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Strategy for a better understanding of key atmospheric parameters

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Turbulent Parameters Overview: integrated quantities

- **Fried parameter ro**
  - definition: level of high spatial frequencies, related to Cn^2 integral
  - impact on design and performance of AO/MCAO/Interfero !!
- **Outer-Scale Lo**
  - definition: fit of low spatial frequencies with Von Karman model
  - impact on design and performance for ELT-AO/MCAO and Interfero

    stroke of DMs, requirements for tip/tilt, AO PSF shape, OPD amplitude
  - question: validity of Von Karman model for large scales??
- **Mean wind speed V and τo**
  - definition: ad-hoc , in practice: fit of temporal PSD, correlation time...
  - impact on sampling frequency and performance
- **Isoplanatic angle θo:** rough evalution of anisoplanatism

Turbulent Parameters Overview: distributed quantities

- **Cn^2 profile**
  - impact on MCAO/GLAO/MOAO design and performance/sky coverage
  - impact on AO performance/sky coverage
- **Outer-Scale profile Lo(h)**
  - impact on MCAO design (DM requirements) and performance
    particularly for ELTs
- **Wind speed profile V(h)**
  - influences global temporal PSD: derived from wind profile
    through Taylor hypothesis for each individual layer
  - impact on sampling frequency and performance
  - question: validity of Taylor hypothesis for large diameters/bases??

Distributed quantities give fine understanding of spatial/temporal behavior crucial for new demanding systems: MCAO, XAO...

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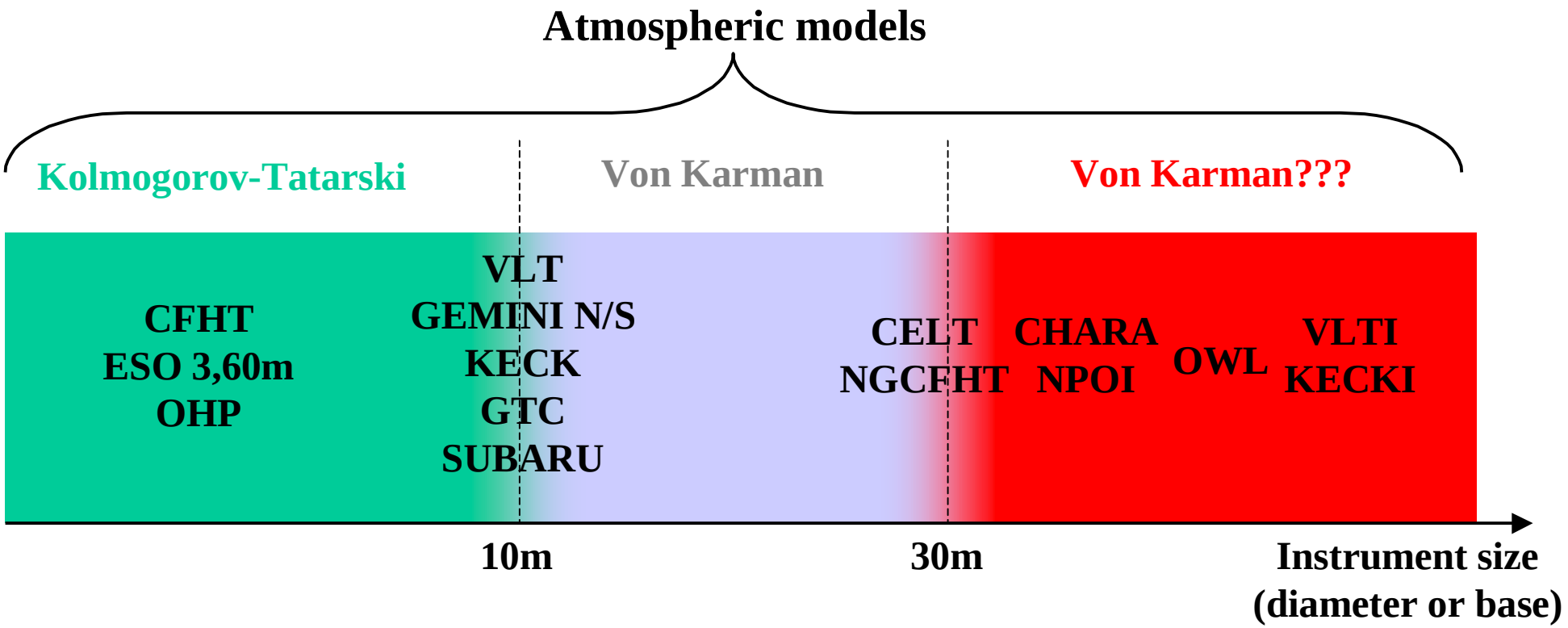
New Instruments New Spatial/Temporal Scales

- towards lower spatial frequencies:



