

COSMOS 2007: Color, Light, and Spectra Inquiry

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August 16, 2008

Draft 1: August 16, 2008

Note: This document is just a brief, scattered sketch of the inquiry designed by Ryan Montgomery and Jeremy Wertheimer from UCSC and Diane Wong, Julia Kregenow from UCB as part of the CfAO PDP 2007 and Cluster 7, COSMOS 2007. The questions and presentations are from the actual inquiry 2007.

1 Content Goals

- White light is composed of all colors.
- Continuous spectrum (from solid bodies, blackbody)
- Emission spectrum (chemical signature of gas)
- There are more than just visible colors. Invisible radiation is still “light.”
- The primary colors are RGB.
- The secondary colors are CMY.

2 Stations

- White and black lights
 - Set up overhead projectors with large diffraction gratings.
 - Make slit on overhead surface.
 - Project one rainbow onto poster on wall.
 - Elicit students to comment about what they see (perhaps they’ll notice rainbow on opposite side).
 - Turn off overhead and lay long black light tube over slit and turn on.

- “Black light” will be project with some small overlap of the white light’s blue and farther to the blue.
 - Really push students to quantify that there is some overlap between the white light source blue and the black light source blue.
 - Caveat: black light is not “ultra-violet” because we can see it. It is just very blue.
 - There is even fluorescence of material due to weak very blue light dispersed from the white light source.
 - Caveat: black light tube uses different physics than overhead projector’s white light.
 - Works to detect black light with fluorescence of highlighters (including their markings), white things, glow-in-dark stars, etc.
 - Students may get dejected that they can’t answer why black light works (emission) but emphasize that they have to understand the properties/nature of the black light (light) before figuring out what’s in the black light anyway..
 - Students can also project full rainbow then cover the slit with gel filters and see the transmission functions.
- Rayboxes and filters
 - Attack misconception that primary colors are red, blue, and yellow (which are just art class’s approximation of CMY).
 - Advanced work will involve multiple dichroic filters.
 - $R = C + M$
 - $G = Y + C$
 - $B = M + Y$
- Continuous and emission sources (as well as Mystery Box)
 - Range of emission tubes so students can see how discrete lines change with elements.
 - Have students figure out that roughly quantity of lines in certain color dominates the overall color without the diffraction grating.
 - The spectrum will reflect the shape of the source (fat versus skinny, curly compact fluorescent versus straight).
 - White light is composed of all colors.
 - When the source is a hot solid body (incandescent bulb), the spectrum really is continuous. Every wavelength/color.
 - When the source is a compact fluorescent light, the spectrum has many, many discrete lines roughly evenly spaced through all the colors so that the overall effect is white light.

3 Questions

- Rainbow and filters
 - Why do some colors disappear when you use the filters with the rainbow?
 - Why do colors absorb their own color, but reflect others?
 - Why do the filters absorb only certain colors?
 - Why do some colors disappear when you put different colored filters over the spectrum?
 - Why is it that the green sheet blocks out the purple shade on the board?
 - Why is it that when you put red sheet over the overhead you only see the red on the board?
 - Why is it that the red sheet only made red and orange stand out while the blue sheet just made the colors darker?
 - Why is it that orange makes blue go away and not really any other color?
 - Why does the orange filter do (seemingly) nothing?
 - How come when you put the different colored sheets in front of the rainbow light, with some colors the rainbow colors change and with other colors the rainbow stays the same?
 - How do the color filters affect the light's color?
 - Why is the filters effect most obvious in red?
- Reflected colors
 - Where does the reflected color come from?
 - Why does the reflection change to the opposite color?
 - Why does the blue square reflect blue on one side and orange on the other?
 - Why is your reflection in the mirror the same color that is closest to the light and the color the mirror appears to be when you look at it, the same color as the light that is emitted?
 - How many colors reflected?
 - Why is red blocking the colors?
 - How come blue doesn't shine as much as yellow and orange?
 - Why is the light purple?
 - How does the purple cause the glowing?
 - What causes the colors to change in the overhead?
- Different bulbs, different spectra

