

APPENDIX

Appendix

This appendix consists of a compilation of Figures with simulation results from the galaxy sample discussed in Chapter 5 and Chapter 6. For the five galaxies NGC 3810, NGC 3893, NGC 4254, NGC 5676 and NGC 6643 tables are provided, listing the results from the least squares comparison between the measured and simulated kinematics. Furthermore it includes figures presenting the gas density match for the range of modelled pattern speeds and figures, comparing the measured and simulated velocity fields for the best fitting pattern speed along all of the observed position angles of the spectrograph.

A NGC 3810

Table A.1 χ^2/N of the comparison between observed and simulated kinematics for NGC 3810. $N = 971$ data points. The errors refer to 1σ χ^2/N -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]							
	3.15	3.43	5.04	6.14	6.45	7.00	7.79	
20	0.678	0.807	0.821	0.817	0.820	0.819	0.747	χ^2/N
	0.010	0.049	0.009	0.006	0.008	0.014	0.008	$\pm (1\sigma)$
45	0.771	0.909	1.534	3.357	3.212	1.595	—	χ^2/N
	0.005	0.011	0.125	0.857	1.267	0.159	—	$\pm (1\sigma)$
60	0.872	1.093	1.493	3.161	3.780	4.882	3.270	χ^2/N
	0.019	0.039	0.060	0.179	0.554	1.494	1.120	$\pm (1\sigma)$
85	1.165	(1.420)	2.217	3.248	3.404	2.857	—	χ^2/N
	0.035	(0.235)	0.139	0.634	0.644	0.396	—	$\pm (1\sigma)$
100	1.411	2.128	3.286	3.867	4.047	2.476	—	χ^2/N
	0.264	0.450	0.362	0.873	0.973	0.115	—	$\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

Table A.2 $\text{median}(\chi^2)$ of the comparison between observed and simulated kinematics for NGC 3810. The errors refer to 1σ $\text{median}(\chi^2)$ -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]							
	3.15	3.43	5.04	6.14	6.45	7.00	7.79	
20	0.295	0.310	0.333	0.349	0.368	0.395	0.343	$\text{median}(\chi^2)$
	0.005	0.010	0.005	0.004	0.005	0.008	0.004	$\pm (1\sigma)$
45	0.361	0.380	0.482	0.692	0.711	0.664	—	$\text{median}(\chi^2)$
	0.009	0.007	0.018	0.099	0.106	0.029	—	$\pm (1\sigma)$
60	0.414	0.416	0.492	0.786	0.919	1.027	0.697	$\text{median}(\chi^2)$
	0.009	0.007	0.008	0.054	0.059	0.169	0.016	$\pm (1\sigma)$
85	0.423	(0.415)	0.502	0.679	0.810	0.854	—	$\text{median}(\chi^2)$
	0.011	(0.036)	0.008	0.028	0.030	0.056	—	$\pm (1\sigma)$
100	0.456	0.443	0.587	0.850	1.011	0.863	—	$\text{median}(\chi^2)$
	0.053	0.046	0.037	0.056	0.089	0.011	—	$\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

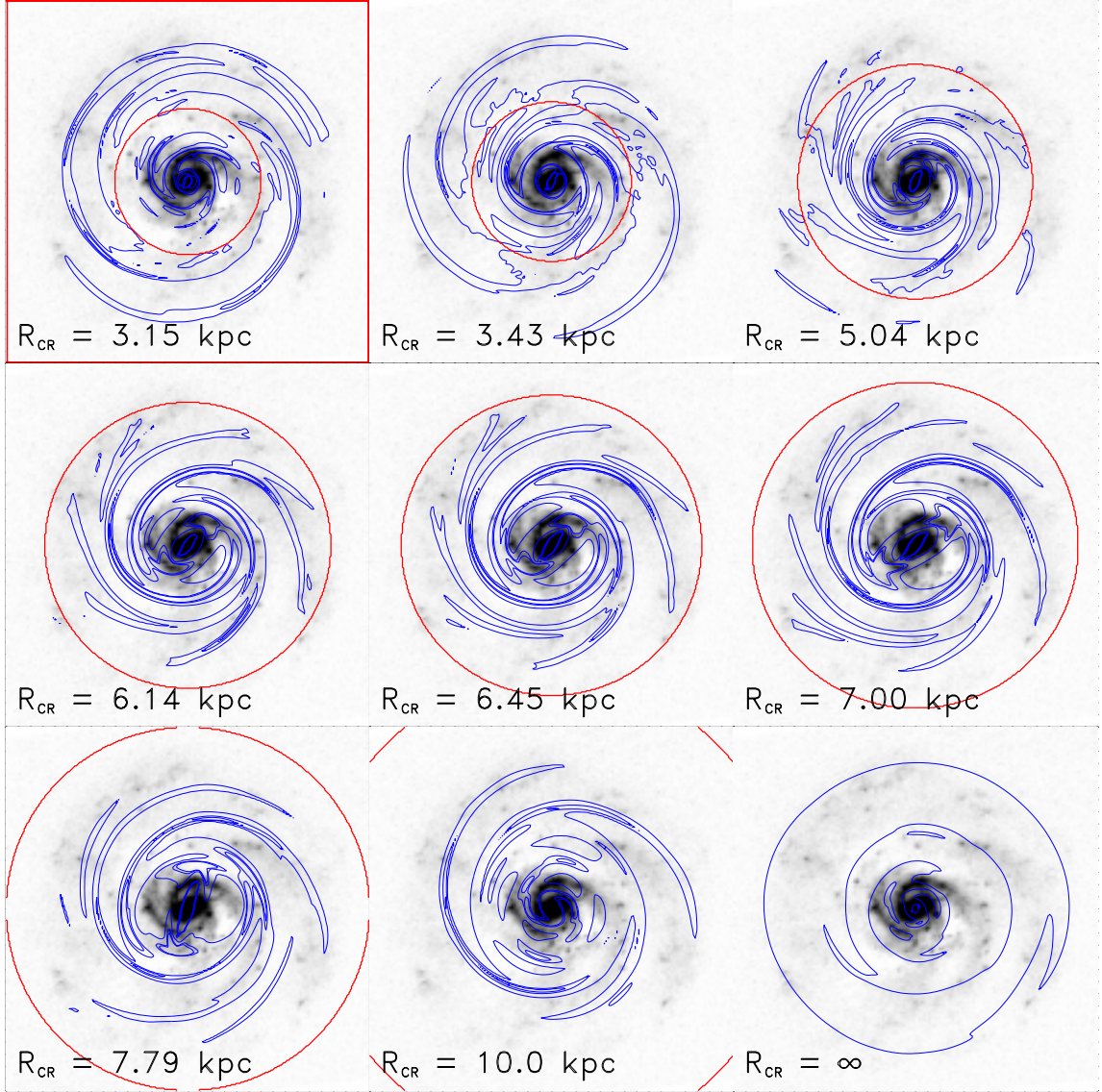
NGC 3810, $f_d = 60\%$ 

Figure A.1 Morphology comparison between the simulated gas density field (in contours) and the the observed structure of NGC 3810 (underlying, contrast enhanced image). Shown are the results for the $f_d = 60\%$ runs. Displayed is always the last time step during a simulation run (see Table 6.1). The red circle gives the location of the corotation resonance, that applies to the particular simulation. The red bordered panel displays the simulation with the best matching parameter set.

NGC 3810, $f_d = 20\%$, $R_{CR} = 3.15$ kpc

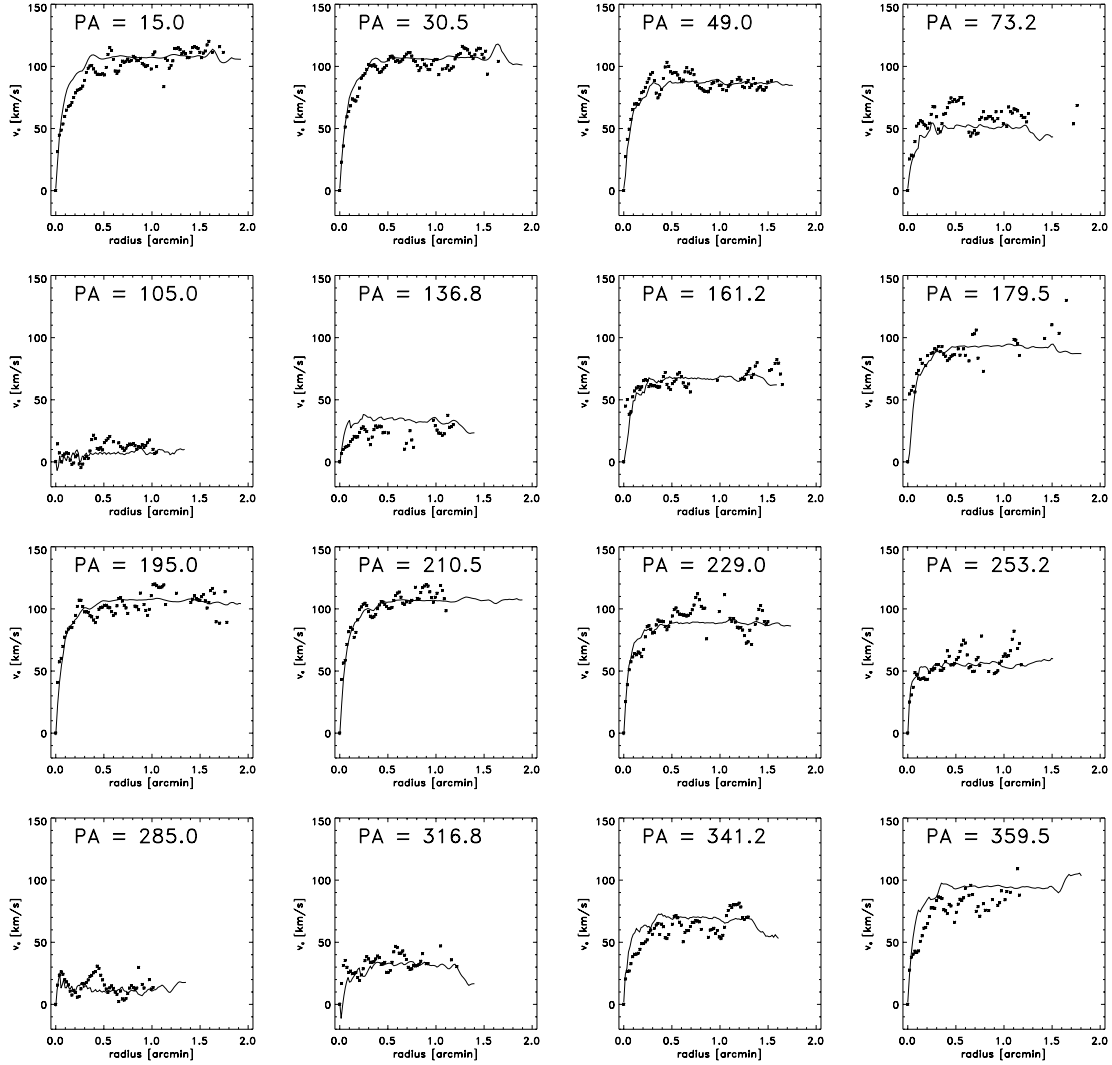


Figure A.2 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 3810 with a light disk ($f_d = 20\%$) and $R_{CR} = 3.15$ kpc.

