SOAR Adaptive Optics Concept

July 12, 2001, CTIO

Meeting goals:

- **Form a discussion group for SOAR-AO project from CTIO, NOAO, MSU, UNC**
  critics, science case, ideas
  To inscribe yourself: e-mail to atokovinin@ctio.noao.edu
- **Present the work done to date**
- **Collect suggestions**

Materials at: http://www.ctio.noao.edu/~atokovin/soar/

AO project goals:

- **Enhance SOAR science**
  NIR? **– > Gemini MCAO is 4 times** (1.5^m) **better**
  Visible? **– > SOAR science is nearby, z=0!**
  15 mas pixels, 4K detector – > $60''$ **FoV**
- **Test bench for GSMT and LSST**
  expertize, test concepts
  (now NOAO is weak in adaptive optics)

AO requirements: Compensate large FoV
to diffraction limit
in the visible
with uniform PSF and
full sky coverage.

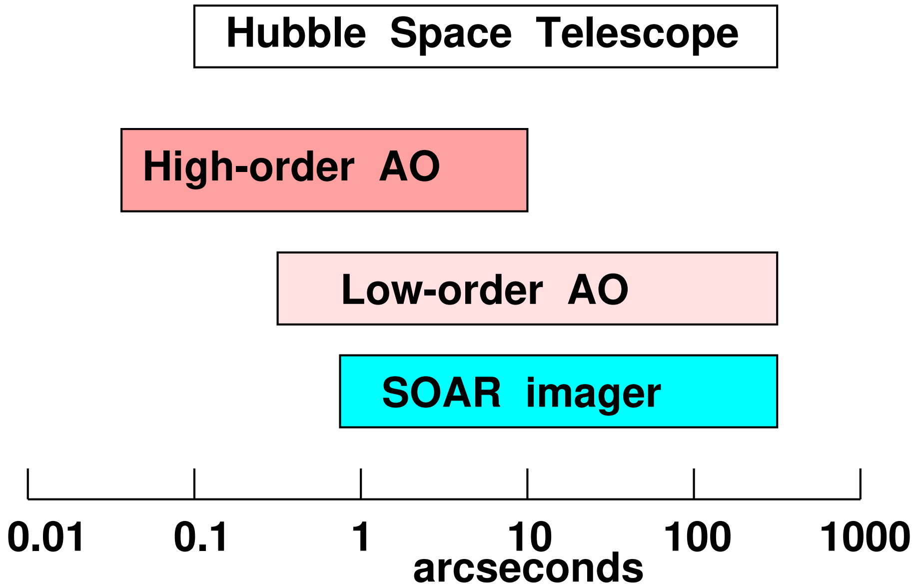
What SOAR AO can do?

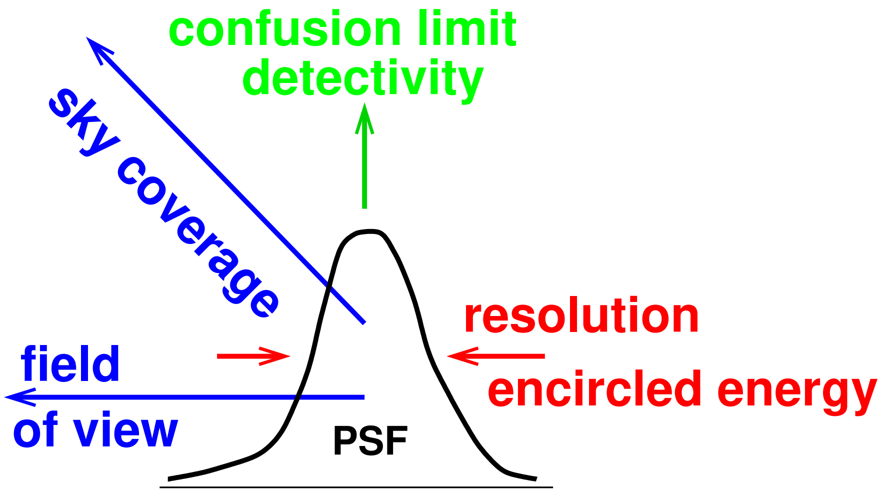
2x seeing improvement – > 8 m for faint source detection
Diffraction-limited – > resolution 2x HST

Realistic solutions

Option	Zernike	Sub-apert.	Guide stars	FoV	FWHM gain
Tip-tilt	3	4.2 m	3 NGS, 17^m	$5'$	1.1
Low AO	21	0.9 m	3 NGS, 15^m	$5'$	1.3
High AO	66	0.5 m	1 NGS, 10^m	$10''$	16

New/other solutions?





- **Strehl ratio**
  Fried resolution = Strehl/Strehl(atm.)
  intensity of central pixel
- **FWHM**
- **Encircled energy** $E(r)$
- **Detectivity:** ***Signal-to-noise*** $= \frac{n_{\rm star} E(r)}{r\sqrt{\pi m_{\rm backg}}}$

Equivalent Detectivity Diameter, EDD:

