MHD simulations of colliding galaxies

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Magnetic fields on scales from kiloparsecs to kilometres:
properties and origin
Kraków, May the 18^{th}, 2010

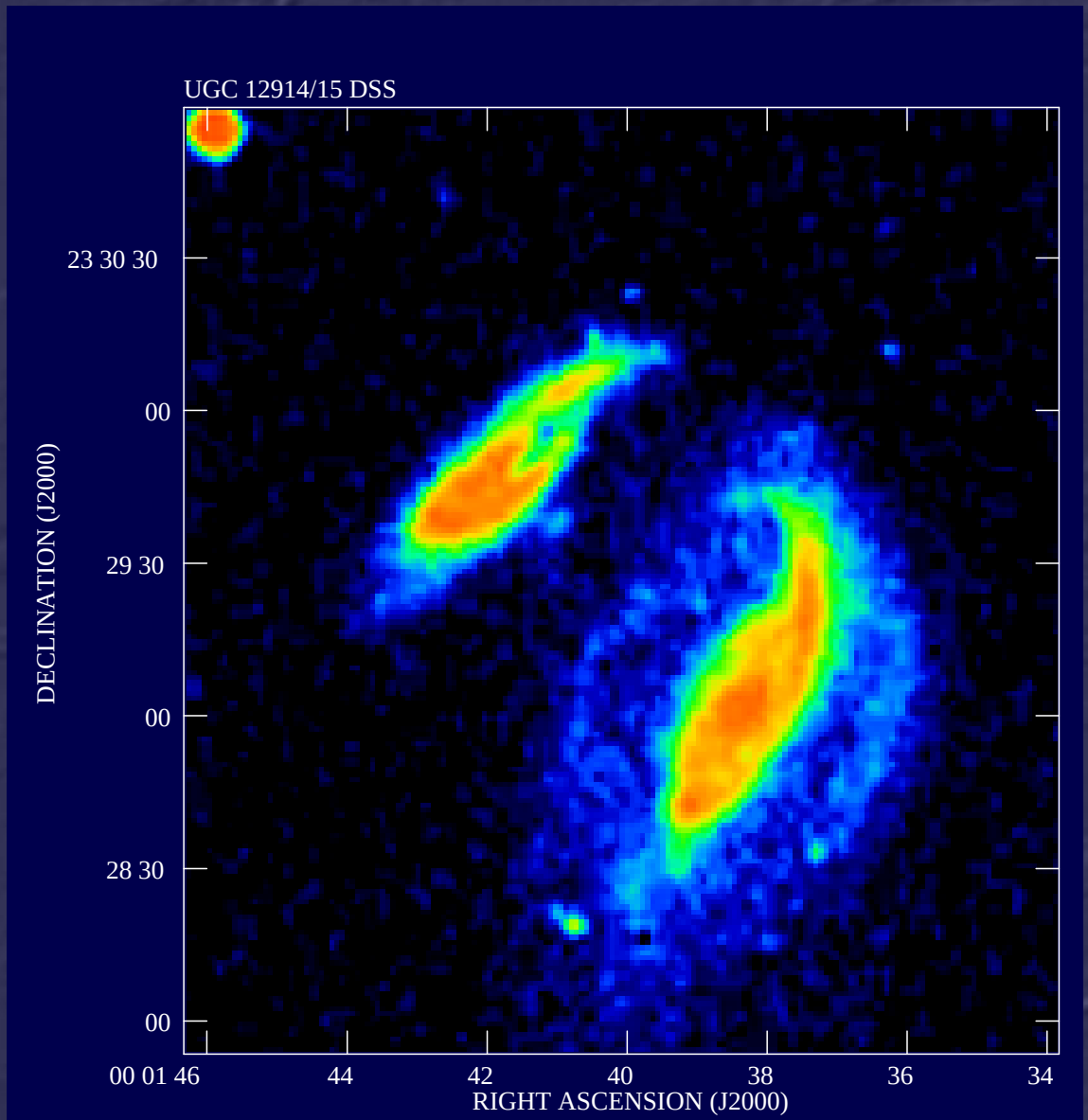
outline

- the object
- the model
- results
- summary

