

Contents

1. Introduction	1
1.1. Motivation	1
1.2. Star and Planet Formation	2
1.2.1. Dust Evolution in Protoplanetary Disk	3
1.2.2. Gas structure in Protoplanetary Disk	5
1.3. Observations of Protoplanetary Disks	6
1.3.1. Structure in dust continuum emission	7
1.3.2. Gas observations and Kinematic Tracers	8
1.4. Spiral Structures in Protoplanetary Disks	9
1.4.1. Spirals arising from Gravitational Instability	11
1.4.2. Spirals arising from Planet-Disk Interaction	13
1.5. The young star Elias 2-27	15
2. Observations	17
2.1. Observing with ALMA	17
2.2. Elias 2-27 Observations	19
2.2.1. Imaging dust continuum emission	20
2.2.2. Imaging molecular gas emission	21
3. Dust Spiral Structure	24
3.1. Previous analysis of Continuum Emission in Elias 2-27	24
3.2. Tracing the Spiral Morphology	26
3.3. Contrast variations along the Spiral	30
3.4. Spectral Index Analysis	33
4. Gas distribution as traced by CO isotopologues in Elias 2-27	38
4.1. Previous analysis of CO isotopologues in Elias 2-27	38
4.2. Channel and moment maps	39
4.3. Tracing the emitting layer in ^{13}CO and C^{18}O	49
4.4. Tracing the kinematics in ^{13}CO and C^{18}O	53
4.5. Features in the channel maps of C^{18}O and ^{13}CO	57
5. Tracing CN emission in Elias 2-27	61
5.1. CN as tracer of spiral shocks	61
5.2. CN Emission Analysis	62

6. Smooth-Particle Hydrodynamic Simulations of a Gravitationally Unstable Disk	69
6.1. Theoretical Considerations	70
6.2. SPH Simulation Results	71
6.2.1. Hydrodynamical Model Setup	71
6.2.2. Radiative Transfer Calculation and Simulated ALMA Observations .	73
6.2.3. Dust Simulations	73
6.2.4. Gas Simulations	74
7. Discussion	79
7.1. Dust structure and multi-wavelength emission	79
7.2. Asymmetries and Perturbations in the Gas	80
7.3. CN Emission Analysis	83
7.4. Comparison with SPH simulations	84
7.5. Spiral Structure Origin	85
8. Conclusion	86
Bibliography	88
Appendix A. Additional Azimuthal cuts Spectral Index	107
Appendix B. Rejected SPH Simulations	110