- XAO also ask for higher spatial and temporal frequencies

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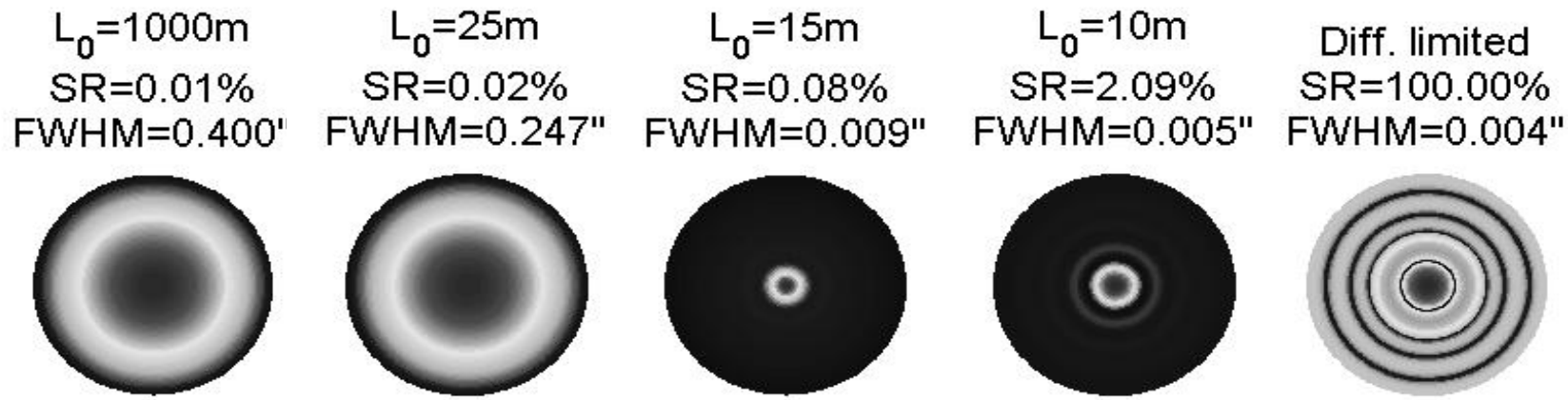
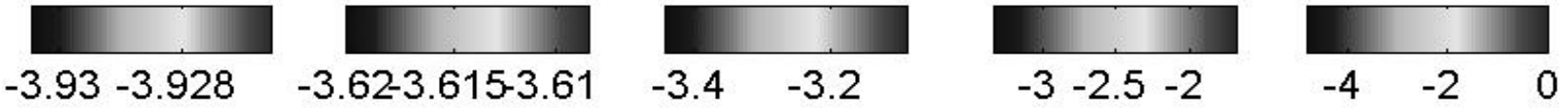
Outer scale effects on ELTs without any phase correction



OWL PSF(log-scale) versus Outer Scale (r_0=0.8m@2.2μm)



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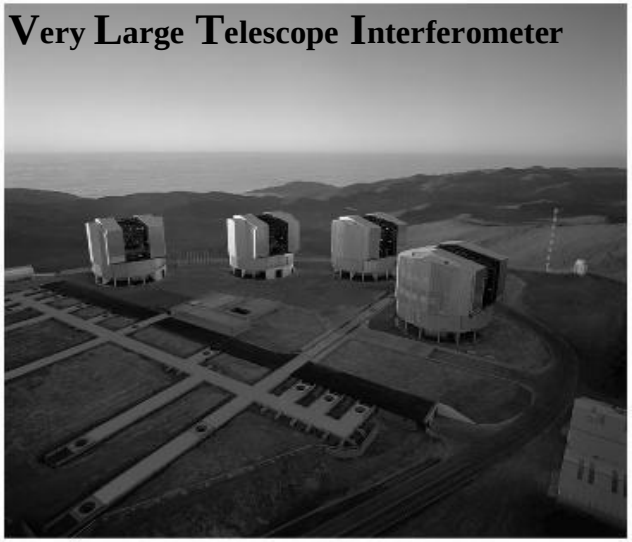
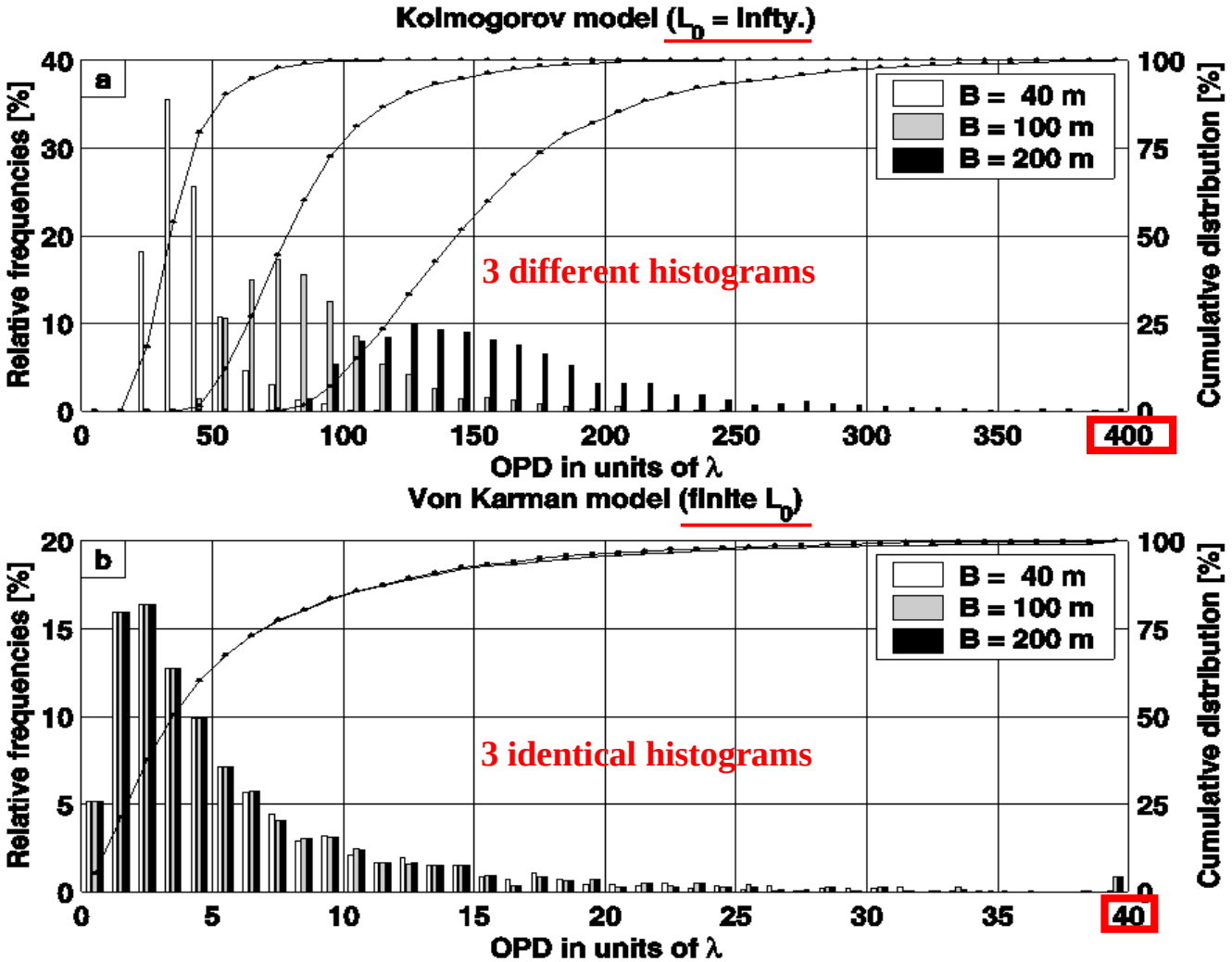
Impact of Lo on Interferometers