NGC 3810, $f_d = 85\%$, $R_{CR} = 3.15$ kpc

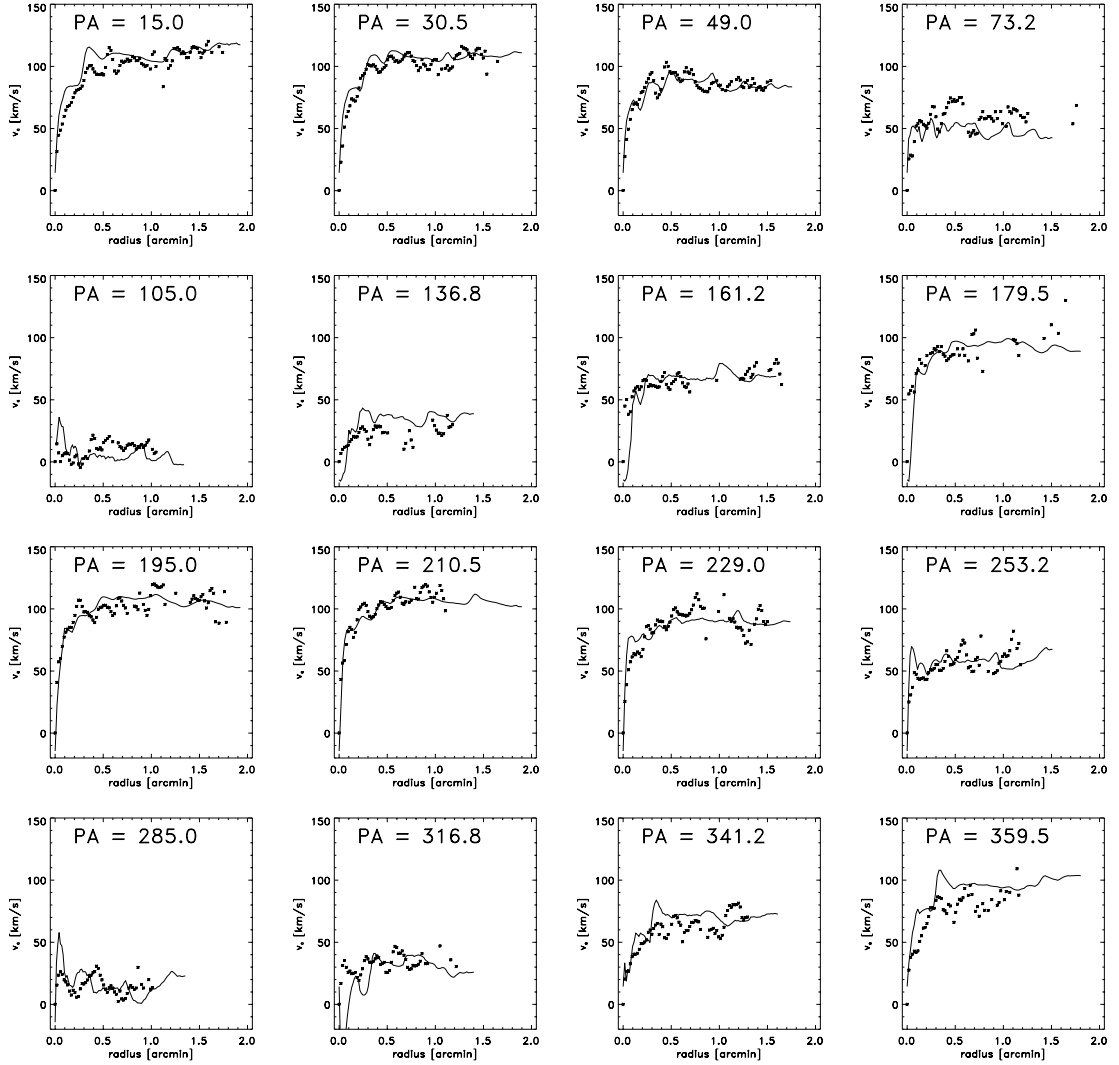


Figure A.3 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 3810 with a heavy disk ($f_d = 85\%$) and $R_{CR} = 3.15$ kpc.

NGC 3810, $f_d = 60\%$, $R_{CR} = 3.15$ kpc, selected data

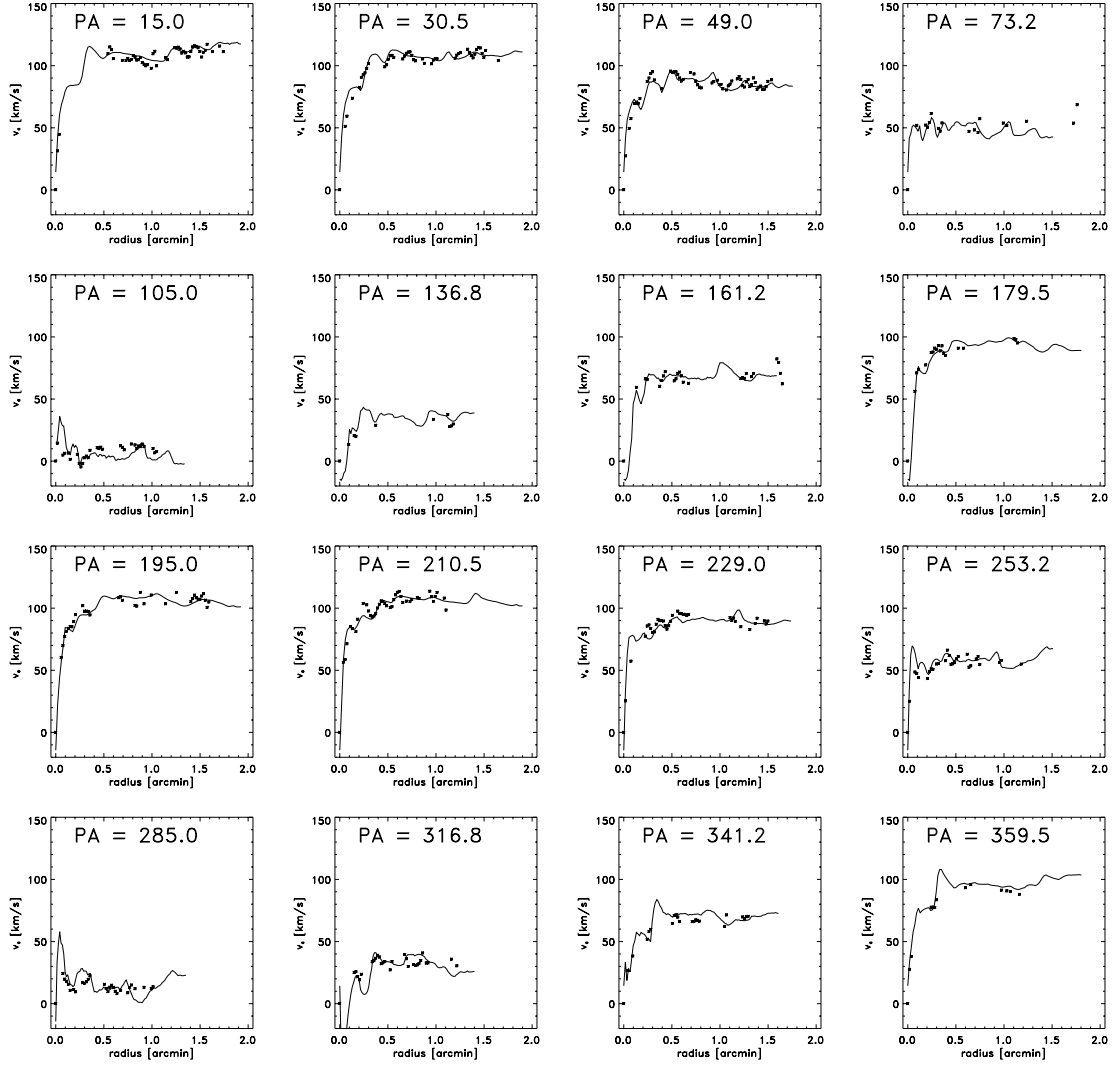


Figure A.4 Comparison of a selection of the measured kinematics (data points) and simulated (continuous line) kinematics. A selection criterion was introduced to only look at parts of the observed velocity field where the gas dynamics is mainly induced by gravity. About 49 % of the initial data points are used for comparison. See Section 4.3.2.1 for a description of the method. The results are displayed for NGC 3810 with a medium disk ($f_d = 60\%$) and $R_{CR} = 3.15$ kpc.

Table A.3 χ^2/N and median(χ^2) of the comparison between observed and simulated kinematics for NGC 3810. Considered were only $N = 474$ selected data points.

Disk fraction f_d [%]	20	45	60	85	100
χ^2/N	0.319	0.220	0.221	0.314	0.427
median(χ^2)	0.107	0.122	0.115	0.134	0.125

B NGC 3893

Table B.1 χ^2/N of the comparison between observed and simulated kinematics for NGC 3893. $N = 911$ data points. The errors refer to 1σ χ^2/N -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	3.18	5.47	6.46	7.06	7.55	8.56	9.84	∞	
20	(1.382) (0.018)	1.355 0.003	1.355 0.005	1.343 0.002	1.343 0.004	1.327 0.005	1.307 0.009	1.455 0.005	χ^2/N $\pm (1\sigma)$
45	— —	1.217 0.005	1.213 0.010	1.173 0.005	1.148 0.008	1.127 0.018	1.383 0.025	1.423 0.009	χ^2/N $\pm (1\sigma)$
60	(1.145) (0.031)	1.095 0.004	1.118 0.012	1.147 0.018	1.205 0.009	1.455 0.048	1.744 0.131	1.393 0.013	χ^2/N $\pm (1\sigma)$
85	(1.046) (0.040)	1.144 0.018	(1.114) (0.032)	1.461 0.067	1.566 0.046	1.540 0.049	1.570 0.050	1.426 0.022	χ^2/N $\pm (1\sigma)$
100	(1.053) (0.033)	1.046 0.005	1.251 0.015	1.240 0.037	1.365 0.050	1.694 0.113	1.868 0.056	1.526 0.027	χ^2/N $\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

