

# Optical Design and Predicted Performance of LyRIC Spectroscopy

## LyRIC: Lyman UV Radiation from Interstellar Medium and Circum-galactic Medium

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103–105 nm

O VI wavelength range

103.2 / 103.8 nm doublet

R ≈ 2986

Spectral resolution

≈ 100 km/s velocity scale, 3000 requirement

28.5"

Spatial resolution

0.5° × 0.5' slit field, 30" requirement

248 PU\*

Detectable surface brightness

3σ · 3 ks · R ~ 3000, 500 PU requirement

### 01 Why map O VI emission?

#### SCIENTIFIC MOTIVATION

- **Trace warm-hot gas:** The O VI doublet is the best tracer of warm-hot diffuse gas in the ISM and CGM.
- **Reveal spatial structure:** Emission mapping complements absorption sightlines by revealing the morphology and distribution of gas.
- **Probe gas dynamics:** Spatially resolved spectra help characterize kinematics linked to accretion, outflows, and feedback.

Targets: CGM / Galactic halo / HVCs / SNRs / superbubbles

### 02 Compact optical design

#### LONG-SLIT IMAGING SPECTROSCOPY

- LyRIC's compact optical design meets the **size constraints** for an external payload on the Chinese Space Station.

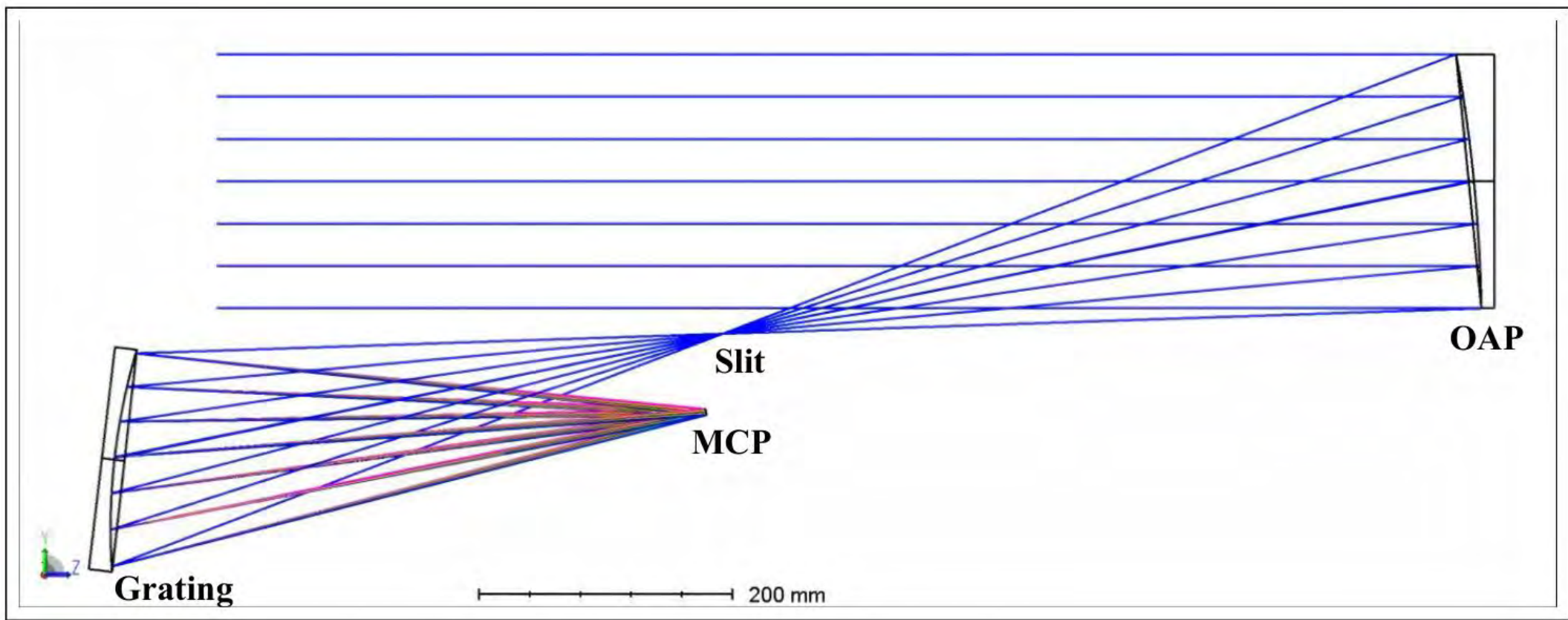


Fig. 1. Optical layout of LyRIC

| Parameter                      | Specification                                 |
|--------------------------------|-----------------------------------------------|
| Primary mirror                 | Off-axis parabola; 200 mm aperture            |
| Focal length of primary mirror | 600 mm (F/3.0)                                |
| Slit size                      | 5.5 × 0.11 mm                                 |
| Grating                        | Holographic VLS concave grating               |
| Groove density / order         | 1205 grooves mm <sup>-1</sup> / 4th order     |
| Detector                       | Microchannel-plate detector; 40 μm pixel size |

- Two optical interactions limit throughput losses.
- The grating combines dispersion, focusing and aberration correction.

