Performance of Coherent Doppler Lidar for General Space-Based Conditions with Pulse Accumulation

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Support for GTWS Coherent Lidar Simulation

DEFINITION OF LOS VELOCITY ACCURACY

- **Velocity field is random**

- **Definition of velocity accuracy requires definition of truth "v_{truth}"**

- **Accuracy composed of bias and random error e**

$$\hat{v} = v_{truth} + e + BIAS$$

- **Bias of estimate = $< \hat{v} - v_{truth} >$**
  $< x >$ denotes ensemble average of x

- **Random error $\sigma^2 = < [\hat{v} - < \hat{v} >]^2 >$**

- **Definition of truth depends on application**

SPACE-BASED VELOCITY ESTIMATE:
FIXED STARE WITH PULSE ACCUMULATION

- True velocity is the average of the LOS velocity over the measurement plane

- "Good" estimates have a Gaussian PDF with standard deviation g (random error)

- "Good" estimates are unbiased if backscatter is uncorrelated with the LOS velocity

- Random error is typically dominated by effects of wind turbulence and backscatter variability

- "Bad" estimates described by the fraction b of uniformly distributed estimates

- Threshold signal level determined by fraction of "bad" estimates

LARGE NUMBER OF INPUT PARAMETERS

λ - laser wavelength (1.5 - 10.1 μm)

Δt - pulse width (0.2-2.0 μsec FWHM)

Δr - pulse target extent (30-300 m FWHM)

Δp - range-gate length (250-2000 m)

σ_{turb} - radial velocity fluctuations from turbulence

σ_{vLO} - shot-to-shot uncorrelated instrumental radial velocity error

β - backscatter statistics (mean, spatial correlation, PDF)

v_{search} - velocity search space (10-100 m/s)

v_{shear} - velocity shear (0-50 m/s/km)

U - pulse energy

A - telescope aperture

PRF - pulse repetition frequency

L - pulse accumulation track length

EFFECTIVE GAUSSIAN SIGNAL SPECTRUM MODEL

- simplifies analysis with four parameters
- Φ_1 - effective photons per LOS range-gate
- M - number of data samples per LOS range-gate
- N - pulse accumulation
- Ω - effective normalized spectral width

  $\Omega = 2\, w_v\, M\, T_S/\lambda$

  w_v - spectral width in velocity space

- valid for the weak to moderate signal regime
- simple scaling laws for threshold signal level Φ_1^K

