Turkey's Next Big Science Project: DAG the 4 Meter Telescope

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Introduction

- **DAG project**: "Eastern Anatolia Observatory" in Turkish.
- Launched in **2012.**
- Fully funded by Turkish Government.

Location: *Erzurum, Turkey*	Optics: *Ritchey-Chretien; Diffraction Limited with aO+AO*
Altitude: *3170 m*	*f: 56m*
Mount: *Alt-Az*	
Diameter: *4 m*	FoV: *30 arcmin*

- The low order figuring errors (optical train of M1-M2-M3) are defined in terms of **Zernike coefficients** and referred to the M1 surface area.
- The high order figuring errors are defined using the **phase structure functions**.
- **GLAO** (ground layer adaptive optics) design is developed concurrently with the telescope.

Design Requirements

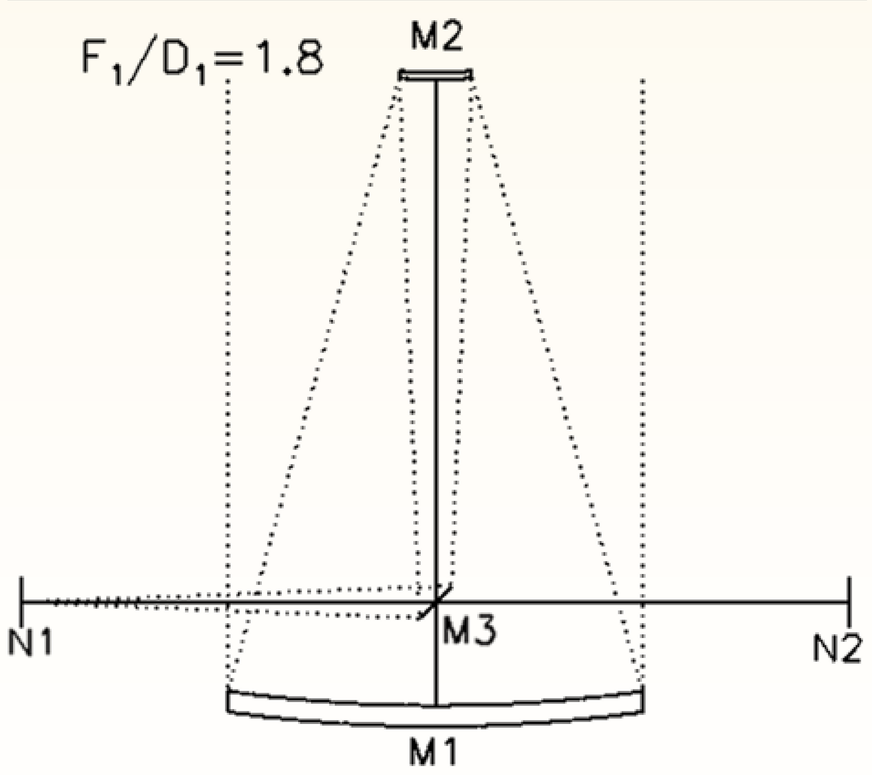
- **Telescope Central Obscuration**
  Target: 20-30%, Goal: <20%
- **Ritchey-Chrétien Optical Configuration**
  to cancel off-axis coma & sperical abbreation
- **Nasmyth Focal Plane**
  M1 + AO + post-AO ➔ *d*(M3F) = 5 m
- **Normalized Parameters for Two Mirror Telescope**

$$\begin{pmatrix} k & \text{ratio } D_2/D_1 \text{ when the telescope FoV is } 0^o \\ m_2 & \text{ratio } F_T/F_1 \text{, M2 lateral magnification} \\ \rho & \text{ratio of the radius of curvature of the mirrors } R_2/R_1 \\ \beta & \text{back focal distance (M1 vertex to focal plane) in units of } F_1 \end{pmatrix}$$