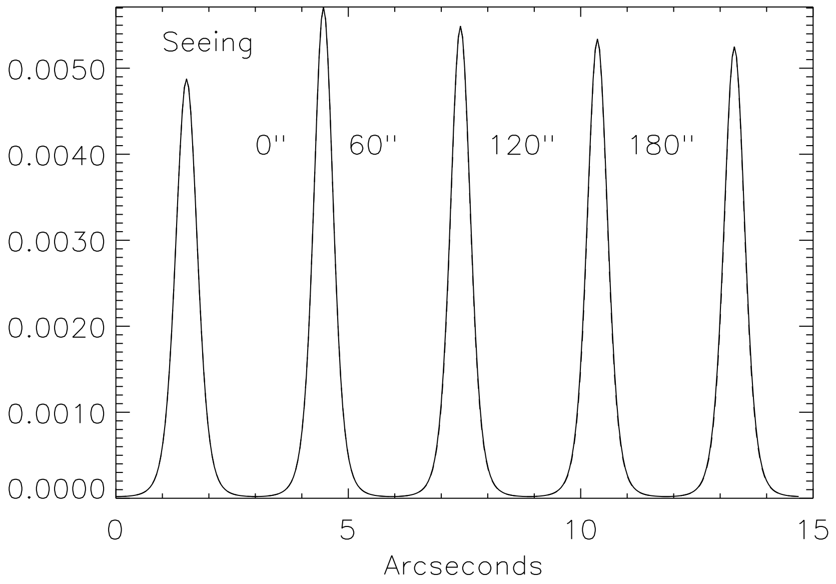
$$\mathrm{EDD} = \frac{2}{\max[E(r)/r]}$$

Seeing at Cerro Pachon

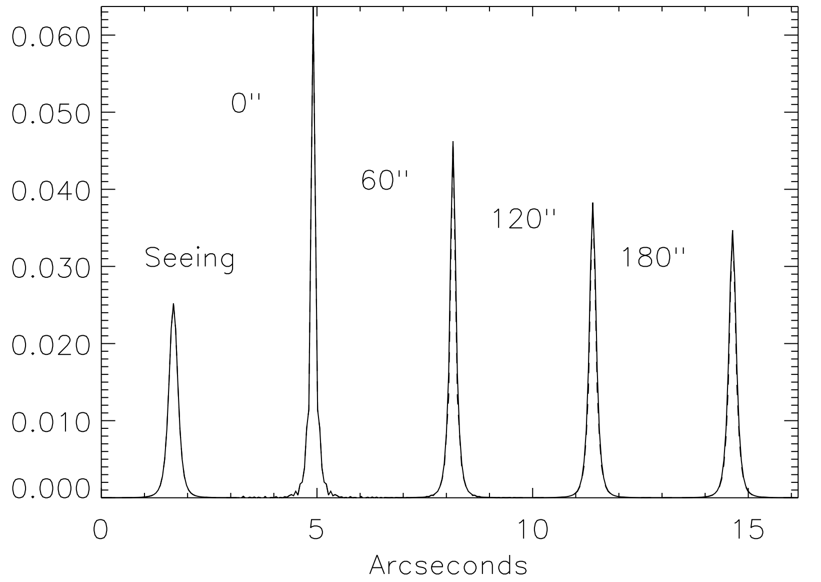
Gemini-Pachon report

- **Median, zenith:** $r_0 = 15$ **cm at 0.5 micron**
  FWHM $= 0.68''$ **(degradation by 1.23 at** $z = 45°$ **!!!)**
- **First quartile (25%):** $r_0 = 20$ **cm**
  FWHM $= 0.49''$
- **Vertical distribution:**
  7 layers, 0-16 km, 65% in the ground layer
- **Free atmosphere (1 km above Tololo):**
  median FWHM $= 0.50''$ **(40% in the ground layer?)**
- **Outer scale** $L_0 = 25$ **m (variable)**
  Significant influence on FWHM!
- **Not modeled:**
  Telescope shake
  Static aberrations, dome seeing