CAPON λ=2.0 μm τ=0.5 μsec (FWHM) v_{search}=20.0 m/s M=150 A

Δr=75.00 m Δp=1125.00 m Ω_{eff}=11.2422 zenith angle=45.0^o

σ_h=1.7861 m/s σ_v=1.2630 m/s σ_{vLO}=0.5 m/s

ε=2.66e-5 m^2/s^3 L_{0h}=200.0 km s_v=1.4513 m/s w_v=1.4990 m/s

shots=100 track length=100.000 km shot separation=1.0 km

shear=5.0 m/s/km L_{0beta}=200.0 km σ_β/β=1.0

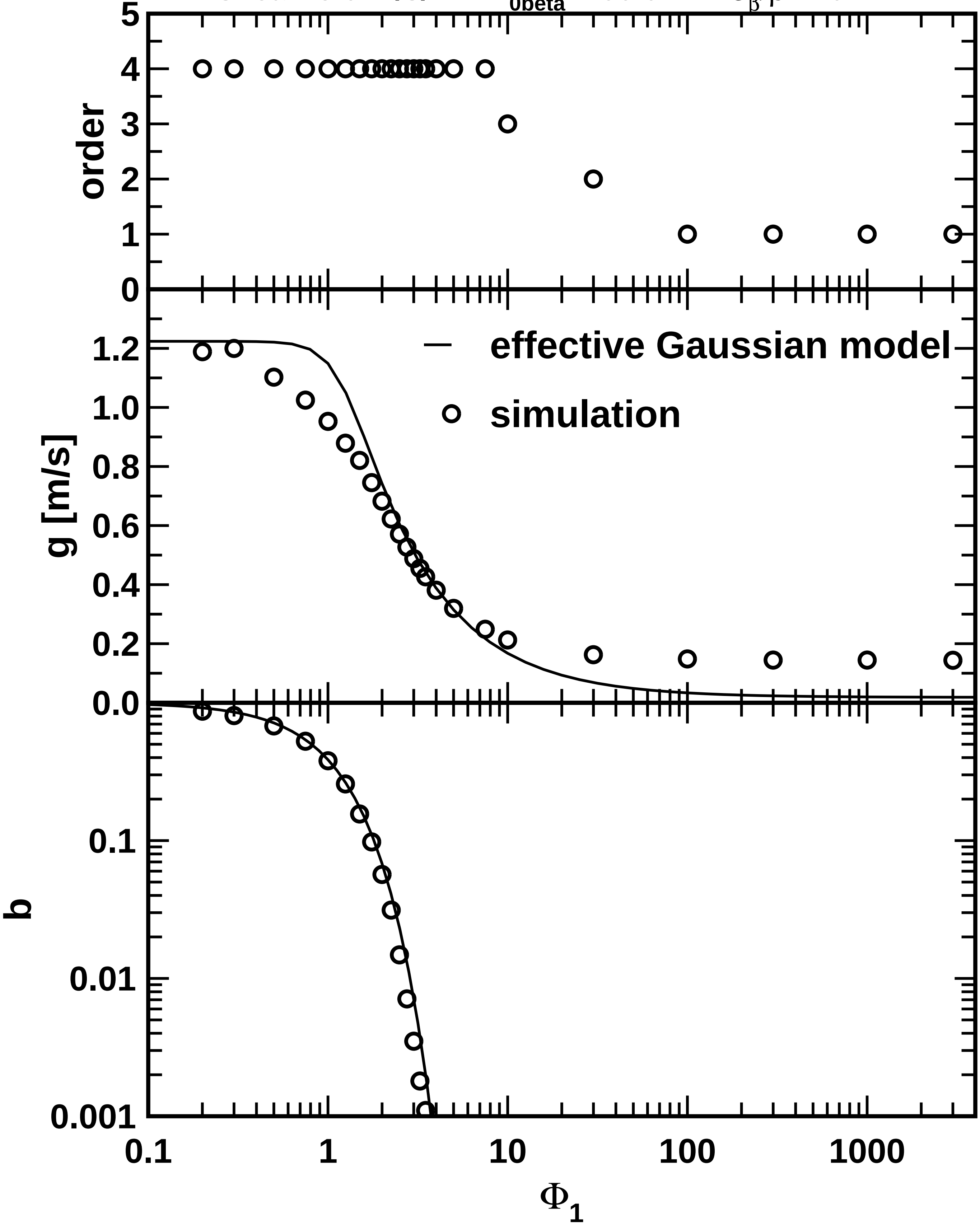


