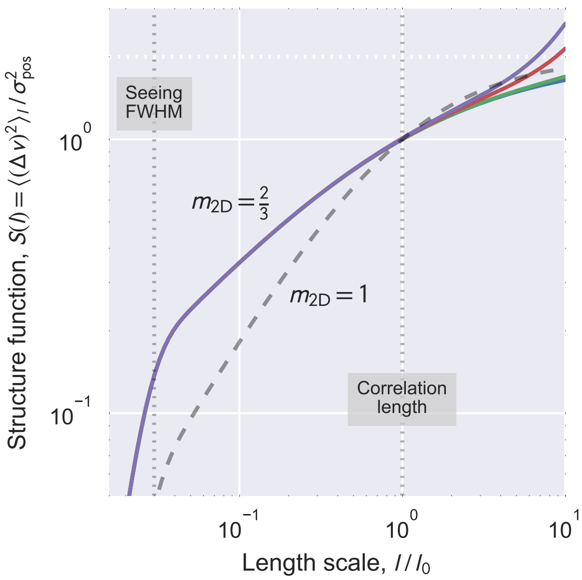

Figure 1. Idealized plane-of-sky normalized structure function $S(l) = 2\,[1 - C(l)]$ for turbulent velocity autocovariance of the form $C(l) = 1/\,[1 + (l/l_0)^{m_{2D}}]$, where l_0 is the correlation length of the turbulence. Results for Kolmogorov-like turbulence ($m_{2D} = 2/3$) and a steeper spectrum ($m_{2D} = 1$) are shown. In the first case, different colored lines show the effect of an uncorrected linear velocity gradient on the scale of the map (size $10 l_0$), with total amplitude of (top to bottom) 2.0, 1.0, 0.1, and 0.0 times the turbulent velocity dispersion, $\sigma_{\rm pos}$. At small scales, the effect of seeing is shown, assuming a Gaussian FWHM of $0.03 l_0$.

Figure 1 illustrates how various effects modify the purely turbulent structure functions for a highly idealized case. The most promising range of length scales for measuring the turbulent velocity spectrum is between a few times the seeing width and about half the correlation length, l_0, of the turbulence. At scales larger than l_0, the structure function flattens as it tends towards the asymptotic value of 2 for a homogeneous random field. If there is a linear velocity gradient across the map, then the structure function will steepen again at the largest scales. Alternatively, if the turbulent velocity dispersion is inhomogeneous, being larger in the center of the map than in the periphery, then the structure function slope will become negative at the largest scales (not illustrated). The figure does not include the effects of noise, but that is easily dealt with in the case that the noise is "white" (spatially uncorrelated, such as shot noise), since the effect is to simply add a constant value to the structure function at all scales. This can be estimated either from the variance of velocity differences at separations significantly less than the seeing width or from independent observations of the same spatial point, and then subtracted from the observed structure function prior to analysis. Spatially correlated "noise" due to systematic instrumental effects is more difficult to deal with, since it will add a spurious scale-dependent term to the structure function.

Previous studies of the velocity structure function in Orion have been carried out based on slit spectra (Castañeda 1988; O'Dell & Wen 1992; Wen & O'Dell 1993). Table 1 compares these results with our own for different emission lines, ordered from lower to higher ionization. In spite of the differences in methodology, a broad agreement is seen, with both the magnitude of the velocity dispersion and the steepness of the structure function slope increasing with ionization. The most directly comparable methodology to our own is that of O'Dell & Wen 1992 who used the flux-weighted mean velocity of the [O I] λ6300 line. The fitted range of $6''$ to $85''$ extends to larger scales than in studies of other lines, and this biases the slope determination towards lower values due to the slight curvature of the structure function.

Table 1. Comparison of structure function slopes

Reference	Ion	Method	σ^2 (km s^{-1})	Range ($''$)	Slope
O'Dell & Wen 1992	[O I]	Mean	3:	6–85	0.68:
This paper	[S II]	Mean	5.4	7–32	0.80 ± 0.12
This paper	[N II]	Mean	5.6	8–22	0.82 ± 0.11
Wen & O'Dell 1993	[S III]	Comp A	13.8	5–20	0.92:
This paper	Hα	Mean	9.4	8–22	1.17 ± 0.08
This paper	[O III]	Mean	10.2	8–22	1.18 ± 0.09
Castañeda 1988	[O III]	Comp A	13.7	3–15	0.86 ± 0.05
This paper	[O III]	Comp A	15.3	3–15	0.73 ± 0.05

The other studies are harder to compare with our own since they are based on multi-component Gaussian fits to the line profiles, such as shown in Figure **??**. In order to check the effects of this methodological difference, we have calculated the [O III] structure function for the strongest component of the three-Gaussian decomposition of our line profiles (component A, see §), with results that are also included in Table 1. We find a slightly larger plane-of-sky velocity dispersion and shallower structure function than we found using the mean velocity of the entire profile, which is consistent with the results of Castañeda (1988) for the same line. Experimentation shows that this is partly due to under-determination of the Gaussian fits, particularly for components A and B, which are severely blended at most positions. This results in a fitting degeneracy between the velocity separation $v_A - v_B$ and the flux ratio $F_A/F B$ of the two components, which spuriously contributes to the variation in v_A.

The structure function slopes obtained by Mc Leod et al. (2015), based on integral field spectroscopy with the MUSE instrument (Weilbacher et al. 2015) are significantly flatter than all other studies, and we have decided not to include them in the comparison table. For example, they obtain a slope of 0.29 for [O III] and 0.0 for [O I]. This appears to be the result of uncorrected fixed-pattern noise in their mean velocity maps, which can be seen as tartan-like horizontal and vertical stripes in their Fig. 10. We will show in a following paper that once these instrumental artifacts have been removed, the MUSE results are consistent with other studies.

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