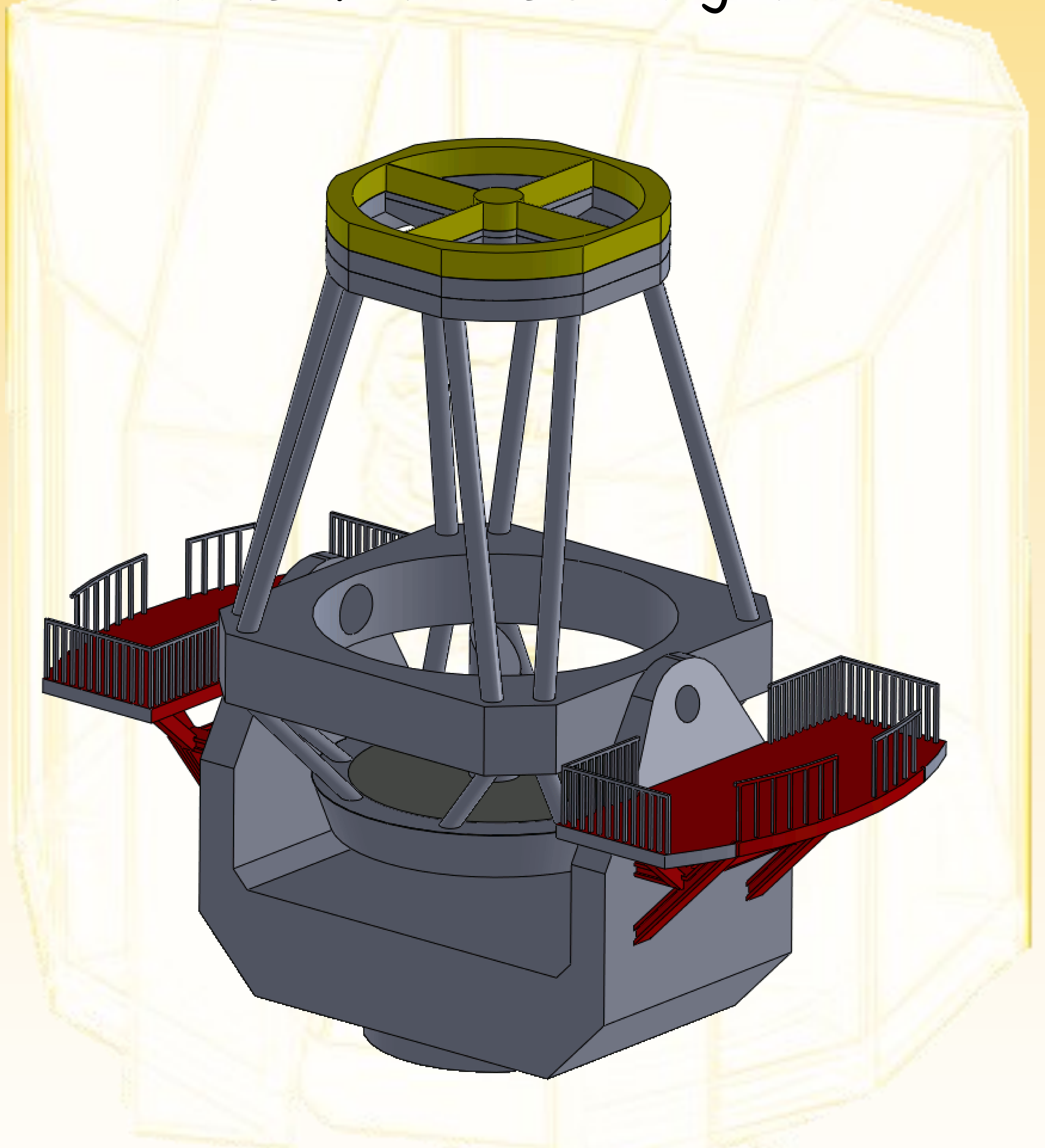
$$\beta = \frac{1}{F_1}\left(\overline{M3F} + \overline{M1M3}\right), \quad m_2 = \frac{F_T}{F_1}, \quad k = \frac{1+\beta}{1+m_2}, \quad \rho = \frac{m_2 k}{m_2 - 1}$$

- **Single Guide Star Diffraction Limited AO mode**
  Isoplanatic diameter is used : $FoV_{SSAO}[''] = \frac{6546}{\langle h \rangle w_0}$
  w0 : local seeing
  <h>: turbulent layer altitude
  ➔ FoV = 0.27—2.7 mm (40-400 pixels @7μm)
- **Improved Seeing Mode — GLAO**
  Assumed a corrected FoV of 5' (10' at most)
- **Seeing Limited Imaging Mode**
  FoV= 10'/20'(target/goal) w/seeing=0.5"@500nm

Telescope Optical Dimensions



Years of dreams coming true...



Wavefront Error Budgeting

- **M1** : a thin modern monolithic mirror with aO.
- **M2** : controlled mirror: decentering and tip-tilt; stiffness will be ensured by thickness;
- **M3** : an elliptical mirror; inclined 45 degrees; stiffness will be ensured by thickness;
- **N1** : a GLAO system for seeing = 0.2" over FoV = 4'
- **GLAO + deformable mirror + WF sensors** :
  ➔ a single conjugate natural guide star (SCAO)
  ➔ high angular resolution AO system
- **N2 (non-AO)** : seeing limited large FoV instruments
- **aO** : cannot compensate aberrations due to optical turbulence; because time scale ~1 - 10 ms (much faster than the aO system loop rate).