Figure 15 Frehlich, JTech, Vol. 13, 646-658, 1996

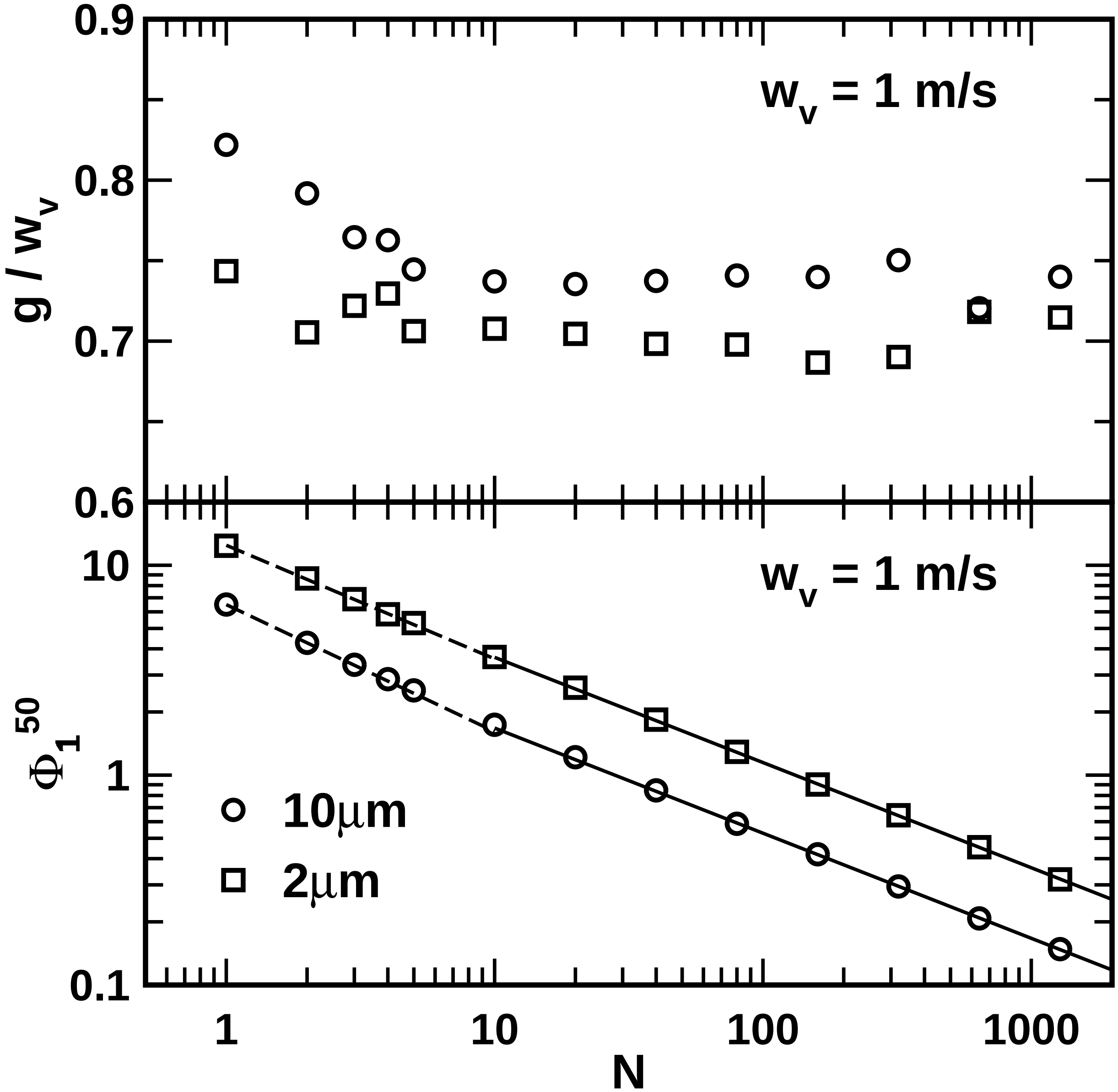


Figure 16 Frehlich, JTech, Vol. 13, 646-658, 1996

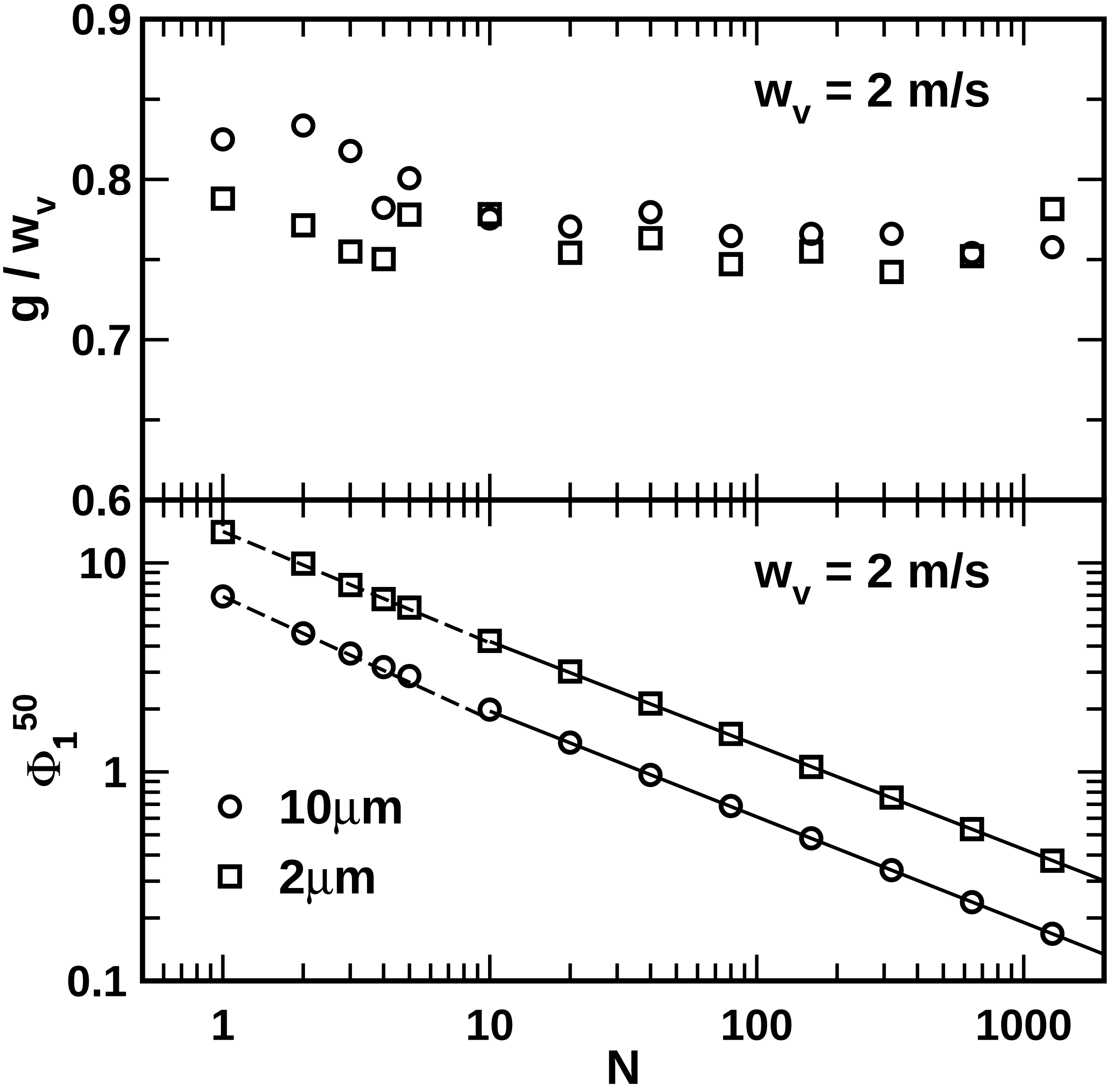


Figure 17 Frehlich, JTech, Vol. 13, 646-658, 1996