Statistics of OPD standard deviation on UT-VLTI





Turbulent Parameter Measurement

- **Turbulence strength:**
  - **ro:** DIMM and all systems
  - **Cn^2 profile:** SCIDAR, MASS, Balloon, temperature probes on mast
    cross-validation with AO/MCAO performance in FoV
  - **very high spatial frequency PSD:** NAOS-CONICA PSF wings
- **Outer-Scale:**
  - **global Lo:** GSM, VLTI (Vinci, FSU), NAOS, MACAO,
  - **profile Lo(h):** MAD data, specific balloons?
  - **Von Karman validation:** multi-baseline VLTI data
- **Wind speed:**
  - **mean wind speed:** all instruments with temporal resolution
  - **wind speed profile:** SCIDAR, Balloon
  - **Taylor hypothesis validation:** temporal PSD of VLTI data?

Turbulent Parameter Estimation

- **Large variety of existing/planned instruments could be used in a major multi-instrument campaign at Paranal**
- **All instruments give complementary and cross-validating data simultaneous use required**
- **Statistical processing of each instrument data**

  → **turbulence parameters**

  → **no need to synchronize instruments**

Generalized Seeing Monitor GSM

Systematic measurement of the Outer-Scale L_0

The *Generalized Seeing Monitor* has been developed at the Département d 'Astrophysique de l 'Université de Nice

Principle:

- Angle of Arrival [AA] measurement on four 10cm telescopes
- ro estimation from differential AA variance
- Lo estimation from AA covariances

Main result from different campaigns:

Oukaimden (Maroc), Calern (France), Paranal, San Pedro Martir (Mexico)

- **median Lo between 20m and 30m for all sites**
- ~20% L_0 < 10 m ~ Ø VLT, Keck, Gemini << bases on VLTI, ...

• **R. Conan et al., JOSAA, 2000**
•**Martin, R. Conan et al., A&A, 2000**
•**Ziad, R. Conan et al., AO, 2000**

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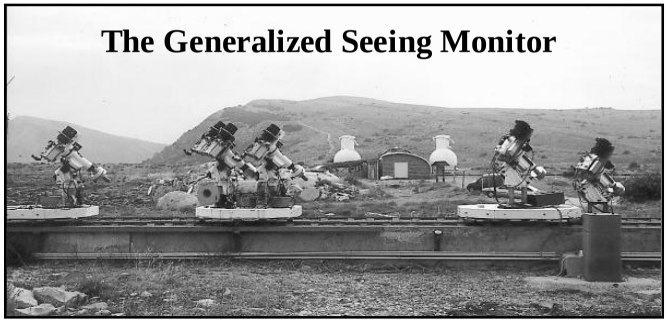
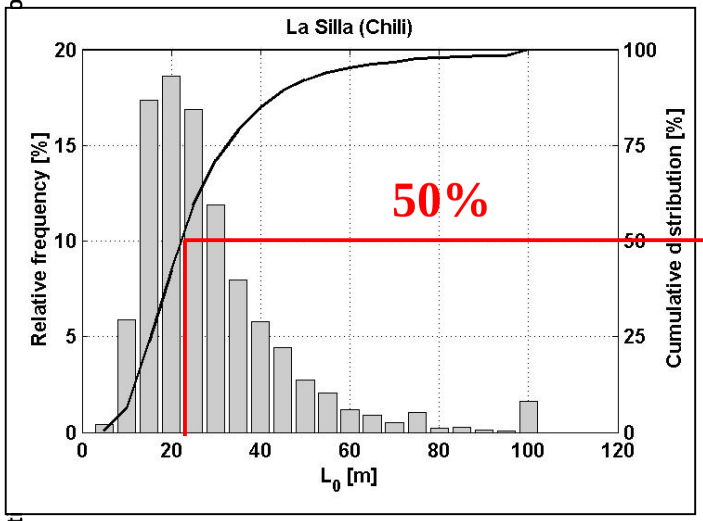
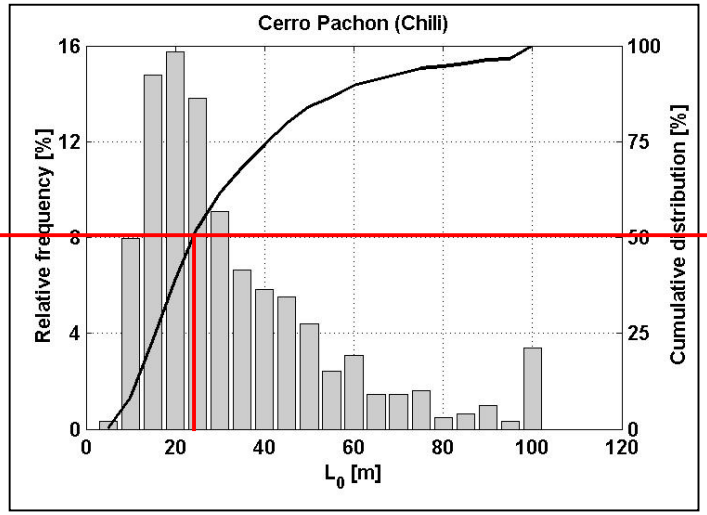
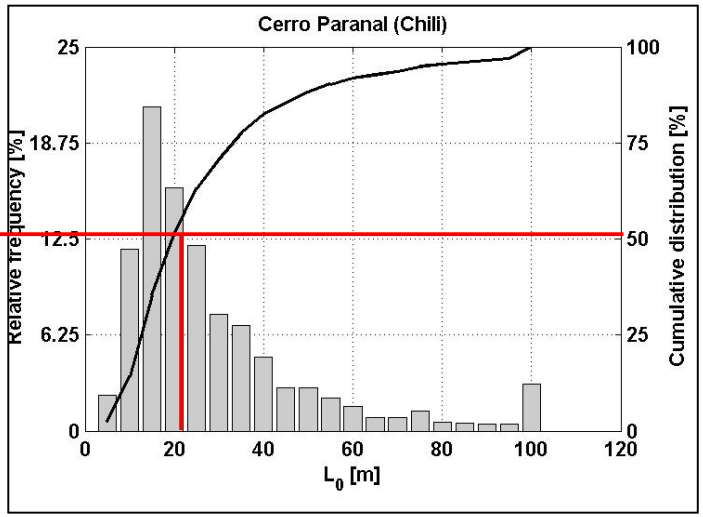


