

Planetary Radiation Budgets

Robert Kandel and Michel Viollier
Laboratoire de Météorologie Dynamique
LMD – IPSL, Ecole Polytechnique
Palaiseau, France

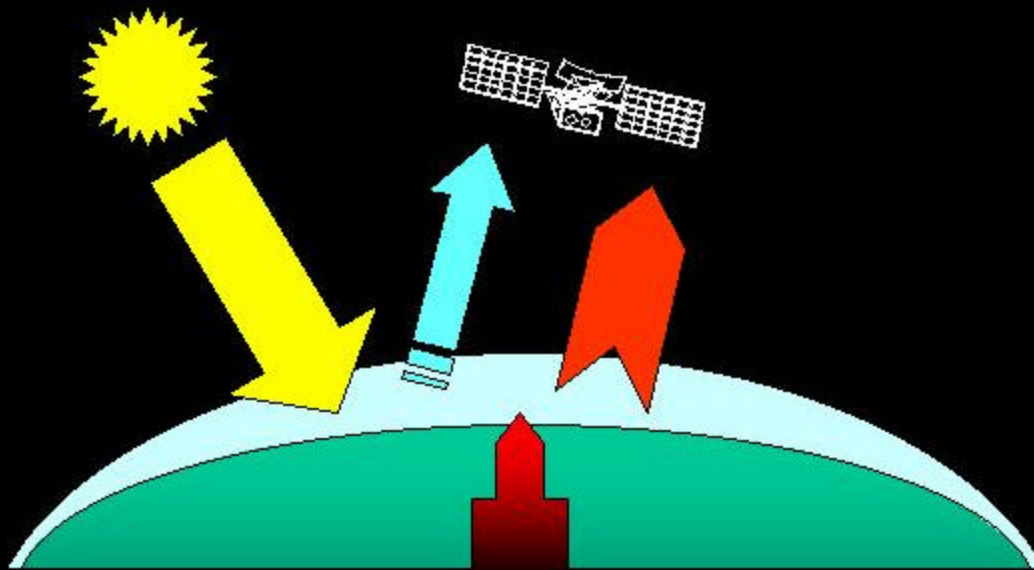


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**Radiation Balance : $R_N =$
absorbed SW flux – emitted LW flux
(averaged over the planetary surface)**