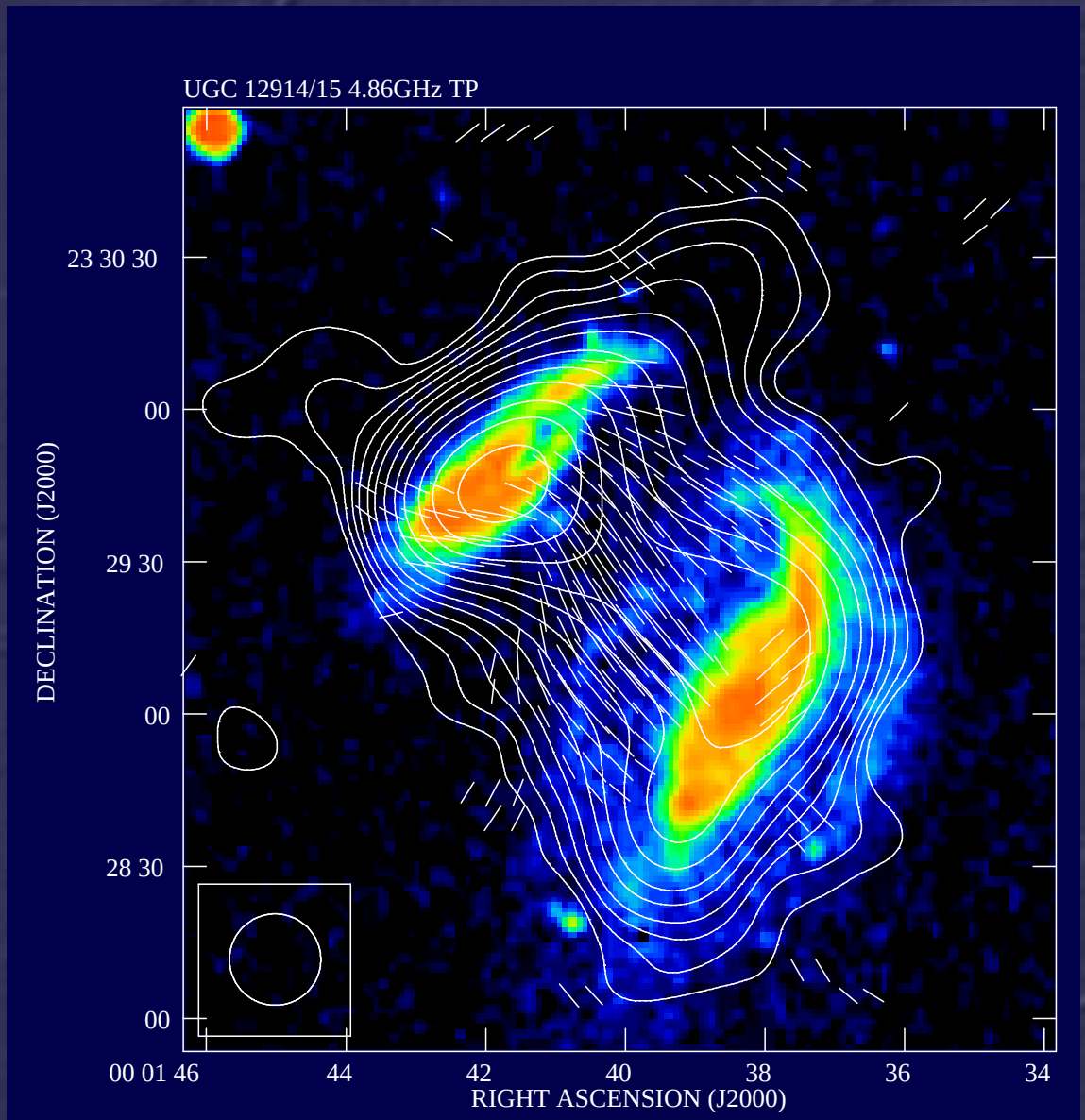
the object

- two “normal” galaxies
- counter-rotating disks
- both following FIR–radio relation
- almost head-on collision

UGC 12914/15


UGC 12914/15 DSS
23 30 30
00
29 30
00
28 30
00
DECLINATION (J2000)
00 01 46
44
42
40
38
36
34
RIGHT ASCENSION (J2000)