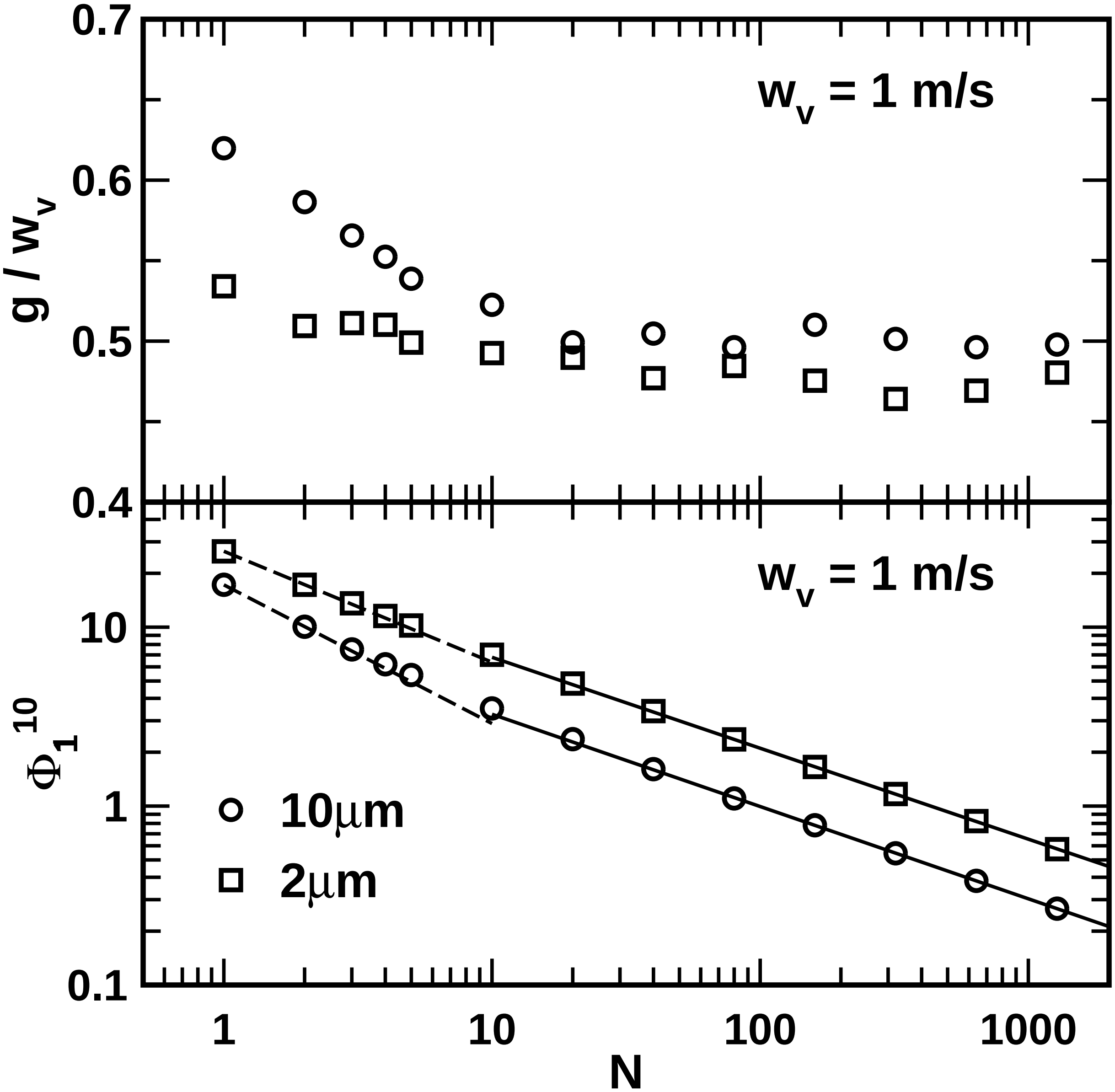


Figure 18 Frehlich, JTech, Vol. 13, 646-658, 1996

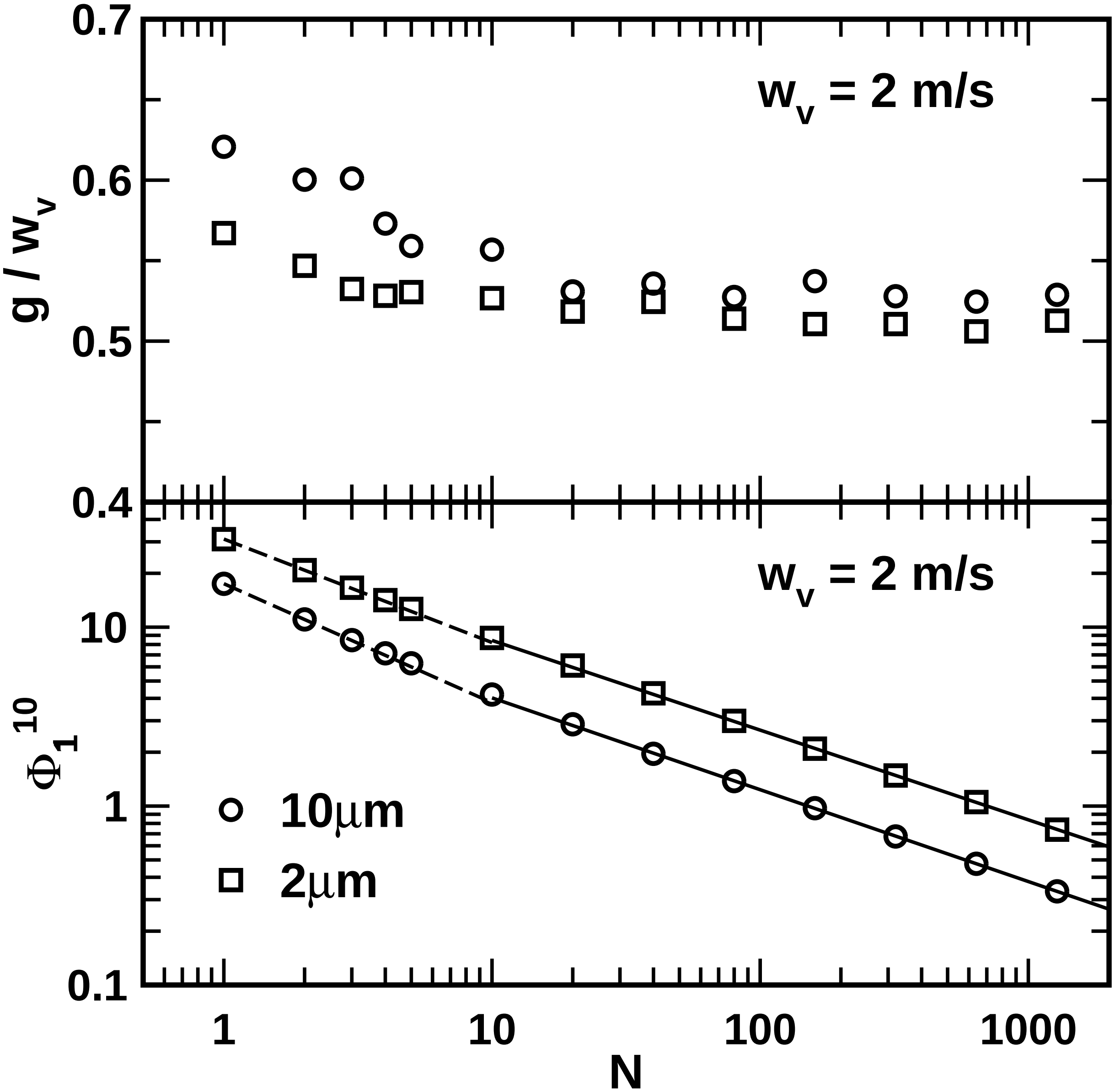
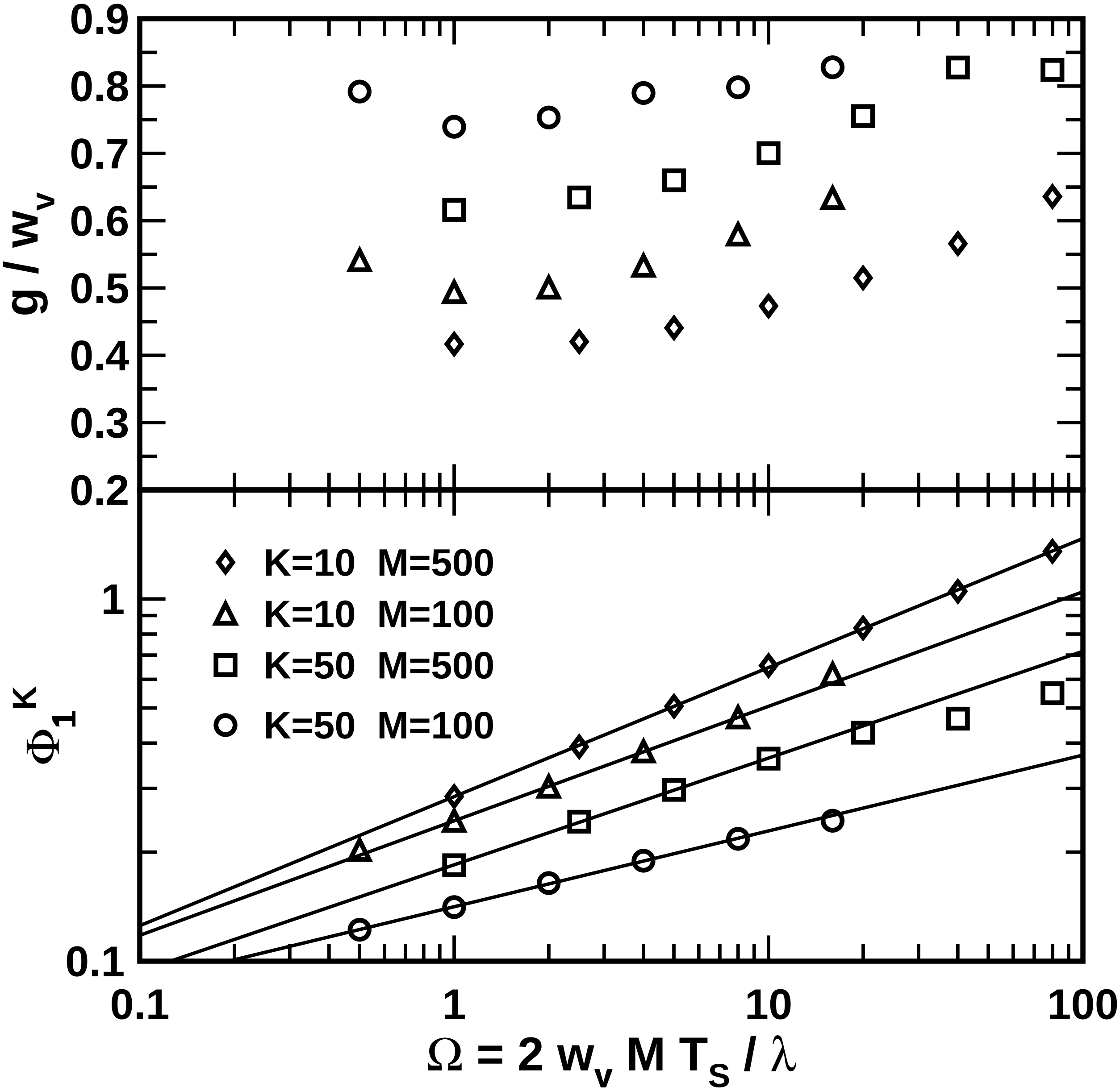