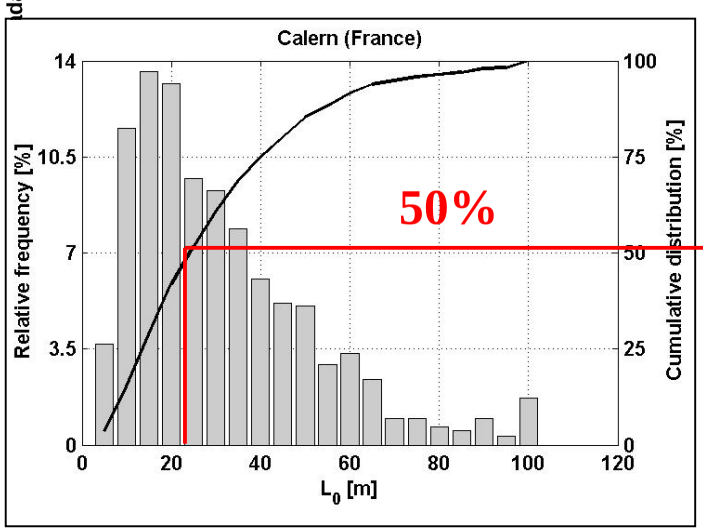
Generalized Seeing Monitor

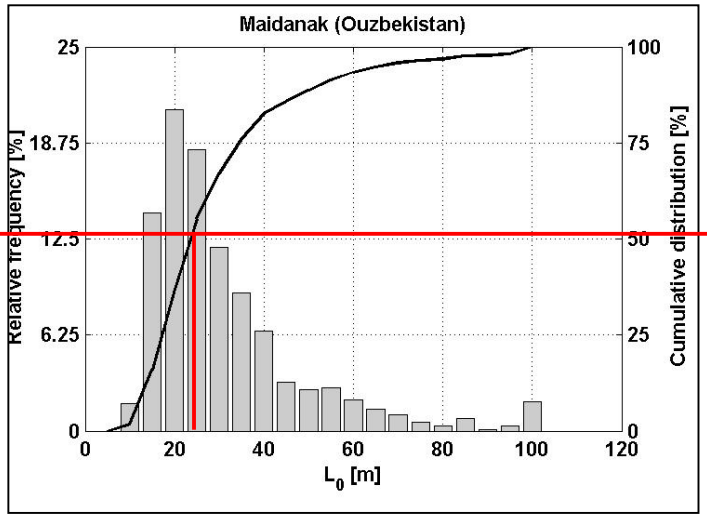
A unique tool for systematic surveys

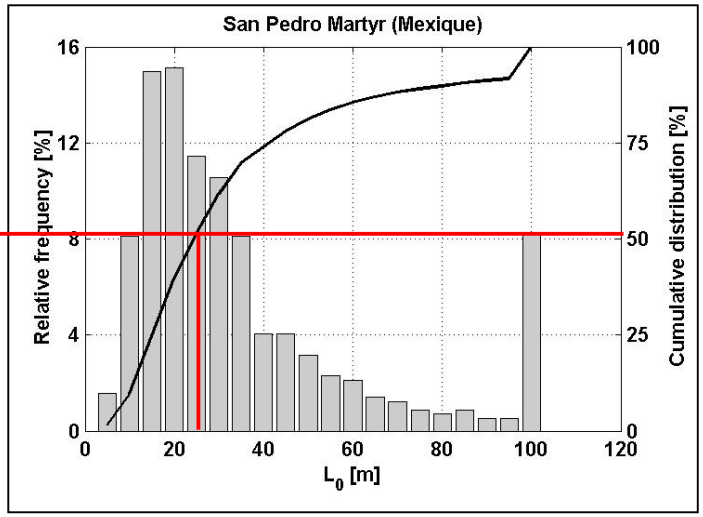








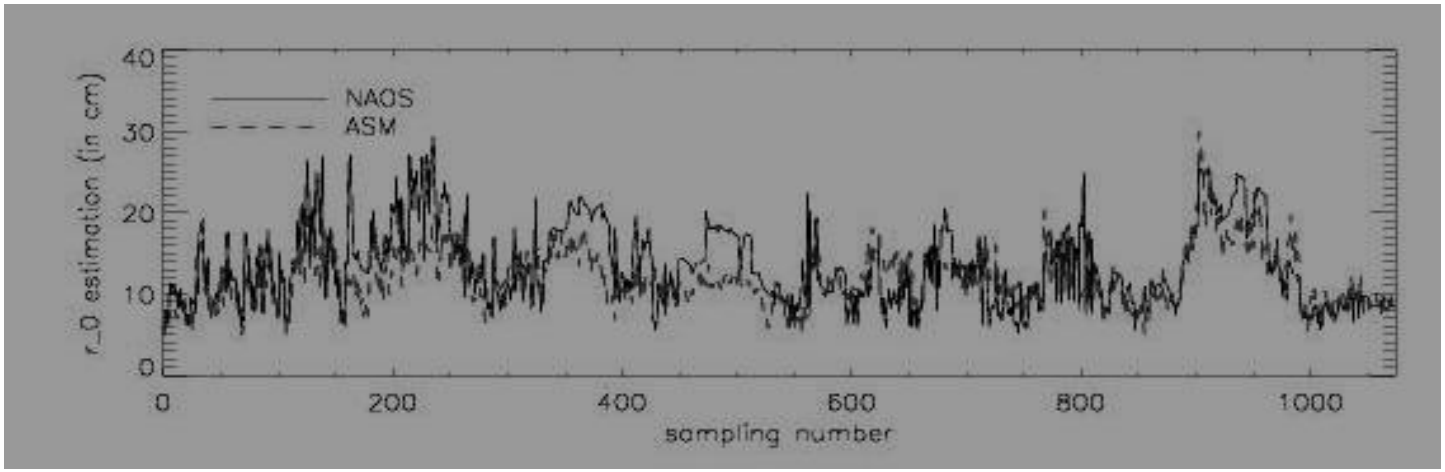


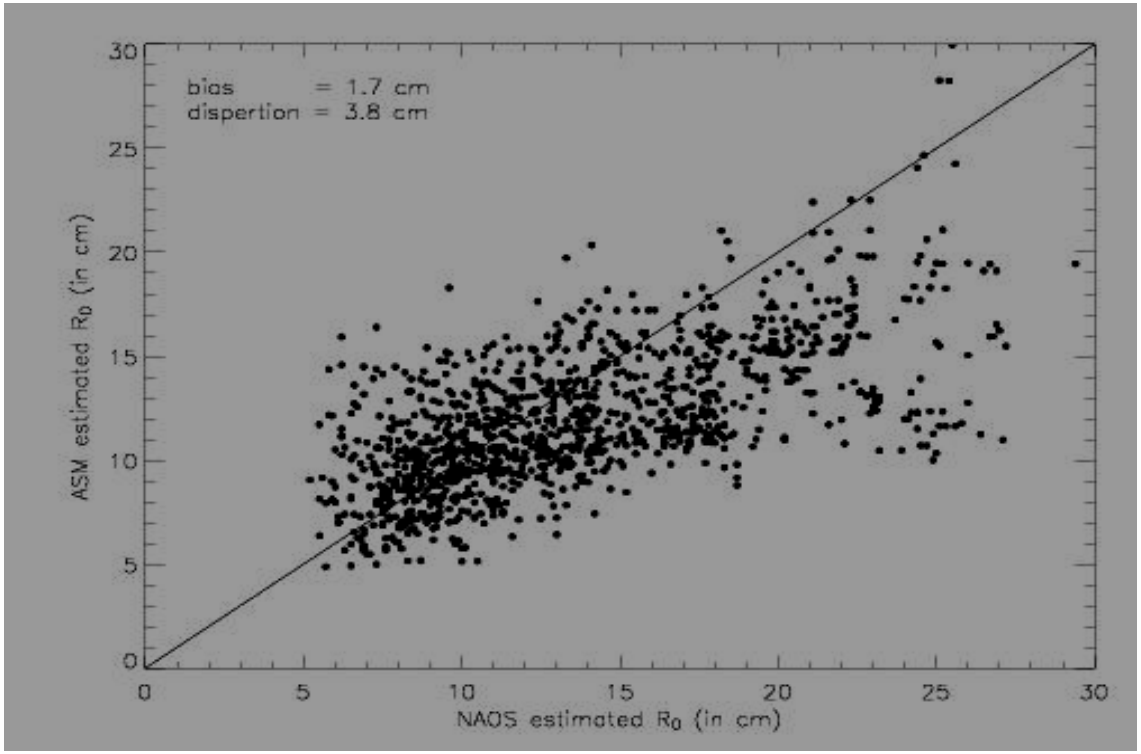


Turbulent Parameter Estimation with NAOS/CONICA

- **NAOS: VLT high order AO: 15x15 DM ; 14x14 vis. SH-H. ; 500Hz sampling freq.**
  - Zernike variances (spatial spectrum 60cm to 8m scales)
