The central kiloparsec of Seyfert galaxies: Integral-field spectroscopy with OASIS

Ivana Stoklasová[1], Pierre Ferruit[2], Eric Emsellem[2], Bruno Jungwiert[1], Emmanuel Pécontal[2], Sebastian F. Sánchez[3]

[1]Astronomical Institute, Academy of Sciences of the Czech Republic, Boční II 1401a, 141 31 Prague, Czech Republic; ivana.stoklasova@matfyz.cz
[2]Université de Lyon, France; Université Lyon 1, F-69007; CRAL, Observatoire de Lyon, F-69230 Saint-Genis-Laval; CNRS, UMR 5574; ENS de Lyon, France
[3]Centro Astronómico Hispano Alemán, Calar Alto, CSIC-MPG, C/Jesús Durbán Remón 2-2, 04004 Almería, Spain

Narrow-line regions of Seyfert galaxies

In the classical paradigm of active galactic nuclei (AGN), the narrow-line regions (NLRs) consist of gas extending beyond the nuclear torus out to kiloparsec distances (Fig. 1), ionised by the AGN. These scales make the NLRs suitable for spatially resolved observations of the interplay between the AGN and their host galaxies, such as the transport of gas toward the galactic nucleus, the role of gravitational instabilities, the feedback of the nucleus including outflows, and the origin of gas in the central regions of active galaxies.

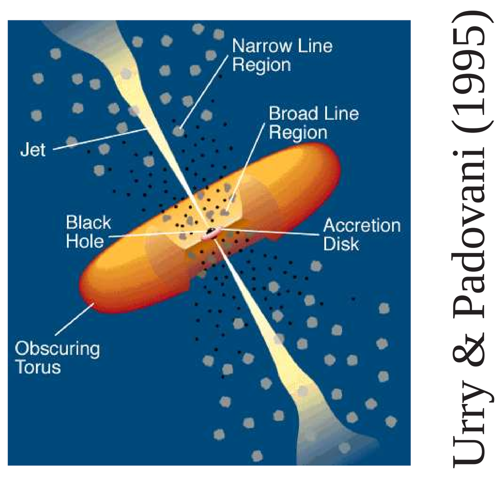

Fig. 1. Unified model of AGN. The size of the nuclear torus is on the scale of ~pc. The NLRs extend to ~ $10^2 - 10^3$ pc.

Observations and data analysis

We observed a sample of 16 nearby ($0.002 < z < 0.05$, i.e. $16 - 220$ Mpc) Seyfert galaxies with the use of the optical integral-field unit OASIS mounted at CFHT. We covered the central few kiloparsecs with the spatial sampling of $0.27'' - 0.41''$ and the spectral sampling ~ 1.9 Å. The observed spectral range contains Hα, Hβ, and the forbidden doublets of [N I], [N II], [S II], [O I], and [O III]. We derived fully 2D maps of physical quantities characterising the ionised gas, such as surface brightness, mean LOS velocities, LOS velocity dispersion, electron density, and interstellar reddening. We plot spatially resolved spectral diagnostic diagrams, which reflect the ionisation level, metallicity, temperature and density of the NLR gas. We performed stellar-population modelling with the use of the synthetic evolutionary library of Bruzual & Charlot (2003, MNRAS 344, 1000), and derived stellar velocities and the stellar-population ages. For details see Stoklasová et al. (2009, A&A 500, 1287).