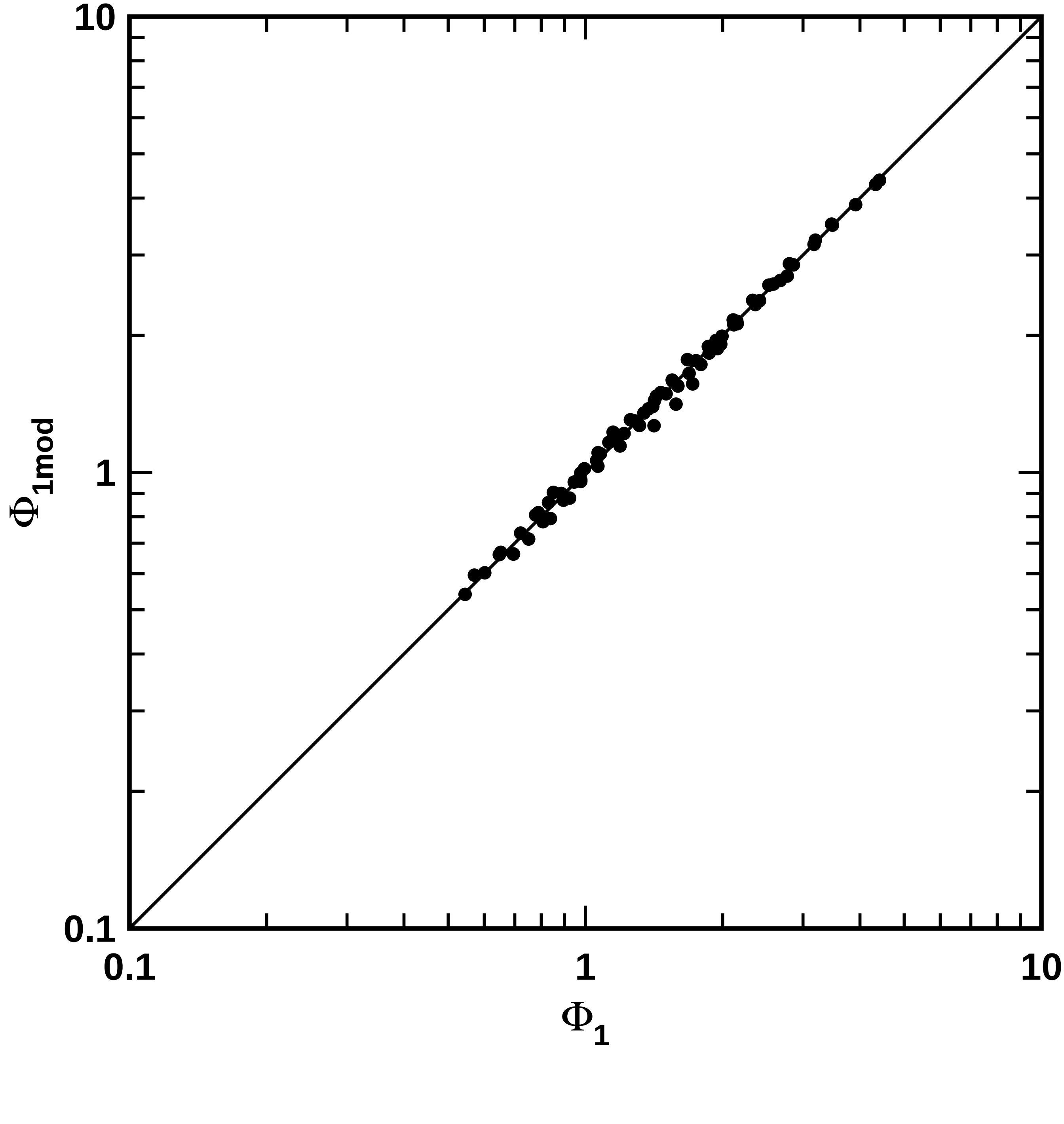
Figure 19 Frehlich, JTech, Vol. 13, 646-658, 1996



$\Phi_{1mod}(M,\Omega,N,b)=4.708201\ N^{-0.528988}\ M^{0.148501}\ \Omega^{0.289007}$