  - Zernike temporal spectra (up to 250Hz)
  - Estimation of ro , Lo (up to few 10m) , mean wind speed
- **CONICA: IR-camera ; 1 to 5 microns**
  - PSF profiles → HF phase spatial PSD (scales below actuator spacing)
  - PSF evolution in the field → anisoplanatism effects, linked to Cn^2 profile

Estimation of ro: Comparison NAOS/ASM





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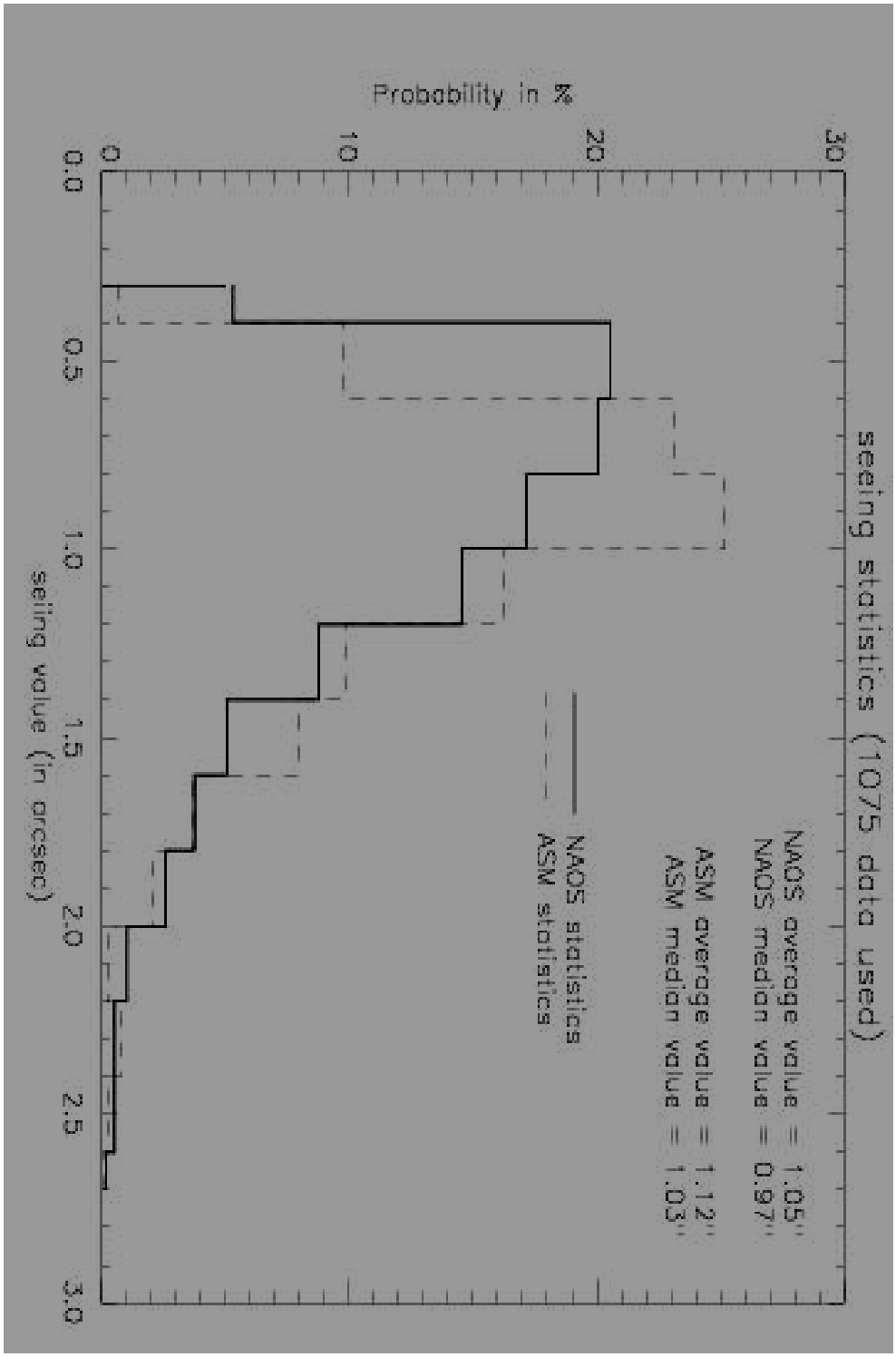
Seeing (λ/ro) statistics: Comparison NAOS/ASM