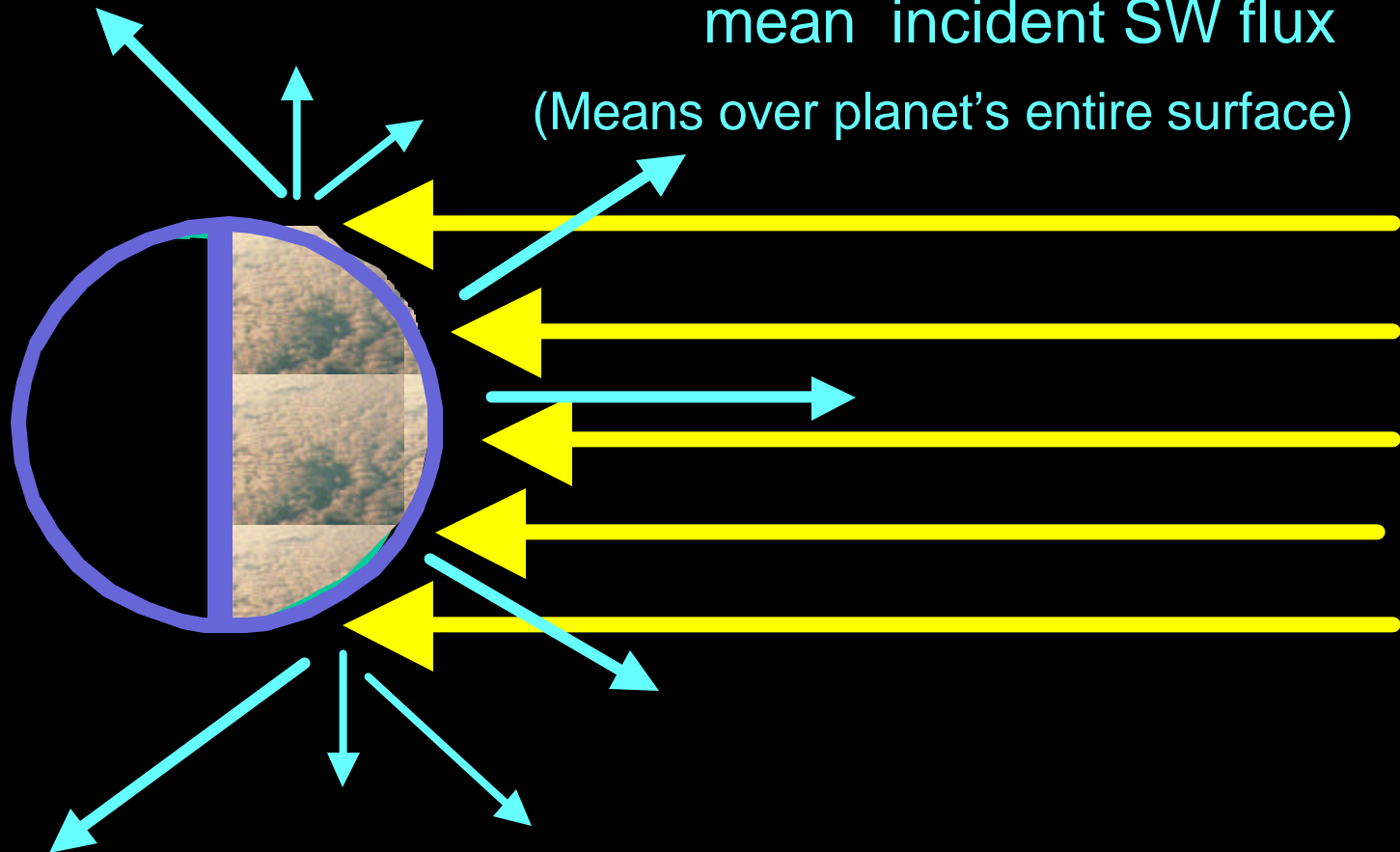
Energy Balance : $R_N - P = 0$

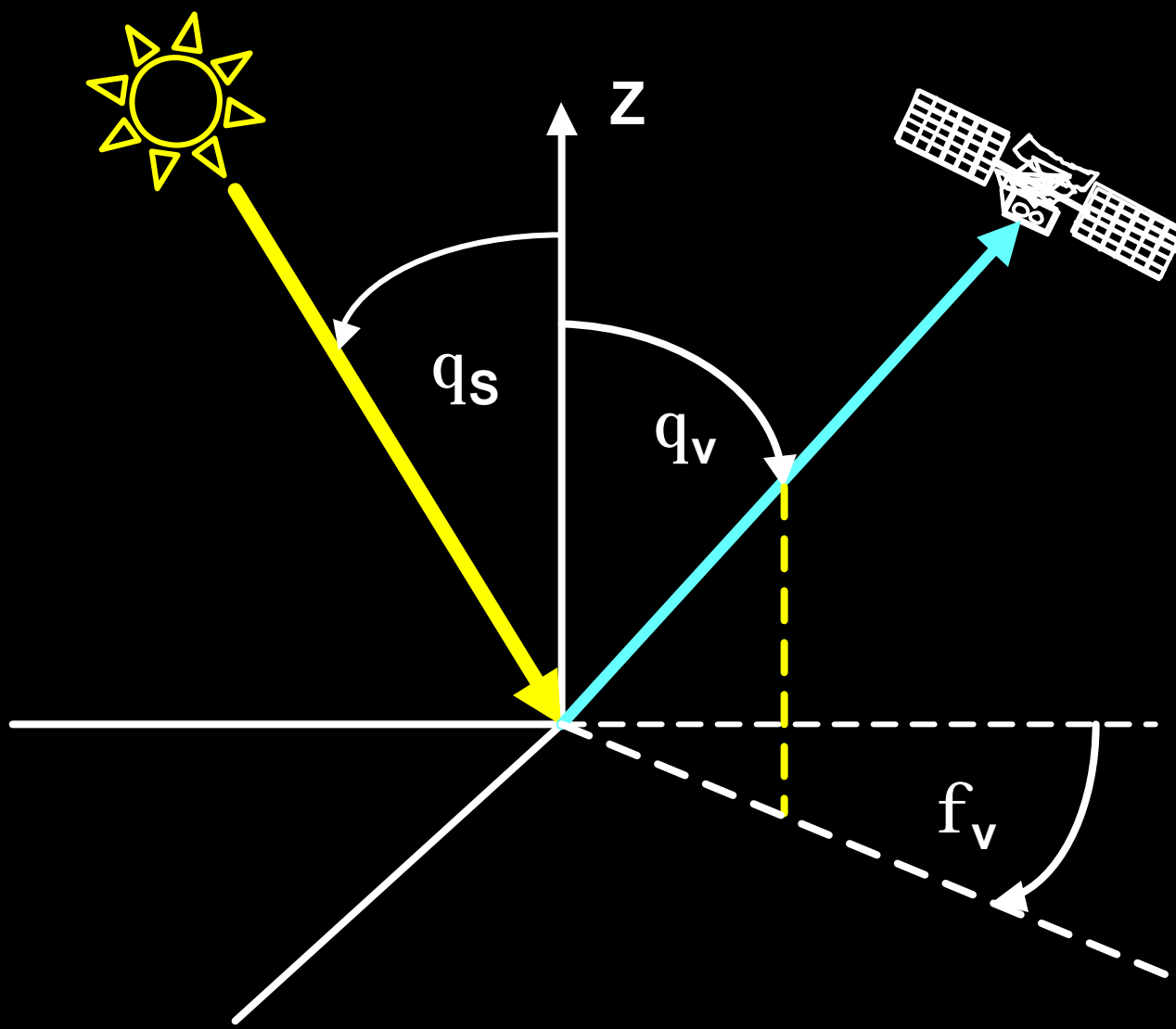
P = average energy flux from the planetary interior

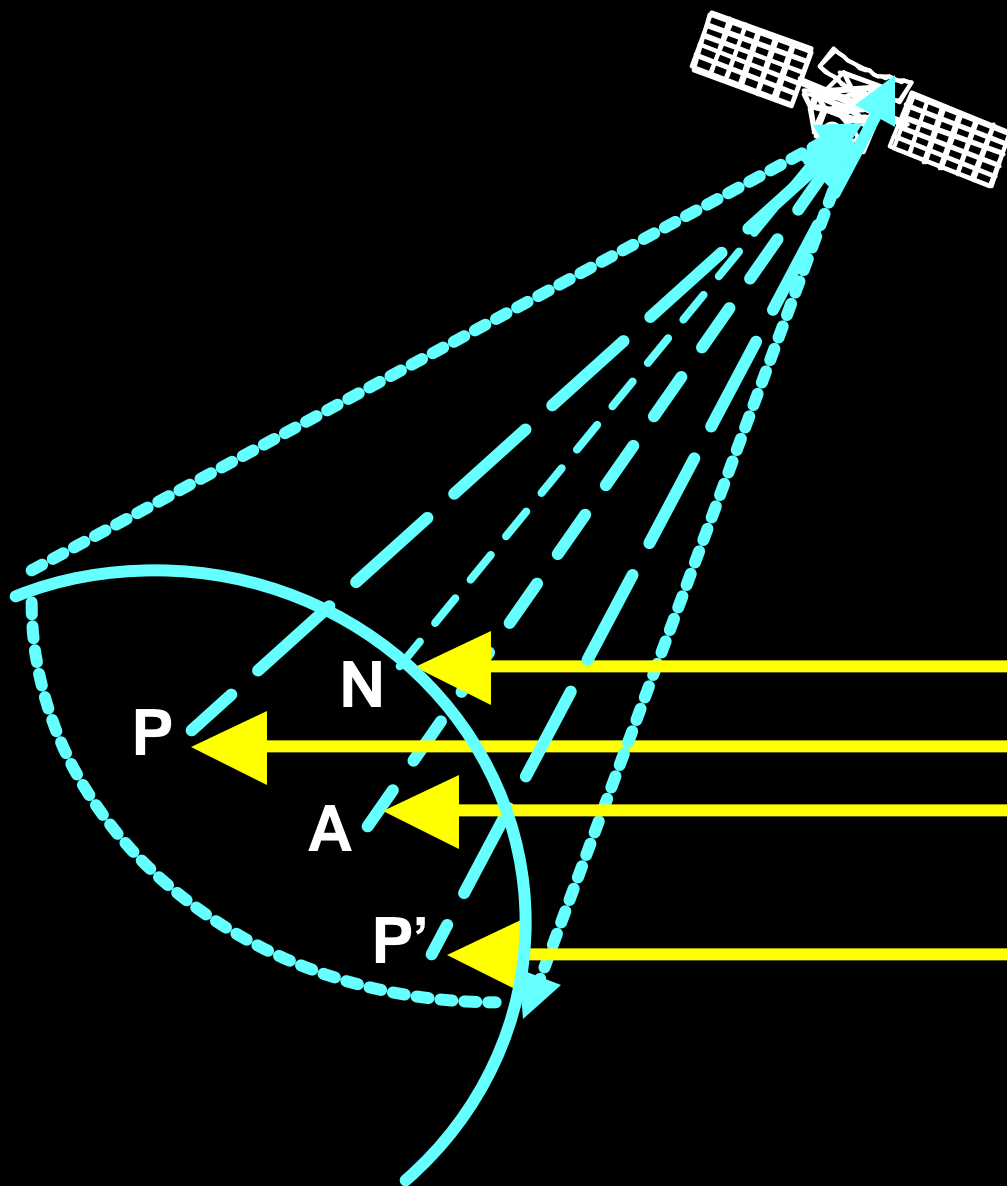
$$\text{Absorbed SW flux} = \frac{1}{4} (S_0/a^2) (1 - A)$$

$$\text{Bond Albedo } A = \frac{\text{mean reflected SW flux}}{\text{mean incident SW flux}}$$