Table B.2 median(χ^2) of the comparison between observed and simulated kinematics for NGC 3893. The errors refer to 1σ median(χ^2)-variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	3.18	5.47	6.46	7.06	7.55	8.56	9.84	∞	
20	(0.457) (0.017)	0.463 0.005	0.440 0.005	0.464 0.006	0.448 0.005	0.448 0.003	0.446 0.007	0.472 0.007	median(χ^2) $\pm (1\sigma)$
45	— —	0.431 0.005	0.430 0.008	0.431 0.013	0.414 0.006	0.368 0.008	0.478 0.009	0.467 0.008	median(χ^2) $\pm (1\sigma)$
60	(0.361) (0.013)	0.405 0.008	0.365 0.010	0.414 0.010	0.390 0.006	0.467 0.012	0.467 0.024	0.470 0.008	median(χ^2) $\pm (1\sigma)$
85	(0.346) (0.015)	0.472 0.008	(0.374) (0.015)	0.485 0.025	0.444 0.019	0.446 0.014	0.552 0.018	0.528 0.016	median(χ^2) $\pm (1\sigma)$
100	(0.366) (0.014)	0.368 0.007	0.469 0.011	0.431 0.013	0.481 0.025	0.512 0.024	0.556 0.028	0.609 0.019	median(χ^2) $\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

NGC 3893, $f_d = 100\%$

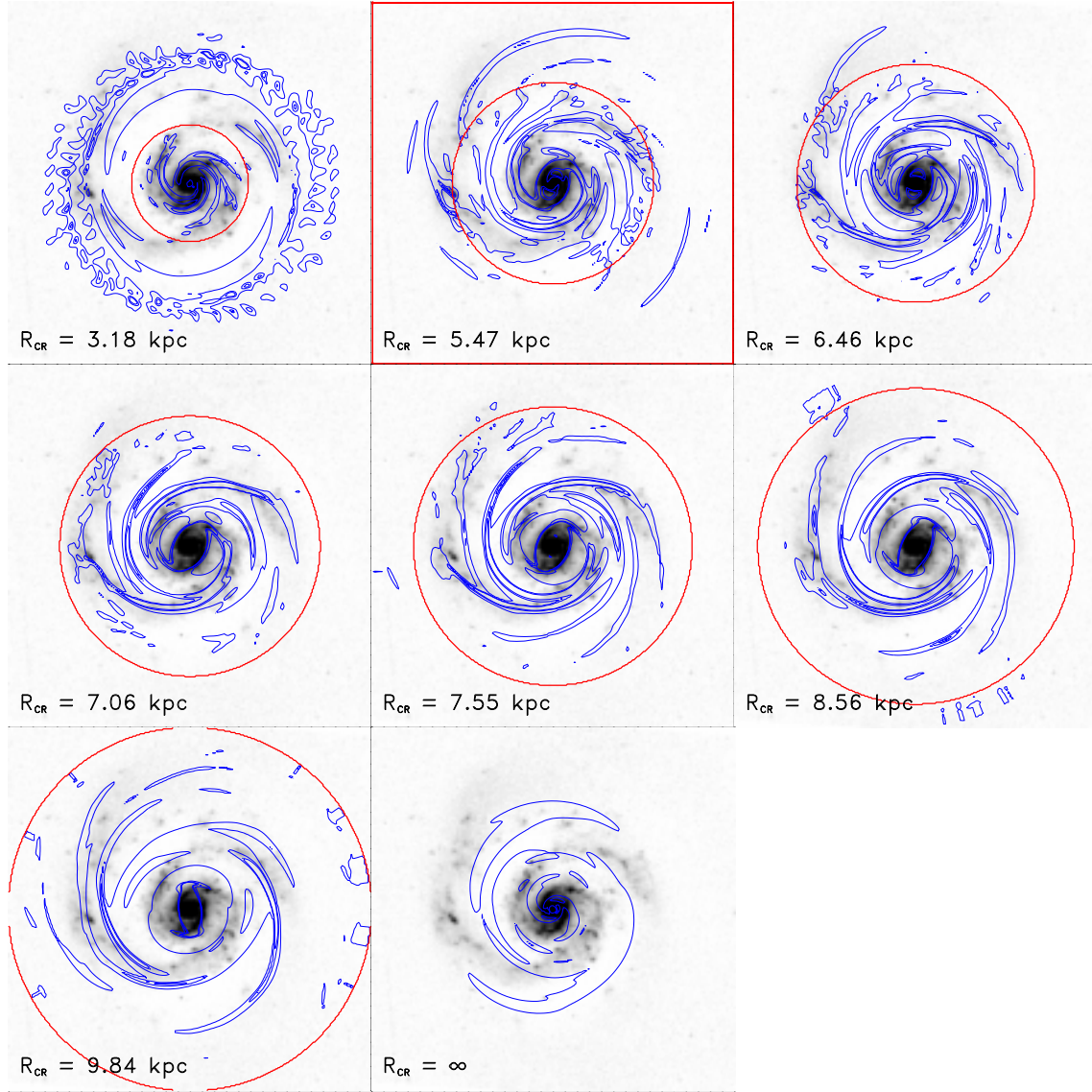


Figure B.1 Morphology comparison between the simulated gas density field (in contours) and the the observed structure of NGC 3893 (underlying, contrast enhanced image). Shown are the results for the maximal disk scenario $f_d = 100\%$. Displayed is always the last time step during a simulation run (see Table 6.2). The red circle gives the location of the corotation resonance, that applies to the particular simulation. The red bordered panel displays the simulation with the best matching parameter set.

NGC 3893, $f_d = 20\%$, $R_{CR} = 5.47$ kpc

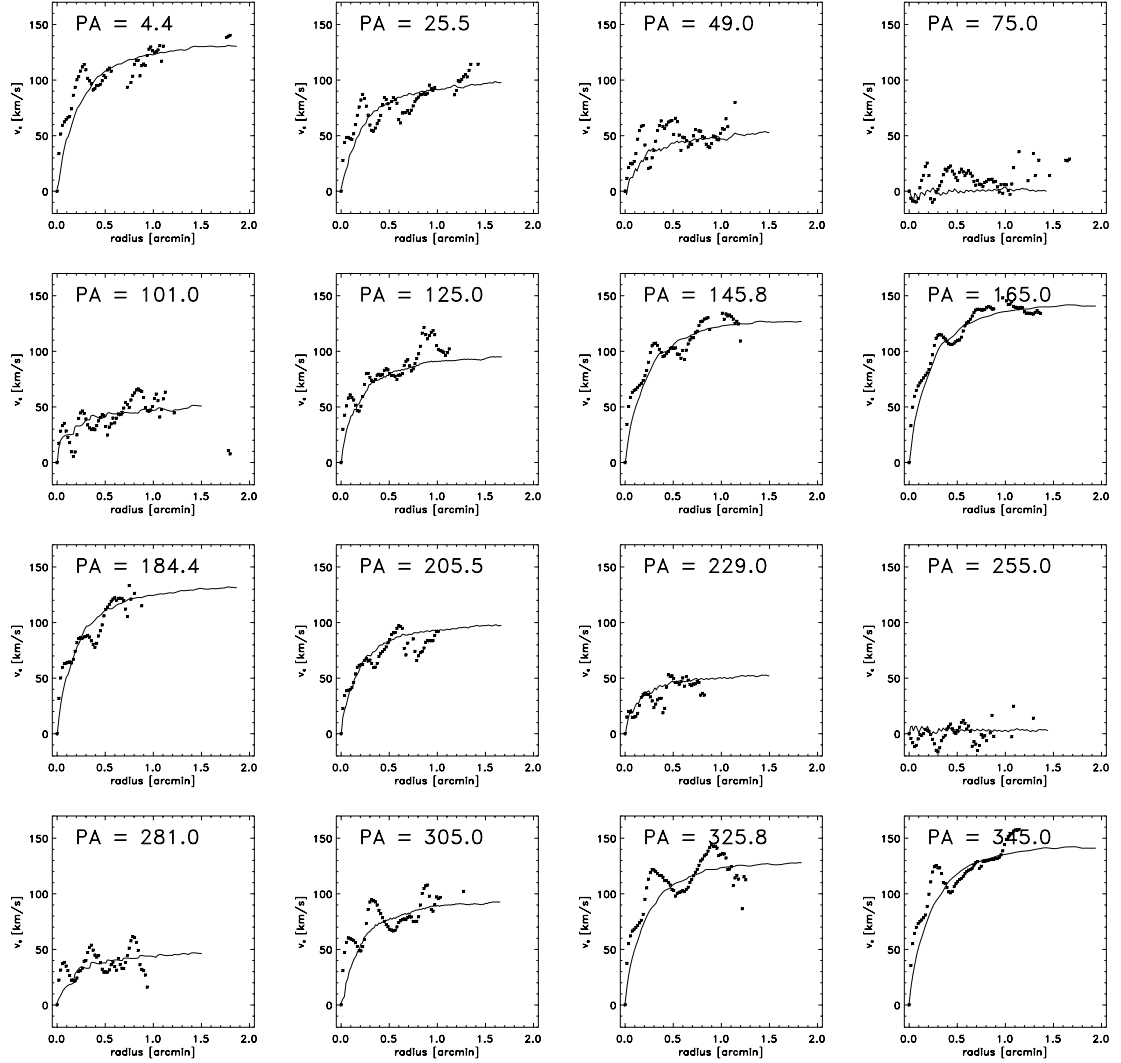


Figure B.2 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 3893 with a light disk ($f_d = 20\%$) and $R_{CR} = 5.47$ kpc.