UGC 12914/15


UGC 12914/15 4.86GHz TP
23 30 30
00
29 30
00
28 30
00
DECLINATION (J2000)
00 01 46
44
42
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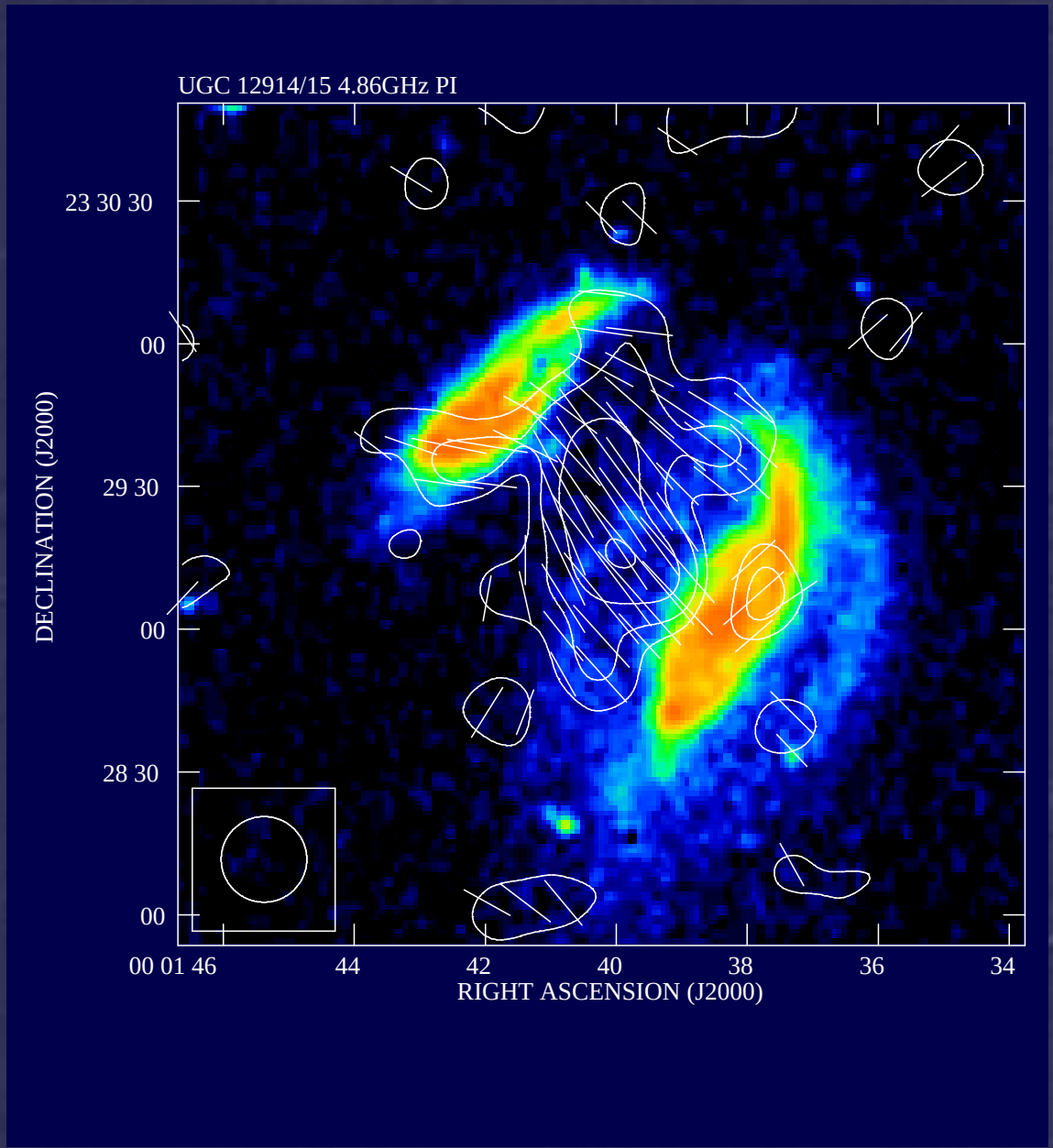
UGC 12914/15