Stellar populations

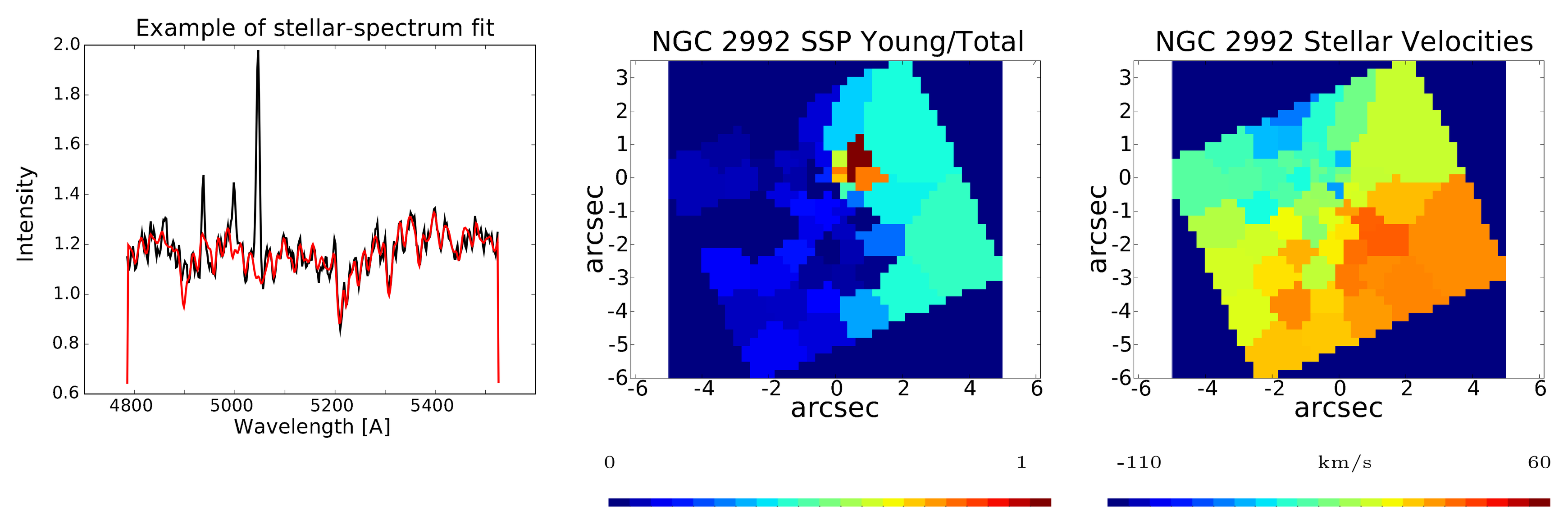

Fig. 2. Stellar-population modelling. Left: example of a stellar-population fit (red) to data (black). Middle: mass fractions of young (100 Myr) stellar populations in NGC 2992. Right: stellar velocities in NGC 2992.

S-shaped velocity fields of ionised gas

Most of the observed mean LOS velocity fields reveal departures from circular motions. 80% of our Seyfert 2 sample exhibit twisted (S-shaped) isocontours of mean LOS velocities of gas (Fig. 3), which do not have counterparts in the stellar velocities that we measure. In general, these are signatures of motion in a non-axisymmetric potential (spiral, bar, warp), or outflows from the galactic nucleus.