- Why do two lights that look the same have different spectra?
- Why do different colored lights not display certain wavelengths of the spectra?
- Why do different colored lights produce different rainbows?
- Why do rainbows appear?
- Why do some of the colors not show other colors and the white lights have a broader color spectrum?
- Why do some lights give you the full spectrum of colors when looked at through the diffraction grating, while others only show a partial spectrum?
- Multiple Colors
 - When you put up the three filters (pink, yellow, and blue) you get a back light of red, green, and yellow. Why?
 - What is the relationship between colors that bounce back and go through?
 - Why is it that the yellow side always stays closest to the light and the blue always stays on the other side of the glass?
 - If blue filters out red, does that mean blue absorbs or reflects red?
 - How are multiple colors shown through one piece of glass?
 - Why does some color mix while some don't?
 - Why does the color of the light change when the lens is put farther from the light source?
 - What colors do other colors consist of?
 - Why does the blue filter absorb as much as the red one?
 - How do the colors add? Why?
 - Does the color of the light affect how the rainbow looks? The amount of light?
 - Why is red special?
- Shape of spectrum
 - Why do different shapes appear?
 - Why do the amounts (lengths?) of certain colors change depending on the light?
- Strength of lens
 - Why do the bright lines vary amongst the different light sources?
 - Why are some color beams more prominent than others (when you look through the screen)?
- Black light

- Why is it called “black” light? Why not blue light?
- Why does the black light make objects glow brighter?
- What factors affect which colors glow in black light?
- Why does black light effect only some things? For example, only certain shades of white.
- Why does the black light make yellow and white stuff appear to glow?
- Why doesn’t blue (highlighter) glow in the dark?
- What does the black light do? Why does it make white things blue and nothing else?
- Why does black light “super-charge” things that glow in the dark?
- Why do certain objects look ‘bright” in the blue light?
- Why does the purple light make everything white glow? (Highlighters, glow in the dark.)
- Why are you able to see some object under black light and not white light?
- Why does everything white absorb the dark light?
- Why does the black light ‘excite” certain colors?
- Why don’t certain materials light up to the black light?

- QWWNDWATT

- What are the glasses made out of?
- What is in the glass that makes the glass change colors?
- Why does one color go through and another reflect off?
- Why do the colors change when the glass is at different angles?
- What is the glass made out of?
- Is it a mirror or see through?
- Why is it that you flip it it’s still the same color?
- Is the raybox suppose to be parallel?
- Why does the glass look yellow?
- Why when you turn the glass does it change colors?
- When you twist the glass why does color change?
- Why do some colors go through the glass while others reflect off the glass?
- Why does the color change when you turn the filter?
- When you put the piece of glass at an angle, why does the glass reflect another color?
- Why does the color become darker when you tilt the lens?

- Why are different LDG's stronger? (LDG = linear diffraction grating)
- What exactly causes the spectrum/rainbow?
- What is the diffraction grater made out of?
- Does the shape and clarity effect the spectrum?
- Who discovered this?
- How does color play a role in this?
- Why is it the long tubes are longer spectrums?
- What are diffraction gratings made of and how do they work?
- Why does the shape look different if the plastic is on its side?
- Why do we see the rainbows?
- Why are they on the side of the screen?
- How come even though you're not looking at the light you scan still see the wavelength?
- How come the light reflects a rainbow only when you look through the little plastic thing?
- Why is it that when you place one of the squares against or near the light it stays same color but when you place it further away it makes a rainbow shade?
- Why does each filter absorb its projected color?
- How come there is a projected rainbow if the screen is clear?
- Why do different LDG's let you see different colors (for the orange light)?
- Is it the LDG or the light or the combination of both that makes the rainbows?

4 Presentations

- Why do some bulbs reflect the whole rainbow and some just reflect certain colors?
 - You're seeing emission, not absorption!
 - Neon: red, orange, yellow; 2 lines
 - Mercury: blue, green, yellow; 3 lines
 - Argon: purple; 4 lines
 - Nitrogen: red, orange, yellow, green, purple; 1 line
 - Hydrogen: blue, orange, indigo; 3 lines
 - Helium: blue, purple, green, yellow, red; 4 lines
 - Red: red, orange, green, blue; 0 lines
 - Green: purple, blue, indigo, green, orange, red; 0 lines