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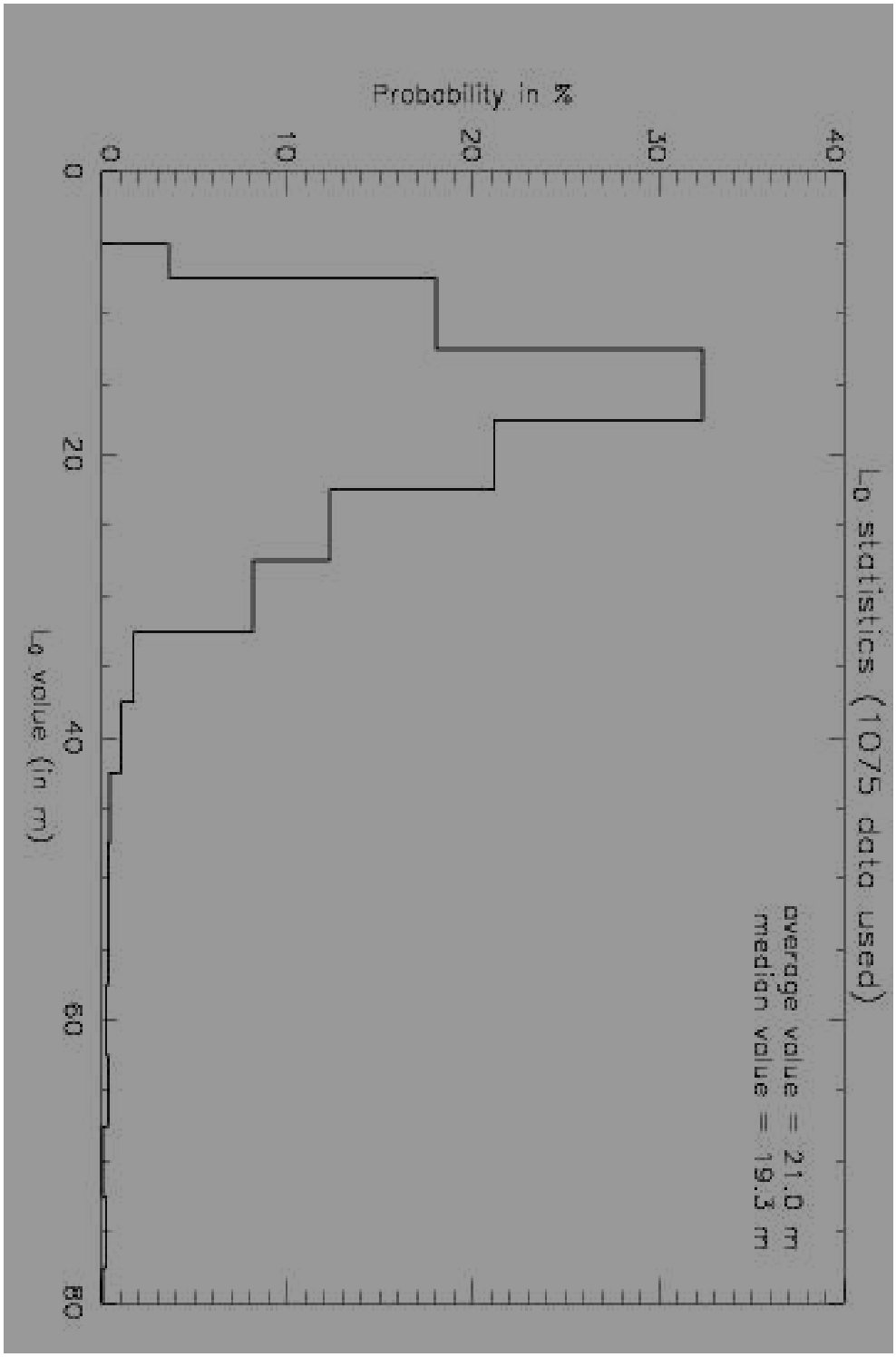
Estimation of Lo with NAOS



