

# SWIR SKY GLOW AND CLOUD COMPARISON BETWEEN URBAN AND RUAL MEASUREMENTS

David Dayton, John Gonglewski, Chad St. Arnauld

Applied Technology Associates  
1300 Britt SE  
Albuquerque NM, 87123

1 June 2009

Technical Paper

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.



**AIR FORCE RESEARCH LABORATORY**  
**Directed Energy Directorate**  
**3550 Aberdeen Ave SE**  
**AIR FORCE MATERIEL COMMAND**  
**KIRTLAND AIR FORCE BASE, NM 87117-5776**

# REPORT DOCUMENTATION PAGE

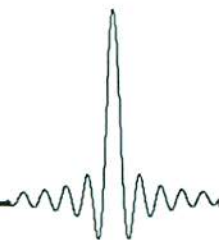
Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

<b>1. REPORT DATE (DD-MM-YYYY)</b> 01/06/2009		<b>2. REPORT TYPE</b> Technical Paper		<b>3. DATES COVERED (From - To)</b> 1 March 2001- June 1, 2009	
<b>4. TITLE AND SUBTITLE</b>  SWIR Sky Glow and Cloud Comparison Between Urban and Rural Measurements				<b>5a. CONTRACT NUMBER</b> F29601-01-D-0051 TO 2 DF297490	
				<b>5b. GRANT NUMBER</b>	
				<b>5c. PROGRAM ELEMENT NUMBER</b> 6DTESQ	
<b>6. AUTHOR(S)</b>  *David Dayton, John Gonglewski, Chad St. Arnauld				<b>5d. PROJECT NUMBER</b>  8G10	
				<b>5e. TASK NUMBER</b> SQ	
				<b>5f. WORK UNIT NUMBER</b> AD	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> Air Force Research Laboratory      *Applied Technology Associates 3550 Aberdeen Ave SE                      1300 Britt SE Kirtland AFB, NM 87117-5776              Albuquerque, NM 87123				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  Air Force Research Laboratory 3550 Aberdeen Ave SE Kirtland AFB NM 87117-5776				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b> AFRL/RDSE	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b> AFRL-RD-PS-TR-2010-1003	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  Approved for public release					
<b>13. SUPPLEMENTARY NOTES</b> Accepted for publication at the Optics and Photonics Symposium; 2 September 2009; Berlin, Germany. 377AWB-2009-0983; 27 Jul 2009. "Government Purpose Rights"					
<b>14. ABSTRACT</b> Low light passive SWIR imaging: natural night time sources. SWIR Sky Glow: High Altitude Chemical Luminescence. Cloud Reflection: moon. Sensors Unlimited SWIR Camera: 50 e-noise per pixel, F/1.4 Lens.					
<b>15. SUBJECT TERMS</b>					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>
<b>a. REPORT</b> Unclassified	<b>b. ABSTRACT</b> Unclassified	<b>c. THIS PAGE</b> Unclassified			John Gonglewski
			SAR	20	<b>19b. TELEPHONE NUMBER (include area code)</b> 505- 846-4405

Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std. Z39.18

ATA



# SWIR Sky Glow and Cloud Comparison Between Urban and Rural Measurements

**David Dayton**

Applied Technology Associates 1300 Britt SE, Albuquerque, NM 87123

**John Gonglewski, Chad St. Arnauld**

Air Force Research Laboratory-RDSE, 3500 Aberdeen, Kirtland AFB, 87109

ATA

# Introduction



- **Low Light Passive SWIR Imaging**
  - Natural Night Time Sources
  - **SWIR Sky Glow**
    - High Altitude Chemical Luminescence
  - Cloud Reflection
  - Moon
- **Sensors Unlimited SWIR Camera**
  - 50 e- Noise per Pixel
  - F/1.4 Lens