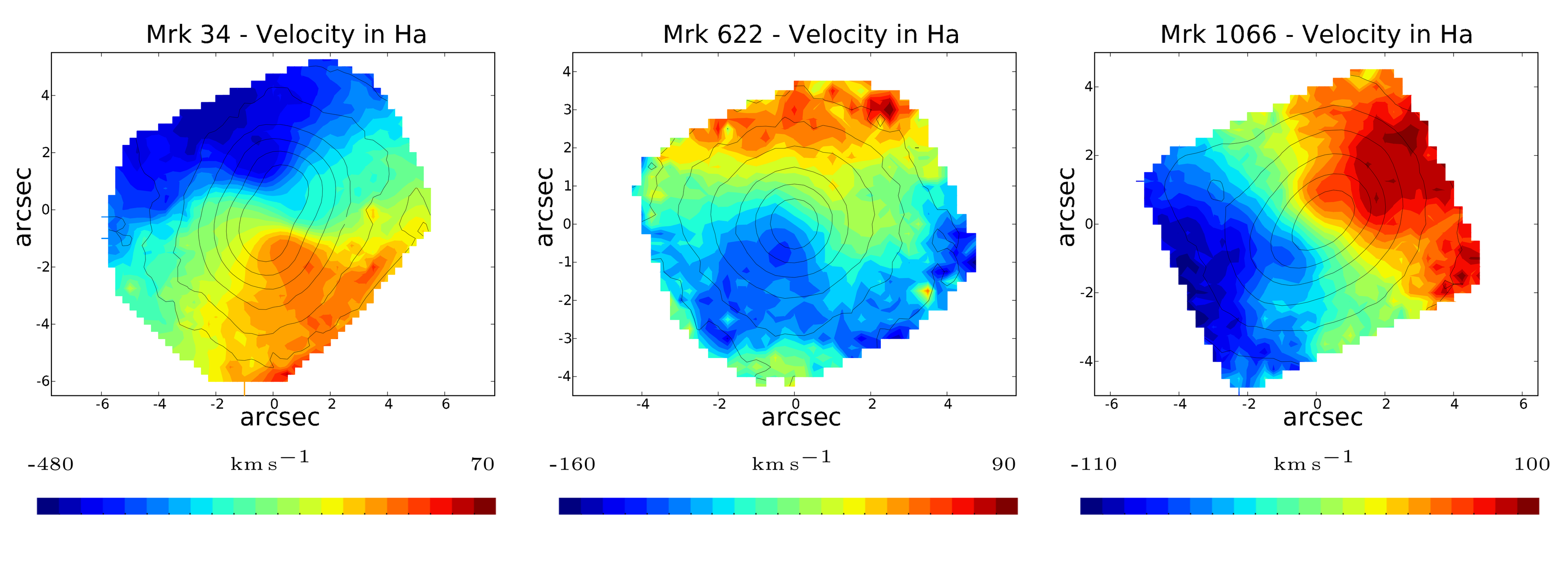

Fig. 3. S-shaped isocontours of mean LOS velocities. North is up, east to the left. The black contours represent surface brightness isocontours.