UGC 12914/15 4.86GHz PI
23 30 30
00
29 30
00
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DECLINATION (J2000)
00 01 46
44
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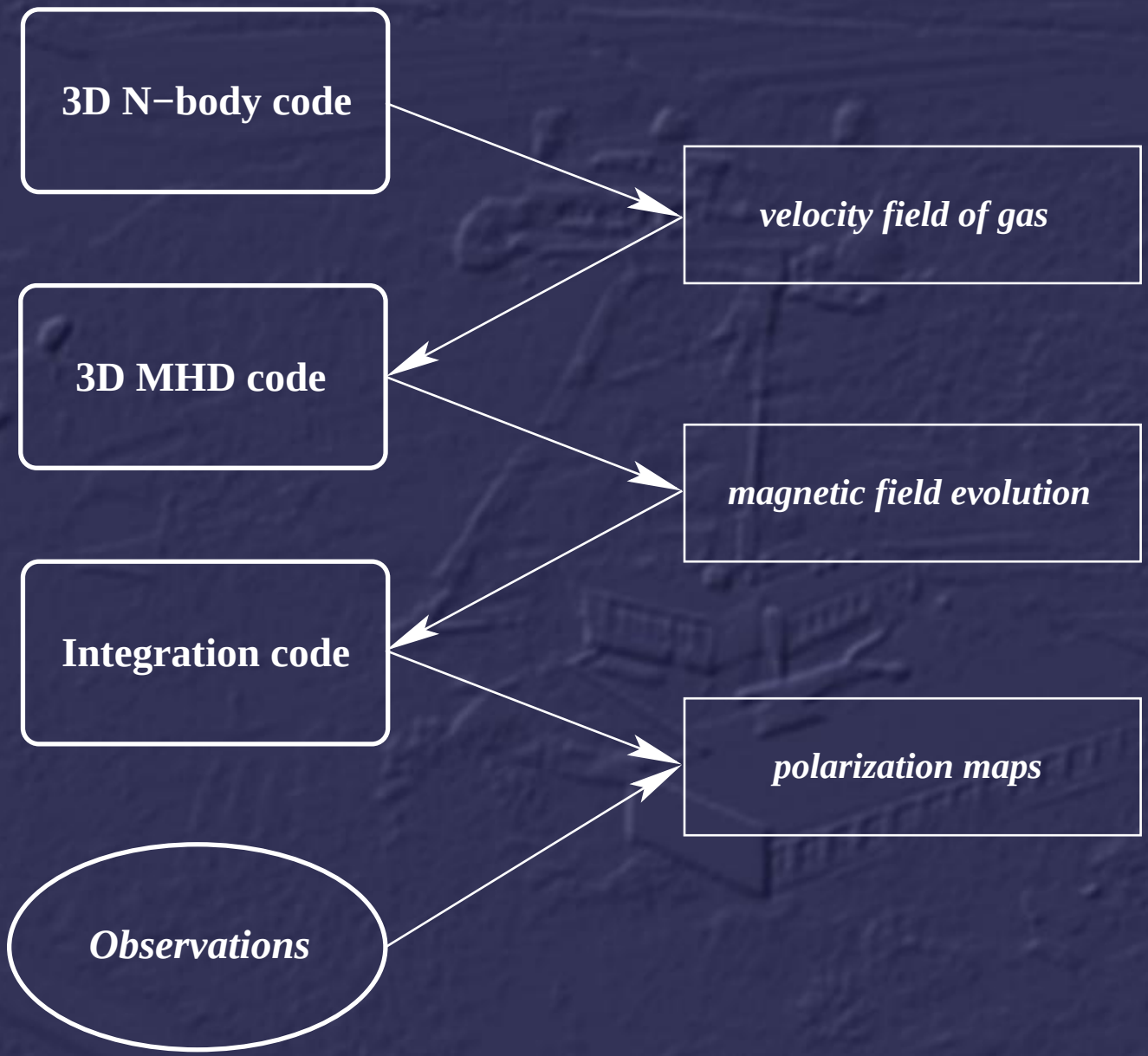
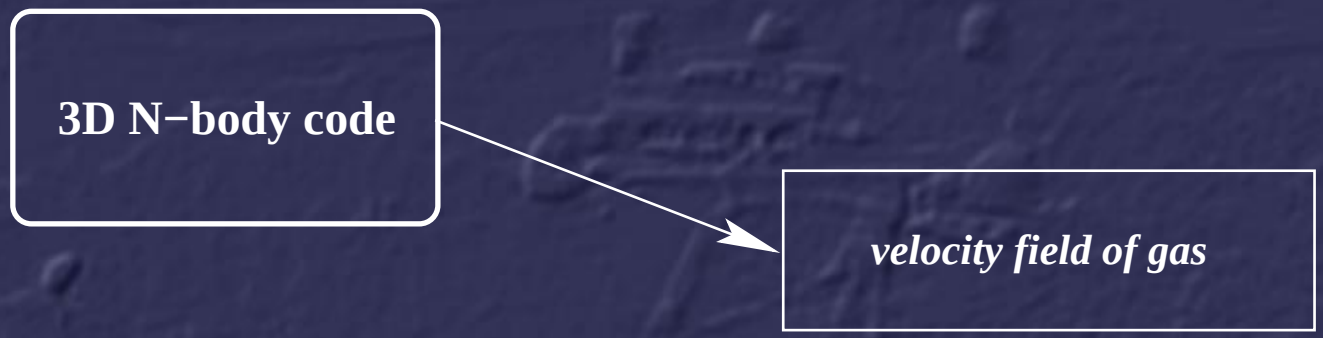
the model