ATA

# SWIR Sky Glow

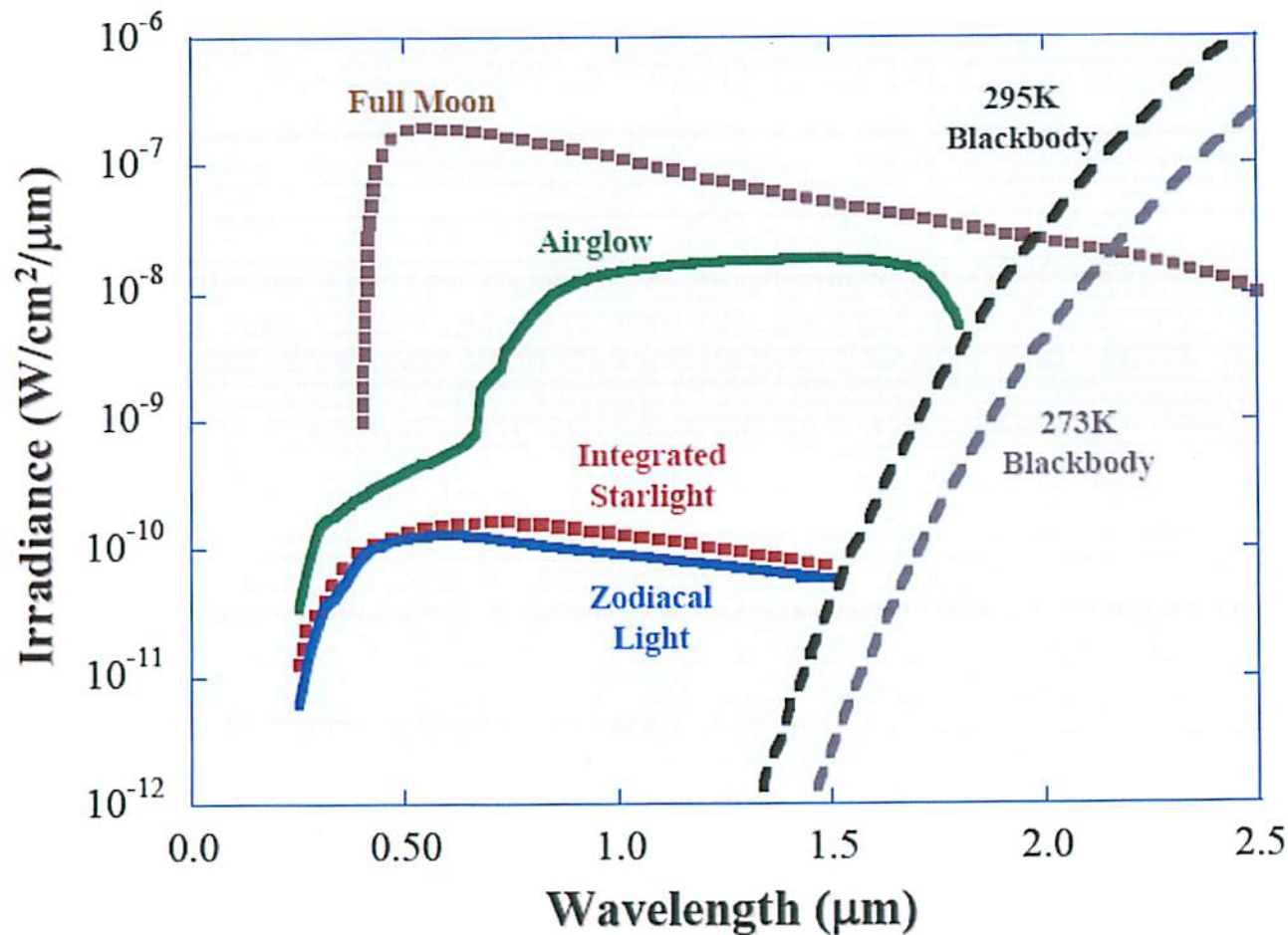


- **SWIR Sky Glow**

- **Vibration and Rotation States of Hydroxyl OH**
- **Complex Chemical Interactions Involving Ozone**
  - UV Radiation Charges During the Day
  - Reverse Process Produces SWIR photons at Night

ATA

# Natural Night Sky Irradiance Sources



ATA

# SUI 320KTX Camera



- 320x240x40 $\mu$ m pixels
- 50 e- Read Noise  
2.3x10<sup>-10</sup> NEI
- Rolling Shutter
- Spectral Response  
0.9 – 1.7  $\mu$ m

**ATA**

# Measurements



- 
- **Collected Between 11 Pm and 1 Am**
  - **No Moon**
  - **Partly Cloudy Conditions**
    - **City Lights Reflected from Cloud Bottoms**
    - **Mie Scattering varies with Scatter Angle**