average percent error=3.330 b_{min}=0.005 b_{max}=0.4

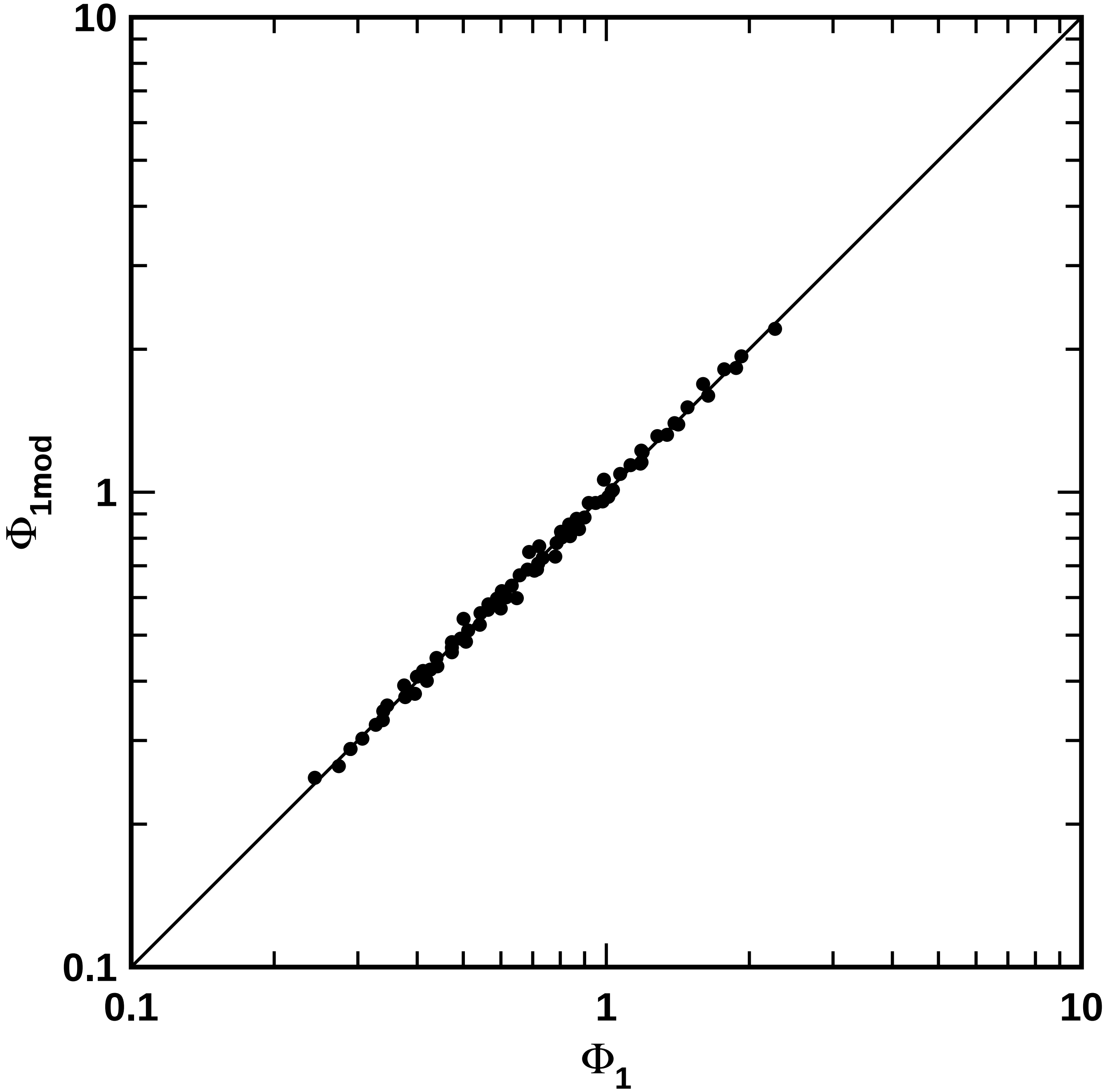
threshold single shot Φ_1 at b=0.1



$$\Phi_{1mod}(M,\Omega,N,b)=1.304073\ N^{-0.506371}\ M^{0.274183}\ \Omega^{0.192710}$$

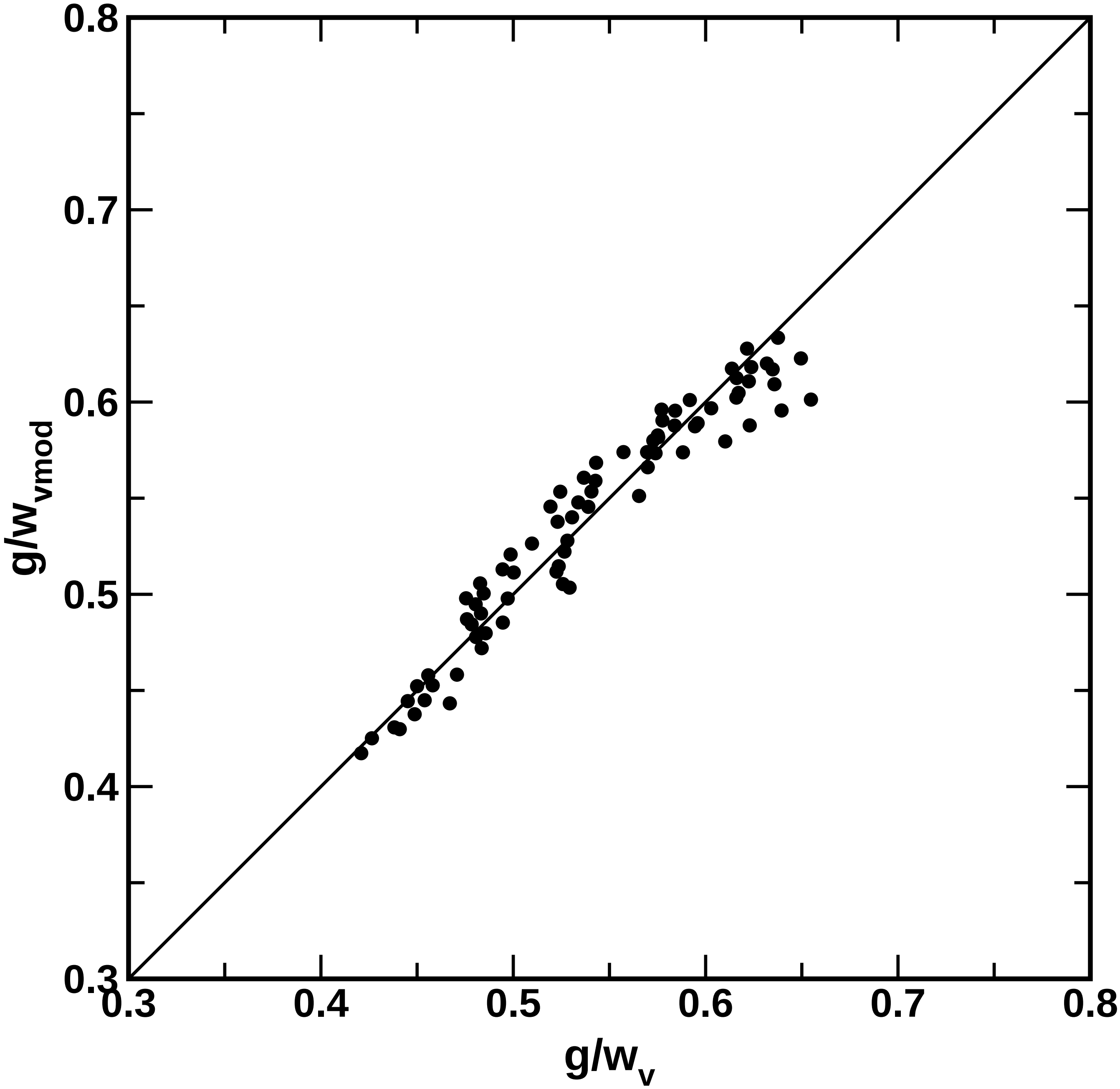
average percent error=3.211 b_{min}=0.05 b_{max}=0.8

