ISUAL Design Concept

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Sprite Example

Sprite Image obtained by Berkeley/NCKU 1999 Sprite Campaign.
Major Science objectives:

- 1. Determine the location and timing of luminous phenomena above thunderclouds to investigate their spatial, temporal and spectral properties.
- 2. Obtain a global survey of upper atmospheric optical flash transients (sprites, elves, blue jets etc.)
- 3. Global survey of aurora and airglow
1. Detailed observation of individual sprites.
   - Pointing: Dip down to reduce range.
   - Location: Storms
   - Imager Wavelength: N2 1st positive, 427.8 nm
   - Photometer Wavelength: UV bands, N2 2nd positive, 427.8 nm, N2 1st positive
   - Spatial Resolution: ~2km
   - Time resolution: 1 - 30 msec (programmable)
   - Mode: Burst Mode
   - Sensitivity: SNR >20 at 100 KR at 30 msec
• 2. Global survey of upper atmospheric optical flash transients (sprites, elves, blue jets etc.).
  – Pointing: Limb view (largest coverage possible).
  – Location: Storms
  – Imager Wavelength: N2 1st positive, 427.8 nm
  – Photometer Wavelength: UV bands, N2 2nd positive, 427.8 nm, N2 1st positive
  – Spatial Resolution: ~2km
  – Time resolution: 1 - 30 msec (programmable)
  – Mode: Continuous Sprite Mode
  – Sensitivity: SNR >20 at 100 KR at 30 msec
3. Global survey of aurora and airglow
   - Pointing: Limb view.
   - Location: All latitudes
   - Imager Wavelength: All Wavelength
   - Photometer Wavelength: All Wavelength
   - Spatial Resolution: ~2km
   - Time resolution: 1 sec (programmable)
   - Mode: Continuous Aurora mode
   - Sensitivity: SNR > 8 at 1 kR
Sprite Intensity Calibration

Sprite observed at 600 km distance
Sprite Intensity Calibration

• STAR #2 at V=4.11 delivers 23 photons/cm²/s/A = 68000 photons/cm²/s = 2000 photons/cm²/frame. Its video signal, summed over all six pixels using its FWHM * peak, is about 1000 videoUnits. These two numbers establish the necessary absolute photometric calibration for this frame, namely

• 2 photons/cm²/videoUnit.
• Sprite =255 video units = 512 photons/cm²/pixel/frame
Sprite Intensity Calibration

Number of photons per Rayleigh =
$10^6 / (4\pi)/30$ solid angle per frame.

Where solid angle per pixel (50 mm lens 24 mm detector 480 TV lines) = $3.9 \times 10^{-7}$ strd.

The number of Rayleighs required to produce 256 video units is 500 k Rayleighs.
A parent cloud to ground flash precedes the sprite event usually by a few (3 msec) [Raiderden and Mende 1995] and can illuminate the thunderstorm cloud above with very high intensity light. The ISUAL instrument therefore uses four techniques to minimize the parent lightning interference.

1) By observing the flashes near the limb or on the limb it is possible to get spatial separation between the two sources of intensity.

2) By using appropriate spectral filtering it is possible to maximize the sprite induced spectral bands and cut down on the spectral bands produced by cloud to ground lightning.

3) By using a trigger photometer and only turning on ISUAL imager at the appropriate time it is possible to remove some of the parent lightning intensity.

4) By using a CCD type which has anti-blooming gate.
ISUAL Imager Filters

ICCD Filter Curves

Filter Transmittance (%)

Detector QE (%)

Wavelength (nm)

S25

3 5 4 1 6 2 3 5 4 1 6 2
ISUAL Imager Filters

- Filter 1. N2 1st positive band filter for observing Sprites. Remove the lightning induced Balmer alpha line at 656.3 nm and the airglow 760 nm O2 band
- Filter 2. 762 nm O2 (0,0) atmospheric band for observing airglow (waves) and aurora
- Filter 3. 427.8 nm energetic electron induced emissions (sprites and aurora)
- Filter 4. 630 nm auroral and airglow emissions
- Filter 5. 557.7 nm auroral and airglow emissions.
- Filter 6. OH waves and or O+ auroral emission (Different altitude limb profile)
1. Ultraviolet filter. Looking at N2 LBH bands. Upper state lifetime is 0.14 ms resulting in some quenching at lower altitudes. The altitude of unit optical depth is about 40 km in this range perhaps possible to see sprites while attenuating lightning.