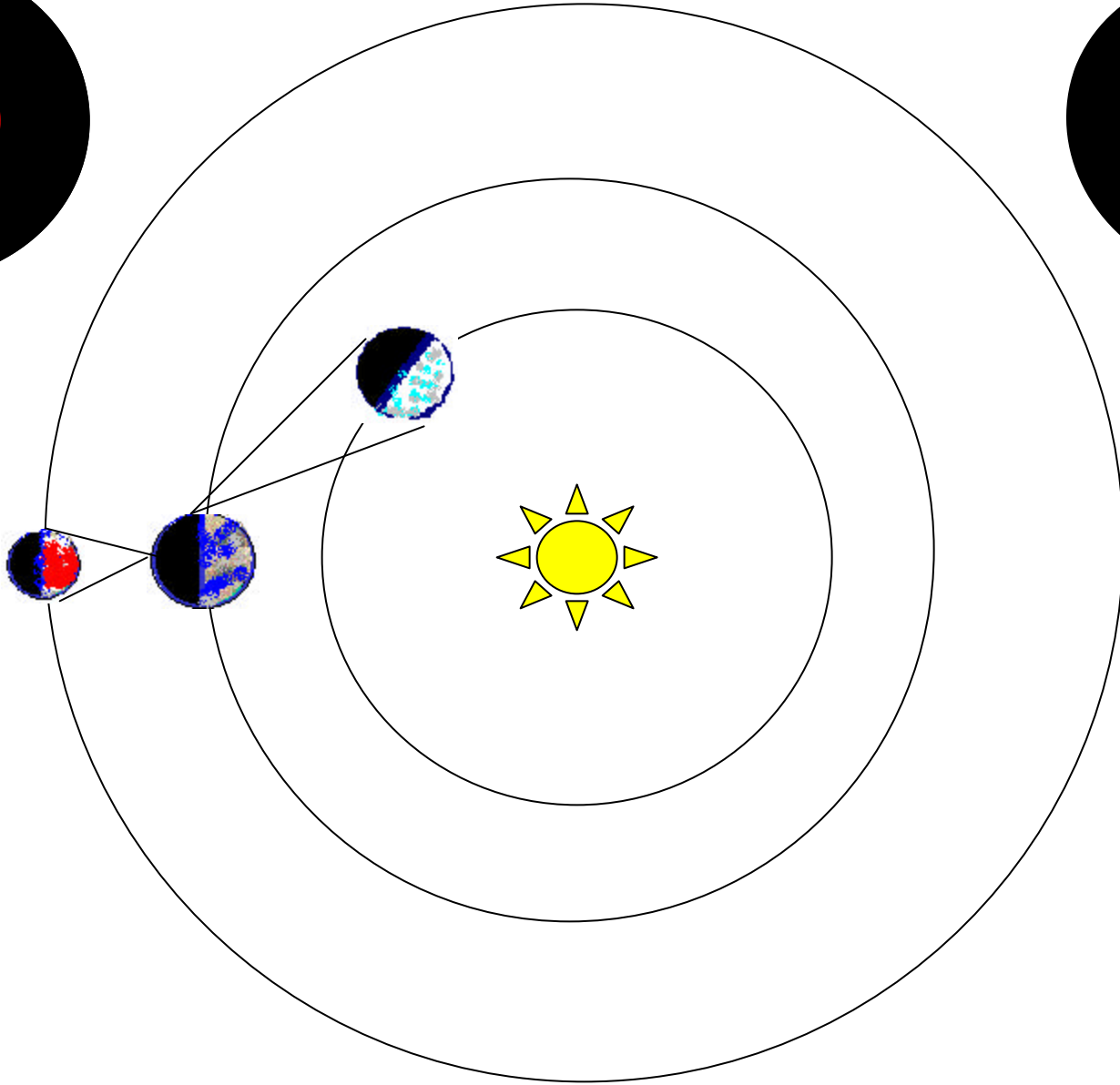
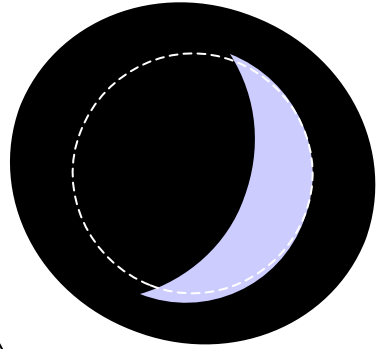
(Means over planet's entire surface)

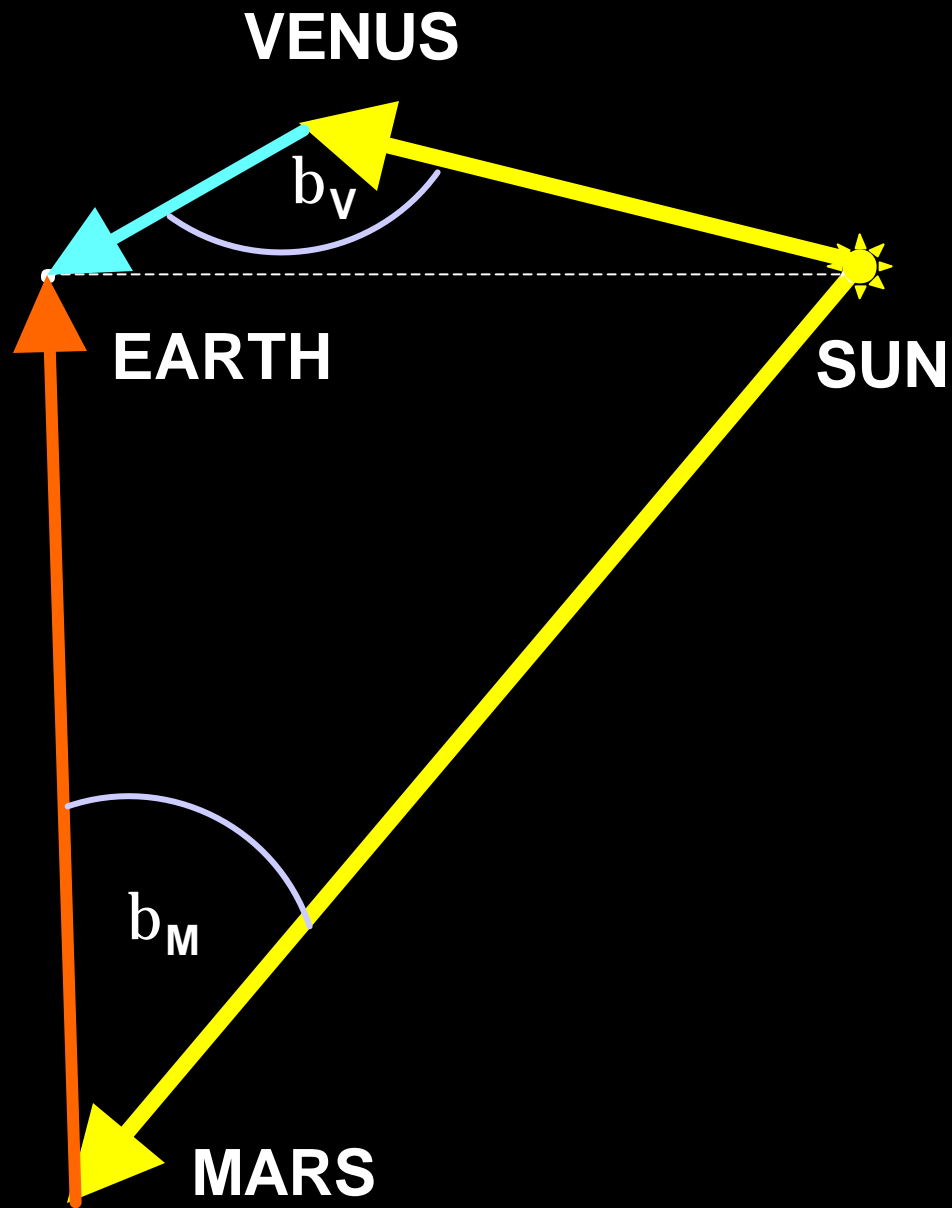






Each *radiance* measured (e.g. from A or N) is a single sample of directions ($q_s ; q_v, f_v$) contributing to the fluxes emerging at those points.