Tip-tilt compensation: 1 NGS off-axis

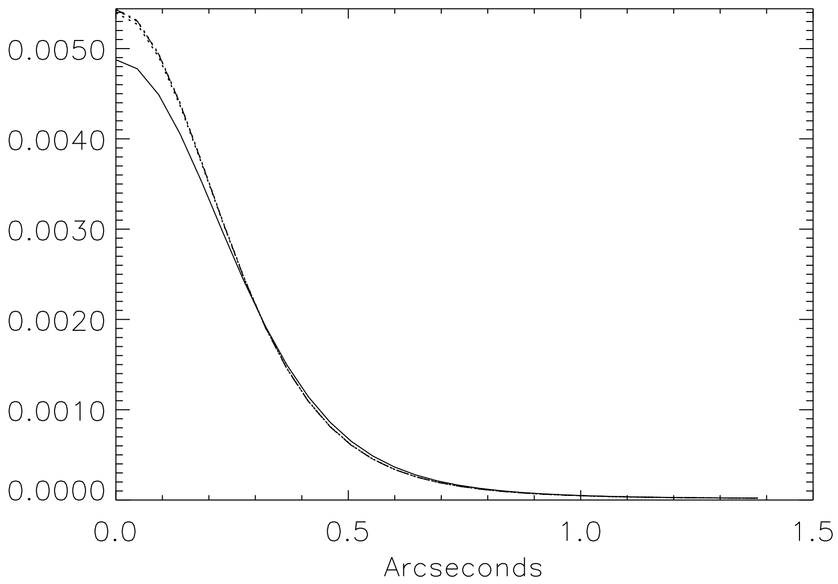


Median seeing, 0.5 micron

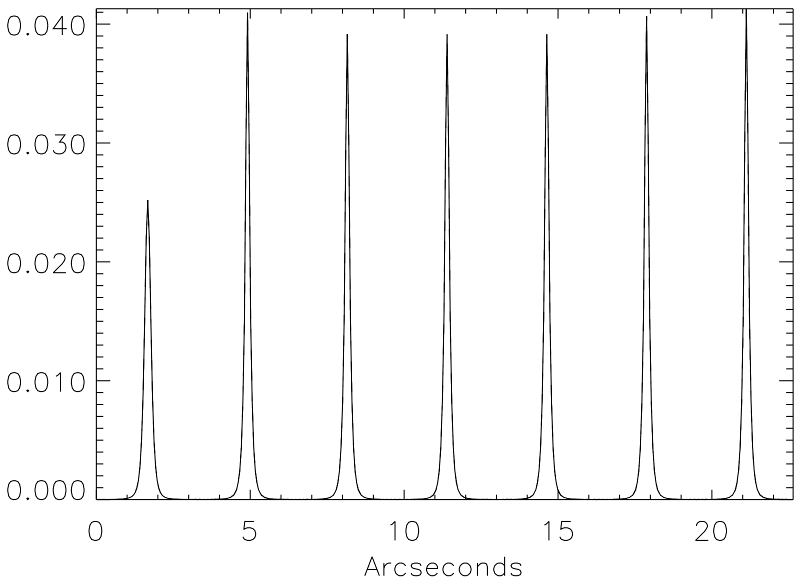


Good seeing, 2.2 micron

Tip-tilt: 3 NGSs around FoV

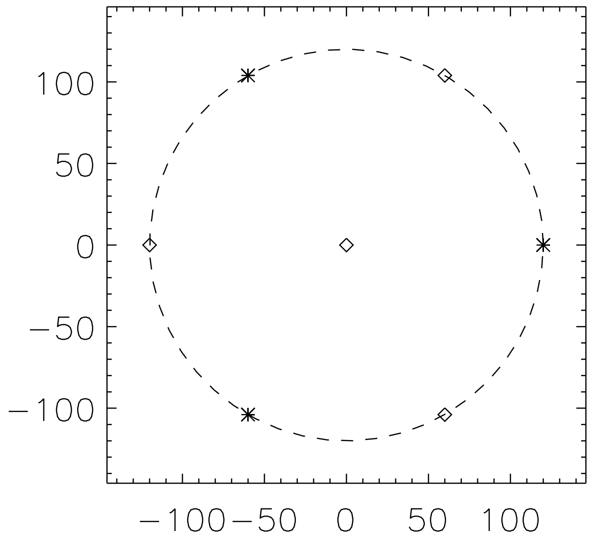


Median seeing, 0.5 micron

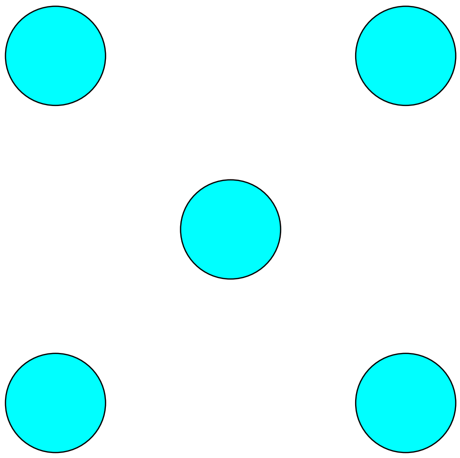


Good seeing, 2.2 micron