NGC 3893, $f_d = 60\%$, $R_{CR} = 5.47$ kpc

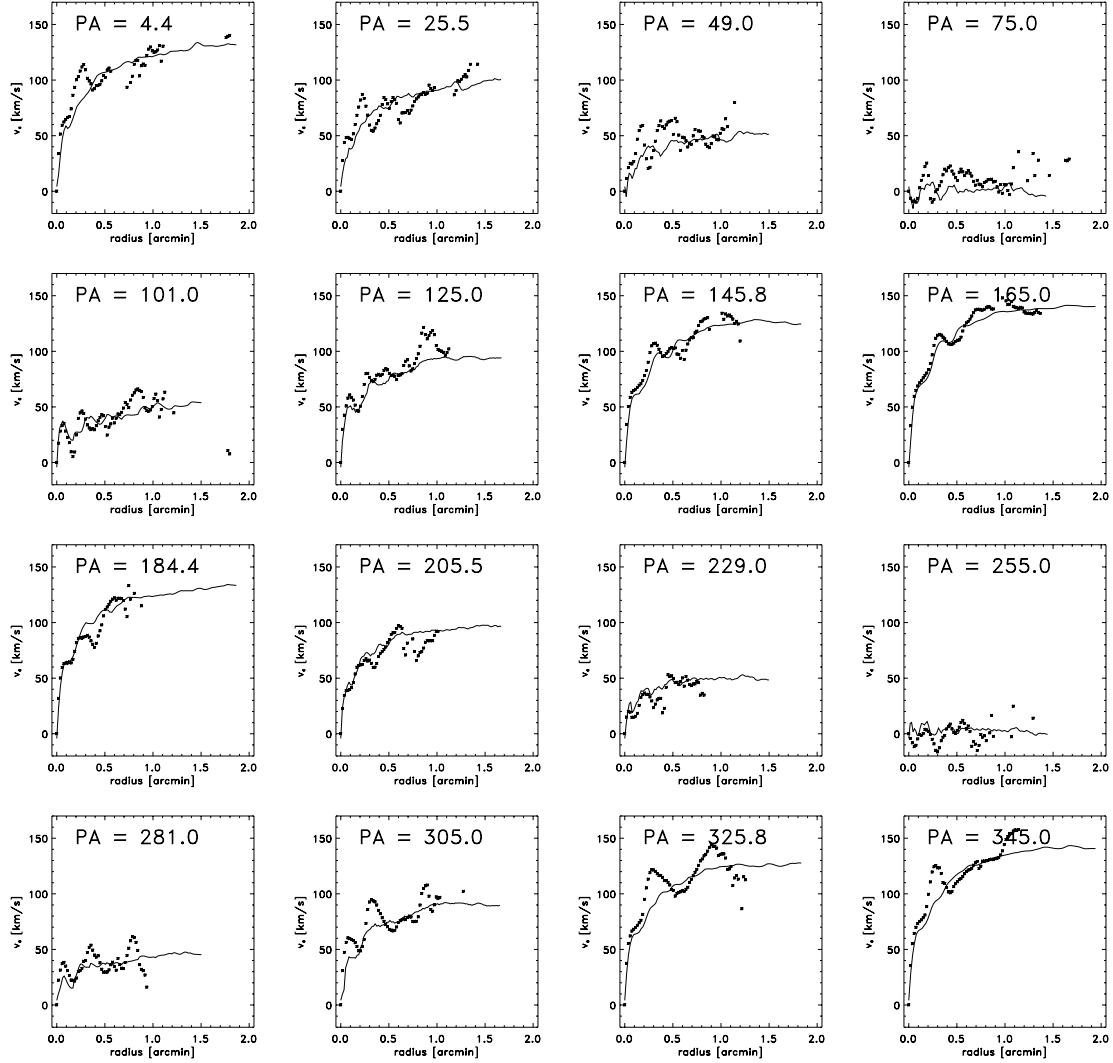


Figure B.3 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 3893 with a medium disk ($f_d = 60\%$) and $R_{CR} = 5.47$ kpc.

NGC 3893, $f_d = 100\%$, $R_{CR} = 5.47 \text{ kpc}$

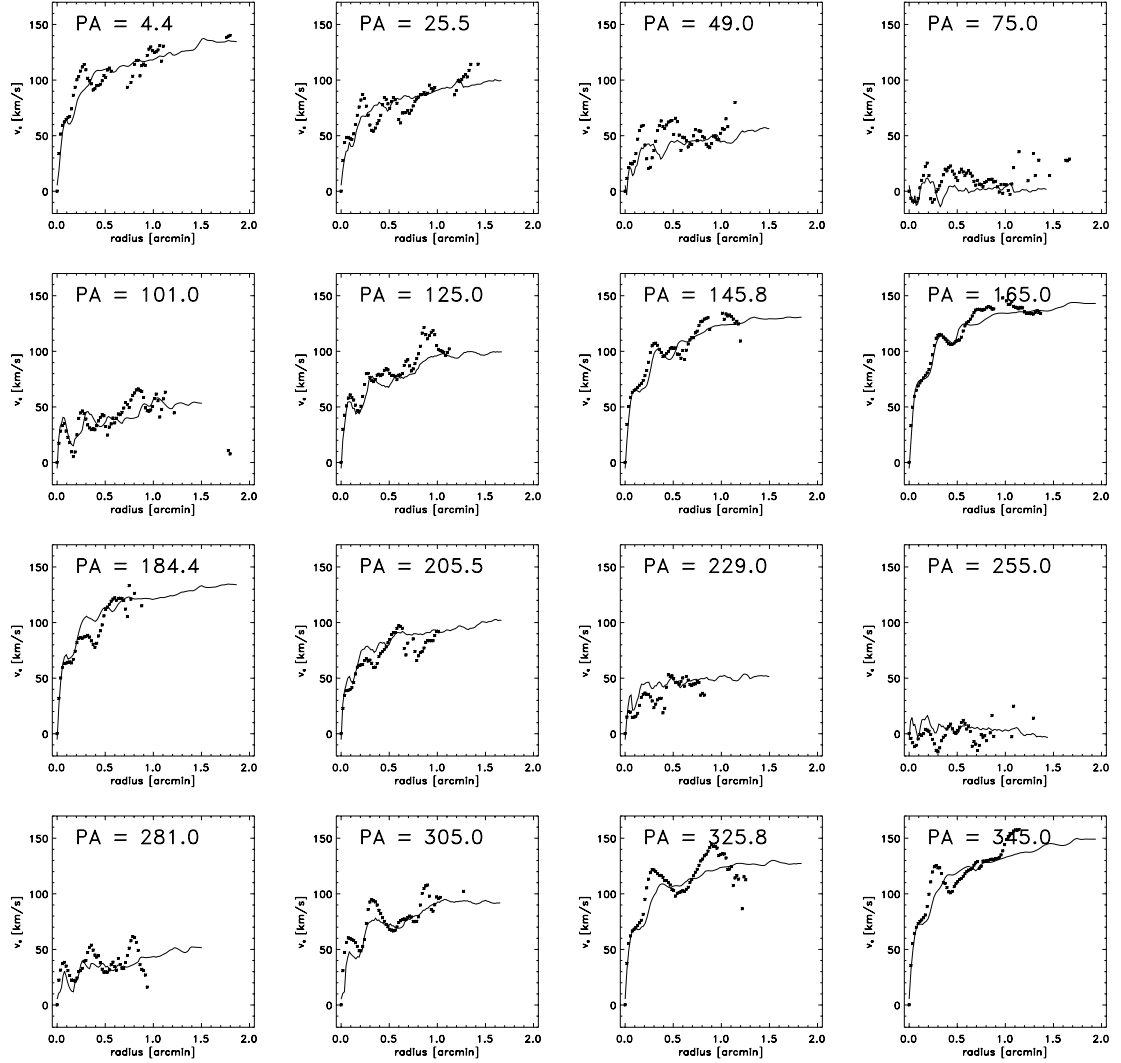


Figure B.4 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 3893 with a maximal disk ($f_d = 100\%$) and $R_{CR} = 5.47 \text{ kpc}$.

NGC 3893, $f_d = 100\%$, $R_{CR} = 5.47$ kpc, selected data

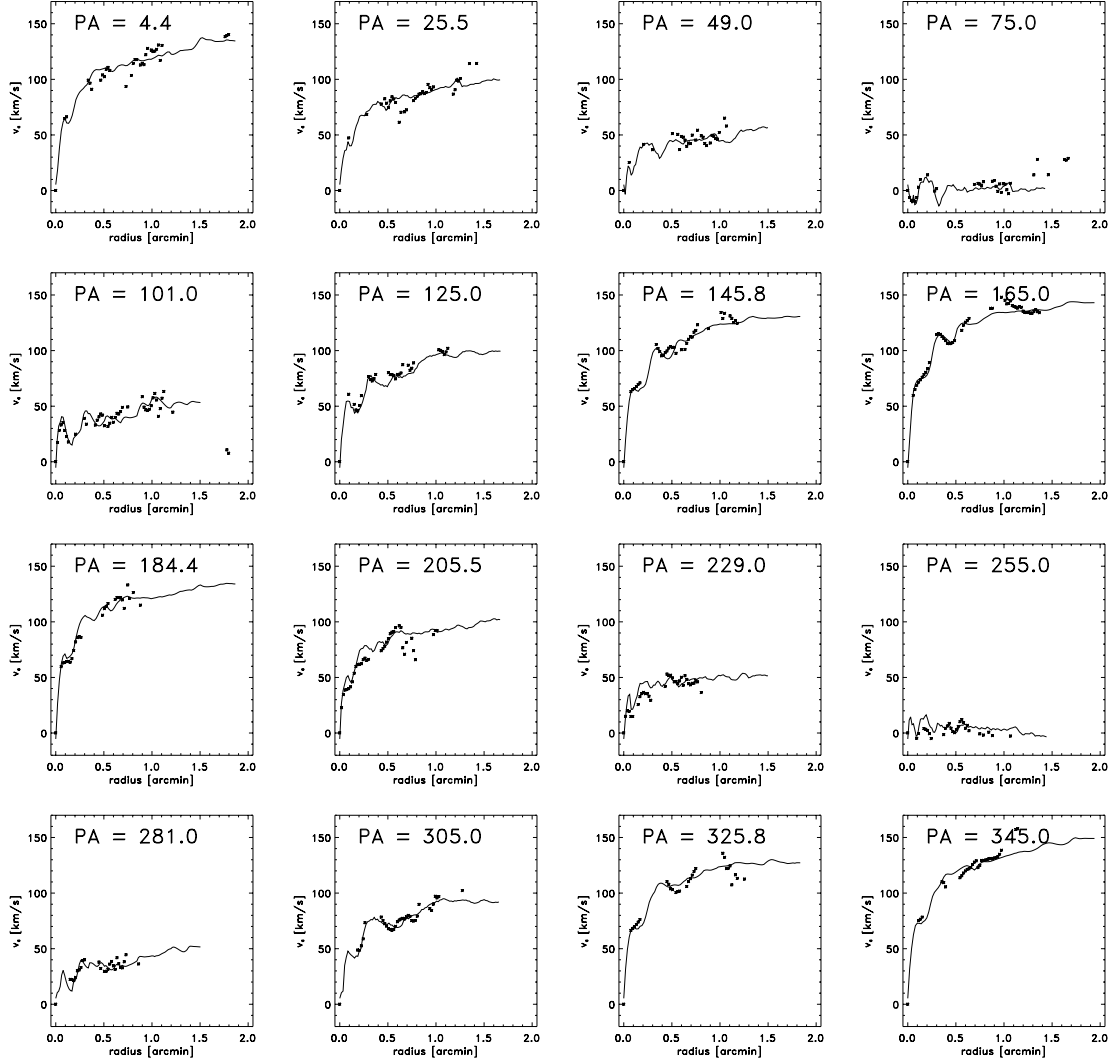


Figure B.5 Comparison of a selection of the measured kinematics (data points) and simulated (continuous line) kinematics. A selection criterion was introduced to only look at parts of the observed velocity field where the gas dynamics is mainly induced by gravity. About 60 % of the initial data points are used for comparison. See Section 4.3.2.1 for a description of the method. The results are displayed for NGC 3893 with a maximal disk ($f_d = 100\%$) and $R_{CR} = 5.47$ kpc.

Table B.3 χ^2/N and median(χ^2) of the comparison between observed and simulated kinematics for NGC 3893. Considered were only $N = 512$ selected data points.

Disk fraction f_d [%]	20	45	60	85	100
χ^2/N	0.774	0.650	0.602	0.794	0.601
median(χ^2)	0.236	0.197	0.202	0.213	0.182

C NGC 4254

For NGC 4254 the procedure was slightly different than for the other galaxies. The simulations were evaluated at the last timestep of the run without calculating a confidence limit of the χ^2 -value. It was, however, made sure that the timestep that was analyzed was representative. All runs went past the initialization phase.