Bond Albedo Estimates Old and New

Allen Chamberlain

PLANET	1955	1979
Mercury	0.060	0.056
Venus	0.61	0.72
EARTH	0.34	0.39
Mars	0.15	0.16
Jupiter	0.41	0.45
Saturn	0.42	0.75
Uranus	0.45	0.90
Neptune	0.54	0.82
Pluto	0.16	0.15

Bond Albedo Estimates Old and New

Astronomy

textbook Univ. Website 2003 ?!?

PLANET	1955	1979	1999	2002	TCAEP	NSSDC
Mercury	0.060	0.056	0.06	0.06	0.119	0.119
Venus	0.61	0.72	0.72	0.76	0.750	0.750
EARTH	0.34	0.39	0.39	0.40	0.304	0.304
Mars	0.150	0.16	0.16	0.16	0.16	0.250
Jupiter	0.41	0.45	0.70	0.51	0.70	0.343
Saturn	0.42	0.75	0.75	0.50	0.75	0.342
Uranus	0.45	0.90	0.90	0.66	0.90	0.30
Neptune	0.54	0.82	0.82	0.62	0.82	0.29
Pluto	0.16	0.15	0.15	0.50	0.145	0.4-6

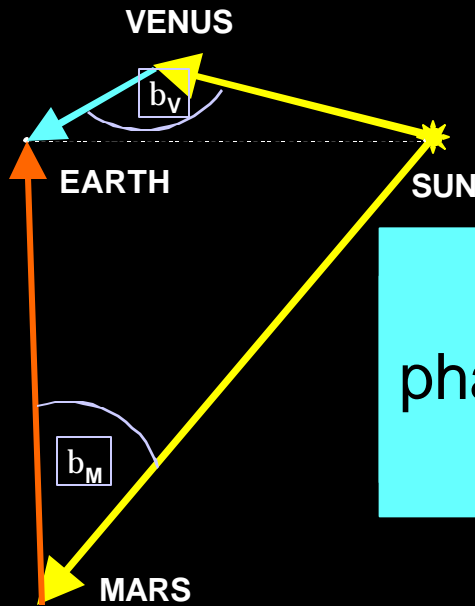
?!?

Bond albedo $A = p q$

both geometric albedo p and phase integral q have changed

geometric albedo $p =$

$$\frac{\text{planet's brightness at Sun angle } \beta = 0}{\text{brightness of a perfectly diffusing disk of same size}}$$



phase integral $q = 2 \int_0^p \left[\overline{L(\mathbf{b})} / \overline{L(0)} \right] \sin \mathbf{b} d\mathbf{b}$

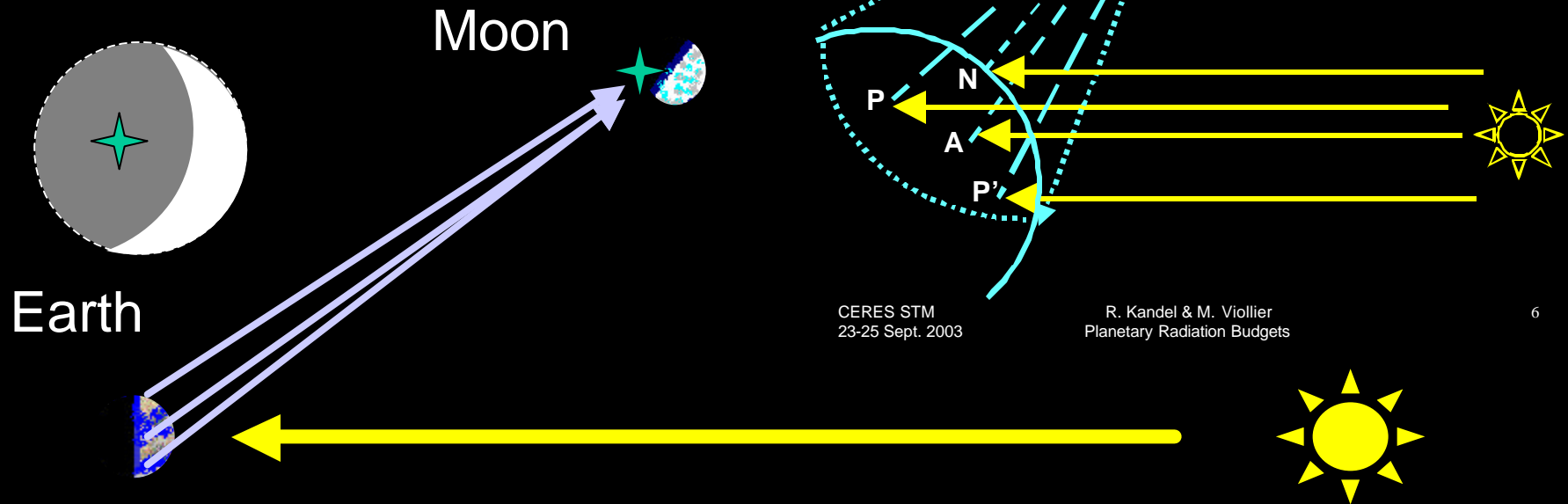
Bond albedo $A = p q$

both **geometric albedo p** and **phase integral q** have changed

	Allen 1955			NSSDC 2003		
Planet	p	q	A	p	q	A
Mercury	0.093	0.65	0.060	0.106	1.12	0.119
Venus	0.49	1.24	0.61	0.65	1.15	0.750
EARTH	0.34	1.00	0.34	0.367	0.83	0.306
Mars	0.136	1.10	0.150	0.150	1.67	0.250
Jupiter	0.37	1.11	0.41	0.52	0.66	0.343
Saturn	0.42	1.00	0.42	0.47	0.73	0.342
Uranus	0.41	1.10	0.45	0.51	0.59	0.300
Neptune	0.50	1.08	0.54	0.41	0.71	0.290
Pluto	0.16	1.00	0.16	0.5- 0.7	0.8	0.4- 0.6

Ground-based Earth albedo ?