Low-order AO: geometry

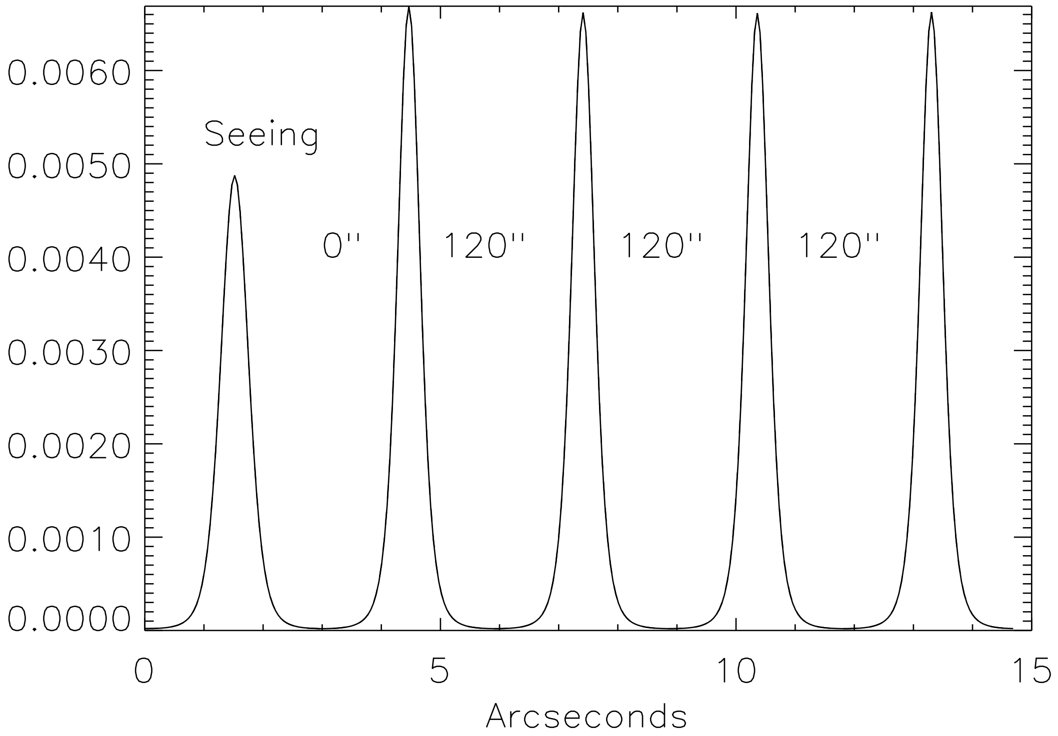


3 NGSs at 2 arcmin. from FoV center



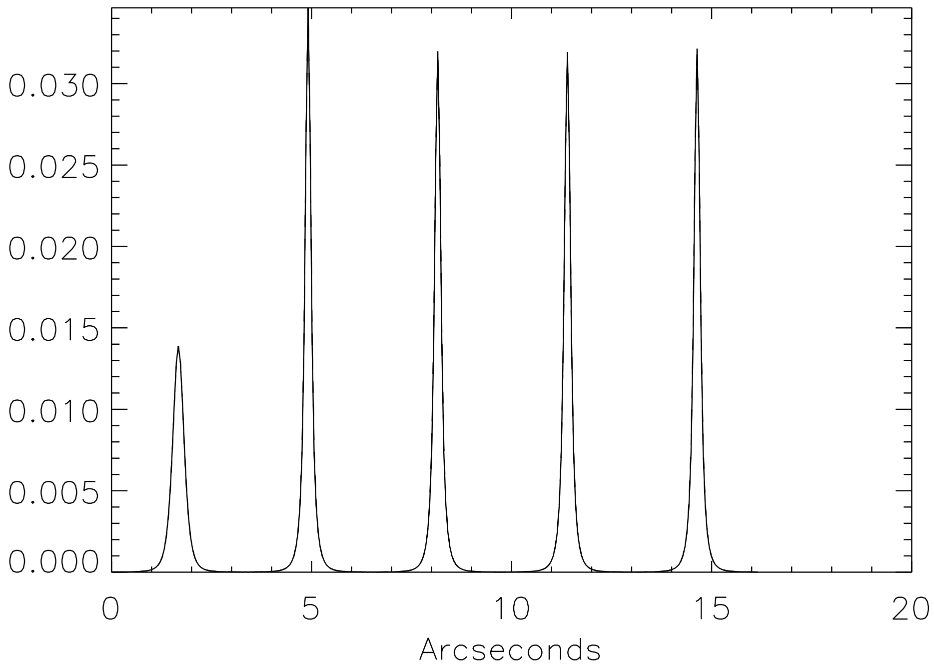
Why not MCAO? See beam footprints at 10 km, 5 arcmin. FoV

Low-order AO: PSF uniformity



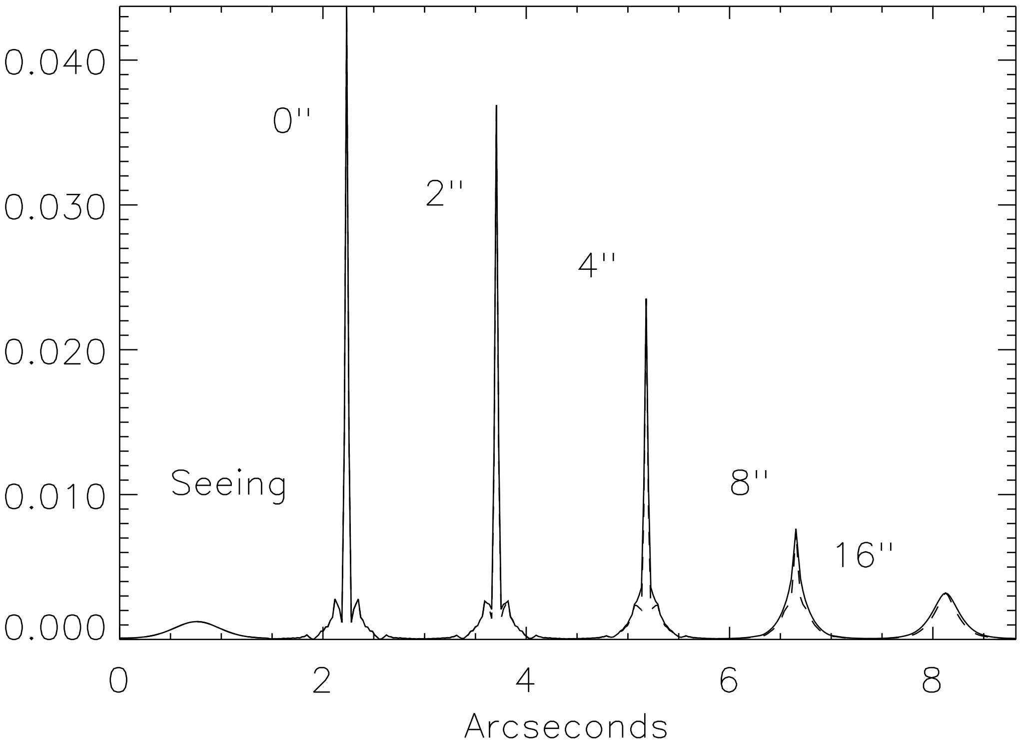
Median seeing, 0.5 micron, three 15^m NGSs