Few meter precision for 20m Lo

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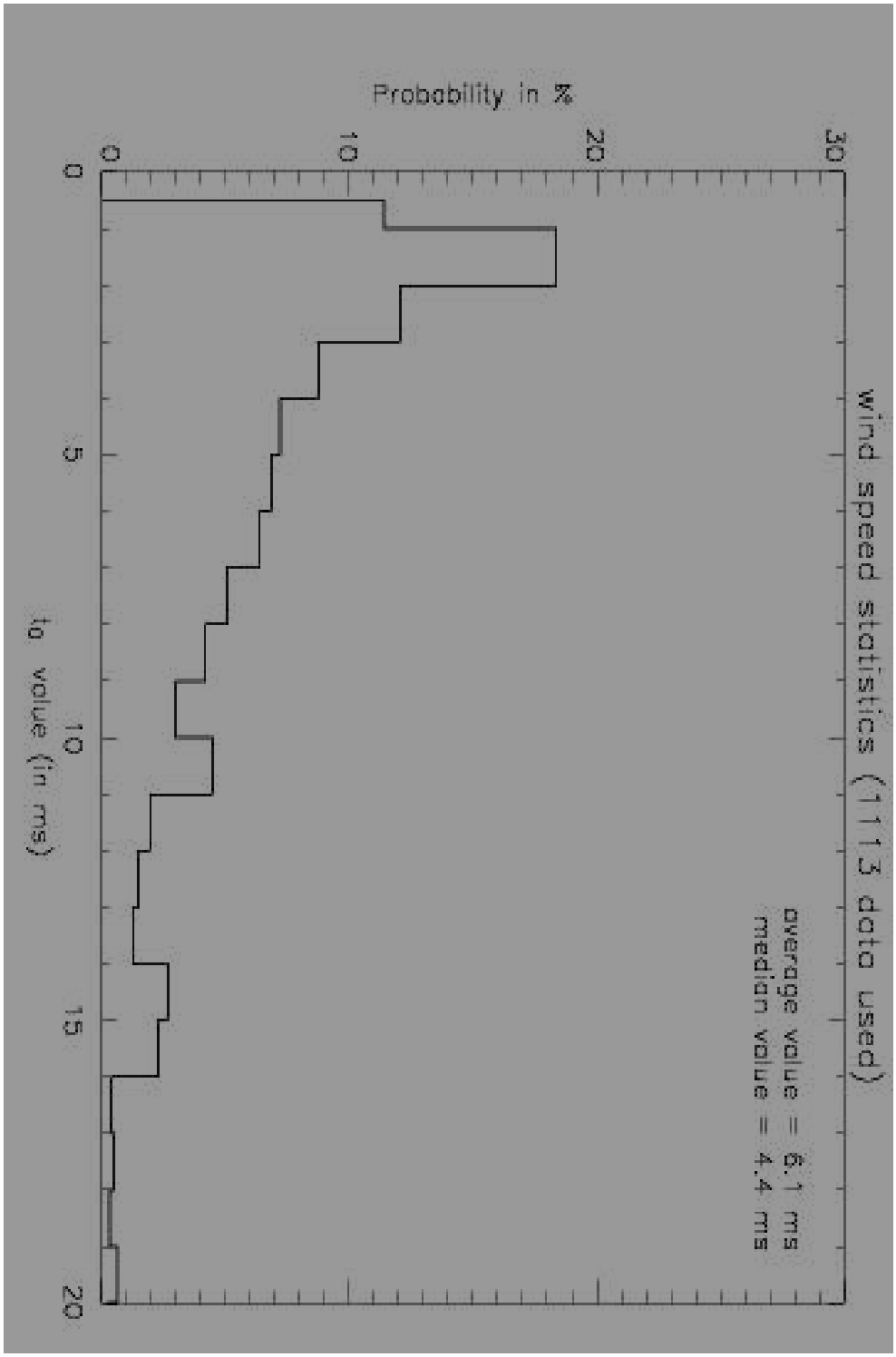
Mean wind speed statistics with NAOS



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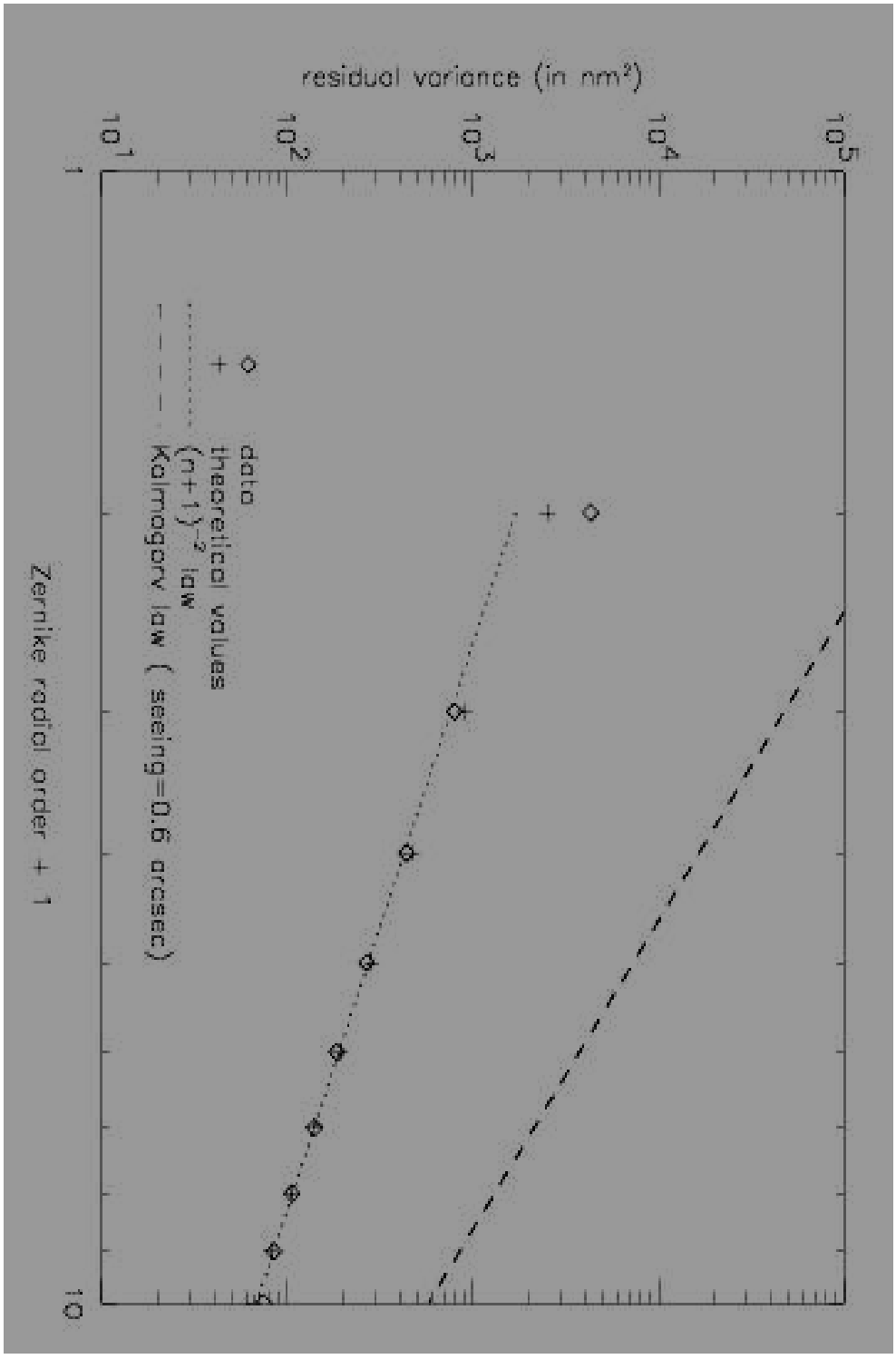
NAOS Zernike Residual Variance