Replacing the satellite by an observer, on the Moon –
It's still the same problem,
but *worse*



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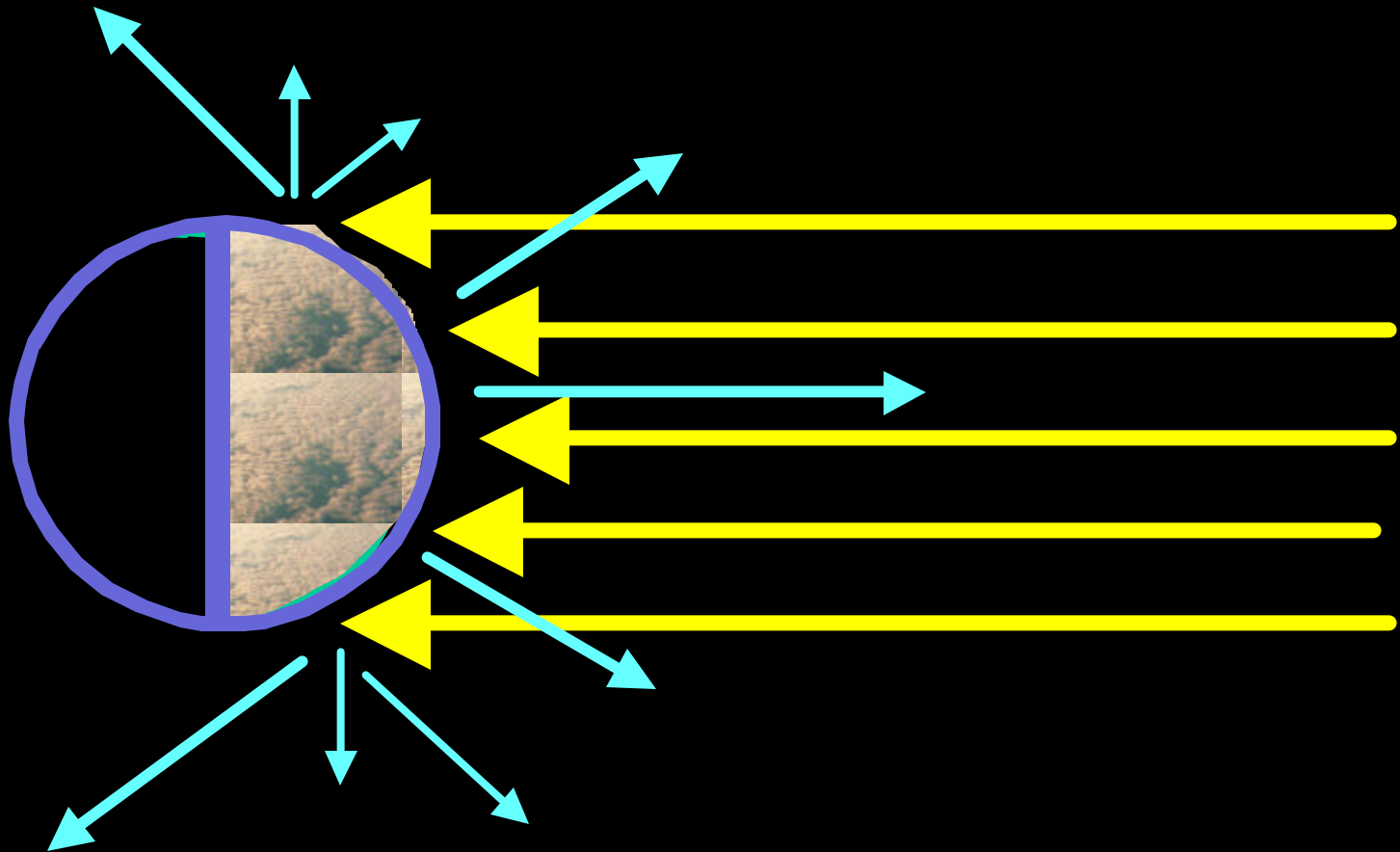
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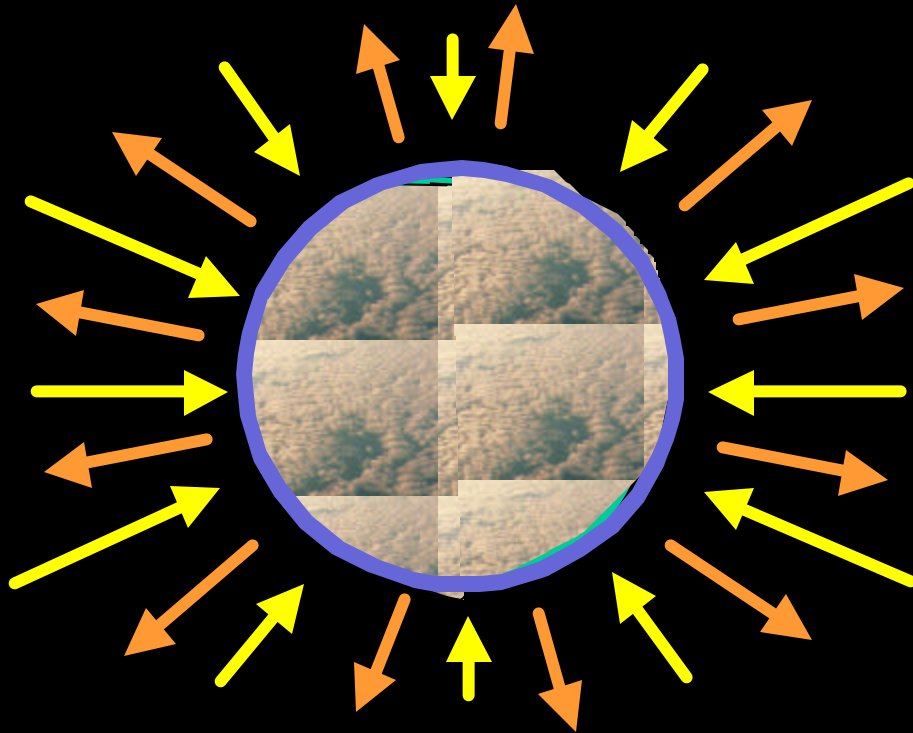
Radiation Balance