Misalignment between gas and stars

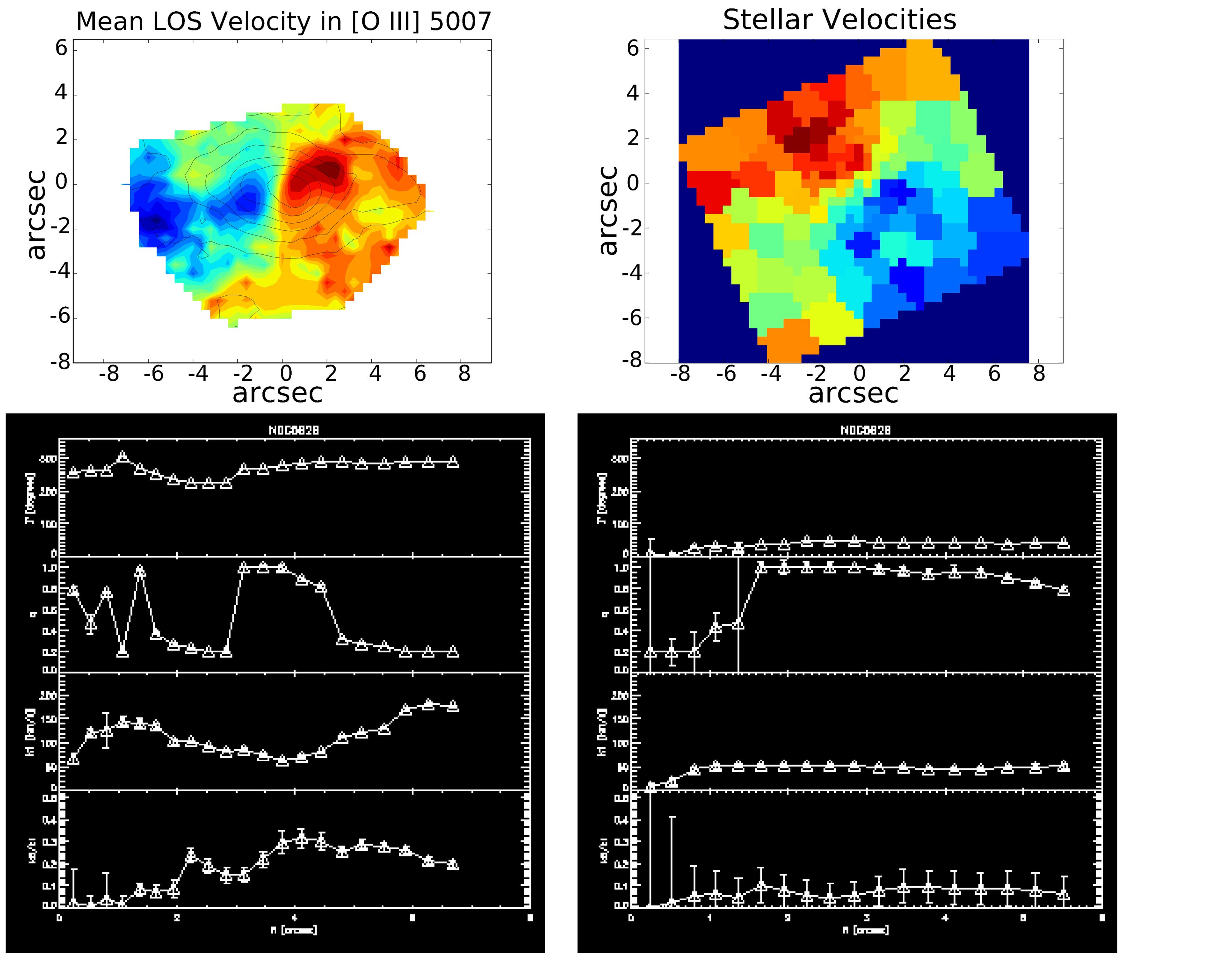

Fig. 4. Misaligned mean LOS velocity fields (top row) of gas (left) and stars (right) in NGC 5929, and their harmonic analysis using the kinemetry tool of Krajnović et al. (2006, MNRAS 366, 787). While stars show dominantly circular motion with a typical spiral-galaxy velocity curve (third curve from the top in the right black pannel) and departures from it below 10% (curve in the bottom of right black panel), the gas motions cannot be easily associated with circular rotation along an axis misaligned with the stars: the kinemetric analysis shows an unusual best-fit circular velocity profile and departures from it as large as 40% (third and fourth row of the left black pannel, respectively).

Outflow in NGC 4051

NGC 4051 has been suspected to have an outflow in [O III] lines. We trace its 2D properties with spatial resolution of 50 pc (Fig. 5), in surface brightness and in kinematics. The outflow reaches projected velocities of ~ 550 km s^{-1} and is approximately parallel to the radio jet. It is not present in low-ionisation lines. Infrared data for NGC 4051 were interpreted as an inflow by Riffel et al. (2008, MNRAS 385, 1129), and therefore detailed modelling is necessary.

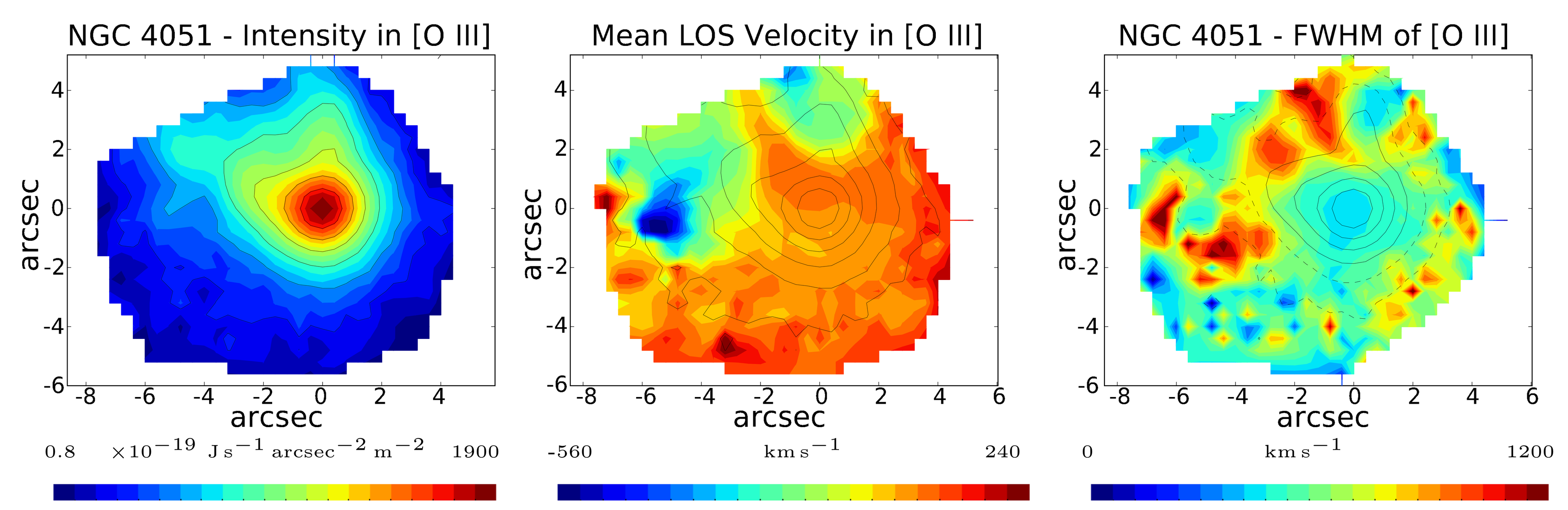

Fig. 5. NGC 4051. Outflow in NGC 4051 – map of surface brightness (left), mean LOS velocity, and LOS vel. dispersion (right) in [O III].