Table C.1 χ^2/N of the comparison between observed and simulated kinematics for NGC 4254. $N = 1077$ data points.

f_d [%]	corotation radius R_{CR} [kpc]					timestep [Myrs]
	6.4	7.58	8.27	10.03	11.6	
20	0.831	0.847	0.845	0.832	1.078	1125.9
44.4	0.817	0.833	0.906	0.879	1.354	965.1
60	0.831	0.856	0.937	0.978	1.492	1125.9
85	0.832	0.923	1.016	1.086	—	804.4
100	1.042	1.174	1.324	1.573	—	772.3

Figures showing the gas density distributions and the gas velocity field comparison have been presented in Chapter 5, i.e. Figure 5.2 and Figure 5.3 respectively.

D NGC 5676

Table D.1 χ^2/N of the comparison between observed and simulated kinematics for NGC 5676. $N = 546$ data points. The errors refer to 1σ χ^2/N -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	7.65	8.6	9.6	10.6	11.6	12.6	13.6	14.16	
20	1.362 0.022	1.324 0.012	1.330 0.027	1.408 0.048	1.492 0.159	1.632 0.125	1.967 0.140	— —	χ^2/N $\pm (1\sigma)$
45	1.857 0.122	1.839 0.142	1.744 0.113	1.843 0.160	1.825 0.208	1.690 0.045	1.958 0.137	2.107 0.187	χ^2/N $\pm (1\sigma)$
60	(1.568) (0.040)	(1.521) (0.037)	(1.501) (0.049)	— —	1.872 0.067	2.276 0.191	2.821 0.184	3.170 0.181	χ^2/N $\pm (1\sigma)$
85	(1.865) (0.179)	1.860 0.172	1.816 0.154	(2.006) (0.209)	(2.171) (0.246)	(2.516) (0.351)	3.186 0.577	— —	χ^2/N $\pm (1\sigma)$
100	2.465 0.396	(2.067) (0.255)	(2.313) (0.337)	(2.539) (0.408)	3.067 0.585	(2.990) (0.553)	(3.473) (0.716)	(4.382) (1.021)	χ^2/N $\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

Table D.2 $\text{median}(\chi^2)$ of the comparison between observed and simulated kinematics for NGC 5676. The errors refer to 1σ $\text{median}(\chi^2)$ -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	7.65	8.6	9.6	10.6	11.6	12.6	13.6	14.16	
20	0.486 0.015	0.486 0.012	0.448 0.012	0.436 0.013	0.468 0.010	0.531 0.025	0.580 0.039	— —	$\text{median}(\chi^2)$ $\pm (1\sigma)$
45	0.721 0.048	0.706 0.041	0.633 0.038	0.633 0.045	0.650 0.065	0.650 0.022	0.728 0.016	0.817 0.027	$\text{median}(\chi^2)$ $\pm (1\sigma)$
60	(0.608) (0.021)	(0.592) (0.018)	(0.572) (0.023)	— —	0.534 0.029	0.656 0.042	0.726 0.042	0.866 0.033	$\text{median}(\chi^2)$ $\pm (1\sigma)$
85	(0.597) (0.029)	0.524 0.029	0.480 0.032	(0.419) (0.052)	(0.375) (0.059)	(0.572) (0.043)	0.740 0.067	— —	$\text{median}(\chi^2)$ $\pm (1\sigma)$
100	0.787 0.104	(0.661) (0.065)	(0.578) (0.040)	(0.606) (0.060)	0.740 0.096	(0.792) (0.096)	(0.822) (0.133)	(1.017) (0.189)	$\text{median}(\chi^2)$ $\pm (1\sigma)$

Note: Values in brackets refer to runs that terminated before ending the initialization phase of the simulation.

NGC 5676, $f_d = 45\%$

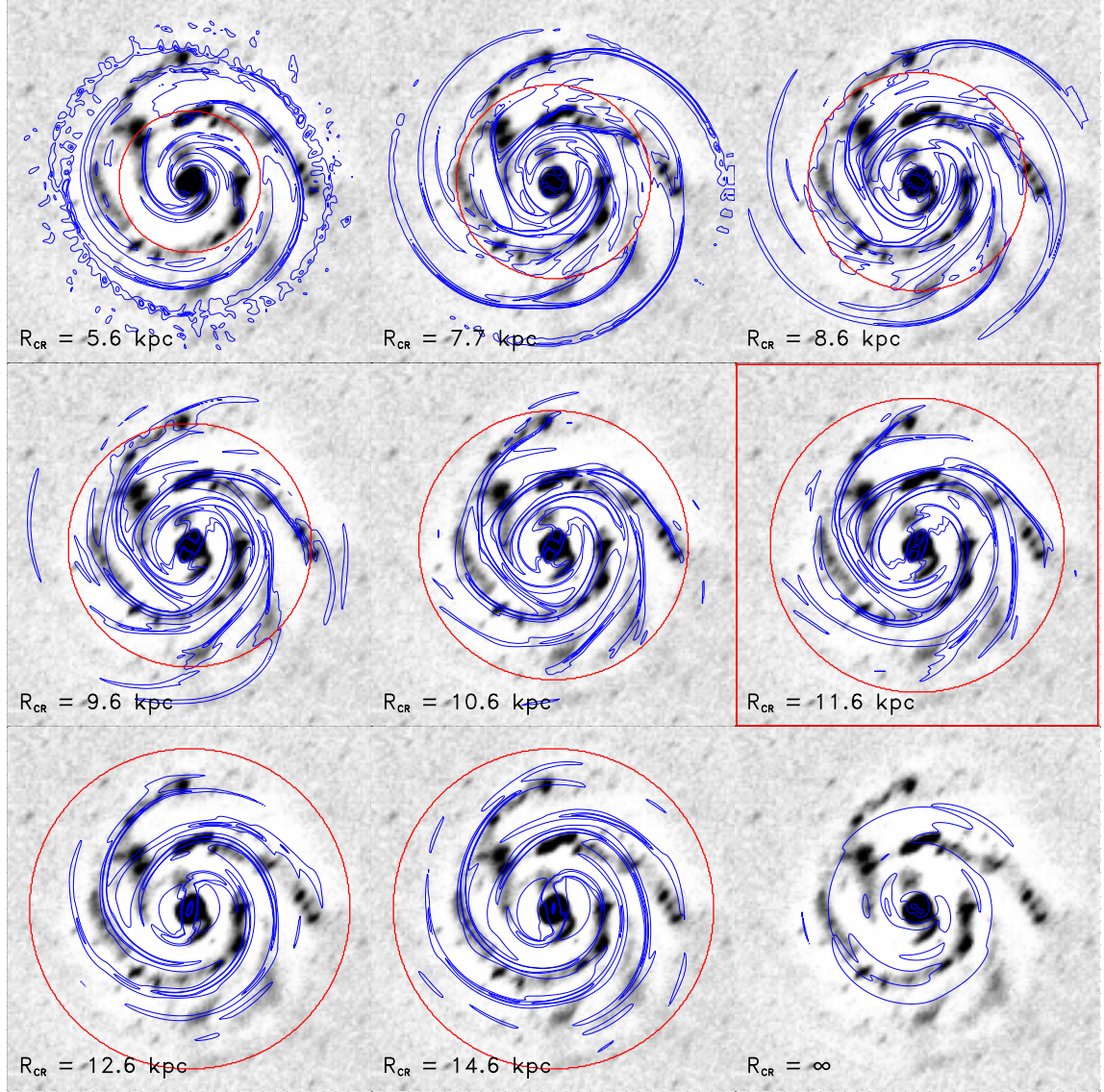


Figure D.1 Morphology comparison between the simulated gas density field (in contours) and the the observed structure of NGC 5676 (underlying, contrast enhanced image). Shown are the results for the $f_d = 45\%$ runs. Displayed is always the last time step during a simulation run (see Table 6.3). The red circle gives the location of the corotation resonance, that applies to the particular simulation. The red bordered panel displays the simulation with the best matching parameter set.

NGC 5676, $f_d = 20\%$, $R_{CR} = 9.6$ kpc

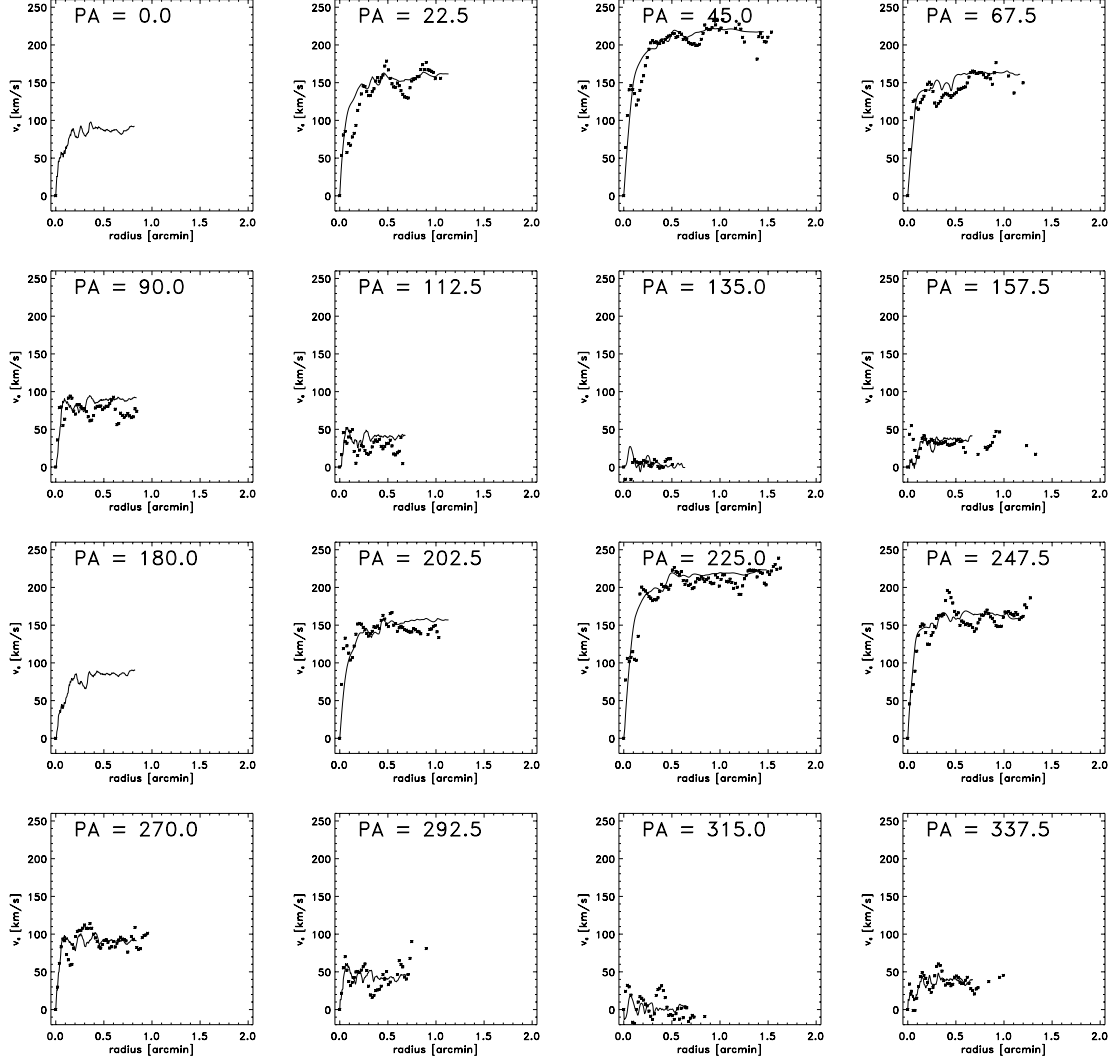


Figure D.2 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 5676 with a light disk ($f_d = 20\%$) and $R_{CR} = 9.6$ kpc.