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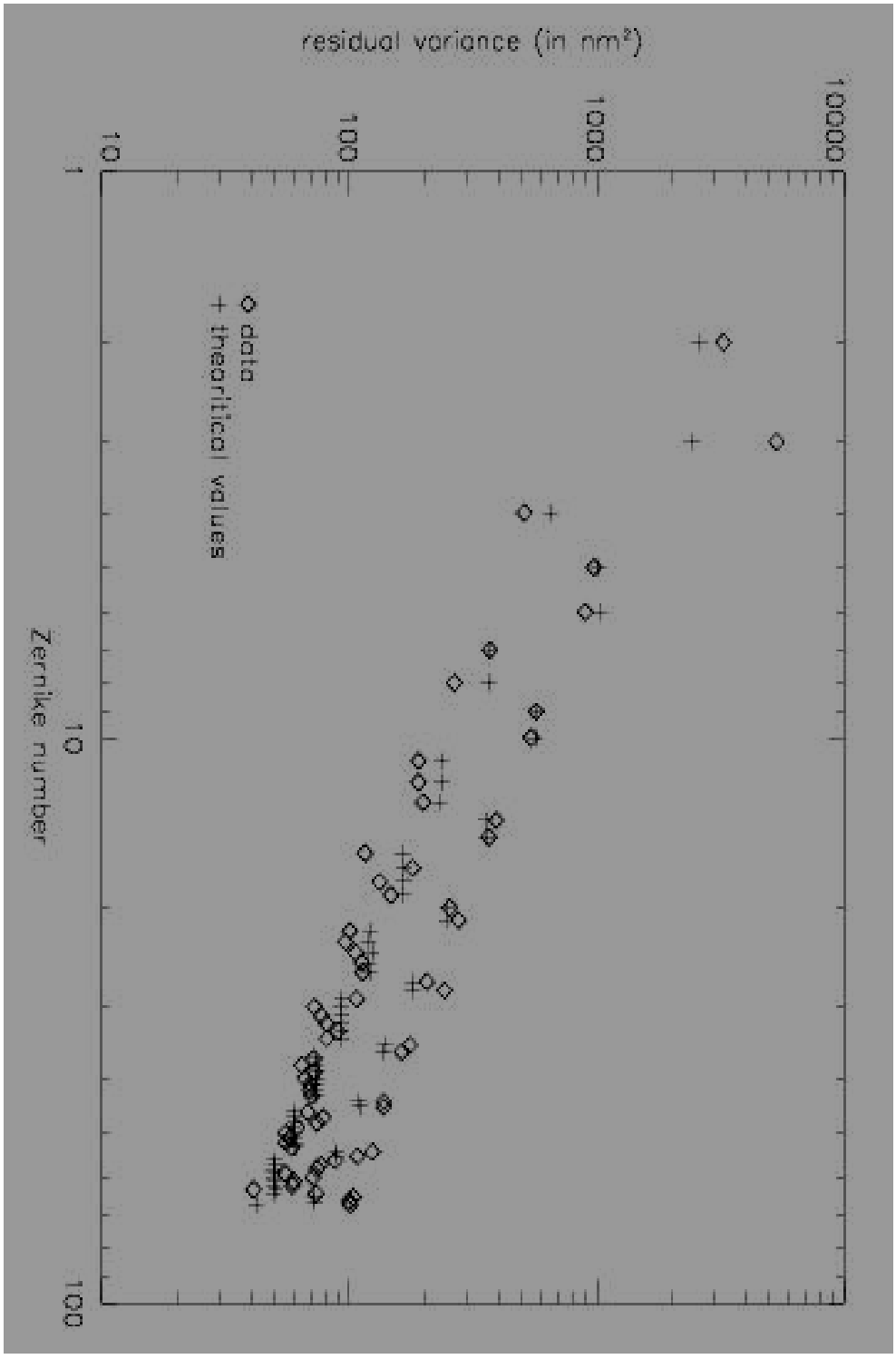
NAOS Zernike Residual Variance



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Proposed Plan

- **Process existing data on various systems**
  - compare turbulent parameters estimated with different data/methods
  - analyze and improve processing procedures
- **Multi-instrument campaign at Paranal**
  - record simultaneous data on ASM/Scidar/GSM/MASS/Balloons and NAOS/MACAO/MAD/VLTI…
  - extract/compare turbulence parameters
  - study/validate models (Von Karman, Taylor…)
  - define key parameters and propose a site testing plan for ELTs
- **Site testing**

  systematic measurement of key parameters on long time period

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