3D N−body code
velocity field of gas
3D MHD code
magnetic field evolution
Integration code
polarization maps
Observations

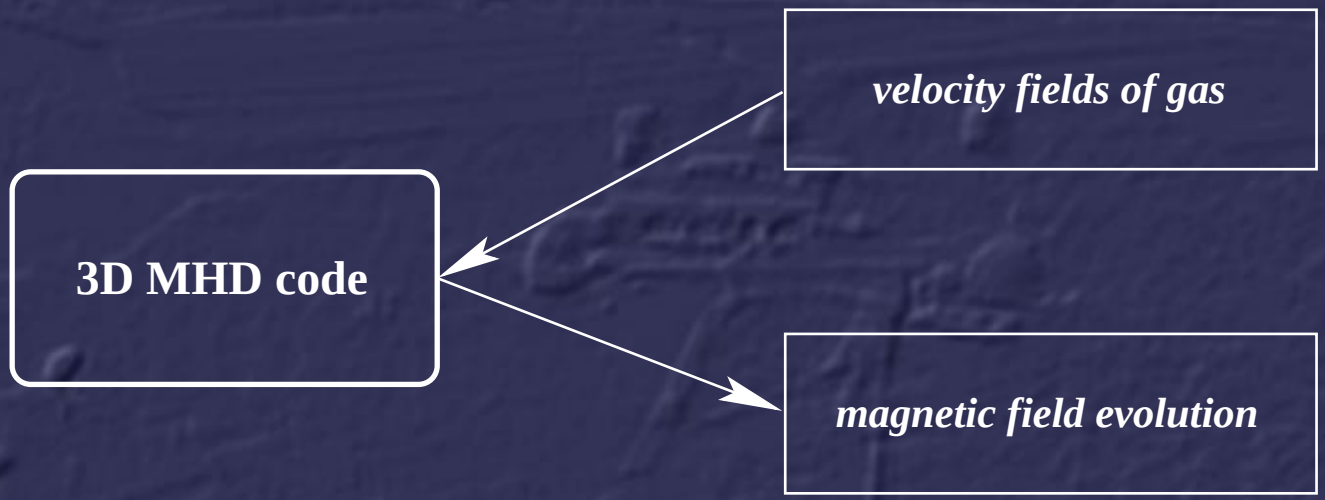
the model



N-body, sticky-particle code

- 203 840 particles:
  - 65 536 halo
  - 32 768 bulge
  - 65 536 stars
  - 40 000 gas
- gas complexes:
  - inelastic collisions
  - fragmentation
  - mass exchange
  - coalescence
  - selfgravitation