- The instruments focal plane receives **aberrations** as a combination of **(1)** optical turbulence aberrations (residual if AO is on), **(2)** aO-corrected telescope pseudo or slow varying static aberrations and **(3)** instruments internal optics aberrations.
- The AO system will be **dimensioned** to compensate for optical turbulence aberrations.
- But as **residuals** will be seen by the AO system,
- they will be **compensated** up to the AO system's cut-off frequency

Error Budget Metrics

- The basic metrics:
  a) the WFE standard deviation (or RMS),
  b) the Strehl ratio,
  c) the FWHM of the PSF, and
  d) the energy proportion within a given aperture shape.
- Thus, using the WFE and the Strehl metrics for budgeting is sufficient and practical as the WFE can be measured during manufacturing.

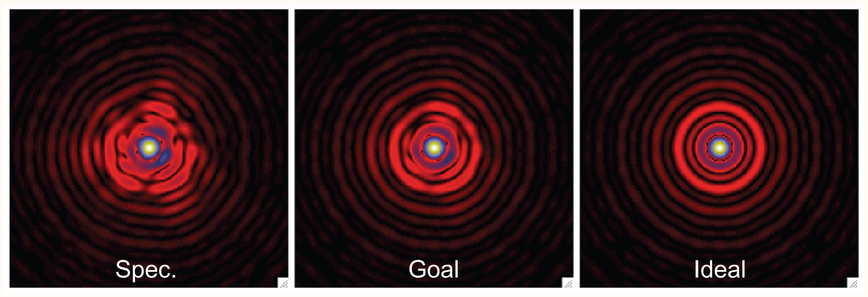
Mirror Manufacturing Error Budget

- An AO system is able to correct wavefront aberrations, up to the AO cutoff spatial frequency
- It separates WFE into low and high order components.
- The best DM actuator pitch for DAG AO is 40 cm, and
- Therefore phase aberrations **>2 λ_{AO} (80 cm)** are partially corrected.

Low Order WFE:

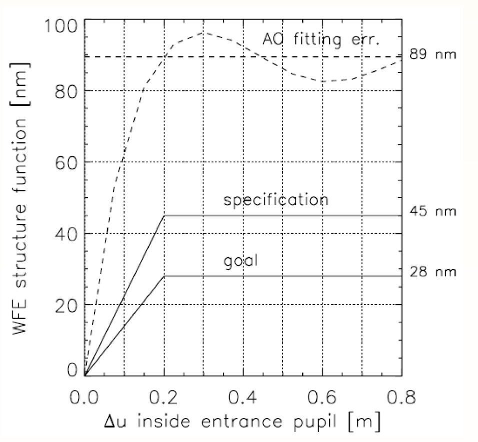
- A pitch λ_{AO} = 40 cm
  ➔ allows ~80 actuators.
  ➔ compansate all Zernike Poly. up to $j_{max}(80)=79$ or radial order *n=11.*
- Maréchal's law (@500 nm)
  ➔ Strehl ratio = 86% for spec.
  ➔ Strehl ratio = 96% for goal.
  The first value is easily achievable,
  The second is more challenging.

N	j-indexes	|*aj*| spec	nm goal
2	5-6	14.6	7.3
3	7-10	7.5	3.8
4	11-15	4.7	2.4
5	16-21	3.3	1.7
6	22-28	2.5	1.2
Quadratic Sum to a_{29} to a_{78}			
7-11	29-78	9.3	4.7
Total Error (nm):		31	15



High Order WFE:

- The performance of the AO is limited by the fitting error.
- Consider: 0.5" seeing, DM pitch of 0.4 m
  ➔ fitting error of 68 nm.
- Strehl decrease should be **< 0.95** (goal 0.98) @ J-band (1.25 μm).



CONCLUSION

- Total length is kept under 10m; d(M1M2) is 6.5m.
- FoV=10' in seeing limited mode (cannot be larger in RC systems)
- Corresponding CCD array size is about 2400 pixels @typical seeing of 0.5"
- Mosaic CCD arrays with curvature adjusted installations might increase FoV
- In GLAO, FoV=6' limited more by turbulent isoplanatic patch, which is in principle smaller than this, then by off-axis defocus.

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Web Page

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DAG

ATASAM Atatürk Üniversitesi Astrofizik Araştırma Merkezi

Site Location