Low-order AO: PSF uniformity in K



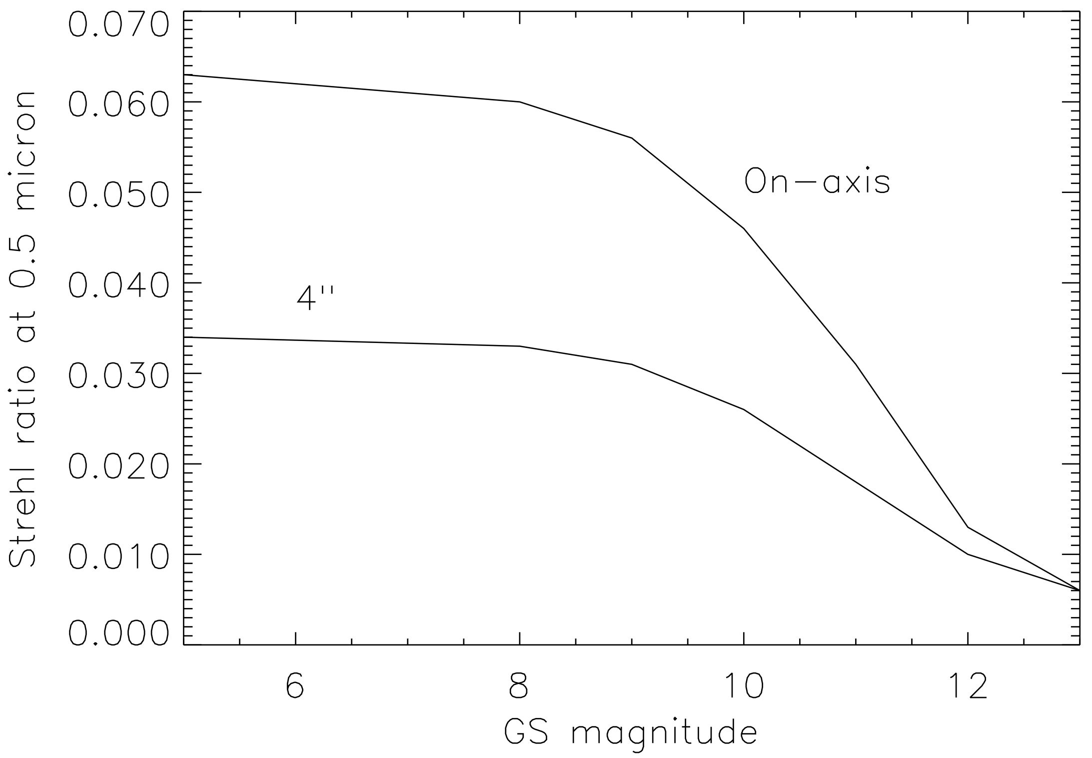
Median seeing, 2.2 micron, three 15^m NGSs

High-order AO: PSF uniformity



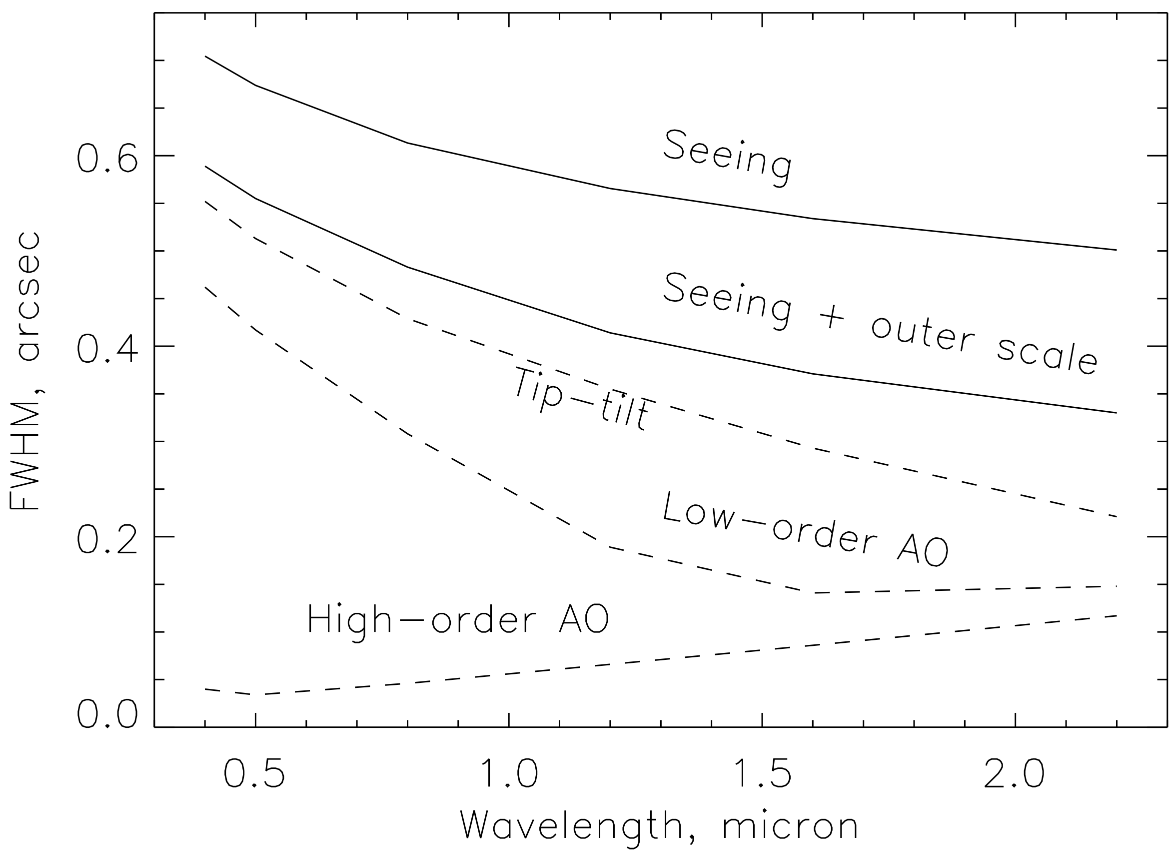
Median seeing, 0.5 micron, one 5^m NGS
We can 'flatten' FoV with less on-axis Strehl