$$R_N = \text{absorbed SW flux} - \text{emitted LW flux}$$

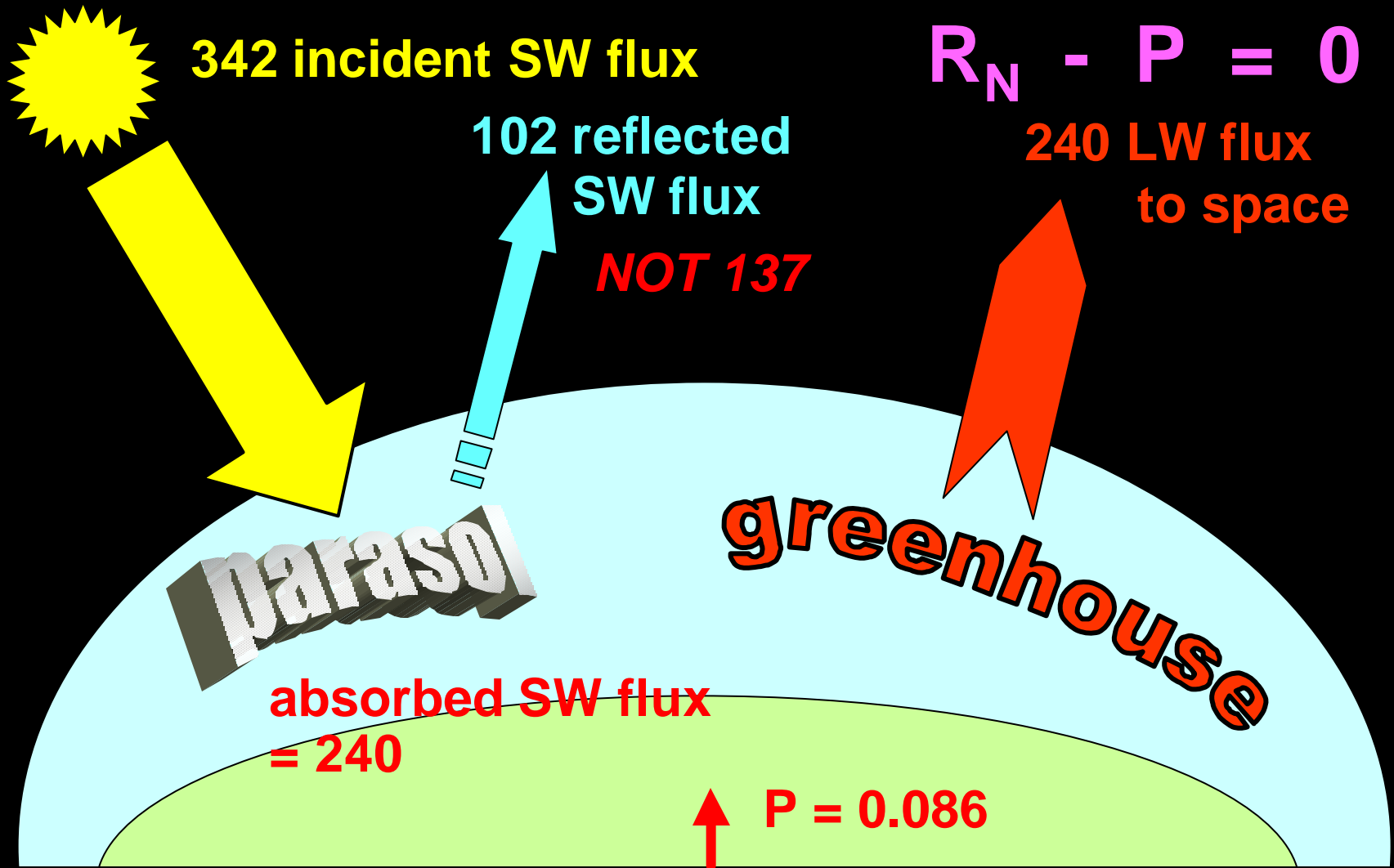


Radiation Balance

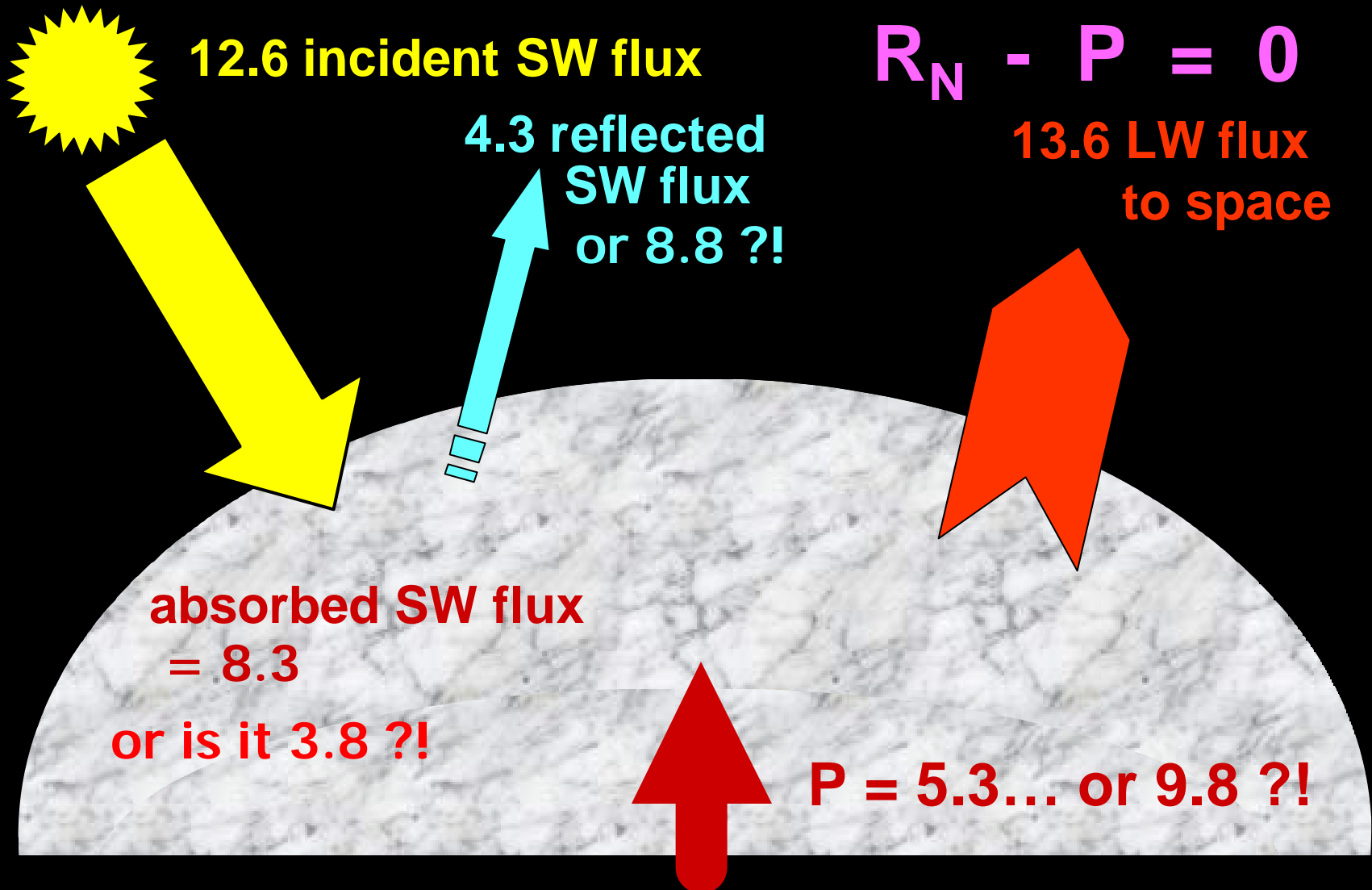
$$R_N = \text{absorbed SW flux} - \text{emitted LW flux}$$



Earth's Energy Balance :



Jupiter's Energy Balance :