the model



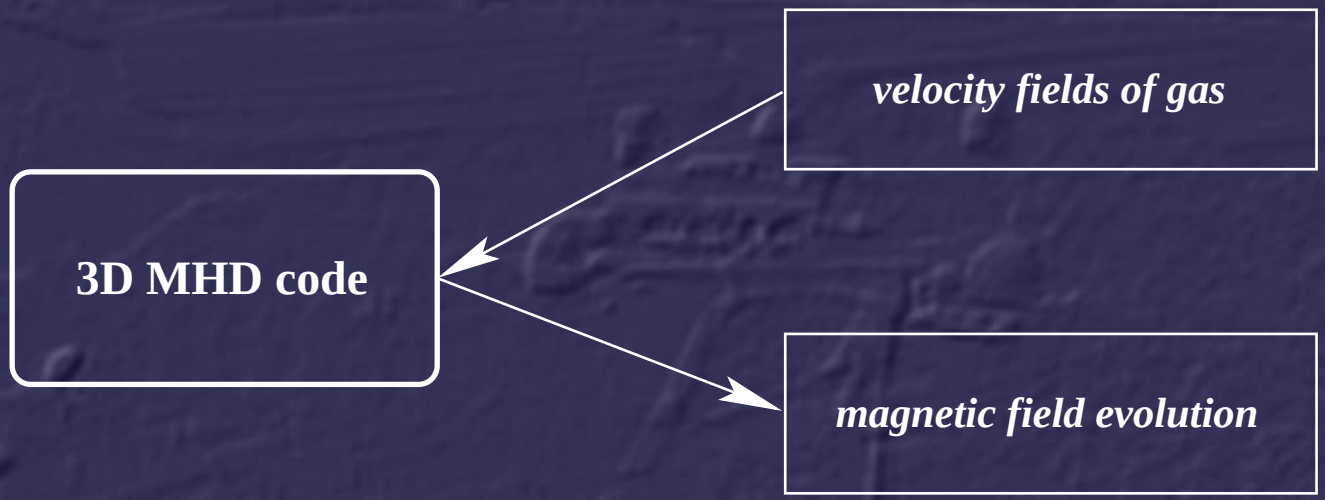
2^{nd} order TVD scheme

- cartesian grid (200×200×250)
- resolution 150 pc
- cube size 30×30×37.5 kpc
- induction (dynamo) equation

$$\frac{\partial}{\partial t}\vec{B} = \nabla \times (\vec{v} \times \vec{B}) + \nabla \times (\alpha\ \vec{B}) - \nabla \times (\eta\ \nabla \times \vec{B})$$

- outflow boundary condition

the model



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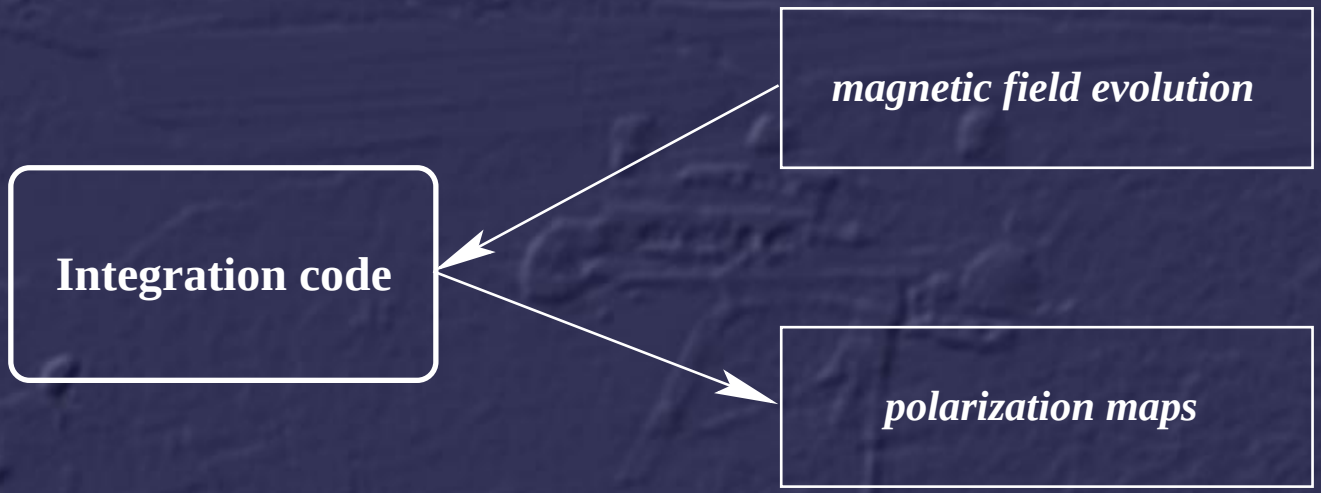