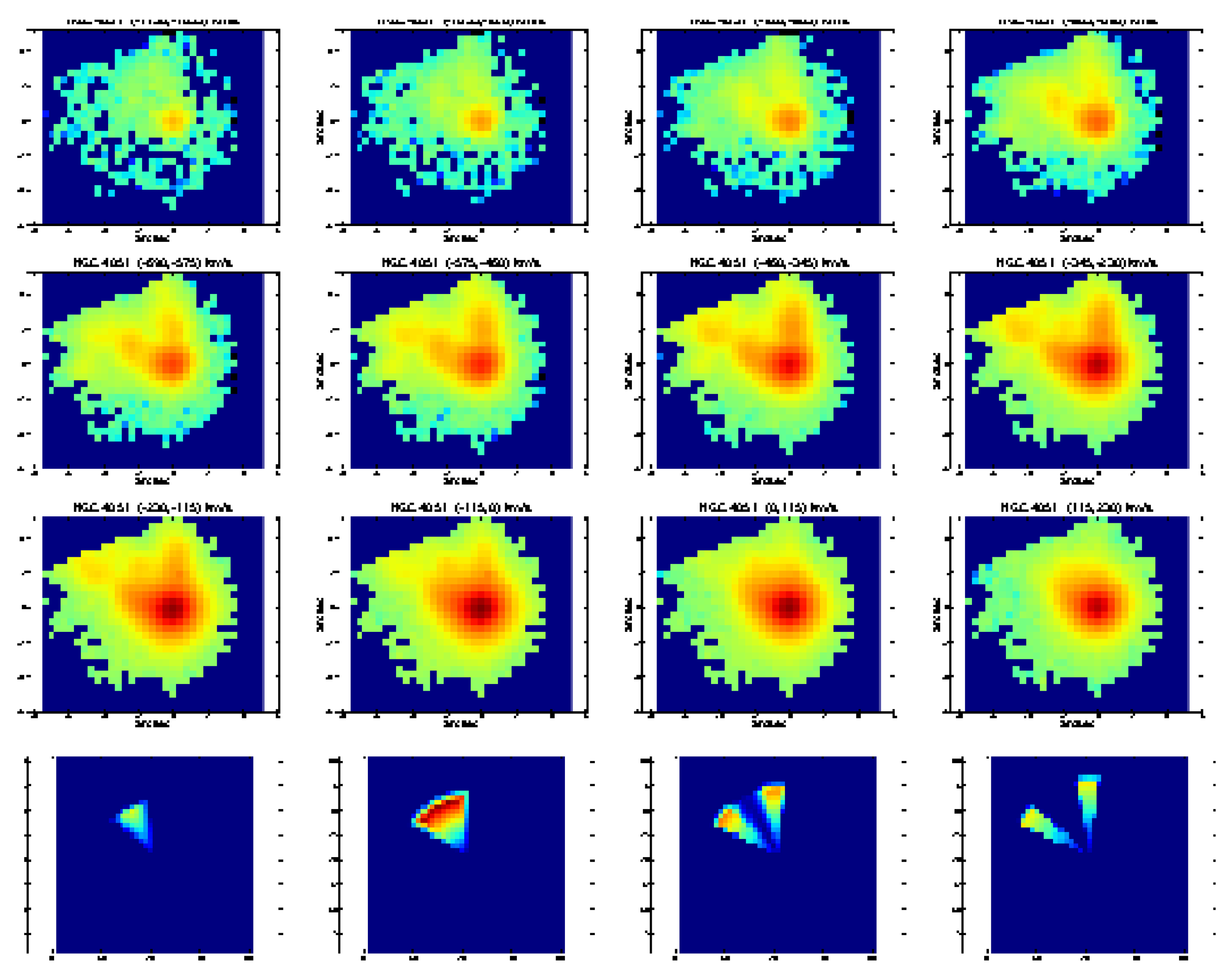

Fig. 6. NGC 4051 – velocity channel maps, and their analytic model as an outflow along a hollow cone (bottom row).

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