- Blue: red, green, blue, purple, yellow, orange; 2 lines
 - Clear: all thin; 0 lines
 - Frosted: all thick; 0 lines
 - Spiral: all, same shape; 0 lines
 - Yellow: red, orange, green, purple, fat
 - Musty yellow: red, yellow, green, Venn diagram; 0 lines
 - Orange: red, orange, yellow, green, purple; 0 lines
 - “Reflect” is the incorrect term for the formed question because there is no reflection taking place. A more proper verb would be “produce.”
 - Discrepancies between materials: gas → produces lines as opposed to solids, which produce one horizontal line mixed with all the colors (spectrum)
 - Figure example: nitrogen gas-tube spectrum (with discrete emission lines) versus solid (clear light bulb) spectrum with full, continuous rainbow
- Mystery box spectrum
 - (Light bulbs) constants in data:
 - * Violet
 - * Green or blue
 - * Green, yellow, teal
 - * Orange, yellow
 - * Red, yellow, orange
 - * Violet or red
 - Figure: Mystery box spectrum—continuous spectrum with a few discrete emission lines at purple, teal, red-orange
 - Question 1: What is the difference between gas lights and regular light bulbs?
 - * Gas lights produce it’s own unique color with the vapor it contains.
 - * Light bulbs coated with different colors and do not give off its own original color.
 - * Gas lights have gaps and the spectrum are shaped similar to its original shape.
 - * Regular light bulbs are not shaped similar to its structure and the spectrum appears as a thin line.
 - Question 2: Why is it that some spectrum appear thinner/fatter than others?
 - * When you place light bulb vertically, the filament is flat if you look at it horizontally, which makes the spectrum appear skinny because the filament has a flat surface area.

- * When you place light bulb so that the filament has circular structure the spectrum will appear fatter because it has a larger surface area.
 - Figure; two bulbs with different filaments and how the spectrum is affected
- White vs Black: The Visual Showdown
 - So, we looked at white light and “black” light.
 - White light is made of ROYGBIV
 - * Did you know that white light is also made up of ultra-violet light? It’s not visible, but we can prove it’s existence using a highlighter.
 - * The colors of the visual spectrum decrease in brightness as you look from left to right (red to purple).
 - * We can see colorful things, such as a piece of green paper, because it absorbs all of the colors of the spectrum except for green, which it reflects back.
 - Now about “black” light...
 - * Really UV rays. So how can we see them?
 - * With our resources here, we can’t test why. But we can guess that something happens in the tube.
 - * So what about highlighters and some clothing... and stuff. Why do they shine so bright?
 - * Highlighters and a lot of laundry soap have chemicals that react to UV light.
- Black light
 - Question: Why does the purple light make everything white glow?
 - Conclusion: black light needs a white surface to be visible.
- Who’s in the Club?
 - How do the reflectors work?
 - * Each absorb some light but act as filters for others.
 - * The light absorbed shines through; the filtered reflects.
 - * The light reflected \neq light contained in light absorbed.
 - * Therefore, they are opposites.
 - Out of all possible colors, why do only 2 show? Where did the other colors go?
 - * Wonder what colors were made up of other colors.
 - * We experimented and founded The Club!
 - * Figure: “The new color wheel” shows pie chart with, clockwise: Green, aqua, blue, pink, red, yellow
 - What is the club????

- * Took tile and put it in front of a light. Put another reflector in front/behind the first.
- * Primary colors = Red, Blue, Green (no yellow!)
- Primary Colors—Red, Green, Blue
 - Opposites (figure): 6-pointed asterisk: Red-green opposite; blue-orange opposite; violet-yellow opposite
 - Secondary colors: Aqua, Magenta, Yellow
 - Figure: ray box with white light entering green (primary) filter, allowing through just green light, which then passes through red (primary) filter, and no light exits
 - Figure: ray box with white light entering green (primary) filter, allowing through just green light, which then passes through yellow (secondary) filter, and green line still shines through

5 Materials

- Dichroic filter sets of RGB and CMY (2)
- Gel filters
- Rayboxes (4)
- Gas emission tubes (variety)
- Hand-held diffraction gratings (10)
- Large diffraction grating for overhead projectors (2)
- Overhead projectors (2)
- 12" black light tube
- Question strips
- Markers
- Posters
- Colored pencils
- Tape
- Large dark room with tables and individual lamps
- Mystery box (gas emission tube operated without obstructing enclosure so continuous light source can be seen through it, all in a box with thin slit. Cover with image of *e.g.*, Ring Nebula, for astronomical effect)

6 Debrief 2007

- Need 2nd small black light
- Be more heavy-handed in facilitation early
- There was hang up on shape of filament and effect on spectra (does not affect continuous versus emission)—use hot-dog bulb; seen in curly compact fluorescent bulb
- Emphasize drawing
- Focus on hypothesizing and controlling variables
- Bulb **burn** safety needed
- Ray boxes color mixing as important avenue of seeing white light is all colors
- It was good to have teacher fellow explain what to put on posters; emphasize drawings
- Follow up synthesis or lecture to address misconceptions: never really discuss spectrum
- Also mention the empowering of the process and the process goals (asking questions, refining questions, etc).