### 05 Technology developments

#### TOWARD ENGINEERING VERIFICATION

**Lyman-UV coatings:** Al/LiF/eMgF<sub>2</sub> achieved >50% average reflectance over 102–108 nm.

**Gratings:** The CAFE concave VLS blazed grating achieved 51% groove efficiency at 106.4 nm.

**UV Detectors:** Photon-counting MCPs remain the baseline for faint diffuse emission.

### SUMMARY

LyRIC is a compact Lyman-UV long-slit spectrograph designed as an external payload for the Chinese Space Station, mapping diffuse O VI emission in the Milky Way and nearby galaxies. The optical design minimizes reflections while providing a predicted spatial resolution of  $\approx 28.5''$  and spectral resolution of  $R \approx 2986$ . LyRIC can detect diffuse emission with a surface brightness of approximately 248 PU at  $3\sigma$  over a 3 ks exposure, supporting future studies of warm-hot gas distribution, kinematics, and galactic baryon cycle.

References: Ji et al. (2020), arXiv:2012.07384; Lou, Ji & Wang (2019), Applied Optics 58, 1016; Ren et al. (2023), Applied Optics 62, 9414.

\* 1 PU = 1 photon cm<sup>-2</sup> s<sup>-1</sup> sr<sup>-1</sup>

### 03 Predicted optical performance

#### ZEMAX + PHYSICAL-OPTICS MODELING

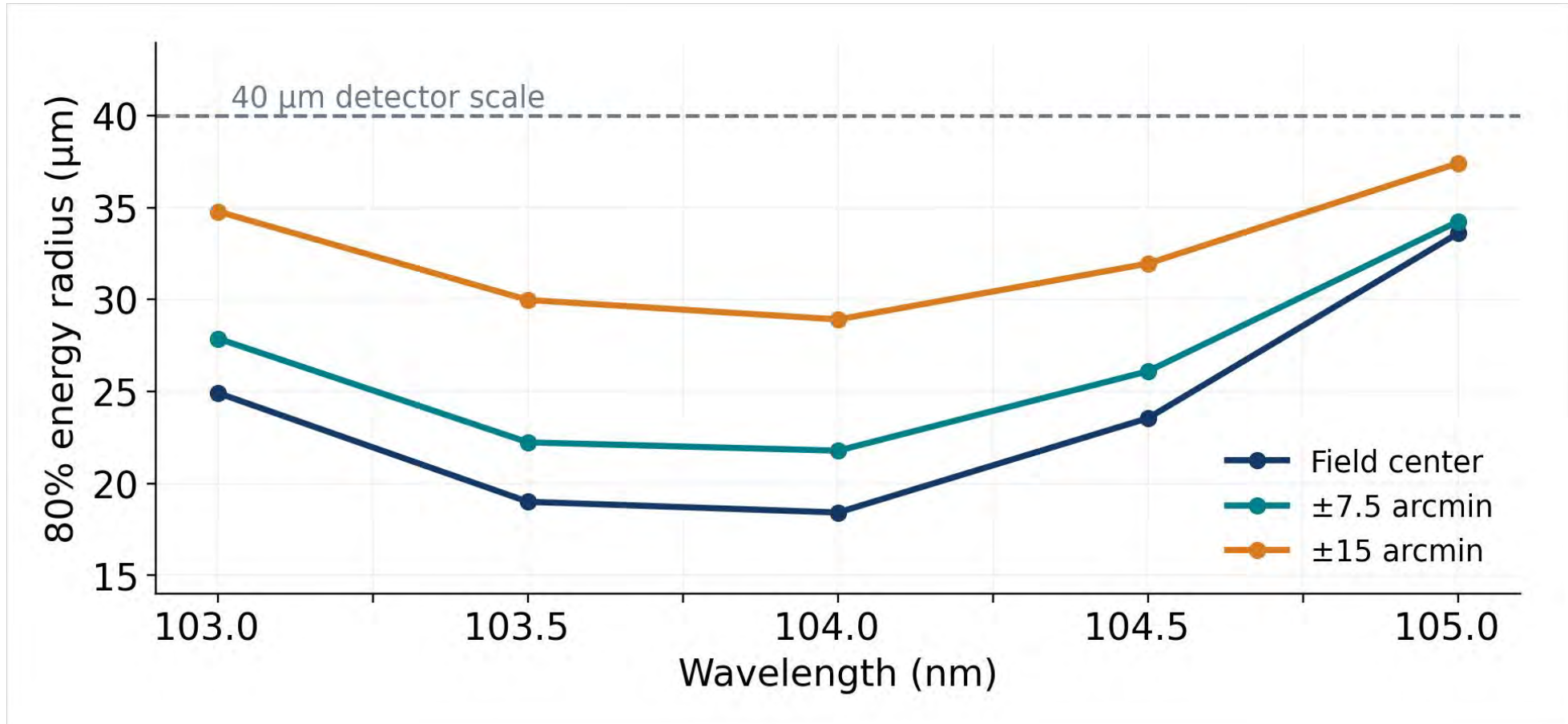


Fig. 2. 80% energy radii remain below 40 μm across the evaluated wavelengths and field of views.