What we need : Bond albedo, M_{LW} , R_N
with error bars and discussion

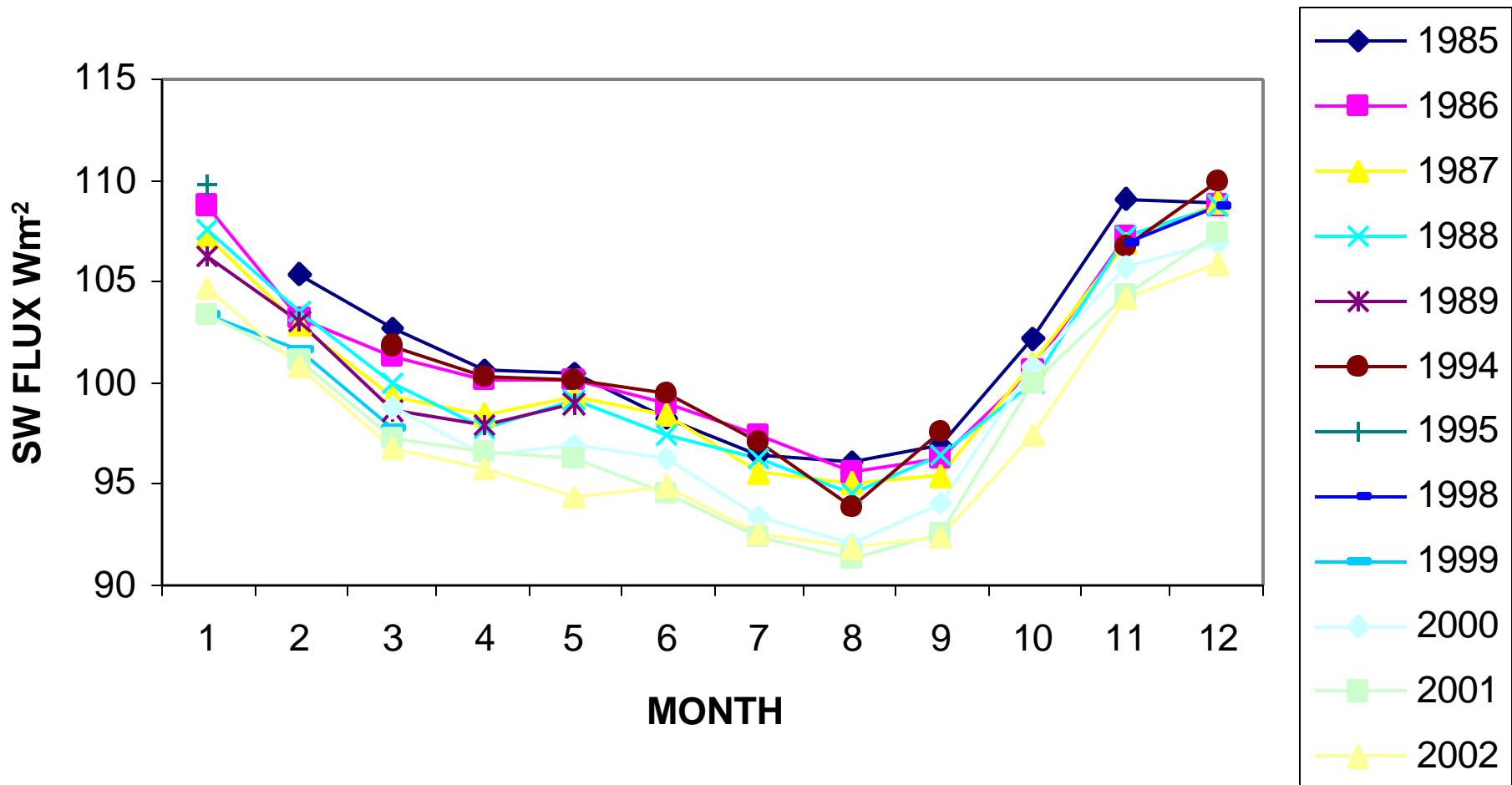
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Uranus	0.30	0.66	0.90	0.30
Neptune	0.20	0.62	0.82	0.29
Pluto	0.4-0.6	0.50	0.145	0.4-6

Error bars also needed
for planetary LW flux (or T_e) and P

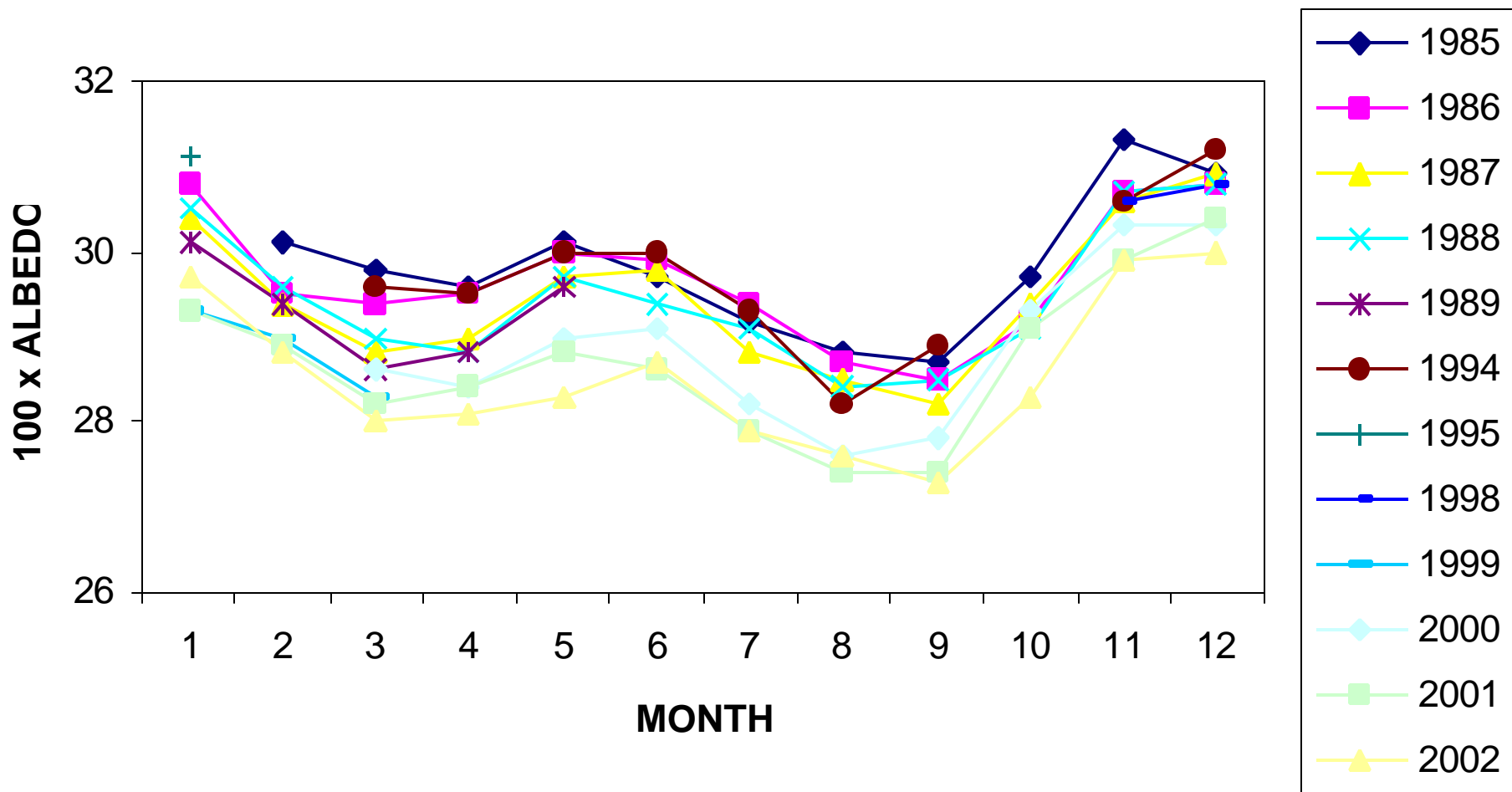
And we need to make astronomers better aware of
what we have learned about planet Earth !

