PLANETARY NEBULAE: THEIR EVOLUTION AND ROLE IN THE UNIVERSE
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CFHT Fabry-Perot 2D Spectroscopy in Hα of the Planetary Nebula NGC 40: Universal Multifractal Analysis and Turbulent Status

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Using CFHT/SIS Fabry-Perot interferograms of the planetary nebula NGC 40, we present an investigation of the statistical properties of fluctuating gas motions using structure functions traced by Hα emission-line centroid velocities (Grosdidier et al. 2002). We consider the structure functions $\langle|\Delta v(r)|^p\rangle$ of order p, i.e. the spatially averaged moments of order p of the spatial velocity increments at projected spatial scale r of NGC 40's velocity field. In this poster, we test for i) Structure-function scaling related to turbulence in the nebula, $\langle|\Delta v(r)|^p\rangle \sim r^{\zeta(p)}$, and ii) Nonlinearity of the observed scaling exponents $\zeta(p)$s, as expected for intermittent turbulent flows. The first order structure function is indeed found to scale at the smallest scales with $\zeta(1) = H \approx 0.68$. This value is larger than the value expected in the case of incompressible or compressible turbulence, for which one would obtain $H = {}^1/_3$ or ${}^1/_2$, respectively. This result suggests that the Hα layer is thick compared to the projected spatial separations (O'Dell & Castañeda 1987, and references therein). We can give a more quantitative description of the turbulent status of the PN NGC 40 through the examination of the structure function for different orders. Additionally we can discuss the nature of the turbulence in terms of Universal Multifractals, a continuous-scale limit of multiplicative cascades (Schertzer & Lovejoy 1987) and derive the level of intermittency in the nebula. The function $\zeta(p)$ is indeed found to be nonlinear and well reproduced with the following Universal Multifractal parameters: $\alpha \approx 1.90$–2 (the field is highly multifractal with a gaussian generator) and $C_1 \approx 0.08$ (the field suffers significant intermittency, which is incompatible with monofractal additive stochastic models usually introduced in similar studies): $\zeta(p) = p \times H - C_1(p^\alpha - p)/(\alpha - 1)$. Fig. 1 shows the hierarchy of exponents $\zeta(p)$ along with its best Universal Multifractal fit. Our results on the Wolf-Rayet ring nebula M 1-67 (Grosdidier et al. 2001) led to the same level of multifractality ($\alpha \approx 1.9$) but with smaller intermittency ($C_1 \approx 0.04$). Preliminary results on the Orion nebula (Grosdidier 2002) reveal a turbulent status relatively similar to that of the PN NGC 40. On the whole, such a study

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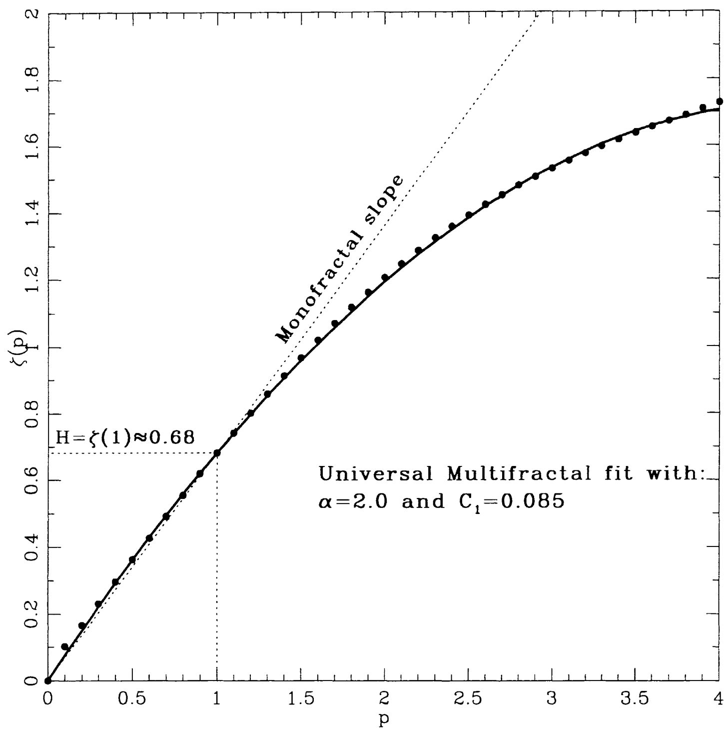

Figure 1. Velocity structure function analysis of NGC 40. The corresponding $\zeta(p)$ function (dots) demonstrates the multiaffinity of NGC 40's velocity field. A Universal Multifractal fit is also shown as a solid curve.

provides a way to quantify turbulence in PN, and more generally in other HII regions (with potential implications for the estimation of temperature fluctuations) and give insight on astrophysical turbulence for its own sake.

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