- With an 80 μm line FWHM and 0.432 nm/mm dispersion,  $\Delta\lambda \approx 0.0346$  nm and  $R \approx 2986$  at 103.2 nm.
- **Spatial resolution  $\approx 28.5''$ .**

### 04 Sensitivity to diffuse emission

#### PHOTON-COUNTING MODEL — PREDICTION

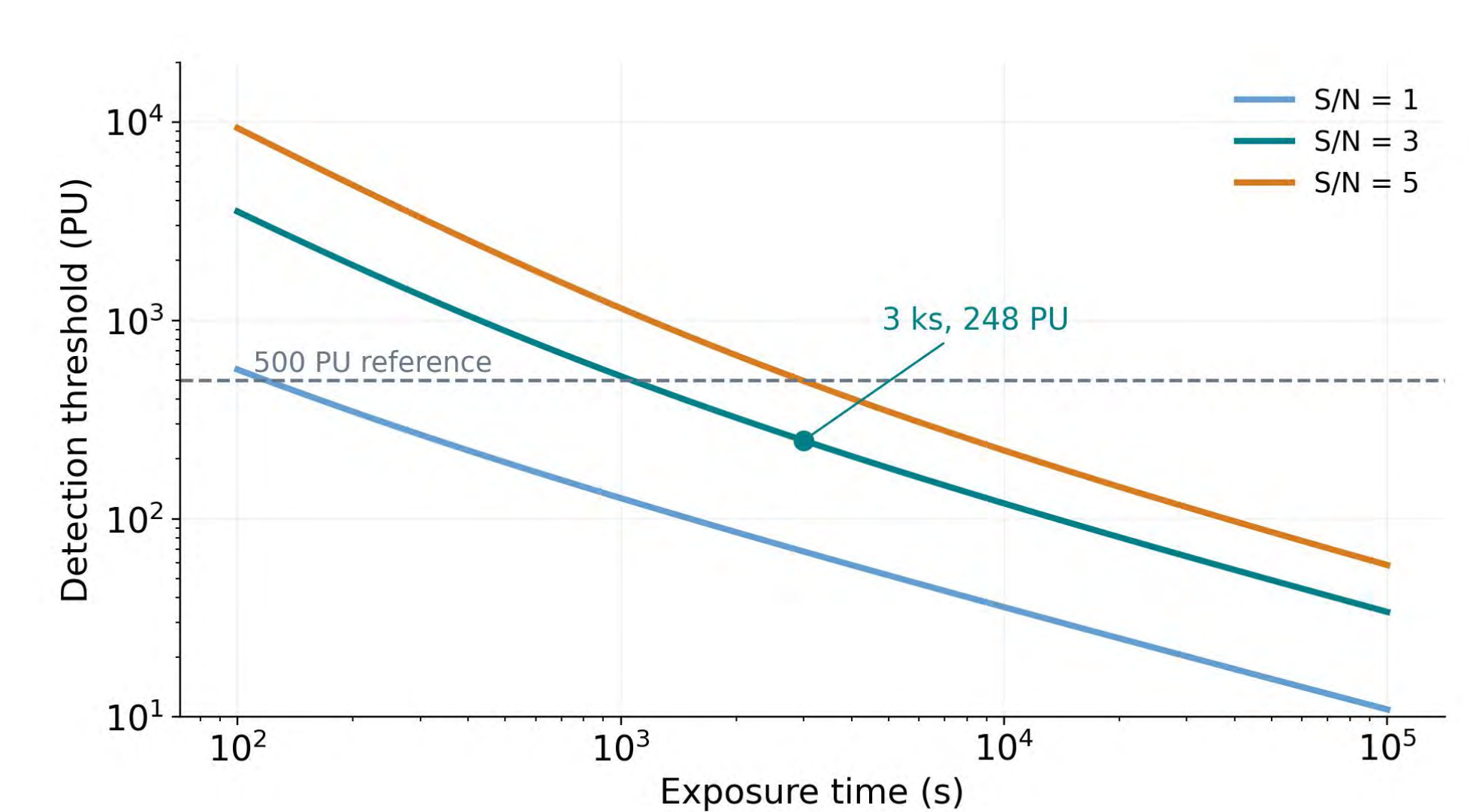


Fig. 3. Minimum detectable radiance as a function of exposure time for different signal-to-noise ratio (S/N) requirements.

- **$A_{\text{eff}} \approx 21.9$  cm<sup>2</sup>**
- A photon-counting sensitivity model yields a  $3\sigma$  detection of approximately **248 PU for a 3 ks exposure at  $R \sim 3000$** , reaching well below the 500 PU surface-brightness requirement.
- Mirror reflectance: 60%, grating efficiency: 30%, MCP QE: 43%, contamination loss: 10%.