High-order AO: limiting magnitude

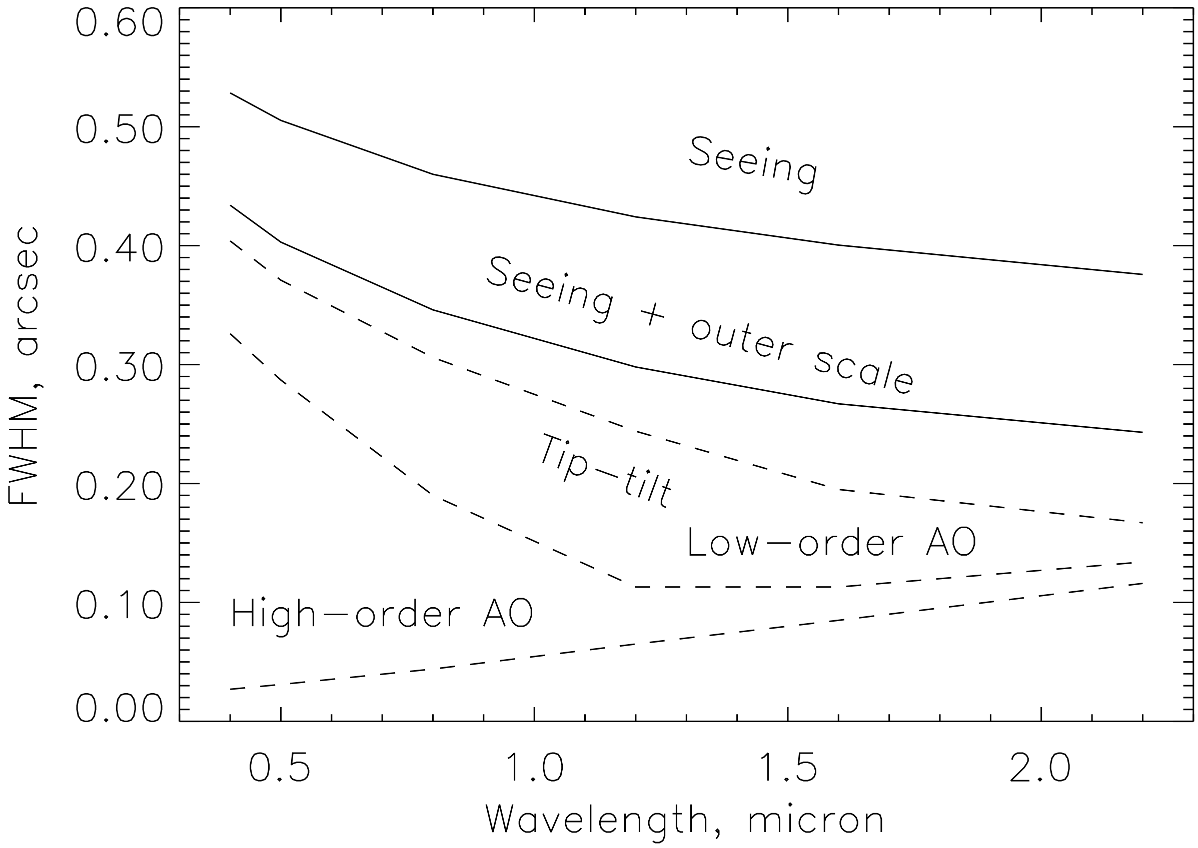


Median seeing, 0.5 micron

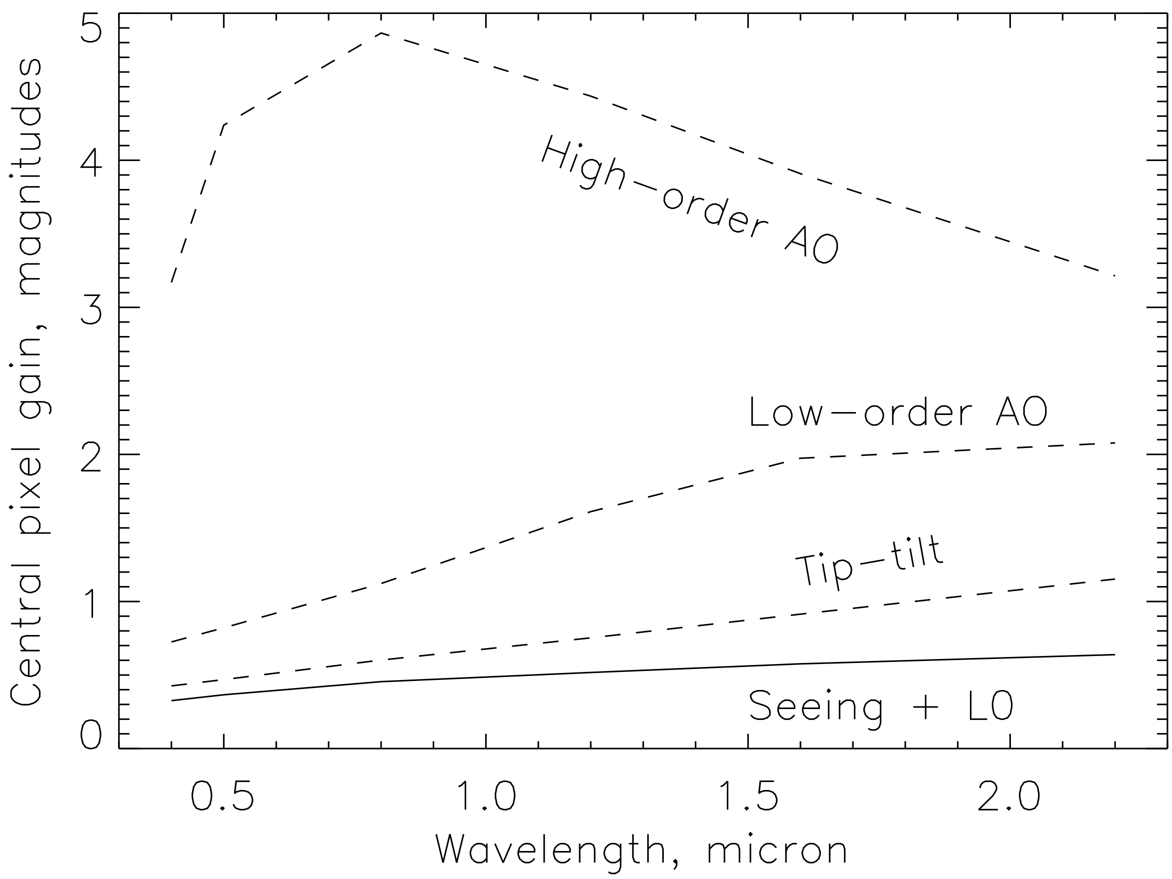
FWHM gains: median seeing, $r_0 = 15$ cm