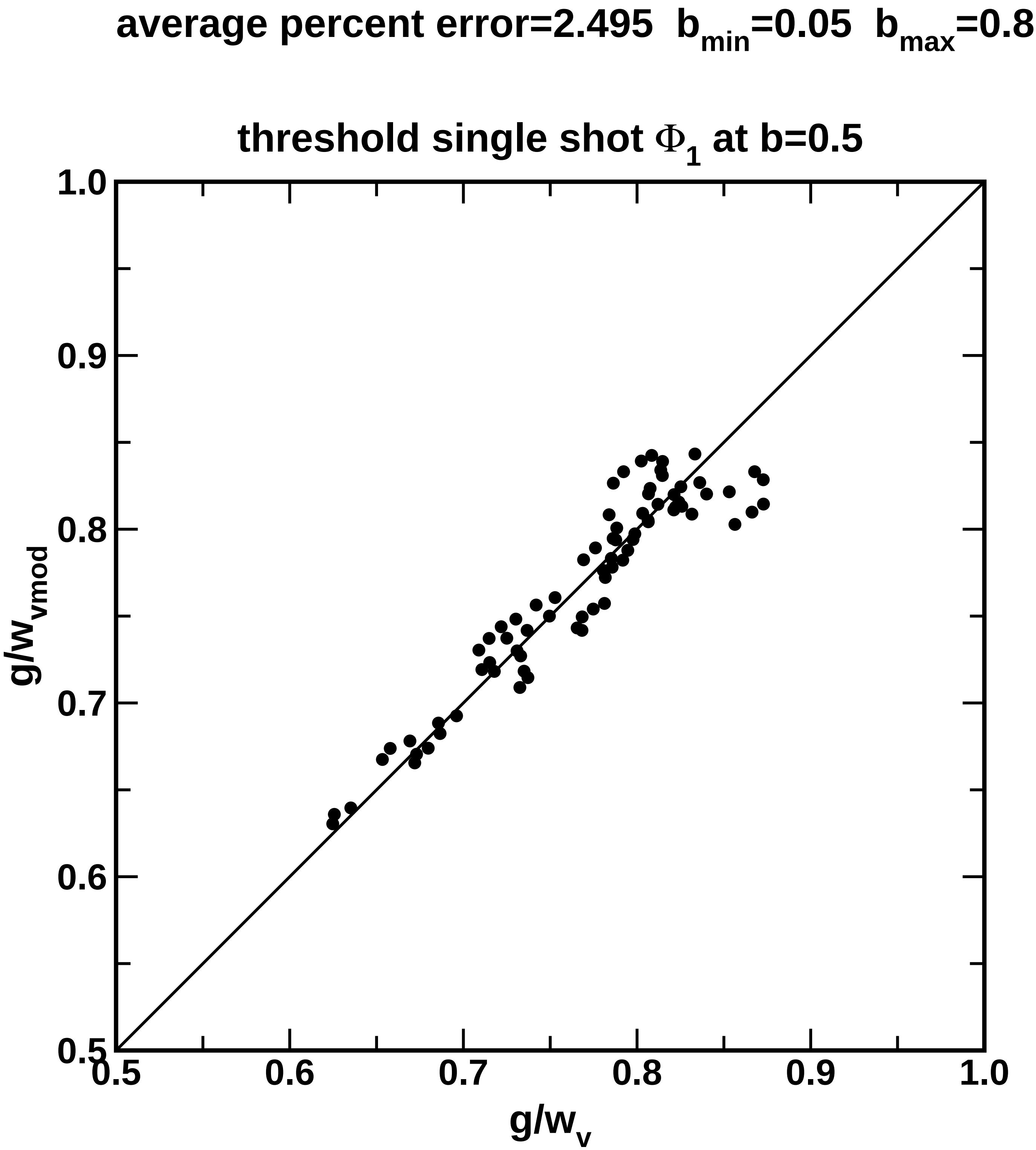
threshold single shot Φ_1 at b=0.5



average percent error=2.911 b_{min}=0.005 b_{max}=0.4

threshold single shot Φ_1 at b=0.1





average percent error=2.495 b_{min}=0.05 b_{max}=0.8
threshold single shot Φ_1 at b=0.5
1.0
0.9
0.8
0.7
0.6
0.5
g/w_{vmod}
0.5
0.6
0.7
0.8
0.9
1.0
g/w_v

SUMMARY

- Performance in threshold region described by four basic parameters

- Simple scaling laws for threshold signal level and LOS velocity error at threshold

- Full parameter space must be investigated

- Determine atmospheric conditions for validity of the effective Gaussian signal model

- Spatial velocity and backscatter statistics over the measurement plane are required

- Hope to incorporate general performance predictions in GTWS modeling efforts