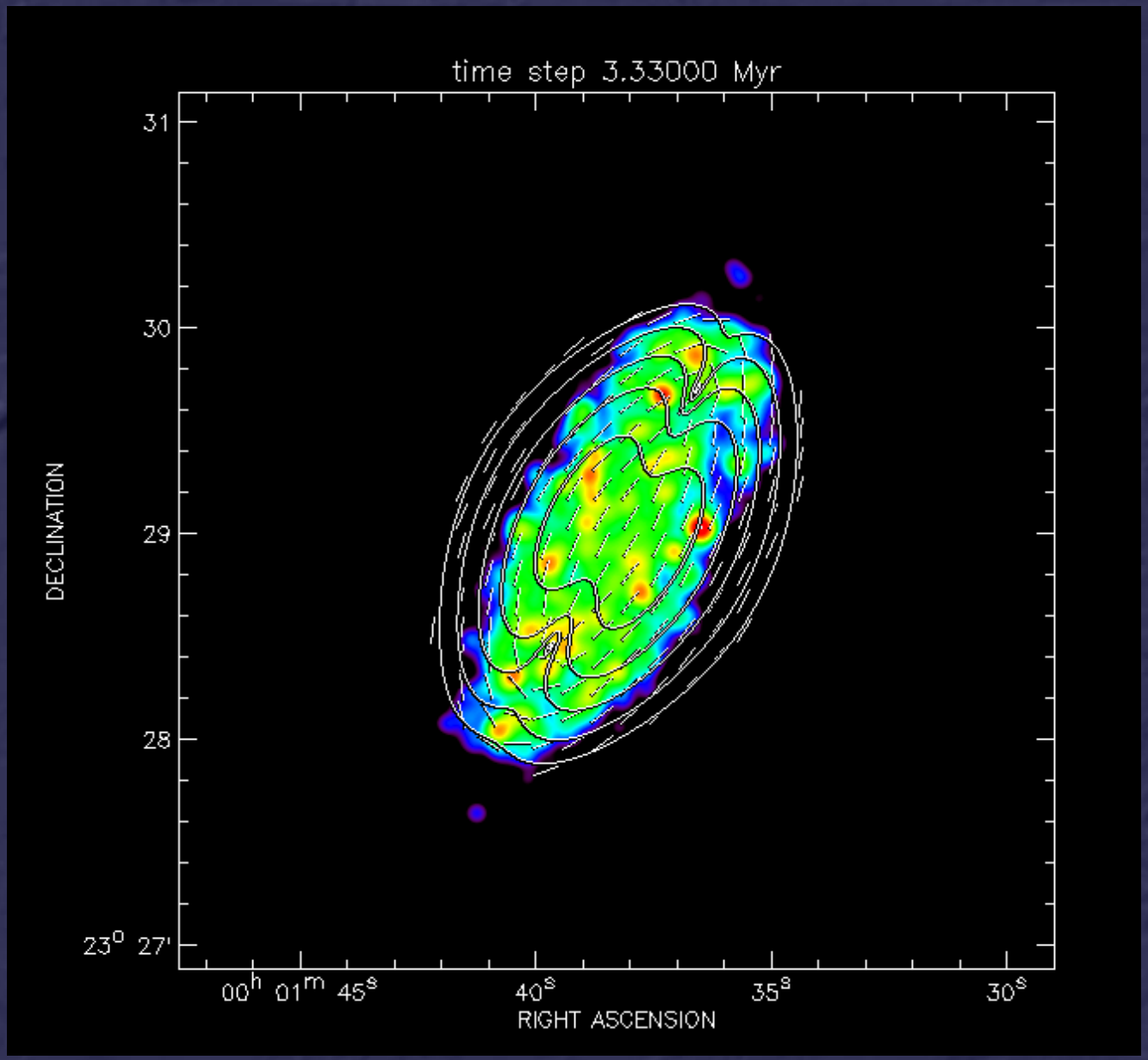
- B-cube orientation (line of sight orientation)
- integration along the line of sight

$$\frac{d}{dl}\begin{pmatrix} I \\ Q \\ U \end{pmatrix} = \begin{pmatrix} \epsilon_I & 0 & 0 \\ p\epsilon_I \cos 2\chi & \cos\Delta & -\sin\Delta \\ p\epsilon_I \sin 2\chi & \sin\Delta & \cos\Delta \end{pmatrix} \begin{pmatrix} 1 \\ Q \\ U \end{pmatrix}$$