ATA

# Bar Chart 100 Yds 5" Separation



ATA

# Bar Chart 200 Yds 5" Resolution



# Comparison with Intensified CCD Camera

Note: Excess Noise (Scintillations) in ICCD Camera



ICCD Camera



SWIR Camera

Irradiance  $\sim 1.2 \times 10^{-8} \text{ W/cm}^2$

ATA

# Image Comparison Near Horizon Looking Away from City (~ 20 Deg)



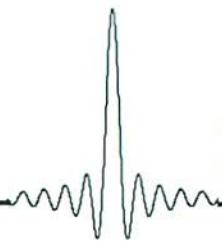
ICCD Camera



SWIR Camera

Sky Glow Radiance  $\sim 2.9 \times 10^{-8} \text{ W/cm}^2$   
Cloud Radiance  $\sim 3.5 \times 10^{-9} \text{ W/cm}^2$

ATA

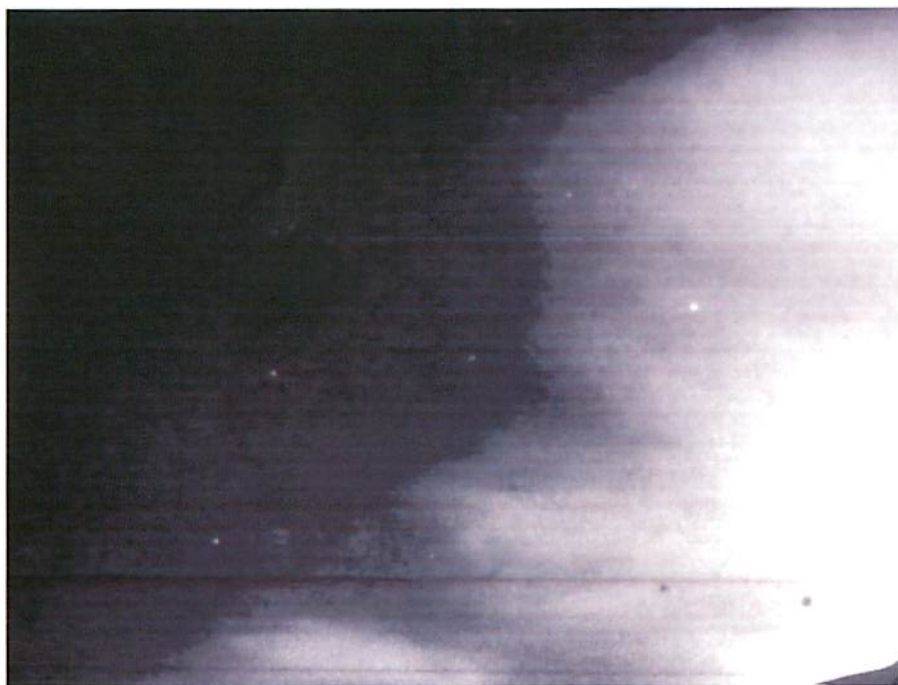