NGC 5676, $f_d = 85\%$, $R_{CR} = 9.6$ kpc

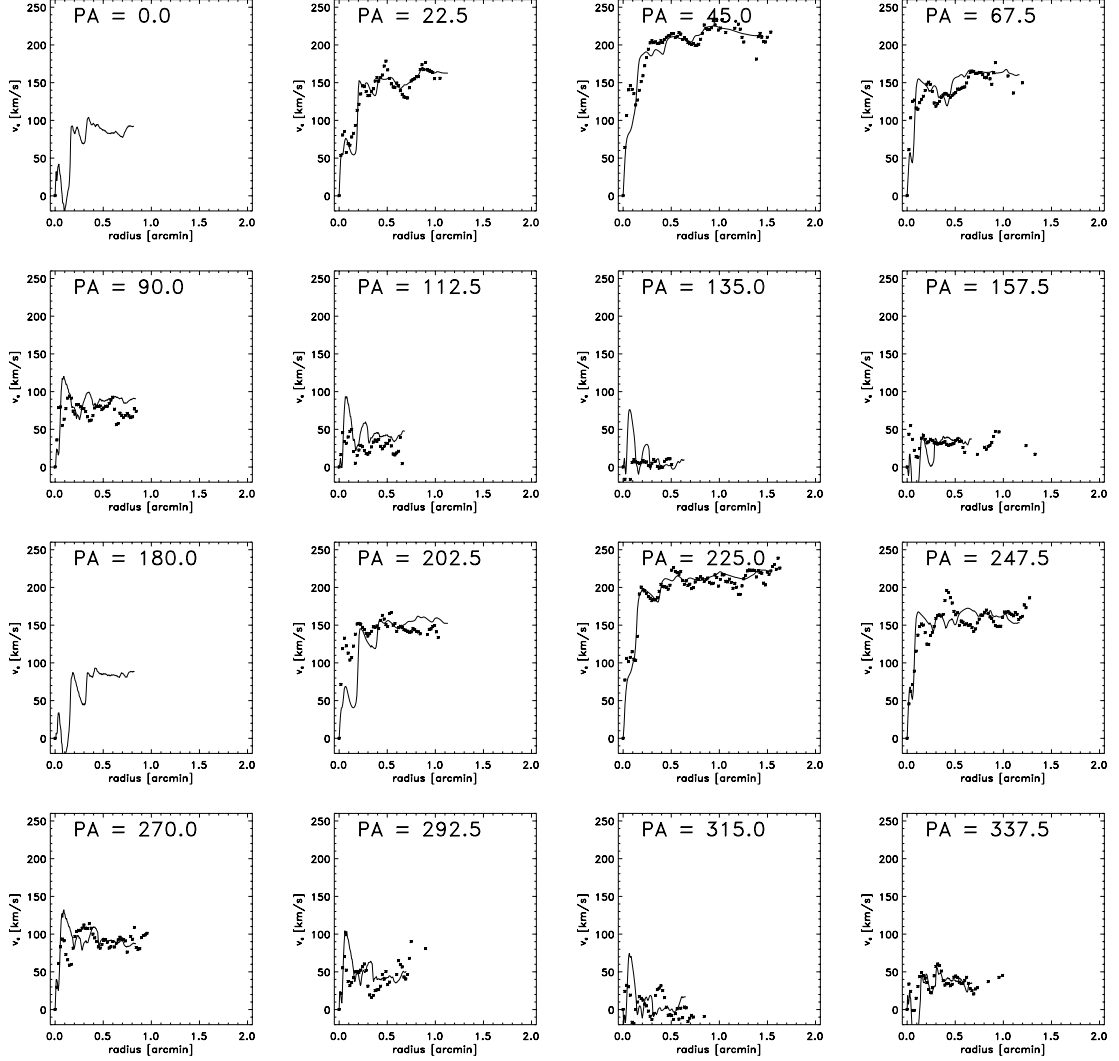


Figure D.3 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 5676 with a heavy disk ($f_d = 85\%$) and $R_{CR} = 9.6$ kpc.

NGC 5676, $f_d = 20\%$, $R_{CR} = 11.6$ kpc

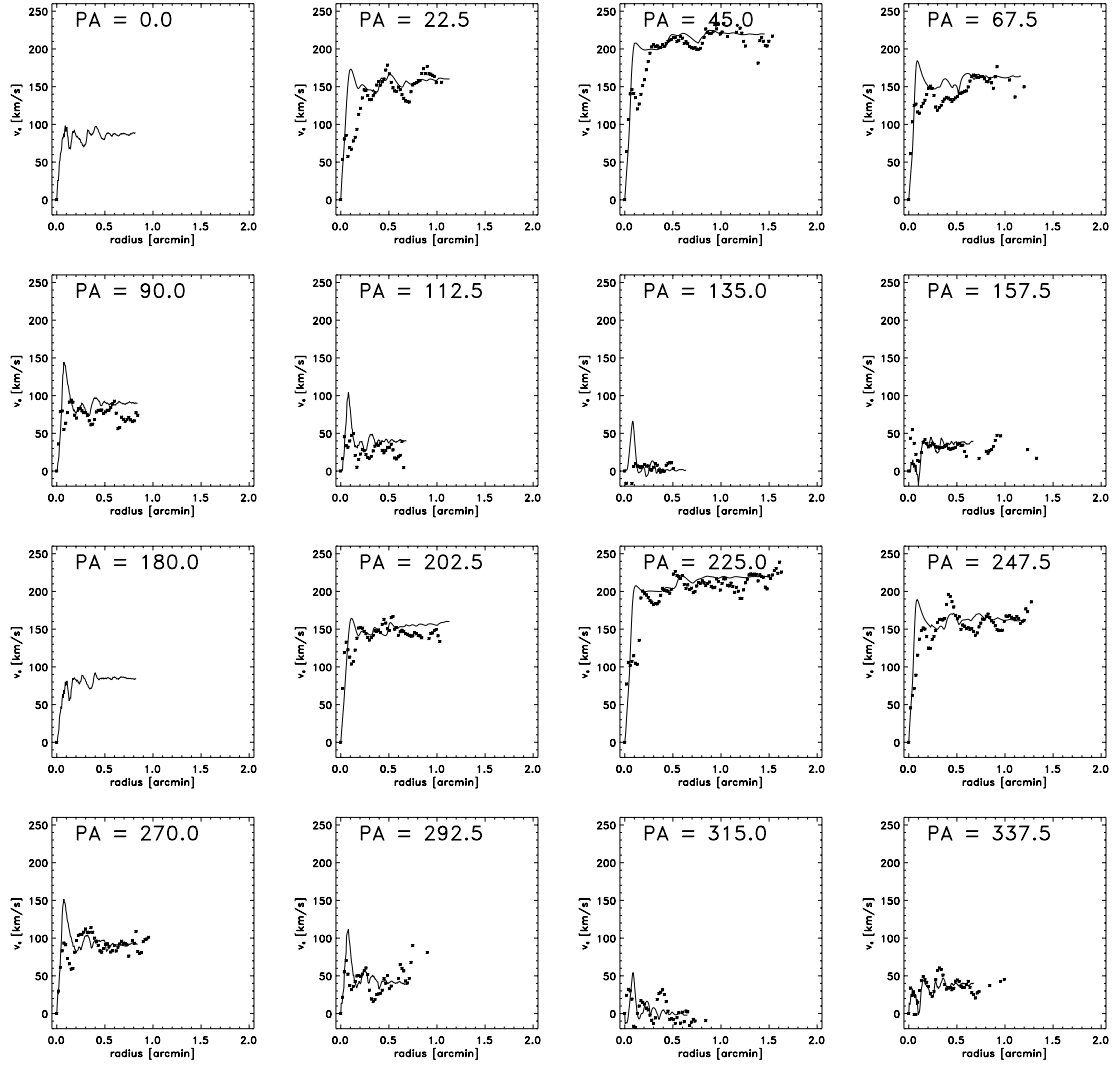


Figure D.4 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 5676 with a light disk ($f_d = 20\%$) and $R_{CR} = 11.6$ kpc.