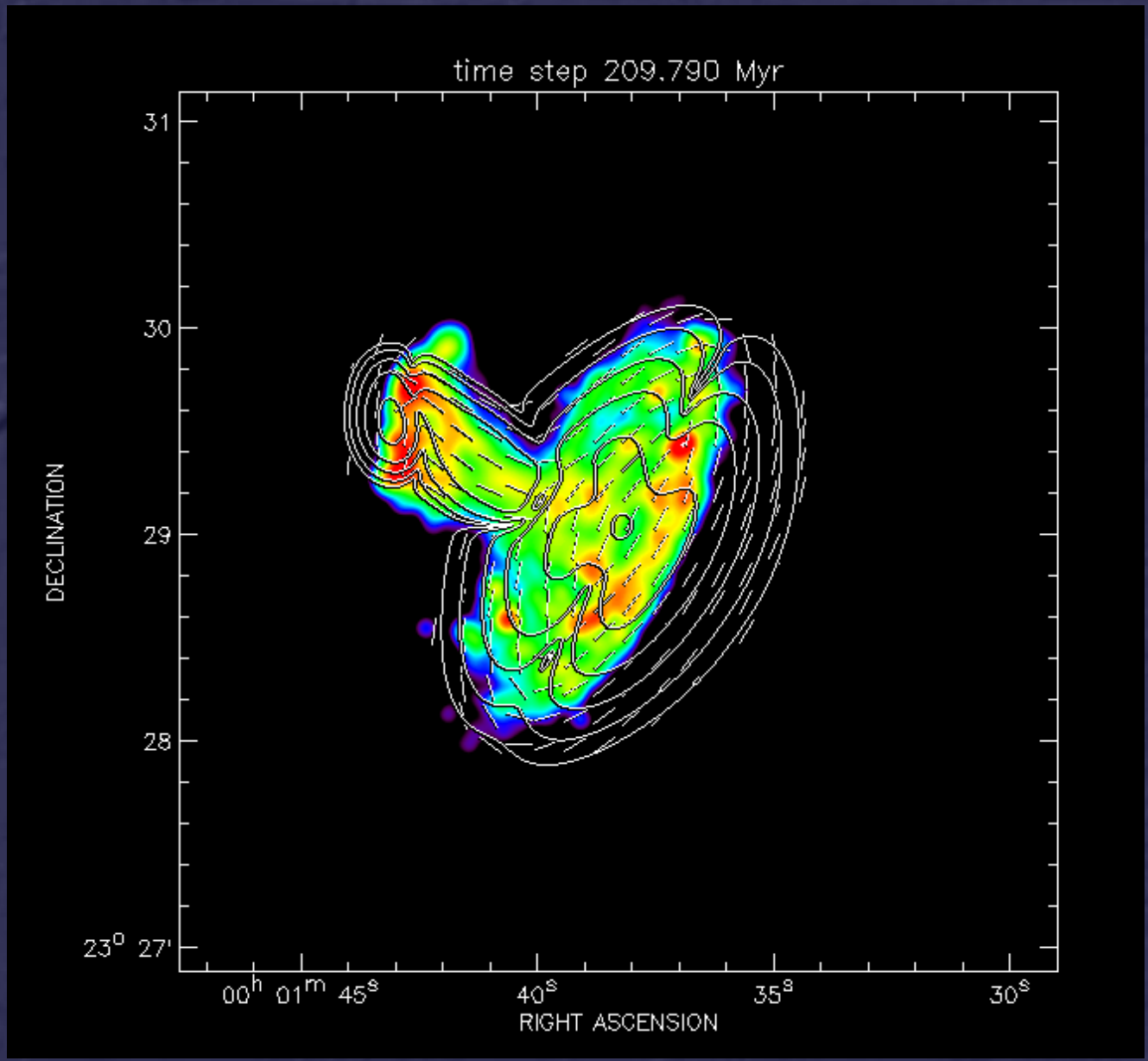
$$\epsilon_I \propto n_{rel} B_{\perp}^{(\gamma+1)/2}, \Delta \propto n_{th} B_{\parallel} dl$$

- convolution with Gaussian beam

results


time step 3.33000 Myr
31
30
29
28
DECLINATION
23° 27'
00h 01m 45s
40s
35s
30s
RIGHT ASCENSION

results


time step 209.790 Myr
31
30
29
28
23° 27'
DECLINATION
00h 01m 45s
40s
35s
30s
RIGHT ASCENSION

summary

- the code is working :)
- we traced the head-on ICM–ICM collision
- the magnetic field was pulled-out from UGC 12914, and remained in the bridge
- high regularity of magnetic field in the bridge was reproduced

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- we traced the head-on ICM–ICM collision
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still a lot to do . . .

- "magnetize" UGC 12915 before the collision
- describe unpolarized emission correctly
- back-reaction of magnetic field onto the medium – requires full MHD