2. Ultraviolet filter. The altitude of unit optical depth is about 40 km in this range. It might be possible to see sprites and much attenuated lightning.

3. 337.0 nm N2 2nd positive band requires higher electron energies.

4. N2 + 427.8 nm Energetic electron detector in sprites and aurora.

5. N2 1st positive emission “bread and butter” sprite measurement.

6. 777.4 O lightning.
ISUAL Observing Scenario

- Scenario of ISUAL viewing the limb/near limb region
ISUAL observing geometry

Side View of ROCSAT orbit

- Sat. Altitude
- Elevation (dip)
- Range
- Altitude of phenomena
Range for 891 km altitude

Elevation (dip) angle
Observing Parameters

- Satellite Altitude: 891.00 km
- View angle to solid earth tangent: -28.68
- Limb view to phenomena: -27.5
- Range: 3373.01 km
- Height of observation: 60.00 km
Imager

- Focal length: 62.5 mm
- F number: 1.56
- Diameter of aperture: 40 mm
- Area of aperture: 12.6 cm²
- Field of view per pix: 0.039 degree
- Etendu per pixel: $6 \times 10^{-6}$
- Photon grasp: $10^6 / (4\pi) \times 6 \times 10^{-6} = 6 / (4\pi) = 0.5$ photons/ R/sec/pix
- Optical Efficiency: 1.5%
- Counting efficiency: 7.5 counts per kR / sec/pix
- 500 kR for 5 msec: 18.75
ISUAL Spectrophotometer

Spectrophotometer

- FOV: 20 x 3.15 degrees
- Diameter of aperture: 24 mm
- Area of aperture: 4.5 cm²
- Etendu (full field): 0.0868 Sterad-cm²
- Photon grasp: \(10^6 / (4\pi) \times 0.0868 = 6/ (4\pi) = 6,908\) photons/ R/sec/pix
- Optical Efficiency: 2.5%
- Counting efficiency: 172 counts per R / sec/pix
- 500 kR for 0.1 msec: 5181
## ISUAL Imager Detector

- Number of pixels (vert.): 80.00
- Number of pixels (horiz): 512.00
- Pixel in microns at image intensifier: 43.00 µm
- Image size (vert.): 3.44 mm
- (horiz.): 22 mm
- Pixel size at layer limb.: 2.14 km
- Image size vertical: 170 km
- Image size horizontal: 1093 km
- Range to bottom pixel: 2201 km
Imager Counting Rate 30 m sec exposure

Sprite Intensity (R)

1.00 10.00 100.00 1000.00 10000.00 10,000 100,000 1,000,000 10,000,000
Photometer Count rate (1 m sec) for 5 x 20 km sprite.

- Range = 3350 km
- Range = 2000 km
- Range = 1000 km
Imager Counting Rate 5 m sec exposure

Sprite Intensity (R)

1.00
10.00
100.00
1000.00
10,000
100,000
1,000,000
10,000,000
Photometer counting rate (Airglow/aurora)

Photometer Counting Rate for background airglow
(100 micro sec)

Airglow Intensity (R)

100 1,000 10,000

1

10

100

1000

1000

100

10
Photometer counting rate (Airglow/aurora)

Photometer Counting Rate for airglow (1 sec)

Airglow Intensity (R)

- 1000
- 10000
- 100000
- 1000000
- 10000000

- 100
- 1,000
- 10,000
- 100,000
- 1,000,000
- 10,000,000

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