# Image Comparison Bright Clouds Looking Towards Albuquerque (~ 40 Deg)



City Reflection off Clouds

City Reflection off Clouds + Sky Glow



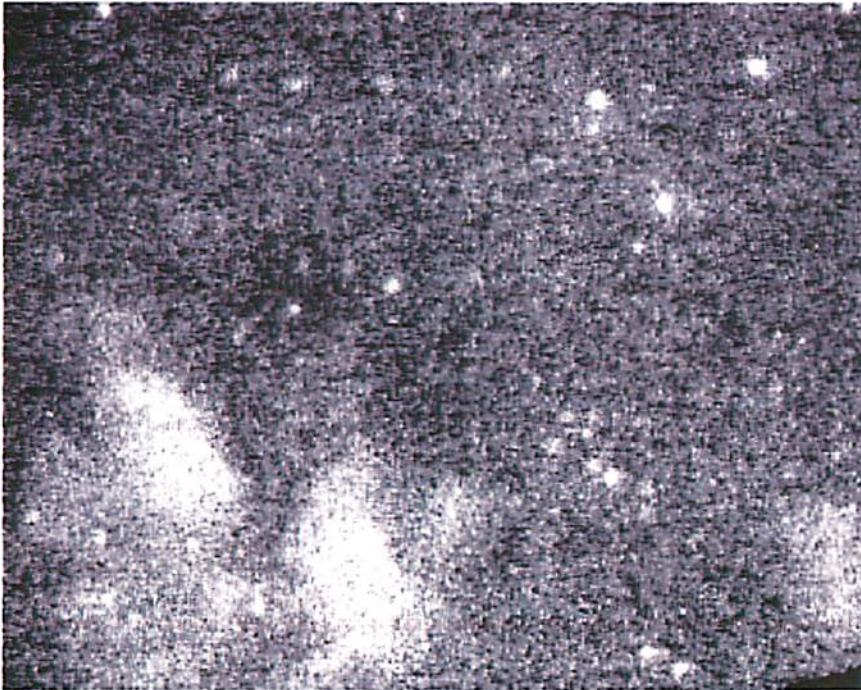
ICCD Camera

SWIR Camera

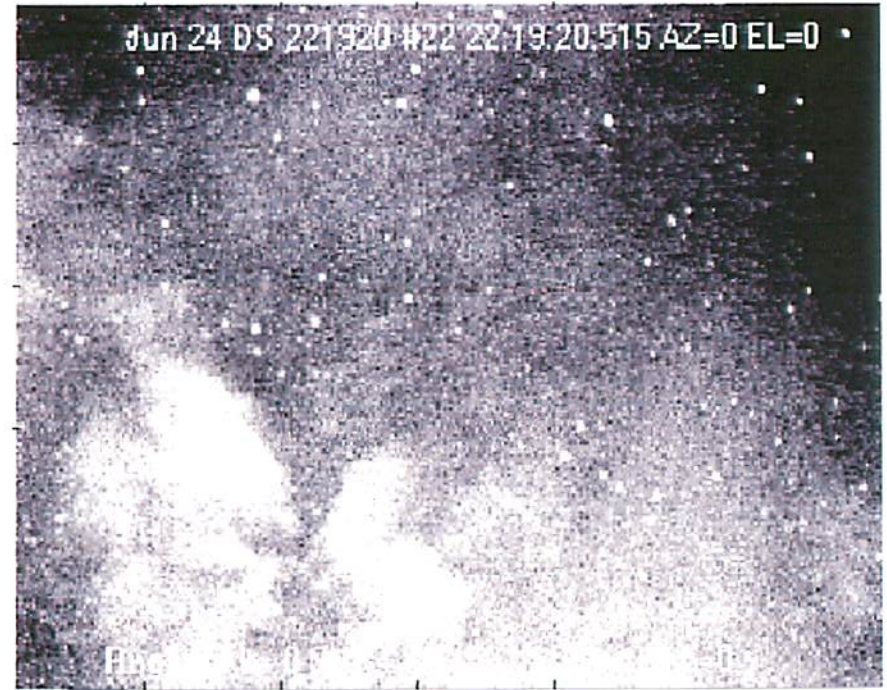
Sky Glow Irradiance  $\sim 2.1 \times 10^{-8}$  W/cm<sup>2</sup>  
Cloud Irradiance  $\sim 2.1 \times 10^{-8}$  W/cm<sup>2</sup>

ATA

# Image Comparison Near Zenith (~ 80 Deg)



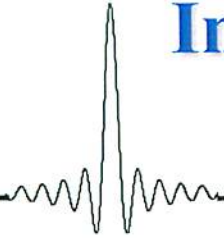
ICCD Camera



SWIR Camera

Sky Glow Radiance  $\sim 4.2 \times 10^{-9}$  W/cm<sup>2</sup>  
Cloud Radiance  $\sim 7.6 \times 10^{-9}$  W/cm<sup>2</sup>

