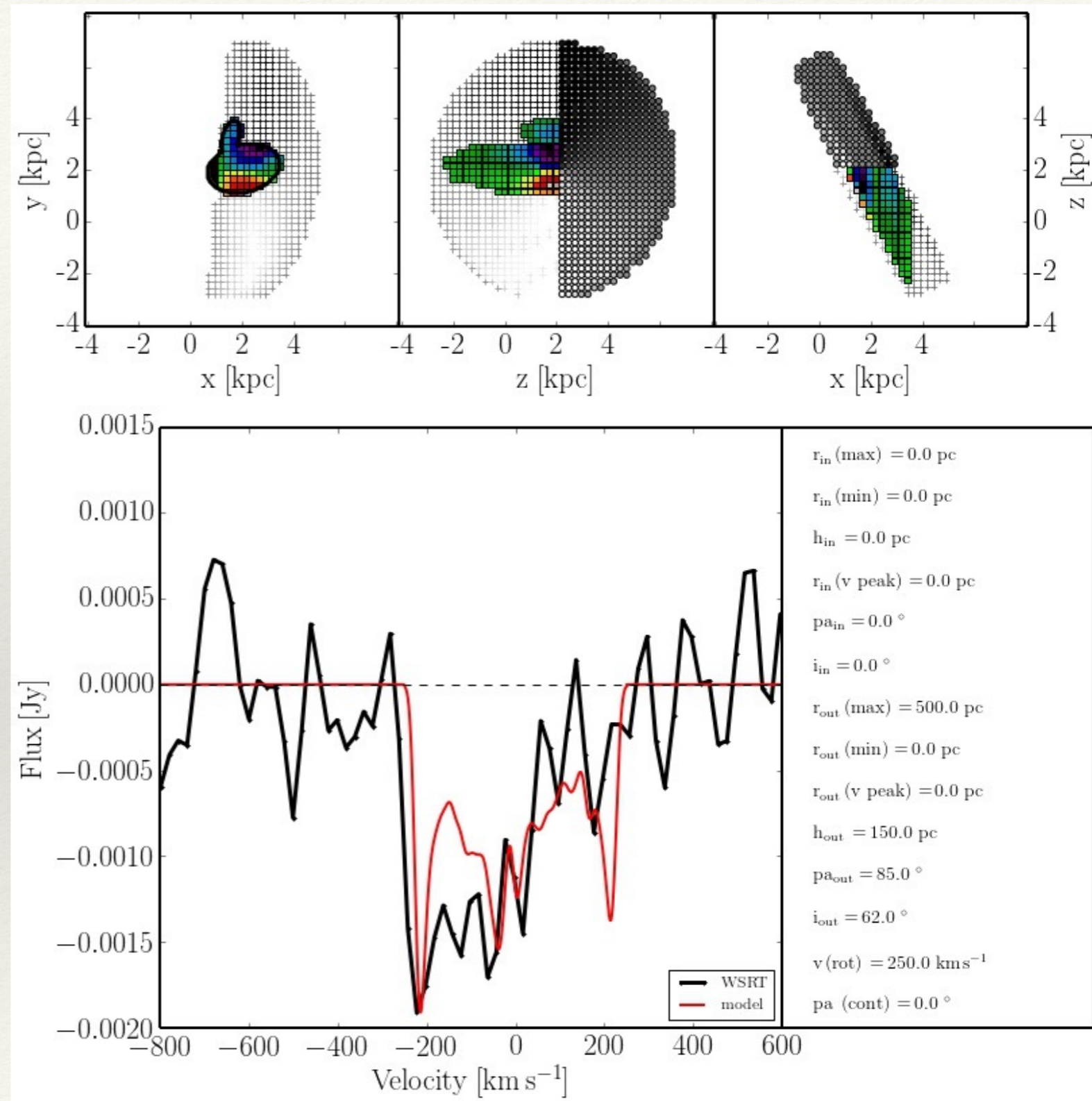$pa\ (cont) = 20.0\,°$

J143521.7+505123

- What about the narrower lines?
- How well do we reproduce them?
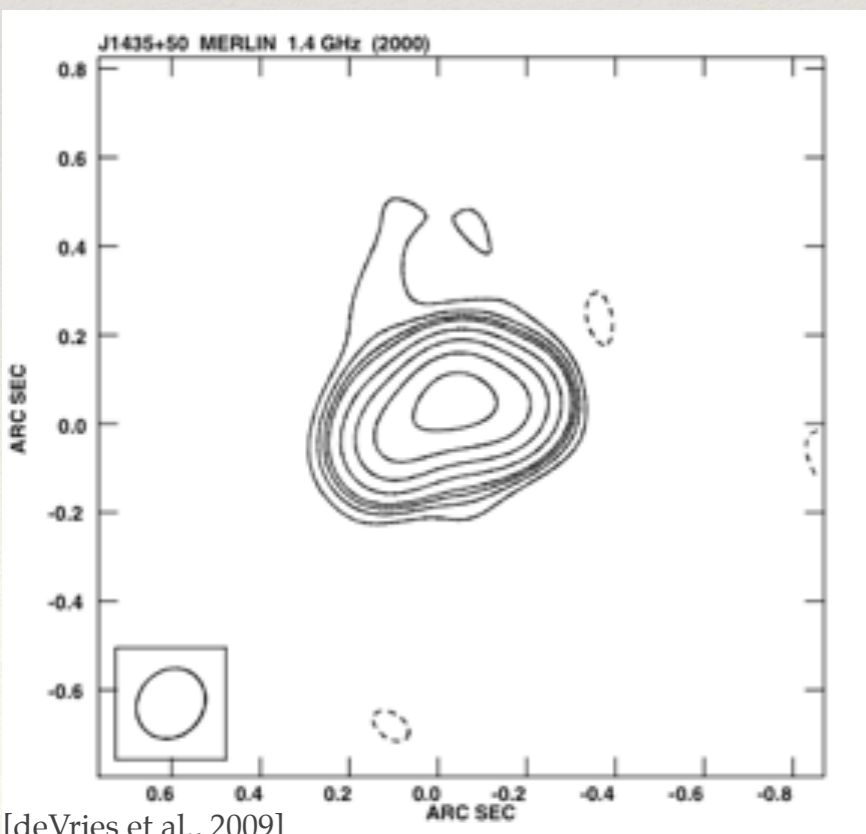
[deVries et al., 2009]

J143521.7+505123

- The width of the line and some peaks are well reproduced.
- **Promising for further development**

Summary and future developments

- **Apply the model to all sources for which we know the radio continuum:**
  - Which part of the lines are explained by disks?
    - **Are all the narrow and medium lines large scale or circum-nuclear disks?**
  - **can we explain the non-detections?**
    - different rotation curve?
    - different inclination of the disk w.r.t. continuum?

- Similar computing experiments [Pihlstrom, et al. 2003, Curran, et al., 2013] show compact sources should have high HI column density lines. We do not observe this. Why?