*not just global annual means,
also the annual cycle of global means,
and much more !*

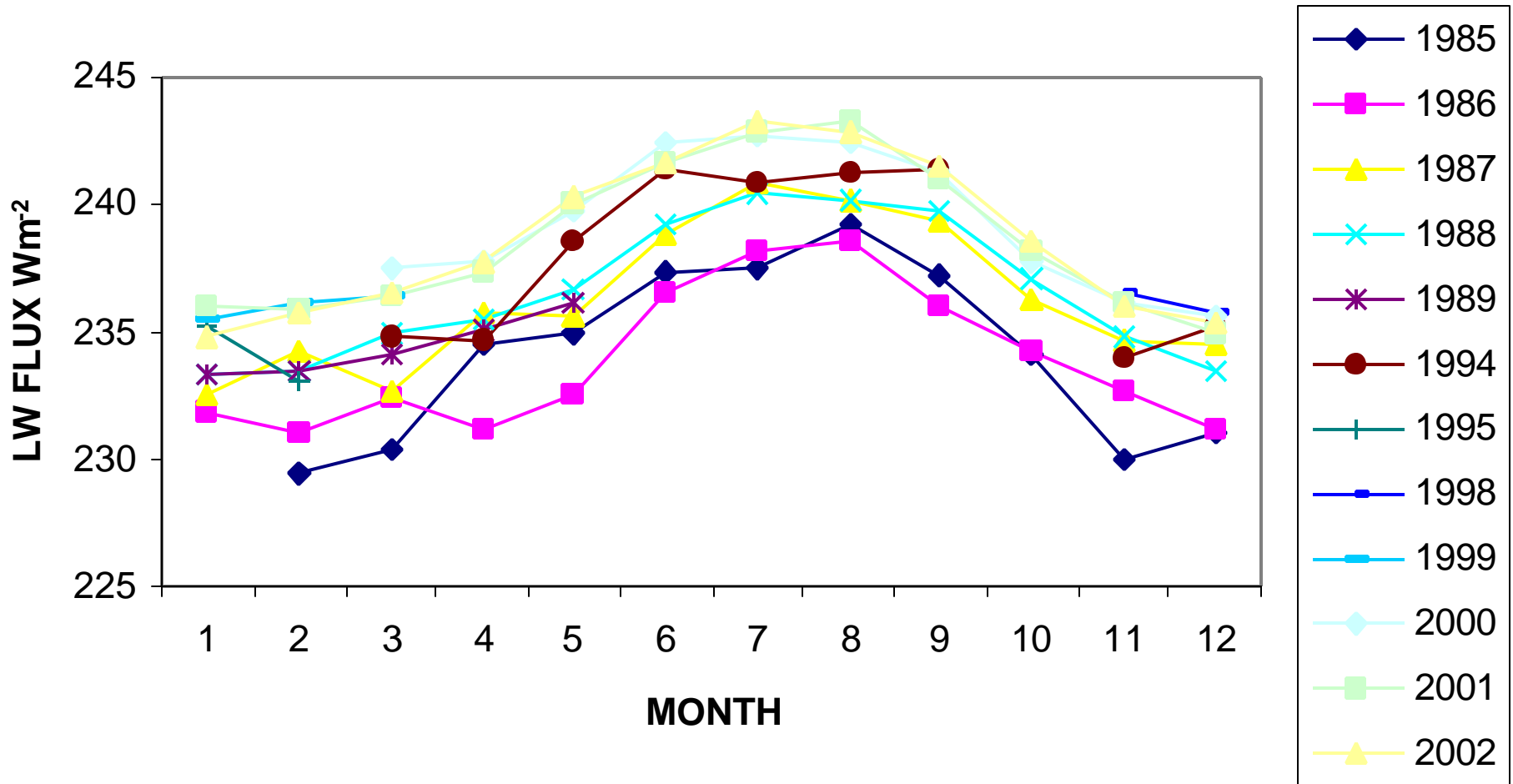
Example : Global mean reflected SW flux



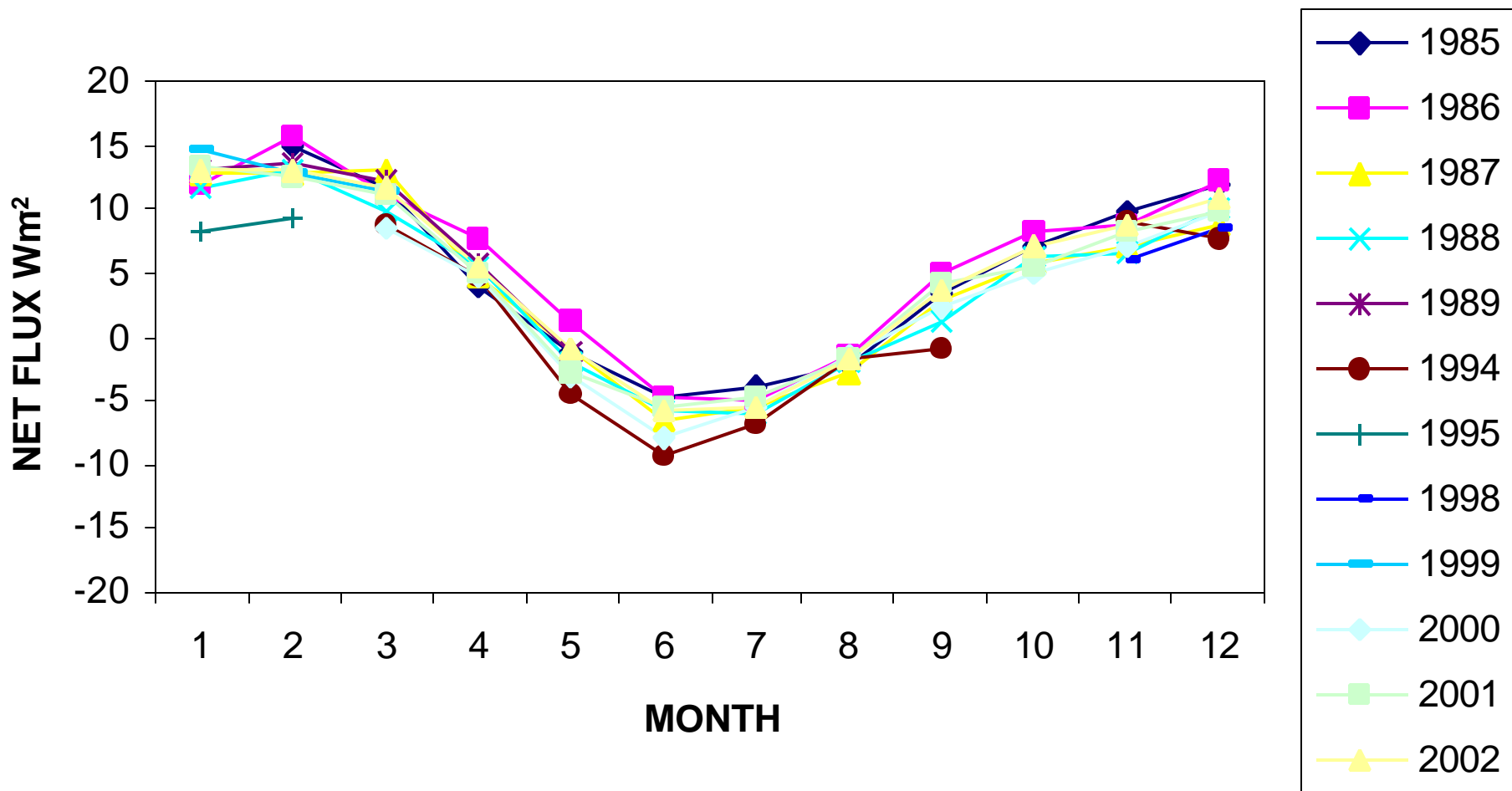
ALBEDO GLOBAL MEANS



LW GLOBAL MEANS



NET GLOBAL MEANS



Some things are settled, others not

We need to make astronomers better aware of what we have learned about planet Earth !