FWHM gains: good seeing, $r_0 = 20$ cm

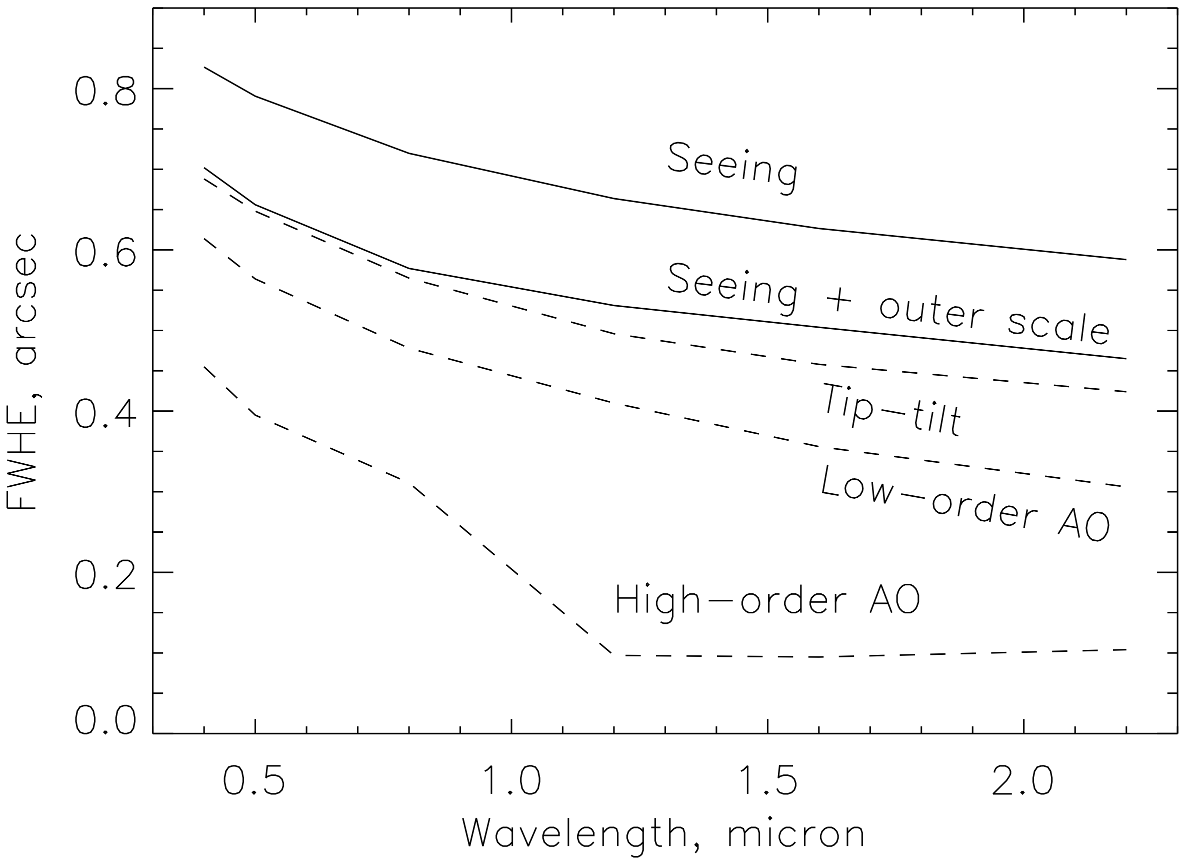


Intensity of the central pixel



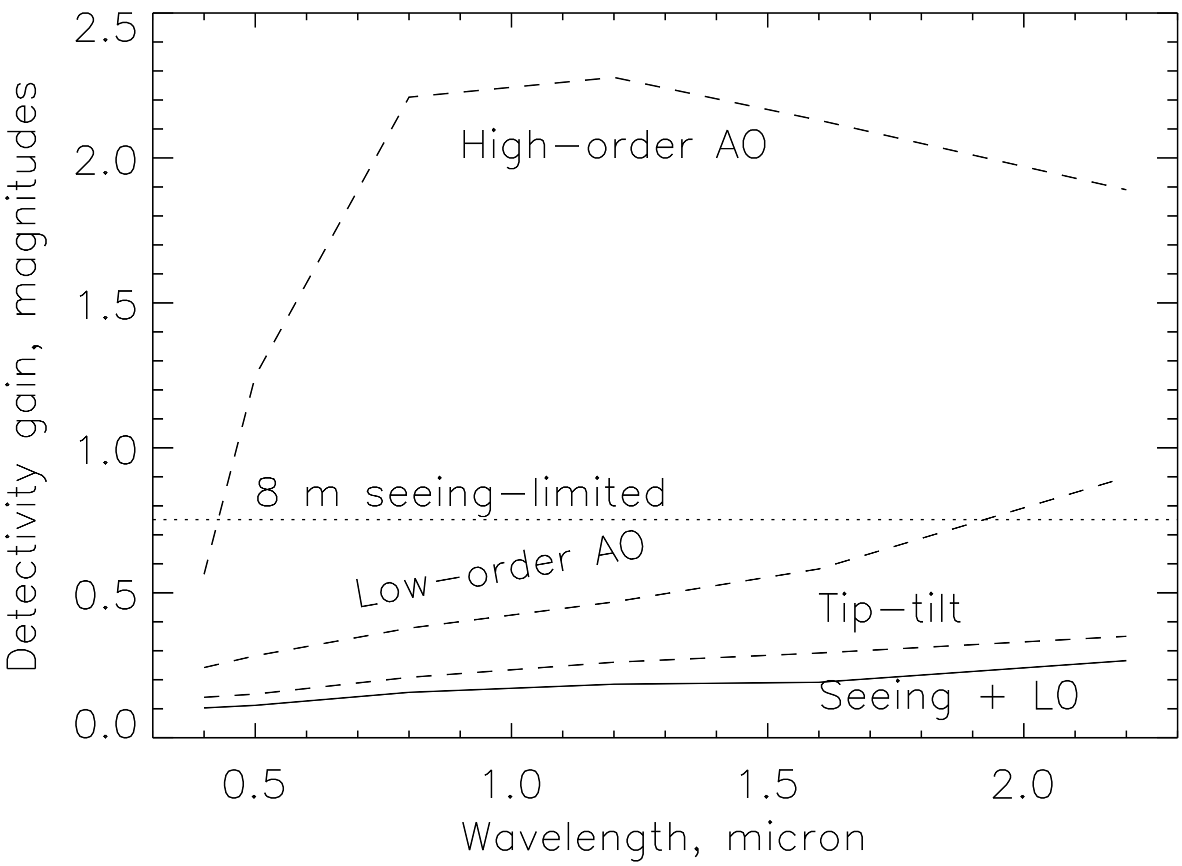
Gains for median seeing

Encircled energy



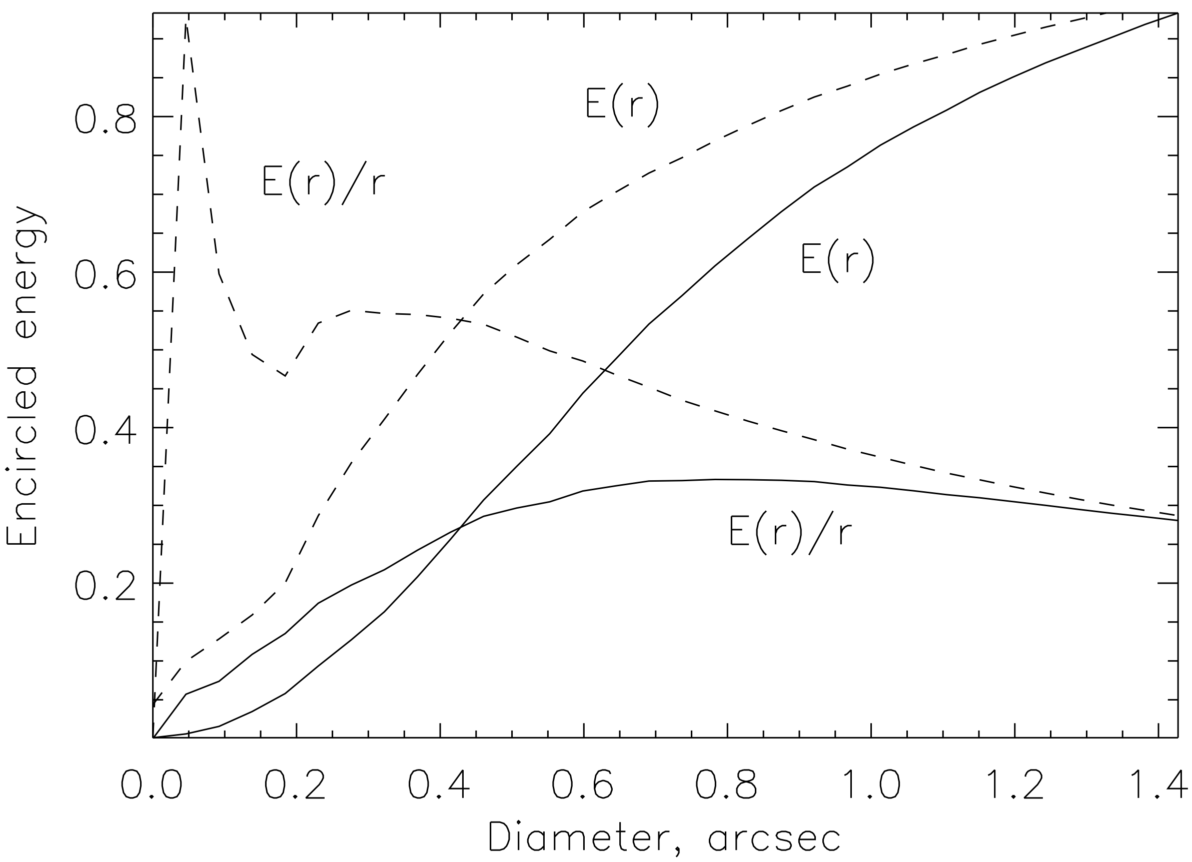
Median seeing

Detectivity



Median seeing

Detectivity: high-order AO



Median seeing, on-axis, 0.5 micron

Performance summary

Option	FoV	FWHM	Detect. gain	Strehl K-band	Sky cover.
Seeing	$5'$	$0.55''$	**0**	**0.08**	**Full**
t-t	$5'$	$0.51''$	0.04^m	**0.13**	**Full**
Low AO	$5'$	$0.42''$	0.17^m	**0.20**	**Fair**
High AO	$\approx 10''$	$0.034''$	(1.11^m)	**0.86**	**Low!!**

Upgrades:

High-order + Rayleigh LGS (spinning?)
$0.4''$ ***median seeing over*** $5'$ ***FoV?***

High-order + sodium LGS (+tomography?)
Diffraction-limited uniform PSF over $30''$***?***
Better sky coverage?