NGC 5676, $f_d = 85\%$, $R_{CR} = 11.6$ kpc

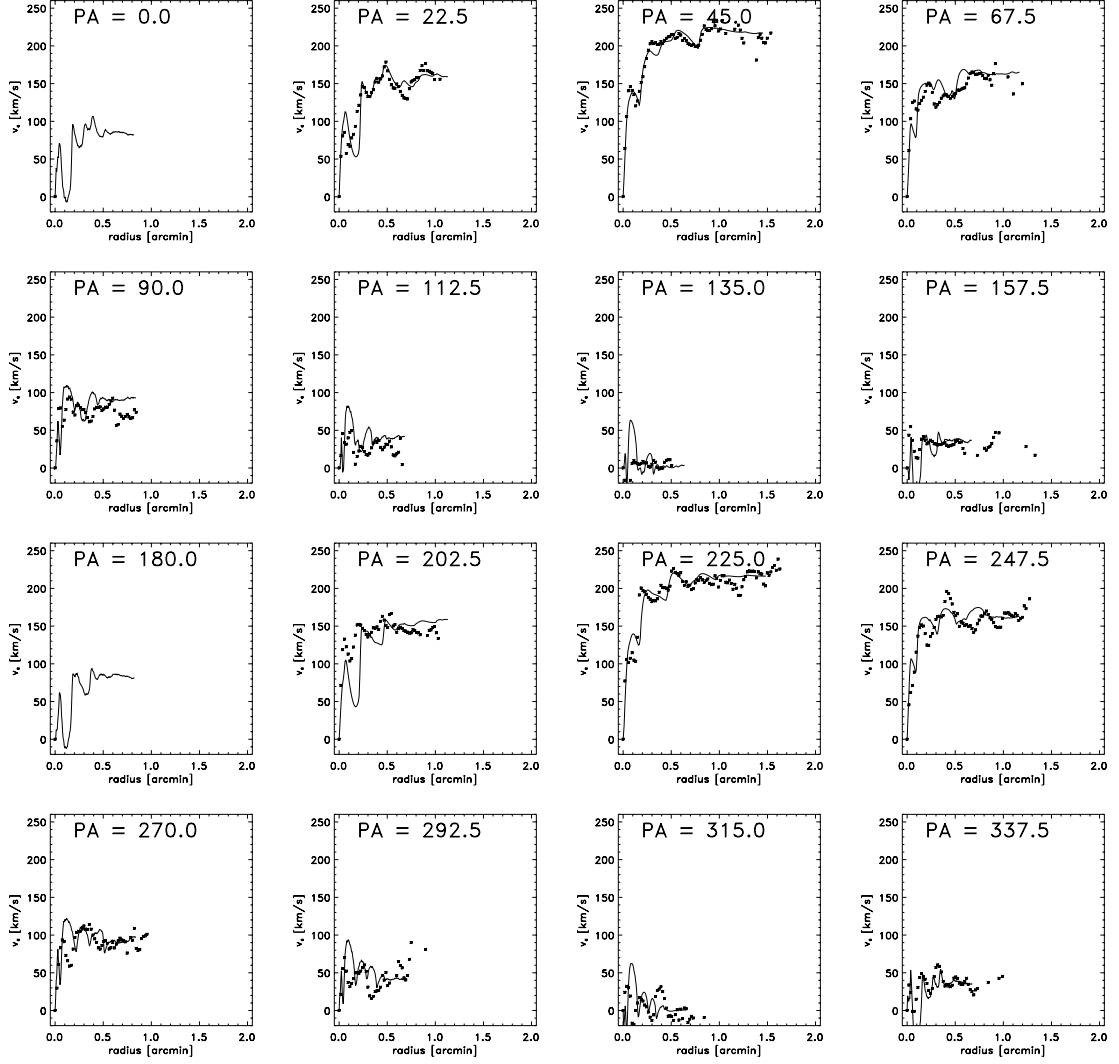


Figure D.5 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 5676 with a heavy disk ($f_d = 85\%$) and $R_{CR} = 11.6$ kpc. Note that this simulation did not run past the initialization phase.

E NGC 6643

Table E.1 χ^2/N of the comparison between observed and simulated kinematics for NGC 6643. $N = 715$ data points. The errors refer to 1σ χ^2/N -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	4.18	5.1	6.0	6.5	7.00	8.0	9.0	10.0	
20	1.025	1.048	1.023	1.050	1.128	1.170	1.171	1.237	χ^2/N
	0.021	0.023	0.018	0.017	0.027	0.036	0.050	0.059	$\pm (1\sigma)$
45	1.176	1.162	1.256	1.259	1.269	1.427	1.765	2.061	χ^2/N
	0.075	0.061	0.096	0.082	0.080	0.086	0.183	0.412	$\pm (1\sigma)$
60	1.292	1.395	1.510	—	1.509	2.005	2.767	2.858	χ^2/N
	0.064	0.118	0.164	—	0.115	0.249	0.649	0.759	$\pm (1\sigma)$
85	1.005	1.003	0.992	0.988	1.014	1.088	1.146	1.106	χ^2/N
	0.015	0.008	0.014	0.012	0.012	0.026	0.054	0.078	$\pm (1\sigma)$
100	1.924	2.095	1.966	2.167	—	2.582	3.380	4.564	χ^2/N
	0.147	0.284	0.070	0.319	—	0.390	0.337	0.452	$\pm (1\sigma)$

Table E.2 $\text{median}(\chi^2)$ of the comparison between observed and simulated kinematics for NGC 6643. The errors refer to 1σ $\text{median}(\chi^2)$ -variations after simulation has passed the initialization phase.

f_d [%]	corotation radius R_{CR} [kpc]								
	4.18	5.1	6.0	6.5	7.00	8.0	9.0	10.0	
20	0.404	0.405	0.389	0.407	0.403	0.415	0.429	0.513	$\text{median}(\chi^2)$
	0.021	0.009	0.012	0.007	0.010	0.010	0.016	0.041	$\pm (1\sigma)$
45	0.421	0.472	0.520	0.482	0.464	0.507	0.553	0.802	$\text{median}(\chi^2)$
	0.025	0.031	0.039	0.039	0.040	0.035	0.069	0.120	$\pm (1\sigma)$
60	0.404	0.486	0.592	—	0.511	0.661	0.752	0.953	$\text{median}(\chi^2)$
	0.028	0.010	0.065	—	0.030	0.098	0.118	0.179	$\pm (1\sigma)$
85	0.390	0.349	0.342	0.372	0.377	0.371	0.356	0.380	$\text{median}(\chi^2)$
	0.009	0.008	0.007	0.014	0.008	0.010	0.016	0.034	$\pm (1\sigma)$
100	0.499	0.655	0.652	0.652	—	0.852	1.145	1.586	$\text{median}(\chi^2)$
	0.032	0.061	0.029	0.093	—	0.094	0.136	0.256	$\pm (1\sigma)$

NGC 6643, $f_d = 45\%$

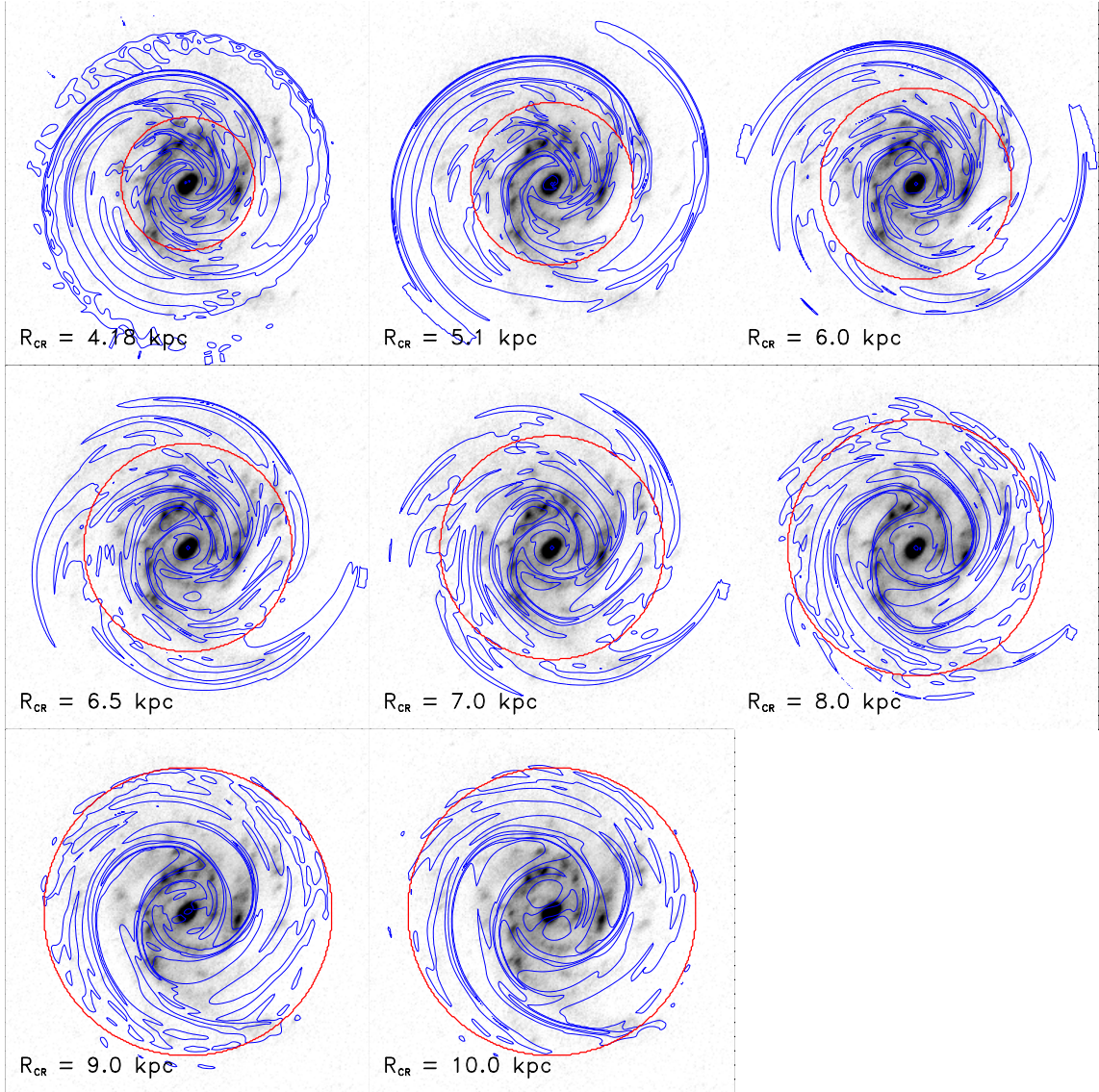


Figure E.1 Morphology comparison between the simulated gas density field (in contours) and the the observed structure of NGC 6643 (underlying, contrast enhanced image). Shown are the results for the $f_d = 45\%$ runs. Displayed is always the last time step during a simulation run (see Table 6.4). The red circle gives the location of the corotation resonance, that applies to the particular simulation.