ATA



# Image Comparison Near Zenith (~ 90 Deg)



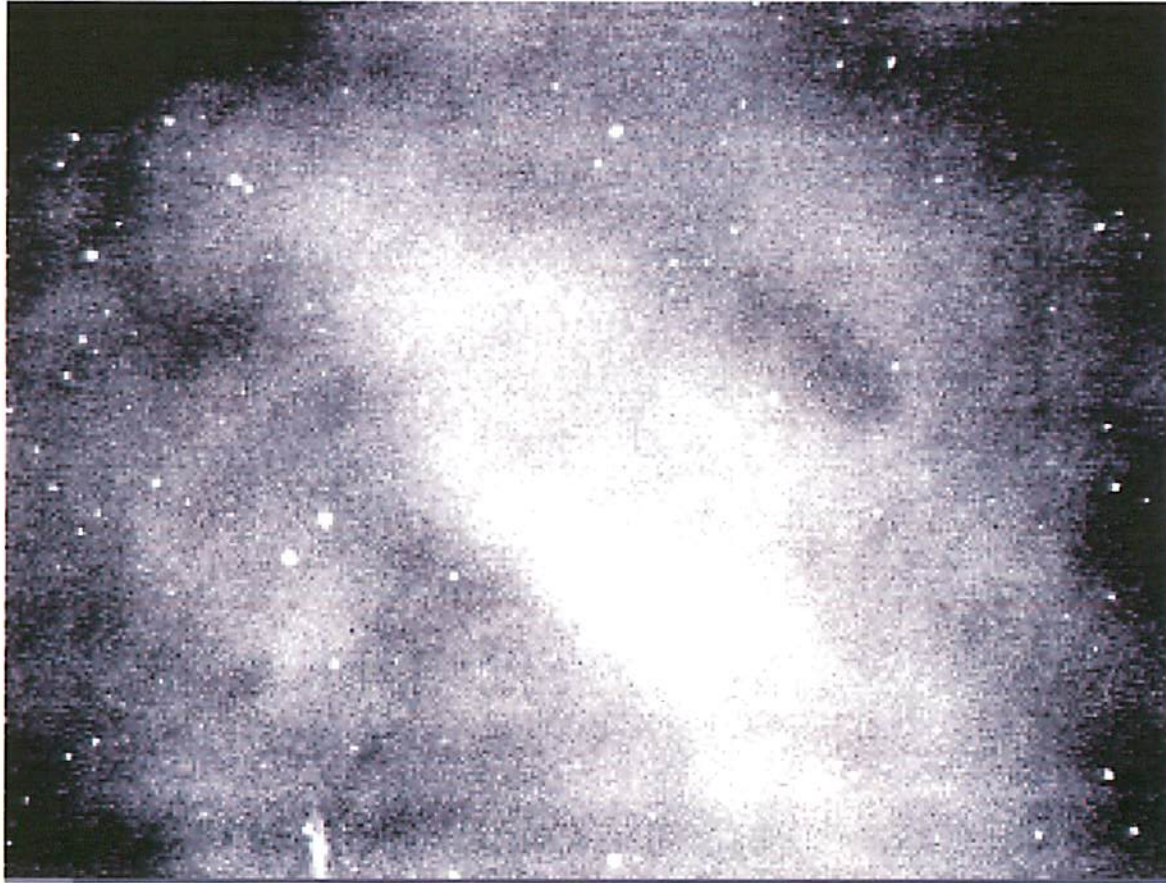
ICCD Camera



SWIR Camera

Sky Glow Radiance ~  $-3.0 \times 10^{-9}$  W/cm<sup>2</sup>  
 $4.24 \times 10^{-9}$  W/cm<sup>2</sup>