NGC 6643, $f_d = 20\%$, $R_{CR} = 6.5$ kpc

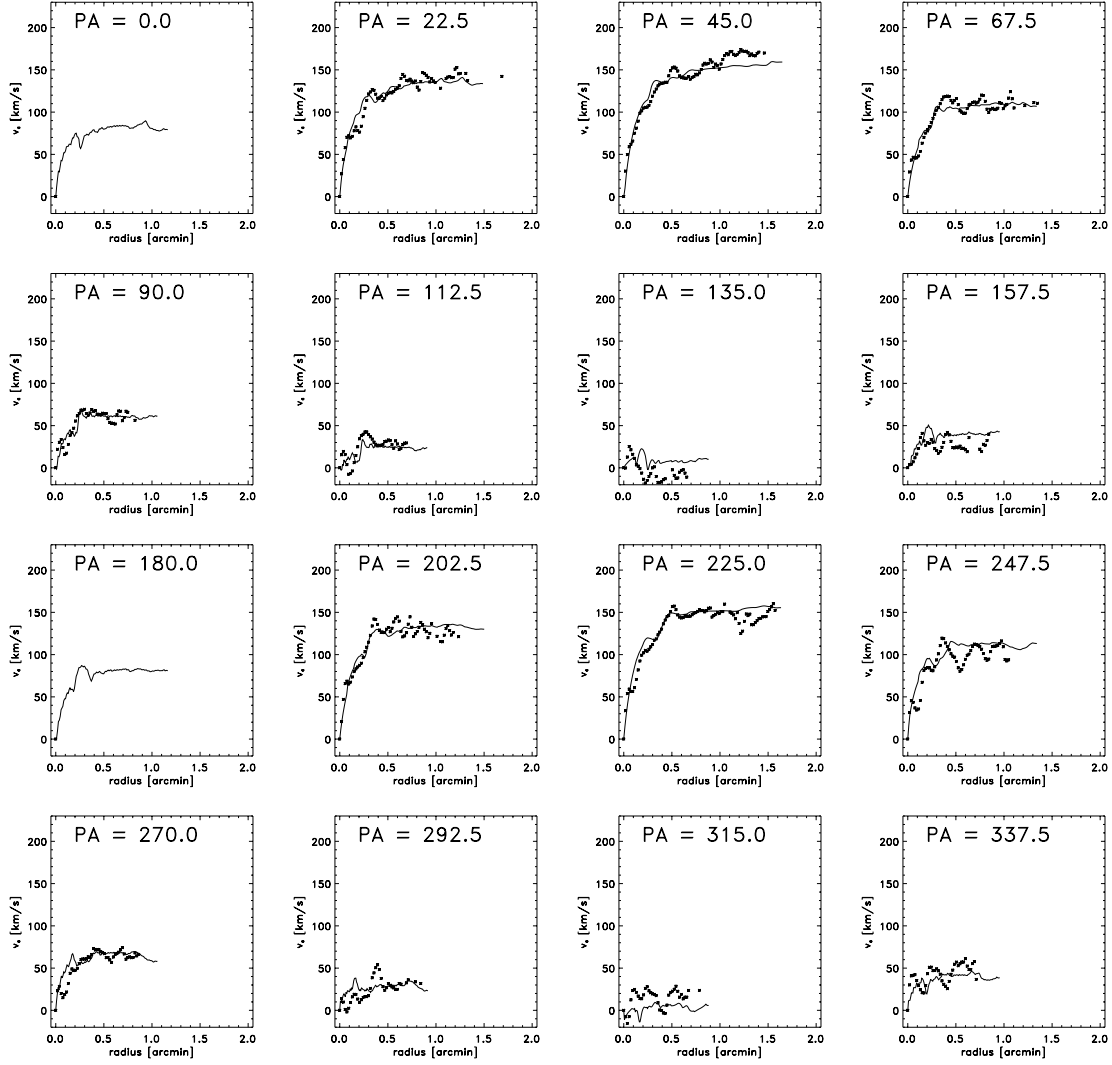


Figure E.2 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 6643 with a light disk ($f_d = 20\%$) and $R_{CR} = 6.5$ kpc.

NGC 6643, $f_d = 85\%$, $R_{CR} = 6.5$ kpc

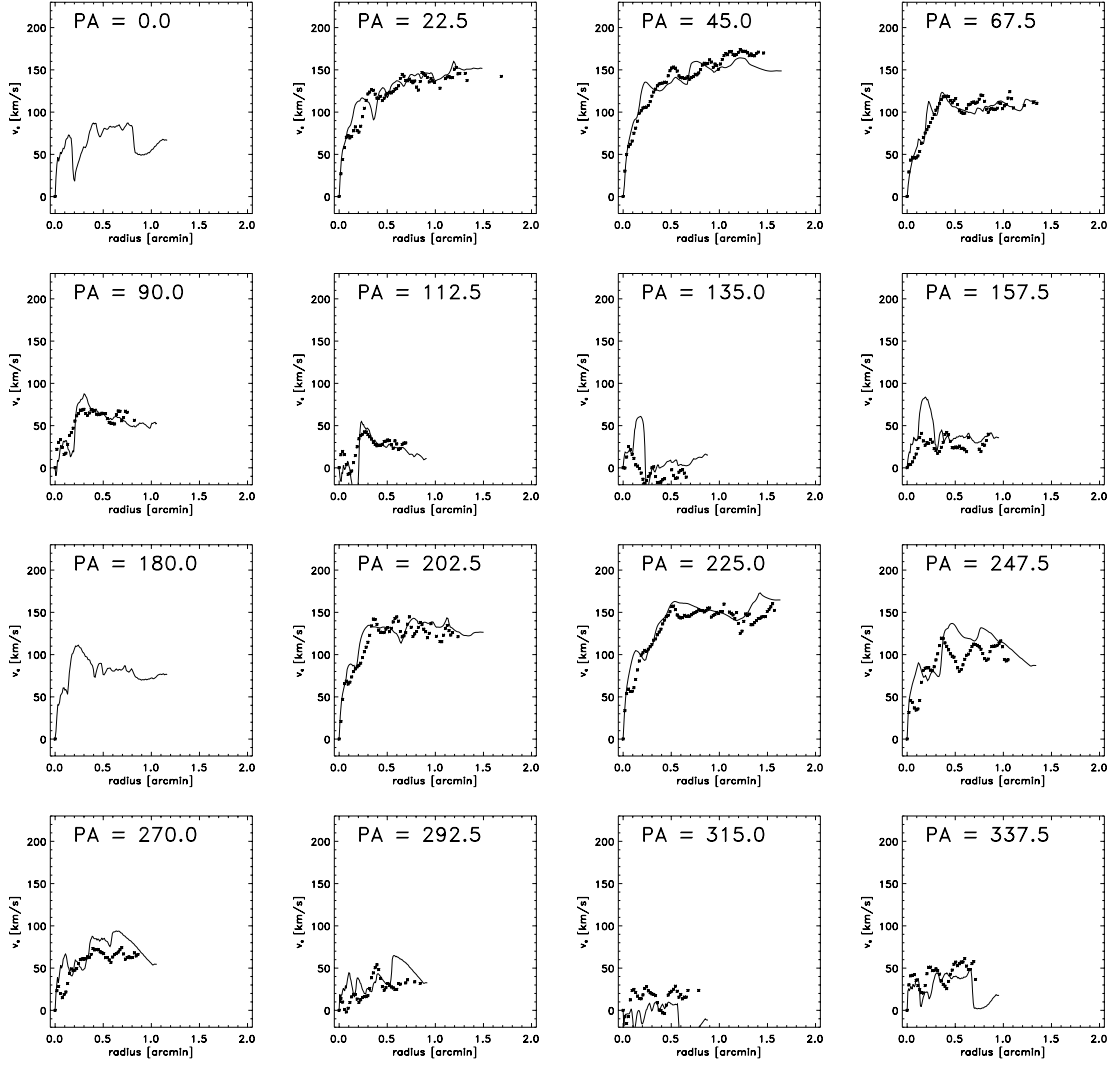


Figure E.3 Comparison of the measured (data points) and simulated (continuous line) kinematics. The results are displayed for NGC 6643 with a heavy disk ($f_d = 85\%$) and $R_{CR} = 6.5$ kpc.

NGC 6643, $f_d = 45\%$, $R_{CR} = 6.5$ kpc, selected data

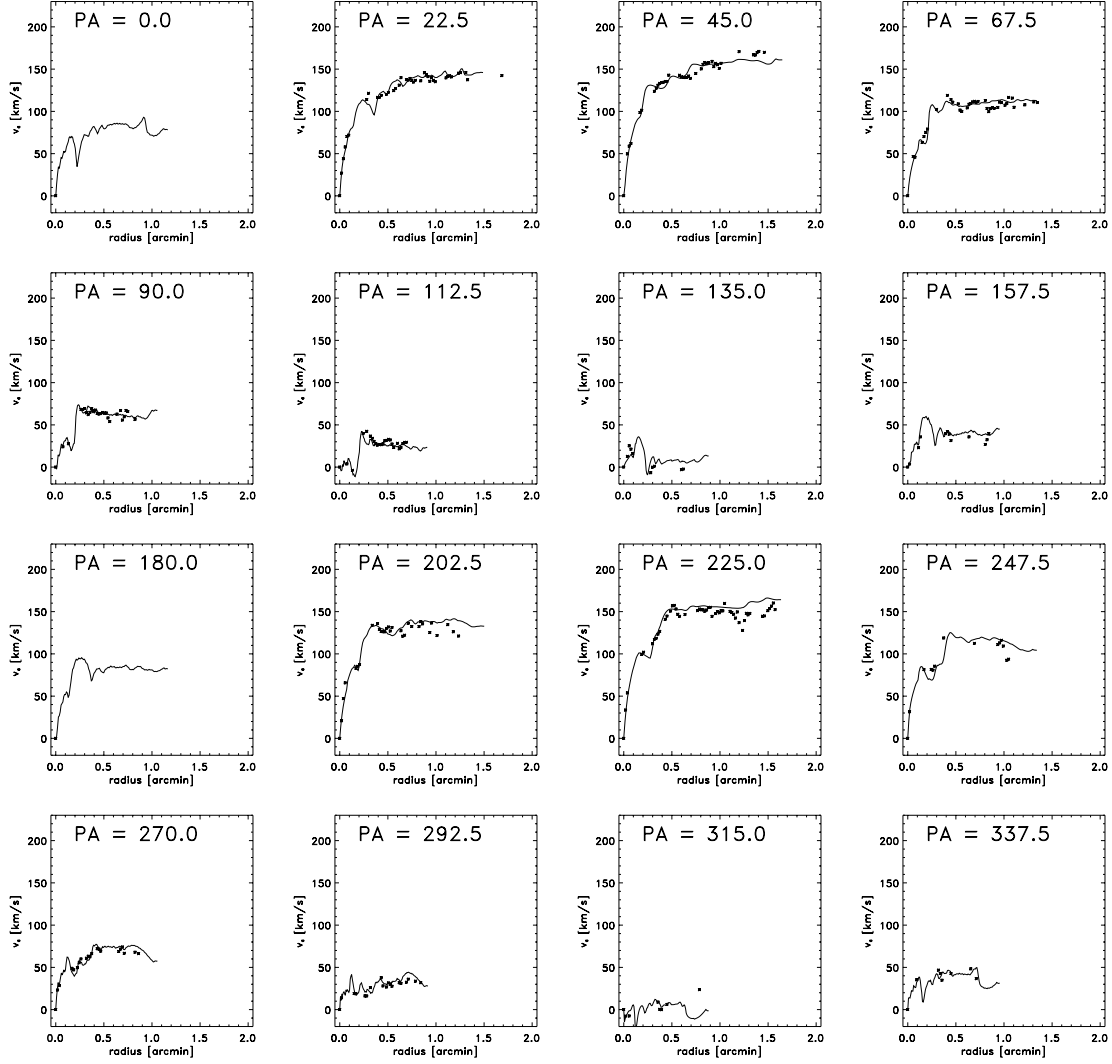


Figure E.4 Comparison of a selection of the measured kinematics (data points) and simulated (continuous line) kinematics. A selection criterion was introduced to only look at parts of the observed velocity field where the gas dynamics is mainly induced by gravity. About 47 % of the initial data points are used for comparison. See Section 4.3.2.1 for a description of the method. The results are displayed for NGC 6643 with a medium disk ($f_d = 45\%$) and $R_{CR} = 6.5$ kpc.

Table E.3 χ^2/N and median(χ^2) of the comparison between observed and simulated kinematics for NGC 6643. Considered were only $N = 331$ selected data points.

Disk fraction f_d [%]	20	45	60	85	100
χ^2/N	0.653	0.745	0.737	1.600	3.272
median(χ^2)	0.236	0.222	0.222	0.276	0.255