# Traveling Waves



**ATA**

# Variation With Angle



**Zenith Angle**

**SWIR SKY Glow Radiance**

**20**

**$2.9 \times 10^{-8}$  W/cm<sup>2</sup>**

**40**

**$2.1 \times 10^{-8}$  W/cm<sup>2</sup>**

**80**

**$4.2 \times 10^{-9}$  W/cm<sup>2</sup>**

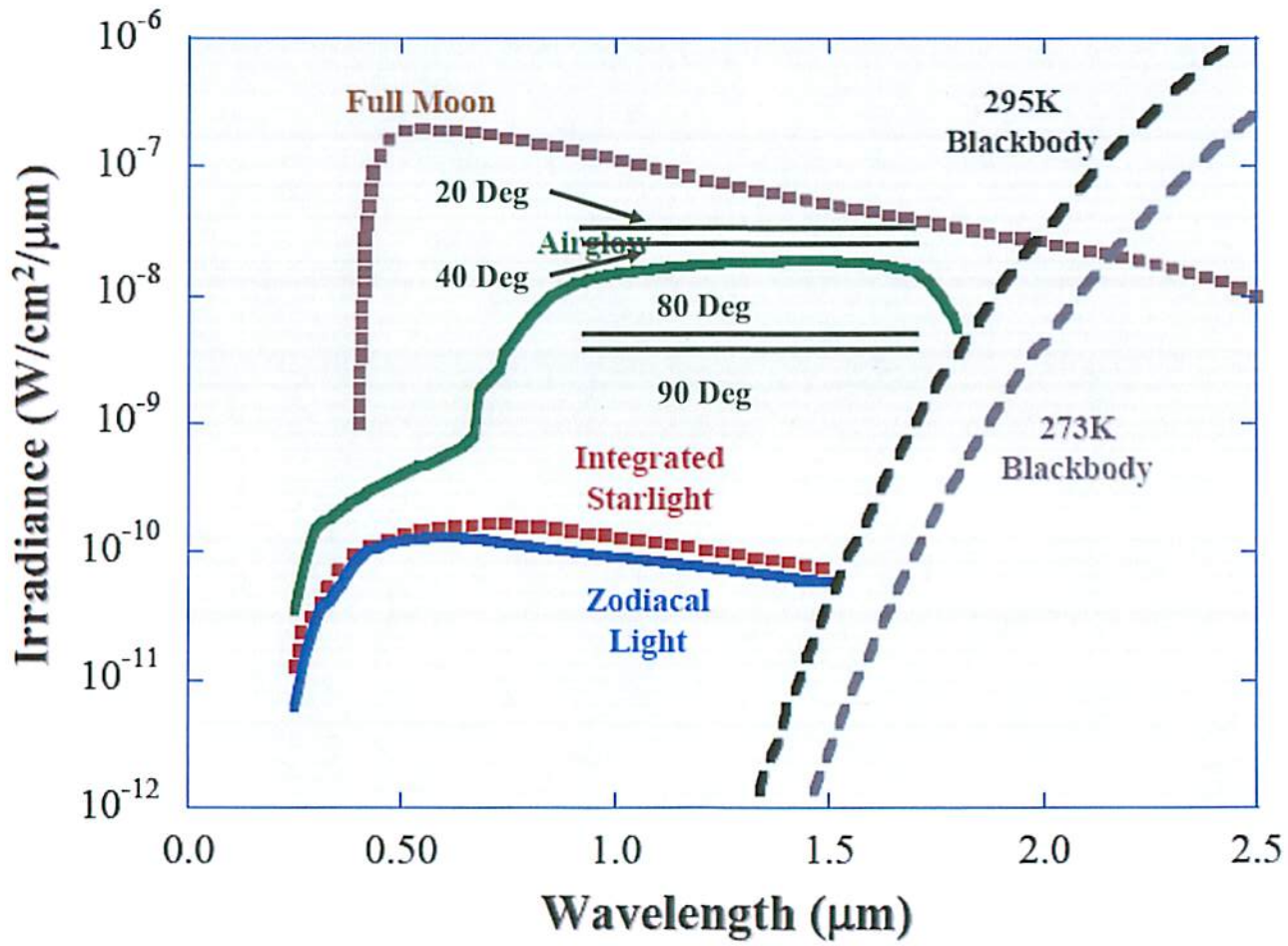
**90**

**$3.0 \times 10^{-9}$  W/cm<sup>2</sup>**

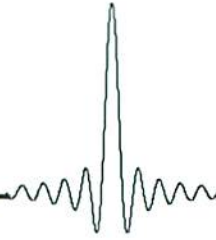
**Integrated Measurement Over Sensor Bandwidth**

ATA

# Measured Data Vs Models



ATA



# Conclusions



- **SWIR Sky Glow**

- Chemical Luminescence
- Illumination for Passive Night Imaging
- Competes Favorably with Intensified Visible
- Measurements Compare Well to Published Models
- Order of Magnitude Variation with Zenith Angle

## DISTRIBUTION LIST

DTIC/OCP 8725 John J. Kingman Rd, Suite 0944 Ft Belvoir, VA 22060-6218	1	cy
AFRL/RVIL Kirtland AFB, NM 87117-5776		2 cy
John Gonglewski Official Record Copy AFRL/RDSE		1 cy